HOW SMALL IS IT? PUSHING MAHLI TO THE LIMIT IN THE SEARCH FOR MUDSTONES AT GALE CRATER, MARS.

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Introduction: Since landing at Gale crater in August of 2012, the Mars Handlens Imager (MAHLI) on the Curiosity rover has been an extremely useful tool for the characterization of Mars surface rocks. Although the moniker "handlens imager" correctly indicates that it is used by our rover like a terrestrial geologists handlens, its powers of resolution are rather limited when compared to what a geologist on Earth might see with a 10x handlens.

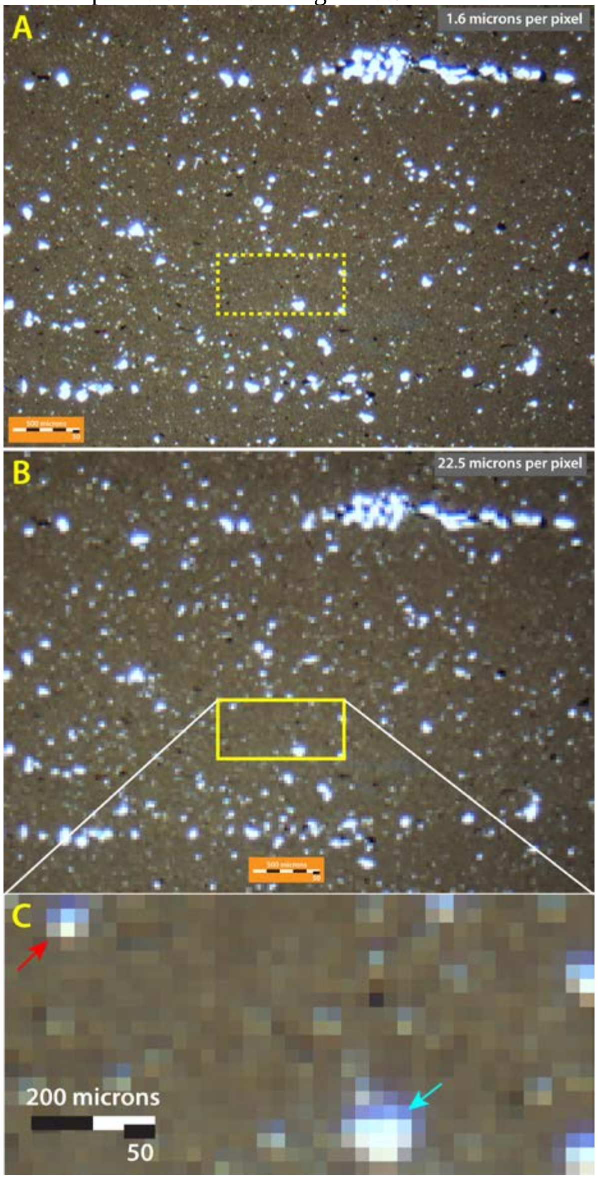
Although MAHLI is superior in optical performance to say a Hastings Triplet loupe, what makes the difference for resolution is the "sensor" behind the lens. Whereas MAHLI has a 2 megapixel sensor [1], the human eye has an outsized advantage with with a "sensor' that measures in several hundred megapixels. Because of this, a human eye with hendlens combination has no problem recognizing filaments in a microbial mat, whereas such a feat is impossible for MAHLI.

Given the abundance of mudstone lithologies encountered at Gale crater so far [2], the fact that the nominal resolution of MAHLI is 14 microns per pixel [1] means that strictly speaking we can only resolve particles as small as 45 to 60 microns in size. This is by definition coarse silt, although it still falls within the mudstone category of commonly used classification schemes [3]. The question that keeps arising with regard to interpreting MAHLI images is this: are we limited to state that a rock is coarse siltstone because our camera does not allow further differentiation, or can we go beyond this limitation when we examine MAHLI images?

It is the objective of this contribution to suggest a practical solution on the basis of image analogs from terrestrial mudstones.

Human Eye vs MAHLI: For illustration we can examine how a highly resolved image of a mudstone, acquired with a microscope is experienced by a human observer, and how this would differ to what we might see in a MAHLI image of the same scene (Fig. 1).

Figure 1 (next column): (A) low magnification photomicrograph (4.5 mm wide) of a mudstone with a component of scattered sand grains. At a pixel resolution of 1.6 microns, sand grains and quartz silt appear as well resolved bright spots, whereas the finer matrix between them is more difficult to make out and looks rather homogenous. (B) the same image at a pixel resolution of 22.5 microns, a common resolution achieved in MAHLI close-ups. (C) enlarged portion of B, showing the area marked by yellow rectangle in A and B. Comparing what we see in that rectangle between (A) and (B) shows that the degraded image (in B) still identifies the sand and coarse silt grains, and that the matrix is more fuzzy but not materially different in appearance. In (C) we see that the quartz sand (turquoise arrow) and coarse silt (red arrow) are readily noted, and that the matrix which already looked close to homogenous in (A) now largely consists of random pixels of variable brightness.



In tests with multiple samples, the sub-20 micron matrix of shales has the appearance of Fig. 1C when the image is rendered at the resolution of close-up MAHLI images. The texture could be described as random single pixel variability (RSPV). For comparison, let us now examine some MAHLI images of Murray Fm mudstone.

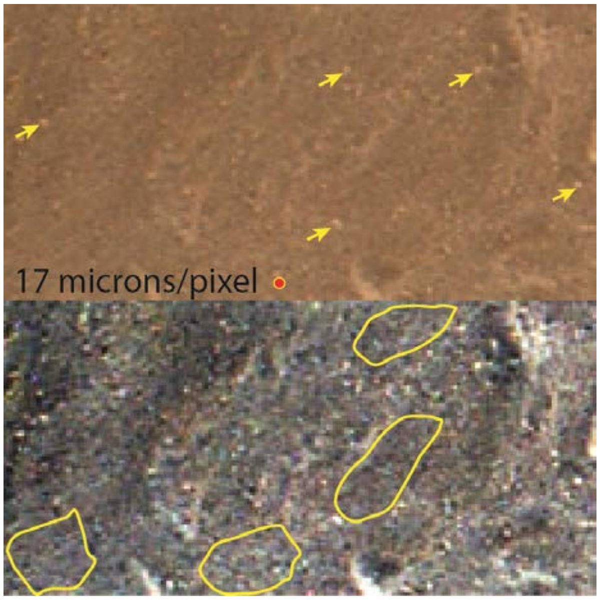


Figure 2: Shows a 200 by 100 pixel portion of the brushed surface of the Maturango target (Pahrump). Upper image is unprocessed, some surface dust grains pointed out by arrows. Red circle is 62 microns in size. At bottom the same FOV color stretched. Dust grains are brighter, and large areas (in yellow lines) can be picked that show RSPV characteristics.

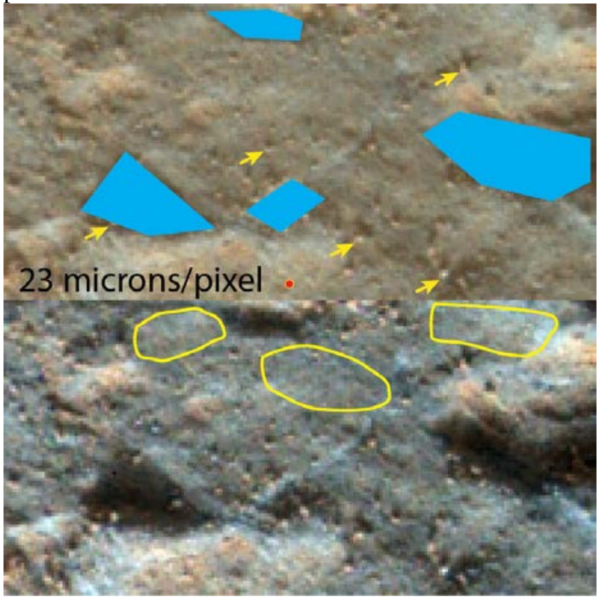


Figure 3: Same as in Fig. 2 for the Goldstone target (DRT), in the Chinle outcrop at Pahrump. Here small crystal molds and x-tal pseudomorphs (blue, upper image) are scattered through the matrix. There is surface dust (arrows), and if the color stretched lower image is examined one finds that dust free matrix areas (in yellow lines) between the x-tal molds show again RSPV characteristics.

Figure 4: Same as in Fig. 2 for the Aubures target (DRT) in the Hartmann's Valley member of the Murray Fm. There is surface dust (arrows), and if the color stretched lower image is examined one finds that dust free matrix areas (in yellow lines) again show RSPV characteristics.

Discussion and Conclusion: Comparing Figs. 2, 3, and 4 to Fig. 1 shows comparable RSPV characteristics. This suggests that even though we are not able to see particles in any detail, it is a rational assumption that random single pixel variability in Murray mudstones implies a mudstone fabric dominated by particles that are in the 20 micron and smaller size range. In case of the Chinle interval (Fig. 3) this would indicate that laminae originated as mud with scattered x-tals of probably evaporite association, and that the mudstone component is similarly fine grained as at Maturango (Fig. 2). Likewise, in the case of the Hartmann's Valley example (Fig. 4) the Murray matrix is similarly fine grained as at Maturango, even though sand grains occur mixed in with this matrix in nearby targets.

Thus, the matrix mud of the Murray appears to be similar throughout. Scattered sand grains within this matrix, such as in the Hartmann's Valley member, are puzzling, and may indicate that denser mud aggregates (sand size?) rather than dispersed or flocculated fines were present at the time of deposition. The former option would imply a radically different and more energetic depositional setting.

References: [1] Grotzinger, J., et al. (2015) *Science*, 9 October 2015. [2] Edgett, K. et al. (2012) Space Sci. Rev.. v. 170, p. 259-317. [3] Lazar et al., (2015) Mudstone Primer, SEPM.