THE MARKER BAND IN GALE CRATER: A SYNTHESIS OF ORBITAL AND GROUND OBSERVATIONS.

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Introduction: The "Marker Band" (previously called the Marker Bed and Marker Horizon [1-4]) in Gale crater is a distinctive indurated and dark-toned unit observed in the strata of Mount Sharp. From orbital data, the Marker Band (MB) was mapped across much of the western and southern edges of Mount Sharp, spanning over 80 km in distance and 1.6 km in elevation [4]. CRISM spectra of the MB show no hydration signatures and broad absorptions around ~1 and 2 µm interpreted to be from high-Ca pyroxene [4]. Favored origins for the MB based upon orbital observations included a more indurated sulfate, a sandstone, and a volcanic ash deposit. The Curiosity rover recently reached the MB and is now collecting critical in situ measurements to test these postulated and other origins and make new discoveries at the finer mm- to cm-scale that could not be assessed from orbital data. Here we provide a summary of several of the most crucial MB observations made by the rover thus far from sols 3640-3645 and 3668-present.

Results: The initial Curiosity observations of the MB (Fig. 1) occurred along a narrow strip (~7 m wide)

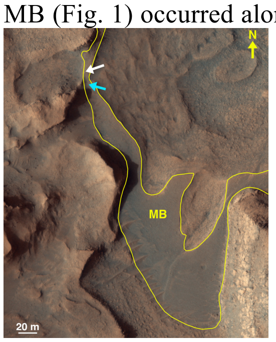

Fig. 1. HiRISE color image showing where Curiosity crossed over the MB (white arrow) and attempted to drill it (blue arrow). The rover will drive to the south where the MB is wider and darker for another drill attempt and additional observations.

where orbital data did not show high-Ca pyroxene or darker surfaces. The total thickness of the MB is ~0.5 m at the current location, although it varies further north and south [5]. Observations of the surface of the MB from Mastcam and Navcam panoramic mosaics show there is no concentration of darker sand on the surface at this current location which had been proposed to explain the CRISM high-Ca signature [4]. Exposures of the MB erode into especially prominent overhanging unsupported ledges that can extend outward 10's of cm or into large (>50 cm) pieces that are collecting along its base (Fig. 2).

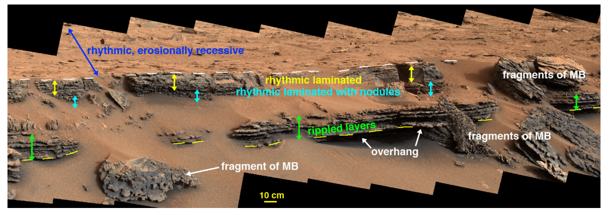

Fig. 2. Mastcam sol 3642 ML103019 mosaic of the MB showing various features.

Rover data taken of the MB (Fig. 2) show it varies vertically in morphology and composition. The upper section is ~15 cm thick and appears as rhythmic layering (Fig. 3). The layers vary in their thickness and lithology and are bundled at a scale of ~1cm/2mm [6]. APXS data show a generally basaltic composition with elevated Cl, Mn, Fe, Zn, and Br compared to sands [7].

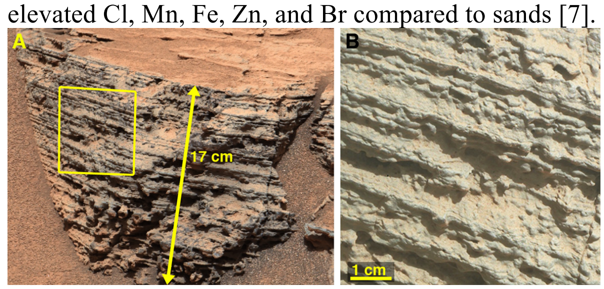

Fig. 3. (A) Mastcam sol 3688 MR103297 image showing rhythmic layers in the MB. Yellow box notes location of (B) which is a MAHLI image of rhythmic laminae.

Moving downward in the rhythmic laminae section, there are numerous nodules, including hollowed out ones, that increase in abundance until they dominate the lower ~10 cm of the section (Figs. 2,3). The nodules can be up to ~1 cm in diameter and are enriched in Fe and Mn [8].

The lower section of the MB has thicker laminae with undulating surfaces that could be ripples formed in water due to their symmetric appearance [9]. The lower section extends outward as overhangs (Fig. 2) more so than the upper section, indicating it is either more resistant to erosion or has been shielded by the overlying MB materials. Large fragments of the lower section have fallen off to expose broader surfaces that show linear ropey or honeycomb morphologies (Fig. 4). These distinct weathering morphologies indicate higher standing more resistant crests spaced at ~4-5 cm distance and with less resistant material that is more easily eroded and removed by the wind in between. APXS and ChemCam measurements determined these resistant crests are high in metals (~40 wt% FeO) [7,8].

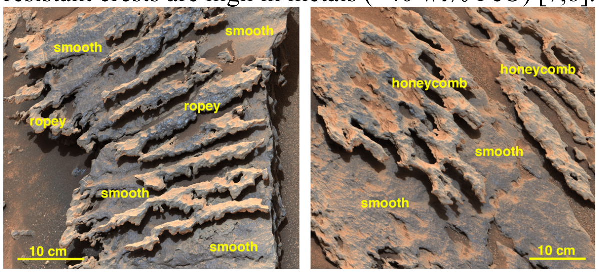

Fig. 4. Examples of the lower section morphologies in the MB include ropey (left; sol 3640 MR103000) and honeycomb (right; sol 3640 MR103004) erosional expressions with a smoother surface beneath.

A few mm beneath the eroded ropey and honeycomb surfaces is a smoother massive morphology that can display shallow undulations. The edges of the lower smoother materials are eroding into ropey and honeycomb morphologies, indicating that these materials could be the same as those above it but with lower rates of erosion affecting them.

Two drill attempts were made on the surface of the MB where the lower rippled section was exposed (Fig. 5). The ripples here are symmetrical with rounded crests spaced ~5 cm apart (Fig. 5). The first attempt (Amapari) failed to reach more than a few mm depth while the second drill (Amapari 2) reached several mm before stopping due to fracturing that broke loose a slab of MB material from the surroundings (Fig. 5). APXS data [7] indicate the drill tailings have an enrichment of FeO (~40 wt%), Zn (~2 wt%), Mn (>1 wt%), Cl (~3 wt%), Cu (~1000 ppm), and Br (~0.4 wt%), with significant submillimeter variability [8], which is much higher in metal contents relative to other units previously explored by Curiosity [7,8]. Another drill attempt is expected to be made further south where the MB is aerially more extensive.

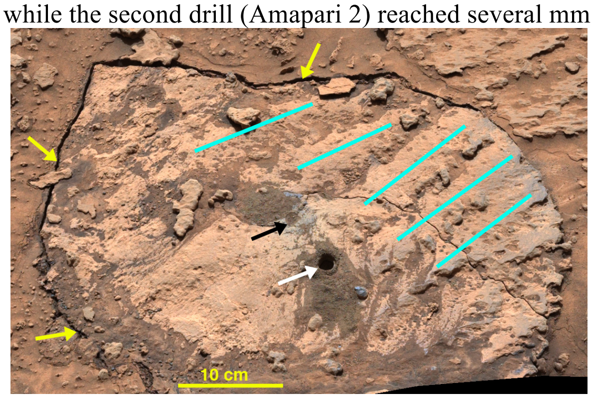

Fig. 5. Mastcam sol 3682 image ML103264 of MB surface. Ripple crests (blue lines), Amapari drill hole (black arrow) and Amapari 2 drill hole (white arrow) are noted. During drilling, the entire slab broke loose (yellow arrows), which stopped the drill.

Discussion: Orbital data suggested that the MB represented a unique stratigraphic horizon/band within Mount Sharp and Curiosity data has confirmed these orbital observations. The MB has a distinct metal-rich geochemistry unlike any other materials previously analyzed by the rover, which likely explains its erosional appearance as a resistant ledge within the strata. The rippled finely layered morphology is reminiscent of sandstone lenses observed in the stratigraphy below, but its occurrence on the MB across hundreds of meters [9] is unique. Hence, the MB is indeed a marker of a regional and relatively brief change in the environment within Gale crater.

It should be noted that the region where Curiosity is exploring the MB is at the lowest elevations of the band within Mount Sharp. This means that features observed in the band here may differ from MB features seen to the southwest at higher elevations. If we assume the MB observed here and elsewhere in Mount Sharp formed as one unit [4], then a lacustrine origin would require the water was at least 1.6 km deep (depending on the amount of differential compaction of the sequence) to explain the MB seen at the higher elevations in the southwest. Alternatively, if any water ponded at just the lower elevations in Gale where the rover is now exploring the MB [5] then only here would we expect water ripples and nodules rich in Fe and Mn [8]. For these reasons, it is not feasible to make assumptions that the MB we are investigating with Curiosity at this low elevation would apply to the MB observed across all of Mount Sharp. If the MB represents an eolian deflation surface [3] then it may have eroded down to the level of the water table enabling shallow water ponds and the formation of the ripples. A volcanic ash origin is still plausible and consistent with the high FeO and MnO concentrations and finely laminated nature of the MB, as well as its distribution across Mount Sharp, though water is still necessary to explain the ripples at the Curiosity location. Post-depositional processes, including diagenesis and fluid flow, could also explain several of the morphologies and geochemistries that have been measured by Curiosity, but whether this would require an event that occurred across all of Mount Sharp is unconstrained.

References: [1] Milliken, R. et al. (2010) *Geophy. Res. Letts,* doi:10.1029/2009GL041870. [2] Sheppard, R.Y. et al. (2021) *JGR*, doi:10.1029/2020JE006372. [3] Rapin W. et al. (2021) Geol. Doi:10.1130/G48519.1. [4] Weitz, C.M. et al. (2022) *JGR*, doi:10.1029/2022JE007211. [5] Dietrich W. et al., this conference. [6] Lewis K. et al., this conference; [7] Thompson L. et al., this conference. [8] Gasda et al., this conference. [9] Gupta S. et al., this conference.