

AQUEOUS PROCESSES AND MICROBIAL HABITABILITY OF GALE CRATER SEDIMENTS FROM THE BLUNTS POINT TO THE GLEN TORRIDON CLAY UNIT. B. Sutter^{1,2}, A.C. McAdam³, C.N. Achilles³, E.B. Rampe², P.D. Archer^{1,2}, L.M. Thompson⁴, D.W. Ming², J.C. Stern³, C.H. House⁵, R. Navarro-González⁶, M. Millan^{3,7}, J.L. Eigenbrode³, ¹Jacobs, Houston, TX, brad.sutter-2@nasa.gov, ²NASA/JSC, Houston, TX, ³NASA/GFSC, Greenbelt, MD, ⁴Planetary Space Sci. Centre, Univ. New Brunswick, Canada, ⁵Penn. State Univ., Univ. Park, PA, ⁶Universidad Nacional Autónoma de México, México, ⁷Georgetown Univ., Wash., D.C.

Introduction: A driving factor for sending the Mars Science Laboratory, Curiosity rover to Gale Crater was the orbital detection of clay minerals in the Glen Torridon (GT) clay unit [e.g., 1]. Clay mineral detections in GT suggested a past aqueous environment that was habitable, and could contain organic evidence of past microbiology. The mission of the Sample Analysis at Mars (SAM) instrument onboard Curiosity was to detect organic evidence of past microbiology and to detect volatile bearing mineralogy that can inform on whether past geochemical conditions would have supported microbiological activity. The objective of this work was to 1) evaluate the depositional/alteration conditions of Blunt's Point (BP) to GT sediments 2) search for evidence of organics, and 3) evaluate microbial habitability in the BP, Vera Rubin Ridge (VRR), and GT sedimentary rock.

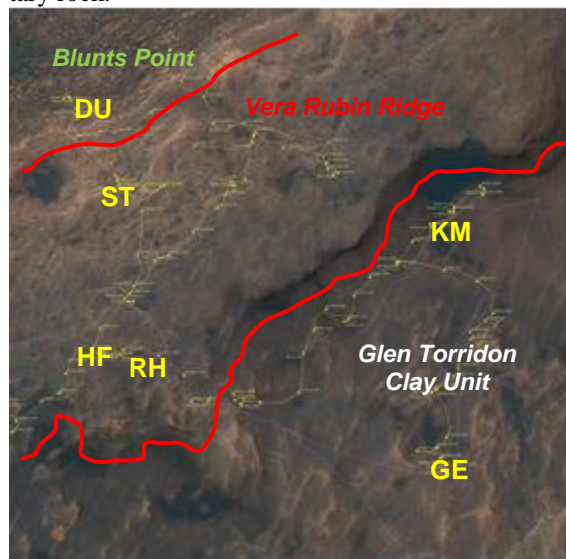


Fig. 1. Location of drilled samples.

Materials/Methods: Drilled samples (Fig.1) were acquired at Duluth (DU) (BP unit, ~5 m stratigraphically below VRR); Stoer (ST), Highfield (HF), and Rock Hall (RH) (from VRR, spans ~40 m of stratigraphy); and Kilmarie (KM) and Glen Etive (GE) (from GT, collected -14 m and +9 m in elevation, respectively, relative to VRR top).

Most samples are laminated mudstones suggesting lacustrine depositional environments while GE occurs

in cross bedded sandstone suggesting fluvial or shallow water depositional settings.

SAM-evolved gas analysis (EGA) involved heating a sample (~35 °C min⁻¹) to ~870 °C where He carrier gas (~0.8 sccm; 25 mbar) swept evolved gases from the SAM oven to a quadrupole mass spectrometer for identification. Evolved gases (e.g., SO₂, CO₂, etc.) released at characteristic temperatures from volatile bearing phases were used to identify mineral and/or organic phases. CheMin X-ray diffraction [2] and Alpha Particle X-ray Spectrometer (APXS) provided supporting mineralogical and total chemical data of the samples analyzed by SAM.

Results/Discussion: The evolved H₂O (1.1 – 2.0 wt% H₂O) release pattern of the DU sample was similar to the Glen Torridon KM and GE samples which were consistent with bassanite, amorphous Fe (e.g., ferrihydrite) and nontronite (Fig. 1). The VRR ST and HF patterns were characterized by a sharp low-temperature gypsum water release. While RH did not possess gypsum water, the most intense peak was attributed to akaganeite and a higher temp shoulder (~ 350°C) attributed to CheMin-detected ferripyrophyllite also detected in ST and HF.

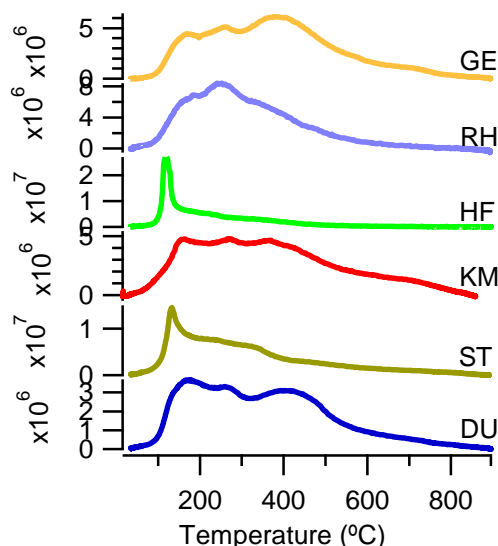


Fig. 2. Evolved water as detected by SAM-EGA.

Evolved SO₂ indicated crystalline and/or poorly crystalline Fe- and Mg-sulfate and possibly Fe-sulfide in all samples. The amount of sulfur detected by SAM-

EGA was always far lower (<1 wt.% SO_3) than the amounts detected by APXS (5.8-15.3 wt.% SO_3), which indicated that CaSO_4 dominated the S species in all materials. CaSO_4 decomposition temperature is beyond the SAM-EGA temperature range.

The RH sample was the only sample to evolve significant O_2 and NO indicating the presence of oxychlorine (0.6 ± 0.4 wt. % ClO_4) and nitrate (0.02 ± 0.01 wt.% NO_3), respectively. All samples had between 0.32 and 2.1 wt. % Cl measured by APXS suggesting that the oxychlorine free samples likely consisted of chlorides.

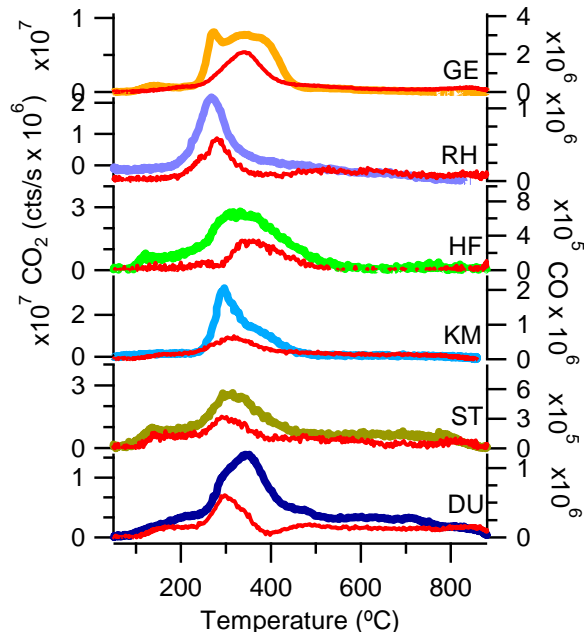


Fig. 3. Evolved CO_2 (colored) and CO (red) release versus temperature.

Co-evolved CO_2 and CO were consistent with oxidized organics (e.g., carboxylates) though CheMin siderite detection in KM coupled with laboratory analog EGA indicated that carbonate contributed to evolved CO_2 in KM [2,3] (Fig. 3). SAM-GCMS analysis detected ppb levels of sulfur bearing organics [4] indicating that oxidized organics dominate these samples.

Similarities in S and water-bearing phases in these samples suggests that these materials could have been exposed to similar geochemical depositional and/or diagenetic chemistry and mineralogy. All samples have $\text{CaSO}_4 \gg \text{Fe-MgSO}_4$ indicating that CaSO_4 fluids dominated diagenetic alteration after deposition. The lack of nitrate and oxychlorine phases (except RH) suggest fluids lacked nitrate and were dominated by chlorides. Oxychlorine and nitrate detection in RH could represent a late stage alteration episode that was limited in extent in the VRR. The similarities in DU, KM, and GE evolved water (Fig. 2) suggest that, despite being separated by

VRR, these materials could have shared similar aqueous conditions.

While similar depositional conditions could have occurred with all samples, VRR/DU sediments had greater post-depositional alteration than the GT sediments. The GT samples consist of relatively higher carbon and higher phyllosilicate and relatively lower Fe^{3+} phases compared to the VRR/DU samples (Fig. 4). This suggests VRR/DU were exposed to greater post-depositional alteration compared to GT. VRR/DU could have been deposited with similar carbon and phyllosilicate levels as GT, but post-depositional fluids caused alteration of phyllosilicates to Fe^{3+} phases and corresponding loss of organic-C and carbonate.

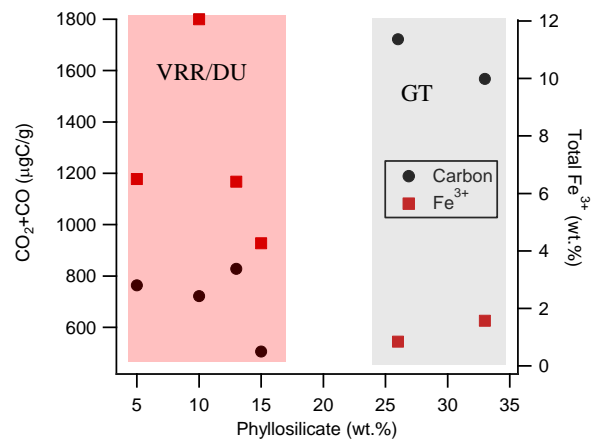


Fig 4. Total C and Fe^{3+} versus phyllosilicate content. VRR/DU and GT sample groups indicated by red and gray shading, respectively.

The lack of nitrate in the GT samples suggests that nitrogen could have been a limiting nutrient for ancient microbial processes. The low C/N ratio ($\sim 4/1$) in RH suggests that only RH could have supported a microbial community. The variation in alteration intensity and geochemistry (e.g., acidic pHs in VRR) between the BP, VRR, and GT materials does not preclude microbiological activity. However, despite sufficient carbon (up to $1722 \mu\text{gC/g}$) to support a small microbiological community limited nitrogen could have caused nutritional challenges for microbial populations in the GT sediments.

References:

- [1] Milliken et al. (2010), *GRL*, 37, L04201, doi:10.1029/2009GL041870.
- [2] Rampe E.B. et al. (2020), *LPS LI* #1601.
- [3] Archer P.D. et al. (2020), *LPS LI*.
- [4] Millan M. et al. (2020), *LPS LI*.