

COMPARING THE DETECTION OF CARBON AT THE PHOENIX LANDER AND MARS SCIENCE LABORATORY ROVER LANDING SITES. B. Sutter^{1,2}, P.D. Archer^{1,2}, A.C. McAdam³, P.B. Niles², R. Navarro-Gonzalez⁴, A.G. Fairen⁵, W.V. Boynton⁶, D. Hamara⁶, D.W. Ming², J.L. Eigenbrode³, P.R. Mahaffy³, .¹Jacobs, Houston, TX 77058, brad.sutter-2@nasa.gov, ²NASA/JSC Houston, TX 77058, ³NASA/GFSC, Greenbelt, MD 20771. ⁴Universidad Nacional Autónoma de México, México, D.F. 04510, Mexico, ⁵Cornell, Ithaca, NY. ⁶Univ. of Ariz, Tucson, AZ.

Introduction: Evolved gas analysis of surface materials at the Phoenix Lander (PL) and Mars Science Laboratory (MSL) landing sites has resulted in the detection of evolved CO₂. Sources of these CO₂ detections include organic-C and carbonate [e.g.,1,2,3,4]. Recent analysis presented here has resulted in detection of previously unreported CO₂ detections and possibly reduced carbon phases from PL soils. The objectives of this work are to 1) Compare and contrast the evolved CO₂ releases between the two landing sites, 2) Evaluate potential detections of additional organic-C phases at the PL site as compared to Gale Crater, and 3) Discuss the implications of these results relative to understanding the nature of carbon across Mars.

Materials & Methods: The PL landed on impact crater ejecta deposit consisting of volcanic ash in the arctic Northern Plains region. The landscape consists of polygonal morphology attributed to icy-soil (5 cm below the surface). The two PL samples evaluated here consisted of scooped loose surface (Baby Bear, BB) and subsurface (icy-soil sublimation lag) (Wicked Witch, WW) materials. The MSL Curiosity rover landing site occurs in the equatorial Gale Crater. The Gale Crater samples consisted of scooped loose unconsolidated eolian sediments (Rocknest, RN; Gobabeb, GB) and drilled mudstones (Cumberland, CB; Telegraph Peak, TP) and a sandstone (Big Sky, BS).

Table 1. Operating parameters for TEGA and SAM instrumentation on Mars

	TEGA	SAM
Max temp (°C)	1000	870
Heating rate (°C/min)	20	35
Purge gas	N ₂	He
Purge rate (sccm)	0.04	0.8
Analysis pressure (mbar)	12	25
Sample particle size (µm)	< 1000	< 150

The PL's Thermal Evolved Gas Analyzer (TEGA) and the MSL's Sample Analysis at Mars (SAM) instrument utilize evolved gas analysis to analyze surface materials for carbon (Table 1). Samples were heated in an oven and evolved gases were detected by a mass spectrometer (MS). Evolved CO₂, and other gases released at characteristic temperatures from volatile bearing phases were used to identify mineral and/or organic

phases. Despite differences in TEGA and SAM operations (Table 1), first-order comparisons between the PL and MSL surface materials can be made. The Wicked Witch low-temperature analysis (WW-LT) utilized a higher MS emission current than BB and Wicked Witch high-temperature (WW-HT) analyses in an effort to enhance sensitivity to organics in the LT analysis.

Results/Discussion: Evolved CO₂ was detected in both the BB-surface and WW-subsurface materials. The BB released CO₂ between 300 and 700°C with a peak at 520°C (Fig. 1). This CO₂ release coincided with an evolved O₂ release peak at 460°C suggesting that organic combustion could have contributed to the evolved CO₂.

The WW sample was characterized by at least two CO₂ releases. The WW-LT sample evolved CO₂ beginning at 250°C and peaked at 340°C as this was the maximum temperature of this analysis. After cooling, the same WW sample was heated again to 1000°C (WW-HT). The evolution of CO₂ began at ~370°C in the WW-HT analysis which is consistent with the previous WW-LT analysis that should have decomposed most CO₂ evolving species below 340°C. The first WW-HT CO₂ release (CO₂-1) peaked at 524°C and was followed by second CO₂ (CO₂-2) release that gradually rose for the remainder of the analysis (Fig. 1) and did not peak until the sample began to cool down (data not shown) [1]. An inefficient MS ion-pump was believed to have prevented the CO₂-2 release from returning to baseline level before reaching 1000°C. The WW-HT CO₂-1 peak was consistent with detection of organics or Fe-carbonate, while the CO₂-2 release was attributed to Fe-Ca-carbonate [1].

Similar CO₂ evolving species may be present in the BB and WW materials. The CO₂ releases detected in the WW-LT and first release in WW-HT when combined, yield a CO₂ release at temperatures similar to the BB CO₂ release (Fig. 1). Furthermore, both the BB and WW-HT have CO₂ peaks at similar temperatures. This suggests that similar CO₂ evolving species may be present in the BB surface and WW subsurface icy-soil. Following the interpretation of the WW sample, the BB CO₂ may have been derived from organic-C and/or Fe-carbonate.

Gale Crater eolian materials evolved CO₂ at temperatures similar to the Northern Plains samples (Fig. 1), suggesting that similar carbon bearing phases could be

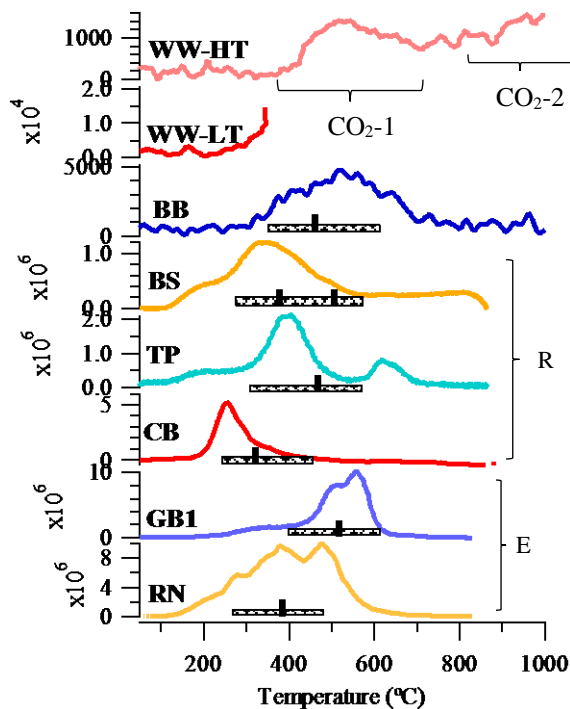


Fig. 1. Evolved CO_2 detected by TEGA from the BB and WW (WW-LT, and WW-HT) samples compared to SAM analyses of the eolian (E) RN, GB1, and sedimentary rock (R) CB, TP, BS samples. Cross-hatched bars indicate temperature range detected of O_2 evolution (data not shown). Solid tick marks on bars indicate O_2 peak temperature.

present at both landing sites. Evolved O_2 in the RN, and GB1 samples suggests organic combustion could have contributed to evolved CO_2 . The RN and GB unconsolidated eolian fines tended to evolve CO_2 at mostly higher temperatures than the sedimentary rock (Fig. 1). Similarly BB and WW evolved most of their CO_2 at temperatures higher than the Gale Crater sedimentary rock. These results demonstrate that the loose surface materials at the Northern Plains and Gale Crater landing sites could contain similar carbon species.

The evolved CO_2 temperatures for the Gale Crater sedimentary rock were consistent with organic-C sources as their temperatures were too low to be derived from carbonate sources. The Gale Crater TP sample did have a second less-intense high-temperature CO_2 release (620°C peak) (Fig. 1) that was consistent with carbonate. The sedimentary rock samples also evolved oxygen (Fig.1) at similar CO_2 evolution temperatures suggesting organic combustion could have contributed to evolved CO_2 .

Contrary to the sedimentary rock, the higher evolved CO_2 temperatures of the Gale Crater eolian (RN, GB) and Northern Plains (BB, WW) samples were consistent with both organic-C and/or carbonate sources. However, higher CO_2 evolution temperatures in RN, GB1,

BB, and WW indicate that carbonate could also have contributed to evolved CO_2 . Measured soil solution pHs (7.8) at the PL landing site, suggested dissolved soil solution carbonate [5]. Because these two landing sites are thousands of km apart, suggests the loose unconsolidated eolian sediment and soils could also be similar across Mars and consist of organic-C and carbonate.

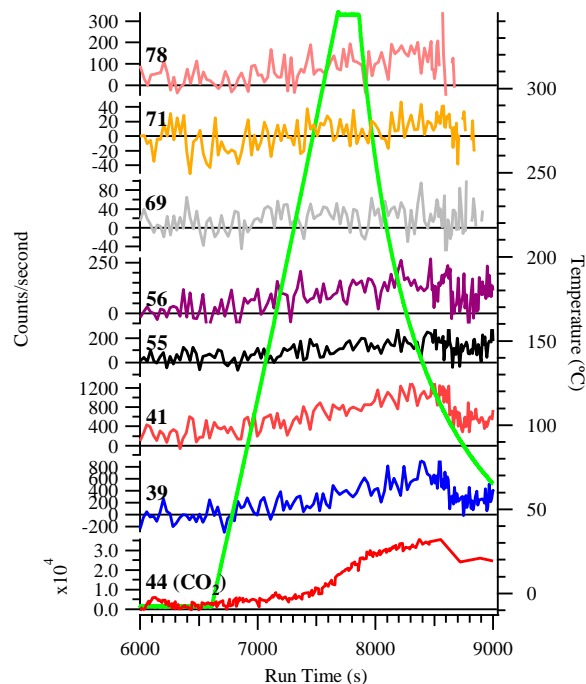


Fig. 2. TEGA detection of select masses (left axis) with temperature (green plot) (right axis) versus time from the WW-LT analysis.

Possible detections of mass 39 (C_3H_3) and 41 ($\text{C}_3\text{H}_5, \text{C}_2\text{H}_3\text{N}$) fragments were noted in the more sensitive TEGA WW-LT analyses (Fig. 2) at temperatures $<340^\circ\text{C}$. A gradual rise of these masses with CO_2 just above background suggest these organic fragments could be present in the WW sample. These masses have not been detected above background levels at low temperatures in the Gale Crater samples.

Conclusions: Evolved CO_2 detections in the Northern Plains and Gale Crater suggests that surface C could be present in all surface materials across Mars. The possible detection of organic-C suggests that the radiation environment has not completely eliminated near surface organics on Mars. Widespread presence and carbonate concentrations existing throughout potentially younger eolian surface materials can be used to constrain evolution of martian atmospheric CO_2 [e.g., 6].

References: [1]Boynton W.V. et al.(2009)*Science* 325,61 [2]Leshin,L.A. et al. (2013)*Science* 341. [3] Ming, D.W. et al.(2014)*Science* 343. [4]Sutter et al. (2017) *JGR*, 122, doi:10.1002/2016JE005225. [5]Hecht M.H. et al., (2009) *Science* 325,64. [6]Hu, R. et al.(2015)*Nature Comm* 6 10.1038/ncomms10003