EVOLVED GAS ANALYSES OF SEDIMENTARY MATERIALS IN GALE CRATER, MARS: RESULTS OF THE CURIOUSITY ROVER'S SAM ANALYSIS AT MARS (SAM) INSTRUMENT FROM YELLOKNIFE BAY TO THE STIMSON FORMATION. B. Sutter1,2, A.C. McAdam1, E.B. Rampe1,2, D.W. Ming2, P.R. Mahaffy3, R. Navarro-Gonzalez4, J.C. Stern5, J.L. Eigenbrode3, P.D. Archer1,2, Jacobs, 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

Introduction: The Sample Analysis at Mars (SAM) instrument aboard the Mars Science Laboratory rover has analyzed 10 samples from Gale Crater. All SAM-evolved gas analyses have yielded a multitude of volatiles (e.g., H2O, SO2, H2S, CO2, CO, NO, O2, HCl) [1,2,3,4,5]. The objectives of this work are to 1) Characterize the evolved H2O, SO2, CO2, and O2 gas traces of sediments analyzed by SAM through sol 1178. 2) Constrain sediment mineralogy/composition based on SAM evolved gas analysis (SAM-EGA), and 3) Discuss the implications of these results relative to understanding the geochemical history of Gale Crater.

Materials & Methods: Rocknest (RN) is an eolian drift material that occurs 50 m from the John Klein (JK) and Cumberland (CB) lacustrine mudstones. Windjana (WJ) is a fluvial sandstone stratigraphically higher and located 4 km to the SW of JK and CB. The Confidence Hills (CH), Mojave (MJ), Telegraph Peak (TP), and Buckskin (BK) fluvial/lacustrine mudstones occur above WJ near the base of Mt. Sharp. The unaltered Big Sky (BY) and altered Greenhorn (GH) materials are eolian sandstones that are above BK (Fig. 1). Rocknest was acquired with a scoop while the other samples were drilled (1.6 cm diameter x 6 cm deep) from sedimentary rock. All analyzed samples were sieved to less than 150 μm.

Samples delivered to the SAM oven were heated (~35 °C min−1) from ambient to ~−860°C. The evolved gases were swept from the oven by a He stream (~0.8 scm; 25 mbar) to a quadrupole mass spectrometer (QMS) for identification. Evolved gases (e.g., H2O, CO2, etc.) released at characteristic temperatures from volatile bearing phases were used to identify mineral or organic phases.

Results/Discussion: Water – All samples contain H2O (~1-2 wt.%, Fig. 1) and have releases ~500°C that can be attributed to atmospherically adsorbed water, structural water in amorphous phases, phyllosilicate interlayer H2O, hydrated salts (e.g. bassanite, perchorlate, chlorate,), and/or akaganeite dehydroxylation [1]. The 450-500°C peaks in the CH, MJ, and TP traces can be attributed to H2O from dehydroxylation of jarosite detected by CHEMIN [7]. The 750-800°C peaks in CB, JK, and MJ traces result from smectite dehydroxylation [2]. The wide ~500°C peak in BK, BY, and GH can be attributed to glass matrix, vesicle, and/or trapped magmatic water in x-ray amorphous phases (e.g., volcanic glass) [8].

SO2 - Sulfur dioxide was mostly released above 500°C (Fig. 2). More SO2 evolved from WJ, Murray Formation (CH, MJ, TP, BK), and altered Stimson (GH) (2.6 to 6.5 wt.% SO2) than Sheepbed Mudstone (CB, JK) and less altered Stimson (BY) (0.2-0.7 wt.% SO2) samples. The SO2 release temperatures are consistent with Fe- or Al-sulfates but the non-detection of Fe or Al sulfates by CheMin in RN, WJ, BY, and GH suggest that these sediments contain amorphous or trace crystalline Fe and/or Al sulfate or adsorbed sulfate [3,9,10]. CheMin detection of sulfides in JK and CB suggest that partial Fe-sulfide oxidation to Fe-sulfate may have released SO2. Some SO2 evolved from in CH, MJ, and TP is attributed to the thermal decomposition of jarosite detected by CheMin [7]. Jarosite cannot account for all of the evolved SO2; thus some SO2 could be derived from amorphous Fe/Al sulfates. CB exhibited a low SO2 release at ~300°C (Fig. 2), which is coincident with O2 evolution from oxochlorine thermal decomposition (not shown) and likely resulted from sulfide oxidation directly to SO2. Another possible source of evolved SO2 in some sediments (e.g., RN, JK, CB, GH) could be

Figure 1. Evolved water detected by SAM-EGA. Elevation and sedimentary rock units are designated: Sheepbed mudstone (SH), Kimberly sandstone (K), Murray mudstone (M), Stimson sandstone (ST).
through catalytic reactions of Ca- and/or Mg-sulfate with other minerals in Gale Crater sediments [11].

\( \text{CO}_2 \) \( - \) \( \text{CO}_2 \) releases have been detected over the entire SAM temperature range (Fig. 3). Atmospherically adsorbed \( \text{CO}_2 \) and SAM background decomposition products are candidates for \( \text{CO}_2 \) evolved at \(<\)200°C. All samples exhibit \( \text{CO}_2 \) releases between 200 and 450°C which could be contributions from SAM background and/or martian organics. However, oxalate derived from meteoritic sources could also evolve \( \text{CO}_2 \) between 200 and 700°C [12]. \( \text{CO}_2 \) releases between 500 and 700°C are also consistent with carbonates in RN, TP, and GH. Subtle \( \text{CO}_2 \) releases \( >700°C \) are candidates for a refractory organic source in RN, CH, MJ, BK, BY, and GH [13].

\( \text{O}_2 \) \( - \) All samples evolve \( \text{O}_2 \) below 550°C with three sediments (CH, MJ, BK) yielding \( \text{O}_2 \) releases above 600°C (Fig. 4). All \( \text{O}_2 \) releases below 550°C are attributed to oxychlorine (e.g., chlorate/perchlorate) decomposition while sulfate thermal decomposition is likely providing \( \text{O}_2 \) above 600°C. The variation of \( \text{O}_2 \) release temperature below 500°C is likely caused by variation in oxalate ions and/or variation in mineral species that catalyzed oxychlorine thermal decomposition.

Conclusions: SAM-EGA results demonstrate that Gale Crater sediments have been exposed to alkaline (phyllosilicates, carbonates) and acidic solutions (Fe/Al-sulfate). Despite the presence of highly oxidized minerals (chlorates/perchlorates), \( \text{CO}_2 \) evolution temperatures are consistent with the existence of carbon oxidation states ranging from reduced carbon in Gale Crater sediments though oxidized C (oxalates, carbonates). These results demonstrate that despite oxidizing/acidic geochemistry, the preservation of reduced organic biosignatures on Mars is possible.