MARS PHOENIX SCOUT THERMAL EVOLVED GAS ANALYZER (TEGA) DATABASE: THERMAL DATABASE DEVELOPMENT AND ANALYSIS. B. Sutter[1,2], D. Archer[1,2], P.B. Niles[2], T.C Stein[3], D. Hamara[4], W.V. Boynton[4], and D.W. Ming[2], [1]Jacobs, Houston TX 77058 (brad.sutter-2@nasa.gov), [2]NASA Johnson Space Center, Houston, TX, [3]Washington Univ. St. Louis, MO, [4]Univ. of Arizona, Tucson, AZ.

Introduction: The Mars Phoenix Scout Lander mission in 2008 examined the history of water, searched for organics, and evaluated the potential for past/present microbial habitability in a martian arctic ice-rich soil [1]. The Thermal Evolved Gas Analyzer (TEGA) instrument measured the isotopic composition of atmospheric CO_2 and detected volatile bearing mineralogy (perchlorate, carbonate, hydrated mineral phases) in the martian soil [2-7]. The TEGA data are archived at the Planetary Data System (PDS) Geosciences Node but are reported in forms that require further processing to be of use to the non-TEGA expert. The soil and blank TEGA thermal data are reported as duty cycle and must be converted to differential power (mW) to allow for enthalpy calculations of exothermic/endothermic transitions. The exothermic/endothermic temperatures are also used to determine what phases (inorganic/organic) are present in the sample.

The objectives of this work are to: 1) Describe how interpretable thermal data can be created from TEGA data sets on the PDS and 2) Provide additional thermal data interpretation of two Phoenix soils (Baby Bear, Wicked Witch) and include interpretations from three unreported soils (Rosy Red 1, 2, and Burning Coals).

TEGA Calorimetry Data Processing: The TEGA thermal data are currently reported in the PDS as oven and shield duty cycle. Duty cycle is a fractional value of the time (ms) which power was applied over a 300 ms interval to maintain a particular oven or shield temperature or to achieve a particular temperature at a certain time. The conversion of the duty cycle into power is calculated where Power (W) = voltage (V) * current (Amps) * duty cycle. The raw voltage and raw current data in the PDS are noisy and were fit to a 6th order polynomial to provide "cleaner" data for power calculations (Fig. 1). The user is advised to use the oven power data for determining the thermal properties of the soil sample as the oven is in more intimate contact with the sample than the oven shield.

Once the power has been determined, differential power must be calculated. This step involves determining the reference power that will be subtracted from the calculated power. The reference power plot is generated by fitting a 5th order polynomial to the calculated power data and subtracting that fitted plot from the power data to yield the differential power plot (Fig. 1).This results in endothermic peaks pointing up and exothermic peaks pointing down (Fig. 1) as was done in [2]. Calorimetry convention, however, dictates that the inverse be presented (endotherm-down, exotherm-up) and thus the data was subsequently multiplied by -1 for presentation

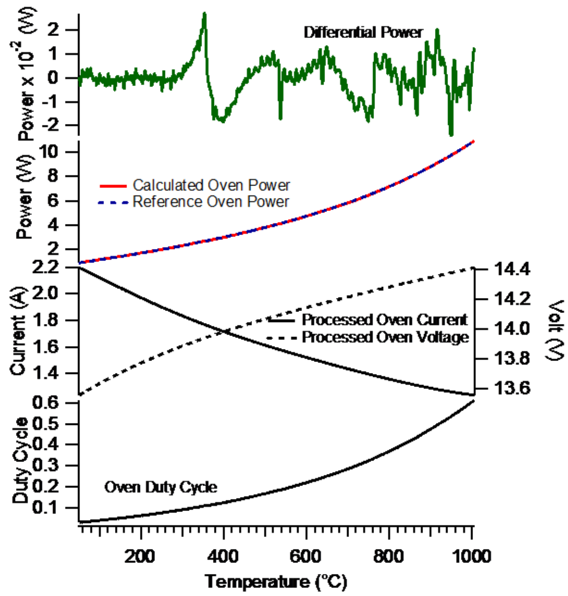

Fig. 1. Oven duty cycle, processed oven current and voltage, oven power and oven power fit and differential oven power for the first high temperature heating of the of Burning Coals sample (sol 129).

purposes in Fig. 2. Because all eight TEGA ovens could not be fabricated with identical coil wrappings, the amount of power (V*A*duty cycle) required to maintain a particular temperature and temperature ramp rate varied between ovens. All TEGA ovens had the same temperature ramp rate (20°C min^{-1}), but the power required to maintain those ramp rates varied from oven to oven. This difference is why one set of reference power settings as a function of temperature cannot be calculated in advance to provide a single reference power plot for all ovens. A reference power plot must, instead, be calculated for each oven. This approach is not ideal because sample thermal transitions could be argued to affect the calculated reference fit. However, the power range during the run occurs over 10 W whereas detectable thermal transitions in mineral phases typically occur in the 10 to 200 mW range. The reference power plot fit is thus not likely to be affected by the lower power thermal transitions that become apparent when the fitted reference power plot is subtracted from the calculated power (Fig. 1). The fitted power plot does not appear to be any different from the calculated power plot (Fig. 1). However, once the subtraction occurs, a difference is evident at the mW range as indicated by the differential power plot (Fig. 1). Power plots will be added to the

PDS to enhance user access to interpretable TEGA thermal data..

The final step in the differential power processing was the subtraction of the second heating from the first heating. All samples were heated twice. The first heating captures all the thermal transitions associated with the sample and any background (oven) thermal transitions. The sample was then heated under the same conditions again on the next day to capture only background transitions. The differential power day 2 data was subtracted from the day 1 data to capture the differential power data attributed to the thermal characteristics of the soil. The resulting differential power plot was then multiplied by -1 to yield a plot where endothermic and exothermic peaks point down and up, respectively in order to follow literature convention (Fig. 2).

TEGA Calorimetry Results: The TEGA instrument consisted of eight ovens connected to a magnetic sector mass spectrometer (MS) [2]. The MS detected evolved gases during soil heating. Five soils and one blank (empty oven) were examined by heating samples from Mars ambient to 1000°C at 20°C min^{-1} under a N_2 carrier gas (1 sccm) for the first three soils analyzed: Baby Bear (BB), Wicked Witch (WW), and Rosy Red 1 (RR1). Gas over pressuring difficulties encountered with RR1 did not permit carrier gas use for Burning Coals (BC) and Rosy Red 2 (RR2).

BB, RR1, and RR2 were surface samples while WW and BC were from the subsurface. The BB soil occurred at the surface near the boundary of two polygons [1]. All remaining samples were acquired within the Wonderland polygon. The WW sample was a sublimation lag of icy soil at the ice table 5 cm below the surface. The BC subsurface sample was acquired just above the ice table [1].

Three endothermic transitions were observed in the surface Baby Bear (BB) sample (Fig. 2). Endotherm *a* is consistent with kieserite dehydration and/or dehydroxylation of Fe-oxyhydroxides, nontronite, or kaolinite. Endotherm *b* coincides with evolved water that is consistent with dehydroxylation of saponite, montmorilonite, chlorite or serpentine [3]. Endotherm *c1* has no associated gas release but is consistent with decomposition of $MgSO_4$ which was detected by Wet Chemistry Laboratory [8]. Analyses of kieserite by TEGA analog instrument yields similar *c*-type endotherm (data not shown). The non-detection of SO_2 may be related to poor sensitivity of the mass spectrometer to SO_2 or thermal soil reactions that scrubbed SO_2 preventing SO_2 detection [9].

The two surface Rosy Red (RR1, RR2) samples have exotherms *d1/d2* as well has endotherms *c2/c3* in common with BB (Fig. 2). The source of the d1/d2 exotherm is unknown at this time. Endotherms *c2/c3* similar to BB *c1*, could be derived from $MgSO_4$ *decomposition*. The two RR2 endotherms *e* and *f* are consistent with carbonates of varying Ca contents.

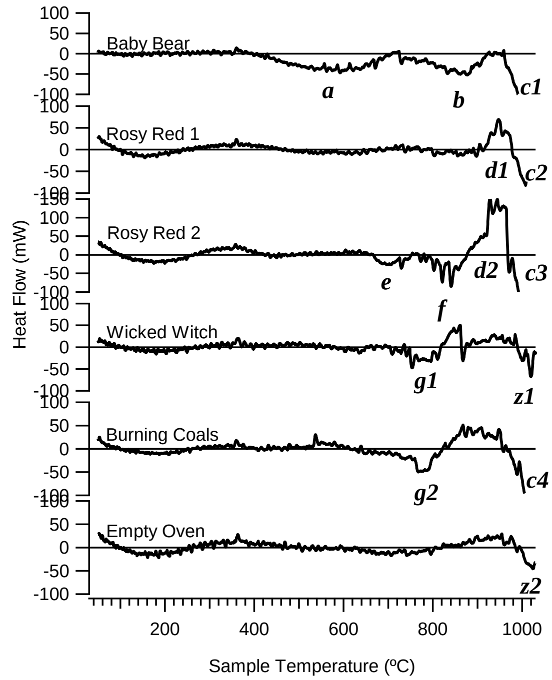

Fig. 2. TEGA differential power results from the Phoenix Landing site 5 soils and empty oven.

The subsurface Wicked Witch sample had one endotherm *g1* associated with CO_2 release which is consistent with a calcium rich carbonate [2,6,7]. The high temperature endotherm *z1* has similar low intensity as the empty oven *z2* endotherm suggesting this is related to instrumentation.

The subsurface Burning Coals (BC) sample has endotherm *g2* similar to WW consistent with Ca rich carbonate and endotherm *c4* similar to BB, RR1 and RR2 consistent with $MgSO_4$. The *c* endotherms all have greater intensity than the *z* endotherms suggesting the *c* endotherms are sample related.

The phase identifications for the RR and BC soils are tentative at this time due to difficulties in assessing evolved gases detections related to over pressuring difficulties encountered with these samples. Detailed analyses of evolved gas data will be presented in the future to assist in the thermal data interpretation of the RR and BC samples.

References: [1] Arvidson et al. (2009) *JGR, 114*. [2] Boynton et al. (2009) *Science, 325*, 61. [3] Smith et al. (2009) *Science, 325*, 58. [4] Hecht et al. (2009) *Science, 325*, 64. [5] Niles et al. (2010) *Science, 329*, 1334. [6] Cannon et al. (2012) *GRL, 39*. [7] Sutter et al. (2012) *Icarus 218*, 290. [8] Kounaves et al. (2010) *GRL, 37*. [9] Sutter et al. (2011) *NATAS Conf. 39th*, 244.