CHEMICAL AND MINERALOGICAL CHARACTERIZATION OF A HEMATITE-BEARING RIDGE ON MAUNA KEA, HAWAII: A POTENTIAL MINERALOGICAL PROCESS ANALOG FOR THE MOUNT SHARP HEMATITE RIDGE. T. G. Graff1, R. V. Morris2, D. W. Ming2, J. C. Hamilton3,4, M. Adams3, A. A. Fraeman5, R. E. Arvidson6, J. G. Catalano5, and S. A. Mertzman6, 1Jacobs, NASA JSC, Houston, TX 77058 (trevor.g.graff@nasa.gov), 2NASA JSC, ARES, Houston, TX, 3University of Hawaii, Hilo, HI, 4Pacific International Space Center for Exploration Systems, Hilo, HI, 5Washington University in St. Louis, St. Louis, MO, and 6Franklin and Marshall College, Lancaster, PA.

Introduction: The Mars Science Laboratory (MSL) rover Curiosity landed in Gale Crater in August 2012 and is currently roving towards the layered central mound known as Mount Sharp [1]. Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) hyperspectral data indicate Mount Sharp contains an ~5 km stratigraphic sequence including Fe-Mg smectites, hematite, and hydrated sulfates in the lower layers separated by an unconformity from the overlying anhydrous strata [1,2,3].

Hematite was initially detected in CRISM data to occur in the lower sulfate layers on the north side of the mound [2]. [3] further mapped a distinct hematite detection occurring as part of a ~200 m wide ridge that extends ~6.5 km NE-SW, approximately parallel with the base of Mount Sharp. It is likely a target for in-situ analyses by Curiosity.

We document here the occurrence of a stratum of hematite-bearing breccia that is exposed on the Puu Poliahu cinder cone near the summit of Mauna Kea volcano (Hawaii) (Fig.1). The stratum is more resistant to weathering than surrounding material, giving it the appearance of a ridge. The Mauna Kea hematite ridge is thus arguably a potential terrestrial mineralogical and process analog for the Gale Crater hematite ridge. We are acquiring a variety of chemical and mineralogical data on the Mauna Kea samples, with a focus on the chemical and mineralogical information already available or planned for the Gale hematite ridge.

Samples and Methods: We report here data for two hand samples from the hematite ridge (HW13MK001A and HW13MK029) and two hand samples from nearby subparallel strata (HW13MK025 and HW13MK032). The presence of specular hematite was obvious in the field from the grey color (hematite cement) and individual up to mm-sized individual crystals.

Size fractions (<150 μm and 500-1000 μm) were obtained by grinding and dry sieving. Major element chemistry with weight loss on ignition (LOI) and Fe-redox was obtained on bulk sample. VNIR spectra (ASD: 0.35-2.5 μm) and XRD powder patterns (CheMin-IV: 4-50° 2θ Co) were obtained on the <150 μm size fraction of bulk sampled obtained by grinding and dry sieving.

Results: Major element chemistry (Table 1) shows that the breccia samples are highly altered compared to the average composition of unaltered Hawaïan tephra (AUHT from [4]). The ridge samples have 28-43 wt.% Fe₂O₃T compared to 12 wt.% in AUHT. The other two samples contain high concentrations of SO₃ (~9 wt.%) consistent with acid sulfate alteration [e.g., 4].

### Table 1. Major element chemistry.

<table>
<thead>
<tr>
<th></th>
<th>AUHT</th>
<th>001A</th>
<th>029</th>
<th>025</th>
<th>032</th>
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<tbody>
<tr>
<td>SiO₂</td>
<td>49.69</td>
<td>30.27</td>
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<td>Al₂O₃</td>
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<td>9.45</td>
<td>17.09</td>
<td>27.67</td>
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<tr>
<td>Cr₂O₃</td>
<td>0.003</td>
<td>0.005</td>
<td>0.004</td>
<td>0.005</td>
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<tr>
<td>Fe₂O₃T</td>
<td>12.02</td>
<td>43.49</td>
<td>27.52</td>
<td>4.38</td>
<td>25.95</td>
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<tr>
<td>MnO</td>
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<td>0.37</td>
<td>0.44</td>
<td>0.06</td>
<td>0.08</td>
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<tr>
<td>MgO</td>
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<td>8.82</td>
<td>3.57</td>
<td>1.21</td>
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<tr>
<td>CaO</td>
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<td>2.00</td>
<td>4.31</td>
<td>3.64</td>
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<td>Na₂O</td>
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<td>0.89</td>
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<td>K₂O</td>
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<td>P₂O₅</td>
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<td>0.59</td>
<td>1.37</td>
<td>1.40</td>
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<tr>
<td>SO₃</td>
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<td>nd</td>
<td>0.45</td>
<td>8.86</td>
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<tr>
<td>Total</td>
<td>99.71</td>
<td>99.80</td>
<td>99.76</td>
<td>99.51</td>
<td>100.06</td>
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<tr>
<td>LOI</td>
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<td>5.63</td>
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<td>FeO</td>
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<td>1.67</td>
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<td>Fe₂O₃</td>
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<td>42.84</td>
<td>25.97</td>
<td>3.46</td>
<td>26.78</td>
</tr>
</tbody>
</table>

AUHT = Average Unaltered Hawaïan Tephra

The chemical trends are shown more clearly in Figure 2 where the data are ratioed to AUHT. The XRD patterns (not shown) confirm the presence of hematite in these samples. For the SO₃-rich samples, Al₂O₃>Fe₂O₃ for HW13MK025 and vice versa for HW13MK032, suggesting (and confirmed by XRD)
alunite and jarosite, respectively. Both minerals have 
been previously reported on Mauna Kea [e.g., 4,5]  
The XRD patterns (not shown) also show the presence 
of clay minerals as indicated by the presence of the 
001 and 02l peaks near 1.5 and 0.45 nm, respective-
ly. Clay minerals are also indicated by the VNIR spec-
tra (Figure 3; compare with spectra published by [5]) 
for the hematite ridge samples (Mg-OH = 2.32 µm; Al-
OH = 2.21 µm). Spectral features for the alunite and 
jarosite, inferred by chemical evidence and assigned by 
XRD, are also present in the VNIR spectra (jarosite = 
1.85 and 2.27 µm; alunite = 1.77 and 2.18 µm). The 
spectrum for HW13MK032 may also include a contri-
bution from kaolinite (or halloysite) at 2.18 and 2.21 
µm [5].

Discussion: Chemical and mineralogical data doc-
ument the presence of a hematite-bearing ridge on 
Mauna Kea volcano. Clay minerals are associated with 
the hematite and also with sulfate-bearing phases (alu-
nite and jarosite) located in strata proximate to the 
ridge. Sulfate-bearing phases were not detected on the 
hematite ridge itself. We tentatively suggest an acid-
sulfate process where Fe2+ is leached from basaltic 
tephra (reducing conditions not required) and alunite 
is precipitated. Subsequent Fe2+ oxidation precipitates 
Fe3+ as either jarosite or hematite. Hematite is favored 
over jarosite under hydrothermal conditions (forced 
hydrolysis) [6]. The alunite fingerprint may not be as 
significant on Mars because the Al2O3, Na2O, and K2O 
contents of martian surface materials (e.g., ~10, ~2, 
and ~0.5 wt.%, respectively [7]) are less than the cor-
responding values for AUHT (Table 1).

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sources (BLNR), and the cultural Hawaiian Kahu Kū 
Mauna Council (KKMC). We are greatly appreciative 
of the shared knowledge and sustained efforts of these 
organizations in the protection and preservation of the 
unique cultural and natural resources of Mauna Kea.

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