CRATERS OF THE MOON NATIONAL MONUMENT BASALTS AS ANALOGS FOR MARTIAN ROCKS AND METEORITES. Christopher T. Adcock[1], Arya Udry[1], Elisabeth M. Hausrath[1], and Oliver Tschauner[1,2], [1] Department of Geoscience, University of Nevada, Las Vegas (adcockc2@unlv.nevada.edu), [2] High Pressure Science and Engineering Center, University of Nevada, Las Vegas.

Introduction: Craters of the Moon National Monument (COTM) in Idaho, USA, is a 1600 km^2 arid to semi-arid region that is home to over 60 relatively young (2,050 to 18,340 years before present [y.b.p.]), basalt lava flows. The region has been used as a lunar or martian planetary analog since the late 1960's because of landscape features such as caves, secondary minerals similar to some which may be on Mars, and the basaltic terrain and geomorphology [1-9]. In particular, the high phosphate content of some of the flows is of both planetary and astrobiological interest. Phosphate is a bio-essential compound and Mars in general has elevated phosphorus compared to Earth [10, 11]. Usui et al. (2008) [6] suggested some of the high phosphate flows of COTM could be analogs for martian rocks like the Gusev Crater Wishstone class, although they did not indicate specific flows.

Following previous authors, we examined the chemistry and petrogenesis of COTM basalts compared to basaltic martian surface rocks, martian meteorites, and meteorite clasts to investigate compositional analogs for martian rocks or pre-shock analogs for martian meteorites. We then examined the chemical weathering rinds of the basaltic flows at COTM as indicated by changes in porosity depth over time to determine a field weathering relationship at COTM. COTM basalts were then compared to weathered rocks at Gusev Crater, Mars, to investigate aspects of chemical weathering on that planet. The work presented here is part of a forthcoming paper from American Mineralogist by the same authors [12].

Methods: We compared the chemistry and CIPW norms of 8 COTM flow basalt eruptive periods to a range of martian meteorites, clasts within martian meteorites, and basaltic rocks analyzed on Mars. Analysis data were sourced from the literature in the form of microprobe analyses for COTM [13-16] and Alpha Particle X-ray Spectrometer (APXS) from rover missions or microprobe analyses for the martian materials (sources compiled in [12]). This method generated more than 600 comparisons of COTM and martian materials. Therefore, we used a sum of squares best-fit method, followed by calculated CIPW norm comparisons between rocks with the best fits to determine the most similar compositional matches.

To study field weathering relationships at COTM, we examined a set of six COTM basalts spanning the range of flow ages in the region (2,050 to 18,340 y.b.p.) [14, 15]. Samples from each of the six flows were collected and prepared as petrographic thin sections. Anhydrous preparation methods and epoxy impregnation were used to preserve weathered material. Thin sections were analyzed by Scanning Electron Microscopy (SEM) using backscattered electron (BSE) imagery and Energy Dispersive Spectroscopy (EDS) in a JEOL JSM 5600 (EMiL Facility, UNLV). Analyses and imaging were performed at 20 KeV. Subsequent off-line image analysis was performed using *Adobe Photoshop CS6* software. Relative changes in porosity and fracturing with depth (depth of chemical weathering) were investigated using backscattered electron (BSE) image mosaics collected from the weathered surface into unweathered core material to a depth of at least 1200 μm into the sample. Plots of porosity with depth were constructed from the mosaics by first aligning, rotating, and cropping the mosaic images such that 10 μm thick "slices" parallel to the weathered sample surface could be processed and contrast enhanced to determine the amount of open micro-porosity as an area % value. The resulting values were recorded and then plotted against depth. Depth of developed porosity was then judged in three different ways (detailed further in [12]).

Results and Discussion: Results of our comparative chemical analysis suggest COTM basalts are generally more petrologically evolved and differ from the martian materials – with some exceptions. COTM rocks of the >18,000 year old Kimama flow have relatively high FeO, TiO_2, and P_2O_5 contents similar to the Wishstone and Watchtower class rocks analyzed at Gusev Crater by the Mars Exploration Rover *Spirit*. This is consistent with the previous work by Usui et al. (2008) [6]. The youngest basalts of COTM, such as those of the Minidoka (3890 y.b.p.) and Blue Dragon (2050 y.b.p.) flows have similarities in SiO_2, alkali contents, and mineralogical norms with select clasts in meteorite Northwest Africa – NWA – 7034. These similarities between COTM and Mars over a range of flow ages suggest that COTM basalts have the potential to shed important light on specific igneous processes occurring on Mars, including martian metasomatization processes that may have occurred to enrich P in rocks such as Wishstone class or Cl enrichments in a number of other martian rocks minerals [6, 17]. Future data from Mars may yield more compositional analogs from COTM.

Results of our investigation of chemical weathering at COTM indicate that depths of incipient weathering in COTM rocks increase with time at an average rate of 2.75×10^{-2} μm y^{-1} with R^2 of 0.59 to 0.88 depending on the method used (Figure 1). This is comparable to other terrestrial advance rates [18-23]. Surprisingly, this rate also indicates chemical weathering strongly outpaces physical weathering even in this arid to semi-arid environment [24]. Chemical weathering is primarily of the matrix glass (Figure 2), and it may be functioning as the profile-controlling phase [25]. Weathering rates of glass and other minerals can help constrain conditions (e.g. pH, temperature) of alteration, and so weathering at COTM may have implications for chemical weathering in glass-rich rocks on Mars [26-28]. Of the altered martian rocks we compared to COTM, altered surfaces of the Mazatzal rock at Gusev Crater show the most similarities to weathered surfaces at COTM, and comparisons using COTM as an analog suggest Gusev Crater martian rocks have undergone significantly more aqueous alteration than that experienced by basaltic flows at COTM.

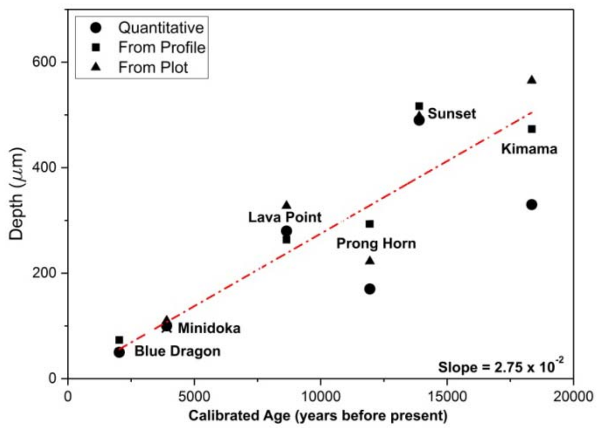

Figure 1. Depth of developed porosity versus age for all interpretation approaches. Average slope of linear fit (red dashed line) is 2.75 x 10^{-2}. Modified after [12].

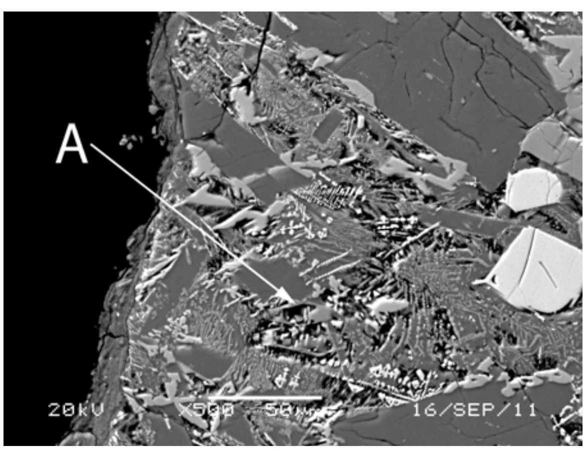

Figure 2. BSE image of Kimama basalt in thin section. Image shows development of porosity (A). The porosity appears to be from the dissolution of glass in the groundmass. Scale bar = 50 µm.

Further details can be found in the forthcoming article *Craters of the Moon National Monument Basalts as Unshocked Compositional and Weathering Analogs for Martian Rocks and Meteorites* in American Mineralogist [12].

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