DETERMINING SULFUR CONCENTRATIONS IN A BASALTIC FLOOD ERUPTION: TYING CHEMISTRY TO ATMOSPHERIC MODELING

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Introduction: Flood basalt deposits have been documented on Earth as well as on other terrestrial planets (e.g. Mars) [1-3]. The massive size of these eruptions and their relatively long duration (years to centuries) results in enormous quantities of gasses (e.g., CO_2, H_2O, SO_2) released into the atmosphere [4] and these eruptions have the ability to alter planetary climates and influence habitability. Flood lava eruptions have been observed and documented in the past, but the 2014-2015 Holuhraun eruption in Iceland is the most well-documented event to be monitored and sampled in real-time [5-8]. The flow was emplaced between August 2014 and February 2015 and covers ~85 km^2. In September 2014, Schmidt et al. (2015) observed a dramatic increase in the daily output of SO_2 and documented the presence of SO_2 at extreme distances from the source. From these observations and scarce records of previous flood basalt gas emissions, a clear need for improved atmospheric and climate models as a function of flood basalt gas emission was identified.

Here, we present preliminary geochemical results from basalts sampled along the Holuhraun lava flow during a 2018 Goddard Instrument Field Team expedition to the Icelandic Highlands. These data will improve current atmospheric and climate models and help assess how similar eruptions can impact planetary habitability.

Sample Descriptions and Analysis Methods: Geochemical results are presented for 5 basalts representing variation in location, cooling rate, and oxidation states (Fig. 1, Table 1). The basalts were characterized by X-ray fluorescence (XRF) spectroscopy to measure bulk rock composition, X-ray diffraction (XRD) to assess the mineralogy, and by evolved gas analysis mass spectrometry (EGA-MS) in which samples are heated and volatiles evolved are measured by a mass spectrometer (e.g., [9]) to detect and characterize any S-bearing volatiles.

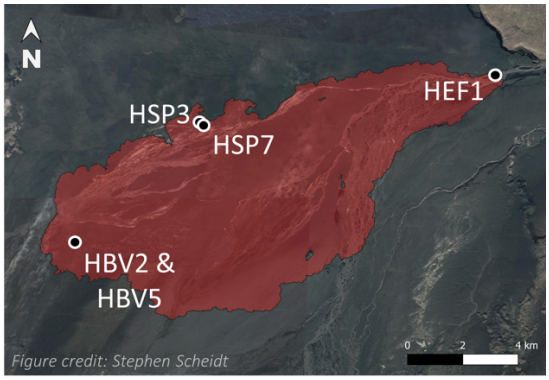

Figure 1. Holuhraun lava field (red) and location of sample collection.

Table 1. Sample descriptions and XRF results

	Samples	Location	FeO (wt. %)	Fe_2O_3 (wt. %)	SO_3 (wt. %)	S (ppm)
HBV2	massive basalt	vent	10.15	2.30	0.24	30.0
HBV5	red scoria	vent	2.02	11.87	0.42	52.5
HEF1	massive basalt	toe of flow	10.60	2.29	0.22	27.5
HSP3	massive basalt; spreading center	flow margin	10.77	1.75	0.17	21.2
HSP7	a'a' basalt; slow-cooling wall	flow margin	9.84	3.07	0.22	27.5

Sulfur Detections in Holuhraun Basalts: Chemical analyses of the 5 basalts show SO_3 abundances between 0.17-0.42 wt. % (Table 1). With exception of HSP7, no S-bearing mineral phases were detected with XRD. A sulfide, possibly pyrite, was identified at trace abundances (~0.2 wt. %) in HSP7 (Fig. 2). SO_2 was evolved during EGA of HBV2 and HBV5. The temperature of the most intense SO_2 evolution, near 550 °C from both samples is consistent with the presence of Fe-sulfates or Fe-sulfides in both samples (Fig. 3). These minerals were not detected by XRD but may be trace minerals present at abundances below the instrument detection limit. This SO_2 could also derive from S in X-

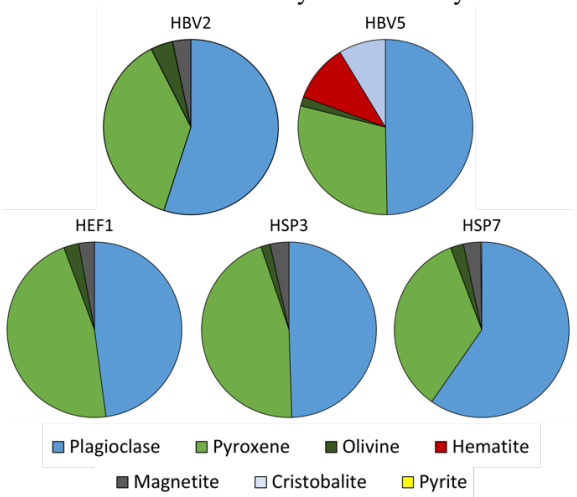

Figure 2. Mineralogy of basalts from the Holuhraun lava field.

ray amorphous material in the samples (e.g., basaltic glass).

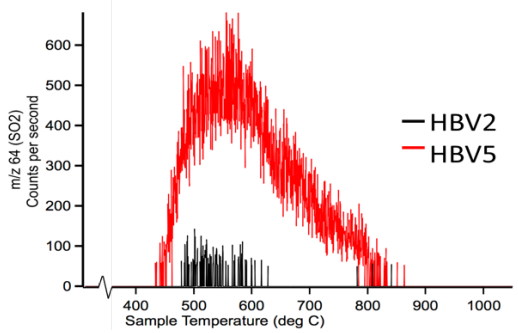

Figure 3. EGA SO_2 profiles of HBV2 and HBV5.

Improving Atmospheric Models: Based on the sulfur concentration estimated in the Holuhraun parental melt [9] and SO_3 measured in the sampled basalts, 90-97% of melt-derived S degassed into the atmosphere during the Holuhraun eruption. Future work will involve the analyses of additional basalts with a wider variety of cooling rates and spatial distributions. Linking spatial volumes of oxidized basalts (e.g., HBV5), total flow volume, S in the parent melt, and measured S in basalts at Holuhraun, will feed into new atmospheric model parameters to better constrain sulfur degassing estimates for past and future eruptive events.

Impacts to Planetary Habitability: Like Earth, volcanic eruptions on Mars are believed to have altered the planet's past climate, promoting a *more* habitable environment [10]. Studies of analog flood basalts on Earth are essential for characterizing climatically-relevant gases, like SO_2, and the impact they have on processes like aerosol production, greenhouse gas warming, etc. Incorporating SO_2 degassing parameters of intermediate-sized eruptions (e.g., Holuhraun, Columbia River) into models (e.g., Global Circulation Models (GCMs) such as the Goddard Earth Observing System-5 GCM) will better inform how large-scale flood basalt eruptions on Earth (e.g. Deccan Trap) and Mars influenced climate on a planetary scale. Since martian flood basalt eruptions are widespread in both space and time, improved models of how gaseous species affected atmospheric conditions will provide important inputs to studies of martian climate history, alteration processes, and habitability, and may also resolve contradictions between current paleoclimate models and the observed scale of aqueous activity early in Mars geologic history.

Acknowledgments and References: Support for this research was provided by NASA's Planetary Science Division Research Program. **References:** [1] Lancaster et al., 1995, [2] O'Hara, 2000, [3] Head et al., 2011, [4] Davis et al., 2017, [5] Gudmundsson et al., 2014, [6] Sigmundsson et al., 2015, [7] Schmidt et al., 2015, [8] Pederson et al., 2017, [9] Morgan et al. 1988 [10] Hartely et al., 2017 [11] Halevy and Head, 2014.