DIFFERENTIATING BASALTIC ERUPTION STYLE WITH X-RAY DIFFRACTION ANALYSIS. K. T. Wall[1], M. C. Rowe[1], and B. S. Ellis[2], [1]Washington State University, School of the Environment, Pullman WA 99164-2812 USA, [2]Institute for Geochemistry and Petrology, ETH Zurich, 8092 Zurich, Switzerland

Introduction: Investigations of Mars geology have long been focused on unveiling the planet's volcanic history and potential habitability. Of particular interest is the apparent transition from explosive to effusive volcanism over time, and the sources of volatiles in these earlier eruptions—whether within the magma, or significant quantities of external water. Identifying the eruption style of a Martian volcanic deposit may provide valuable information about the conditions of the magma and mantle sources, or the possibility of a water-rich environment at the time of volcanism.

On Earth, explosive basaltic eruptions occur in two major styles: magmatic and phreatomagmatic. Magmatic eruptions (i.e. plinian) are thought to occur in part do to high magmatic volatile content (primarily water and carbon dioxide), while phreatomagmatic eruptions occur when magma interacts with surface water or groundwater. Past efforts to distinguish between these two styles have used characteristics of the pyroclasts, such as grain shape, size and vesicularity. However, these characteristics can often overlap between styles and may change over time with alteration. An alternative method, focusing on groundmass crystallinity, may be of more practical use by current and future Mars missions.

We propose that evidence of eruption style may be preserved in the groundmass crystallization of volcanic ejecta. Occurring in varying degrees between basalts (and even within single pyroclasts), groundmass crystallization often shows a strong correlation to post-eruption cooling rate. Pillow lavas, for example, with their glassy rinds and crystalline interior, provide evidence that initially glassy groundmass, preserved on the outside via rapid quenching, continues to crystallize in the slower-cooling interior. Prior studies of basaltic pumice clasts reveal increasing groundmass crystallinity from exterior to interior, suggesting that crystallization continues within the groundmass after individual clasts are ejected [1]. We further investigate whether variance in crystallinity may be connected to different cooling rates between eruption styles, focusing in particular on the rapid water-quenching of phreatomagmatic eruptions vs. the slower air-cooling of magmatic eruptions.

Methods: Using X-ray diffraction (XRD), a technology available to the current Mars Science Laboratory, the first step of this project aims to establish a methodology for determining eruption style via crystallinity. In order to quantify crystallinity, this method follows the procedure described by Rowe et al. (2012) of using the different X-ray diffraction patterns produced by crystalline and amorphous materials [2]. A material like basalt, with mixed crystalline and amorphous content, creates a diffraction pattern with individual high intensity, sharp peaks (produced by crystalline material) superimposed on one low, broad peak (representing the amorphous component). With a linear background applied to eliminate excess background noise, the integrated area of the pattern represents the total crystalline plus amorphous material. Adding a curvilinear background which follows the broad amorphous peak shape, the integrated area above the background then represents the peaks of the crystalline material alone. Dividing the "crystalline" area by the "total" area provides a relative crystallinity estimate for the sample.

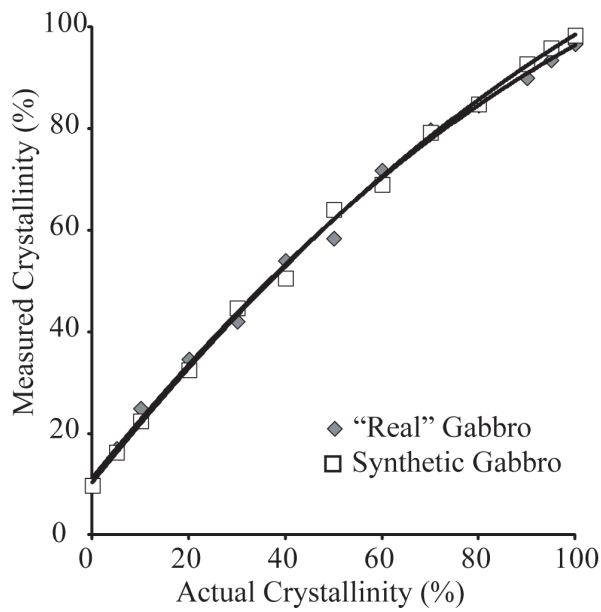

Figure 1: Calibration curve for "real" and synthetic crystalline gabbro mixtures with amorphous glass.

To determine *absolute* crystallinity for samples, a calibration curve must be constructed to account for errors caused by potential overlapping peaks and the presence of background noise in the analysis. This study recreated the Rowe et al (2012) method for rhyolites, creating a calibration curve specific to basalts. Powder mixtures were made of crystalline gabbro in varying proportions with 100 percent amorphous glass, to simulate basalts of varying crystallinity (Figure 1).

These powders were analyzed by XRD using a Cu K-alpha X-ray source; with a 3 second dwell time and 0.03 degree step size over a 10 to 50 degree 2theta range. JADE software was used to determine the "crystalline" and "total" integrated areas of the diffraction patterns, needed to calculate the relative crystallinity. This crystallinity value was then compared to the known crystallinity (the percent of gabbro in the mixture) to derive a calibration curve. Now able to calibrate results, we used this technique to analyze basalts from varying eruption styles, in order to correlate style with crystallinity.

Results: Phreatomagmatic samples, including a basaltic sand from Surtsey and ash lapilli from Newberry, Oregon, yielded fairly constant and relatively low groundmass crystallinity values ranging from ~45-50%. In comparison, basaltic plinian samples from Mt. Etna and Tarawera volcanoes had higher groundmass crystallinities, ranging from approximately ~60-85% crystalline. Samples from other eruptive styles such as Strombolian and lava fountaining produced intermediate crystallinity values between these two endmembers. In all cases, clast size had a significant effect on crystallinity, with larger clasts yielding higher groundmass crystallinities.

Since it is impractical (if not impossible) for a Mars rover to pick groundmass from a sample, we also analyzed whole-rock versions of each sample to maintain an analog to the current and future rovers' limited capabilities. Phenocrysts in the whole-rock samples altered the crystallinity by only a few percent, and the overall crystallinity variance caused by different groundmass textures remained apparent.

References: [1] Szramek et al. (2010), *American Mineralogist, 95,* 503-509. [2] Rowe et al. (2012), *American Mineralogist, 97,* 1685-1699.