Preliminary Results from the HOTTech-2 Venus Weathering Experiment. A. Z. Longo[1] (azlongo@live.unc.edu), X. Liu[1], E. S. Bullock[2], and I. S. Chi[3], [1]Department of Earth, Marine, and Environmental Sciences, University of North Carolina at Chapel Hill, Chapel Hill, NC 27599-3315, [2]Carnegie Institution for Science, Washington, DC, 20015, [3]NASA John H. Glenn Research Center, Cleveland, OH 44135.

Introduction: Rocks exposed on the surface of Venus are subjected to extreme conditions. The most notable features of the planet's atmosphere are its pressure (93 bars), its temperature (~460 degrees C), and the presence of oxidizing species such as SO_2 [1]. In aggregate, these factors can be expected to alter exposed rocks over geologic timescales [2-4]. Our understanding of the nature of this alteration is limited, as the conditions on the Venusian surface are unlike any encountered on the surface of Earth.

Last summer, we initiated a multi-year experimental study of Venusian weathering processes. This project dovetails with the community's Venus Exploration Roadmap [5], as it addresses priorities such as the study of Venus' modern habitability and preparations for the upcoming VERITAS, DAVINCI+, and EnVision missions. Our broad, multi-faceted study is enabled by an international partnership between UNC-Chapel Hill, the NASA Glenn Research Center (GRC), the Carnegie Institution of Science, and the German Aerospace Center (DLR). The two novel goals of our study are described below.

1. *Determine how weathering processes on Venus affect trace element mobility and the elemental compositions of rock and mineral samples*. On Earth, trace element concentrations can be used to decipher a sample's weathering history through scales such as the Mafic Index of Alteration (MIA) and the Chemical Index of Alteration (CIA) [6]. As the magnitude of alteration increases, a sample will become depleted in mobile trace elements. We will attempt to construct a Venusian Index of Alteration (VIA). Because Venus' atmosphere drives unique weathering pathways, we anticipate that different trace elements will be mobile on Venus and Earth. It is hypothesized that material which is weathered out of the tesserae might be transported to the plains by wind, deposited as unconsolidated sediment, and potentially lithified into friable sedimentary rock [7]. A VIA would help us understand the composition of these deposits, as they are likely enriched in mobile elements. It will also support efforts to understand Venus' modern habitability. Some studies postulate that microbial life might persist in the planet's atmosphere at altitudes between 48 and 70 km [8]. In this scenario, the only plausible, consistent source of trace metals would be particles liberated by weathering and injected into the atmosphere by aeolian currents.

2. *Collect visible and near-infrared (VNIR) spectra of basaltic, granitic, and altered samples in order to inform the data analysis plan for the upcoming Venus Emissivity Mapper (VEM) instrument*. Climate models suggest that Venus may have possessed a temperate climate and hydrosphere for up to 3 billion years [9]. One of the goals of DLR's VEM investigation is to search for deposits of aqueously-altered minerals which were deposited in habitable environments [10]. VNIR mapping enabled the detection of widespread exposures of clay, carbonate, and sulfate minerals on Mars [11]. However, Venus is distinct because the weathering processes intrinsic to its surface can potentially replicate key mineral proxies for aqueous alteration without the presence of water. Without a more comprehensive understanding of Venusian weathering, data from VEM could be misinterpreted as false-positive detections of ancient habitable environments. We will mitigate this risk by collaborating with DLR to collect high-fidelity VNIR spectra of weathered and unweathered whole-rock samples.

Gas	Mixing Ratio
CO_2	0.965
N_2	0.035
SO_2	1.80×10^{-4}
OCS	5.10×10^{-5}
H_2O	3.00×10^{-5}
CO	1.20×10^{-5}
H_2S	2.00×10^{-6}
HCl	5.00×10^{-7}
HF	2.50×10^{-9}

Table 1. The composition of GEER's Standard Venus Atmosphere, used during the HOTTech-2 experiment.

Methods: In August of 2023, we exposed a preliminary set of samples to a simulated Venus atmosphere in NASA's Glenn Extreme Environments Rig (GEER). GEER is the most advanced Venus high-temperature and high-pressure chamber in the world. The vessel has an internal volume of 811 L, and it can indefinitely maintain an eight-gas atmosphere to an accuracy of ppm level for the concentration of each gas [12]. Five whole-rock and five powdered samples were included as a secondary payload in the Hot Operating Temperature Technology-2 (HOTTech-2) test. Standard Venus temperatures and pressures (~460 degrees C, ~90 bars) were maintained for 10 days. The atmosphere was GRC's Standard Venus Mix (Table 1), which approximates the mixture of gases present near the surface of Venus.

We attempted to select samples which are well-characterized and archetypical of larger rock classes. The HOTTech-2 secondary payload included a vesicular basalt from Hawaii, two distinct basalt types from the Galapagos, a sample of Half Dome granodiorite, and a nearly pure carbonate. Powdered samples were ground to an average diameter of 10 microns, which is below the expected 30-micron thickness of a Venusian weathering rind [13].

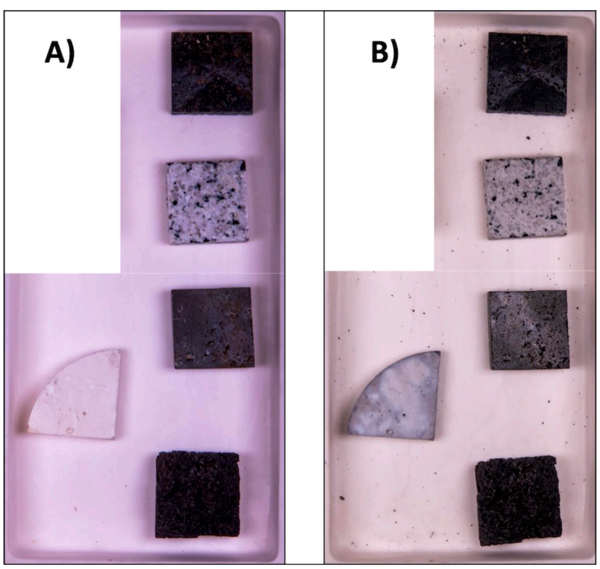

Figure 1. Polished whole-rock chips before (A) and after (B) exposure to a simulated Venus atmosphere. Top to bottom: Vesicular Galapagos basalt, Half Dome granodiorite, Galapagos basalt, calcite, Hawaii basalt.

Results: Several visual changes to our samples were noted following the HOTTech-2 experiment (Figure 1). The calcite developed a dark grey weathering rind across its entire surface, including the face which was in contact with the alumina sample tray. This coating is likely to be anhydrite [4], though we have not yet confirmed this through chemical analysis. There also appear to be qualitative reductions in the extent of the iron oxide patina on a Galapagos basalt and in the diameters of the biotite grains in the granodiorite. Unfortunately, due to the compressed schedule for this experiment, we were unable to confirm these observations with high-resolution pre-test data.

While some of the powdered samples experienced changes in color and composition, their textures and grain sizes appear to be unmodified. We are also probing the origin of a handful of mm-scale black flakes which appeared on the alumina sample trays during the weathering trial. We are planning to conduct chemical analyses of this material at GRC.

Images and chemical analyses of the bulk samples obtained using the Energy Dispersive Spectrometer (EDS) on the scanning electron microscope (SEM) at the Carnegie Institution for Science will be presented at the meeting. These data will allow us to determine if there were textural and major-element changes to the samples during the HOTTech-2 test. EDS measurements will enable comparisons to published studies on Venusian weathering, and they will establish a baseline set of measurements which can inform the primary objectives of this study.

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