REACTION RATES ON VENUS: THE EFFECTS OF SUPERCRITICAL VERSUS GASEOUS CO_2 ON MINERAL WEATHERING
E. J. Merchak[1], S. T. Port[2], V. F. Chevrier[1], N. Nawar[1] [1]University of Arkansas, Fayetteville AR 72703, [2] NASA Postdoctoral Program Fellow, NASA Glenn Research Center, Cleveland, OH 44135. (ejmercha@uark.edu)

Introduction: The surface of Venus is drastically different than Earth, with temperature and pressure that reach up to 735 K and 92 bar at the average planetary radius (6051.5 km) [1]. At these high temperatures and pressures the primarily CO_2 atmosphere changes from a gaseous state in the highlands to a supercritical fluid in the lowlands (Fig. 1) [1]. This supercritical atmosphere may have an effect on reaction thermodynamics and kinetics with surface minerals compared to its gaseous counterpart. To investigate this potential effect, we will experimentally examine the chemical interactions between various minerals and CO_2 at both lowland (supercritical) and highland (subcritical) conditions on Venus.

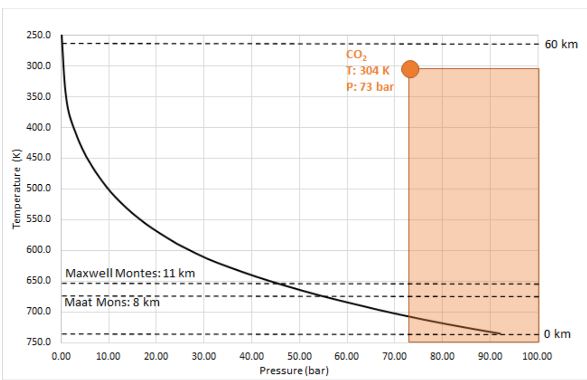

Figure 1: Temperature versus pressure profile of Venus' atmosphere highlighting the critical point of CO_2 in the atmosphere.

Though data is scarce, several pieces of evidence point to a surface primarily composed of basaltic rock. Shield volcanos, known to be composed of basaltic rock on Earth, were detected by radar remote sensing in the highlands [2]. The Venera and Vega missions used X-ray Fluorescence and Gamma Ray Spectrometry to measure the abundances of several key elements at the surface which pointed to a basaltic composition [2]. We will be experimenting with olivine ($(Mg,Fe)_2SiO_4$) as well as pyroxenes because they are commonly found in basaltic rock on Earth [2, 3]. The endmembers of the pyroxene group, enstatite-ferrosilite ($(Mg,Fe)SiO_3$) and wollastonite ($CaSiO_3$), have different stabilities at Venus conditions which we will experimentally investigate using a chamber capable of reproducing Venusian surface conditions [4]. There have been several discussions on wollastonite's potential to buffer CO_2 through equilibrium with calcite; testing this mineral in the chamber will provide further information on this reaction pathway on Venus, and if supercritical CO_2 has any effects on the reaction rate [5-8]. We have also chosen to analyze two types of feldspars, orthoclase ($KAlSi_3O_8$) and anorthite ($CaAl_2Si_2O_8$) due to their presence in igneous rocks [9]. Some modeling on the stability of igneous rock in Venus conditions has been completed, but more experimental data is required to verify the proposed reactions [10].

Methods: In order to investigate the effects of supercritical versus gaseous CO_2, the experiments will be completed in a Venus simulation chamber and a Lindberg tube oven. We will run experiments at different conditions along the adiabatic gradient in the Venusian atmosphere (653 K, 45 bar for the highlands and 735 K, 95 bar for the lowlands). In the tube oven experiments the pressure will be 1 bar because the system is open. This will allow us to directly compare the effects of supercritical versus gaseous CO_2 and isolate the effects of pressure from the effects of temperature.

Figure 2: Venus simulation chamber at the University of Arkansas. The pressure vessel is shown towards the middle with the heating sleeve to the left and pressure gauges on top.

The Venus simulation chamber was purchased from Parr Instruments in 2016. The pressure vessel is a 500 mL cylinder made of stainless steel 316 (Fig. 2). The chamber connects to a computer that records the internal pressure and temperature at set intervals for the entirety of the experiments. The internal temperature and pressure have been demonstrated stably for up to 100 hours (Fig. 3). An Agilent HP 6890 Gas Chromatograph (GC) will be added to the chamber for analysis of the gas during the experiments. This GC will be equipped with a Flame Ionization Detector to determine the carbon composition of the gas (CO and CO_2) as well as Flame Photometric Detector to detect sulfur compounds (SO_2, COS and H_2S).

Each mineral will be ground using an alumina-ceramic pulverizing dish and then sieved to >62 µm. A gram of each powdered sample will be placed in the chamber before the chamber is evacuated to 30 psi and then flushed with CO_2. The chamber will then be filled with CO_2 and heated until reaching the desired temperature and pressure. For lowland experiments the chamber will reach 95 bar and 735K which is equivalent to the conditions found at the surface [1]. For highland conditions we will operate at 653K and 45 bar which is equivalent to conditions at around 11 km altitude on Venus [1]. The gas will be extracted using the GC to measure any atmospheric composition changes throughout the experiment.

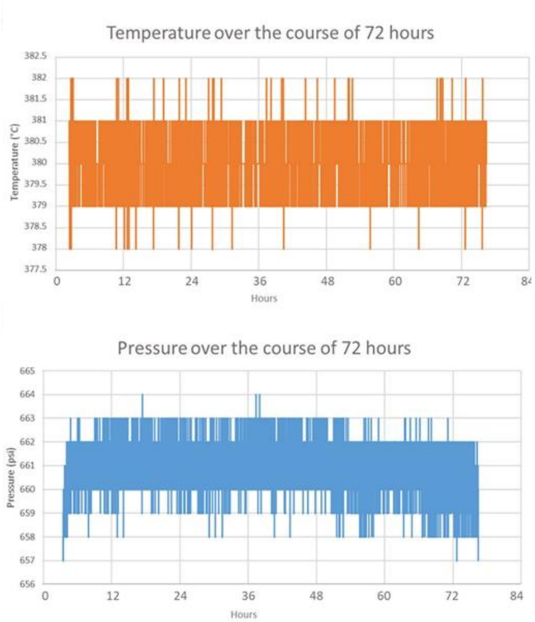

Figure 3: Pressure and temperature data collected from a 72-hour experiment in the Venus simulation chamber. The temperature fluctuates between 4 degrees over the course of the experiment and the pressure fluctuates 7 psi (0.48 bar).

Alongside the chamber experiments, we will place samples inside a Lindberg tube oven at the same lowland and highland temperatures and chemical atmosphere but at 1 bar pressure.

Before and after each experiment, the powdered sample will be analyzed using a Scanning Electron Microscope (SEM) and Energy-dispersive X-ray spectroscopy (EDS) to evaluate any chemical changes that have occurred. Samples will also be analyzed using X-Ray Diffraction (XRD) to examine any changes to the mineralogical composition.

Significance of this Work: There are still many aspects of Venus that remain unknown. The two upcoming NASA missions, DAVINCI and VERITAS, and the ESA Venus mission, EnVision, will investigate scientific questions that remain unanswered. DAVINCI will focus on the composition of the atmosphere and will drop a probe that will obtain data at different intervals during its decent to the surface. VERITAS will study the surface's geochemistry and geomorphology through various imaging techniques. EnVision will obtain atmospheric and surface measurements which will provide more information on the surface environment.

With scientific focus on the atmosphere and the surface of Venus, information regarding the interactions between the CO_2 atmosphere and the surface minerals has become of prime importance. We will obtain data that will determine if and what the effects of supercritical CO_2 are on the surface of Venus and how it compares to the gaseous atmosphere of the highlands. Any experimental data obtained regarding the near surface environment will be beneficial for the planning stages of these missions to ensure successful missions and data collection.

Acknowledgments: This work is funded by NASA Solar System Workings grant #80NSSC21K0161

References: [1] Seiff et al. (1986) The Venus International Reference Atmosphere 3-58 [2] Treiman (2007) Exploring Venus as a Terrestrial Planet. 176, 7-22 [3] Gill (2011) Igneous Rocks and Processes: A Practical Guide [4] Zolotov (2018) *Reviews in Mineralogy and Geochemistry*. 84**,** 351-392. [5] Fegley and Treiman (1992) American Geophysical Union 7-71 [6] Lewis and Prinn (1984) Planets and their Atmospheres: Origin and Evolution [7] Nozette and Lewis (1982) *Science* 216. 181-183 [8] von Zahn et al. (1983) *University of Arizona Press* 299-430 [9] Faure, 1998; Gill, 2011 [10] Klose and Zolotov, 1992 Lunar and Planetary Science Conference XXIII, 1992, pp. 699-700.