SPINIFEX TEXTURES IN MARTIAN LAVAS: CRYSTALLIZATION EXPERIMENTS ON YAMATO 980459. K. A. Hottendorf[1], V. Payré[1], K. Iacovino[2], J. A. Dancer[1], K. Prissel[3], M. R. Salvatore[4], C. S. Edwards[4], J. Filiberto[5], and G. Moore[6]; [1]Department of Earth and Environmental Sciences, University of Iowa (khottendorf@uiowa.edu), [2]Amentum, NASA Johnson Space Center, [3]Department of Earth, Atmospheric, and Planetary Sciences, Purdue University, [4]Department of Astronomy and Planetary Science, Northern Arizona University, [5]ARES, NASA Johnson Space Center, [6] Los Alamos National Laboratory

Introduction: Robotic geologists (rovers, landers, and orbiters) have returned a substantial volume of data that specifically relate to the petrology of martian igneous rocks, which are invaluable in understanding magmatic processes on Mars. One of the best ways to understand this returned data is with experimental petrology. Building a repository of experimental samples with martian compositions can provide us with a library of analog samples with which we can compare to findings from the martian surface.

By constraining the range of textures in martian compositions that correspond to specific temperatures, viscosities, cooling rates, etc., experimental databases would allow for quick interpretations of such textures observed by rovers and landers in martian rocks. Spinifex textures - large skeletal olivine or pyroxene dendrites surrounded by smaller dendrites or glass- form in a highly constrained parameter space within ultramafic to mafic, Mg-rich, high-temperature, low-viscosity rocks that have undergone a high degree of undercooling – crystallized at temperatures far below their liquidus. Spinifex is commonly found in specific stratigraphic locations in thick ultramafic-mafic lava flows and transient lava lakes (Figure 1) [1-2]. If spinifex is seen on Mars, it might help to constrain what part of a lava flow's stratigraphy is being observed in combination with revealing the lava flow's temperature, viscosity, composition, and more. Finding spinifex on Mars would also support those lavas being derived from a primitive melt, allowing them to be used to calculate mantle potential temperature at their time of eruption. This would be a useful value for comparing mantle thermal properties in different locations and ages on Mars and for comparing against Earth [1]. Having an experimental repository of spinifex textures made from martian compositions will allow for an easier identification of these primitive lavas by rover.

Crystallization Experiment Method: We used Yamato 980459 (Y98) as our starting composition. Y98 is a 170 Ma olivine-phyric shergottite composed of pyroxene (≤0.4 mm), olivine (≤1.1 mm), spinel, and mesostasis. Y98 is thought to have cooled as a thin lava flow on the surface of Mars and originated from a mantle derived melt [3].

For our crystallization experiments, oxide and silicate powders are combined, mixed with a mortar and pestle, melted into a glass at 1500 °C with an fO_2 of FMQ+1 for 1 hour before being quenched, and then powdered again with a mortar and pestle. Powders are then pressed into pellets, sintered to a platinum wire, and then inserted into a Deltech 1-atm gas mixing vertical tube furnace for either a continuous temperature (isothermal) experiment or a temperature changing (dynamic) experiment with a cooling rate of 35 °C/hr or 10 °C/hr [4]. Isothermal experiments are meant to study equilibrium and quick cooling textures, while dynamic experiments are meant to produce larger crystals (mm scale). Experimental crystallization temperatures, T_C, cover the temperature space between the liquidus (T_L) and solidus (T_S) at 50 °C increments. T_L and T_S were initially estimated using alphaMELTS 2.0 [5] and published experiments on the Y98 composition [3], and then confirmed in our initial experiments. In isothermal experiments, we bring each sample above T_L = 1475 °C for 1 hour and then drop the temperature as quickly as possible (~655 °C/hr) to the targeted T_C, where it stays for the remaining duration of the experiment (24 – 80 hrs). Dynamic experiments are held above T_L for 1 hour before cooling 35 °C/hr or 10 °C/hr to T_C, at which point the temperature is held constant for the rest of the experiment. All experiments have an fO_2 of FMQ+1 and are quenched by dipping the sample in a bucket of water. Once samples have been produced they are cut in half with a diamond wire saw, mounted in an epoxy-hardener mixture, and then analyzed with a JEOL8530F electron microprobe.

Results: Olivine and pyroxene spinifex textures with crystals large enough to be seen with a human/rover eye (mm scale) are observed in our samples (Figure 2). The isothermal experiments at a T_C of 1200 °C and 1250 °C have olivine spinifex textures, while the dynamic experiments at a T_C of 1150 °C, 1200 °C, and 1250 °C with a cooling rate of 35 °C/hr have pyroxene spinifex textures. The isothermal and dynamic samples also contained other crystal textures such as small dendritic olivine and pyroxene as well as euhedral olivine, pyroxene, and spinel. The phases present are primarily Mg-rich. The dynamic experiments contained chemical zoning in their pyroxenes while the isothermal experiments had chemically homogenous pyroxenes.

Discussion: Previous experiments by First and Hammer 2016 [3] on Y98 with 2 distinct cooling rates produced textures similar to those in our experiments.

Both this study and [3] experiments had a diverse set of pyroxene textures that include euhedral, dendritic, and spinifex. However, our dynamic experiments had multiple zoned pyroxene populations while [3] had a lack of zoning in their samples. The lack of zoning in [3] experiments is likely due their experimental method, a slow initial cooling rate followed a quick cooling rate. This method allows for more elemental dispersal than our dynamic experiments and more closely mimicked the lack of zoning in our isothermal samples.

Some martian compositions, including Y98's (49.15 wt% SiO_2, 0.66 wt% alkalis, 18.9 wt% MgO, and 0.51 wt% TiO_2), are similar to that of primitive terrestrial ultramafic lavas and komatiites (30-52 wt% SiO_2, <1 wt% alkalis, >18 wt% MgO, and <1 wt% TiO_2 [6]). Our samples and others produced by ultramafic-mafic martian compositions [7] also exhibit textures (spinifex) similar to that of primitive terrestrial ultramafic lavas and komatiites. The fact that spinifex has not yet been identified in a primitive lava on Mars, despite having the compositions that are capable of producing the texture, leads us to 3 hypotheses: 1) spinifex does not exist in large quantities on Mars, 2) spinifex has not been abundant in study areas on Mars, and/or 3) spinifex has been abundant but missed in study areas on Mars.

It has long been theorized that komatiitic lavas have occurred in Mars' history [8], and are even still preserved on the modern martian surface today in regions like Syrtis Major Planum (SMP) [8]. There is indirect evidence that supports [8-9] and dismisses [10] the presence of komatiites being present in SMP in the form of spectral and morphological observations. The Mars Sample Return (MSR) mission has the unique opportunity to gather data on possible komatiite candidates and even return one to Earth due to its unique location in Jezero crater, which borders SMP to the east. Such samples could provide a robust record of the composition and temperature of the martian mantle.

Conclusions: Our crystallization experiments performed using the Y98 composition have generated experimental igneous textures large enough to be seen with a rover on Mars today, and have the potential to be seen in samples from the MSR mission. More experimental work will help to better understand what rovers on Mars have seen in the past and prepare for what they may see in the future. This and future work done to increase our library of experimental samples with martian compositions will help us to better constrain what magmatic processes have occurred to form the igneous rocks that we see on Mars.

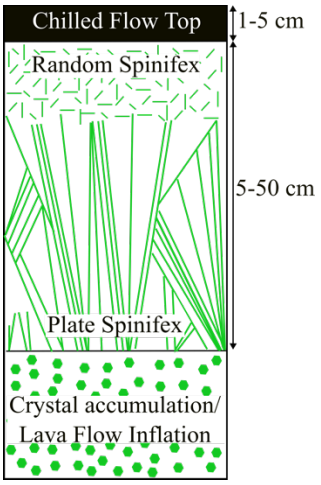


Figure 1: Inspired by [2]. Not to scale stratigraphic column of a komatiite lava flow. When present, spinifex are between the crust of the lava and a cumulate layer of euhedral olivine or pyroxene..

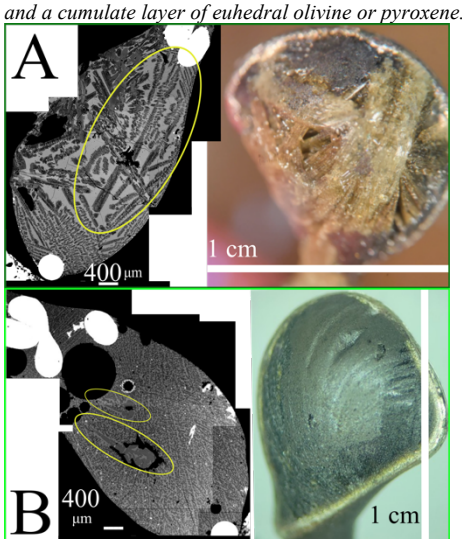


Figure 2: A) Dynamic sample with T_C = 1150 ℃ and a cooling rate of 35 ℃/hr. Left is a backscatter electron (BSE) image and right is the sample, large dendrites circled in BSE. B) Isothermal sample with T_C = 1250℃. Left is a BSE image and the right is the sample, large dendrites circled in BSE. Both samples exhibit large dendrites that can be seen with the human eye and have a spinifex texture.

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