CHARACTERIZING ELYSIUM'S MAGMATIC EVOLUTION AND CHEMISTRY INITIAL STUDY. H. Fuqua Haviland[1], S. Karunatillake[2], D. Susko[2], L. Ojha[3], D. Baratoux[4], M. Toplis[4], and R. El Maarry[5]. [1]NASA Marshall Space Flight Center (heidi.haviland@nasa.gov), [2]Louisiana State University, [3]John Hopkins University, [4]GET, Toulouse, France, [5]Birkbeck College, London, UK.

Introduction: The Elysium volcanic province (EVP) is a location of great geologic interest on Mars. EVP is notable not only for the presence of three shield volcanoes, Elysium, Alber, and Hecates, but also for some of the most recent eruptions on the planet, with some interpretations suggesting activity even in the last few million years. Its predominantly Amazonian surface age and isolation in the northern hemisphere away from other volcano-tectonic regions make it an ideal locale to investigate igneous compositions during the most recent geologic period on Mars. Specifically, EVP experienced an extended period of volcanism; compared to large igneous provinces on Earth, the martian context has persisted orders of magnitude longer. Therefore, changes in mantle chemistry, pressure, and temperature are expected, as well as changes in fractional crystallization processes and crustal contamination. Due to the coarse length scale of the observation resolution and lack of resolved local features, these systems appear much simpler than their terrestrial counterpart. In addition, regional scale changes in eruptive processes of any given martian volcanic province over geologic time are still poorly understood. Related investigations are crucial for understanding how the martian crust and mantle have evolved in the absence of Earth-like plate-tectonics. Consequently, this project helps fill this knowledge gap by assessing the compositional evolution of Elysium as a major martian volcanic province, using remote sensing data sets (Mars Odyssey Gamma Ray and neutron Spectrometer suite (GRS), and gravity) and modeling (petrologic and thermoelastic).

By analyzing data based on predictions from petrologic modeling, we develop an expansive geologic history for the region that spans over 3 Ga. Our work shows a compositional transition in Elysium's volcanism coupled to differences in geologic age between NW and SE regions [1] (mapped Geology summarized in Fig. 1). The continuity of volcanic activity, and the notable spatiotemporal changes in the abundance of heat-producing radioactive elements (K and Th) along with others (Al, Ca, and Fe in particular) make this region an ideal case study for the evolution of volcanism on Mars [1,2]. Here we perform a detailed petrological and thermoelastic modeling to test the emerging hypothesis that compositional variability within EVP resulted from spatiotemporal changes in the depth of magma formation and present initial results.

Methods: We use two primary methods: first, we constrain the pressure and temperature conditions of EVP as a case study of geologically recent magmatic evolution on Mars using GRS informed surface chemistry constraints and pMELTS modeling. Second, we place constraints on the density of the EVP melt through thermoelastic modeling and a local gravity analyses.

Task 1: GRS informed petrological melt modeling. First, we characterize chemically and geologically distinct regions within EVP. Our previous work verified that Elysium's compositional signature reflects primary igneous processes coupled to mantle sources, not secondary alteration or dust cover [1]. However, our ongoing work suggests a need to revise the EVP regions to ensure better spatial and temporal resolution of magmatic evolution in the context of GRS resolution. We identify the compositional trends from mapped geology, impact crater-based geochronology, and the GRS based chemical maps.

Next, we derive melt conditions consistent with regional compositions. Our previous work performed melt modeling in the martian context [3,4]. Similarly, here we use pMELTS software to thermodynamically model partial melting of the underlying mantle. Seven oxide (SiO2, FeO, Al_2O_3, CaO, K_2O, TiO_2, and MgO) mass fractions (wt%) derived from GRS data, 10 - 30 kbar pressure (P) range, and 1000 to 2000 °C temperature (T) range, comprise the initial parameter space. The P and T ranges correspond to crustal heat flow of 18 mW/m^2, with a mean surface temperature of 273 K, 100 km depth (corresponding to the 10 kbar constraint) [5,6]. The P and T conditions will be further refined with geophysical datasets, including a local gravity study with estimates on the pressure gradient across the lithosphere and upper mantle. We also test a range of H_2O wt% for martian magmas, and the latest bulk silicate Mars compositional model [7] as inputs to our pMELTS calculations including dry and wet martian mantle end members [e.g., 8 and references therein]. Mantle hydration is naturally variable and dependent on the condition of melting; also, the martian mantle hydration may be highly heterogeneous [9]. We identify the optimal melt conditions for EVP among the multiple plausible models across the range of P, T. (one example oxide and the effects of P-T is summarized in Fig. 2).

Task 2: Gravity constrained thermoelastic modeling. We place constraints on the density of the EVP melt through thermoelastic modeling and gravity analysis. First, we perform a local gravity study comparing topography from the Mars Orbiter Laser Altimeter [10] and the spherical harmonic gravity field of Mars (the JPL gravity model, [11]). Localized gravity and topography are obtained by applying a band-limited localization window to the global gravity and topography fields to obtain admittance and correlation spectra [12]. Sections of EVP with high gravity/topography correlation will be analyzed first. Porosity and compaction are considered in the interpretation of these results. A best-fit load density, elastic lithosphere and crustal thicknesses within EVP are obtained. This method follows the successful implementation of a local gravity study at the Medusae Fossae Formation on Mars, bounding density with topography and gravity [12].

Next, we calculate the temperature dependent elastic properties of each melt, after crystallization for a range of P and T conditions for direct comparison with geophysical datasets. These calculations are performed for each model composition generated in Task 1 using the open source mineral physics software BurnMan [13]. Third order Birch-Murnahan equations of state are applied to martian appropriate minerals (starting from [14]) to obtain the elastic properties at depth for each model P and T. Then each model will be compared with local gravity and heat flow observations (Fig. 3). Additionally, bulk geophysical parameters (mass, moment of inertia (MOI)) are used as a final discriminator. These parameters have been used in a similar methodology which scales the Earth to similar exoplanets and provides key information on interior structure [15]. Therefore, EVP is a region of great geologic interest on Mars and this project will help add understanding of the spatiotemporal evolution of this region.

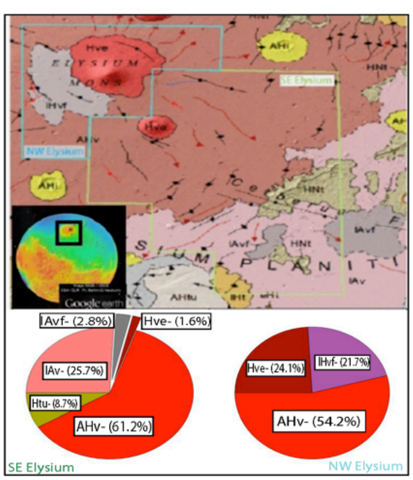


Fig. 1. *The geographic location of EVP, along with the preliminary demarcation into distinct regions, by [1]. The lower pie charts show the areal distribution of different mapped geologic units.*

Fig. 2. *Oxide compositions of the liquids in terms of degree of partial melting, using H_2O wt% of 39 ppm (solid lines) and 185 ppm (dashed lines). Each curve represents a specific pressure. The 10 kbar is the curve furthest to the right and progress to the left by 2 kbar increments (up to 30 kbar). Melt % indicated as number (3, through 50). Triangles represent the average oxide compositions in three preliminary EVP regions. Arrows designate P=10 kbar, T_e=100 km, T=273 K, 185 ppm H_2O which corresponds to ~50 wt% SiO_2 and ~5 wt% FeO for a 3% melt.*

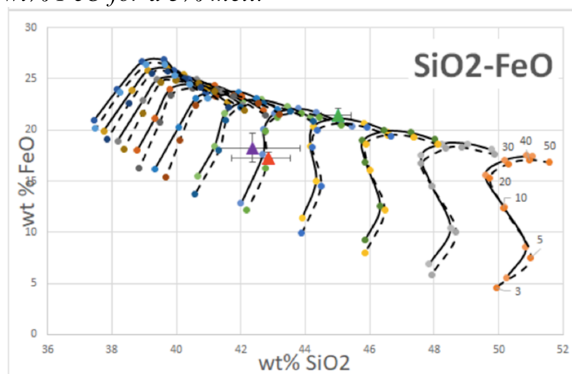
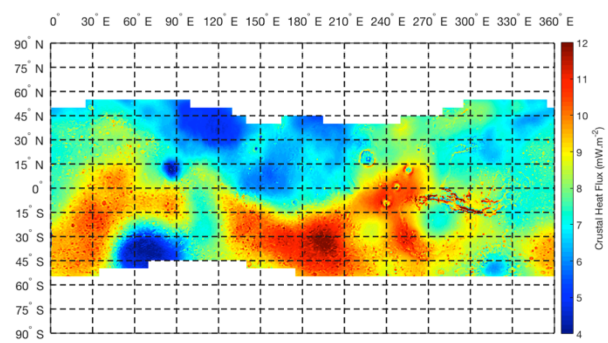


Fig. 3. *Initial Heat flow computed from the distribution of HPE and crustal thickness models. Areas of the polar regions where HPE concentration is affected by the presence of shallow sub-surface ice have been excluded from the calculation.*



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