USING MESSENGER DATA TO MODEL THE THERMOCHEMICAL EVOLUTION OF MERCURY'S INTERIOR. P. Bose[1], M. S. Duncan[1], and S. D. King[1], [1]Department of Geosciences, Virginia Tech, Blacksburg, VA, USA (priyanka18@vt.edu).

Introduction: Mercury, the smallest terrestrial planet, has been classified as a geochemical endmember of the inner solar system, but is the solar system's least studied planet [1]. Understanding how Mercury's interior evolved will provide insights about the formation conditions of the inner solar system, how magma evolves under highly reduced conditions, and the best constraints for modeling how mass and heat are transferred in a thin mantle. MESSENGER provided information about the surface composition of Mercury from three spectrometers (the XRS, GRS and NS); and used geophysical instruments (the MDIS, MLA, and Radio Science systems) to determine both the surface geological features and investigate the core and mantle's composition and structure [2]. These data indicated Mercury is made up of four layers: a crust (~35 km thick), a mantle (365 km), and a core (2040 km) [3,4]. This data placed constraints on Mercury's tectonic and thermal history, as lobate scarps were found indicating that tectonic shortening has occurred [5], and that Mercury's crust is generally richer in S and Mg and poorer in Fe than the other terrestrial planets [6]. The specific compositional differences of the surface have been split into nine regions [7]; here, we focus on the Northern Volcanic Plains to determine how the interior of Mercury thermochemically evolved.

The Northern Volcanic Plains, which formed about 3.5 Ga [8], is the largest smooth igneous deposit on the surface of Mercury. This was the last major volcanic depositional event on the Mercurian surface, and as such will provide insights into Mercury's interior. Under additional assumptions, such as a homogeneous mantle composition and no significant magma fractionation occurred during ascent, the major element composition of the NVP can constrain both the source rock of the mantle, and the melting processes in the mantle.

Motivation: Prior thermochemical evolution models of Mercury used an Earth-based solidus which accounts for a significantly higher Fe concentration and oxidation state than the MESSENGER data indicates [9-11]. The high S and low Fe concentrations on the surface, and a high metal/silicate ratio indicate low oxygen fugacity (fO_2) conditions during the planet's formation [12]. Given the large effect of Fe on the solidus temperature, any melting model of Mercury's interior would greatly overestimate both the melt amount and composition generated at any point in time (Figure 1). These previous models would not provide enough melt to form the large expanse of the NVP. There are also no self-consistent thermochemical evolution models for Mercury's interior that account for the evolution of the mantle as the interior of Mercury thermochemically evolved, as they all assume the mantle is one uniform temperature.

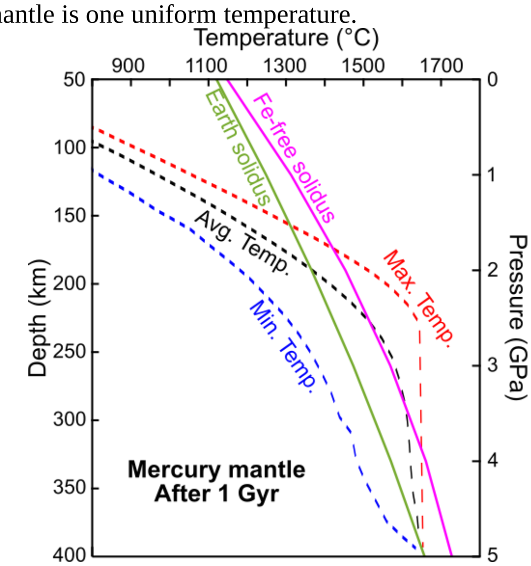

Figure 1: Three mantle melt thermal profiles after 1 year of melting [blue, black, and red dashed lines represent the minimum, average, and maximum thermal profiles, **13]**, the peridotite-based solidus used in prior thermochemical models [solid green line; **10]**, and a more Mercury-relevant solidus [solid pink line; **11]**.

Methods: A MATLAB code, based on a modified NORMs calculator [7], converted Messenger's elemental ratios data to the idealized mineralogy for the NVP regions. Our calculator first allocated the appropriate cations to the sulfides, then ran a standard NORMs calculation with the remainder of the cations to the silicates. We also incorporated the remaining MnO, not consumed in sulfides, into the silicate minerals (e.g., (Mg, Mn) SiO_3 as seen experimentally [14]).

We are building a three-layer, 1D thermal model for Mercury to track the energy changes in the Mercurian core, mantle, and crust, as the planet cools [e.g., 15,16]. This model will be geochemically rigorous as we will include a mantle solidus and use a mantle adiabat to determine the mantle's melt fraction as a function of time. The parameters we will vary are the initial mantle and core temperatures and the mantle's viscosity. With the NORMs mineralogical analyses, we will be able to vary the mantle's rheologic properties in our model. We will be able to model how the mantle thermally evolved as the planet cools. The solidi that we will use in the model will be Mercury-appropriate, as it will reflect the low Fe content and more reduced conditions of the mantle. To ensure the model is realistic, results will be compared to known constraints, such as the radial shortening estimates from previous work [15] and the timing of the NVP deposit [8].

Preliminary Results: With the modified NORMs calculator [7], we re-evaluated the low- and high-Mg regions of the NVP mineralogy in terms of the possible sulfides present. Within both regions of the NVP, the sulfides were FeS, TiS, and CrS, and the silicates were dominated by Fe-free orthopyroxene and olivine (Figure 2). This reflects the highly reduced nature of the planet and its mantle.

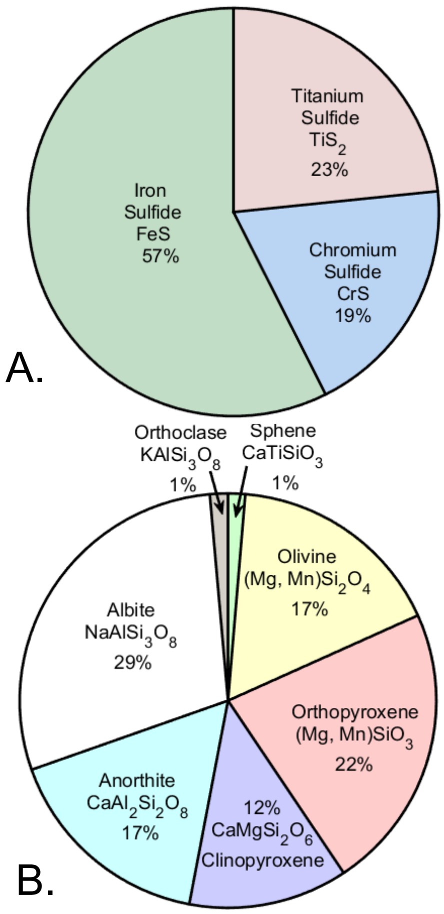

Figure 2: NORM results for the NVP **(A)** Sulfides are dominated by FeS, then TiS_2, and CrS. (**B**) Silicates are dominated by orthopyroxene and olivine.

Using these mineralogies, we can assess the basic rheological properties of the mantle, which will then constrain our 1D thermal model, shown in Figure 3. The preliminary results show an initial increase in mantle temperature during the first ~ 1.5 Gyr, and then a steep decrease from 1.5 Gyr to 4.5 Gyr (present day) [16]. As such, the NVP is assumed to represent the current state of the Mercurian mantle.

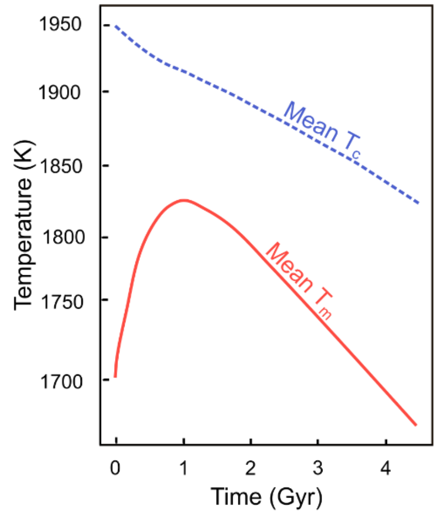

Figure 3: Very preliminary calculated thermal profiles from the 1D model over time, without mantle melt. The mean temperatures of the core and mantle are shown as the blue dashed line and the red solid line, respectively.

Conclusions/Implications: Using the NORMs calculator, we will assess the sensitivity of the Si and S concentrations in the model, to determine a range of mineralogies for the NVP region of Mercury. Using these mineralogies, we are building a geochemically rigorous 1D thermal model for Mercury to track mantle melt fractions as the planet cools. Currently the thermal model only includes the mantle, however, we will add in the thermal evolution of the crust and core. This will provide insights into the general evolution of the Mercurian interior, which will provide insights for heat transfer constraints in a thin mantle, how magma acts under highly reduced conditions, and the planetary formation conditions of the inner solar system.

References: [1] Vander Kaaden et al. (2019) *Space Sci. Rev.*, *215*, *49*. [2] Solomon and Anderson. (2019) *Mercury: The View After MESSENGER*, 1–29. [3] Charlier and Namur. (2019) *Elem.*, *15*, 9–14. [4] Margot et al. (2019) *Mercury: The View After MESSENGER*, 85–113. [5] Watters et al. (2009). *EPSL*, *285*, 283–296. [6] Nittler et al. (2019) *Mercury: The View After MESSENGER*, 30–51. [7] Vander Kaaden et al. (2017) *Icarus*, *285*, 155–168. [8] Byrne. (2016) *GRL*, *43*, 14. [9] Takahashi. (1990) *JGR*, *95*, B10. [10] Hirschmann. (2000) *G3*, *1*, 10. [11] Namur et al. (2016a) *EPSL*, *439*, 117–128. [12] Namur et al. (2016b) *EPSL*, *448*, 102–114. [13] Tosi et al. (2013) *JGR*, *118*, 12. [14] Vander Kaaden and McCubbin. (2016) *GCA*, *173*, 246–263. [15] Hauck et al. (2019) *Mercury: The View After MESSENGER*, 516–543. [16] Grott et al. (2011) *EPSL*, *307*, 135–146.