THERMAL PROPERTIES OF GLASSY AND MOLTEN PLANETARY THOLEIITES. A. Sehlke[1,3], A.M. Hofmeister[2], and A. G. Whittington[3], [1]NASA Ames Research Center, Moffett Field CA, USA (alexander.sehlke@nasa.gov), [2]Department of Earth and Planetary Sciences, Washington University in Saint Louis MO, USA, [3]Department of Geological Sciences, University of Missouri, Columbia MO, USA.

Introduction: Heat transport plays a crucial role in the thermal evolution of high-temperature, magmatic regimes on Earth [1] and presumably on other planetary bodies, such as the Moon, Mars and Mercury. Thermal diffusivity (*D*) has been measured for terrestrial glasses and melts, spanning a compositional range from basalt to rhyolite, [2]. The observed low values for thermal diffusivity and viscosity for basaltic melts, suggest that basalts transfer heat much more efficiently by advection than by conduction alone, and that partially molten zones in Earths' mantle quickly become more thermally insulating than non-molten zones, potentially contributing to melt localization during decompression melting.

In the present study, we provide new thermal diffusivity and heat capacity data starting at room temperature up to ~1000 K (for *D*) and 1750 K (for C_P) for a variety of synthetic planetary tholeiite glasses and liquids. Their viscosity and density were already measured [3], thus providing a comprehensive view of their transport properties.

Methods: Thermal diffusivity (*D*) was measured with a Netzsch Laser Flash Apparatus (LFA) 427 between room temperature and up to ~1000 K on quenched glass disks, usually with thicknesses between ~0.6 to 1.1 mm. Specific heat (C_P) was measured using a Netzsch Differential Scanning Calorimeter (DSC) 404 Pegasus F1 from room temperature to ~1775 K for glass chips with a mass up to ~40 mg. The glass density (*ρ*) was obtained using the Archimedean method, whereby sample weights are measured in air and immersed in ethanol at room temperature.

Results: *Thermal diffusivity*. Figure 1 shows the range of measured thermal diffusivity for glassy samples (D_{gl}). We observe that Mg-rich composition generally show higher values of *D*, including compositions proposed for Mercury and Io. In contrast, we find that compositions with higher Fe-contents generally have lower values of thermal diffusivity at the same temperatures, whereby titanium-rich lunar mare basalt (LM) and Martian shergottite are lowest. Thermal diffusivities from room temperature to ~ 1000 K were fitted using the equation $D_{gl} = FT^{-G} + HT$, whereby F, G and H are fitting parameters. The transition from glass to liquid is characterized by an abrupt decrease in *D*, which occurs around ~1000 K. On average, the thermal diffusivity of the melts (D_{melt}) is 0.360±0.035 $mm^2\ s^{-1}$. Measurements of D_{melt} immediately above the glass transition are thwarted by rapid re-crystallization and deformation of the samples, whereby only one or two data points could be measured.

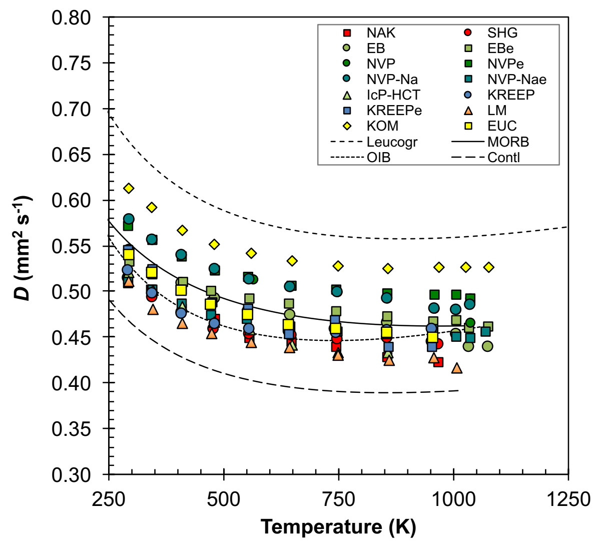

Figure 1: Thermal diffusivity (*D*) of investigated glassy samples measured from room temperature up to the onset of the glass transition (last data point). For context, fitting lines for terrestrial samples [2] are plotted. Some sample abbreviations explained: NAK = Nakhlite, SHG = Shergottite, EB = Enstatite Basalt, EBe = Enstatite Basalt (evolved), NVP = Norther Volcanic Plains, NVPe = Norther Volcanic Plains (evolved), NVP-Na = Norther Volcanic Plains Na-enriched, NVP-Nae = Norther Volcanic Plains Na-enriched (evolved), IcP-HCT = Intercrater Plains - Heavily Cratered Terrain, KREEPe = lunar KREEP (evolved), LM = Ti-rich Lunar Mare, KOM = Komatiite, EUC = Eucrite, Leucogr = Leucogranite, Contl = Continental rift basalt.

Heat capacity. Heat capacities of glasses are well fitted with the Maier-Kelly equation in the form of $C_P = a + bT + cT^{-2}$, whereby a, b, and c are fitting parameters. The average glass transition temperature (T_g) for our samples is 995±50 K, coinciding with the drop in thermal diffusivities mentioned earlier. At temperatures above the glass transition, specific heat remains constant within analytical uncertainty.

Thermal conductivity. Using measurements of *D*, C_P and *ρ*, we calculated thermal conductivity for the glasses according to $k = D\ C_P\ \rho$, using linearized density $\rho = \rho_{298}\ [1 - \alpha(T - 298)]$ where *α* is the typical, constant thermal expansivity of $25 \times 10^{-6}\ K^{-1}$ [4]. The results for thermal conductivity of glasses and melt are plotted in Figure 2 and Figure 3, respectively. With some exceptions, Mg-rich glasses (e.g., basaltic komatiites such as EBe, IcP-HCT) tend to have higher thermal conductivity than the samples with higher Fe-contents (e.g., lunar KREEP; Martian Nakhlite and Shergottite). However, the trend in compositional dependence on thermal conductivity for glasses is not as clear for melts, where Mg-rich and Fe-rich melts are both, high and low, in thermal conductivity.

Discussion: The change in thermal conductivity from glass to melt can be positive (komatiite, eucrite, Shergottite, lunar mare, Mercury NVP) or negative (enstatite basalt, KREEP, Mercury IcP), depending on the relative magnitudes of the increase in specific heat and the decrease in thermal diffusivity observed at the glass transition temperature. This observation is consistent with results obtained on terrestrial glasses and melts previously studied [2]. Interestingly, our samples span as wide a range in thermal conductivity as terrestrial leucogranite and PMORB, for both glasses and melts. Therefore, models of planetary evolution and igneous processes should use composition-specific thermal conductivity data wherever possible.

Comparison to terrestrial lavas. The suite of planetary melts is generally less thermally insulating than terrestrial MORBs, an observation that has implications for melt generation and accumulation. In particular, lunar KREEP basalt and Mercurian NVP and IcP-HCT basaltic komatiites have low thermal conductivities. Consequently, partially molten regions producing these melts will also have low thermal conductivities, enhancing the productivity of decompression melting. This feedback mechanism may contribute to the large volumes of magma produced, and observed as extended lava flow features (e.g., sinuous rilles located in the Procellarum-KREEP Terrane on the Moon) and flood style volcanism (Northern Volcanic Plains on Mercury).

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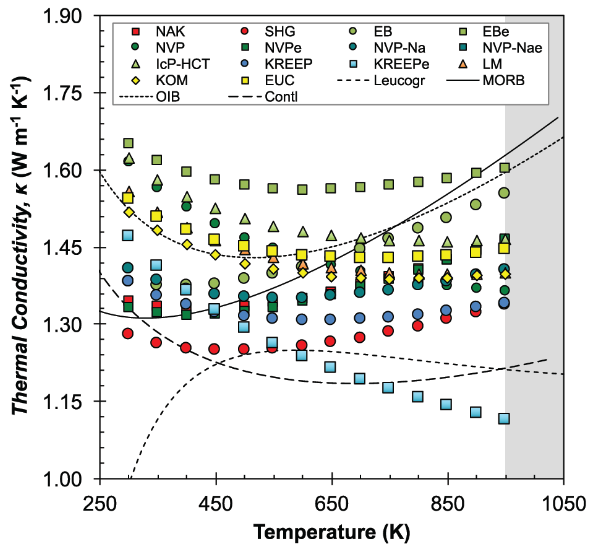

Figure 2: Thermal conductivity (κ) of investigated glassy samples from room temperature up to their melting points. For context, fitting lines for terrestrial samples are plotted again, bold solid lines represent thermal conductivities for melts as indicated. Gray area (T > 950 K) represents temperature interval where melting and some re-crystallization is observed.

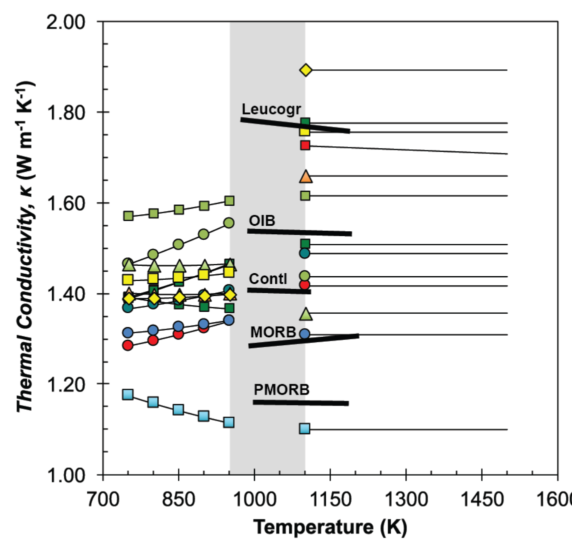

Figure 3: Thermal conductivity (κ) of melts above 1000K, calculated assuming that measured C_P and D of liquids are independent of temperature. For comparison, thermal conductivities for terrestrial melts [2] are given. Gray area (950 – 1100 K) represents temperature interval where melting and some re-crystallization is observed. Symbols for samples as indicated in Fig. 1 and Fig. 2.