RELATIONSHIPS AMONG REGOLITH THERMAL CONDUCTIVITIES AND SEISMIC VELOCITIES: APPLICATION TO INSIGHT STUDIES.

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Introduction: Studies of the thermal and seismic properties of planetary regoliths are complex because of uncertainties and variability in composition, particle and pore geometrical shape, size distribution, and three-dimensional physical connectivity. Therefore, correlations among physical properties that relate to geophysical parameters that may be measured directly or indirectly are potentially useful for studying regoliths. Studies of relationships among seismic velocities and thermal conductivities of terrestrial rocks and minerals indicate general positive correlations, often with non-Gaussian scatters in the correlations that may result in part from heterogeneity in samples used for thermal conductivity determinations. Plots of laboratory data for seismic velocities versus thermal conductivity under ambient conditions for minerals and rocks are shown in Figs. 1 and 2, respectively. These data indicate linear relationships within the limitations of the data chosen.

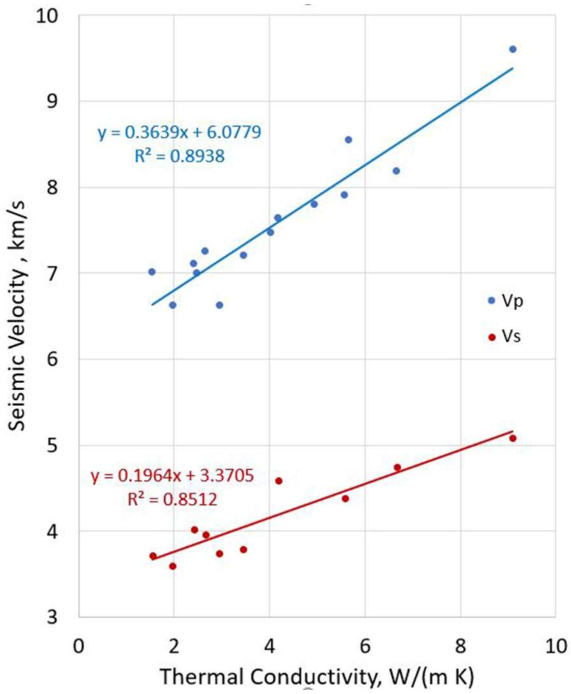

Fig 1: Plot of mineral P- and S-wave velocities versus thermal conductivity for data from [1 (Tab. 6 & Fig 9)]. Velocities corrected to 1 atmos. For comparison with thermal conductivities.

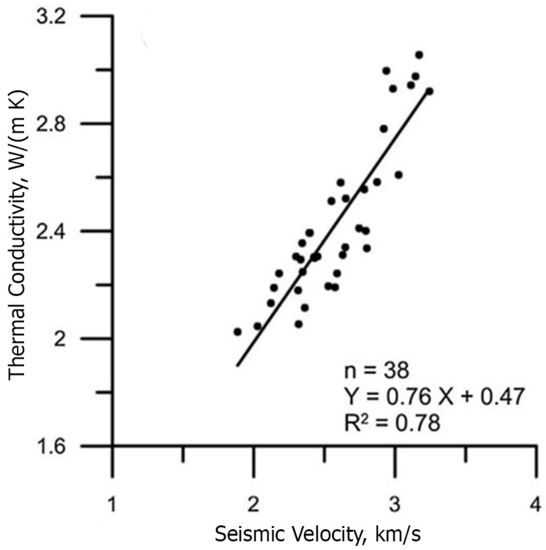

Fig 2: Plot of thermal conductivity versus compressional-wave velocity for sedimentary and igneous core samples taken from a borehole in a horst in the Rhine Graben. Reproduced from [2].

In this contribution we have compiled and collated thermal and seismic velocity data relevant to the Mars regolith and present a preliminary relationship for the regolith at the InSight landing site.

InSight Regolith: Regolith properties were assessed at the InSight landing site prior to landing and summarized in [3] using many published studies and ongoing work by the InSight Science Team. These properties included regolith grain size, density, seismic velocity, and thermal conductivity. Data collected after touchdown of the InSight lander have generally supported and placed additional constraints on pre-landing predictions. Based on experimental data compressional- (Vp) and shear- (Vs) wave velocities were predicted to increase substantially in the first 5 m depth of the regolith. Velocities are shown for a medium density model in Fig. 3. Dense, and very dense differ in density by about 175 kg/m^3 at a depth of 5 m, and the maximum difference in seismic velocities at 5 m was calculated to be less than 10 m/s. Preliminary Insight results are consistent with a regolith density of 1300 kg/m^3 [4], corresponding to the medium density model.

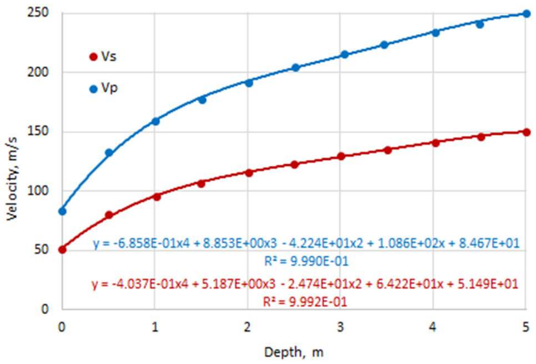

Fig 3: Plot of predicted regolith seismic velocities as a function of depth. Solid curves are third-order polynomial trend fits to data points (dots)

Limited laboratory measurements of thermal conductivity as a function of bulk density indicate a positive correlation for quartz particles [5]. No consistent trend was measured for glass beads or olivine. Data are only available for 25-30 µm quartz and thermal conductivity was found to increase with increasing gas pressure from 0.5 torr to 20.0 torr. We calculated an increase in thermal conductivity with bulk density of 5.3 x 10^{-7} W/(m K) per km/m^3 at a gas pressure of 6 torr and 6.7 x 10^{-7} W/(m K) per km/m^3 at a gas pressure of 8 torr, bracketing the pressure at the InSight landing site. Based on these and other studies, using an equation from [3], and a shallow thermal conductivity determination made by the InSight HP^3 mole [6], thermal conductivities have been estimated for the depth range from 0 to 5 m, as shown in Fig. 4. These thermal conductivities are plotted against seismic velocity in Fig. 5, correlated by depth.

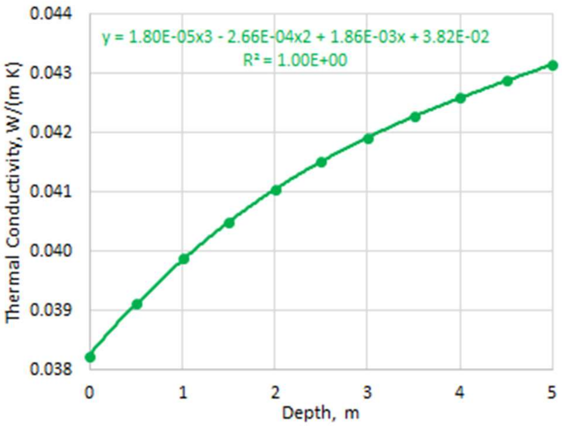

Fig 4: Estimated regolith thermal conductivities as a function of depth at the InSight landing site based on a relationship between thermal conductivity and bulk density and a measured thermal conductivity of 0.039 W/(m K) in the near surface.

Discussion: Rigorous laboratory and field data are lacking to establish a reliable relationship among Mars regolith thermal conductivities and seismic velocities. Published studies, studies published in preparation for the InSight lander mission, and preliminary results from the InSight mission suggest an approximately linear relationship among thermal conductivities and seismic velocities at the InSight lander site. However, the rough correlation of these parameters may result from their derivation from equations essentially based on the same parameter – density.

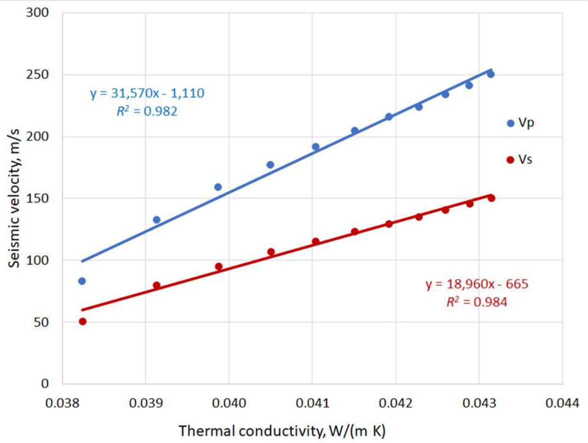

Fig 5: Predicted seismic velocities versus calculated thermal conductivities for the upper 5 m of the regolith at the InSight landing site with linear trend fits.

There is a significant difference in slopes and intercepts of the lines for the relationship between thermal conductivity and seismic velocity for terrestrial rocks at ambient pressure shown in Fig. 2 and the relationships for the InSight Mars regolith shown in Fig. 5. Transposing axes for Fig. 2 and changing velocity units from to m/s the recalculate slope is $V=1{,}316K–0.47$, where V is seismic velocity and K is thermal conductivity. This contrasts with $Vp=31{,}570K-1{,}110$ and $Vs=18{,}960K-665$ for the InSight regolith under Mars atmospheric conditions. The mineral samples (Fig. 1) were crushed so the difference between the two data sets cannot be explained in terms of solid versus particulate material. The primary difference in the samples was the low gas pressures Mars regolith studies.

This preliminary study indicates that a useful relationship exists among thermal conductivity and seismic velocities for the Mars regolith. Further laboratory and field studies are needed to confirm and extend this tentative conclusion.

References: [1] Horai, K. (1971) JGR, 76, 1278-1308. [2] Gu et al. (2017) *Geothermics, 66*, 61-72. [3] Morgan, P. et al. (2018) Space Sci. Rev, 214:104, 47 pp. [4] Kenda et al (2020) JGR, 125, e2020JE006387. [5] Presley, M, Christensen, P. R., (2010) JGR, 115, E07003, 20 pp. [6] Grott et al. (2021) this meeting.