IRON METEORITE THERMAL INERTIAS: IMPLICATIONS FOR 16 PSYCHE

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Introduction: We have measured the density, thermal conductivity, and specific heat capacity of subsamples from four iron meteorites with nickel concentrations between 5-8% (IIAB Agoudal, IAB-MG Canyon Diablo, IVA Muonionalusta and IIAB Sikhote-Alin) at temperatures between 5-300 K. From these we calculate their thermal inertia $\Gamma = (\kappa\ \rho\ c_p)^{1/2}$ across this temperature range. These thermal inertias display a strong temperature dependence, increasing with rising temperature from less than 100 J m^{-2} K^{-1} $s^{-1/2}$ at temperatures below 10 K to roughly 10,000 J m^{-2} K^{-1} $s^{-1/2}$ near room temperature. Additionally, the data show an inflection point: from 5 K to 55 K there is a rapid increase in thermal inertia, while above 55 K, there is a much more gradual increase, with a saturation appearing near 300 K.

Psyche Thermal Inertia: Our new data provide a useful ground truth in understanding remotely sensed thermal inertias of potentially metal rich asteroids, including 16 Psyche, target of the NASA Psyche mission. Psyche is classified as an M type asteroid on the basis of its mostly featureless spectra and its high radar albedo, although its spectrum does show non-metallic components. Its bulk density of 3780 ± 340 kg m^{-3} [1] is consistent with a dominantly metallic rubble pile of about 50% porosity. Its high radar albedo, 0.34 ± 0.08 [2], implies a surface bulk density around 3500 kg m^{-3} [3,4] which is only about 7% lower than its overall bulk density.

The thermal inertia of Psyche based on ALMA observations in millimeter and submillimeter wavelengths [5] estimates a thermal inertia of 280 J m^{-2} K^{-1} $s^{-1/2}$. For an object with an average surface temperature at around 120 K, this is significantly higher than that of S or C type asteroids, which tend to fall between 2 and 100 J m^{-2} K^{-1} $s^{-1/2}$. However, the average thermal inertia for our four iron meteorites at 120 K is just under 7000 J m^{-2} K^{-1} $s^{-1/2}$.

Surface of Psyche: Of the three components of the thermal inertial equation, two of them depend on porosity P: density obviously varies as (1 - P) while an empirical relationship [6] suggests that meteorite thermal conductivity varies as (1 - P)/P. Thus one might expect thermal inertia to vary as $(1 - P)/P^{1/2}$. To use this relationship to estimate the surface porosity of Psyche, we scale the conductivity to match the measured conductivity of our samples at P = 1%; doing so, we find that the Psyche thermal inertia requires a surface porosity ranging from 67% if the surface is metallic, to 40% if it is half metal, half ordinary chondrite. However, the density of such a surface would range from 2600 – 2800 kg m^{-3} which is significantly lower than the inferred radar density. This difference may represent a change in porosity from the meter-scale depth measured by radar wavelengths to the centimeter-scale depth measured by thermal inertia. For example, one might hypothesize a thin surface of accreted chondritic material or even chondritic dust, overlying a “bedrock” of iron-nickel.

References: [1] Elkins-Tanton L. T. et al. (2020) *Journal of Geophysical Research: Planets* 125:e06296. [2] Shepard M. K. et al. (2021) *The Planetary Science Journal* 2:id.125 [3] Ostro S. J. et al. (1985) *Science* 229:442-446. [4] Shepard M. K. et al. (2017) *Icarus* 281:338-403 [4] de Kleer K. et al. (2021) *Planetary Science Journal* 2:149 [5] Flynn G. J. et al. (2018) *Chemie der Erde* 78:269–298.