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 IAB 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.