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Mid-IR spectral effects of regolith porosity: Implications for surface mineralogy of Trojan asteroids

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1. Introduction

Mid-infrared (MIR; 5-35 μm) spectra of Jupiter's Trojan asteroids (hereafter Trojans) exhibit silicate emission features, not unlike a comet comae [1], [2], [3] (Figure 1A). The resemblance between Trojan and comet comae spectra was initially perplexing, because asteroid regoliths are optically thick and comet comae are optically thin. To explain this resemblance, researchers hypothesized that Trojan surfaces must consist of a fine grained, 'fluffy' regolith of silicates or the regolith is made of silicates suspended in a transparent matrix [1], [2], [3]. For this abstract we will hereafter use 'regolith porosity' to refer to how fluffy a regolith is.

The MIR spectra of silicates changes with gain size due to relative contributions from volume and surface scattering (*e.g.,* [4], [5]). Large grains and closely packed regoliths show a strong contribution from surface scattering in the center of strong molecular vibration bands, where absorption coefficients are large. As grain size decreases (and grains are well separated), volume scattering begins to dominate throughout the absorption band, resulting in the band center appearing as a peak rather than a dip [5].

Olivine transparency features shift toward shorter wavelengths, and exhibit increasingly asymmetric behaviors with a decrease in particle size [6], [5]. Additionally, the spectral contrast of fine-grained silicate (< 74 μm) spectra is dependent on composition [7]. [2] presents mixtures of olivine-rich meteorites with potassium bromide (KBr), an IR-transparent salt, and compares the spectrum of the mixture to Trojan (624) Hektor's spectrum. Their results indicate a KBr diluted sample is a better match to Hektor's MIR spectrum than are spectra of pure powdered silicates, indicating Trojans have a porous or salty regolith, dominated by volume scattering throughout the MIR.

To understand the MIR spectral region with respect to regolith porosity we will test the following hypothesis: Porosity in regoliths of fine-grained silicates have a systematic and quantifiable effect on the band position, shape, and spectral contrast of MIR spectra.

2. Methods

We focus on the olivine forsterite in this study. Our sample is natural, and thus contains some contamination from other mineral phases. We separated the forsterite from other phases by hand. In order to control for the effect of grain size, we ground the forsterite using an agate mortar and pestle and sieved into the following grain sizes: < 20 μm, < 45 μm, and < 63 μm. We selected these size ranges because [8] found that surface scattering gives way to volume scattering, inverting the restrahlen bands, for grain sizes around 65 μm, and MIR spectra of Trojan asteroids exhibit this apparent inversion [1].

To simulate the effects of regolith porosity, we mixed the forsterite powders with KBr powder ground and sieved into the same size range bins. Each forsterite powder sample has been be mixed with a KBr in ratios from 0% to 90% with 10% intervals by weight. We did not press our samples into sample cups; rather, we fill sample cups with the forsterite powder + KBr mixture and level the surface by scraping. MIR measurements were taken using an Agilent Cary 600 Series Fourier transform infrared (FTIR) spectrometer and PIKE Technologies EasiDiff diffuse reflectance accessory. We measured spectra from 4000 to 400 cm^{-1} with a 4 cm^{-1} resolution in diffuse reflectance mode.

3. Results

By comparing bands to [9], we estimate the Mg# is between 70-90, which agrees with other forsterite collected from the same region. We will perform microprobe analyses to confirm these estimates of Mg#. Some regolith porosity effects that can been seen from Figure 1B include: the Christiansen Feature at ~ 8.8 μm decreases in spectral contrast, and shifts slightly to the longer wavelengths as regolith porosity increases, the restrahlen bands

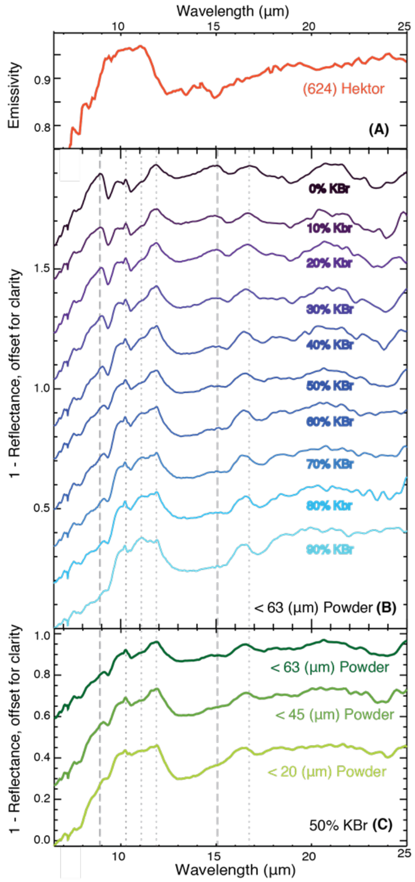

Figure 1: (A) Emission spectra of Hektor, taken with the Spitzer Space Telescope (modified from [1]).(B) FTIR measurements of forsterite powder at each regolith porosity. Dotted lines: restrahlen bands identified in the 0% KBr measurement, dashed lines: Christiansen features. (C) FTIR measurements of each size range with 50% KBr.

around 10 and 12 µm do not shift wavelengths but do decrease in spectral contrast, and the broad 13 µm transparency feature deepens with increased regolith porosity. The effect of regolith porosity appears to be dependent on grain size (Figure 1C). At a first glance, the smaller size ranges appear to look more similar to higher regolith porosities of larger grain sizes.

4. Summary and Conclusions

Trojan asteroids are a substantial group of primitive bodies that carry insight into the building blocks that make the larger bodies in our Solar System as well as the formation mechanisms that shaped it. Trojans are thought to have formed in the primordial Kuiper belt [10], [11], [12]. The surface composition of asteroids can be indicative of formation region [13]. Mg-rich crystalline silicates tended to form in the inner Solar System, and Fe-rich silicates formed in the outer Solar System [14], [13]. Thus, knowing the Mg# is useful for constraining formation region of Solar System objects, such as comets or Trojans. Preliminary results support the hypothesis that regolith porosity has a systematic effect on silicate features in the MIR.

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