

STUDY OF REFLECTANCE SPECTRA OF LABORATORY MIXTURES OF ORGANICS RELEVANT TO CERES. A. N. Rentas Marchand^{1, 2}, R. T. Daly², K. R. Stockstill-Cahill², L. C. Mayorga², and J. M. Sunshine³.

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Introduction: While studying Ceres, Dawn's Visible and Infrared Spectrometer (VIR) detected an absorption feature near 3.4 μm interpreted as evidence for aliphatic organic materials [1–3]. Due to this discovery, it is now of even greater interest to study the dwarf planet's astrobiological potential.

Ceres' organics were detected near impact craters, with the strongest spectral features located near Ernutet crater [1–6]. The origin of the organics has been contested [1–2, 6–7] and questions remain about whether the organics' origin are endogenic or exogenic, although results from numerical impact models currently favor an endogenic origin [7]. Regardless of their origin, Ceres' impact record suggests the organics experienced shock processes via impacts.

Prior studies have investigated how shock processes affect organic compounds [e.g., 8–11]. However, most of these earlier studies cannot be directly leveraged to interpret VIR data since most of them did not measure IR reflectance spectra and most used compounds that differ from the organics on Ceres. Korochantsev et al. [10–11] is an exception, but that work appears reported in abstracts only. It is important to look at shock effects because experiments at ambient pressure can underestimate the survival of organics during impacts. For instance, [12] determined that amino acids pyrolyze at the same rates at 7000 K and 100 GPa as they would at 1 atm and 900 K.

To constrain the effects of impact and shock processes on the reflectance spectra of organics relevant to Ceres, we plan to conduct hypervelocity impact experiments on gilsonite (another name for asphaltite). Asphaltite/gilsonite is a spectral analog for Ceres' organics [13]. Some impact experiments will have organics in the target; others will use organics in the impactor to assess endogenic vs. exogenic origins.

To prepare for the experiments, we studied the reflectance spectra of various laboratory mixtures of gilsonite with serpentine and pumice to understand how the spectra vary as a function of mixing ratios. These mixtures help constrain the detection limits of gilsonite in the experiments.

Methods: We created 10 mixtures of gilsonite plus serpentine and 11 mixtures of gilsonite plus pumice (Fig. 1). We chose serpentine and pumice for different reasons. Serpentine occurs on Ceres in mixtures with organics [1], but has spectral features near 3.4 μm that overlap with the organic bands. Pumice does not occur on Ceres, but its 3.4 μm region is more neutral, dominated by broad water- and OH-related absorptions.

We collected reflectance spectra in the Laboratory for Spectroscopy in Planetary Environmental Conditions (LabSPEC) at APL from 400 to 8000 nm. Spectra were collected under vacuum conditions (10^{-6} torr) using an SVC HR-1024i point spectrometer (400–1800 nm) and Bruker Vertex 70 lab FTIR (1800–8000 nm). For additional information on LabSPEC, see [14].

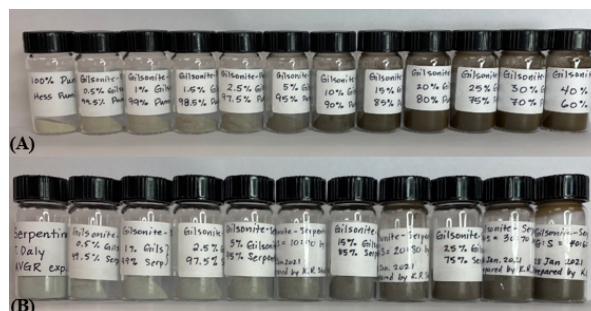


Fig. 1. Laboratory mixtures of gilsonite with pumice and serpentine. (A) The first container is a sample of the powdered pumice. The following 11 containers are mixtures of gilsonite plus pumice. The ratios are: 0.5/99.5, 1/99, 1.5/98.5, 2.5/97.5, 5/95, 10/90, 15/85, 20/80, 25/75, 30/70, and 40/60 weight %. (B) The first container is a sample of serpentine. The following 10 containers are mixtures of gilsonite plus serpentine. The ratios are: 0.5/99.5, 1/99, 2.5/97.5, 5/95, 10/90, 15/85, 20/80, 25/75, 30/70, and 40/60 weight %.

After obtaining these spectra, we measured the band depths at six absorption features. The absorption features and their band assignments are as follow: 3280 nm aromatic CH, 3385 nm aliphatic CH₃, 3415 nm aliphatic CH₃ and aromatic CH₃, 3490 nm aliphatic CH₃, 3500 nm aliphatic CH₂, and 3665 nm Ar₃CH or aldehyde [15]. Band depths were calculated using the formula from Clark and Roush [16].

Results: Figures 2 and 3 show the reflectance spectra of the mixtures from 3100 to 3800 nm. The samples all show the absorptions listed in the previous paragraph. The feature at 3280 nm manifests as a shoulder. Even in the mixtures with 0.5 wt. % gilsonite, the spectra have clear absorptions and measurable band depths at 3385, 3415, 3490, and 3500 nm (Figure 4). The less prominent features at 3280 nm and 3665 nm become indistinct below ~5 wt. % gilsonite. The depth of the 3415 nm band does not change as quickly in mixtures with >15% gilsonite as it does in mixtures with less gilsonite (Figure 4). The four strongest bands approach saturation in the 40/60 mixtures.

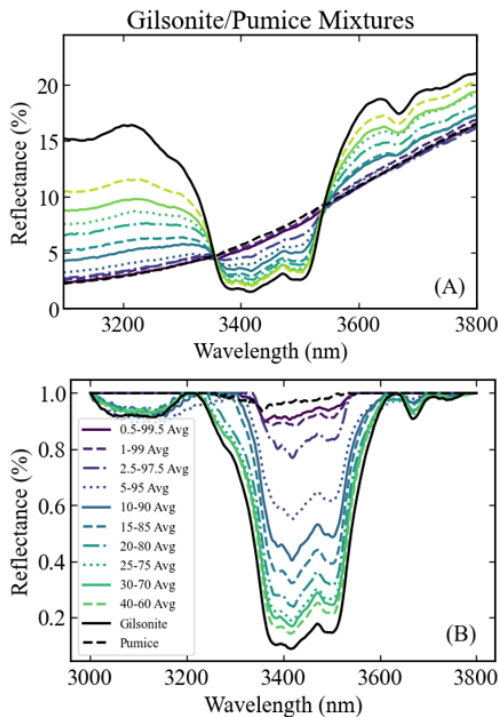


Fig. 2. (A) Reflectance spectra of gilsonite, pumice, and gilsonite/pumice mixtures, (B) continuum-removed spectra. The legend in (B) applies to (A).

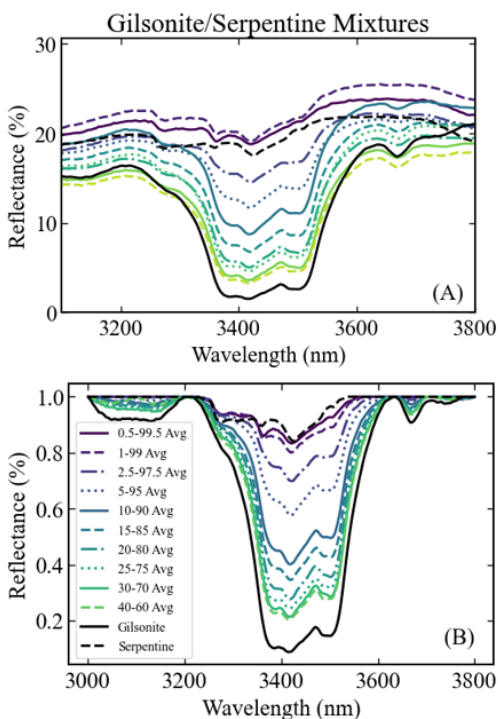


Fig. 3. (A) Reflectance spectra of gilsonite, serpentine, and gilsonite/serpentine mixtures, (B) continuum-removed spectra. The legend in (B) applies to (A).

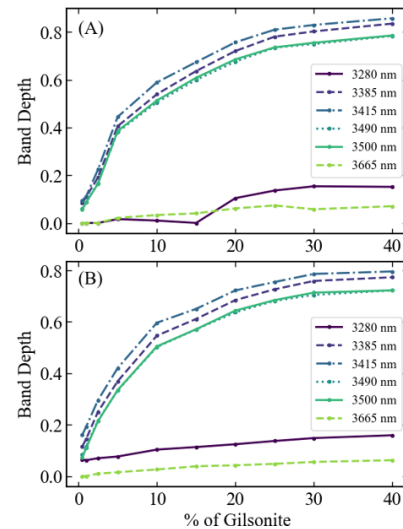


Fig. 4. Band depth at six absorption features versus the percentage of gilsonite in the (A) gilsonite plus pumice and (B) gilsonite plus serpentine mixtures.

Discussion: In the mixtures, spectral signatures of gilsonite are evident in mixing ratios akin to Ceres' inferred abundances of aliphatic organics. The estimated abundance of organics on Ceres depends on assumptions in spectral mixing models [e.g., 1–2, 5]. Although the 15/85 mixture is a higher ratio than inferred from spectral mixing models of Ceres that assume an asphaltite endmember, using this higher ratio ensures that any spectral changes in the 3.4 μm region induced by impact shock should be easily noticeable.

Conclusion: Spectral studies of these laboratory mixtures testify that we can observe the 3.4 μm feature and identify spectral changes related to changes in mineral abundances. Thus, the 15/85 mixture is suitable to be used in impact experiments to assess the effects of shock on aliphatic organics like those on Ceres.

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References: [1] De Sanctis et al. (2019) *MNRAS*, 482, 2407–2421. [2] Raponi et al. (2019) *Icarus*, 318, 99–100. [3] Kaplan et al. (2018) *Clays Clay Miner.*, 66, 173–189. [4] Vinogradoff et al. (2021) *Minerals*, 11, 719. [5] Raponi et al. (2021) *Life*, 11, 9. [6] Pieters et al. (2018) *MAPS*, 53, 1983–1998. [7] Bowling et al. (2020) *EPSL*, 534, 116069. [8] Blank et al. (2001) *Orig. Life Evol. Biosph.*, 31, 15–51. [9] Cooper et al. (2014) *EPSL*, 385, 206–215. [10] Korochantsev et al. (1996) *M&PSA*, 31, A73. [11] Korochantsev et al. (2001) *M&PSA*, 36, A104. [12] Blank & Miller (1998) *Proc. 21st Int. Sym. Shock Waves*, 1467–1472. [13] De Sanctis et al. (2018) *MAPS*, 53, 1844–1865. [14] Hibbitts et al. (2019) *Icarus*, 326, 37–47. [15] Moroz et al. (1998) *Icarus*, 134, 253–268. [16] Clark & Roush (1984) *JGR*, 89, 6329–6340.