Evidence of Shock Darkening/Impact Melt on Near-Earth Asteroid (52768) 1998 OR2

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Introduction: S-complex asteroids dominate the large near-Earth asteroid (NEA) population and some have been linked to ordinary chondrite meteorites [e.g., 1]. There is, however, a discrepancy between the percentage of ordinary chondrites in the meteorite collection (~85%) [2] versus the percent of NEAs with ordinary chondrite-like compositions. Several non-compositional effects on an asteroid surface and in the observation process can alter the visible and near infrared (VNIR) spectrum (0.35-2.5 µm) of the asteroid, potentially leading to a misidentification of meteorite analogs. We analyze VNIR spectra of NEA 1998 OR2 and find some of the first evidence of shock darkening processes altering an NEA surface.

Spectroscopy Derived Surface Mineralogy: Visible spectra (0.45-0.93 µm) of 1998 OR2 were collected on 2020 April 16 using the Robotic Automated Pointing Telescope for Optical Reflectance Spectroscopy I (RAPTORS I) telescope at the University of Arizona. The measured low resolution (R~30) visible spectra were combined with MITHNEOS [1] archival near infrared (NIR; 0.78-2.49 µm) spectra from the NASA Infrared Telescope Facility. The combined VNIR spectroscopy shows a very flat spectrum with two shallow absorption bands which are diagnostic of olivine and pyroxene surface mineralogy [3]. The best matching taxonomic classification for the observed spectrum is Xn-type, as measured by the SMASS online tool [4]. The absorption bands were noted to be suppressed compared to typical absorption bands seen on S-complex asteroids, indicating the likely precense of an alteration process or non-compositional affects on the data. Measurements of the following diagnostic band parameters were taken: Band I at 0.926 ± 0.003 µm and Band II at 2.07 ± 0.02 µm; Band I depth of 4.5 ± 0.15% and Band II depth of 4.0 ± 0.21%; Band Area Ratio of 1.13 ± 0.05. Further analysis of these band parameters using the equations from [5-6] indicate that this is a composition consistent with H chondrites.

Non-compositional Effects: In order to understand the suppressed band features of the VNIR spectra, we investigated effects from phase reddening, space weathering, grain size, and shock darkening. We were able to rule out phase reddening because the NIR observations were at a relatively low phase angle (40.2°) and 1998 OR2's observed spectrum was very flat. Principal component analysis was used to eliminate the hypothesis that space weathering or grain size effects were causing the observed spectral features. Shock darkening is an ideal candidate for explaining the observed spectral features because it causes supressed absorption band features without reddening the asteroid spectrum. Shock darkening is also supported by principal component analysis placing 1998 OR2 near the end of the shock darkening trend measured by [1] in principal component space.

Meteorite Analog: A comparison of meteorites in the RELAB database with 1998 OR2's spectrum using the Modeling For Asteroids (M4AST) tool returned shock darkened ordinary chondrite McKinney as the best potential meteorite analog [7-8]. In order to perform our own analysis, shock darkened H5 ordinary chondrite Chergach was selected for comparison with 1998 OR2. Our sample of Chergach was loosely broken apart and the dark and light lithologies were separated by hand. The dark and light lithologies were separately crushed and dry sieved to < 45 µm. Spectra of each endmember were obtained with an ASD spectrometer to obtain a VNIR spectrum for comparison with 1998 OR2. Both the meteorite spectra and the 1998 OR2 spectrum were continuum corrected and normalized at 1.5 µm. An aerial mixing model was used to mathematically mix the two endmembers and calculate a chi-squared value to quantify the goodness of fit between the meteorite mixture and 1998 OR2's spectrum. The mixture with the lowest chi-squared value was chosen as the best fit for the mixture and allows us to constrain the amount of shock darkened material on the asteroid. The best-fit match with 1998 OR2 corresponds to a 37:63 light/dark lithology mixture.

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References: [1] Binzel R. P. et al. (2019) Icarus, 324, 41. [2] Grossman J. (2021) Meteoritical Bulletin, https://www.lpi.usra.edu/meteor/metbull.php. [3] Reddy V. et al. (2015), in *Asteroids IV*. [4] Slivan, S. 2013, MIT Dept. of Earth, Atmospheric, and Planetary Sciences, http://smass.mit.edu/busdemeoclass.html [5] Sanchez J. A. et al. (2020), *Astronomical Journal*, 159. [6] Dunn T. L. et al. (2010) Icarus, 208, 789. [7] Popescu M. et al. (2012) *Astronomy and Astrophysics*, 544. [8] Birlan M. et al. (2016), in DPS, Vol. 48, Abstract #325.17.