VNIR Reflectance Spectroscopy of Five G-class Asteroids: Implications for Mineralogy and Geologic Evolution. J. T. Germann[1] and S. K. Fieber-Beyer[1,2], [1]Dept. of Space Studies, Box 9008, Univ. of North Dakota, Grand Forks, ND 58202. jusgermann@gmail.com. [2]Visiting astronomer at the IRTF under contract from the NASA, which is operated by the Univ. of Hawaii Mauna Kea, HI 97620. sherryfieb@hotmail.com

Introduction: The Tholen G-class asteroids are a relatively small taxon (~30 members) with visible spectral properties similar to the C-class barring a steeper UV slope blueward of 0.5-µm [1]. Ceres is classified as a member of the G-class and, being the largest asteroid in the solar system, has been the subject of many scientific studies [2–5]. However, the majority of the G-class are understudied in the visible- infrared (VNIR) spectral range (~0.4-2.5-µm).

Our study seeks to investigate two research questions: 1. What VNIR spectral properties are common among the G-class asteroids, and 2. What are the mineralogic interpretations of the features observed in each asteroid's spectrum? Our current study investigates the VNIR spectral properties of five G-class asteroids ((1) Ceres, (13) Egeria, (19) Fortuna, (84) Klio, and (130) Elektra) examining each spectrum for subtle absorptions features. As such, we have measured the absorption features and related these features to features produced by minerals such as brucite and the phyllosilicates.

Although multiple studies have attempted to relate the G-class asteroids to the carbonaceous chondrite meteorites [6–8], rigorous band analyses have not been conducted to attempt mineralogical characterizations. For example, past studies relied on techniques such as curve matching. However, with the recent improvements in the capabilities of reflectance spectroscopy, as well as the advances in laboratory studies, we are now able to measure the subtle G-class absorptions and relate them to minerals and mixtures measured in the laboratory [9–11]. While Ceres has been well studied, our investigation shows that Ceres should not be considered as an analog for the G-class, but rather that each asteroid should be considered individually when attempting to probe the surface minerals and relate those minerals to our terrestrial meteorite collection.

Data and Methods: SMASSII archived spectra (0.4-0.9-µm) were used for the visible components of the spectra used in our study [12]. Reduced NIR (~0.7-2.52-µm) spectra of (84) Klio and (130) Elektra were retrieved from the Reddy Main Belt Asteroid spectral archive [13]. The near-infrared spectra of asteroids (1) Ceres, (13) Egeria, and (19) Fortuna were obtained July 21, 2016 at the NASA IRTF using the SpeX instrument [14] in the low-resolution mode (0.68-2.54-µm). Asteroid and standard star observations were interspersed within the same airmass range to allow modeling of atmospheric extinction. Data were reduced using previously outlined procedures [15,16].

Results: Our results show that Ceres exhibits a single, broad VNIR absorption feature centered at ~1.3-µm. Asteroids Egeria, Fortuna, Klio and Elektra each show a strong absorption feature located at 0.7-µm. In addition, 0.95- and 1.14-µm absorption features are present in Egeria, Fortuna, and Elektra, while the 1.25-, and 1.4-µm features are only observed in Egeria and Fortuna. Lastly, a measurable 2.3-µm feature is noted in Elektra's spectrum. See Figure 1.

Discussion and Interpretation: Minerals such as brucite, carbonates, and phyllosilicates are consistently suggested as possible surface minerals for the G, and C-class asteroids [17–20]. [9] conducted a laboratory investigation to study the VNIR spectral properties of brucite, carbonate, and clay mixtures. The results of the study showed that absorptions were produced at 0.95-, 1.4-, and ~2.45-µm. It has also been determined that the 0.7-µm feature is produced by the Fe^{2+}-Fe^{3+} charge transfer in oxidized iron phyllosilicates [21], and that this feature diminishes when the Fe-bearing phyllosilicates are heated beyond ~400 ºC [8]. [10] conducted a laboratory investigation of ammoniated phyllosilicates and reported that ammonia related features are produced at 1.56-, 2.05-, and 2.12-µm.

In our study, all asteroids, excluding Ceres, contain a 0.7-µm absorption feature indicating the presence of oxidized Fe-bearing phyllosilicates. Egeria, Fortuna, and Elektra contain 0.95-, and 1.14-µm features, indicating the presence of a brucite, carbonate, and clay mixture. Egeria also contains a 2.3-µm feature, which is also related to phyllosilicates.

We did not find features related to reported ammoniated phyllosilicate features [10]. However, the 3.0-µm feature is present in Ceres [22]. Although this feature is outside the scope of our study, the 3.0-µm absorption has been proposed to be related to ammoniated phyllosilicate minerals based off measurements from the DAWN VIR spectrograph [18]. The lack of a 0.7-µm feature in the spectrum of Ceres could also be a telltale sign of low-grade metamorphism of Fe-bearing phyllosilicate minerals resulting in the production of ammoniated phyllosilicates at Ceres' surface.

Conclusions and Future Work: Besides Ceres' single absorption feature, the majority of absorption features measured in our five asteroids were subtle. Despite this, most of these features were measurable and have consistent band centers. As such, this is indicative of surface minerals present on multiple asteroids, and not random noise. If the mineralogical correlations we propose are accurate, then Egeria, Fortuna, Klio and Elektra likely have surface minerals that have a phyllosilicate component. We are still investigating whether the specific phyllosilicate end-members can be determined, as well as investigating the potential geologic history of these bodies.

Due to Ceres' lack of a 0.7-μm feature, it is likely that Ceres' surface has undergone a secondary low-grade metamorphism event producing ammoniated phyllosilicates—the presence of which has been proposed by multiple researchers [23–26]. The lack of evidence for ammoniated minerals in our G-class asteroid pilot study suggests primitive surface mineralogies when compared to Ceres. Our pilot has investigated 5 G-class asteroids in preparation for a larger investigation of the entire G-class to determine if there are any trends in the VNIR spectral properties, to study the surface mineralogy, and to examine the geologic history of the G-class.

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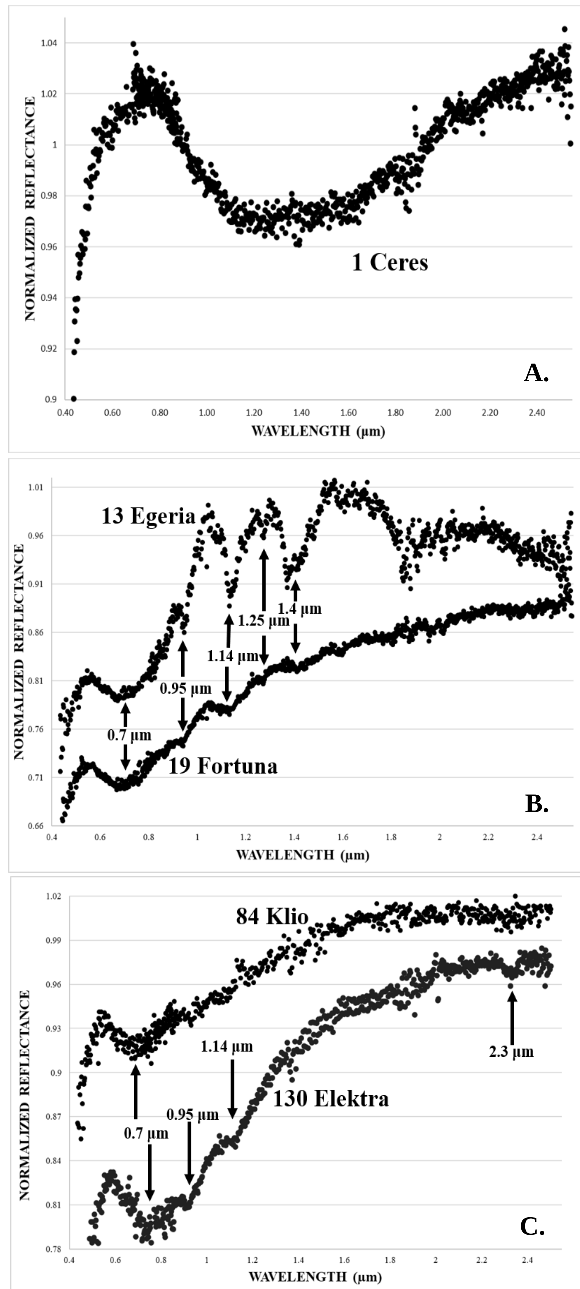

Fig 1. VNIR spectra of five G-class asteroids with measured absorption features labeled. (A.) 1 Ceres, (B.) 13 Egeria, 19 Fortuna, (C.) 84 Klio, 130 Elektra.