SPECTROSCOPIC STUDY OF Fe, Mg, Ca and Na CARBONATE MINERALS: IMPLICATIONS FOR MAPPING ASTEROIDAL AND PLANETARY SURFACES. C. B. Kiddell and E. A. Cloutis, 1Dept. of Geography, University of Winnipeg, 515 Portage Avenue, Winnipeg, MB, Canada R3B 2E9; kiddell-c@webmail.uwinnipeg.ca; e.cloutis@uwinnipeg.ca.

Introduction: Carbonaceous chondrite meteorites (CCs) are ancient and pristine materials, providing crucial insights into the solar system's geological evolution [1]. With rich organic content, CCs could influence the development of life on Earth and other planetary bodies. Moreover, they offer valuable perspectives on early solar system processes, often displaying signs of aqueous and hydrothermal alteration [2]. Their scientific importance is evidenced by the fact that two carbonaceous Near-Earth Asteroids (NEAs), Bennu and Ryugu, were targets of recent sample return missions. Their selection for sample return was largely driven by the fact that both show spectral signatures in the 3400 nm region, indicating the presence of carbonates and/or organics [3][4].

On September 24, 2023, NASA’s Origins, Spectral Interpretation, Resource Identification, and Security–Regolith Explorer (OSIRIS-REx) successfully returned a sample of NEA Bennu to Earth for analysis. While the sample will provide many insights about Bennu, it is likely not representative of the asteroid's full geological diversity. Previous research has shown the presence of carbonate veins and variation in organic abundances across Bennu's surface, which OSIRIS-REx may not have sampled [5]. Hayabusa-2, JAXA’s recent mission to NEA Ryugu, has identified similar spectral features of carbonates and organics [6].

To gain insights into the carbonate mineralogy of Bennu and Ryugu, as well as asteroid Ceres, and Mars, we are undertaking a spectroscopic study of carbonates, organic compounds, and natural terrestrial samples that contain carbonates and/or organics.

This study aims to analyze how C-O and C-H absorption bands in the 2300, 3400, and 4000 nm regions vary with composition and polymorphs of Ca, Mg, Fe, and Na carbonates.

Methodology: The samples for this study include ~25 Fe-Mg-Ca-Na carbonate minerals. Spectra were measured at the Reflectance Experiment Laboratory (RELAB) at Brown University using a bidirectional spectrometer and at the University of Winnipeg Centre for Terrestrial and Planetary Exploration (C-TAPE) using an ASD LabSpec 4 and Bruker Vertex 70 FTIR. The spectrometers collect data in the near-to-far-infrared regions, encompassing the regions of interest indicated in objective 1.

Results: Figure 1 illustrates the spectral variability of four carbonate minerals: magnesite, calcite, ankerite, and trona.

The absolute reflectance values acquired for the samples within the 2000-4000 nm wavelength range from approximately 8% to 92%, indicating substantial variability in reflectance. Calcite exhibits the largest fluctuations in absolute reflectance. Specifically, at the ~2300 nm absorption feature, the absolute reflectance for magnesite was approximately 81%, for calcite was around 69.5%, for ankerite was about 71%, and for trona was roughly 74%. While notable, absolute reflectance can vary due to any number of factors, such as grain size, viewing geometry, presence of opaques, etc.

The absorption band positions for each sample in the 2300 nm region are approximately 2304 nm for magnesite, 2339 nm for calcite, 2320 nm for ankerite, and 2230 nm for trona.

Likewise, the absorption band positions in the ~3400 nm region are around 3428 nm for magnesite, 3483 nm for calcite, 3498 nm for ankerite, and 3740 nm for trona.

In the ~4000 nm region, the absorption band positions were approximately 3951 nm for magnesite, 3981 nm for calcite, 3997 nm for ankerite, and 4037 nm for trona.

Discussion: The reflectance spectra of the four carbonate minerals exhibit discernible variations in absorption band positions, depths, and shapes, attributable to both compositional and physical characteristics. The absorption features observed at approximately 2300 nm, 3400 nm, and 4000 nm wavelengths are associated with carbon-oxygen bonds. Variations in their positions arise from differences in crystal structure and
specific cations that are present. This ongoing study includes a larger suite of Fe/Mg/Ca/Na carbonates.

The presence of multiple absorption bands in multiple wavelength regions provides multiple opportunities for carbonate detection and characterization. For instance some wavelength regions may be obscured by absorption bands due to other commonly co-occurring phases (e.g., 2300 nm region and clays; 3400 nm region and organics), while other spectral regions are less ambiguous and/or can serve to verify specific carbonate detections. This arises from the fact that different carbonate minerals show variations in absorption band positions in multiple wavelength regions.

**Conclusion:** The spectral measurements and analysis of carbonate minerals will assist in studying the surfaces of near-Earth and main-belt asteroids as well as Mars, thus is applicable to multiple planetary bodies. As carbonates can be sensitive tracers of conditions prevalent at the time of their formation, their detection and characterization can provide insights into the geological history and evolution of the solar system. This study will also assist in analyzing the global geological diversity of NEAs, including those from which samples have been returned to Earth: Bennu and Ryugu.

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