The Ries Impact Structure as an Analogue for Jezero Crater's Marginal Carbonates

M. J. O. Svensson[1], G. R. Osinski[1], T. A. Goudge[2], F. J. Longstaffe[1], L. L. Tornabene[1]
[1]Institute for Earth and Space Exploration, Dept. of Earth Sciences, University of Western Ontario, London, Ontario, Canada, N6A 5B7.
[2]Jackson School of Geosciences, The University of Texas at Austin, Austin TX.

Western Institute for Earth & Space Exploration

msvenss@uwo.ca

Introduction

The origin of carbonate-bearing units in the marginal regions of Jezero crater, a ~45 km diameter impact structure located in the Nili Fossae region of Mars, has been the subject of some debate [e.g., 1–7], specifically pertaining to whether these carbonates have lacustrine origins. Until recently, the inlets, outlets and fan deposits were considered the primary evidence of lacustrine activity [4, 8, 9]. Horgan et al. (2020) generated new maps of Jezero using hyperspectral data collected by CRISM in concert with imagery captured by HiRISE. They found a greater spectral diversity and a more distinct morphology in carbonates that exist between the western delta and the crater rim than previously thought and hypothesized that these carbonates could be associated with precipitation from the water column at the paleolake margins.

Objectives / Methodology

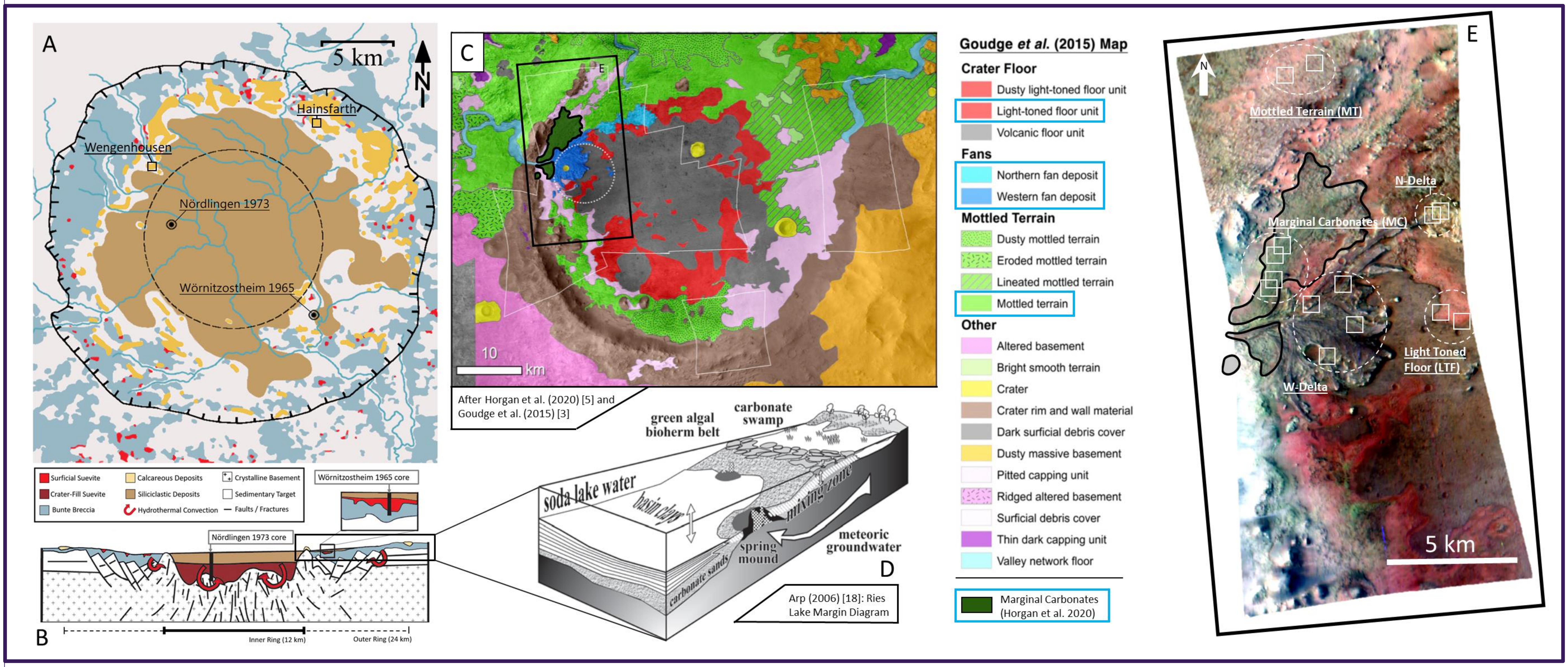
In this study, we aim to assess how much spectral variability might be expected for genetically distinct carbonates at Jezero crater. As an analogy, we studied the spectral variability of genetically distinct carbonates at the Ries impact structure, which were previously documented in detail and further characterized here using powder X-ray diffraction (*p*XRD), back-scatter electron (BSE) imagery, and visible to near infrared (VNIR) spectroscopy. We applied the Spectral Angle Mapper (SAM) algorithm [10] to quantify spectral differences between genetically distinct carbonate deposits and used an ANOVA test to determine whether significant differences existed between the carbonate groups both at the Ries impact structure and Jezero crater.

Carbonate Units at the Ries

The ~24 km diameter, ~ 14.8 Ma [11] Ries crater in southern Germany is a complex impact structure that hosts post-impact lacustrine carbonates at its basin margins (Fig. 1). These carbonates occur as palustrine limestones, carbonate sands, calcitic spring mounds and dolomitic algal bioherms [12, 13 & references therein]. At this point in this study, spectra were collected from the Hainsfarth (algal bioherms) and Wengenhousen (palustrine limestone) outcrop locations, and the Wörnitzostheim 1965 and Nördlingen 1973 drill cores (carbonate sands; Fig. 1; Fig. 2). Dolomitic algal bioherms are among the most common types of lake margin deposits at the Ries, so all other Ries carbonate spectra were compared to this unit for SAM and ANOVA analyses.

Carbonate Units at Jezero

Carbonate-bearing units at Jezero crater have been categorized based largely on their spectral properties, and geomorphological context [e.g., 3, 5, 6]. These carbonates can be grouped into four main categories: (1) carbonate fill occurring as a component of Jezero's light-toned floor (LTF), (2) marginal carbonates (MC) exposed along the base of the crater wall (primarily in the north of the basin), (3) deltaic carbonates occurring in northern delta (N-Delta) and in possible point bars of the western delta (W-Delta), and (4) watershed carbonates occurring in the regionally extensive mottled terrain unit (MT) [3–5] (Fig. 1). Spectra were collected from CRISM data (Fig. 2) [14], which was pre-processed using the techniques described in [15] and [16]. All Jezero carbonate spectra were compared to the MC unit for SAM and ANOVA analyses.



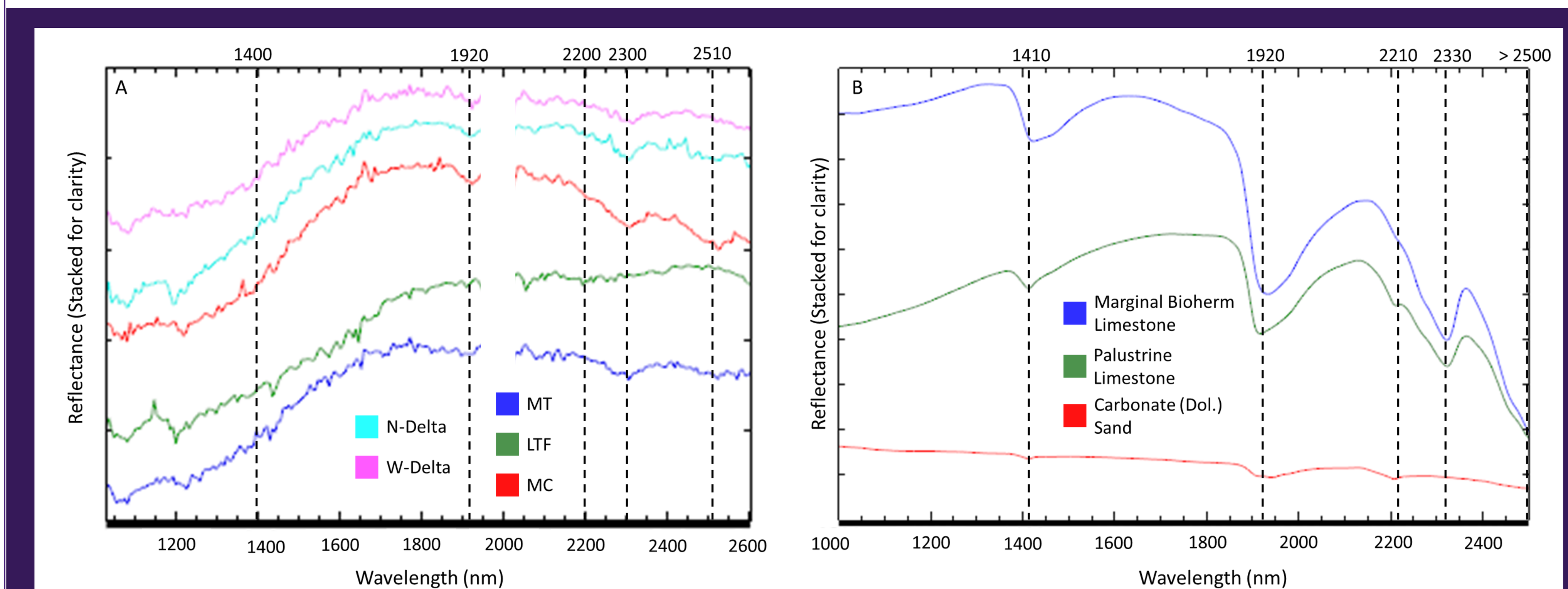


Figure 2: Example reflectance spectra of carbonate bearing units at Jezero crater (a) and the Ries impact structure (b). Common features are indicated by dashed lines with their respective wavelength measurement indicated along the upper x-axis. ~1400 and 2200 nm features indicate the presence of OH and OH-Al bonds, respectively. The 1920 nm feature indicates H_2O, and the paired 2300 and 2500 nm features indicate CO_3. A 2300 nm feature may also indicate (Mg, Fe)-OH bonds. Erroneous absorptions introduced by the volcano scan correction in the CRISM spectra have been removed. Spectra from Jezero crater were collected from DISORT-corrected CRISM cubes as described in [15] and [16].

Figure 1: The geological map of the Ries impact structure (a) [modified from 17] highlighting major geological units, outcrop locations (squares) and drill core locations (circles). The cross section (b) highlights areas of potential hydrothermal convection, and lithologically distinct units sampled by drill core [17]. An isometric view of the Ries crater-lake's margin environments (d) depicts settings for various carbonate units and distinguishes lacustrine deposits based on their depositional setting [18]. The geomorphic map of Jezero crater (c) highlights the location of the major units, denoted in the adjacent legend, and the approximate location of the CRISM image from which spectra were collected for this study (HRL000040FF_07_RA1831_TRR3; e). Blue boxes in the legend for figure 1c highlight the units studied here. Locations where CRISM spectra were collected in figure 1e are indicated by the white squares.

Discussion Points and Future Work

Spectral Features: Ries and Jezero spectra show multiple common features as indicated by the dotted lines in Figure 2. These features indicate the presence of CO_3-bearing material as well as water- and / or hydroxyl-bearing material such as carbonates with slight spectral diversity attributed to variations in hydrated mineralogy.

Analysis of Variance: ANOVA tests had the null hypothesis that SAM results from genetically distinct carbonates would not be significantly different from one another. The null hypothesis was successfully rejected.

Significance: These results support the work of Horgan et al. (2020), suggesting that the MC unit's spectral diversity may be owing to the origins of the unit.

Future Work: Datasets used here were small (Ries n=9; Jezero n=15), and the effects of surface roughness and grainsize in the Ries samples remains to be mitigated. Furthermore, spectra from additional localities at the Ries and Jezero are to be added to the dataset. ANOVA tests will be repeated to better test the hypothesis.

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CRC Canada
EPMA Earth and Planetary Materials Analysis Laboratory
NSERC CRSNG
Laboratory for Stable Isotope Science The University of Western Ontario
Ontario
RIESKRATER-MUSEUM NÖRDLINGEN