Mineralogical Characterization by XRD of Gypsum Dunes at White Sands National Monument. Application to Gypsum Detection on Mars

Barbara Lafuente[1], Sara King[2], Lori Fenton[2], Janice L. Bishop[2,3], Philippe Sarrazin[2], David Blake[3], Robert T. Downs[1], Briony Horgan[4], Gabriel Garcia[2]
[1]University of Arizona, Tucson, AZ [2]Carl Sagan Center, SETI Institute, Mountain View, CA [3]NASA Ames Research Center, Moffett, Mountain View, CA [4]Arizona State University, Phoenix, AZ

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Introduction

- The presence of gypsum ($CaSO_4 \cdot 2H_2O$) in Olympia Undae was reported on the basis of OMEGA imaging spectrometer data [1]. The goal of this study is to clarify our understanding of the origin and history of the gypsum-rich sand dunes at Olympia Undae using the terrestrial analog White Sands dune field [2].
- Field and lab analysis of mineral abundance and grain size have been performed on White Sands material from several dunes using a visible/near–infrared (VNIR) spectrometer [3] and an X-ray diffraction system (XRD).
- Here we present the analysis carried out using a Terra (Olympus NDT) portable field X-ray diffraction (XRD) instrument (Fig. 1).

Fig. 1. Terra XRD (Olympus NDT)

X-ray diffraction (XRD)

- XRD analysis consists of interpreting the positional relationship of diffracted intensities. Each crystalline phase has a unique diffraction pattern, and consequently XRD is the gold standard for identifying materials.
- Calcium sulfates can be easily distinguished by their XRD patterns (Fig. 2). Depending on the amount of water within the crystal structure, calcium sulfates are found in three different phases: gypsum ($CaSO_4 \cdot 2H_2O$), bassanite ($CaSO_4 \cdot 0.5H_2O$) and anhydrite ($CaSO_4$), and the sulfite hannebachite ($CaSO_3 \cdot 0.5H_2O$).
- The Terra XRD instrument is based on the technology of the CheMin (CHEmistry and MINeralogy) instrument onboard the Mars Science Laboratory (MSL) rover Curiosity, which is providing the mineralogical and chemical composition of scooped soil samples and drilled rock powders collected at Gale Crater [4].
- Using Terra at White Sands contributes to "ground truthing" gypsum–bearing environments on Mars. Figure 3 shows the geometry of the CheMin instrument, similar to that of the Terra instrument.

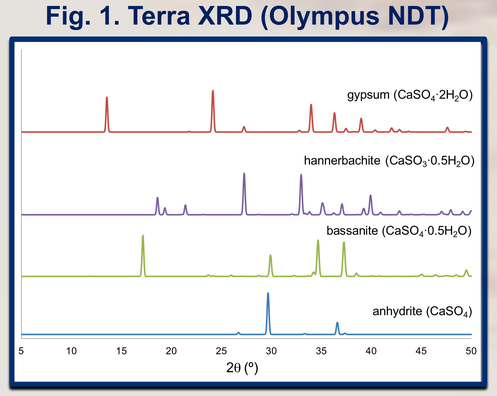

Fig. 2. Calculated XRD patterns of four calcium sulfates and sulfite.

Experimental

- Samples from the dunes 1, 2 and 3 were analyzed in the field by XRD. Relative mineral abundance was estimated using the Reference Intensity Ratio (RIR) method which requires calibration against standards [5].
- In order to analyze the grains in dune 3 with more detail, size fractions were prepared in the lab from samples collected at flag 4 farther up the dune) and 7 (farther down the dune).
- Samples collected from the crest of ripple 1 at dune 3 contained coarse grains with different colors [2]. The sorted grains were analyze by VNIR [3] and Raman spectroscopy.

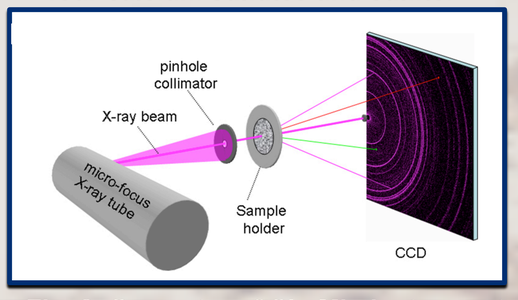

Fig. 3. Geometry of CheMin instrument.

Results

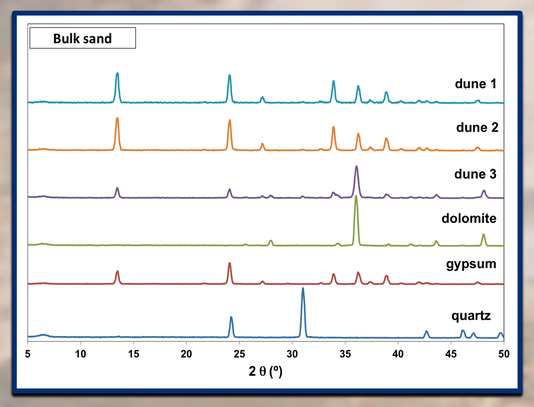

Fig. 4. Measured XRD patterns of field samples compared to mineral standards.

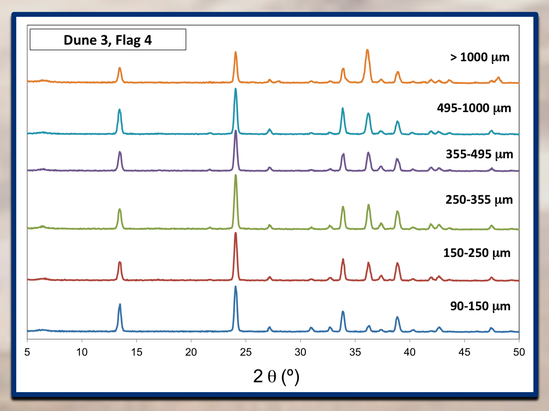

Fig. 5. Measured XRD patterns of size separates from Dune 3, Flag 4.

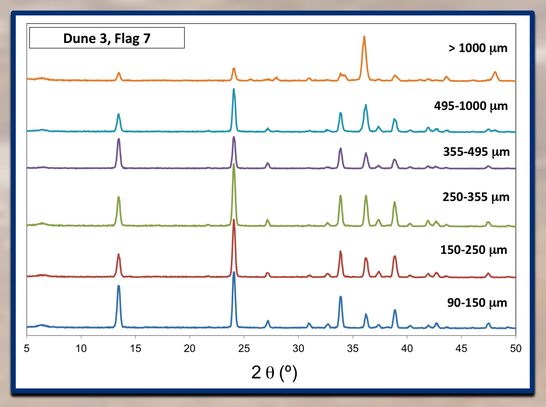

Fig. 6. Measured XRD patterns of size separates from Dune 3, Flag 7.

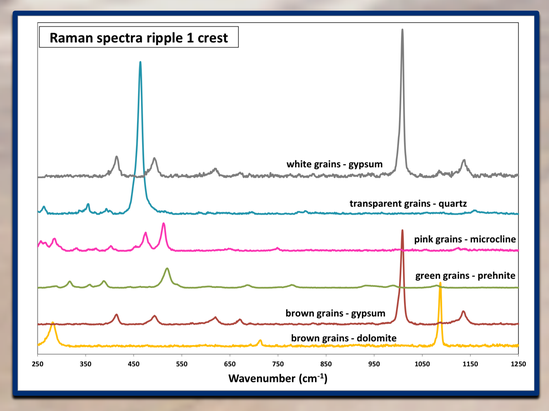

Fig. 7. Raman spectra of grains sorted by color from the crest of Ripple 1.

Summary

- Samples from dune 1 and 2 show quartz abundance at 5.6 and 2.6% respectively, while dolomite has been detected in some locations at dune 3 as high as 80% (Fig. 4).
- At dune 3 (Figs. 5-6), gypsum is dominant for all grains < 1000 µm. Dolomite is more common in the coarse grains (> 1000 µm). The flag 7 sand shows a greater abundance of dolomite in grains > 1000 µm (62%) than the flag 4 (36%) as expected because of their location on the dune. Coarse grains are heavier than gypsum so they are not as easily moved by wind and tend to be rolled along the ground.
- The brown grains are composed of gypsum and dolomite while the green grains contain prehnite. The pink grains contain microcline and from VNIR results, also hematite, gypsum and calcite [3]. The transparent and the white grains are primarily quartz and gypsum, respectively.
- The identification of gypsum in most of the sand by XRD is unambiguous even when it is mixed with other phases.

References, Acknowledgements, and contact

[1] Langevin *et al.* (2005) Sulfates in the north polar region of Mars detected by OMEGA/Mars Express, *Science* 307, 1584-1586. [2] Fenton *et al.* (2014) LPSC XLV, Abst. #2855. [3] King *et al.* (2014) LPSC XLV, Abst. #2284. [4] Blake *et al.* (2012) Characterization and calibration of the CheMin mineralogical instrument on MSL, *Space Sci. Rev.* 170, 341-399. [5] Lafuente *et al.* (2013) AGU, Abst. #P23C-1801.
Acknowledgements: funding from NASA's PG&G program is much appreciated.
Contact information: barbaralafuente@email.arizona.edu / lfenton@seti.org / jbishop@seti.org.