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VNIR spectroscopy of the Atacama salars: An analogue study for Mars evaporate deposits

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Abstract

A high priority for determining the past habitability of Mars includes identification and characterization of hydrated minerals within ancient Martian aqueous environments. Sulfates, found in a variety of hydrous environments on Earth, can aide our understanding of past Martian environments if their context can be constrained. In the present study, we combine both spaceborne (Landsat, Hyperion) and field (ASDinc FieldSpec) VNIR observations to study the mineralogy of various sulfate-rich salt flats (salars) in the Atacama desert region of Chile as an analogue for Martian evaporites. There is good agreement between remote sensing and field observations on the major classes of minerals present in the salars and their spatial distribution, that are easily identified from VNIR spectroscopic data.

1. Introduction

Sulfates, on the surface of Mars, were first detected by the spectral imager OMEGA (on-board the Mars Express Mission) [1, 2]. They are often associated with 100's km wide, thick, sedimentary deposits and sometimes mixed with clays [1-6]. On Earth, sulfates form in a wide range of conditions including: shallow lakes, deep marine basins, periglacial environments, hydrothermal systems, and acidic rainfalls (e.g. [7]). The geological context of Martian sulfates is, however, poorly understood.

We propose to study sulfate-rich deposits in the Chilean Atacama Desert found in a similar context to those found on Mars. The Atacama is a hyper-arid desert spread across the Andes long volcanic ridge. In the Atacama region, meteoric water infiltrates from elevated areas in the Andes Mountains, dissolving salts from volcanic-origin soil and transporting them towards lower areas. In these lower areas, the dissolved salts are concentrated due to evaporation forming shallow lagoons and salt flats which are filled with mixed clays and sulfates [8]. The geological context and composition of this site, plus its proximity to a volcanic mountain range, make it an ideal Martian analogue site. In addition, this site is well-known to host extremophile microbial life, providing links to astrobiology (ongoing joint study with Leiden University, NL).

2. Datasets

High-resolution remote sensing data from hyperspectral (Hyperion) and multispectral (ALI, Landsat) imaging instruments were used to characterize, and map, the mineralogy of the Atacama salars from space. Landsat 8 reflectance data provide a full coverage of the area, whereas Hyperion data are only available at selected locations, including the Cordillera de la Sal (Figure 1). Landsat imagery has previously been demonstrated to be efficient at mapping salar zonation [9] and was, therefore, used to select field sites within a diverse range of terrains.

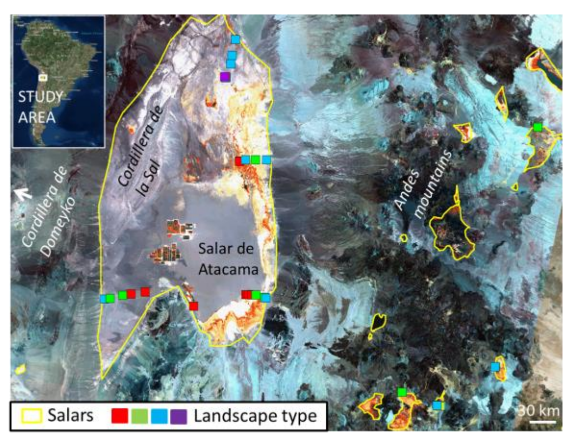

Figure 1: The location of the salars (as mapped from space, yellow outlines) and landscape types (as observed on the field, colored squares) are reported on these Landsat 8 color composites of reflectance bands 7-6-5. Cf. text for more details.

A field campaign was carried out in February 2015. VNIR reflectance values were measured in the field at selected sites (squares on Figure 1), and samples were collected to be further analyzed by Raman spectroscopy and XRD at the VU University Amsterdam. The aim of the field survey was to quantitatively constrain the mineralogy and provide ground-truth to the remote sensing analyses.

3. Results

Core (grey tones) and marginal (orange to white) zones within the salars are easily distinguished on the Landsat 8 7-6-5 band color composite (Figure 1). Each colored zone was visited in the field. Outcrops were classified into multiple types based on their morphology. The main categories include (1) sharp, blocky thick halite crust (red squares on Figure 1), (2) smooth, indurated, ondulated surface (green squares), (3) muddy surface with polygonal cracks, and a thin salt layer in depressions (blue squares). To the first order these morphologies correlate to mineralogy, according to field spectra. The mineralogic assemblages were dominated by; halite (1), clays (3), or gypsum and other sulfates (2) (Figure 2). More diversity in terms of morphologies and mineralogies is observed locally, and additional categories were made. Ongoing lab analysis should provide more constraints on those additional categories by the conference time.

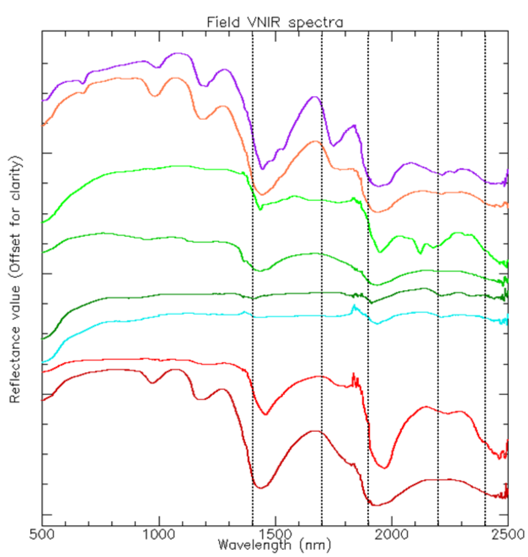

Figure 2: VNIR reflectance spectra of field outcrops at various sites. Colors correspond to the morphologic types mapped on Figure 1.

4. Discussion and Further Work

VNIR spectra can easily discriminate between clay-dominated and salt-dominated sediments; as well as different types of salt crusts. Mineral zonation is observed within the salars on a scale of dozen of meters, and appears to be a function of the distance to the (ground)water sources. An example is given in the Salar de Atacama, where clays and gypsum are observed in the salar margins, whereas halite dominates the mineralogy of the rocks at its center, further away from the discharge zone. Distinct mineral assemblages appear to be present in the various salars. The relationship with the bedrock composition and geographic location is being investigated. Space and field VNIR spectra will be compared to Raman and XRD analyses of collected field samples. This step will allow us to discuss the benefits and limitations of VNIR spectroscopy when applied to evaporites deposits on both Earth and Mars.

Acknowledgements

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