THE COMPOSITION OF PUNA GRAVEL RIPPLE FIELDS: A TERRESTRIAL ANALOG FROM TIR REMOTE-SENSING AND SPECTROSCOPY

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Introduction: The southern part of the Altiplano-Puna Plateau of the Andes has a base elevation of ~ 3.5 to 4.5 km. The lower atmospheric pressure and the cold, dry, windy climate make it an ideal site as a Martian analog for aeolian landforms, such as ripple-like bedforms that are potential analogs for Martian Transverse Aeolian Ridges (TARs) [1]. Our understanding of how aeolian activity modifies the Martian surface relies on our observtions of terrestrial field and remote-sensing data. Of critical importance is our ability to link field and remote-sensing observations so that we may better interpret planetary data sets where ground truth is difficult without rover data [2].

In association with field activities of NASA MFRP grant NNX10AP79G, this work maps composition from thermal infrared (TIR) data acquired by the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) instrument. Bedrock, gravel and sand samples were collected from the Puna to determine high resolution thermal emission spectra, which are directly comparable to ASTER, allowing sub-pixel analysis of composition and an analysis of spatial distribution. By combining these results with grain-size analysis of samples, constaints can be placed on the processes creating the TAR-like ripples in the Puna [3,4]. For example, composition is a proxy for clast density, which is important to calculating the energies required for suspension, saltation and creep of aeolian sediments.

Background: The Puna is regionally dominated by extensive ignimbrite sheets, but significant fluvial and aeolian modification has occurred, for example, the area has yardang fields which resemble the Medusae Fossae Formation of Mars [e.g. 5,6]. Gravel ripples are distributed throughout the area in distinct fields in the region of Catamarca, Argentina centered around 26°45'S 67°45'W. Ripple fields are separated by topographic barriers, but the synoptic view of the region in Google Earth reveals southeast trending, high albedo sand streaks traversing across the entire area, suggesting sand transport throughout the region (Figure 1). Numerious climbing and falling dunes can also be found, especially downwind of the Puna area. The source of the sand streaks is not known, but likely candidates include eroded playas, ignimbrites, bedrock and dunes. Trenching of gravel bedforms revealed interbedded layers of sand in the gravel-dominated subsurface. This would indicate that saltating sand is transported periodically as a sand sheet, which could also be important for inducing gravel movement through ballistic impacts.

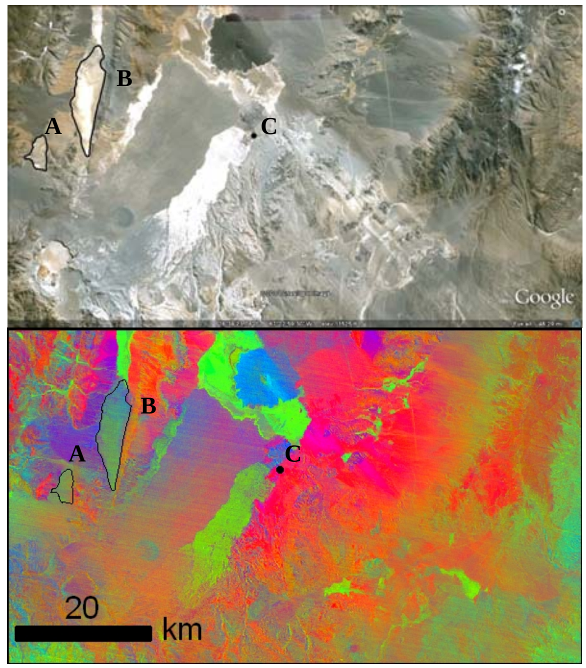

Figure 1. The upper image is a screen capture of the Puna site showing the higher albedo sand cover, streaking from the NW to SE. The lower image shows the same area with the compositional diversity of the area highlighted by a decorrelation stretch of ASTER TIR data (bands 14, 12, 10, respectively).

Approach: To accurately determine the spatial distribution of mineral composition [7,8,9] of Puna sediments, a quantitative analysis of bulk mineralogy was carried out by combining the spectral deconvolution of both (1) a seamless, multispectral, radiometrically balanced mosaic of the ASTER TIR remote sensing data and (2) high resolution thermal emission spectroscopy of samples using a Nicolet Nexus 670 spectrometer [9]. Samples were collected during a field campaign in December 2010, each representing a point measurement at the sub-pixel scale of the ASTER data. A detailed description of the instrument, setup and lab techniques are found in [10,11]. Spectra of different sediment size fractions from samples were also acquired. Samples were sieved to yield a gravel fraction representing grains > 4 mm, a coarse sand fraction between 4 and 1.88 mm, a medium sand fraction between 1.88 and 0.437 mm and a fine sand fraction of < 0.437 mm. The lab results were used for a detailed, systematic analysis of composition. The comparison of high resolution laboratory data to satellite data were used to assess ASTER composition retrievals and the spatial distribution of ripple field sediments.

Preliminary Results: The high resolution spectra of the samples of bedrock, gravel and sand are presented here with initial observations below (Figure 2).

Barchan Site: At this location, two distinct populations of small ripples were distinguished by composition, where one set was dominated by coarse milky quartz gravel (spectra 023) and the other andesite gravel (spectra 027). These locations can be seen in Google Earth and ASTER data where dark- and light-colored sediments make a visible contact (Figure 1C). High quartz concentration shows as a red color in the ASTER image, where as high andesite composition shows as a blue color (Figure 1). Sieved sample spectra from each of the two areas revealed that the major difference exists in the coarse gravel fraction, where the fine sand fractions were nearly identical in composition (spectra 024 and 020). The sand fraction is composed of smaller grains of quartz, andesite, biotite and to a much lesser degree, pumice. The coarse quartz gravel is probably locally derived from local bedrock outcrops, where finer quartz grains were clear and may have an ignimbrite origin.

Puruya Site: This area is site to the largest ripples in the region. Previous investigations were carried out at the smaller field at location A (10.2 km^2) [3,4], but a much larger field of ripples (47.1 km^2) can be seen from the 15 meter resolution ASTER data to the northeast at location B (Figure 1). Both of these areas are characterized by a green color in the decorrelation stretch of the ASTER data, as well as the yardangs elsewhere in the region. High resolution spectra of the sandy sediments (012) and the yardang material (003 and 002) have similar spectra. The fine sand fraction spectra is dominated by the fine-grained pumice in the sand. Overall, each sieved fraction of sand from this area has a much higher pumice content than elsewhere in the Puna. Small quartz grains in the Puruya sands are more angular than quartz grains from downwind (southeast) sites. Sand found near the downwind Barchan Site had well-rounded quartz grains.

Future Work: Future analysis will be the linear deconvolution of spectra and image data respectively. The decorrelation stretch (Figure 1) shows a good representation of the distribution of composition, but linear deconvolution will hopefully provide quantitative maps of pumice, quartz and andesite. Samples will be sieved at higher resolution to obtain more accurate grain-size distributions, which is important for the Puruya Site because the fine fraction (for example, < 80 µm) obscures the composition of sand important to the story of sand transport from one end of the ripple field to the other. The work has implications for understanding the sand transport systems of the Puna and Mars.

References: [1] Bourke et al., 2003. *Lunar and Planetary Science XXXIV*, Lunar and Planetary Institute, 321 Houston (CD-ROM), Abstract 2090. [2] Sullivan, R. et al. (2007), *Lun. Planet. Sci. XXXVIII*, 2048. [3] Milana, J.P. (2009), *Geology* 37, 343-346 doi:10.1130/G25382A.1, [4] de Silva, 2010, Geology, doi:10.1130/G30780C.1. [5] Mandt, K.E. et al. (2008), JGR 113, doi:10.1029/2008JE003076. [6] de Silva, S.L. et al. (2009), Icarus 204, doi:10.1016/j.icarus.2009.06.031. [7] Ramsey M.S. et al. (1999), GSA Bull., 111, 646-662. [8] Bandfield J.L. et al. (2002), JGR, 107, E11, 5092. [9] Scheidt at al. (*2010, in press*), GSA-Bull. [10] Ruff et al. (1997), JGR, 102, 14899-14913. [11] Ramsey M.S. and Christensen P.R. (1998), JGR, 103, 577-596.

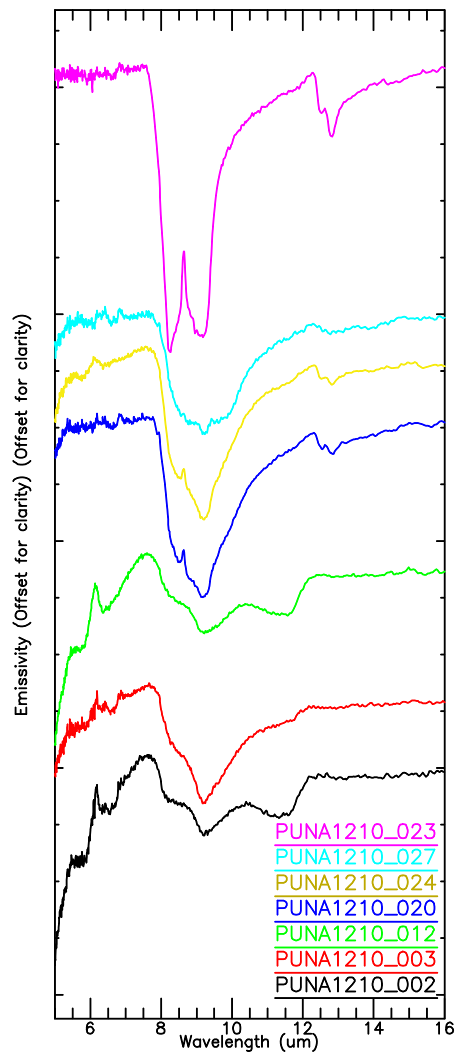

Figure 2. Spectra of Puna gravel, sand and bedrock.