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Deposits of the Peruvian Pisco Formation compared to layered deposits on Mars

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1. Introduction

Deposits of the Peruvian Pisco Formation are morphologically similar to the mounds of Juventae Chasma at the equatorial region on Mars (Fig. 1). By analyzing these deposits, we hope to gain information about the environmental conditions that prevailed during sediment deposition and erosion, hence conditions that might be applicable to the Martian layered and hydrated deposits.

Mariner 9 data of the Martian mid-latitudes have already shown evidence of the wind-sculptured landforms that display the powerful prevailing eolian regime [1]. In addition, [2] reported on similarities between Martian erosional landforms and those of the rainless coastal desert of central Peru from the Paracas peninsula to the Rio Ica. As indicated by similar erosional patterns, hyper-arid conditions and unidirectional winds must have dominated at least after deposition of the sediments, which are intermixed volcaniclastic materials and evaporate minerals at both locations. Likewise, variations in composition are displayed by alternating layers of different competence. The Pisco formation bears yardangs on siltstones, sandstones and clays with volcaniclastic admixtures [3] whereas the presence of sulphate minerals and the omnipresent mafic mineralogy has been reported for the layered mounds of Juventae Chasma equally [4]. Likewise, a volcanic airfall deposition and lacustrine formation have been proposed for the sulphate-rich deposits of Juventae Chasma [5,6].

In order to find out about potential spectral similarities, we performed a detailed spectral analysis of the surface by using LANDSAT and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) VNIR/ SWIR data (visible to near-infrared and shortwave infrared region).

2. Data sets and Methods

We used the LANDSAT 7 ETM+ (NASA's Enhanced Thematic Mapper) panchromatic band with 15 m spatial resolution to study the morphology in detail and the appropriate visible and reflected infrared bands with 30 m spatial resolution to look at spectral properties in general. According to [7], Landsat ETM+ 5/7-band ratios help to discriminate between altered (clay minerals, alunite) versus unaltered and iron-stained hydrothermally altered rocks with high 3/1 ratios indicating iron oxides and sulphates. ASTER onboard the Earth Observing System (EOS) of NASA's Terra spacecraft, records radiation from the Earth in 14 spectral bands and enables geological mapping and mineral exploration. A detailed spectral study was performed by using On-Demand Level 2 Surface Reflectance data of the ASTER instrument. The data product contains atmospherically corrected data for both VNIR and SWIR sensors. VNIR data generally uses three VNIR bands (between 0.52 and 0.86 µm) from ASTER Level-1B image. The SWIR (with Crosstalk-Uncorrected) is generated using six SWIR bands (between 1.60 and 2.43 µm) from ASTER Level-1B image. For the purpose of spectral analysis in order to show the full wavelength range of the spectra, we combined VNIR and SWIR data in ENVI. The procedure comprises georeferencing of the data and resampling of SWIR to the higher resolution of the VNIR dataset. ASTGTM/GEDM 2 (ASTER Global Digital Elevation Model) was used to study extent and thickness of the deposits in order to compare them with the Juventae deposits. The data are posted with a ~30-m grid at the equator via USGS and are referenced to the 1984 World Geodetic System (WGS84)/ 1996 Earth Gravitational Model (EGM96) geoid (usgs.gov).

3. Spectral and morphologic observations

The Pisco formation extends ~150 km along the Peruvian coast with a width of 15 km. The light-toned layered mounds show variable thicknesses of ~100 m and display 10 m thick competent layers. For comparison, [8] have calculated a layer thicknesses of ~100 m for Juventae Chasma.

Like on Mars, the mounds stand out from their surroundings not only by their wind-eroded shapes but also by their spectral properties, which are best displayed by ASTER-VIS and multispectral classification of LANDSAT ETM+ bands 1-7 (Fig. 2). A clearer distinction was possible by using ASTER data, which in contrast to Landsat ETM+, have a finer spectral resolution in the VNIR enabling mineral determination. Hence discriminating between iron and clay mineralogy is facilitated by sufficient resolution and between phyllosilicates and carbonate minerals when using the six SWIR bands. The absorption wavelength associated with argillic (e.g. alunite, kaolinite, and dickite), phyllic (sericite) and propylitic (e.g. calcite, epidote, and chlorite) alteration moves progressively from 2.165 through 2.209 µm and to 2.36 µm respectively. We observe high band 5 absorption features of the target region, which according to [9] indicate the presence of alunite, dickite, buddingtonite and kaolinite, a feature that is absent in the surrounding regions (Fig. 3).

4. Preliminary Conclusions and Future Work

We identified morphological similarities between the Juventae mounds and the Pisco formation indicating the material was exposed to comparable environmental conditions since its deposition (strong eolian regime, hyperarid). To a certain extent, sediments of both places also share common compositional characteristics (volcaniclastics, salts). Nevertheless, our orbital observations did not point to a clear match in spectral observations. Future work will include lab experiments i.e. bi-directional reflectance measurements of the Pisco samples at room temperature and under vacuum conditions in the wavelength range between 0.5 and 2.5 µm after [10]. By using higher spectral resolution and in situ samples, we hope to get a more detailed mineral allocation and finally to show whether the Pisco deposits represent a potential spectral analogue to the Martian deposits.

Acknowledgements

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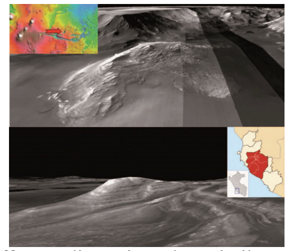

Fig. 1: Different dimensions but similar morphology - Juventae Chasma- (top) and Pisco mounds (bottom) (MOLA, HRSC, GDEM).

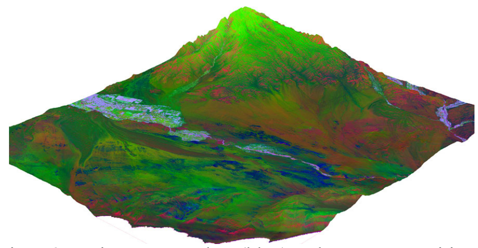

Fig. 2: Pisco mounds (blue) share compositional characteristics, which apparently are absent in their surroundings (LANDSAT PCA, ASTER GDEM 3x exag., 10 km across).

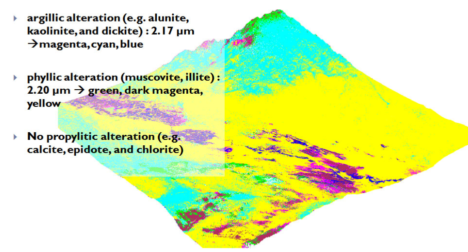

Fig. 3: Pisco mounds (blue, magenta) are located in regions that show argillic alteration i.e. alunite, kaolinite and dickite mineralogy (ASTER, spectral angle mapper & GDEM 3x exag. 10 km across).

References

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