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AEOLIAN SAND AS A TOOL FOR UNDERSTANDING MARS: THERMAL INFRARED REMOTE SENSING OF VOLCANICLASTIC MARS–ANALOG SAND DUNES IN CHRISTMAS LAKE VALLEY, OREGON, U.S.A.

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INTRODUCTION: On Earth, aeolian sand dunes are used as tools of scientific inquiry. Holocene and Pleistocene dunes preserve clues about Quaternary climate variations and human activities ranging from Ice Age hunting practices to Twentieth Century warfare. Modern dunes contain the sedimentary textures and structures necessary for interpreting ancient sandstones, and they provide natural laboratories for investigation of aeolian physics and desertification processes. The dunes of Mars can likewise be used as scientific tools. Dunes provide relatively dust-free surfaces. From a remote sensing perspective, martian dunes have much potential for providing clues about surface mineralogy and the interaction between the surface and atmosphere. Such information can in turn provide insights regarding crust composition, volcanic evolution, present and past climate events, and perhaps weathering rates. The Mars Global Surveyor Thermal Emission Spectrometer (TES) is expected to reach the planet in September 1997. TES will provide 6 to 50 micrometer spectra of the martian surface at ground resolutions of 3 to 9 km. Sandy aeolian environments on Mars might provide key information about bedrock composition. To prepare for the TES investigation, I have been examining a thermal infrared image of a Mars-composition analog dune field in Christmas Lake Valley, Oregon.

COMPOSITION AND GEOLOGIC SETTING: The “Shifting Sand Dunes” dune field is located at the eastern end of Christmas Lake Valley, in what was once the Pleistocene Fort Rock Lake [1]. Much of the sand that makes up the Shifting Sand Dunes dune field is reworked Mt. Mazama airfall from its terminal eruption 6,800 years ago, plus material deflated from the lake bed [1, 2]. The main constituents of the dunes are volcanic glass and devitrified glass fragments, plagioclase crystals, basalt lithic fragments, aggregates of silt and clay-size volcanic ash, pyroxenes, opaque oxide minerals (mostly magnetite), and trace occurrences of fossil fragments and other minerals [3].

THERMAL INFRARED IMAGE: The thermal infrared images used in this study was obtained by the NASA Ames Research Center C-130 Earth Resources airborne Thermal Infrared Multispectral Scanner (TIMS) on 21 September 1991. The image has 6 spectral bands between 8 and 12 micrometers and a ground resolution of 9 m/pixel. The raw image was converted to calibrated radiance, from which normalized emittance was computed for each of the six bands, following the method of Realmutto [4]. Atmospheric effects were corrected using an empirical method described by Edgett and Anderson [5]. The resulting 6-

band image provides quantitative determination of the surface emissivity. Dune spectra in the image match spectra obtained in our laboratory using samples collected from the field area [3, 5].

ACTIVE DUNES, INACTIVE DUNES, AND INTERDUNE AREAS FROM EMISSIVITY VARIATION: This study shows that in a modern dune field, the location of active dunes, interdune surfaces, and inactive dunes can be mapped using emissivity in the thermal infrared band that shows the most spectral variation [6]. In this case, TIMS band 3 (9.2 micrometers) had the most variation, although the entire emissivity range was only from 0.89 to 1.0. Active dunes had the lowest emissivities (0.89 to 0.91), inactive dunes were distinguished by higher emissivities (.094 to 1.0), and interdune surfaces had intermediate values (0.90 to 0.95). These emissivity variations result from differences in particle size, as inactive dunes tend to have finer-grained silt and dust on them.

LINEAR UNMIXING USING IMAGE ENDMEMBERS: Quantitative estimates of thermal infrared spectral emissivity are ideally suited to unmixing analysis. For grains larger than the wavelength (e.g., dune sand), a linear unmixing approach provides geologically useful results [7]. In the present study, image endmembers were selected for a preliminary unmixing study: (1) “regular sand,” which contains nearly 50% plagioclase and nearly 20% volcanic glass; (2) “dark sand,” which consists mainly of basalt clasts (> 25%) and glass (> 30%); (3) “mud chips,” which are volcanic ash aggregates broken into sand-sized pieces, (4) sagebrush and grass; and (5) thick vegetation, such as an alfalfa farm near the dunes. The most important result of this preliminary unmixing work is an image that shows the distribution of ash aggregates and “dark sand,” both of which vary throughout the dune field as a function of proximity to the source. The volcanic ash aggregates, in particular, are locally eroded from a layer that caps the Pleistocene lake beds that underlie the dunes [3].

SUMMARY: This study highlights the use of thermal infrared spectra to map local contributions of sand to a dune field, and to distinguish active versus inactive dune fields. Mapping of local contributions to active dune fields on Mars using TES or other multispectral images has potential to provide indications of local bedrock composition.

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