1995LPI....26..355E

MULTISPECTRAL THERMAL INFRARED OBSERVATIONS OF SEDIMENTS IN VOLCANICLASTIC AEOLIAN DUNE FIELDS: IMPLICATIONS FOR THE MARS GLOBAL SURVEYOR THERMAL EMISSION SPECTROMETER.

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Summary: Multispectral thermal infrared images of volcaniclastic dune fields at Christmas Lake Valley, Oregon; Moses Lake, Washington; and Great Sand Dunes National Monument, Colorado; provide natural settings to test and understand the utility of thermal infrared spectroscopy for observation of composition and aeolian sorting in dune fields and low albedo regions on Mars. One example of our results: linear unmixing analysis of dunes at Christmas Lake Valley, Oregon, has allowed mapping of the contribution of a volcanic ash aggregate sand that is being added to the dune system from local source deposits.

Introduction: *Mars Global Surveyor* (*MGS*) is scheduled for launch in November 1996, with arrival at Mars around September 1997 and mapping to begin January 1998. The *MGS* Thermal Emission Spectrometer (TES) will map Mars with 3 to 9 km spatial resolution between 6 and 50 µm [1]. Sandy aeolian environments on Mars will provide key spectral information regarding relatively unaltered surface mineral composition [2, 3]. Mars sand is likely quartz-free and analogous to terrestrial volcaniclastic dunes dominated by materials such as plagioclases, pyroxenes, basalt lithic grains, and glasses [4]. We have obtained thermal infrared images of selected volcaniclastic dune fields in North America that allow assessment of key dune characteristics related to composition, such as mineral identification, observation of grain mixing and sorting, and status of interdune and dune activity.

Dune Fields: Three active dune fields were chosen for study. Each has a composition and geomorphic setting that is analogous to dunes on Mars. The first dune field is the Shifting Sand Dunes, located at the eastern end of Christmas Lake Valley, Oregon. The setting resembles intracrater dune fields on Mars, and the sands are composed of plagioclase (about 50%), volcanic glass (10 - 30%), basalt lithic fragments, volcanic ash aggregates, pyroxenes, metal oxides (mostly magnetite), and trace other minerals [5]. The second dune field is located near Moses Lake, Washington. The Moses Lake dunes are reworked from sediments deposited by the Channeled Scablands floods, analogous to outflow channels on Mars. The Moses Lake dunes contain a mixture of basalt lithic fragments (60 to 80%), metal oxides (*e.g.*, magnetite), and quartz [6]. The third dune field resembles the intracrater sand seas of Hellespontus [7], the Great Sand Dunes National Monument of Colorado. The Great Sand Dunes contain nearly 60% volcanic rock fragments and less than 30% quartz [8].

TIMS Data: The infrared images were obtained by the NASA Ames Research Center C-130 Earth Resources airborne Thermal Infrared Multispectral Scanner (TIMS). TIMS has 6 spectral bands between 8 and 12 µm [9, 10]. Images with about 9 m/pixel resolution were obtained over the Shifting Sand Dunes, Oregon, in September 1991, October 1991, and July 1992. TIMS images of the Moses Lake, Washington, dunes were obtained in September 1991 (about 15 m/pixel resolution) and in July 1992 (3 m/pixel resolution). The Colorado Great Sand Dunes were observed in June 1992 (16 m/pixel) and in August 1994 (15 m/pixel and 3 m/pixel). In addition to *MGS* TES, study of these TIMS images contributes to preparation for the *Earth Observing System A* Advanced Spaceborne Thermal Emission and Reflectance Radiometer, and provides new insights about the geology of these dune fields [5, 11, 12].

Active, Inactive Dunes, and Interdune Areas from Emissivity Variation: 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 [13]. For the Oregon Shifting Sand Dunes, TIMS band 3 (9.2 μm) has the most variation, although the entire range is only from 0.89 to 1.0. Most surfaces in the dune field have emissivities 0.89 to 0.95. In the Shifting Sand Dunes TIMS image, active sand has the lowest emissivity (0.89 to 0.91). Inactive dunes are distinguished by higher emissivities (0.94 to 1.0). Inactive dunes have higher emissivities because they are vegetated and trap finer particles among the vegetation. Both fine particles and vegetation have relatively high emissivities and flat thermal infrared spectra. In the absence of vegetation (as on Mars), inactive dunes partly covered by dust might be distinguished in this manner. The Moses Lake, Washington, dunes were buried by 2-4 cm of ash from the 1980 eruptions of Mt. St. Helens [14]. At Moses Lake, active dunes have emissivities as low as 0.89 in the 9 to 10 μm range, inactive dunes covered by ash have emissivities near 1.0. Interdune surfaces at both the Oregon and Washington dune sites have intermediate emissivities (0.90 to 0.95), depending upon the nature of the interdune surface (depositional surfaces dominated by dust have a higher emissivity).

Aeolian Sorting: Sorting by composition is commonly enhanced in volcaniclastic dune fields, owing to larger differences in grain density compared to typical quartz-feldspar dunes [4]. For example, at the Shifting Sand Dunes of Oregon, some grains are low-density pumice, while others are high-density materials like magnetite [5]. Spatial variation in dune sand composition can be readily seen in the TIMS images of the Shifting Sand Dunes [5, 13] and Great Sand Dunes National Monument. Spectacular color variations in images derived from principle component analysis of the Great Sand Dunes TIMS images acquired in 1994 appear to indicate aeolian sorting according to grain composition; sorted deposits represent the range of silicate compositions, from quartz granule ripples in some areas to basaltic lags in others.

Linear Unmixing: Emissivity images derived from TIMS data are ideally suited for linear unmixing analysis. The linear unmixing approach used here was developed by M.S. Ramsey [15, 16]. Five spectral endmembers were chosen from the September 1991 TIMS image of the Shifting Sand Dunes of Oregon. Two of the endmembers represent vegetation, three represent dune materials. The sand endmembers include: (1) "regular sand," which contains nearly 50% plagioclase and nearly 20% volcanic glass shards, (2) "dark sand," which consists mainly of basalt lithic fragments (> 25%) and glass (> 30%), and (3) "mudchips," which are volcanic ash aggregates broken into sand-, granule-, and pebble-sized clasts. The resulting endmember map shows the distribution of these three sand types throughout the dune field [see 5, 13]. The most important result is the distribution of ash aggregate sands, which varies throughout the dune field as a function of proximity to the aggregate source. The volcanic ash aggregates are locally eroded from a layer that caps the Pleistocene lake beds that underlie the dunes [5].

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