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Enceladus: Correlation of Surface Particle Distribution and Geology

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Abstract

The surface of Enceladus consists almost completely of water ice [1,2]. The band depths of water ice absorptions are sensitive to the size of particles covering the surface. Thus, ice absorption features can be used to map variations of icy particles across the surface. The water ice band depths were compared to water ice models that represent theoretically calculated reflectance spectra for a range of particle diameters between 2 µm and 1 mm [2,3,4]. Cassini VIMS observations show that the particle diameter of water ice increases toward younger tectonically altered surface units with the largest particles exposed in relatively "fresh" surface material. The smallest particles were generally found in old densely cratered terrains. The largest particles are concentrated at the south polar active zones. In general, the particle diameters are strongly correlated with geologic features and surface ages, indicating a stratigraphic evolution of the surface that is caused by cryovolcanic resurfacing and impact gardening.

Distribution of particle sizes

The Visual and Infrared Mapping Spectrometer [5] has observed Enceladus with high spatial resolution during multiple Cassini fly-bys in orbits 3, 4, 11, 61, 120, 121, 131, 136, 141, 142. Based on these data we have measured the band depths of water ice absorptions at 1.5 and 2µm over Enceladus' surface and mapped their distribution. The spatial resolution of VIMS image cubes (< 30 km/pixel) is sufficient to distinguish the three major geologic units on Enceladus: heavily cratered terrain, fractured and ridged terrain and complex tectonically deformed regions of troughs and ridges known as Sulci [6], which include the south pole region. Although it is assumed that these geological units are composed completely of water ice, the band depths of the water ice absorptions change significantly between the individual units. Surface ages, as derived from the impact flux models of [7,8] indicate the cratered terrain being oldest and the Sulci the youngest unit [2,9].

From the distribution of particle sizes across the surface of Enceladus we can conclude that the largest particle diameters are inside the tectonically deformed regions, with a decrease in size outwards from the fractures. These occur not only at the south pole but also in older tectonic regions [2].

Correlation with geology

The basic correlation between particle diameter, geologic unit and age suggests the following relative stratigraphic sequence [2,10]: (1) Formation of a primary crust (heavily cratered terrain); (2) Mechanical weathering of the surface particles by microimpacts and sputtering during the last 4 billion years; (3) Tectonic disruption of the surface and deposition of new material with large particles. This process was probably repeated multiple times and formed the widespread ridged and fractured terrains. Although this newly deposited material has undergone mechanical weathering of the particles by microimpacts and sputtering, these particles are larger due to a shorter exposure time; (4) Recent deposition of larger particles in the south polar region. If the larger particles in the tectonically deformed regions have the same cryovolcanic origin as at the south pole, the volcanic activity must have evolved with time indicating a change in the eruption rate. However, there are still different possibilities to explain these observations [2]: (1) The eruption zones and thus the internal heat distribution may have moved from north to south within the last billion years [2,7] or within the last 200 million [2,8] with the recent south polar tiger stripes marking the actual center of the volcanic activity on Enceladus. (2) Cryovolcanic eruptions might have occurred all over the satellite, dependent on the age model, for the last billion or million years, respectively, and shrunk to a small zone at the south pole, which would be

indicative of a probable decrease in internal heat transfer. (3) The intensity of cryovolcanic eruptions was different at different locations and times with a maximum in the south polar region.

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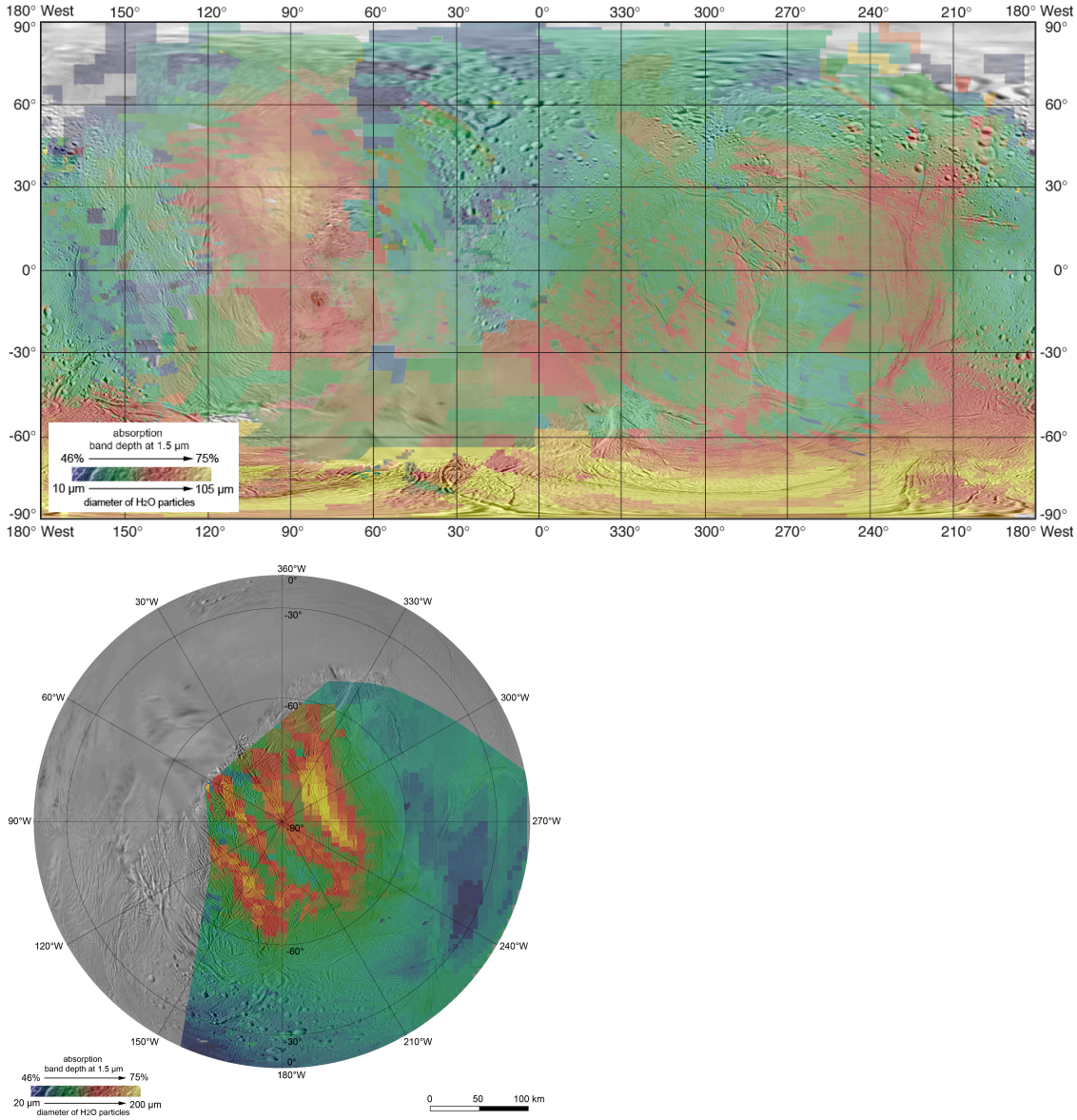

Fig. 1 Global VIMS composition map of Enceladus based on VIMS observations overlayed on the corresponding ISS map [11]