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The topography of Enceladus

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Abstract

The surface of Enceladus modeled so far has relief of not more than ~2 km both at small (10 km) and larger (100 km) scales. This suggests that the lithosphere has been at most only a few kilometers thick over its history. A stereo-derived height model of the region between Enceladus' leading side and the Saturn-facing side (Fig. 2) strengthens the role of warm ice upwellings in forming large-scale topography on Enceladus. We observe a 250 km-scale bulge up to 1 km high that correlates with its geologic boundary. The bulge is consistent with the presence of convection-related warm ice at depth isostatically adjusted to surrounding cooler, non-convective regions.

1. Introduction

Enceladus is an intriguing body. Some terrains are heavily cratered and presumably ancient, others, however, are uncratered and therefore young, notably the South Polar Region which is currently active [1, 2]. To explore the nature of these terrains topography can substantially help because it holds clues on the interior structure of the body and the processes that have shaped the surface.

Limb profiles derived from Voyager- and Cassini images [3, 4] have provided first information on the global shape of Enceladus showing residuals to a best-fit ellipsoid in the range of ±1 km. Such low limb topography implies a thin lithosphere and related to that, a warm interior through Enceladus' history. Detailed morphologic studies, however, have become possible only when contiguous topographic models based on Cassini data were available [5, 6]. These models have shown large-scale depressions 90-175 km across and 800-1500 m deep (Fig. 1) that surprisingly do not correlate with geologic boundaries [5]. Whether such depressions occur also in other regions on Enceladus was unknown. In this paper we report on Cassini-derived topography of regions not mapped so far (Fig. 2). We show their morphology in comparison with previously mapped regions [5] and discuss implications for formational processes and the interior structure of Enceladus.

2. Observations

While the anti-Saturn-facing side of Enceladus (Fig. 1) exhibits a pronounced ovoid-shaped (200 x 140 km) up to 2 km deep depression uncorrelated with geologic boundaries (Fig. 3), there is a 250 km scale, up to ~1 km high bulge between Enceladus' leading- and Saturn-facing side (Figs. 2, 3) that correlates with its geologic boundaries. The bulge is superimposed by 300-500 m scale parallel linear ridges and troughs.

3. Figures

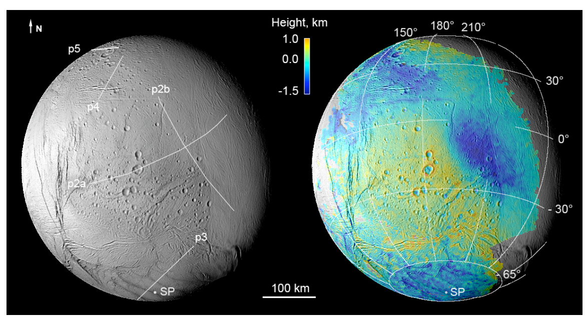

Figure 1: Cassini stereo-derived topography (horizontal resolution 3-8 km, vertical accuracies 50-500 m) of Enceladus' anti-Saturn-facing side (180°). This model reveals several depressions notably the ovoid depression close to the equator which does not correlate with the boundary between older cratered terrain to the west and younger resurfaced terrain to the east (see also p2a in Fig. 3).

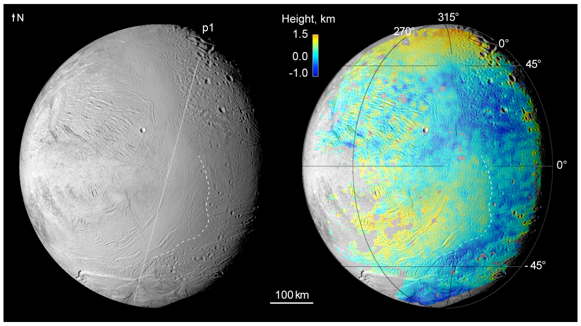

Figure 2: Stereo-derived topography (horizontal resolution ~10 km, vertical accuracies 200-400 m) covering the area between the leading (270°E) and Saturn-facing side (0°) of Enceladus. The dashed line (left) marks the boundary between resurfaced and cratered terrain which coincides with the topographic boundary (right) (comp. Fig.1).

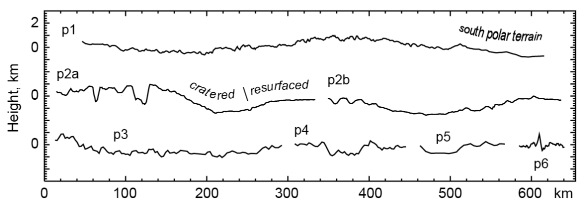

Figure 3: Profiles showing the morphology of depressions on Enceladus (for profile location see Fig.1 and 2). P1 features a large-sale shallow depression and a bulge associated with the formation of resurfaced terrains. In contrast, p2a and p2b cover an ovoid depression which is smaller in scale, distinct at the bottom, but not correlating with geologic boundaries. Note also the 22 km crater featured by p2a. This crater has relief of ~1.6 km and appears to be unrelaxed suggesting lithospheric thicknesses of at least 2 km at the time of formation. P3 features a more shallow depression related to the south polar terrain, and p4 and p5 reveal depressions that have linear boundaries and trough-like cross sections. For comparison, p6 profiles the Harran Sulci (2°N, 130°E), an extensional feature on Enceladus.

4. Summary and Conclusions

Large-scale depressions on Enceladus uncorrelated with geologic boundaries were suggested to be (i) the result of tidally driven warm upwellings including ice melting, and/or lowering the surface porosity due to enhanced temperatures, or diametrically opposed, (ii) cool dense ice lying below the depressions and containing clathrate hydrates [5]. Recently obtained topographic data strengthen the role of warm ice upwellings. We observe a 250 km-scale up to 1 km high bulge that has undergone strong resurfacing and which has distinct boundaries to surrounding lower-lying cratered terrains. The topography of the bulge is consistent with the presence of convection-related warm ice at depth in isostatic equilibrium with surrounding non-convecting cooler ice [5]. Extensional features at the surface of the bulge may simply result from brittle deformation of the top ice layer by the expanding warm ice.

References

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