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214 – Enceladus

214.01 – The heterogeneous ice shell thickness of Enceladus

Saturn's moon Enceladus is the smallest Solar System body that presents an intense geologic activity on its surface. Plumes erupting from Enceladus' South Polar terrain (SPT) provide direct evidence of a reservoir of liquid below the surface. Previous analysis of gravity data determined that the ice shell above the liquid ocean must be 30-40 km thick from the South Pole up to 50° S latitude (Iess et al., 2014), however, understand the global or regional nature of the ocean beneath the ice crust is still challenging. To infer the thickness of the outer ice shell and prove the global extent of the ocean, we used the self-similar clustering method (Bonnet et al., 2001; Bour et al., 2002) to analyze the widespread fractures of the Enceladus's surface. The spatial distribution of fractures has been analyzed in terms of their self-similar clustering and a two-point correlation method was used to measure the fractal dimension of the fractures population (Mazzarini, 2004, 2010). A self-similar clustering of fractures is characterized by a correlation coefficient with a size range defined by a lower and upper cut-off, that represent a mechanical discontinuity and the thickness of the fractured icy crust, thus connected to the liquid reservoir. Hence, this method allowed us to estimate the icy shell thickness values in different regions of Enceladus from SPT up to northern regions.
We mapped fractures in ESRI ArcGis environment in different regions of the satellite improving the recently published geological map (Crow-Willard and Pappalardo, 2015). On these regions we have taken into account the fractures, such as *wide troughs* and *narrow troughs*, located in well-defined geological units. Firstly, we analyzed the distribution of South Polar Region fracture patterns finding an ice shell thickness of ~ 31 km, in agreement with gravity measurements (Iess et al., 2014). Then, we applied the same approach to other four regions of the satellite inferring an increasing of the ice shell thickness from 31 to 70 km from the South Pole to northern regions. By these findings, we prove the global extent of the ocean underneath the ice crust of the satellite.

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214.02 – True Polar Wander of Enceladus From Topographic Data

Besides the relative motion of lithospheric plates, the Earth as a whole moves with respect to its rotation pole, as shown by paleomagnetic, astrometric and geodetic measurements [1]. Such so-called *true polar wander* (TPW) occurs because our planet's moments of inertia change temporally owing to internal thermal convection and to the redistribution of surficial mass during ice ages. Thus, to conserve angular momentum while losing rotational energy, Earth's axis of maximum moment of inertia aligns with its spin axis. Theoreticians suspect similar reorientations of other celestial bodies but supporting evidence is fragmentary, at best [2]. Here we report the discovery of a global series of topographic lows on Saturn's satellite Enceladus indicating that this synchronously locked moon has undergone reorientation by ~55°. We use improved topographic data from spherical harmonic expansion of Cassini limb [3,4,5] and stereogrammetric [5,6,7] measurements to characterize regional topography over the surface of Enceladus. We identify a group of nearly antipodal basins orthogonal to a topographic basin chain tracing a non-equatorial circumglobal belt across Enceladus' surface. We argue that the belt and the antipodal regions are fossil remnants of old equator and poles, respectively. These lows are argued to arise from isostasic compensation [7,8] with their pattern reflecting variations in internal dynamics of the ice shell. Our hypothesis is consistent with many geological features visible in Cassini images [9].

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214.03 – Enceladus' tidal dissipation revisited

A series of chemical and physical evidence indicates that the intense activity at Enceladus' South Pole is related to a subsurface salty water reservoir underneath the tectonically active ice shell. The detection of a significant libration implies that this water reservoir is global and that the average ice shell thickness is about 20-25km (Thomas et al. 2016). The interpretation of gravity and topography data further predicts large variations in ice shell thickness, resulting in a shell potentially thinner than 5 km in the South Polar Terrain (SPT) (Cadek et al. 2016). Such an ice shell structure requires a very strong heat source in the interior, with a focusing mechanism at the SPT. Thermal diffusion through the ice shell implies that at least 25-30 GW is lost into space by passive diffusion, implying a very efficient dissipation mechanism in Enceladus' interior to maintain such an ocean/ice configuration thermally stable.
In order to determine in which conditions such a large dissipation power may be generated, we model the tidal response of Enceladus including variable ice shell thickness. For the rock core, we consider a wide range of rheological parameters representative of water-saturated porous rock materials. We demonstrate that the thinning toward the South Pole leads to a strong increase in heat production in the ice shell, with a optimal thickness obtained between 1.5 and 3 km, depending on the assumed ice viscosity. Our results imply that the heat production in the ice shell within the SPT may be sufficient to counterbalance the heat loss by diffusion and to power eruption activity. However, outside the SPT, a strong dissipation in the porous core is required to counterbalance the diffusive heat loss. We show that about 20 GW can be generated in the core, for an effective viscosity of 10^{12} Pa.s, which is comparable to the effective viscosity estimated in water-saturated glacial tills on Earth. We will discuss the implications of this revisited tidal budget for the activity of Enceladus and the long-term evolution of its interior.

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