Geophysical Research Abstracts
Vol. 19, EGU2017-13423, 2017
EGU General Assembly 2017

Tectonic Activity on Enceladus in the Context of a Pressurized Global Ocean or Regional Sea

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The rich history of tectonic activity on Enceladus has the potential to provide constraints on the internal structure of the satellite. The South Polar region is dominated by tectonic extension whereas the Southern Curvilinear Terrain surrounding it is interpreted as a compressional feature. Other tectonised terrains in the leading hemisphere and the trailing hemisphere of the satellite may constitute ancient analogues to the South Polar Terrain. The North Pole also presents evidence for recent tectonic extension.

To explain the origin of the tectonic pattern featuring regions of extension at both poles, one of them being surrounded by an annulus of compressive tectonics, we study the stress field generated by a pressurized internal water reservoir. Recent geodetic data show that Enceladus likely features a global ocean, although the ice is thinner at the poles, especially the South Pole. Earlier models proposed that water is limited to a regional sea at the South pole. We consider both cases. Regardless of its geometry, the internal water body is likely to be overpressurised as it loses heat and water expands upon freezing.

Our model considers an axisymmetric ice shell with an indentation representing the region of thinned ice at the South Pole. The regional sea and the global ocean (when present) exert a uniform pressure of 10 kPa to the base of the ice shell. If the base of the ice shell is fixed, failure takes place only at the South Pole. If the base of the ice shell is sliding, failure also takes place at the North Pole as the shell is pushed against the rigid core. This is the only case where failure at mid-latitude takes place by shear faulting without tensile cracking at the surface. If the base of the ice shell is in contact with the overpressurised ocean, the entire surface of the satellite undergoes failure by tensile cracking. If the intensity of the overpressure is reduced, failure concentrates at the South Pole. There is no local maximum in tension at the North Pole.

The model that best matches observations is one where the water is limited to the South Pole, although the ice shell is free to slide on the internal rocky core. Pressurisation of a global ocean results in failure everywhere over the shell, which is contrary to observations. Therefore, if the ocean is indeed global, its overpressure must be limited, perhaps due to loss of water through geyser activity. Extension at the North Pole requires a grounded (although freely slipping) ice shell and may correspond to an earlier time in the tectonic history of Enceladus, although the effect of a thinner ice shell at the North Pole, which has not been studied at this time, may also allow fracturing at the North Pole.