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Subsidence of SPT and tectonics of Enceladus

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Abstract

Enceladus, a satellite of Saturn, is the smallest celestial body in the Solar System where volcanic activity is observed. It is concentrated in the South Polar Terrain (SPT) where the mass is ejected into space with the rate ~200 kg/s. We suggest here the following tectonic consequences of this mass loss: subsidence of SPT, flow of matter in the mantle and motion of adjacent plates towards SPT. Some of these processes are modeled using numerical and laboratory simulations.

1. Introduction

Enceladus, a satellite of Saturn, is the smallest celestial body in the Solar System where volcanic activity is observed Every second, the mass of ~200 kg is ejecting into space from the South Polar Terrain (SPT) – Fig. 1. - [1, 2, 3, 4, 5].

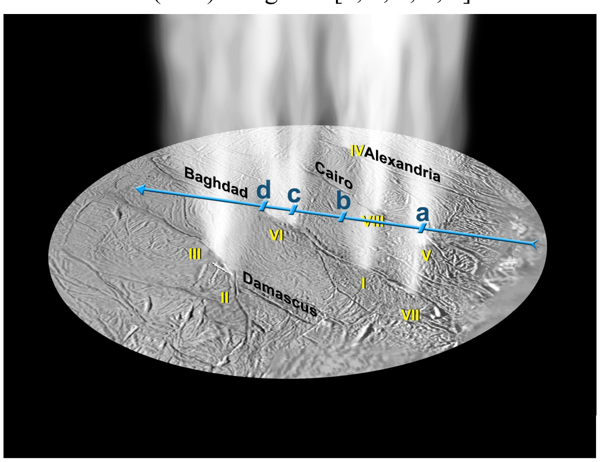


Figure 1: The jets from 'tiger stripes' in the South Polar Terrain on Enceladus (after NASA PIA10355).

The loss of matter from the body's interior should lead to global compression of the crust. Typical effects of compression are: thrust faults, folding and subduction. However, such forms are not dominant on Enceladus. We propose here special tectonic model that could explain this paradox.

2. Subsidence of SPT and tectonics

The volatiles escape from the hot region through the fractures forming plumes in the space – Fig.1. The loss of the volatiles results in a void, an instability, and motion of solid matter into the hot region to fill the void *in statu nascendi*. The motion includes – Fig. 2:

(i) Subsidence of the 'lithosphere' of SPT.
(ii) Flow of the matter in the mantle.
(iii) Motion of plates adjacent to SPT towards the active region.

If emerging void is being filled by the subsidence of SPT only, then the velocity of subsidence is ~0.05 mm·yr^{-1}. However, all three types of motion are probably important, so the subsidence is slower but mantle flow and plates' motion also play a role in filling the void.

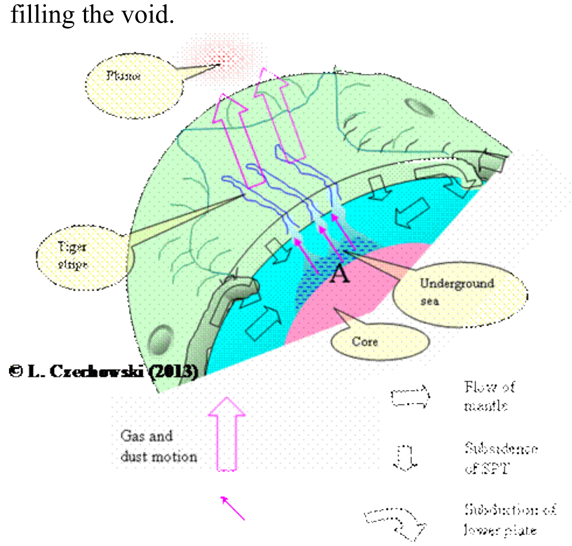


Figure 2: A scheme of suggested processes in the activity center (after [6]).

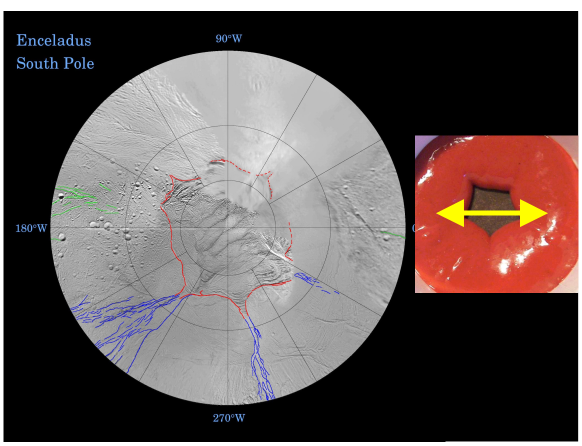
Note that in our model the reduction of the crust area is not a result of compression but it is a result of the plate sinking. Therefore the compressional surface features do not have to be dominant.

3. Models of subsidence

The numerical model of suggested process of subsidence is developed. It is based on the typical set of equation: Navier-Stokes equation for incompressible viscous liquid, equation of continuity and equation of heat conduction. The Newtonian and non-Newtonian rheologies are used. The preliminary results of the model indicate that the the subsidence rate of ~0.05 $mm{\cdot}yr^{-1}$ is possible if we assume Newtonian rheology of the ice. For non-Newtonian rheology more probable value is ~0.01 $mm{\cdot}yr^{-1}$. In this case the velocity of motion of the 'mantle' material is higher.

4. Experimental model

Fig. 3 presents the map of the STP (left hand part of the figure). One can see the low polygonal region surrounded by the characteristic 'arcs'. In the laboratory model we consider the regular pentagonal plate (modelof STP) sinking in viscoelastic material. This rheology corresponds to assumption that icy plates are warm enough to creep like glaciers. The STP is modelled by regular pentagonal plate that sinks into the viscoelastic material. The right hand side of the Fig. 3 presents the situation 150 hours after beginning of sinking. The most of the plate is already covered by the material – the size of the plate is given by the yellow double arrow. Note 'kinks', that are formed above vertices of the plate. Contrary to expectations (the viscoelastic material behaves like the fluid for the considered time scale) these 'kinks' appear to be stable features. This fact suggests that 'plates' adjacent to the SPT could behave like a glaciers.



]Figure 3. The image of STP (left hand side, after NASA). Model of subsidence is on the right part of the figure. (after [6]).

5. Summary and Conclusions

Our hypothesis is a natural consequence of observed mass loss. This mass loss is a main factor driving tectonic motions. Of course, it does not exclude some form of solid state convection in the icy mantle, but in fact this convection is not needed.

The time of operation of this form of tectonics is not known. There are some observations suggesting that the activity in the STP is now decreasing. The periodic changes of activity are possible. Other observations suggest that in the past there were other centers of activity similar to the present STP [1]. The indication of the future activity centers is less certain. However, the ovoid-shaped depression up to 2 km deep, of size 200×140 km with the center at 200E, 15S is a good candidate [7].

Acknowledgements

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