EPSC Abstracts
Vol. 11, EPSC2017-705, 2017
European Planetary Science Congress 2017

Present and future 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 follow here our previous suggestions that this mass loss is a main driving mechanism of the Enceladus tectonics.

1. Introduction

Every second, the mass of ~200 kg is ejecting into space from the South Polar Terrain (SPT) of Enceladus [1, 2, 3, 4, 5, 6].

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. In previous presentations we propose here special tectonic model that could explain this paradox [6, 7] and Fig. 1.

The volatiles escape from the hot region through the fractures forming plumes in the space. The loss of the volatiles results in a void and motion of matter into the hot region to fill the void *in statu nascendi*. The motion includes – Fig. 1: (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} [6, 7].

Note that in this 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.

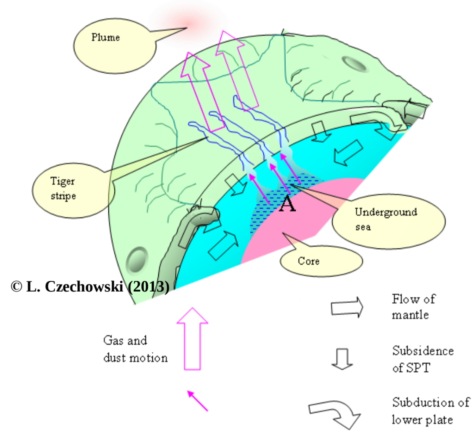
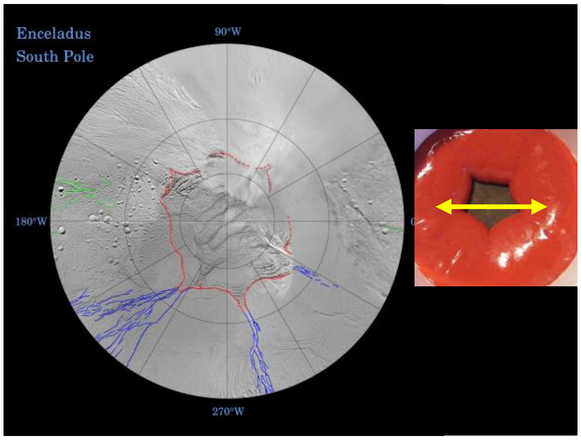


Figure 1: A scheme of suggested processes in the activity center (after [7]).

In 2014 [7] presents results of experimental modelling. Fig. 2 gives 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 observe the results of sinking the regular pentagonal plate (model of STP) in viscoelastic material. Rheology of this material corresponds to assumption that icy plates are warm enough for creeping. The right hand side of the Fig. 2 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.



]Figure 2. The image of STP (left hand side, after NASA). Model of subsidence is on the right part of the figure. (after [7]).

3. Numerical model of subsidence

The numerical model of suggested process of subsidence is improved. It is still 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 rheology could be used. Thermal convection also could be included. The preliminary results (without thermal convection) indicate that the subsidence rate of ~0.04 mm·yr^{-1} is possible if we assume Newtonian rheology (i.e. for n=1). For ice the non-Newtonian rheology (with n=2.5-4) however is more probable. In this case the subsidence rate is substantially lower ~0.02 mm·yr^{-1} but the velocity of motion of the 'mantle' material is higher.

If thermal convection is included the results could be substantially different. Note that even the direction of the plates' motion could be different. Intensive thermal convection could force adjacent plates to move into or out of the SPT. More numerical simulations are necessary to achieve better understanding of the true processes below SPT..

4. Evolution of tectonics

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 for the observed activity.

The time of operation of present form of tectonics is not known. We believe that it is a periodic process. There are some traces that could be attributed to past active centers similar to the present STP. Moreover, the ovoid-shaped depression down to 2 km deep, of size 200×140 km with the center at 200E, 15S is a good candidate [6, 7] for the future center of activity. The depression could indicate the partial melting of the mantle. It could lead to an increase of tidal heating and consequently formation of the center of activity.

Acknowledgements

We are grateful to the ICM.

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