**PAST, PRESENT AND FUTURE TECTONICS OF ENCELADUS** L. Czechowski[1]. [1]University of Warsaw, Faculty of Physics, Institute of Geophysics, ul. Pasteura 5, 02-093 Poland (lczech@op.pl).

**Introduction:** 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 [e.g. 1, 2, 3]. We follow here our previous suggestions that this mass loss is a main driving mechanism of the Enceladus tectonics [1, 2].

**Proto-Enceladus hypotheses:** The mass of matter ejected in space by volcanic activity of Enceladus is 200 kg $s^{-1}$. For such a small body it is a significant value. It means that just after the accretion Enceladus could be substantially larger. We will refer here this larger body as proto-Enceladus [2]. Two assumptions could be used for calculation of the size of proto-Enceladus: (i) the present rate of mass out flow could be treated as the average or (ii) densities of proto-Enceladus and Mimas were the same because the satellites accreted in the same part of the nebula. Both approaches give similar size of proto-Enceladus [2].

There are some traces of past activity on the surface of Enceladus [4]. The traces could be interpreted as indication that the past activity was similar to the present one (similar features), but we do not know how old are these traces. They could be relatively young.

The recent paper [6] suggests that Enceladus was formed ~100 Myr ago. It does not contradict of our hypotheses that the mass loss is a main driving mechanism of the Enceladus tectonics but the hypotheses of proto-Enceladus could be unnecessary. In the next considerations the 'traditional' age of Enceladus is assumed.

Some possible changes of the orbits during the first 30 Myr after formation of Solar System (cf. e.g. [7]) are also not critical for the present hypothesis, because we do not consider those initial processes.

**Present activities:** 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 [5]. However, such forms are not dominant on Enceladus. In previous presentations we proposed special tectonic model that could explain this paradox [1, 2, 5] 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 South Polar Terrain,
(ii) flow of the matter in the mantle,
(iii) motion of plates adjacent to SPT towards the active region.

Note that during these processes 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.

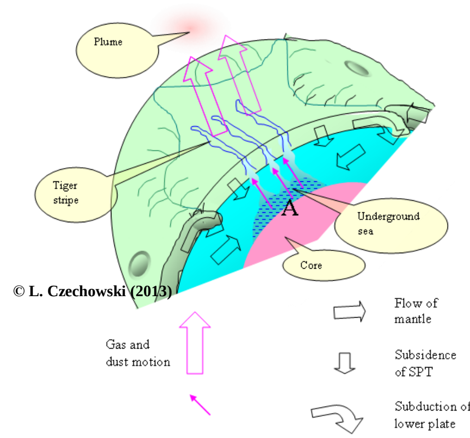


Figure 1: A scheme of suggested processes in the activity center (after [1]).

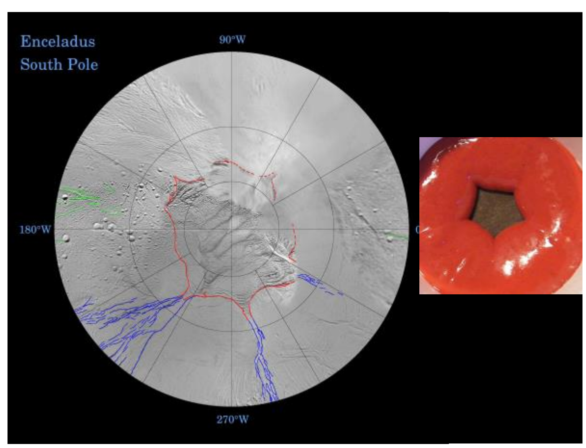


Figure 2. The image of STP (left hand side, after NASA). Laboratory model of subsidence is on the right part of the figure [5]

**Model of processes:** [1, 5] present 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 (right hand side of the figure) we observe the results of sinking of the regular pentagonal plate (model of STP) in viscoelastic material. Rheology of this material corresponds to assumption that icy plates and the mantle below 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.

**Numerical model:** The model is described in [5]. The Newtonian and non-Newtonian rheology were used. The preliminary results (without thermal convection) indicate that the subsidence rate of ~0.04 $mm \cdot yr^{-1}$ 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 $mm \cdot yr^{-1}$ 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.

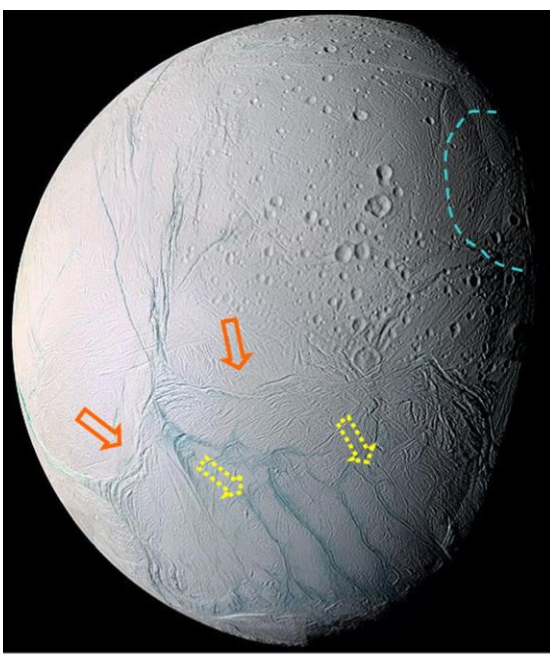

Figure 3. Surface features in cryovolcanic center (SPT) of Enceladus (NASA, PIA06254). Solid arrows show the arcuate scarps convex southward. Analogy with terrestrial subduction zones suggests that the polar plate is there subducted- e.g. [1]. Dashed arrows indicate two tiger stripes. Blue dashed line shows an ovoid depression which may be an activity center in the future as suggested by [1].

**Future activity**: The time of operation of the present form of tectonics is not known. We believe that it is a periodic process. The activity in the present place will be decreasing and a new center of activity will be formed. Note that the ovoid-shaped depression down to 2 km deep, of size 200×140 km with the center at 200E, 15S is a good candidate for this future center. The depression indicates the partial melting of the mantle. It could lead to an increase of tidal heating and consequently the beginning of formation of the center of activity.

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**References:**

[1] Czechowski, L. (2014) Enceladus - the vanishing satellite presenting in EGU 2014, Vienna.
[2] Czechowski, L. (2014) Planet. Sp. Sc. 104, 185-199
[3] Kargel, J.S. (2006) Enceladus: Cosmic gymnast, volatile miniworld. *Science* 311, 1389–1391.
[4] Spencer, J. R., *et al*. (2009), Enceladus: An Active Cryovolcanic Satellite, in: M.K. Dougherty et al. (eds.), *Saturn from Cassini-Huygens*, Springer, Sciencep. 683.
[5] L. Czechowski (2017) Present and future tectonics of Enceladus. Presented in EPSC 2017.
[6] Ćuk, M., Dones, L., Nesvorný, D. (2016). Dynamical evidence for a late formation of Saturn's Moons. The Astrophysical Journal, 820, 2, article ID 97, 1-16.
[7] Batygin, K., Brown, M.E. (2010). Early dynamical evolution of the Solar System: pinning down the initial conditions of the Nice Model. The Astrophysical Journal, 716: 2:1323.