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Evolution of 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 endogenic activity is observed in the form of cryovolcanism. 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].

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.

The motion towards the active region mentioned in (iii) could lead to compression of STP. However, the sinking of the STP plate reduces essentially compressive forces acting from the plates surrounding the STP region. Therefore, the termal processes below tiger stripes are sufficient to keep open the active fractures. Note that the present situation in STP is similar to situation of the Philippine Plate, where back-arc spreading is observed (back arc spreading indicates extensive forces).

Of course, the continuous loss of mass will cause eventually the increase of compression forces, which will ultimately lead to closing fissures and stopping activity in the STP region.

A new activity center will probably be created in the oval region given in Fig. 3. 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.

The heating will lead to the emergence of strong convection currents which, acting on the shell, lead to the formation of fissures similar to the current tiger stripes.

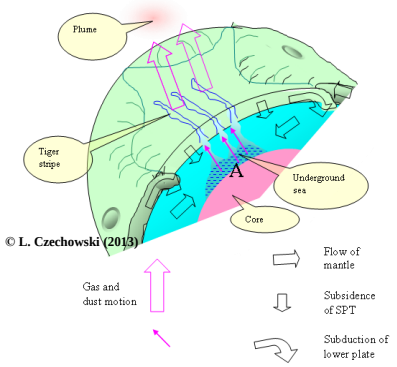

Figure 1: A scheme of suggested processes in the activity center (after [1]). Note that the present situation in STP is similar to situation of the Philippine Plate, where back-arc spreading is observed.

Proto-Enceladus hypotheses: The mass of matter ejected in space by volcanic activity of Enceladus is 200 kg s^{-1}. 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].

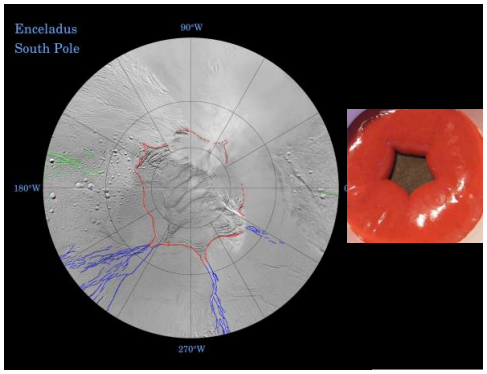

Figure 2. The image of STP (left hand side, after NASA). Laboratory model of subsidence is on the right part of the figure [5]. The subsidency of the central plate reduces significantly compressional forces resulting from interaction with otaczjącyh płyt.

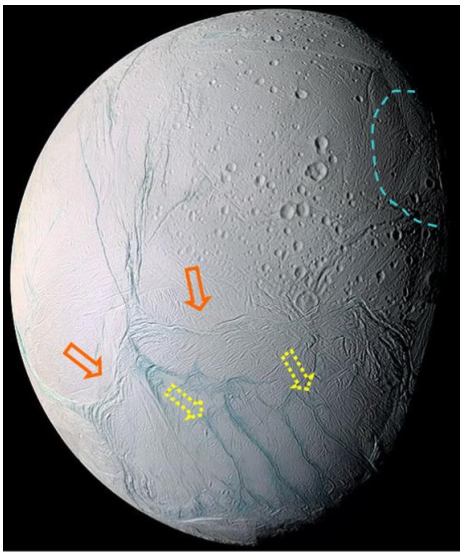
Figure 3. Surface features in the cryovolcanic center (SPT) of Enceladus (NASA, PIA06254). Solid arrows show the arcuate scarps convex southward. Analogy with terrestrial subduction zones suggests that the polar plate is there subducted- e.g. [1]. Dashed arrows indicate two tiger stripes. Blue dashed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

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.

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