ENCELADUS AND ORIGIN OF THE LIFE IN THE SOLAR SYSTEM. L. Czechowski[1] , [1]University of Warsaw, Faculty of Physics, Institute of Geophysics, ul. Pasteura 7, 02-093 Warszawa, Poland, lczech@op.pl .

Introduction: Enceladus is a medium sized icy satellite (MIS) of Saturn. MIS are built of mixtures of rocks and ices. Enceladus with its radius of 250 km is one of the smallest of MIS, however, contrary to the rest of them, it is geologically active.

According to [1]: "For life to have emerged […] on the early Earth, a sustained source of chemically transducible energy was essential. The serpentinization process is emerging as an increasingly likely source of that energy. Serpentinization of ultramafic crust would have continuously supplied hydrogen, methane, […] to off-ridge alkaline hydrothermal springs that interfaced with the metal-rich carbonic Hadean Ocean" (see also [2]).

We consider here conditions for origin of life in the early Enceladus and possible proliferation of the life.

Mass of serpentinite: The serpentinization on the Earth is often considered with hydrothermal activity in neovolcanic zones along mid-oceanic spreading centers. The total length of present spreading centers is ~80 000 km. However, only in small part of them the hydrothermal activity really occurs. Even if in Hadean oceans the hydrothermal activity was more widespread, still only small part of terrestrial rocks could be serpentinized.

After [3] we consider the following reaction of serpentinization:

Mg_2SiO_4 (forsterite) + $MgSiO_3$ (enstatite) + $2H_2O$ --> $Mg_3Si_2O_5(OH)_4$ (antigorite).

This reaction releases 241 000 J per kg of serpentine produced. A simple calculations (e.g. [4]) indicate that mass fraction of silicates f_{mas} in Enceladus is ~0.646, hence the total mass of its silicate is ~6.97 10^{19} kg.

[4] considered the process of differentiation and core forming in Enceladus. He found that the result of differentiation is a relatively cold core of loosely packed grains with water between them. At that time, there is not mechanism of removing the water.

Since terrestrial rocks are permeable up to the pressure of ~300 MPa then the entire core of Enceladus was probably permeable for liquids and gases. This could lead to formation of extensive hydrothermal convective systems. Note that in Enceladus most of silicate could be serpentinized (contrary to the Earth). It indicates that total mass of serpentinized silicate in Enceladus could be larger than on the Earth.

T-p conditions in Enceladus: The pressure in the center of Enceladus is ~2.3 10^7 Pa that correspond to pressure on the depth 2300 m in the terrestrial ocean.

The evolution of temperature in the Enceladus interior for the first a few hundreds Myr is considered by [4] (no tidal heating is included). If Enceladus accreted later than 2.4 Myr after formation of CAI then the temperature allows for existing the life even in the center of the satellite. It is possible that for hundreds of Myr the conditions in the interior of Enceladus were more favorable for origin of life than on the Earth [5, 6].

Proliferation of life: We do not know the probability of life origin. The life could be a common phenomenon originating in relatively short time if conditions are favorable. However, it is possible also that the life had originated only one time in the Universe. If this option is true then the transport of primitive organism is critical.

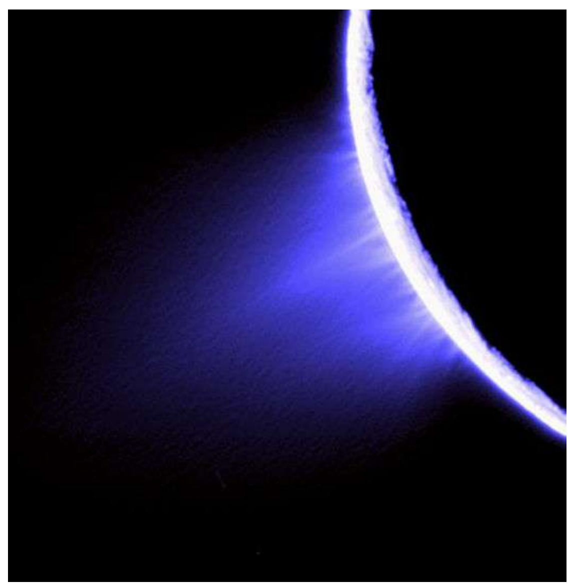

Fig. 1 The cryo-volcanic activity of Enceladus could be responsible for transport of living organisms from the core to E-ring. Image presents jets in the southern hemisphere of Enceladus. Processed picture taken by Cassini (on Nov. 27th, 2005) – NASA.

From the core to the surface. The volcanic activity offers occasion to transport organisms from the core to the surface of early Enceladus. The form of this activity could be essentially the same as present – Fig. 1.

From the surface to E-ring. The existence of E-ring is an evidence that cryo-volcanic jets could eject gas and solid particles (possibly with primitive organism) into orbit around Saturn.

From E-ring to an orbit around Sun. The mechanism of gravity assist could be responsible for acceleration of some particles from the orbit around the Saturn into orbit around the Sun. The existence of several satellites of Saturn increases the probability of this mechanism. The sequence of close encounters with these satellites could eventually transfer enough energy to the grains to leave the orbit around Saturn.

From orbit of Saturn to terrestrial planets. To reach the terrestrial planets from the orbit close to Saturn the grain must be substantially decelerated. There are a few possible mechanisms of loosing energy: Poynting-Robertson mechanism (for grains larger than a few μm), Yarkovsky diurnal effect (if the grain is a retrograde rotator) and Yarkovsky seasonal effect (for grains of diameter of a few meters); e.g. [7]. Deceleration leads the particle to move closer to the Earth and other terrestrial planets.

After [6] we consider here the Poynting-Robertson effect which is effective for the grains size of E-ring particles. Assume the grain on the circular orbit of with radius R and the photons radially emitted by the Sun. In a grain's frame of reference the photons have some tangent component of the velocity. It gives rise to tangential force opposite to the velocity of the grain**.** This force is given by formula (e.g. [7]):

$$F_{PR}=v\, W/c^2, \qquad (1)$$

where v is orbital velocity of the grain, W is the power of Sun's radiation and c is speed of light. The power of drag is:

$$P_{\text{drag}}= -F_{PR}\, v= v^2\, D/(R^2\, c^2). \qquad (2)$$

Note that $D=C_{SunE}\, S_{gr}\, (R_E)^2$, where C_{SunE} = 1350 W m^{-2} is the Solar constant at the Earth orbit, $S_{gr}= \pi\, r_{gr}^2$ is the cross section of the grain, r_{gr} is the grain radius and R_E is the radius of the Earth's orbit. Note also that the orbital energy of the grain is given by:

$$E_{orb} = -½\, G\, Mm/R\, . \qquad (3)$$

Comparison of dE_{orb}/dt and P_{drag} and integration indicate that time of falling from the orbit with radius R_i to the orbit with radius R_e is given by:

$$t = [D/(4\, mc^2)](R_i^2-R_e^2)\, , \qquad (4)$$

where m is the mass of the grain.

Figure 2 presents time of falling from the orbit with the radius 9.5 AU to a given orbit as a result of Poynting-Robertson effect. The grains density is assumed to be 1000 kg m^{-3}. For the grain's radius of 10 μm the time of reaching Earth's orbit from the Saturnian one is ~650 000 yr. Note that for large grains (e.g. ~1 m) other processes, like Yarkovsky effect, could be more effective than the Poynting-Robertson effect.

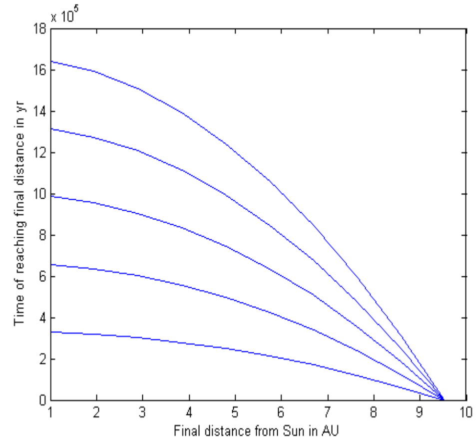

Fig. 2. Time of reaching a given orbit from the orbit at 9.5 AU from the Sun as a result of Poynting-Roberstson effect. The grains' radius: 5μm (the lowest line), 10 μm, 15μm, 20 μm, 25 μm (the uppermost line) After [6].

Decelaration in the upper atmosphere. Small ratio of mass of the considered particles to their cross section makes possible to decelerate them in upper atmospheres of terrestrial planets without substantial increase of temperature – e.g. [7]. During deceleration of larger bodies the dissipation of heat could be high, but cooling effect of ablation would reduce the temperature.

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