EPSC Abstracts
Vol. 5, EPSC2010-48, 2010
European Planetary Science Congress 2010

Internal water ocean on Titan: Place for prebiological and biological processes

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Abstract

Beneath the crust of Saturn's moon Titan may lurk a huge watery ocean, buried below several tens of kilometers of ice. The temperatures of Titan's ocean could have been relatively warm and all conditions inside liquid body (liquid water which exists within long geological period, complex organic and inorganic chemistry and energy sources for support of biological processes) seem compatible with the emergence and sustaining of life.

1. Introduction

The most recent models of the Titan's interior lead to the conclusion that a substantial liquid layer exists today under relatively thin ice cover. Lorenz has found that the internal oceans are mandated for the large icy satellites [1]. Thermal evolution models also predict the existence of thick (~300 km) liquid layer with relatively thin (~80 km) ice cover [2]. Spohn and Schubert have shown that even radiogenic heating in a chondritic core alone may suffice to keep a water ocean inside large icy satellites [3]. Taking into account non-Newtonian viscosity of the water ice in planetary condition, the water ocean on Titan might have survived to date due to only radioactive heat source. Life may have originated on Titan during its warmer early history and then developed adaptation strategies to cope with the increasingly cold conditions. The Cassini spacecraft's data show some features consisting with possible ocean inside the satellite [4]. So, the existing of liquid water ocean within icy world can be a consequence of the physical properties of water ice, and they neither require the addition of antifreeze substances nor any other special conditions.

2. Chemical composition

Mass balance calculations modeled an extraction of the elements into the aqueous phase from chondritic material show that Titan's extensive subsurface ocean likely contains dissolved salts from exogenic and endogenic materials resembling to carbonaceous chondrite rocks incorporated into the satellite during its formation and released at the time of planetary differentiation. The presence of solutes into oceanic water is probably unavoidable in the context of water-rock interaction either early in the history of the satellite or at the present time. The low and high-temperature alteration of primitive accreted material leads to form of a complex water solution of such cations as K, Na, Mg, Ca, Mn, Fe and anions as SO_4^{2-}, Cl^-, Br^-, CO_3^{2-}, HCO_3^- and others along with nitrogen compounds. Phosphorus, sulfur, micro- and macronutrients have to be abundant inside bottom Titan's rocks. Even a very gentle extraction of a sample of the meteorite (4 days at 20 °C) yields a large essential inorganic components, such as PO_4^{3-}, SO_4^{2-}, Cl^-, Ca^{2+}, Mg^{2+}, Na^+, K^+ as well as organic matter [5]. So, an aqueous weathering would release nutrients to fluid where they would be available to microorganisms.

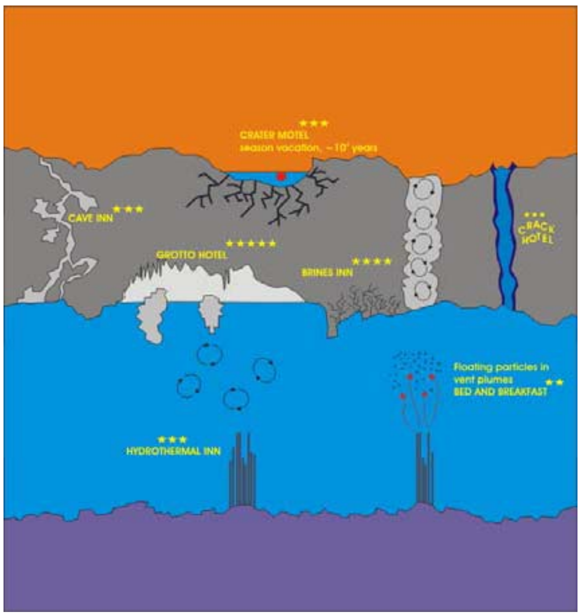
The temperatures of Titan's ocean could have been relatively warm and all conditions inside liquid body seem compatible with the emergence and sustaining of life.

3. Exobiological application

Recent attempts to establish a lower limit for the time required for emergence of life suggest that 10-100 million years was enough in case of Earth. The existence time of the Titan's juvenile ocean was enough for arising of the first protoliving objects. Life may have originated on Titan during its warmer early history and then developed adaptation strategies to cope with the increasingly cold conditions.

All requirements needed for exobiology — liquid water which exists within long geological period, complex organic and inorganic chemistry and energy sources for support of biological processes are on Saturnian moon.

The putative internal water ocean along with complex atmospheric photochemistry provide some exobiological niches on this body: (1) an upper layer of the internal water ocean; (2) pores, veins, channels and pockets filled with brines inside of the lowest part of the icy layer; (3) the places of cryogenic volcanism; (4) set of caves in icy layer connecting with cryovolcanic processes; (5) the brine-filled cracks in icy crust caused by tidal forces; (6) liquid water pools on the surface originated from meteoritic strikes; (7) the sites of hydrothermal activity on the bottom of the ocean.



On Earth life exists in all niches where water exists in liquid form for at least a portion of the year. Possible metabolic processes, such as nitrate/nitrite reduction [6], sulfate reduction and methanogenesis could be suggested for Titan [7]. Excreted products of the primary chemoautotrophic organisms could serve as a source for other types of microorganisms (heterotrophes). Subglacial life may be widespresd among such planetary bodies as Jovanian and Saturnian satellites and satellites of other giant planets, detected in our Galaxy at last decade.

Galileo spacecraft has given indications, primarily from magnetometer and gravity data, of the possibility that three of Jupiter's four large moons, Europa, Ganymede and Callisto have such oceans also. The existing of liquid water ocean within icy world can be consequences of the physical properties of water ice, and they neither require the addition of antifreeze substances nor any other special conditions.

Subglacial life may be widespread among such planetary bodies as Jovanian satellites, Titan, and satellites of others giant planets, detected in our Galaxy at last decade.

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