EPSC Abstracts
Vol. 6, EPSC-DPS2011-1218, 2011
EPSC-DPS Joint Meeting 2011

Implications of possible internal liquid water oceans on Europa and other giant planets' satellites

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Abstract

The icy satellites around Jupiter and Saturn have been revealed as recently or presently active bodies of high interest for geology and astrobiology. Several of them show promising conditions for internal structures involving liquid water oceans. The surface features observed on Jupiter's Europa and Ganymede as well as Saturn's Titan and Enceladus moons display interesting evidence and multicomplex geological figures, which resemble terrestrial geoterrains in terms of structure and possibly followed similar formation mechanisms. All aforementioned satellites consist of differentiated interiors that are stratified into a high density rocky core, a mantle and an icy crust. The confirmation of the presence of a liquid water ocean within these satellites would have important implications on the existence of solid bodies with internal liquid water in the outer Solar System well beyond the "habitable zone", with important astrobiological consequences. Indeed, an underground liquid ocean could provide a possible habitat by resembling terrestrial life-hosting environments like the deep oceans and the hydrothermal active vents. In this study we review the surficial aspects of Europa, Ganymede, Titan, and Enceladus and connect them to possible models of interior structure, with emphasis on the astrobiological implications [1].

1. Introduction

Icy satellites of the gaseous giants, Jupiter and Saturn, at orbits beyond the ice-line, constitute extremely interesting planetary bodies due to – among other - their unique geological and surface composition characteristics [2], the possible internal water ocean underneath their icy crust and the habitability potential. Two of the largest Jovian satellites, Ganymede and Europa, as well as Saturn's Enceladus and Titan, show not only surface features similar to the terrestrial planets and especially the Earth, but also internal heating and occasionally volcanism. Hereafter we summarize some of the characteristics of these moons.

Europa and Ganymede present a major diversity in terms of appearance and surface geological structures and therefore in terms of the surface-shaping forces. Europa seems to be subject to active tectonism and cryovolcanism since it displays a young, smooth and active surface (Fig.1). On the contrary, Ganymede is heavily cratered on most of its surface and internal processes like cryovolcanism seem to have played only a minor role in the surface modification since there is little indication of resurfacing. In general, erosion as well as mass movement and landform degradation seem to play an important role in resurfacing as it reduces the topographic relief by moving surface materials to a lower gravitational potential [3]. Titan and Enceladus' surface expressions are very different in terms of composition, materials and size, they highly resemble the Earth's geomorphology. Titan's surface consists of structures like mountains, ridges, faults and canyons, formed most probably by tectonic processes, as discovered by the Cassini-Huygens mission. Titan, other than its atmospheric uniqueness, is also the only among outer planet satellites where aeolian and fluvial processes operate to erode, transport, and deposit material [3].

2. Interior models and liquid water subsurface oceans in giant planets' satellites

Our current knowledge of the icy moons' internal stratification and their composition is being built on a combination of spacecrafts data, laboratory experiments, and theoretical geophysical modeling. Resembling Earth's moon in terms of structure, icy moons consist of a core, a mantle, and a crust, with the specificity of the existence of a liquid ocean lying within the icy mantle. Evidence for hydrated sulfate salts on the surfaces of Europa and Ganymede from spectroscopic data support the possible existence of subsurface oceans [e.g. 4 and references therein) suggesting the deposition of minerals following internal hydrothermal events. In addition, Galileo's magnetometer, detected induced magnetic fields at Europa and Ganymede that imply the presence of an electrically conductive subsurface layer [e.g. 5]. Furthermore, the detection of a low viscosity layer underneath the icy crust again endorses the presence of a subsurface liquid ocean inducing recent geological activity. Currently, for Titan's and Enceladus' case, all the geophysical models that try to explain their support the existence of an oceanic layer that decouples the mantle from the icy crust.

3. Figures

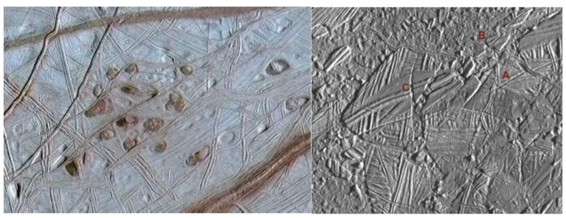

Figure 1: (left) Lenticulae on Europa (reddish semi-circular spots in the middle of the image. (right) Conamara Chaos, area covered with big blocks of crust that are mixed and moved suggesting they floated on a liquid layer (Galilleo Project/NASA). The area of chaos terrain shows plate-like features (marked with A) with ridges and valleys, and regions lower than the plates (marked with B). Also, plate displacement is obvious with surface expressions like faults or ridges deviating from their linear structure (marked with C).

4. Conclusions

In conclusion, the confirmation of the existence of a subsurface liquid ocean underneath the crust of the icy moons of Jupiter and Saturn will revolutionise our perspective regarding the habitability potentials of such planetary bodies. Indeed, liquid water may exist well outside the traditional habitability zone, which is merely based on the presence of liquid water on the surface. For planetary habitability, the principal criteria are the presence of liquid water anywhere on the body, as well as the existence of environments able to assembly complex organic molecules and provide energy sources: this can well be underneath the surface in some cases, if stability conditions are met. The four satellites described in this study seem to fulfill some or all of the above requirements. However, it is of high priority to revisit these bodies with new missions and advanced instrumentation (such as gravitational and magnetic field sounding systems and in situ element detectors) in order to obtain altimetry and in situ monitoring of tidally-induced surface distortion data [5] that could unveil in detail the internal stratigraphy of the moons and the specificity of the subsurface oceans. Future large missions, or smaller dedicated ones, to the Galilean and Khronian systems would allow us to better understand the mechanics behind the astrobiological potential of worlds with subsurface oceans, and shed some light on the emergence of life on our own planet.

Acknowledgements

This research has been co-financed by the European Union (European Social Fund – ESF) and Greek national funds through the Operational Program "Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF) - Research Funding Program: Heracleitus II. Investing in knowledge society through the European Social Fund.

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