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Cryovolcanic activity and morphotectonic features on Titan and Enceladus – Connection to terrestrial geology

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Abstract

Long-lasting investigations, measurements and analysis by the Cassini-Huygens mission since 2004, showed that Saturn's fascinating satellites, Titan and Enceladus, present complex, dynamic and Earth-like geology [e.g. 1]. Endogenous as well as exogenous dynamic processes, have created diverse terrains with extensive ridges and grooves, impact units, icy flows and caldera-like structures, layered plains and stable liquid lakes [e.g. 2]. In addition, Cassini's RADAR has partially revealed the topography of the surfaces, indicating severe types of surface expressions [3]. Due to this complex topography, combined with spectroscopic studies that showed a variety of surface composition, Titan and Enceladus are capable of having active volcanic (referred to as cryovolcanic) and tectonic activity. In order to investigate Titan's and Enceladus' internal and surface processes and structures it is necessary to study their geology. The Cassini-Huygens mission lacks the opportunity to acquire a rock sample, to take *in situ* chemical composition measurements as well as images that reveal in detail the morphology and topography. Thus, a comparative study to terrestrial volcanic and tectonic systems is essential. This study presents the processes that trigger the volcanic and tectonic systems on Earth, the volcanic systems that are internally created and also the surface expressions such as calderas, domes, lava flows and types of pyroclastic depositions which can find correspondence on Titan and Enceladus.

1. Observations on Titan

As far as Titan is concerned, studies have speculated that atmospheric conditions on the satellite resemble those of early Earth, though at a much lower temperature [4]. The basic morphotectonic surficial features identified on Titan are mountains [5], ridges [6], faults [7] as well as rectangular drainage patterns controlled most likely by tectonism which resemble the terrestrial ones in shape and structure but not in size [2]. Evidence for cryovolcanic activity is assumed to be present, especially from data attributed by the Visual and Infrared Mapping Spectrometer instrument (VIMS) [8;9;10]. The changes of the surface morphology, bright surface fluctuations, caldera-like and lobate flow edifices are some indications of volcanic activity. The areas, which are believed to present such cryovolcanic evidences, are Sotra Patera, Hotei Regio, and Tui Regio with sizes ranging from 230 to 1500 km (much larger than the terrestrial areas of volcanic depositions or basins). In 2006, Cassini RADAR revealed multiple probable volcanic calderas and nested lakes followed by the suggestion that buoyant plumes from unknown depths trapped in the thin crust formed magma chambers that supplied the possible volcanic activity [11]. In addition, a recent study of VIMS and RADAR data suggests Sotra Patera and Hotei Regio as two of the strongest cryovolcanic candidates on Titan and Tui Regio as a possible one [8]. Furthermore, two more studies come to enhance this theory. One by indicating temporal changes in surface albedo for Tui Regio and Sotra Patera [9] while another, that studies the tidal potential of the moon, suggests that all three features are connected to the satellite's deep interior [12].

2. Observation on Enceladus and comparison with Earth

Enceladus is an active cryovolcanic world as it presents the spectacular volcanic phenomenon of Geysers. On Earth, a geyser is a hot spring characterized by intermittent discharge of water ejected turbulently and accompanied by a vapour phase. The combined observations of Saturn's moon

Enceladus by the Cassini CAPS, INMS and UVIS instruments detected water vapor geysers in which were present molecular nitrogen (N_2), carbon dioxide (CO_2), methane (CH_4), propane (C_3H_8), acetylene (C_2H_2), and a number of other components, together with all of the decomposition products of water [13]. In 2005 several Cassini images showed fountain-like sources on the South pole of Enceladus which are geysers erupting –possibly- from pressurized subsurface reservoirs of liquid water which should be above 273º K. It is thought that the geysers' eruptions follow a similar model to the Earthly one (like the one that Strokkur Geyser follows –Fig.1) although the temperatures differ as Earth is much warmer, reaching 370º K. It is believed that underneath Enceladus' surface lies a liquid ocean as an underground reservoir of water and a source that supplies geysers in the same way as particular hydrological conditions trigger geysers on Earth. Ice particles mixed with liquid water are being expelled from at least one part of Enceladus's surface out to distances of 300 km. Confirming earlier theories concerning the existence of geysers on Enceladus, recent research identified a population of E-ring grains rich in sodium salts which can originated only from liquid water [14]. Thus, the geyser activity arising from a water subsurface 'ocean' seems to supply the E-ring of Saturn with icy particles.

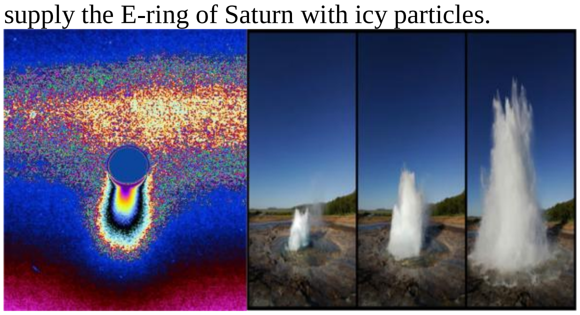

Figure 1: (left) The ice jets of Enceladus send particles streaming into space hundreds of kilometers above the south pole of this spectacularly active moon (NASA). (right) Three stage eruption of Geyser Strokkur in Iceland (Courtesy of Christoph Achenbach)

3. Conclusions

In conclusion, Titan and Enceladus are both unique subjects for geologic research, as they resemble many terrestrial features and activities. Titan is the only moon in the solar system with a substantial atmosphere where the organic chemistry is an analog of the processes that may have been present in the early terrestrial atmosphere. In addition, the late identification and study of Enceladus ocean imply that it resembles to Earth's oceans [17] while this discovery could have implications for the search for extraterrestrial life as well as our understanding of how planetary moons are formed. Furthermore, a comparative study between Titan, Enceladus and Earth since all display -at least in shape and structure- similar surficial expressions will shed light to our current knowledge of the Saturnian satellites' surface morphology.

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