EPSC Abstracts
Vol. 10, EPSC2015-330, 2015
European Planetary Science Congress 2015

Possible evidence for a methane source in Enceladus' ocean

Alexis Bouquet (1,2), Olivier Mousis (3), J. Hunter Waite (2), and Sylvain Picaud (4)
(1) University of Texas at San Antonio, Department of physics & Astronomy, San Antonio, Texas, USA (2) Southwest Research Institute (6220 Culebra Road, San Antonio, TX 78228, USA), (3) Aix Marseille Université, CNRS, LAM (Laboratoire d'Astrophysique de Marseille) UMR 7326, 13388, Marseille, France (4) Université de Franche-Comté, Institut UTINAM, CNRS/INSU, UMR 6213, Observatoire des Sciences de l'Univers de Besançon, France
(alexis.bouquet@gmail.com)

Abstract

We have investigated the evolution of the composition of the putative internal ocean of Enceladus. We used a thermodynamical statistical model to assess the formation of clathrate hydrates in an ocean with the composition of the plumes observed by the Cassini probe. We find that in our initial scenario as well as in alternative ones, clathrates form and efficiently deplete methane in the ocean, below plume levels. An additional source of methane in the ocean or ulterior dissociation of the clathrates are required to explain the abundances of methane detected in the plumes..

1. Introduction

Enceladus is geologically active, with plumes of water vapor and dust emanating from its south polar terrain [1]. An internal liquid ocean is the most prominent explanation as the source of Enceladus' plumes [2]. Here we used a subglacial lake model [3] in order to investigate the time evolution of species dissolved in Enceladus' hypothesized ocean. This allowed us to compare the results of the different processes at work in our model with the composition of the plumes as measured by the Cassini INMS mass spectrometer [4,5].

2. Model and hypothesis

The model used in this work has been first elaborated to mimic the evolution of Lake Vostok's composition in Antarctica [3], namely the largest subglacial lake known on Earth. In our system, water and the different gases are delivered to the internal ocean when melting occurs due to the slow downward motion of the overlying gas-rich ice layers, and gas-free water leaves the lake as ice accretes to the bottom of the ice sheet in regions where ice moves outward [3,6]. Once the solubility limit has been reached for the species dominant in the ocean, bubbles could form but fugacity and temperature conditions in the liquid layer allow instead clathrate formation. We then computed the composition of clathrates forming at these conditions and investigated how it would affect the proportions of species dissolved in the water of the ocean. To determine the equilibrium conditions of clathrates potentially forming in the deep ocean, we computed the gas fugacities via the resolution of the Redlich-Kwong equation of state [7]. We used a statistical thermodynamic model based on the description of the guest-clathrate interaction by a spherically averaged Kihara potential with a nominal set of potential parameters [3,8,9]. In our computations, we used an ocean composition derived from the values measured in the plumes by Cassini INMS, i.e., the starting hypothesis is that those plumes are representative of the composition of the ocean. We investigated the behavior of five detected species prone to clathration: CO_2, CO, CH_4, N_2 and H_2S. Noble gas (Ar, Kr, Xe) were also considered in order to make predictions to be compared with future measurements. Our calculations take place at a depth of 30km (~3MPa on Enceladus) and at a temperature of 0°C. Those conditions are representative of the range of values generally admitted [4,5,10].

3. Results

We found that the "steady state" composition ultimately reached by the ocean (Fig. 1) cannot match the one of the plumes, as CH_4 is very efficiently trapped into the clathrate phase and its proportion among dissolved species always falls below plume levels. Tests of other mixtures with more CH_4 in the starting liquid composition did not solve this question as the efficiency of the trapping always brings CH_4 levels below the expected value. Kr and Xe were also found to be noticeably depleted (by one order of magnitude). A calculation of the density of clathrates hosting the volatiles seen in the plumes show those clathrates should have lower density than the environning salt water, they therefore should ascend to the top of the ocean.

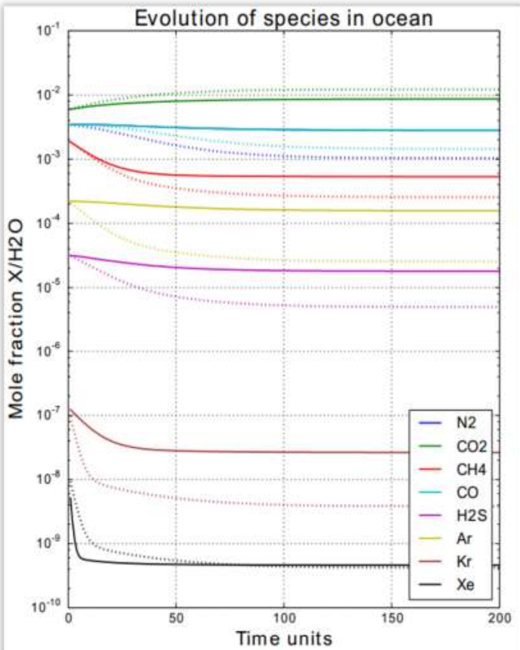

Figure 1: Evolution of the mole fraction of considered species by time units of the model.The full lines represent a scenario of structure I clathrate formation, the dotted lines represent a scenario of structure II formation. The initial values are the mole fractions deduced from the plumes (or from planetesimal formation models in the case of noble gases)

6. Summary and Conclusions

We find that due to clathrate formation, methane in Enceladus' ocean should be depleted below plume levels. This suggests a constant addition of methane in the ocean or ulterior dissociation of clathrates. The source explanation is supported by evidence of hydrothermal activity in the plumes [11], pointing to serpentinization as a possible provider of methane. Future investigations will focus on the transport of clathrates in the ocean after their formation in order to determine to what extent they are involved in the process of plumes formation. It should also be noted that the conditions for capture of volatiles in clathrates are likely to be met in most of the subglacial oceans of the solar system (Jovian moons, Ceres).

In: Bouquet et al., Possible evidence for a methane source in Enceladus' ocean , Geophysical Research Letters, Volume 42, Issue 5, pp. 1334-1339

Acknowledgements

O. Mousis is supported by CNES.
Support by the Cassini Project through JPL subcontract no. 1405853 is acknowledged.
Support by the Rosina Project through JPL subcontract no. 1296001 is acknowledged.

References

[1]Spencer J. R. et al. (2006) *Science*, *311*, 1401-1405.
[2]Potsberg F. et al. (2009 *Nature*, *459*, 1098-1101.
[3]Mousis O. et al. (2013) *Astrobiology, 13(4),* 380-390.
[4]Waite J. H. et al. (2009) *Nature, 460,* 487-490.
[5] Kempf S. et al. (2014) *Space Science Reviews*, submitted.
[6]McKay C. P. et al. (2003) *Geophysical Research Letters*, *30*, 10.1029/2003GL017490.
[7]Redlich O., and Kwong J.N.S. (1949) *Chemical Reviews*, *44*, 233-244.
[8]Mousis O. et al. (2010) *Faraday Discussions*, *147*, 509-525.
[9]Mousis O. et al. (2012) *The Astrophysical Journal*, *757:146*, 7 pp.
[10]Matson D. et al. (2012), Enceladus: a hypothesis to bring both heat and chemicals to the surface, *Icarus 221,* 53-62.
[11]Hsu,H.-W. *et al.,* Ongoing hydrothermal activities within Enceladus. *Nature* **519**, 207–210 (2015)