EVOLUTION OF THE COMPOSITION OF ENCELADUS' INTERNAL OCEAN. Alexis Bouquet[1,2], Olivier Mousis[1], Sylvain Picaud[1], J. Hunter Waite[2], and William B. McKinnon[3], [1]Université de Franche-Comté, Institut UTINAM, CNRS/INSU, UMR 6213, Observatoire des Sciences de l'Univers de Besançon, France (alexis.bouquet@gmail.com), [2]Southwest Research Institute, 6220 Culebra Road, San Antonio, TX 78228, USA [3]Department of Earth and Planetary Sciences and McDonnell Center for the Space Sciences, Washington University in St. Louis, Saint Louis, MO 63130, USA.

Introduction: Enceladus is geologically active, with plumes of water vapor and dust emanating from its south polar terrain [1]. An internal liquid layer is the most prominent explanation as the source of Enceladus' plumes [2]. Here we made the assumption that the physical properties of Enceladus' internal sea are similar to those envisaged for Lake Vostok, Antarctica. We used a subglacial lake model [3] to investigate the time evolution of species dissolved in the satellite's hypothesized sea. 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].

Model and hypothesis: The model is based on a model of 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 regional sea when melting occurs due to the slow downward motion of the overlying gas-rich ice layers. Gas-free water leaves Enceladus' sea 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 may form but fugacity and temperature conditions in the liquid layer allow may also result in clathrate formation. We computed the composition of clathrates forming under these conditions and investigated how this would affect the proportions of species dissolved in the water of the sea. To determine the equilibrium conditions of clathrates potentially forming in the deep ocean on Enceladus, 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 a sea 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 sea. We investigated the behavior of five detected species prone to clathration: CO_2, CO or N_2, CH_4, and H_2S [e.g., 4]. 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 10km (~1MPa on Enceladus) and at a temperature of 0°C. Those conditions are representative of the range of values generally admitted [4,5,10].

Results: We found that the "steady state" composition ultimately reached by the regional sea (Fig. 1) cannot match that of the plume, 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 problem 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).

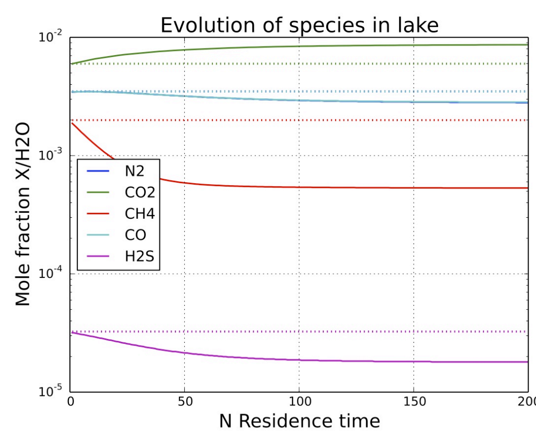

Fig 1. Evolution of dissolved species in Enceladus' sea as a function of residence time (defined as the time required for all the water of the ocean or sea to be renewed through the melting-freezing cycle of water flowing through the volume of the ocean or sea). N_2 is superimposed with CO.

Discussion: We deduce that the plume cannot be supplied only by the sea and that clathrates are brought up with the liquid water, eventually dissociated leading to the release of their guests and contributing to the composition of the plume. This hypothesis is supported by the fact that the density of the mixed clathrates formed in our model was found to be lower than the expected density of the salt water that constitutes the ocean. Clathrates are thus expected to float at the water surface and, as a consequence, they might be easily expelled with liquid water. Note that our estimations are conservative because we computed the density of the clathrate phase assuming a full filling of the cages, which is not the case in reality.

The next step is to constrain the quantity of clathrates needed to reach the measured plume composition and to investigate whether it leads to constraints on the ambiguities in the plume's composition.

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