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Resultant endogenous features on Europa's surface from evolution of fluids of the H_2O-$MgSO_4$-CO_2 system

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Abstract

Here we propose a geochemical model that describes the evolution of potential Europa's endogenous fluids, and explains the formation of several geological features distinctive of the Europa's surface. To do that, we use experimental data from the system H_2O-$MgSO_4$-CO_2 as the main composition of the fluids and, assuming that the tectonic context affects the ascent of the fluids.

1. Introduction

An approach to the chemical composition of Europa's surface is determined mainly from the data obtained by the Galileo Near-Infrared Mapping Spectrometer (NIMS). Water ice-I, hydrated magnesium sulfate and carbon dioxide have been detected, and the last two are associated with structures related to resurfacing events [1, 2, 3, 4, 5]. The endogenic origin of these compounds is supported by both, the self-induced magnetic field of the moon which is explained by the existence of a salty ocean just below the icy crust [6] and the association of these materials with some geological features presumably formed by resurfacing processes. The presence of volatiles in the fluids is convenient since they can promote buoyancy [7].

The geochemical model performed considers that a cryomagma with composition H_2O-$MgSO_4$-CO_2 basically might suffer four processes in Europa: (a) Cryomagmatic extrusion due to instantaneous depressurization caused by crust fracturation, (b) Crystal fractionation inside the icy shell forming a cryomagmatic chamber, (c) Cryomagmatic extrusion from a previous stabilized cryomagmatic chamber, with strong outgassing, and (d) Cryomagmatic extrusion with gradual cooling. The model uses experimental data reported in [7] and [8]. From them it is possible to explain how several geological features such as the deposits around fractures or chaotic terrains are formed.

2. Methodology

Experiments have been performed in a thermostated high pressure cell equipped with a sapphire window which allows the monitoring of the runs by Raman spectroscopy. In the one hand, it has been determined the CO_2 solubility in $MgSO_4$ aqueous solutions at several low temperatures and high pressures, useful to estimate the variation of the cryomagma density in function of pressure. In the other hand, it has been evaluated the mineral transformations and volume changes which occur when some mixtures formed by CO_2-clathrate hydrate, hydrated sulfate minerals and water ice-I suffer temperature-pressure variations at equilibrium and non-equilibrium conditions.

3. Results

The phase diagram of the system H_2O-$MgSO_4$-CO_2 at several salt concentrations (0, 5, 17 and 30 wt %) and at Europa inner conditions (Fig. 1) suggests that CO_2-clathtrate hydrate, epsomite ($MgSO_4 \cdot 7H_2O$), meridianiite ($MgSO_4 \cdot 11H_2O$) and water ice-I might stabilize inside the icy shell. During rising, fluids of this system evolve depending of the paths, velocity and its initial composition. These factors define the characteristics of the final surface structure formed. As an example of the results from this approach, figure 1 shows the evolution of a fluid at 30 wt % of salt if it is stuck before arriving to the surface. If cooling occurs at certain level, the cryomagma would suffer crystal fractionation, segregating clathrate minerals. If the shell is fractured later, and some faults cross the cryomagmatic chamber, the depressurization might cause clathrate hydrates dissociation. The resulting fluid is rich in dissolved gases and poor in salts, since they were previously separated in the form of sulfate minerals due to their higher density. It is likely that a secondary fluid with these characteristics rises in an explosive way, forming cryoclastic deposits (Fig. 2).

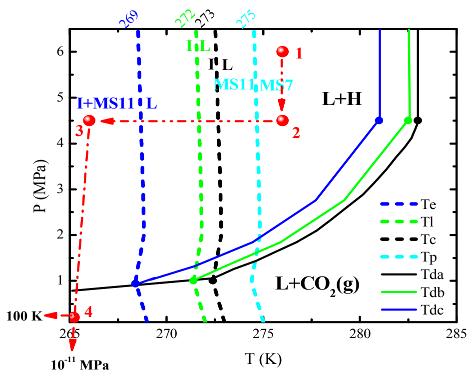

Figure 1: Trajectory (in red) of a fluid destabilized from a differentiated cryomagmatic chamber. H: CO_2-clathate, I: water ice I, L: fluid, MS11: meridianiite, MS7: epsomite, Te: eutectic temperature of the system H_2O-$MgSO_4$, Tl: *liquidus* temperature when L=5 % $MgSO_4$, Tc: crystallization temperature when L=0 % $MgSO_4$, Tp: peritectic temperature, transformation of MS7 to MS11 when L= 30% $MgSO_4$, Tda: clathrate equilibrium temperature when L=0 % $MgSO_4$, Tdb: clathrate equilibrium temperature when L=5 % $MgSO_4$, Tdc: clathrate equilibrium temperature when L=17 % $MgSO_4$.

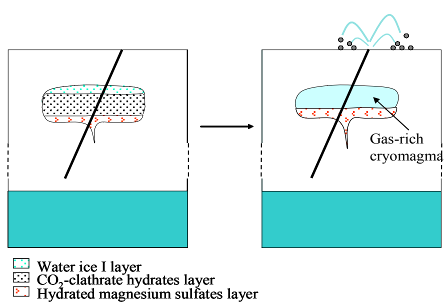

Figure 2: Europa crust sketch (not scaled) where fluid degassing from a cyomagmatic chamber with stabilized clathtrates promotes explosive eruption.

Acknowledgements

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References

[1] McCord T. B., Hansen G. B., Clark R. N., Martin P. D., Hibbitts C. A., Fanale F. P., Granahan J. C., Segura M., Matson D. L., Johnson T. V., Carlson R. W., Smythe W. D. and Danielson G. E.: Non-water-ice constituents in the surface material of the icy Galilean satellites from the Galileo near-infrared mapping spectrometer investigation. J. Geophys. Res. 103, 8603-8626, 1998.

[2] McCord T. B., Hansen G. B., Fanale F. P., Carlson R. W., Matson D. L., Johnson T. V., Smythe W. D., Crowley J. K., Martin P. D., Ocampo A., Hibbitts C. A. and Granahan J. C.: Salts on Europa's surface detected by Galileo's near infrared mapping spectrometer. Science 280, 1242-1245, 1998.

[3] McCord T. B., Hansen G. B., Matson D. L., Johnson T. V., Crowley J. K., Fanale F. P., Carlson R. W., Smythe W. D., Martin P., Hibbitts C. A., Granahan J. C. and Ocampo A.: Hydrated salt minerals on Europa's surface from the galileo near-infrared mapping spectromenter (NIMS) investigation. J. Geophys. Res. 104, 11827-11851, 1999.

[4] Dalton J. B., Prieto-Ballesteros O., Kargel J. S., Jamieson C. S., Jolivet J. and Quinn R.: Spectral comparison of heavily hydrated salts with disrupted terrains on Europa. Icarus 177, 472-490, 2005.

[5] Hansen G. B. and McCord T. B.: Widespread CO_2 and other non-ice compounds on the anti-Jovian and trailing sides of Europa from Galileo/NIMS observations. Geophys. Res. Lett. 35, L01202, 2008.

[6] Kivelson M. G., Khurana K. K., Russell C. T., Volwerk M., Walker R. J. and Zimmer C.: Galileo magnetometer measurements: a stronger case for a subsurface ocean at Europa. Science 289, 1340-1343, 2000.

[7] Bonales L. J., Muñoz-Iglesias V. and Prieto-Ballesteros O.: Raman spectroscopy as a tool to study the solubility of CO_2 in magnesium sulphate brines: application to the fluids of Europa's cryomagmatic reservoirs. Eur. J. Mineral. 25(3), 63, 2013.

[8] Muñoz-Iglesias V., Prieto-Ballesteros O. and Bonales L. J.: Conspicuous assemblages of hydrated minerals from the H_2O–$MgSO_4$–CO_2 system on Jupiter's Europa satellite. Geochim. Cosmochim. Acta, 125, 466-475, 2014.