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Fractional precipitation experiments of Europa satellite cryomagmas using Raman spectroscopy as analyzed tool

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Abstract

There are evidences about the existence of a salty ocean or liquid reservoirs bellow the icy surface of Europa satellite. Non water ice materials detected at the surface, if they have endogenic origin, will be the result of the evolution of these inner briny cryomagmas. Fractional precipitation experiments of brines with different composition (neutral, alkaline and acid) have been carried out up to 300 bar, and studied "in situ" by Raman spectroscopy.

1. Introduction

Reflectance spectra of the non water ice materials, associated to chaotic terrains and faults, fit well with a mixture composed by magnesium sulfate, sodium sulfate, sodium carbonate and sulfuric acid hydrates [1, 2, 3]. The structural relationship of the hydrates to the surface features indicates an endogenic origin. Other data which supports the presence of brines inside Europa are: 1) The observed self-induced magnetic field, that may be caused by the flow of electrolytic salts, [4]. 2) Theoretical models of aqueous differentiation of carbonaceous chondrites, which show several brines as the result [5, 6]. Thermal evolution of the satellite may promote the rise of the cryomagmas to the surface, suffering differentiation processes due to the decrease in temperature. In this study it has been performed experimentally the fractional precipitation of the brines postulated by the previous theoretical models [7, 8, 9].

2. Procedure

Chemical compositions of the brines analyzed were: $MgSO_4$-Na_2SO_4-H_2O (neutral), Na_2CO_3-Na_2SO_4-H_2O (alkaline), $MgSO_4$-H_2SO_4-H_2O (acid) and $MgSO_4$-Na_2SO_4-H_2SO_4-H_2O (acid). Solutions have been prepared heating and stirring the solutions about 323 K to the complete dissolution of the salts. Their cooling was started once they get the room temperature. Temperature has been decreased about 5 K each 24 hours to complete solidification of the systems. Raman spectra of the supernatant have been taken at each temperature of the cooling. Experiments at 1 bar have been performed introducing the solutions in a round-bottom flask submerged in a cooling bath. At 300 bar it has been employed a high pressure cell equipped with a thermocouple, a pressure transducer and a sapphire window to take the spectra "in situ". To refrigerate the system, the cell is surrounded by a rubber tubing through which passes the coolant from the cooling bath.

3. Results

The fractional precipitation process has been observed in the four brines studied. Similar results were obtained at 1 and 300 bar. Theoretical phase diagrams have been taken as references in order to know what minerals promote the decrease in the anions concentration along the cooling [7, 8, 9, 10, 11]. Fig. 1 shows the Raman spectra of an experiment performed for the alkaline brine at 1 bar, as an example. Major peaks of sulfate ion (SO_4^{2-}) and carbonate ion (CO_3^{2-}) appear at 970 cm^{-1} and 1063 cm^{-1}, respectively. In Fig. 2 it is appreciated the decrease of the anions concentrations along the cooling. Initial concentrations were 4.5 molal of Na_2CO_3 and 0.7 molal of Na_2SO_4. In this case, the drop on the ions concentrations was due to the formation of natron ($Na_2CO_3.10H_2O$), mirabilite ($Na_2SO_4.10H_2O$) and ice.

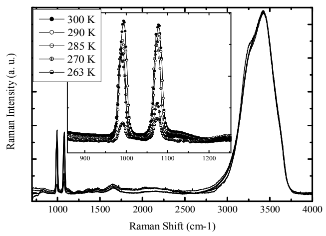

Figure 1. Raman spectra at several temperatures along the cooling of the alkaline brine at 1 bar.

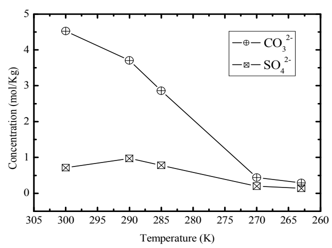

Figure 2. Carbonate and sulfate ions concentration versus temperature along the cooling of the alkaline brine at 1 bar.

4. Conclusions

Fractional precipitation of each brine resulted in different final mineral assemblages in function of the initial chemical composition. A pressure up to 300 bar did not imply significant changes in the process. If the brine does not suffer fractional differentiation and it crystallizes inside a cryomagmatic chamber, the final mineral assemblage would correspond with the respective eutectic composition.

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