AN ENTHALPY METHOD TO SIMULATE THE CRYOMAGMATIC EVOLUTION OF IMPACT INDUCED MELT BENEATH OCCATOR CRATER ON CERES. M. A. Hesse[1], J. C. Castillo-Rogez[2], J. E. C. Scully[2], [1]Department of Geological Science, The University of Texas at Austin, Austin TX 78712, USA (e-mail address: mhesse@jsg.utexas.edu), [2]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA.

Introduction: The persistence and mobility of brines in the volatile rich crusts of icy satellites and asteroids is an essential component of both intrusive and extrusive cryovolcanic processes. Due to low temperatures, the formation of brines is only possible in presence of salts that reduce the water ice melting point significantly. The phase behavior is eutectic, due to limited solid-solution between the ice/hydrates and the salts, (Figure 1*a*). In eutectic systems, heat and mass transfer are strongly coupled, because melting/freezing is very sensitive to compositional changes. In particular, the addition of small amounts of salt can lead to a finite and potentially large drop in the melting temperature of the system. However, the amount of melt formed at the eutectic temperature is proportional to the amount of salt present and hence potentially small. The eutectic phase behavior also determines the compositional evolution of the extruded/erupted brines.

It is therefore important to understand the coupled mass and energy transport in these cryomagmatic systems. Here we propose to develop a numerical model that describes these couplings and we test it against spacecraft observations from the Dawn mission. In particular, the observed compositional zonation of the Cerealia Facula (CF) in Occator crater on Ceres provides potentially strong constraints on the evolution of the magma chamber that is believed to be impact induced. The facula shows an increase in ammonium chloride toward the top of the central dome [1] (Figure 1*b,c*), which is also one of the youngest regions on Occator's floor [2 and references therein].

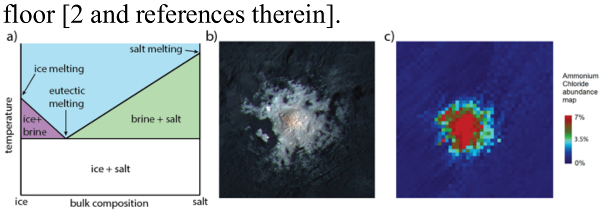

Figure 1.a) Binary eutectic phase diagram. b) Color enhanced image of Cerealia Facula on Ceres from the Dawn Framing Camera. c) Abundance of ammonium chloride in Cerealia Facula, inferred from the Dawn VIR spectrometer [1].

Enthalpy method: Thermal evolution models for planetary evolution and cryomagmatic processes are commonly formulated in terms of temperature, T. This is possible because melting is typically assumed to occur incrementally over a finite temperature interval [3,4] so that the volume fractions are a simple function of T. This approach breaks down in eutectic systems where a finite amount of melting occurs at the eutectic temperature, T_e. During melting at the eutectic temperature, T is not sufficient to describe the state of the system, in particular the volume fractions of the phases. These volume fractions are determined by the total energy/enthalpy of the system, H, and its total composition, C. Therefore, we propose an "enthalpy model" that evolves both H and C and allows the representation of the eutectic phase behavior. In magma dynamics, enthalpy methods have been developed for systems with solid solutions [5,6], but to our knowledge this approach has not been extended to eutectic systems. Here we propose to develop an enthalpy method for simple parametrized binary and ternary eutectic phase diagrams. This model will track the evolution of enthalpy and composition of the system. This requires the consideration of both advective mass and energy transport driven by the over pressure induced by the volume expansion during brine solidification [7]. This model will highlight feedback such as the increasing concentration of salts into the brine and related changes in melt productivity.

Modeling cryomagmatism at Occator crater: We will apply the enthalpy method to the thermal and compositional evolution of the potential impact induced melt at the center of Occator crater on Ceres [2,8]. This will build on our previous work modeling the evolution of the cryomagma chamber [4]. This previous model assumed constant composition and linear melting over a prescribed temperature interval.

The new enthalpy model will track the compositional evolution of the cryomagma chamber and hence make a prediction of the erupted compositional sequence, which can be compared to observed zonation of CF and provide constraints on the state of the cryomagma chamber. A ternary eutectic system should be able to reproduce the observed increase of ammonium chloride in the brine.

References:

[1] Raponi A. et al. (2018) *Icarus*, in press. [2] Scully et al. (2018) Icarus, in press.. [3] Castillo-Rogez J. C. and McCord T. B. (2010) Icarus, 205(2), 443-459. [4] Hesse M. A. and Castillo-Rogez J. C. (2018) LPS XLIX, Abstract 1679. [5] Katz (2008) *J. Pertol.*, 49(12), 2099-2121. [6] Hesse and Jordan (2016), *Geochem. Geophys. Geosyst*. 16. [7] Quick, L., et al., LPSC XLIX. [8] Bowling et al. (2018) Icarus, in press..