INVESTIGATING EFFECTS OF SUBSURFACE CRYOVOLCANIC CHAMBER PRESSURIZATION ON CERES AND ICY MOONS – FRACTURING, CRYOVOLCANISM AND SURFACE RESPONSE

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Introduction: Evidence of volcanism of the molten rock variety has been observed on many planetary bodies in our solar system. However a question remains of if warm, salty, water-ice ever extruded to the surface of Ceres and icy moons, leaving raised morphology and salt deposits behind. The Dawn spacecraft has imaged several features on the surface of Ceres that suggest cryovolcanic activity [1-4]. Previous studies suggest overpressurization could have driven fluids from a subsurface reservoir on Ceres [5,6]. These processes may also occur on icy moons such as Europa and Enceladus [e.g. 7-9]. Here, we analyze how a pressure increase in a cryovolcanic chamber in Ceres' subsurface could drive dike-like fractures towards the surface, enabeling the formation of bright deposits and/or deform the surface. On Earth's seafloor we see this process at hydrothermal vents; seismic data and modeling indicate the occurance of the fractures beneath [10-12].

Methods: We model dike propagation using a finite element program, FRANC2d [13] that calculates displacements and stresses, given: a specific body geometry, imposed loads, material parameters, and boundary conditions. FRANC2d then determines the fracture direction and distance of propagation using the calculated stress results. First we assume a cooling and freezing magmatic lens pressurized 1-2% over the lithostatic load, σ_L (see Fig. 1 showing model set-up). Hydrostatic pressure acts outward within the dike as it propagates to the surface and so changes with depth as: $P_d = P_1 - \rho_m g h$ where P_d is the dike pressure, P_1 is the pressure at the base of the dike $P_{int} = 1.1 * \sigma_L$ is the pressure within the chamber, σ_L is the lithostatic load $= \rho_c g D$, $\rho_c = 1300$ kg/m^3 is the density of the crust above the chamber [14], $g = 0.28$ m/s^2 is gravity on Ceres [3], D is the chamber depth, ρ_m is the cryomagma density, and h is the distance the fluid has traveled above the chamber. Initial analyses explored a chamber, 100 km wide x 10 km thick, D=40 km beneath the surface (Fig. 1). Fig. 2 shows example results of the σ_1 stress field during the pressurization of the chamber at over lithostatic load as well as dike propagation distance and location [15].

Effects of fractures containing water or refrozen liquid are shown to affect surface response [7]. The response of the surface above the chamber to over pressurization in the subsurface and subsequent dike propagation and thermal evolution will be calculated using models of subsidence [16]. This study also investigates temperature profiles above the chamber.

Results: In this study, we explore fracturing and surface response for Ceres and Europa. Thermal profiles above the chamber will be calculated following calculations for convection and heat transfer. Heat loss from the convecting chamber follows $q \sim k\Delta T/d$, where q denotes the heat out, k stands for the thermal conductivity, ΔT denotes the temperature difference between the crust and cryomagma, and d represents the chamber thickness [17,18].

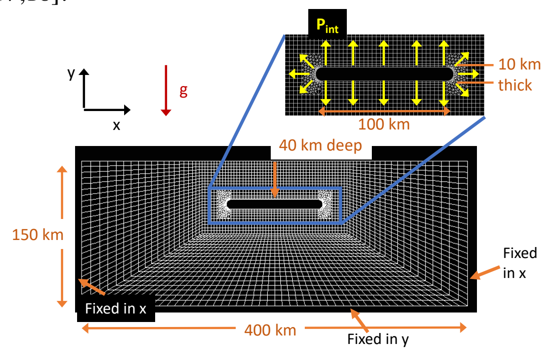

Figure 1. Model setup with material parameters: Young's Modulus = 1E9 Pa [3] and Poisson's ratio = 0.3 for ice [15].

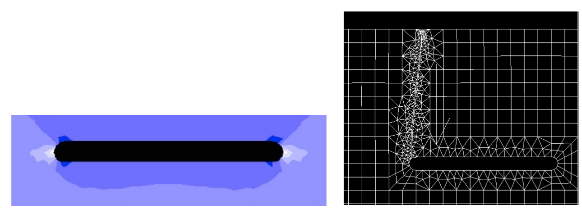

Figure 2. Example of **a.** σ_1 stress field around pressurized magma chamber. Bright blue = tensional stress, with gradients to red denoting increasing compressional stress **b.** Dike propagation from chamber to surface. Fracture initiated at points on chamber of highest tensional stress shown in a.

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