WHAT CAN SILICATE VOLCANISM TELL US ABOUT CRYOVOLCANISM? S. A. Fagents[1], [1]Hawai'i Institute of Geophysics and Planetology, University of Hawai'i at Mānoa, 1680 East-West Rd., Honolulu, HI 96822; fagents@hawaii.edu

Introduction: A range of mechanisms has been invoked to explain geologic features interpreted to have resulted from ascent and eruption of cryovolcanic materials on icy satellites. Youthful surfaces, smooth plains, and a range of unique landforms have all been attributed to cryovolcanism, but our understanding of the mechanisms that operate in ice shells to deliver materials to the surface is far from complete. Without a perfect terrestrial analog for these icy resurfacing processes, silicate volcanism is commonly used as a familiar but imperfect analog process by which to understand the generation, transport, and emplacement of cryogenic fluids.

A working definition of cryovolcanism is "the eruption of liquid or vapor phases (with or without entrained solids) of water or other volatiles that would otherwise be frozen solid at the normal temperature of an icy satellite's surface". One can debate the robustness of such a definition, but it provides a framework with which to explore potential eruptive mechanisms. However, there are fundamental differences in material properties, internal structures, and planetary environment that require caution in applying models of terrestrial volcanic mechanisms to icy satellites. Here I highlight some key issues and processes that are of relevance to icy satellites with water/brine oceans.

Key Issues: In most cases, we are concerned with an ice shell overlying a water layer that may serve to decouple the ice shell from the silicate interior. This internal structure differs substantially from that of terrestrial planets. The resulting possibility of non-synchronous rotation, in addition to diurnal tides, produce stress conditions within the ice shell that may exert a strong influence the movement of fluids.

Furthermore, the unique properties of H_2O cause fundamentally different behavior from rock/magma. Water is denser than ice, so while silicate melts are able to rise through mantle/crustal rocks due to their buoyancy, the same is not true for water with respect to ice; such fluids would need to be pressurized in some way in order to ascend. In addition, decompression melting, which is a fundamentally important melt generation mechanism in upwelling mantle on terrestrial planets, simply does not work for upwelling ice. Production of liquid bodies within the ice shell would require delivery from the ocean, or in situ melting of contaminant-rich ice by a solid-state thermal plume.

Some proposed mechanisms for delivering material from a subsurface ocean to the surface of an ice shell are illustrated in Fig. 1. In examining the details of these mechanisms, we find that some models of terrestrial volcanic processes can be used for icy satellites when care is taken with model parameters, e.g., appropriate fluid viscosities, densities, volatile solubilities, and gravity. For example, for liquid rising in a crack, similar physics applies, with the inclusion of a pressure term to overcome negative buoyancy. Similarly, the dimensions of putative viscous surface flows can be used to constrain fluid properties, using emplacement models developed for silicate lava flows and domes.

In considering of the potential role of volatiles exsolving from the liquid phase during decompression, application of appropriate solubility laws and viscosities can allow an understanding of the dynamics of gas-driven flows. In silicate magmas, exsolving gases provide additional buoyancy to silicate magmas, and their expansion accelerates the magma up the conduit. In contrast, exsolving cryomagmatic volatiles (CO_2, SO_2, CO, NH_3, etc.) will effectively decouple from low-viscosity fluids (water, brine) and be lost to the satellite exterior. This process, in addition to vaporization of a water column exposed to vacuum conditions, might provide a mechanism for driving vapor-rich sprays of water droplets.

Concluding Comments: This contribution is intended to inspire discussion about the validity and limits of applicability of models of silicate volcanism with a view to further elucidating cryovolcanic processes. In general, application of our experience with terrestrial volcanism to understand cryovolcanism must be made selectively and with due consideration of the unique characteristics of the satellite in question. However, the broader question of how cryovolcanism initiates at depth requires further attention.

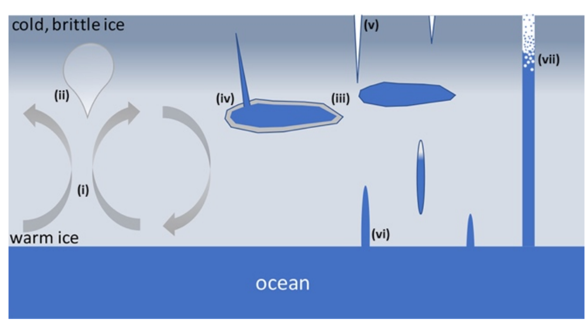

Fig. 1. Potential cryomagmatic mechanisms: (i) solid state convection or (ii) diapiric ascent of warm ice; (iii) formation of melt lenses within the ice; (iv) partial freezing can pressurize fluid and induce ascent; (v) propagation of fractures down from surface, or (vi) upwards from ocean–ice interface; (vii) exsolution of volatiles.