American Mineralogist, Volume 92, pages 1550–1560, 2007

Solidification and microstructures of binary ice-I/hydrate eutectic aggregates

Christine McCarthy,[1,2,*] Reid F. Cooper,[2] Stephen H. Kirby,[1] Karen D. Rieck,[3] and Laura A. Stern[1]

[1]U.S. Geological Survey, 345 Middlefield Road, Menlo Park, California 94025, U.S.A.
[2]Brown University, Department of Geological Sciences, Providence, Rhode Island 02912, U.S.A.
[3]State University of New York at Albany, Department of Earth and Atmospheric Sciences, Albany, New York 12222, U.S.A.

Abstract

The microstructures of two-phase binary aggregates of ice-I + salt-hydrate, prepared by eutectic solidification, have been characterized by cryogenic scanning electron microscopy (CSEM). The specific binary systems studied were H_2O-Na_2SO_4, H_2O-$MgSO_4$, H_2O-NaCl, and H_2O-H_2SO_4; these were selected based on their potential application to the study of tectonics on the Jovian moon Europa. Homogeneous liquid solutions of eutectic compositions were undercooled modestly ($\Delta T \sim 1$–5 °C); similarly cooled crystalline seeds of the same composition were added to circumvent the thermodynamic barrier to nucleation and to control eutectic growth under (approximately) isothermal conditions. CSEM revealed classic eutectic solidification microstructures with the hydrate phase forming continuous lamellae, discontinuous lamellae, or forming the matrix around rods of ice-I, depending on the volume fractions of the phases and their entropy of dissolving and forming a homogeneous aqueous solution. We quantify aspects of the solidification behavior and microstructures for each system and, with these data, articulate anticipated effects of the microstructure on the mechanical responses of the materials.

Keywords: Crystal growth, ice, salt-hydrate, phase equilibria, eutectic reaction, thermodynamics, aqueous solutions, lunar and planetary studies, icy satellites