NS42A-05

New insights into the electrical properties of ice and permafrost

Grimm, R E, D. Stillman*, J.A. MacGregor, C.L. Dinwiddie, R.N. McGinnis, D.M. Hooper

The electrical properties of lab-created ice, salt hydrates, and ice-silicate mixtures were measured across a wide range of frequency (1 mHz-1 MHz) and temperature (180-273 K) and were compared to similar measurements of natural polar ice and permafrost. From these measurements we derived an updated, comprehensive view of charge movement within frozen materials, especially those with high impurity concentrations (soluble and/or insoluble). This new perspective will improve field mapping of subsurface ice and adsorbed water by dielectric spectroscopy (a.k.a. complex resistivity) and enable better prediction of radar attenuation in the cryosphere of the Earth and other icy bodies in the Solar System. Laboratory and natural ices with soluble impurities (salts and acids) in trace quantities have been extensively studied in the literature; we found that that an upper limit to the relaxation frequency corresponds to chloride saturation of the ice lattice at a few hundred uM. Higher initial salinity results in freezing-point depression and the formation of salt hydrates. The former can lead to electrically connected brine channels (see companion abstract by Grimm and Stillman, MR10), whose DC conductivity is well described by Archie's Law. Higher dielectric relaxation frequencies in salt hydrates indicate defect concentrations up to a few orders of magnitude greater than impurity-saturated ice. Broadband measurements of a meteoric Antarctic ice core (Newall Glacier) revealed new electrical behavior not previously seen by classical tests. Although this sample's bulk chlorinity was ~4 uM, it exhibited two dielectric relaxations; from Jaccard theory and our previous measurements, these relaxations are separable into ices with chlorinities of 2 and 30 uM. This double relaxation produces dielectric attenuation at 243 K that is an order of magnitude greater than would have been predicted if the bulk chlorinity value had been assumed. Further investigation is needed to understand how these two populations of ice formed. Laboratory mixtures of ice and high-surface area silicates (e.g., smectite) have similar electrical properties to natural permafrost taken from the US Army Corps of Engineers Permafrost Tunnel in Fox, Alaska. Five dielectric relaxations are evident, which we interpret as due to defect rotation in ice, rotation of adsorbed interfacial water, hydrate-silicate interfacial polarization, and transverse and longitudinal interfacial polarizations in the adsorbed water. Hydrate relaxations were not detected. The ice relaxation shifts to higher frequency with decreasing saturation, which we interpret as increasing defect density in the proximity of pore walls. In materials with lower surface area (i.e., lacking smectites), the rotation and transverse polarization of the interfacial water were not observed. Our interpreted longitudinal polarization of adsorbed water, where protons move parallel to the silicate surface, has been generically called "anomalous low-frequency dispersion," and is often evident in silicate samples above freezing.

Keywords: [0702] CRYOSPHERE / Permafrost, [0738] CRYOSPHERE / Ice, [0925] EXPLORATION GEOPHYSICS / Magnetic and electrical methods, [3914] MINERAL PHYSICS / Electrical properties

Grimm, R.E., **D.E. Stillman** J.A. MacGregor, C.L Dinwiddie, D.M. Hooper, 2009, New insights into the electrical properties of ice and permafrost, Eos Trans. AGU, 90(52), Fall Meet. Suppl., Abstract NS42A-05.