Grain Size Dependent Creep of Ice I at Low Temperature: Preliminary Results

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Grain-size-dependent creep is important to planetary rheology, because it tends to be favored over dislocation creep at low differential stresses, σ. We have endeavored to characterize this mechanism in water ice, the principal building material of most of the large and small moons of the outer solar system, to aid in the extrapolation of laboratory results to the low-stress, low-strain rate environments of the interiors and surfaces of these icy moons. Having previously determined creep laws for mechanisms $n>3$ (where strain rate $\propto \sigma^n$), we now ask if fine-grained ice I follows a different law.

Grain-size-dependent creep can be promoted in the laboratory by making grain sizes smaller. We have developed an efficient "pressure quenching" method for fabricating fine-grained ice samples. We first hydrostatically pressurize ice I samples of "standard" grain size ($\approx$ 250 μm) to approximately 300 MPa to convert them completely to ice II, then drop pressure to < 50 MPa in less than 1 second. Our previous studies of the kinetics of the ice II$\rightarrow$I transformation suggest that sluggish transformation kinetics and the retarded growth of ice I effectively produce a high density of ice I nuclei and a resultant fine grain size of ice I once reversion is complete. The entire process is conducted in our triaxial gas deformation apparatus, and the already jacketed sample is immediately ready for mechanical testing following the pressure quench.

SEM examination of samples pressure-quenched at T $\leq$ 200 K shows an average grain size of 0.5-3.0 μm. Deformation tests carried out on 3 pressure-quenched samples at strain rates of 8 x 10^{-6} and 8 x 10^{-7} s^{-1} to strains > 20% reveal a material with significantly lower strength and lower s sensitivity than "standard" ice. The difference corresponds to about one order of magnitude in strain rate, under ordinary laboratory conditions; higher contrasts can be expected under planetary conditions. SEM study of deformed samples of pressure-quenched ice shows a variety of unusual deformation textures and microstructures. Samples commonly exhibit elongated grains oriented normal to compression. In some areas this elongation is so pronounced that the material appears finely banded, with aspect ratios of some grains approaching 100:1.

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