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The effect of rock fraction on the flow law of debris-laden ice at high confining pressures

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The properties of debris-laden ice are important when considering the behaviour of ice, both on the earth and in other solar system bodies. The flow of ice sheets, the stability of permafrost, and the evolution of icy bodies are all dependent on the rheology of the materials from which they are made. This is often not exclusively pure ice, but rather a mixture of water ice and impurities. At the base of ice sheets and glaciers there is often an ice-rock layer several metres thick, where rock fractions range from 0 – 60 vol%. Icy satellites of the outer planets also consist of mixtures of ices and rock, at a range of ratios, dependent on the history and evolution of the body.

Computer simulations are often used to model the behaviour of ice and ice-rich bodies over geological time periods, and so material properties are required as input parameters for these models. Therefore, to fully understand and model the behaviour of terrestrial and extra-terrestrial ice, it is necessary to understand the properties of ice-rock mixtures as a function of internal and external variables, including the rock fraction. One way to determine these properties is through experimental studies.

There are currently few experimental studies in the literature which investigate the changes to the properties when impurities such as rock are included within the ice. Those which do exist are often high rock fraction, low confining pressure studies, with applications to terrestrial permafrost regions, but with little information regarding the behaviour of rock fractions intermediate between pure ice and 50-60 vol% rock. This lack of data means that numerical models of ice flow cannot include the true rheology of all of the materials present, but must assume that only pure ice properties are applicable.

Here we will present experimental observations of the deformation of ice-rock mixtures at a range of external conditions, with rock volume fractions ranging from 0 vol% to 50 vol%. The conditions used (confining pressures of 48 MPa, temperatures from 253 K - 263 K) are mostly applicable to the interiors of icy planetary bodies, but the results can also be applied to infer behaviour at some terrestrial conditions.

We will show that the impurity fraction of an ice-rock mixture affects the viscosity of the sample as a function of the rock fraction, demonstrating an exponential relationship. We derive flow laws from the results, of a form similar to previously published results, but with some important differences in the values of the experimentally determined flow law parameters. Our findings suggest that it is not only the rock fraction which is an important consideration for these flow laws, but that flow law parameters are potentially also dependent on the rock composition, and the size and shape of the rock particles.