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Investigating brittle-ice behavior and onset in Antarctic Ice cores in preparation for the Hercules Dome Ice Core Project

Content

Ice cores are incredible archives of paleoenvironmental data, that contain important information about past climates. Reliable and accurate measurements of ice cores are critical for interpreting past conditions. However, a primary obstacle encountered with ice-coring projects is the presence of brittle ice. Following the bubble closure in ice, internal deformation quickly squeezes the bubbles, raising their internal air pressure to near the overburden level. When the pressure is high enough (~5.5 – 11.4 MPa), the release of external pressure during core recovery can allow the internal stresses to exceed the fracture strength of the ice, which results in fracturing, and the observed brittle ice behavior. This zone is known as the "brittle ice zone" (BIZ). While characteristics like site accumulation rate and temperature are likely significant to brittle ice onset and behavior, obvious or direct correlations are not apparent, and thus the exact cause and nature of this zone are still not well-understood.

Here, we will estimate brittle ice onset and magnitude for the Hercules Dome site and provide guidance for the field-season operations and drilling, as well as estimates for ice quality and sampling expectations for principal investigators. In addition, this project will also help lead to a potential greater understanding of brittle-ice behavior, and the principal physical properties responsible for its onset and severity. For this project, data analyses will primarily focus on the three previously drilled ice core sites: Siple Dome, South Pole, and WAIS Divide.

These sites were specifically selected in part because Siple Dome and the South Pole act as "end-member" brittle-ice zone sites. We hypothesize that: 1) overall brittleness is likely proportional to mean bubble and grain size in ice, with larger bubbles and grains, equating to higher overall brittleness; 2) that chessboard sub-grain boundaries developed on bubbles provide a preferred path for long-distance fracture propagation, and thus a mechanism for the development of brittle ice. To test our hypotheses, we will start by synthesizing existing brittle ice data from core samples for our identified sites, such as site characteristics (mean annual temperature and accumulation). Second, we will analyze new samples taken from the end member sites (Siple Dome and South Pole), specifically targeting visible brittle-ice fracture surfaces. These surfaces will be examined in thin-section through cross-polarizers in order to reveal any evidence of fractures initiating along bubble axes, that are also exploiting grain or sub-grain boundaries during propagation. We expect to see a statistically significant direct relationship between mean bubble sizes and overall documented brittleness, as well as with stepped fracture surfaces and visible sub-grain boundaries.

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