

Scanning Electron Microscopic Characterization of U.S. ITASE Firn/Ice Cores

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Our understanding of the physical properties of firn, particularly grain size and its correlation with other parameters, such as chemistry, has been revolutionized by recent methodologies. A scanning electron microscope (SEM), in combination with energy dispersive spectroscopy (EDS) was used to describe the physical and chemical characteristics of samples collected during the 2002, 2006 and 2007 ITASE traverses. SEM analysis allows for the determination of firn grain area sans the pore filler required for thin-section analysis with an optical microscope and universal stage. Because no filler is required, porosity and internal surface volume can also be calculated. Additionally, EDS analysis of impurities provides an assessment of the relationship between chemical content, chemical location (i.e. in grain boundaries or within the crystal lattice) and grain growth.

Comparison of grain sizes from 3 cores collected on the 2002 traverse using traditional methods versus SEM has shown grain sizes from SEM images to be substantially smaller (37-59%). Grain size measurements from 3 cores collected during the 2006 traverse revealed an increase in grain size between 60 and 70 meters larger than that seen for the 10 meter increments observed at shallower depths. This trend was accompanied by a marked increase in sample variance. Samples above 60 meters had on average 12 times less variance than samples below 60 meters. Porosity calculations indicated a site specific difference (06-1 was 6-7% less porous than both 06-2 and 06-3). Chemical impurities analyzed at 30, 60, and 90 meters in all three 2006 cores were found to contain Na, Si, Ca, Cl, S, and K (although not in all impurities, nor at all depths). Most of the impurities examined were soluble species and observed on crystal facets, rather than at grain boundaries.

Traditional methods of grain size measurement rely on birefringence patterns; however, if the c-axes of adjacent grains are identical individual grains may be indistinguishable, resulting in artificially high measurements. This likely explains the differences in average grain area observed between techniques. The marked increase in both grain size and variance could be related to a higher frequency of low angle grain boundaries below 60 meters. Low angle grain boundaries have less energy and therefore sublimate less rapidly, making the boundaries difficult to see or absent, again potentially resulting in an artificially inflated average grain size and a lower sample population. Alternatively, the increased sample variance could be a result of the predicted pattern of grain growth, in which a few large grains grow at the expense of smaller grains. The observation of site specific trends in porosity underscores the advantages of using the SEM for both grain size and porosity measurements; as if only grain size had been calculated the data would have shown the sites to be very similar. Finally, the finding of chemical impurities located primarily in the crystal lattice in firn is contrary to observations in ice, where the impurities are primarily located at the grain boundaries,

suggesting migration during densification. This could potentially alter the chemical signal and therefore, interpretation of paleoclimate records.

The synthesis of grain size, porosity, chemical data, stratigraphy and others to be completed in the future (including crystallographic orientation patterns) provide a detailed understanding of the interplay between chemistry and physical structure in ice sheets. It is the combination of these details and their relationships that will greatly enhance our understanding of firn metamorphism and the interpretation of paleoclimate records.