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Microfabric and structures in glacial ice: A case study of Storglaciären, Sweden

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Microstructural processes and their relationship to flow are important for understanding the mechanical behavior of ice. Similar to rocks in active orogens, glacial ice develops both structures and fabrics that reflect deformation. Crystallographic preferred orientation (CPO), associated with mechanical anisotropy, develops as ice deforms by dynamic recrystallization, with the dominance of intracrystalline glide on the basal plane. This directly reflects the conditions and mechanisms of deformation and influences the overall strength. In coarse grained, warm ice ($T > -10^{o}C$) in valley glaciers and deep in ice sheets, a multimaxima CPO pattern develops in the marginal and basal ice at high angles to the plane of maximum shear strain. This pattern typically appears as a diamond arrangement in stereographic projection. Deformation mechanisms that produce such patterns are poorly understood. Storglaciären, a polythermal valley glacier in northern Sweden, was chosen to better constrain the rheologic properties of natural ice through microstructural analysis and to establish the relationship of the microfabric to the macroscale structures. Planar structures defined by bubble alignment and concentration include bedding, foliation, and blue bands (bubble-free veins of ice). These were mapped in the ablation zone. Primary stratification becomes indistinguishable from foliation at high strains in the marginal and basal ice, and both become nearly parallel to the plane of maximum shear strain. Recrystallized grains in thick and thin section are locally variable in both size (1mm–7cm in one thin section) and shape, and have weak or no shape-preferred orientation (SPO), reflecting recrystallization involving highly mobile grain boundaries. Bubbles influence recrystallization and are reorganized on the grain scale during recrystallization. Locally, bubbles pin grain boundaries, but more broadly, there appears to be an inverse correlation between bubble concentration and grain size and grain boundary smoothness. Fabric in samples that have undergone prolonged shear display roughly symmetrical multimaxima patterns centered around the pole to foliation. The angular distances between maxima suggest a possible twin relationship that may have developed from a preexisting single-maximum fabric.