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Composition and microstructure of marine ice in the Southern McMurdo ice Shelf, Antarctica

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Marine ice forms from a mixture of sea water and glacial melt water at the base of ice shelves and is thought to enhance ice shelf stability by adding dense ice mass or filling bottom crevasses, rifts or inverted depressions. Although widespread in Antarctic ice shelves, the physical and chemical properties of marine ice remain poorly understood. The aim of the study is to understand processes of marine ice formation and its influence on the behavior of the Southern McMurdo Ice Shelf (SMIS). The SMIS is a small ice shelf ($\sim$5000 km^2) adjacent to the western margin of the Ross Ice Shelf that flows southwest at velocities between 4 and 7 m a^{-1}. As the ice becomes grounded in the south it slows to 1 to 2 m a^{-1} and a broad zone of dark ice crops out on the surface of the ice shelf. This ice contains marine debris and macrofossils and has a negative surface mass balance of -0.16 m a^{-1}.

Eight ice cores between 2.5 and 10 m in length were extracted from the ice shelf surface at a distance of 0.5 to 6 km from shore from within and beyond the dark ice zone. Ice from within the dark ice zone is more depleted in heavy isotopes than sea water but more enriched than glacier ice (-4 to +3 $^0/_{00}\delta^{18}$O and -35to +25 $^0/_{00}\delta$D), with a total salinity between 0.03 and 0.9 ppt. In vertical thin section, granular or elongated ice crystals 2 – 15 mm in size commonly show single-maximum anisotropic fabrics, characteristic of frazil ice crystals derived from a supercooled mix of sea- and glacier water at the bottom of the ice shelf. Occasionally fold-like textures of frazil ice crystals with multiple maxima ice fabrics indicate exposure to post-accumulation stress. Ice extracted $\sim$2 to 6 km away from shore marks the boundary with meteoric ice. The meteoric ice shows equigranular ice crystals with air bubbles, weaker or isotropic ice crystal fabrics and low salinities of $<$ 0.01 ppt on average. The ice is enriched in heavy isotopes with ratios plotting along the meteoric water-line of δD = 8.18 δ^{18}O + 7.53 (r = 0.99). Blocks of ice were also cut from an ice-cored moraine at the southern edge of the ice shelf. In the moraine ice, water isotope ratios also indicate a mixed sea- and glacier water origin, with -8 to -12 $^0/_{00}\delta^{18}$O, -80 to -100 $^0/_{00}\delta$D and salinities of 0.03 to 0.4 ppt. The moraine ice crystals commonly have a size of 20 – 60 mm, with multiple maxima crystal-orientation fabrics indicating recrystallization and grain growth within this old marine ice.

Data from this study suggests that marine ice forms in thick layers of frazil ice crystals below SMIS and becomes deformed at the ice margin or after grounding as evident from complex multiple maxima orientation fabrics. Marine ice is characterized by higher salinity, more enriched δ^{18}O and δD values than meteoric ice, and ice fabrics that have a strong preferred orientation with frequently elongated crystals.