Introduction. Ice cores from the Dome-Fuji site in Antarctica have been examined by others using dielectric spectroscopy, Raman spectroscopy, inelastic incoherent neutron scattering (IINS), and neutron diffraction, both powder and single crystal. These experiments provided evidence for partial proton ordering of ice which had been kept below 237 K for many millennia in the Antarctic ice sheet. Determining whether or not Antarctic ice is proton ordered is important; the creep of ice is controlled by the abundance and mobility of defects in the crystal structure; in ice Ih, proton disorder provides abundant defects to ensure ready creep. However, if the ice were proton ordered, then one would expect it to flow differently. This could have consequences for models of ice sheet dynamics and, consequently, global climate change. Creep processes also control convection inside the icy moons of the outer solar system; altering the rate at which this occurs may have far-reaching effects on models of their thermal evolution. To examine the possibility that old Antarctic ice is partially proton ordered, we have carried out a powder neutron diffraction study of such a sample, exercising particular care to keep it below the proposed ordering temperature (237 K) from sample collection through to end-of-analysis. The diffraction experiment was carried out using the POLARIS powder diffractometer. The POLARIS 90° detector bank can easily resolve the diagnostic Bragg peaks of ice XI. Moreover, the high neutron flux on this station allows us to overcome the very strong incoherent contribution to the background scattering which might easily be confused with the diagnostic 131 peak of ice XI at 2.15 Å. A cadmium mask was constructed to collimate out any scattering which did not originate in the sample. Diffraction data were collected at 100 K in the 90° detector banks of the POLARIS diffractometer for ~36 hours (6134.3 μAhr).

Results. It is clear from the diffraction pattern (Fig. 1) that the 131 Bragg peak due to ice XI is absent. Indeed the pattern is fitted very well with a pure ice Ih model. In order to place an upper limit on the possible abundance of proton ordered ice in the sample, a two-phase refinement was tried, incorporating ice XI. Inclusion of the extra phase produced no real improvement in the fit (χ² drops only very minimally from 2.128 to 2.119). The refined phase fraction of ice XI is 2.3 ± 1.3 wt %, a value which is considerably less than the expected 20 % fraction of ice XI, and is not statistically significantly different from zero.

Conclusion. On the basis of this study, we conclude that it is unlikely that ice Ih becomes partially proton ordered at the temperatures encountered in the earth’s ice sheets. This work is reported in detail in Fortes et al. (2004).

Figure 1. The diffraction pattern of the Antarctic ice sample. Tic marks are for pure ice Ih.

5Mae and Fukazawa, ISIS Experimental Report, RB10625 (SXD).