

**Supplementary Figure 1. Schematic illustration showing workflow for 3D ice melting experiments**. Involving sample preparation, deformation experiments on *KOWARI*, neutron tomography on *DINGO*, and followed by segmentation and visualization.



**Supplementary Figure 2.** Illustrations of 3D tomographic images of DH-29 and LDH-35. The black arrows show the orientation of the compression in the deformed samples. (a, b) Image of DH-29 before and after deformation with location of water highlighted in blue. (c, d) Image of LDH-35 before and after deformation with layers of dry compacted and matrix filled D2O + H2O ice, calcite-rich D<sub>2</sub>O ice. Water can be identified as small blue grains. In undeformed samples such as DH-29 the greyscale image of the 3D surface of the cylindrical sample illustrates an irregular distribution of water (Fig. 2a, blue areas) in the upper portion of the sample. After deformation (Fig. 2b) water appears as elongate concentrations adjacent to the end faces of the sample, in an XY-plane, adjacent to where the piston was in contact with the sample (Fig. 2b, at the top) or adjacent to inherited calcite-rich layers (Fig. 2d).



Supplementary Figure 3. Illustrations of phase-labelled 3D tomographic images of DHC-06 (a), -23 (b), LDH-35 (c) and DH-29 (d). 3D surface rendering of undeformed and deformed samples (first row) + cut off (second row) of all labelled phases. In the third row, 3D rendered surface of the pores and the labelled phases H2O, Mix-1 and Mix-2 before and after deformation are shown.



Supplementary Figure 4. Representative <a>-axis neutron diffraction pole figures. Minima and maxima of density are indicated to the right of each pole figure, which are lower hemisphere, equal area projections. (a – c) Pole figures obtained from DHC-20 and LDH-35, which are weaker than the at -7 and at -1 °C fabrics. (d) Pole figures for D1-1 deformed at -1 °C (Table 1) showing a very good symmetrical cone around the centre of the pole figure corresponding to compression axis (X). (e) Pole figures for D1\_7 deformed at -7 °C (Table 1) showing a cluster of [c]-axes around the centre of the pole figure corresponding to compression axis (X). The polar angle  $\chi$  is the angle between the compression axis ( $\chi = 0^\circ$ ) and the maximum contour for the [c]-axes.