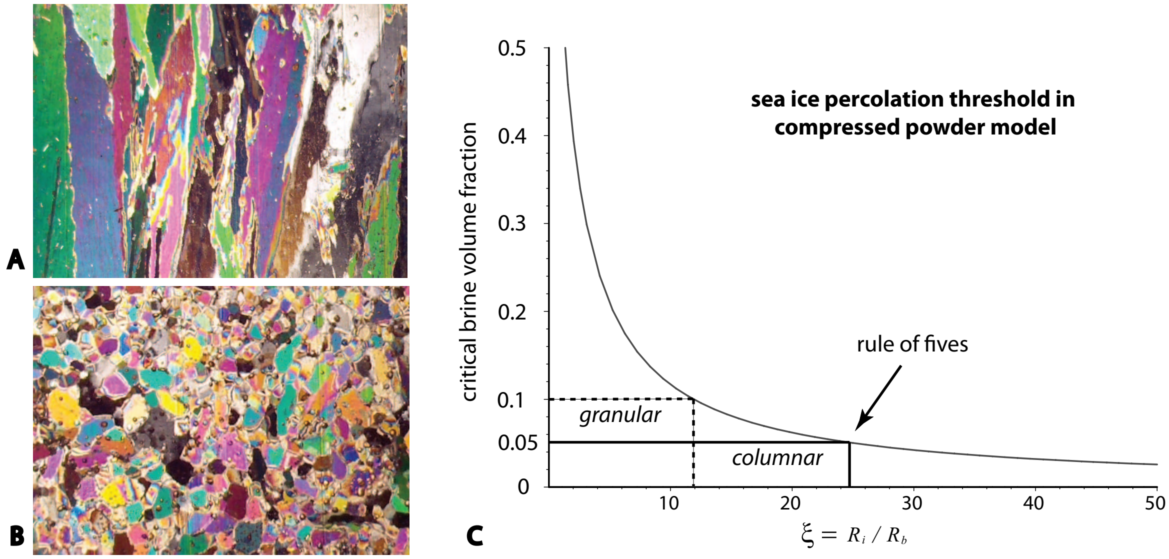

Figure 2: (A) Columnar and (B) granular microstructures. (C) Percolation threshold in the compressed powder model as a function of the ratio of the particle radii.

roughly similar to the ice-brine microstructure of sea ice, where the ice grains have radius R_i and the brine inclusions have radius R_b (or half the thickness of a brine film enveloping an ice grain), with $\xi = R_i/R_b$ in this case. We have estimated a range of ξ values from photomicrographs of granular microstructures, such as the granular snow-ice in Figure 2 (C), and obtained a representative value of around $\xi \approx 12$, leading to a threshold value of around $\phi_c \approx 10\%$, as illustrated in Figure **??**. Finer grained granular microstructures will likely have an even higher threshold.

Percolation theory (*32, 39, 40*) has been used to model transport in disordered materials where the connectedness of one phase, like brine in sea ice, dominates effective behavior. Consider the square ($d = 2$) or cubic ($d = 3$) network of bonds joining nearest neighbor sites on the integer lattice $\mathbb{Z}^d$. The bonds are assigned fluid conductivities $\kappa_0 > 0$ (open) or 0 (closed) with probabilities p and $1 - p$. There is a critical probability p_c, $0 < p_c < 1$, called the *percolation threshold*, where an infinite, connected set of open bonds first appears. In $d = 2$, $p_c = \frac{1}{2}$, and in $d = 3$, $p_c \approx 0.25$. Let $\kappa(p)$ be the permeability of this random network in the vertical direction. For $p < p_c$, $\kappa(p) = 0$. For $p > p_c$, near the threshold $\kappa(p)$ exhibits