From: *The Avalanche Review*. Vol. 1, No. 4, January 15, 1983, Page 6

THE REMARKABLE SNOW CRYSTAL

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Snow crystals are truly remarkable. Consider the highly symmetrical atmospheric forms. We tend to dismiss their symmetries as simply a manifestation of the hexagonal arrangement of H_2O molecules in the ice lattice. However, other substances are rarely found in nature with such a spectacular mimicry of molecular symmetry. A dendritic snow crystal spanning 10 mm may consist of some 10^{18} H_2O molecules. Just why a large proportion of these molecules form almost identical macroscopic patterns on 6 corners of the dendrite is not fully understood. Apparently, the cloud molecules are impacting equally on all sides of the growing crystal. A molecule may find temporary residence (adsorption) on the crystal surface, but a permanent home can only be found if the molecule is able to migrate to a place where it will fit in with its neighbours The physics is complicated. The resulting patterns are somewhat of a surprise.

Another curious feature which is fundamentally tied in to the physics of crystal growth is that snow crystals can develop either as thin plates or long columns depending critically on the cloud temperature (0 to -5 °C as plates; -5° to -10 °C as columns; -10° or colder as plates). Cloud physicists have developed a theory of ice crystal growth which treats molecular impact, adsorption, migration and incorporation each as a function of temperature; a fundamental explanation for the plate to column to plate variation emerges nicely from this theory.

When the snow crystal reaches the ground, more curiosities appear as recrystallization goes to work. Molecules move to new sites where they are even more 'at home'. The movement never ends.

The hexagonal symmetry is lost macroscopically, although not at the molecular level. Sometimes rounded surfaces predominate; sometimes the crystals are faceted; sometimes molecules bunch together and migrate 10,000 layers at a time across a face; sometimes these layers spiral around to form a hollow 'cup'; sometimes polycrystalline aggregates merge to form a single crystal; sometimes recrystallization builds or even nucleates at crystal bonds, sometimes growth occurs into the pore space; and probably important changes occur that have yet to be identified.

Explanations of snow recyrstallization have been proposed. The main factors are: temperature, temperature gradient, density, pressure, and the current crystal morphology. An important question is when can we expect rounded grains, and when faceted grains. The traditional explanation that faceted grains require a high temperature gradient could be an oversimplification. In the past, we have explained the rounded morphology as the equilibrium form of a crystal evolving toward minimum surface energy. However, molecules tend to lock into flat layers, and a rounded surface is not automatically guaranteed as the minimum surface energy configuration.

At relatively cold temperatures and low temperature gradients, it may be possible that snow crystals transform into small faceted prisms. Whether the prisms are plate-like or column-like should depend on the temperature, perhaps following the cloud physics described above, except driven by much slower growth rates. One should not expect these prisms to have a high degree of hexagonal symmetry due to the complex geometry of interconnected grains; molecular impact is no longer as symmetrical as on a crystal growing while suspended in a cloud.

The point is that rounded shapes may require both low temperature gradients *and* temperatures not too far below 0 °C. Why warmer temperatures? Perhaps only at warmer temperatures is there enough molecular disorder on the surface of the ice crystal to break the natural tendency to form a facet.

So we have a question for those who look at snow crystals: Under what conditions do you observe rounded and faceted crystals? Sorry, we can't tell you the right answer from first principles, although as usual we will be happy to provide a theory to explain your observations.