MAR06-2005-000112

Abstract for an Invited Paper
for the MAR06 Meeting of
the American Physical Society

Stalactite Growth as a Free-Boundary Problem[1]

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As far back in recorded history as the writings of the Elder Pliny in the first century A.D. are found references to the fascinating structures found in limestone caves, particularly stalactites. Although the subject of continuing inquiry since that time, the chemical mechanisms responsible for their growth have only been well-established since the 19th century, and there has been no quantitative understanding of the morphological evolution of these strange and beautiful forms. In this talk I will describe a synthesis of calcium carbonate chemistry, diffusion, thin-film fluid dynamics, and nonlinear dynamics which shows that stalactites evolve according to a novel geometric growth law which exhibits extreme amplification at the tip. Studies of this model show that a broad class of initial conditions is attracted to an ideal parameter-free shape, not previously known in science, which is strikingly close to a statistical average of natural stalactites. Similar hydrodynamic and geometric considerations lead to a quantitative theory for the shapes of icicles, and an understanding of why stalactites and icicles look so similar, despite the vastly different physics underlying their growth.

[1]Supported by NSF ITR Grant PHY0219411