# GEOCHEMICAL SELF-ORGANIZATION IN AGATES AND ZEBRA DOLOMITES: OBSERVATIONS, MODELING, TESTING

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Self-organization is the ability of a system to acquire a spatial pattern through its own dynamics. Good examples in rocks: igneous orbicules, agates, fibrous textures, sets of stylolites, metamorphic banding, zebra dolomites, oscillatory zoning, and many more. Necessary conditions for self-organization are disequilibrium and positive feedback.

The task in modeling each case includes selecting geologically probable mechanisms, imagining a plausible feedback, modeling it and the reaction-transport dynamics mathematically, and critically testing model predictions against evidence – especially evidence not used in constructing the model in the first place. Because different feedbacks may produce very similar spatial predictions one should test model predictions independently. The modeling should include scaling, linear instability analysis, and numerical solution. The scaling should aim to make all terms in the continuity eqns of the same order of magnitude. Linear instability analysis generates "phase" maps in parameter space consisting of fields of different system behaviors.

Agates from many places display identical associations of alternating properties: layers of alternating fiber size, alternating fiber-twist period, and alternating trace and isotopic content. Wang, Merino, & Deloule (1990, 1995) proposed a crystal-growth-transport theory that accounts for such alternations as well as for the systematic fibrous texture. Their model works through two feedbacks: a *"self-catalytic" feedback* which produces the concentric layering, and a *morphological instability* of the crystallization front which produces the characteristic fibrous texture of agate quartz.

The supposed self-catalytic growth is: Hydrous Silica w/ Traces $\xrightarrow{C}$ qtz + cations + $H_2O$. Cations released by each increment of quartz growth further accelerate the growth of the next increment of quartz. Growth proceeds by spurts. Each spurt of growth and slowing-down generates a couplet of bands – one made of thick, untwisted fibers, the other of very thin, twisted fibers, as observed. The model predicts that the formation of alternating banding requires that the growth take place from very concentrated forms of silica, $>$ about 1 gram $SiO_2/cm^3$. This implies that agates must crystallize from silica gels, not from aqueous solutions. A new comprehensive geological model, still unpublished, accounts for the formation and emplacement of such gels in basalts at the time of eruption, with fast agate crystallization at many hundreds of degrees.

Why is agate quartz always fibrous? Yifeng Wang attributed the genesis of a fibrous texture to a new mechanism, *morphologically unstable crystallization fronts*. Such unstable fronts are characterized by gradient (growth rate) $> 0$. Thus, any perturbation in an initially planar front soon grows longer and generates other perturbations around itself. The advancing front becomes a forest of fingers, each finger being one fiber. The front leaves behind a fibrous texture.

Zebra dolomites consist of parallel veins that forcibly displace the host carbonate as they grow. The local induced stress generated by each vein was calculated by Fletcher & Merino, 2001, and decays with distance. Incipient veins that are too close to their neighbors are redissolved by pressure solution, leaving the surviving veins more regularly spaced than before. This new feedback probably operates in metamorphism too.