Crystal growth and the fast reaction paradox: Mathematical resolution and implications for habit and compositional zoning

P. ORTOLEVA*

Department of Chemistry, Indiana University, Bloomington, Indiana 47405, U.S.A.

ABSTRACT

Fast reactions in the medium from which a crystal is growing (e.g., $H^+ + HCO_3^- \leftrightarrow H_2CO_3$) occurring near the crystal surface can conflict with the stoichiometry of crystal formula-unit creation (e.g., CO_3^{2-} is readily incorporated in calcite but H^+ is not). As a result, a thin fast-reaction boundary layer (FRBL) is created within which the fast reactions are out of equilibrium even though they are maintained at equilibrium far from the crystal surface. The FRBL corrects the fluxes of components to and from the surface of the crystal; not taking the FRBL into account leads to violation of mass conservation. This "paradox" is resolved by showing how the equations of crystal growth can be solved in the fast-reaction limit without violating mass conservation. As this paradox was not understood in the literature, models and geological conclusions drawn should be re-examined.

Keywords: Crystal growth, oscillatory crystal zoning, calcite, equilibrium, multiscale analysis