American Mineralogist, Volume 96, pages 682–689, 2011

The fractional latent heat of crystallizing magmas

S.A. Morse*

Department of Geosciences, University of Massachusetts, 611 North Pleasant Street, Amherst, Massachusetts 01003-9297, U.S.A.

Abstract

The fractional latent heat of a crystallizing system is simply the latent heat of fusion divided by the total enthalpy. When plotted against temperature, this function displays robust pulses with the successive saturation of each incoming crystal phase. Each pulse endures for tens of degrees, corresponding to tens to hundreds of thousands of years in large magma bodies. From an original 1963 development by P.J. Wyllie using a synthetic system, I show that the liquidus slopes (degrees per gram of solid produced) decrease discontinuously at the arrival of a new phase, and their inverse, the crystal productivity, undergoes sharp upward pulses at the same time. The overall liquidus slope increases continuously, interrupted by small downward jumps, with the evolution of the multicomponent melt. The crystal productivity pulses feed the fractional latent heat pulses, which dominate the crystallization history of a melt. These elementary relationships govern the near-solidus growth of dihedral angles in cumulates as they relate to the liquidus events. The latent heat ordinarily approximates to about 80% of the total enthalpy budget, but jumps to 100% (by definition) when solidification occurs by isothermal adcumulus growth and approaches 100% when mafic phases such as augite and Fe-Ti oxides are over-produced (relative to their equilibrium saturation) in layered intrusions. The feedback of latent heat to a self-regulating cooling history of large magma bodies is deduced here in principle. The overall results help to clarify the crystallization history of mafic magmas. In particular, they support the solidification of floor cumulates by interchange with parent magma and without the help of compaction.

Keywords: Latent heat, enthalpy, solidification, mafic magma, layered intrusions, crystal productivity, Skaergaard intrusion