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Solidification of trapped liquid in rocks and crystals

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Abstract

Trapped liquid in an igneous cumulate solidifies over a range of time and temperature that can be retrieved by use of the lever rule in binary solutions applied to plagioclase using the range in the An content found for the individual rock studied. The An range, so called, when measured in sufficient detail, defines the solidification history. The instantaneous solid composition along the solidus defines the zoning of the plagioclase as it follows the trapped liquid on the liquidus. The reference bulk composition of the trapped liquid is given by an intercept on the initial solid-liquid lever, defined by the fraction of plagioclase in the trapped parent magma times the residual porosity. The mafic fraction is assumed to solidify by reaction independently of the plagioclase zoning. The residual porosity is estimated from the content of evolved components in the trapped liquid and can also be calculated from the An range itself when that is calibrated to a value independently determined from the evolved components. Examples from a recent treatment of residual porosity are given for the solidification of selected rock compositions from the Kiglapait and Skaergaard intrusions. The same principles apply to the solidification of melt inclusions, with the difference that the latter tends to sample an evolved sheath by capture, rather than a parent magma trapped by closure of a cumulate, because only the cumulate has had time to exchange the evolved rejected solute owing to its slow solidification. Experimental examples of melt inclusions trapped at liquidus conditions demonstrate the highly evolved composition of the sheath compared to the bulk glass composition. The application of the solidification principle to presumed liquid immiscibility in the Skaergaard intrusion suggests that the melt inclusions are evolved during the capture process and then solidified as given by the An range in the plagioclase. The hypothesis of liquid immiscibility is not needed in this analysis. The very different end-stage feldspar histories of the two intrusions is attributed to the sequestering of low-melting feldspar components in the trapped liquids of the Skaergaard cumulates, compared to the lesser amounts trapped in the Kiglapait cumulates.

Keywords: Solidification, cumulates, trapped liquid, residual porosity, melt inclusions, An range, Kiglapait, Skaergaard, end-stage histories