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Magma chamber dynamics in a silicic LIP revealed by quartz zoning

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Crystal zoning of different mineral species represents a response to changing crystallisation conditions and has been used to gain insight into the history of magmas (e.g. Anderson 1976). Growth zones define a crystal stratigraphy (Wiebe 1968) which yields information on the variations of intensive parameters and the relative timing of magmatic processes. Thanks to the development of modern microanalytical techniques, quartz is being increasingly used as a source of petrological information (e.g. Muller et al. 2005; Wark et al. 2007). The main advantages of quartz in comparison with other minerals are its chemical stability and physical strength.

This study is focussed on the characterisation of quartz populations in the Mesoproterozoic Gawler Range Volcanics (GRV) and Hiltaba Suite (HS) granite of South Australia on the basis of texture, cathodoluminescence (CL), and trace element content. The volcano-plutonic province (Gawler SLIP) is a silicic-dominated large igneous province emplaced in an intracontinental setting. The study involves a wide array of quartz occurrences in different, but genetically associated, volcanic and intrusive rocks (lavas, ignimbrites, shallow and deeper intrusions).

Primary (syn-crystallisation) CL textures in quartz are better preserved in rapidly cooled volcanic and hypabyssal units than in slowly cooled granite samples. Intersection relationships of CL textures indicate episodes of growth and resorption. The dykes have homogeneous quartz populations, and CL zones can be correlated among quartz phenocrysts within single dykes. The volcanic units contain multiple quartz populations coexisting in the same sample. Each of these populations records a complex history of crystallisation and resorption events. Both the dykes and the volcanic units contain quartz crystals with CL-bright, Ti-rich rims that truncate internal growth textures (reverse zoning).

CL zones are characterised by different trace element (Al, Ti, Fe) content, and CL brightness is correlated with Ti content. Because of the relation between Ti content of quartz and crystallisation temperature (Ti-in-quartz geothermometer; Wark and Watson, 2006), CL can be used as a proxy for temperature. Based on Ti content, crystallisation temperature of dykes and volcanic units can be estimated in the range 740-870C. Significant variations in Ti content between adjacent zones were measured (?80 ppm), corresponding to deltaT ?180C in crystallisation temperature. The largest variations were measured between the bright rim and the core in volcanic units.

The homogeneity of quartz populations in single dykes is interpreted as evidence that quartz crystals shared the same crystallisation history and probably crystallised largely after isolation of these small magma batches in separate intrusions. The volcanic units tapped a larger part of the magma characterised by a dynamic regime which resulted in juxtaposition of different quartz populations, each with different crystallisation histories. Alternating events of crystallisation and resorption, reverse zoning, and partially melted granite enclaves in volcanic units are consistent with non-monotonous thermal evolution of the GRV-HS magma and suggest the occurrence of different thermal pulses. The described textural features are best explained by re-heating and convective stirring of the magma chamber (self-mixing; Couch et al. 2001). Heat input represented both the engine for convection and the cause of re-melting of previously crystallised magma, and was possibly supplied by underplating of mafic magma.

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