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Zircon dissolution and crystallization chronologies in magmas based on numerical modeling and crystal size distribution measurements

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Improved methods of geochronological dating and in situ isotopic and trace elemental distribution in zircons requires a new physical model that explains their behaviour during crustal melting. We earlier presented results of numerical modelling of zircon dissolution and growth, including oscillatory zoning in melts of variable compositions, water contents, T and thermal histories (Bindeman and Melnik, 2016; Melnik and Bindeman, 2018) melting and crystallization of major minerals. We here employ variable Temperature-time histories related to periodic intrusion of sills and growth/crystallization of magma bodies. Minor 3-20°C variations in temperature result in no zircon dissolution but strongly influence zircon growth and lead to variations in coeval Y, Hf, REE concentrations with magnitudes of up to a factor of two comparable to those observed in nature. More significant temperature fluctuations result in initial minor dissolution at higher temperatures but a continuous growth after that. Our ongoing efforts target thermal fields of growing intrusions and around periodicaly intruded sills, and we explore in detail survivability and regrowth of zircon inside and outside of sills of different thickness, temperature and composition, and their effects on surrounding rocks, on timescales of their conductive cooling and heating, respectively. We present data for 16Ma, 10-15 meter wide Maxwell Lake dike of the Columbia River Basalt group intruded into the Jurassic tonalite within a Wallowa mountains, Oregon. Dike operated for ∼4-6 years (Petcovic and Dufek, 2005; Karlstrom et al. 2019) as a supply channel to surface lavas, and melted several meters of granite on its contacts. Upon termination of magma flow in the dike, granite quenched to glassy fine-grained glassy aggregate. We observed bimodal size distribution of zircons in the granite and small rapidly nicleated, elongated zircons and apatites. The obtained Temperature-time history was used to test-run our model zircon dissolution/crystallization histories. We additionally reexamine previously published and newly measured concave up and linear zircon crystal size distributions in pyroclastic (thus rapidly quenched) rocks. Heating, followed by cooling for similar amount of time leads to dissolution followed by nucleation and growth, but the final size zircon remains smaller than the original one due to geometrical skin effect within the cell. We also present initial results of SIMS and NanoSIMS investigation of zirconium and other trace element concentration in glass around zircons in search for diffusive-dissolution gradients (Zr increasing toward the zircon/melt boundary), or growth features (Zr trough next to the boundary). This studies should indicate conditions in melts immidiately prior to eruptive quench that serves as a tool to test our model in nature and to investigate particular magmatic features.

Bindeman and Melnik (2016) J Petrology 57, 437, DOI: 10.1093/petrology/egw013; Melnik and Bindeman (2018) Am Min, doi.org/10.2138/am-2018-6182. Petcovic and Dufek (2005) JGR, 10.1029/2004JB003432; Karlstrom et al. (2019) Frontiers in Earth Sci. (in press). Supported by RFFI grant 18-01-00352 and the University of Oregon.