European Mineralogical Conference
Vol. 1, EMC2012-524-1, 2012
European Mineralogical Conference 2012

Tracking the evolution of a giant magmatic system from assembly to supereruption

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The characteristics of large magma bodies prior to eruption (volume, composition, duration of magma assembly, crystal content, degree of heterogeneity) are closely related consequences of the balance between the rate of magma influx and the rate of cooling. The products of caldera-related silicic supereruptions, and less voluminous associated precursor and post-caldera activity preserve information about the thermal and chemical states of the system at the moment of evacuation of the magma chamber. Numerous studies of the Oligocene Fish Canyon Tuff (∼5000 km3; San Juan Volcanic Field, Colorado, USA) and related eruptive products of the La Garita caldera (pre-caldera Pagosa Peak Dacite and post-caldera Nutras Creek Dacite) have addressed the origin and evolution of large-volume crystal-rich magmas. We use the presence of zircon in all eruptive products of the Fish Canyon magmatic system to gain a high-resolution geochronologic control on the thermal evolution of the magmatic system by using the trace element composition of U-Pb dated zircons as a proxy for magma crystallinity. New analytical protocols allow us to obtain age, chemical and isotopic information from the exact same volume of single zircon crystals (Schoene et al., 2010) allowing us to trace magma crystallinity as a function of time. Zircon U-Pb dates record ∼400,000 years of crystallization from zircon saturation (∼760°C) to eruption. Variations in trace element composition in U-Pb dated zircons can be attributed to trace element fractionation imposed by co-crystallization of titanite. Due to the relatively high modal abundance of titanite (∼0.5-1 vol.%) in Fish Canyon magma and the extreme compatibility of the rare earth elements (REE) in this phase, titanite is the major control on many trace element concentrations and ratios (e.g. Yb/Dy) in coexisting zircons via varying degrees of depletion of these elements in the host melt. Modeling of compositional variations as a result of fractional crystallization suggests that the range of zircon compositions can be explained by 50-70% crystallization of a fractionating assemblage containing 0.5-1 vol.% titanite. The period of cooling centered around 28.4 Ma and is marked by an apparent crystallinity that is ∼30% higher than at the time of eruption, implying that the Fish Canyon magma was perilously close to complete solidification, hence 'plutonic death', prior to late reheating. We estimate the duration of the reheating event from the age difference of the chemically most evolved (highest Yb/Dy) and the youngest dated zircon to be ∼170 ka. This duration for reactivation of the near solidus crystal mush is in excellent agreement with estimates derived from numerical modeling of remelting by upward percolation of a hot gas-phase derived from underplated mafic magma ('gas sparging'; Bachmann and Bergantz, 2003). This investigation, which is the first in which high resolution U-Pb zircon geochronology has been coupled with geochemical modeling of systematic compositional variations in an accessory mineral, ties together many of the threads which have been developed independently during previous studies of the Fish Canyon magmatic system and ties related processes into an absolute time frame.

References: Bachmann, O., Bergantz, G.W. (2003), Geology, 31, 789-792. Schoene, B., Latkoczy, C., Schaltegger, U., Günther, D. (2010), Geochim. Cosmochim. Acta, 74, 7144-7159.