Hot and cold zircon growth in the Sierra Nevada Batholith, USA

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The normally-zoned, Late Cretaceous Sierran Crest intrusive complexes (Tuolumne, John Muir, Whitney, Sonora) of the Sierra Nevada batholith form the last volumetrically significant pulse of batholithic magmatism. Previous high-precision U/Pb zircon dating on some of these intrusions (particularly Tuolumne) has shown that they were constructed over several million years. In addition, they are all characterized by distinctive and somewhat enigmatic, K-feldspar megacryst-bearing granodiorites/granites (e.g. Cathedral Peak, Mono Creek, Whitney, Topaz Lake) that comprise the inner units of the complexes, and which are characterized by abundant 'antecrystic' (recycled) zircon.

Zircon trace element data from the intrusive complexes shows that the chemical environment in which zircon crystallized during their growth and consolidation changed dramatically between the outer, more mafic, marginal units and the inner, megacryst-bearing units. Zircon saturation temperatures ($T_{zrc,sat}$) are similar and low (ca. 700°C) for most of the units among all of the intrusions, but Ti-in-zircon model temperatures ($T_{zrn,Ti}$) contrast strongly between outer marginal units and the inner megacryst-bearing units. In marked contrast to the more mafic outer units, zircons from the inner megacryst-bearing intrusions are characterized by low $T_{zrn,Ti}$, (at or near the wet granite solidus) high Yb/Gd, low Th/U, high and very similar Hf, and high Eu/Eu*. In addition, $T_{zrn,Ti}$ values are similar to $T_{zrc,sat}$ for the megacrystic units but for the marginal units $T_{zrn,Ti}$ values are >> $T_{zrc,sat}$.

The offset between $T_{zrn,Ti}$ and $T_{zrc,sat}$ for the outer marginal units likely indicates that the magmas were strongly zircon undersaturated initially and formed at high temperatures (typical of amphibole dehydration). In contrast, zircon from the inner, megacrystic units crystallized predominantly at low temperature ($T_{zrn,Ti} \approx T_{zrc,sat}$) under conditions of high fO_2, and in equilibrium with titanite, which exerts particularly strong control on the the MREEs (high Yb/Gd). If the low $T_{zrn,Ti}$ values for the megacrystic units are indicative of anatectic conditions for the magmas that formed these intrusions ($T_{zrn,Ti} \approx T_{zrc,sat}$) then there was a profound arc-scale shift in magma generation conditions that accompanied the end-stage of the batholith to much cooler (and more water-rich?) conditions.