Zircon morphologies and compositions: Tools to detect antecrystic zircons in granitic rocks

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There are three types of zircons in igneous rocks. Autocrystic zircons belong to the host rock and their crystallisation age is used to date the emplacement/final crystallization age of the magma. Xenocrystic zircons are from extra-magmatic sources including crustal source materials that underwent partial melting. The third type, antecrystic zircons are related to preceding magmatic pulses in the entire thermal and crystallization history of the magmatic system that in some tectonomagmatic settings can be sustained for $>=10^7$ yrs. Therefore, antecrysts may show only subtle age and/or compositional differences from autocrysts. In volcanic systems, several checks are available to distinguish antecrysts from autocrysts, in particular, stratigraphic constraints and 'double-dating' approaches. However, such constraints are rarely available in the plutonic realm and analytical errors associated with spot dating techniques (LA-ICP-MS or SHRIMP) generate sufficiently large age uncertainties that distinction of the two types based on age is impossible.

Here, we combine zircon morphological, textural and compositional information to help identify antecrystic zircons in plutonic rocks. In a study of 24 granitic rocks from Queensland, we observed multi-modal distributions in zircon morphology as recorded by length-to-width ratios. U-Pb ages and cathodoluminescence indicate resorbed zircon cores with ages similar to the emplacement age and these are interpreted as antecrystic. Comparing compositional parameters (Th/U, U, Zr/Hf, Ce/Ce*, Eu/Eu*, and Ti temperature of zircon - T_{Tiz}) between zircon rims and cores reveal normal and reverse compositional zoning patterns in zircons from each granite.

We also calculated T_{Tiz}, assuming a magma Ti activity of 1, and zircon saturation temperature (T_{Zrsat}) determined from the whole-rock composition. Their differences identify zircons that can be interpreted as autocrystic when $T_{Zrsat} > T_{Tiz}$ (Zr-saturated magmatic conditions), and antecrystic when $T_{Tiz} > T_{Zrsat}$ (Zr-undersaturated conditions). A limitation of this approach is potential underestimation of the proportion of antecrysts because both geothermometers provide only minimum temperature estimates. Our approach reveals that the presence of antecrystic zircons in granitic rocks is significant and supports models for the incremental assembly of plutons.