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A simple method for in-situ zircon U-Th-He dating

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In situ U-Th-He dating of zircon by laser ablation offers significant advantages over the current practice of whole grain degassing and dissolution:

1. It dramatically increases sample throughput. Measuring the U and Th content of zircon by isotope dilution requires dissolution in hydrofluoric acid at high temperature and pressure using a Parr bomb for up to 48 hours. In contrast, measuring the U and Th content by LA-ICP MS, SIMS, or EMPA can be done in a matter of minutes.
2. The process of in-situ measurements of U and Th content of grains yields U-Th-Pb ages as a by-product. Thus, in-situ dated zircon crystals are double-dated by default, opening up exciting new research opportunities in detrital geochronology.

We here propose a simple four step procedure to measure in-situ U-Th-He ages without the need to know any absolute U, Th, or He concentrations:

1. Polish and mount two sets of grains in indium: a standard of known U-Th-He age, and the sample of interest, whose age is unknown.
2. Ablate the grains and measure the raw helium signal (in A, V, or Hz) of the sample along with helium measurements of the age standard.
3. Measure the U and Th signals of the standard and the sample by LA-ICP-MS (in Hz).
4. Obtain the U-Th-He age of the sample by scaling its U, Th, and He signals to those of the standard.

In practice, the standard and the unknown are combined on a pairwise basis. This is done by calculating the normalised U, Th, and He concentrations of the standard from its known age and measured Th/U ratio, and then using this normalised composition as a benchmark against which to compare the U, Th, and He signals of the unknown. The Th/U ratio of the standard can be determined from its measured ^{208}Pb/^{206}Pb ratio, removing the need to use NIST glass as a reference material:

$$\frac{^{232}Th}{^{238}U} = \frac{^{208}Pb(e^{\lambda_{238}t} - 1)}{^{206}Pb(e^{\lambda_{232}t} - 1)} \quad (1)$$

It is important to note that the Th/U ratio only needs to be determined for the standard. In other words, the use of Equation 1 does not require U-Th-Pb concordance of the sample.

The pairwise dating makes one assumption, namely that the ablation pit volume is the same for the U-Th-He age standard and the sample. Violation of this assumption may result in systematic errors. It is straightforward to correct these errors by defining a 'scaling factor' for the ablation pit depth measured, for example, by interferometric microscopy. However, performing depth measurements adds another analytical step and partly defeats the purpose of the pairwise dating method. As a potential solution to this problem, we propose an LA-ICP-MS-based 'drill rate proxy' to be used instead of the interferometric microscope. The idea behind the drill rate proxy is that the beam intensity of a stoichiometric nuclide, such as ^{29}Si should increase proportionally with the rate of laser ablation. If this is correct, then the average ratio (fSi) of the time-resolved ^{29}Si spectrum of the unknown sample over that of the standard should equal the ratio of the ablation pit depths (fD). It then suffices to divide the normalised helium signal by fSi to account for the differential drill rates.

We have applied the pairwise dating method on three shards of Sri Lanka zircon, obtaining ages that are in good agreement with previously published conventional U-Th-He ages.