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Laser ablation zircon (U-Th)/He dating across the geological timescale

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Laser-ablation zircon (U-Th)/He dating is an emerging thermochronological technique that allows extracting a cooling age from a single domain in zircon. In contrast to conventional whole-grain (U-Th)/He technique, where only 3-5 grains are usually analysed per sample, the laser-ablation technique allows dating of tens to hundreds of grains in a single sample. When applied to bedrock, this in-situ thermochronometer, combined with zircon trace element chemistry and U/Pb dating by LA-ICP-MS, provides a powerful dataset for deciphering geochemical information, time of crystallisation and upper crustal cooling. We tested this multi-method technique by analysing intrusions of different age: (1) Mesozoic plutons in the Southern Canadian Cordillera, (2) Paleozoic plutons in the Canadian Appalachians, and (3) Paleoproterozoic plutons of the Canadian Shield. We carried out both whole-grain and laser-ablation (U-Th)/He dating on these samples to compare the results between the two techniques.

The (U-Th)/He dates obtained by laser-ablation technique are more dispersed than their whole-grain counterpart in all the samples. The largest dispersion is seen in our Paleoproterozoic sample. We attribute the dispersion of the laser ablation (U-Th)/He dates to three main factors that in part depend on their age and geological context: (1) He redistribution between zones of different U and Th concentration due to diffusion and the separation of He from its parent nuclides during α-disintegration and diffusion. This factor affects especially the strongly zoned grains in the Mesozoic samples. (2) Radiation-damage accumulation and damage annealing of zircon throughout its long thermal history; and (3) influence of deformation and hydrothermal fluid events affecting the zircon since crystallisation. These factors especially affected the Paleoproterozoic sample. Our study shows that careful evaluation of laser-ablation (U-Th)/He data can fulfil two goals from a single analytical technique. Firstly, screening of unzoned and oscillatory zoned grains with low degree of radiation damage and alteration can result in reliable laser-ablation (U-Th)/He sample age estimation. Secondly, anomalous He-retentive domains, U-Pb discordance and trace-element signatures indicative of alteration can provide information on regional or local deformation and hydrothermal events.