In-Situ Double Dating:

In situ (U-Th-Sm)/He and U-Pb double dating (Figures 1 and 2) involves grain mounting and polishing in Teflon, grain characterization using microscopy methods, 4He and parent isotope measurement via laser ablation and age calculation using online freeware (http://resochronometer.london-geochron.com). Many grains can be mounted simultaneously and analytical targets can be meticulously selected to avoid issues like mineral/gas inclusions, parent isotope zonation or natural abrasion. Ages can be calculated using either pairwise (utilizing standards of known age) or absolute (calculating ages based on the parent and daughter abundances measured) approaches. Successful analysis of both zircon and apatite using these techniques has been demonstrated through extensive research carried out in the John de Laeter Centre at Curtin University (Perth, Australia).

Isotopic Mapping / Profiling:

The RESOchron instrument combines in-situ laser ablation micro-sampling and noble gas mass spectrometry. It is uniquely suited to 1- and 2-dimensional visualization and quantification of He distribution in zircon (and other minerals) at the micrometer scale (Figure 3). High-resolution He “maps” for a set of zircon crystals allow us to investigate the impact of U-Th zoning, radiation damage and inclusions on He distribution and on the fundamental assumptions inherent to conventional (U-Th-Sm)/He dating and geochronology. The He maps, in combination with characterization information from other imaging techniques (i.e., cathodoluminescence, confocal Raman microscopy and LA-ICPMS elemental maps) provide the first opportunity to visualize the impact of the primary underlying reasons for problematic zircon (U-Th-Sm)/He ages. The observations suggest that grain characterization is imperative prior to conventional thermochronology analysis.

APPLICATION NOTES (June 2016)

In-situ Thermochronology & Geochronology

(U-Th-Sm)/He dating is used to place temporal constraints on low temperature geological processes. The method involves the determination of the abundances of U, Th and Sm, and of He – a product of their radioactive decay in minerals of interest (e.g., apatite, zircon, titanite, etc.). Advances in laser ablation techniques have prompted a foray into in-situ (U-Th-Sm)/He dating with encouraging results. Using this approach, researchers are now able to explore new fields of application that include (1) the development of new diamond exploration techniques in highly weathered terrains, (2) qualitative and quantitative imaging of helium distribution in minerals, (3) the development of new dating methods for platinum group minerals based on 100Pt-4He decay scheme with application for platinum ore exploration, and (4) more comprehensive reconstructions of cooling trajectories in dated minerals provided by the integration of U-Pb data. The applications described below demonstrate the unique ability of the RESOchron instrumentation suite to obtain in-situ (U-Th-Sm)/He and U-Pb ages on the same crystals (double dating) in addition to providing elemental and isotopic maps, allowing more robust thermal history reconstructions.

Figure 1. Flow chart showing steps required for in-situ double dating.

Figure 2. (A) Topographic AFM image of a shallow ‘4He ablation pit in zircon. Note the simple ‘top-hat’ cross-sectional profile with a well-defined, flat bottom. (B) SEM image of first, shallow ablation pit for helium measurement and (C) after second ablation pit for U, Th, Sm, Pb and trace element analysis.

Figure 3. CL image (a) and He concentration map (b) of a zircon with U-rich core and U-depleted rim generated by SEM and RESOchron instruments, respectively. Note that He distribution correlates well with CL intensity and therefore with U distribution. Understanding the intra-grain distribution of He, U and Th is essential for correct interpretation of (U-Th)/He results.
Improved Thermal History Modelling:

Characterization of U-Th distribution in (U-Th-Sm)/He dated minerals is critically important for accurate thermal history reconstruction\(^9\). Coupling of the RESOchron to an ICP-MS allows us to establish the 2-dimensional distribution of U-Th prior to (U-Th-Sm)/He dating (Figure 4). These U-Th maps can be converted into concentration profiles assuming an equivalent sphere geometry\(^10\), and these can be incorporated into He production-diffusion modelling packages (Figure 4). The results permit better parametrization of the model and, ultimately more accurate thermal modelling results. In addition, elemental mapping by LA-ICPMS permits collection of all the data necessary for U-Pb geochronology, so that we can also calculate crystallization ages. These analyses provide the starting point (or maximum limit) for the subsequent low-temperature history reconstructions which shed light on processes such as exhumation and denudation, petroleum basin maturation, structural evolution and ore system preservation.

Figure 4. CL image (a) and U and Th concentration maps (b,c) of a zircon with a U-rich rim and U-depleted core generated by SEM and RESOchron instruments, respectively. (d) U-Th zoning profiles calculated for equivalent sphere geometry that can be readily imported into available thermal history modelling packages and used for accurate thermal history reconstruction.

Industry and University collaboration has resulted in the RESOchron; instrumentation that represents a significant advance in geohistory research. A RESOchron coupled to an ICPMS (not supplied by ASI) enables researchers to: 1. Rapidly determine both the (U-Th)/Pb and (U-Th-Sm)/He ages on a single mineral; 2. Avoid using hazardous chemicals for mineral dissolution; 3. Generate up to 50 mineral ages in the time it previously took to obtain a single age result. Combining the well-established RESOlution and Alphachron™ technologies, RESOchron integrates a 193nm excimer laser ablation sampling system, ultra-high vacuum (UHV) sample cell and He/\(^{4}\)He mass spectrometer.

RESOchron protocols extend conventional (U-Th-Sm)/He whole grain techniques by permitting sampling of a precisely defined, defect-free volume of the crystal. This new instrument platform permits more accurate and cost-effective thermochronology and geochronology age determination in addition to novel applications such as He distribution visualisation and thermal history reconstruction.

References:

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