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Multi-method dating of individual apatite and zircon grains: faster and less expensive methods for detrital studies.

Scott A. Jess
Geo-and Thermochronology Research Group, Department of Geoscience, University of Calgary
Eva Enkelmann
Geo-and Thermochronology Research Group, Department of Geoscience, University of Calgary
William Matthews
Geo-and Thermochronology Research Group, Department of Geoscience, University of Calgary

Summary

Geochronology and thermochronology are valuable tools for studying a wide range of geological problems. Applications within the oil and gas industry include provenance studies[1], stratigraphic correlation[1] and basin thermal history modelling[2]. However, current analytical workflows are costly and time consuming; particularly when applied to detrital samples where many measurements are required to adequately describe the parent population. We present new laser-ablation measurement methods for U/Pb, fission-track (FT) and (U-Th-Sm)/He dating that allow 'double' and 'triple' dating of individual mineral grains. Multi-method dating provides both the time of crystallization[3] and the time at which a grain cooled through upper crustal temperatures (250–50ºC)[4]. Hence, this approach provides valuable information regarding potential provenance regions and/or post-depositional thermal histories (burial/uplift). We demonstrate the utility of these methods using two case studies.

Workflow

The multi-method dating analytical workflow includes five steps to extract three radiometric dates (U/Pb, fission-track and (U-Th)/He) from individual grains of apatite or zircon. This integrated approach reduces the cost and time spent for analysis: These five steps include:

- Mineral separation.
- Mounting and polishing.
- Etching of mineral mounts (fission-track only).
- Fission track counting using an optical microscope (fission-track only).
- Laser ablation and mass spectrometer analysis.

This workflow produces values of radiometric decay products (fission-tracks, Pb and He) and the remaining radioactive isotopic concentration (U, Th and Sm) which are used to determine ages for all three systems.

Results

In the first study we dated detrital zircon grains from modern sand collected from a river catchment comprised of a Late Triassic volcanic complex in Southern BC, Canada[5]. We used a double dating method combining U/Pb and FT dating on individual grains. The detrital grains yielded a concordant Late Triassic U/Pb age (207.7 ± 1.7 Ma), consistent with the age of underlying volcanic rocks and a Late Jurassic FT age (147.4 ± 12.1 Ma), consistent with Jurassic–Cretaceous FT ages from underlying basement rocks. The disparity between the U/Pb and FT

ages resulted from reburial of the Triassic volcanic complex during the Cretaceous and may explain the preservation of the volcanic complex over long geologic times.

In the second study we dated apatite grains collected from river sands from the Wenatchee River, WA, USA. Previous whole-grain dating of the same samples poorly reproduced the range and proportions of cooling ages obtained from crystalline rocks within the catchment[6]. Using our innovative laser-ablation (U-Th-Sm)/He dating method we acquired a larger dataset. Our detrital results better describe the range of basement ages and the relative proportions of those ages than the previous whole grain dataset. We interpret this to be the result of two factors: a reduction in grain selection bias in the laser-ablation method, which eliminates the common requirement in whole grain methods to date clear and inclusion free crystals; the ability to measure a larger number of grains to better describe the parent detrital population. This emphasizes that laser ablation (U-Th-Sm)/He analysis is a more effective dating tool for detrital studies where grain selection bias should be avoided, and many grains need to be analyzed.

Conclusions

Collectively, these detrital studies demonstrate the successful application of all three laser-ablation dating approaches which can be applied to modern deposits as well as basin strata. This research lays the foundation for the application of 'triple' dating on individual grains of apatite and zircon (U/Pb, fission-track and (U-Th-Sm)/He). These new methods provide the means of collecting the necessary data for provenance studies, stratigraphic correlation and basin histories from individual samples, producing comprehensive datasets while reducing analytical costs.

References

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