(U-Th)/He dating of apatite

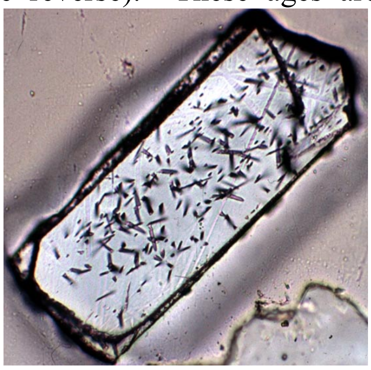
Improved resolution of thermal history reconstruction at low temperatures

Geotrack International, in association with CSIRO Division of Petroleum Resources, Sydney, is pleased to announce this new addition to our range of thermal history reconstruction (THR) services.

Reliable reconstruction of thermal histories in sedimentary basins is a key aspect of reducing exploration risk, e.g. in defining the timing of hydrocarbon generation in source kitchens and identifying tectonic episodes which may have caused disruption of accumulations. This new technique allows further refinement of Geotrack's THR methods, providing:

- improved resolution of the timing of cooling
- independent verification and estimation of maximum paleotemperatures between 50 and 80°C
- improved definition of later heating and cooling episodes of lesser magnitude following the main paleo-thermal peak (revealed by AFTA)
- discrimination between slow cooling and multiple cooling episodes

(U-Th)/He dating, developed and proven by Professor Ken Farley of Caltech, is based on the accumulation and diffusive loss of Helium produced by alpha decay of Uranium and Thorium impurities within apatite grains. By measurement of the amount of radiogenic ^{4}He in an apatite sample, and the amounts of uranium and thorium present, a (U-Th)/He age can be determined (see reverse). These ages are progressively reset by heating, due to the diffusive loss of the radiogenic helium (analogous to the "annealing" of fission tracks), with total loss occurring at temperatures around 80 to 90°C (for timescales involving millions of years). Particularly when integrated with information from AFTA and other thermal indicators (e.g. vitrinite reflectance), this technique allows more precise thermal history constraints to be established at relatively low temperatures (50 to 80°C).



A collaborative Geotrack - CSIRO DPR research program has shown that the (U-Th)/He dating technique is highly complementary to AFTA®. Check our web-site at **www.geotrack.com.au** and follow the links to (U-Th)/He dating for more details, or contact us (details below) for further information.

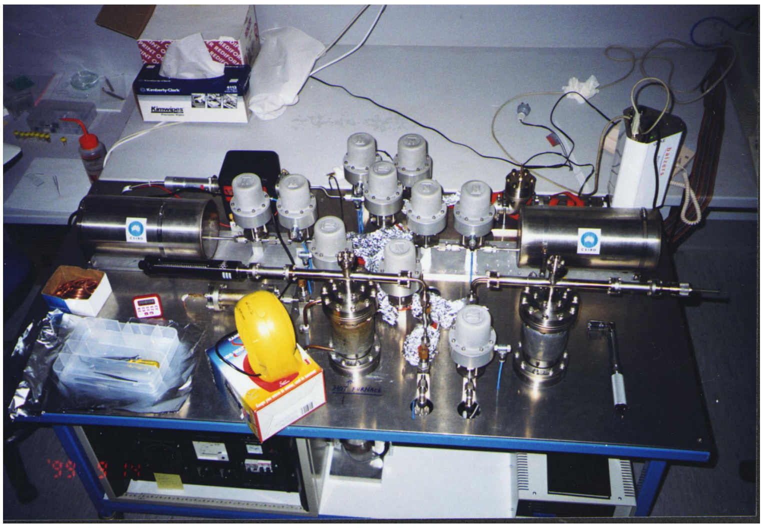
Geotrack International Pty Ltd **ABN 16006 821 209**
37 Melville Road, Brunswick West, Victoria 3055 Australia
telephone: +613 9380 1077 facsimile: +613 9380 1477 email: mail@geotrack.com.au
website: www.geotrack.com.au

(U-Th)/He dating of apatite:

Technical details

Instrumentation

The CSIRO He extraction and analysis facility comprises an all-metal He extraction and gas-handling line connected to a dedicated on-line Balzers Prisma™ 200 quadrupole mass spectrometer. Gas extraction is performed by using either of the 2 identical single vacuum resistance furnaces, where samples are heated to ~900°C for ~15 minutes. The line and furnace are evacuated to ~10^{-8} mbar via ion, turbo and backing pumps. Active gases, particularly hydrogen, are removed using SAES getters. The analysis procedure is operated by LabVIEW™ automation software supplied by Prof. Ken Farley, Caltech.



Helium measurement

^{4}He abundances are determined by isotope dilution using a pure ^{3}He spike, which is calibrated on a regular basis against an independent ^{4}He standard tank. ^{4}He hot blanks (or re-extracts) are performed routinely before and after each sample. If the ^{4}He standard and blank levels are acceptable (<0.05ncc ^{4}He), a sample capsule is dropped into a ceramic crucible within the furnace. After the heating and purification procedures, the extracted gas is handled and measured via the fully automated computer controlled system.

Uranium and thorium Concentration

The U and Th content of degassed apatite samples are determined on a Perkin Elmer Sciex 5000a ICP-MS using the Isotope Ratio application. 100µl of each ^{235}U and ^{230}Th spike solution (about 5ng and 6ng, U and Th respectively) and 200µl of concentrated nitric acid are added to a vial containing the capsule and degassed apatite. 100µl of 0.25ppm U and Th standard solutions (Johnson Matthey) are similarly spiked and acidified. We have determined the ^{235}U/^{238}U ratio of the Johnson Matthey U-standard solution to be 135, close to the natural value of 138.

Blanks are prepared by adding an equivalent amount of nitric acid to washed, empty capsules. The blanks, standards and samples are all diluted to 5% nitric solution with Alpha Q water prior to analysis. Based on replicate analysis of spiked standard solutions, precision for ^{235}U/^{238}U and ^{230}Th/^{232}Th determination is 0.77% and 0.41%, respectively.

Sample selection and grain size measurement

Apatite grains are carefully handpicked in order to avoid U- and Th-rich mineral inclusions that may produce excess He (eg. zircon). Images of selected grains are captured by a CCD video camera mounted on the microscope and measured using image analysis techniques for the purposes of alpha ejection correction calculation. This correction is mathematically calculated using the estimated dimensions of each grain and is applied directly to the final age (discussed in more detail below). Aliquots of ~5-30 grains are sealed into stainless steel capsules and then up to 6 capsules are loaded into the furnace sample holders.

Data interpretation

Software provided by Prof. Ken Farley of Caltech, based on the systematics presented in Farley (2000) and references therein, allows modelling of the (U-Th)/He age expected from any inputted thermal history, in grains of any specified radius. By modelling ages through a variety of different thermal history scenarios, it is possible to define the range of histories giving predictions which are consistent with measured ages. The thermal history framework provided by AFTA forms a solid basis for this procedure. By incorporating both AFTA and (U-Th)/He ages into the modelling, a more restricted range of thermal history solutions can be extracted. For an example of this procedure, check our website at www.geotrack.com.au and follow the links to the (U-Th)/He dating page.

Selected references

Farley, K.A. 2000. Helium diffusion from apatite: general behaviour as illustrated by Durango fluorapatite. *Journal of Geophysical Research*, 105 (B2), 2903-2914.

Farley, K.A., Wolf, R.A. and Silver, L.T. 1996. The effects of long alpha-stopping distances on (U-Th)/He ages. *Geochimica et Cosmochimica Acta*, **60**, 4223-4229.

House, M.A., Farley, K.A. and Kohn, B.P. 1999. An empirical test of helium diffusion in apatite: borehole data from the Otway Basin, Australia. *Earth and Planetary Science Letters*, **170**, 463-474.

Lippolt, H.J., Leitz, M., Wernicke, R.S. and Hagedorn, B. 1994. (Uranium + thorium)/helium dating of apatite: experience with samples from different geochemical environments. *Chemical Geology (Isotope Geoscience Section)*, **112**, 179-191.

Wolf, R.A., Farley, K.A. and Kass, D.M. 1998. Modeling of the temperature sensitivity of the apatite (U-Th)/He thermochronometer. *Chemical Geology*, **148**, 105-114.

Wolf, R.A., Farley, K.A. and Silver, L.T. 1996. Helium diffusion and low-temperature thermochronometry of apatite. *Geochimica et Cosmochimica Acta*, **60**, 4231-4240.