

# **Integrated Thermal History Analysis of Sedimentary Basins Using Multi-kinetic Apatite Fission Track Thermochronology: Examples from Northern Canada \***

**Dale R. Issler <sup>1</sup>**

\*Abstract from 2010-2011 AAPG Foundation Distinguished Lecture presentation.

<sup>1</sup>Geological Survey of Canada, Natural Resources Canada, Calgary, Alberta, Canada ([dissler@nrcan.gc.ca](mailto:dissler@nrcan.gc.ca))

Apatite fission track (AFT) thermochronology is a powerful thermal history analysis approach that is well suited to the study of sedimentary basins. It originated as a geochronological dating method in the 1960s but has been continually evolving as new insight has been gained concerning the time-temperature conditions and mineral compositional factors influencing the thermal annealing of fission tracks in apatite. Fission tracks are linear zones of crystal damage that result from the spontaneous fission of <sup>238</sup>U. They are revealed by polishing and etching mounted grains, allowing their orientations and lengths to be measured. The nominal initial length of fission tracks in apatite is approximately 16  $\mu\text{m}$ . AFT annealing, or shortening of the track lengths, is well characterized through lab and field studies allowing annealing kinetics to be extrapolated to geological timescales. On such timescales, annealing occurs within and somewhat below the temperature range for petroleum generation and can thus be used to constrain petroleum generation histories through numerical modeling. State-of-the-art methodology is being applied to thermal history studies of northern Canadian basins (Beaufort-Mackenzie and Mackenzie Valley regions in the Northwest Territories) and much has been learned that challenges existing data analysis and modeling approaches. In these regions, mixed AFT compositional populations greatly complicate data analysis and thermal modeling.

New concepts of multi-kinetic AFT annealing (Ketcham et al., 1999) based on published laboratory heating experiments (Carlson et al., 1999) have been incorporated into an inverse AFT thermal history model (AFTINV) that was been developed in-house. Statistically distinct AFT kinetic populations can be defined successfully using the  $\text{rmro}$  parameter (Ketcham et al., 1999) which integrates the results of elemental analyses for individual apatite grains. This kinetic parameter method is superior to widely used single-parameter methods based on apatite solubility ( $\text{Dpar}$  or AFT etch figure width) and Cl content. Under this scheme, different AFT kinetic populations act as separate thermochronometers that, when modeled simultaneously, enhance the resolution of the thermal history. For the Beaufort-Mackenzie region, mixed AFT populations are mainly the result of compositionally-related differences in AFT annealing kinetics. Joint inversion of AFT and other thermal maturity data (e.g. %Ro) yields information on the post-depositional heating and cooling histories of the Cretaceous-Cenozoic successions comprising the Beaufort-Mackenzie Basin and the cooling histories of the exhumed source areas from which these sediments were derived. An understanding of these histories is essential to constraining regional tectonics and the timing of petroleum generation.

For the Mackenzie Valley region, Cl content was used previously to define different AFT kinetic populations in a Devonian sample from an exploration well in the Tulita area south of the Norman Wells oil field (Issler et al., 2005). Reanalysis of this data using the *rmro* parameter indicates that the Cl-based results were misleading; new interpretations indicate that low Cl Cretaceous volcanic apatite was mixed with Cl-rich Devonian detrital apatite due to previously unrecognized contamination of drill cuttings. Subsequent data modeling yields thermal histories that are similar to published ones, underscoring the value of an integrated thermal history analysis approach where multiple geological constraints provide a more robust solution. These results highlight the importance of obtaining complete elemental data for the proper characterization and interpretation of AFT data.

### References

- Carlson, W.D., Donelick, R.A. and Ketcham, R.A. 1999. Variability of apatite fission-track annealing kinetics: I. Experimental results. *American Mineralogist*, v. 84, p. 1213-1223.
- Issler, D.R., Grist, A.M. and Stasiuk, L.D. 2005. Post-Early Devonian thermal constraints on hydrocarbon source rock maturation in the Keele Tectonic Zone, Tulita area, NWT, Canada, from multi-kinetic apatite fission track thermochronology, vitrinite reflectance and shale compaction. *Bulletin of Canadian Petroleum Geology*, v. 53, p. 405-431.
- Ketcham, R.A., Donelick, R.A. and Carlson, W.D. 1999. Variability of apatite fission-track annealing kinetics: III. Extrapolation to geological time scales. *American Mineralogist*, v. 84, p. 1235-1255.

ESS contribution no. 20080725