Geological Survey of Canada
Scientific Presentation 94

CHARACTERIZATION, INTERPRETATION, AND MODELLING OF MULTIKINETIC APATITE FISSION-TRACK DATA USING ELEMENTAL DATA

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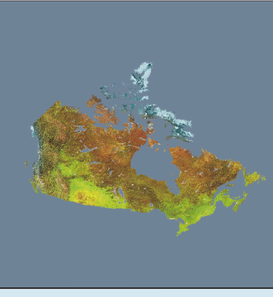
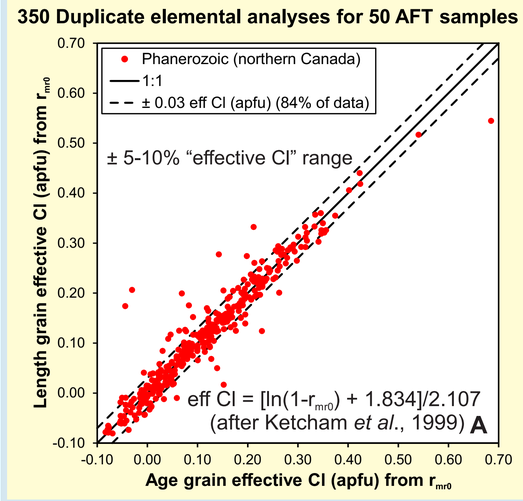


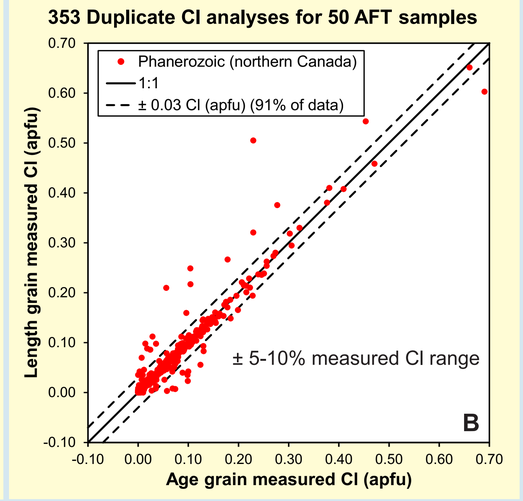
r_{mr0} kinetic parameter

Phanerozoic sedimentary rocks of Canada commonly contain heterogenous apatite with multi-kinetic AFT annealing behaviour. The r_{mr0} parameter resolves AFT kinetic populations better than conventional methods, resulting in more accurate and detailed thermal history reconstructions. r_{mr0} values were calculated for AFT samples with variable cation (Fe, Mn, Mg, Na, Sr, La, Y, Ce) and anion (F, Cl, OH) concentrations using the empirical equation of Carlson *et al.* (1999). The nonlinear r_{mr0} values were converted to "effective Cl" values for better visual display and comparison with the conventional Cl kinetic parameter. "Effective Cl" is the equivalent Cl concentration required to yield an appropriate r_{mr0} value for the Ketcham et al. (1999) annealing model based on the published correlation between Cl and r_{mr0}.

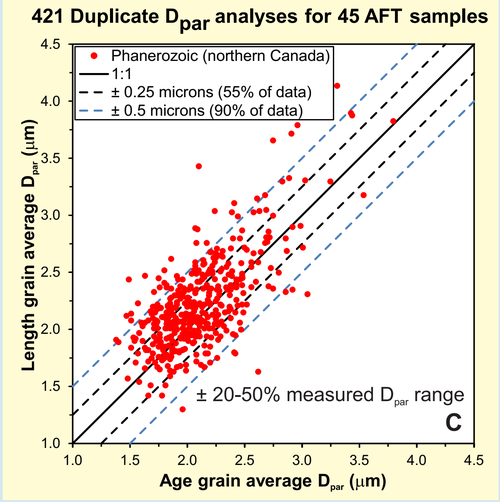
Precision of Apatite Fission Track Annealing Kinetic Parameters



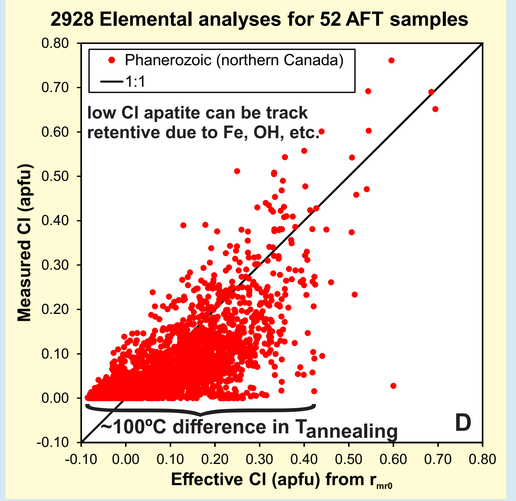
A. Duplicate r_{mr0} analyses, expressed as "effective Cl", are reproducible to within ±0.03 apfu for most of the data, representing ~5-10% measurement uncertainty over the typical range of sample values.



B. The conventional kinetic parameter, Cl content, has a measurement uncertainty that is similar to that for "effective Cl" but it does not account for the effects of variable cation substitutions or OH content.

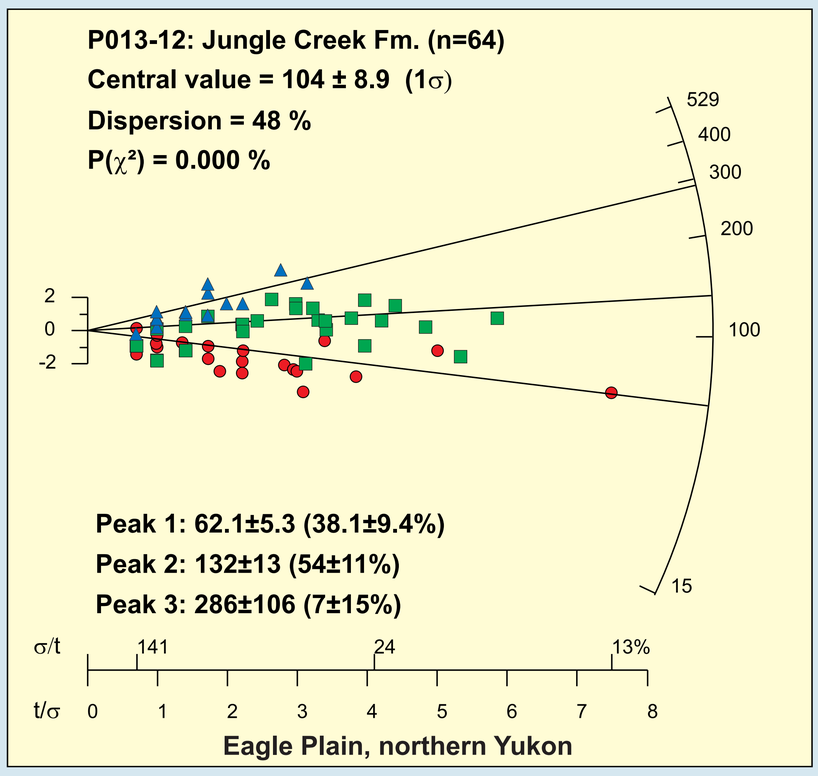


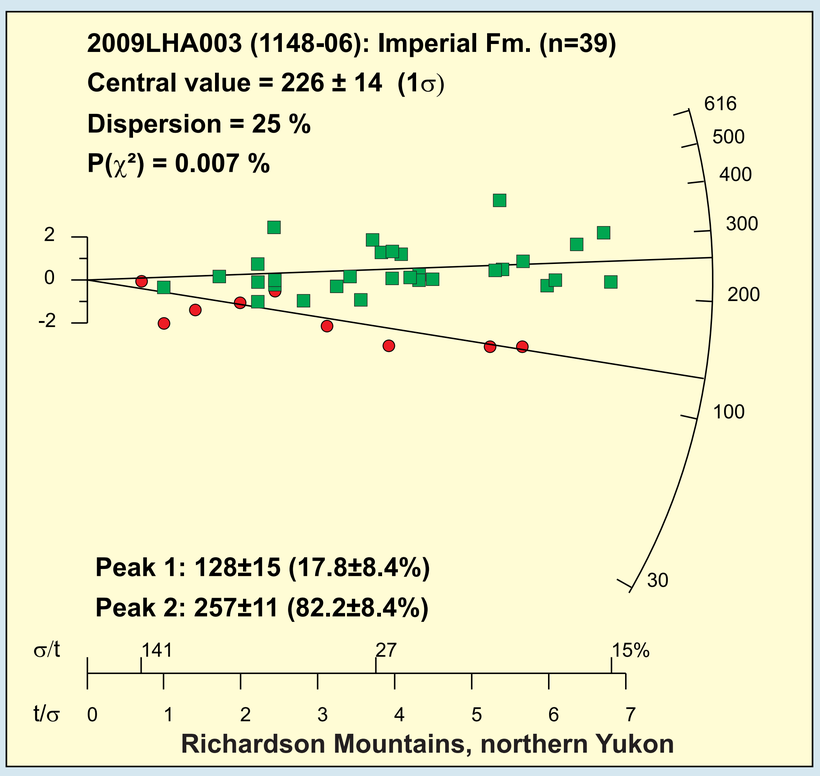
C. Although D_{par} depends on apatite composition, duplicate analyses show that measurement uncertainties can be large, contributing to significant overlap of different kinetic populations in D_{par} space.



D. There can be large differences between measured and "effective" Cl values (40% of values differ by 0.06 to 0.4 apfu) with significant implications for AFT annealing and resolving different kinetic populations.

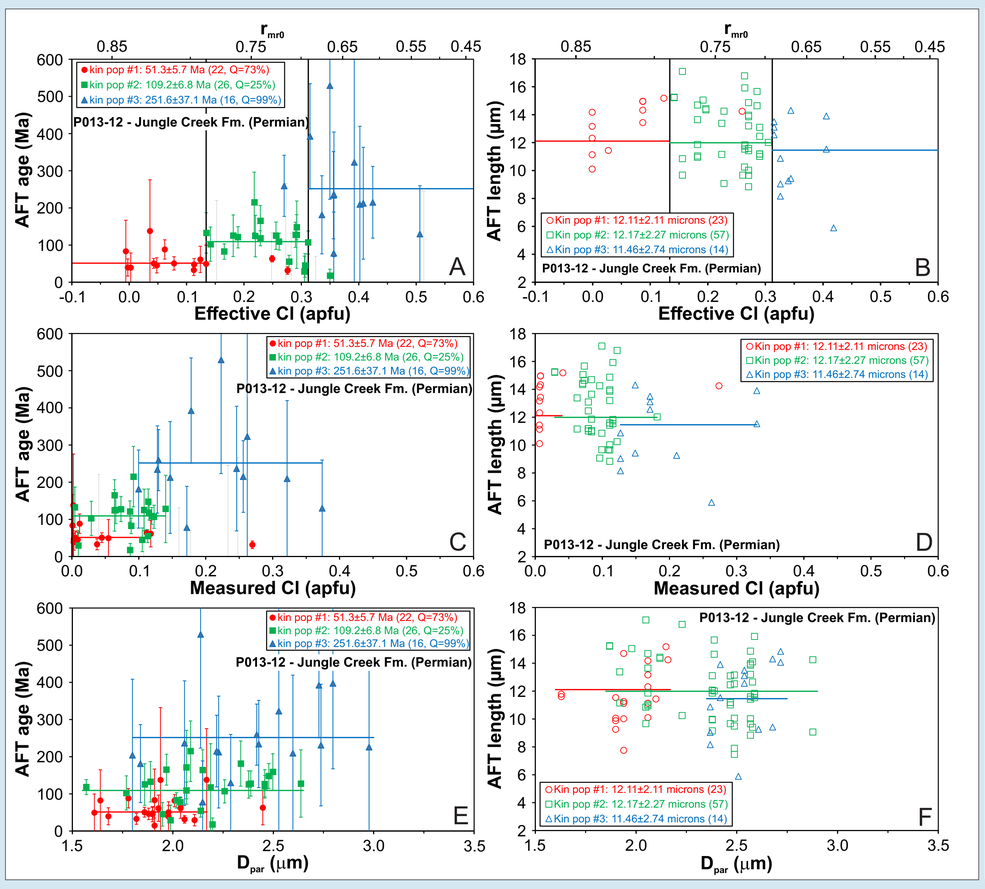
Interpretation of Multi-Kinetic Apatite Fission Track Data

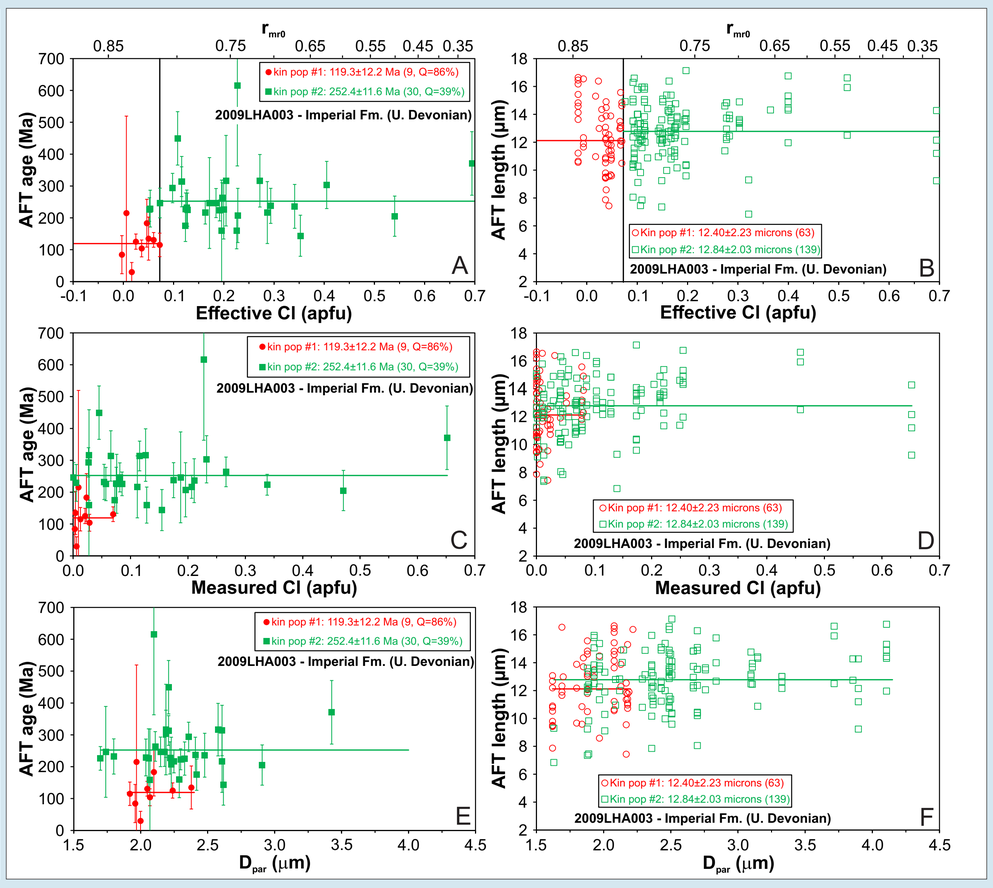




Sample Kinetic Populations

Permian (left panels) and Upper Devonian (right panels) sandstone samples illustrate typical multi-kinetic behaviour of compositionally heterogeneous apatite from Cambrian to Cenozoic sedimentary rocks of the northern Yukon and adjacent Northwest Territories. Single grain AFT age and length data show the least overlap across interpreted population boundaries when plotted with respect to r_{mr0}/effective Cl; ages correspond well with radial plot population ages derived from age mixture modelling (kinetic populations are colour-coded) and all age populations pass the χ^2 test. Some overlap is inevitable using single spot analyses due to measurement uncertainty and possible compositional zoning. The large uncertainty in D_{par}, and the use of Cl only, means that application of these parameters can result in mixed, poorly-defined AFT kinetic populations that can bias model thermal history results.





Procedures for Multi-Kinetic Samples

1. 40 AFT grain ages and 150-200 track lengths (LA-ICP-MS method and Cf-irradiation ideal for this)

2. Elemental data (Fe, Mn, Mg, Na, Sr, La, Y, Ce, F, Cl, Ca, P) for each analyzed grain (need EPMA for OH estimation)

3. Radial plot/age mixture modelling to interpret number of kinetic populations/ages

4. Population interpretation using age/length data plots with respect to r_{mr0}/effective Cl

5. Resolution of uncertain grains (not probed, outlier composition, poor analysis, different provenance); use age, D_{par}, duplicate elemental analysis, quality control procedures

6. Sort data for populations/calculate population kinetic parameters/prepare model input files

Sample is well characterized and ready for modelling, taking full advantage of the different AFT thermochronometers that it contains!

Inverse Thermal Modelling Using Multi-Kinetic Apatite Fission Track Data

Total Annealing Temperatures

Pop. #1: ~ 120ºC

Pop. #2: ~ 160ºC

Pop. #3: > 250ºC

Eagle Plain, northern Yukon

Total Annealing Temperatures

Pop. #1: ~ 115ºC

Pop. #2: ~ 230ºC

Richardson Mountains, northern Yukon

AFTINV, an inverse multi-kinetic AFT thermal model, is used to obtain statistically-acceptable, geologically-constrained thermal solutions (300 Monte Carlo solutions in grey; smoothed exponential mean in red) that fit observed AFT and vitrinite reflectance data. For the Eagle Plain Permian sample, three kinetic populations give two well-resolved heating/cooling phases; Permian-Early Jurassic burial followed by exhumation and then Albian-Cenozoic burial/exhumation. This Permian well sample was obtained from 80 m below the pre-Cretaceous unconformity. Note the highly retentive kinetic parameters and associated total annealing temperatures for kinetic populations 2 and 3.

The Richardson Mountains are at the eastern margin of the Eagle Plain. The Devonian outcrop sample has two kinetic populations that constrain three heating/cooling phases; three thermal peaks coincide with Devonian-Carboniferous, Triassic-Jurassic, and Albian-Cenozoic burial. Within the region, remnant Triassic strata overlie Devonian rocks. This part of the northern Yukon is geologically-complicated and well suited for multi-kinetic AFT studies as illustrated by these two examples. These results demonstrate how multi-kinetic AFT analysis, constrained using elemental data, can extend the time-temperature range and resolution of thermal histories in comparison to conventional methods.

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Permanent link: https://doi.org/10.4095/311302

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Presented at Thermo 2018: 16th International Conference on Thermochronology, Quedlinburg, Germany
Date presented: September 20–21, 2018

Recommended citation
Issler, D.R., Lane, L.S., and O'Sullivan, P.B., 2018. Characterization, interpretation, and modelling of multikinetic apatite fission-track data using elemental data; Geological Survey of Canada, Scientific Presentation 94, 1 poster. https://doi.org/10.4095/311302

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