FTIndex: INDEX TEMPERATURES FROM FISSION TRACK DATA

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FTIndex is a program for calculating index temperatures and lengths that describe the geological time scale predictions of fission-track annealing models, as proposed by Ketcham et al. (1999). It is written in the C programming language. Both an executable version (for Windows) and the source code are included in this download.

Three index temperatures describe high-temperature annealing behavior. The fading temperature (T_F) is the downhole temperature required to fully anneal a fission-track population after a certain number of millions of years, signified by the second subscript. For example, $T_{F,30}$ indicates the temperature required to fully anneal a population of fission tracks after 30 million years. The closure temperature (T_C) is the temperature experienced by a mineral at the time given by its age, assuming a constant-rate cooling history given by the second subscript; e.g. $T_{C,10}$ means closure temperature given a 10°C/m.y. cooling history. The total annealing temperature, T_A, is the temperature at which a fission-track population, fully anneals given a constant heating rate; it is equivalent to the oldest remaining population after a constant cooling episode. Again, the second subscript gives the heating/cooling rate. For both T_C and T_A, cooling is assumed to stop at 20°C.

Low-temperature annealing behavior is modeled by estimating fission-track length reduction given a proposed time-temperature history. The best-constrained low-temperature history is from Vrolijk et al. (1992), which used apatites from deep-sea drill cores from the East Mariana Basin and utilized proposed time-temperature histories based on independent evidence. Two histories are provided by Vrolijk et al. (1992), which are end-members the bound uncertainties in rifting time in the East Mariana Basin. FTIndex calculates reduced length for both end-member cases and the average between them. To convert these to actual lengths, they must be multiplied by an estimated initial track length. The mean length of apatites measured by Vrolijk et al. (1992) was 14.6 ± 0.1 µm. Note that if an annealing model is based on *c*-axis projected lengths then the results will have to be converted to unprojected means to be compared to this value; this can be done with the relation:

$$r_m = 1.396 r_c - 0.4017 \,. \qquad (1)$$

In general, to match the Vrolijk et al. (1992) data to within the uncertainty of the initial track length, the reduced length value for non-projected lengths should be in the range 0.89-0.92, and reduced *c*-axis projected lengths should be in the range 0.92-0.95. A second low-temperature test is for Fish Canyon tuff, for which the assumed thermal history is a constant 20°C for 27.8 million years.

FTIndex Program Operation

The program works by reading a text file that contains the coefficients describing one or more annealing models. It then calculates the index temperatures and writes them to a tab-delimited text file called bench.txt.

An example input file called IndexTest.txt has been provided in Table 1 to illustrate the file format. The basic format is a tab-delimited text file, with eleven columns and the first line a series of headers as shown above. The first column is a model name that will be repeated in the output file. The name should have no spaces. The second column is a numerical code signifying the form of the modeling equation; this form defines the meaning of the numbers in columns six through eleven, marked c_0 through c_5. The third column denotes whether the model describes mean length or mean c-axis projected length; if the former it should be zero, otherwise one. The fourth and fifth columns are for r_{mr0} and κ parameters to translate lengths from one form of apatite to another (Ketcham et al. 1999), according to the equation:

$$r_{lr} = \left(\frac{r_{mr} - r_{mr0}}{1 - r_{mr0}} \right)^{\kappa}, \tag{2}$$

where r_{lr} is the reduced length of a less-resistant apatite, and r_{mr} is the reduced length of the more-resistant apatite whose annealing is described by parameters c_0 through c_5. If no such conversion is desired, set r_{mr0} to 0 and κ to 1.

Unless otherwise noted, for all model equations, time (t) is in seconds and temperature (T) is in Kelvin, and r denotes reduced length while l denotes mean length. The model codes and forms are:

0: Fanning linear, based on Laslett et al. (1987) and Crowley et al. (1991):

$$\frac{\left[\left(1 - r^{c_5}\right)/c_5\right]^{c_4} - 1}{c_4} = c_0 + c_1 \frac{\ln(t) - c_2}{(1/T) - c_3}. \tag{3}$$

1: Fanning curvilinear, based on Crowley et al. (1991) and Ketcham et al. (1999):

$$\frac{\left[\left(1 - r^{c_5}\right)/c_5\right]^{c_4} - 1}{c_4} = c_0 + c_1 \frac{\ln(t) - c_2}{\ln(1/T) - c_3}. \tag{4}$$

2: Model of Carlson (1990):

$$l_{as} = c_3 - c_0 \left(\frac{\mathrm{k}T}{\mathrm{h}} \right)^{c_1} \exp\left(\frac{-c_1 c_2}{\mathrm{R}T} \right) t^{c_1}, \tag{5}$$

Where l_{as} is mean length due to axial shortening, k is Boltzmann's constant (3.2997 x 10^{-27} kcal·K^{-1}), h is Planck's constant (1.5836 x 10^{-37} kcal·s), and R is the universal gas constant (1.987 x 10^{-3} kcal·mol^{-1}·K^{-1}). Note that there are only four fitted parameters in this model, and thus only four should be entered in the file; columns 10 and 11 should be left blank.

3: Model of Laslett and Galbraith (1996):

$$l = c_0 \left[1 - \exp\left(c_1 + c_2 \frac{\ln(t) - c_3}{(1/T) - c_4} \right) \right]^{c_5} \tag{6}$$

Following their convention, in this case the time units are hours rather than seconds. If one fits the model using seconds, as with the other equations listed here, simply add ln(3600)=8.18869 to c_3.

Table 1: Example FTIndex input file.

Name	Model	Lc	rmr0	kappa	C0	C1	C2	C3	C4	C5
L87Dur	0	0	0	1	-4.87	0.000168	-28.12	0	0.35	2.7
C90Dur	2	0	0	1	1.81	0.206	40.6	16.21		
LG96Fap	3	0	0	1	16.713	-4.879	0.000187	-33.385	0.000295	0.3333
K99DRLm	1	0	0	1	-106.18	2.1965	-155.9	-9.7864	-0.48078	-6.3626
K99RNLc	1	1	0	1	-61.311	1.292	-100.53	-8.7225	-0.35878	-2.9633
K99MLcRN	1	1	0.846	0.179	-19.844	0.38951	-51.253	-7.6423	-0.12327	-11.988
K99MLc165	1	1	0.84	0.16	-19.844	0.38951	-51.253	-7.6423	-0.12327	-11.988

References

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