Review of Jensen by Ray Donelick
February 11, 2026
Viola, Idaho

General comments

I love this work and this approach to modeling apatite CFT data. I recommend this paper be published with minor revisions.

I have attached my version of the problem of deconvolving c-axis projected CFT lengths for time-temperature modeling. There is some emphasis on calibration and on constructing a physical model. I provide this to add to the author's work but also, perhaps, to prod the author to clarify – perhaps with a few additional drawings – the physical model of deconvolution he has developed.

I apologize for taking so long to review this. I hope you find this review constructive.

Abstract

Lines 5-6
Reword sentence to: "It is generally accepted that the traditional fission track age equation accurately calculates the cooling age for apatite minerals when the cooling rate is fast." The unedited statement may be true if the traditional age equation is Equation 4-6 of Fleischer et al. (1975) and is used in its entirety, which is rarely is. Compromises are made using this equation at the expense of accuracy. Implicit here is that traditional fission track age equation is properly calibrated.

Lines 10-11
Reword sentence to: "The difficulty is that the track length–age relation is blurred by the spread in lengths due to the inherent spread in fission decay energies, crystallographic anisotropy, and observational uncertainties." In my work, the standard deviation of CFT lengths for single CFT populations about their fitted ellipses is typically about 0.75 microns, which becomes about 0.55 microns when all CFTs are projected onto the c-axis. My gut tells me that about 0.30 of 0.55 microns is real, due to CFTs being formed from a range of fission decay energies (see line 151 also). The remainder is human/analytical error.

Lines 15-16
Regarding "This information may be used to calculate the age of the oldest fission track among the track populations which can constrain the timing of tectonic events and provide the basis for calculation of past temperature." I agree.

1 Fission track age equations

Line 18
Reword "The traditional fission track age equation (Equation 4-6 of Fleischer et al., 1975; Kohn et al., 2024) is…" Two things: 1) Here especially, you need to include reference to the full equation, 2) Write the equation here as I encounter a paywall trying to get Kohn et al. (2024).

Lines 22-23
Regarding "…partial annealing window from 120 °C to 60 °C." it is true that significant, measurable, and useful geological **partial annealing** occurs between 0 °C and 60 °C.

Lines 26-28

Regarding "…so that ideally the oldest tracks are the shortest ones…" We already know that some of the short tracks are younger than some of the longer tracks. This better re-worded "…so that in previous work it is assumed that the oldest tracks are the shortest ones…"

Line 29
Regarding "A given track can therefore be aged by counting the number of shorter tracks…" The word "counting" implies to the fission tracker that we are talking about counting etched fission tracks on a mineral grain surface. But, we are not. These are the random unetched tracks. Please clarify this here.

Lines 34-35
Regarding "…there is no need for the surface track density…to derive the age of a track. Unfortunately, it is difficult to see…" So, because unetched fission tracks are difficult (actually, practically impossible) to see, we fall back on using "surface track density" for which there is "no need". Drop this sentence or flip its meaning. The math might allow something, but reality matters too.

Lines 40-41
Regarding "This means that the relation between histogram columns and the time intervals in which they were generated is non-unique." Re-word to something equivalent such as "This means that etched, confined, nearly horizontal fission tracks from different time intervals may have nearly identical c-axis-projected lengths"

Lines 41-43
Regarding "Fortunately, the blurring is known …and can… be removed from the observed track ength histogram by mathematical deconvolution (Jensen et al., 1992; Donelick et al., 1988)." No, the deconvolution accommodates the blurring, preserving it but not sweeping it under the carpet. Deconvolution does not decrease the blurring.

Lines 44-45
Regarding "The track length histograms were transformed to deconvolved histograms with a tighter relation between histogram columns and time intervals." Re-word this to "transformed to histograms of deconvolved Guassians". Are your CFT populations Gaussians? Defined by?

Lines 48-49
Regarding "In this paper the deconvolution technique presented takes advantage of the c-axis projection method by Donelick et al. (1999)." Presumably, the model referred to is shown as Figure B1 in this paper. Figure B1 here is far from the model of Donelick et al. (1999) as shown in Fig R3 of the ATTACHMENT.

Lines 52 and 146
The term "exact expression" is used to suggest that the equations provided are exact needing no further refinement. None of our mathematical descriptions of fission tracks is exact, and certainly not an expression that is built upon in-exact equations such as the c-axis projection model of Donelick et al. (1999). I am not sure how to reword this…replace "exact" with "more precise"?

Lines 52-55
Regarding "The inversion technique…the priors dominating the histograms." I have trouble with negative-data added to known-error-prone-human-derived-data. Just because the math allows it, does not mean that it should be allowed. We need to know where measured data mis-match

mathematical models of those data as it is in this space that innovation occurs. No sweeping data under the carpet.

Line 55
Re-word "An overview of symbols is…"

2 Application of age nodes

Lines 59-60
Regarding "…to illustrate the calculation of age nodes." Please indicate in the captions for Figures 1,2,3 that the "age nodes" are the y-values plotted in plot C of each figure and tabulated in Table 1.

Line 74
Correct spelling "….of the total number of tracks."

Line 83, Table 1

- Please re-order that Samples, from top to bottom CXII-46, GRO64, GRO21, to match their order of presentation in the text.
- Please show where "Calibration factor" fits into an equation provided or cited.
- How do you calculate "Oldest age"?
- How do you calculate errors of your "Age nodes"?
- 1 sigma or 2 sigma errors?

Line 85
Regarding "…age of the oldest track is 193 (16) Ma." Where does this come from?

3 Discussion

Lines 119-120
Regarding "The inversion set up applied here assumes the track length histogram columns to be normally distributed." This is the first mention of this assumption of normal distribution. See my comments for Lines 44-45, Lines 224-225, and Lines 227-228 where this information would be helpful to know.

Line 120
Regarding "A better distribution is Poisson's distribution." Why? You throw this out there with no basis. Is it theoretical based on energy distribution of fission yields and/or Poissonian etching behavior? Or, is this because Poisssonian slightly better matches observation vs Gaussian? Explain or drop this comment.

Line 129, **4 Conclusion**
Re-word "**4 Conclusions**"

Line 130
Regarding "Equations used to calculate multiple age nodes with deviations for apatite fission track length histograms are updated." This work is great and interesting and I hope the author continues to pursue this interesting approach to apatite fission track time-temperature modeling.

Appendix A

Line 144

Regarding "They are derived from laboratory annealing experiments (Barbarand et al., 2003 and Ravenhurst et al., 2003)…" Really? You did not use Carlson et al. (1999)? If you did not, explain why not. Green et al. (1986) deserves to be cited here as does the Carlson et al. (1999) data set upon which Donelick et al. (1999) is based.

Lines 52 and 146
The term "exact expression" is used to suggest that the equations provided are exact needing no further refinement. None of our mathematical descriptions of fission tracks is exact, and certainly not an expression that is built upon in-exact equations such as the c-axis projection model of Donelick et al. (1999). I am not sure how to reword this…replace "exact" with "more precise"?

Line 154
Is this really "mathematical transposition"? Please verify and clarify if needed.

Line 155
Regarding "The modified random oriented track length histogram with origin in the time-interval i is

Lines 172-175
Regarding "Thus, the short tracks are more likely to be accepted as being horizontal than the long ones when measured in translucent light... Tracks measured in reflected light are not biased in this respect..." I don't agree with either of these statements, but I cannot access Jensen et al. (1992) to see the root argument/equations for these biases. Thus, I allow these statements. My first thought is that you should not mix translucent (or transmitted) and reflected light measurements. Using reflected light to click on a tip is lazy and not compatible with most published annealing experiments. I use reflected light to help me find the track tip when I return to transmitted light to measure.

Line 196
Re-word "where g is the geometrical factor (0.5 for 2pi geometry, 1.0 for 4 pi geometry)"

Line 198
Regarding "Appendix B", the model show in Figure B1 is no where near matching Donelick et al. (1999) or Green (1988). See comments below for Line 281, Figure B1.

Lines 224-225
Regarding "…normalized histograms derived from laboratory annealing and chosen so that their mean track length li is binned according with the columns of the matrix" I see two possibilities here: 1) you have all individual CFT (length, angle to c-axis) data from Barbarand et al. (2003) and Ravenhurst et al. (2003), you have been all of these data into histogram, and those binned histograms define the histograms you are deconvolving from the measured CFT data, or 2) you have a mathematical model describing each of these experimental histograms such as a Gaussian model and a calibration of standard deviation versus mean of all Gaussian models. What are you doing here? Please clarify and explain.

Lines 227-228
Regarding "…c-axis projections of the laboratory annealed tracks described by Barbarand et al. (2003) and Ravenhurst et al. (2003)." I am unaware of either of these papers describing a c-axis projection model. Barbarand et al. (2003) plotted CFT (length, angle) as Cartesian coordinates, purposefully ignoring the ellipse model of Donelick et al. (1999). What exactly is vector G and upon which experimental data is it really based?

Lines 236-237

Regarding "Its elements are therefore chosen to be equal and with sum equal to the number of measured tracks." This statement refers to vector h. Please tell me if I am correct: Vector h contains the deconvolved histograms, the number N of deconvolved histograms = number N CFT of c-axis-projects CFT lengths being deconvolved, and histogram element of h has the same area representing the same amount of time elapsed (of duration: overall oldest CFT age / N).

Line 268
Regarding "leads to the updated expression for the surface track density" which refers to Equation A31, I assume this is this "updated expression" is the "exact expression" referred to in Lines 52 and 146. If this is correct, please state this and connect the dots. Also, I repeat my concern about the word "exact".

Appendix B

Line 281, Figure B1
Figure B1 offers an unrealistic reduced fission track density vs reduced c-axis-projected fission track length model (rc). See Fig R3 in ATTACHMENT to how poorly Figure B1 matches Donelick et al. (1999) and Green (1988). For starters, the minimum reduced c-axis-projected fission track length reported in Carlson et al. (1999) was 0.55 for run HS-21 (Appendix 2). This is a practical minimum rc. As shown in Fig R2 in ATTACHMENT, Donelick et al. (1999) ellipses collapse quickly for rc between 0.55 and 0.40, the latter a likely true minimum rc.

Appendix C

No comment

Appendix D

No comment

Code and data availability
I could not access this information for this review.

Supplement
I could not access this information for this review.

ATTACHMENT

An Approach to c-Axis-Projected CFT Length Deconvolution

Set up the c-axis-projected CFT length distribution for deconvolution:

Step 1: Assumption: For a single population of fission tracks from a single population of apatite grains, the c-axis-projected length histogram is Guassian (skewness and excess kurtosis near 0) having mean value of lcmod and standard deviation value of σcmod (Carlson et al., 1999; Appendices 2 and 3). All biases either cancel each other among different projected length populations - such as variable length frequency versus angle to c-axis – or remain simple - such as the bias against seeing short lengths versus long lengths.

Step 2: Calibrate grain Dpar, Dper, and CFT length:
a. Calibrate Dpar and Dper measurements to Carlson et al. (1999; their Appendix 1): Obtain a calibration equation (commonly linear). Ideally, use Durango (DR in their Appendiix 2) and Fish Canyon Tuff (FC in their Appendix 3) etched 5.5M/20s/21C for direct comparison.
b. Calibrate CFT length measurements to Carlson et al. (1999; their Appendices 2 and 3): Obtain a calibration equation (commonly linear). Ideally use unannealed induced fission tracks in Durango and Fish Canyon Tuff.

Step 3: Measure CFT data for deconvolution: For one or more populations of apatite grains, find CFTs and measure length, angle to c-axis, grain Dpar and Dper at a minimum; ideally including grain/CFT 3D imagery, chemical composition, various isotopic compositions, other CFT features.

Step 4: Process CFT data for deconvolution:
a. Convert measured Dpar and Dper values to Carlson et al. (1999)-equivalents: Done using Step 2a calibration.
b. Calculate Carlson-equivalent lc0 and la0 values for each CFT: Done using the Carlson et al. (1999)-equivalent Dpar and Dper values and the calibrations shown in Fig R1.
c. Convert measured CFT length values to Carlson et al. (1999)-equivalents: Done using Step 2b calibration.
d. Project Carlson et al. (1999)-equivalent CFT lengths onto c-axis: Use a model similar to Donelick et al. (1999) such as shown in Fig R2.
e. Calculate reduced c-axis-projected CFT length for each CFT: Divide c-axis-projected Carlson et al. (1999)-equivalent CFT length (Step 4d) by Carlson et al. (1999)-equivalent lc0 (Step 4b).
f. Weight each c-axis-projected CFT length by a factor of (1/c-axis-projected length): This removes measurement bias against CFTs with shorter lengths.

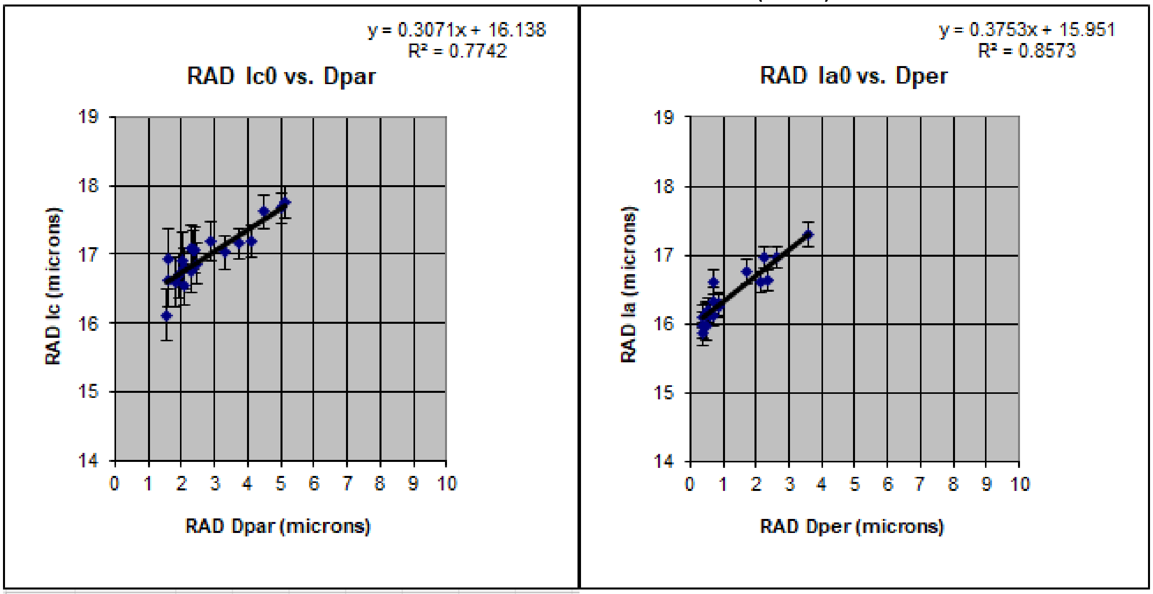
Deconvolve the c-axis-projected CFT length distribution

Step 5: Specify N number of Gaussians for deconvolution: Surely, this should be less than the number of measured CFTs. Gaussians defined by lcmod and σcmod values from Carlson et al., (1999; Appendices 2 and 3).

Step 6: Deconvolve the weighted CFT length distribution from Step 4f into N Gaussians: Each resultant Gaussian represents a single population of CFTs, and each has a mean reduced c-axis-projected mean length – indicating integrated thermal annealing – and an amplitude – indicating duration of time require to accumulate its associated CFTs.

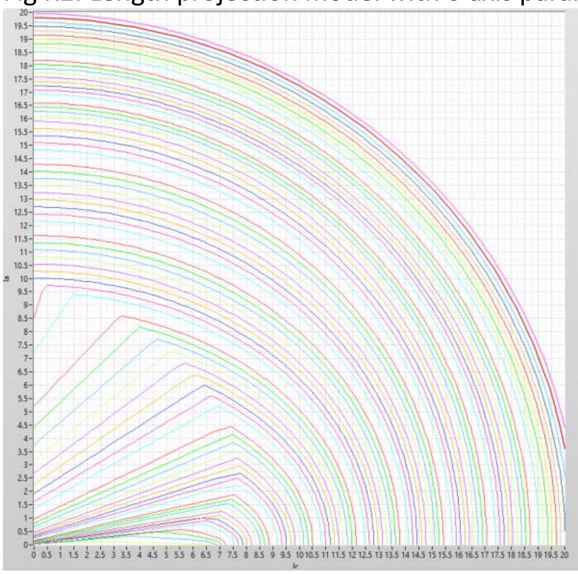
Step 7: Calculate fission track age component of each Gaussian: This is done using a calibration of reduced c-axis-projected mean length vs reduced fission track density rhos/rhos0 such as shown in Fig R3.

Fig R1. Donelick calibration of lc0 versus Dpar and la0 versus Dper (presented in Amsterdam, 2004), same hardware and software as used to measure Carlson et al. (1999).



RAD initial	etch	Dpar	Dper	N CFT	lc0	1dlc0	la0	1dla0
DRA1	1.6M / 40s / 24 C	2.36	0.71	200	17.07	0.14	16.34	0.09
DRA2	5.0M / 20s / 23 C	2.03	0.48	125	16.92	0.2	15.96	0.1
DRA3	5.0M / 20s / 20 C	1.54	0.36	140	16.12	0.19	15.98	0.1
DRA4	5.5M / 20s / 24 C	2.09	0.53	200	16.8	0.15	16.17	0.08
DRA5	5.5M / 20s / 21 C	1.91	0.52	200	16.7	0.16	16.21	0.09
RNA1	1.6M / 40s / 24 C	2.39	0.68	201	17.06	0.17	16.6	0.09
RNA2	5.0M / 20s / 23 C	1.8	0.47	201	16.59	0.18	16.16	0.09
RNA3	5.0M / 20s / 20 C	1.6	0.4	200	16.94	0.22	15.86	0.08
RNA4	5.5M / 20s / 24 C	2.29	0.51	200	17.08	0.17	16.14	0.08
RNA5	5.5M / 20s / 21 C	1.61	0.36	200	16.62	0.19	16.11	0.08
B2A1	1.6M / 40s / 24 C	5.02	3.61	201	17.67	0.11	17.29	0.09
B2A2	5.0M / 20s / 23 C	4.48	2.34	202	17.62	0.12	16.63	0.08
B2A3	5.0M / 20s / 20 C	3.73	2.17	200	17.16	0.11	16.61	0.08
B2A4	5.5M / 20s / 24 C	5.13	2.64	201	17.76	0.12	16.97	0.08
B2A5	5.5M / 20s / 21 C	4.09	2.28	202	17.19	0.12	16.97	0.08
TIA1	1.6M / 40s / 24 C	3.34	1.7	200	17.03	0.12	16.76	0.09
TIA2	5.0M / 20s / 23 C	2.48	0.84	205	16.87	0.15	16.26	0.08
TIA3	5.0M / 20s / 20 C	2.07	0.6	200	16.56	0.15	16.13	0.08
TIA4	5.5M / 20s / 24 C	2.89	0.87	200	17.19	0.14	16.29	0.08
TIA5	5.5M / 20s / 21 C	2.33	0.69	201	16.75	0.15	16.12	0.08

Fig R2. Length projection model with c-axis parallel to the x-axis shown (after Donelick et al., 1999).



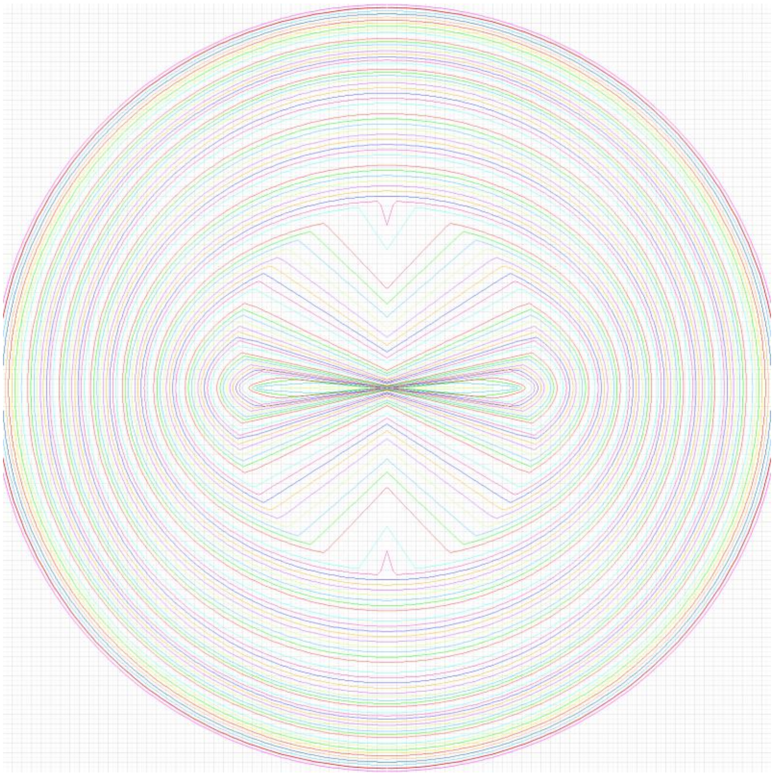


Fig R3. Reduced length l/l0 vs reduced fission track density rhos/rhos0. The c-axis projection model shown in R2 produces the blue curve (c-axis-projected rc) and green curve (mean measured length rm; unintentionally and ironically green colored), the latter very closely matching the published data of Green (1988). The orange curve is from Figure B1 of Jensen (this study; see discussion).