DR2013337

SUPPLEMENTAL FIGURE CAPTIONS

Figure DR1: Maps of eU concentration for three grains from NC-SY-13 showing both the range of severity of core-enriched zonation patterns and the range of bulk eU concentrations that were inferred from the analysis of abraded grains. The plot shows radial concentration profiles calculated from a spherical interpolation of the eU maps.

Figure DR2: Results of forward modeling to assess the use of an exponential regression to fit RDAAM predicted eU-age trends. (A) Simple linear cooling histories that span the range of interest for the Appalachian region that were used as input for forward modeling in HeFTy with the RDAAM. (B-D) Plots showing RDAAM predicted eU-age data points (black circles) that are fit by 3^{rd} order polynomial (gray line) and exponential (black line) regressions with chi-square values for each indicated.

Figure DR3: Forward modeling of the implications of core-enriched zonation and physical abrasion. (A) Two radial eU concentration profiles for zoned apatite grains with 5:1 core-enrichment. The gray shaded region illustrates the portion of the profile that is integrated for a physically abraded grain. The dashed lines indicate the bulk eU concentrations for the whole grain (black) and after the removal of 25 μm by physical abrasion (gray). (B) Results of forward modeling using HeFTy and the RDAAM that show the proportional age deviation for different cases involving abrasion, zonation, and correction for alpha loss using the best-fit thermal histories from inverse modeling described in the paper and the 20 m/Myr average exhumation rate. Age deviation is proportional to the RDAAM predicted age for an untreated grain following standard assumptions in AHe thermochronology, where eU is homogeneously distributed and the age is corrected for alpha loss. Black symbols indicate the reality of zonation for untreated (boxes) and abraded grains (circles) when eU homogeneity is assumed. Gray boxes represent untreated grains that are F_T corrected with knowledge of the zonation pattern. Open circles are representative of abrasion of a grain with homogeneous eU. Finally, stars represent the model conditions that were used for inverse modeling, prior to direct knowledge of zonation patterns from the eU maps and also prior to the ability to model abraded grains in HeFTy.

SUPPLEMENTARY MATERIALS

U-Th/He Analysis Methods

Hand-picked grains were photographed in 2D for use with image-analysis software to determine the alpha-loss correction. Grains were then packaged in high-purity Pt or later Nb microtubes, placed into Pt- or Nb-foil carrier packets, and loaded into an all-metal sample dropper that allowed samples to be introduced to the double-vaccum furnace for heating. Some early samples were heated to only about 960 ˚C, which should be more than adequate to outgas apatites, but the frequent observation of a few percent of refractory ^{4}He in re-extract analyses led us to switch to an 1150˚C-15 minute heating schedule, which appeared to eliminate the re-extract issue, however, re-extracts were performed for every aliquot reported here, so incomplete degassing is not a issue for this dataset. After gettering, the gas was analyzed using a Balzer's Prisma quadrupole mass spectrometer, with abundances being determined two ways: via a ^{3}He spike calibrated for mass discrimination using a 1:1 ^{4}He/^{3}He mix, and manometrically using the ^{4}He beam observed in the calibration shots, which were run before, in the midst of, and after the analysis of each batch of unknowns. Agreement between spiked and manometric data was usually within 1%, and where these values deviate, the cause appears to be interference at mass 3 due to the presence of high hydrogen loads. As a result, all data reported in this paper are based on the manometric calibration. After removal from the vacuum system, samples were sent to the University of Arizona for U, Th, and in later years, Sm ICP/MS isotope-dilution analysis at the laboratory of Dr. Peter Reiners.

Direct Evidence of U and Th zonation

To corroborate the inferential evidence of core-rich zonation observed in the abraded apatite grains from tsamples NC-SY-13 and NC-SY-2 we present eU concentration maps from NC-SY-13 that were gathered as part of a different investigation and will be presented and discussed in full in a forthcoming publication. These eU maps (Figure S1) were generated at Caltech following the analytical protocols and data reduction procedures laid out by Farley et al., (2011) and subsequently employed by other studies (Flowers and Kelley. 2011; Ault and Flowers, 2012). Apatite grains were selected flowing standard grain selection protocols (e.g., Farley, 2002), mounted in epoxy and polished as would be used for SEM or microprobe analysis. We used a Thermo X-series 2 quadrupole ICP-MS fitted with a collision cell interfaced with a New Wave UP-193 laser operating at 193 nm. Using a spot size of 20 μm and a velocity of 1 μm/s, traverses were ablated parallel and perpendicular to the long axis of the grain in a grid pattern. ^{44}Ca, ^{140}Ce, ^{232}Th, and ^{238}U were analyzed continuously using 150 ms sweeps during each traverse. Traverses began and ended in epoxy and the ^{44}Ca was used to determine the grain boundary during data processing.

These three grains nicely illustrate the zonation patterns that were inferred from the analysis of abraded grains. In order to produce the very high eU concentrations seen for several abraded grains (but not see the same high concentrations in the untreated grains) requires the presence of strongly zoned grains such as grain B. Similarly, to produce the lower eU concentrations necessitates weakly zoned grains such as grain C or zoned grains with generally low eU like grain A.

Fitting Exponential Regressions to AHe Data

To test the validity of using an exponential regression to capture the eU-age trend of our abraded data, we forward modeled eU-age data using HeFTy and the RDAAM. Figure DR2 shows that exponential regressions do a fairly good job matching the results of the forward models for a range of plausible cooling rates for the Appalachians and eU concentrations observed for our abraded datasets. The scale of the misfit between the forward model results and the exponential regression is quite small for individual points and only at the very low end of the eU scale (< 5 ppm) does the shape of the regression deviate noticeably from the data it is fitting. The 3rd order polynomial fit is shown for comparison and is not suggested as a substitute for an exponential regression.

Implications of Zonation and Abrasion for Modeling of AHe Data

As stated in the paper, zonation impacts AHe ages in two ways, first through affecting the correction for alpha ejection, the second through the way the age is interpreted in the context of radiation damage. Figure DR3 illustrates these impacts using two hypothetical Appalachian apatites with 5:1 core-enriched zonation patterns that were based on the observations from the eU maps (Figure DR1). The problem of eU dilution is shown here where the bulk eU concentrations of the two grains are 10 and 50 ppm, abraded cores from these grains would produce bulk eUs of 15.5 and 78 ppm, and the core of each grain would be 21 and 105 ppm respectively. Using these two grains, we then forward model ages with the 20 m/Myr exhumation rate and the best-fit thermal histories from our inverse models of NC-SY-13 and NC-SY-2 to explore the impact of zonation and abrasion, the consequence of not knowing about it on AHe data, and the validity of the manner in which we tuned these parameters to generate our inverse model results (Figure DR3).

We use the standard analysis protocols for AHe thermochronology (e.g.,Farley, 2002) as a basis from which to assess the impacts of various combinations of zonation and abrasion and find that aside from measuring the eU distribution and therefore knowing explicitly how to correct an age for alpha ejection there is no universal fix for dealing with a mix of zoned and homogenous eU distributions. For untreated grains that are F_T corrected without knowledge of the eU distribution, zonation of the character we observed in the Appalachians results in ~10% older ages then an untreated grain with a homogeneous eU distribution, corroborating the findings of other studies (Farley et al. 1996; Ault and Flowers, 2012). Abrasion of zoned grains produces ages that are typically within several % of the standard protocol and assumptions, however, abrasion of grains with homogeneous eU results in significantly older ages as a result of the removal of the low He concentration portion of the natural diffusive profile within the grain.

For our inverse models we used the following parameters to best represent our knowledge of the samples, the input data, and the modeling capabilities at the time. (1) For all “grains” (remember these are points from an exponential regression fit to our abraded datasets) we used a radius of 80 μm which as the average of our untreated grains from these samples (Figure 4). (2) Because we did not measure eU distributions for all grains analyzed and the evidence for variable zonation patterns, we used the standard assumption of eU homogeneity. (3) Because the input data was from abraded grains that were not corrected for alpha ejection (as per the assumption of eU homogeneity) we did not correct the model ages for alpha loss. Additionally, we did not redistribution He within the model while running the inverse models. (4) We used the RDAAM (Flowers et al., 2009) to calculate the diffusion kinetics of each model "grain". Figure DR3 shows that modeling AHe ages with these parameters produces ages that are slightly younger then if we had used the standard assumption and protocols and for zoned grains that were subjected to abrasion, but typically the discrepancy is < 5%. Given that it is now possible to model abraded grains directly, we suggest that people do this in the future, but Figure DR3 shows that we did not cause a large bias in our results as a product of the manner in which we modeled our data.

Supplementary Materials References

Ault, A.K., and Flowers, R.M., 2012, Is apatite U-Th zonation information necessary for accurate interpretation of apatite (U-Th)/He thermochronometry data?: Geochimica et Cosmochimica Acta, v. 79, no. C, p. 60-78, doi: 10.1016/j.gca.2011.11.037.

Farley, K.A., 2002, (U-Th)/He dating: Techniques, calibrations, and applications: Reviews in Mineralogy and Geochemistry, v. 47, no. 1, p. 819-844.

Farley, K.A., Shuster, D.L., and Ketcham, R.A., 2011, U and Th zonation in apatite observed by laser ablation ICPMS, and implications for the (U-Th)/He system: Geochimica et Cosmochimica Acta, v. 75, no. 16, p. 4515-4530, doi: 10.1016/j.gca.2011.05.020.

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, v. 60, no. 21, p. 4223-4229.

Flowers, R.M., and Kelley, S.A., 2011, Interpreting data dispersion and "inverted" dates in apatite (U-Th)/He and fission-track datasets: An example from the US midcontinent: Geochimica et Cosmochimica Acta, v. 75, no. 18, p. 5169-5186, doi: 10.1016/j.gca.2011.06.016.

Flowers, R.M., Ketcham, R.A., Shuster, D.L., and Farley, K.A., 2009, Apatite (U-Th)/He thermochronometry using radiation damage accumulation and annealing model: Geochimica et Cosmochimica Acta, v. 73, no. 8, p. 2347-2365, doi: 10.1016/j.gca.2009.01.015.

Table S1: U-Th/He Data for all apatite and zircon analyses from the central and southern Appalachians

Sample	Grains (or mass-mg)	^{4}He (mol)	U (mol)	Th (mol)	Sm (mol)	eU[§] (ppm)	Ft	Age uncorr (Ma)	Age corr (Ma)	± 2σ* (Ma)	Analy. Scatter[#] ± 2σ (Ma)	Th/U
APATITE												
Central Appalachians - Pennsylvania and New Jersey												
APL-BUTL-00-1	1	7.884E-13	3.733E-12	1.341E-11		45.1	0.865	89.1	102.9	6.0		3.59
APL-BUTL-00-2	1	1.443E-12	7.243E-12	1.135E-11		48.2	0.885	112.5	127.0	7.4		1.57
APL-BUTL-00 #1	0.3064	2.196E-11	1.348E-10	1.758E-10		136.8	0.850	96.4	113.2	6.6		1.30
APL-BUTL-00 #2	0.3022	1.810E-11	8.622E-11	1.051E-10		87.4	0.850	125.8	147.8	8.6		1.22
POOLED		*4.229E-11*	*2.320E-10*	*3.056E-10*		*104.2*	*0.851*	*107.5*	*126.1*	*3.5*	*38.8*	*1.32*
APL-CHFD-00-1	1	1.858E-13	4.279E-13	2.566E-14		4.2	0.861	322.1	372.4	21.6		0.06
APL-CHFD-00-2	1	1.398E-13	4.802E-13	2.233E-14		2.5	0.890	218.6	245.0	14.2		0.05
APL-CHFD-00-3	1	3.786E-14	1.880E-13	7.060E-14		3.5	0.815	141.8	173.5	10.1		0.38
APL-CHFD-00 #1	0.2197	1.252E-12	6.904E-12	1.353E-12		7.8	0.850	132.9	156.0	9.0		0.20
APL-CHFD-00 4	1	1.179E-13	6.324E-13	7.752E-14	2.712E-12	7.6	0.849	135.9	159.7	9.3		0.12
APL-CHFD-00 5	1	8.275E-14	4.556E-13	6.387E-14	3.005E-12	7.2	0.837	130.5	155.6	9.0		0.14
APL-CHFD-00 6	1	9.334E-14	3.300E-13	1.609E-13	6.956E-13	4.9	0.843	192.0	227.1	13.2		0.49
POOLED		*1.724E-12*	*8.990E-12*	*1.748E-12*	*6.413E-12*	*6.7*	*0.851*	*139.9*	*164.1*	*5.1*	*79.2*	*0.19*
APL-JJ-99-1	1	3.048E-13	2.309E-12	1.242E-12		69.5	0.800	90.3	112.7	6.5		0.54
APL-JJ-99-2	1	3.452E-13	2.491E-12	1.290E-12		78.5	0.795	95.2	119.4	6.9		0.52
APL-JJ-99 #1	0.2575	1.025E-11	9.339E-11	5.296E-11		97.8	0.850	74.7	87.8	5.1		0.57
APL-JJ-99 #2	0.2659	1.093E-11	8.476E-11	6.613E-11		89.8	0.850	84.2	98.9	5.7		0.78
POOLED		*2.183E-11*	*1.829E-10*	*1.216E-10*		*93.1*	*0.848*	*79.7*	*93.8*	*1.9*	*28.3*	*0.66*
APL-LBCL-00-1	1	5.124E-12	3.213E-11	2.611E-11		639.5	0.826	103.2	124.8	7.2		0.81
APL-LBCL-00-2	1	3.222E-12	2.027E-11	1.346E-11		127.2	0.882	105.9	119.9	7.0		0.66
APL-LBCL-00 #1	0.2418	1.169E-11	2.121E-10	1.393E-10		241.0	0.850	37.0	43.5	2.5		0.66
APL-LBCL-00 #2	0.2427	2.246E-11	2.005E-10	1.280E-10		226.2	0.850	75.2	88.4	5.1		0.64
POOLED		*4.249E-11*	*4.650E-10*	*3.069E-10*		*235.6*	*0.849*	*61.2*	*71.9*	*1.1*	*74.8*	*0.66*
APL-MORR-00-1	1	4.019E-13	2.679E-12	1.299E-12		30.4	0.875	103.7	118.3	6.9		0.48
APL-MORR-00-2	1	6.605E-13	4.884E-12	1.564E-12		35.7	0.875	96.8	110.5	6.4		0.32
APL-MORR-00 3	1	6.620E-13	3.937E-12	3.464E-12	4.070E-13	44.3	0.859	107.4	124.8	7.2		0.88
POOLED		*1.724E-12*	*1.150E-11*	*6.327E-12*	*4.070E-13*	*36.8*	*0.869*	*102.2*	*117.5*	*3.7*	*14.4*	*0.55*
APL-SCDM-00-1	1	9.308E-13	4.225E-12	2.181E-13		15.7	0.895	166.1	185.2	10.7		0.05
APL-SCDM-00-2	1	8.488E-13	3.986E-12	8.349E-13		19.6	0.882	155.2	175.6	10.2		0.21
APL-SCDM-00 #1	0.3341	7.767E-12	3.583E-11	2.692E-12		26.0	0.850	162.6	190.8	11.1		0.08
APL-SCDM-00 #2	0.3258	7.868E-12	3.927E-11	2.828E-12		29.2	0.850	150.6	176.8	10.3		0.07
POOLED		*1.741E-11*	*8.331E-11*	*6.573E-12*		*26.0*	*0.854*	*156.8*	*183.2*	*7.4*	*14.4*	*0.08*
APL-SMT-99-1	1	1.607E-12	3.462E-12	2.514E-11		52.2	0.871	133.8	153.4	8.9		7.26
APL-SMT-99-2	1	1.467E-12	3.229E-12	2.202E-11		105.8	0.857	136.1	158.6	9.2		6.82
APL-SMT-99 #2	0.2278	1.329E-11	3.290E-11	1.933E-10		81.8	0.850	132.2	155.3	9.0		5.88
POOLED		*1.636E-11*	*3.959E-11*	*2.405E-10*		*79.0*	*0.853*	*132.7*	*155.4*	*6.5*	*5.2*	*6.07*

APL-VSP-00-1	1	2.905E-12	1.949E-11	2.201E-11		93.5	0.909	91.0	100.1	5.8		1.13
APL-VSP-00-2	1	3.207E-12	1.874E-11	1.524E-11		75.1	0.913	110.7	121.1	7.0		0.81
APL-VSP-00-3	1	1.981E-12	9.923E-12	9.352E-12		73.3	0.877	125.9	143.3	8.3		0.94
POOLED		*8.093E-12*	*4.815E-11*	*4.660E-11*		*81.4*	*0.903*	*105.6*	*116.9*	*3.7*	*43.3*	*0.97*
Southern Appalachians - Mount Mitchell Transect												
[illegible]												
NC-MM-4a(sml) #2	14	1.759E-12	1.861E-11	1.894E-12		10.5	0.867	71.1	81.9	4.8		0.10
NC-MM-4a 1	1	1.174E-13	1.390E-12	1.269E-13	1.190E-12	14.1	0.857	63.5	74.0	4.3		0.09
NC-MM-4a 2	1	3.200E-13	2.914E-12	1.578E-13	3.798E-12	16.5	0.882	82.8	93.8	5.4		0.05
NC-MM-4a 3	1	3.465E-13	3.131E-12	1.587E-13	3.339E-12	16.8	0.881	83.7	94.9	5.5		0.05
NC-MM-4a 2	2	2.130E-13	2.234E-12	1.652E-13	2.161E-12	21.2	0.816	71.8	87.9	5.1		0.07
NC-MM-4a 4	1	3.213E-14	7.426E-13	4.220E-14	2.683E-13	4.1	0.880	32.9	37.4	2.2		0.06
POOLED		*4.844E-12*	*5.118E-11*	*3.843E-12*	*1.076E-11*	*10.9*	*0.863*	*71.5*	*82.8*	*1.2*	*39.3*	*1.06*
NC-MM-6 #1	8	2.339E-13	2.745E-12	7.903E-13		1.6	0.895	61.6	68.8	4.0		0.29
NC-MM-6 1	1	3.280E-15	4.324E-14	1.379E-14	1.472E-13	3.6	0.757	53.6	70.8	4.1		0.32
NC-MM-6 2	1	5.407E-15	6.878E-14	1.041E-14	2.206E-13	2.9	0.773	57.7	74.5	4.3		0.15
NC-MM-6 3	1	5.167E-15	4.830E-14	9.426E-15	1.915E-13	6.2	0.665	77.3	115.8	6.7		0.20
POOLED		*2.477E-13*	*2.905E-12*	*8.239E-13*	*5.594E-13*	*1.6*	*0.883*	*61.6*	*69.7*	*1.2*	*44.8*	*0.28*
NC-MM-7-1	1	8.736E-13	3.760E-12	1.141E-11		76.4	0.844	105.3	124.6	7.2		3.03
NC-MM-7-2	1	2.854E-13	5.085E-14	7.175E-14		2.0	0.785	2659.3	3231.6	187.4		1.41
NC-MM-7 #1	8	4.531E-13	4.002E-12	1.777E-12		2.3	0.882	79.0	89.5	5.2		0.44
NC-MM-7 3	1	2.263E-14	2.516E-13	7.456E-14	1.066E-12	5.7	0.815	63.6	77.9	4.5		0.30
NC-MM-7 4	1	7.048E-15	7.577E-14	2.166E-14	3.631E-13	1.8	0.817	65.7	80.4	4.7		0.29
POOLED		*1.356E-12*	*8.090E-12*	*1.328E-11*	*1.429E-12*	*5.2*	*0.856*	*93.6*	*109.3*	*2.9*	*43.2*	*1.64*
NC-MM-9-1	1	9.192E-13	7.345E-14	3.184E-14		2.0	0.808	5338.2	6109.1	354.3		0.43
NC-MM-9-2	1	7.180E-13	6.248E-14	8.553E-14		1.1	0.830	4637.9	5283.4	306.4		1.37
NC-MM-9 #1	16	6.045E-13	5.228E-12	6.068E-12		2.7	0.880	70.3	79.8	4.6		1.16
NC-MM-9 3	1	7.328E-15	8.007E-14	1.124E-13	9.481E-14	1.9	0.824	53.1	64.4	3.7		1.40
NC-MM-9 5	1	6.644E-15	5.647E-14	6.162E-14	5.549E-14	2.2	0.777	72.2	92.7	5.4		1.09
POOLED		*6.118E-13*	*5.308E-12*	*6.180E-12*	*9.481E-14*	*2.6*	*0.879*	*70.0*	*79.6*	*1.5*	*6181.1*	*1.16*
NC-MM-14-1	1	1.208E-12	2.183E-13	2.880E-13		5.7	0.809	2658.0	3152.8	182.9		1.32
NC-MM-14-2	1	2.748E-12	9.787E-14	8.838E-14		1.5	0.835	8396.5	9238.6	535.8		0.90
NC-MM-16-1	1	1.504E-13	6.276E-13	9.028E-14		7.4	0.853	176.9	206.8	12.0		0.14
NC-MM-16-2	1	4.705E-14	3.051E-13	8.458E-14		8.6	0.830	111.2	133.7	7.8		0.28
NC-MM-16 (3)	1	1.178E-13	6.276E-13	1.690E-13	1.683E-12	8.9	0.841	133.6	158.5	9.2		0.27
NC-MM-16 (3)	1	3.208E-14	1.884E-13	2.026E-14	9.229E-13	5.6	0.796	124.3	155.7	9.0		0.11
POOLED		*3.473E-13*	*1.749E-12*	*3.641E-13*	*2.606E-12*	*7.8*	*0.840*	*143.9*	*170.9*	*7.0*	*61.6*	*0.21*
Southern Appalachians - Sylva Transect												
NC-SY-2AB (2)	1	1.504E-14	1.972E-13	4.628E-14	9.837E-14	3.0	0.838	55.6	66.3	3.8		0.23
NC SY 2AB 200(2)	3	4.628E-13	3.227E-12	1.453E-12		4.6	0.898	99.8	111.0	6.4		0.45
NC SY 2AB 200(1)	3	1.091E-12	6.528E-12	1.746E-12		7.7	0.902	120.6	133.6	7.7		0.27
NC SY 2AB 100(2)	13	5.369E-13	2.925E-12	1.985E-12		7.4	0.804	121.7	151.0	8.8		0.68
NC SY 2AB 100(1)	11	7.916E-13	3.815E-12	9.848E-13		8.6	0.815	149.7	183.1	10.6		0.26

POOLED		2.897E-12	1.669E-11	6.215E-12	9.837E-14	6.8	0.857	122.5	142.7	4.5	87.7	0.37
NC-SY-3(2)	15	1.016E-12	8.504E-12	6.681E-13		9.2	0.838	90.2	107.4	6.2		0.08
NC-SY-3(1)	10	5.013E-13	4.287E-12	3.509E-13		12.6	0.802	88.2	109.8	6.4		0.08
NC-SY-3 (4)	1	1.552E-13	1.052E-12	7.783E-15	5.261E-14	31.7	0.824	112.9	136.7	7.9		0.01
NC-SY-3 (3)	1	7.201E-13	3.170E-12	2.344E-14	2.987E-12	39.7	0.842	172.1	203.8	11.8		0.01
POOLED		2.393E-12	1.701E-11	1.050E-12	3.040E-12	12.3	0.830	106.3	127.7	3.9	89.9	0.06
NC-SY-5(1)	2	2.752E-14	5.137E-13	1.452E-13		5.7	0.819	38.8	47.4	2.7		0.28
NC-SY-5 (1)	1	3.182E-14	3.849E-13	4.263E-14	2.031E-12	8.9	0.809	60.5	74.7	4.3		0.11
NC-SY-5 (2)	1	1.145E-13	1.003E-12	4.274E-13	2.667E-12	17.6	0.856	79.0	92.2	5.3		0.43
NC-SY-5 (3)	1	5.954E-13	1.263E-12	2.930E-12	2.403E-12	28.9	0.830	232.9	279.7	16.2		2.32
POOLED		1.738E-13	1.902E-12	6.152E-13	4.697E-12	10.1	0.841	64.8	76.9	1.6	45.2	0.32
NC-SY-7-2	1	2.734E-14	2.079E-13	1.958E-12		7.4	0.848	32.1	37.9	2.2		9.42
NC-SY-7 (4)	1	6.498E-14	6.581E-13	1.976E-12	3.915E-13	5.8	0.880	45.0	51.2	3.0		3.00
NC-SY-7 (5)	1	9.164E-14	9.974E-13	3.060E-13	1.739E-12	6.0	0.883	65.6	74.2	4.3		0.31
NC SY 7 120(1)	8	4.484E-13	4.175E-12	3.926E-12		6.0	0.853	68.0	79.7	4.6		0.94
NC SY 7 200(1)	6	1.000E-12	9.313E-12	5.419E-12		8.3	0.885	72.9	82.4	4.8		0.58
NC SY 7 80(1)	19	2.416E-13	1.477E-12	4.027E-12		3.5	0.785	77.5	98.6	5.7		2.73
NC-SY-7-1	1	7.979E-14	5.518E-13	7.747E-14		3.8	0.862	107.5	124.5	7.2		0.14
NC-SY-7-3	1	5.399E-13	5.653E-13	2.074E-13		5.9	0.851	644.3	750.0	43.5		0.37
POOLED		1.954E-12	1.738E-11	1.769E-11	2.130E-12	6.3	0.862	70.2	81.3	1.2	57.4	1.02
NC-SY-8-1	1	1.470E-13	1.463E-12	2.618E-13		11.5	0.866	74.3	85.7	5.0		0.18
NC-SY-8-2	1	5.706E-14	5.359E-13	7.354E-14		5.0	0.881	79.4	90.0	5.2		0.14
NC-SY-8-3	1	1.595E-13	1.522E-12	2.550E-13		6.3	0.895	77.6	86.6	5.0		0.17
POOLED		3.635E-13	3.521E-12	5.903E-13		7.4	0.881	76.5	86.8	2.0	4.6	0.17
NC-SY-9	1	2.782E-14	1.467E-13	1.485E-12	2.409E-13	11.4	0.794	43.9	55.3	3.2		10.12
NC-SY-9(2)	2	3.144E-14	3.813E-13	1.839E-13		1.1	0.885	57.2	64.6	3.7		0.48
NC-SY-9-3	1	2.411E-14	2.549E-13	9.512E-14		3.5	0.843	67.1	79.5	4.6		0.37
NC-SY-9(1)	2	1.718E-13	1.794E-12	5.464E-13		7.6	0.864	68.9	79.7	4.6		0.30
NC-SY-9-1	1	2.444E-14	1.685E-13	3.383E-13		2.4	0.852	76.5	89.7	5.2		2.01
NC-SY-9-2	1	8.150E-15	6.198E-14	6.276E-14		1.1	0.836	82.1	98.1	5.7		1.01
POOLED		2.878E-13	2.808E-12	2.712E-12	2.409E-13	3.6	0.855	64.6	75.5	1.1	31.5	0.97
NC-SY-10-1	1	4.658E-14	4.136E-13	2.697E-14		6.9	0.823	85.3	103.5	6.0		0.07
NC-SY-10-2	1	2.215E-13	2.195E-12	3.628E-14		10.2	0.890	77.3	86.8	5.0		0.02
NC-SY-10-3	1	1.781E-13	1.650E-12	1.324E-14		16.6	0.872	82.8	94.9	5.5		0.01
NC-SY-10(1)	3	1.974E-13	2.067E-12	4.203E-14		8.2	0.848	73.2	86.2	5.0		0.02
POOLED		6.436E-13	6.326E-12	1.185E-13		10.1	0.867	77.9	89.8	1.9	16.2	0.02
NC-SY-11(1)	3	9.186E-13	7.330E-12	2.639E-12		23.2	0.859	89.0	103.4	6.0		0.36
NC-SY-11(2)	1	5.521E-13	8.058E-15	2.818E-14		0.1	0.892	12307.7	13031.8	755.8		3.50
NC-SY-11 (3)	1	9.638E-14	1.092E-12	1.441E-13	9.076E-13	12.9	0.851	65.7	77.2	4.5		0.13
NC-SY-11 (4)	1	3.448E-14	3.133E-13	9.285E-15	1.020E-12	5.6	0.827	82.7	99.8	5.8		0.03
POOLED		1.049E-12	8.734E-12	2.793E-12	1.928E-12	19.4	0.857	86.0	100.2	2.0	28.5	0.32

NC-SY-12-1	1	7.583E-14	1.981E-13	8.659E-13		11.8	0.773	146.6	189.2	11.0		4.37
NC-SY-12-2	1	1.856E-13	2.779E-13	3.762E-12		12.2	0.838	125.2	149.2	8.7		13.54
NC-SY-12 (3)	1	5.488E-14	1.287E-13	4.718E-13	8.688E-13	8.4	0.757	174.1	229.2	13.3		3.67
NC-SY-12 (4)	1	1.574E-13	2.257E-13	1.242E-12	2.895E-13	20.4	0.746	234.7	313.2	18.2		5.50
POOLED		*3.163E-13*	*6.047E-13*	*5.099E-12*	*8.688E-13*	*11.4*	*0.807*	*136.7*	*169.1*	*7.7*	*80.0*	*8.43*
NC-SY-13 2	1	5.359E-14	6.060E-13	1.106E-13	7.765E-13	4.9	0.865	65.0	75.0	4.4		0.18
NC-SY-13 3	1	1.183E-13	1.274E-12	4.969E-13	1.174E-12	18.1	0.865	65.4	75.5	4.4		0.39
NC SY 13 200(1)	3	3.777E-13	2.906E-12	3.347E-12		7.4	0.885	79.1	89.3	5.2		1.15
NC SY 13 400(1)	1	4.020E-13	3.425E-12	3.233E-13		7.5	0.916	88.3	96.3	5.6		0.09
NC SY 13 200(2)	3	4.671E-13	3.762E-12	9.643E-13		6.0	0.892	90.1	100.9	5.9		0.26
NC SY 13 100(1)	13	8.046E-13	5.973E-12	6.720E-12		20.2	0.795	82.4	103.4	6.0		1.13
NC-SY-13 1	1	8.887E-14	6.952E-13	1.847E-13	9.921E-13	12.9	0.825	92.0	111.3	6.5		0.27
NC SY 13 100(2)	14	9.605E-13	5.854E-12	1.063E-11		20.8	0.790	89.1	112.6	6.5		1.82
NC SY 13 180(1)	4	1.991E-12	1.189E-11	8.078E-12		24.2	0.877	111.1	126.6	7.3		0.68
NC SY 13 180(2)	5	1.058E-12	5.776E-12	5.902E-12		12.0	0.867	113.9	131.1	7.6		1.02
POOLED		*6.321E-12*	*4.216E-11*	*3.676E-11*	*2.943E-12*	*13.2*	*0.853*	*96.0*	*112.4*	*1.9*	*38.2*	*0.87*
NC-SY-14a 1	1	2.295E-13	1.217E-12	2.566E-12	2.792E-12	53.6	0.786	96.9	123.1	7.1		2.11
NC-SY-14	1	2.577E-13	1.604E-12	8.089E-13	2.574E-12	39.2	0.808	109.7	135.4	7.9		0.50
NC SY 14A	7	2.035E-12	8.810E-12	1.307E-11		18.2	0.854	132.1	154.4	9.0		1.48
NC-SY-14	1	1.505E-14	7.636E-14	3.714E-14	1.386E-12	2.9	0.783	125.5	159.9	9.3		0.49
NC-SY-14a 3	1	8.114E-14	2.552E-13	6.974E-13	2.659E-13	4.0	0.824	149.3	180.8	10.5		2.73
NC SY 14B	3	9.699E-13	3.318E-12	4.576E-12		18.8	0.838	169.7	202.0	11.7		1.38
NC-SY-14a 2	1	1.508E-13	5.637E-13	1.317E-13	1.710E-12	9.1	0.858	190.6	221.5	12.8		0.23
POOLED		*3.739E-12*	*1.584E-11*	*2.189E-11*	*8.728E-12*	*18.0*	*0.841*	*137.0*	*162.5*	*4.8*	*70.8*	*1.38*
Southern Appalachians - Hornbuckle Creek												
H4	1	2.994E-14	4.443E-13	3.320E-14	1.176E-12	16.0	0.814	50.4	61.9	3.6		0.07
H4	1	4.792E-14	6.008E-13	2.624E-14	1.585E-12	8.3	0.843	60.1	71.2	4.1		0.04
H4	5	8.445E-14	1.030E-12	8.663E-14	2.570E-12	9.1	0.776	61.2	78.8	4.6		0.08
H4	1	4.095E-14	4.221E-13	1.107E-13	1.157E-12	15.0	0.816	69.6	85.1	4.9		0.26
H4	5	1.319E-13	1.371E-12	8.498E-14	3.459E-12	10.1	0.782	72.1	92.0	5.3		0.06
H4	1	5.476E-14	3.516E-13	2.926E-14	9.673E-13	11.8	0.783	115.6	147.2	8.5		0.08
H4	1	6.240E-14	3.561E-13	2.215E-14	2.825E-13	8.9	0.835	131.7	157.4	9.1		0.06
POOLED		*4.524E-13*	*4.576E-12*	*3.932E-13*	*1.120E-11*	*10.3*	*0.799*	*73.7*	*92.1*	*1.5*	*75.4*	*0.09*
H8	1	5.197E-14	6.565E-13	3.208E-14	1.488E-12	13.3	0.846	59.6	70.4	4.1		0.05
H8	1	1.511E-13	1.396E-12	6.854E-15	2.087E-12	27.7	0.847	82.5	97.2	5.6		0.00
H8	1	1.453E-14	1.328E-13	1.151E-14	1.322E-13	3.9	0.798	82.1	102.7	6.0		0.09
H8	5	3.615E-13	2.025E-12	4.908E-13	1.392E-12	12.2	0.801	129.1	160.7	9.3		0.24
H8	5	7.374E-13	2.849E-12	9.058E-13	2.882E-12	17.9	0.802	183.0	227.2	13.2		0.32
H8	1	9.627E-14	5.496E-13	8.202E-14	1.388E-13	18.5	0.790	129.5	163.4	9.5		0.15
H8	1	2.038E-13	1.148E-12	3.548E-13	1.337E-12	38.6	0.783	126.3	160.8	9.3		0.31
H8	1	2.765E-14	2.771E-13	5.866E-14	1.992E-13	11.8	0.773	73.0	94.2	5.5		0.21
POOLED		*1.644E-12*	*9.034E-12*	*1.943E-12*	*9.657E-12*	*16.7*	*0.803*	*132.1*	*164.0*	*4.4*	*104.1*	*0.22*
H9	1	1.678E-14	1.733E-13	3.983E-13	2.443E-13	5.9	0.834	48.7	58.3	3.4		2.30
H9	1	3.554E-13	2.144E-12	1.222E-12	8.313E-13	30.8	0.846	112.3	132.5	7.7		0.57

H9		1	6.963E-13	3.224E-12	6.495E-13	1.229E-12	51.8	0.827	157.4	189.7	11.0		0.20
H9		5	4.106E-13	2.826E-12	6.201E-13	1.335E-12	14.9	0.796	105.9	132.7	7.7		0.22
H9		5	2.723E-13	2.070E-12	6.253E-13	1.134E-12	5.0	0.807	94.3	116.6	6.8		0.30
H9		1	5.226E-14	3.306E-13	8.202E-14	1.246E-13	11.6	0.789	114.5	144.7	8.4		0.25
H9		1	6.931E-14	4.478E-13	1.059E-13	2.157E-13	10.6	0.814	112.3	137.7	8.0		0.24
H9		1	2.096E-13	1.407E-12	1.061E-12	3.590E-13	35.8	0.814	97.4	119.5	6.9		0.75
	POOLED		*2.082E-12*	*1.262E-11*	*4.764E-12*	*5.472E-12*	*14.4*	*0.819*	*116.2*	*141.6*	*3.3*	*72.8*	*0.38*
H11		1	3.249E-14	2.005E-13	4.613E-14	2.854E-13	3.4	0.856	117.2	136.7	7.9		0.23
H11		1	3.178E-14	1.515E-13	1.269E-13	1.851E-13	2.7	0.836	134.1	160.0	9.3		0.84
H11		1	1.496E-14	6.757E-14	1.919E-14	1.145E-13	2.0	0.799	157.5	196.4	11.4		0.28
H11		5	1.780E-13	1.230E-12	1.924E-13	1.088E-12	5.6	0.816	106.7	130.5	7.6		0.16
H11		5	9.492E-14	5.581E-13	1.061E-13	7.356E-13	3.9	0.803	124.1	154.1	8.9		0.19
H11		1	2.346E-14	9.575E-14	2.659E-14	2.002E-13	2.4	0.804	174.0	215.6	12.5		0.28
H11		1	8.211E-14	2.620E-13	8.680E-14	3.304E-13	4.0	0.837	220.0	261.9	15.2		0.33
	POOLED		*3.756E-13*	*2.304E-12*	*5.173E-13*	*2.609E-12*	*4.2*	*0.816*	*118.2*	*144.5*	*4.0*	*67.4*	*0.22*
H12		1	4.991E-14	4.148E-13	2.068E-14	9.105E-13	27.2	0.773	90.4	116.7	6.8		0.05
H12		1	3.518E-13	2.424E-12	4.853E-14	4.677E-12	30.9	0.868	109.7	126.2	7.3		0.02
H12		1	1.639E-13	1.072E-12	2.989E-13	1.574E-12	12.1	0.854	109.4	127.9	7.4		0.28
H12		1	1.965E-13	1.361E-12	2.771E-14	2.221E-12	35.2	0.833	109.3	130.9	7.6		0.02
H12		6	4.901E-13	3.287E-12	2.071E-13	5.592E-12	18.1	0.807	111.8	138.2	8.0		0.06
H12		1	2.604E-13	1.446E-12	2.052E-14	3.314E-12	10.5	0.872	135.8	155.4	9.0		0.01
H12		6	7.274E-13	2.922E-12	6.379E-13	5.374E-12	18.3	0.796	179.2	224.2	13.0		0.22
H12		1	5.648E-13	1.861E-12	2.842E-14	3.250E-12	29.4	0.858	227.4	264.2	15.3		0.02
	POOLED		*2.240E-12*	*1.293E-11*	*1.261E-12*	*2.366E-11*	*18.4*	*0.824*	*128.6*	*155.6*	*4.4*	*73.3*	*0.10*
CH01		1	1.991E-13	9.474E-13	2.075E-13	7.036E-12	5.1	0.885	147.7	166.6	9.7		0.22
CH01		1	2.633E-13	1.636E-12	8.202E-13	6.585E-12	15.6	0.858	108.8	126.6	7.3		0.50
CH01		5	3.947E-13	2.604E-12	1.402E-12	1.248E-11	13.8	0.819	101.4	123.6	7.2		0.54
CH01		5	5.793E-13	4.287E-12	1.327E-12	2.025E-11	10.5	0.881	94.8	107.5	6.2		0.31
CH01		1	8.136E-14	6.706E-13	1.654E-13	3.784E-12	13.7	0.810	86.0	105.9	6.1		0.25
CH01		1	4.648E-13	1.236E-12	4.071E-13	7.079E-12	18.0	0.835	257.8	307.4	17.8		0.33
	POOLED		*1.617E-12*	*1.098E-11*	*4.316E-12*	*5.377E-11*	*10.8*	*0.857*	*101.4*	*118.2*	*2.7*	*94.1*	*0.39*
ZIRCON													
NC-SY-8		1	2.731E-12	8.985E-12	7.288E-12		274.3	0.797	195.3	244.1	34.6		0.81
NC-SY-8		1	6.134E-12	2.106E-11	3.754E-12		354.1	0.826	212.6	256.4	38.1		0.18
	POOLED		*8.865E-12*	*3.004E-11*	*1.104E-11*		*323.2*	*0.817*	*207.0*	*252.4*	*20.4*	*17.4*	*0.37*
NC-SY-10		1	3.884E-12	1.616E-11	3.923E-12		186.5	0.852	173.6	203.2	24.0		0.24
NC-SY-10		1	5.071E-12	2.051E-11	2.346E-12		344.5	0.830	183.5	220.4	28.2		0.11
	POOLED		*8.955E-12*	*3.667E-11*	*6.269E-12*		*249.8*	*0.839*	*179.1*	*212.7*	*14.5*	*24.2*	*0.17*

NOTES

General

* Uncertainties are calculated using our lab's long-term reproducibility of the Durango apatite age standard, 2s = 5.8%

For pooled ages, lowered uncertainties reflect propagation of component uncertainties through summing of measured quantities.

[#] Analytical Scatter - Is a simple 2-sigma standard deviation of measured ages, given as a measure of scatter in the component analyses for the pooled age.

[§] eU - Values calculated by using Ft factor to determine effective spherical radius to model mass of sample analyzed. Uncertainties of 25% apply.

For Pooled Ages
Any analyses older than 250 Ma were rejected from pooled age (Gray Text)
Pooled Ft value determined as weighted average, using He concentrations as weights
Pooled ages determined using alpha correction applied to He abundance, before age calcuLation
eU values on pooled ages are for comparison purposes only, as kinetics of component grains could be quite varied and will be non-linear.

Figure DR1 - McKeon et al.

Supplemental Figure - Direct evidence of U and Th zonation

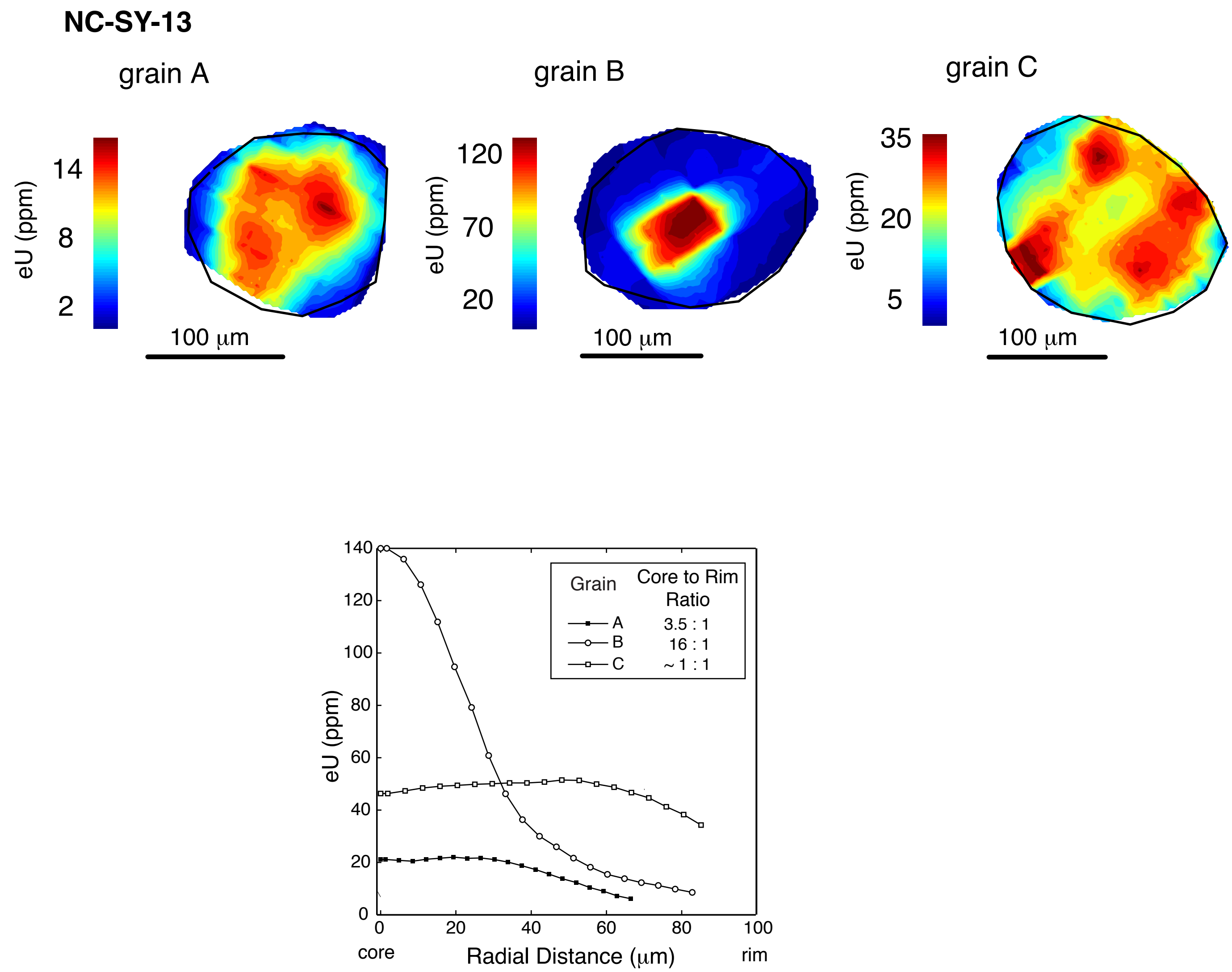

Figure DR2 - McKeon et al.

Supplemental Figure - Exponential Regressions of RDAAM Fowards Models

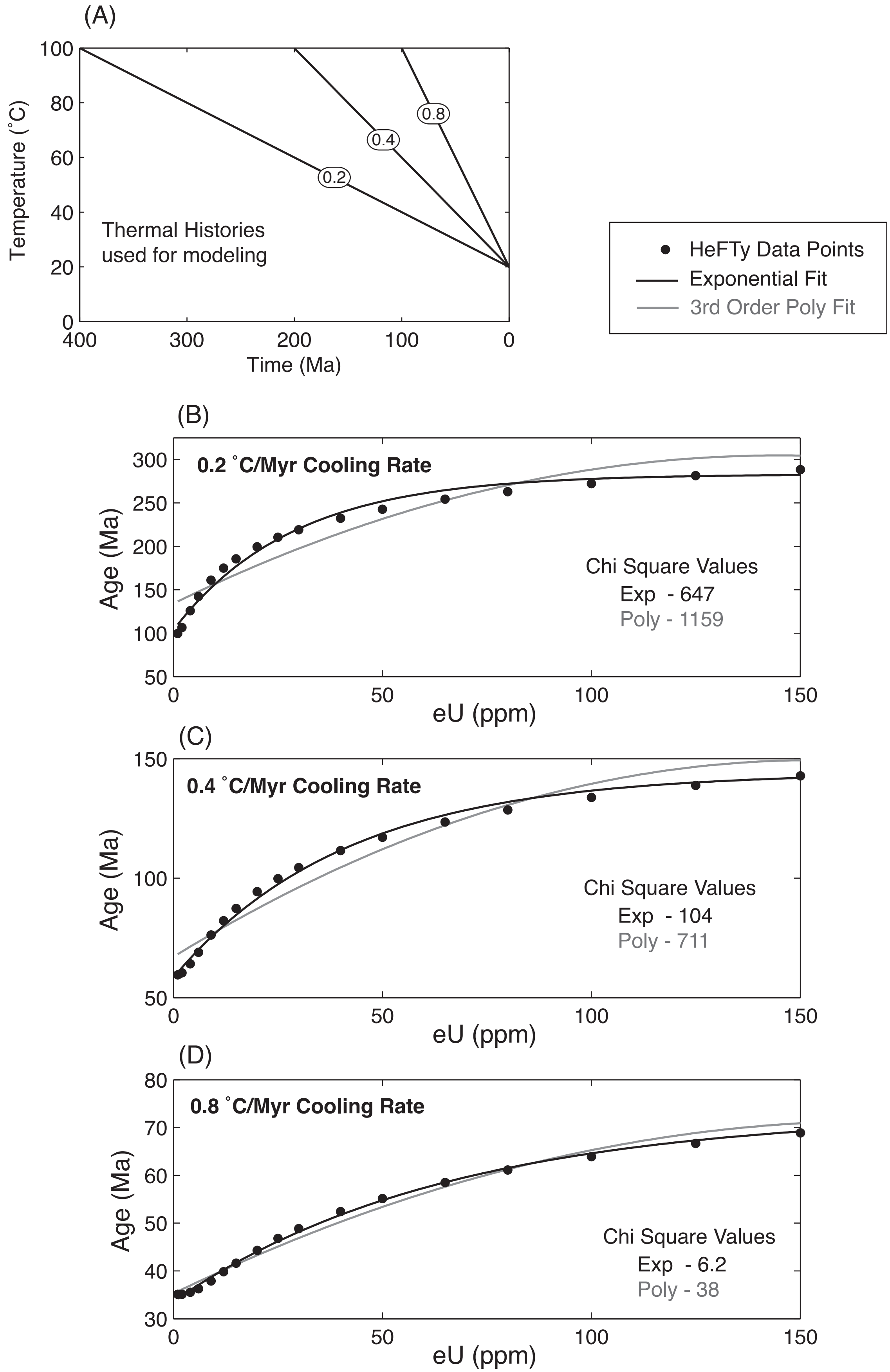

Figure DR3 - McKeon et al.

Supplemental Figure - Modeling the effects of zonation and abrasion