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Supplement of

Combined linear-regression and Monte Carlo approach to modeling exposure age depth profiles

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S1. Simulated CN depth profiles

Our simulation process is conducted with following steps:

1. For each scenario, we first produce an ideal depth profile based on given exposure age, inheritance, production rate, attenuation, density, etc.
2. Next, we produce a suite of simulated depth profiles with each sample deviated from the true value based on an imposed error distribution which defined as “deviation of sample concentration. In addition, an independent analytical uncertainty is also assigned for each sample. The mean of the sample depth is the same as the true value; but an uncertainty is assigned for each sample depth. The remaining parameters (density, production rate, attenuation) are the same as the ideal profile, with no imposed uncertainty.
3. For each profile within the suite, we estimate the exposure age and inheritance based on the samples generated in step 2, using both least-squares linear regression and forward modeling (Bayesian Monte Carlo) approaches.
4. From the analysis suite we compare the resulting distributions of the estimated age and inheritance using both methods with the true value and with each other.

S1.1 Deviation of sample concentrations

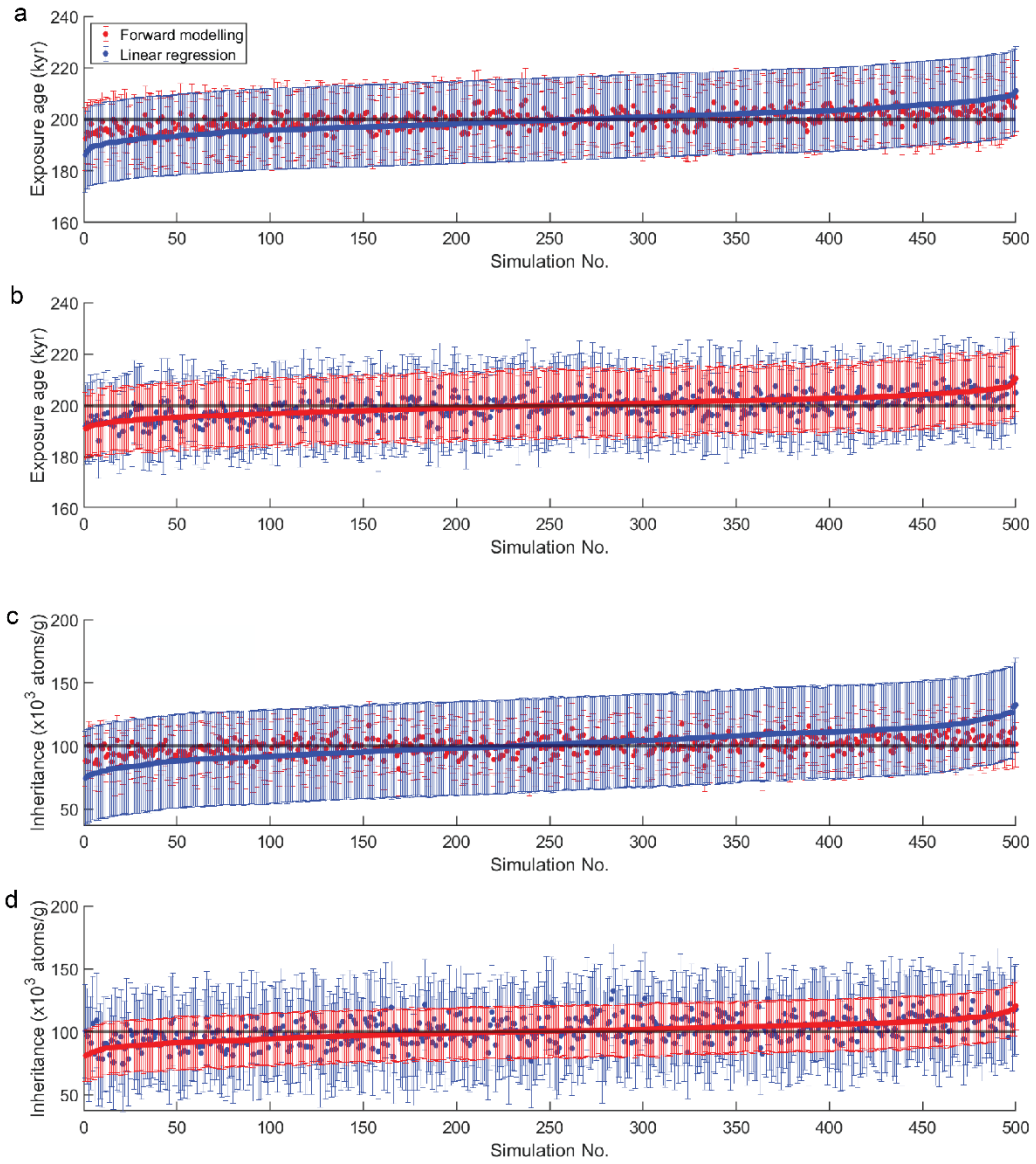

Figure S1 Distributions of age (a and b) and inheritance (c and d) estimation results for 500 simulated CN profiles with 2% imposed deviation of sample concentration. a. Distribution of exposure age, sorted by mean age estimated from linear regression (eq. 4). b. Distribution of exposure age, sorted mean age estimated using a forward approach. c. Distribution of inheritance, sorted by mean inheritance estimated from linear regression (eq. 4). d. Distribution of inheritance, sorted by mean inheritance estimated using a forward approach.

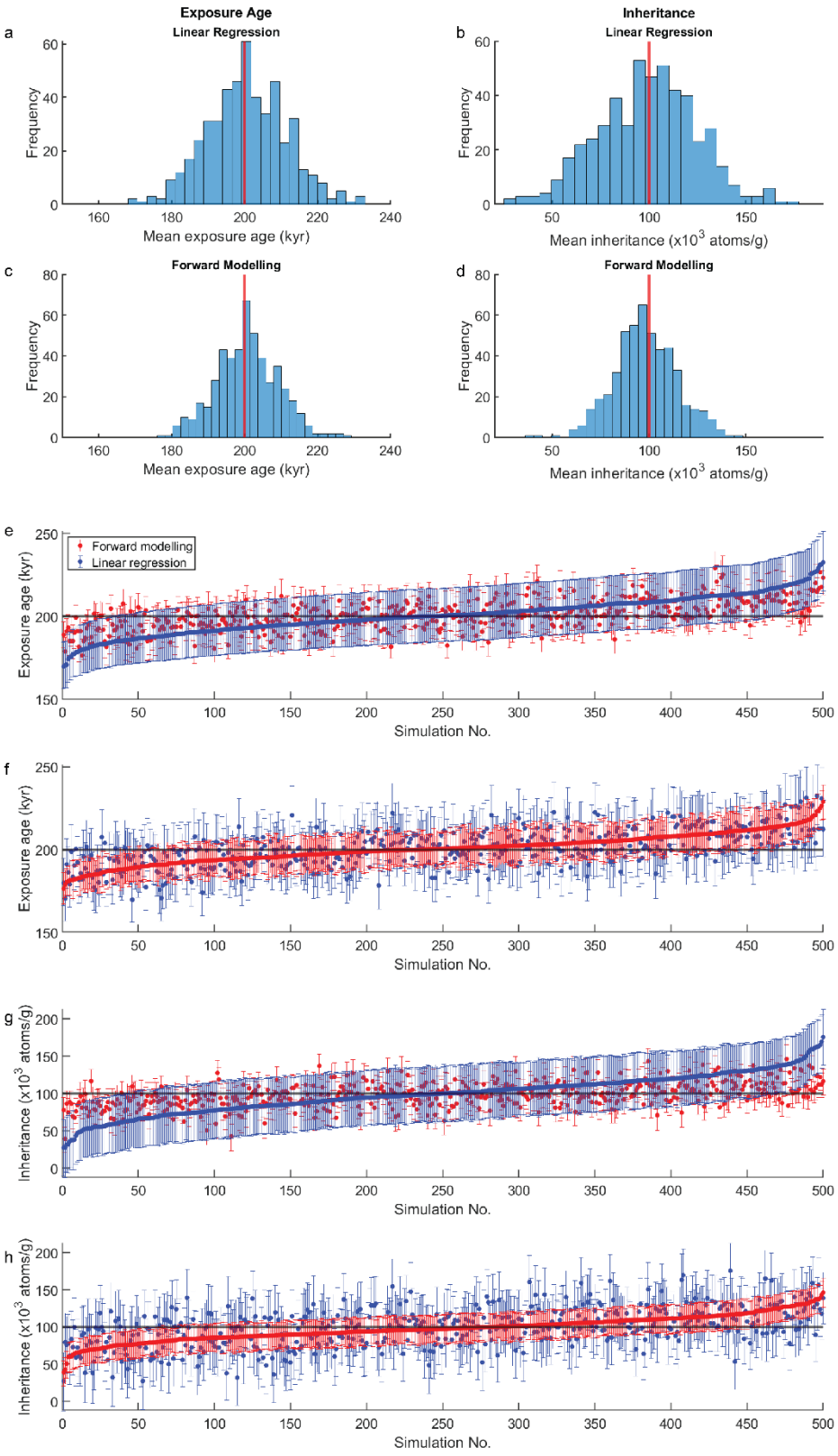

Figure S2 Distribution of age (a, b, e, f) and inheritance (c, d, g, h) estimation results for 500 simulated CN profiles with 5% imposed deviation of sample concentration. a. and b. Histogram of the mean exposure age estimated from linear regression and a forward approach. c. and d. Histogram of mean inheritance estimated from linear regression a forward approach. e. Distribution of exposure age, sorted by mean age estimated from linear regression (eq. 4). f. Distribution of exposure age, sorted mean age estimated using a forward approach. g. Distribution of inheritance, sorted by mean inheritance estimated from linear regression (eq. 4). h. Distribution of inheritance, sorted by mean inheritance estimated using a forward approach.

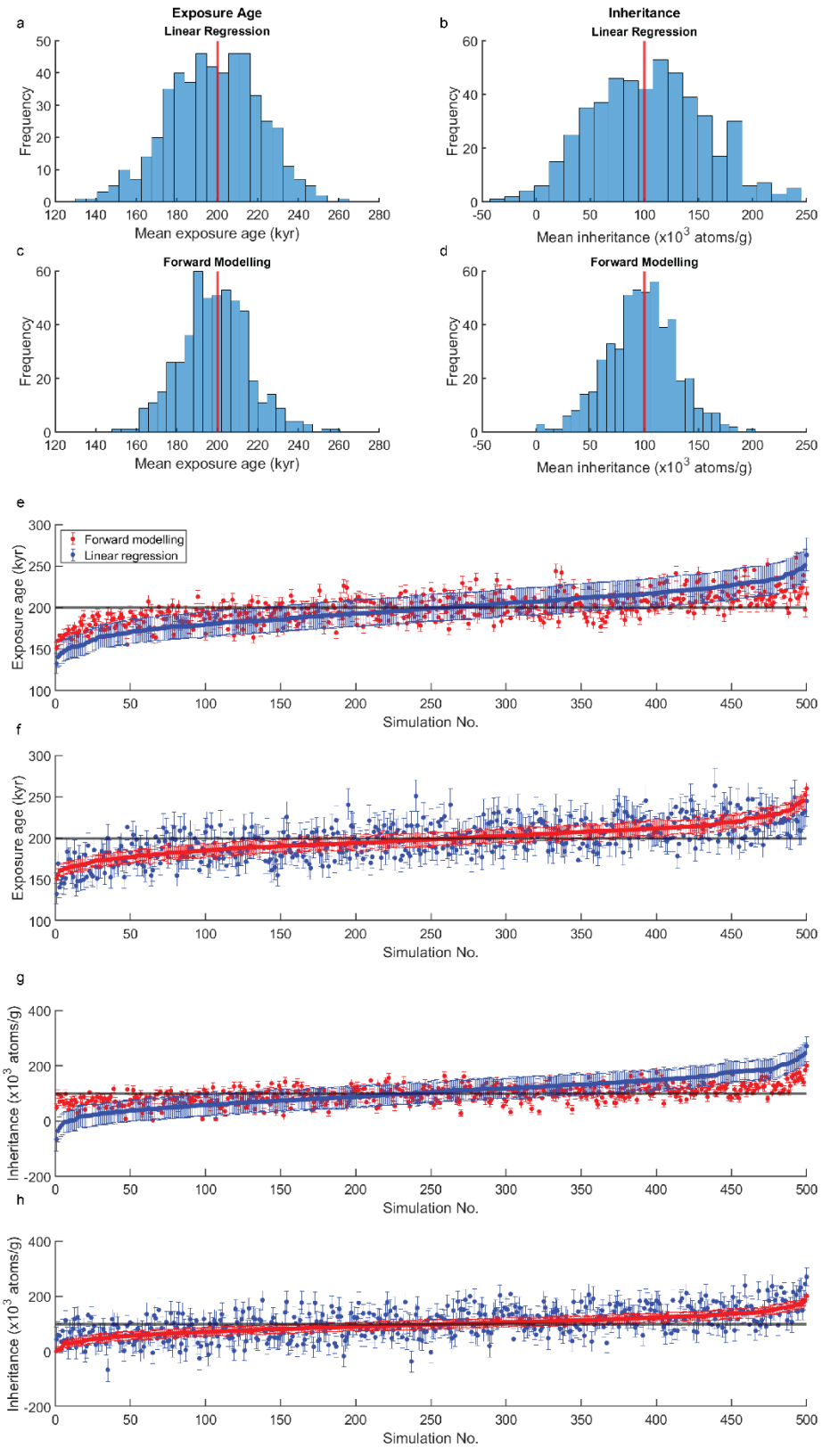

Figure S3 Distribution of age (a, b, e, f) and inheritance (c, d, g, h) estimation results for 500 simulated CN profiles with 10% imposed deviation of sample concentration. a. and b. Histogram of the mean exposure age estimated from linear regression and a forward approach. c. and d. Histogram of mean inheritance estimated from linear regression a forward approach. e. Distribution of exposure age, sorted by mean age estimated from linear regression (eq. 4). f. Distribution of exposure age, sorted mean age estimated using a forward approach. g. Distribution of inheritance, sorted by mean inheritance estimated from linear regression (eq. 4). h. Distribution of inheritance, sorted by mean inheritance estimated using a forward approach.

S1.2 Denudation depth

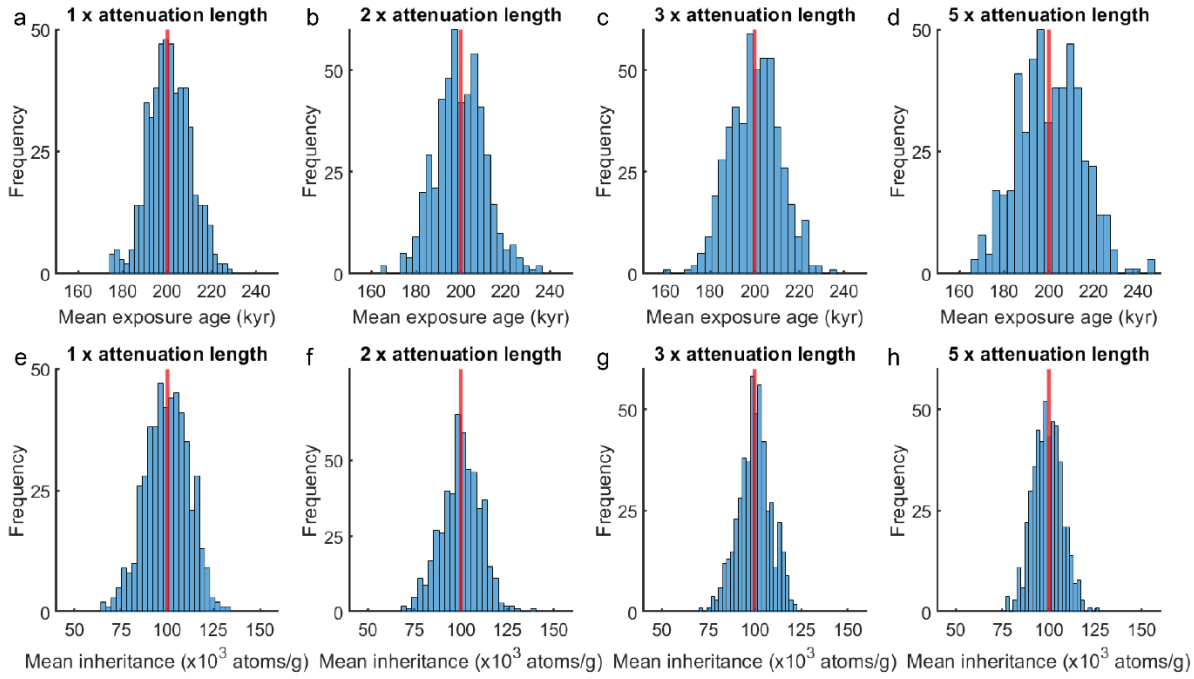

Figure S4 Distribution of mean exposure age (a-d) and inheritance (e-h) estimated from a forward approach for 500 simulated (5000 atoms/g) CN profiles with 5% imposed deviation of sample concentration and with total denudation equals to 1 (a and e), 2 (b and f), 3 (c and g) and 5-times (d and h) attenuation length of spallation. Red vertical line annotates the true age and true inheritance.

S1.3 Deep sample profile

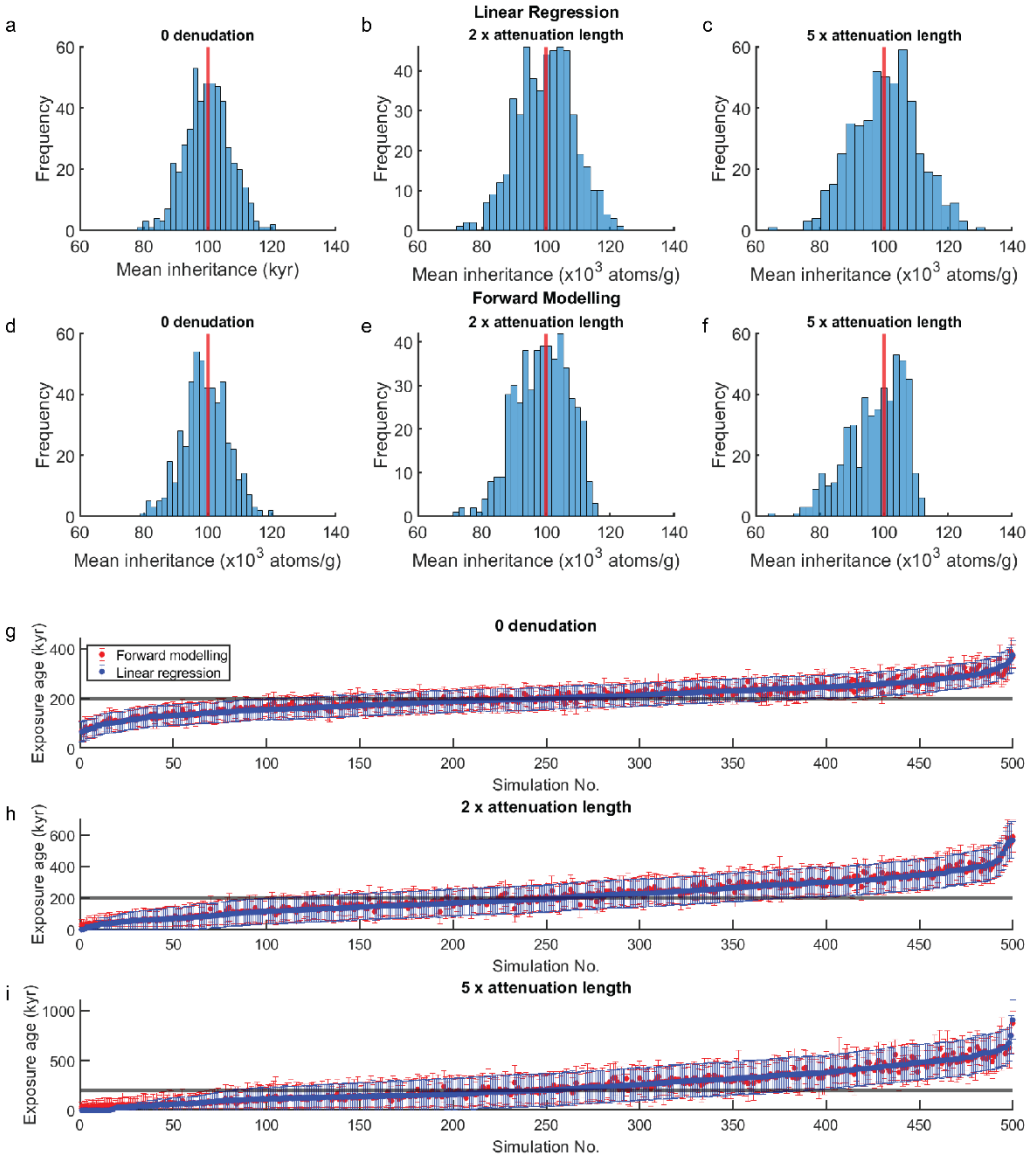

Figure S5 Distribution of estimation results from linear regression and a forward approach for 500 simulated CN deep (3-5 m) profiles with denudations equal to 0 (a, d, g), 2 (b, e, h), and 5-times (c, f, i) attenuation length, and with 5% imposed deviation of sample concentration. 500 groups of inversion results. a-f. Histograms of the mean inheritance estimated from linear regression (a-c) and a forward approach (d-f). g-h. Distribution of exposure age, sorted by mean age estimated from linear regression.

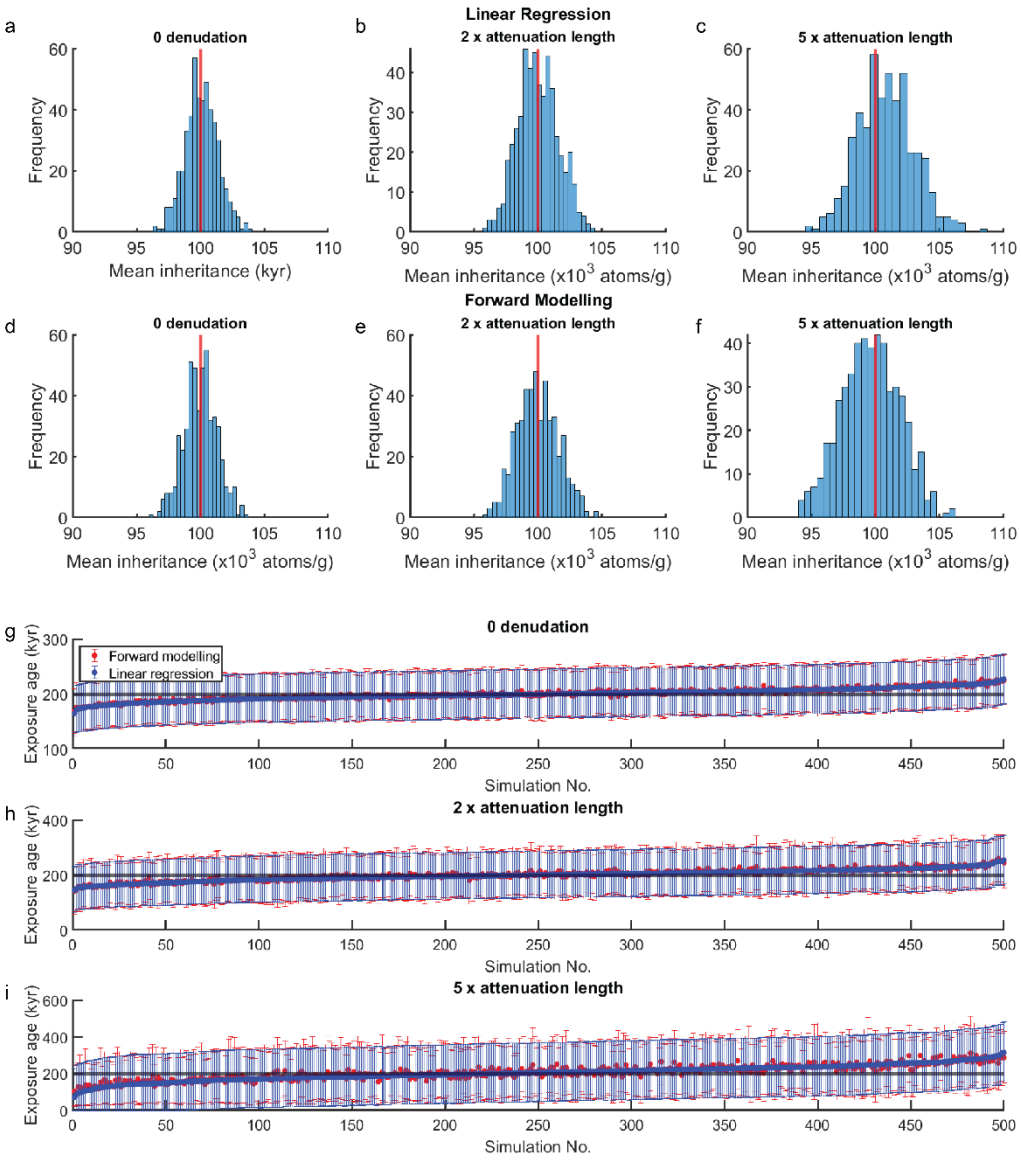

Figure S6 Distribution of estimation results from linear regression and a forward approach for 500 simulated CN deep (3-5 m) profiles with denudations equal to 0 (a, d, g), 2 (b, e, h), and 5-times (c, f, i) attenuation length, and with 1% imposed deviation of sample concentration. 500 groups of inversion results. a-f. Histograms of the mean inheritance estimated from linear regression (a-c) and a forward approach (d-f). g-h. Distribution of exposure age, sorted by mean age estimated from linear regression.

S2. Case Examples

Table S1 ^{10}Be concentration and the production rate at each sample depth for the two sample sites.

Beida River Terrace (Wang et al., 2020)			Lees Ferry Terrace (Hidy et al, 2010)		
Sample ID	^{10}Be Concentration; C_1[1] (10^5 atoms/g)	P_{zn} (atoms/(g×yr))	Sample ID	^{10}Be Concentration (10^5 atoms/g)	P_{zn} (atoms/(g×yr))
BT2-2-20	14.33 ± 0.39	13.82 ± 0.91	GC-04-LF-404.30s	5.69±0.17	6.35 ± 0.48
BT2-2-45	9.84 ± 0.36	9.94 ± 0.65	GC-04-LF-404.60s	4.07±0.11	4.09 ± 0.48
BT2-2-75	5.68 ± 0.23	6.69 ± 0.44	GC-04-LF-404.100s	2.92±0.09	2.27 ± 0.39
BT2-2-110	4.09 ± 0.21	4.22 ± 0.28	GC-04-LF-404.140s	2.03±0.06	1.26 ± 0.29
BT2-2-150	2.96 ± 0.11	2.84 ± 0.19	GC-04-LF-404.180s	1.57±0.05	0.7 ± 0.2
BT2-2-180	2.63 ± 0.08	1.68 ± 0.11	GC-04-LF-404.220s	1.34±0.04	0.39 ± 0.13

1 C1 is the concentration prior to the onset of loess accumulation, following the approach introduced by Hetzel et al., (2004).

Table S2 Values for parameters used in exposure age calculation.

Parameter	Values (Wang et al., 2020)	Values (Hidy et a., 2010)
Surface production rate (nucleon-negative muon-fast muon) (atom/(g×yr))	23.4, 0.0958, 0.0413 [1]	9.51, 0. 0596, 0.0314 [2]
Density (g/cm^3)	2.2	2.2-2.5 (uniform distribution)
Attenuation (nucleon- negative muon-fast muon) (g/cm^2)	167, 873, 2125 [1]	160±5, 1070, 2434 [2]
Eroded thickness (cm)	40±10 (normal distribution)	0-30 (uniform distribution)

1 The production rate for nucleon is calculated based on the "LSD" scaling scheme (Lifton et al., 2014), the production rates and attenuation length for negative and fast muons are approximated from the site-specific muon production rate at depth using model 1B from Balco, 2017.

2 5-term approximation for muogenic production is applied in the original paper, here we use a 2-term exponential approximation calculated using model 1B from Balco, 2017.