Tectonics

Supporting Information for

Differential exhumation of the Eastern Cordillera in the Central Andes: Evidence for south-verging backthrusting (Abancay Deflection, Peru)

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** Now at GET, Université de Toulouse, CNRS, IRD, UPS, (Toulouse), France.*

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Introduction

This document includes extra-information regarding thermochronological ages (AHe & AFT) computation and details about the 2D and 3D modeling (2D time-temperature modeling outputs (QTQt; Gallagher, 2012) and 3D thermo-kinematic modeling results (Pecube; Braun, 2003; Braun et al., 2012)). We collected 33 samples into crystalline bedrock trough five high-altitudinal profiles (Ocobamba, Lucma, Incahuasi, Abancay and Limatambo) and 4 individual samples over the Abancay Deflection (Figure S44). The field trip took place between April and June 2016. The AHe (Table S2) and AFT (Figures S1-S27) analyses were performed respectively at GEOPS laboratory (Université Paris Saclay, France) and ISTerre laboratory (University Grenoble Alpes, France). Computed age uncertainties are available in the data tables (main article text). Additionally, we provide 8 videos (Movies S1-S8) presenting the tectono-morphic evolution (topography, exhumation rates and surface thermochronological ages evolution) of the southern and northern Abancay Deflection according to the best-fitting Pecube modeling outcomes (discussion in the main article text). For each modeled crustal blocks, we provide graphics exhibiting observed data vs. predicted ones for validation of Pecube 3D modeling (Figures S41-S42). Modeling outcomes are all compared to age-elevation relationships and QTQt modeling (Table S1 and Figures S28-S37) to derive the exhumation histories of studied areas (Figure S43).

Text S1. Present-day geothermal gradient computation for the Abancay Deflection

Using the simplified heat equation from Braun et al. (2006), we estimated the geothermal gradient for the Abancay Deflection.

List of parameters:
$T_{surface}$: Temperature at the surface (K; °C)
T_{bottom}: Temperature at the base of the crust (K; °C)
zc: Crustal depth (km)
κ: Thermal diffusivity (km^2/Ma)
H: Heat production for the crust (K/Ma)
ρ: Density of the crust (kg/m^3)
c: Specific heat capacity (J/kg/K)

Processed values for these parameters are displayed in the Table S3.

We firstly computed the thermal conductivity (k; Equation 1) and the heat production rate (A; Equation 2):

$$k = \kappa \times \rho \times c \quad (1)$$

$$A = (H \times \rho \times c) \times 10^6 \quad (2)$$

k: Thermal conductivity (W/m/K)

A: Heat production rate (μW/m^3)

We then obtained the heat flow (q0; Equation 3; mW/m^2).

$$q0 = \left(\left(\frac{(Tbottom - Tsurface) \times k}{zc \times 10^3}\right) + ((A \times (zc \times 10^3))\right) \times 10^3 \qquad (3)$$

From this computed heat flow, we computed a temperature at z km-depth (Tz; Equation 4; °C):

$$Tz = Tsurface + \left(\frac{q0 \times z \times 10^3}{k}\right) - \left(\left(\frac{A}{2 \times k}\right) \times (z \times 10^3)^2\right) \qquad (4)$$

We finally approximate the geothermal gradient (G; °C/km) performing the following average (Equation 5):

$$G = \frac{(Tz - Tsurface)}{z} \qquad (5)$$

For example using these values:

$T_{surface}$ = 298,15 K (25°C)
T_{bottom}: 833,15 K (560°C)
zc: 56 km
κ: 40 km^2/Ma → 1.26 ×10^{-6} m^2/s
H: 279,15 K/Ma → 2.04 ×10^{-13} °C/s
ρ: 2750 kg/m^3
c: 800 J/kg/K

$$k = 1.26 \times 10^{-6} \times 2750 \times 800 = 2.79\ W/m/K$$

$$A = (2.04 \times 10^{-13} \times 2750 \times 800) \times 10^6 = 0.45\ \mu W/m^3$$
$$A = 4.48 \times 10^{-7}\ W/m^3$$

$$q0 = \left(\left(\frac{(560 - 25) \times 2.79}{56 \times 1000}\right) + \left(4.48 \times 10^{-7} \times (56 \times 1000)\right)\right) \times 1000 = 51.74\ mW/m^2$$
$$q0 = 5.17 \times 10^{-2}\ W/m^2$$

$$T_5 = 25 + \left(\frac{5.17 \times 10^{-2} \times 5 \times 1000}{2.79}\right) - \left(\left(\frac{4.48 \times 10^{-7}}{2 \times 2.79}\right) \times (5 \times 1000)^2\right) = 115.76°C$$

$$G = \frac{(115.76 - 25)}{5} = \mathbf{18°C/km}$$

Text S2. Neighborhood Algorithm (NA) inversions with Pecube

We used Pecube in inverse mode to quantitatively constrain parameter values (tectono-morphic scenarios; Figures S38 and Tables S3-S4) that best reproduce the input thermochronological data. Pecube uses the implemented Neighborhood Algorithm (NA; Sambridge, 1999a;b), which explores the parameter space by progressive misfit minimization and permits to rapidly converge toward a best-fitting tectono-morphic scenario. The Misfit function (Equations 6 and 7) measures the difference between observed and predicted data, with three different parts: the thermochronological ages (M1; Equation 6), the fission track-length distributions (Kuiper test for comparison between observed and predicted track-length distributions) and the thermal history (M2: Equation 7):

$$M1 = \sqrt{\sum_{i=0}^{N1} \frac{(A_o^i - A_p^i)^{2/dA_i^2}}{N1}} \qquad (6)$$

With A_o, the observed thermochronological ages, dA, the analytical error, A_p, the predicted ages from Pecube and N1 the total number of implemented ages.

$$M2 = \sqrt{\sum_{i=0}^{N2} \frac{(T_o^i - T_p^i)^{2/dT_i^2}}{N2}} \qquad (7)$$

For the thermal histories, T_o is the implemented temperature derived from QTQt, dT is the error of these temperatures (95% reliability; QTQt; Gallagher, 2012), T_p is the predicted temperature by Pecube and N2 is the total number of steps defining the thermal history. More details regarding the misfit functions are available in the Pecube user guide on GitHub following this link: https://github.com/jeanbraun/Pecube.

Text S3. Limitation for fault geometry at the surface with Pecube

Implementation of complex fault systems cannot be modeled with Pecube because of geometrical and fault-velocity computational issues. Although the Apurimac fault system trace at the surface is curved (x/y axis; Figure 2), we approximate it in Pecube by a straight and oblique fault separating the Altiplano from the Eastern Cordillera. The geometry of the fault at depth (z axis) is explored with PECUBE and discussed in the manuscript.

Text S4. Topography / relief inversed with Pecube – non convergent parameters

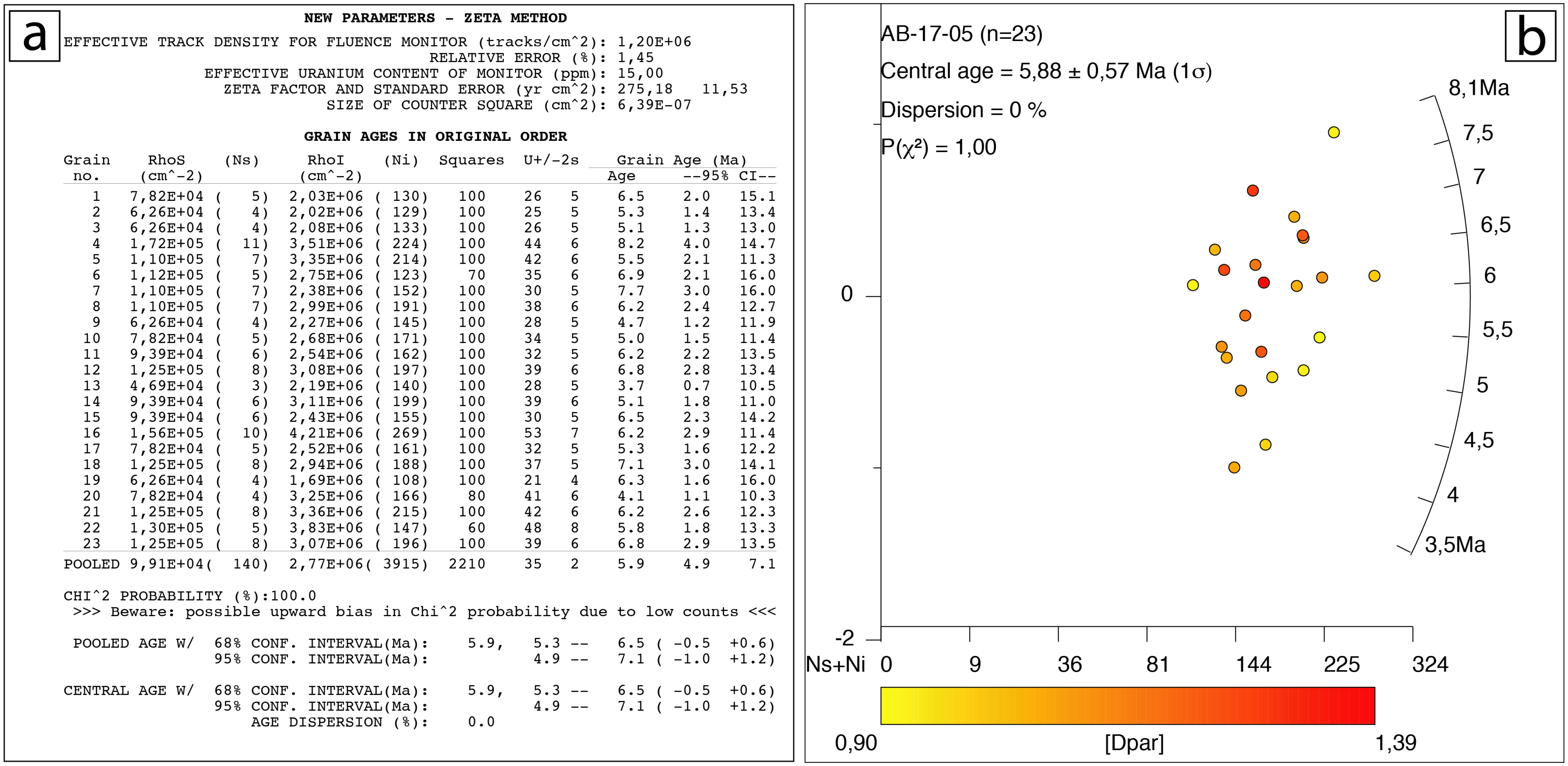
The relief amplification factor did not converge during PECUBE inverse modeling and cannot be quantified for the Altiplano and the Eastern Cordillera (Figures S39 and S40). We notwithstanding further explored this parameter through forward modeling to assess to what extent it is needed for our thermochronological data. Trial-and-error approach using PECUBE forward models suggests an increase in topographic relief between 10 and 0 Ma to reproduce accurately the observed thermochronological data (although this parameter is not a first order control on the exhumation history). Since the relief-amplification factor can be interpreted as a proxy for incision, we linked this needed relief increase to the large-scale capture of the Abancay Deflection system by the Urubamba and Apurimac drainage network (Gérard et al. in press) and subsequent incision since ~10 Ma. From our thermochronological record and literature data interpretation (van Heiningen et al., 2005; Gérard et al., in press), we further propose that the capture of the Abancay Deflection likely occurred during the late Miocene/early Pliocene around ~5 Ma and that associated erosion started slightly after.

Text S5. Pecube outcomes imposing a warmer geothermal gradient (30°C/km)

To test the robustness of our computed geothermal gradient for the Abancay Deflection (~20°C/km), which is crucial for exhumation computation, we performed the same inversion as presented in the manuscript for both the Altiplano and the Eastern Cordillera model with identical parameters except for the geotherm, imposing a warmer geothermal gradient of 30°C/km as compiled and accepted for the Bolivian Eastern Cordillera (Barnes et al., 2008).

For the Altiplano block model, we explored exhumation rates for the entire crustal block between 40 Ma to present-day for values ranging from -10 to 10 km/m.y (subsidence vs. exhumation). This parameter nicely converge to 0.45±0.10 km/m.y. (Figure S45a). Processing this best-fitting rate into forward modeling we observed that, counter intuitively, even if the geothermal gradient is warmer, the area needs twice exhumation rather than if a colder geothermal gradient is used (0.2±0.1 km/m.y. with a gradient of 18°C/km). Ages and T-t paths are less reproducible and predicted thermochronological ages are, in most of the cases, younger than the observed data (Figure S45b and c). Consequently, the ~20°C/km geotherm seems to be the most suitable gradient for this part of the Altiplano.

For the Eastern Cordillera black model, we explored exhumation rates for the entire crustal block between 50 Ma to present-day for values ranging from 0 to 5 km/m.y. At the same time, we inverted the timing for the Apurimac fault system activation (between 0 and 14 Ma) and the fault velocity (0 to 10 km/m.y.). These three parameters nicely converge to values of 0.2±0.1 km/m.y. (Figure S46a), 7±1 Ma and 1.4±0.4 km/m.y. respectively (Figure S46b). Exhumation rate for the entire crustal block with this warmer geotherm is identical with the one obtained with the 18°C/km gradient. The timing for faulting initiation is quite similar too (7±1 Ma vs. 5±2 Ma). The fault velocity is, however, divided by ~2 (1.4±0.4 km/m.y. (30°C/km) vs. 2.9±0.6 (18°C/km)), which is quite logical as the geothermal gradient is multiplied by ~2. Whatever the geothermal gradient imposed, tectonic is needed through the Apurimac fault system to reproduce the thermochronological ages (Figure S46c and d). The data reproducibility is, nevertheless, lower with the warmer geotherm and predicted ages are older than observed ones (Figure S46c), especially for the AHe system. The ~20°C/km geotherm, in that case, seems to be the most suitable gradient for this part of the Eastern Cordillera.



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                      NEW PARAMETERS - ZETA METHOD
EFFECTIVE TRACK DENSITY FOR FLUENCE MONITOR (tracks/cm^2): 1,20E+06
                                       RELATIVE ERROR (%): 1,45
               EFFECTIVE URANIUM CONTENT OF MONITOR (ppm): 15,00
                 ZETA FACTOR AND STANDARD ERROR (yr cm^2): 275,18   11,53
                            SIZE OF COUNTER SQUARE (cm^2): 6,39E-07

                      GRAIN AGES IN ORIGINAL ORDER

Grain     RhoS     (Ns)      RhoI     (Ni)  Squares  U+/-2s   Grain Age (Ma)
 no.    (cm^-2)            (cm^-2)                            Age    --95% CI--

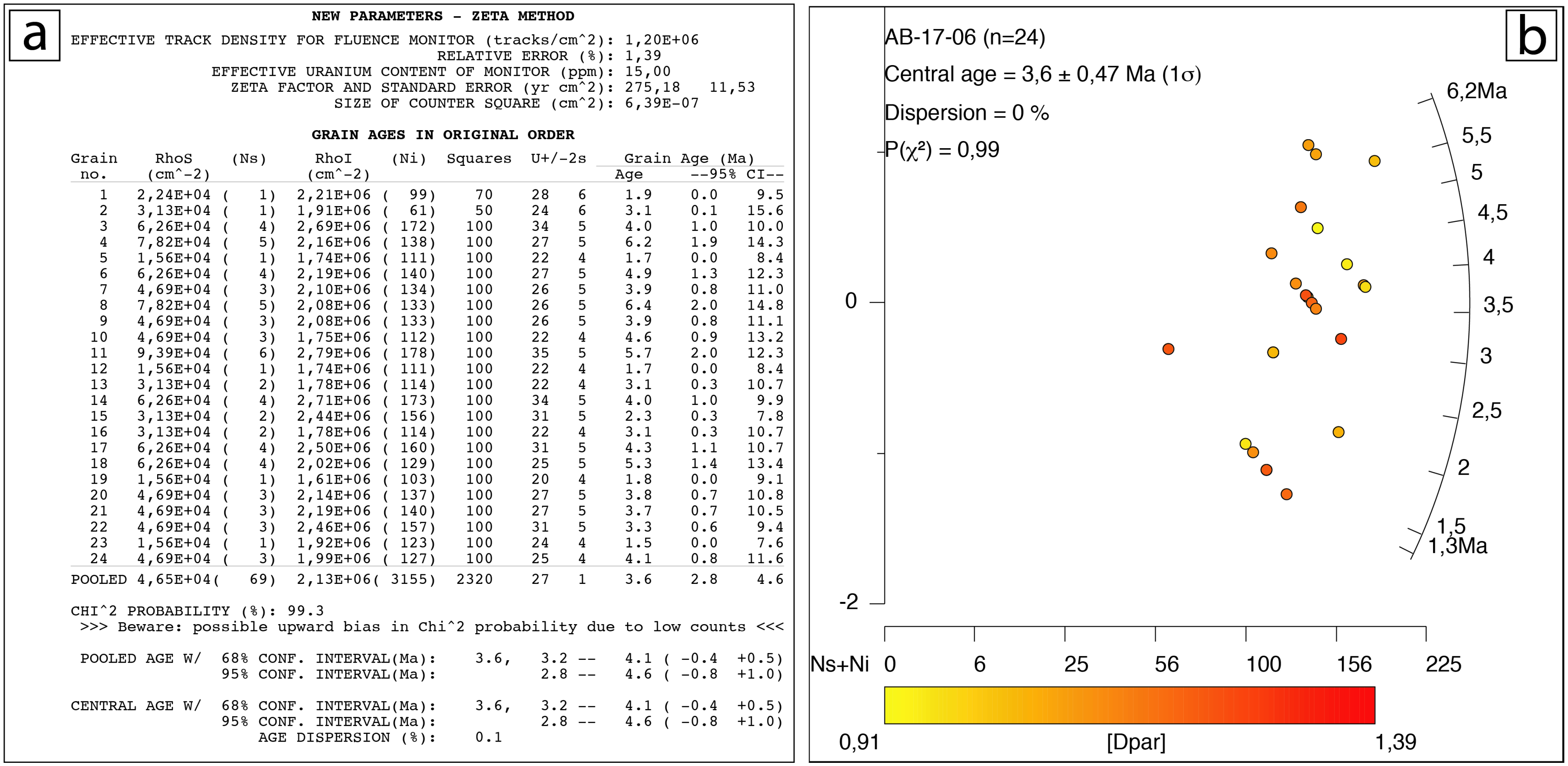
   1   7,82E+04 (    5)  2,03E+06 ( 130)    100     26    5    6.5      2.0    15.1
   2   6,26E+04 (    4)  2,02E+06 ( 129)    100     25    5    5.3      1.4    13.4
   3   6,26E+04 (    4)  2,08E+06 ( 133)    100     26    5    5.1      1.3    13.0
   4   1,72E+05 (   11)  3,51E+06 ( 224)    100     44    6    8.2      4.0    14.7
   5   1,10E+05 (    7)  3,35E+06 ( 214)    100     42    6    5.5      2.1    11.3
   6   1,12E+05 (    5)  2,75E+06 ( 123)     70     35    6    6.9      2.1    16.0
   7   1,10E+05 (    7)  2,38E+06 ( 152)    100     30    5    7.7      3.0    16.0
   8   1,10E+05 (    7)  2,99E+06 ( 191)    100     38    6    6.2      2.4    12.7
   9   6,26E+04 (    4)  2,27E+06 ( 145)    100     28    5    4.7      1.2    11.9
  10   7,82E+04 (    5)  2,68E+06 ( 171)    100     34    5    5.0      1.5    11.4
  11   9,39E+04 (    6)  2,54E+06 ( 162)    100     32    5    6.2      2.2    13.5
  12   1,25E+05 (    8)  3,08E+06 ( 197)    100     39    6    6.8      2.8    13.4
  13   4,69E+04 (    3)  2,19E+06 ( 140)    100     28    5    3.7      0.7    10.5
  14   9,39E+04 (    6)  3,11E+06 ( 199)    100     39    6    5.1      1.8    11.0
  15   9,39E+04 (    6)  2,43E+06 ( 155)    100     30    5    6.5      2.3    14.2
  16   1,56E+05 (   10)  4,21E+06 ( 269)    100     53    7    6.2      2.9    11.4
  17   7,82E+04 (    5)  2,52E+06 ( 161)    100     32    5    5.3      1.6    12.2
  18   1,25E+05 (    8)  2,94E+06 ( 188)    100     37    5    7.1      3.0    14.1
  19   6,26E+04 (    4)  1,69E+06 ( 108)    100     21    4    6.3      1.6    16.0
  20   7,82E+04 (    4)  3,25E+06 ( 166)     80     41    6    4.1      1.1    10.3
  21   1,25E+05 (    8)  3,36E+06 ( 215)    100     42    6    6.2      2.6    12.3
  22   1,30E+05 (    5)  3,83E+06 ( 147)     60     48    8    5.8      1.8    13.3
  23   1,25E+05 (    8)  3,07E+06 ( 196)    100     39    6    6.8      2.9    13.5
POOLED 9,91E+04(  140)  2,77E+06( 3915)   2210     35    2    5.9      4.9     7.1

CHI^2 PROBABILITY (%):100.0
 >>> Beware: possible upward bias in Chi^2 probability due to low counts <<<

 POOLED AGE W/  68% CONF. INTERVAL(Ma):    5.9,   5.3 --   6.5 ( -0.5  +0.6)
                95% CONF. INTERVAL(Ma):           4.9 --   7.1 ( -1.0  +1.2)

CENTRAL AGE W/  68% CONF. INTERVAL(Ma):    5.9,   5.3 --   6.5 ( -0.5  +0.6)
                95% CONF. INTERVAL(Ma):           4.9 --   7.1 ( -1.0  +1.2)
                    AGE DISPERSION (%):    0.0
```

Figure S1. AFT single-grain data (a) and radial plots (b) for sample AB-17-05. See Figure S44 for location.



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                         NEW PARAMETERS - ZETA METHOD
EFFECTIVE TRACK DENSITY FOR FLUENCE MONITOR (tracks/cm^2): 1,20E+06
                                       RELATIVE ERROR (%): 1,39
                 EFFECTIVE URANIUM CONTENT OF MONITOR (ppm): 15,00
                   ZETA FACTOR AND STANDARD ERROR (yr cm^2): 275,18    11,53
                              SIZE OF COUNTER SQUARE (cm^2): 6,39E-07

                         GRAIN AGES IN ORIGINAL ORDER
Grain    RhoS     (Ns)     RhoI     (Ni)  Squares   U+/-2s    Grain Age (Ma)
 no.    (cm^-2)           (cm^-2)                          Age      --95% CI--
   1  2,24E+04 (    1)  2,21E+06 (  99)    70     28    6     1.9      0.0      9.5
   2  3,13E+04 (    1)  1,91E+06 (  61)    50     24    6     3.1      0.1     15.6
   3  6,26E+04 (    4)  2,69E+06 ( 172)   100     34    5     4.0      1.0     10.0
   4  7,82E+04 (    5)  2,16E+06 ( 138)   100     27    5     6.2      1.9     14.3
   5  1,56E+04 (    1)  1,74E+06 ( 111)   100     22    4     1.7      0.0      8.4
   6  6,26E+04 (    4)  2,19E+06 ( 140)   100     27    5     4.9      1.3     12.3
   7  4,69E+04 (    3)  2,10E+06 ( 134)   100     26    5     3.9      0.8     11.0
   8  7,82E+04 (    5)  2,08E+06 ( 133)   100     26    5     6.4      2.0     14.8
   9  4,69E+04 (    3)  2,08E+06 ( 133)   100     26    5     3.9      0.8     11.1
  10  4,69E+04 (    3)  1,75E+06 ( 112)   100     22    4     4.6      0.9     13.2
  11  9,39E+04 (    6)  2,79E+06 ( 178)   100     35    5     5.7      2.0     12.3
  12  1,56E+04 (    1)  1,74E+06 ( 111)   100     22    4     1.7      0.0      8.4
  13  3,13E+04 (    2)  1,78E+06 ( 114)   100     22    4     3.1      0.3     10.7
  14  6,26E+04 (    4)  2,71E+06 ( 173)   100     34    5     4.0      1.0      9.9
  15  3,13E+04 (    2)  2,44E+06 ( 156)   100     31    5     2.3      0.3      7.8
  16  3,13E+04 (    2)  1,78E+06 ( 114)   100     22    4     3.1      0.3     10.7
  17  6,26E+04 (    4)  2,50E+06 ( 160)   100     31    5     4.3      1.1     10.7
  18  6,26E+04 (    4)  2,02E+06 ( 129)   100     25    5     5.3      1.4     13.4
  19  1,56E+04 (    1)  1,61E+06 ( 103)   100     20    4     1.8      0.0      9.1
  20  4,69E+04 (    3)  2,14E+06 ( 137)   100     27    5     3.8      0.7     10.8
  21  4,69E+04 (    3)  2,19E+06 ( 140)   100     27    5     3.7      0.7     10.5
  22  4,69E+04 (    3)  2,46E+06 ( 157)   100     31    5     3.3      0.6      9.4
  23  1,56E+04 (    1)  1,92E+06 ( 123)   100     24    4     1.5      0.0      7.6
  24  4,69E+04 (    3)  1,99E+06 ( 127)   100     25    4     4.1      0.8     11.6
POOLED 4,65E+04(   69)  2,13E+06( 3155)  2320     27    1     3.6      2.8      4.6

CHI^2 PROBABILITY (%): 99.3
 >>> Beware: possible upward bias in Chi^2 probability due to low counts <<<

 POOLED AGE W/  68% CONF. INTERVAL(Ma):    3.6,   3.2 --   4.1 ( -0.4  +0.5)
                95% CONF. INTERVAL(Ma):           2.8 --   4.6 ( -0.8  +1.0)

CENTRAL AGE W/  68% CONF. INTERVAL(Ma):    3.6,   3.2 --   4.1 ( -0.4  +0.5)
                95% CONF. INTERVAL(Ma):           2.8 --   4.6 ( -0.8  +1.0)
                     AGE DISPERSION (%):    0.1
```

Figure S2. AFT single-grain data (a) and radial plots (b) for sample AB-17-06. See Figure S44 for location.

a

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                      NEW PARAMETERS - ZETA METHOD
EFFECTIVE TRACK DENSITY FOR FLUENCE MONITOR (tracks/cm^2): 1,20E+06
                                       RELATIVE ERROR (%): 1,34
               EFFECTIVE URANIUM CONTENT OF MONITOR (ppm): 15,00
                 ZETA FACTOR AND STANDARD ERROR (yr cm^2): 275,18    11,53
                            SIZE OF COUNTER SQUARE (cm^2): 6,39E-07

                      GRAIN AGES IN ORIGINAL ORDER
Grain     RhoS     (Ns)      RhoI     (Ni)  Squares  U+/-2s   Grain Age (Ma)
 no.     (cm^-2)            (cm^-2)                          Age     --95% CI--
   1  6,26E+04 (   4)  3,32E+06 ( 212)   100     41    6     3.2     0.8     8.1
   2  6,26E+04 (   4)  2,86E+06 ( 183)   100     36    5     3.8     1.0     9.4
   3  7,82E+04 (   5)  2,80E+06 ( 179)   100     35    5     4.8     1.5    11.0
   4  1,56E+04 (   1)  2,36E+06 ( 151)   100     30    5     1.3     0.0     6.2
   5  1,56E+04 (   1)  2,49E+06 ( 159)   100     31    5     1.2     0.0     5.9
   6  6,26E+04 (   4)  3,13E+06 ( 200)   100     39    6     3.4     0.9     8.6
   7  3,13E+04 (   2)  2,22E+06 ( 142)   100     28    5     2.5     0.3     8.6
   8  1,56E+04 (   1)  3,10E+06 ( 198)   100     39    6     1.0     0.0     4.7
   9  3,13E+04 (   2)  3,08E+06 ( 197)   100     39    6     1.8     0.2     6.1
  10  6,26E+04 (   4)  3,88E+06 ( 248)   100     49    6     2.8     0.7     6.9
  11  7,82E+04 (   5)  3,02E+06 ( 193)   100     38    6     4.4     1.4    10.2
  12  7,82E+04 (   5)  2,69E+06 ( 172)   100     34    5     4.9     1.5    11.4
  13  1,10E+05 (   7)  3,44E+06 ( 220)   100     43    6     5.4     2.1    11.0
  14  7,82E+04 (   5)  3,26E+06 ( 208)   100     41    6     4.1     1.3     9.4
  15  9,39E+04 (   6)  3,96E+06 ( 253)   100     49    6     4.0     1.4     8.6
  16  7,82E+04 (   5)  2,61E+06 ( 167)   100     33    5     5.1     1.6    11.8
  17  1,10E+05 (   7)  3,04E+06 ( 194)   100     38    6     6.1     2.4    12.5
  18  9,39E+04 (   6)  2,72E+06 ( 174)   100     34    5     5.8     2.1    12.6
  19  6,26E+04 (   4)  2,68E+06 ( 171)   100     33    5     4.0     1.0    10.1
  20  7,82E+04 (   5)  2,43E+06 ( 155)   100     30    5     5.5     1.7    12.7
  21  4,69E+04 (   3)  2,85E+06 ( 182)   100     36    5     2.9     0.6     8.1
  22  6,26E+04 (   4)  2,19E+06 ( 140)   100     27    5     4.9     1.3    12.3
POOLED 6,40E+04(   90)  2,92E+06( 4098)  2200     36    1     3.6     2.9     4.5

CHI^2 PROBABILITY (%): 84.6
 >>> Beware: possible upward bias in Chi^2 probability due to low counts <<<

 POOLED AGE W/  68% CONF. INTERVAL(Ma):     3.6,    3.2 --    4.1 ( -0.4  +0.4)
                95% CONF. INTERVAL(Ma):             2.9 --    4.5 ( -0.7  +0.9)

CENTRAL AGE W/  68% CONF. INTERVAL(Ma):     3.6,    3.2 --    4.1 ( -0.4  +0.4)
                95% CONF. INTERVAL(Ma):             2.9 --    4.5 ( -0.7  +0.9)
                     AGE DISPERSION (%):    0.4
```

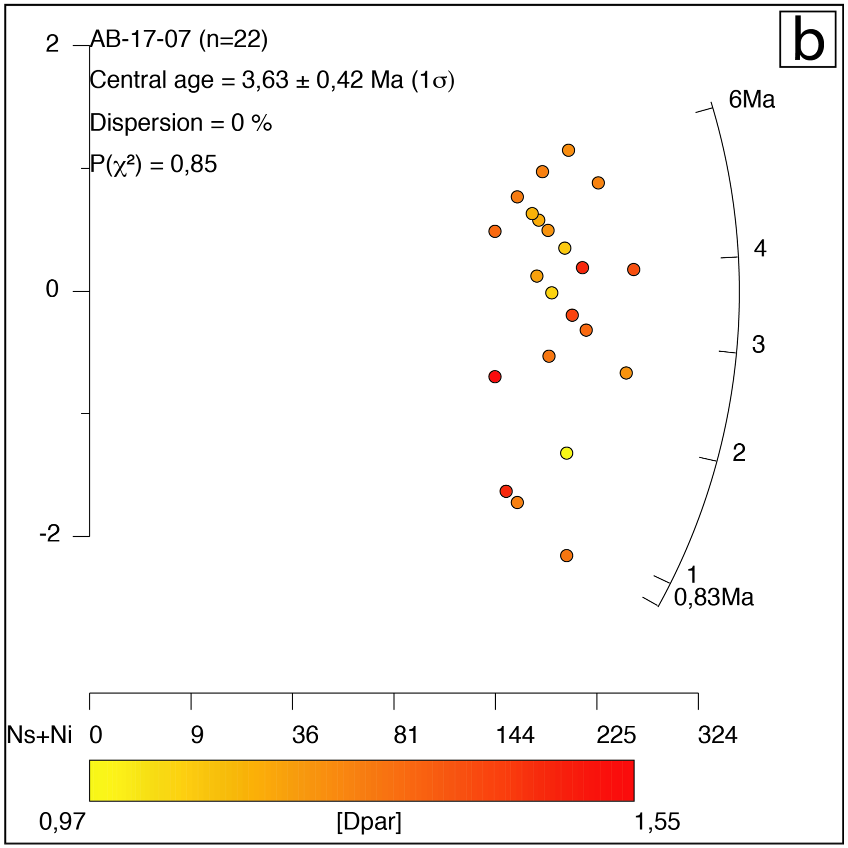


Figure S3. AFT single-grain data (a) and radial plots (b) for sample AB-17-07. See Figure S44 for location.

a

```
                    NEW PARAMETERS - ZETA METHOD
EFFECTIVE TRACK DENSITY FOR FLUENCE MONITOR (tracks/cm^2): 1,20E+06
                                       RELATIVE ERROR (%): 1,29
               EFFECTIVE URANIUM CONTENT OF MONITOR (ppm): 15,00
                 ZETA FACTOR AND STANDARD ERROR (yr cm^2): 275,18   11,53
                            SIZE OF COUNTER SQUARE (cm^2): 6,39E-07

                    GRAIN AGES IN ORIGINAL ORDER

Grain    RhoS    (Ns)     RhoI    (Ni)  Squares  U+/-2s    Grain Age (Ma)
 no.   (cm^-2)          (cm^-2)                           Age    --95% CI--

   1  1,41E+05 (   9)  4,43E+06 ( 283)   100     55    7    5.4     2.4   10.1
   2  7,82E+04 (   5)  3,15E+06 ( 201)   100     39    6    4.2     1.3    9.8
   3  6,26E+04 (   4)  2,90E+06 ( 185)   100     36    5    3.7     1.0    9.3
   4  9,39E+04 (   6)  3,79E+06 ( 242)   100     47    6    4.2     1.5    9.1
   5  4,69E+04 (   3)  4,05E+06 ( 259)   100     51    6    2.0     0.4    5.7
   6  9,39E+04 (   6)  3,97E+06 ( 254)   100     50    6    4.0     1.4    8.6
   7  6,26E+04 (   4)  3,36E+06 ( 215)   100     42    6    3.2     0.8    8.0
   8  6,26E+04 (   4)  4,88E+06 ( 312)   100     61    7    2.2     0.6    5.5
   9  1,25E+05 (   8)  4,24E+06 ( 271)   100     53    7    5.0     2.1    9.8
  10  9,39E+04 (   6)  3,43E+06 ( 219)   100     43    6    4.6     1.6   10.0
  11  1,41E+05 (   9)  4,99E+06 ( 319)   100     62    7    4.7     2.1    9.0
  12  7,82E+04 (   5)  4,08E+06 ( 261)   100     51    6    3.3     1.0    7.5
  13  3,13E+04 (   2)  3,15E+06 ( 201)   100     39    6    1.8     0.2    6.0
  14  1,56E+04 (   1)  3,35E+06 ( 214)   100     42    6    0.9     0.0    4.4
  15  9,39E+04 (   6)  4,05E+06 ( 259)   100     51    6    3.9     1.4    8.5
  16  1,25E+05 (   8)  5,34E+06 ( 341)   100     67    7    4.0     1.7    7.7
  17  1,10E+05 (   7)  4,88E+06 ( 312)   100     61    7    3.8     1.5    7.7
  18  7,82E+04 (   5)  3,69E+06 ( 236)   100     46    6    3.6     1.1    8.3
  19  3,13E+04 (   2)  3,30E+06 ( 211)   100     41    6    1.7     0.2    5.7
  20  1,56E+05 (  10)  6,45E+06 ( 412)   100     80    8    4.1     1.9    7.5
  21  3,13E+04 (   2)  3,26E+06 ( 208)   100     41    6    1.7     0.2    5.8
  22  6,26E+04 (   4)  4,07E+06 ( 260)   100     51    6    2.6     0.7    6.6
  23  9,39E+04 (   6)  4,60E+06 ( 294)   100     57    7    3.5     1.2    7.4
  24  1,25E+05 (   8)  4,29E+06 ( 274)   100     54    7    4.9     2.1    9.6
  25  9,39E+04 (   6)  3,80E+06 ( 243)   100     47    6    4.2     1.5    9.0
POOLED 8,51E+04(  136)  4,06E+06( 6486)  2500     51    2    3.5     2.9    4.2

CHI^2 PROBABILITY (%): 93.6
 >>> Beware: possible upward bias in Chi^2 probability due to low counts <<<

 POOLED AGE W/  68% CONF. INTERVAL(Ma):    3.5,   3.1 --   3.8 ( -0.3  +0.4)
                95% CONF. INTERVAL(Ma):           2.9 --   4.2 ( -0.6  +0.7)

CENTRAL AGE W/  68% CONF. INTERVAL(Ma):    3.5,   3.1 --   3.8 ( -0.3  +0.4)
                95% CONF. INTERVAL(Ma):           2.9 --   4.2 ( -0.6  +0.7)
                    AGE DISPERSION (%):    0.2
```

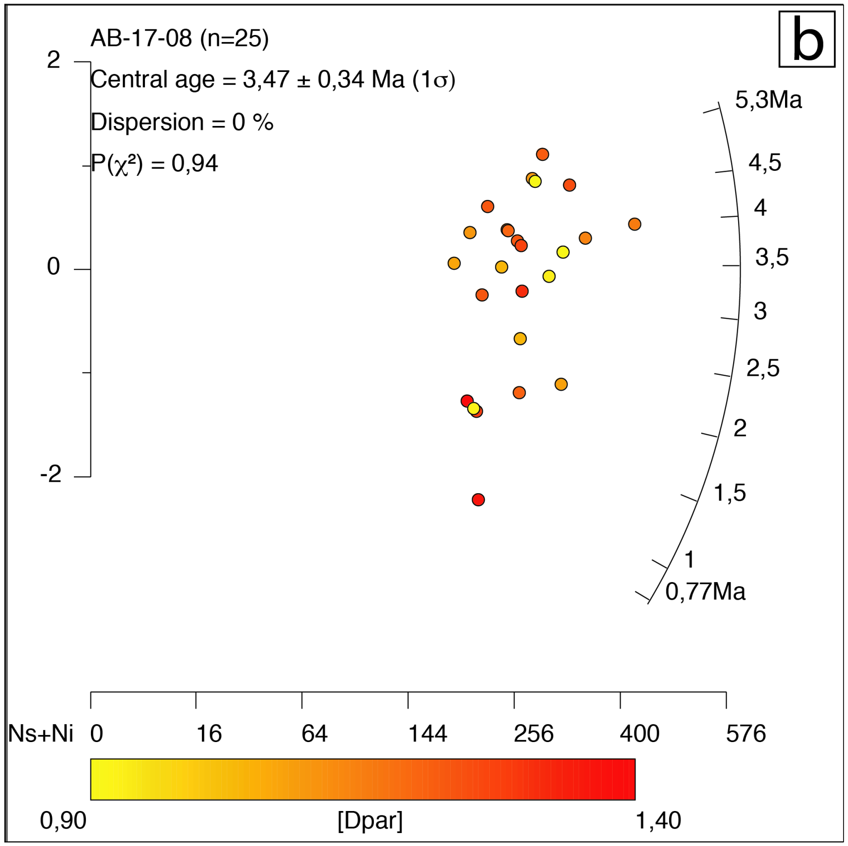
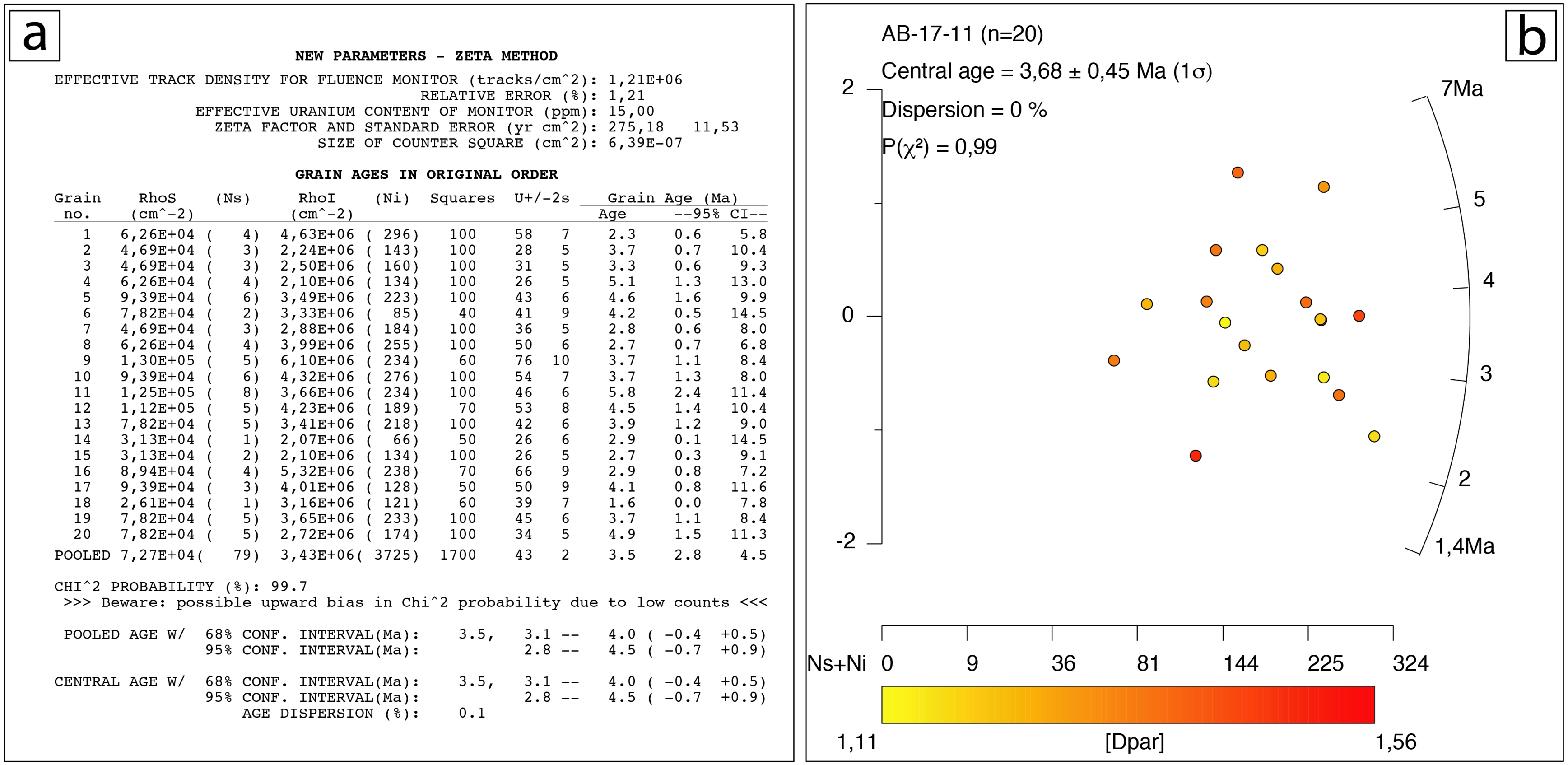


Figure S4. AFT single-grain data (a) and radial plots (b) for sample AB-17-08. See Figure S44 for location.



```
                    NEW PARAMETERS - ZETA METHOD
EFFECTIVE TRACK DENSITY FOR FLUENCE MONITOR (tracks/cm^2): 1,21E+06
                                       RELATIVE ERROR (%): 1,21
               EFFECTIVE URANIUM CONTENT OF MONITOR (ppm): 15,00
                 ZETA FACTOR AND STANDARD ERROR (yr cm^2): 275,18   11,53
                           SIZE OF COUNTER SQUARE (cm^2): 6,39E-07

                    GRAIN AGES IN ORIGINAL ORDER

Grain    RhoS     (Ns)      RhoI     (Ni)  Squares  U+/-2s   Grain Age (Ma)
 no.   (cm^-2)            (cm^-2)                           Age    --95% CI--
   1  6,26E+04 (    4)  4,63E+06 ( 296)    100     58    7   2.3     0.6    5.8
   2  4,69E+04 (    3)  2,24E+06 ( 143)    100     28    5   3.7     0.7   10.4
   3  4,69E+04 (    3)  2,50E+06 ( 160)    100     31    5   3.3     0.6    9.3
   4  6,26E+04 (    4)  2,10E+06 ( 134)    100     26    5   5.1     1.3   13.0
   5  9,39E+04 (    6)  3,49E+06 ( 223)    100     43    6   4.6     1.6    9.9
   6  7,82E+04 (    2)  3,33E+06 (  85)     40     41    9   4.2     0.5   14.5
   7  4,69E+04 (    3)  2,88E+06 ( 184)    100     36    5   2.8     0.6    8.0
   8  6,26E+04 (    4)  3,99E+06 ( 255)    100     50    6   2.7     0.7    6.8
   9  1,30E+05 (    5)  6,10E+06 ( 234)     60     76   10   3.7     1.1    8.4
  10  9,39E+04 (    6)  4,32E+06 ( 276)    100     54    7   3.7     1.3    8.0
  11  1,25E+05 (    8)  3,66E+06 ( 234)    100     46    6   5.8     2.4   11.4
  12  1,12E+05 (    5)  4,23E+06 ( 189)     70     53    8   4.5     1.4   10.4
  13  7,82E+04 (    5)  3,41E+06 ( 218)    100     42    6   3.9     1.2    9.0
  14  3,13E+04 (    1)  2,07E+06 (  66)     50     26    6   2.9     0.1   14.5
  15  3,13E+04 (    2)  2,10E+06 ( 134)    100     26    5   2.7     0.3    9.1
  16  8,94E+04 (    4)  5,32E+06 ( 238)     70     66    9   2.9     0.8    7.2
  17  9,39E+04 (    3)  4,01E+06 ( 128)     50     50    9   4.1     0.8   11.6
  18  2,61E+04 (    1)  3,16E+06 ( 121)     60     39    7   1.6     0.0    7.8
  19  7,82E+04 (    5)  3,65E+06 ( 233)    100     45    6   3.7     1.1    8.4
  20  7,82E+04 (    5)  2,72E+06 ( 174)    100     34    5   4.9     1.5   11.3
POOLED 7,27E+04(   79)  3,43E+06( 3725)   1700     43    2   3.5     2.8    4.5

CHI^2 PROBABILITY (%): 99.7
 >>> Beware: possible upward bias in Chi^2 probability due to low counts <<<

 POOLED AGE W/  68% CONF. INTERVAL(Ma):    3.5,   3.1 --   4.0 ( -0.4  +0.5)
                95% CONF. INTERVAL(Ma):           2.8 --   4.5 ( -0.7  +0.9)

CENTRAL AGE W/  68% CONF. INTERVAL(Ma):    3.5,   3.1 --   4.0 ( -0.4  +0.5)
                95% CONF. INTERVAL(Ma):           2.8 --   4.5 ( -0.7  +0.9)
                    AGE DISPERSION (%):    0.1
```

Figure S5. AFT single-grain data (a) and radial plots (b) for sample AB-17-11. See Figure S44 for location.

a

```
                        NEW PARAMETERS - ZETA METHOD
EFFECTIVE TRACK DENSITY FOR FLUENCE MONITOR (tracks/cm^2): 1,21E+06
                                       RELATIVE ERROR (%): 1,17
               EFFECTIVE URANIUM CONTENT OF MONITOR (ppm): 15,00
                 ZETA FACTOR AND STANDARD ERROR (yr cm^2): 275,18   11,53
                            SIZE OF COUNTER SQUARE (cm^2): 6,39E-07

                        GRAIN AGES IN ORIGINAL ORDER
Grain    RhoS     (Ns)     RhoI     (Ni)  Squares  U+/-2s   Grain Age (Ma)
 no.   (cm^-2)           (cm^-2)                          Age      --95% CI--
   1   3,91E+04 (    1)  1,41E+06 (  36)     40     17   6     5.3     0.1    27.4
   2   0,00E+00 (    0)  2,03E+05 (  13)    100      3   1     9.1     0.3    54.4
   3   1,88E+05 (   12)  5,46E+06 ( 349)    100     68   7     5.8     2.9    10.1
   4   0,00E+00 (    0)  6,26E+04 (   4)    100      1   1    31.4     1.1   247.3
   5   1,56E+04 (    1)  1,56E+05 (  10)    100      2   1    18.7     0.4   115.9
   6   1,56E+04 (    1)  5,95E+05 (  38)    100      7   2     5.0     0.1    25.9
   7   0,00E+00 (    0)  1,83E+05 (   7)     60      2   2    17.3     0.6   114.4
   8   1,25E+05 (    8)  3,44E+06 ( 220)    100     43   6     6.2     2.6    12.1
   9   1,25E+05 (    8)  4,52E+06 ( 289)    100     56   7     4.7     2.0     9.2
  10   0,00E+00 (    0)  2,01E+05 (   9)     70      2   2    13.3     0.5    83.8
  11   2,74E+05 (    7)  7,75E+06 ( 198)     40     96  14     6.0     2.3    12.3
  12   0,00E+00 (    0)  9,39E+04 (   6)    100      1   1    20.3     0.7   139.8
  13   1,56E+04 (    1)  3,60E+05 (  23)    100      4   2     8.2     0.2    44.4
  14   3,13E+04 (    2)  1,03E+06 (  66)    100     13   3     5.4     0.6    18.9
  15   2,50E+05 (    4)  7,82E+06 ( 125)     25     97  17     5.5     1.4    14.0
  16   5,22E+04 (    2)  1,04E+06 (  40)     60     13   4     8.9     1.0    32.0
  17   1,41E+05 (    9)  4,43E+06 ( 283)    100     55   7     5.4     2.4    10.2
  18   1,88E+05 (   12)  5,20E+06 ( 332)    100     64   7     6.1     3.1    10.6
  19   6,26E+04 (    4)  1,39E+06 (  89)    100     17   4     7.8     2.0    19.8
  20   7,82E+04 (    4)  1,62E+06 (  83)     80     20   4     8.3     2.1    21.3
  21   0,00E+00 (    0)  9,39E+04 (   6)    100      1   1    20.3     0.7   139.8
  22   0,00E+00 (    0)  7,82E+04 (   5)    100      1   1    24.7     0.8   179.1
  23   7,34E+04 (    3)  1,64E+06 (  67)     64     20   5     7.8     1.5    22.7
  24   0,00E+00 (    0)  7,82E+04 (   5)    100      1   1    24.7     0.8   179.1
  25   6,26E+04 (    4)  1,60E+06 ( 102)    100     20   4     6.8     1.7    17.2
  26   2,50E+05 (   16)  6,90E+06 ( 441)    100     86   8     6.1     3.4     9.9
  27   0,00E+00 (    0)  1,10E+05 (   7)    100      1   1    17.3     0.6   114.4
  28   3,13E+04 (    2)  4,54E+05 (  29)    100      6   2    12.3     1.3    45.2
  29   2,61E+05 (    5)  6,26E+06 ( 120)     30     78  14     7.1     2.2    16.6
  30   0,00E+00 (    0)  7,82E+04 (   5)    100      1   1    24.7     0.8   179.1
POOLED 6,46E+04(  106)  1,83E+06( 3007)   2569     23   1     5.9     4.7     7.2

CHI^2 PROBABILITY (%):100.0
 >>> Beware: possible upward bias in Chi^2 probability due to low counts <<<

 POOLED AGE W/  68% CONF. INTERVAL(Ma):    5.9,   5.3 --   6.5 ( -0.6  +0.7)
                95% CONF. INTERVAL(Ma):           4.7 --   7.2 ( -1.1  +1.4)

CENTRAL AGE W/  68% CONF. INTERVAL(Ma):    5.9,   5.3 --   6.5 ( -0.6  +0.7)
                95% CONF. INTERVAL(Ma):           4.7 --   7.2 ( -1.1  +1.4)
                   AGE DISPERSION (%):    0.0
```

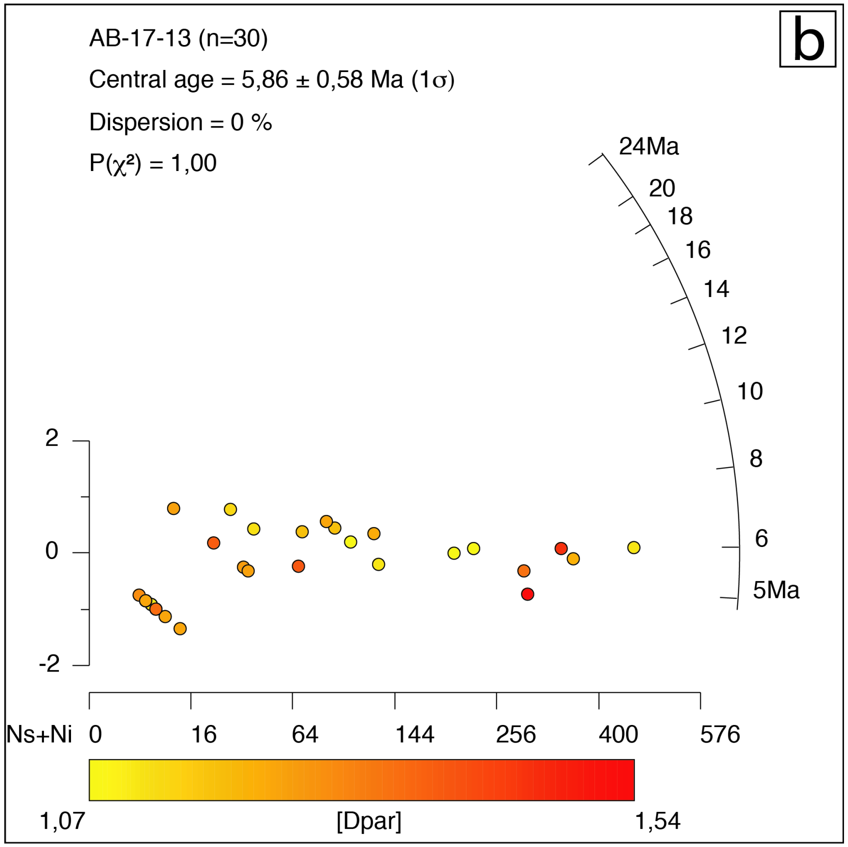
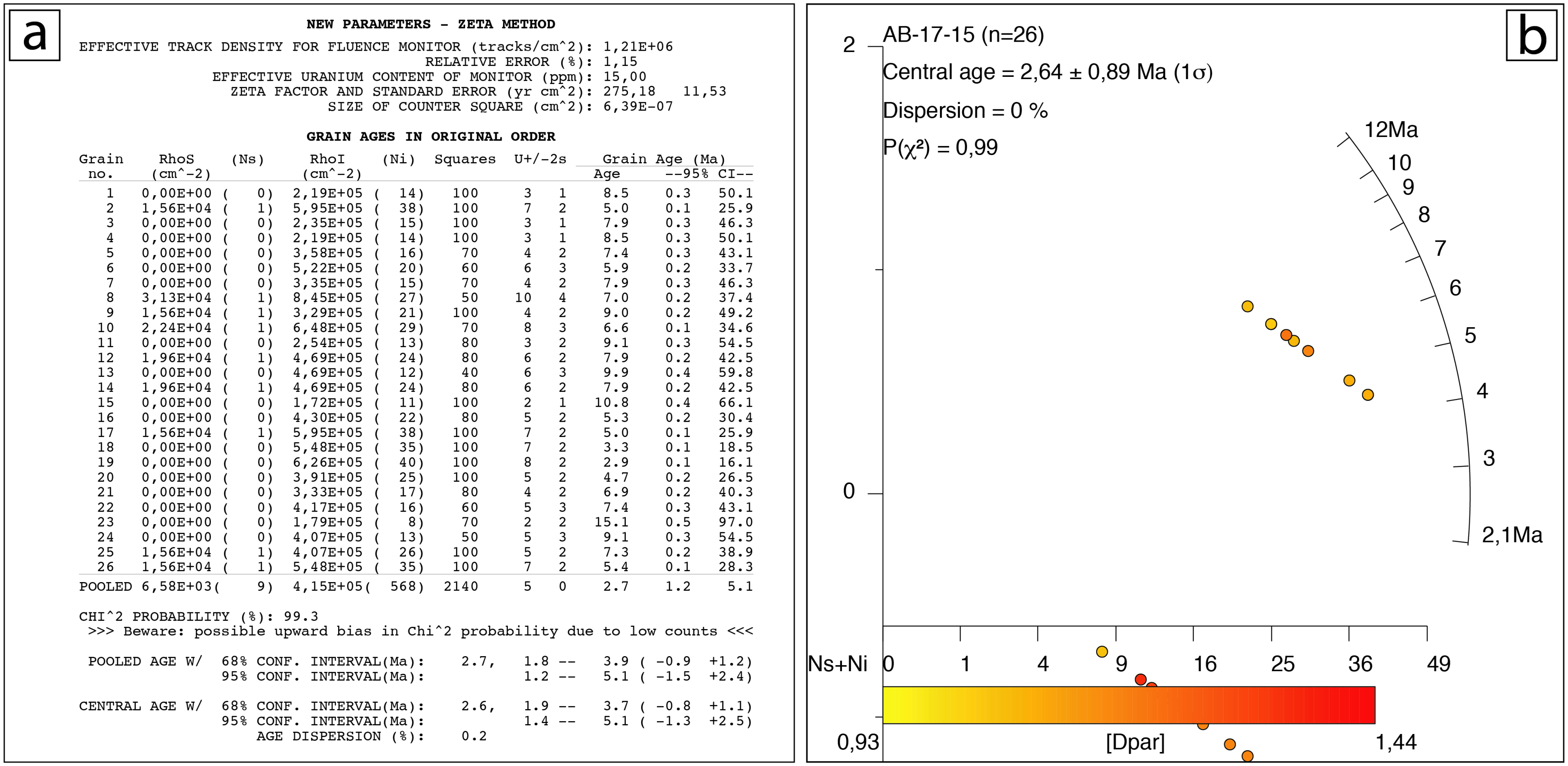


Figure S6. AFT single-grain data (a) and radial plots (b) for sample AB-17-13. See Figure S44 for location.



```
                          NEW PARAMETERS - ZETA METHOD
EFFECTIVE TRACK DENSITY FOR FLUENCE MONITOR (tracks/cm^2): 1,21E+06
                                       RELATIVE ERROR (%): 1,15
                EFFECTIVE URANIUM CONTENT OF MONITOR (ppm): 15,00
                 ZETA FACTOR AND STANDARD ERROR (yr cm^2): 275,18   11,53
                            SIZE OF COUNTER SQUARE (cm^2): 6,39E-07

                          GRAIN AGES IN ORIGINAL ORDER

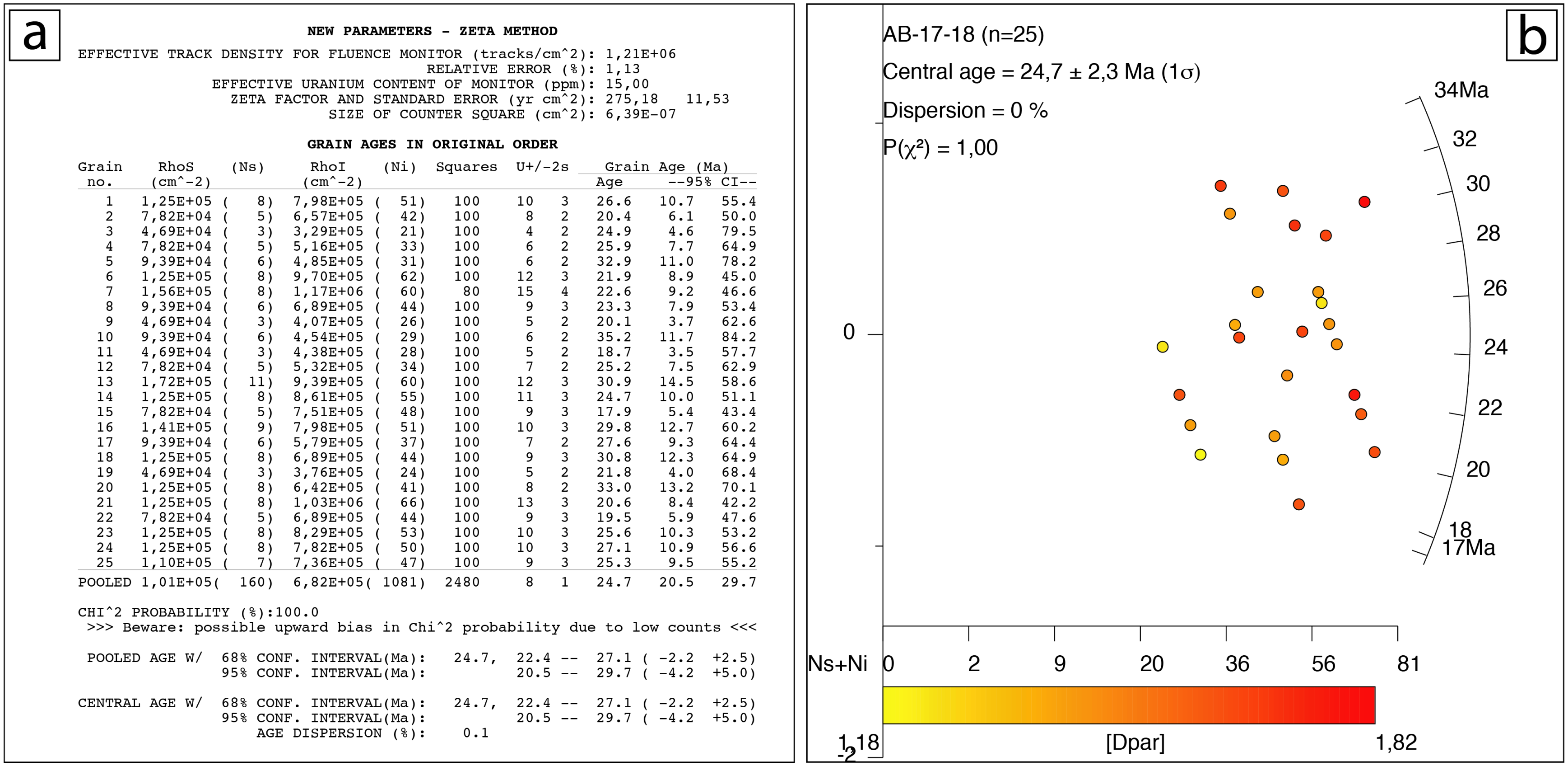
Grain    RhoS    (Ns)     RhoI    (Ni)  Squares  U+/-2s    Grain Age (Ma)
 no.    (cm^-2)          (cm^-2)                          Age     --95% CI--
   1   0,00E+00 (   0)  2,19E+05 (  14)   100     3   1    8.5    0.3   50.1
   2   1,56E+04 (   1)  5,95E+05 (  38)   100     7   2    5.0    0.1   25.9
   3   0,00E+00 (   0)  2,35E+05 (  15)   100     3   1    7.9    0.3   46.3
   4   0,00E+00 (   0)  2,19E+05 (  14)   100     3   1    8.5    0.3   50.1
   5   0,00E+00 (   0)  3,58E+05 (  16)    70     4   2    7.4    0.3   43.1
   6   0,00E+00 (   0)  5,22E+05 (  20)    60     6   3    5.9    0.2   33.7
   7   0,00E+00 (   0)  3,35E+05 (  15)    70     4   2    7.9    0.3   46.3
   8   3,13E+04 (   1)  8,45E+05 (  27)    50    10   4    7.0    0.2   37.4
   9   1,56E+04 (   1)  3,29E+05 (  21)   100     4   2    9.0    0.2   49.2
  10   2,24E+04 (   1)  6,48E+05 (  29)    70     8   3    6.6    0.1   34.6
  11   0,00E+00 (   0)  2,54E+05 (  13)    80     3   2    9.1    0.3   54.5
  12   1,96E+04 (   1)  4,69E+05 (  24)    80     6   2    7.9    0.2   42.5
  13   0,00E+00 (   0)  4,69E+05 (  12)    40     6   3    9.9    0.4   59.8
  14   1,96E+04 (   1)  4,69E+05 (  24)    80     6   2    7.9    0.2   42.5
  15   0,00E+00 (   0)  1,72E+05 (  11)   100     2   1   10.8    0.4   66.1
  16   0,00E+00 (   0)  4,30E+05 (  22)    80     5   2    5.3    0.2   30.4
  17   1,56E+04 (   1)  5,95E+05 (  38)   100     7   2    5.0    0.1   25.9
  18   0,00E+00 (   0)  5,48E+05 (  35)   100     7   2    3.3    0.1   18.5
  19   0,00E+00 (   0)  6,26E+05 (  40)   100     8   2    2.9    0.1   16.1
  20   0,00E+00 (   0)  3,91E+05 (  25)   100     5   2    4.7    0.2   26.5
  21   0,00E+00 (   0)  3,33E+05 (  17)    80     4   2    6.9    0.2   40.3
  22   0,00E+00 (   0)  4,17E+05 (  16)    60     5   3    7.4    0.3   43.1
  23   0,00E+00 (   0)  1,79E+05 (   8)    70     2   2   15.1    0.5   97.0
  24   0,00E+00 (   0)  4,07E+05 (  13)    50     5   3    9.1    0.3   54.5
  25   1,56E+04 (   1)  4,07E+05 (  26)   100     5   2    7.3    0.2   38.9
  26   1,56E+04 (   1)  5,48E+05 (  35)   100     7   2    5.4    0.1   28.3
POOLED 6,58E+03(    9)  4,15E+05(  568)  2140     5   0    2.7    1.2    5.1

CHI^2 PROBABILITY (%): 99.3
 >>> Beware: possible upward bias in Chi^2 probability due to low counts <<<

 POOLED AGE W/  68% CONF. INTERVAL(Ma):    2.7,   1.8 --   3.9 ( -0.9  +1.2)
                95% CONF. INTERVAL(Ma):           1.2 --   5.1 ( -1.5  +2.4)

CENTRAL AGE W/  68% CONF. INTERVAL(Ma):    2.6,   1.9 --   3.7 ( -0.8  +1.1)
                95% CONF. INTERVAL(Ma):           1.4 --   5.1 ( -1.3  +2.5)
                    AGE DISPERSION (%):    0.2
```

Figure S7. AFT single-grain data (a) and radial plots (b) for sample AB-17-15. See Figure S44 for location.



```
                    NEW PARAMETERS - ZETA METHOD
EFFECTIVE TRACK DENSITY FOR FLUENCE MONITOR (tracks/cm^2): 1,21E+06
                                       RELATIVE ERROR (%): 1,13
               EFFECTIVE URANIUM CONTENT OF MONITOR (ppm): 15,00
                 ZETA FACTOR AND STANDARD ERROR (yr cm^2): 275,18   11,53
                            SIZE OF COUNTER SQUARE (cm^2): 6,39E-07

                    GRAIN AGES IN ORIGINAL ORDER
Grain    RhoS     (Ns)      RhoI     (Ni)  Squares  U+/-2s   Grain Age (Ma)
 no.    (cm^-2)            (cm^-2)                          Age     --95% CI--
   1   1,25E+05 (    8)  7,98E+05 (   51)   100     10    3   26.6    10.7    55.4
   2   7,82E+04 (    5)  6,57E+05 (   42)   100      8    2   20.4     6.1    50.0
   3   4,69E+04 (    3)  3,29E+05 (   21)   100      4    2   24.9     4.6    79.5
   4   7,82E+04 (    5)  5,16E+05 (   33)   100      6    2   25.9     7.7    64.9
   5   9,39E+04 (    6)  4,85E+05 (   31)   100      6    2   32.9    11.0    78.2
   6   1,25E+05 (    8)  9,70E+05 (   62)   100     12    3   21.9     8.9    45.0
   7   1,56E+05 (    8)  1,17E+06 (   60)    80     15    4   22.6     9.2    46.6
   8   9,39E+04 (    6)  6,89E+05 (   44)   100      9    3   23.3     7.9    53.4
   9   4,69E+04 (    3)  4,07E+05 (   26)   100      5    2   20.1     3.7    62.6
  10   9,39E+04 (    6)  4,54E+05 (   29)   100      6    2   35.2    11.7    84.2
  11   4,69E+04 (    3)  4,38E+05 (   28)   100      5    2   18.7     3.5    57.7
  12   7,82E+04 (    5)  5,32E+05 (   34)   100      7    2   25.2     7.5    62.9
  13   1,72E+05 (   11)  9,39E+05 (   60)   100     12    3   30.9    14.5    58.6
  14   1,25E+05 (    8)  8,61E+05 (   55)   100     11    3   24.7    10.0    51.1
  15   7,82E+04 (    5)  7,51E+05 (   48)   100      9    3   17.9     5.4    43.4
  16   1,41E+05 (    9)  7,98E+05 (   51)   100     10    3   29.8    12.7    60.2
  17   9,39E+04 (    6)  5,79E+05 (   37)   100      7    2   27.6     9.3    64.4
  18   1,25E+05 (    8)  6,89E+05 (   44)   100      9    3   30.8    12.3    64.9
  19   4,69E+04 (    3)  3,76E+05 (   24)   100      5    2   21.8     4.0    68.4
  20   1,25E+05 (    8)  6,42E+05 (   41)   100      8    2   33.0    13.2    70.1
  21   1,25E+05 (    8)  1,03E+06 (   66)   100     13    3   20.6     8.4    42.2
  22   7,82E+04 (    5)  6,89E+05 (   44)   100      9    3   19.5     5.9    47.6
  23   1,25E+05 (    8)  8,29E+05 (   53)   100     10    3   25.6    10.3    53.2
  24   1,25E+05 (    8)  7,82E+05 (   50)   100     10    3   27.1    10.9    56.6
  25   1,10E+05 (    7)  7,36E+05 (   47)   100      9    3   25.3     9.5    55.2
POOLED 1,01E+05(  160)  6,82E+05( 1081)  2480      8    1   24.7    20.5    29.7

CHI^2 PROBABILITY (%):100.0
 >>> Beware: possible upward bias in Chi^2 probability due to low counts <<<

 POOLED AGE W/  68% CONF. INTERVAL(Ma):   24.7,  22.4 --  27.1 ( -2.2  +2.5)
                95% CONF. INTERVAL(Ma):          20.5 --  29.7 ( -4.2  +5.0)

CENTRAL AGE W/  68% CONF. INTERVAL(Ma):   24.7,  22.4 --  27.1 ( -2.2  +2.5)
                95% CONF. INTERVAL(Ma):          20.5 --  29.7 ( -4.2  +5.0)
                    AGE DISPERSION (%):    0.1
```

Figure S8. AFT single-grain data (a) and radial plots (b) for sample AB-17-18. See Figure S44 for location.

a

```
                        NEW PARAMETERS - ZETA METHOD
EFFECTIVE TRACK DENSITY FOR FLUENCE MONITOR (tracks/cm^2): 1,22E+06
                                       RELATIVE ERROR (%): 1,12
               EFFECTIVE URANIUM CONTENT OF MONITOR (ppm): 15,00
                 ZETA FACTOR AND STANDARD ERROR (yr cm^2): 275,18   11,53
                            SIZE OF COUNTER SQUARE (cm^2): 6,39E-07

                        GRAIN AGES IN ORIGINAL ORDER

Grain    RhoS     (Ns)      RhoI     (Ni)  Squares  U+/-2s    Grain Age (Ma)
 no.    (cm^-2)            (cm^-2)                           Age      --95% CI--
   1   5,63E+05 (    9)  3,38E+06 (   54)    25     42   11    28.2     12.1    56.7
   2   2,19E+05 (    7)  2,22E+06 (   71)    50     27    7    16.8      6.4    35.7
   3   3,13E+05 (   20)  2,63E+06 (  168)   100     32    5    20.0     11.8    31.7
   4   4,23E+05 (   27)  3,00E+06 (  192)   100     37    5    23.6     15.1    35.2
   5   9,39E+04 (    6)  9,55E+05 (   61)   100     12    3    16.8      5.8    37.8
   6   8,29E+05 (   53)  6,37E+06 (  407)   100     79    8    21.8     16.0    29.0
   7   1,02E+06 (   65)  8,22E+06 (  525)   100    101    9    20.7     15.8    27.1
   8   8,76E+05 (   14)  7,76E+06 (  124)    25     96   17    19.1     10.0    32.8
   9   2,61E+05 (   10)  2,71E+06 (  104)    60     33    7    16.3      7.5    30.7
  10   4,38E+05 (   14)  5,23E+06 (  167)    50     64   10    14.2      7.5    24.2
  11   1,41E+05 (    9)  7,82E+05 (   50)   100     10    3    30.5     13.0    61.6
  12   5,65E+05 (   13)  4,96E+06 (  114)    36     61   12    19.3      9.8    33.9
  13   5,54E+05 (   17)  7,11E+06 (  218)    48     88   12    13.2      7.5    21.4
  14   7,56E+05 (   29)  5,92E+06 (  227)    60     73   10    21.4     14.0    31.5
  15   7,20E+05 (   23)  4,10E+06 (  131)    50     51    9    29.5     18.0    45.9
  16   3,76E+05 (   24)  2,30E+06 (  147)   100     28    5    27.4     16.9    42.1
  17   1,10E+05 (    7)  5,95E+05 (   38)   100      7    2    31.3     11.6    69.5
  18   7,82E+05 (   25)  5,76E+06 (  184)    50     71   11    22.8     14.3    34.6
  19   4,43E+05 (   17)  2,82E+06 (  108)    60     35    7    26.5     14.8    44.0
  20   2,50E+05 (   16)  2,00E+06 (  128)   100     25    4    21.1     11.6    35.2
  21   2,82E+05 (   18)  1,83E+06 (  117)   100     23    4    25.9     14.7    42.4
  22   2,82E+05 (    9)  1,66E+06 (   53)    50     20    6    28.8     12.3    57.9
  23   1,30E+05 (    5)  1,02E+06 (   39)    60     13    4    22.0      6.6    54.3
  24   4,07E+05 (   13)  3,85E+06 (  123)    50     47    9    17.9      9.1    31.3
  25   8,14E+05 (   26)  6,70E+06 (  214)    50     83   11    20.4     13.0    30.6
POOLED 4,32E+05(  476)  3,42E+06( 3764)  1724     42    2    21.1     18.6    24.0

CHI^2 PROBABILITY (%): 87.0
 >>> Beware: possible upward bias in Chi^2 probability due to low counts <<<

 POOLED AGE W/  68% CONF. INTERVAL(Ma):   21.1,  19.8 --  22.5 ( -1.3  +1.4)
                95% CONF. INTERVAL(Ma):          18.6 --  24.0 ( -2.5  +2.9)

CENTRAL AGE W/  68% CONF. INTERVAL(Ma):   21.1,  19.8 --  22.5 ( -1.3  +1.4)
                95% CONF. INTERVAL(Ma):          18.6 --  24.0 ( -2.5  +2.9)
                   AGE DISPERSION (%):    0.3
```

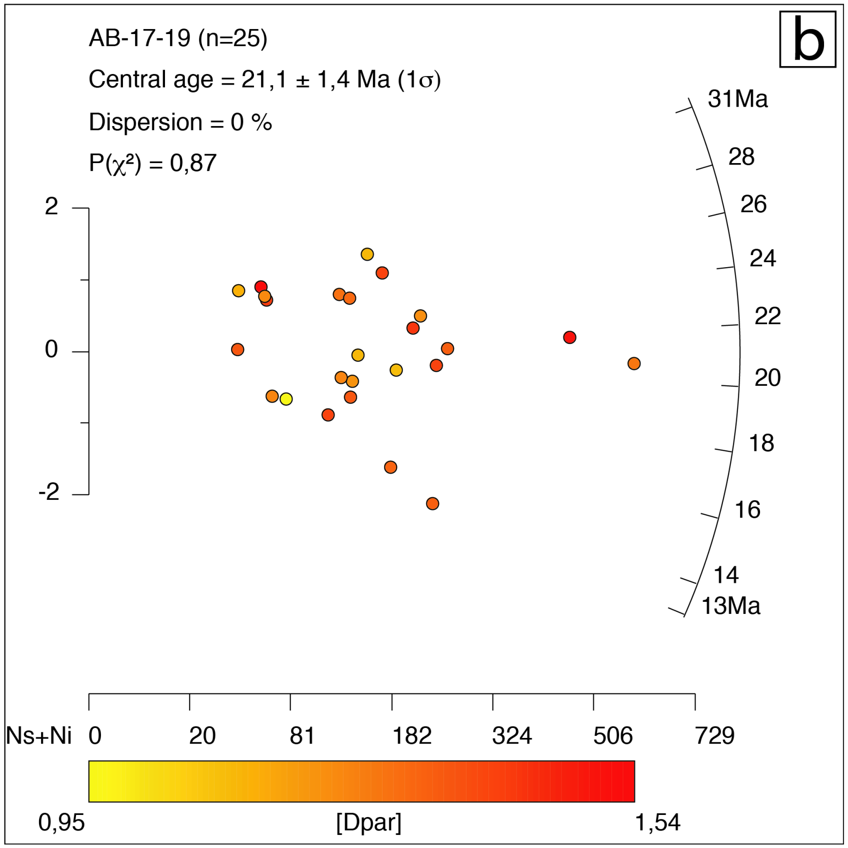
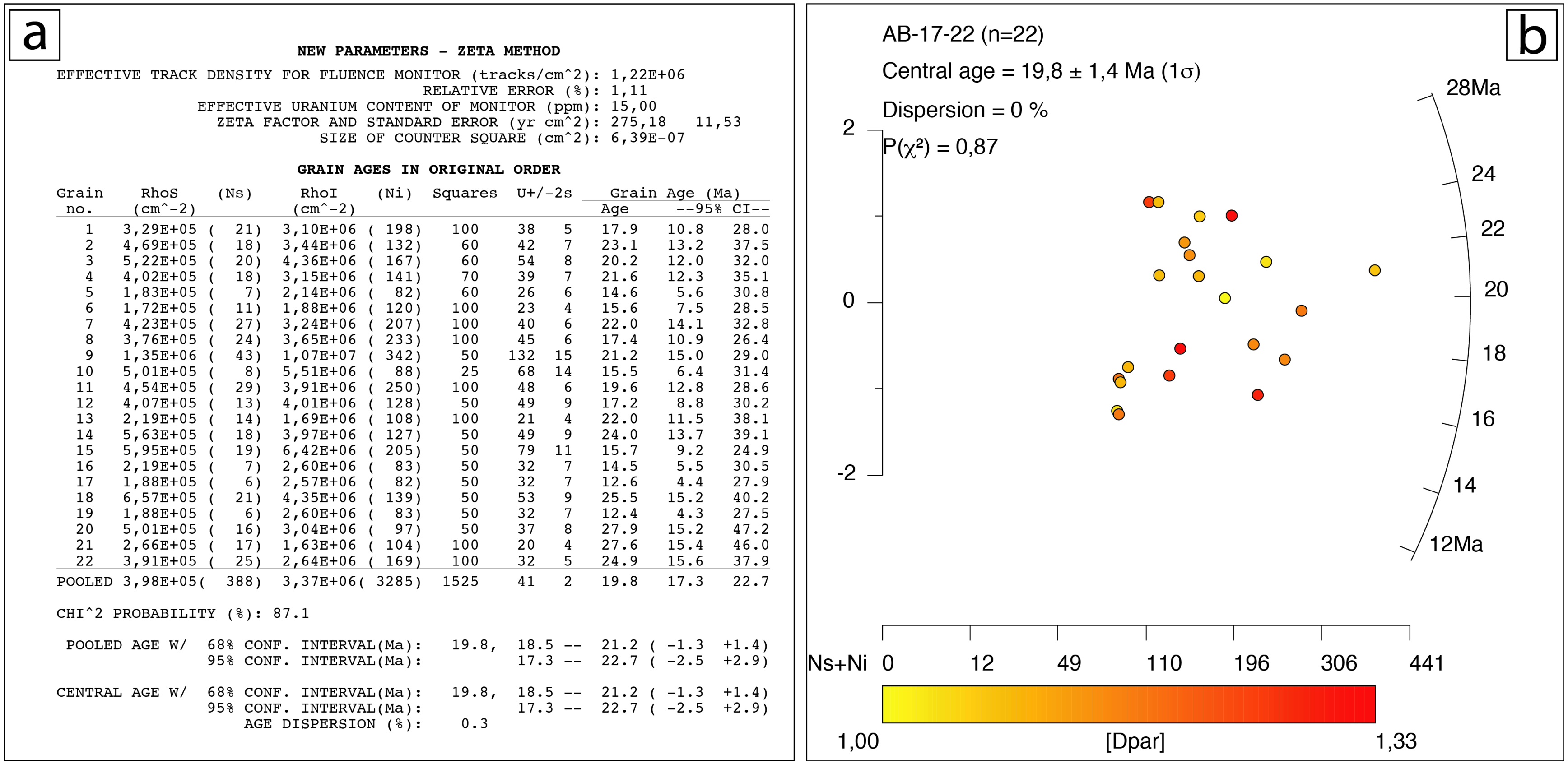


Figure S9. AFT single-grain data (a) and radial plots (b) for sample AB-17-19. See Figure S44 for location.



```
                         NEW PARAMETERS - ZETA METHOD
EFFECTIVE TRACK DENSITY FOR FLUENCE MONITOR (tracks/cm^2): 1,22E+06
                                       RELATIVE ERROR (%): 1,11
               EFFECTIVE URANIUM CONTENT OF MONITOR (ppm): 15,00
                 ZETA FACTOR AND STANDARD ERROR (yr cm^2): 275,18   11,53
                            SIZE OF COUNTER SQUARE (cm^2): 6,39E-07

                         GRAIN AGES IN ORIGINAL ORDER

Grain    RhoS    (Ns)     RhoI    (Ni)  Squares  U+/-2s    Grain Age (Ma)
 no.   (cm^-2)          (cm^-2)                          Age     --95% CI--

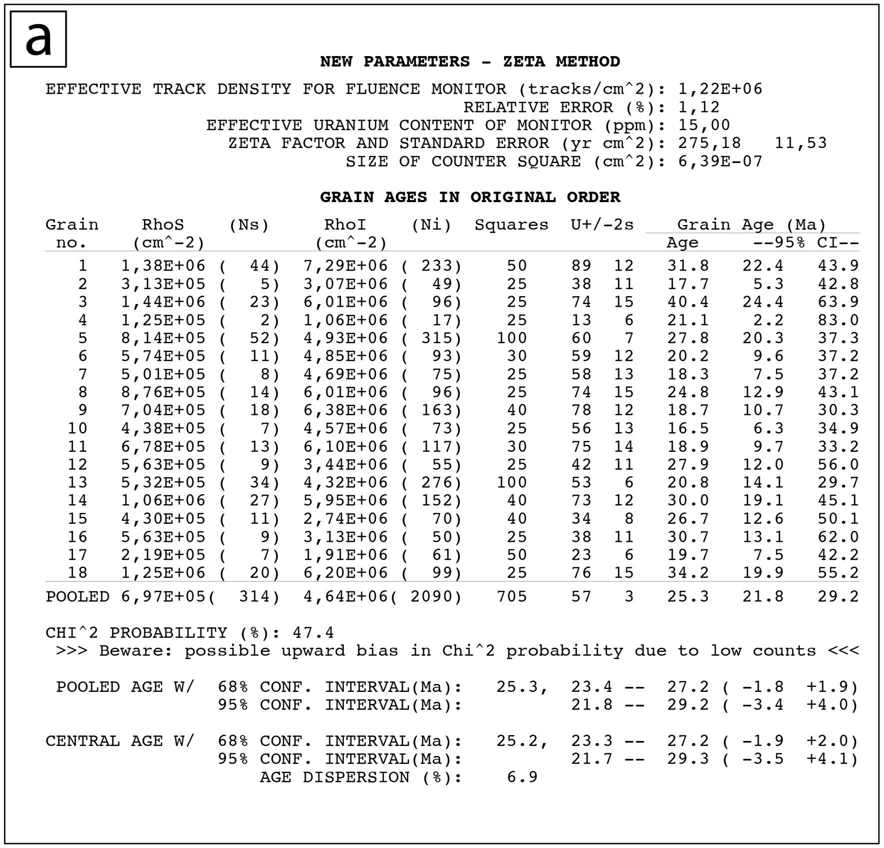
   1   3,29E+05 (  21)  3,10E+06 ( 198)   100     38   5   17.9    10.8    28.0
   2   4,69E+05 (  18)  3,44E+06 ( 132)    60     42   7   23.1    13.2    37.5
   3   5,22E+05 (  20)  4,36E+06 ( 167)    60     54   8   20.2    12.0    32.0
   4   4,02E+05 (  18)  3,15E+06 ( 141)    70     39   7   21.6    12.3    35.1
   5   1,83E+05 (   7)  2,14E+06 (  82)    60     26   6   14.6     5.6    30.8
   6   1,72E+05 (  11)  1,88E+06 ( 120)   100     23   4   15.6     7.5    28.5
   7   4,23E+05 (  27)  3,24E+06 ( 207)   100     40   6   22.0    14.1    32.8
   8   3,76E+05 (  24)  3,65E+06 ( 233)   100     45   6   17.4    10.9    26.4
   9   1,35E+06 (  43)  1,07E+07 ( 342)    50    132  15   21.2    15.0    29.0
  10   5,01E+05 (   8)  5,51E+06 (  88)    25     68  14   15.5     6.4    31.4
  11   4,54E+05 (  29)  3,91E+06 ( 250)   100     48   6   19.6    12.8    28.6
  12   4,07E+05 (  13)  4,01E+06 ( 128)    50     49   9   17.2     8.8    30.2
  13   2,19E+05 (  14)  1,69E+06 ( 108)   100     21   4   22.0    11.5    38.1
  14   5,63E+05 (  18)  3,97E+06 ( 127)    50     49   9   24.0    13.7    39.1
  15   5,95E+05 (  19)  6,42E+06 ( 205)    50     79  11   15.7     9.2    24.9
  16   2,19E+05 (   7)  2,60E+06 (  83)    50     32   7   14.5     5.5    30.5
  17   1,88E+05 (   6)  2,57E+06 (  82)    50     32   7   12.6     4.4    27.9
  18   6,57E+05 (  21)  4,35E+06 ( 139)    50     53   9   25.5    15.2    40.2
  19   1,88E+05 (   6)  2,60E+06 (  83)    50     32   7   12.4     4.3    27.5
  20   5,01E+05 (  16)  3,04E+06 (  97)    50     37   8   27.9    15.2    47.2
  21   2,66E+05 (  17)  1,63E+06 ( 104)   100     20   4   27.6    15.4    46.0
  22   3,91E+05 (  25)  2,64E+06 ( 169)   100     32   5   24.9    15.6    37.9
POOLED 3,98E+05(  388)  3,37E+06( 3285)  1525     41   2   19.8    17.3    22.7

CHI^2 PROBABILITY (%): 87.1

 POOLED AGE W/  68% CONF. INTERVAL(Ma):   19.8,  18.5 --  21.2 ( -1.3  +1.4)
                95% CONF. INTERVAL(Ma):          17.3 --  22.7 ( -2.5  +2.9)

CENTRAL AGE W/  68% CONF. INTERVAL(Ma):   19.8,  18.5 --  21.2 ( -1.3  +1.4)
                95% CONF. INTERVAL(Ma):          17.3 --  22.7 ( -2.5  +2.9)
                    AGE DISPERSION (%):    0.3
```

Figure S10. AFT single-grain data (a) and radial plots (b) for sample AB-17-22. See Figure S44 for location.



```
                    NEW PARAMETERS - ZETA METHOD
EFFECTIVE TRACK DENSITY FOR FLUENCE MONITOR (tracks/cm^2): 1,22E+06
                                       RELATIVE ERROR (%): 1,12
               EFFECTIVE URANIUM CONTENT OF MONITOR (ppm): 15,00
                 ZETA FACTOR AND STANDARD ERROR (yr cm^2): 275,18   11,53
                             SIZE OF COUNTER SQUARE (cm^2): 6,39E-07

                    GRAIN AGES IN ORIGINAL ORDER

Grain     RhoS     (Ns)      RhoI     (Ni)  Squares  U+/-2s   Grain Age (Ma)
 no.    (cm^-2)            (cm^-2)                            Age    --95% CI--
   1   1,38E+06 (   44)  7,29E+06 ( 233)     50     89  12    31.8    22.4    43.9
   2   3,13E+05 (    5)  3,07E+06 (  49)     25     38  11    17.7     5.3    42.8
   3   1,44E+06 (   23)  6,01E+06 (  96)     25     74  15    40.4    24.4    63.9
   4   1,25E+05 (    2)  1,06E+06 (  17)     25     13   6    21.1     2.2    83.0
   5   8,14E+05 (   52)  4,93E+06 ( 315)    100     60   7    27.8    20.3    37.3
   6   5,74E+05 (   11)  4,85E+06 (  93)     30     59  12    20.2     9.6    37.2
   7   5,01E+05 (    8)  4,69E+06 (  75)     25     58  13    18.3     7.5    37.2
   8   8,76E+05 (   14)  6,01E+06 (  96)     25     74  15    24.8    12.9    43.1
   9   7,04E+05 (   18)  6,38E+06 ( 163)     40     78  12    18.7    10.7    30.3
  10   4,38E+05 (    7)  4,57E+06 (  73)     25     56  13    16.5     6.3    34.9
  11   6,78E+05 (   13)  6,10E+06 ( 117)     30     75  14    18.9     9.7    33.2
  12   5,63E+05 (    9)  3,44E+06 (  55)     25     42  11    27.9    12.0    56.0
  13   5,32E+05 (   34)  4,32E+06 ( 276)    100     53   6    20.8    14.1    29.7
  14   1,06E+06 (   27)  5,95E+06 ( 152)     40     73  12    30.0    19.1    45.1
  15   4,30E+05 (   11)  2,74E+06 (  70)     40     34   8    26.7    12.6    50.1
  16   5,63E+05 (    9)  3,13E+06 (  50)     25     38  11    30.7    13.1    62.0
  17   2,19E+05 (    7)  1,91E+06 (  61)     50     23   6    19.7     7.5    42.2
  18   1,25E+06 (   20)  6,20E+06 (  99)     25     76  15    34.2    19.9    55.2
POOLED 6,97E+05(  314)  4,64E+06( 2090)    705     57   3    25.3    21.8    29.2

CHI^2 PROBABILITY (%): 47.4
 >>> Beware: possible upward bias in Chi^2 probability due to low counts <<<

 POOLED AGE W/   68% CONF. INTERVAL(Ma):   25.3,  23.4 --  27.2 ( -1.8   +1.9)
                 95% CONF. INTERVAL(Ma):          21.8 --  29.2 ( -3.4   +4.0)

CENTRAL AGE W/   68% CONF. INTERVAL(Ma):   25.2,  23.3 --  27.2 ( -1.9   +2.0)
                 95% CONF. INTERVAL(Ma):          21.7 --  29.3 ( -3.5   +4.1)
                     AGE DISPERSION (%):    6.9
```

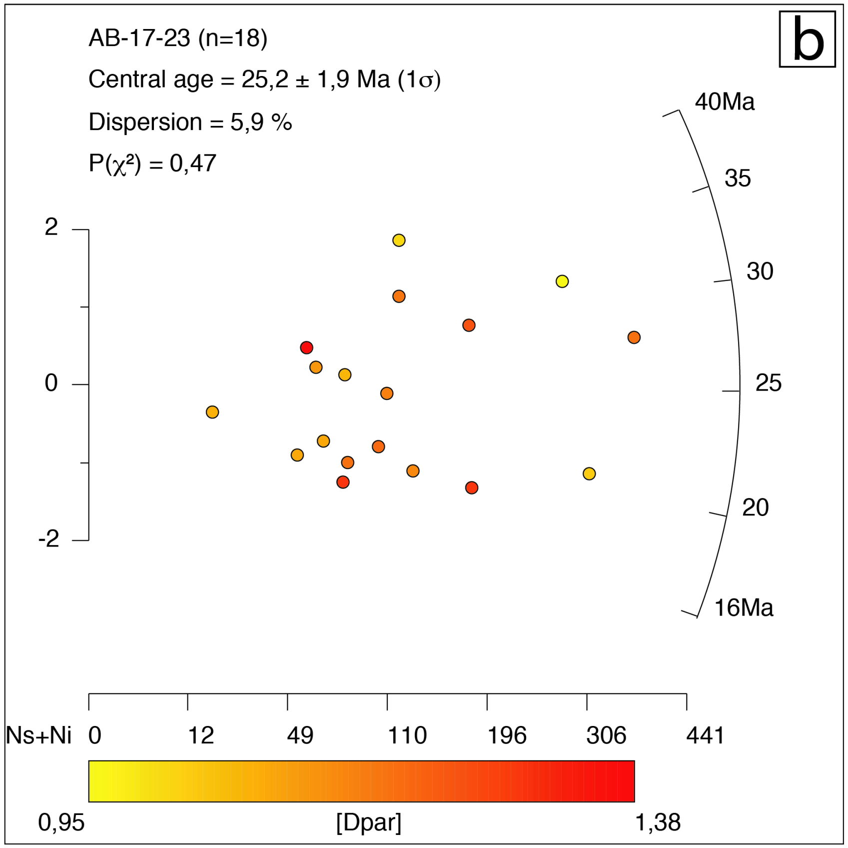


Figure S11. AFT single-grain data (a) and radial plots (b) for sample AB-17-23. See Figure S44 for location.

a

```
                          NEW PARAMETERS - ZETA METHOD
EFFECTIVE TRACK DENSITY FOR FLUENCE MONITOR (tracks/cm^2): 1,23E+06
                                       RELATIVE ERROR (%): 1,14
               EFFECTIVE URANIUM CONTENT OF MONITOR (ppm): 15,00
                 ZETA FACTOR AND STANDARD ERROR (yr cm^2): 275,18   11,53
                            SIZE OF COUNTER SQUARE (cm^2): 6,39E-07

                          GRAIN AGES IN ORIGINAL ORDER

Grain    RhoS    (Ns)     RhoI    (Ni)  Squares  U+/-2s     Grain Age (Ma)
 no.    (cm^-2)          (cm^-2)                           Age     --95% CI--
   1   2,51E+06 (  77)  9,10E+06 ( 279)     48   111  14   46.3   35.6   60.4
   2   1,38E+06 (  22)  6,95E+06 ( 111)     25    85  16   33.6   20.1   53.0
   3   1,63E+06 (  26)  8,39E+06 ( 134)     25   103  18   32.8   20.6   49.9
   4   2,07E+06 (  33)  7,45E+06 ( 119)     25    91  17   46.8   30.7   69.0
   5   2,06E+06 (  79)  8,06E+06 ( 309)     60    99  11   42.9   33.1   55.7
   6   1,38E+06 (  44)  5,70E+06 ( 182)     50    70  10   40.8   28.6   56.8
   7   1,56E+06 (  50)  5,70E+06 ( 182)     50    70  10   46.3   33.1   63.4
   8   1,28E+06 (  41)  5,45E+06 ( 174)     50    67  10   39.8   27.5   55.9
   9   1,31E+06 (  84)  6,21E+06 ( 397)    100    76   8   35.6   27.7   45.6
  10   1,47E+06 (  94)  7,12E+06 ( 455)    100    87   8   34.7   27.4   44.0
  11   1,63E+06 (  26)  7,45E+06 ( 119)     25    91  17   36.9   23.1   56.5
  12   1,58E+06 ( 101)  8,34E+06 ( 533)    100   102   9   31.9   25.4   40.0
  13   1,44E+06 (  46)  7,36E+06 ( 235)     50    90  12   33.0   23.5   45.3
  14   2,11E+06 (  54)  8,57E+06 ( 219)     40   105  14   41.6   30.2   56.1
  15   1,94E+06 (  31)  6,95E+06 ( 111)     25    85  16   47.1   30.5   70.4
  16   2,57E+06 (  41)  9,01E+06 ( 144)     25   110  19   48.0   33.0   68.1
  17   1,20E+06 (  23)  5,95E+06 ( 114)     30    73  14   34.1   20.7   53.4
  18   1,82E+06 (  29)  1,01E+07 ( 162)     25   124  20   30.3   19.6   44.9
POOLED 1,65E+06(  901)  7,30E+06( 3979)    853    89   3   38.1   34.1   42.6

CHI^2 PROBABILITY (%): 51.7

 POOLED AGE W/  68% CONF. INTERVAL(Ma):    38.1,  36.0 --  40.3 ( -2.1  +2.2)
                95% CONF. INTERVAL(Ma):           34.1 --  42.6 ( -4.0  +4.5)

CENTRAL AGE W/  68% CONF. INTERVAL(Ma):    38.2,  36.0 --  40.4 ( -2.1  +2.3)
                95% CONF. INTERVAL(Ma):           34.1 --  42.8 ( -4.1  +4.6)
                    AGE DISPERSION (%):     4.0
```

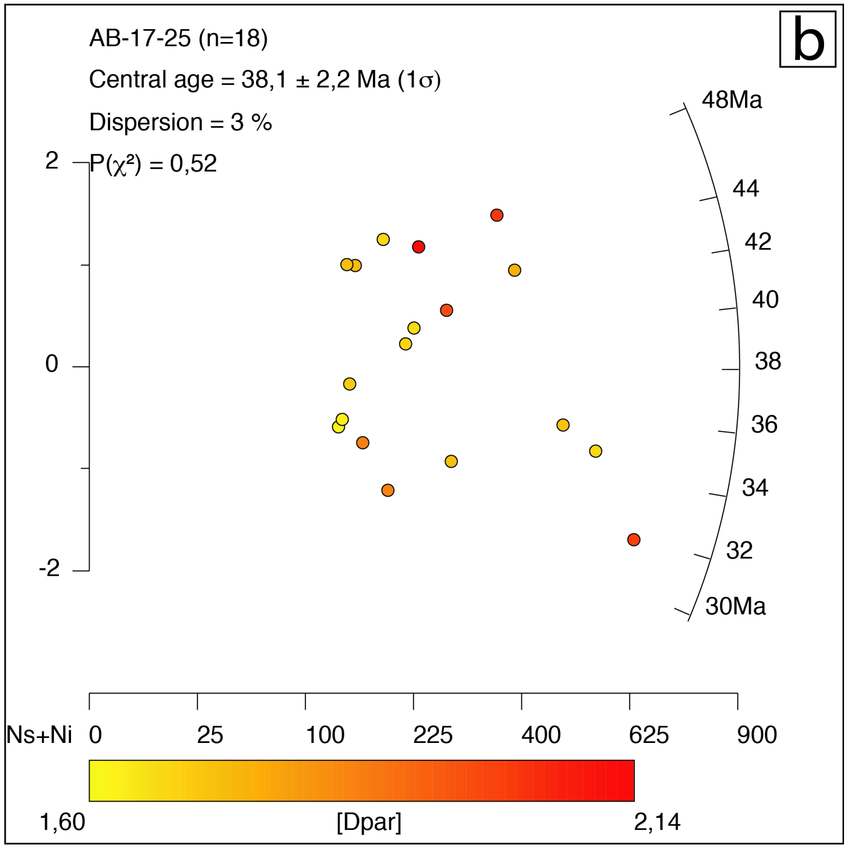


Figure S12. AFT single-grain data (a) and radial plots (b) for sample AB-17-25. See Figure S44 for location.

a

```
                          NEW PARAMETERS - ZETA METHOD
EFFECTIVE TRACK DENSITY FOR FLUENCE MONITOR (tracks/cm^2): 1,23E+06
                                        RELATIVE ERROR (%): 1,16
                EFFECTIVE URANIUM CONTENT OF MONITOR (ppm): 15,00
                  ZETA FACTOR AND STANDARD ERROR (yr cm^2): 275,18   11,53
                             SIZE OF COUNTER SQUARE (cm^2): 6,39E-07

                          GRAIN AGES IN ORIGINAL ORDER

Grain    RhoS    (Ns)     RhoI    (Ni) Squares   U+/-2s    Grain Age (Ma)
 no.    (cm^-2)          (cm^-2)                           Age     --95% CI--

   1   2,82E+05 (   9)  2,22E+06 (  71)     50    27   6   21.7    9.4   42.9
   2   3,13E+05 (  10)  2,85E+06 (  91)     50    35   7   18.8    8.6   35.7
   3   3,76E+05 (   6)  2,63E+06 (  42)     25    32  10   24.7    8.4   56.8
   4   4,07E+05 (  13)  2,54E+06 (  81)     50    31   7   27.4   13.8   48.9
   5   3,13E+05 (  12)  2,95E+06 ( 113)     60    36   7   18.1    9.0   32.5
   6   3,13E+05 (   8)  1,96E+06 (  50)     40    24   7   27.4   11.1   57.3
   7   1,88E+05 (   6)  1,75E+06 (  56)     50    21   6   18.5    6.4   41.8
   8   3,13E+05 (  16)  2,88E+06 ( 147)     80    35   6   18.5   10.2   30.8
   9   3,13E+05 (   8)  3,21E+06 (  82)     40    39   9   16.8    6.9   34.0
  10   2,50E+05 (   4)  2,19E+06 (  35)     25    27   9   20.0    5.0   53.8
  11   1,96E+05 (   5)  2,86E+06 (  73)     40    35   8   11.9    3.6   28.2
  12   1,49E+05 (   4)  1,97E+06 (  53)     42    24   7   13.2    3.4   34.5
  13   1,88E+05 (   6)  2,00E+06 (  64)     50    24   6   16.2    5.6   36.3
  14   4,17E+05 (  16)  2,63E+06 ( 101)     60    32   6   26.9   14.7   45.5
  15   2,50E+05 (  16)  2,13E+06 ( 136)    100    26   4   20.0   11.0   33.4
  16   2,50E+05 (   8)  2,57E+06 (  82)     50    31   7   16.8    6.9   34.0
  17   3,76E+05 (  24)  3,10E+06 ( 198)    100    38   5   20.6   12.8   31.3
  18   4,17E+05 (  16)  3,36E+06 ( 129)     60    41   7   21.1   11.6   35.3
  19   3,60E+05 (  23)  2,97E+06 ( 190)    100    36   5   20.6   12.6   31.6
  20   1,25E+05 (   8)  8,29E+05 (  53)    100    10   3   25.9   10.5   53.8
  21   4,85E+05 (  31)  3,99E+06 ( 255)    100    49   6   20.6   13.6   29.9
  22   3,91E+05 (  20)  3,23E+06 ( 165)     80    39   6   20.6   12.2   32.6
  23   1,83E+05 (   7)  1,56E+06 (  60)     60    19   5   20.1    7.6   43.0
  24   1,56E+05 (  10)  1,03E+06 (  66)    100    13   3   25.9   11.7   49.9
POOLED 2,96E+05(  286)  2,48E+06( 2393)   1512    30   1   20.2   17.4   23.4

CHI^2 PROBABILITY (%): 99.9
 >>> Beware: possible upward bias in Chi^2 probability due to low counts <<<

 POOLED AGE W/  68% CONF. INTERVAL(Ma):   20.2,  18.7 --  21.8 ( -1.5  +1.6)
                95% CONF. INTERVAL(Ma):          17.4 --  23.4 ( -2.8  +3.2)

CENTRAL AGE W/  68% CONF. INTERVAL(Ma):   20.2,  18.7 --  21.8 ( -1.5  +1.6)
                95% CONF. INTERVAL(Ma):          17.4 --  23.4 ( -2.8  +3.2)
                    AGE DISPERSION (%):    0.1
```

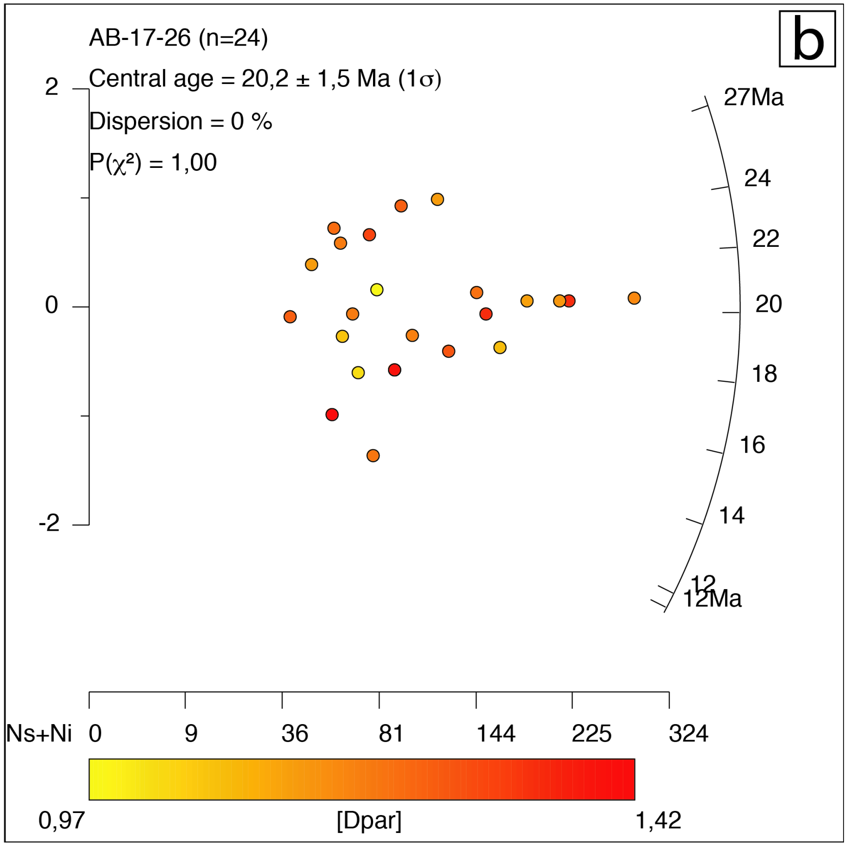
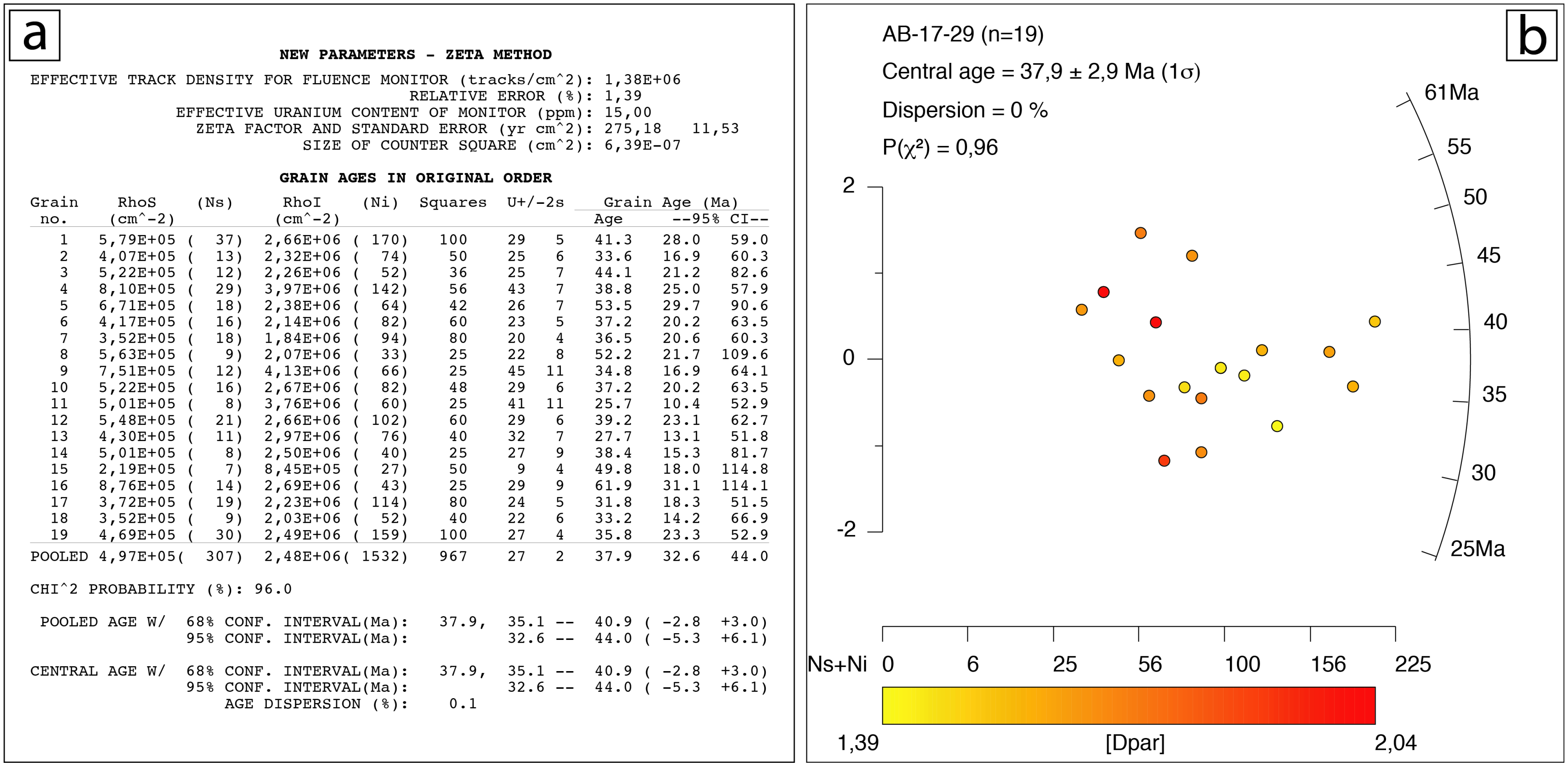


Figure S13. AFT single-grain data (a) and radial plots (b) for sample AB-17-26. See Figure S44 for location.



```
                         NEW PARAMETERS - ZETA METHOD
EFFECTIVE TRACK DENSITY FOR FLUENCE MONITOR (tracks/cm^2): 1,38E+06
                                       RELATIVE ERROR (%): 1,39
               EFFECTIVE URANIUM CONTENT OF MONITOR (ppm): 15,00
                 ZETA FACTOR AND STANDARD ERROR (yr cm^2): 275,18   11,53
                            SIZE OF COUNTER SQUARE (cm^2): 6,39E-07

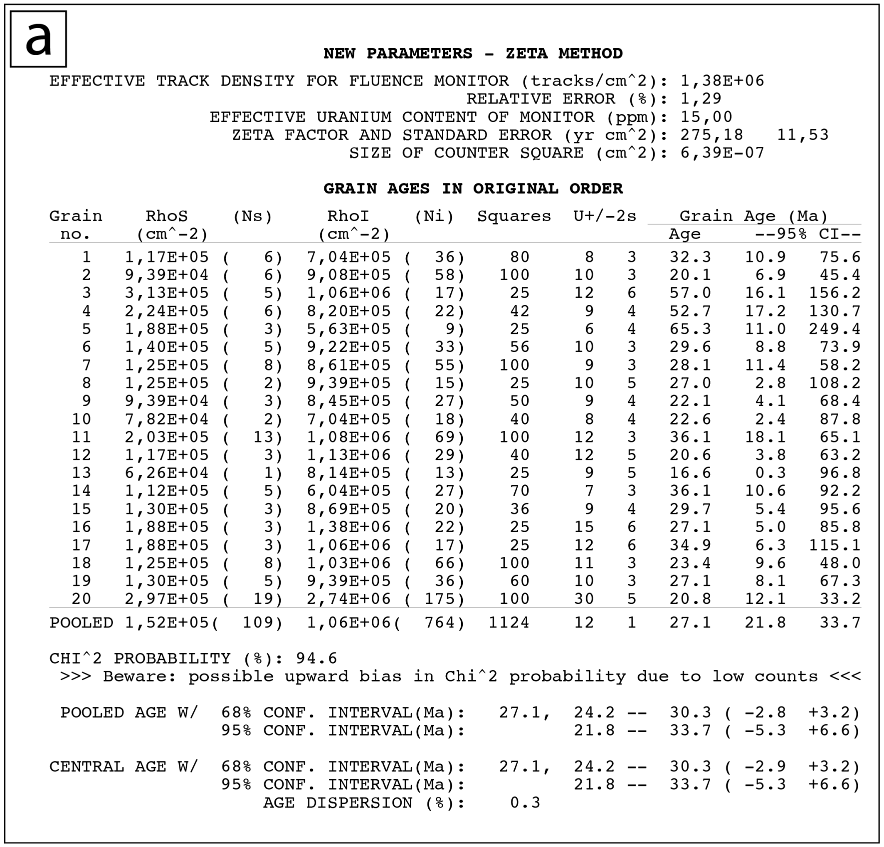
                         GRAIN AGES IN ORIGINAL ORDER
Grain     RhoS     (Ns)       RhoI     (Ni)  Squares  U+/-2s    Grain Age (Ma)
 no.     (cm^-2)             (cm^-2)                            Age    --95% CI--
   1   5,79E+05 (  37)  2,66E+06 ( 170)    100     29    5    41.3    28.0    59.0
   2   4,07E+05 (  13)  2,32E+06 (  74)     50     25    6    33.6    16.9    60.3
   3   5,22E+05 (  12)  2,26E+06 (  52)     36     25    7    44.1    21.2    82.6
   4   8,10E+05 (  29)  3,97E+06 ( 142)     56     43    7    38.8    25.0    57.9
   5   6,71E+05 (  18)  2,38E+06 (  64)     42     26    7    53.5    29.7    90.6
   6   4,17E+05 (  16)  2,14E+06 (  82)     60     23    5    37.2    20.2    63.5
   7   3,52E+05 (  18)  1,84E+06 (  94)     80     20    4    36.5    20.6    60.3
   8   5,63E+05 (   9)  2,07E+06 (  33)     25     22    8    52.2    21.7   109.6
   9   7,51E+05 (  12)  4,13E+06 (  66)     25     45   11    34.8    16.9    64.1
  10   5,22E+05 (  16)  2,67E+06 (  82)     48     29    6    37.2    20.2    63.5
  11   5,01E+05 (   8)  3,76E+06 (  60)     25     41   11    25.7    10.4    52.9
  12   5,48E+05 (  21)  2,66E+06 ( 102)     60     29    6    39.2    23.1    62.7
  13   4,30E+05 (  11)  2,97E+06 (  76)     40     32    7    27.7    13.1    51.8
  14   5,01E+05 (   8)  2,50E+06 (  40)     25     27    9    38.4    15.3    81.7
  15   2,19E+05 (   7)  8,45E+05 (  27)     50      9    4    49.8    18.0   114.8
  16   8,76E+05 (  14)  2,69E+06 (  43)     25     29    9    61.9    31.1   114.1
  17   3,72E+05 (  19)  2,23E+06 ( 114)     80     24    5    31.8    18.3    51.5
  18   3,52E+05 (   9)  2,03E+06 (  52)     40     22    6    33.2    14.2    66.9
  19   4,69E+05 (  30)  2,49E+06 ( 159)    100     27    4    35.8    23.3    52.9
POOLED 4,97E+05(  307)  2,48E+06( 1532)    967     27    2    37.9    32.6    44.0

CHI^2 PROBABILITY (%): 96.0

 POOLED AGE W/   68% CONF. INTERVAL(Ma):    37.9,   35.1 --   40.9 ( -2.8   +3.0)
                 95% CONF. INTERVAL(Ma):            32.6 --   44.0 ( -5.3   +6.1)

CENTRAL AGE W/   68% CONF. INTERVAL(Ma):    37.9,   35.1 --   40.9 ( -2.8   +3.0)
                 95% CONF. INTERVAL(Ma):            32.6 --   44.0 ( -5.3   +6.1)
                    AGE DISPERSION (%):      0.1
```

Figure S14. AFT single-grain data (a) and radial plots (b) for sample AB-17-29. See Figure S44 for location.



```
                           NEW PARAMETERS - ZETA METHOD
EFFECTIVE TRACK DENSITY FOR FLUENCE MONITOR (tracks/cm^2): 1,38E+06
                                       RELATIVE ERROR (%): 1,29
               EFFECTIVE URANIUM CONTENT OF MONITOR (ppm): 15,00
                 ZETA FACTOR AND STANDARD ERROR (yr cm^2): 275,18   11,53
                            SIZE OF COUNTER SQUARE (cm^2): 6,39E-07

                           GRAIN AGES IN ORIGINAL ORDER
Grain     RhoS     (Ns)       RhoI     (Ni)  Squares  U+/-2s    Grain Age (Ma)
 no.     (cm^-2)             (cm^-2)                           Age     --95% CI--
   1   1,17E+05 (    6)  7,04E+05 (   36)    80      8    3    32.3    10.9    75.6
   2   9,39E+04 (    6)  9,08E+05 (   58)   100     10    3    20.1     6.9    45.4
   3   3,13E+05 (    5)  1,06E+06 (   17)    25     12    6    57.0    16.1   156.2
   4   2,24E+05 (    6)  8,20E+05 (   22)    42      9    4    52.7    17.2   130.7
   5   1,88E+05 (    3)  5,63E+05 (    9)    25      6    4    65.3    11.0   249.4
   6   1,40E+05 (    5)  9,22E+05 (   33)    56     10    3    29.6     8.8    73.9
   7   1,25E+05 (    8)  8,61E+05 (   55)   100      9    3    28.1    11.4    58.2
   8   1,25E+05 (    2)  9,39E+05 (   15)    25     10    5    27.0     2.8   108.2
   9   9,39E+04 (    3)  8,45E+05 (   27)    50      9    4    22.1     4.1    68.4
  10   7,82E+04 (    2)  7,04E+05 (   18)    40      8    4    22.6     2.4    87.8
  11   2,03E+05 (   13)  1,08E+06 (   69)   100     12    3    36.1    18.1    65.1
  12   1,17E+05 (    3)  1,13E+06 (   29)    40     12    5    20.6     3.8    63.2
  13   6,26E+04 (    1)  8,14E+05 (   13)    25      9    5    16.6     0.3    96.8
  14   1,12E+05 (    5)  6,04E+05 (   27)    70      7    3    36.1    10.6    92.2
  15   1,30E+05 (    3)  8,69E+05 (   20)    36      9    4    29.7     5.4    95.6
  16   1,88E+05 (    3)  1,38E+06 (   22)    25     15    6    27.1     5.0    85.8
  17   1,88E+05 (    3)  1,06E+06 (   17)    25     12    6    34.9     6.3   115.1
  18   1,25E+05 (    8)  1,03E+06 (   66)   100     11    3    23.4     9.6    48.0
  19   1,30E+05 (    5)  9,39E+05 (   36)    60     10    3    27.1     8.1    67.3
  20   2,97E+05 (   19)  2,74E+06 (  175)   100     30    5    20.8    12.1    33.2
POOLED 1,52E+05(  109)  1,06E+06(  764)  1124     12    1    27.1    21.8    33.7

CHI^2 PROBABILITY (%): 94.6
 >>> Beware: possible upward bias in Chi^2 probability due to low counts <<<

 POOLED AGE W/  68% CONF. INTERVAL(Ma):   27.1,  24.2 --  30.3 ( -2.8  +3.2)
                95% CONF. INTERVAL(Ma):          21.8 --  33.7 ( -5.3  +6.6)

CENTRAL AGE W/  68% CONF. INTERVAL(Ma):   27.1,  24.2 --  30.3 ( -2.9  +3.2)
                95% CONF. INTERVAL(Ma):          21.8 --  33.7 ( -5.3  +6.6)
                    AGE DISPERSION (%):    0.3
```

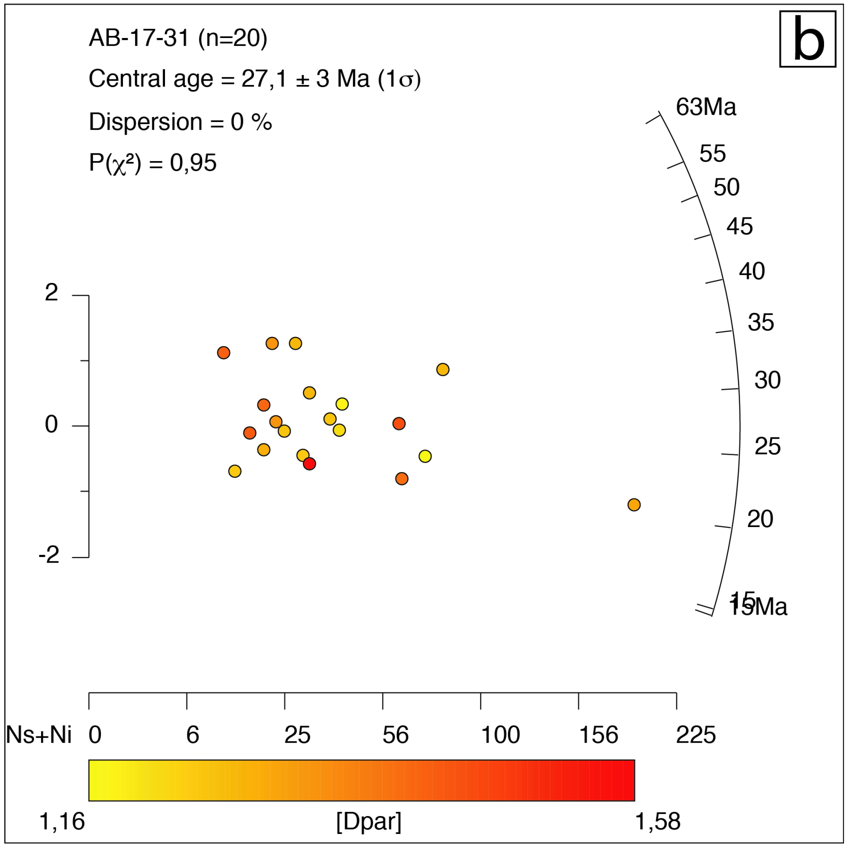


Figure S15. AFT single-grain data (a) and radial plots (b) for sample AB-17-31. See Figure S44 for location.

a

```
                      NEW PARAMETERS - ZETA METHOD
EFFECTIVE TRACK DENSITY FOR FLUENCE MONITOR (tracks/cm^2): 1,39E+06
                                       RELATIVE ERROR (%): 1,24
               EFFECTIVE URANIUM CONTENT OF MONITOR (ppm): 15,00
                 ZETA FACTOR AND STANDARD ERROR (yr cm^2): 275,18   11,53
                            SIZE OF COUNTER SQUARE (cm^2): 6,39E-07

                      GRAIN AGES IN ORIGINAL ORDER
Grain    RhoS     (Ns)       RhoI     (Ni)  Squares   U+/-2s    Grain Age (Ma)
 no.    (cm^-2)             (cm^-2)                            Age      --95% CI--

   1   1,79E+05 (   8)  1,21E+06 (  54)     70      13   4    28.7     11.6    59.5
   2   2,19E+05 (   7)  1,38E+06 (  44)     50      15   4    30.9     11.5    67.6
   3   6,26E+04 (   1)  6,26E+05 (  10)     25       7   4    21.5      0.4   132.7
   4   1,56E+05 (  10)  9,08E+05 (  58)    100      10   3    33.2     15.0    64.6
   5   1,60E+05 (   5)  1,85E+06 (  58)     49      20   5    16.9      5.1    40.5
   6   1,56E+05 (   7)  1,92E+06 (  86)     70      21   5    15.8      6.1    33.3
   7   1,96E+05 (   5)  9,78E+05 (  25)     40      11   4    39.0     11.4   100.7
   8   1,96E+05 (   5)  1,88E+06 (  48)     40      20   6    20.4      6.2    49.5
   9   1,56E+05 (   4)  8,61E+05 (  22)     40       9   4    35.7      8.7   101.3
  10   1,04E+05 (   4)  5,74E+05 (  22)     60       6   3    35.7      8.7   101.3
  11   7,45E+04 (   2)  5,22E+05 (  14)     42       6   3    29.0      3.0   117.6
  12   1,56E+05 (   5)  1,13E+06 (  36)     50      12   4    27.2      8.1    67.4
  13   1,17E+05 (   3)  1,45E+06 (  37)     40      16   5    16.2      3.0    48.7
  14   5,16E+05 (  33)  4,29E+06 ( 274)    100      46   6    23.0     15.5    33.0
  15   1,88E+05 (   3)  1,38E+06 (  22)     25      15   6    27.1      5.0    86.0
  16   2,35E+05 (   6)  1,25E+06 (  32)     40      14   5    36.4     12.2    86.2
  17   0,00E+00 (   0)  5,01E+05 (   8)     25       5   4    17.2      0.6   110.8
  18   1,56E+05 (  10)  1,08E+06 (  69)    100      12   3    28.0     12.7    53.8
  19   1,56E+05 (   5)  9,08E+05 (  29)     50      10   4    33.7      9.9    85.4
  20   1,96E+05 (  10)  1,35E+06 (  69)     80      15   4    28.0     12.7    53.8
POOLED 1,90E+05(  133)  1,45E+06( 1017)   1096      16   1    24.9     20.4    30.4

CHI^2 PROBABILITY (%): 98.5
 >>> Beware: possible upward bias in Chi^2 probability due to low counts <<<

 POOLED AGE W/  68% CONF. INTERVAL(Ma):   24.9,  22.5 --  27.6 ( -2.4  +2.7)
                95% CONF. INTERVAL(Ma):          20.4 --  30.4 ( -4.5  +5.5)

CENTRAL AGE W/  68% CONF. INTERVAL(Ma):   24.9,  22.5 --  27.6 ( -2.4  +2.7)
                95% CONF. INTERVAL(Ma):          20.4 --  30.4 ( -4.5  +5.5)
                    AGE DISPERSION (%):    0.1
```

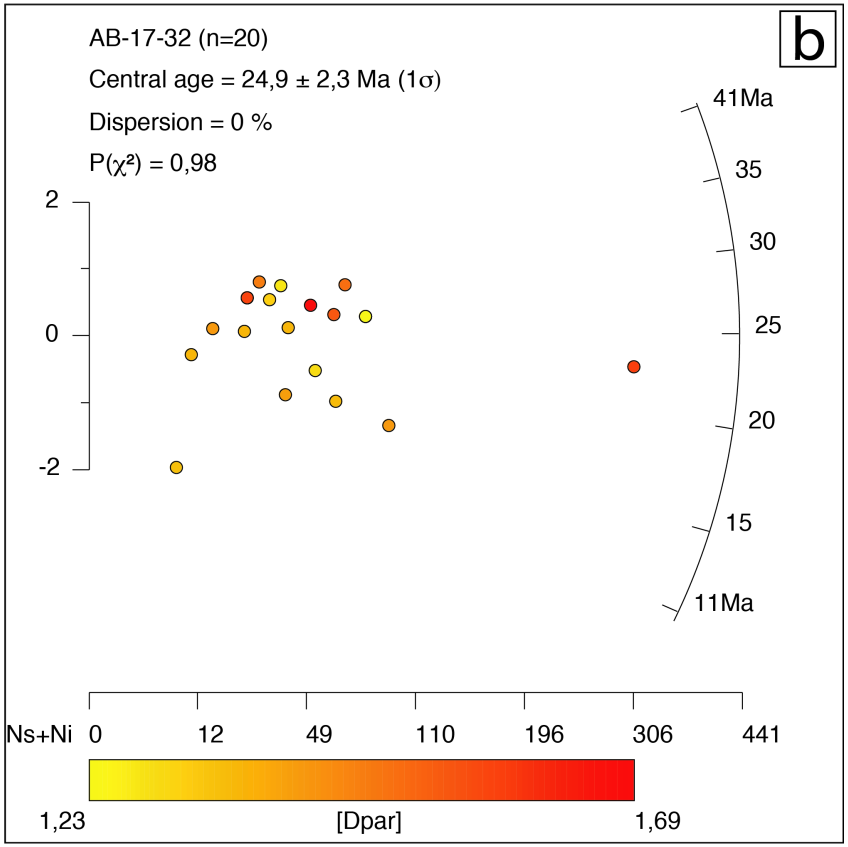


Figure S16. AFT single-grain data (a) and radial plots (b) for sample AB-17-32. See Figure S44 for location.

a

```
                         NEW PARAMETERS - ZETA METHOD
EFFECTIVE TRACK DENSITY FOR FLUENCE MONITOR (tracks/cm^2): 1,39E+06
                                       RELATIVE ERROR (%): 1,21
               EFFECTIVE URANIUM CONTENT OF MONITOR (ppm): 15,00
                 ZETA FACTOR AND STANDARD ERROR (yr cm^2): 275,18   11,53
                            SIZE OF COUNTER SQUARE (cm^2): 6,39E-07

                         GRAIN AGES IN ORIGINAL ORDER

Grain     RhoS    (Ns)      RhoI    (Ni)  Squares  U+/-2s    Grain Age (Ma)
 no.    (cm^-2)           (cm^-2)                           Age      --95% CI--

   1   2,19E+05 (  14)  1,88E+06 ( 120)   100     20    4   22.5    11.8    38.8
   2   1,34E+05 (   6)  1,43E+06 (  64)    70     15    4   18.3     6.3    41.1
   3   1,79E+05 (   8)  1,05E+06 (  47)    70     11    3   33.0    13.3    69.2
   4   6,26E+04 (   2)  8,14E+05 (  26)    50      9    3   15.7     1.7    58.5
   5   2,50E+05 (  16)  2,28E+06 ( 146)   100     25    4   21.1    11.6    35.1
   6   2,35E+05 (   9)  1,72E+06 (  66)    60     19    5   26.4    11.4    52.4
   7   2,15E+05 (  11)  2,50E+06 ( 128)    80     27    5   16.6     8.0    30.3
   8   3,73E+05 (  10)  3,09E+06 (  83)    42     33    7   23.3    10.6    44.4
   9   2,03E+05 (  13)  1,28E+06 (  82)   100     14    3   30.6    15.5    54.5
  10   6,26E+04 (   2)  6,57E+05 (  21)    50      7    3   19.4     2.1    74.1
  11   7,82E+04 (   3)  1,17E+06 (  45)    60     13    4   13.4     2.5    39.6
  12   1,56E+05 (   3)  3,08E+06 (  59)    30     33    9   10.2     1.9    29.8
  13   1,96E+05 (   5)  1,68E+06 (  43)    40     18    6   22.8     6.9    55.8
  14   1,25E+05 (   4)  6,26E+05 (  20)    50      7    3   39.3     9.5   113.2
  15   1,17E+05 (   3)  2,23E+06 (  57)    40     24    6   10.6     2.0    30.9
  16   3,65E+05 (   7)  3,50E+06 (  67)    30     38    9   20.4     7.7    43.3
  17   1,56E+05 (   3)  1,10E+06 (  21)    30     12    5   28.5     5.2    90.8
  18   4,69E+05 (  21)  3,80E+06 ( 170)    70     41    6   23.7    14.2    37.2
  19   1,96E+05 (  10)  2,07E+06 ( 106)    80     22    4   18.3     8.4    34.4
  20   7,45E+04 (   2)  8,94E+05 (  24)    42     10    4   17.0     1.8    63.9
  21   6,26E+04 (   4)  9,08E+05 (  58)   100     10    3   13.7     3.5    35.5
  22   1,30E+05 (   3)  2,00E+06 (  46)    36     22    6   13.1     2.5    38.7
POOLED 1,87E+05(  159)  1,76E+06( 1499)  1330     19    1   20.2    16.8    24.3

CHI^2 PROBABILITY (%): 93.1
 >>> Beware: possible upward bias in Chi^2 probability due to low counts <<<

 POOLED AGE W/  68% CONF. INTERVAL(Ma):   20.2,  18.4 --  22.2 ( -1.8  +2.0)
                95% CONF. INTERVAL(Ma):          16.8 --  24.3 ( -3.4  +4.1)

CENTRAL AGE W/  68% CONF. INTERVAL(Ma):   20.2,  18.4 --  22.2 ( -1.8  +2.0)
                95% CONF. INTERVAL(Ma):          16.8 --  24.3 ( -3.4  +4.1)
                    AGE DISPERSION (%):     0.2
```

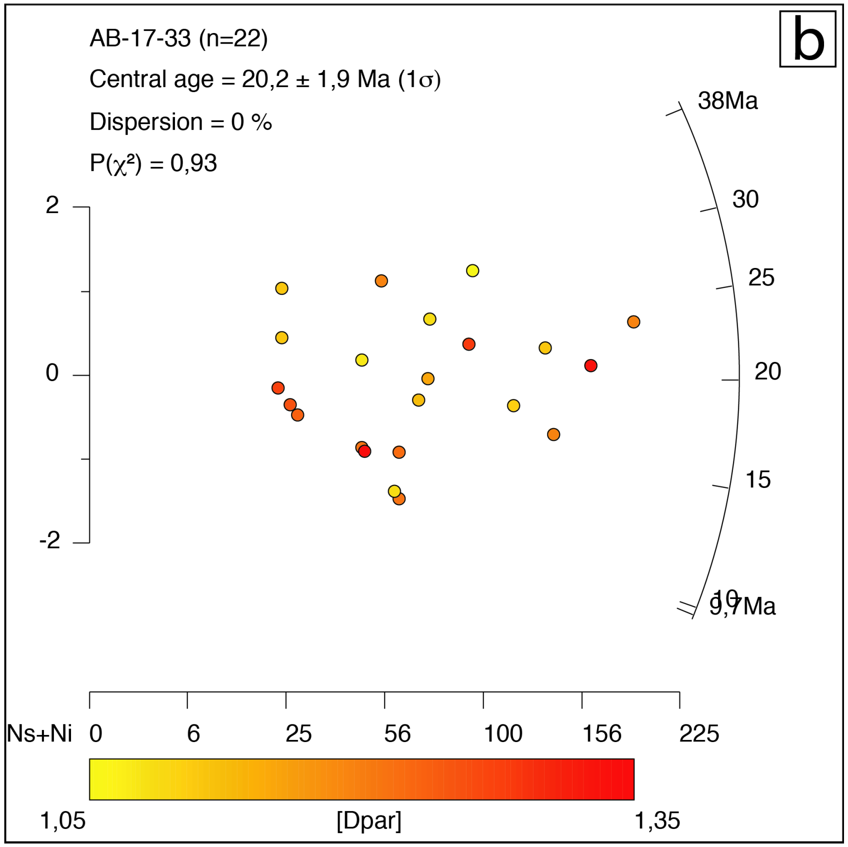


Figure S17. AFT single-grain data (a) and radial plots (b) for sample AB-17-33. See Figure S44 for location.

a

```
                          NEW PARAMETERS - ZETA METHOD
EFFECTIVE TRACK DENSITY FOR FLUENCE MONITOR (tracks/cm^2): 1,40E+06
                                       RELATIVE ERROR (%): 1,13
               EFFECTIVE URANIUM CONTENT OF MONITOR (ppm): 15,00
                 ZETA FACTOR AND STANDARD ERROR (yr cm^2): 275,18   11,53
                            SIZE OF COUNTER SQUARE (cm^2): 6,39E-07

                          GRAIN AGES IN ORIGINAL ORDER
Grain     RhoS    (Ns)       RhoI     (Ni)  Squares  U+/-2s    Grain Age (Ma)
 no.    (cm^-2)            (cm^-2)                             Age     --95% CI--
   1  2,82E+05 (  18)  2,22E+06 ( 142)    100     24   4     24.5    14.0    39.8
   2  1,04E+05 (   4)  1,36E+06 (  52)     60     15   4     15.3     3.9    40.1
   3  1,88E+05 (   6)  1,66E+06 (  53)     50     18   5     22.2     7.6    50.4
   4  9,39E+04 (   6)  1,28E+06 (  82)    100     14   3     14.4     5.0    31.9
   5  3,65E+05 (   7)  2,61E+06 (  50)     30     28   8     27.4    10.3    59.4
   6  6,26E+04 (   2)  1,31E+06 (  42)     50     14   4      9.8     1.1    35.1
   7  4,78E+05 (  11)  4,61E+06 ( 106)     36     49  10     20.2     9.7    37.1
   8  2,50E+05 (   4)  2,00E+06 (  32)     25     22   8     24.8     6.2    67.4
   9  6,26E+04 (   4)  1,06E+06 (  68)    100     11   3     11.7     3.0    30.2
  10  1,76E+05 (   9)  9,39E+05 (  48)     80     10   3     36.5    15.5    73.9
  11  2,82E+05 (   9)  1,47E+06 (  47)     50     16   5     37.2    15.8    75.6
  12  2,82E+05 (   9)  1,78E+06 (  57)     50     19   5     30.7    13.2    61.5
  13  0,00E+00 (   0)  6,89E+05 (  11)     25      7   4     12.5     0.4    76.2
  14  5,22E+04 (   1)  6,26E+05 (  12)     30      7   4     18.1     0.4   107.4
  15  3,44E+05 (  11)  1,97E+06 (  63)     50     21   5     33.9    15.9    63.9
  16  3,13E+05 (  10)  1,82E+06 (  58)     50     19   5     33.5    15.1    65.1
  17  1,88E+05 (   3)  1,63E+06 (  26)     25     17   7     23.2     4.3    72.0
  18  1,88E+05 (   6)  1,60E+06 (  51)     50     17   5     23.1     7.9    52.5
POOLED 1,95E+05(  120)  1,63E+06( 1000)    961     17   1     23.0    18.7    28.3

CHI^2 PROBABILITY (%): 66.4
 >>> Beware: possible upward bias in Chi^2 probability due to low counts <<<

 POOLED AGE W/   68% CONF. INTERVAL(Ma):   23.0,   20.7 --   25.6 ( -2.3  +2.6)
                 95% CONF. INTERVAL(Ma):           18.7 --   28.3 ( -4.3  +5.3)

CENTRAL AGE W/   68% CONF. INTERVAL(Ma):   23.0,   20.7 --   25.6 ( -2.3  +2.6)
                 95% CONF. INTERVAL(Ma):           18.7 --   28.3 ( -4.3  +5.3)
                    AGE DISPERSION (%):     0.6
```

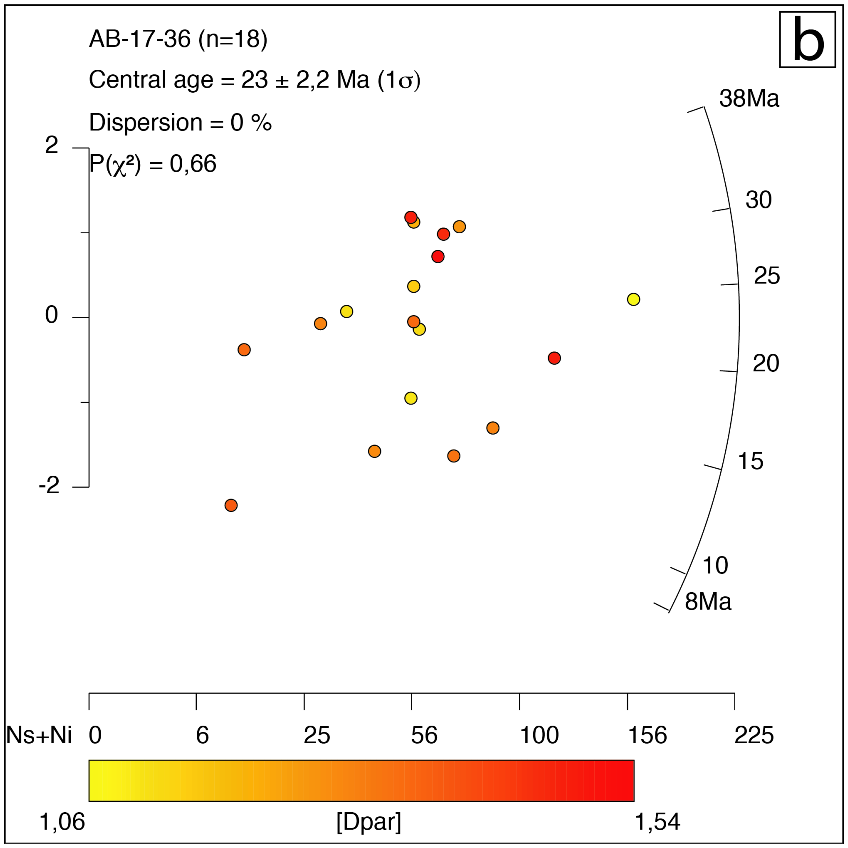
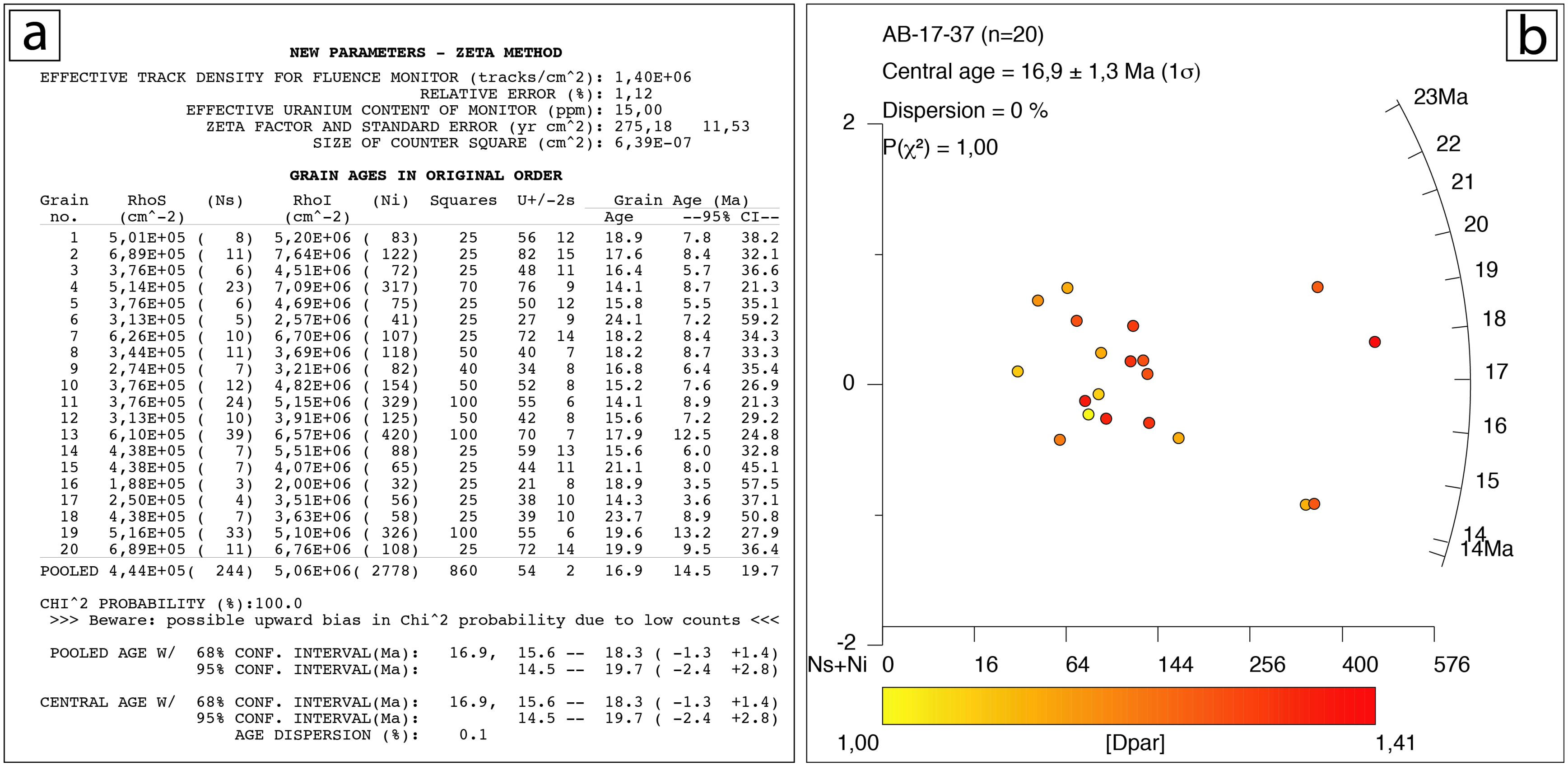


Figure S18. AFT single-grain data (a) and radial plots (b) for sample AB-17-36. See Figure S44 for location.



```
                          NEW PARAMETERS - ZETA METHOD
EFFECTIVE TRACK DENSITY FOR FLUENCE MONITOR (tracks/cm^2): 1,40E+06
                                       RELATIVE ERROR (%): 1,12
               EFFECTIVE URANIUM CONTENT OF MONITOR (ppm): 15,00
                 ZETA FACTOR AND STANDARD ERROR (yr cm^2): 275,18   11,53
                            SIZE OF COUNTER SQUARE (cm^2): 6,39E-07

                          GRAIN AGES IN ORIGINAL ORDER

Grain    RhoS    (Ns)     RhoI    (Ni)  Squares  U+/-2s    Grain Age (Ma)
 no.    (cm^-2)          (cm^-2)                          Age     --95% CI--
   1   5,01E+05 (   8)  5,20E+06 (  83)     25   56  12   18.9     7.8   38.2
   2   6,89E+05 (  11)  7,64E+06 ( 122)     25   82  15   17.6     8.4   32.1
   3   3,76E+05 (   6)  4,51E+06 (  72)     25   48  11   16.4     5.7   36.6
   4   5,14E+05 (  23)  7,09E+06 ( 317)     70   76   9   14.1     8.7   21.3
   5   3,76E+05 (   6)  4,69E+06 (  75)     25   50  12   15.8     5.5   35.1
   6   3,13E+05 (   5)  2,57E+06 (  41)     25   27   9   24.1     7.2   59.2
   7   6,26E+05 (  10)  6,70E+06 ( 107)     25   72  14   18.2     8.4   34.3
   8   3,44E+05 (  11)  3,69E+06 ( 118)     50   40   7   18.2     8.7   33.3
   9   2,74E+05 (   7)  3,21E+06 (  82)     40   34   8   16.8     6.4   35.4
  10   3,76E+05 (  12)  4,82E+06 ( 154)     50   52   8   15.2     7.6   26.9
  11   3,76E+05 (  24)  5,15E+06 ( 329)    100   55   6   14.1     8.9   21.3
  12   3,13E+05 (  10)  3,91E+06 ( 125)     50   42   8   15.6     7.2   29.2
  13   6,10E+05 (  39)  6,57E+06 ( 420)    100   70   7   17.9    12.5   24.8
  14   4,38E+05 (   7)  5,51E+06 (  88)     25   59  13   15.6     6.0   32.8
  15   4,38E+05 (   7)  4,07E+06 (  65)     25   44  11   21.1     8.0   45.1
  16   1,88E+05 (   3)  2,00E+06 (  32)     25   21   8   18.9     3.5   57.5
  17   2,50E+05 (   4)  3,51E+06 (  56)     25   38  10   14.3     3.6   37.1
  18   4,38E+05 (   7)  3,63E+06 (  58)     25   39  10   23.7     8.9   50.8
  19   5,16E+05 (  33)  5,10E+06 ( 326)    100   55   6   19.6    13.2   27.9
  20   6,89E+05 (  11)  6,76E+06 ( 108)     25   72  14   19.9     9.5   36.4
POOLED 4,44E+05(  244)  5,06E+06( 2778)    860   54   2   16.9    14.5   19.7

CHI^2 PROBABILITY (%):100.0
 >>> Beware: possible upward bias in Chi^2 probability due to low counts <<<

 POOLED AGE W/  68% CONF. INTERVAL(Ma):   16.9,  15.6 --  18.3 ( -1.3  +1.4)
                95% CONF. INTERVAL(Ma):          14.5 --  19.7 ( -2.4  +2.8)

CENTRAL AGE W/  68% CONF. INTERVAL(Ma):   16.9,  15.6 --  18.3 ( -1.3  +1.4)
                95% CONF. INTERVAL(Ma):          14.5 --  19.7 ( -2.4  +2.8)
                    AGE DISPERSION (%):    0.1
```

Figure S19. AFT single-grain data (a) and radial plots (b) for sample AB-17-37. See Figure S44 for location.

a

```
                      NEW PARAMETERS - ZETA METHOD
EFFECTIVE TRACK DENSITY FOR FLUENCE MONITOR (tracks/cm^2): 1,40E+06
                                     RELATIVE ERROR (%): 1,11
                 EFFECTIVE URANIUM CONTENT OF MONITOR (ppm): 15,00
                   ZETA FACTOR AND STANDARD ERROR (yr cm^2): 275,18   11,53
                              SIZE OF COUNTER SQUARE (cm^2): 6,39E-07

                      GRAIN AGES IN ORIGINAL ORDER
Grain    RhoS    (Ns)      RhoI     (Ni)  Squares  U+/-2s    Grain Age (Ma)
 no.   (cm^-2)           (cm^-2)                            Age     --95% CI--
   1  7,36E+05 (  47)  7,90E+06 ( 505)    100     85   8   18.0    13.0    24.2
   2  6,89E+05 (  44)  7,31E+06 ( 467)    100     78   7   18.2    13.0    24.8
   3  5,63E+05 (  18)  4,66E+06 ( 149)     50     50   8   23.5    13.4    38.0
   4  6,73E+05 (  43)  6,48E+06 ( 414)    100     69   7   20.1    14.3    27.4
   5  7,82E+05 (  25)  8,42E+06 ( 269)     50     90  11   18.0    11.4    27.0
   6  5,63E+05 (  18)  5,48E+06 ( 175)     50     59   9   20.0    11.5    32.2
   7  1,02E+06 (  39)  1,07E+07 ( 409)     60    114  12   18.4    12.9    25.6
   8  6,89E+05 (  22)  7,51E+06 ( 240)     50     80  11   17.8    10.9    27.4
   9  5,95E+05 (  19)  5,32E+06 ( 170)     50     57   9   21.7    12.6    34.7
  10  9,55E+05 (  61)  9,56E+06 ( 611)    100    102   9   19.2    14.6    25.3
  11  7,38E+05 (  33)  7,69E+06 ( 344)     70     82   9   18.6    12.5    26.5
  12  7,67E+05 (  49)  6,54E+06 ( 418)    100     70   7   22.6    16.4    30.4
  13  6,57E+05 (  42)  6,59E+06 ( 421)    100     70   7   19.3    13.6    26.4
  14  7,36E+05 (  47)  7,54E+06 ( 482)    100     81   8   18.8    13.6    25.4
  15  3,13E+05 (  10)  3,94E+06 ( 126)     50     42   8   15.5     7.2    29.0
  16  5,95E+05 (  19)  5,57E+06 ( 178)     50     60   9   20.7    12.1    33.1
  17  7,51E+05 (  48)  7,15E+06 ( 457)    100     77   7   20.3    14.7    27.3
  18  5,11E+05 (  16)  4,31E+06 ( 135)     49     46   8   23.0    12.7    38.4
  19  5,81E+05 (  26)  6,06E+06 ( 271)     70     65   8   18.6    11.9    27.7
  20  5,48E+05 (  21)  5,97E+06 ( 229)     60     64   9   17.8    10.7    27.7
POOLED 6,94E+05(  647)  6,94E+06( 6470)  1459     74   2   19.3    17.1    21.7

CHI^2 PROBABILITY (%):100.0

 POOLED AGE W/   68% CONF. INTERVAL(Ma):   19.3,  18.1 --  20.4 ( -1.1  +1.2)
                 95% CONF. INTERVAL(Ma):          17.1 --  21.7 ( -2.1  +2.4)

CENTRAL AGE W/   68% CONF. INTERVAL(Ma):   19.3,  18.1 --  20.4 ( -1.1  +1.2)
                 95% CONF. INTERVAL(Ma):          17.1 --  21.7 ( -2.1  +2.4)
                    AGE DISPERSION (%):    0.0
```

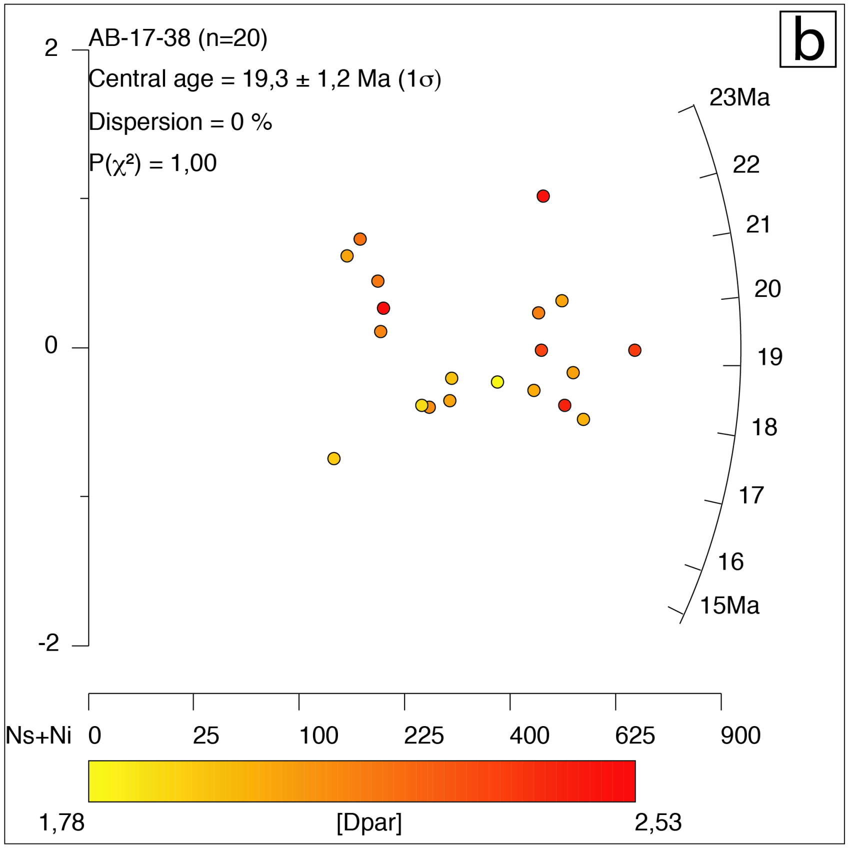


Figure S20. AFT single-grain data (a) and radial plots (b) for sample AB-17-38. See Figure S44 for location.

a

```
                          NEW PARAMETERS - ZETA METHOD
EFFECTIVE TRACK DENSITY FOR FLUENCE MONITOR (tracks/cm^2): 1,41E+06
                                     RELATIVE ERROR (%): 1,11
               EFFECTIVE URANIUM CONTENT OF MONITOR (ppm): 15,00
                 ZETA FACTOR AND STANDARD ERROR (yr cm^2): 275,18   11,53
                            SIZE OF COUNTER SQUARE (cm^2): 6,39E-07

                          GRAIN AGES IN ORIGINAL ORDER

Grain     RhoS     (Ns)       RhoI     (Ni)  Squares  U+/-2s    Grain Age (Ma)
 no.    (cm^-2)             (cm^-2)                            Age     --95% CI--
   1   2,61E+05 (    4)  5,15E+06 (   79)     24     55  12    10.2      2.6    26.0
   2   6,89E+05 (   44)  6,89E+06 (  440)    100     74   7    19.4     13.8    26.4
   3   3,39E+05 (   13)  3,70E+06 (  142)     60     40   7    17.9      9.2    31.2
   4   4,47E+05 (   20)  4,72E+06 (  211)     70     50   7    18.4     11.0    29.0
   5   4,38E+05 (    7)  4,95E+06 (   79)     25     53  12    17.5      6.7    36.9
   6   4,69E+05 (   30)  4,69E+06 (  300)    100     50   6    19.4     12.8    28.1
   7   5,48E+05 (   35)  5,20E+06 (  332)    100     55   6    20.4     13.9    28.9
   8   4,07E+05 (   26)  4,77E+06 (  305)    100     51   6    16.6     10.6    24.6
   9   4,85E+05 (   31)  5,02E+06 (  321)    100     54   6    18.7     12.5    27.0
  10   6,26E+05 (   32)  6,92E+06 (  354)     80     74   8    17.5     11.8    25.1
  11   5,87E+05 (   30)  5,16E+06 (  264)     80     55   7    22.0     14.5    32.1
  12   5,95E+05 (   38)  6,15E+06 (  393)    100     66   7    18.7     13.0    26.1
  13   4,69E+05 (   21)  5,30E+06 (  237)     70     57   7    17.2     10.4    26.8
  14   5,63E+05 (   36)  5,63E+06 (  360)    100     60   6    19.4     13.3    27.2
  15   4,07E+05 (   26)  5,32E+06 (  340)    100     57   6    14.9      9.5    22.0
  16   3,44E+05 (   22)  3,43E+06 (  219)    100     37   5    19.5     11.9    30.1
  17   4,07E+05 (   26)  4,18E+06 (  267)    100     45   6    18.9     12.1    28.2
  18   2,35E+05 (   15)  2,41E+06 (  154)    100     26   4    19.0     10.3    32.0
  19   5,63E+05 (   18)  5,23E+06 (  167)     50     56   9    21.0     12.0    33.9
  20   5,01E+05 (   32)  4,66E+06 (  298)    100     50   6    20.8     13.9    29.9
POOLED 4,77E+05(  506)  4,96E+06( 5262)   1659     53   2    18.6     16.4    21.0

CHI^2 PROBABILITY (%): 99.9

 POOLED AGE W/  68% CONF. INTERVAL(Ma):   18.6,  17.4 --  19.8 ( -1.1  +1.2)
                95% CONF. INTERVAL(Ma):          16.4 --  21.0 ( -2.2  +2.5)

CENTRAL AGE W/  68% CONF. INTERVAL(Ma):   18.6,  17.4 --  19.8 ( -1.1  +1.2)
                95% CONF. INTERVAL(Ma):          16.4 --  21.0 ( -2.2  +2.5)
                    AGE DISPERSION (%):    0.1
```

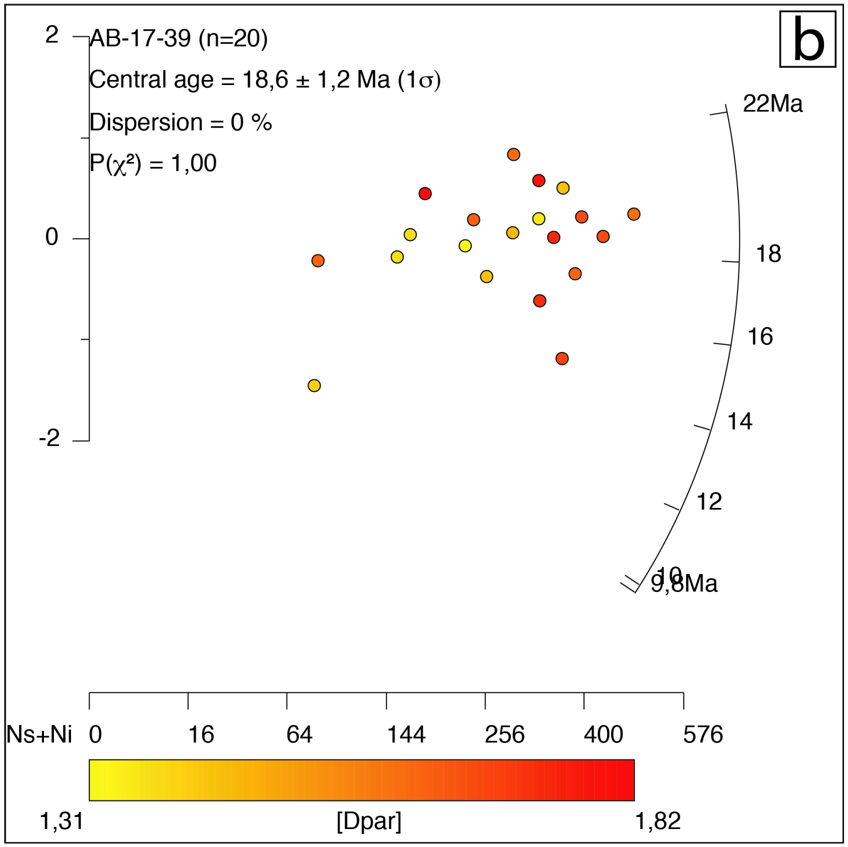
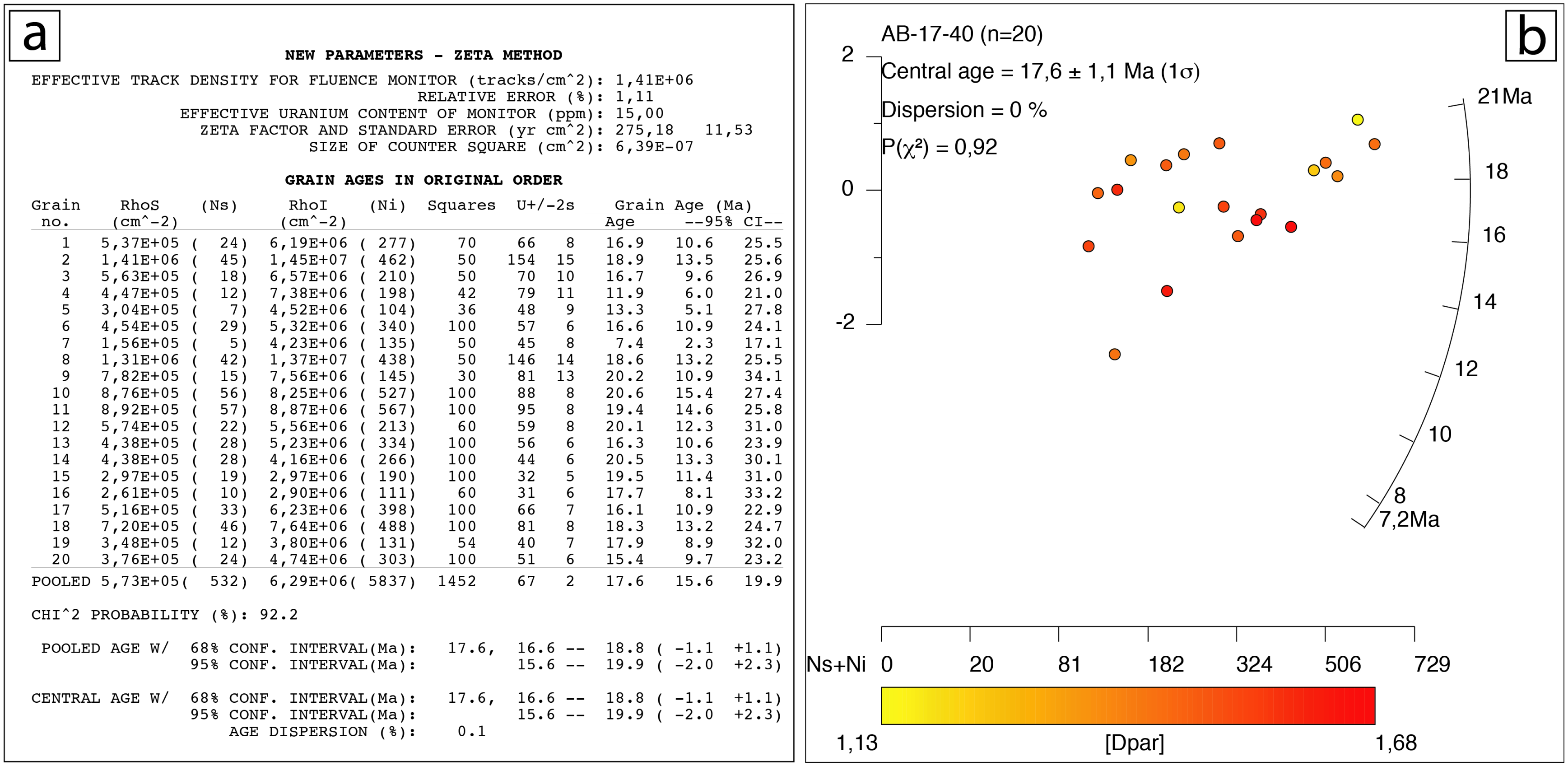


Figure S21. AFT single-grain data (a) and radial plots (b) for sample AB-17-39. See Figure S44 for location.



```
a
                           NEW PARAMETERS - ZETA METHOD
EFFECTIVE TRACK DENSITY FOR FLUENCE MONITOR (tracks/cm^2): 1,41E+06
                                       RELATIVE ERROR (%): 1,11
               EFFECTIVE URANIUM CONTENT OF MONITOR (ppm): 15,00
                 ZETA FACTOR AND STANDARD ERROR (yr cm^2): 275,18   11,53
                            SIZE OF COUNTER SQUARE (cm^2): 6,39E-07

                           GRAIN AGES IN ORIGINAL ORDER

Grain    RhoS     (Ns)       RhoI     (Ni)  Squares  U+/-2s   Grain Age (Ma)
 no.    (cm^-2)            (cm^-2)                            Age    --95% CI--

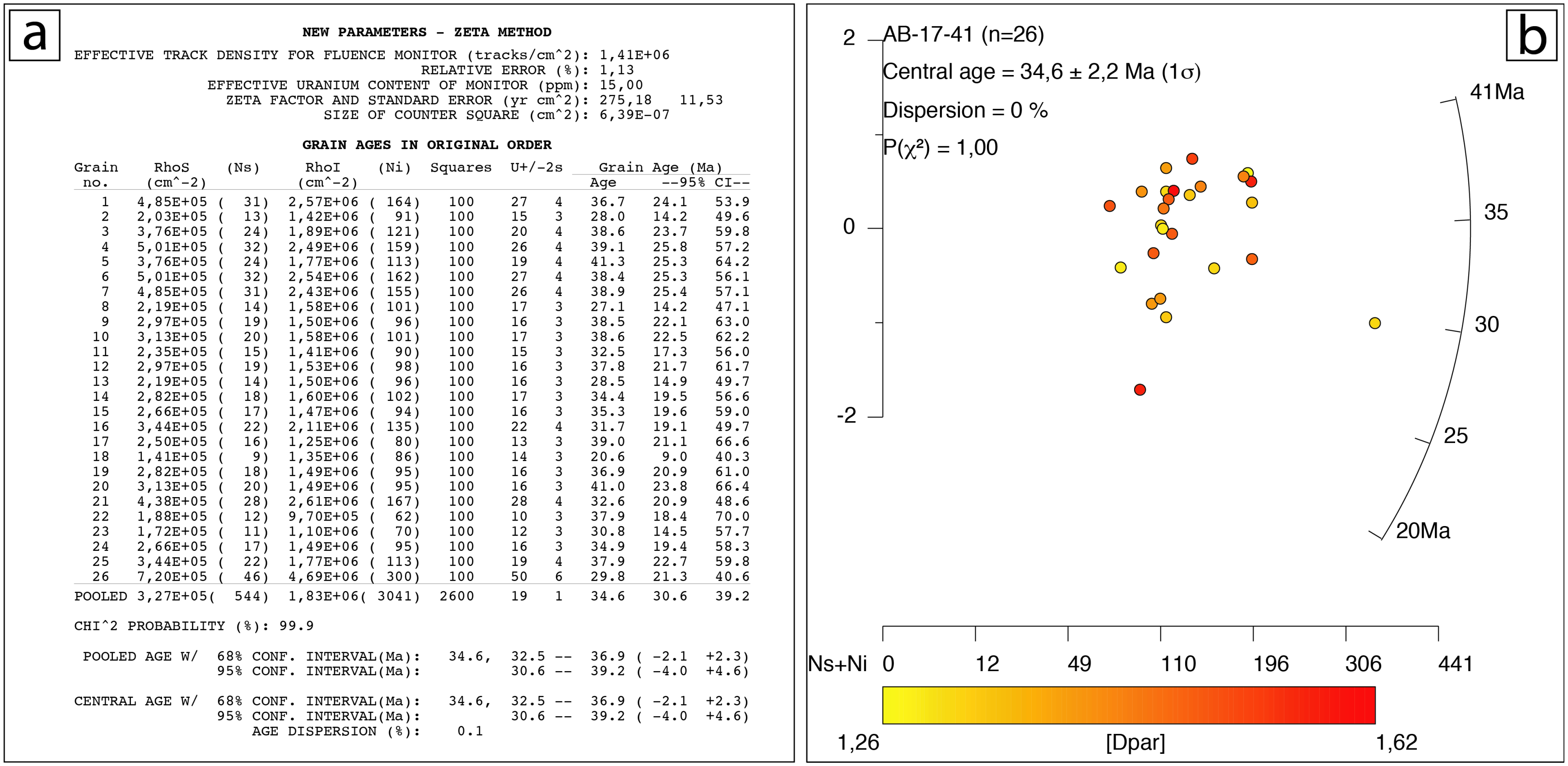
   1  5,37E+05 (  24)  6,19E+06 ( 277)     70     66    8    16.9    10.6    25.5
   2  1,41E+06 (  45)  1,45E+07 ( 462)     50    154   15    18.9    13.5    25.6
   3  5,63E+05 (  18)  6,57E+06 ( 210)     50     70   10    16.7     9.6    26.9
   4  4,47E+05 (  12)  7,38E+06 ( 198)     42     79   11    11.9     6.0    21.0
   5  3,04E+05 (   7)  4,52E+06 ( 104)     36     48    9    13.3     5.1    27.8
   6  4,54E+05 (  29)  5,32E+06 ( 340)    100     57    6    16.6    10.9    24.1
   7  1,56E+05 (   5)  4,23E+06 ( 135)     50     45    8     7.4     2.3    17.1
   8  1,31E+06 (  42)  1,37E+07 ( 438)     50    146   14    18.6    13.2    25.5
   9  7,82E+05 (  15)  7,56E+06 ( 145)     30     81   13    20.2    10.9    34.1
  10  8,76E+05 (  56)  8,25E+06 ( 527)    100     88    8    20.6    15.4    27.4
  11  8,92E+05 (  57)  8,87E+06 ( 567)    100     95    8    19.4    14.6    25.8
  12  5,74E+05 (  22)  5,56E+06 ( 213)     60     59    8    20.1    12.3    31.0
  13  4,38E+05 (  28)  5,23E+06 ( 334)    100     56    6    16.3    10.6    23.9
  14  4,38E+05 (  28)  4,16E+06 ( 266)    100     44    6    20.5    13.3    30.1
  15  2,97E+05 (  19)  2,97E+06 ( 190)    100     32    5    19.5    11.4    31.0
  16  2,61E+05 (  10)  2,90E+06 ( 111)     60     31    6    17.7     8.1    33.2
  17  5,16E+05 (  33)  6,23E+06 ( 398)    100     66    7    16.1    10.9    22.9
  18  7,20E+05 (  46)  7,64E+06 ( 488)    100     81    8    18.3    13.2    24.7
  19  3,48E+05 (  12)  3,80E+06 ( 131)     54     40    7    17.9     8.9    32.0
  20  3,76E+05 (  24)  4,74E+06 ( 303)    100     51    6    15.4     9.7    23.2
POOLED 5,73E+05(  532)  6,29E+06( 5837)  1452     67    2    17.6    15.6    19.9

CHI^2 PROBABILITY (%): 92.2

 POOLED AGE W/  68% CONF. INTERVAL(Ma):   17.6,  16.6 --  18.8 ( -1.1  +1.1)
                95% CONF. INTERVAL(Ma):          15.6 --  19.9 ( -2.0  +2.3)

CENTRAL AGE W/  68% CONF. INTERVAL(Ma):   17.6,  16.6 --  18.8 ( -1.1  +1.1)
                95% CONF. INTERVAL(Ma):          15.6 --  19.9 ( -2.0  +2.3)
                   AGE DISPERSION (%):     0.1
```

Figure S22. AFT single-grain data (a) and radial plots (b) for sample AB-17-40. See Figure S44 for location.



```
                          NEW PARAMETERS - ZETA METHOD
EFFECTIVE TRACK DENSITY FOR FLUENCE MONITOR (tracks/cm^2): 1,41E+06
                                       RELATIVE ERROR (%): 1,13
               EFFECTIVE URANIUM CONTENT OF MONITOR (ppm): 15,00
                 ZETA FACTOR AND STANDARD ERROR (yr cm^2): 275,18   11,53
                            SIZE OF COUNTER SQUARE (cm^2): 6,39E-07

                          GRAIN AGES IN ORIGINAL ORDER

Grain    RhoS     (Ns)      RhoI     (Ni)  Squares  U+/-2s   Grain Age (Ma)
 no.    (cm^-2)            (cm^-2)                          Age     --95% CI--

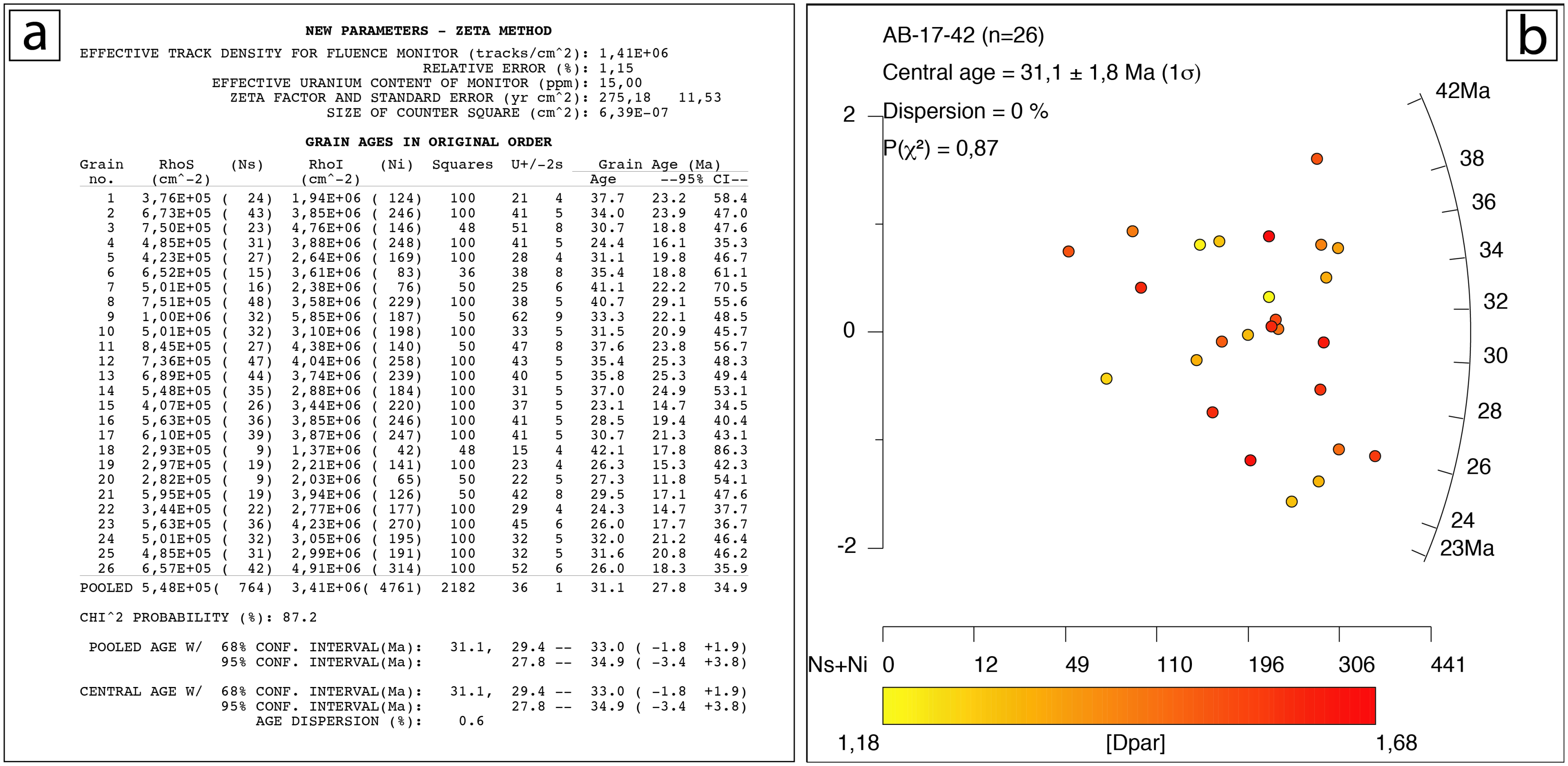
   1   4,85E+05 (   31)  2,57E+06 ( 164)    100     27   4   36.7    24.1    53.9
   2   2,03E+05 (   13)  1,42E+06 (  91)    100     15   3   28.0    14.2    49.6
   3   3,76E+05 (   24)  1,89E+06 ( 121)    100     20   4   38.6    23.7    59.8
   4   5,01E+05 (   32)  2,49E+06 ( 159)    100     26   4   39.1    25.8    57.2
   5   3,76E+05 (   24)  1,77E+06 ( 113)    100     19   4   41.3    25.3    64.2
   6   5,01E+05 (   32)  2,54E+06 ( 162)    100     27   4   38.4    25.3    56.1
   7   4,85E+05 (   31)  2,43E+06 ( 155)    100     26   4   38.9    25.4    57.1
   8   2,19E+05 (   14)  1,58E+06 ( 101)    100     17   3   27.1    14.2    47.1
   9   2,97E+05 (   19)  1,50E+06 (  96)    100     16   3   38.5    22.1    63.0
  10   3,13E+05 (   20)  1,58E+06 ( 101)    100     17   3   38.6    22.5    62.2
  11   2,35E+05 (   15)  1,41E+06 (  90)    100     15   3   32.5    17.3    56.0
  12   2,97E+05 (   19)  1,53E+06 (  98)    100     16   3   37.8    21.7    61.7
  13   2,19E+05 (   14)  1,50E+06 (  96)    100     16   3   28.5    14.9    49.7
  14   2,82E+05 (   18)  1,60E+06 ( 102)    100     17   3   34.4    19.5    56.6
  15   2,66E+05 (   17)  1,47E+06 (  94)    100     16   3   35.3    19.6    59.0
  16   3,44E+05 (   22)  2,11E+06 ( 135)    100     22   4   31.7    19.1    49.7
  17   2,50E+05 (   16)  1,25E+06 (  80)    100     13   3   39.0    21.1    66.6
  18   1,41E+05 (    9)  1,35E+06 (  86)    100     14   3   20.6     9.0    40.3
  19   2,82E+05 (   18)  1,49E+06 (  95)    100     16   3   36.9    20.9    61.0
  20   3,13E+05 (   20)  1,49E+06 (  95)    100     16   3   41.0    23.8    66.4
  21   4,38E+05 (   28)  2,61E+06 ( 167)    100     28   4   32.6    20.9    48.6
  22   1,88E+05 (   12)  9,70E+05 (  62)    100     10   3   37.9    18.4    70.0
  23   1,72E+05 (   11)  1,10E+06 (  70)    100     12   3   30.8    14.5    57.7
  24   2,66E+05 (   17)  1,49E+06 (  95)    100     16   3   34.9    19.4    58.3
  25   3,44E+05 (   22)  1,77E+06 ( 113)    100     19   4   37.9    22.7    59.8
  26   7,20E+05 (   46)  4,69E+06 ( 300)    100     50   6   29.8    21.3    40.6
POOLED 3,27E+05(  544)  1,83E+06( 3041)  2600     19   1   34.6    30.6    39.2

CHI^2 PROBABILITY (%): 99.9

 POOLED AGE W/  68% CONF. INTERVAL(Ma):   34.6,  32.5 --  36.9 ( -2.1  +2.3)
                95% CONF. INTERVAL(Ma):          30.6 --  39.2 ( -4.0  +4.6)

CENTRAL AGE W/  68% CONF. INTERVAL(Ma):   34.6,  32.5 --  36.9 ( -2.1  +2.3)
                95% CONF. INTERVAL(Ma):          30.6 --  39.2 ( -4.0  +4.6)
                    AGE DISPERSION (%):    0.1
```

Figure S23. AFT single-grain data (a) and radial plots (b) for sample AB-17-41. See Figure S44 for location.



```
                          NEW PARAMETERS - ZETA METHOD
EFFECTIVE TRACK DENSITY FOR FLUENCE MONITOR (tracks/cm^2): 1,41E+06
                                       RELATIVE ERROR (%): 1,15
               EFFECTIVE URANIUM CONTENT OF MONITOR (ppm): 15,00
                 ZETA FACTOR AND STANDARD ERROR (yr cm^2): 275,18   11,53
                            SIZE OF COUNTER SQUARE (cm^2): 6,39E-07

                          GRAIN AGES IN ORIGINAL ORDER

Grain    RhoS     (Ns)      RhoI    (Ni)  Squares  U+/-2s    Grain Age (Ma)
 no.    (cm^-2)            (cm^-2)                          Age     --95% CI--
   1   3,76E+05 (  24)  1,94E+06 ( 124)   100    21   4   37.7   23.2   58.4
   2   6,73E+05 (  43)  3,85E+06 ( 246)   100    41   5   34.0   23.9   47.0
   3   7,50E+05 (  23)  4,76E+06 ( 146)    48    51   8   30.7   18.8   47.6
   4   4,85E+05 (  31)  3,88E+06 ( 248)   100    41   5   24.4   16.1   35.3
   5   4,23E+05 (  27)  2,64E+06 ( 169)   100    28   4   31.1   19.8   46.7
   6   6,52E+05 (  15)  3,61E+06 (  83)    36    38   8   35.4   18.8   61.1
   7   5,01E+05 (  16)  2,38E+06 (  76)    50    25   6   41.1   22.2   70.5
   8   7,51E+05 (  48)  3,58E+06 ( 229)   100    38   5   40.7   29.1   55.6
   9   1,00E+06 (  32)  5,85E+06 ( 187)    50    62   9   33.3   22.1   48.5
  10   5,01E+05 (  32)  3,10E+06 ( 198)   100    33   5   31.5   20.9   45.7
  11   8,45E+05 (  27)  4,38E+06 ( 140)    50    47   8   37.6   23.8   56.7
  12   7,36E+05 (  47)  4,04E+06 ( 258)   100    43   5   35.4   25.3   48.3
  13   6,89E+05 (  44)  3,74E+06 ( 239)   100    40   5   35.8   25.3   49.4
  14   5,48E+05 (  35)  2,88E+06 ( 184)   100    31   5   37.0   24.9   53.1
  15   4,07E+05 (  26)  3,44E+06 ( 220)   100    37   5   23.1   14.7   34.5
  16   5,63E+05 (  36)  3,85E+06 ( 246)   100    41   5   28.5   19.4   40.4
  17   6,10E+05 (  39)  3,87E+06 ( 247)   100    41   5   30.7   21.3   43.1
  18   2,93E+05 (   9)  1,37E+06 (  42)    48    15   4   42.1   17.8   86.3
  19   2,97E+05 (  19)  2,21E+06 ( 141)   100    23   4   26.3   15.3   42.3
  20   2,82E+05 (   9)  2,03E+06 (  65)    50    22   5   27.3   11.8   54.1
  21   5,95E+05 (  19)  3,94E+06 ( 126)    50    42   8   29.5   17.1   47.6
  22   3,44E+05 (  22)  2,77E+06 ( 177)   100    29   4   24.3   14.7   37.7
  23   5,63E+05 (  36)  4,23E+06 ( 270)   100    45   6   26.0   17.7   36.7
  24   5,01E+05 (  32)  3,05E+06 ( 195)   100    32   5   32.0   21.2   46.4
  25   4,85E+05 (  31)  2,99E+06 ( 191)   100    32   5   31.6   20.8   46.2
  26   6,57E+05 (  42)  4,91E+06 ( 314)   100    52   6   26.0   18.3   35.9
POOLED 5,48E+05(  764)  3,41E+06( 4761)  2182    36   1   31.1   27.8   34.9

CHI^2 PROBABILITY (%): 87.2

 POOLED AGE W/  68% CONF. INTERVAL(Ma):   31.1,  29.4 --  33.0 ( -1.8  +1.9)
                95% CONF. INTERVAL(Ma):          27.8 --  34.9 ( -3.4  +3.8)

CENTRAL AGE W/  68% CONF. INTERVAL(Ma):   31.1,  29.4 --  33.0 ( -1.8  +1.9)
                95% CONF. INTERVAL(Ma):          27.8 --  34.9 ( -3.4  +3.8)
                    AGE DISPERSION (%):    0.6
```

Figure S24. AFT single-grain data (a) and radial plots (b) for sample AB-17-42. See Figure S44 for location.

a

```
                     NEW PARAMETERS - ZETA METHOD
EFFECTIVE TRACK DENSITY FOR FLUENCE MONITOR (tracks/cm^2): 1,42E+06
                                      RELATIVE ERROR (%): 1,17
              EFFECTIVE URANIUM CONTENT OF MONITOR (ppm): 15,00
                ZETA FACTOR AND STANDARD ERROR (yr cm^2): 275,18   11,53
                           SIZE OF COUNTER SQUARE (cm^2): 6,39E-07

                     GRAIN AGES IN ORIGINAL ORDER

Grain    RhoS    (Ns)      RhoI    (Ni)  Squares  U+/-2s   Grain Age (Ma)
 no.   (cm^-2)           (cm^-2)                          Age    --95% CI--

   1   6,57E+05 (  42)  5,65E+06 ( 361)   100     60   6   22.7   16.0   31.2
   2   5,32E+05 (  34)  4,88E+06 ( 312)   100     52   6   21.3   14.4   30.3
   3   6,78E+05 (  26)  5,61E+06 ( 215)    60     59   8   23.7   15.0   35.4
   4   5,16E+05 (  33)  4,69E+06 ( 300)   100     50   6   21.5   14.5   30.7
   5   5,63E+05 (  36)  5,32E+06 ( 340)   100     56   6   20.7   14.2   29.1
   6   5,32E+05 (  17)  5,35E+06 ( 171)    50     57   9   19.5   11.0   31.9
   7   1,41E+05 (   9)  1,00E+06 (  64)   100     11   3   27.8   12.0   55.1
   8   7,04E+05 (  45)  6,65E+06 ( 425)   100     70   7   20.7   14.8   28.1
   9   4,69E+05 (  30)  4,68E+06 ( 299)   100     50   6   19.6   12.9   28.5
  10   4,07E+05 (  13)  2,44E+06 (  78)    50     26   6   32.7   16.5   58.6
  11   3,35E+05 (  15)  2,55E+06 ( 114)    70     27   5   25.8   13.9   44.0
  12   3,58E+05 (  16)  2,77E+06 ( 124)    70     29   5   25.3   13.9   42.4
  13   5,95E+05 (  19)  5,16E+06 ( 165)    50     55   9   22.6   13.2   36.1
  14   5,63E+05 (  36)  5,95E+06 ( 380)   100     63   7   18.5   12.7   26.0
  15   3,29E+05 (  21)  2,72E+06 ( 174)   100     29   4   23.6   14.2   37.0
  16   5,16E+05 (  33)  3,90E+06 ( 249)   100     41   5   25.9   17.4   37.1
  17   7,15E+05 (  32)  5,54E+06 ( 248)    70     59   8   25.2   16.8   36.4
  18   2,50E+05 (   8)  1,63E+06 (  52)    50     17   5   30.4   12.3   63.3
  19   6,42E+05 (  41)  5,07E+06 ( 324)   100     54   6   24.7   17.3   34.1
  20   4,38E+05 (   7)  3,82E+06 (  61)    25     40  10   22.8    8.6   48.8
  21   6,26E+05 (  10)  7,07E+06 ( 113)    25     75  14   17.5    8.0   32.8
  22   5,16E+05 (  33)  3,90E+06 ( 249)   100     41   5   25.9   17.4   37.1
  23   5,63E+05 (  18)  3,13E+06 ( 100)    50     33   7   35.2   19.9   58.1
  24   7,04E+05 (  45)  6,71E+06 ( 429)   100     71   7   20.5   14.7   27.8
  25   4,07E+05 (  13)  4,07E+06 ( 130)    50     43   8   19.7   10.1   34.4
POOLED 5,15E+05(  632)  4,46E+06( 5477)  1920     47   2   22.4   19.9   25.3

CHI^2 PROBABILITY (%): 98.1

 POOLED AGE W/  68% CONF. INTERVAL(Ma):   22.4,  21.1 --  23.8 ( -1.3  +1.4)
                95% CONF. INTERVAL(Ma):          19.9 --  25.3 ( -2.5  +2.8)

CENTRAL AGE W/  68% CONF. INTERVAL(Ma):   22.4,  21.1 --  23.8 ( -1.3  +1.4)
                95% CONF. INTERVAL(Ma):          19.9 --  25.3 ( -2.5  +2.8)
                    AGE DISPERSION (%):    0.2
```

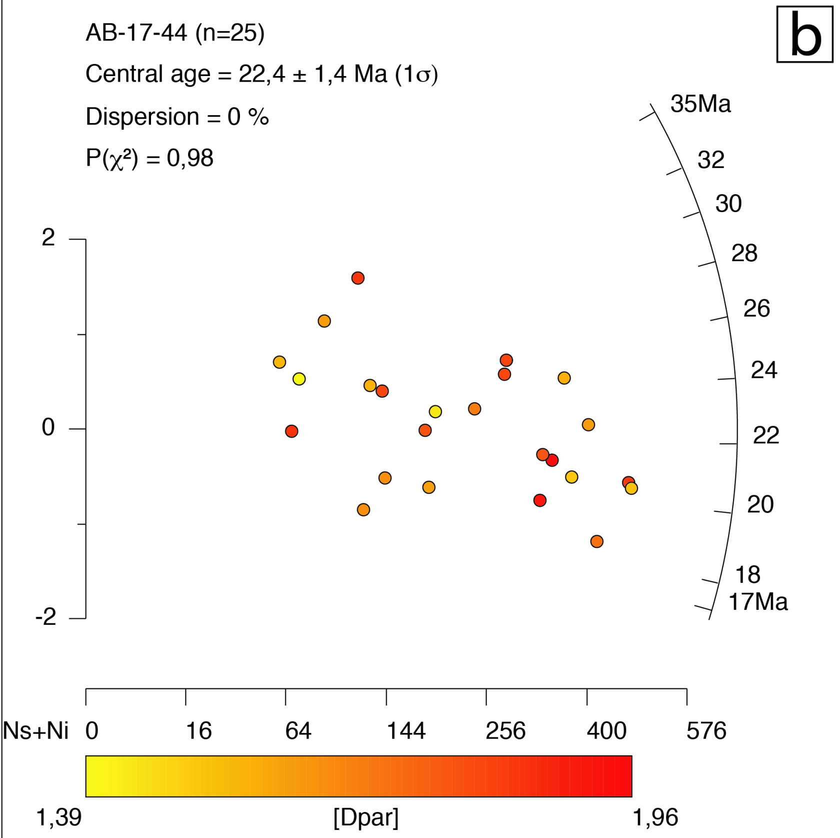
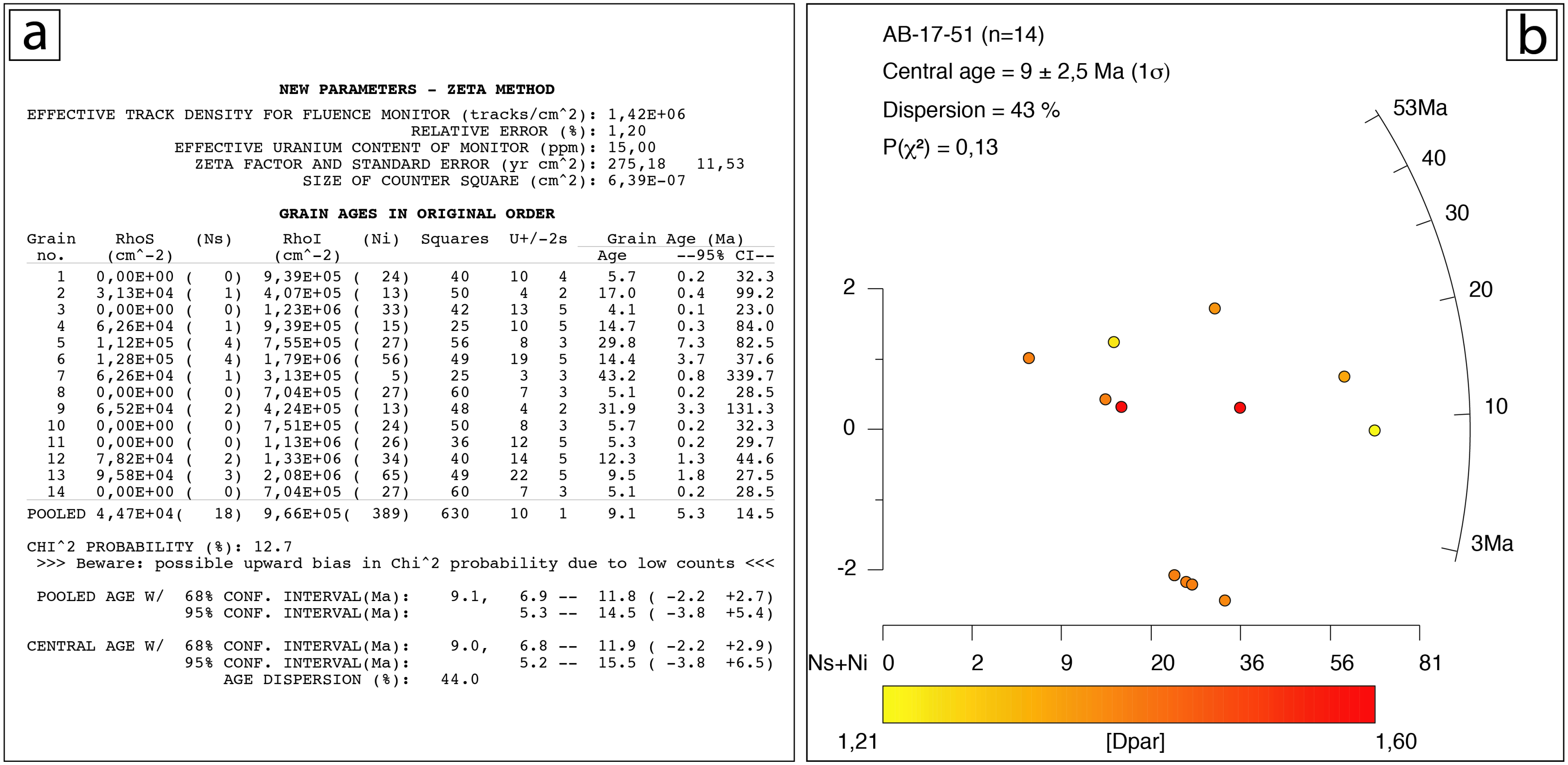


Figure S25. AFT single-grain data (a) and radial plots (b) for sample AB-17-44. See Figure S44 for location.



```
                       NEW PARAMETERS - ZETA METHOD
EFFECTIVE TRACK DENSITY FOR FLUENCE MONITOR (tracks/cm^2): 1,42E+06
                                      RELATIVE ERROR (%): 1,20
               EFFECTIVE URANIUM CONTENT OF MONITOR (ppm): 15,00
                 ZETA FACTOR AND STANDARD ERROR (yr cm^2): 275,18   11,53
                            SIZE OF COUNTER SQUARE (cm^2): 6,39E-07

                       GRAIN AGES IN ORIGINAL ORDER
Grain    RhoS    (Ns)      RhoI    (Ni)  Squares  U+/-2s   Grain Age (Ma)
 no.    (cm^-2)           (cm^-2)                          Age     --95% CI--
   1  0,00E+00 (    0)  9,39E+05 (  24)     40     10   4    5.7     0.2    32.3
   2  3,13E+04 (    1)  4,07E+05 (  13)     50      4   2   17.0     0.4    99.2
   3  0,00E+00 (    0)  1,23E+06 (  33)     42     13   5    4.1     0.1    23.0
   4  6,26E+04 (    1)  9,39E+05 (  15)     25     10   5   14.7     0.3    84.0
   5  1,12E+05 (    4)  7,55E+05 (  27)     56      8   3   29.8     7.3    82.5
   6  1,28E+05 (    4)  1,79E+06 (  56)     49     19   5   14.4     3.7    37.6
   7  6,26E+04 (    1)  3,13E+05 (   5)     25      3   3   43.2     0.8   339.7
   8  0,00E+00 (    0)  7,04E+05 (  27)     60      7   3    5.1     0.2    28.5
   9  6,52E+04 (    2)  4,24E+05 (  13)     48      4   2   31.9     3.3   131.3
  10  0,00E+00 (    0)  7,51E+05 (  24)     50      8   3    5.7     0.2    32.3
  11  0,00E+00 (    0)  1,13E+06 (  26)     36     12   5    5.3     0.2    29.7
  12  7,82E+04 (    2)  1,33E+06 (  34)     40     14   5   12.3     1.3    44.6
  13  9,58E+04 (    3)  2,08E+06 (  65)     49     22   5    9.5     1.8    27.5
  14  0,00E+00 (    0)  7,04E+05 (  27)     60      7   3    5.1     0.2    28.5
POOLED 4,47E+04(   18)  9,66E+05(  389)    630     10   1    9.1     5.3    14.5

CHI^2 PROBABILITY (%): 12.7
 >>> Beware: possible upward bias in Chi^2 probability due to low counts <<<

 POOLED AGE W/  68% CONF. INTERVAL(Ma):    9.1,   6.9 --  11.8 ( -2.2  +2.7)
                95% CONF. INTERVAL(Ma):           5.3 --  14.5 ( -3.8  +5.4)

CENTRAL AGE W/  68% CONF. INTERVAL(Ma):    9.0,   6.8 --  11.9 ( -2.2  +2.9)
                95% CONF. INTERVAL(Ma):           5.2 --  15.5 ( -3.8  +6.5)
                    AGE DISPERSION (%):   44.0
```

Figure S26. AFT single-grain data (a) and radial plots (b) for sample AB-17-51. See Figure S44 for location.

a

```
                    NEW PARAMETERS - ZETA METHOD
EFFECTIVE TRACK DENSITY FOR FLUENCE MONITOR (tracks/cm^2): 1,42E+06
                                      RELATIVE ERROR (%): 1,23
               EFFECTIVE URANIUM CONTENT OF MONITOR (ppm): 15,00
                 ZETA FACTOR AND STANDARD ERROR (yr cm^2): 275,18   11,53
                            SIZE OF COUNTER SQUARE (cm^2): 6,39E-07

                    GRAIN AGES IN ORIGINAL ORDER

Grain    RhoS     (Ns)      RhoI     (Ni)  Squares  U+/-2s    Grain Age (Ma)
 no.    (cm^-2)            (cm^-2)                          Age     --95% CI--
   1   8,38E+04 (    3)  1,87E+06 (  67)     56     20    5    9.2     1.8    26.7
   2   2,79E+04 (    1)  1,65E+06 (  59)     56     17    5    3.8     0.1    19.2
   3   1,41E+05 (    9)  2,93E+06 ( 187)    100     31    5    9.6     4.2    18.2
   4   2,01E+05 (    9)  2,75E+06 ( 123)     70     29    5   14.5     6.4    28.0
   5   1,60E+05 (    5)  3,58E+06 ( 112)     49     38    7    9.0     2.8    21.0
   6   1,12E+05 (    4)  1,68E+06 (  60)     56     18    5   13.5     3.4    35.1
   7   1,04E+05 (    4)  3,21E+06 ( 123)     60     34    6    6.6     1.7    16.7
   8   1,12E+05 (    3)  3,47E+06 (  93)     42     37    8    6.6     1.3    19.0
   9   1,30E+05 (    3)  1,65E+06 (  38)     36     17    6   16.2     3.0    48.5
  10   0,00E+00 (    0)  2,59E+06 (  58)     35     27    7    2.4     0.1    12.8
  11   2,24E+05 (    8)  4,05E+06 ( 145)     56     43    7   11.0     4.6    21.8
  12   0,00E+00 (    0)  2,14E+06 (  41)     30     23    7    3.3     0.1    18.4
  13   9,78E+04 (    3)  4,92E+06 ( 151)     48     52    9    4.1     0.8    11.6
  14   1,25E+05 (    2)  2,00E+06 (  32)     25     21    7   13.1     1.4    47.7
  15   0,00E+00 (    0)  2,69E+06 (  43)     25     28    9    3.2     0.1    17.5
  16   0,00E+00 (    0)  2,00E+06 (  51)     40     21    6    2.7     0.1    14.7
  17   1,25E+05 (    2)  2,44E+06 (  39)     25     26    8   10.8     1.2    38.6
  18   0,00E+00 (    0)  1,63E+06 (  26)     25     17    7    5.3     0.2    29.7
  19   2,35E+05 (    3)  2,58E+06 (  33)     20     27    9   18.6     3.5    56.4
  20   0,00E+00 (    0)  1,56E+06 (  40)     40     17    5    3.4     0.1    18.9
  21   1,30E+05 (    2)  1,30E+06 (  20)     24     14    6   20.9     2.2    80.0
  22   1,25E+05 (    2)  1,88E+06 (  30)     25     20    7   14.0     1.5    51.2
  23   0,00E+00 (    0)  1,79E+06 (  56)     49     19    5    2.4     0.1    13.3
  24   0,00E+00 (    0)  1,86E+06 (  50)     42     20    6    2.7     0.1    15.0
  25   3,13E+04 (    1)  2,66E+06 (  85)     50     28    6    2.6     0.1    13.2
  26   0,00E+00 (    0)  2,52E+06 (  58)     36     27    7    2.4     0.1    12.8
  27   0,00E+00 (    0)  8,14E+05 (  13)     25      9    5   10.7     0.4    63.9
POOLED 8,75E+04(    64)  2,51E+06( 1833)   1145     26    1    6.8     5.3     8.9

CHI^2 PROBABILITY (%):  9.0
 >>> Beware: possible upward bias in Chi^2 probability due to low counts <<<

 POOLED AGE W/  68% CONF. INTERVAL(Ma):    6.8,   6.0 --   7.8 ( -0.9  +1.0)
                95% CONF. INTERVAL(Ma):           5.3 --   8.9 ( -1.6  +2.0)

CENTRAL AGE W/  68% CONF. INTERVAL(Ma):    6.6,   5.6 --   7.7 ( -1.0  +1.2)
                95% CONF. INTERVAL(Ma):           4.8 --   9.0 ( -1.8  +2.4)
                    AGE DISPERSION (%):   39.1
```

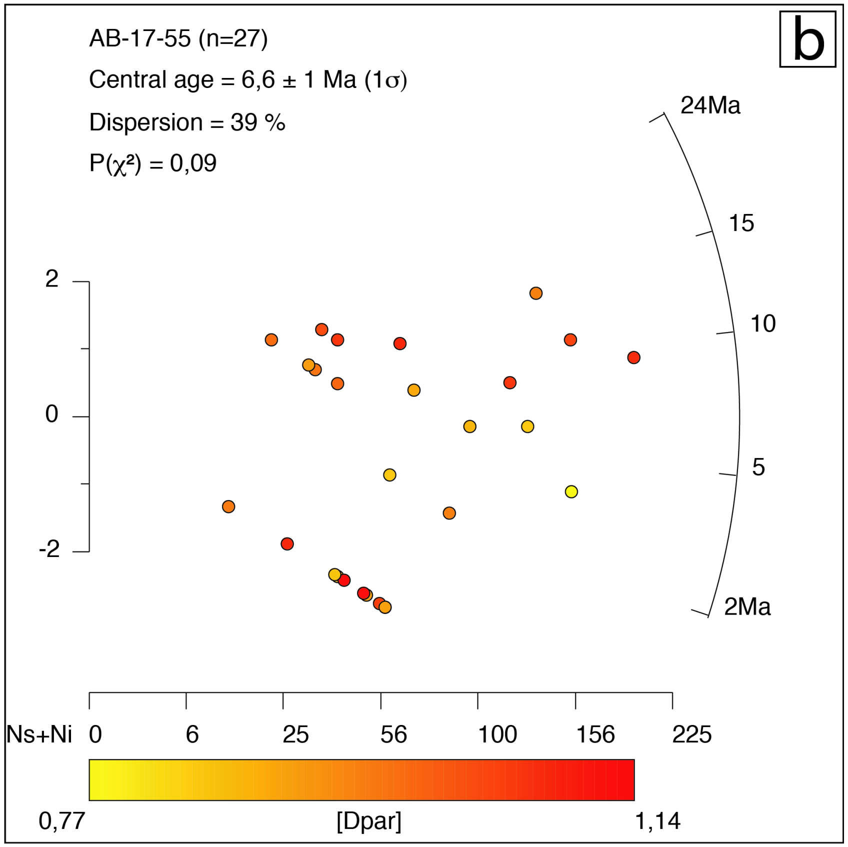


Figure S27. AFT single-grain data (a) and radial plots (b) for sample AB-17-55. See Figure S44 for location.

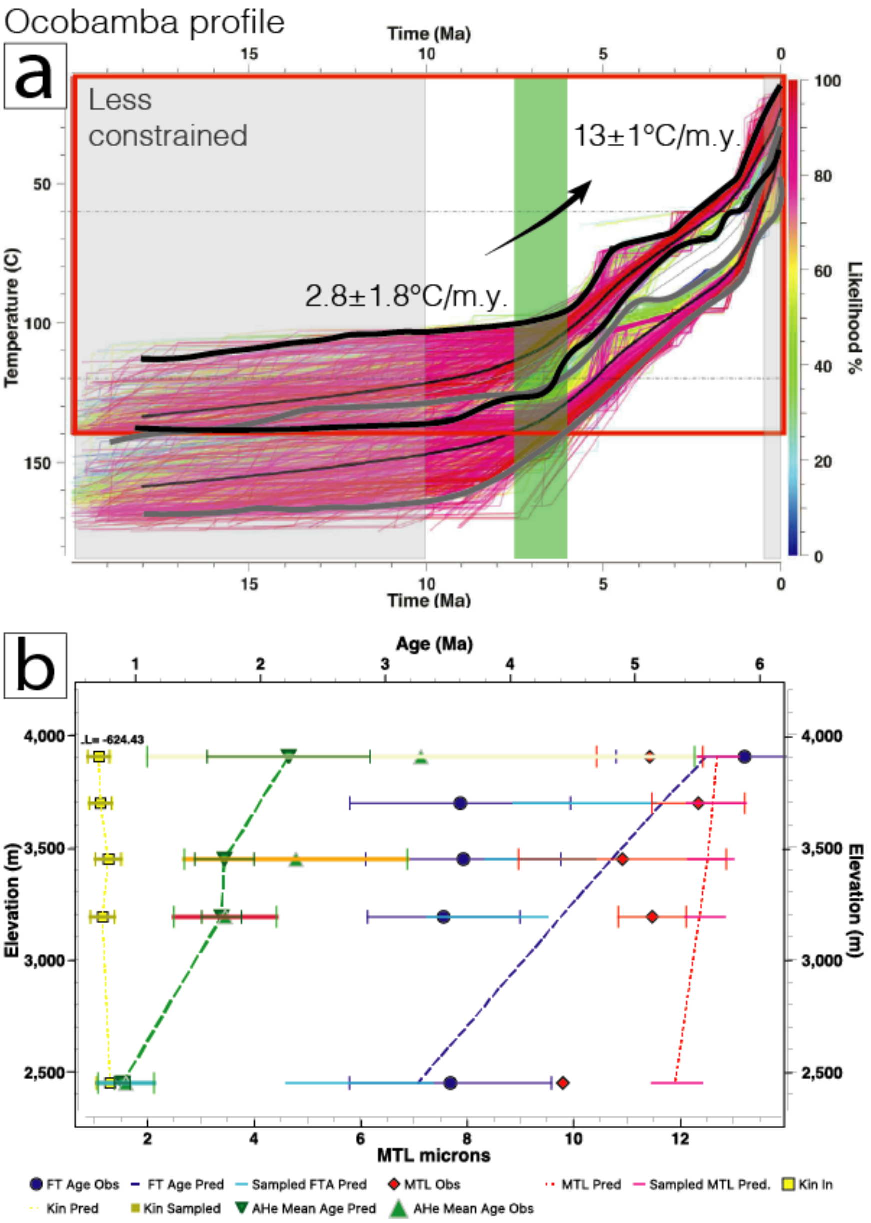


Figure S28. QTQt inversion results for the Ocobamba high-altitudinal profile. a) Time-temperature paths obtained by inversion of AHe and AFT thermochronology data from the Ocobamba age-elevation profile using QTQt (AB-17-05 to AB-17-11). The red square shows the explored time and temperature range for inversion. The colored lines show the T-t paths for the top and the bottom samples with their respective likelihood (see color scale on right). The solid black and grey lines show the expected model and its 95% reliable interval for the thermal histories of the top and bottom samples, respectively. The grey lines in between represent the expected cooling paths for the intermediate samples. The green vertical band indicates the well-constrained acceleration of cooling at ~6.5 Ma. Cooling rates derived from QTQt are indicated on the graph. b) Graph of observed vs. predicted data. Fit of best-fit model predictions to the data. FT: Fission Track; MTL: Mean Track Length; AHe: Apatite Helium; Obs: Observed; Pred: Predicted.

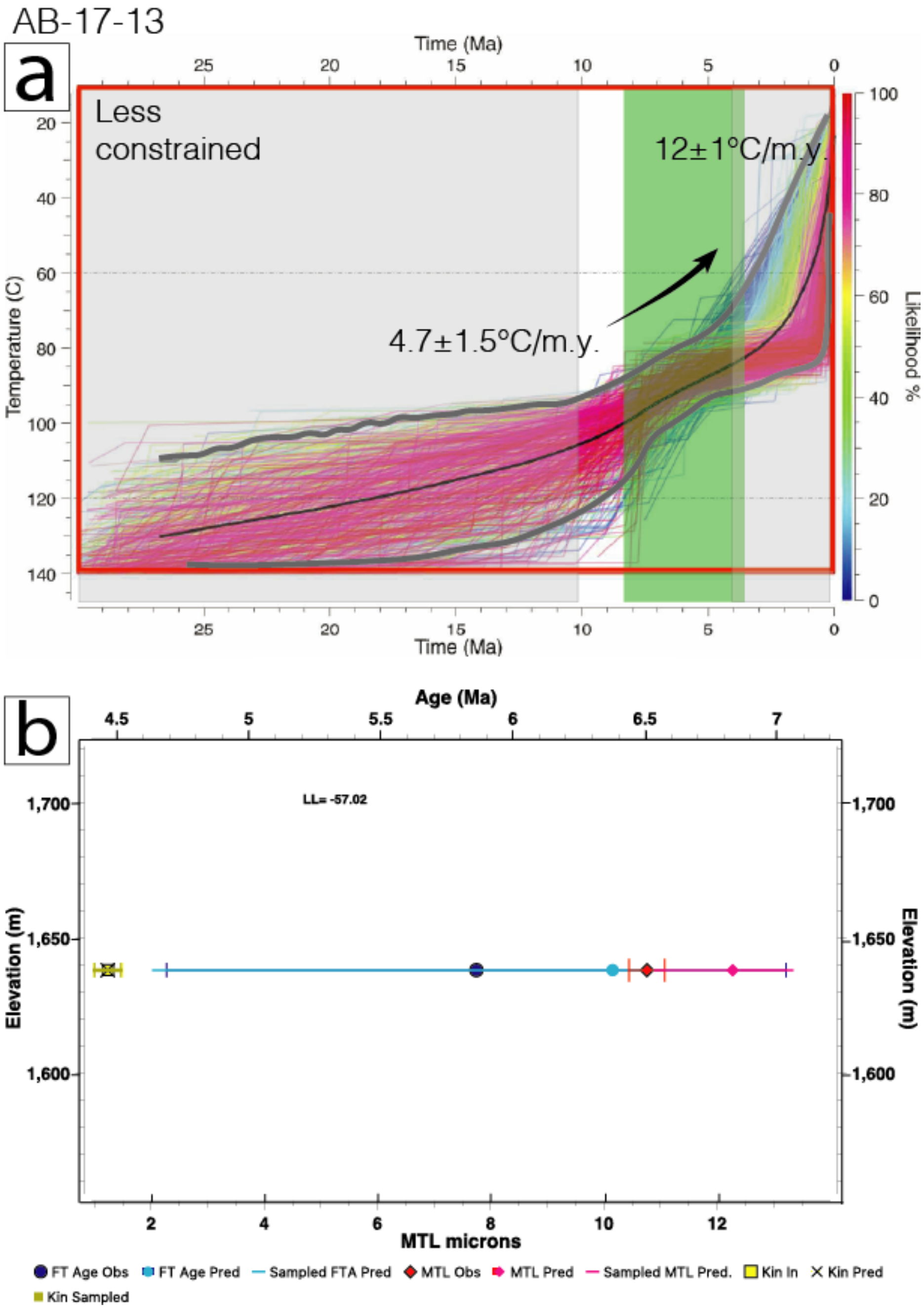


Figure S29. QTQt inversion results for the AB-17-13 sample. a) Time-temperature paths obtained by inversion of AFT data from the AB-17-13 sample using QTQt. The red square shows the explored time and temperature range for inversion. The colored lines show the T-t paths for the unique sample with its respective likelihood (see color scale on right). The solid grey lines show the expected model and its 95% reliable interval for the thermal histories of the sample. The green vertical band indicates the well-constrained acceleration of cooling at ~6 Ma. Cooling rates derived from QTQt are indicated on the graph. The apparent ~3–2 Ma cooling acceleration is a model bias and is not constrained by the data. b) Graph of observed vs. predicted data. Fit of best-fit model predictions to the data. FT: Fission Track; MTL: Mean Track Length; Obs: Observed; Pred: Predicted.

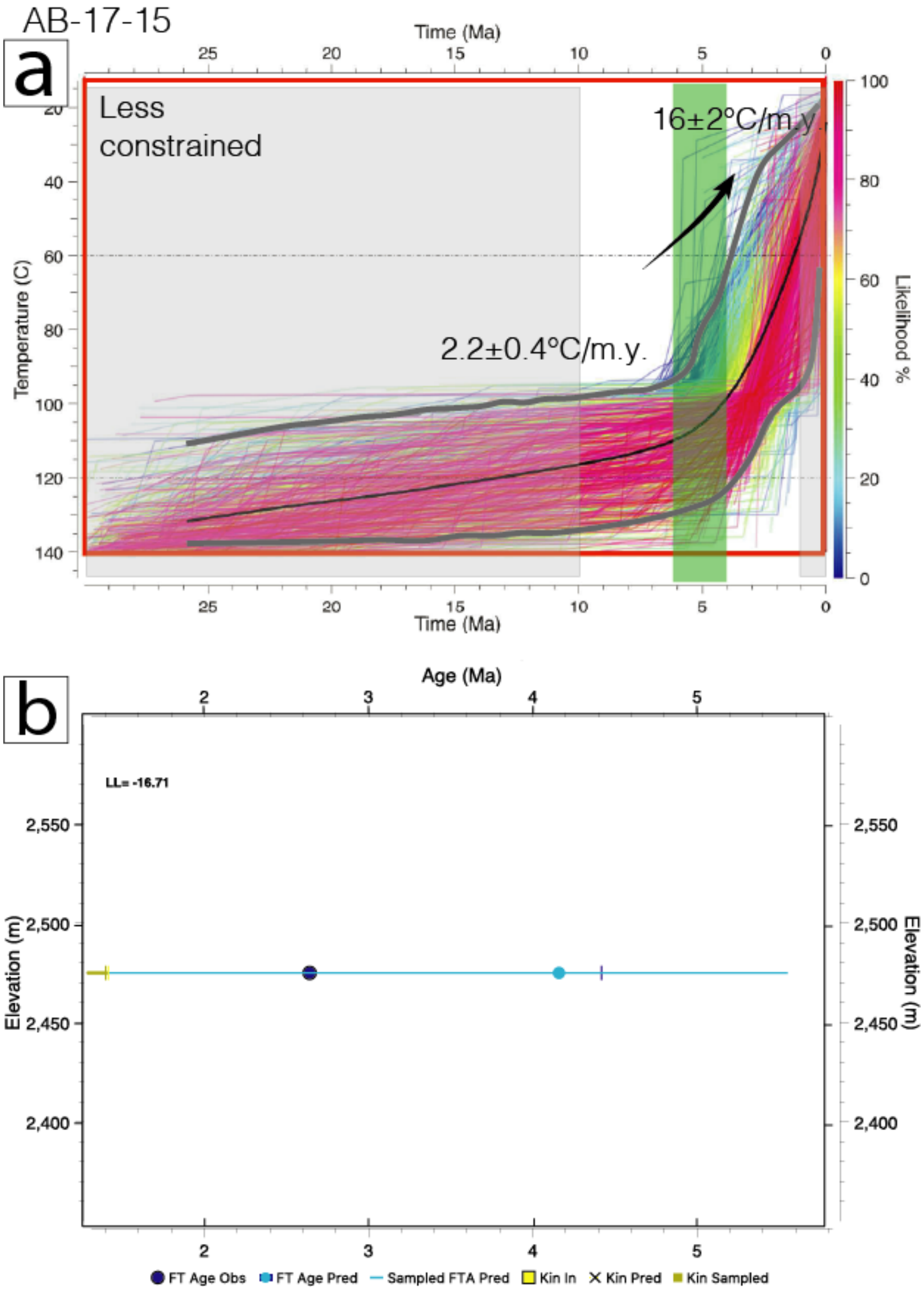


Figure S30. QTQt inversion results for the AB-17-15 sample. a) Time-temperature paths obtained by inversion of AFT data from the AB-17-15 sample using QTQt. The red square shows the explored time and temperature range for inversion. The colored lines show the T-t paths for the unique sample with its respective likelihood (see color scale on right). The solid grey lines show the expected model and its 95% reliable interval for the thermal histories of the sample. The green vertical band indicates the well-constrained acceleration of cooling at ~5 Ma. Cooling rates derived from QTQt are indicated on the graph. b) Graph of observed vs. predicted data. Fit of best-fit model predictions to the data. FT: Fission Track; Obs: Observed; Pred: Predicted.

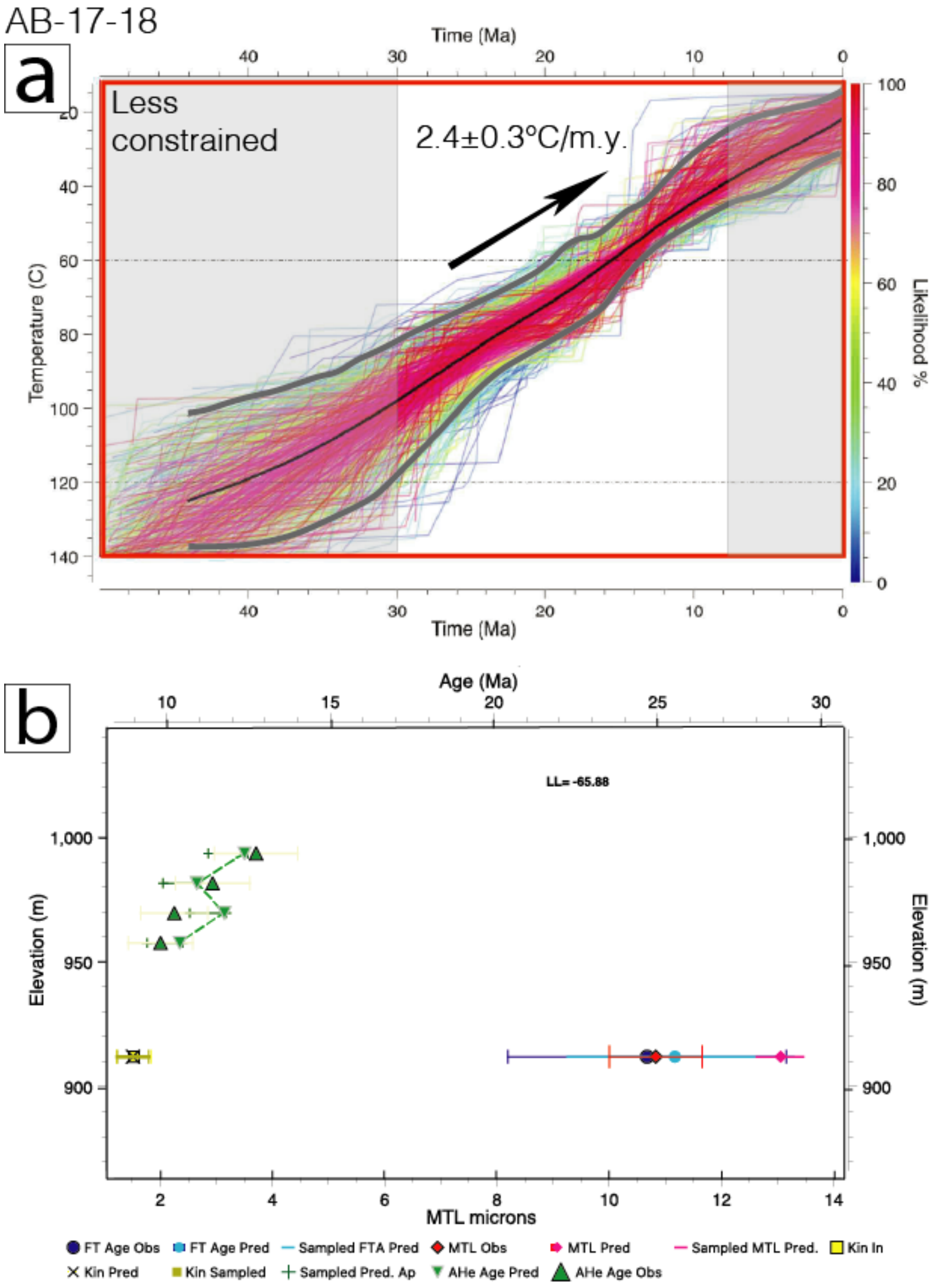


Figure S31. QTQt inversion results for the AB-17-18 sample. a) Time-temperature paths obtained by inversion of AHe and AFT data from the AB-17-18 sample using QTQt. The red square shows the explored time and temperature range for inversion. The colored lines show the T-t paths for the unique sample with its respective likelihood (see color scale on right). The solid grey lines show the expected model and its 95% reliable interval for the thermal histories of the sample. Cooling rate derived from QTQt is indicated on the graph. b) Graph of observed vs. predicted data. Fit of best-fit model predictions to the data. FT: Fission Track; MTL: Mean Track Length; AHe: Apatite Helium; Obs: Observed; Pred: Predicted.

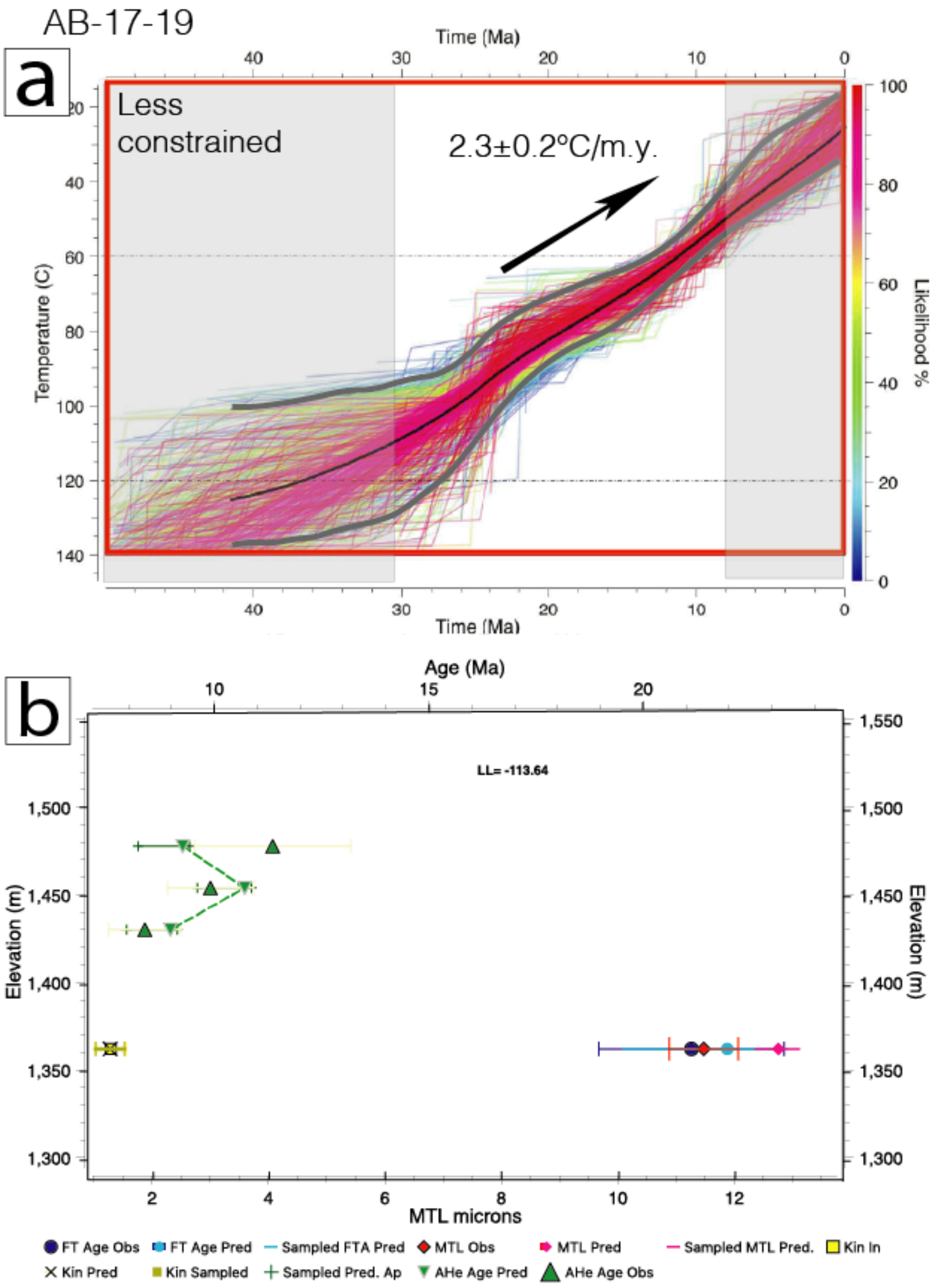


Figure S32. QTQt inversion results for the AB-17-19 sample. a) Time-temperature paths obtained by inversion of AHe and AFT data from the AB-17-19 sample using QTQt. The red square shows the explored time and temperature range for inversion. The colored lines show the T-t paths for the unique sample with its respective likelihood (see color scale on right). The solid grey lines show the expected model and its 95% reliable interval for the thermal histories of the sample. Cooling rate derived from QTQt is indicated on the graph. b) Graph of observed vs. predicted data. Fit of best-fit model predictions to the data. FT: Fission Track; MTL: Mean Track Length; AHe: Apatite Helium; Obs: Observed; Pred: Predicted.

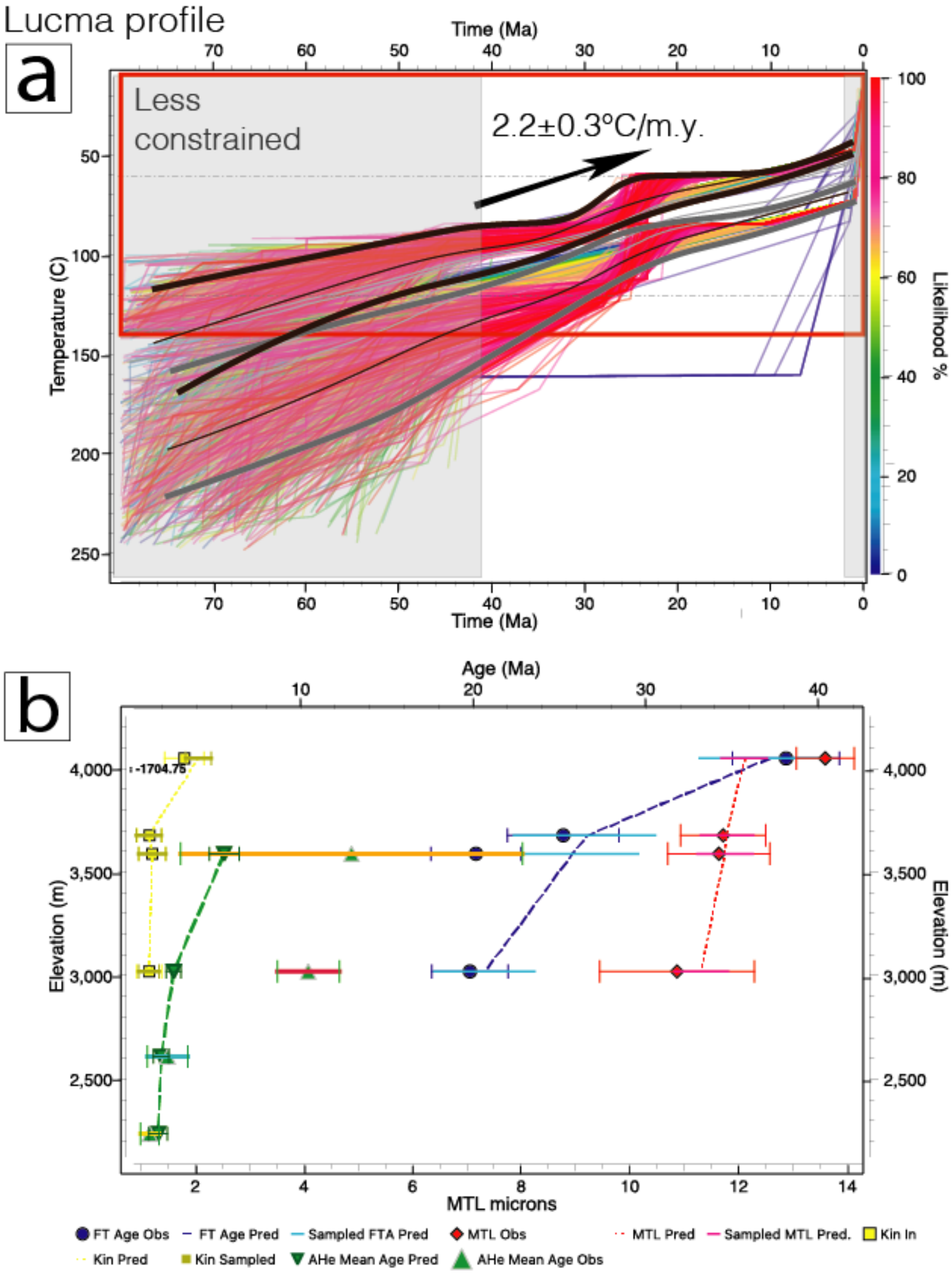


Figure S33. QTQt inversion results for the Lucma high-altitudinal profile. a) Time-temperature paths obtained by inversion of AHe and AFT thermochronology data from the Lucma age-elevation profile using QTQt (AB-17-21 to AB-17-28). The red square shows the explored time and temperature range for inversion. The colored lines show the T-t paths for the top and the bottom samples with their respective likelihood (see color scale on right). The solid black and grey lines show the expected model and its 95% reliable interval for the thermal histories of the top and bottom samples, respectively. The grey lines in between represent the expected cooling paths for the intermediate samples. Cooling rate derived from QTQt is indicated on the graph. b) Graph of observed vs. predicted data. Fit of best-fit model predictions to the data. FT: Fission Track; MTL: Mean Track Length; AHe: Apatite Helium; Obs: Observed; Pred: Predicted.

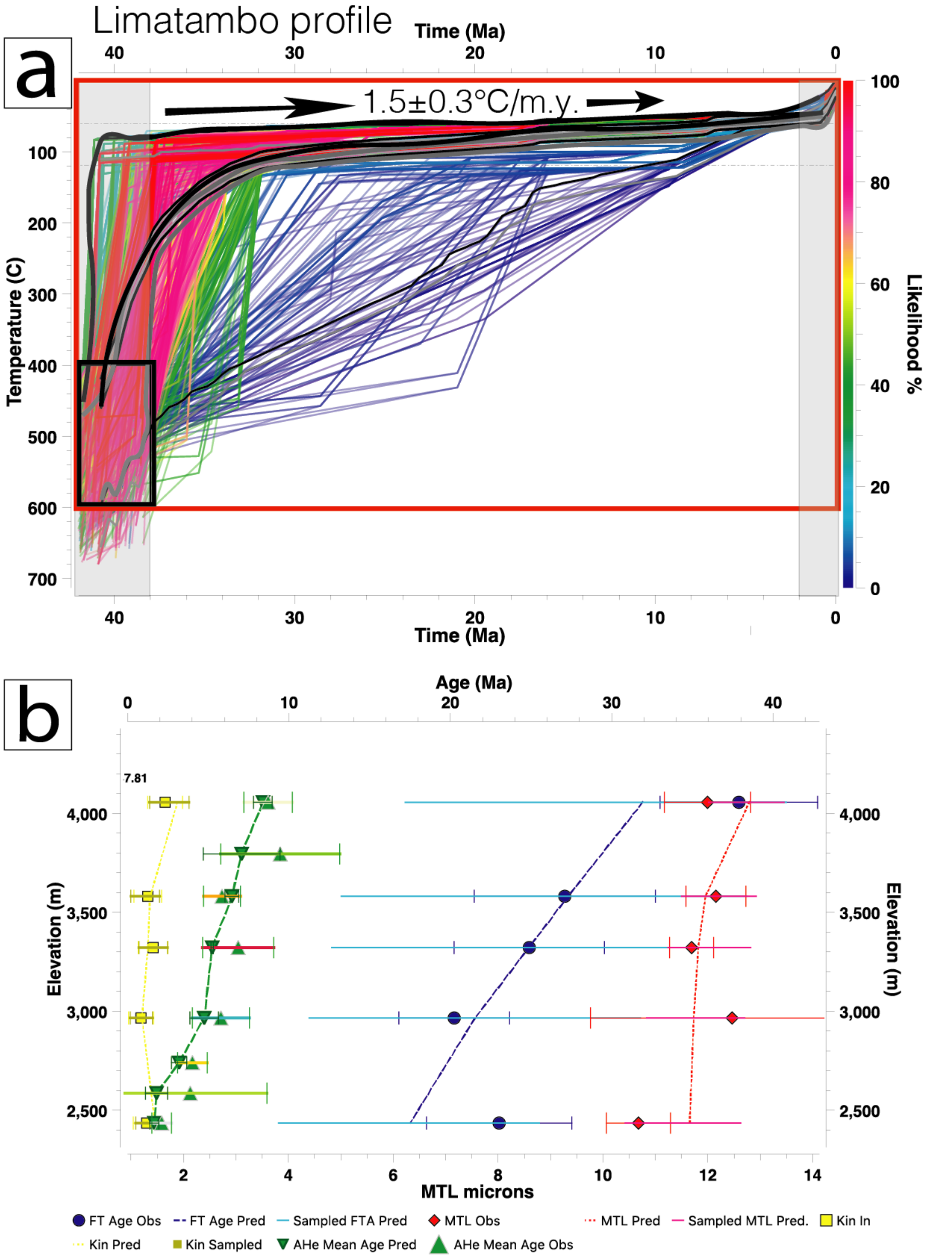


Figure S34. QTQt inversion results for the Limatambo high-altitudinal profile. a) Time-temperature paths obtained by inversion of AHe and AFT thermochronology data from the Limatambo age-elevation profile using QTQt (AB-17-29 to AB-17-36). The red square shows the explored time and temperature range for inversion. The black square corresponds to the pluton emplacement age and temperature constraints (Table S1). The colored lines show the T-t paths for the top and the bottom samples with their respective likelihood (see color scale on right). The solid black and grey lines show the expected model and its 95% reliable interval for the thermal histories of the top and bottom samples, respectively. The grey lines in between represent the expected cooling paths for the intermediate samples. Cooling rate derived from QTQt is indicated on the graph. b) Graph of observed vs. predicted data. Fit of best-fit model predictions to the data. FT: Fission Track; MTL: Mean Track Length; AHe: Apatite Helium; Obs: Observed; Pred: Predicted.

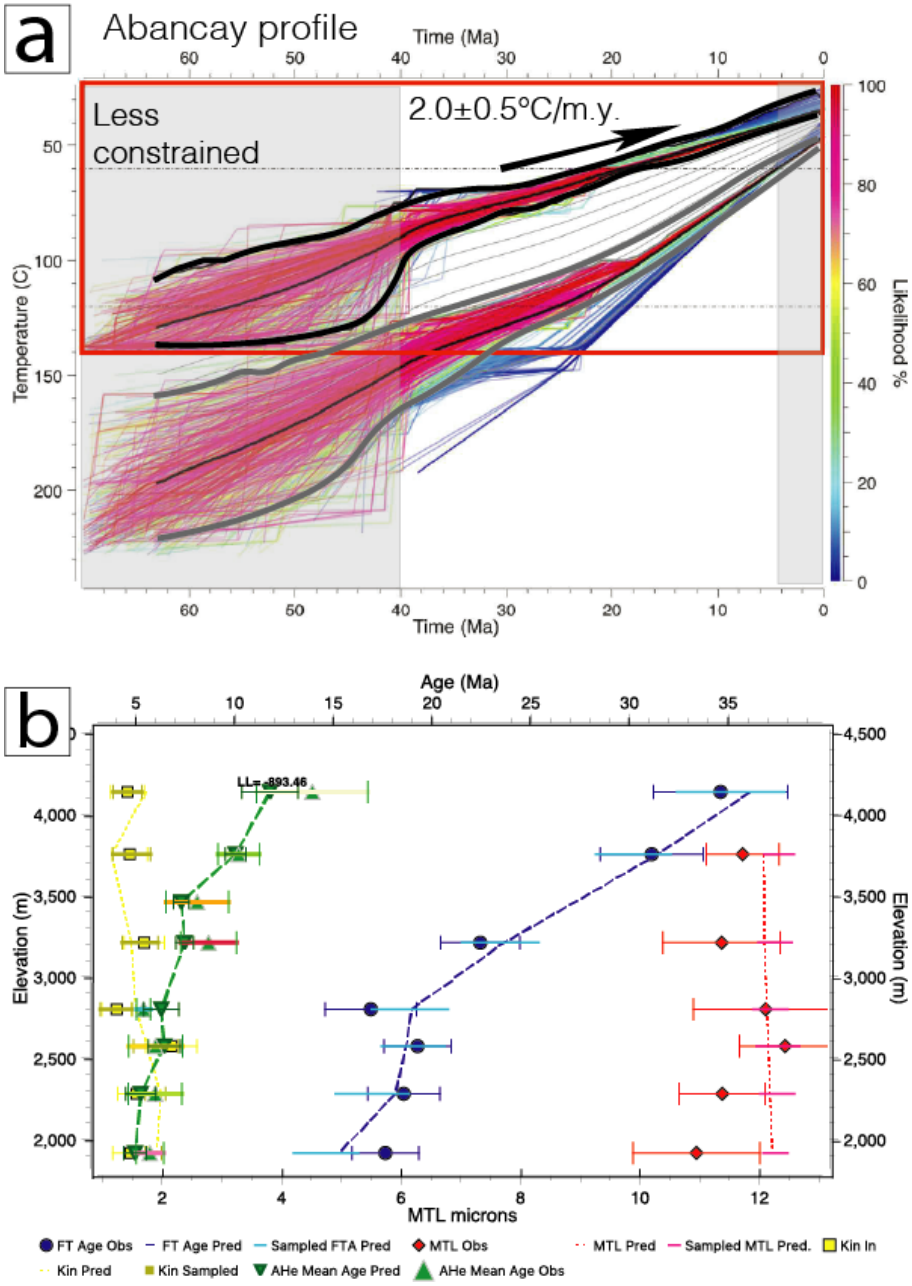


Figure S35. QTQt inversion results for the Abancay high-altitudinal profile. a) Time-temperature paths obtained by inversion of AHe and AFT thermochronology data from the Abancay age-elevation profile using QTQt (AB-17-37 to AB-17-44). The red square shows the explored time and temperature range for inversion. The colored lines show the T-t paths for the top and the bottom samples with their respective likelihood (see color scale on right). The solid black and grey lines show the expected model and its 95% reliable interval for the thermal histories of the top and bottom samples, respectively. The grey lines in between represent the expected cooling paths for the intermediate samples. Cooling rate derived from QTQt is indicated on the graph. b) Graph of observed vs. predicted data. Fit of best-fit model predictions to the data. FT: Fission Track; MTL: Mean Track Length; AHe: Apatite Helium; Obs: Observed; Pred: Predicted.

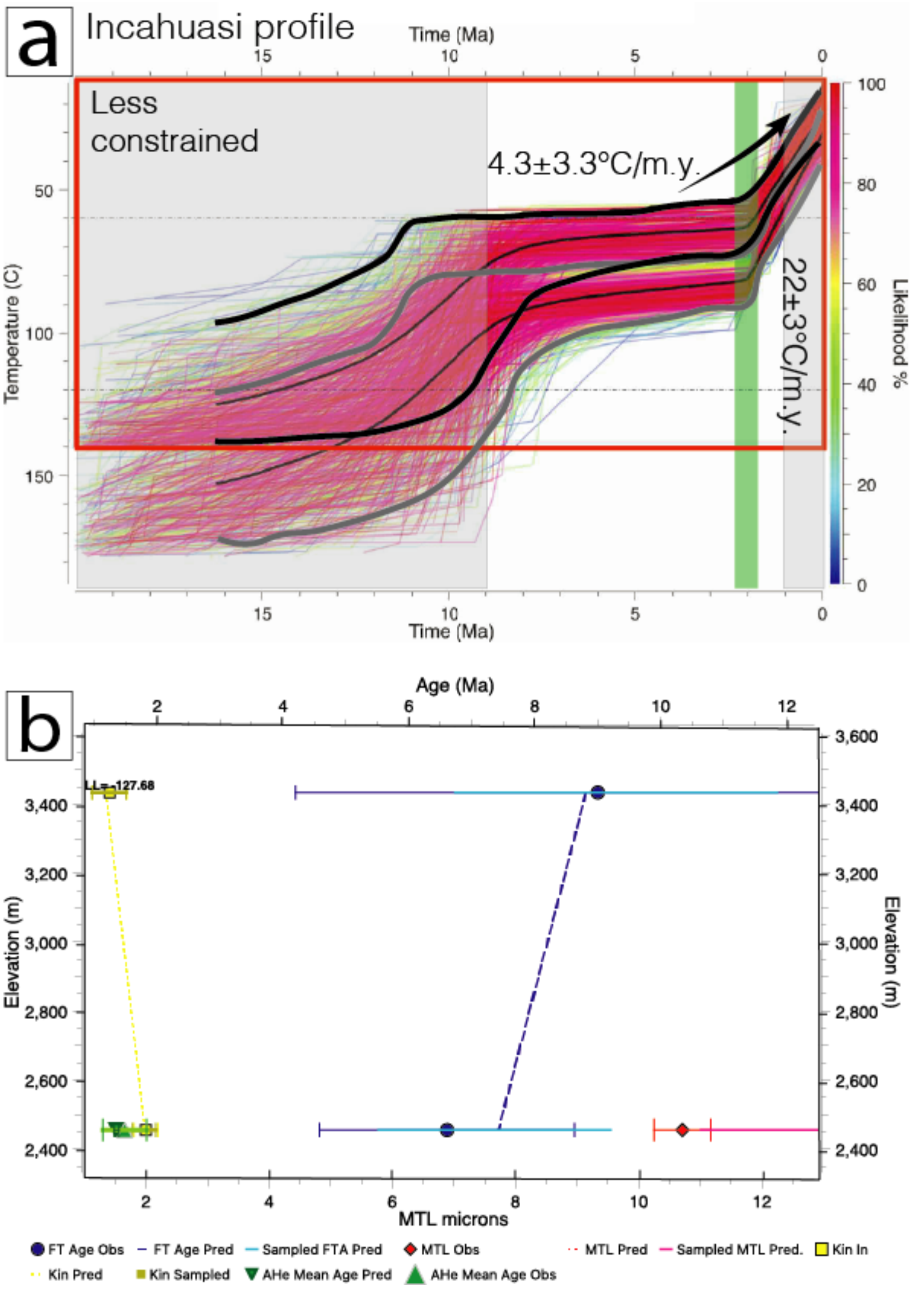


Figure S36. QTQt inversion results for the Incahuasi high-altitudinal profile. a) Time-temperature paths obtained by inversion of AHe and AFT thermochronology data from the Incahuasi age-elevation profile using QTQt (AB-17-51 and AB-17-55). The red square shows the explored time and temperature range for inversion. The colored lines show the T-t paths for the top and the bottom samples with their respective likelihood (see color scale on right). The solid black and grey lines show the expected model and its 95% reliable interval for the thermal histories of the top and bottom samples, respectively. The green vertical band indicates the well-constrained acceleration of cooling at ~2 Ma. Cooling rates derived from QTQt are indicated on the graph. b) Graph of observed vs. predicted data. Fit of best-fit model predictions to the data. FT: Fission Track; MTL: Mean Track Length; AHe: Apatite Helium; Obs: Observed; Pred: Predicted.

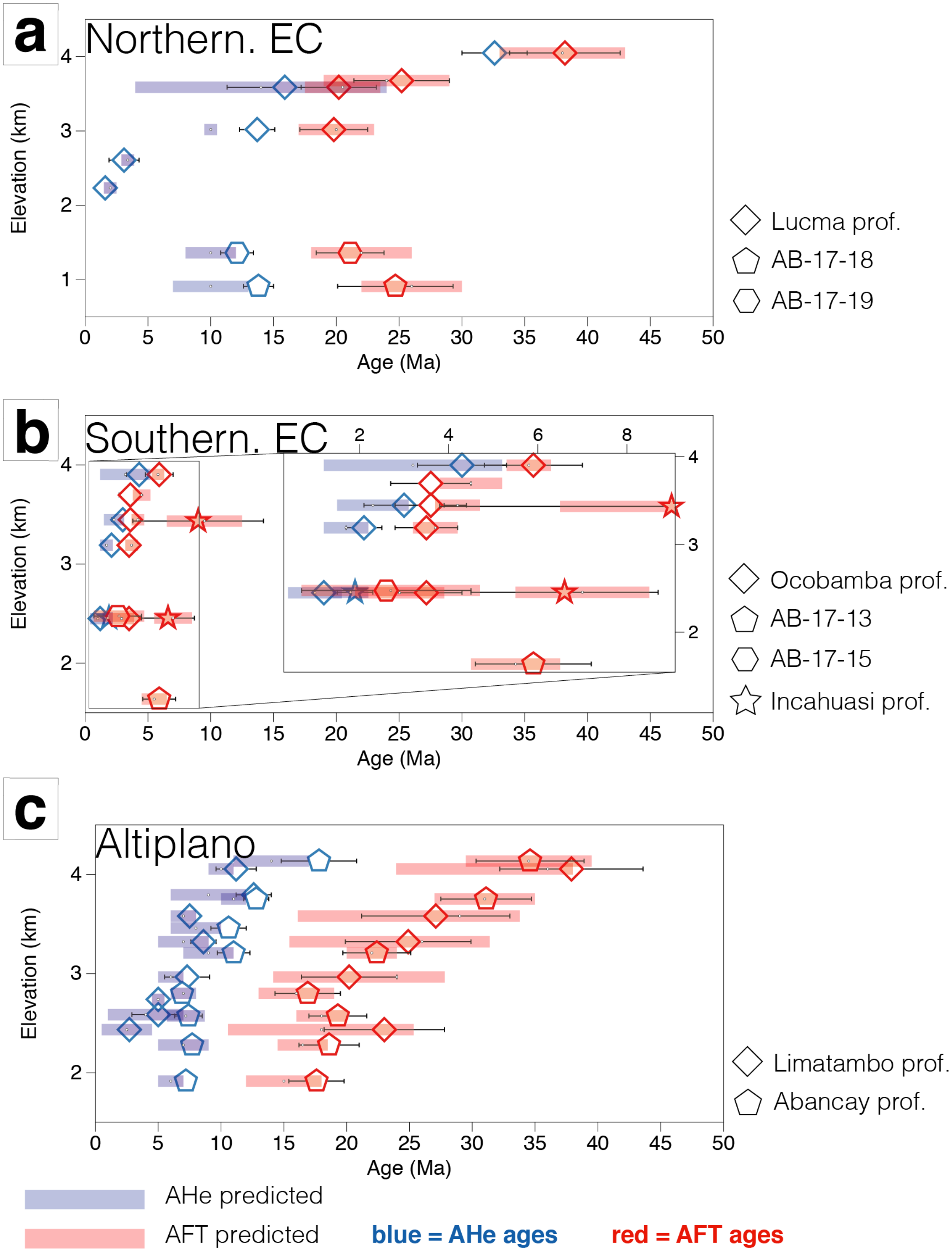


Figure S37. Observed vs. predicted thermochronological ages (AFT & AHe) modeled with QTQt. Panels a, b and c refer to the data associated to the northern Eastern Cordillera, the southern Eastern Cordillera and the Altiplano respectively (see Figure 4 for the location).

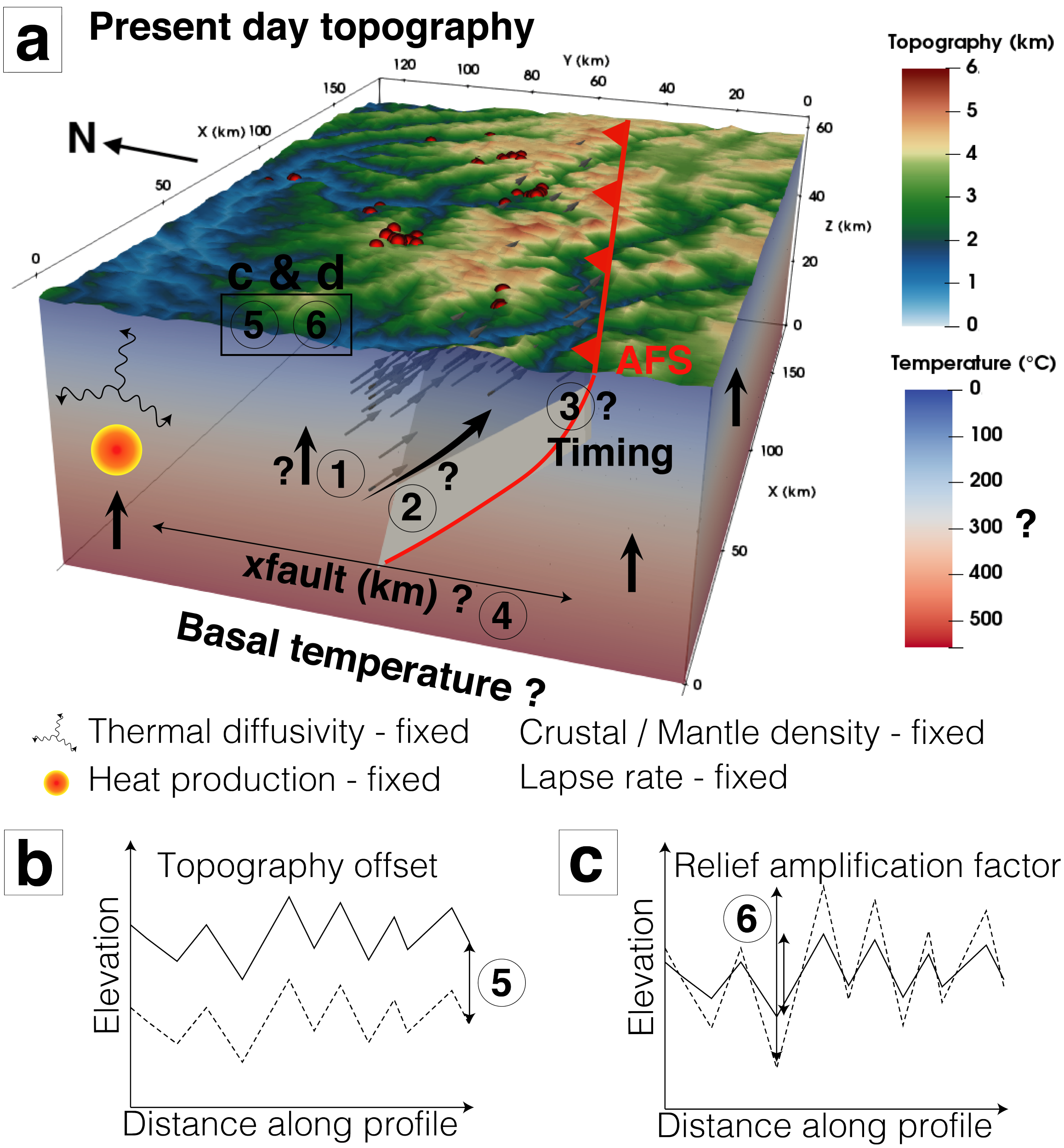


Figure S38. Parameters implemented and/or explored in Pecube through time. a) Example of the Eastern Cordillera crustal block (see Figure 2 for location). Red balls mark the location of the thermochronological data. Numbers and question marks refer to explored parameters. 1: Crustal block exhumation (km/Ma); 2: Fault velocity (km/Ma); 3: Timing of fault activation (Ma); 4: x fault (km), proxy for the fault geometry (fault dip). AFS: Apurimac fault system. b) Synthetic topographic profile presenting the topography-offset parameter evolution through time (5). c) Synthetic topographic profile presenting the relief amplification factor evolution through time (6).

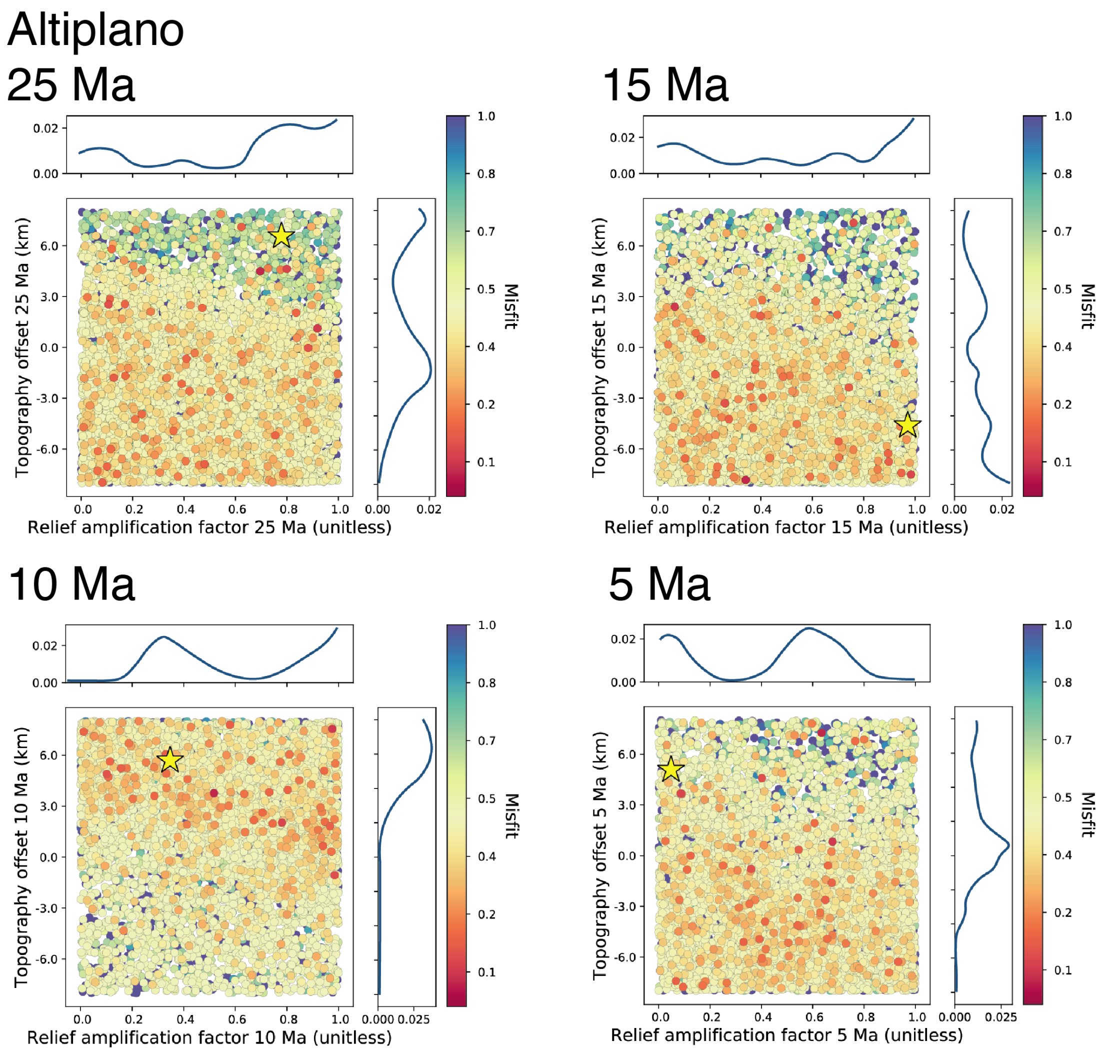
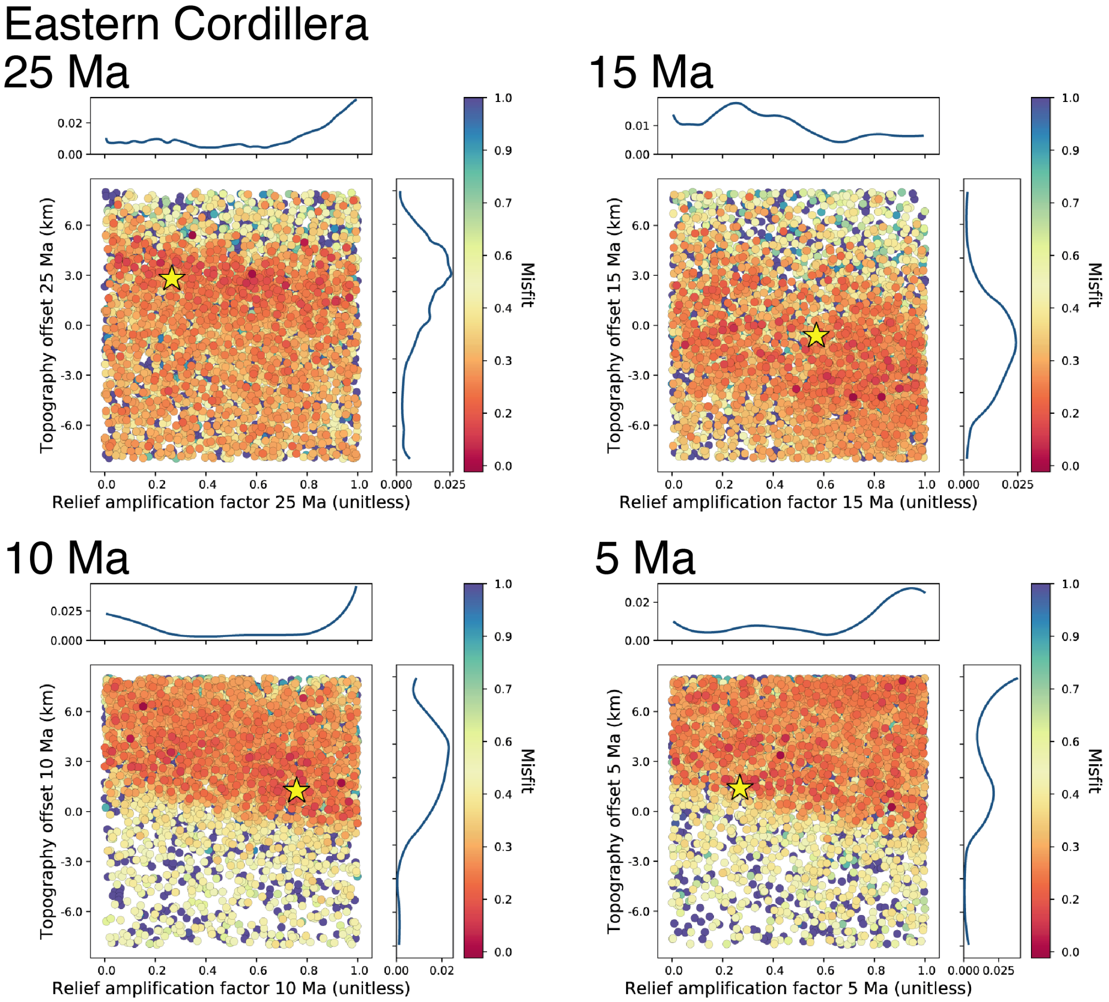


Figure S39. Pecube inversion results for landscape evolution parameters through time for the Altiplano block (performed using a 18°C/km geotherm). Y-axis is the topography-offset parameter; X-axis is the relief amplification factor. These outcomes correspond to a unique inversion with all the parameters free for each time period. These parameters do not converge toward a unique solution.


Eastern Cordillera

25 Ma

15 Ma

10 Ma

5 Ma

Figure S40. Pecube inversion results for landscape evolution parameters through time for the Eastern Cordillera block (performed using a 18°C/km geotherm). Y-axis is the topography-offset parameter; X-axis is the relief amplification factor. These outcomes correspond to a unique inversion with all the parameters free for each time period. These parameters do not clearly converge toward a unique solution.

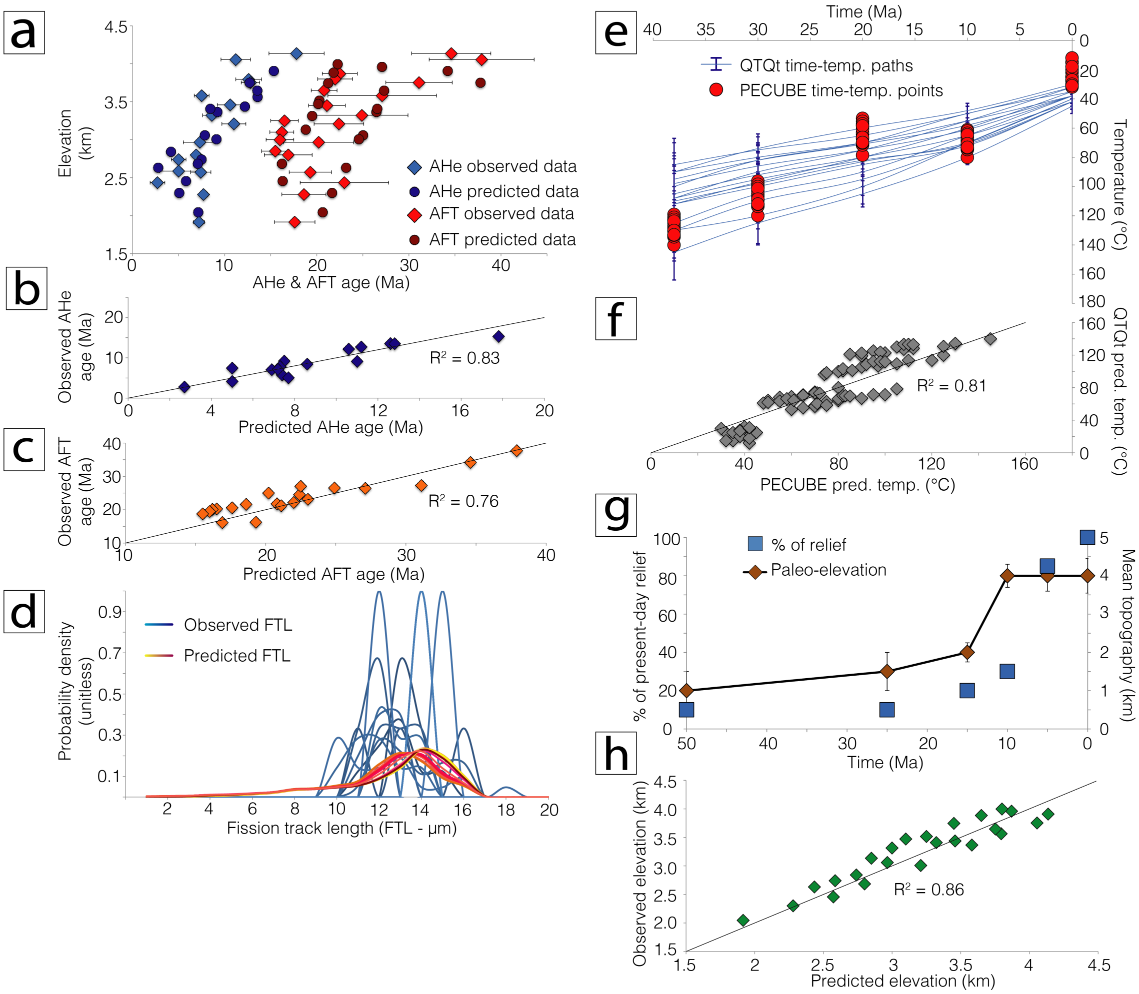


Figure S41. Observed data vs. predicted ones from Pecube best-fitting model for the Altiplano crustal block (performed using a 18°C/km geotherm). a) Age-elevation plot for observed AHe and AFT ages vs. predicted ones. b) Implemented AHe ages in function of predicted AHe ages. c) Implemented AFT ages in function of predicted AFT ages. d) Probability density function for implemented fission track length vs. predicted ones. e) Direct comparison of Time-temperature paths derived from QTQt modeling and T-t paths derived from Pecube. f) Implemented temperature (QTQt) in function of predicted ones computed with Pecube. g) Implemented modeled mean topography evolution (Sundell et al., 2019) and percentage of present-relief for forward modeling. h) Implemented topography (GTOPO30) in function of the predicted one by Pecube after landscape evolution computation. In any case, the data reproducibility is very satisfactory.

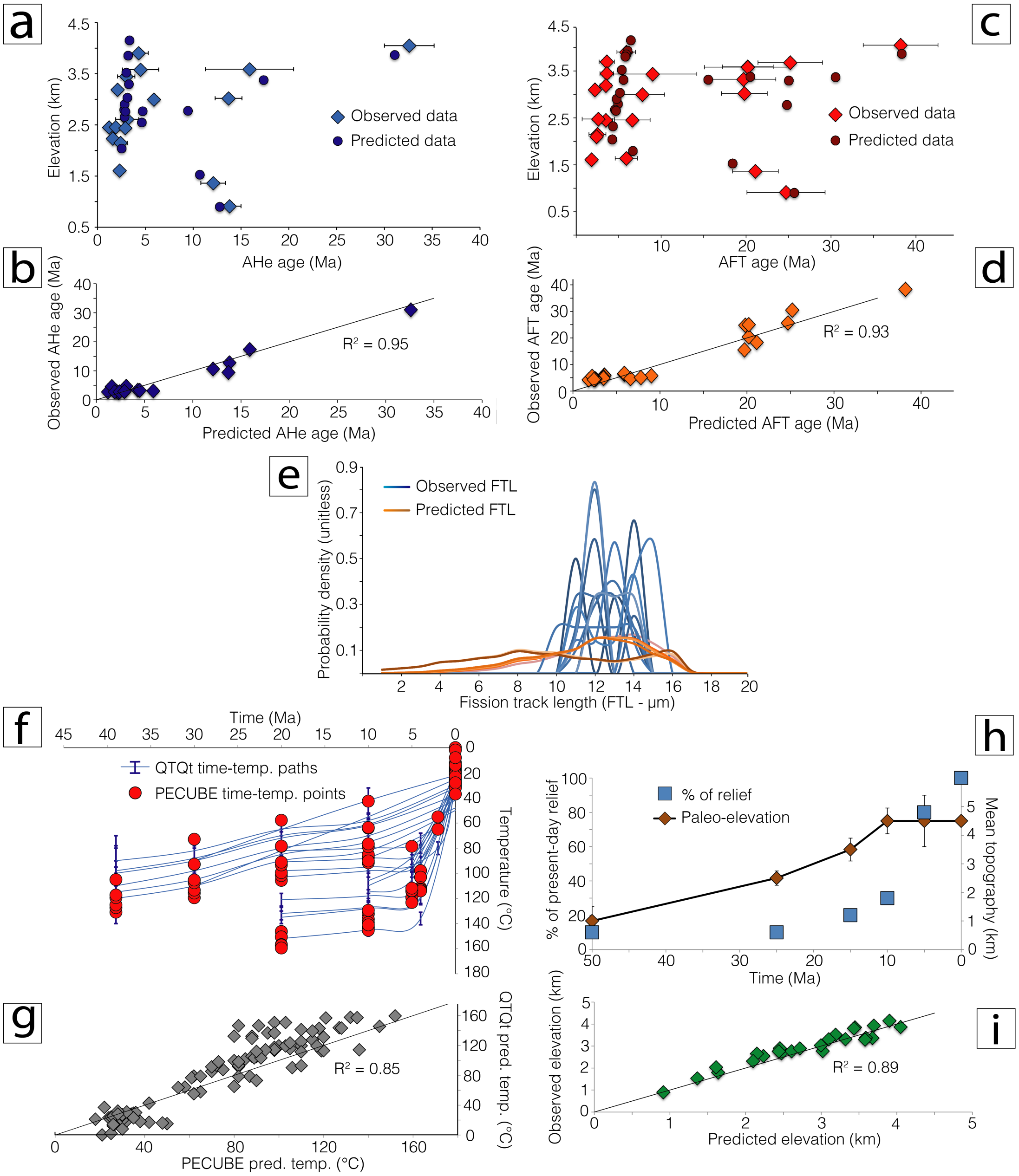


Figure S42. Observed data vs. predicted ones from Pecube best-fitting model for the Eastern Cordillera crustal block (performed using a 18°C/km geotherm). a) Age-elevation plot for observed AHe ages vs. predicted ones. b) Implemented AHe ages in function of predicted AHe ages. c) Age-elevation plot for observed AFT ages vs. predicted ones. d) Implemented AFT ages in function of predicted AFT ages. e) Probability density function for implemented fission track length vs. predicted ones. f) Direct comparison of Time-temperature paths derived from QTQt modeling and T-t paths derived from Pecube. g) Implemented temperature (QTQt) in function of predicted ones computed with Pecube. h) Implemented modeled mean topography evolution (Sundell et al., 2019) and percentage of present-relief for forward modeling. i) Implemented topography (GTOPO30) in function of the predicted one by Pecube after landscape evolution computation. In any case, the data reproducibility is very satisfactory.

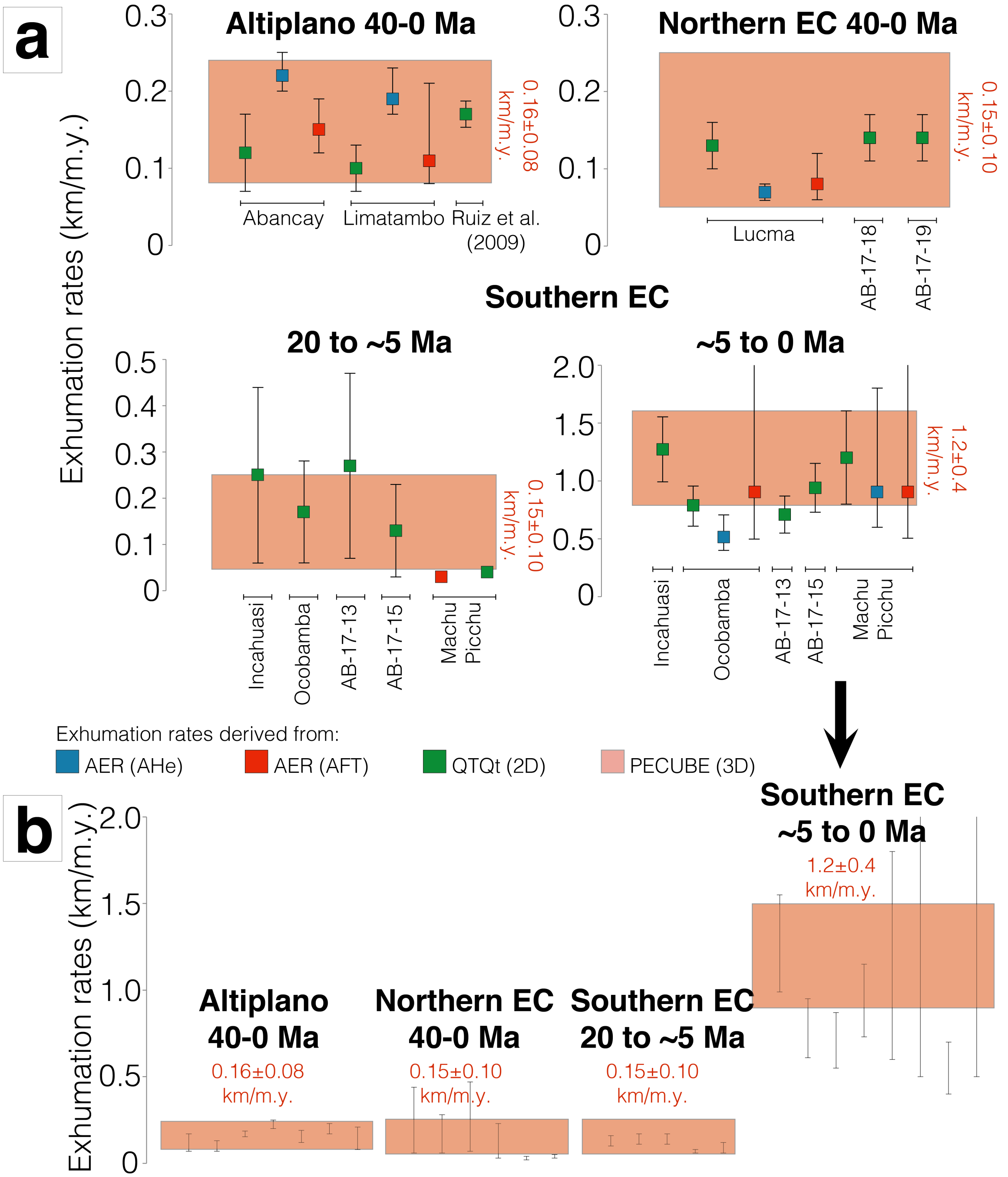


Figure S43. Exhumation rates derived from AER, QTQt and Pecube. a) Exhumation rate data per vertical profile and individual samples of the Abancay Deflection. b) Compilation of the data displayed in a.

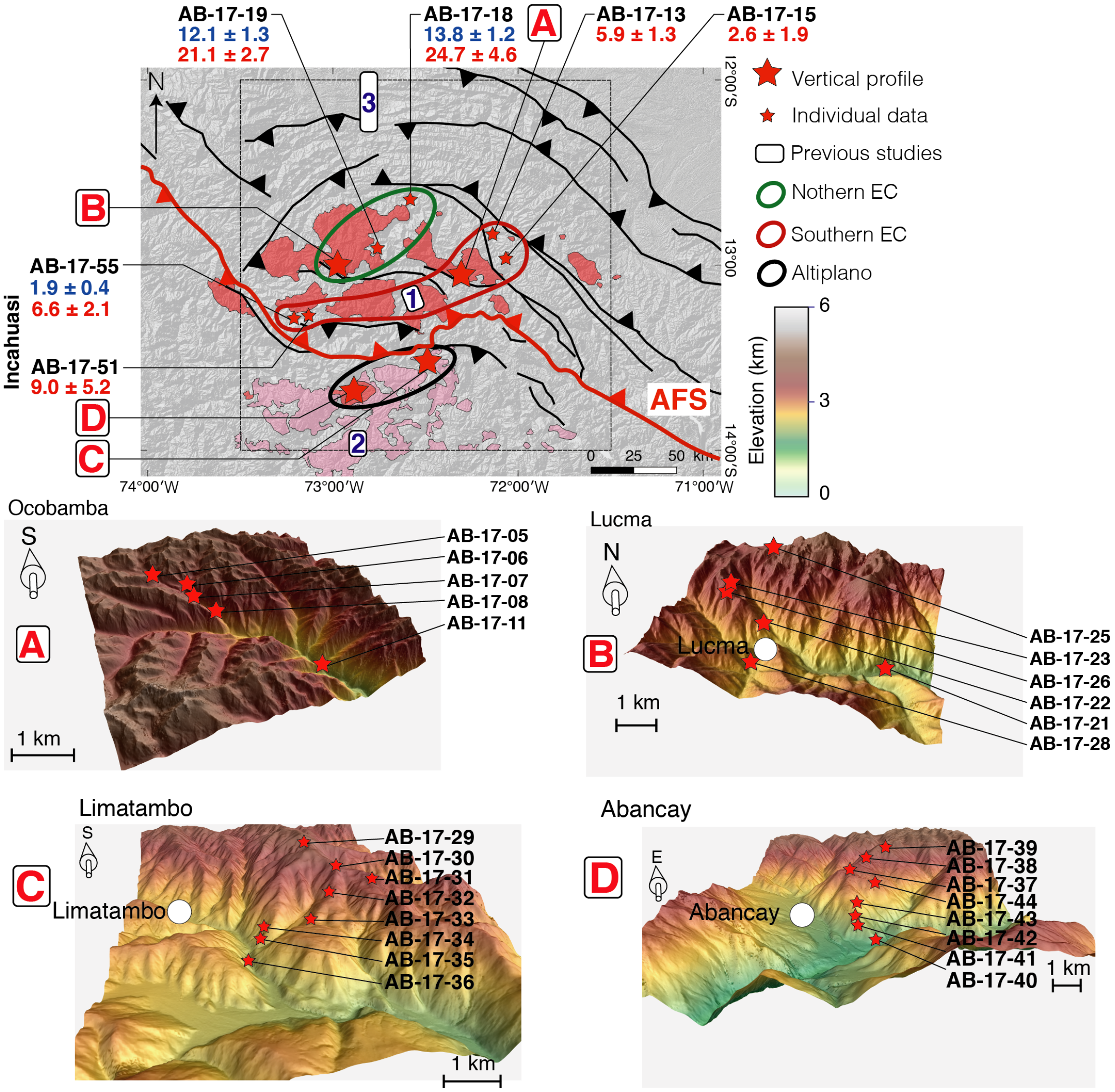


Figure S44. Sample locations within the Abancay Deflection. Red and pink polygons are respectively Permo-Triassic and Eocene plutons. Previous studies are: 1: Gérard et al. (in press) and Kennan (2008); 2: Ruiz et al. (2009); 3: Espurt et al. (2011) and Gautheron et al. (2013). Blue and red numbers below sample names refer to AHe mean ages and AFT central ages for individual samples and the two-sampled-point Incahuasi vertical profile. Red capital letters refer to the other sampled vertical profiles (A: Ocobamba profile; B: Lucma profile; C: Limatambo profile & D: Abancay profile). Green, red and black contours mark the latitudinal segmentation of the Abancay Deflection defining three areas according to thermal histories modeled with QTQt. The black dashed square frames the Abancay Deflection. AFT: Apurimac fault system; EC: Eastern Cordillera.

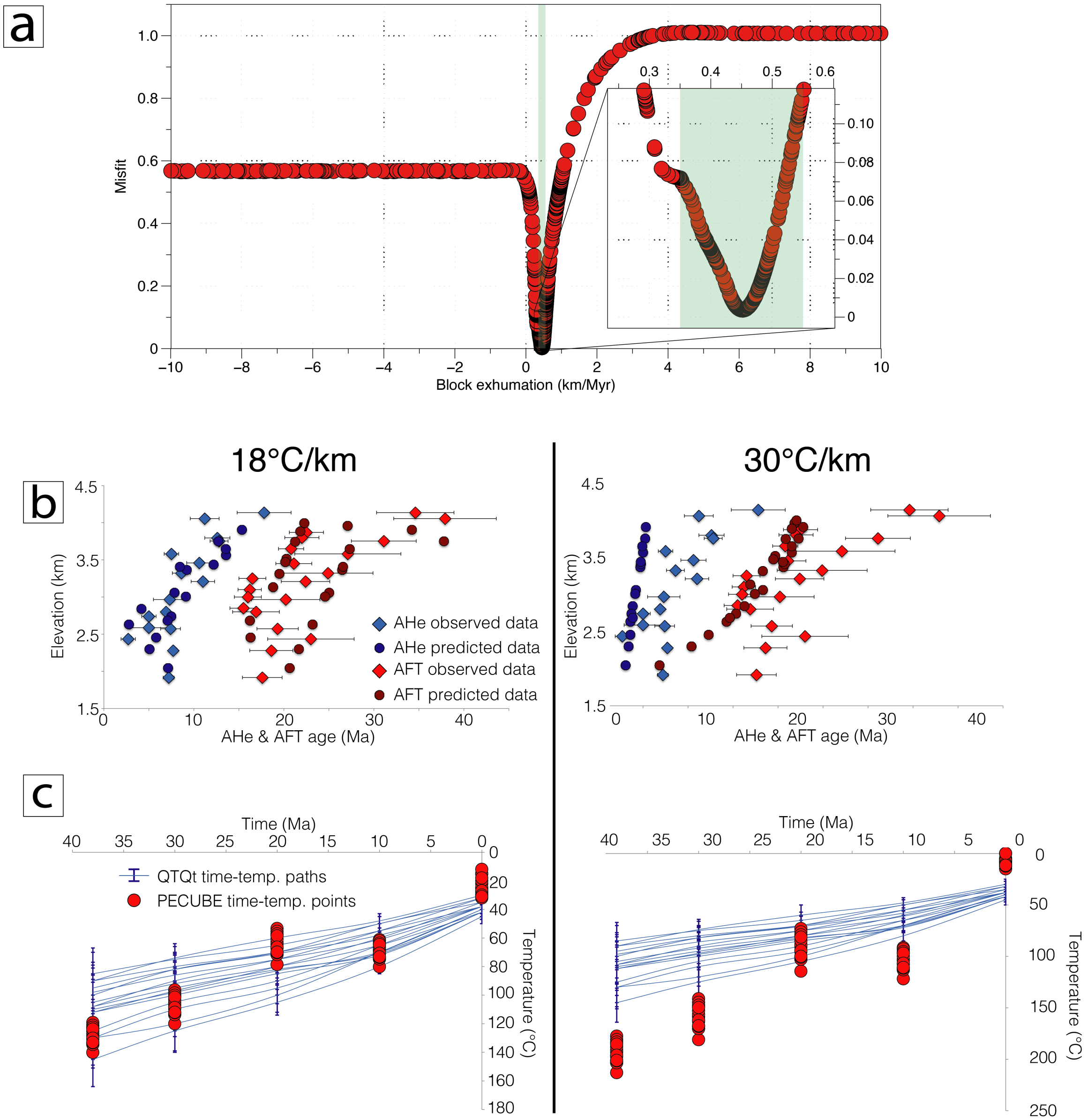


Figure S45. 3D Pecube inversion results for the Altiplano crustal block imposing a geothermal gradient of 30°C/km. The total sample size for inverse modeling is 1000. a) 1D parameter space and inversion results for crustal-block exhumation. Each point corresponds to one forward model. Lowest misfit value obtained corresponds to an exhumation rate of ~0.45 km/m.y. b and c) Observed data vs. predicted ones from Pecube best-fitting model for the Altiplano crustal block. A geothermal gradient of 18°C/km is imposed on left panels, while one of 30°C/km is implemented on right panels. b) Age-elevation plot for observed AHe and AFT ages vs. predicted ones. c) Direct comparison of time-temperature paths derived from QTQt and ones computed with Pecube best-fitting model. With a 30°C/km geothermal gradient, predicted ages are too young in most of cases for the Altiplano model.

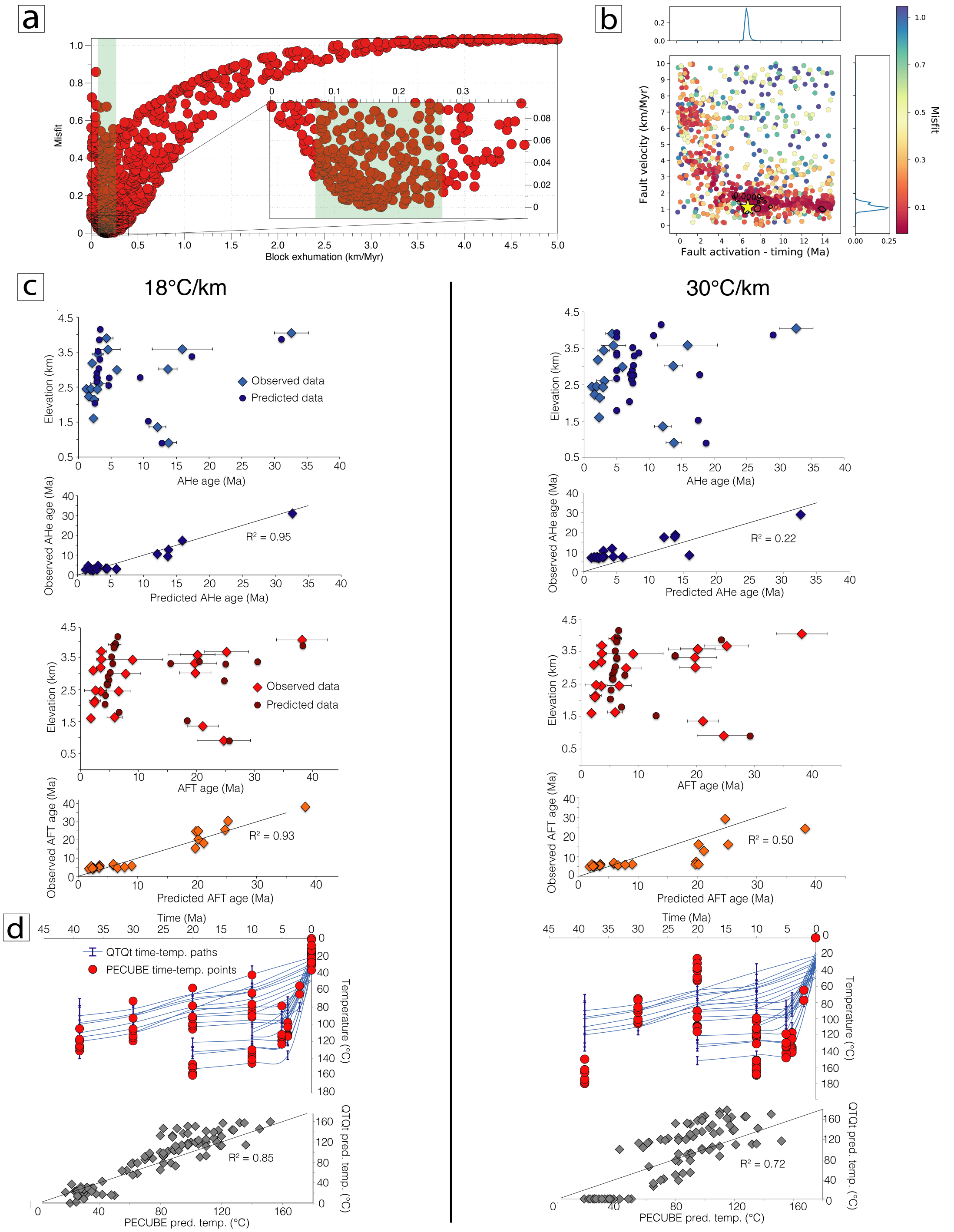


Figure S46. 3D Pecube inversion results for the Eastern Cordillera crustal block imposing a geothermal gradient of 30°C/km. The total sample size for inverse modeling is 1000. a) 1D parameter space and inversion results for crustal-block exhumation. Each point corresponds to one forward model. Lowest misfit value obtained corresponds to an exhumation rate of ~0.2 km/m.y. b) 2D parameter space and inversion results for the fault velocity vs. activation timing of the Apurimac fault system. Each colored point corresponds to one forward model. Blue curves (up and right subpanels) are the probability density for each parameter. The yellow stars in panels a and b are the best-fitting model. Models converge for values of 7±1 Ma for the fault activation timing and a fault velocity of 1.4±0.4 km/m.y since that time. c and d) Observed data vs. predicted ones from Pecube best-fitting model for the Eastern Cordillera crustal block. A geothermal gradient of 18°C/km is imposed on left panels, while one of 30°C/km is implemented on right panels. c) Direct comparison of observed thermochronological data (AHe and AFT) with ones predicted with Pecube best-fitting model. d) Direct comparison of time-temperature paths derived from QTQt and ones computed with Pecube best-fitting model. With a 30°C/km geothermal gradient, predicted ages are too old in most of cases for the Eastern Cordillera model.

Parameter	Value	Profile or individual data	Reference / Justification
Time explored (Ma)	0 - 20	Ocobamba	Time interval with the age range extended to twice the oldest thermochronological age obtained to avoid a modeling bias. Except for Limatambo; the time interval explored is framed by the batholith crystallization age (40±2 Ma; Perello et al., 2003). For the Limatambo profile, we imposed in QTQt a temperature ranging from 400°C to 600°C (>> to the AHe and AFT closure temperature) between 42 and 38 m.y.
	0 - 30	AB-17-13	
	0 - 30	AB-17-15	
	0 - 50	AB-17-18	
	0 - 50	AB-17-19	
	0 - 80	Lucma	
	0 - 42	Limatambo	
	0 - 70	Abancay	
	0 - 20	Incahuasi	
Explored temperature (°C)	0 – 140	All except Limatambo	Closure temperature for AHe and AFT systems (Ault et al., 2019).
	0 – 600	Limatambo	For Limatambo: temperature for pluton emplacement.
Explored $\delta T/\delta t$ (°C/My)	1000	All	Maximum exploration – no constrains
Geothermal gradient (°C/km)	25±15	All excepted individual data (AB-17-xx)	Geothermal exploration for common values in orogens. This range includes our computed gradient for the Abancay Deflection region (18±4°C/km) and accepted values for the Eastern Cordillera further south in Bolivia (26±8°C/km; Barnes et al., 2008).
Present-day temperature (°C)	25±10	All	N.A.*
Lapse rate (°C/km)	6±2	All	Estimated from Gonfiantini et al. (2001) and Klein et al. (1999).
Allow the geothermal gradient to vary over time	Yes	All	N.A.*
Reheating	No	All	No evidence for reheating (burial) of the samples.
Number of iteration	Prior = 100000 Post = 200000	All	N.A.*
Etchant	5.5 M	All	Analytical protocol
Annealing model (AFT)	N.A.*	All	Ketcham et al. (2007)
Radiation damage model (AHe)	N.A.*	All	Gautheron et al. (2009)

Note:

*N.A. = not applicable.

Table S1. QTQt parameters for thermochronological data modeling

Sample number	Arithmetic mean age (Ma)	Error - Standard deviation (Ma)
<u>Ocobamba profile</u>		
AB-17-05	4.3	1.0
AB-17-07	3.0	0.9
AB-17-08	2.1	0.4
AB-17-11	1.2	0.2
<u>Punctual data</u>		
AB-17-18	13.8	1.2
AB-17-19	12.1	1.3
<u>Lucma profile</u>		
AB-17-21	1.6	0.4
AB-17-22	13.7	1.4
AB-17-25	32.6	2.6
AB-17-26	15.9	4.6
AB-17-28	3.1	1.2
<u>Limatambo profile</u>		
AB-17-29	11.2	1.6
AB-17-30	12.6	1.4
AB-17-31	7.5	0.8
AB-17-32	8.6	1.0
AB-17-33	7.3	1.8
AB-17-34	5.0	0.8
AB-17-35	5.0	2.1
AB-17-36	2.7	0.8
<u>Abancay profile</u>		
AB-17-37	6.9	0.4
AB-17-38	7.4	1.1
AB-17-39	7.7	0.3
AB-17-40	7.2	0.6
AB-17-41	17.8	3.0
AB-17-42	12.8	1.0
AB-17-43	10.6	1.4
AB-17-44	11.0	1.3
<u>Incahuasi profile</u>		
AB-17-55	1.9	0.4

Table S2. Apatite (U-Th-Sm)/He data – Mean ages and errors for Pecube modeling

Parameter	Value	Reference
Crustal density (kg/m^3)	**2721**±65	Arndt et al. (1997) ; Waples and Waples (2004)
Mantle density (kg/m^3)	**3095**±147	Waples and Waples (2004)
Lapse rate (°C/km)	**6**±1	Klein et al. (1999) ; Gonfiantini et al. (2001)
Heat flow (mW/m^2)	**57**±5	Henry and Pollack (1988) ; Davies (2013)
Thermal conductivity (W/m/°C)	**2.8**±0.2	Henry and Pollack (1988)
Geothermal gradient (°C/km)	**18**±4	This study
Heat production (mean for the crust; µW/m^3)	**0.9**	Springer (1999)
Specific thermal capacity (J/kg/K)	**900**±200	Arndt et al. (1997); Waples and Waples (2004)
Thermal diffusivity (km^2/Ma)	**40**±11	Arndt et al. (1997); Whittington et al. (2009)
Heat production through time (°C/Ma)	**6**	This study
Base model temperature (°C)	**560**	This study
Crust thickness (Moho depth; km)	**56**±7	Mcglashan et al. (2008); Lloyd et al. (2010) Assumpção et al. (2013); Chulick et al. (2013); Ma and Clayton (2014); Bishop et al. (2017)
Elastic thickness (km)	**17.5**±2.5	Pérez-Gussinyé et al. (2008)
Young modulus (Pa)	**1.10^{11}**	Standard value
Poisson's coefficient (unitless)	**0.25**	Standard value

Note: Displayed results and errors were computed from the literature (Arithmetic mean and standard deviation). Pecube does not take into account these parameter values dispersion. Implemented values into Pecube are in bold.

Table S3. Thermal and rheological parameters for Pecube modeling.

Parameter	Range
Altiplano model	
Crustal block exhumation (km/m.y.)	0 – 5
Basal temperature - 56 km depth (°C)	400 – 800 (13°C/km – 26°C/km)
Eastern Cordillera model	
Crustal block exhumation (km/m.y.)	0 - 2
x fault – 25 km depth – proxy for fault dip (km)	-50 (26°) – 0 (vertical – 90°)
Fault velocity (km/m.y.)	0 – 5
Timing for fault activation (Ma)	0 – 10
Common parameters explored for the Altiplano and the Eastern Cordillera	
Topography offset (km)	
At 25 Ma	-6 – 6
At 15 Ma	-6 – 6
At 10 Ma	-6 – 6
At 5 Ma	-6 – 6
Relief amplification factor (unitless)	0 – 1
At 25 Ma	0 – 1
At 15 Ma	0 – 1
At 10 Ma	0 – 1
At 5 Ma	0 – 1

Note: Pecube inversions were performed processing 12 successive iterations. The sample size for the first iteration is 984 and 480 for all other iterations. The number of resample cells is 288 (for n iteration) meaning a 60 % resampling of the previous best-fitting models (from n-1 iteration). The total sample size for inverse modeling is 6744 (Figures 8a, 9a and 9b).

Table S4. Explored parameters and ranges for thermochronological data inversion (Pec modeling)

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