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## Mesozoic evolution of NW Africa: implications for the Central Atlantic Ocean dynamics

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► **To cite this version:**

Rémi Leprêtre, Jocelyn Barbarand, Yves Missenard, Cécile Gautheron, Rosella Pinna-Jamme, et al..  
Mesozoic evolution of NW Africa: implications for the Central Atlantic Ocean dynamics. *Journal of  
the Geological Society*, 2017, 174 (5), pp.817 - 835. 10.1144/jgs2016-100 . hal-01676091

**HAL Id: hal-01676091**

**<https://hal.sorbonne-universite.fr/hal-01676091>**

Submitted on 5 Jan 2018

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1 **Mesozoic evolution of Northwest Africa: implications for the Central Atlantic**  
2 **Ocean dynamics**

3  
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7  
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15

16 **Abbreviated title:** Mesozoic Evolution of NW Africa

17  
18 **Abstract**

19 The Central Atlantic Ocean opened during the Early Jurassic and represents the oldest  
20 portion of the Atlantic Ocean. Although the American margin has been well-studied, the onshore  
21 evolution of its African counterpart is poorly understood. We investigated the evolution of a ~1300  
22 km transect across the Reguibat Shield (Morocco, Mauritania, Algeria) in the northern West African  
23 Craton using low-temperature thermochronology. Fourteen samples were dated using apatite  
24 fission-track analysis. Nine of these samples were also dated using (U-Th-Sm)/He analysis. Fission-  
25 track ages range from  $118 \pm 10$  to  $497 \pm 61$  Ma, with mean track lengths between  $11.2 \pm 0.4$  and  $12.5$   
26  $\pm 0.2$   $\mu\text{m}$ . (U-Th-Sm)/He single-grain ages range from  $32 \pm 3$  Ma to  $396 \pm 32$  Ma. Through forward and  
27 inverse thermal modeling, we demonstrate that the craton underwent kilometeric exhumation  
28 between the Early-Middle Jurassic and the Late Cretaceous. Based on our new results, published data  
29 on Northwest Africa and data from the conjugate eastern North American passive margin, we show  
30 that this post-rift Early-Middle Jurassic/Early Cretaceous exhumation affected both margins in a

31 similar areal extent and simultaneously. Transient mantle dynamic support is suggested as  
32 accounting for the major erosional phase recorded on both margins.

33

34 **Supplementary material:** methodology for thermal modeling, individual thermal modeling for all  
35 samples and the relationship between apatite chemistry and (U-Th)/He ages are available at  
36 <https://figshare.com/s/05461f8ec0de274456c6>

37 **Keywords**

38 Low-temperature thermochronology – West African Craton – Central Atlantic Ocean – post-rift  
39 evolution of passive margin – Reguibat Shield

40

41

42           **Introduction**

43           In the past two decades, substantial evidence has been presented to show that passive  
44 margins are anything but passive. For example, the Atlantic-type margins have been thoroughly  
45 studied and show repeated uplift or burial events in the course of their post-rift history (Gallagher *et*  
46 *al.*, 1998; Turner *et al.*, 2008; Holford *et al.*, 2009; Japsen *et al.*, 2006, 2012; Cogné *et al.*, 2012; Green  
47 *et al.*, 2013; Leprêtre *et al.*, 2015; Wildman *et al.*, 2015). These studies have demonstrated that the  
48 precise determination of the timing of burial/uplift phase of the onshore margins can offer a better  
49 understanding of the stratigraphical record along the margins (Japsen *et al.*, 2012). Despite the  
50 evidence that passive margins are active features in plate tectonics, these studies also highlight the  
51 poor knowledge we have on the underlying mechanisms controlling these processes (Japsen *et al.*,  
52 2012; Green *et al.*, 2013 and references therein).

53           In order to better understand the underlying mechanisms controlling rift and post-rift  
54 evolution, it is necessary to assess the simultaneous uplift/burial events on conjugate passive  
55 margins (*e.g.* Turner *et al.*, 2008; Green & Duddy, 2010). In this study, we compare the stratigraphical  
56 record of the conjugate margins of the Central Atlantic Ocean during the Mesozoic and the vertical  
57 evolution of the onshore domains. These margins have received considerable attention in the past  
58 (eastern North America: Sheridan & Grow, 1988; Miall, 2008; Northwest Africa: von Rad *et al.*, 1982;  
59 Poag & Schlee, 1984), although there have been a limited number of comparison studies focusing on  
60 their respective stratigraphical records (Jansa & Wiedmann, 1982; von Rad & Sarti, 1986) and no  
61 study has ever compared the two margins considering their onshore evolutions. Many low-  
62 temperature thermochronology studies have been undertaken along the onshore eastern North  
63 American passive margin (Crowley, 1991; Wang *et al.*, 1994; Boettcher & Milliken, 1994; Roden-Tice  
64 *et al.*, 2000; Roden-Tice & Wintsch, 2002; Grist & Zentilli, 2003; Lorencak *et al.*, 2004; Spotila *et al.*,  
65 2004; Roden-Tice & Tice, 2005; Taylor & Fitzgerald, 2011; Roden-Tice *et al.*, 2012). However, along  
66 the Northwest African passive margin, a similarly large coverage of onshore data is still lacking (first

67 data in Leprêtre *et al.*, 2014 and 2015) to achieve a detailed comparison of both margins and  
68 addressing this issue is a major goal of this study.

69 This study reports low-temperature thermochronology (LTT) data across the whole range of  
70 the northern West African Craton, which is the main continental domain of the eastern Central  
71 Atlantic Ocean (Fig. 1a). We used apatite fission-track and (U-Th-Sm)/He (AFT and AHe, respectively)  
72 LTT and thermal modeling techniques (Gallagher, 2012) to constrain the timing and amplitude of  
73 erosion/burial events for Mesozoic-Cenozoic times. Given a 40-120°C thermal sensitivity, these  
74 methods provide insights into the evolution of the uppermost 3-4 km of the crust (Gallagher *et al.*,  
75 1998; Flowers *et al.*, 2009; Gautheron *et al.*, 2009, Djimbi *et al.*, 2015). We then combine our new LTT  
76 study with the wealth of LTT data on the eastern American passive margin and the sedimentary  
77 records of both conjugate passive margins. These data form the basis of our comparison between the  
78 two margins and discussion of the Mesozoic evolution of the Central Atlantic Ocean.

79

## 80 **Geological setting**

81 Within the northern West African Craton (NWAC), the Reguibat Shield is a flat basement  
82 domain, divided into a western Archean domain (> 2.5 Ga; Potrel *et al.*, 1998; Schofield *et al.*, 2012)  
83 and an eastern Eburnean domain (2-2.2 Ga; Lahondère *et al.*, 2001; Peucat *et al.*, 2005). Its  
84 westernmost tip is part of the Variscan Mauritanides (Villeneuve, 2008; Michard *et al.*, 2010). North  
85 and south of the Reguibat Shield, the Tindouf and Taoudeni basins display a km-scale Paleozoic infill  
86 (Boote *et al.*, 1998), unconformably lying on the Neoproterozoic rocks (Fig. 1b). Both basins have  
87 large-scale synclinal shapes with low (5-10°) dipping flanks, with the exception of the steeper  
88 northern flank of the Tindouf Basin, which was involved in the Variscan deformation (Burkhard *et al.*,  
89 2006). Most authors acknowledge the existence of a continuous sedimentary realm until the Early  
90 Carboniferous (Bertrand-Sarfati *et al.*, 1991; Legrand-Blain & Perret-Mirouse, 2000). On top of

91 Paleozoic formations, unconformable horizontal Mesozoic-Cenozoic formations are observed. The  
92 oldest Mesozoic deposits are Early Cretaceous rocks in the Tindouf Basin (Gevin, 1960; Fabre, 2005).  
93 In the eastern Taoudeni Basin (Tanezzrouft), the oldest Mesozoic deposits are possibly Late  
94 Cretaceous (Fabre *et al.*, 1996) (Fig. 1). This hiatus of more than 100 Myr (from Late  
95 Carboniferous/Permian to at least Early Cretaceous) differentiates the WAC from the central and  
96 eastern Sahara domains where post-Variscan deposits can be as old as Triassic in central Sahara  
97 (Busson, 1972; Boudjema, 1987).

98         The Tarfaya-Laayoune-Dakhla Basin (TLDB; Fig. 1b) is a NE-SW oriented basin which bounds  
99 the Atlantic Ocean. This basin formed during the opening of the Central Atlantic Ocean, with an  
100 estimated break-up in the Late Sinemurian (~190 Ma; Labails *et al.*, 2010). The basin is built on a 100-  
101 km wide stretched crustal domain with a crust thickness that varies from 27 to 7 km oceanward  
102 (Klingelhoefer *et al.*, 2009). The thick Mesozoic-Cenozoic infill reaches more than 10 km (AUXINI,  
103 1969; Martinis & Visintin, 1966; Ratschiller, 1968; Ranke *et al.*, 1982; Fig. 1c) and represents a  
104 reliable record of the large-scale changes, which occurred during that time. On top of Triassic clastic-  
105 evaporitic deposits, the Middle-Late Jurassic witnesses the build-up of a large carbonate platform  
106 that ended in the Neocomian (up to the Barremian). The margin was then buried under  
107 unconformable km-scale continental clastic deposits before marine conditions resumed in Aptian-  
108 Albian and continued during the Late Cenomanian-Turonian times. The early Paleogene environment  
109 was still marine but characterized by shallower depths before becoming continental from the Eocene  
110 onwards. Paleogene formations lie unconformably on the Early and Late Cretaceous in TLDB.  
111 Neogene deposits are scarce, thin and usually continental.

112

## 113 **Sampling and methodology**

114 *Sampling*

115           The dataset presented here consists of 29 samples and allows us to present a ~1300 km E-W  
116 LTT transect of the NWAC from the Atlantic passive margin to the Panafrican suture in the east. Our  
117 new data adds two AFT data to the 11 existing AFT data in the western Reguibat Shield (Leprêtre *et*  
118 *al.*, 2015), four new AFT and three new AHe datasets to the existing four AFT and one AHe datasets  
119 (Leprêtre *et al.*, 2014) and eight new AFT and 6 new AHe datasets for the eastern Reguibat Shield  
120 (Fig. 1b). For the reader's information, the complete dataset encompassing samples from Leprêtre *et*  
121 *al.* (2014, 2015) are presented in Supplementary data (Tables S1, S2).

122           The Reguibat Shield was geographically divided into three regions on the basis of the LTT  
123 results. With the exception of one AFT age (256 Ma from TEN1153 sample, in central Reguibat  
124 Shield), AFT age ranges largely overlap between western and central domains (Fig. 2). Mean track  
125 lengths (MTLs) are also comparable between these two domains whereas MTLs from the eastern  
126 domain are shorter (Fig. 3). Western and central Reguibat Shield domains are differentiated based on  
127 their AHe age ranges. AHe ages from western Reguibat Shield are younger than 127 Ma (only one  
128 replicate is older) whereas they range from 38 to 191 Ma for central Reguibat Shield (4 of 11 AL10  
129 replicates are out of the trend) with significantly older AHe ages at eU > 20 ppm. Compared to  
130 central Reguibat Shield (AFT range: 139 to 256 Ma; AHe range: 38 to 269 Ma when excluding the two  
131 anomalously old AL10 replicate; see Table 2), eastern Reguibat Shield yielded significantly older AFT  
132 ages (237 to 497 Ma against 139 to 256 Ma for central Reguibat; Table 1; Fig. 2, 3) and shows a larger  
133 scattering of the AHe data (32 to 384 Ma).

134

### 135 *Low-temperature thermochronology*

136           Samples were processed at the GEOPS laboratory (Université Paris-Sud, Orsay, France). AFT  
137 dating was carried out using the external detector method (Gleadow & Duddy, 1981) for calculating  
138 the central age (Galbraith & Laslett, 1993) using the Zeta calibration (Hurford & Green, 1983). Zeta  
139 calibration was done with a CN5 glass dosimeter and Durango/Fish Canyon apatite standards

140 (Hurford, 1990;  $\zeta = 368 \pm 10$  for RL). Neutron irradiation was carried out at Garching facility  
141 (Germany). Spontaneous tracks were revealed by etching in 5M HNO<sub>3</sub> for 20 seconds at 20±1°C. The  
142 size of the etch pit made between the track and polished apatite surface (Dpar) was measured and  
143 used as a kinetic parameter for fission track annealing (Carlson *et al.*, 1999). Dpar measurements act  
144 as a proxy for compositional and structural variations in apatite (Barbarand *et al.*, 2003). Horizontal  
145 confined track-lengths were measured using a LEICA microscope with a x1000 magnification and a  
146 digitizing tablet linked via a drawing tube to the microscope. AFT ages, lengths and Dpar  
147 measurements are given in Table 1 and figures 2-4.

148 AHe analysis was carried out on euhedral inclusion-free apatite crystals with a minimum of  
149 four replicates per sample. Crystal dimensions and geometry were measured along the three axes  
150 and grains were placed into a platinum basket. Ejection factors and sphere equivalent radius were  
151 determined using the Monte Carlo simulation from Ketcham *et al.* (2011). More details on He, U, Th  
152 and Sm content determination can be found in Gautheron *et al.* (2013). The analysis was  
153 calibrated using internal and external age standards (Durango: McDowell *et al.*, 2005; Limberg Tuff:  
154 Kraml *et al.*, 2006). The error on the AHe age at 1 $\sigma$  is estimated to be a maximum of 8% reflecting  
155 uncertainty in the ejection factor (FT) correction and standard dispersion. The final He, U-Th-Sm  
156 content and AHe age are reported in Table 2.

157 AHe closure temperature was defined after Dodson (1973) depending on apatite grain size,  
158 the cooling rate and on He diffusion coefficient. It has been shown that a pure apatite crystal “free-  
159 default crystals” yield closure temperature of *c.a.* 30-40°C depending on chemical content (Djimbi *et al.*  
160 *et al.*, 2015). For natural apatite, the closure temperature is tightly linked to the alpha-recoil damage  
161 fraction (Shuster *et al.*, 2006; Shuster & Farley, 2009). This behavior has been incorporated into two  
162 predictive models by Flowers *et al.* (2009) and Gautheron *et al.* (2009). These models consider that  
163 recoil damage annealing follows kinetics similar to fission-tracks, after the results of Ketcham *et al.*  
164 (2007). Different closure temperatures can be monitored through the relationship of AHe age vs.

165 efficient uranium (eU). The eU represents the amount of radioactive elements contributing to the  
166  $^4\text{He}$  production and its amount controls the closure temperature for a given thermal history (Shuster  
167 *et al.*, 2006). Thus, scattered AHe ages emphasize, at first order, differences in AHe closure  
168 temperatures between replicates in the same sample. Moreover, the damage-annealing rates can be  
169 influenced by the apatite chemistry (Gautheron *et al.*, 2013; Djimbi *et al.*, 2015). In particular,  
170 Gautheron *et al.* (2013) demonstrated that complex thermal histories in slow moving geological  
171 settings can greatly enhance the scattering in the data given the chemistry differences between  
172 grains. Also, the  $^4\text{He}$  apatite content can increase through implantation from rich eU neighbors  
173 crystals in the rock (Spiegel *et al.*, 2009; Gautheron *et al.*, 2012) or for low eU apatite, this effect has  
174 also been observed (Kendra *et al.*, 2013; Murray *et al.*, 2014; Janowski *et al.*, 2017). Helium  
175 implantation produces an artificial aging trend for the more exposed apatite crystals. In addition, the  
176 analysis of broken apatite crystals can add scattering to the data (Brown *et al.*, 2013).

### 177 *Thermal modeling*

#### 178 Modeling procedure

179 Inverse thermal modeling was performed using the software QTQt (Gallagher, 2012) while  
180 HeFTy (Ketcham, 2005) was used for forward modeling. We used the fission track annealing kinetics  
181 of Ketcham *et al.* (2007) and the He-trapping/diffusion model of Flowers *et al.* (2009). The Flowers *et al.*  
182 *et al.* (2009) radiation damage accumulation and annealing model is empirically calibrated and is not  
183 well-representative of the physical processes of diffusion compared to the Gautheron *et al.* (2009)  
184 model but it gives better predictions, mainly for low-eU apatite (< 20 ppm; majority of our samples,  
185 see Table 2). QTQt works with a probabilistic Bayesian approach for inverse modeling. It samples  
186 numerous thermal histories and from them builds a population of models selected according to the  
187 degree of agreement between data and model—this is the burn-in phase. It then proceeds with  
188 inverse modeling, which is called the post burn-in phase. For each phase, the user can choose the

189 number of iterations, depending on the complexity of its own data set. In QTQt, the fit between the  
190 data and the model is defined by the Log Likelihood (LL; details are given in Gallagher, 2012).

191

## 192 Strategy for thermal modeling

193 The strategy for the thermal modeling of the LTT data relies on the geological context of the  
194 study. Importantly for this study, we consider, following Burov (2011), that deformation of old  
195 lithospheres (> 1Ga) is mostly controlled by the rheology of the lithosphere which is dependent on its  
196 age. The Reguibat Shield is an old lithosphere (> 2 Ga; Potrel *et al.*, 1998; Lahondère *et al.*, 2001;  
197 Peucat *et al.*, 2005; Schofield *et al.*, 2012; Bea *et al.*, 2013) and as such, its deformation will involve  
198 the whole lithosphere with wavelengths > 500 km. We thus infer that samples separated from each  
199 other by less than few hundred kilometers should behave coherently and share similar thermal  
200 paths. Furthermore, it implies that stratigraphical unconformities located on the boundaries of the  
201 Reguibat Shield can give precious information for the evolution of its basement since the latter is  
202 rarely wider than 400 km (Fig. 1).

203 For eastern Reguibat Shield, two major stratigraphical constraints were used: (1)  
204 unconformable Cambrian deposits on the NWAC basement (Trompette, 1973; Deynoux, 1980 for  
205 Taoudeni Basin; Boote *et al.*, 1998 for Tindouf Basin); (2) unconformable poorly-dated upper  
206 Cretaceous deposits on the eastern boundary of the Reguibat basement. We used a large  
207 temperature box (20-180°C) for the 470-230 Ma interval as no constrain exists for this period. Firstly,  
208 a general thermal path was modeled with inverse modeling for eastern Reguibat shield samples that  
209 have both AFT and AH data (Fig. 6a-c, 7a; Fig. S2-7). By combining AFT and AHe datasets, we can  
210 achieve a better resolution of the thermal history path. The important temperature/time (or (T,t))  
211 nodes obtained in this first modeling were used as constraints for other eastern Reguibat Shield  
212 samples where only AFT data were available (CH2 and DEG6, Fig. S2-3). Only final models are  
213 presented in the results (Fig. 6a, 7a). Considering the old LTT ages of samples from eastern Reguibat

214 Shield ( $> 237 \pm 21$  Ma), we only used the constraint that rocks were at surface during Cambrian. In  
215 the course of thermal modeling, no stable solutions were obtained for samples GH20 and IG3.

216 For central Reguibat Shield only one meaningful stratigraphical constraint was used: Lower  
217 Cretaceous deposits rest unconformably on the Paleozoic succession in the Tindouf Basin and directly  
218 on the basement in the east of the TLDB (Fig. 1b). This Lower Cretaceous unconformity is distant  
219 from the samples by less than 400 km. We suggest that it likely implies that even samples from the  
220 interior of the Reguibat Shield were at or close to the surface at this time. We used here a two-step  
221 approach for thermal modeling.

222 Firstly, we carried out a phase of forward modeling to explain the AHe age-eU positive  
223 correlation (Fig. 5b, 8). In this phase, we consider the AHe data of all samples as these data should  
224 behave coherently given that they are restricted to cratonic areas and the entire AHe dataset  
225 samples a larger eU range than any one sample. Various thermal paths were tested to check their  
226 AHe predictions and compare them to the measured data. Given that the AFT ages are all younger  
227 than 250 Ma, the tested thermal history paths are chosen in order to display cooling initiated by the  
228 Early Jurassic. Using the initial forward modeling step, we have identified the scenarios that best  
229 explain the observed AHe data. These scenarios yield (T,t) constraints, *i.e.* compulsory nodes in the  
230 (T,t) space through which the thermal path must go to fit the AHe age-eU relationship. Secondly, we  
231 then performed inverse modeling that included these (T, t) constraints, so as to investigate the  
232 degree of freedom left to fit the AFT data. The same stratigraphic constraint was used for all samples.  
233 All detailed individual models are presented figures S8-15 and only the final thermal paths are  
234 presented in figure 7b.

235 The two new samples from the western Reguibat Shield were modeled using the (T, t)  
236 constraints determined in Leprêtre *et al.* (2015) (Fig. S16-17 and Text S1). One detailed thermal  
237 modeling is presented in figure 6c and all thermal paths for the western Reguibat Shield are shown in  
238 figure 7c.

239 Finally, considering the predictions made by the He-trapping/diffusion models (Flowers *et al.*,  
240 2009; Gautheron *et al.*, 2009), we advocate that for a given thermal history path, single-grain AHe  
241 ages are expected to display a correlation with eU. As a methodological consequence for our thermal  
242 modeling, we removed the single-grain AHe ages that were outliers from the mean AHe age-eU  
243 correlation, *i.e.* in our samples, being outliers by more than 50-100 Ma or a very different eU value  
244 (*e.g.* Flowers and Kelley, 2011). Using these “outlier” replicates would impede the thermal modeling  
245 as the model would attempt to fit out-of-trend data and lead to either no acceptable solutions being  
246 found (in the case of HeFTy) or to a thermal model with bad fit for many replicates (*e.g.* QTQt, Fig.  
247 S1). A clear assumption is made here that favors an acceptable goodness of fit for the majority of  
248 replicates, which belong to a common AHe age-eU trend, instead of trying to explain all the  
249 replicates resulting in a poor fit between predicted and observed data. Following this criteria, one  
250 single-grain AHe age of nine was removed in sample CH1 and TL3 for being too far from the mean  
251 AHe age-eU correlation (Fig. 5d, i; Table 2). Also, 3 of 11 replicates were removed in sample AL10 for  
252 the same reason (Fig. S1).

253

## 254 **Results**

255 The new and published AFT and AHe ages presented for 29 samples give the first  
256 comprehensive dataset across the whole Reguibat Shield. Based on the data location and their  
257 thermal histories, the studied area has been divided into western, central and eastern domains.  
258 Published data from the western and central Reguibat Shield (Leprêtre *et al.*, 2014; 2015) are only  
259 briefly summarized, but the complete Reguibat dataset is presented together in Tables S1 and S2.

### 260 *LTT results*

261 The eastern domain shows the oldest and the most scattered AFT ages, ranging from  $237 \pm$   
262  $21$  to  $497 \pm 61$  Ma (Table 1). MTLs are slightly shorter than in the other domains, between  $11.2 \pm 0.4$

263 and  $12 \pm 0.2 \mu\text{m}$  (Fig. 3). Track length distributions (TLDs) are largely unimodal and spread around the  
264 mean (Fig. 4). Dpar measurements range from  $1.7 \pm 0.2$  to  $2.1 \pm 0.2 \mu\text{m}$ . AHe ages corrected from  
265 alpha ejection range from  $32 \pm 3$  to  $384 \pm 31$  Ma with eU contents that range from 2 to 32 ppm. No  
266 clear trend in the AHe age vs. eU plot exists (Fig. 5a) and the very variable AHe ages for similar eU  
267 contents suggest that process other than a variable diffusion coefficient. This process will be  
268 discussed later.

269 In the central Reguibat Shield, new AFT ages range from  $150 \pm 8$  to  $202 \pm 14$  Ma (Table 1) and  
270 are in agreement with published data ( $139 \pm 9$  to  $256 \pm 21$  Ma; Leprêtre *et al.*, 2014). New MTLs  
271 range from  $11.4 \pm 0.3$  to  $12.0 \pm 0.2 \mu\text{m}$  and are undistinguishable from the  $11.9 \pm 0.2$  to  $12.4 \pm 0.2 \mu\text{m}$   
272 range for published data (Fig. 3, 4). Dpar measurements range from  $1.6 \pm 0.2$  to  $2.1 \pm 0.5 \mu\text{m}$ . AHe  
273 ages corrected from alpha ejection range from  $38 \pm 3$  to  $396 \pm 32$  Ma (Table 2) with eU content  
274 ranging from 7 to 83 ppm. Overall, they are younger than AFT ages with the exception of some  
275 replicates from samples AL10 and TGH3163. AHe age vs. eU plot shows a general positive correlation  
276 (Fig. 5b).

277 In the western Reguibat Shield, the two new samples yielded AFT ages of  $137 \pm 12$  Ma and  
278  $118 \pm 10$  Ma with no measurable confined lengths (Table 1). Published AFT ages range from  $107 \pm 8$   
279 to  $175 \pm 16$  Ma, with mean track length (MTL) ranging from  $11.8 \pm 0.2 \mu\text{m}$  to  $12.5 \pm 0.2 \mu\text{m}$  (Leprêtre  
280 *et al.*, 2015). Track length distributions (TLDs) are largely unimodal, slightly spread around the mean  
281 with some complex shapes but for samples with few confined lengths (Fig. 3, 4). Dpar measurements  
282 range from  $1.5 \pm 0.2$  to  $1.8 \pm 0.3 \mu\text{m}$ . Overall, AFT ages are quite homogenous, with a mean around  
283 130-140 Ma. All AFT ages are younger than the 190 Ma rifting (Labails *et al.*, 2010). AHe ages  
284 corrected from the alpha-ejection range from  $14 \pm 1$  Ma to  $185 \pm 15$  Ma, with an eU content ranging  
285 from 7 to 71 ppm. AHe age vs. eU plot shows positive correlations when samples are grouped by  
286 region (Fig. 5c) and these AHe age-eU relationships reflect thermal histories with successive  
287 reheating/cooling events (Leprêtre *et al.*, 2015). Leprêtre *et al.* (2015) demonstrated that AHe age

288 scattering within each data set could be explained by radiation damage effects with a secondary role  
289 played by variations in apatite chemistry.

290

### 291 *Thermal modeling results*

292 For each domain of the Reguibat Shield, we present one representative thermal model with  
293 all predicted vs. measured AFT and AHe data (Fig. 6). All individual models are presented in detail in  
294 the supplementary data (Fig. S2-S17).. A synthesis with all the thermal paths is given in figure 7. The  
295 models for western Reguibat Shield are highly dependent on the constraints determined by Leprêtre  
296 *et al.* (2015) as neither AHe nor length data are available for the two new samples (Fig. 6g-h).

297 Sample GH3 illustrates the general shape of the thermal paths for the eastern Reguibat  
298 Shield (Fig. 1b, 6a-c). Thermal paths obtained from the inverse modeling for 6 of the 8 samples of this  
299 domain are presented in figure 7a. For the best constrained, double LTT dated samples (TL3, GH3,  
300 CH1 and CH3), thermal paths show a major cooling episode during the Early Cretaceous. This cooling  
301 is variable among samples. At the very end of the Jurassic, samples were generally at temperatures  
302 higher than 60°C (except for TL3) and were not undergoing cooling. Results are similar for AFT-dated  
303 samples CH2 and DEG6. Whereas the western and central domains suffered post-Early Cretaceous  
304 reheating, samples from the eastern domain cooled by  $30 \pm 10^\circ\text{C}$  and stayed at relatively low  
305 temperatures up to the present-day.

306 For the central Reguibat Shield, the forward modeling with AHe datasets clearly favored the  
307 scenario involving the occurrence of a Jurassic-Early Cretaceous cooling event followed by a low-  
308 amplitude reheating step (Fig.8; Table S3). Five forward scenarios were tested: a small Middle  
309 Jurassic-Lower Cretaceous cooling with stable thermal conditions during Late Cretaceous (HT1); a  
310 large Jurassic-Early Cretaceous cooling ( $> 40^\circ\text{C}$ ) bringing samples close to the surface (HT2 and HT3)  
311 before reheating episode; a continuous slow cooling (HT4); a major cooling between Early and Late

312 Cretaceous (HT5). HT1, HT4 and HT5 all provide too young AHe ages compared to the HT2 and HT3.  
313 This preliminary treatment confirms the necessity to set a constraint related to the Lower Cretaceous  
314 unconformity in the Tindouf Basin and the TLDB. It is also in line with our consideration regarding the  
315 wavelength of cratonic deformation at large wavelength. The inverse modeling was conducted using  
316 the Lower Cretaceous unconformity and constraints deduced from the forward modeling. The latter  
317 suppose that samples were (1) at temperatures higher than 80°C before Early-Middle Jurassic and (2)  
318 reheated after the beginning of the Early Cretaceous by 20-40°C. We let the inverse modeling  
319 determine the temperature before the Jurassic, between 0 and 200°C. Samples with double LTT  
320 datings display similar thermal paths (Fig. 6d-f, 7b). A significant cooling event ( $\Delta T > 40^\circ\text{C}$ ) is recorded  
321 between the beginning of the Jurassic (220-190 Ma) with minimum temperatures reached in the  
322 Early Cretaceous (150-140 Ma) ranging from 55 to 45°C. Samples underwent a small reheating event  
323 (by 20-25°C) until the beginning of the Late Cretaceous (with the exception of a later and stronger  
324 reheating for sample TEN1153). Afterwards, samples cooled down to present-day temperature.

325         The two samples from the western Reguibat Shield yield similar results than the other  
326 samples (Fig. 6g-h, 7c). Their thermal path shows an important cooling from Early-Middle Jurassic to  
327 Early Cretaceous, from temperatures higher than 100°C to 35-40°C. A reheating phase occurred until  
328 the beginning of Late Cretaceous (between 100-80 Ma), reaching temperatures as high as 65-70°C. It  
329 is followed by a rapid cooling event until early Cenozoic up to 35-40°C before a slow cooling until  
330 present.

331

## 332 **Discussion**

### 333 *Interpretation of LTT data*

#### 334 *AFT and AHe ages*

335 Data show a clear increase of AFT and AHe ages towards the east and both datasets also  
336 display more scattering eastwards (Fig. 2). From the LTT data and our thermal modelings one can  
337 clearly see that samples stayed in the Partial Retention Zone (PRZ)/Partial Annealing one (PAZ) for a  
338 long time. This more or less protracted stay within the PRZ strongly impacts the distribution of AHe  
339 ages with respect to the eU (Fig. 5). For example, the curved positive trend of the AHe age-eU plot in  
340 figure 5b can be explained by low-eU apatites experiencing greater diffusive loss of He (causing  
341 younger AHe ages) than high-eU apatites during a short time in the PRZ during Early Cretaceous (10-  
342 30 Myrs at  $T > 50-60^{\circ}\text{C}$ ; Fig. 7b). This short stay within the PRZ was sufficient to partially reset the low-  
343 eU AHe ages in the case of the central Reguibat Shield. We consider for now that the best  
344 explanation for anomalous replicates behavior (mostly showing older AHe than what is expected) lies  
345 in process of implantation of He from minerals neighbouring apatite in the rock (Spiegel *et al.*, 2009).  
346 Up to  $>300\%$   $^4\text{He}$  excess has been estimated in most extreme cases by Gautheron *et al.* (2012).  
347 Moreover, low-eU apatites are logically more sensitive to implantation than high-eU apatite and this  
348 can dramatically distort the AHe ages (Janowski *et al.*, 2017). With this hypothesis, we propose that  
349 implantation and a long residence in the PRZ might explain the larger dispersion of the AHe ages for  
350 the eastern Reguibat Shield compared to the central Reguibat Shield. In the case of the western  
351 Reguibat Shield, Leprêtre *et al.* (2015) demonstrated that the apatite crystal chemistry was  
352 responsible for an enhanced scattering around a mean AHe age-eU trend (their Fig. 5-7). In addition  
353 to eU and equivalent sphere radius, the influence of apatite composition may also explain some of  
354 the scattering seen here given the range of Dpar measurements for the central and eastern Reguibat  
355 Shield samples (Tables S1, S2; further discussion in Text S2; Fig. S18).

### 356 *The NWAC in the Mesozoic*

357 Our results show that the Reguibat Shield experienced significant cooling event between the  
358 Early-Middle Jurassic and the Late Cretaceous. This cooling occurred between Early-Middle Jurassic  
359 and Early Cretaceous for western and central Reguibat Shield whereas it happened later, by the end

360 of the Early Cretaceous, for the eastern Reguibat Shield. Elevated temperatures during the Early  
361 Jurassic can have two origins: (1) a thermal perturbation, linked either to the emplacement of the  
362 Central Atlantic Magmatic Province (CAMP, Verati *et al.*, 2007) or to thermal flux increase in  
363 connection with rifting; (2) a burial under a sedimentary cover which has been removed only after  
364 the break-up. Importantly, the CAMP rocks do not crop out within the Reguibat Shield (Marzoli *et al.*,  
365 1999; Verati *et al.*, 2005). Basal heat flow might have been higher during CAMP magmatism and/or  
366 rifting, but would not be anymore anomalous during Cretaceous (Fig. 7b-c). LTT data from borehole  
367 samples in the cratonic Anti-Atlas domain, north of the Tindouf Basin (Sehrt, 2014) estimate an  
368 average  $40^{\circ}\text{C.km}^{-1}$  palaeogeotherm during the Early-Middle Jurassic/Early Cretaceous without  
369 measurable changes afterward. We thus favor the hypothesis of burial of the Reguibat Shield by a  
370 Paleozoic sedimentary cover. This cover was removed during Lower-Middle Jurassic/Lower  
371 Cretaceous erosion in the western and central Reguibat Shield and fed the clastic deposits of the  
372 TLDB during the Early Cretaceous. Similarly, the reheating in the western and central domains  
373 between 150 and 100 Ma is interpreted as a re-burial of the samples as no large magmatic anomaly  
374 is recorded (Matton & Jebrak, 2009). The timing and, to a lesser extent, the amplitude of the re-  
375 burial differs slightly to that proposed in Leprêtre *et al.* (2014). This can be attributed to the  
376 additional AHe datasets used for thermal modeling in the present study. The models differ in the  
377 onset and duration of the heating after the Upper Jurassic/Lower Cretaceous transition for models of  
378 the central Reguibat (Fig. 7b; Leprêtre *et al.*, 2014, their figure 5). Our present study refines the  
379 Leprêtre *et al.* (2014) models and adds more consistency to them. The heating phase occurred from  
380 the end of Early Cretaceous up to the beginning of Late Cretaceous (Fig. 7b) when the major  
381 Cenomanian-Turonian flooding is recorded. Plus, the beginning of cooling occurred at the beginning  
382 of the Late Cretaceous when the Africa-Europe convergence began. We assert that AHe datasets  
383 have helped to better constrain the post-Jurassic evolution of central Reguibat Shield, in comparison  
384 with our previous investigations using only AFT analysis.

385 Assuming a palaeogeotherm of  $30\text{-}50^{\circ}\text{C.km}^{-1}$  during the cooling and reheating and using the duration  
386 and amplitude of the thermal changes predicted by our thermal models, we estimated the  
387 eroded/deposited rock thicknesses for each event. The ranges of Jurassic/Cretaceous erosion are  
388 between 0.8-2.1 km and 1-1.6 km from western to eastern Reguibat Shield respectively. The  
389 amplitude of re-burial reaches 0.4 to 1.7 km for the western and central domains, with no re-burial in  
390 the eastern Reguibat Shield (Fig. 7a). During the re-burial, the southern TLDB record Albian-Turonian  
391 thicknesses that can reach 1 km (AUXINI, 1969), which are compatible with our estimates. Moreover  
392 this cover might have been even thicker given the subsequent Late Cretaceous erosion. In  
393 comparison with western and central domains, the eastern Reguibat Shield shows a late cooling  
394 event, mostly occurring at the Lower/Upper Cretaceous transition (Fig. 7a). Whether this cooling can  
395 be linked to the one recognized in western and central domains is challenging; however, we believe  
396 that cooling in the eastern domain represents another phenomenon. There is no significant time  
397 lapse between the cooling phase recorded in the western and central Reguibat Shield. If all three  
398 domains were cooled by the same process we would then expect the timing of cooling in the eastern  
399 Reguibat Shield to be approximately the same as the west and central domains, which is not the  
400 case. As there is a significantly delay before the eastern Reguibat Shield cools, this cooling could  
401 better be related to the Austrian phase recognized in the Sahara platform (Boudjema, 1987),  
402 occurring in Aptian-Albian times. The former N/S Panafrican faults separating the WAC from the  
403 Tuareg Shield were reactivated as the northern Tuareg Shield underwent anticlockwise rotation  
404 resulting from the opening of the South Atlantic Ocean. The cooling in the eastern Reguibat Shield  
405 might stem from the large-scale tectonic reorganization at that time.

406 Few other studies have dealt with the evolution of cratonic domains on the NWAC. In the  
407 Anti-Atlas north of the Tindouf Basin, Ruiz *et al.* (2011) and Oukassou *et al.* (2013) demonstrated  
408 using LTT data that the northern tip of the craton also underwent uplift and erosion during  
409 Jurassic/Early Cretaceous times before a reheating step. Further east (Ahnet-Reggane-Timimoun  
410 basins), based on organic matter maturity, AFT and zircon fission-tracks from several wells, Logan &

411 Duddy (1998) proposed a general cooling from Triassic to Early Cretaceous. They also show that the  
412 Variscan erosion is highly reduced in most of the area, in agreement with our results. Eastward, in  
413 the central and eastern Sahara, the evolution becomes more diverse. In the Illizi Basin, LTT and  
414 organic matter maturity were used by English *et al.* (2016) to support Cenozoic uplift undergone by  
415 the Tuareg Shield. However, their borehole data are not able to resolve the Mesozoic history since  
416 they found various likely scenarios for the Jurassic-Cretaceous period, with one scenario involving a  
417 small cooling event in the Early Cretaceous. A limited number of LTT studies have been undertaken  
418 on the Hoggar basement and they are focused on the Cenozoic exhumation without being able to  
419 properly address the Mesozoic history given their poor confined length contents and the abundance  
420 of Cenozoic AFT ages (Carpéna, 1988; Cavellec, 2006; Rougier, 2012; Rougier *et al.*, 2013).

421

## 422 **Evolution of the conjugate passive margins of the Central Atlantic Ocean**

423 Several lines of evidence testify to the existence of common processes on each side of the  
424 northern Central Atlantic Ocean during Jurassic-Cretaceous times. We present them in the following  
425 section.

### 426 *LTT record on the onshore eastern American passive margin*

427 Outcrops from the Appalachian orogen and surroundings basins have been used in numerous  
428 LTT studies but have never been considered as a whole dataset (Crowley, 1991; Wang *et al.*, 1994;  
429 Boettcher & Milliken, 1994; Roden-Tice *et al.*, 2000; Roden-Tice & Wintsch, 2002; Grist and Zentilli,  
430 2003; Lorencak *et al.*, 2004; Spotila *et al.*, 2004; Roden-Tice & Tice, 2005; Taylor & Fitzgerald, 2011;  
431 Roden-Tice *et al.*, 2012). We have collated all of the existing AFT data along eastern North America  
432 (Fig. 9a,c). A clear division in AFT ages is observed with young AFT ages along a 600-km wide strip of  
433 land parallel to the hinge line (*i.e.* the place where the continental crust begin to thin toward the  
434 ocean; Fig. 1b, 9a). The “young” AFT datings range between *c.a.* 80-180 Ma, with the exception of

435 slightly older samples along the Nova Scotia segment in the north. AFT ages become progressively  
436 older landward (up to 600 Ma, beyond 600-700 km off the hinge line). The spatial pattern of AFT age  
437 is strikingly similar to the NWAC (Fig. 9b-c; after the data of Ghorbal *et al.*, 2008; Saddiqi *et al.*, 2009;  
438 Ruiz *et al.*, 2011; Oukassou *et al.*, 2013; this study), with ages being younger (c.a. 100-220 Ma) from  
439 the coast to 600 km. AFT-MTL plots are given for both margins (Fig. 9c-d) and show that there is no  
440 relationship between the age of rifting and length datasets. This significant observation means that  
441 for samples within the 600/700-km proximal land strip, the effects of the Lower Jurassic rifting (c.a.  
442 190 Ma) are barely distinguishable. Both margins seem coherently affected by a more regional event.

443

#### 444 *Along-strike variations of the passive margin stratigraphical record*

445 Passive margin sedimentary infills have been studied along both passive margins and can be  
446 compared to identify the similarities in their evolution. For this comparison, we use the regional  
447 studies of Jansa & Wiedmann (1982) for Northwest Africa, Grew & Sheridan (1988) and Miall (2008)  
448 for eastern North America. In the following, we present only the stratigraphical records from Early-  
449 Middle Jurassic to the end of Early Cretaceous.

450 From north to south along the eastern American passive margin, four segments have been  
451 well-documented: Nova Scotia, the Georges Bank, the Baltimore canyon Trough and the Blake  
452 plateau (Fig. 10). On the African counterpart, we will present the Essaouira, Tarfaya and Senegal  
453 segments.

454 The Nova Scotia and Georges Bank basins and the Baltimore Canyon Trough are defined by  
455 similar stratigraphical formations. The Early Jurassic witnessed the deposition of dolomite and  
456 anhydrite layers. These unconformably overlie Triassic formations and gradually became clastic  
457 deposits moving laterally and upward in the section. On top of the Early Jurassic rocks, a large  
458 carbonate platform aggraded and prograded seaward although a clastic influx still occurred during  
459 Middle- Late Jurassic. During Early Cretaceous, carbonate platforms were buried under a thick clastic

460 influx of coarse sandstones, which even bypassed the platform edge (Jansa & Wiedman, 1982; Wade  
461 & MacLean, 1990). By the end of the Early Cretaceous, clastic sedimentation was still ongoing but  
462 with a lower influx during the Aptian-Turonian interval when a major transgressive period occurred.  
463 South of these three basins, the Blake Plateau has received little attention. Its Middle Jurassic  
464 stratigraphy is less known but the Late Jurassic witnessed the formation of a mixed terrigenous-  
465 carbonated platform and the build-up of a massive carbonate platform occurred during the Early  
466 Cretaceous. The platform was drowned during the Late Cretaceous due to the high-stand sea-level  
467 which brought carbonate facies up to the Appalachian range with the deposition of deep-marine  
468 marls on the former carbonate platform (Poag & Valentine, 1988).

469         On the northwest African passive margin, Jansa & Wiedmann (1982) described very similar  
470 successive facies. In the Essaouira Basin, middle-upper Liassic (Lower Jurassic) records the early post-  
471 rift transgression with the deposition of dolomites and evaporites, subsequently covered during  
472 lower-middle Dogger (Middle Jurassic) by clastics with features characteristic of a marine regression.  
473 A stable carbonate platform was built afterwards up to the end of the Late Jurassic. Carbonate  
474 deposition was interrupted by some clastic deposition before a last regression in Berriasian times.  
475 The Lower Cretaceous formations buried the former platform under kilometer-thick clastics with  
476 large prograding deltas until the Aptian. Marine conditions resumed during Aptian with carbonate  
477 deposition. From the Cenomanian-Turonian onwards, deeper marine conditions prevailed with  
478 outer-shelf to slope type deposit. In the TLDB, the sedimentary record is similar to that in the  
479 Essaouira Basin. Finally, in the southern segment of the Senegal Basin, a large carbonate platform  
480 formed during the Middle-Late Jurassic to the end of Early Cretaceous. In contrast to the northern  
481 segments, deposition of the carbonate platform was not interrupted and small volumes of clastic  
482 sediments deposited in the Senegal Basin (Brownfield & Charpentier, 2003). A carbonate platform  
483 even prevailed until the Late Cretaceous in the southern part of the basin.

484           The overall stratigraphical record on both sides of the Central Atlantic Ocean is strikingly  
485 similar for the considered period. It becomes increasingly different afterwards in the Late Cretaceous  
486 (Jansa & Wiedmann, 1982) during the convergence climax of Africa and Europe. For the whole  
487 margin, the Jurassic witnessed the build-up of an almost continuous carbonate platform, which  
488 ended in the beginning of the Early Cretaceous for the north Central Atlantic Ocean whereas this  
489 build-up persisted until the Late Cretaceous for the southern segments of the margin. Given the LTT  
490 record for both sides of the northern Central Atlantic Ocean described previously, we consider that  
491 this abundant clastic feeding of the margins during the Neocomian must be related to a common  
492 process which will be discussed in the next section.

#### 493 *Evolution of the Central Atlantic Ocean*

494           The Central Atlantic Ocean underwent break-up during the Sinemurian (~190 Ma; Labails *et*  
495 *al.*, 2010). During rifting and the early post-rift stage, a shared stratigraphical record is observed  
496 predictably on both sides of the ocean (Jansa & Wiedmann, 1982; Fig. 10). The spreading rate of the  
497 young Atlantic has been estimated by various authors (Cogné & Humler, 2006; Schettino & Turco,  
498 2009; Labails *et al.*, 2010; Kneller *et al.*, 2012) for the Jurassic period. We present in figure 11 a  
499 compilation of these rates. Even if slight differences exist between the different models, all authors  
500 agree with a significant increase of this rate during Middle and Late Jurassic before a dramatic  
501 decrease in the Early Cretaceous.

502           One must remember that LTT studies only give the simplest thermal paths between  
503 constraint points that can reproduce the data. As such, the Jurassic-Early Cretaceous cooling we  
504 obtained could alternate between discrete phases of accelerations and decelerations of the cooling  
505 rate from the Early-Middle Jurassic to the Early Cretaceous. Considering the regression and clastic  
506 burial of the Jurassic carbonate platforms, we think that an acceleration of the cooling rate would  
507 have occurred during the Late Jurassic/Early Cretaceous because of enhanced exhumation. This  
508 process can also be suggested for the symmetrical clastic feeding on the conjugate American passive

509 margin. Indeed, LTT studies on eastern North America suggest that a significant cooling occurred  
510 over large areas during the Middle-Late Late Jurassic to the Early Cretaceous (Fig. 12a-c). This cooling  
511 event is partially hidden in the northern Appalachian domain (central transect, the portion close to  
512 the Atlantic Ocean in figure 9) where, a strong Early-Late Cretaceous cooling event is attributed to  
513 the passage over/close to the Great Meteor hotspot (Taylor & Fitzgerald, 2011), which could have  
514 disrupted the record of the earliest cooling phase (Fig. 12d).

515 Valid explanations for this Jurassic-Lower Cretaceous uplift must consider the following: (1)  
516 the uplift event affected the onshore domains of either side of the conjugate passive margins and  
517 over a longer wavelength than it is typically the case usually for other passive margins settings (up to  
518 600 km landward compared to less than 200-300 km; see Gallagher *et al.*, 1998); (2) in spite of a  
519 shared spreading history (Labails *et al.*, 2010), the Central Atlantic Ocean behaved differently at that  
520 time and was split into a northern domain, whose margins were uplifted and a southern domain,  
521 which experienced the continuous build-up of carbonate platforms (Fig. 10); (3) it must be followed  
522 by a significant burial stage during the Early Cretaceous on the western and central Reguibat Shield,  
523 with decreasing intensity landward. This burial is not evidenced on the American conjugate margin  
524 and thermal stability has been retained after these changes (*e.g.* Taylor & Fitzgerald, 2011, their fig.  
525 8; Roden-Tice *et al.*, 2012, their fig. 6-7).

526 The exhumation recorded on both margins peaked during the post-rift phase, interrupting  
527 the classical subsidence post-rift phase, associated with the carbonated platform build-up. It is  
528 difficult to argue that early post-rift geomorphological models like scarp retreat or pinned-divide  
529 (Gallagher *et al.*, 1998) could be responsible for the distribution of the AFT ages and the evolution of  
530 the margin. The NW African passive margin is characterized by a low-elevation profile which does not  
531 seem to indicate any erosion retreat and that these rift-related processes usually exert themselves  
532 on more restricted geographical scales (< 300 km inland). Moreover, huge erosion on the coastal  
533 plain (and commonly ONLY studied for high-elevation passive margins) is classically explained by

534 primary controls such as the geometry of the rifting and the flexural rebound (see Bishop, 2007 and  
535 Green *et al.*, 2013 for contrasted reviews). In our studied case, the asymmetrical mechanism of  
536 rifting and the different crust-lithosphere geometries of the conjugate margins do not argue for both  
537 margins to behave in such a similar way (Maillard *et al.*, 2006; Labails *et al.*, 2009). We also discard an  
538 explanation involving regional compression to account for these results in the western and central  
539 domains of the Reguibat Shield and the American conjugate passive margin. Bertotti & Gouiza (2012)  
540 proposed this tectonic hypothesis for northern Morocco over the Late Jurassic/Early Cretaceous.  
541 However, their arguments are based on limited structural evidence that is focused on their study  
542 area. These features could also be explained as being halokinesis features (*e.g.* Saura *et al.*, 2014).  
543 Additionally, pre-Late Cretaceous compressional features have never been described on the  
544 Moroccan-Mauritanian passive margin during this period, before the onset of Africa-Europe  
545 convergence (Rosenbaum *et al.*, 2002).

546         We propose a hypothesis that involves mantle-related dynamic processes to account for the  
547 symmetrical uplifts on both sides of the northern Central Atlantic. The geographical extension of the  
548 eroded area points to a large-scale process, which could be attributed to ascending hot mantle  
549 material below the northern Central Atlantic Ocean. During Late Jurassic-Early Cretaceous,  
550 magmatism is absent across both margins (see the review by Matton & Jebrak, 2009). Scarce basic  
551 magmatic outcrops exist in northern Morocco (Frizon de Lamotte *et al.*, 2008) and in North America  
552 (McHone & Butler, 1984) from this period. Their absence over most of the NWAC can be explained by  
553 lack of structural pathways that allow the magma to pierce through the cratonic domain of the  
554 Reguibat Shield. Spreading of a large shallow plume head below the northern Central Atlantic Ocean  
555 lithosphere is thus not discarded but it would have to have impacted the base of the lithosphere at a  
556 lower temperature than typical plume heads or at great sub-lithospheric depths, which therefore  
557 prevent the development of a large volume of magmatism. Such a large hot mantle would have had  
558 wide reaching effects at this time and would have impacted Northwest Africa and eastern North  
559 America (this study), and even Iberia (*e.g.* Grobe *et al.*, 2014). The timing of the mantle plume is

560 concomitant with the second phase of the rifting between Iberia and Newfoundland (Tucholke *et al.*,  
561 2007). The delay between the increase in Middle-Upper Jurassic spreading rates in the Central  
562 Atlantic Ocean and the Lower Cretaceous clastic influx to the margins (Fig. 10, 11) is consistent with  
563 the lag time for the thermal mantle anomaly to reach the surrounding continents and create uplift.  
564 On a smaller scale, such a mechanism, as proposed here, could be similar to the “hot pulses” linked  
565 to the Icelandic plume that spread out radially beneath the lithosphere as proposed by Hartley *et al.*  
566 (2011) to explain various Cenozoic uplifts in this area of North Atlantic Ocean. In our case, the more  
567 important Mesozoic uplift-burial cycle affecting Northwest Africa is interpreted as being a result of  
568 NW Africa residing closest to an underlying mantle thermal anomaly compared to the conjugate  
569 margin. This has resulted in a stronger dynamic uplift effect which triggered episodes of erosion and  
570 burial that are able to be recorded by LTT methods. After the “dynamic pulse” that pushed upward  
571 the NWAC, its decrease led consequently to an opposite trend in the western and central Reguibat  
572 domains that allowed the re-burial of the margin in the extent revealed by our study, fading  
573 eastward within the craton. A potential contribution of eroding material from the eastern Reguibat  
574 Shield to this burial may be possible. Nevertheless, we are not able to properly evaluate this  
575 contribution since no sedimentary remnants are preserved within the Reguibat Shield nowadays.

576

## 577 **Conclusion**

578 This LTT study evidenced a Lower-Middle Jurassic to Upper Cretaceous kilometric erosion  
579 event that occurred in the previously presumed to be stable Northwest Africa. This result has major  
580 consequences for the Reguibat Shield and Northwest Africa and is probably related to the Central  
581 Atlantic expansion.

582 Along a roughly E-W ~1300 km transect of the Reguibat Shield, we show that kilometer-scale  
583 erosion occurred from Early-Middle Jurassic to the Early Cretaceous for the western and central

584 domains. The eastern domain of the Reguibat Shield also underwent an erosional event but it  
585 occurred later in the Early Cretaceous. The erosion of central and western domains was followed by  
586 subsequent reheating/burial with decreasing intensity landward, before final cooling from Late  
587 Cretaceous to present-day in western and central Reguibat Shield domains. For eastern Reguibat  
588 Shield domain, the brief pulse of erosion can be identified at the Lower-Upper Cretaceous transition  
589 and we may tentatively relate it to the Austrian unconformity.

590           These results have important implications when placed in the wider context of the  
591 geodynamic setting of the Central Atlantic Ocean evolution. We demonstrate a similar pattern of  
592 erosion occurring on the conjugate passive margin of eastern North America during the same period.  
593 This long wavelength uplift event only affected the northern part of the continents surrounding the  
594 young ocean and has an extent compatible with transient large scale mantle processes. A low-  
595 temperature or deeply located sub-lithospheric mantle plume head responsible for this uplift is  
596 concomitant with the second and last phase of rifting in the southern North Atlantic Ocean and could  
597 have played a significant role in triggering its oceanic opening.

598

## 599 **Acknowledgements**

600 We thank Eric Douville for accessing the ICP-MS (LSCE, Gif-sur-Yvette) and Louise Bordier for the U-Th  
601 measurements. This work has been supported by the Académie Hassan II des Sciences, Casablanca,  
602 Morocco. We acknowledged P.F. Green and an anonymous reviewer for the remarks and comments  
603 that greatly helped clarifying and precisising numerous points in the present manuscript.

604

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967 **Figure captions**

968 Fig. 1: Geological map of the Reguibat Shield and location of the samples. (a) Geographical location of  
969 the studied area. The Reguibat Shield belongs to the NWAC, bounded to the East by the Panafrican  
970 suture, separating it from the Tuareg Shield. Tf: Tindouf Basin; Td: Taoudeni Basin; lu: lullemeden  
971 Basin; Ah: Ahnet Basin; O.M: Oued Mya Basin; Gh: Ghadames Basin. (b) Geological map of the  
972 Reguibat Shield. TLDB: Tarfaya-Laayoune-Dakhla Basin. Samples have black or grey labels depending  
973 on whether they are published or new data, respectively. Mixed labels (*e.g.* TGH4072A) indicate that  
974 AFT data have been published but AHe data are new. Cret. : Cretaceous. (c) Simplified stratigraphical  
975 log of the TLDB (modified after Leprêtre *et al.*, 2015). 1: conglomerates and coarse detrital  
976 sediments; 2: coarse to fine sandstones; 3: shales with variable sandy proportion; 4: Shales and clays,  
977 sometimes interbedded with limestones; 5: limestones.

978 Fig. 2: Segmentation of the Reguibat shield based on the LTT results. The data are projected along a  
979 NW-SE transect, perpendicular to the Central Atlantic passive margin. AHe ages are Ft corrected  
980 ages. Errors for AFT and AHe ages are indicated at  $2\sigma$ . The distinction between the three domains of  
981 the Reguibat Shield is evidenced by the dispersion of the data and discussed in the text (section  
982 Sampling). Red outlines correspond to new data.

983 Fig. 3: AFT age vs. MTL plot for the whole Reguibat Shield. The grey bar indicates the timing and  
984 duration of the Jurassic rifting up to break-up, as defined by Labails *et al.* (2010).

985 Fig. 4: Track length distributions for all samples. They are separated by geographical area. Samples  
986 with more than 50 measured confined lengths have their names in black boxes.

987 Fig. 5: Corrected AHe ages vs. eU plots. (a) for the eastern Reguibat Shield; (b) for the central  
988 Reguibat Shield; (c) for the western Reguibat Shield. (d-i) Raw AHe ages vs. eU plots for the eastern  
989 Reguibat with expanded eU scale to better image to relationship between AHe age and eU. Light  
990 colored areas underline the grouping of single-grain AHe ages.

991 Fig. 6: Representative individual modeling for each domain of the Reguibat Shield. (a) Thermal  
992 modeling of sample GH3 in the eastern Reguibat Shield. (b) Predicted single-grain AHe ages against  
993 measured ones. Ages are corrected for Ft. (c) Predicted AFT data against measured ones. (d), (e) and  
994 (f) show the thermal modeling results for sample TGH3163 in the central Reguibat Shield, with the  
995 same legend than (a), (b) and (c), respectively. (g) and (h) show the thermal modeling results for  
996 sample AG167 in the western Reguibat Shield, with the same legend than (a) and (c), respectively.

997 Fig. 7: Inverse thermal modelings for the three Reguibat Shield domains. (a-c) Thermal modeling  
998 results for the eastern Reguibat Shield (a), for the central Reguibat Shield (b) and for the western  
999 Reguibat Shield (after Leprêtre *et al.*, 2015 for AOS, SC, TAS233 and TAS29 samples) (c). The light grey  
1000 box indicates in each panel the duration of the major cooling event. The dark grey box in (b-c) shows  
1001 the duration of the subsequent reheating, which is not recorded in the eastern Reguibat Shield (a).  
1002 For the western domain, black thermal paths correspond to the thermal modelings realized by  
1003 Leprêtre *et al.* (2015). Due to the new AHe data, we have made new thermal modeling for the data  
1004 from the central domain obtained by Leprêtre *et al.* (2014). For all modelings, the way we have  
1005 defined the constraint-boxes is explained within the text. Fig. 8: Forward modeling for the central  
1006 Reguibat Shield. (a) Tested thermal paths with HeFTy software (Ketcham, 2005). (b) Corresponding  
1007 predicted AHe ages for each tested thermal path in (a). The measured Ft-corrected single-grain AHe  
1008 ages are also indicated to ensure direct comparison. A small simplified map of the Reguibat Shield  
1009 shows the segmentation between the different domains.

1010 Fig. 8: Forward and inverse modeling for the central Reguibat Shield. (a) Tested thermal paths with  
1011 HeFTy software (Ketcham, 2005). (b) Corresponding predicted AHe ages for each tested thermal path  
1012 in (a).

1013 Fig. 9: Comparison between AFT datasets of the conjugate passive margins of the northern Central  
1014 Atlantic Ocean. (a, b) DEMs of Northeast America and Northwest Africa, respectively. Colored dots  
1015 locate the AFT samples of the different studies quoted in the text with a color scale for the range of

1016 AFT ages. White lines are the profiles used to project the data with respect to the hinge line. (c, d)  
1017 AFT datings along perpendicular profiles, from the hinge line at  $x=0$ . For the African AFT profile, data  
1018 are from: Ghorbal *et al.* (2008); Saddiqi *et al.* (2009); Ruiz *et al.* (2011); Oukassou *et al.* (2013),  
1019 Leprêtre *et al.* (2014, 2015) and this study. For the American profile, data come from the studies  
1020 quoted in the text. Smaller panels on each profile show the MTL vs. AFT age plot. The grey bar  
1021 indicates the age range of the rifting of the Central Atlantic Ocean (Labails *et al.*, 2010).

1022 Fig. 10: Comparison of Middle Jurassic-Aptian stratigraphical record of Central Atlantic Ocean  
1023 conjugate passive margins. The map at the bottom shows the approximate position of North America  
1024 and West Africa at Chron 25 (154 Ma). Continent contours and the 2 km-depth bathymetry are the  
1025 present-day ones. The basins whose stratigraphy is described in the text are located in dark grey. The  
1026 margins have been divided into a northern and a southern segment, given their respective  
1027 stratigraphy. Only one stratigraphical log is used for the northern segment since all basins shared a  
1028 common evolution during the considered period. Legend for sedimentary rocks: 1. marls; 2.  
1029 carbonates; 3. Dolomites, 4. siltstones and marls; 5. coarse clastics; 6. sandstones to siltstones.  
1030 Legend for the period described on the stratigraphic logs: EJ. Early Jurassic; MJ: Middle Jurassic; LJ:  
1031 Late Jurassic; NC: Neocomian (Berriasian-Hauterivian); BAP: Barremian-Aptian.

1032 Fig. 11: Evolution of the spreading rates in the Central Atlantic Ocean from Early Jurassic to Early  
1033 Cretaceous. This compilation is based on works by Schettino & Turco (2009), Labails *et al.* (2010) and  
1034 Kneller *et al.* (2012).

1035 Fig. 12: Representative thermal paths from the onshore eastern North America. Thermal paths are  
1036 coming from: (a) Nova Scotia in the northern proximal passive margin (Grist & Zentili, 2003); (b) the  
1037 Michigan Basin, deep in the interior of the continent (Wang *et al.*, 1994); (c) the southern Canadian  
1038 Shield (Lorenca *et al.*, 2004); (d) the Northern Appalachian (Taylor & Fitzgerald, 2011). Dark grey box  
1039 defines the main period of uplift in the western and central Reguibat Shield domains in the  
1040 conjugated African passive margin.

1041 Table 1: AFT results\*

	Sample	Rock-type	Location	Elevation (m)	$\rho_s$ ( $10^5 \cdot \text{cm}^{-2}$ ) / Ns	$\rho_i$ ( $10^5 \cdot \text{cm}^{-2}$ ) / Ni	$\rho_d$ ( $10^5 \cdot \text{cm}^{-2}$ ) / Nd	P ( $\chi^2$ ) %	Central age (Ma) $\pm 1\sigma$	U (ppm)	MTL ( $\mu\text{m}$ ) $\pm$ se	Std dev.	Dpar ( $\mu\text{m}$ )
<i>Western domain</i>	AG167	charnockite	13°24'2.07"W	233	0.218	0.195	6.73	74	137 $\pm$ 12	4	-	-	1.72 $\pm$ 0.1
			20°42'56.76"N		323	289	6849		(20)		-		
	AG169	charnockite	13°24'2.07"W	237	0.201	0.207	6.682	93	118 $\pm$ 10	4	-	-	1.54 $\pm$ 0.2
			20°42'56.76"N		309	319	6849		(20)		-		
<i>Central domain</i>	TGH3111B	granite	9°22'12"W	252	3.246	2.598	6.611	65	150 $\pm$ 8	48	11.9 $\pm$ 0.2	1.7	1.63 $\pm$ 0.1
			24° 00'00"N		1097	878	6563		(20)		(101)		
	TEN4065	microgranite	10° 1'47.00"W	258	6.444	4.462	6.595	8	172 $\pm$ 13	82	11.7 $\pm$ 0.3	2	2.06 $\pm$ 0.5
			24°20'23.00"N		883	477	6563		(20)		(35)		
	AL10	granodiorite	7° 7'5.15"W	394	1.334	0.866	7.255	63	202 $\pm$ 14	15	12 $\pm$ 0.2	1.6	1.77 $\pm$ 0.1
			26°37'33.06"N		675	438	6849		(20)		(49)		
	YT7	monzogranite	7°20'37.34"W	384	1.862	1.394	6.825	72	166 $\pm$ 8	25	11.4 $\pm$ 0.3	1.8	1.60 $\pm$ 0.2
			26°28'59.39"N		1380	1033	6849		(20)		(49)		
<i>Eastern domain</i>	IG3	rhyolite	6° 9'0.43"W	366	0.469	0.149	6.968	84	393 $\pm$ 36	3	-	-	1.66 $\pm$ 0.2
			26° 6'22.40"N		543	172	6849		(20)		-		
	CH1	gabbrodiorite	3°35'36.69"W	252	1.098	0.454	7.159	6	307 $\pm$ 26	8	11.5 $\pm$ 0.2	2.1	1.86 $\pm$ 0.2
			25°35'45.94"N		862	356	6849		(20)		(101)		
	CH2	gabbrodiorite	3°35'36.69"W	252	3.105	1.516	7.112	18	264 $\pm$ 21	26	12 $\pm$ 0.2	1.7	1.99 $\pm$ 0.2
			25°35'45.94"N		770	376	6849		(20)		(69)		
	CH3	gabbrodiorite	3°35'36.69"W	252	1.059	0.426	7.064	86	315 $\pm$ 24	7	11.5 $\pm$ 0.3	2.3	1.95 $\pm$ 0.2
			25°35'45.94"N		686	276	6849		(20)		(64)		
	GH3	trondhjemite	6° 3'54.77"W	360	1.177	0.41	7.016	6	359 $\pm$ 27	7	11.5 $\pm$ 0.2	1.9	1.76 $\pm$ 0.2
			25°29'36.53"N		1130	394	6849		(20)		(100)		
	DEG6	gabbro	2°57'15.60"W	355	2.276	0.701	6.111	46	355 $\pm$ 25	12	11.2 $\pm$ 0.4	2.1	1.97 $\pm$ 0.1
			26° 4'50.02"N		1065	328	6849		(20)		(27)		
	GH20	gabbro	6° 0'2.87"W	350	0.471	0.101	5.996	73	497 $\pm$ 61	2	-	-	1.75 $\pm$ 0.1
			25°32'51.89"N		206	44	3012		(10)		-		
	TL3	gabbro	3°10'37.45"W	381	0.818	0.376	6.052	66	237 $\pm$ 21	8	-	-	2.12 $\pm$ 0.2
			27°21'31.99"N		447	207	3012		(20)		-		

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1043 \*  $\rho$  – density of tracks with s and i – spontaneous and induced densities in apatite crystals and the mica detector; d – tracks density of the neutron glass  
1044 monitor (CN5); for  $\rho_s$ ,  $\rho_i$ ,  $\rho_d$ , are written in italics the number of counted tracks. Densities are expressed in  $10^5 t/cm^2$ . MTL – mean track length. Values in  
1045 bracket for central age and MTL are, respectively, the number of single-grain ages and the number of lengths measured.  $1\sigma$  is the standard deviation. Dpar  
1046 corresponds to a kinetic factor determined for each sample (Barbarand *et al.*, 2003).

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1051 Table 2: AHe results\*

	Name	Rs ( $\mu\text{m}$ )	Weight( $\mu\text{g}$ )	$F_r$	$^4\text{He}(\text{ncc/g})$	U (ppm)	Th (ppm)	Sm (ppm)	eU (ppm)	Age (Ma)	Age c. (Ma)
<i>Central</i>	1153-A	80.8	11.85	0.87	46201.6	3.8	11.9	7.0	6.7	57	66 $\pm$ 5
<i>Domain</i>	1153D	34.4	1.17	0.715	120399,0	10.4	31.9	20.3	18.3	55	77 $\pm$ 6
	1153-F	63.2	6.54	0.815	100000.8	7.6	20.3	9.5	12.6	66	81 $\pm$ 6
	1153-H	59	4.69	0.83	63086.4	11.2	22.6	12.5	16.7	31	38 $\pm$ 3
	1153-I	47.5	2.56	0.79	57756,0	5.5	16.8	13.3	9.6	50	63 $\pm$ 5
	3163-A	54.1	3.6	0.809	717183.1	37.7	1.9	27.2	38.3	155	191 $\pm$ 15
	3163-E	66	7.11	0.827	288616.5	16.9	1.4	17.6	17.4	137	166 $\pm$ 13
	3163-I	65.6	6.26	0.847	470679.8	17.8	25.6	24.6	24.1	162	191 $\pm$ 15
	3163G	96.1	17.27	0.875	549045.6	25,0	22,0	NA	30.3	150	172 $\pm$ 14
	AL10-A	46	2.4	0.755	405681.5	22.5	20.6	31.8	27.7	121	161 $\pm$ 13
	AL10-E	39.3	1.18	0.701	675195,0	76.1	26.7	31.3	82.8	67	96 $\pm$ 8*
	AL10-C	50.5	3.53	0.765	229447.2	11.1	11.9	29.3	14.2	134	175 $\pm$ 14
	AL10-L	44.1	1.57	0.679	1341456.8	34.3	31.1	59.4	42.2	263	388 $\pm$ 31*
	AL10-J	37.2	1.22	0.724	231868.3	7.9	10,0	37.4	10.5	182	252 $\pm$ 20
	AL10-I	45.5	2.02	0.76	395904.9	22.4	14.9	41,0	26.3	124	164 $\pm$ 13
	AL10-B	39	1.39	0.726	557702.2	20.6	11.6	37.5	23.7	195	269 $\pm$ 21
	AL10-K	37.9	1.28	0.717	145483.1	12.5	8.8	35.5	14.9	81	112 $\pm$ 9
	AL10-F	38.7	1.23	0.687	129286.7	9.5	15.8	44.8	13.6	79	115 $\pm$ 9
	AL10-G	39.9	1.23	0.707	1327362.4	32.4	26.5	65.3	39.3	280	396 $\pm$ 32*
	AL10-H	42.6	1.58	0.713	236976.2	18.4	18.2	50.1	23.2	85	119 $\pm$ 10
<i>Eastern</i>	CH1-A	47.3	2.43	0.789	79475.1	7.2	6.9	5.3	9	74	93 $\pm$ 7

<i>Domain</i>	CH1-B	56.4	4.13	0.809	28513.1	2.7	3.2	1.4	3.5	68	84 ± 7
	CH1-C	49.4	2.68	0.802	48729.7	13.1	11.1	5.3	15.8	26	32 ± 3*
	CH1-D	40.2	1.45	0.751	205297.8	10.1	12.5	5.6	13.1	130	173 ± 14
	CH1-F	38.8	1.31	0.754	127741.1	11	9.6	3.4	13.3	80	106 ± 8
	CH1-G	64	6.37	0.831	88950.2	6.2	8.5	5.1	8.2	90	108 ± 9
	CH1-H	37.9	1.28	0.717	392039.3	26.1	23.4	6	31.8	102	143 ± 11
	CH1-J	50.6	3.96	0.761	141712.3	5,0	6.5	4.5	6.6	178	234 ± 19
	CH1-K	40.7	1.74	0.723	190623.3	19,0	10.3	14.9	21.6	73	101 ± 8
	CH3-C	50.5	3.04	0.789	119938.2	4.2	5.9	3.7	5.7	175	222 ± 18
	CH3-F	35.5	0.96	0.717	191786.5	13.4	11.3	4.2	16.1	99	138 ± 11
	CH3-A	54.7	4.25	0.79	93992.9	5.7	5.5	3.2	7	111	141 ± 11
	CH3-G	59.2	6.11	0.793	71842,0	3.7	5	2.7	4.9	122	153 ± 12
GH3A	66.1	7.49	0.823	292746.2	8.1	5.6	12.7	9.6	253	307 ± 25	
	GH3B	91.1	21.74	0.876	172995.7	4.7	4.6	6.4	5.9	243	278 ± 22
	GH3-C	71.5	8.99	0.842	56806.1	4.5	3.5	8.9	5.4	88	104 ± 8
	GH3-E	57.9	4.06	0.784	230520.3	6.5	3.8	10.8	7.5	256	326 ± 26
	GH3-F	99	19.03	0.883	21444.4	1.7	0.4	2.2	1.8	98	111 ± 9
IG3-C	43.8	1.72	0.722	332846.2	18.1	18.9	44.7	23	120	166 ± 13	
	IG3-E	39.4	1.31	0.686	191182.1	5	10	48.9	7.8	203	295 ± 24
	IG3-F	36.7	0.99	0.675	118582.6	3.8	10.9	47.2	6.8	146	216 ± 17
	IG3-G	40.6	1.56	0.741	91106.9	3.7	4.9	38.8	5.1	147	198 ± 16
	IG3-I	40.4	1.67	0.721	187725,0	3.9	5.5	49.9	5.6	277	384 ± 31
TL3-L	41.1	1.58	0.745	131554.4	6.3	18.8	29.8	11.1	99	133 ± 11	
	TL3-B	49.4	2.68	0.803	66784.2	8.8	17	23.8	13.1	42	53 ± 4
	TL3-C	41.3	1.57	0.778	73141.8	9.2	43.5	27	19.8	31	40 ± 3*
	TL3-D	39	1.44	0.717	86327.5	6.3	20.9	33.8	11.6	62	87 ± 7

TL3-F	41.4	1.92	0.717	123516.5	7.1	25.1	35.2	13.4	77	107 ± 9
TL3-G	43.5	1.98	0.745	95782.6	6.4	21.9	34.3	12	67	89 ± 7
TL3-J	52	3.29	0.797	93130.9	5.4	17.1	25.4	9.7	80	101 ± 8
TL3-H	47	2.35	0.777	123871.0	8	27.5	36.9	14.9	69	89 ± 7
TL3-K	46.6	2.77	0.746	21915.9	3.6	8.2	19.6	5.7	32	42 ± 3
GH20-A	36.4	1.14	0.702	58542.3	5.8	5.2	129.6	8.1	60	85 ± 7
GH20-C	37.4	1.28	0.703	74174.8	12.9	6.9	26.5	14.7	42	59 ± 5
GH20-D	37.4	1.28	0.703	54325.7	5.9	5.1	31.4	7.3	61	87 ± 7
GH20-F	41.1	1.58	0.745	34723.6	4.1	5.3	30.5	5.7	51	68 ± 5
GH20-H	35.1	1.22	0.663	37173.2	9.5	6.2	37.8	11.2	27	41 ± 3
GH20-G	39.2	1.52	0.711	54027.8	11.1	7	34.3	13.1	34	48 ± 4

1052

1053 \*  $R_s$  (sphere equivalent radius) and  $F_T$  (ejection factor) have been calculated using the developed procedure of Gautheron & Tassan-Got (2010) and Ketcham  
1054 *et al.* (2011). eU (effective uranium) has been calculated with the formula  $[eU] = [U] + 0.24*[Th] + 0.008*[Sm]$ . "Age c." means (U-Th-Sm)/He age corrected  
1055 from alpha-ejection with the  $F_T$ . The error is estimated to be a maximum of 8%.

Figure 1

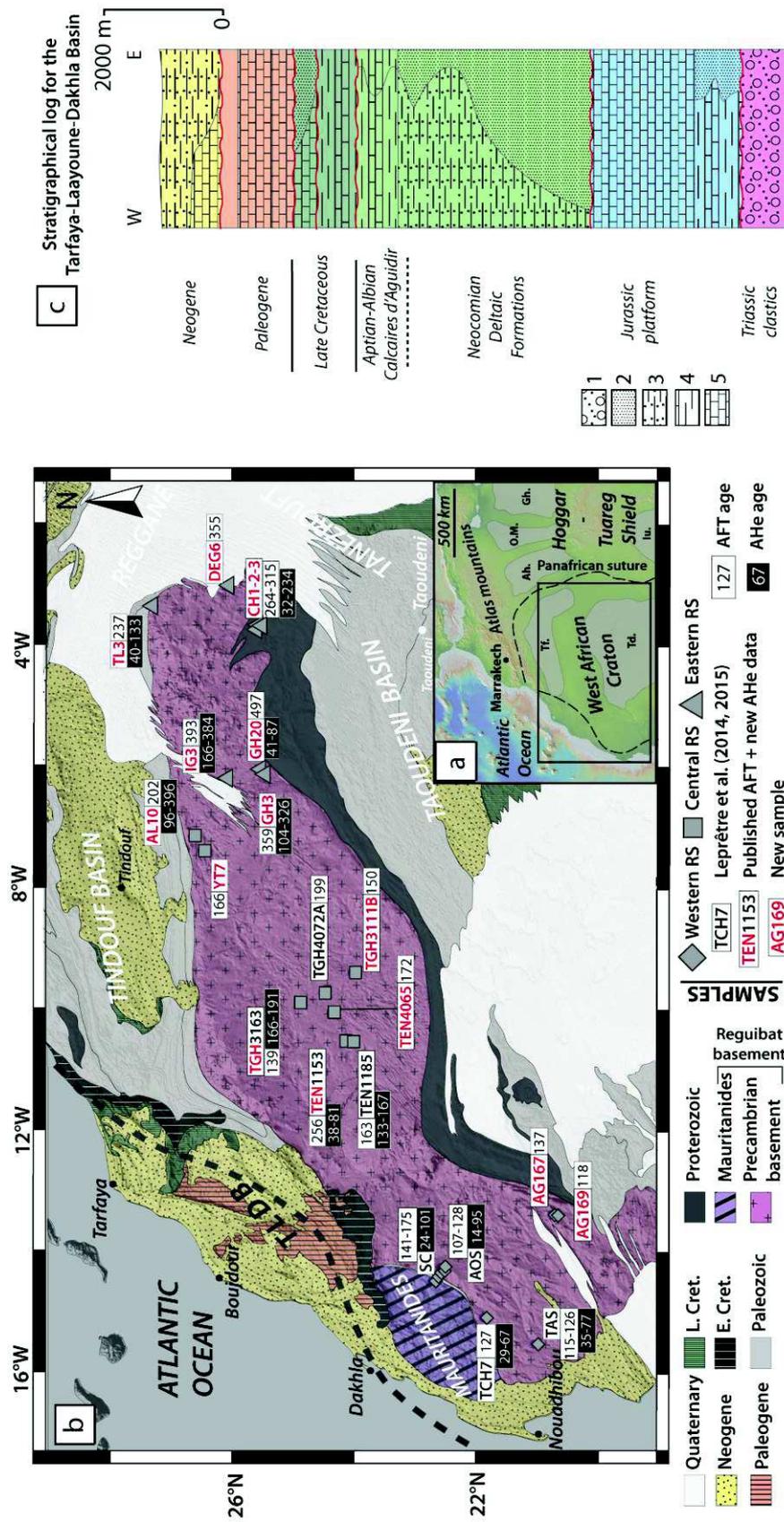


Figure 2

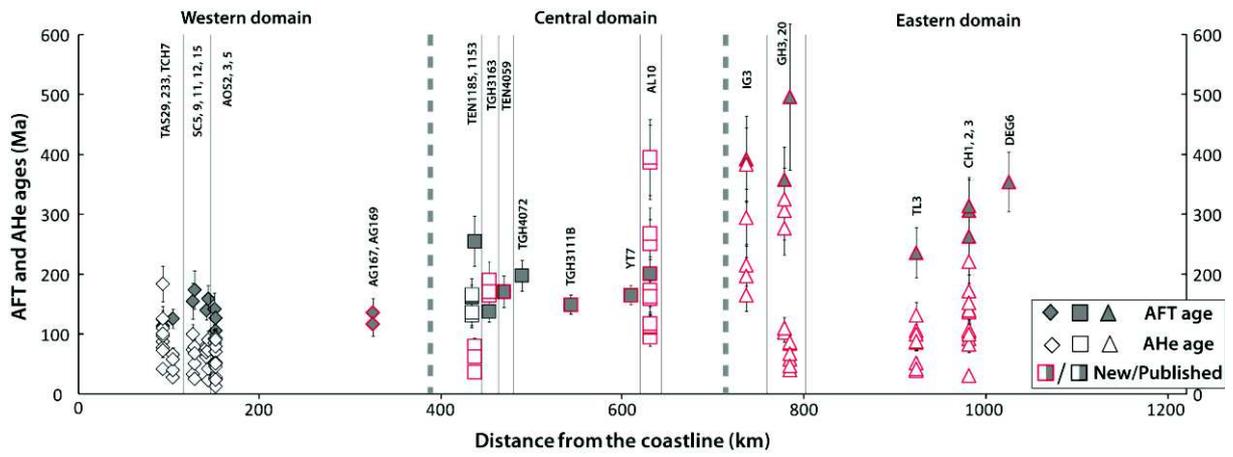


Figure 3

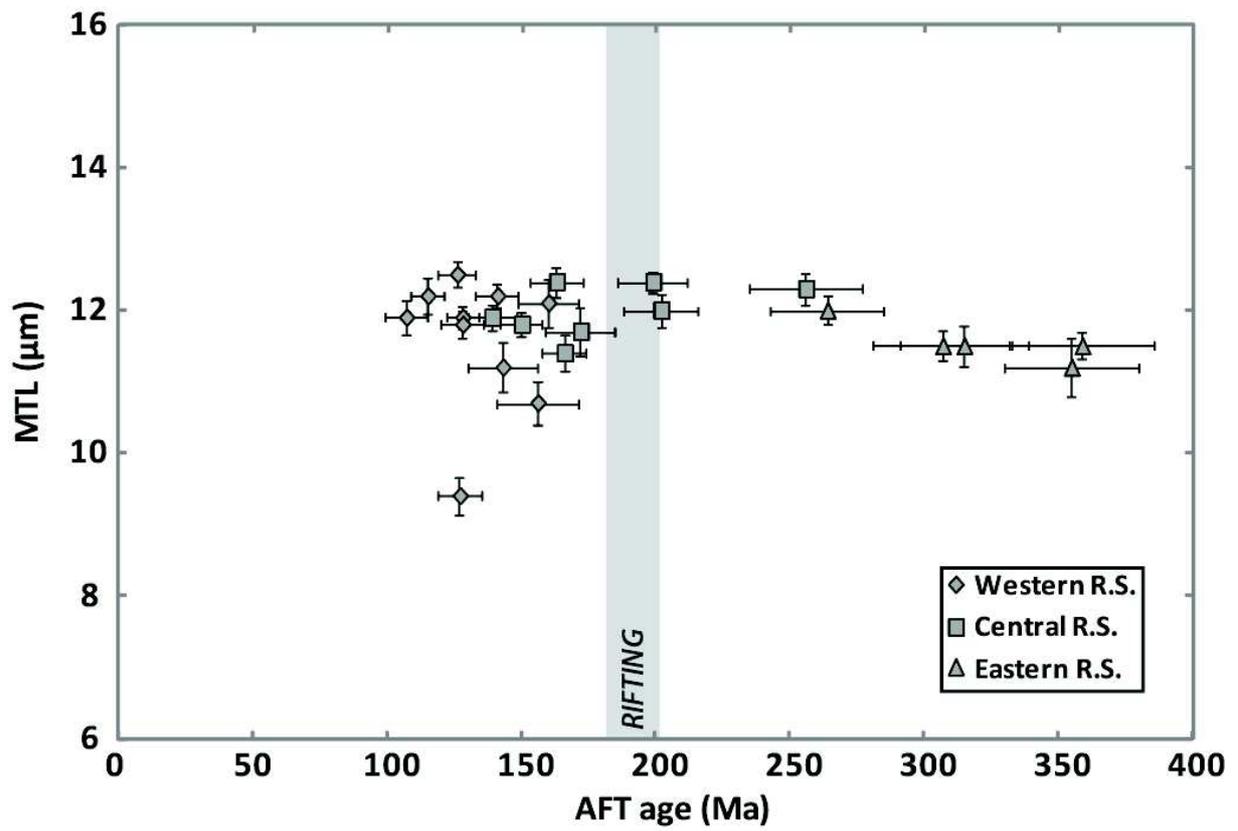


Figure 4

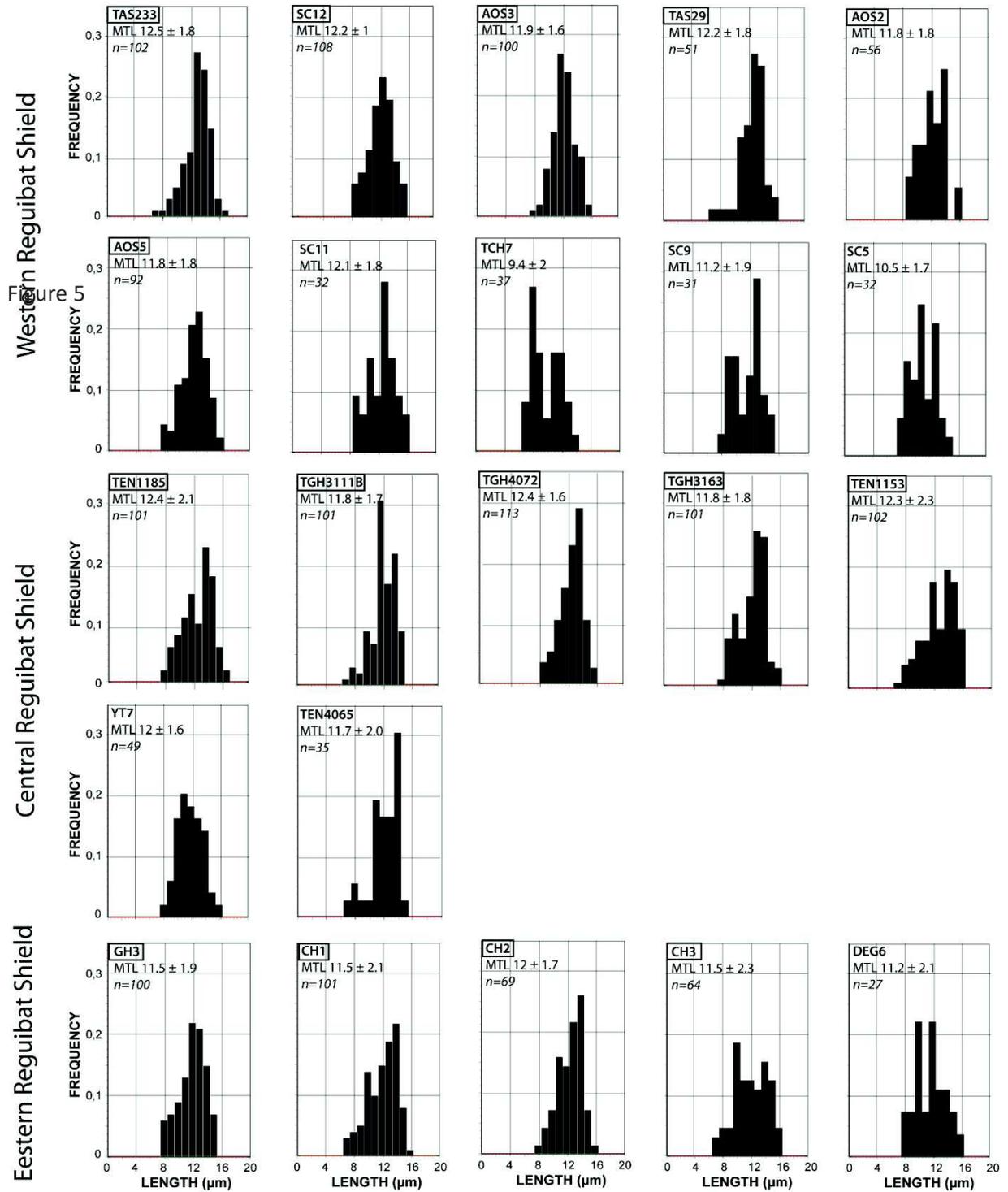


Figure 5

Figure 5

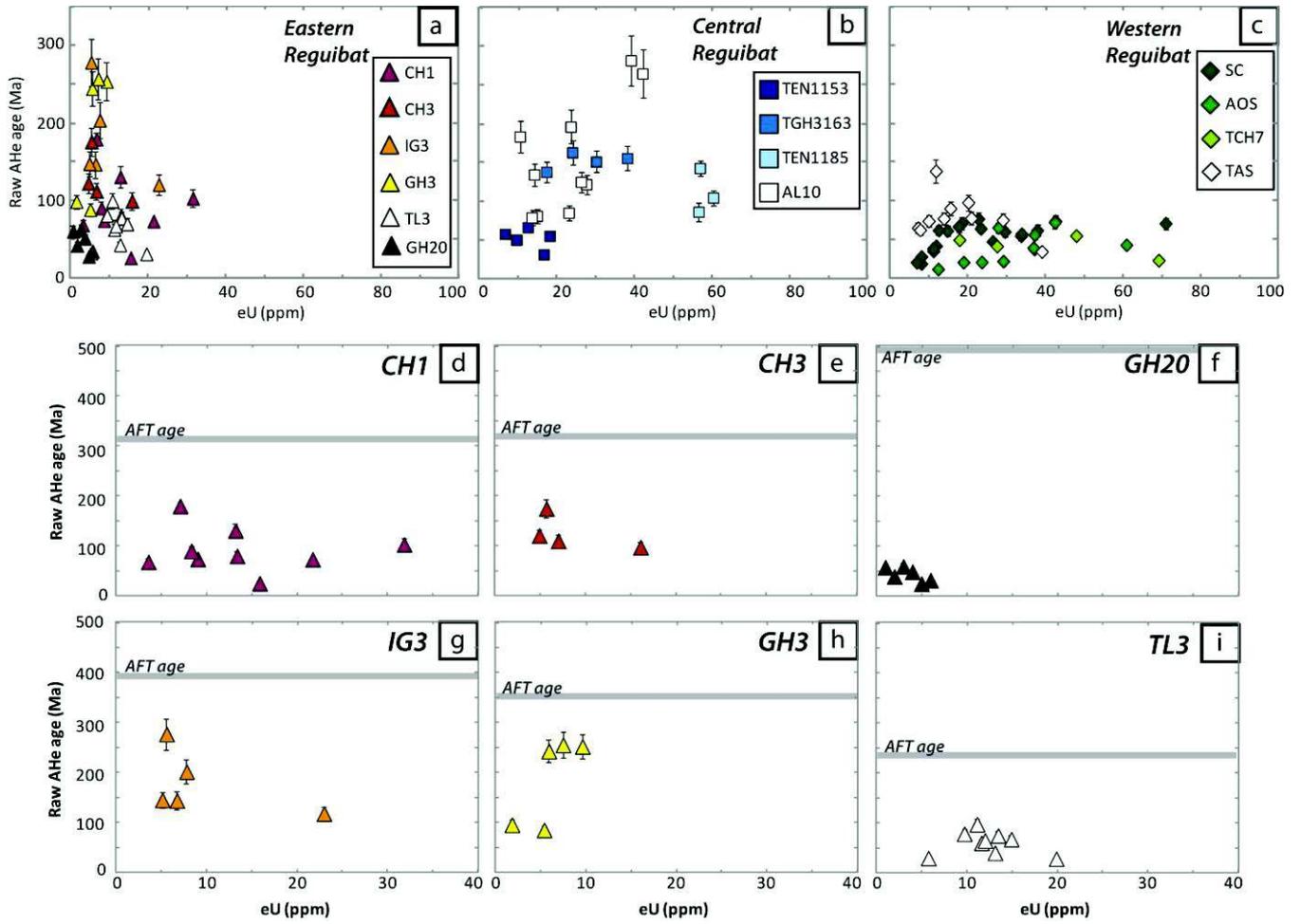


Figure 6

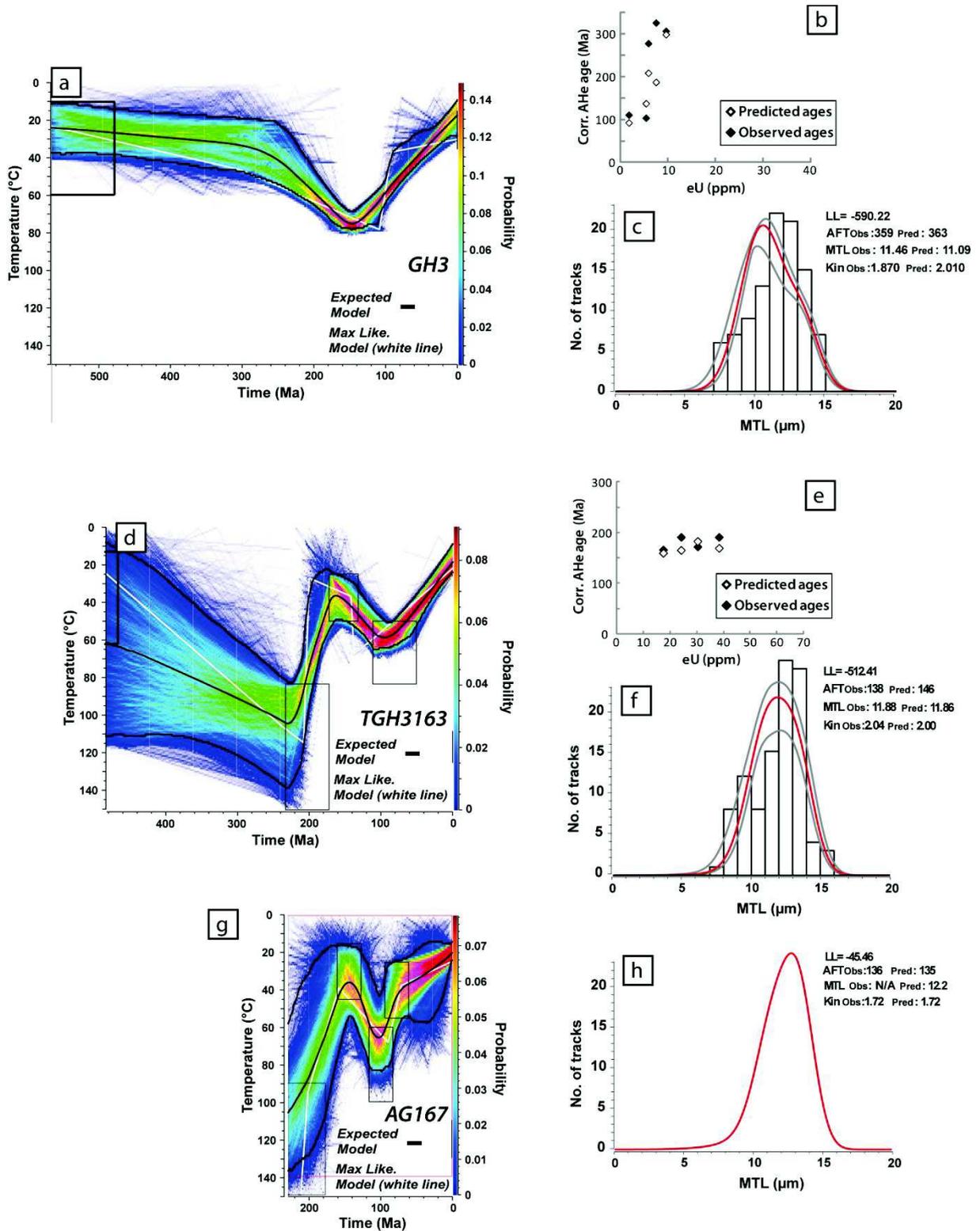


Figure 7

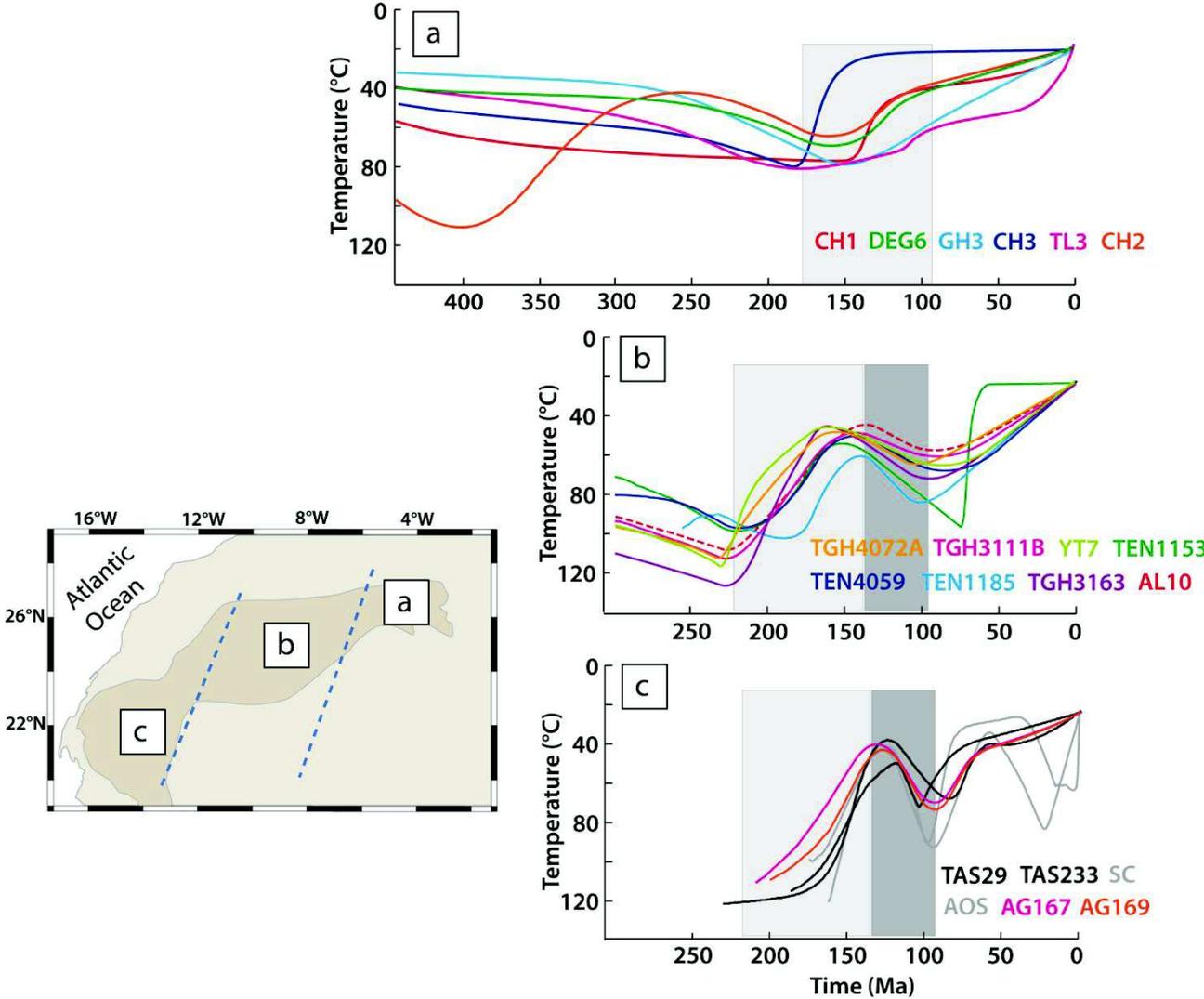


Figure 8

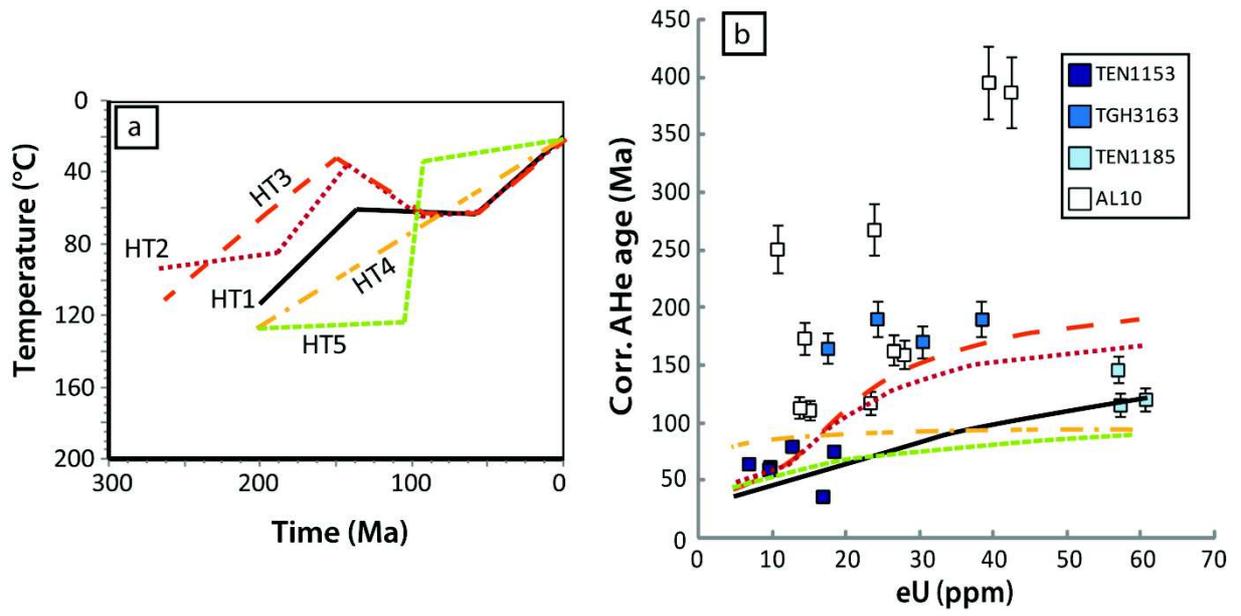


Figure 9

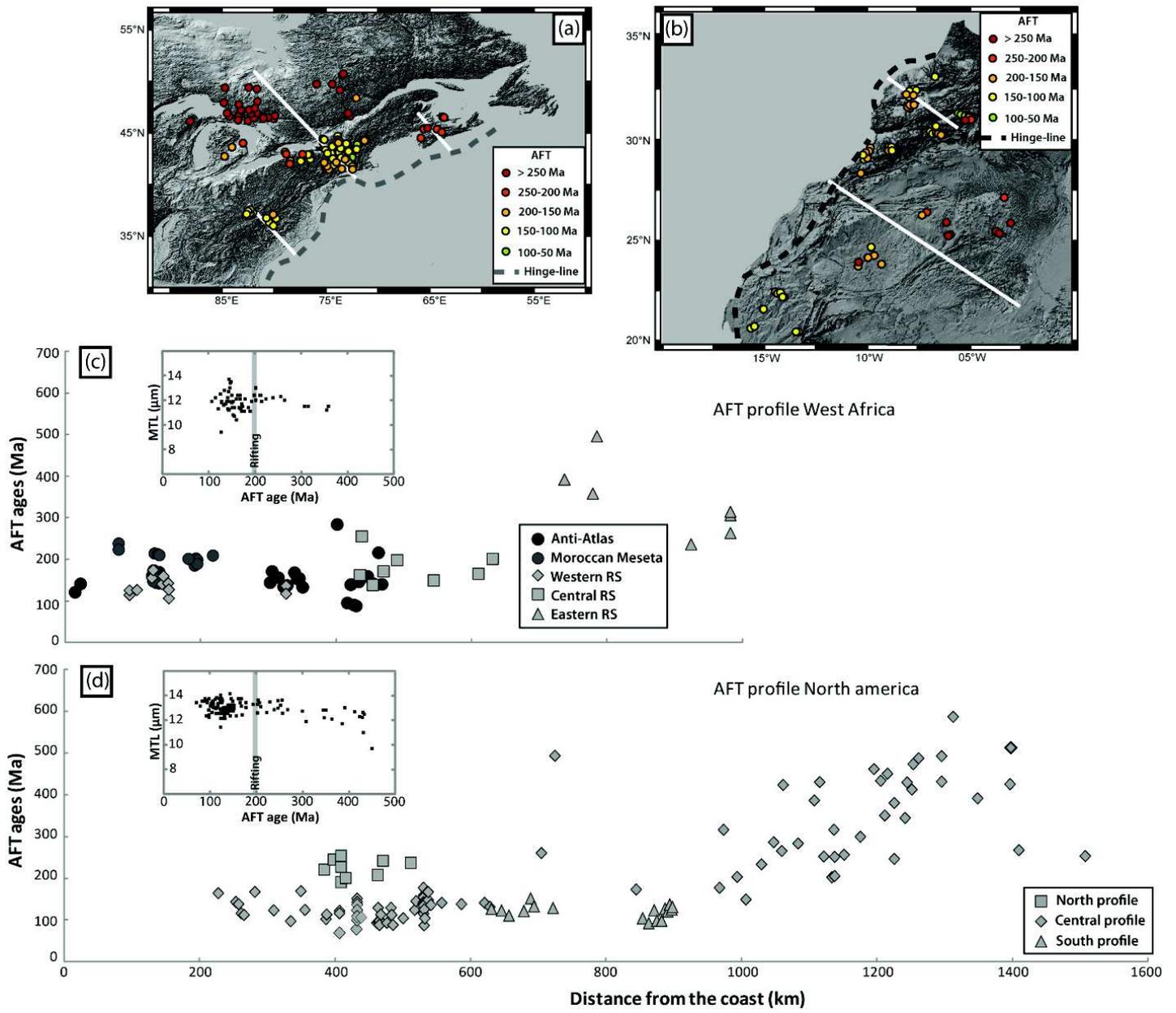


Figure 10

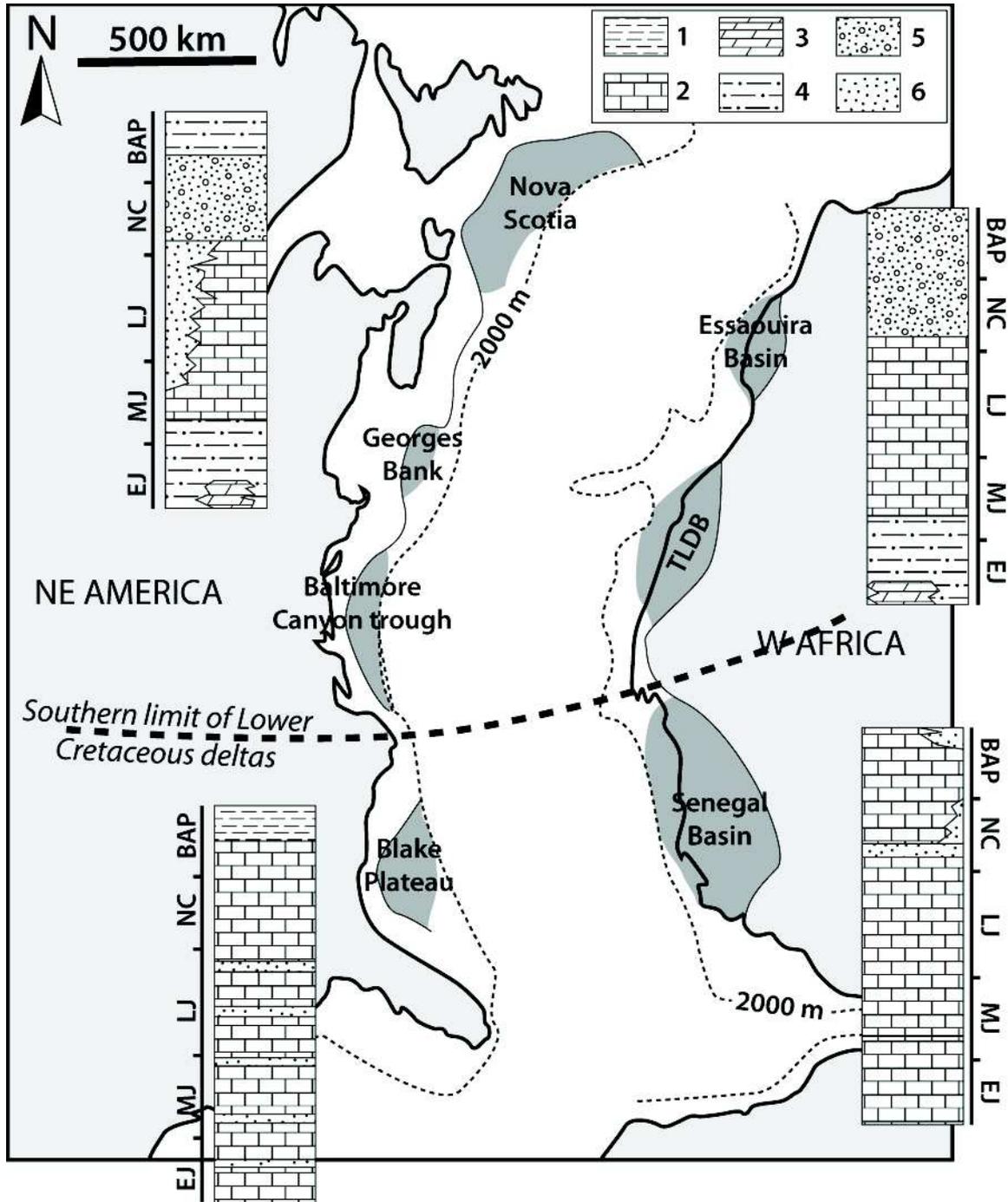


Figure 11

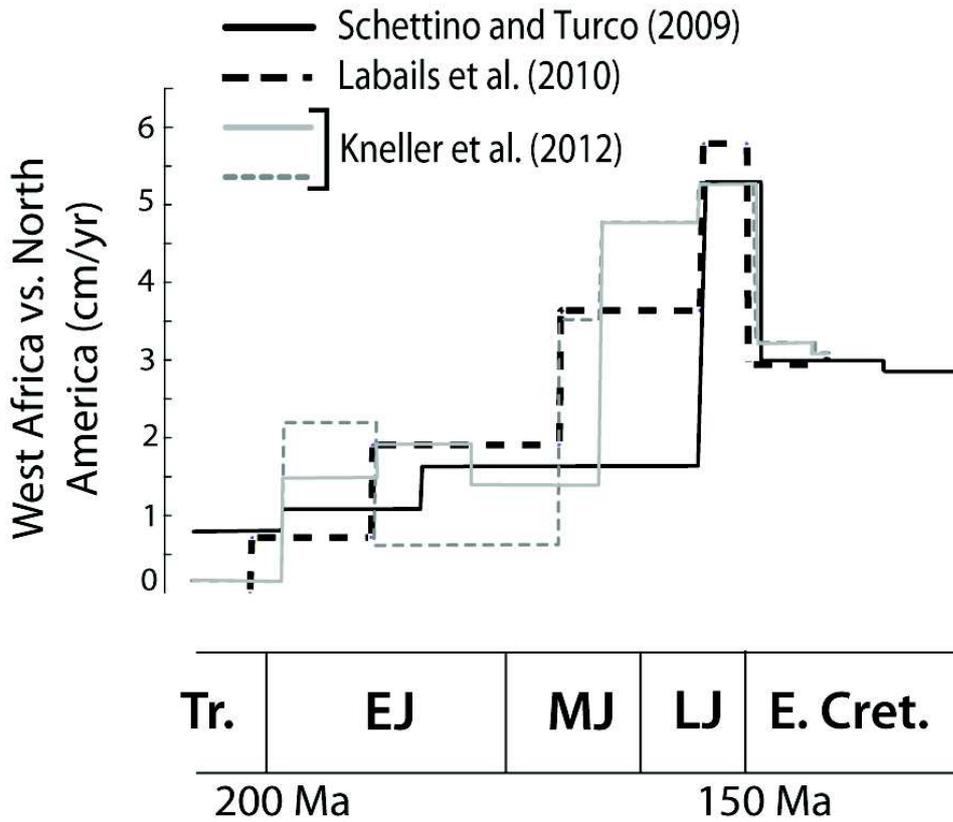
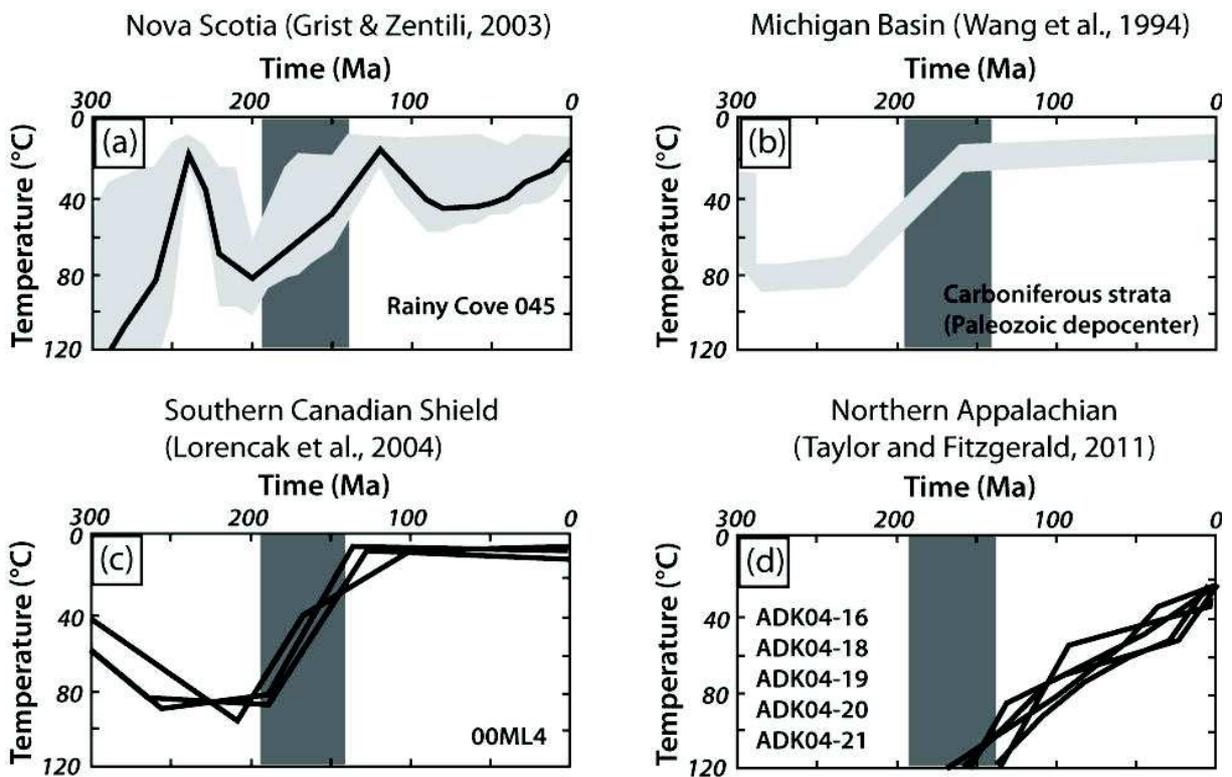


Figure 12



## Supplementary Data

### Text S1 – Modeling procedure for western RS samples

The thermal modeling for western RS samples is briefly recalled here. The reader is invited to read the extensive description given in Leprêtre et al. (2015).

The modeling of samples of the western RS was done through three steps, given the complexity of the dataset. A first step of inverse modeling was used as an exploratory tool to search the (T, t) space. The stratigraphical constraint given by the unconformity of the Lower Cretaceous deposits and a data-dependent constraint implying samples to be at temperatures higher than 110°C before 200 Ma were incorporated in the modeling to narrow the exploration of the (T, t) space.

Second, representative thermal histories obtained in the first step were discriminated using the forward modeling. They implied further restrictions on the available (T,t) paths that were incorporated as constraints in the third step of the modeling. The last step used inverse modeling with all determined constraints during the early steps to explore the degrees of freedom left to the model to better fit the data.

This three-step procedure led to four major constraints that we re-use here to model the AFT ages of AG167 and AG169 samples: (1) samples were at temperatures higher than 110°C before 200 Ma; (2) samples were near or at the surface during the Early Cretaceous; (3) a necessary reheating step occurred until the beginning of the Late Cretaceous; (4) a subsequent cooling up to 40°C by the end of the Late Cretaceous.

### Text S2 – influence of apatite chemistry on the single-grain AHe ages scattering

To investigate the influence of the chemistry on the scattering of the single-grain AHe age, we used the mean thermal paths obtained through thermal modeling for all samples with AHe datasets. With forward modeling, we consider the whole range of Dpar and grain size of single grain within each sample. The grain size range is approximated through the equivalent sphere radius (Rs; see Table 2). The chemistry variations are taken into account through the *rmr0* factor, as defined by Ketcham et al. (2007). An empirical relationship links the Dpar and the *rmr0* through the following equation:

$rmr0 = 0.84 \times [(4.58 - Dpar)/2.98]^{0.21}$ , the *rmr0* being used as the chemical determinant for the forward modeling with HeFTy for our tests.

We tested each final thermal path in forward modeling, varying the values of *rmr0* and Rs. For an eU range, we then reported the obtained AHe age-eU relationship for the four couple (*rmr0*; Rs) tested (Fig. S17). One can see on figure S17 that generally, the single-grain AHe ages scattering can simply depend on these two parameters. Some out-of-trend replicates need others explanations, like the shape of broken apatite crystals (Brown et al., 2013) or contamination (Gautheron et al., 2012).

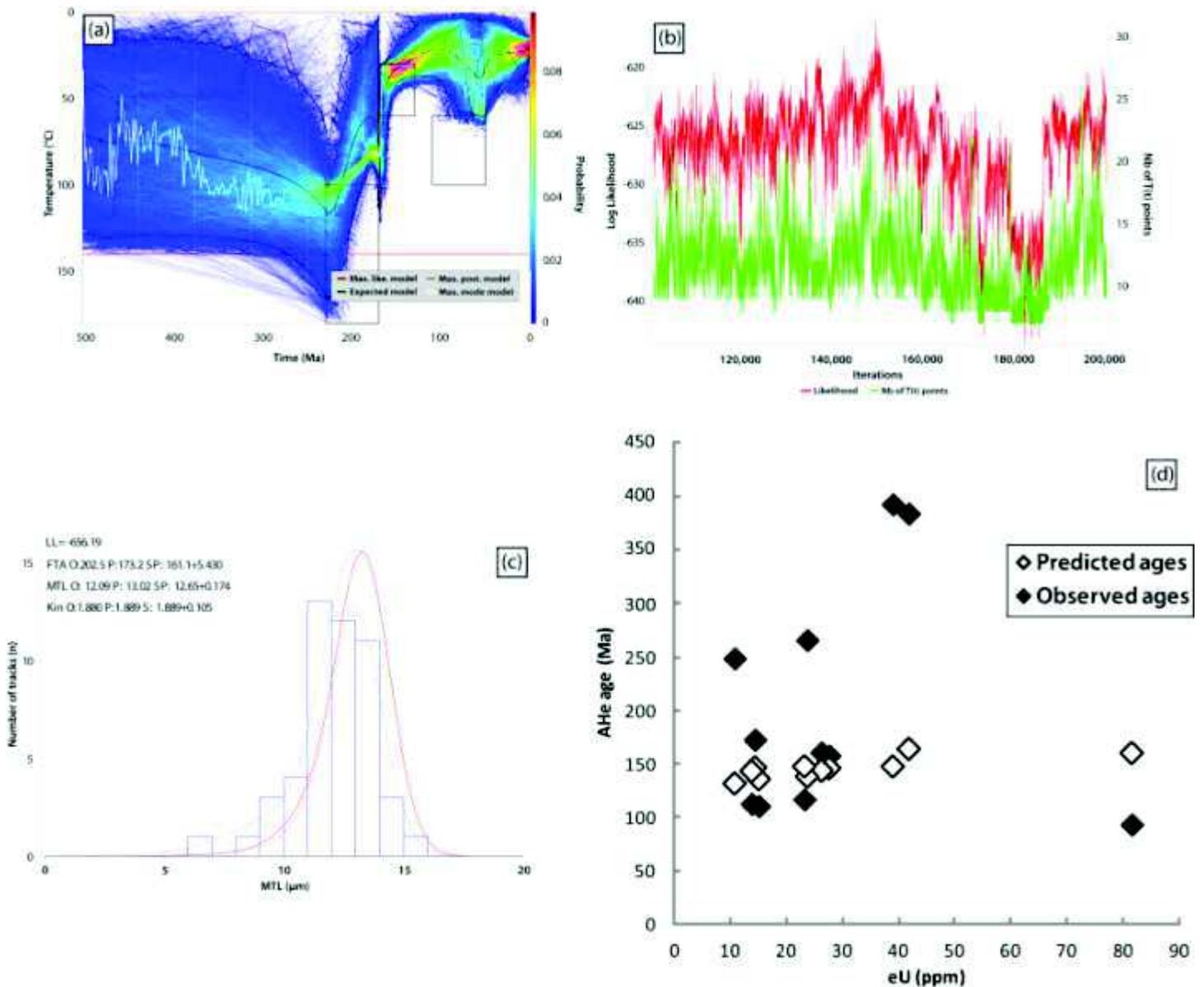


Figure S1: Thermal modeling of AL10 sample with all single-grain AHe ages. The figure must be compared with figure S12. It shows the instabilities produced by the use of anomalous replicates. . (a) Thermal history with different outputs (see details in Gallagher, 2012); (b) Evolution of the LL and the number of T(t) points during the post-burn-in phase; (c) Predicted parameters for the expected model (black line in (a)). In red line is the predicted length distribution (superimposed on blue histogram in other samples). LL: LogLikelihood; FTA: fission track age; MTL: mean track length; Kin: Dpar; O: observed; P: predicted.

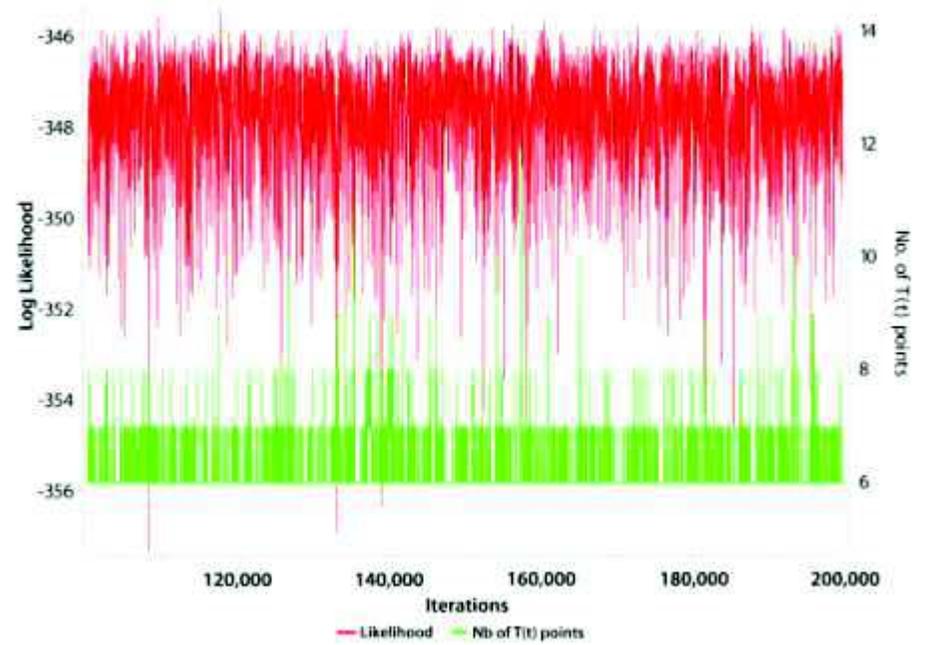
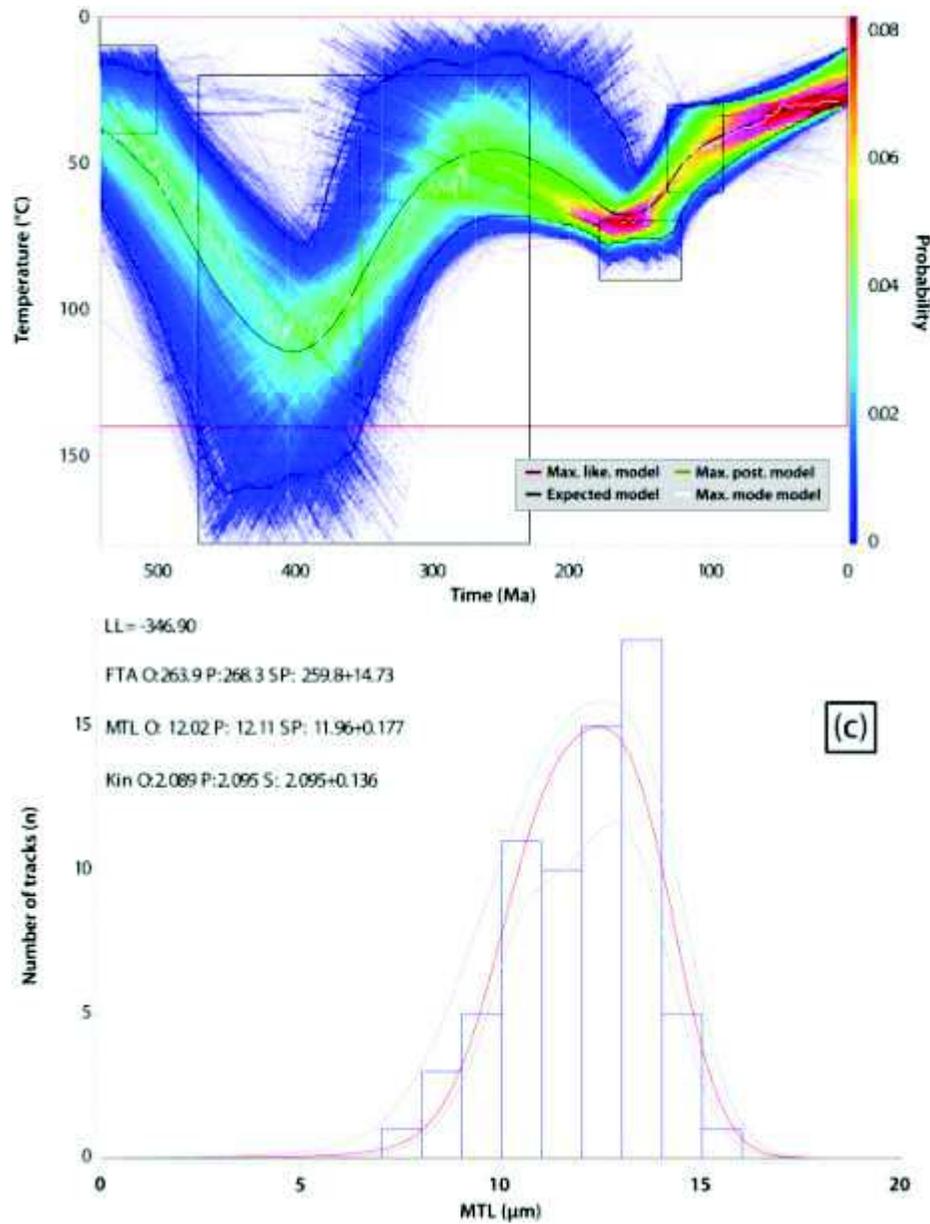


Figure S2: Thermal modeling of CH2 sample. (a) Thermal history with different outputs (see details in Gallagher, 2012); (b) Evolution of the LL and the number of T(t) points during the post-burn-in phase; (c) Predicted parameters for the expected model (black line in (a)). In red line is the predicted length distribution (superimposed on blue histogram in other samples). LL: LogLikelihood; FTA: fission track age; MTL: mean track length; Kin: Dpar; O: observed; P: predicted;

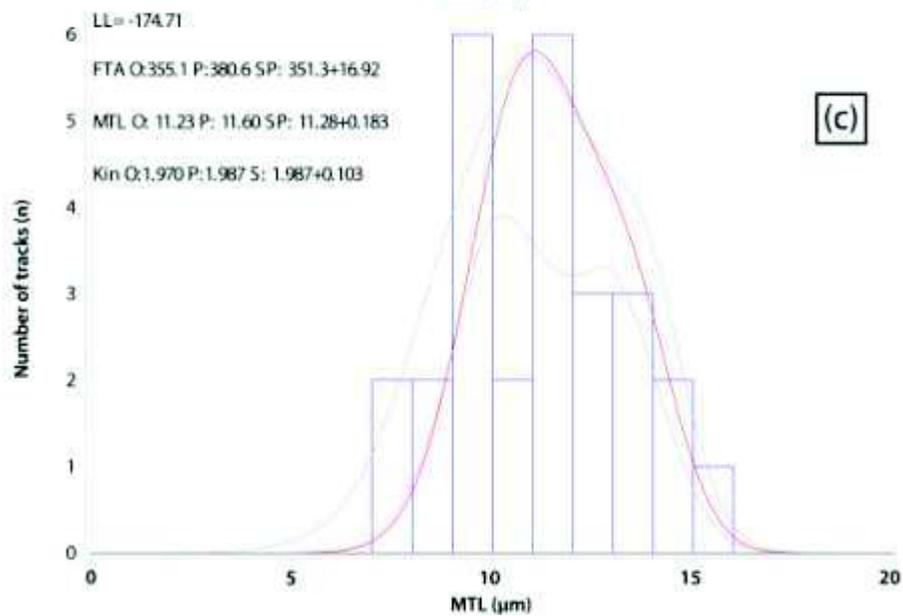
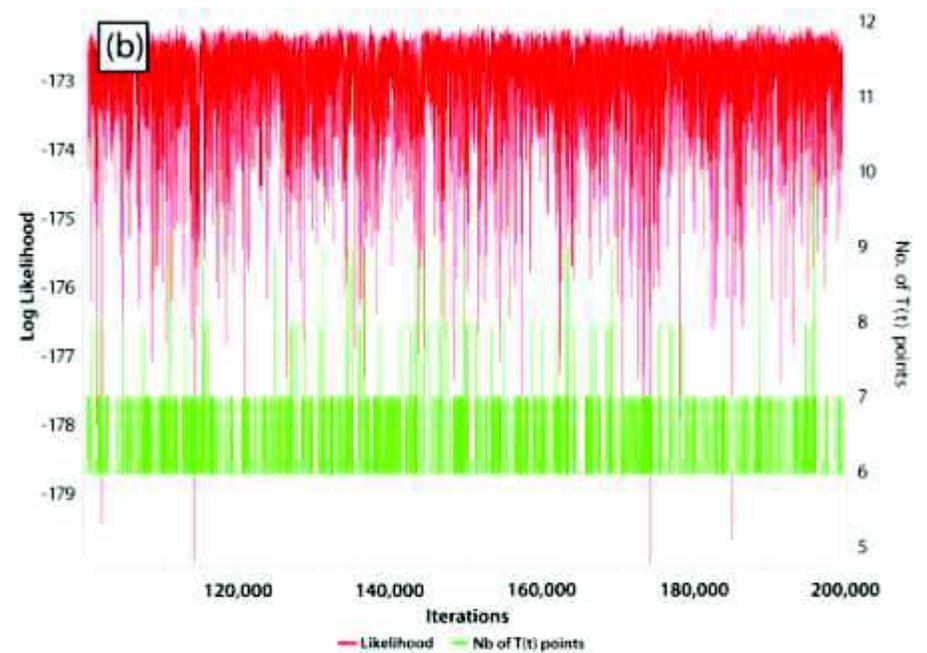
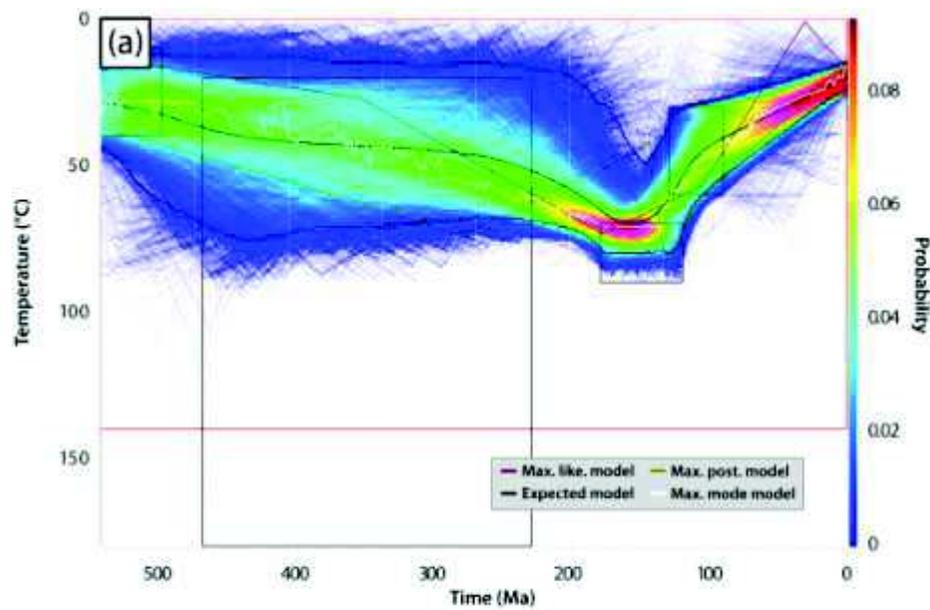


Figure S3: Inverse modeling for samples DEG6. Same legend as in figure S2.

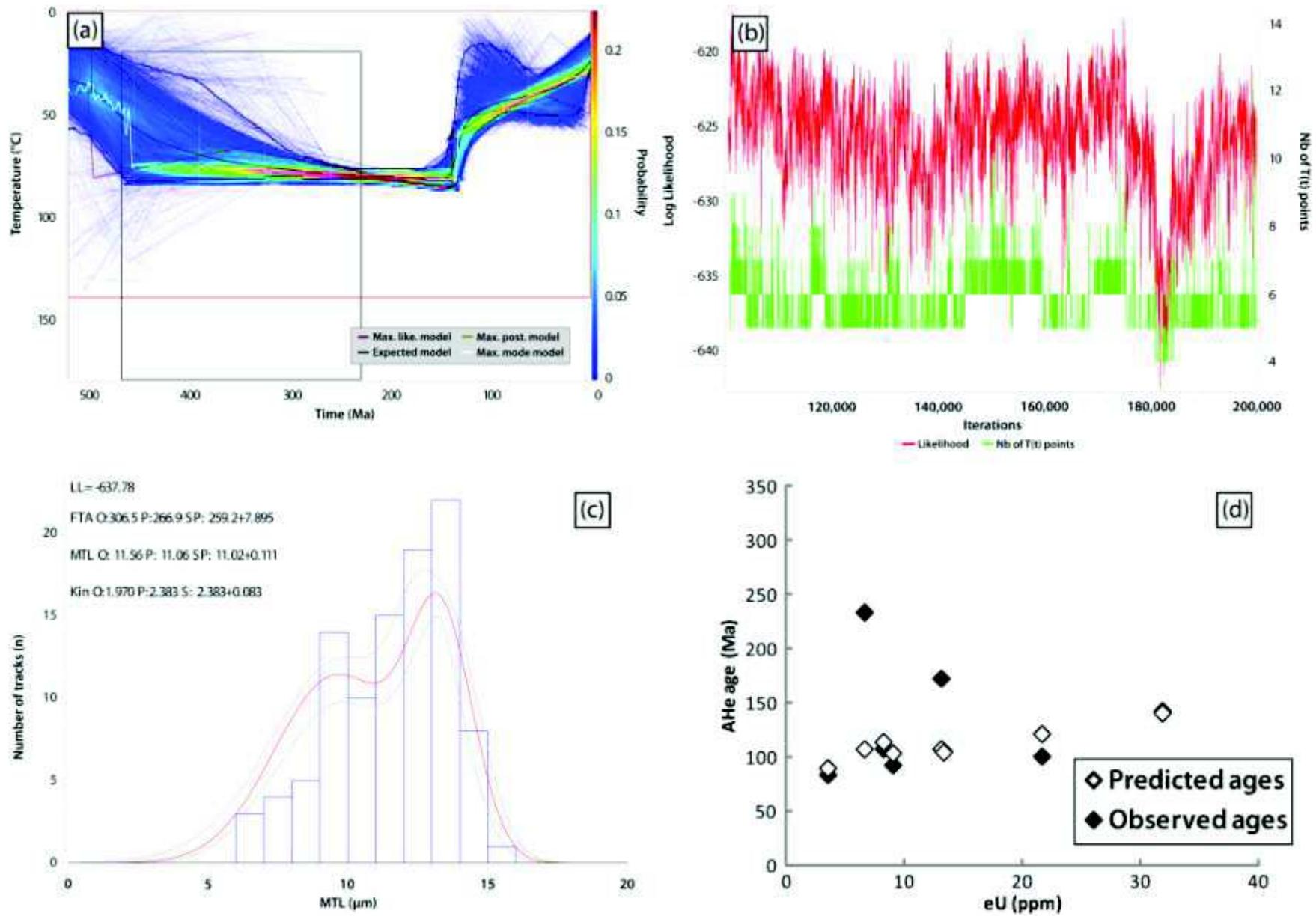


Figure S4: Inverse modeling for sample CH1. Same legend as in figure S2. (d) observed vs. predicted AHe ages.

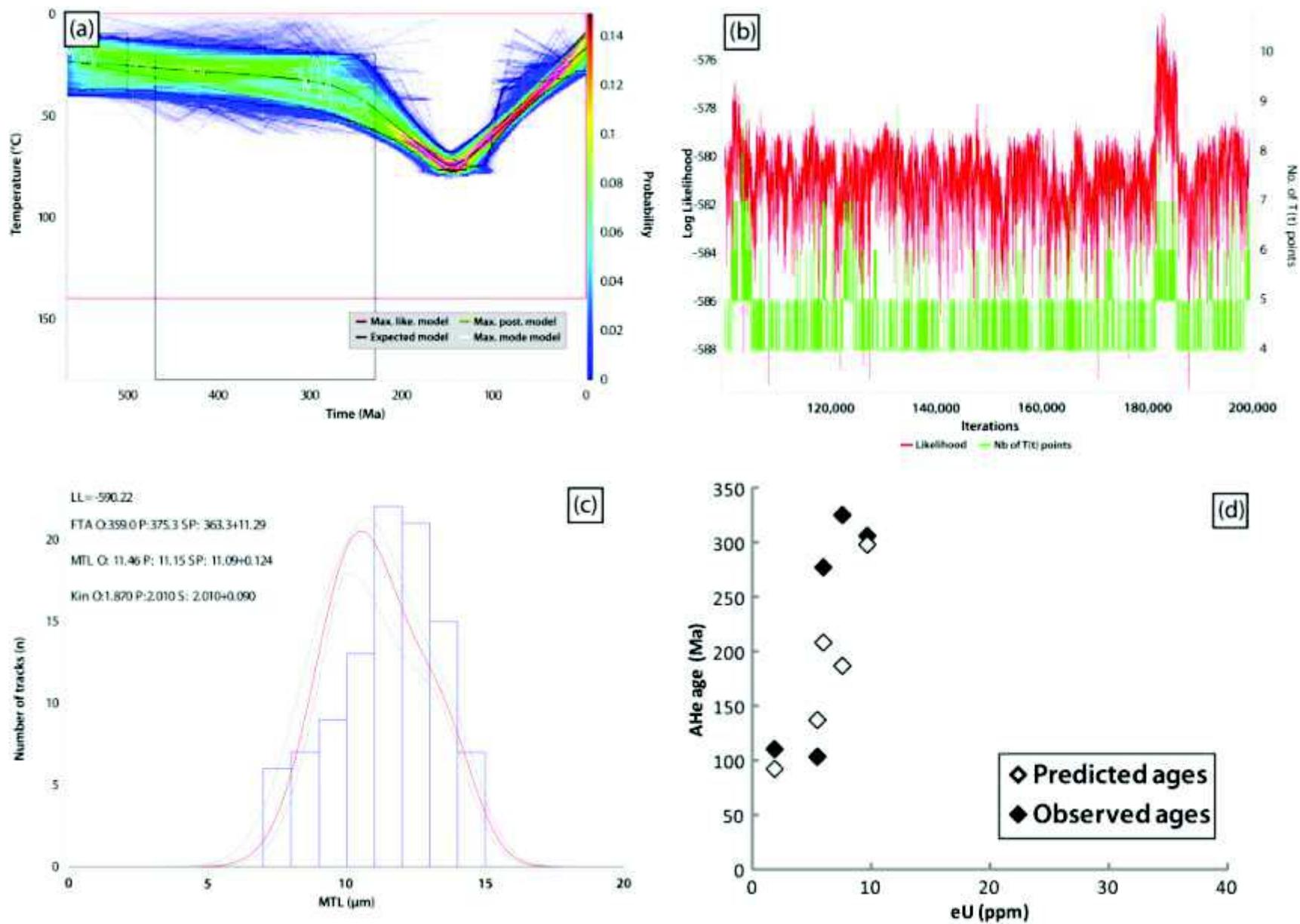


Figure S5: Inverse modeling for sample CH3. Same legend as in figures S2 and S4.

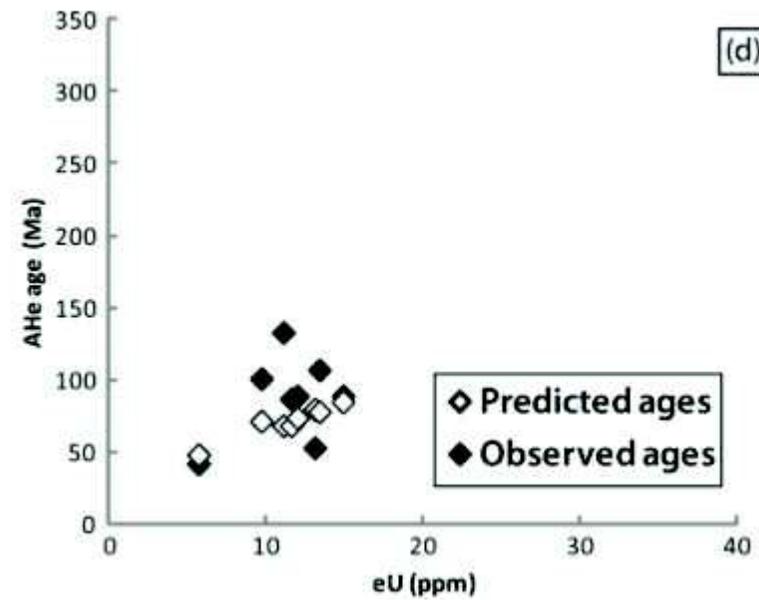
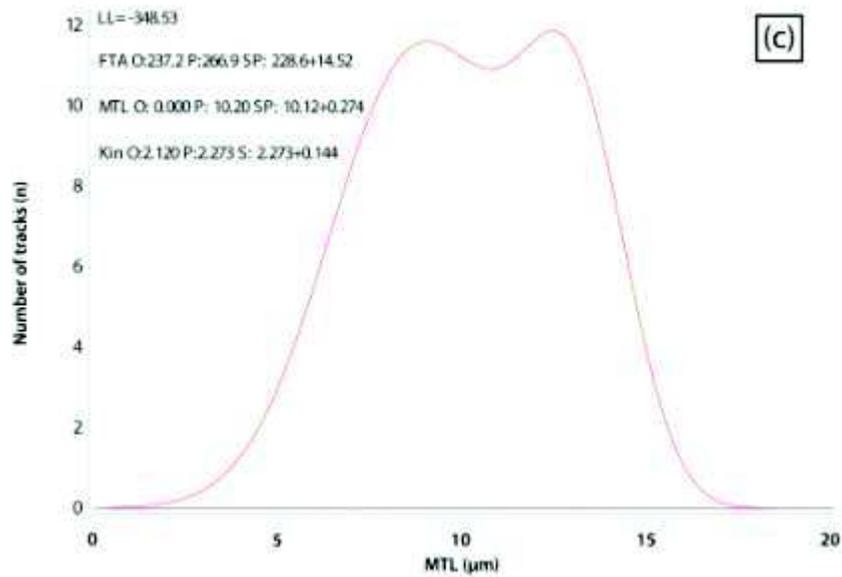
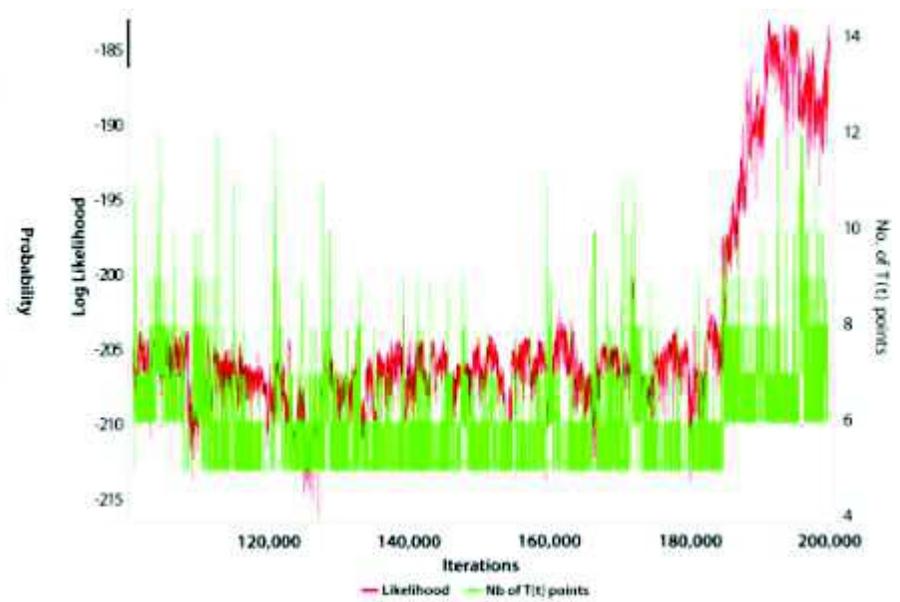
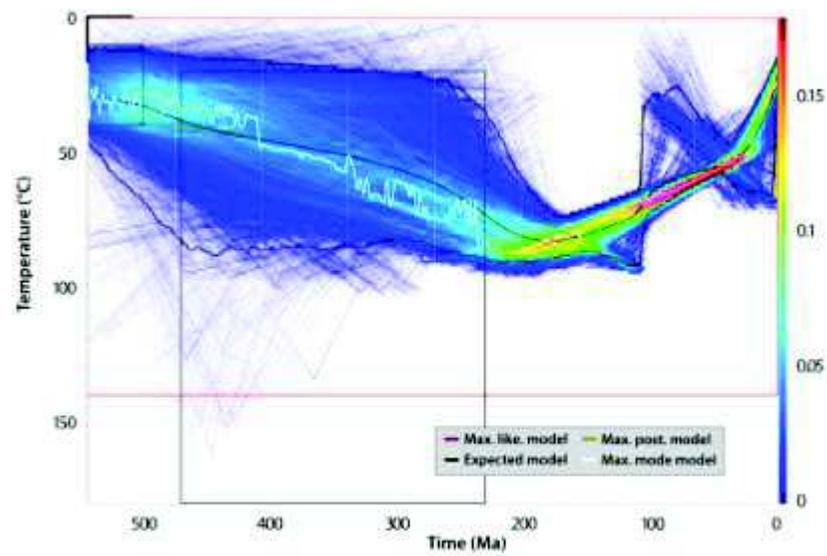


Figure S6: Inverse modeling for sample TL3. Same legend as in figures S2 and S4.

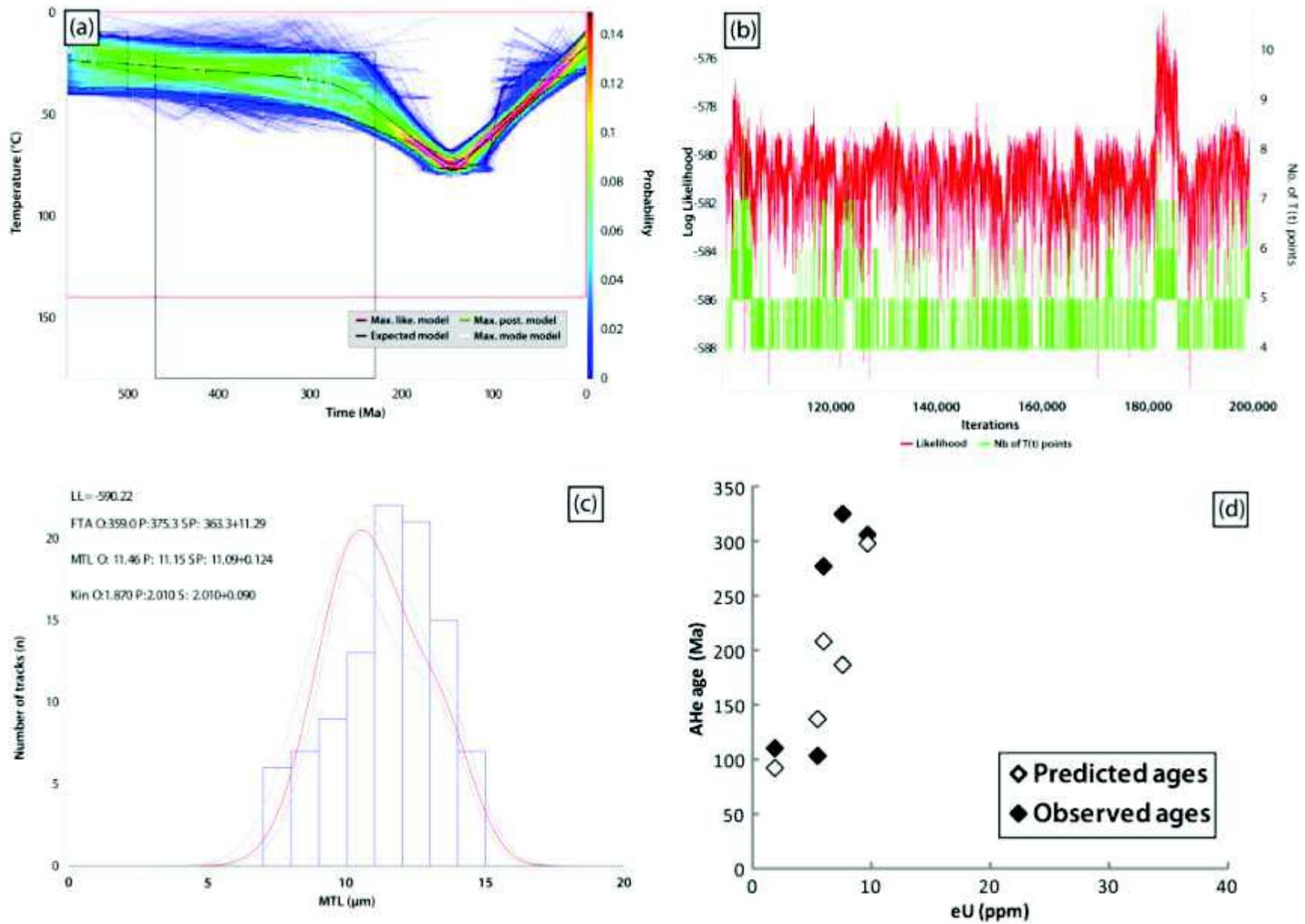


Figure S7: Inverse modeling for sample GH3. Same legend as in figures S2 and S4.

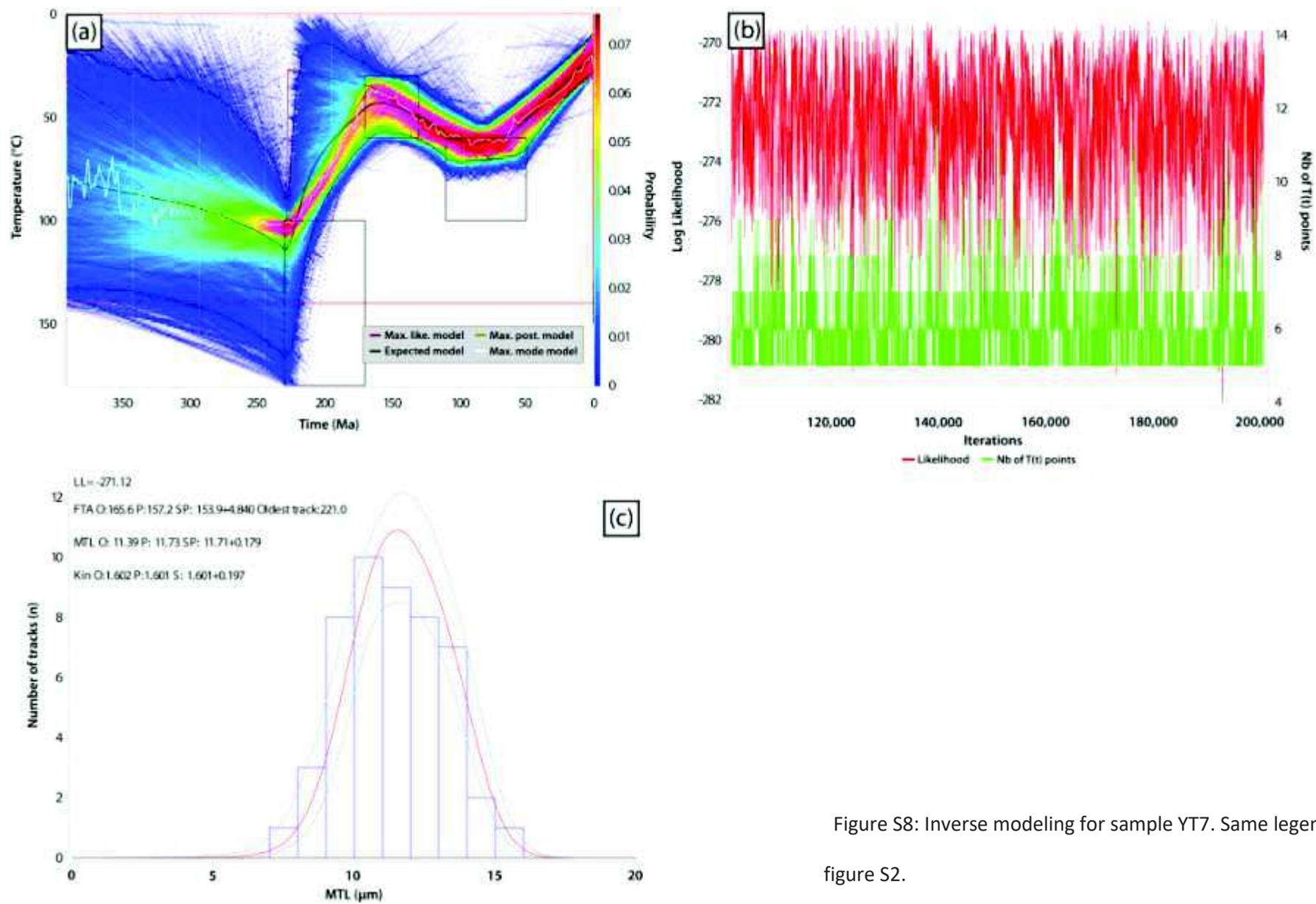


Figure S8: Inverse modeling for sample YT7. Same legend as in figure S2.

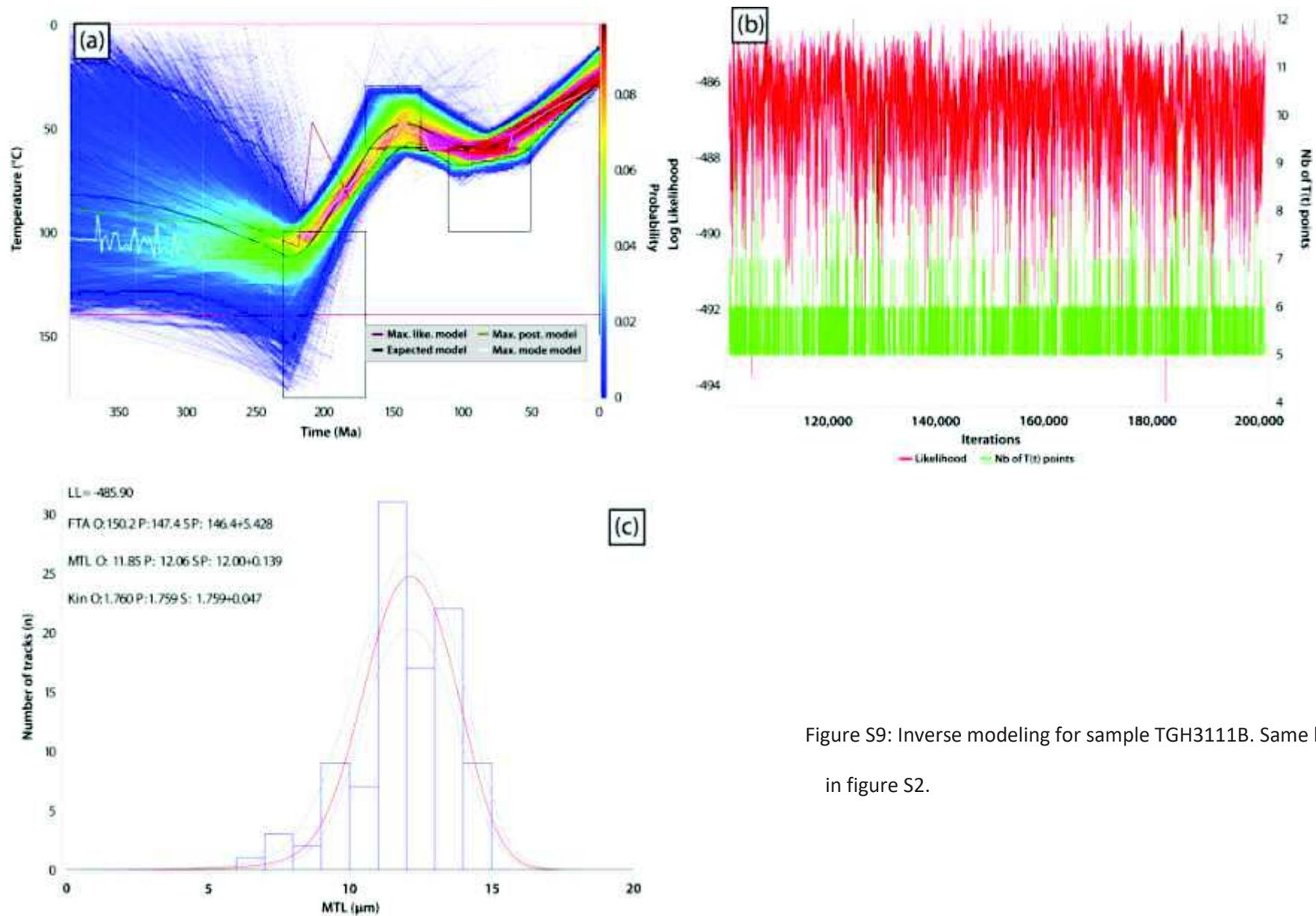


Figure S9: Inverse modeling for sample TGH3111B. Same legend as in figure S2.

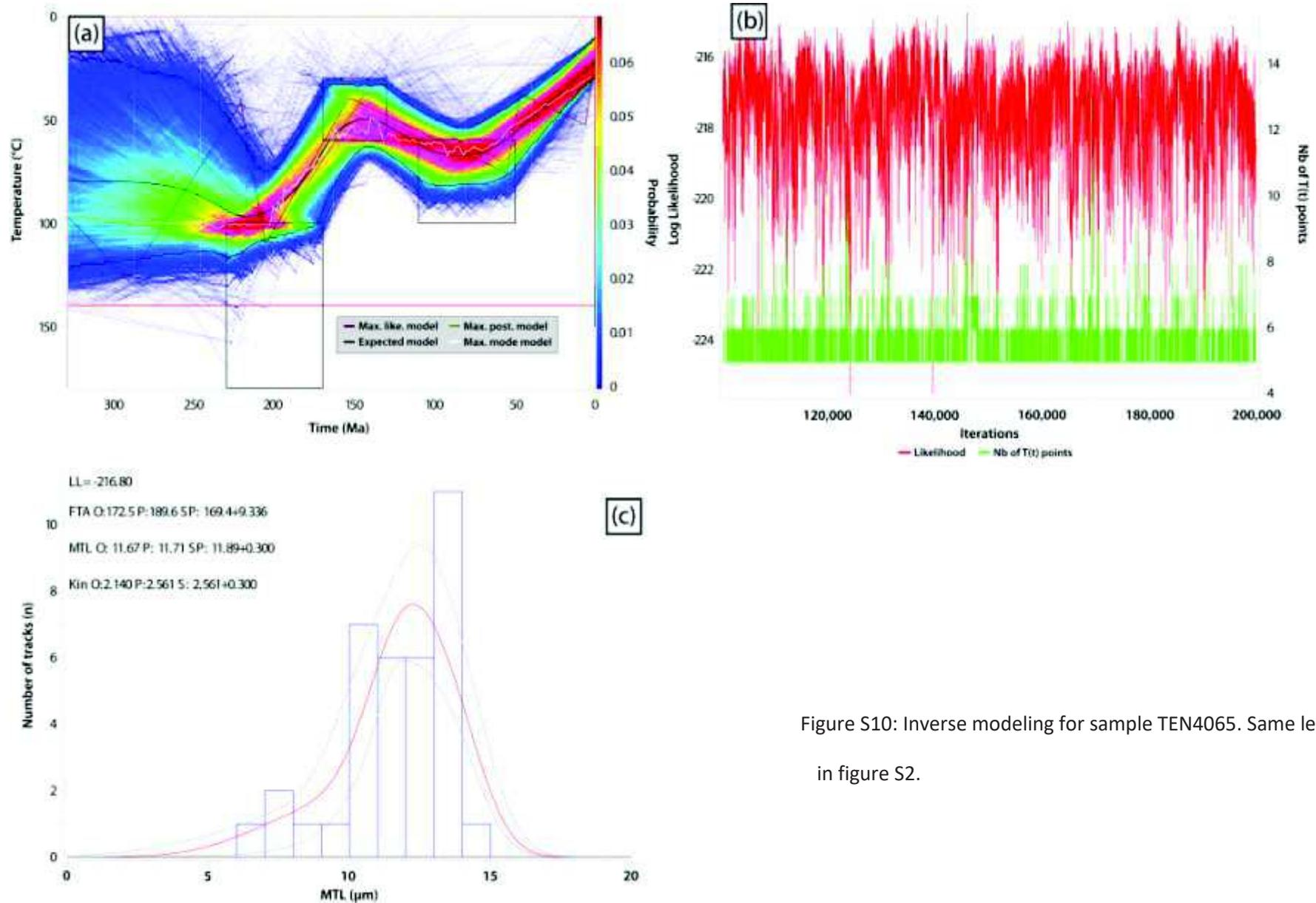


Figure S10: Inverse modeling for sample TEN4065. Same legend as in figure S2.

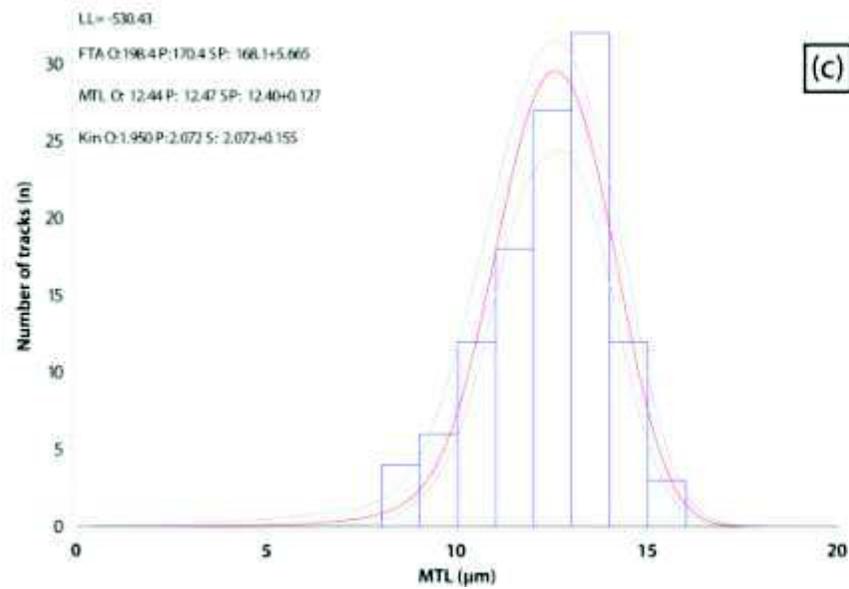
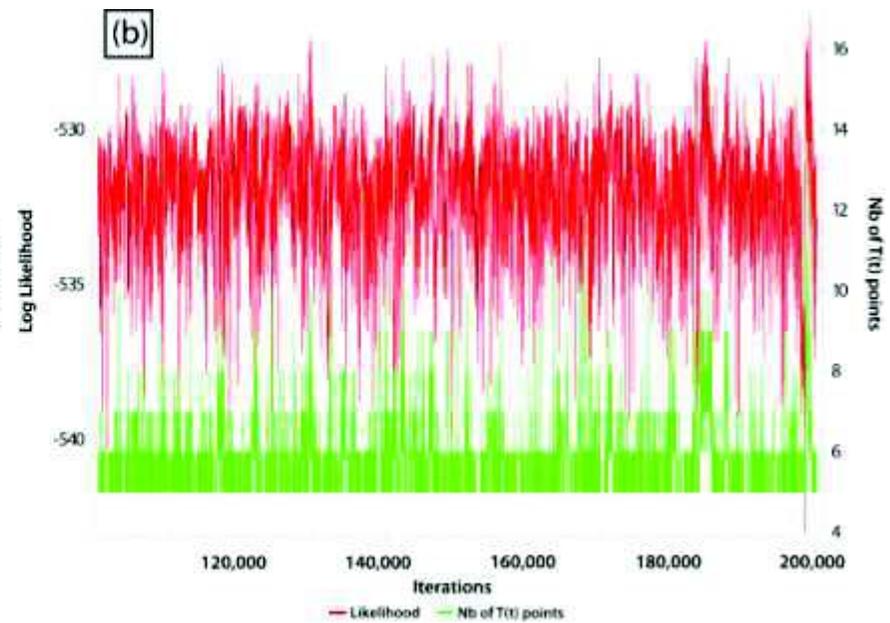
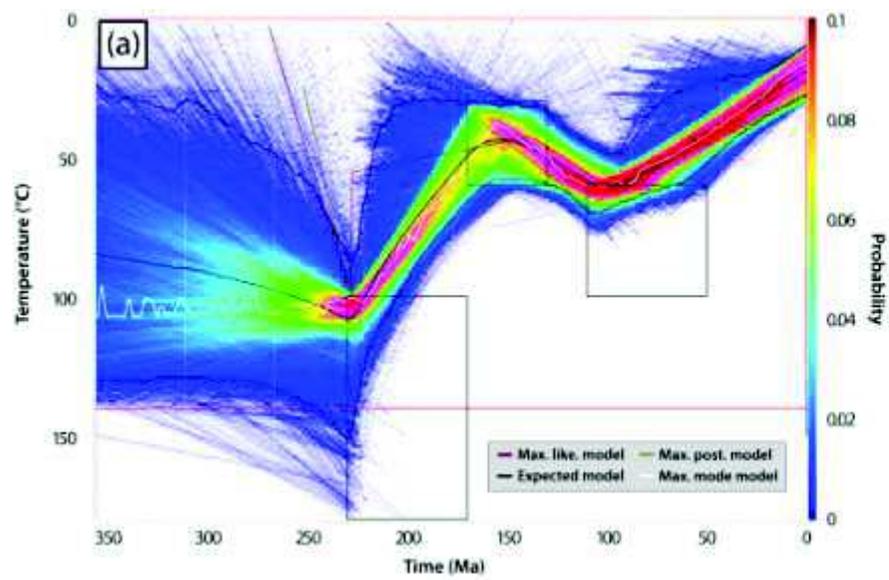


Figure S11: Inverse modeling for sample TGH4072A. Same legend as in figure S2.

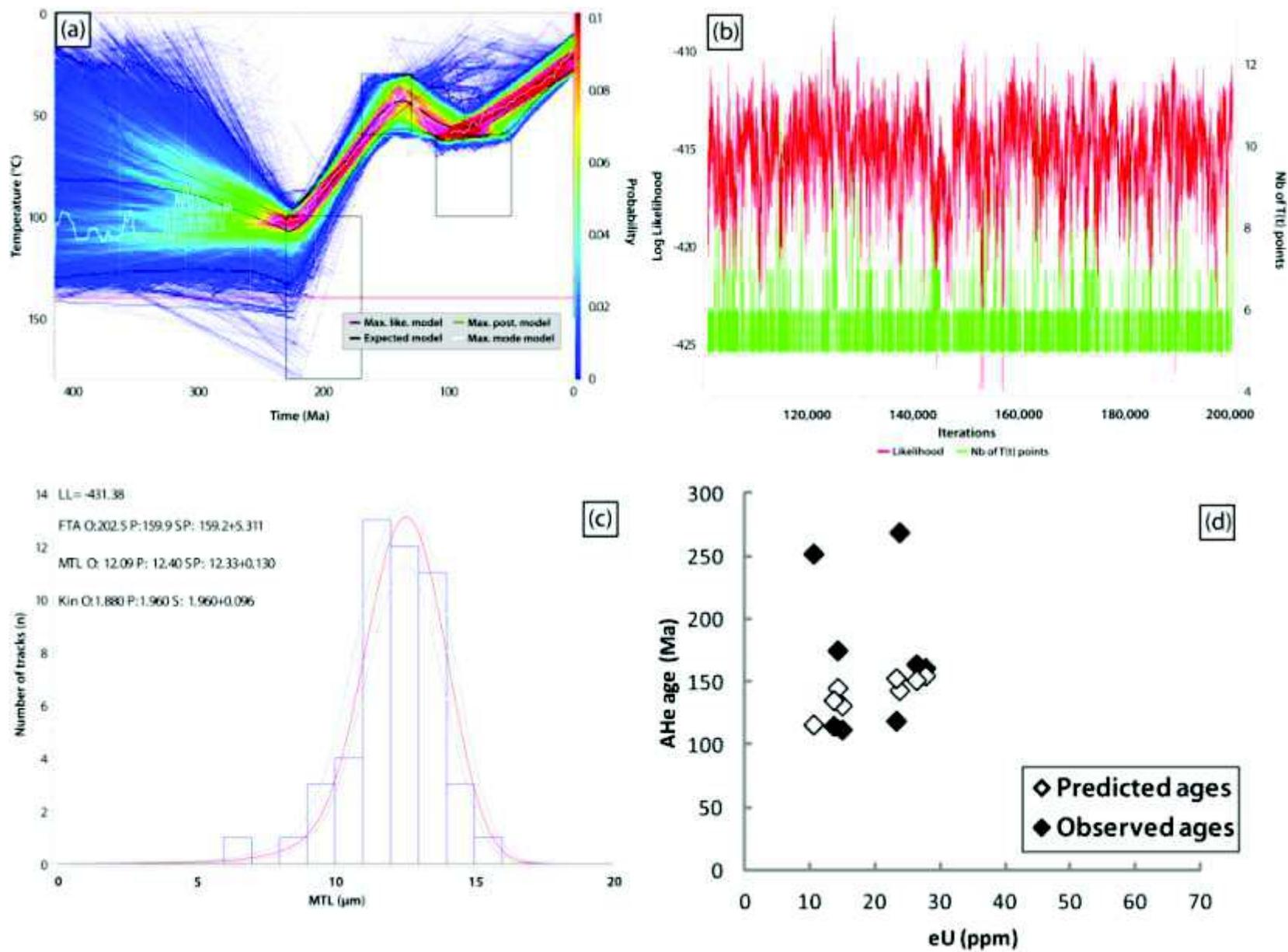


Figure S12: Inverse modeling for sample AL10. Same legend as in figures S2 and S4.

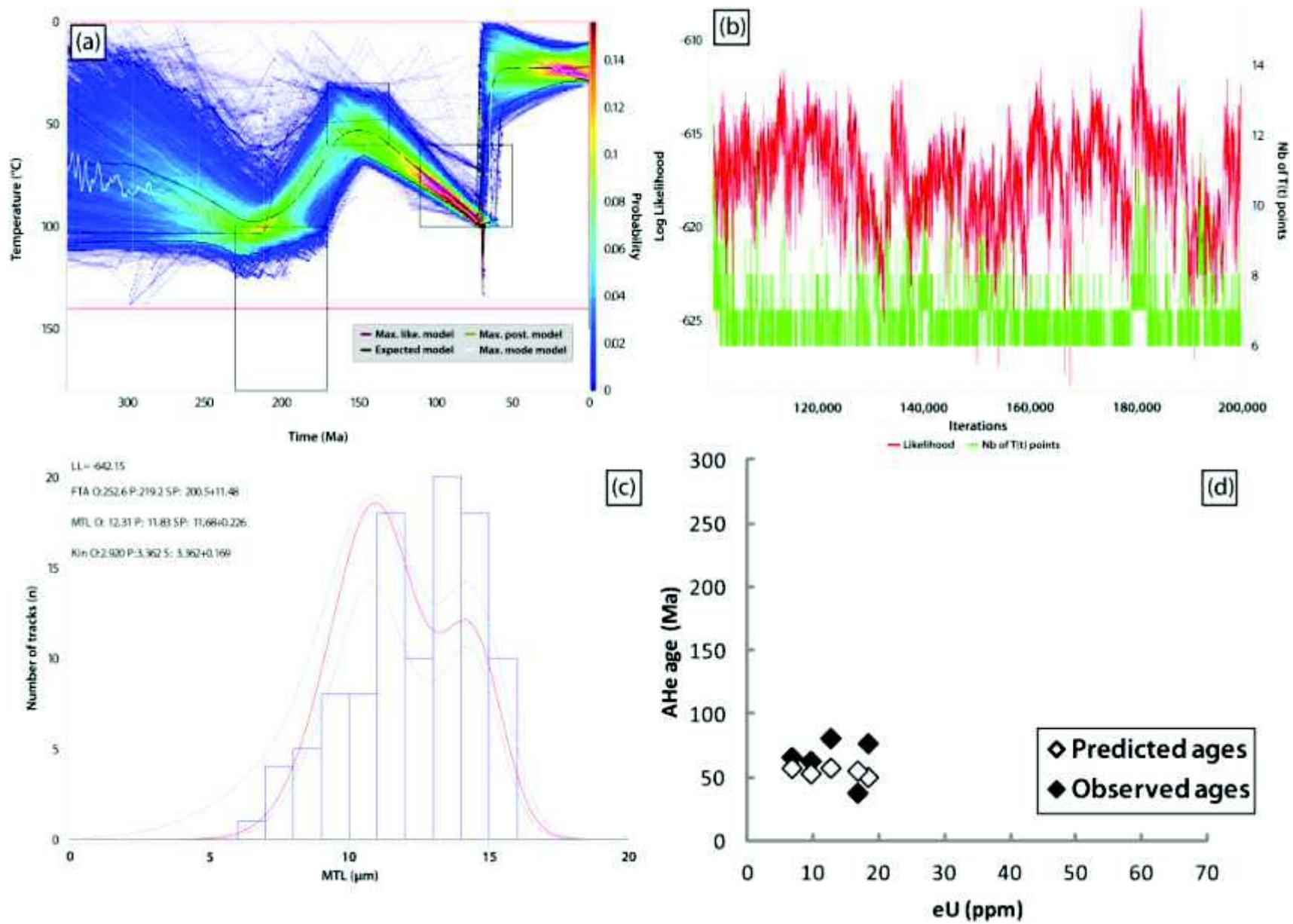


Figure S13: Inverse modeling for sample TEN153. Same legend as in figures S2 and S4.

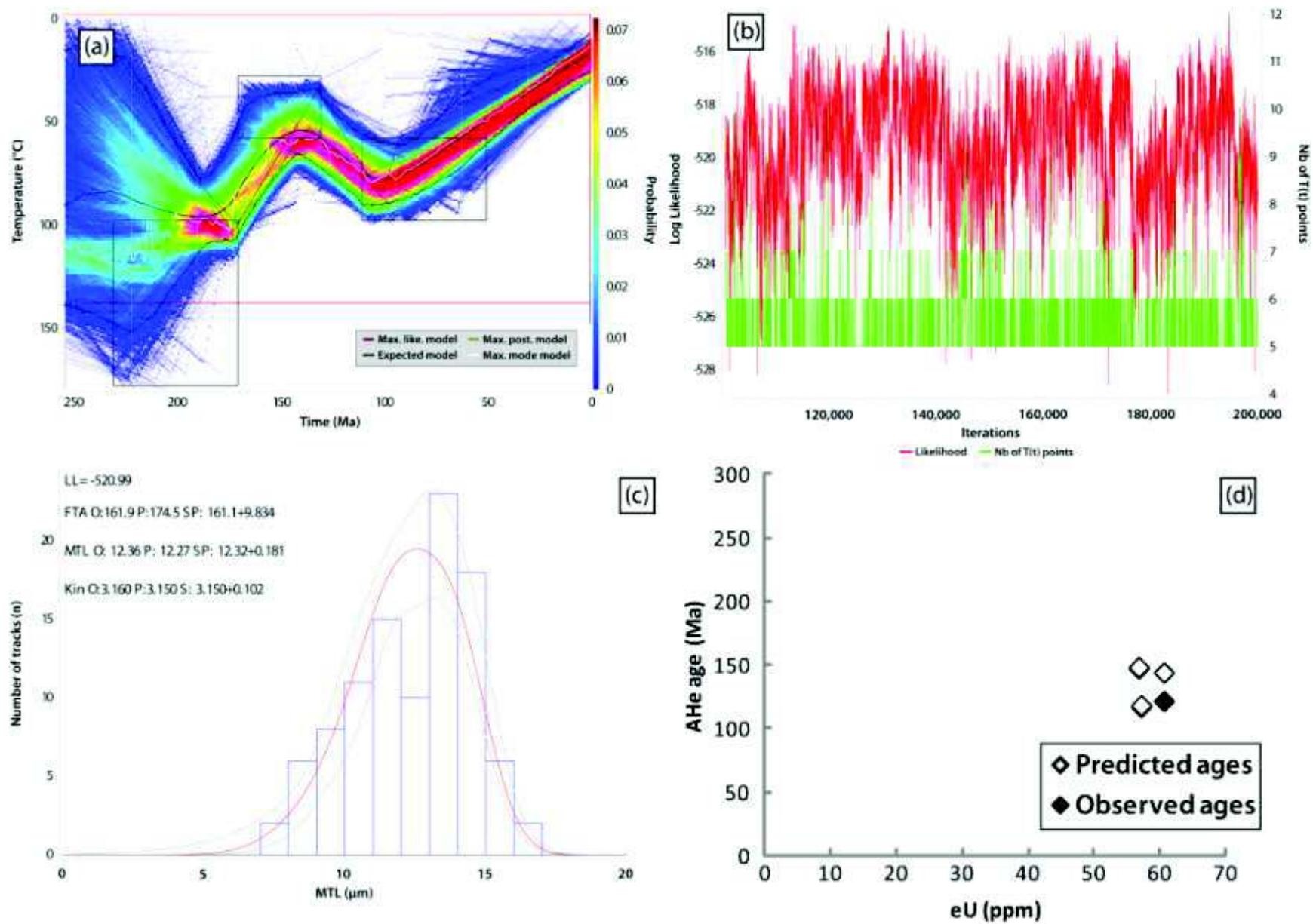


Figure S14: Inverse modeling for samples TEN1185. Same legend as in figures S2 and S4.

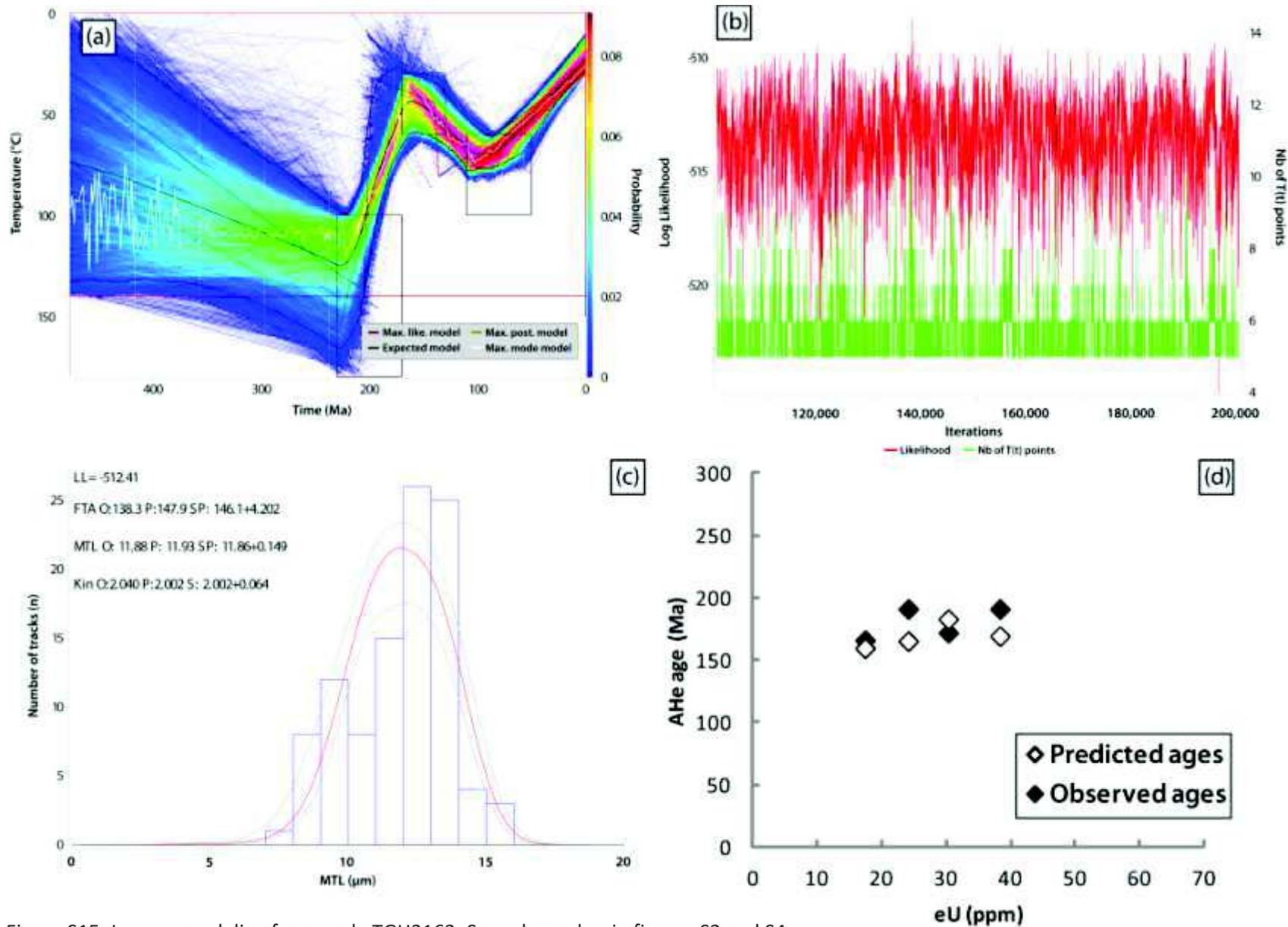


Figure S15: Inverse modeling for sample TGH3163. Same legend as in figures S2 and S4.

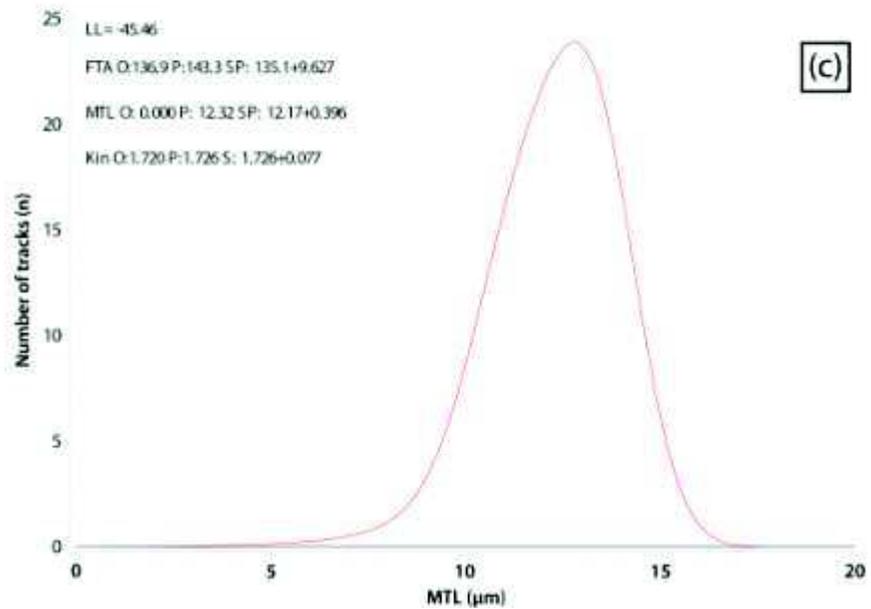
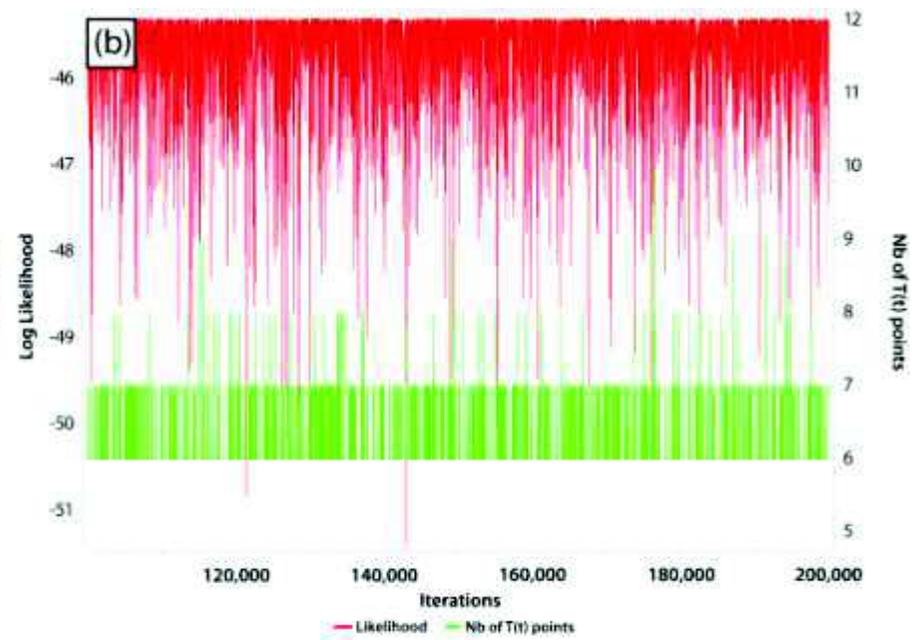
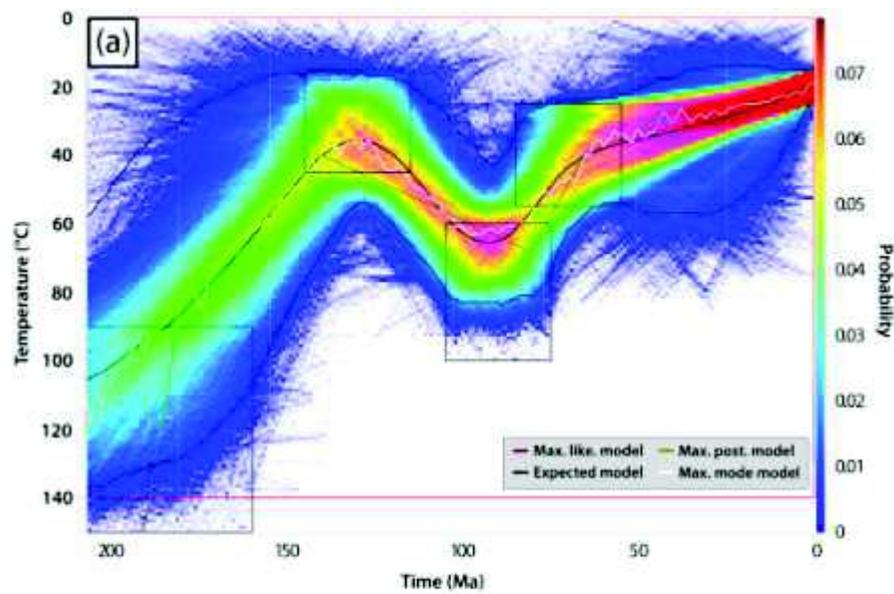


Figure S16: Inverse modeling for sample AG167. Same legend as in figure S2.

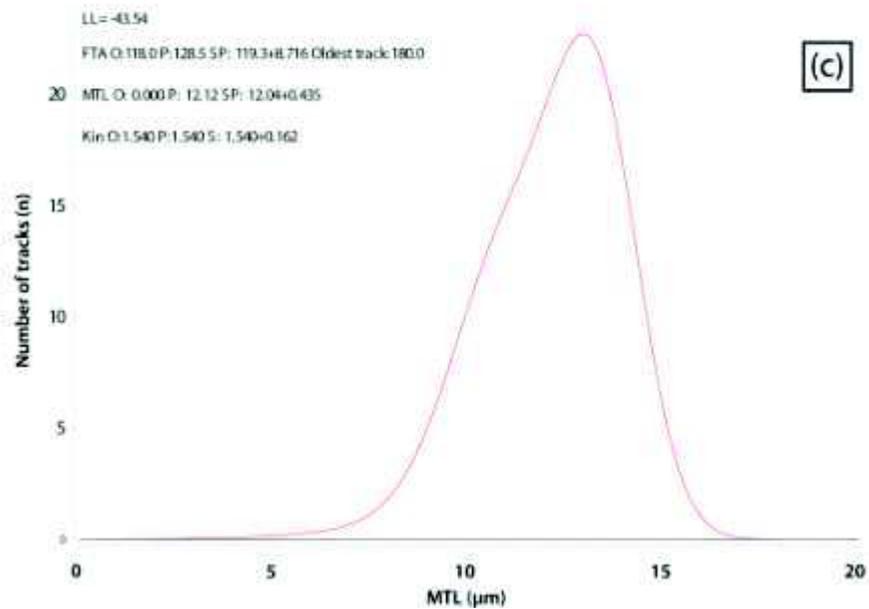
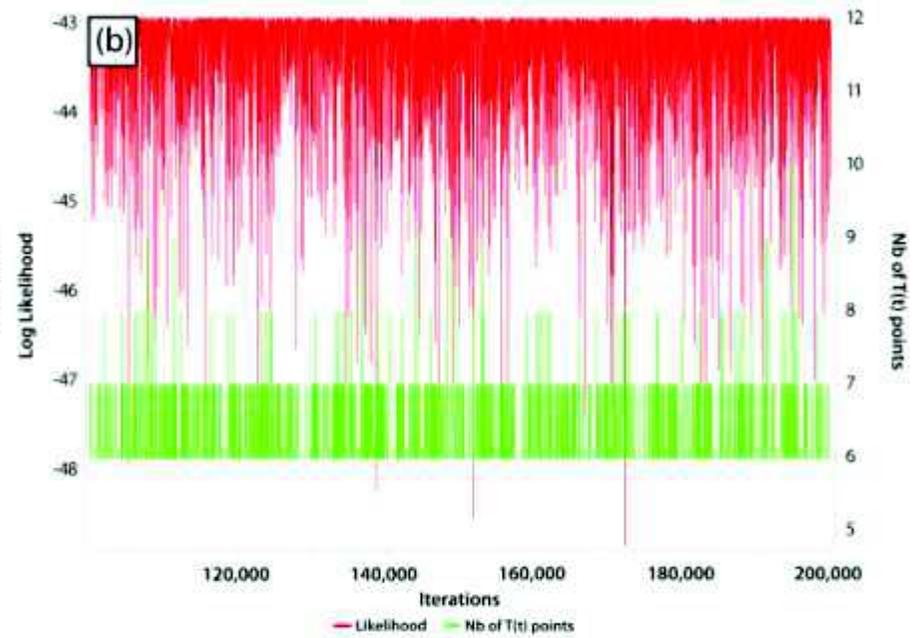
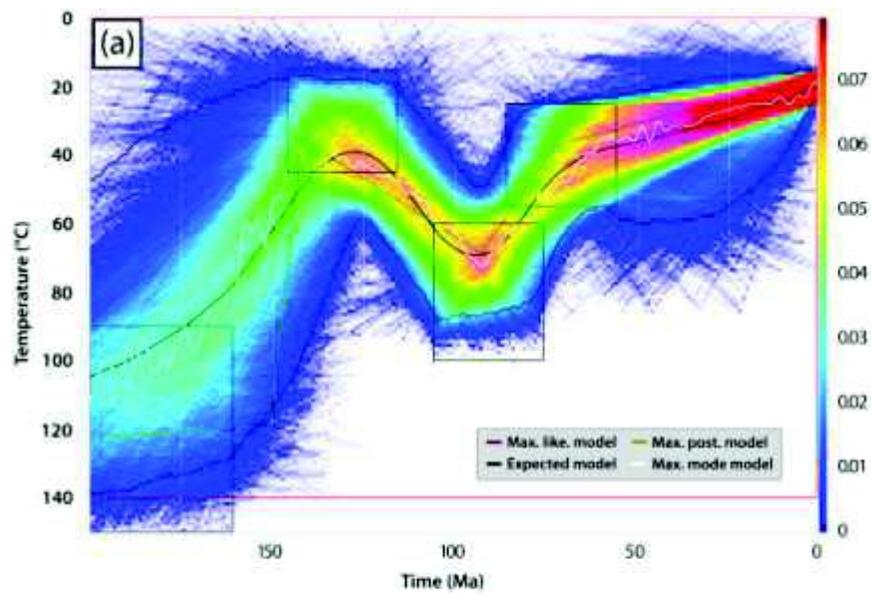


Figure S17: Inverse modeling for sample AG169. Same legend as in figure S2.

Figure S18: Compositional chemical variations in apatites

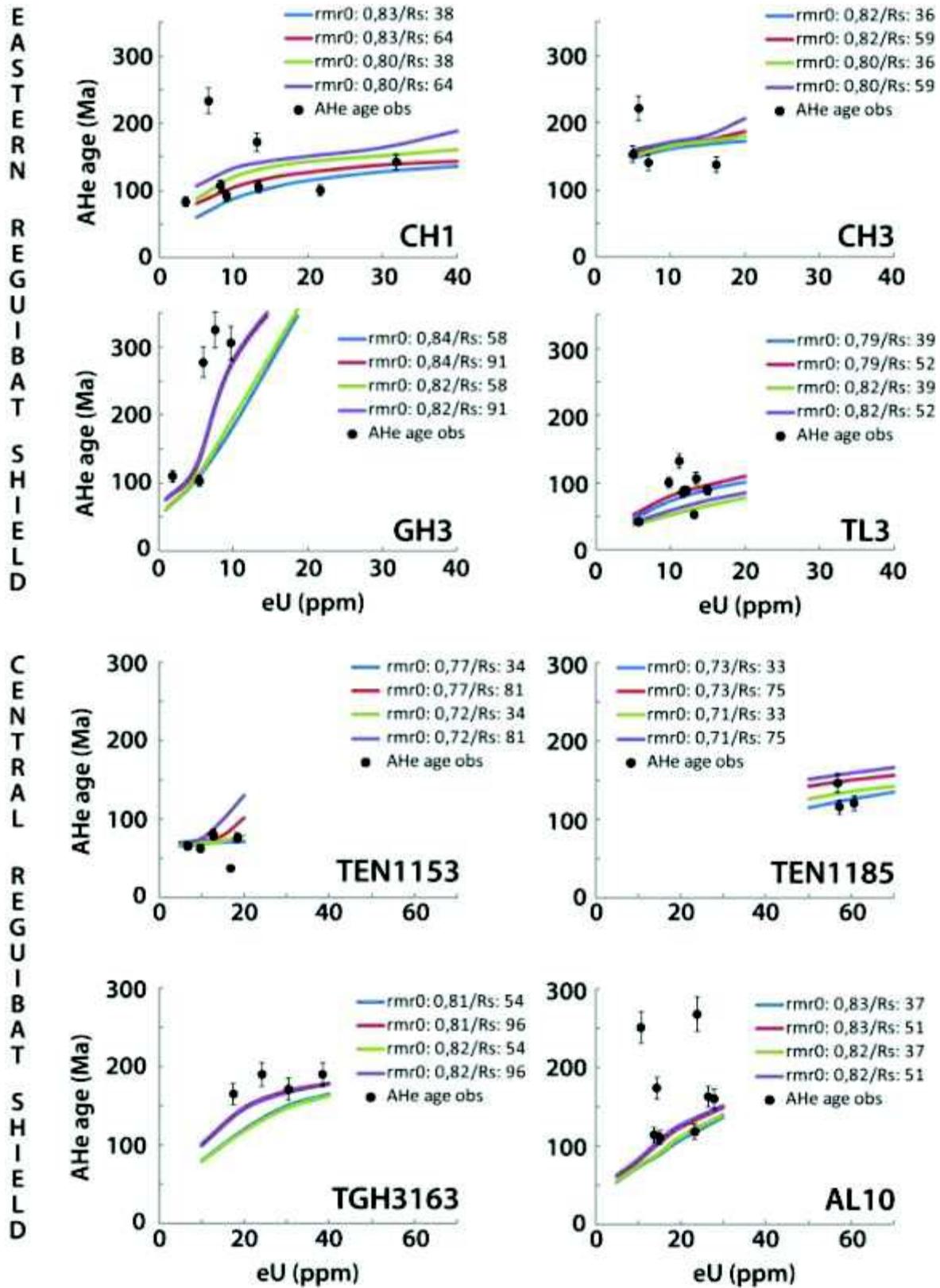


Table S1: AFT results\* for the Reguibat Shield

**Reguibat Central**

Sample	Rock-type	Location	Elevation (m)	$\rho_s$	$\rho_i$	$\rho_d$	P ( $\chi^2$ ) %	Central age (Ma) $\pm 1\sigma$	U (ppm)	MTL ( $\mu\text{m}$ ) $\pm se$	Std dev.	Dpar
TEN1153	gabbro	10° 30' 36"W 24° 1' 12"N	216	0.759 581	0.333 255	6.14 4738	73	256 $\pm$ 21 23	7	12.3 $\pm$ 0.22 102	2.3	2.89 $\pm$ 0.29
TEN1185	gabbro	10° 30' 0"W 24° 6' 36"N	236	2.652 875	1.806 596	6.07 4738	62	163 $\pm$ 10 23	36	12.4 $\pm$ 0.21 101	2.1	1.13 $\pm$ 0.43
TGH3163	granite	9° 52' 48"W 24° 52' 48"N	305	1.546 881	1.219 695	5.99 4738	44	139 $\pm$ 9 20	25	11.9 $\pm$ 0.18 101	1.8	1.95 $\pm$ 0.12
TGH4072A	granite	9° 43' 12"W 24° 28' 48"N	273	1.784 883	0.964 477	5.92 4738	68	199 $\pm$ 13 20	20	12.4 $\pm$ 0.15 113	1.6	1.02 $\pm$ 0.11
TGH3111B	granite	9°22'12"W 24° 00'00"N	252	3.246 1097	2.598 878	6.611 6563	65	150 $\pm$ 8 20	48	11.9 $\pm$ 0.17 101	1.7	1.63 $\pm$ 0.06
TEN4065	microgranite	10° 1'47.00"W 24°20'23.00"N	258	6.444 754	4.462 522	6.595 6563	8	172 $\pm$ 13 20	82	11.7 $\pm$ 0.33 35	2	2.06 $\pm$ 0.53
AL10	granodiorite	7° 7'5.15"W 26°37'33.06"N	394	1.334 675	0.866 438	7.255 6849	63	202 $\pm$ 14 20	15	12 $\pm$ 0.23 49	1.6	1.77 $\pm$ 0.12
YT7	monzogranite	7°20'37.34"W 26°28'59.39"N	384	1.862 1380	1.394 1033	6.825 6849	72	166 $\pm$ 8 20	25	11.4 $\pm$ 0.25 49	1.8	1.60 $\pm$ 0.19

**Reguibat West**

Sample	Rock-type	Location	Elevation (m)	$\rho_s$	$\rho_i$	$\rho_d$	P ( $\chi^2$ ) %	Central age (Ma) $\pm 1\sigma$	U (ppm)	MTL ( $\mu\text{m}$ ) $\pm se$	Std dev.	Dpar
AOS2	syénite neph	14°17'W 22°32'N	400	1.1237 654	1.258 732	6.61 6528	2	107 $\pm$ 8 21	23	11.8 $\pm$ 0.24 56	1.8	1.65 $\pm$ 0.27
AOS3	syénite neph	14°17'W	400	1.899	1.772	6.58	63	128 $\pm$ 6	33	11.9 $\pm$ 0.16	1.6	1.65 $\pm$ 0.27

		22°32'N		1301	1241	6528		21		100		
AOS5	syénite neph	14°17'W	400	1.381	1.308	6.55	1	128 ± 8	24	11.8 ± 0.19	1.8	1.79 ± 0.33
		22°32'N		1153	1092	6528		21		92		
SC11	granite	14°21'38"W	293	0.85	0.627	6.5	50	160 ± 11	12	12.1 ± 0.33	1.8	1.75 ± 0.28
		22°34'36"N		604	446	6528		21		32		
SC12	granite	14°23'00"W	292	1.383	1.155	6.47	27	141 ± 8	22	12.2 ± 0.17	1.8	1.54 ± 0.22
		22°35'14"N		1094	914	6528		21		108		
TCH7	granite	15° 6'37.25"W	194	0.955	0.889	6.52	27	127 ± 8	17	9.4 ± 0.27	2	1.60 ± 0.36
		21°50'54.88"N		916	853	6528		21		37		
SC5	granite	14°29'38.00"W	284	1.04	0.839	6.657	< 1	156 ± 15	15	10.7 ± 0.31	1.7	1.63 ± 0.10
		22°40'50.00"N		1131	913	6563		20		32		
SC9	granite	14°18'56.00"W	318	1.742	1.549	6.641	< 1	143 ± 13	28	11.2 ± 0.35	1.9	1.70 ± 0.11
		22°33'8.00"N		866	770	6563		20		31		
SC15	granite	14°28'52.00"W	282	0.6	0.425	6.626	10	175 ± 16	8	-	-	1.70 ± 0.12
		22°40'17.00"N		482	341	6563		20		-	-	
TAS29	gneiss	15°32'55.96"W	110	0.743	0.778	6.586	11	115 ± 6	14	12.2 ± 0.25	1.8	1.70 ± 0.12
		20°59'34.10"N		1047	1096	6849		20		51		
AG167	charnockite	13°24'2.07"W	233	0.218	0.195	6.73	74	137 ± 12	4	-	-	1.72 ± 0.08
		20°42'56.76"N		323	289	6849		20		-	-	
AG169	charnockite	13°24'2.07"W	237	0.201	0.207	6.682	93	118 ± 10	4	-	-	1.54 ± 0.17
		20°42'56.76"N		309	319	6849		20		-	-	
TAS233	volcanite	15°32'55.96"W	110	0.68	0.651	6.634	87	126 ± 7	12	12.5 ± 0.18	1.8	1.63 ± 0.15
		20°59'34.10"N		797	763	6849		20		102		

**Reguibat East**

Sample	Rock-type	Location	Elevation (m)	$\rho_s$	$\rho_i$	$\rho_d$	P ( $\chi^2$ ) %	Central age (Ma) $\pm 1\sigma$	U (ppm)	MTL ( $\mu\text{m}$ ) $\pm se$	Std dev.	Dpar
IG3	rhyolite	6° 9'0.43"W	366	0.469	0.149	6.968	84	393 $\pm$ 36	3	-	-	1.66 $\pm$ 0.16
		26° 6'22.40"N		<i>543</i>	<i>172</i>	<i>6849</i>		20				
CH1	gabbrodiorite	3°35'36.69"W	252	1.098	0.454	7.159	6	307 $\pm$ 26	8	11.5 $\pm$ 0.21	2.1	1.86 $\pm$ 0.19
		25°35'45.94"N		<i>862</i>	<i>356</i>	<i>6849</i>		20		101		
CH2	gabbrodiorite	3°35'36.69"W	252	3.105	1.516	7.112	18	264 $\pm$ 21	26	12 $\pm$ 0.2	1.7	1.99 $\pm$ 0.17
		25°35'45.94"N		<i>770</i>	<i>376</i>	<i>6849</i>		20		69		
CH3	gabbrodiorite	3°35'36.69"W	252	1.059	0.426	7.064	86	315 $\pm$ 24	7	11.5 $\pm$ 0.29	2.3	1.95 $\pm$ 0.18
		25°35'45.94"N		<i>686</i>	<i>276</i>	<i>6849</i>		20		64		
GH3	trondhjemite	6° 3'54.77"W	360	1.177	0.41	7.016	6	359 $\pm$ 27	7	11.5 $\pm$ 0.19	1.9	1.76 $\pm$ 0.16
		25°29'36.53"N		<i>1130</i>	<i>394</i>	<i>6849</i>		20		100		
DEG6	gabbro	2°57'15.60"W	355	2.276	0.701	6.111	46	355 $\pm$ 25	12	11.2 $\pm$ 0.41	2.1	1.97 $\pm$ 0.11
		26° 4'50.02"N		<i>1065</i>	<i>328</i>	<i>6849</i>		20		27		
GH20	gabbro	6° 0'2.87"W	350	0.471	0.101	5.996	73	497 $\pm$ 61	2	-	-	1.75 $\pm$ 0.13
		25°32'51.89"N		<i>206</i>	<i>44</i>	<i>3012</i>		10		-		
TL3	gabbro	3°10'37.45"W	381	0.818	0.376	6.052	66	237 $\pm$ 21	8	-	-	2.12 $\pm$ 0.19
		27°21'31.99"N		<i>447</i>	<i>207</i>	<i>3012</i>		20				

\*  $\rho$  – density of tracks with s and i – spontaneous and induced densities in apatite crystals and the mica detector; d – tracks density of the neutron glass monitor (CN5); for  $\rho_d$  is written in italics the number of counted tracks. Densities are expressed in  $10^5 \text{t/cm}^2$ . MTL – mean track length. Values in italics for central age and MTL are, respectively, the number of single-grain ages and the number of lengths measured.  $1\sigma$  is the standard deviation. Dpar corresponds to a kinetic factor determined for each sample (Barbarand *et al.*, 2003).

Table S2: AHe results\* for the whole Reguibat Shield

*Reguibat Central*

Name	Rs ( $\mu\text{m}$ )	Weight( $\mu\text{g}$ )	FT	4He(ncc/g)	U (ppm)	Th (ppm)	Sm (ppm)	eU (ppm)	Age (Ma)	Age c. (Ma)*	s.d.
1185C	52,1	3,11	0,756	678000	45,4	63,3	NA	60,6	104	138	11
1185D	74,5	10,33	0,849	868000	44,4	51,6	-	56,8	142	167	13
1185E	33,4	1,02	0,65	530000	39,4	74	-	57,1	86	133	11
1153-A	80,8	11,85	0,87	46201,6	3,8	11,9	7,0	6,7	57	66	5
1153D	34,4	1,17	0,715	120399,0	10,4	31,9	20,3	18,3	55	77	6
1153-F	63,2	6,54	0,815	100000,8	7,6	20,3	9,5	12,6	66	81	6
1153-H	59	4,69	0,83	63086,4	11,2	22,6	12,5	16,7	31	38	3
1153-I	47,5	2,56	0,79	57756,0	5,5	16,8	13,3	9,6	50	63	5
1153-J	71,5	8,33	0,87	58868,8	5,6	17,0	12,9	9,7	50	58	5
3163-A	54,1	3,6	0,809	717183,1	37,7	1,9	27,2	38,3	155	191	15
3163-E	66	7,11	0,827	288616,5	16,9	1,4	17,6	17,4	137	166	13
3163-I	65,6	6,26	0,847	470679,8	17,8	25,6	24,6	24,1	162	191	15
3163G	96,1	17,27	0,875	549045,6	25,0	22,0	NA	30,3	150	172	14
AL10-A	46	2,4	0,755	405681,5	22,5	20,6	31,8	27,7	121	161	13
AL10-E	39,3	1,18	0,701	675195,0	76,1	26,7	31,3	82,8	67	96	8
AL10-C	50,5	3,53	0,765	229447,2	11,1	11,9	29,3	14,2	134	175	14
AL10-L	44,1	1,57	0,679	1341456,8	34,3	31,1	59,4	42,2	263	388	31
AL10-J	37,2	1,22	0,724	231868,3	7,9	10,0	37,4	10,5	182	252	20
AL10-I	45,5	2,02	0,76	395904,9	22,4	14,9	41,0	26,3	124	164	13
AL10-B	39	1,39	0,726	557702,2	20,6	11,6	37,5	23,7	195	269	21

AL10-K	37,9	1,28	0,717	145483,1	12,5	8,8	35,5	14,9	81	112	9
AL10-F	38,7	1,23	0,687	129286,7	9,5	15,8	44,8	13,6	79	115	9
AL10-G	39,9	1,23	0,707	1327362,4	32,4	26,5	65,3	39,3	280	396	32
AL10-H	42,6	1,58	0,713	236976,2	18,4	18,2	50,1	23,2	85	119	10

**Reguibat West**

Name	Rs (µm)	Weight(µg)	FT	4He(ncc/g)	U (ppm)	Th (ppm)	Sm (ppm)	eU (ppm)	Age (Ma)	Age c. (Ma)*	s.d.
AOS3A	57,7	4,14	0,781	379655,5	29,6	40,2	403,0	42,5	74	95	8
AOS3B	48,3	2,56	0,786	368565,3	29,6	47,8	167,0	42,4	72	92	7
AOS3C	58,4	5,02	0,803	168335,8	27,7	28,6	318,0	37,1	38	47	4
AOS3E	55	3,82	0,806	317447,5	50,1	31,7	391,0	60,9	43	54	4
AOS5A	54,4	3,77	0,843	17656,2	9,4	7,6	125,0	12,3	12	14	1
AOS5D	48,7	2,8	0,736	59629,6	17,5	16,4	263,0	23,5	21	29	2
AOS5F	48,2	2,27	0,754	175595,4	29,5	24,2	195,0	36,9	39	52	4
AOS2A	58,6	4,48	0,783	252824,1	31,0	12,2	400,0	37,2	56	72	6
AOS2B	62,7	6,65	0,812	219640,8	23,1	16,3	105,0	27,8	65	81	6
AOS2C	47	2,35	0,777	47197,6	14,8	11,6	152,0	18,8	21	27	2
AOS2D	43,8	1,96	0,756	77464,5	20,3	30,6	179,0	29,1	22	29	2
TCH7A	49,4	2,8	0,802	194360,7	59,4	34,9	179,0	69,2	23	29	2
TCH7B	68,7	8,03	0,833	137470,0	19,1	23,5	339,0	27,5	41	50	4
TCH7C	63,6	6,25	0,823	318644,3	43,4	11,1	229,0	47,9	55	67	5
TCH7D	64,6	6,31	0,838	106663,8	13,5	8,9	267,0	17,8	50	59	5

SC5A	46,9	2,61	0,756	209790,4	20,7	5,3	83,0	22,6	77	101	8
SC5C	56,6	4,35	0,802	26663,6	6,3	6,0	16,0	7,9	28	35	3
SC5D	59,9	5,69	0,802	214046,7	26,8	10,6	14,9	29,5	60	75	6
SC9B	59,9	5,4	0,809	59285,0	6,7	11,6	271,0	11,7	42	52	4
SC9D	41,4	1,92	0,717	282683,0	26,7	37,2	274,0	37,9	62	86	7
SC9E	45,8	2,35	0,761	606340,6	52,0	65,8	401,0	71,0	71	93	7
SC11C	50,3	3,01	0,782	18223,7	4,7	4,0	284,0	7,9	19	24	2
SC11D	68	7,34	0,839	92903,5	7,3	13,5	228,0	12,4	62	74	6
SC11E	53,2	2,98	0,775	157369,9	11,4	25,5	103,0	18,4	71	92	7
SC11F	66,7	5,97	0,815	47092,6	8,2	2,9	266,0	11,0	35	43	3
SC12A	41,6	1,65	0,749	108423,6	9,6	13,1	232,0	14,6	61	82	7
SC12D	64	6,22	0,827	180770,1	19,1	9,4	241,0	23,3	64	78	6
SC12G	49,5	2,44	0,754	222394,6	22,1	12,8	141,0	26,3	48	63	5
SC12F	52,3	2,8	0,77	151382,1	24,6	25,6	360,0	33,7	55	71	6
SC15A	59,7	4,73	0,833	141643,9	10,6	16,3	382,0	17,5	67	80	6
SC15B	56,5	3,7	0,782	16790,6	3,6	8,7	126,0	6,7	21	27	2
SC15F	48,3	2,27	0,747	50901,3	5,6	19,5	90,0	11,0	39	52	4
SC15G	56,5	3,99	0,828	234089,4	25,4	23,6	340,0	33,8	57	69	6
T233-B	52,5	3,31	0,833	87654,0	9,1	2,6	12,9	9,8	74	89	7
T233-H	55,5	4,01	0,803	163091,7	35,9	12,9	9,4	39,0	35	43	3
T233-D	49,3	1,4	0,678	263063,3	27,0	7,2	30,6	29,0	75	111	9
T233-G	58,8	4,58	0,822	55323,1	6,5	1,9	14,3	7,0	65	79	6
T233-F	49,7	2,85	0,786	127884,5	12,9	3,2	12,5	13,7	77	98	8
TAS29A	66,7	5,97	0,815	168827,7	14,1	5,4	12,1	15,4	90	111	9

TAS29B	42,1	2	0,767	238975,6	16,0	16,9	27,9	20,1	98	127	10
TAS29C	50	2,57	0,758	196139,6	19,6	4,9	10,1	20,8	78	102	8
TAS29D	56,9	3,14	0,748	196541,4	10,7	3,9	13,1	11,7	138	185	15
TAS29E	71,4	7,22	0,84	57789,0	7,2	1,8	6,5	7,6	62	74	6

**Reguibat East**

Name	Rs ( $\mu\text{m}$ )	Weight( $\mu\text{g}$ )	FT	4He(ncc/g)	U (ppm)	Th (ppm)	Sm (ppm)	eU (ppm)	Age (Ma)	Age c. (Ma)*	s.d.
CH1-A	47,3	2,43	0,789	79475,1	7,2	6,9	5,3	9,0	74	93	7
CH1-B	56,4	4,13	0,809	28513,1	2,7	3,2	1,4	3,5	68	84	7
CH1-C	49,4	2,68	0,802	48729,7	13,1	11,1	5,3	15,8	26	32	3
CH1-D	40,2	1,45	0,751	205297,8	10,1	12,5	5,6	13,1	130	173	14
CH1-F	38,8	1,31	0,754	127741,1	11,0	9,6	3,4	13,3	80	106	8
CH1-G	64	6,37	0,831	88950,2	6,2	8,5	5,1	8,2	90	108	9
CH1-H	37,9	1,28	0,717	392039,3	26,1	23,4	6,0	31,8	102	143	11
CH1-J	50,6	3,96	0,761	141712,3	5,0	6,5	4,5	6,6	178	234	19
CH1-K	40,7	1,74	0,723	190623,3	19,0	10,3	14,9	21,6	73	101	8
CH3-C	50,5	3,04	0,789	119938,2	4,2	5,9	3,7	5,7	175	222	18
CH3-F	35,5	0,96	0,717	191786,5	13,4	11,3	4,2	16,1	99	138	11
CH3-A	54,7	4,25	0,79	93992,9	5,7	5,5	3,2	7,0	111	141	11
CH3-G	59,2	6,11	0,793	71843,0	3,7	5,0	2,7	4,9	122	153	12
GH3A	66,1	7,49	0,823	292746,2	8,1	5,6	12,7	9,6	253	307	25
GH3B	91,1	21,74	0,876	172995,7	4,7	4,6	6,4	5,9	243	278	22
GH3-C	71,5	8,99	0,842	56806,1	4,5	3,5	8,9	5,4	88	104	8
GH3-E	57,9	4,06	0,784	230520,3	6,5	3,8	10,8	7,5	256	326	26
GH3-F	99	19,03	0,883	21444,4	1,7	0,4	2,2	1,8	98	111	9

IG3-C	43,8	1,72	0,722	332846,2	18,1	18,9	44,7	23,0	120	166	13
IG3-E	39,4	1,31	0,686	191182,1	5,0	10,0	48,9	7,8	203	295	24
IG3-F	36,7	0,99	0,675	118582,6	3,8	10,9	47,2	6,8	146	216	17
IG3-G	40,6	1,56	0,741	91106,9	3,7	4,9	38,8	5,1	147	198	16
IG3-I	40,4	1,67	0,721	187725,0	3,9	5,5	49,9	5,6	277	384	31
TL3-L	41,1	1,58	0,745	131554,4	6,3	18,8	29,8	11,1	99	133	11
TL3-B	49,4	2,68	0,803	66784,2	8,8	17,0	23,8	13,1	42	53	4
TL3-C	41,3	1,57	0,778	73141,8	9,2	43,5	27,0	19,8	31	40	3
TL3-D	39	1,44	0,717	86327,5	6,3	20,9	33,8	11,6	62	87	7
TL3-F	41,4	1,92	0,717	123516,5	7,1	25,1	35,2	13,4	77	107	9
TL3-G	43,5	1,98	0,745	95782,6	6,4	21,9	34,3	12,0	67	89	7
TL3-J	52	3,29	0,797	93130,9	5,4	17,1	25,4	9,7	80	101	8
TL3-H	47	2,35	0,777	123871,0	8,0	27,5	36,9	14,9	69	89	7
TL3-K	46,6	2,77	0,746	21915,9	3,6	8,2	19,6	5,7	32	43	3
											0
GH20-A	36,4	1,14	0,702	58542,3	5,8	5,2	129,6	8,1	60	85	7
GH20-C	37,4	1,28	0,703	74174,8	12,9	6,9	26,5	14,7	42	59	5
GH20-D	37,4	1,28	0,703	54325,7	5,9	5,1	31,4	7,3	61	87	7
GH20-F	41,1	1,58	0,745	34723,6	4,1	5,3	30,5	5,7	51	68	5
GH20-H	35,1	1,22	0,663	37173,2	9,5	6,2	37,8	11,2	27	41	3
GH20-G	39,2	1,52	0,711	54027,8	11,1	7,0	34,3	13,1	34	48	4

\*  $R_s$  (sphere equivalent radius) and  $F_T$  (ejection factor) have been calculated using the developed procedure of Gautheron & Tassan-Got (2010) and Ketcham *et al.* (2011). eU (effective uranium) has been calculated with the formula  $[eU] = [U] + 0.24*[Th] + 0.008*[Sm]$ . "Age c." means (U-Th-Sm)/He age corrected from alpha-ejection with the  $F_T$ . The error is estimated to be a maximum of 8%.

Table S3: Results from forward modeling of central RS samples

*Equivalent sphere radius = 55  $\mu$ m*

<b>eU (ppm)</b>	<b>AHe age (Ma)</b>	<b>HT1</b>	<b>HT2</b>	<b>HT3</b>	<b>HT4</b>	<b>HT5</b>
5	45	37	42	42	45	79
10	55	46	58	55	54	85
15	78	54	81	81	61	88
20	125	63	106	112	67	90
30	165	82	137	151	75	92
40	180	99	152	171	81	94
60	190	120	167	189	90	95

**HT:** Thermal History

**eU:** efficient Uranium