LATE PLIOCENE-PLEISTOCENE INCISION PROPAGATION AND EROSION IN THE EBRO BASIN (NORTH SPAIN)

Vincent Regard[1*], Arnaud Vacherat[1], Stéphane Bonnet[1], Frédéric Mouthereau[1], Jesper Nørgaard[2], and Mads F. Knudsen[2]
1. GET, University of Toulouse, UPS (OMP), CNRS, IRD, CNES, 14 av. Edouard Belin, 31400 Toulouse, France
2. Department of Geoscience, Aarhus University, Denmark

* corresponding author. Vincent.regard@get.omp.eu / ph. +33 561332645

SUPPLEMENTARY MATERIAL

This supplementary material contains additional graphs: a graph of terrace vs elevation for each investigated river, the parameters of cosmogenic depth-profile inversions and P-PINI outputs (see Knudsen et al., 2020).

1 Terrace elevation vs. age

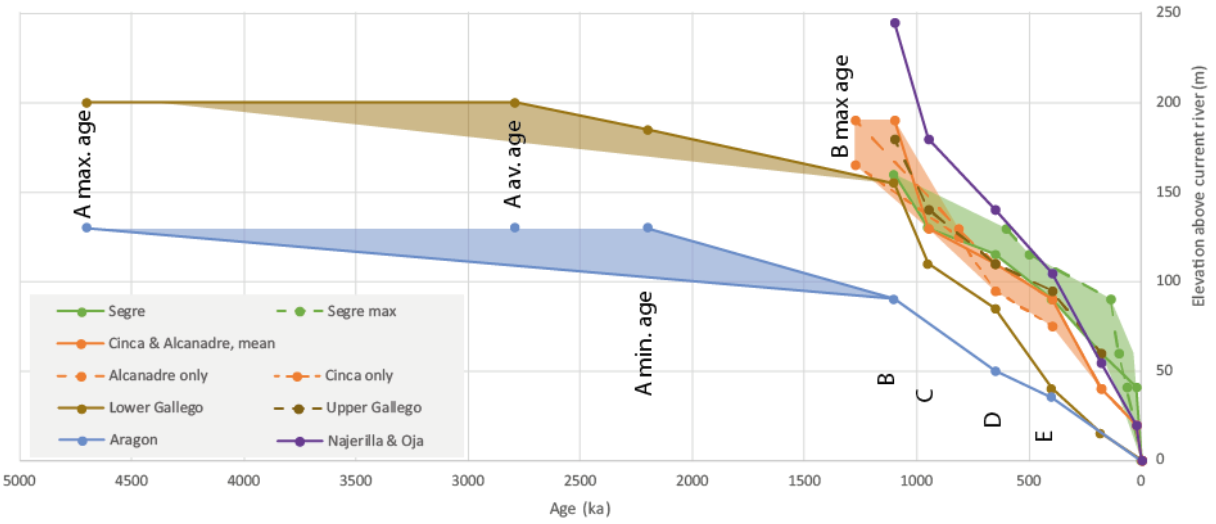

Figure S1. Terrace record vs. elevation. This plot is exhaustive and takes into account the different estimates of the altitude and age of the terraces; the possible chronologies are represented by a transparent colored area. Plain lines correspond to Figure 8. The Segre max dashed line uses younger terrace ages estimates from Stange et al. (2013a) and lower bounds for TSEG1 and 2: C, D, E ages are there 600, 500 and 139 ka, respectively. For Alcanadre and Cinca, the terrace elevation above the river differs depending on the river. In addition, we test an age for B of 1276 ka, instead of 1100 ka. For the Lower Gallego and Aragon, we test the following ages for A: 4700 ka (TARA0), 2200 ka (TARA2), and 2800 ka (age adopted in the main text). For the last million years, all the rivers except the Aragon incised at a rate ranging from 110 to 220 m/Ma; Aragon incised at a rate of 80 m/Ma. For the preceding period, between A (2.2 to 4.7 Ma, following the scenario) and B, the Gallego river (and Ebro river as it is measured at their confluence) incised at a rate between 16 and 89 m/Ma; the Aragon river incised at a rate of 11 to 44 m/Ma.

Table S1. Incision rate evaluations. Input data are in green and consist in elevation above current river course and age evaluation for the Aragon valley and the Zaragoza area (confluence between Gallego and Ebro rivers). Four levels are considered: the latest sediment deposited before basin incision and remaining in the basin; the level A, the level B and the modern configuration. The ages are discussed in the main text. The various estimates for incision rates are in blue; they take into account uncertainties in terrace ages and elevations. The last line represents the increase in incision rates between the period between the emplacement of levels A and B and the B to present period (i.e. the last million years). The threefold increase is an average; in extreme cases there can be no increase or a six-fold increase.

		Zaragoza area			Aragon valley		
	Level age (Ma)		Elevation above current river (m)				
	Max	Min	Max		Min	Max	Min
Latest basin infill sediments	13	7.5	500		500		
Terrace level A	3.5	2.1	220		200	130	130
Terrace level B	1.3	1	140		140	90	90
		Incision rate (m/Ma)					
		Max	Average	Min	Max	Average	Min
top-A		75	39	26			
A-B		100	42	24	50	24	16
B-current		140	122	108	90	78	69
x increase (B-current vs. A-B)		*x6*	*x3*	*x1.1*	*x6*	*x3*	*x1.4*

2 Cosmogenic nuclide depth profiles

The depth concentration profiles were processed thanks to the program provided by Hidy et al. (2010). Here are the main parameters and results. TSEG 1 ouputs are shown (Figure S2).

Table S2. Parameters and outputs for the two profiles for both 10Be and 26Al, with Hidy et al. (2010)'s inversion program.

	Parameters														
	Density g/cm3		Chi	number of profiles	Muon uncertainty (%)	Age (a)		Eros rate (cm/ka)		Erosion threshold (cm)		Inheritance (at/g)		Neutrons att. Length (g/cm2)	
						min	max	min	max	min	max	min	max	mean	std
TSEG1 10Be	2.0	2.4	40	100000	10	400000	1400000	0	0.5	0	200	0	80000	160	10
TSEG1 26Al	2.0	2.4	40	100000	10	400000	1400000	0	0.5	0	200	0	360000	160	10
TSEG2 10Be	2.0	2.4	30	1000000	10	200000	2000000	0	0.25	0	400	0	250000	160	10
TSEG2 26Al	2.0	2.4	30	100000	10	200000	2000000	0	0.25	0	400	0	400000	160	10

	Results											
	Age (ka)				Inheritance (x 10,000 at/g)				Erosion rate (cm/ka)			
	min chi2	Bayesian			min chi2	Bayesian			min chi2	Bayesian		
			min	max			min	max			min	max
TSEG1 10Be	595	693	523	1095	0.23	0.09	0	4.44	0.02	0.01	0	0.1
TSEG1 26Al	492	422	400	971	8.7	6.26	0.27	29.9	0.14	0.17	0.04	0.21
TSEG2 10Be	1980	532	489	1961	23.5	18.7	2.56	24.4	0.09	0.13	0.02	0.18
TSEG2 26Al	499	435	374	1104	2.22	1.3	29.8		0.06	0.09	0	0.16

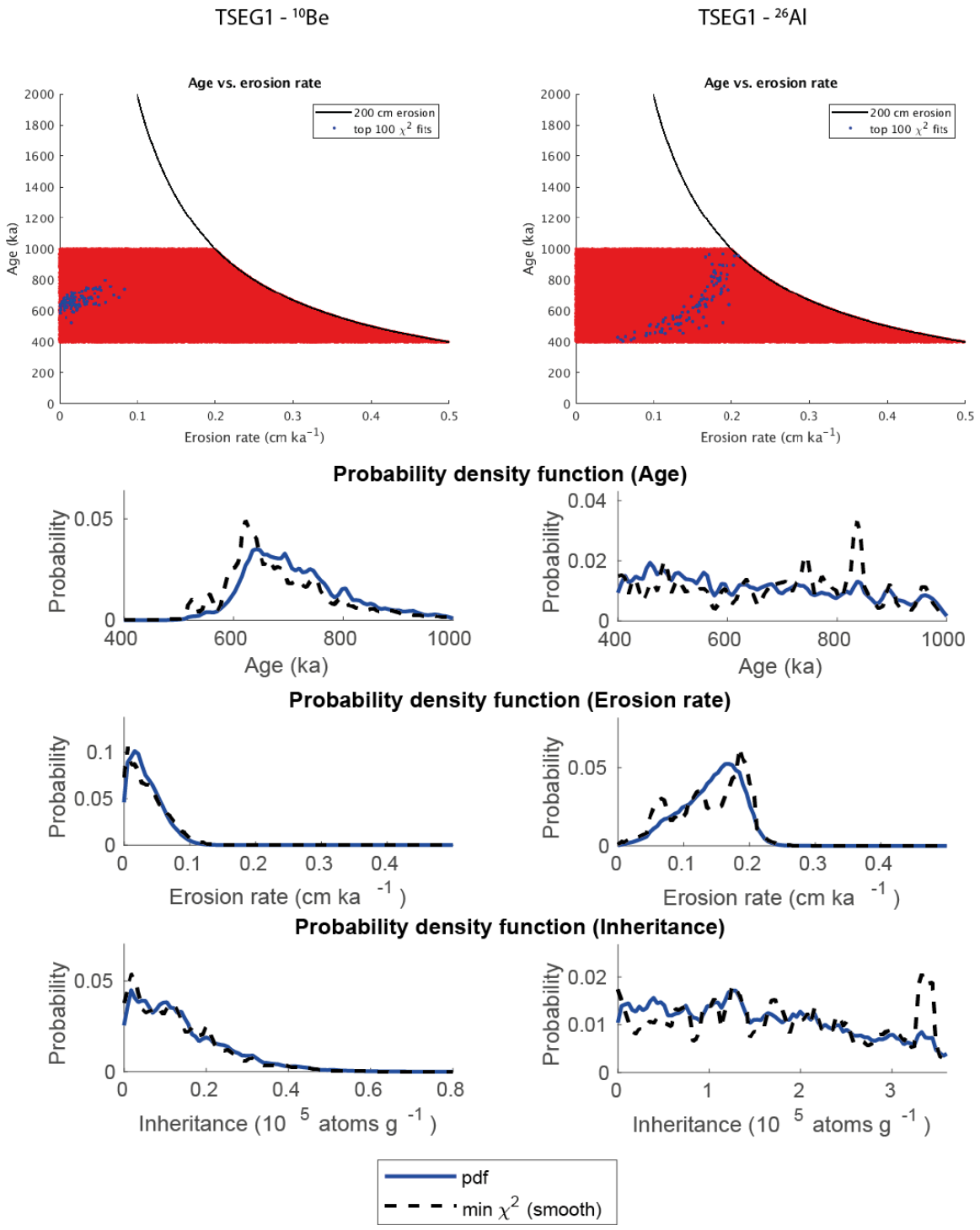

Figure S2. Selected graphical outputs of the Hidy et al. (2010) inversion program (depth profile is in Figure 8 of the main text), for the TSEG 1 profile; for 10Be and 26Al data on the left and right respectively. The top graphs show the range of parameters tested (red), in which the 100 most reliable are shown in blue (best chi2). The corresponding probability density functions are shown in the lower graphs, for age, erosion rate or inheritance.

3 P-Pini results

3.1 TOJA1

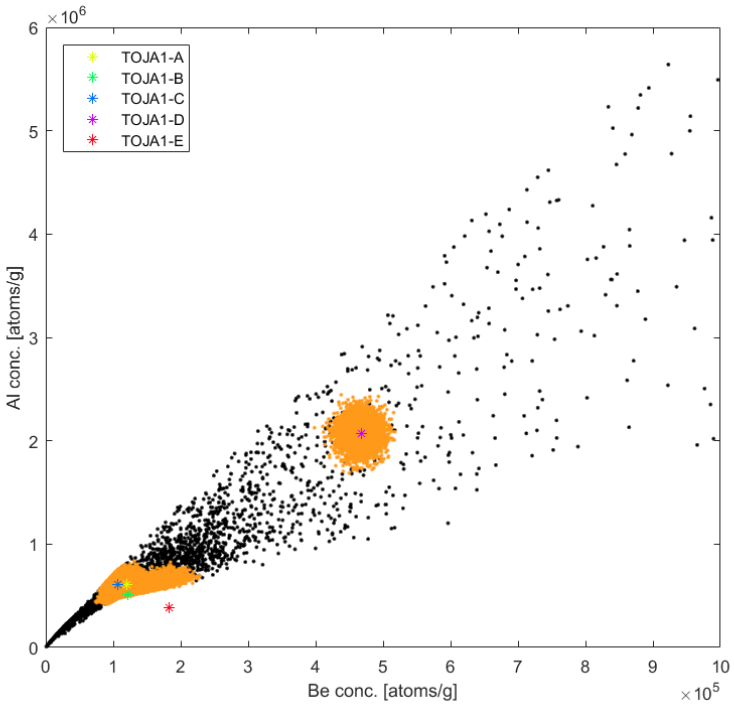

Figure S3. Inventory of 0.1% of the cosmogenic pairs (^{26}Al, ^{10}Be) produced by the P-PINI burial-age model (black dots) for site TOJA1. Colored stars show the (^{26}Al, ^{10}Be) inventories of the five samples from TOJA1 site. Orange dots show the simulated (^{26}Al, ^{10}Be) concentrations accepted by P-PINI; the entire inventory of accepted concentrations is displayed.

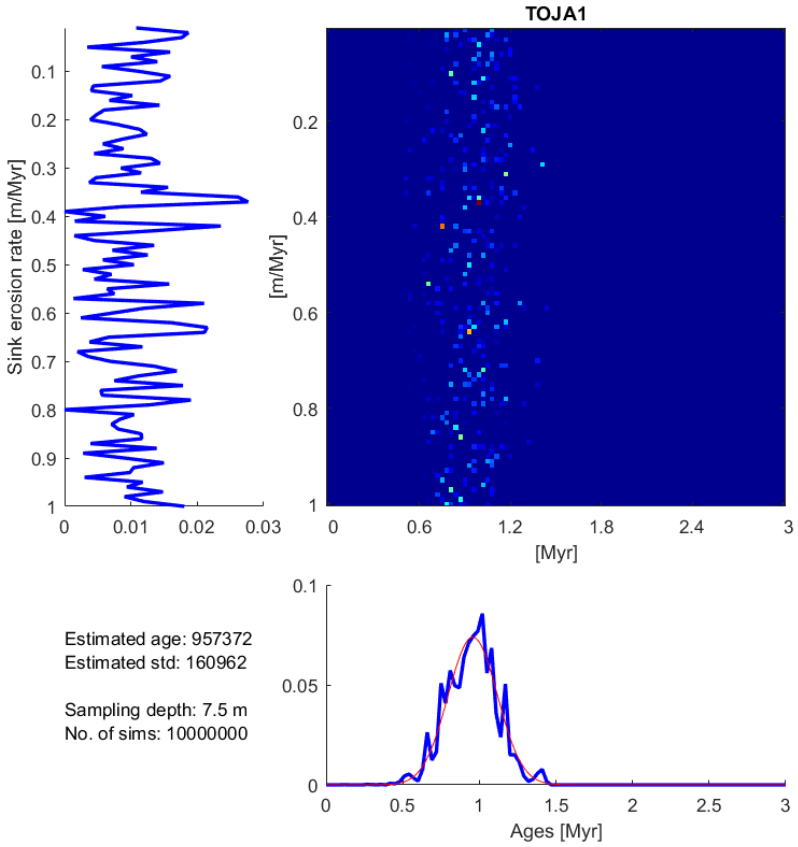

Figure S4. Center panel: the combined probability density distribution for the burial age and erosion rate of TOJA1 site, obtained by multiplying together the probability distributions associated with each of the five samples from this site. Dark blue denotes zero probability, whereas light-blue and reddish colors denote higher probability. Left panel: the marginal probability distribution for the erosion rate (blue line). From this graph no clear erosion rate for sink (site TOJA1, erosion of the terrace surface) can be deduced. Bottom panel: the marginal probability distribution for the burial age (blue line). The red line denotes the Gaussian fit to the probability distribution for the burial age. The probability distribution corresponds to an age of 957,372±160,962 a for TOJA1 terrace deposits.

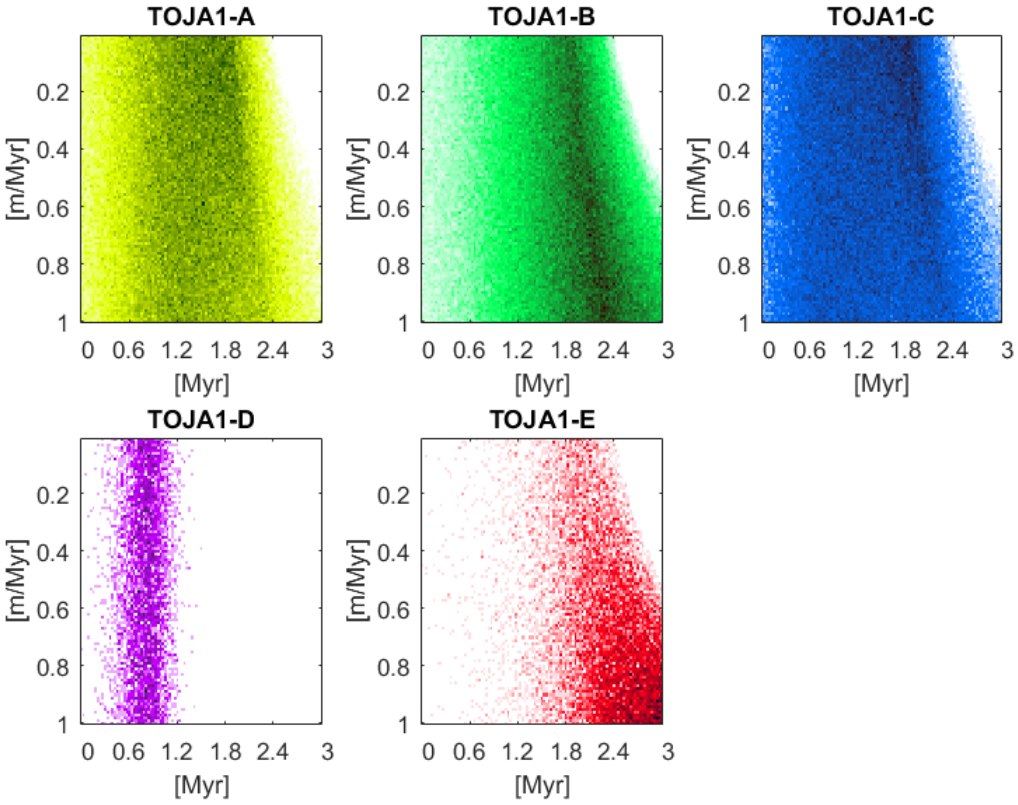

Figure S5. Erosion rates and burial ages associated with the accepted P-PINI simulations for each one of the five samples from TOJA1 site. Darker colors indicate higher number of accepted simulations. Note that Figure S3 represents the common signal deduced from the five samples taken altogether.

3.2 TEBR2

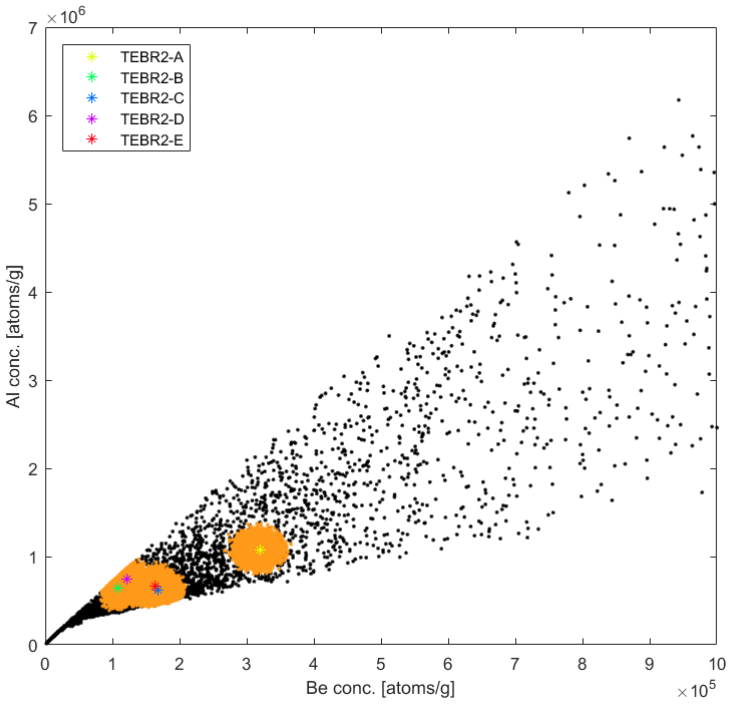

Figure S6. Same as Figure S3 for site TEBR2.

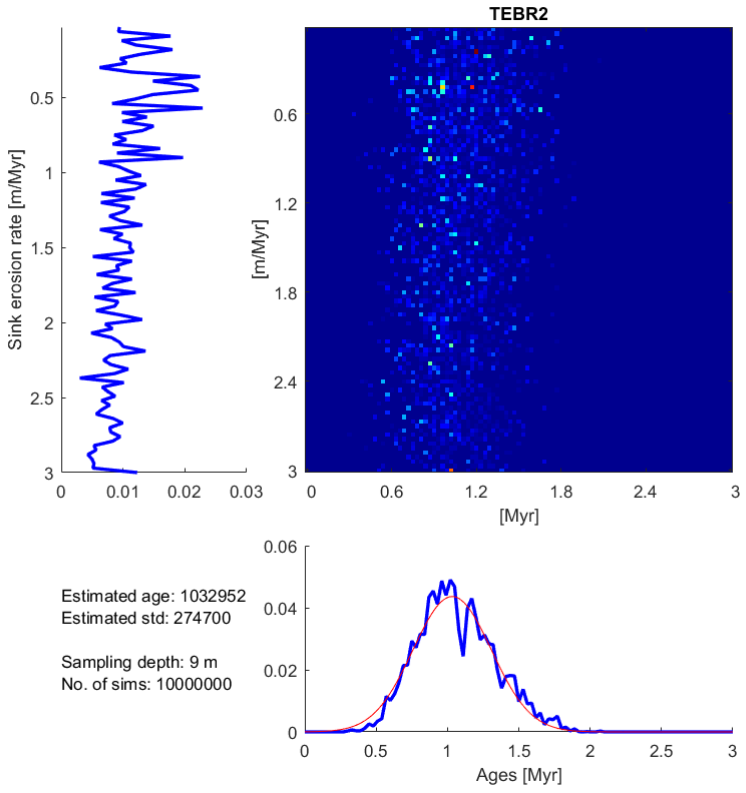

Figure S7. Same as Figure S4, for site TEBR2; it corresponds to an age of 1,033,952±274,700 a.

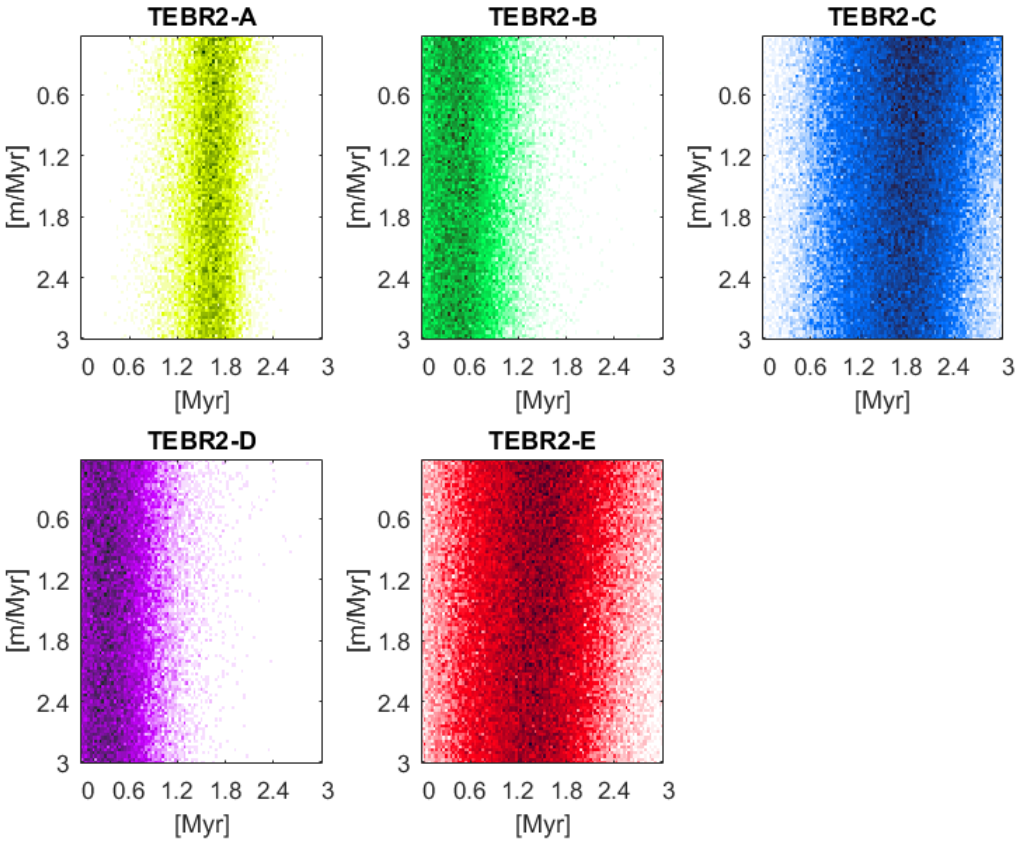

Figure S8. Same as Figure S5 for site TEBR2.

3.3 TARA0

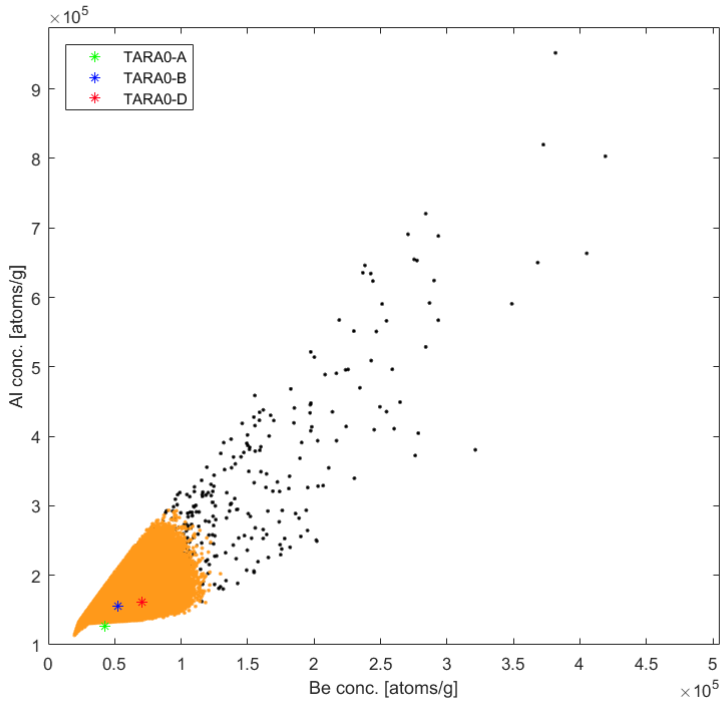

Figure S9. Same as Figure S3 for site TARA0.

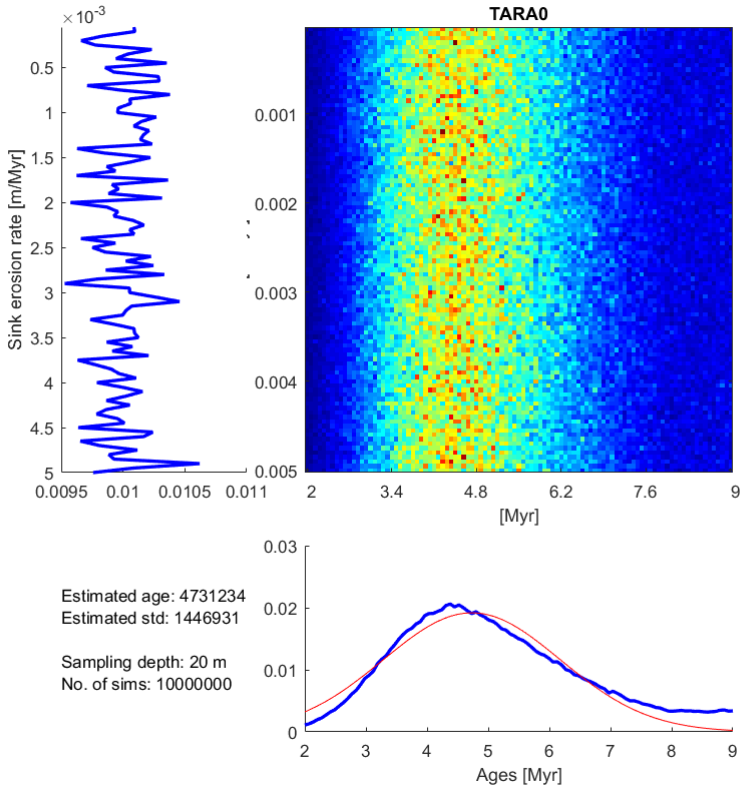

Figure S10. Same as Figure S4, for site TARA0; it corresponds to an age of 4,731,234±1,446,931 a.

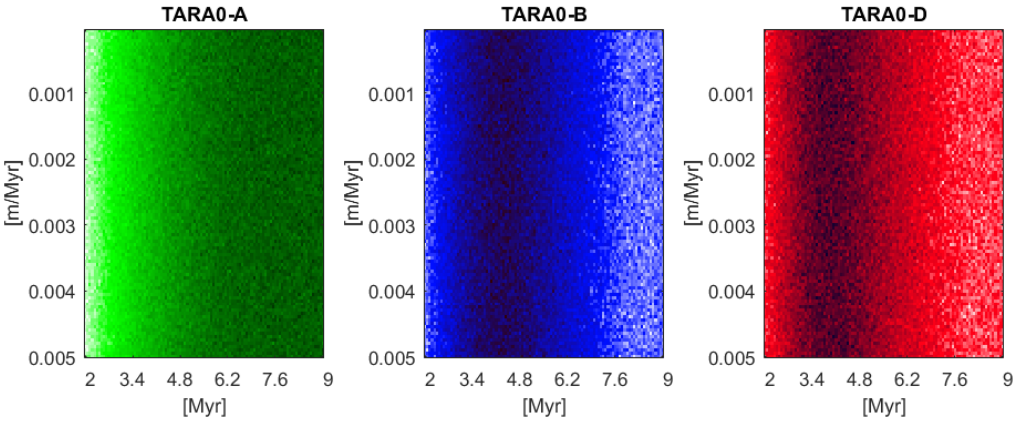

Figure S11. Same as Figure S5 for site TARA0.

3.4 TARA2

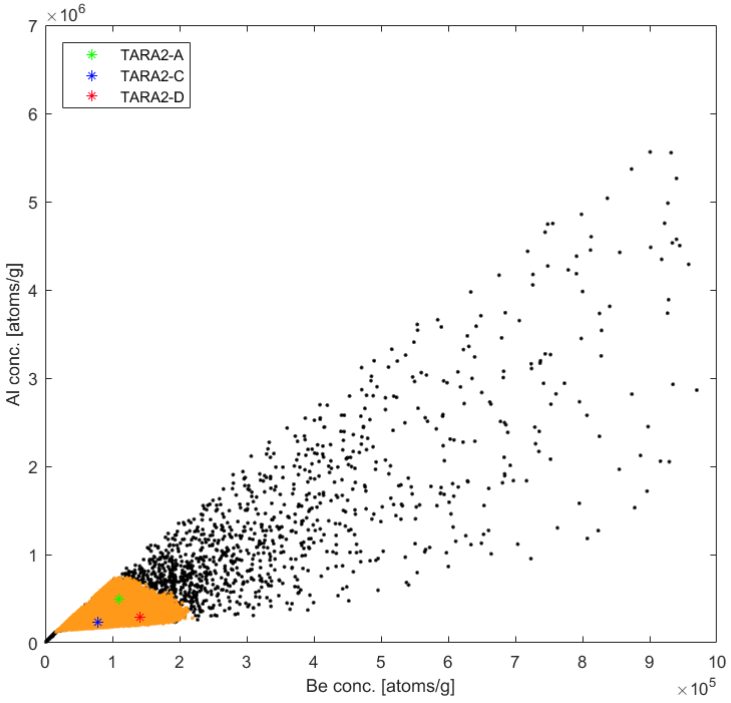

Figure S12. Same as Figure S3 for site TARA2

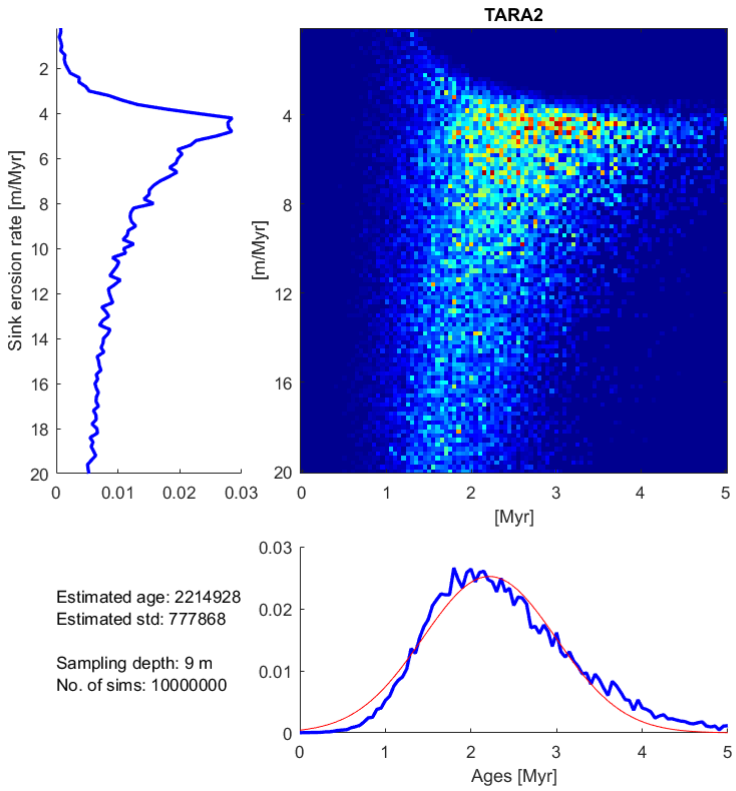

Figure S13. Same as Figure S4, for site TARA2; it corresponds to an age of 2,214,928±777,868 a.

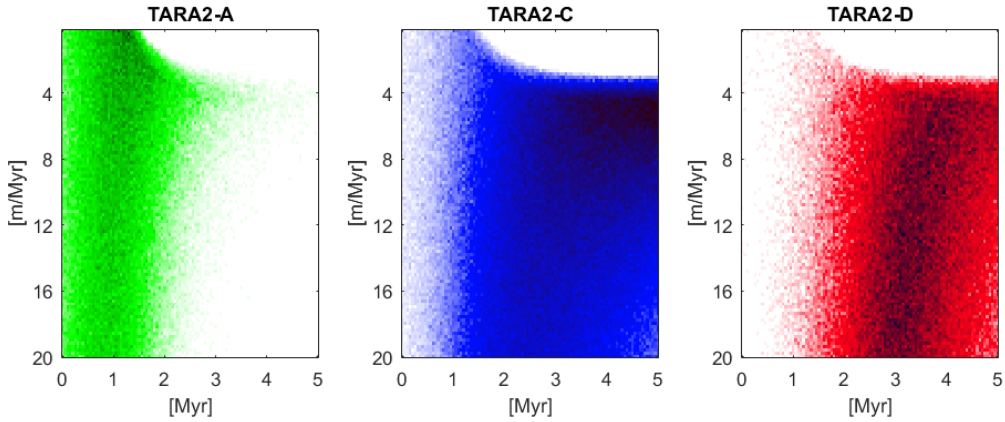

Figure S14. Same as Figure S5 for site TARA2.

3.5 TALC1

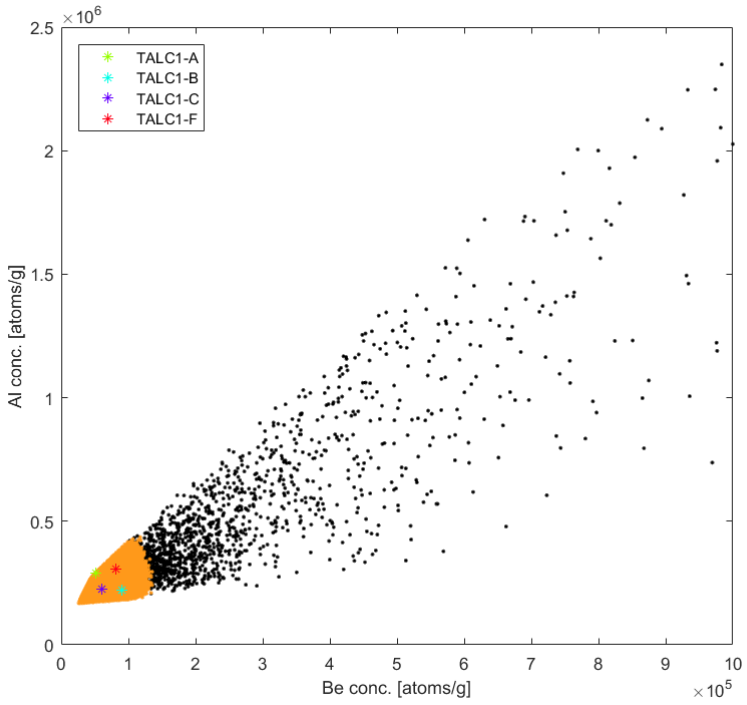

Figure S15. Same as Figure S3 for site TALC1

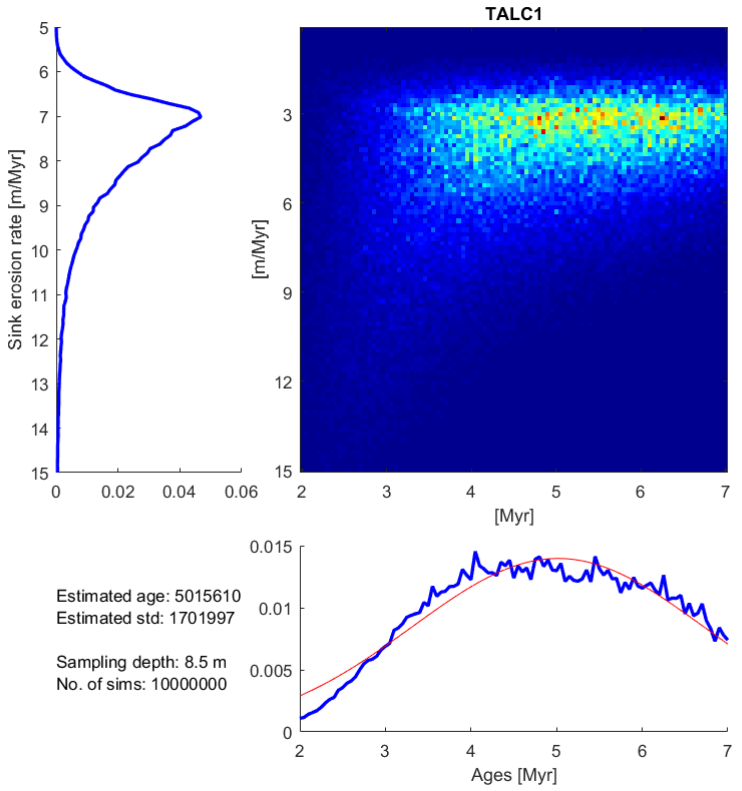

Figure S16. Same as Figure S4, for site TALC1; it corresponds to an age of 5,015,610±1,701,997 a.

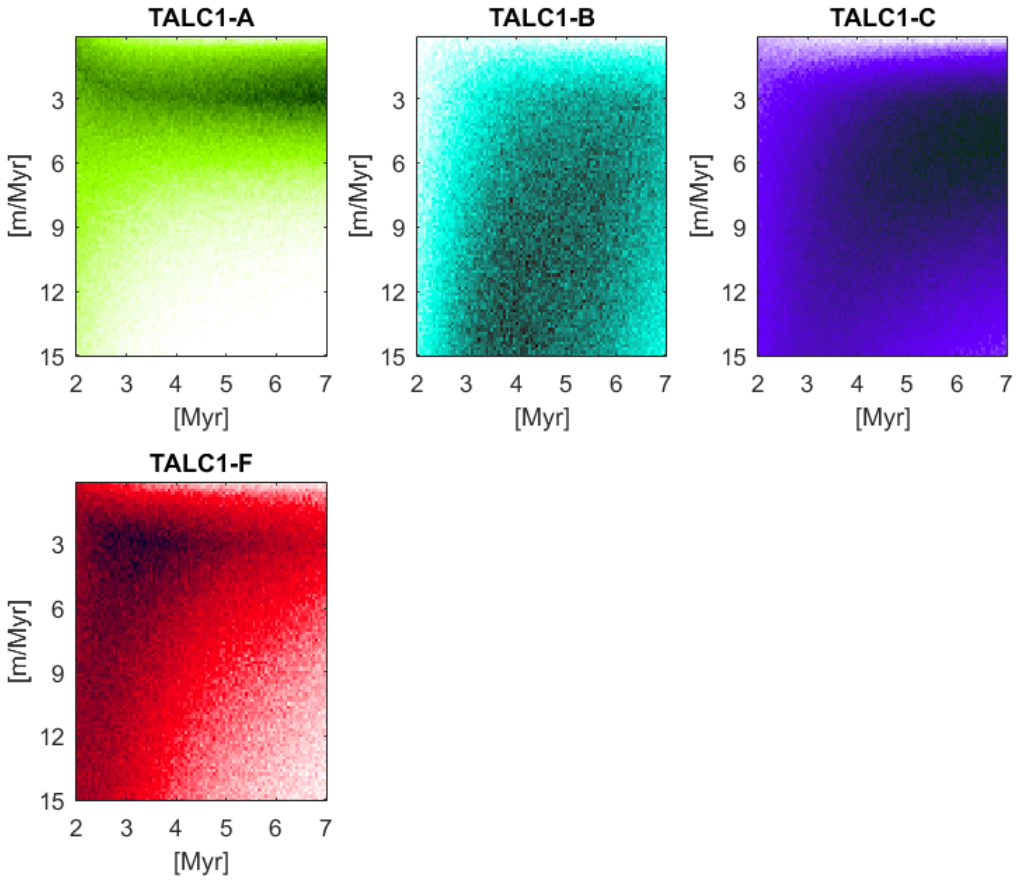

Figure S17. Same as Figure S5 for site TALC1.