

# Supplementary Information to ‘Radiometric dating of Middle Pleistocene carbonates: assessing consistency and performance of the U–Th and U–Pb dating methods’

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## S1 Collector configuration for U–Th analyses

**Table S1.** Collector configuration for U–Th measurements. U and Th were measured separately. An axial secondary electron multiplier (SEM) at mass position 237 was used to monitor and correct for tailing of the  $^{238}\text{U}^+$  beam onto the other detectors during U measurement.

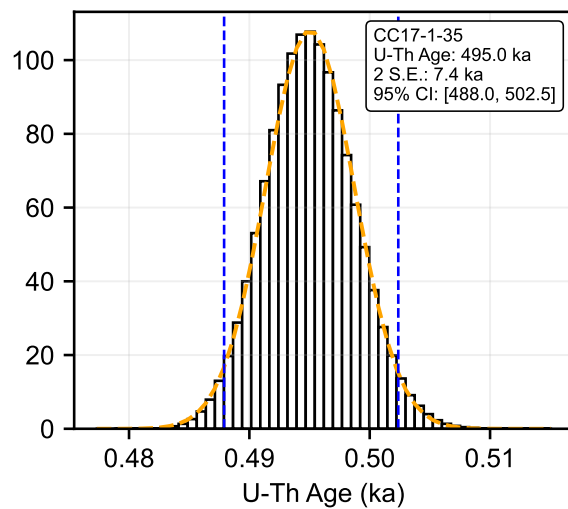
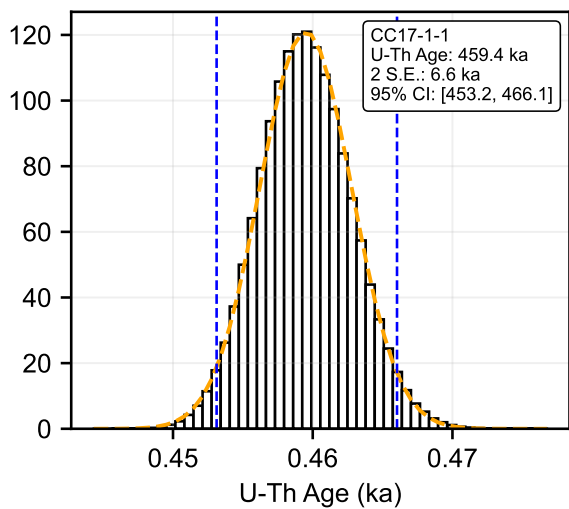
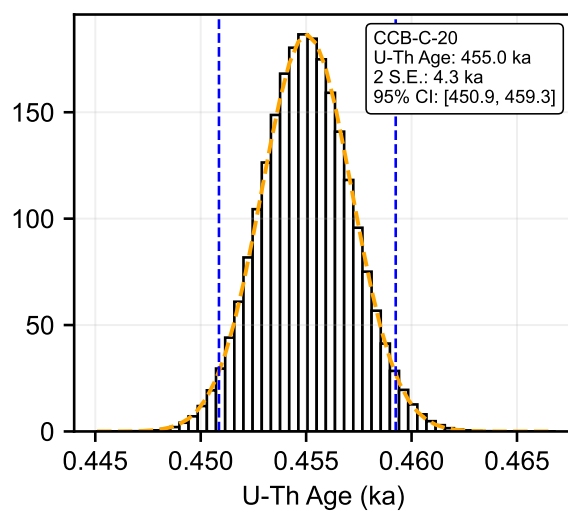
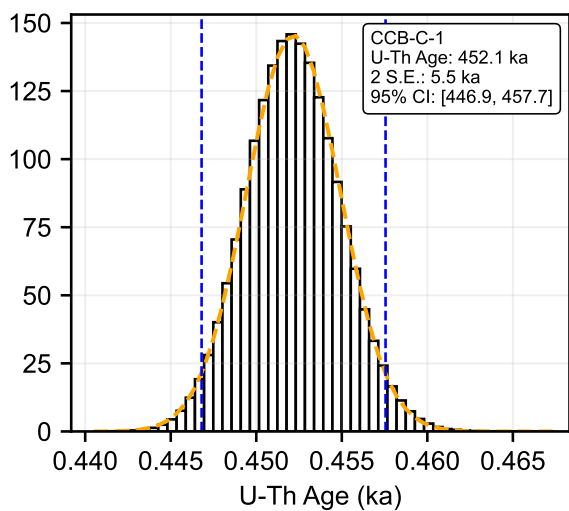
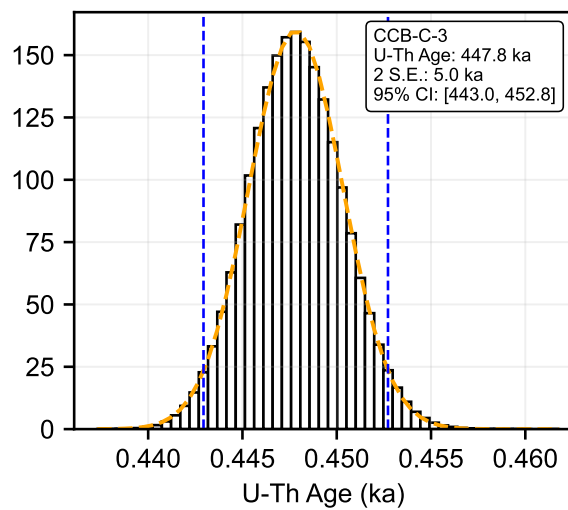
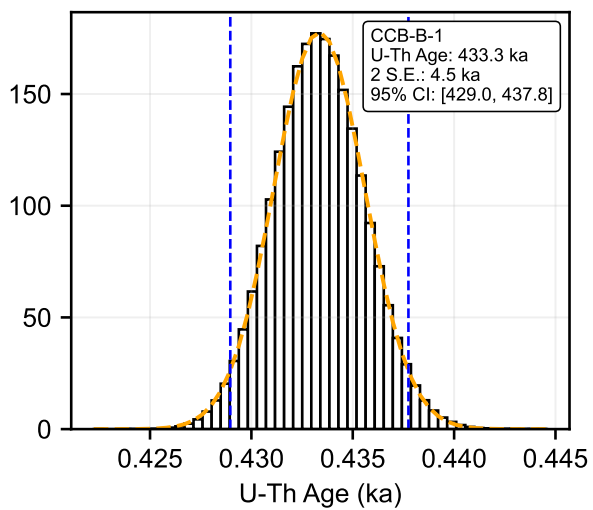
Detector	L4	L3	L2	L1	Ax	H1
Position	−4	−3	−2	−1	0	+1
Amplifier resistor ( $\Omega$ )	$10^{11}$	$10^{13}$	$10^{11}$	$10^{11}$	(SEM)	$10^{10}$
U isotope	$^{233}\text{U}$	$^{234}\text{U}$	$^{235}\text{U}$	$^{236}\text{U}$	237	$^{238}\text{U}$
Th isotope	$^{229}\text{Th}$	$^{230}\text{Th}$		$^{232}\text{Th}$		

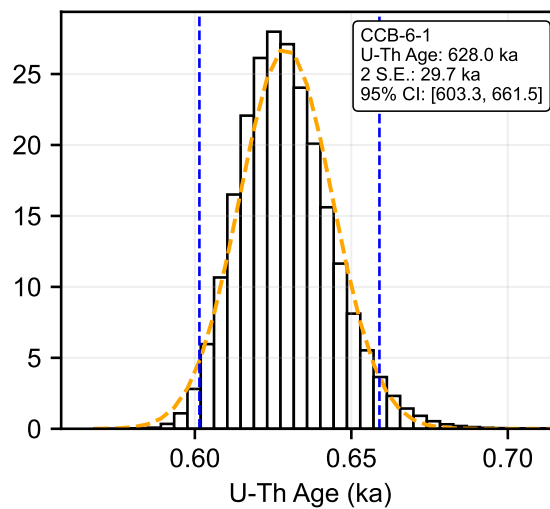
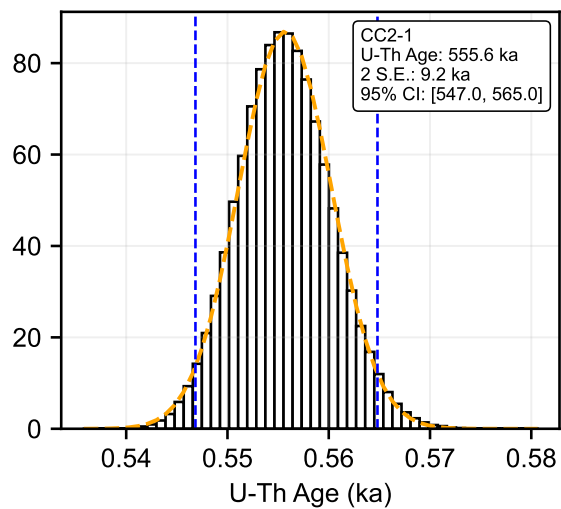
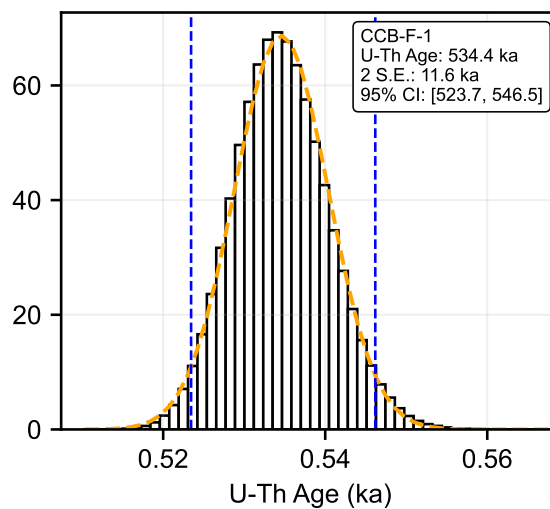
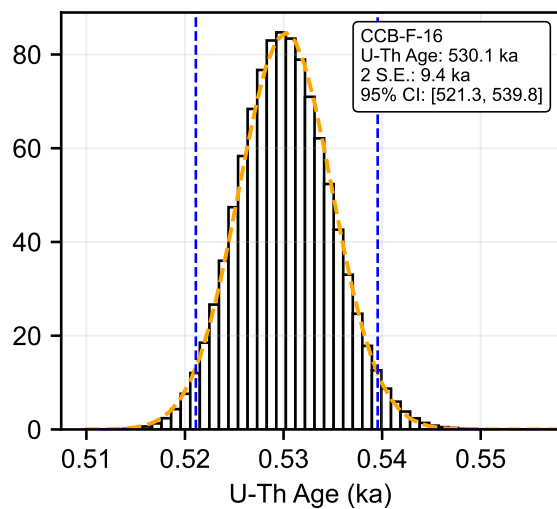
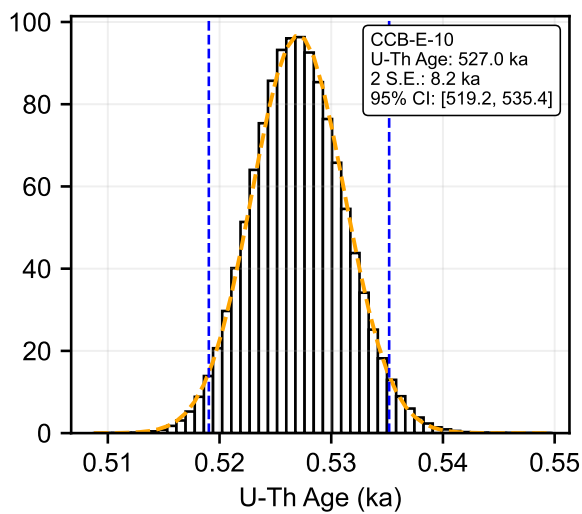
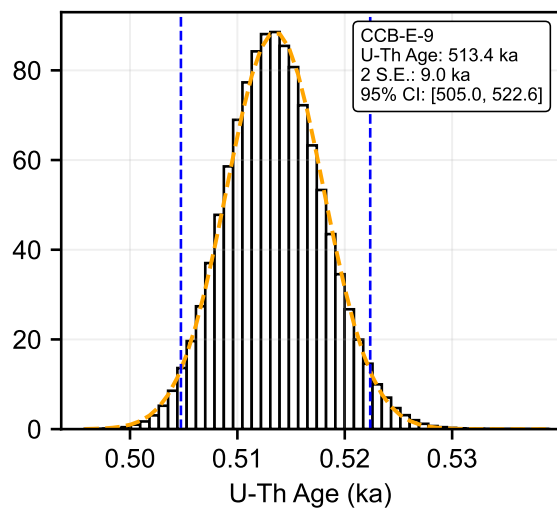
## S2 Monte Carlo age simulation

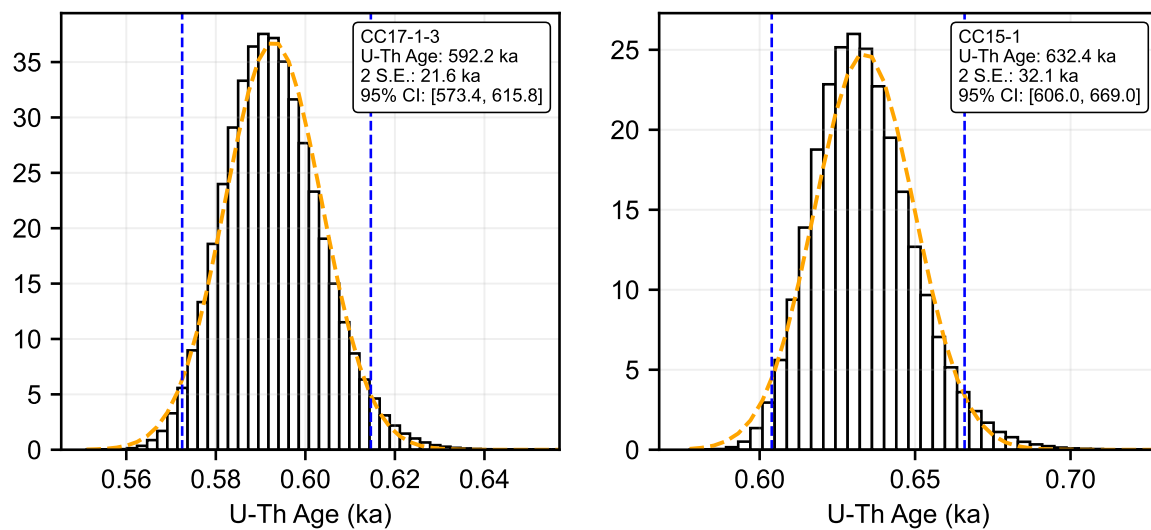
In addition to the algebraic uncertainty propagation approach outlined in the Appendix, Monte Carlo simulation (e.g. Hellstrom, 1998; Ludwig, 2003) was used to calculate U–Th and U–Pb age uncertainties, as well as estimate uncertainty in the age difference. For each trial:

1.  $[^{234}\text{U}/^{238}\text{U}]$  and  $[^{230}\text{Th}/^{238}\text{U}]$  values were randomised within their analytical uncertainties according to univariate Gaussian distributions.
2. U–Pb isochron regression parameters were randomised within uncertainties according to a multivariate Gaussian distribution accounting for uncertainty correlation between the slope and  $y$ -intercept.
3. U–Th and U–Pb ages were calculated numerically using the equations in Broecker (1963) and Pollard et al. (2023) and checked for convergence.
4. The difference between the U–Th and U–Pb ages was calculated.

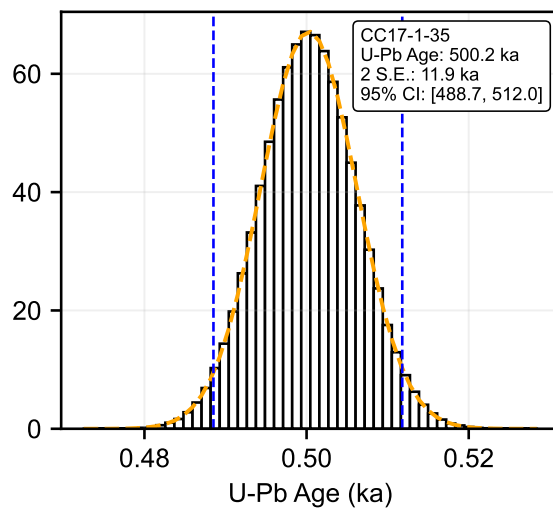
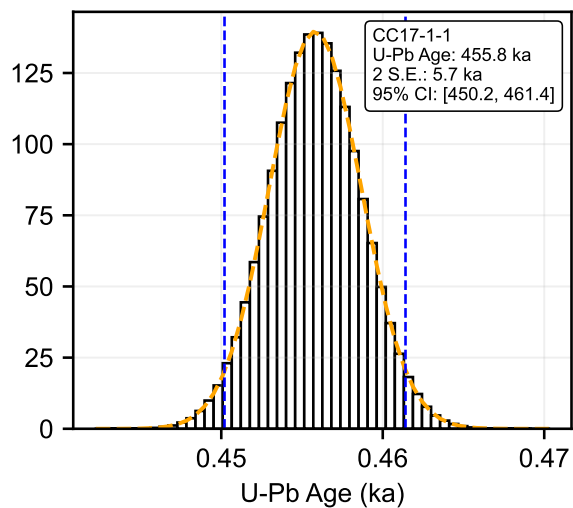
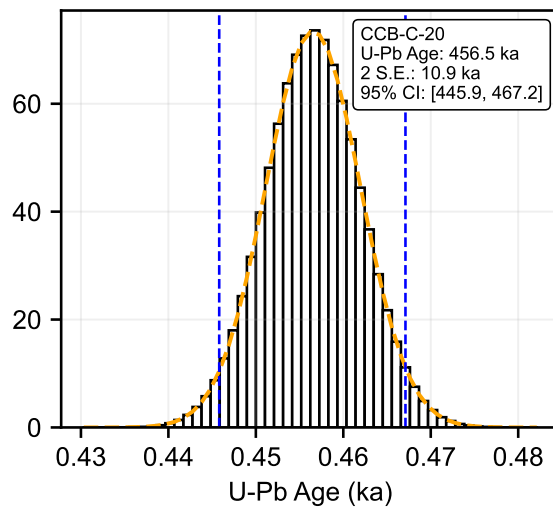
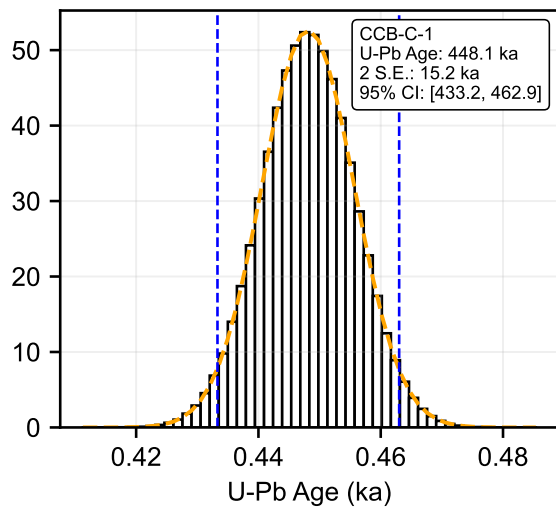
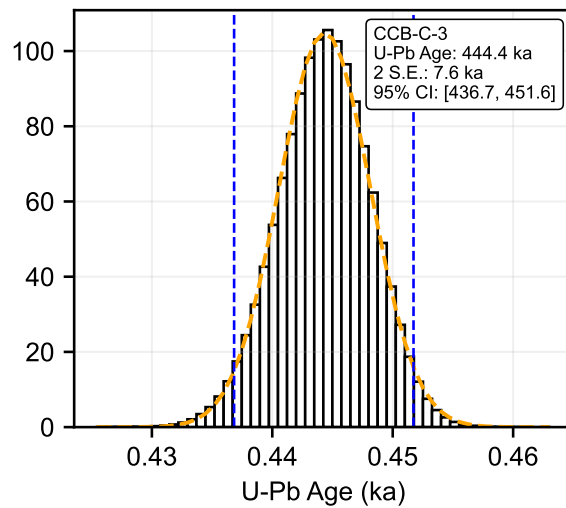
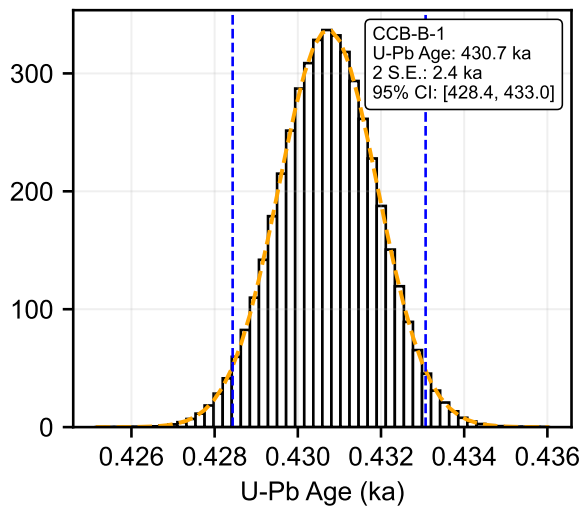
This procedure was then repeated  $10^6$  times for each sample to build up an estimate of the probability density function for U–Th and U–Pb ages, and the age difference. Uncertainties are reported as 95% confidence intervals, estimated from the 2.5 and 97.5 percentiles of simulated ages

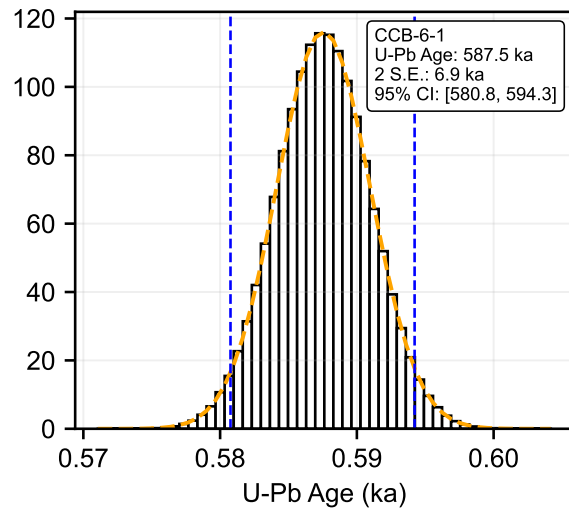
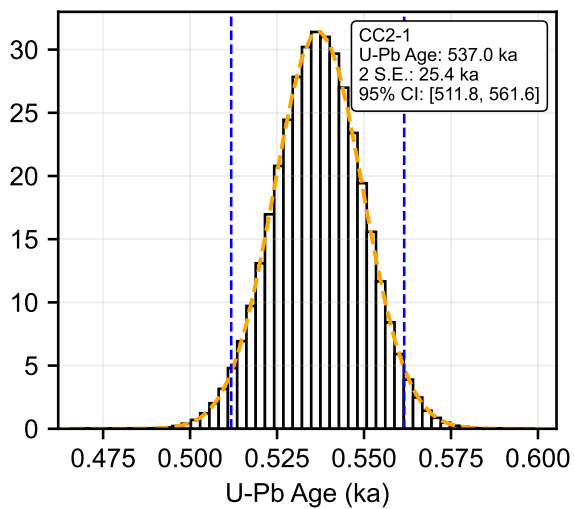
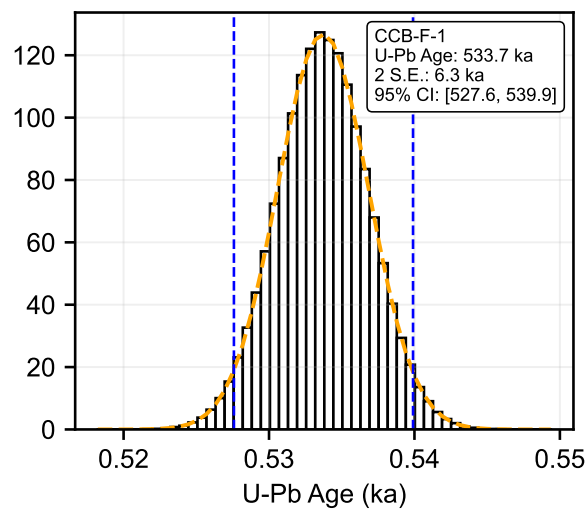
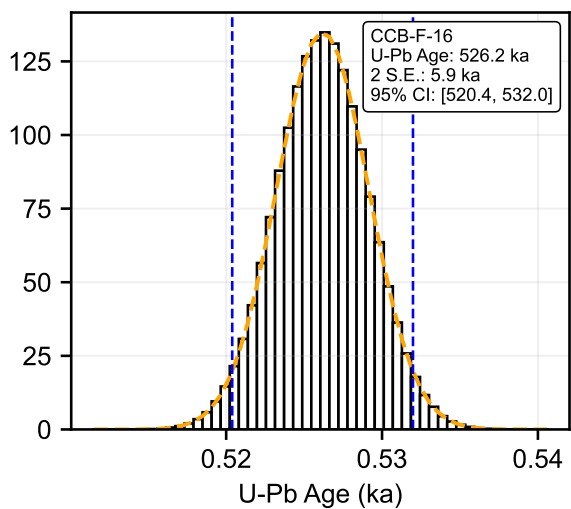
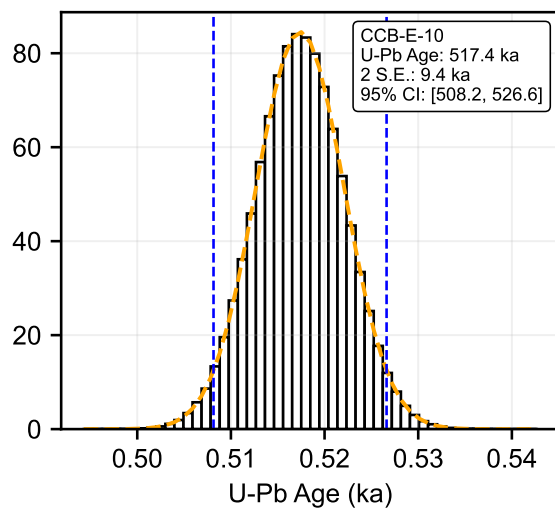
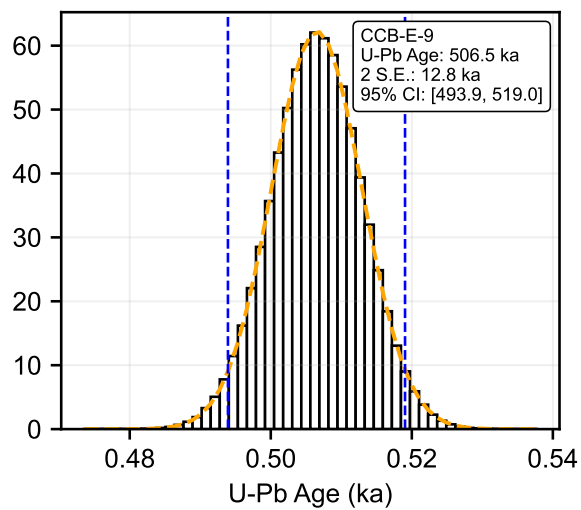


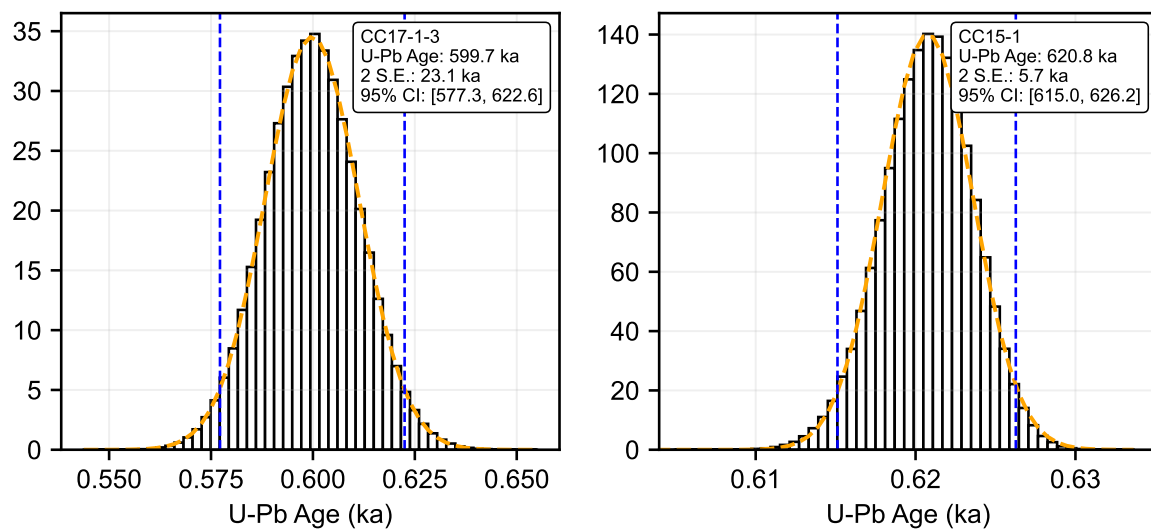




**Figure S1.** Histograms showing the results of U–Th Monte Carlo age simulations. The red curve shows a Gaussian fit to the simulated ages, and the blue vertical lines show estimated 95% confidence limits.

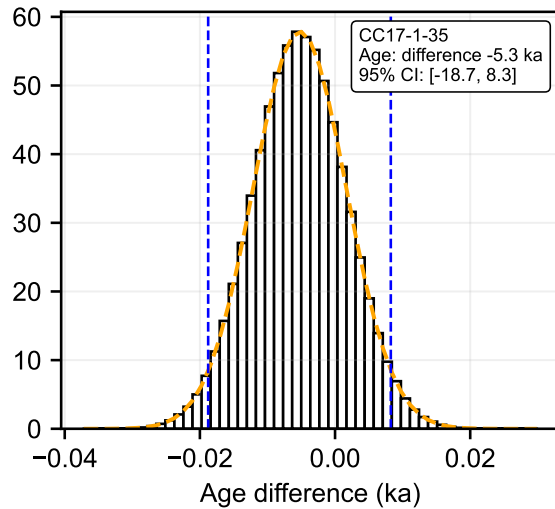
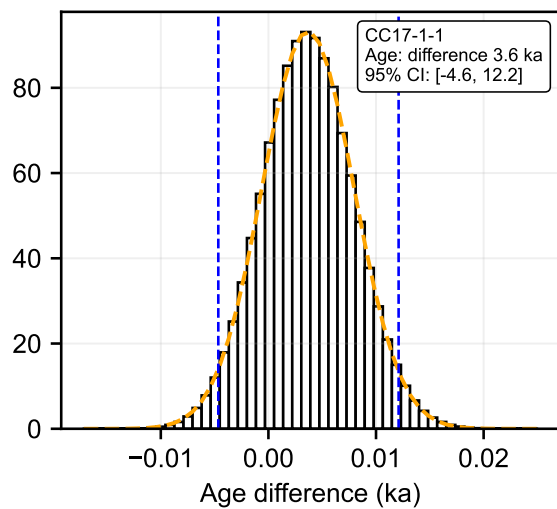
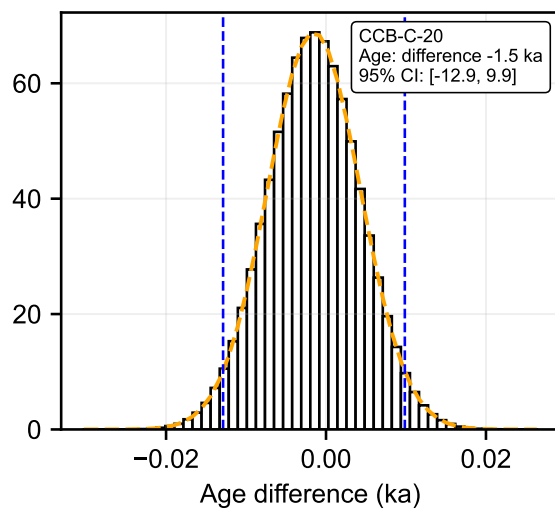
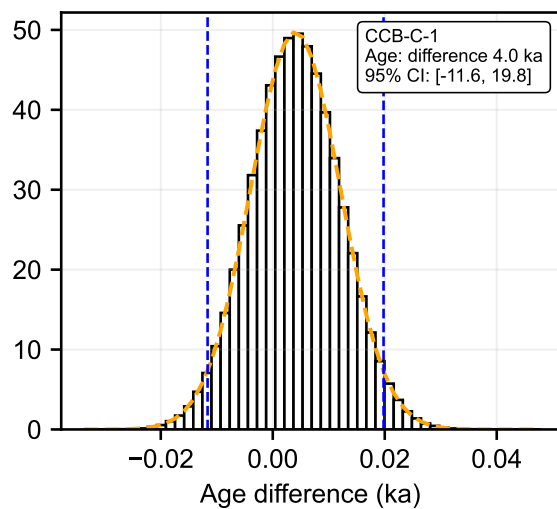
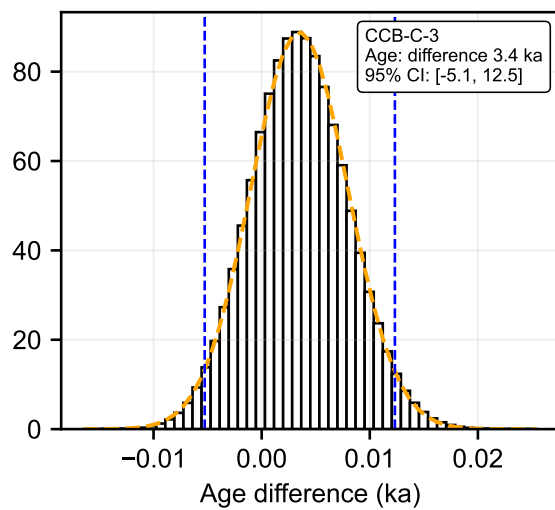
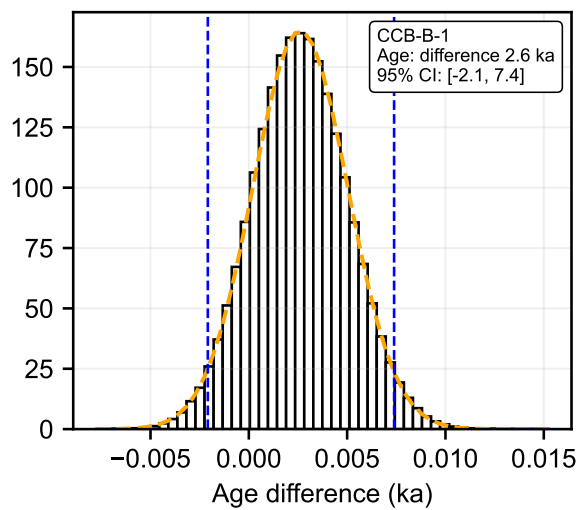




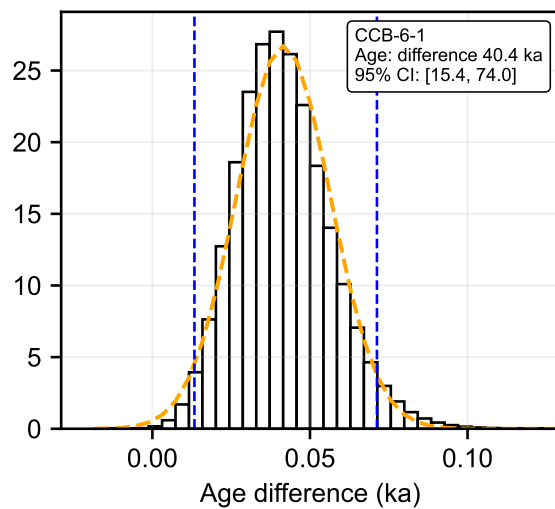
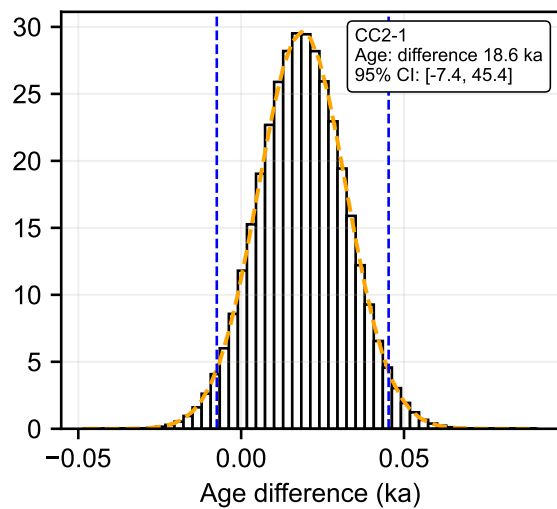
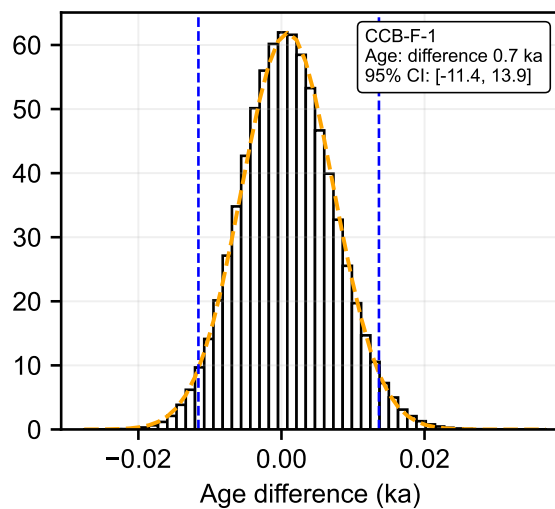
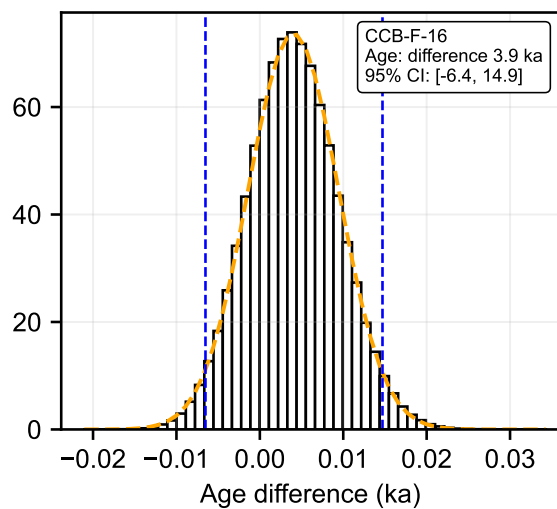
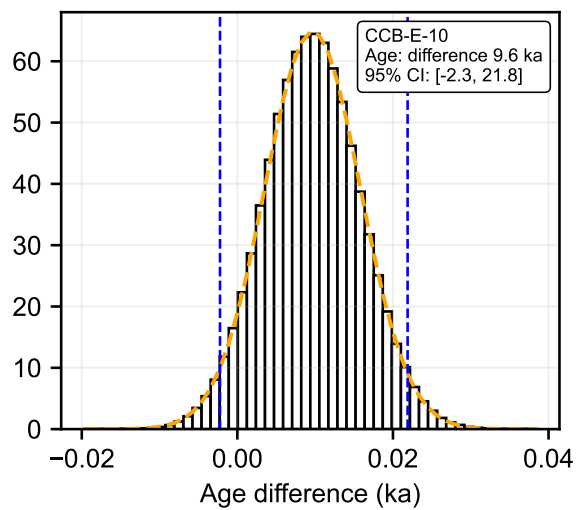
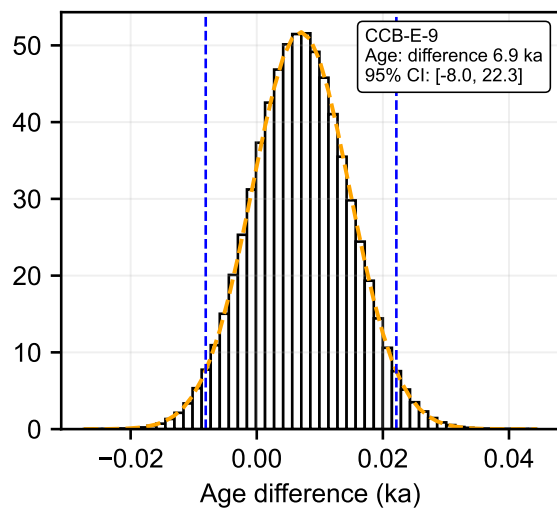


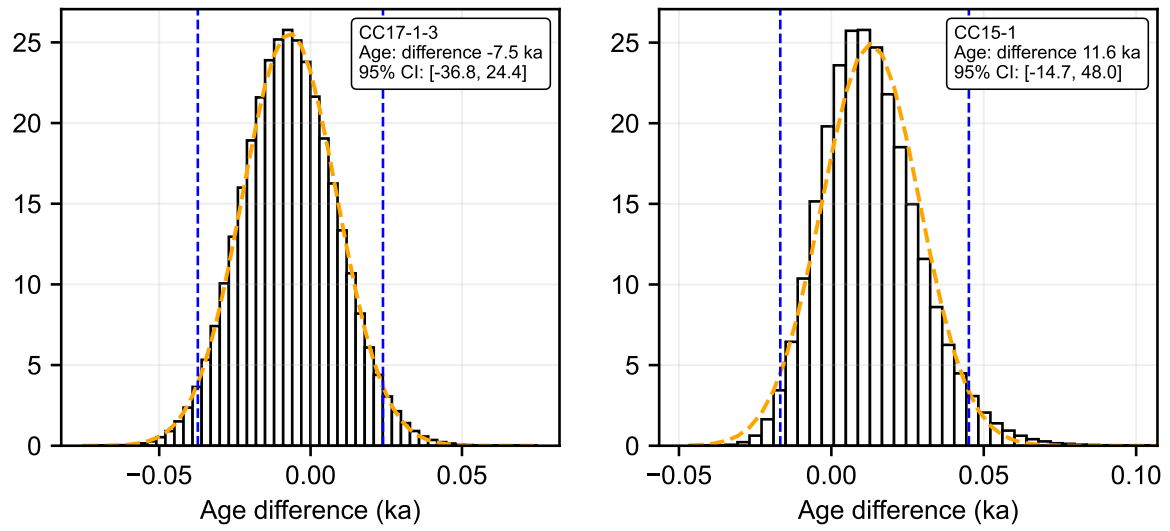
**Figure S2.** Histograms showing the results of U–Pb Monte Carlo age simulations. The red curve shows a Gaussian fit to the simulated ages, and the blue vertical lines show estimated 95% confidence limits.





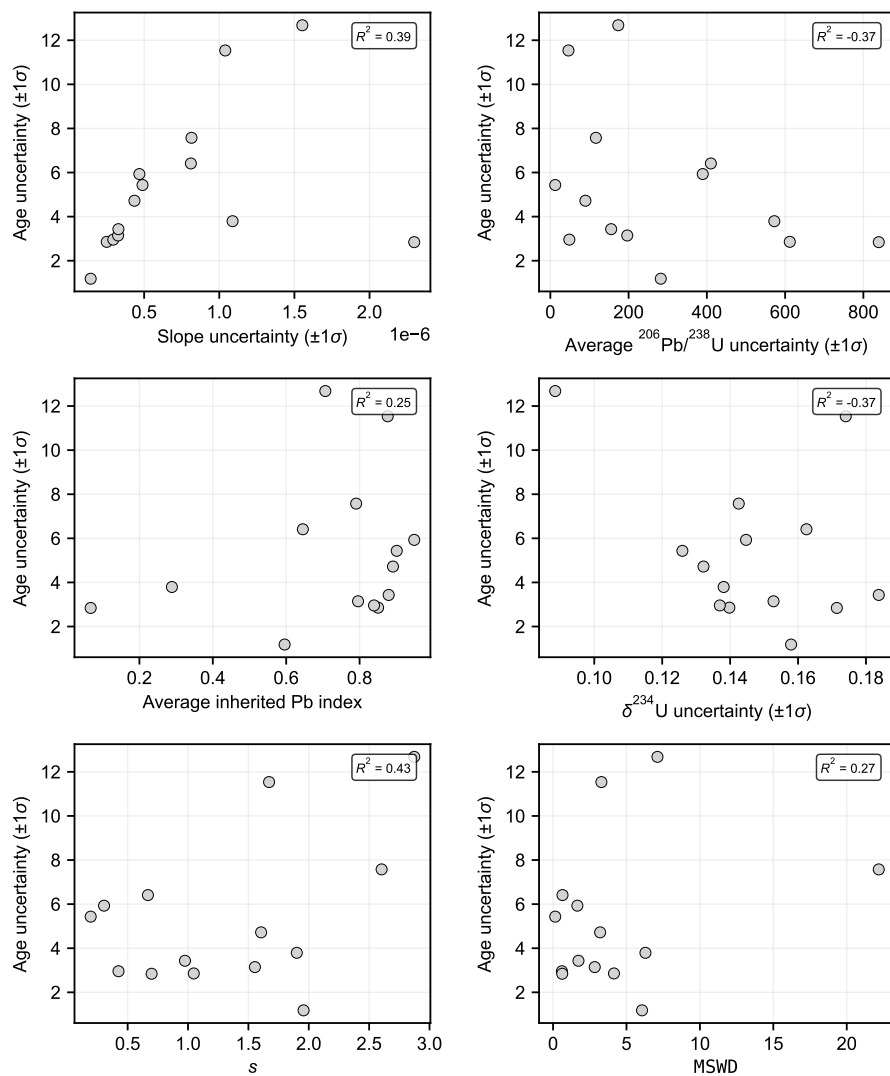
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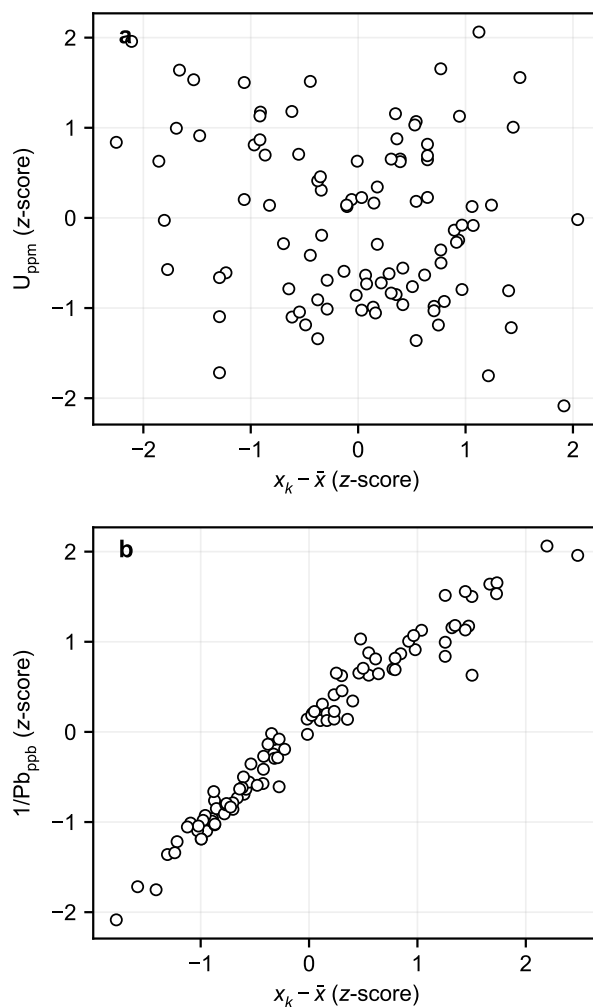
**Figure S3.** Histograms showing the results of Monte Carlo age difference simulations (calculated as:  $t_{Th} - t_{Pb}$ ). The orange curve shows a Gaussian fit to the simulated ages, and the blue vertical lines show estimated 95% confidence limits.

### S3 Potential factors affecting U–Pb isochron age precision



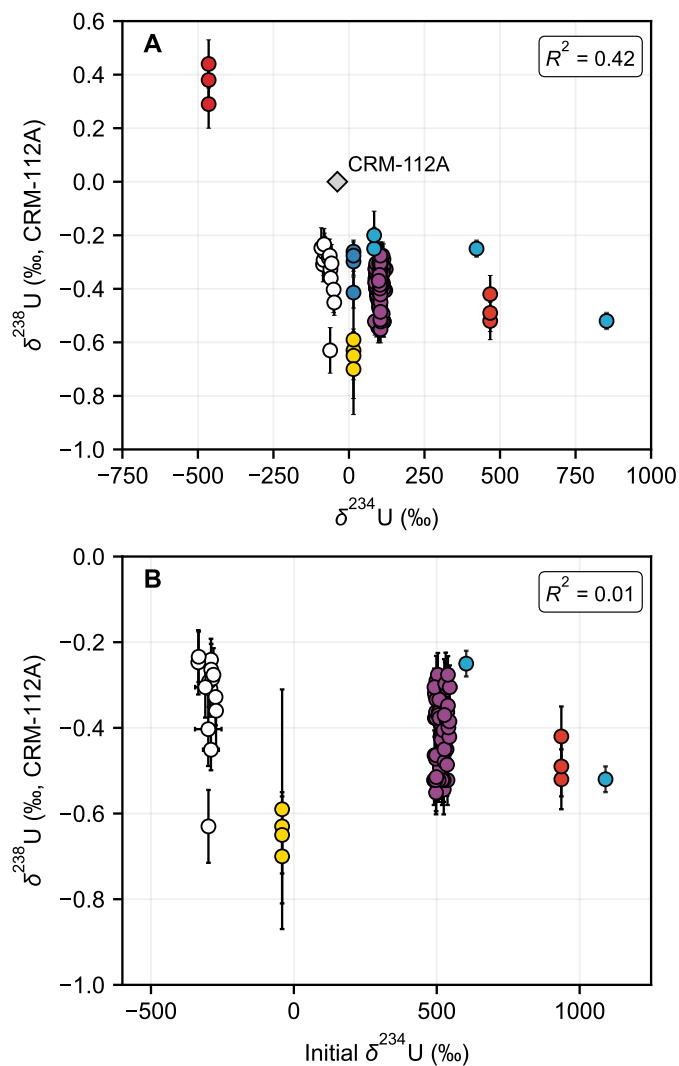
**Figure S4.** U–Pb age uncertainty for each isochron plotted against variables that could plausibly correlate with U–Pb age uncertainties.

# S4 Spread of data along the U–Pb isochron



**Figure S5.** Dispersion of U–Pb data along the regression line plotted against U content (in ppm) and the inverse of total-Pb content (in  $\text{ppb}^{-1}$ ). Data are plotted as a  $z$ -score to allow data points for different isochrons to be plotted together and directly compared. Dispersion of data is calculated as the distance in  $x$  of the least-squares fitted data points ( $x_k$ ) relative to the isochron centroid ( $\bar{x}$ ). See Sect. 4.2 in the main text for further discussion. This shows that data along the isochron is mostly due to variation in total-Pb content (a function mostly of inherited-Pb) rather than U content.

# **S5 Speleothem $\delta^{238}\text{U}$ versus $[\text{}^{234}\text{U}/\text{}^{238}\text{U}]$**



**Figure S6.** Comparison of speleothem  $\delta^{238}\text{U}$  and  $\delta^{234}\text{U}$  values for the samples presented in Fig. 6. The coefficient of determination ( $R^2$ ) is also provided. Where more than one measurement was available for an individual speleothem, an average value was used to compute  $R^2$ , in order to avoid biasing the results according to the number of analyses conducted on a particular sample. Samples that are not analytically resolvable from secular equilibrium were excluded from the plot and  $R^2$  calculation. CRM-112a is plotted for comparison but was not included in the  $R^2$  calculation. (b)  $\delta^{238}\text{U}$  plotted against initial  $\delta^{234}\text{U}$  for speleothem samples where age data is available. Again, a sample average was used to compute  $R^2$  in cases where multiple analyses were made on a single speleothem sample.

## References

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