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Changes in landscape evolution patterns in the northern Alpine Foreland during the Mid-Pleistocene Revolution

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Contents:

Introduction

This supporting information provides detailed information on the results of the depth-profile age calculations using Monte Carlo simulations, including 10 figures that are referenced but not included in the main article.

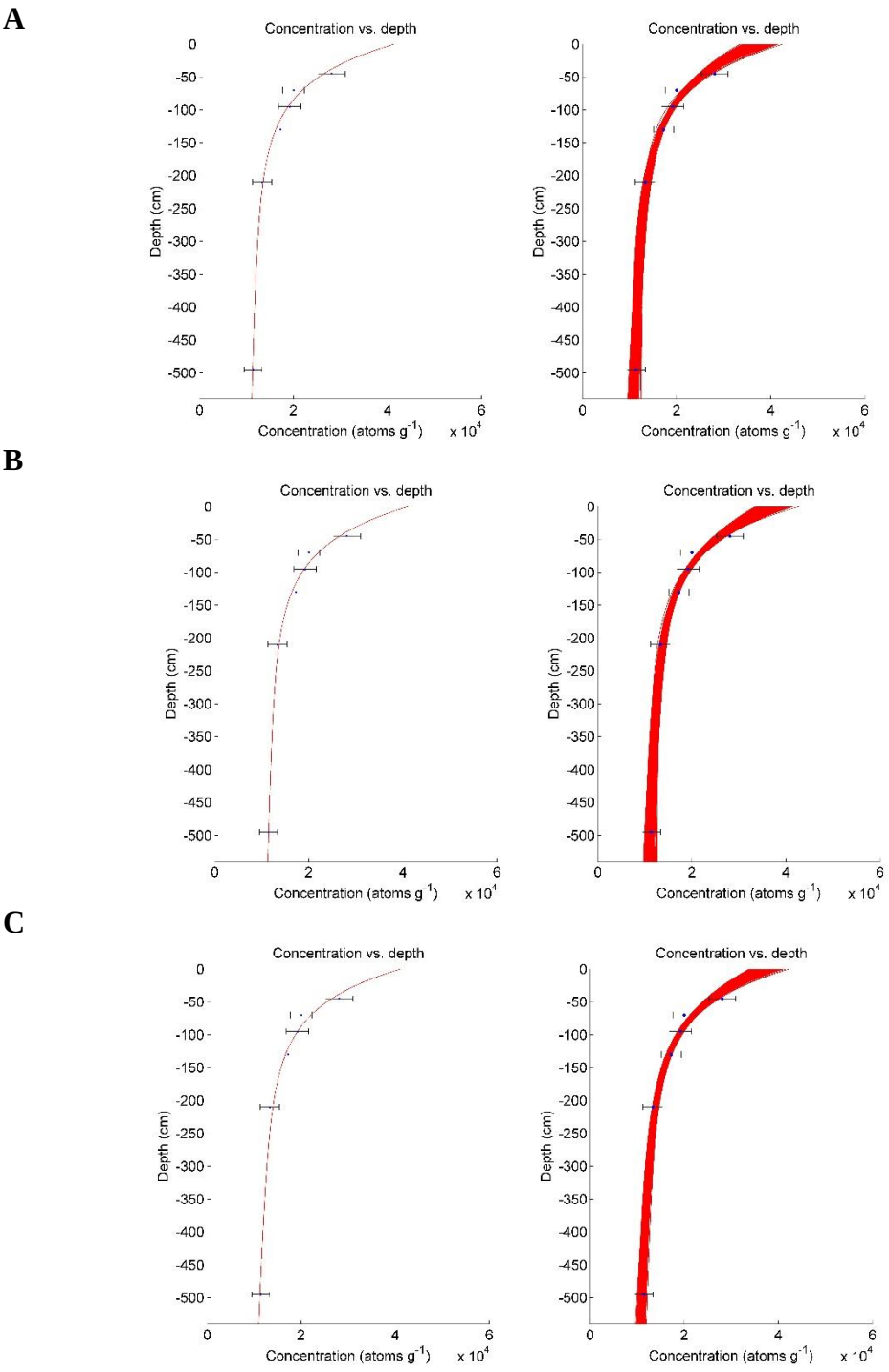
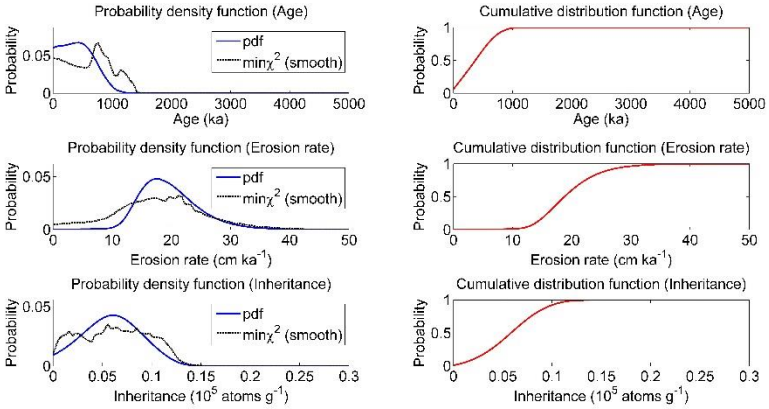


Fig. DR1 Depth profile output of the Monte Carlo age simulation for Ängi: Illustration of the best fit through the samples on the left; and 2σ solution space on the right. Error bars represent 2σ total measurement error. A: 0-150 m net erosion; B: -10-150 m net erosion; C: 100-150 m net erosion.

A



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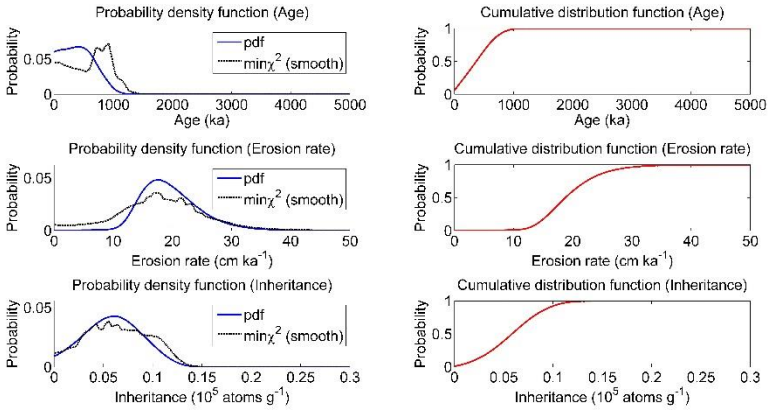

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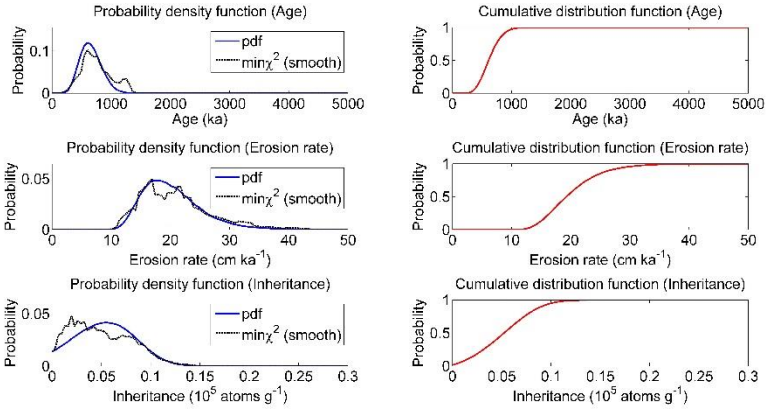
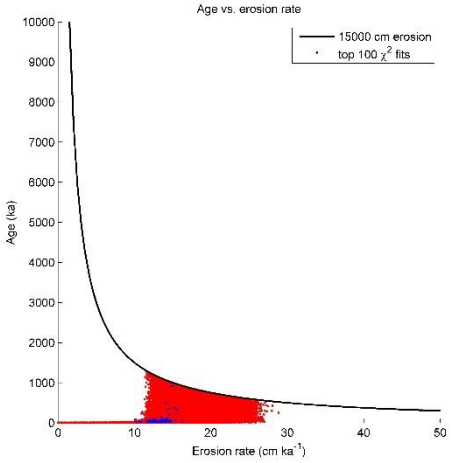


Fig. DR2 Probability density and cumulative distribution functions for the 2σ age, erosion rate and inheritance solution spaces for the six ^{10}Be samples from Ängi. Solid black line indicates the lowest chi-square value. A: 0-150 m net erosion; B: -10-150 m net erosion; C: 100-150 m net erosion.

A



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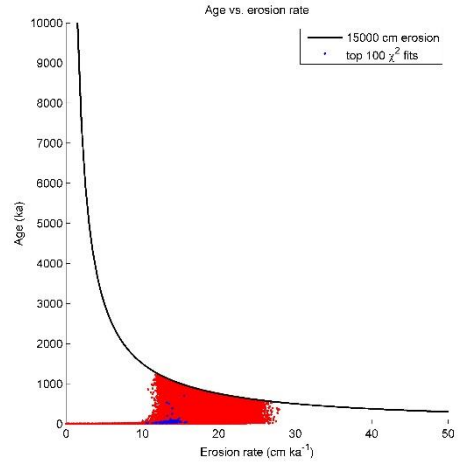

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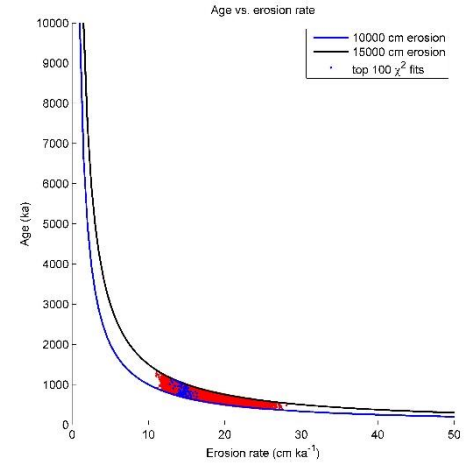


Fig. DR3 Age versus erosion rate plot for the Ängi ^{10}Be depth profile. A: 0-150 m net erosion; B: -10-150 m net erosion; C: 100-150 m net erosion.

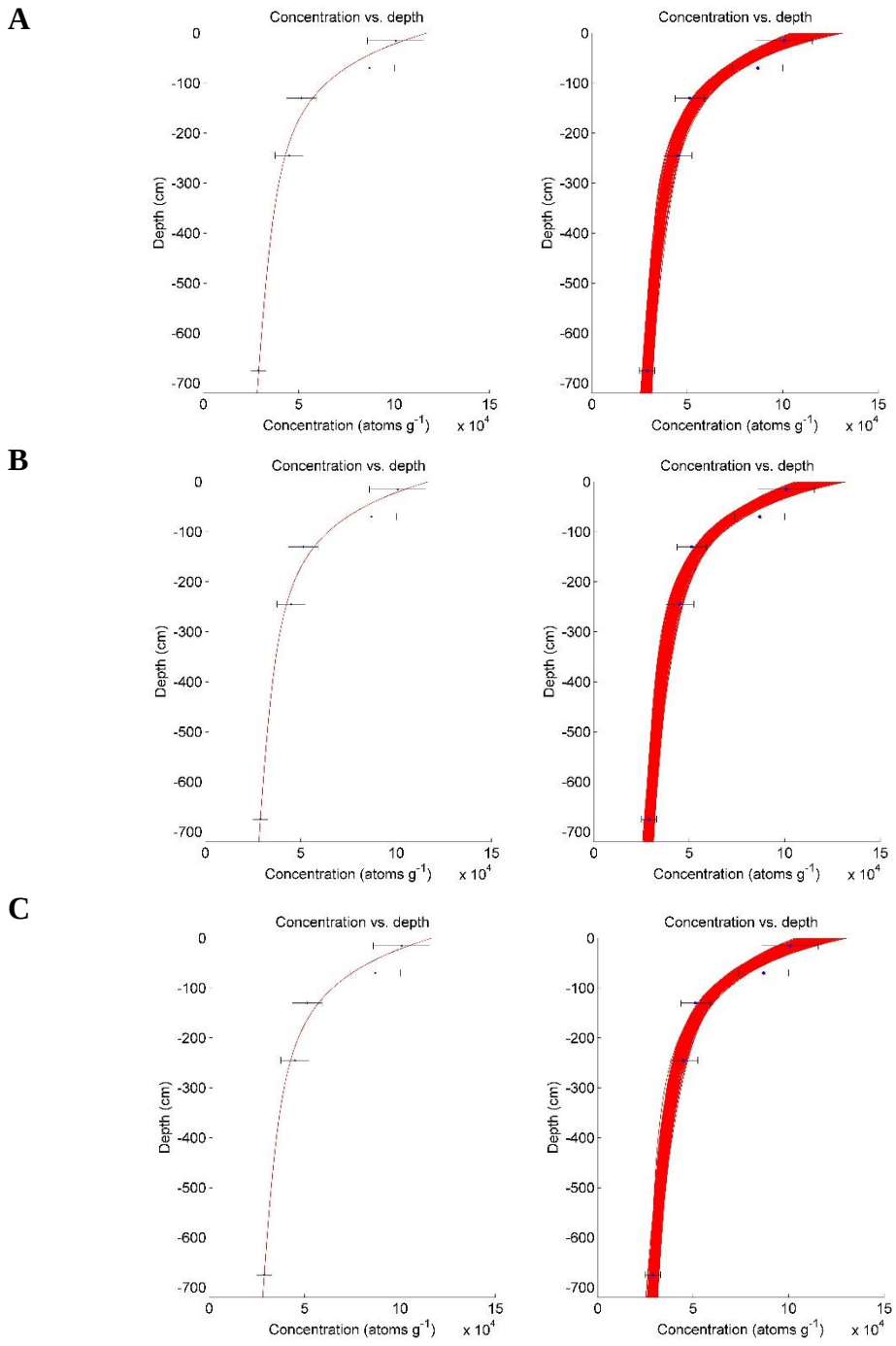
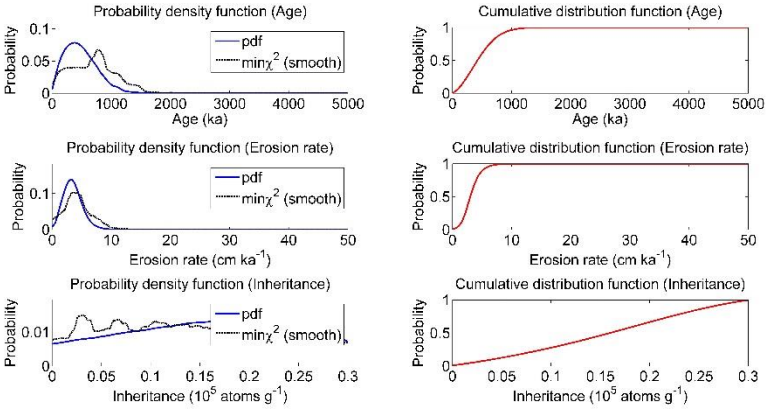


Fig. DR4 Depth profile output of the Monte Carlo age simulation for Rechberg: Illustration of the best fit through the samples on the left; and 3σ solution space on the right. Error bars represent 2σ total measurement error. A0 -28 m net erosion; B: -10-28 m net erosion; C: 10-28 m net erosion.

A



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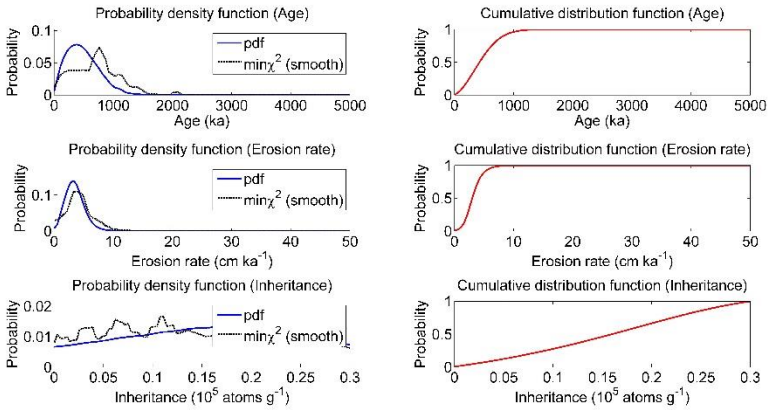

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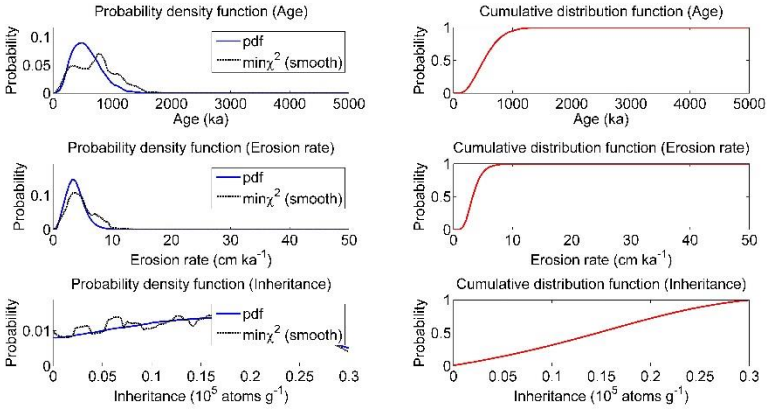
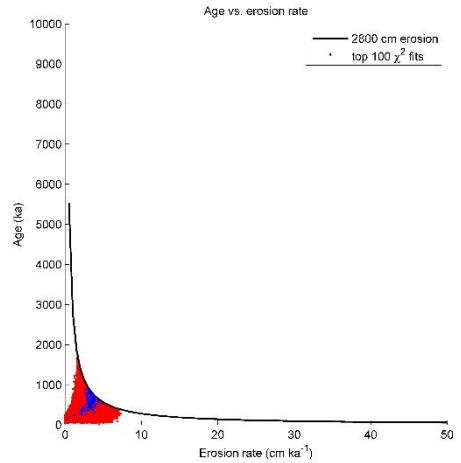


Fig. DR5 Probability density and cumulative distribution functions for the 3σ age, erosion rate and inheritance solution spaces for ^{10}Be depth-profile from Rechberg. Solid black line indicates the lowest chi-square value. A: 0-28 m net erosion; B: -10-28 m net erosion; C: 10-28 m net erosion.

A



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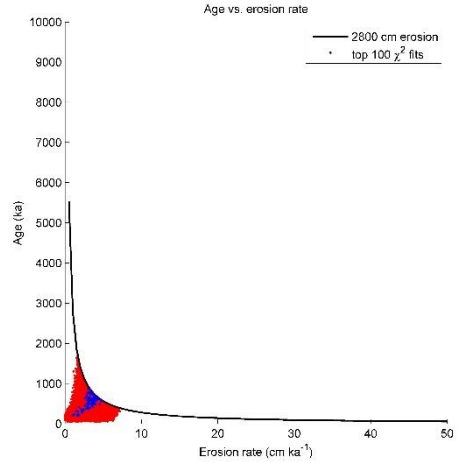

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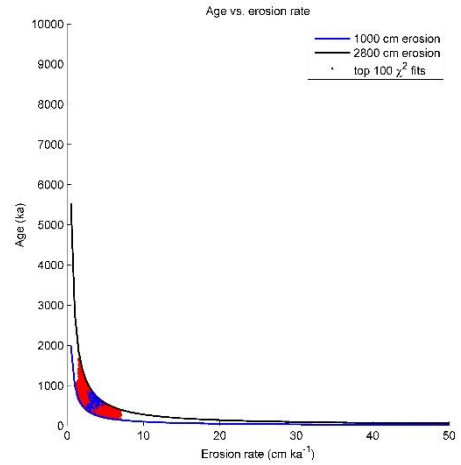
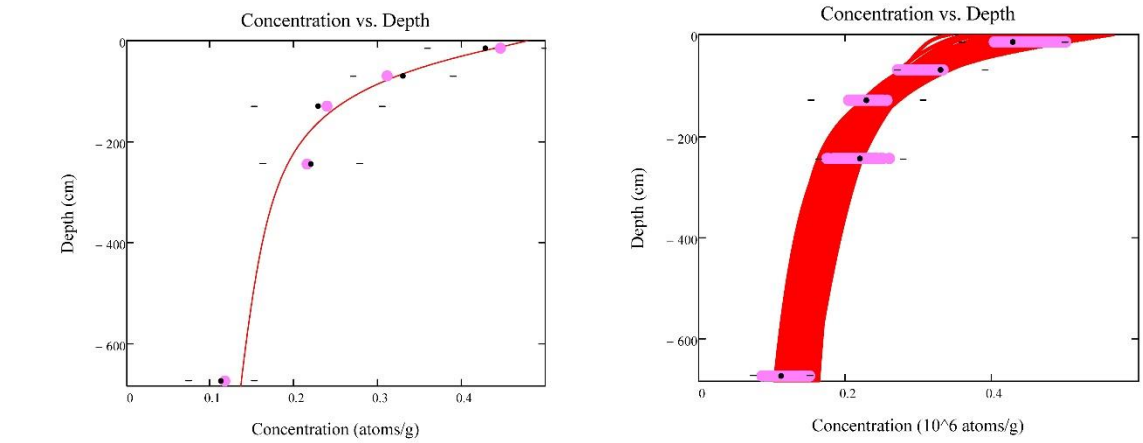


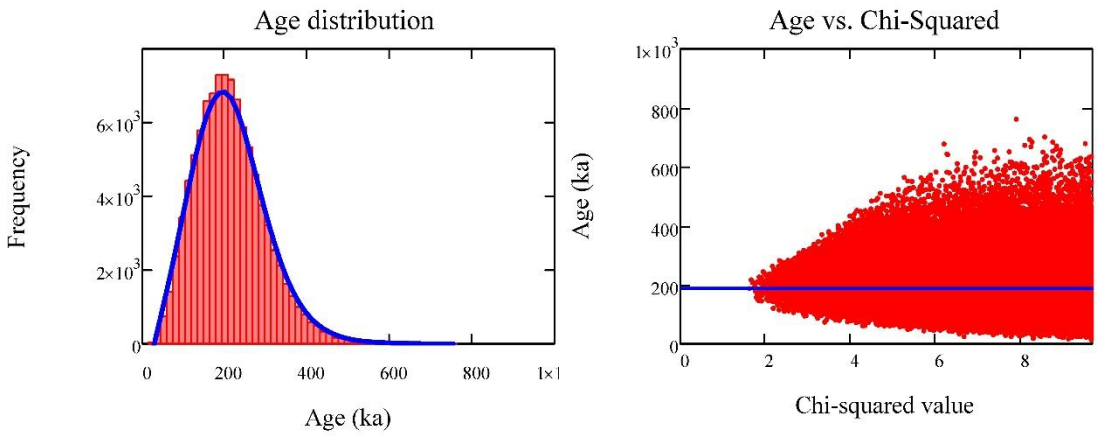
Fig. DR6 Age versus erosion rate plot for the Rechberg ^{10}Be depth profile. A: 0-28 m net erosion; B: -10-28 m net erosion; C: 10-28 m net erosion.



A **B**

Fig. DR7 ^{36}Cl depth profile output of the Monte Carlo age simulation for Rechberg. A: Illustration of the best fit through the samples. B: 2σ solution space. Error bars represent 1σ total measurement error.

A



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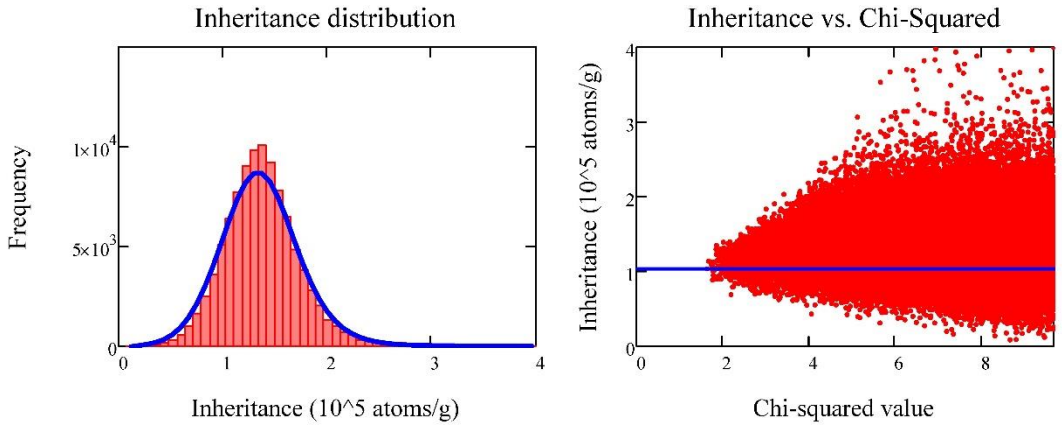

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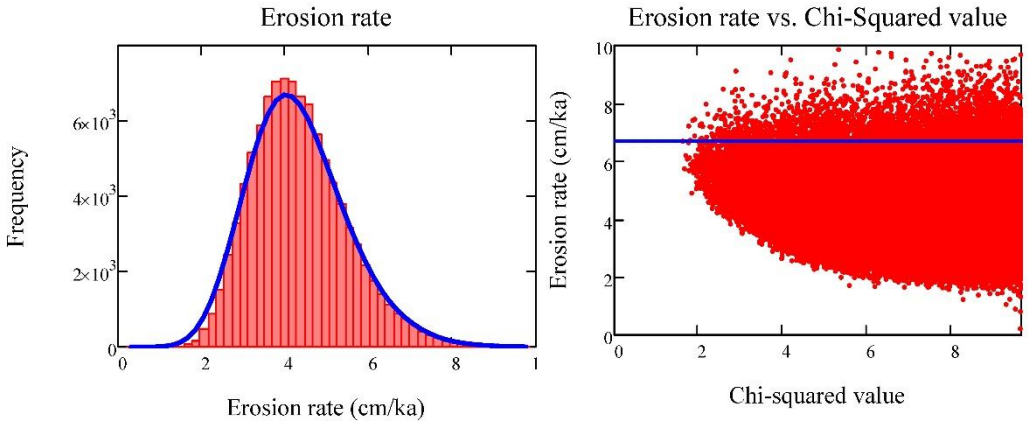


Fig. DR8 Frequency distribution plots for the 2σ age, erosion rate and inheritance solution spaces for the five ^{36}Cl samples from Rechberg. Solid blue line indicates the lowest chi-square value.

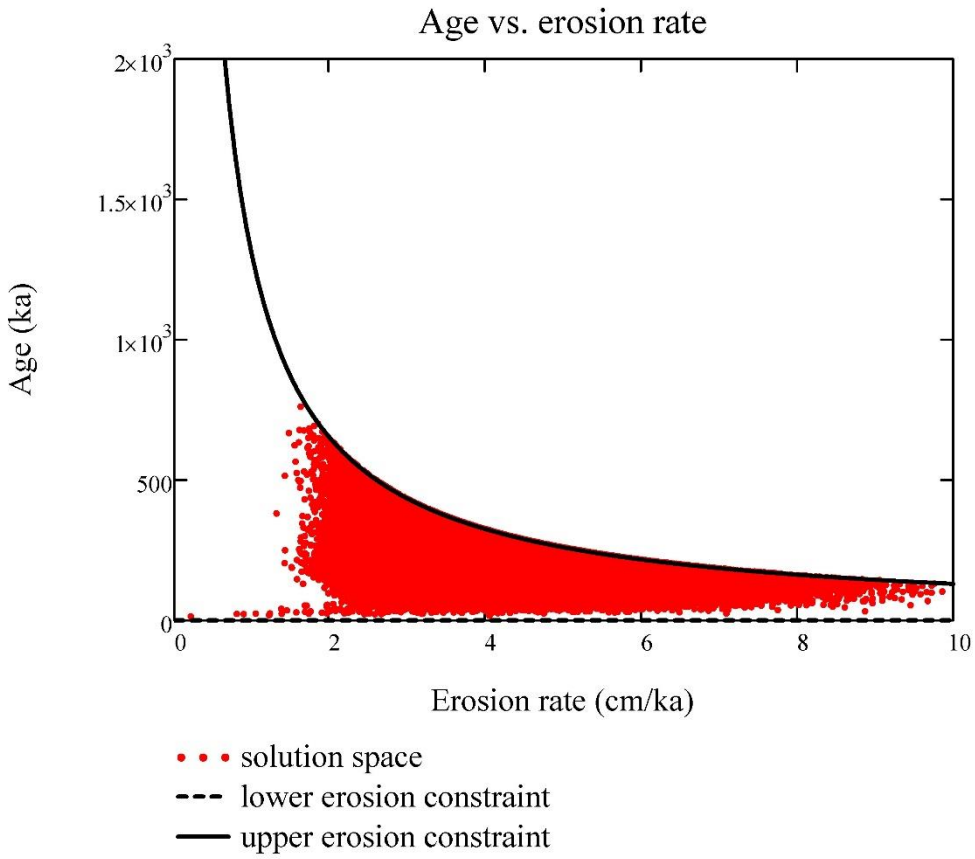


Fig. DR9 Age versus erosion rate plot for the Rechberg ^{36}Cl depth profile.

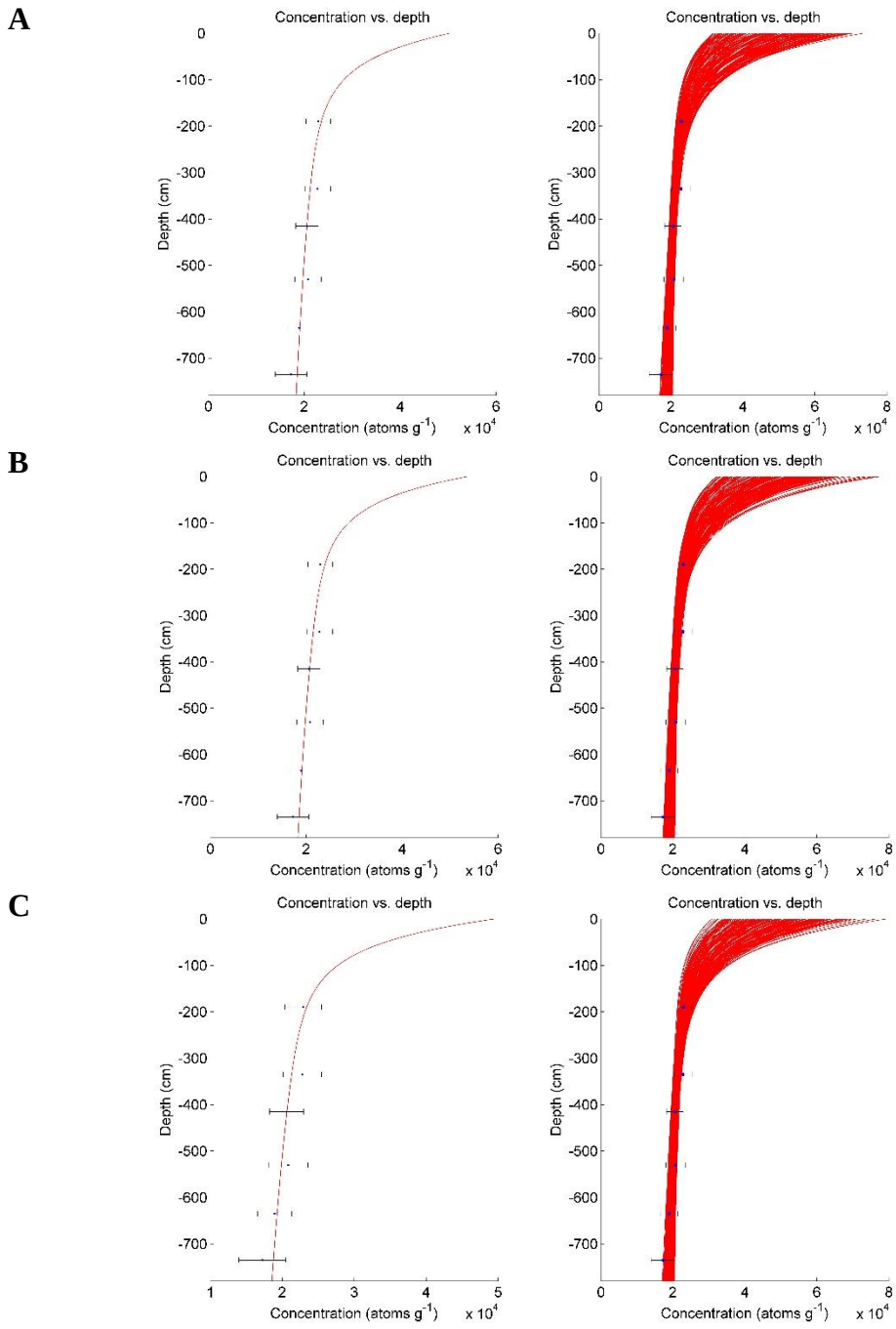
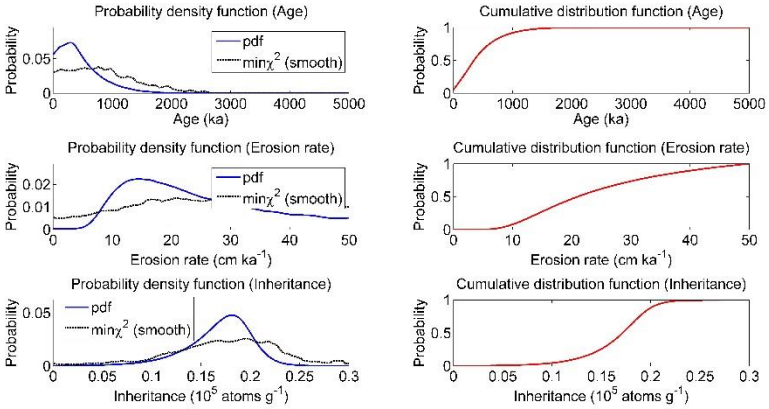


Fig. DR10 Depth profile output of the Monte Carlo age simulation for Irchel Steig: Illustration of the best fit through the samples on the left; and 2σ solution space on the right. Error bars represent 2σ total measurement error. A: θ160 m net erosion; B: -10-160 m net erosion; C: 100-160 m net erosion.

A



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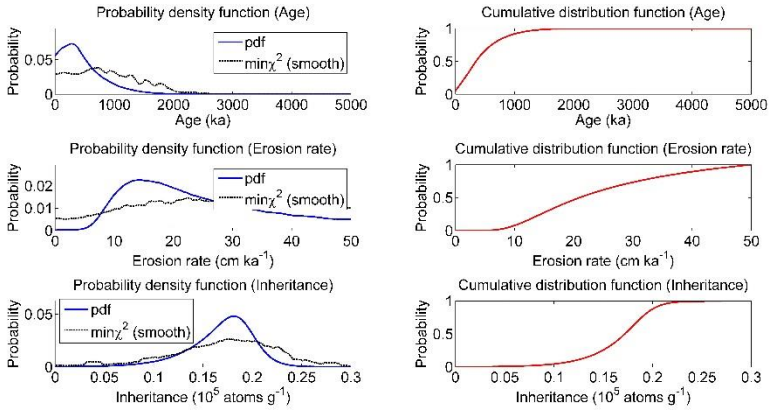

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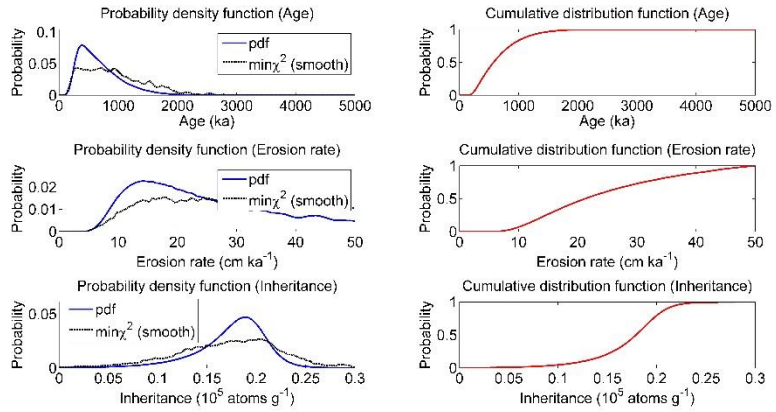
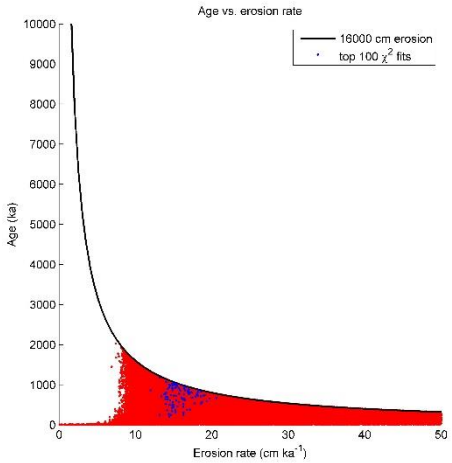


Fig. DR11 Probability density and cumulative distribution functions for the 2σ age, erosion rate and inheritance solution spaces for ^{10}Be depth-profile from Irchel Steig. Solid black line indicates the lowest chi-square value. A: 0-160 m net erosion; B: -10-160 m net erosion; C: 100-160 m net erosion.

A



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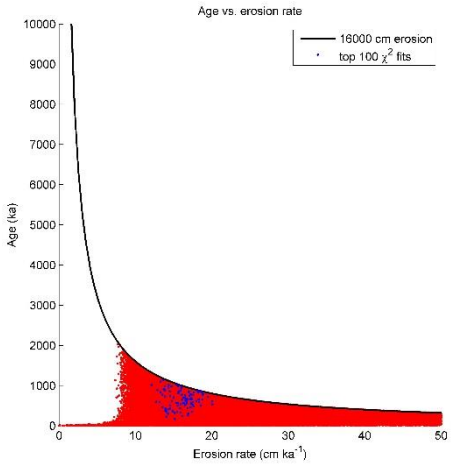

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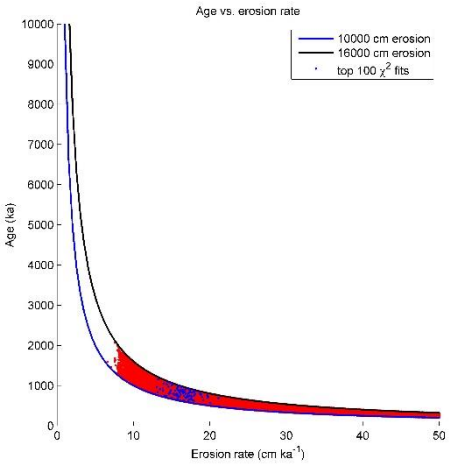


Fig. DR12 Age versus erosion rate plot for the Irchel Steig ^{10}Be depth profile. A: 0-160 m net erosion; B: -10-160 m net erosion; C: 100-160 m net erosion.

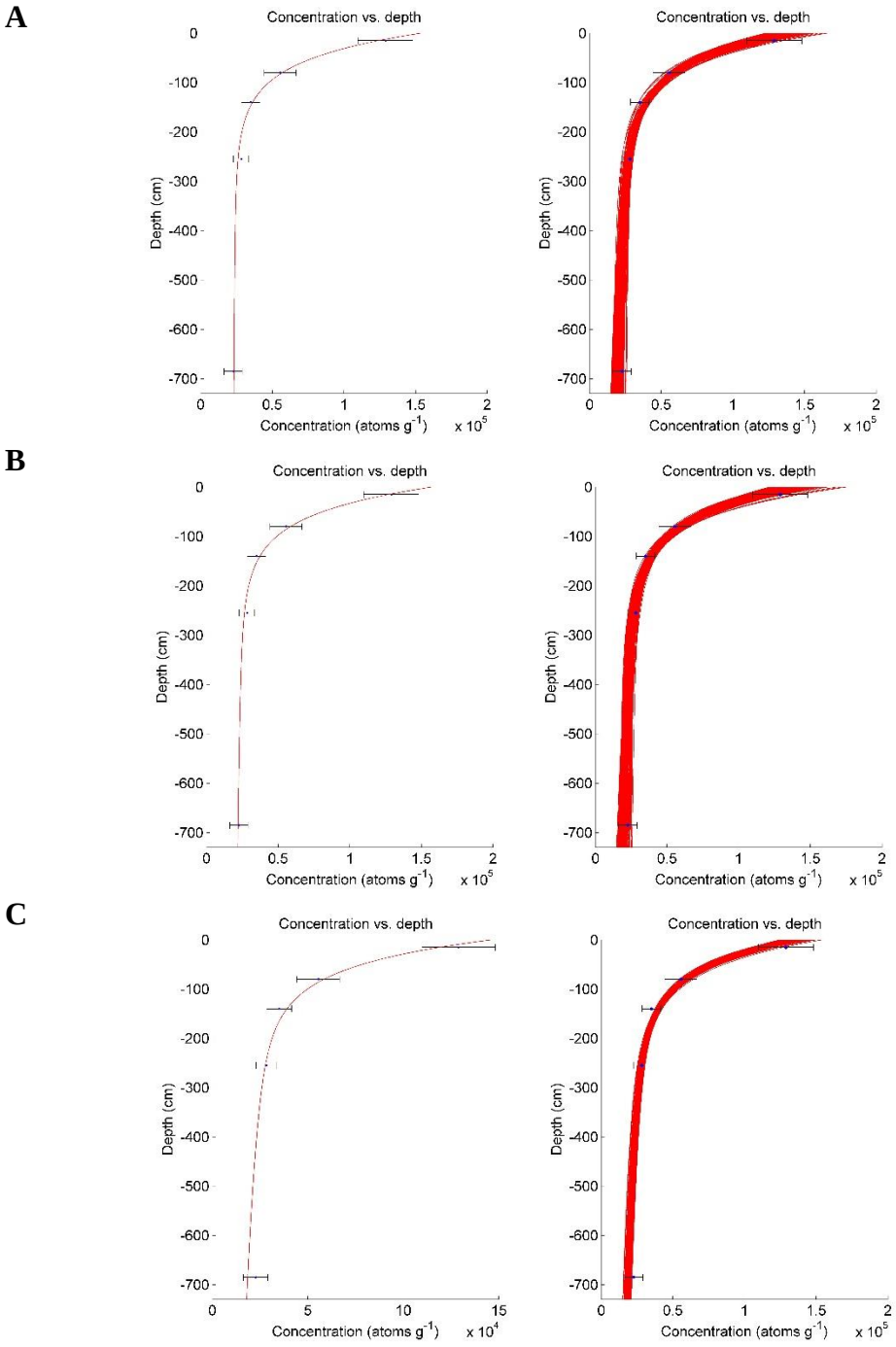


Fig. DR13 Depth profile output of the Monte Carlo age simulation for Wilemer Irchel: Illustration of the best fit through the samples on the left; and 4σ solution space on the right. Error bars represent 4σ total measurement error. A: θ150 m net erosion; B: -10-150 m net erosion; C: 100-150 m net erosion.

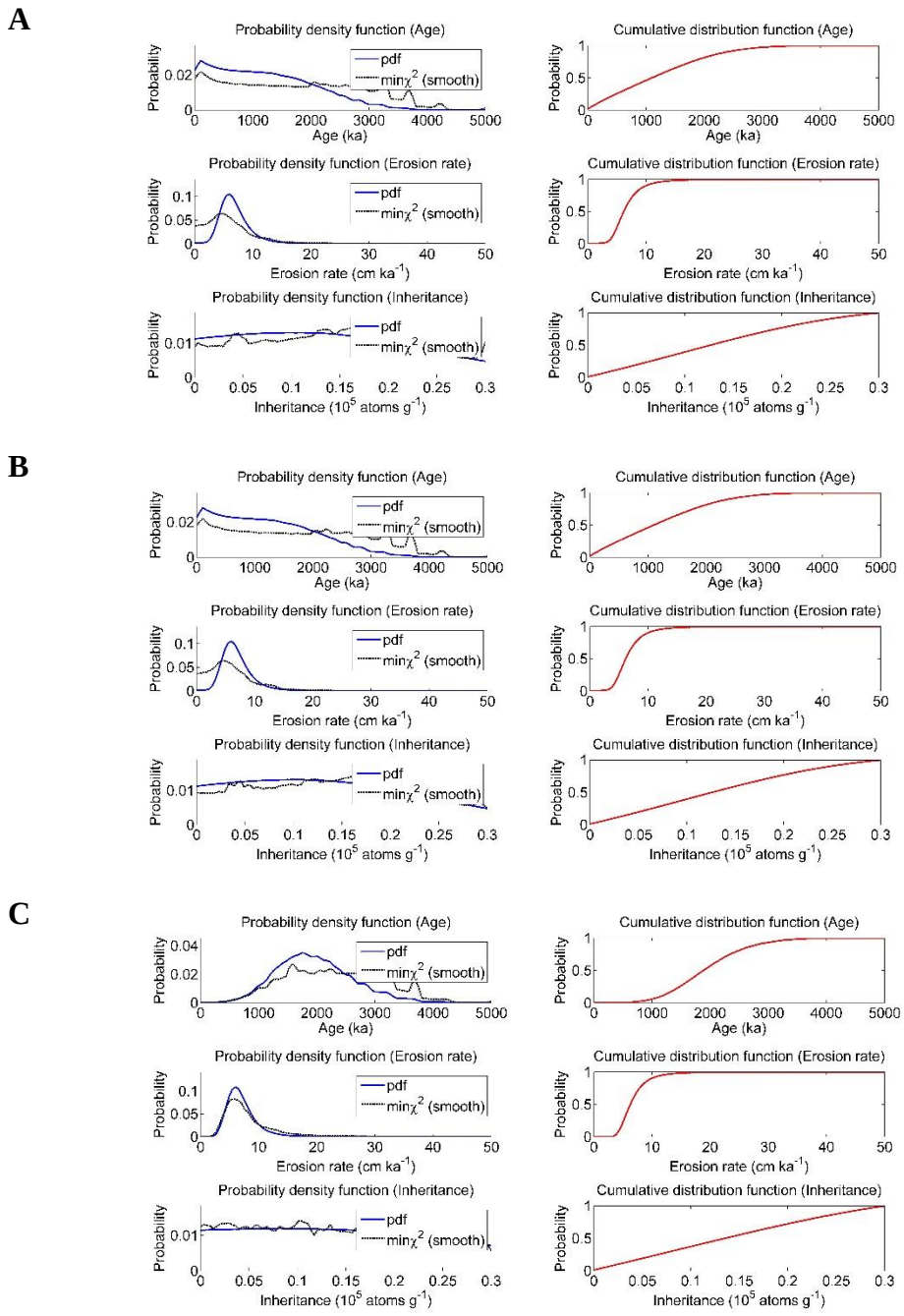
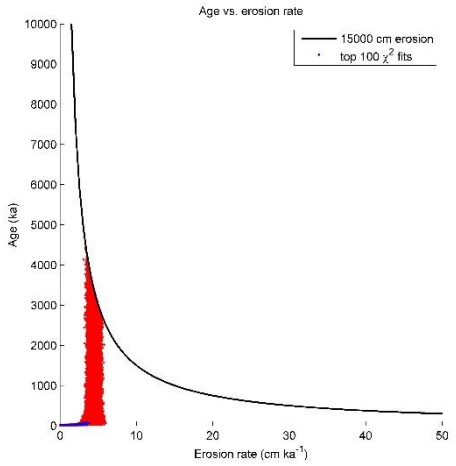


Fig. DR14 Probability density and cumulative distribution functions for the 4σ age, erosion rate and inheritance solution spaces for ^{10}Be depth-profile from Wilemer Irchel. Solid black line indicates the lowest chi-square value. A: 0-150 m net erosion; B: -10-150 m net erosion; C: 100-150 m net erosion.

A



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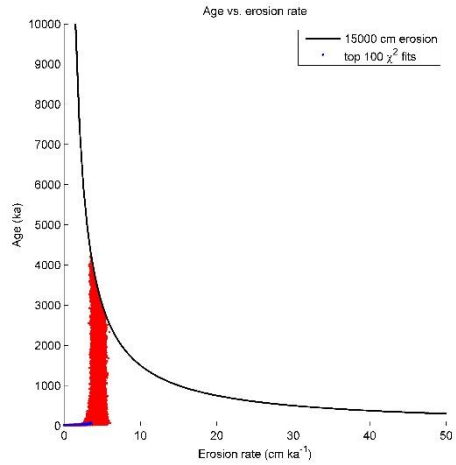

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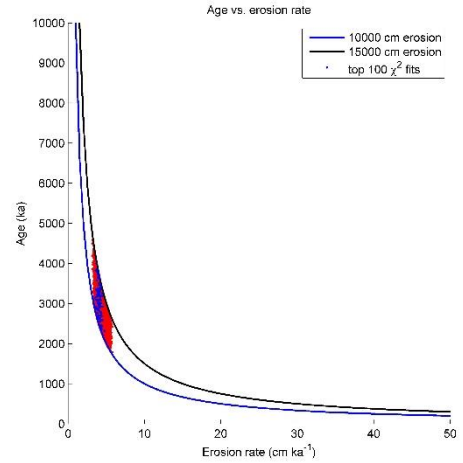


Fig. DR15 Age versus erosion rate plot for the Wilemer Irchel ^{10}Be depth profile. A: 0-150 m net erosion; B: -10-150 m net erosion; C: 100-150 m net erosion.

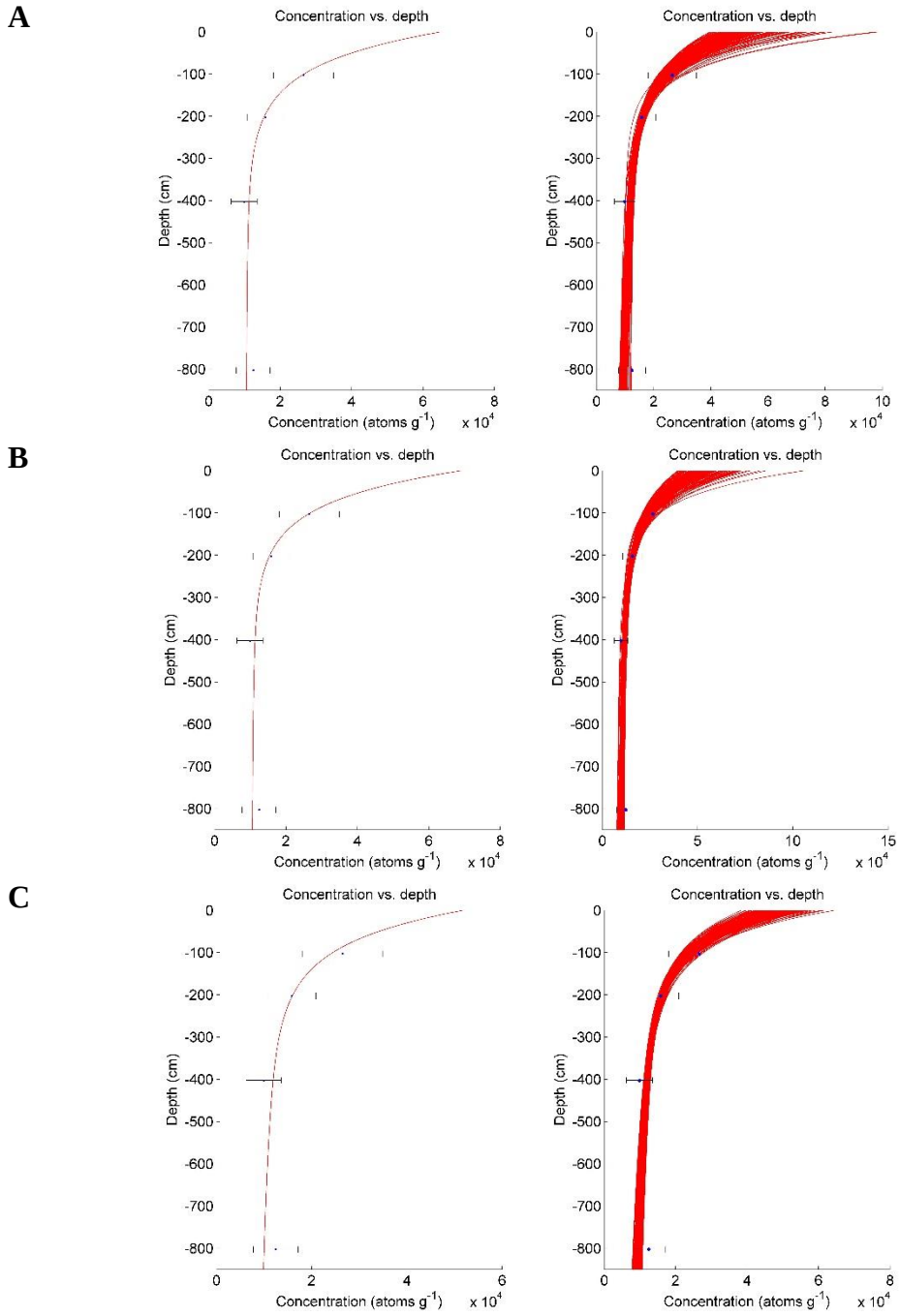
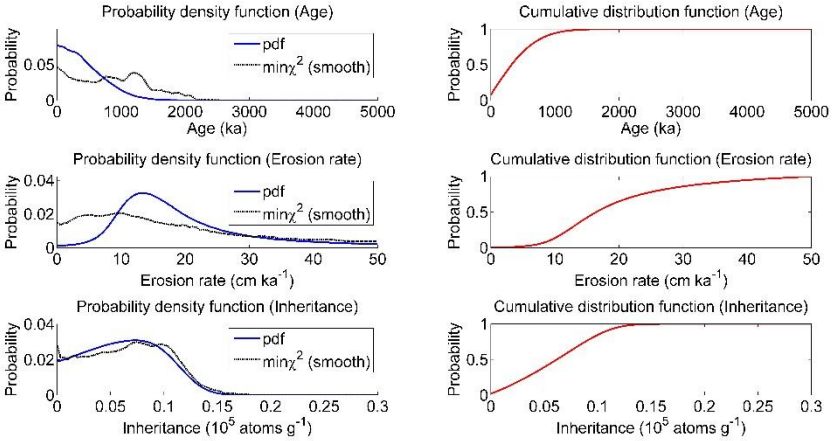


Fig. DR16 Depth profile output of the Monte Carlo age simulation for Mandach: Illustration of the best fit through the samples on the left; and 3σ solution space on the right. Error bars represent 2σ total measurement error. A: 0-150 m net erosion; B: -10-150 m net erosion; C: 100-150 m net erosion.

A



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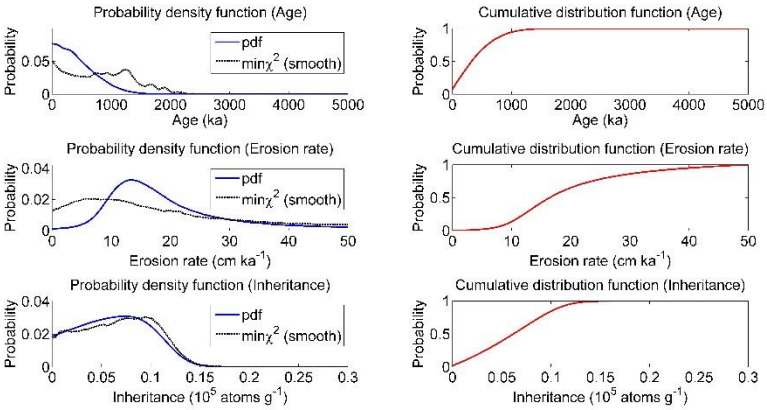


C

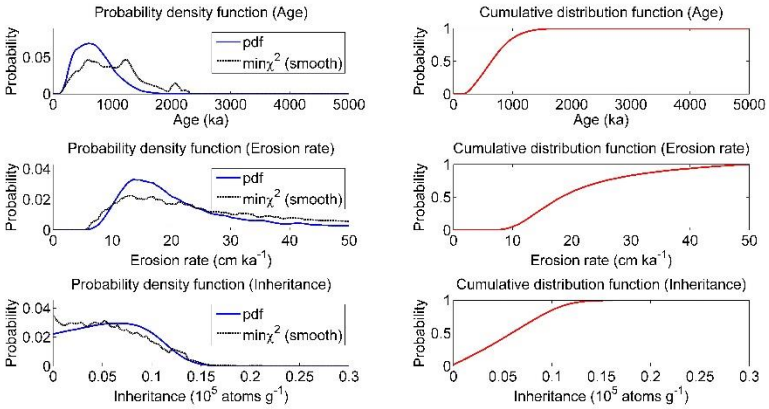
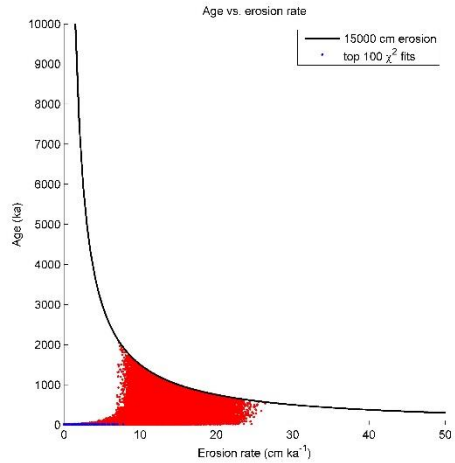
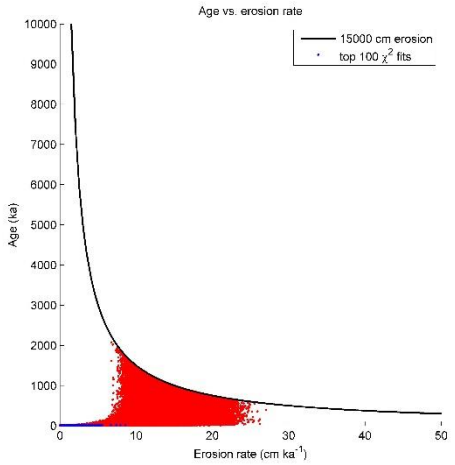


Fig. DR17 Probability density and cumulative distribution functions for the 3σ age, erosion rate and inheritance solution spaces for ^{10}Be depth-profile from Mandach. Solid black line indicates the lowest chi-square value. A: 0-150 m net erosion; B: -10-150 m net erosion; C: 100-150 m net erosion.

A



B



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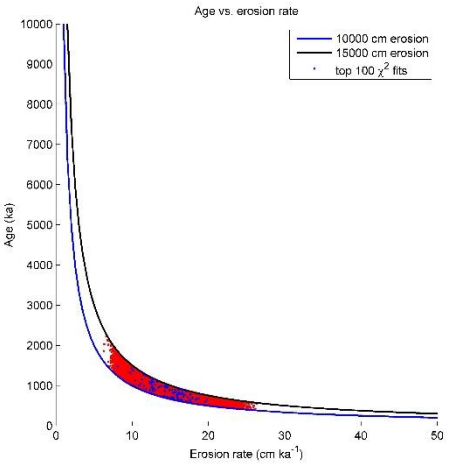


Fig. DR18 Age versus erosion rate plot for the Mandach ^{10}Be depth profile. A: 0-150 m net erosion; B: -10-150 m net erosion; C: 100-150 m net erosion.

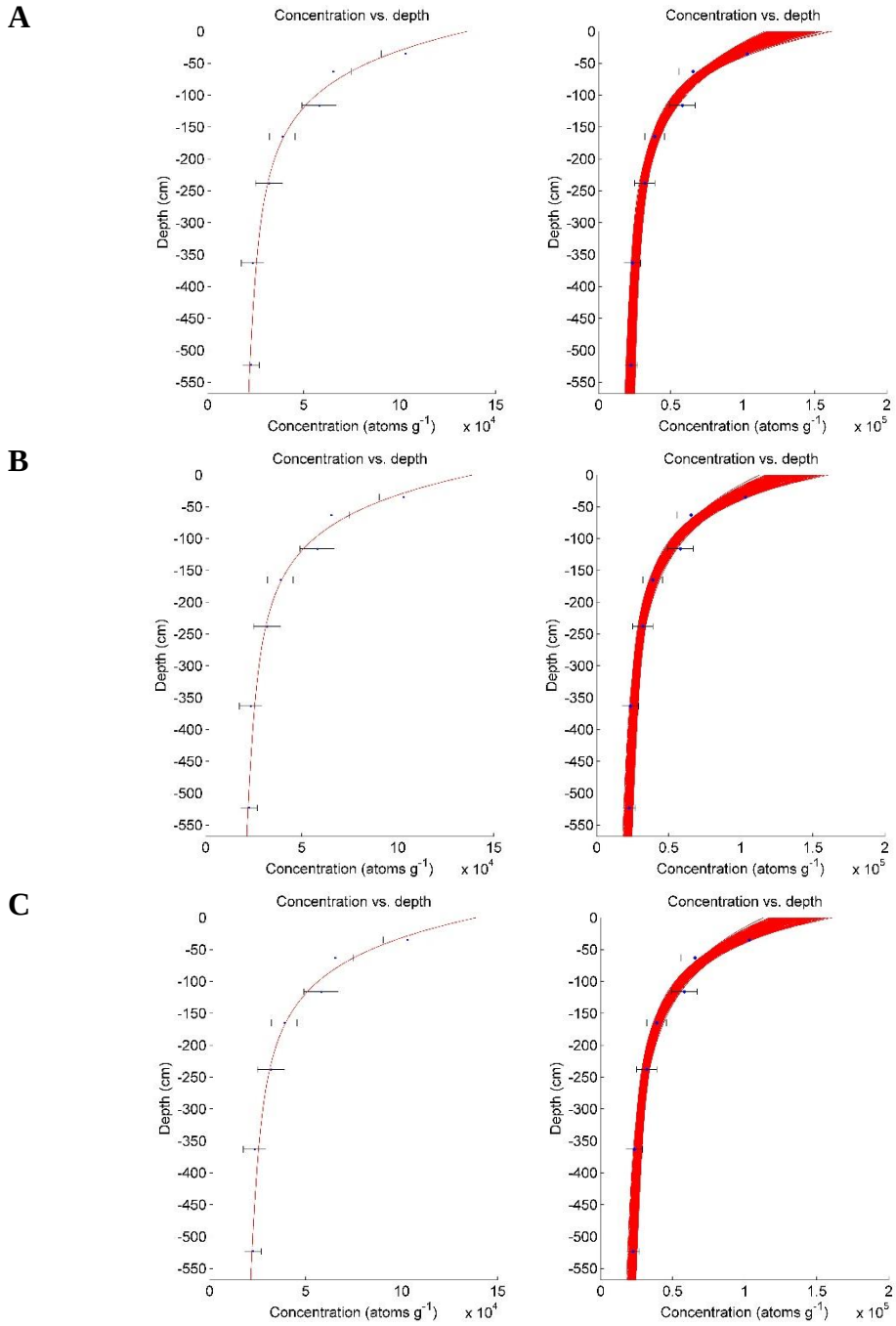
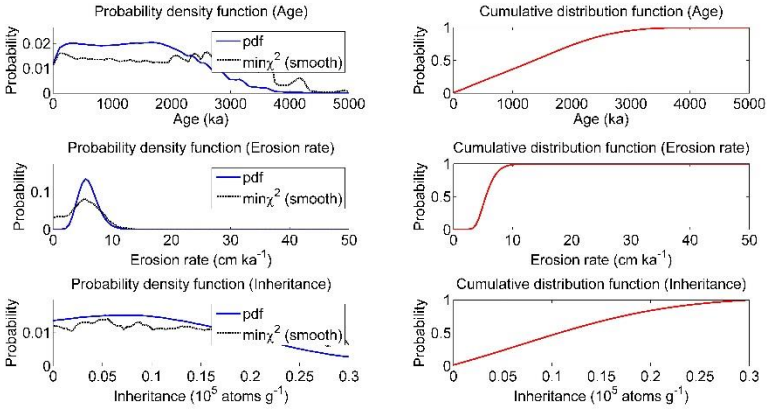


Fig. DR19 Depth profile output of the Monte Carlo age simulation for Stadlerberg: Illustration of the best fit through the samples on the left; and 3σ solution space on the right. Error bars represent 2σ total measurement error. A: θ150 m net erosion; B: -10-150 m net erosion; C: 100-150 m net erosion.

A



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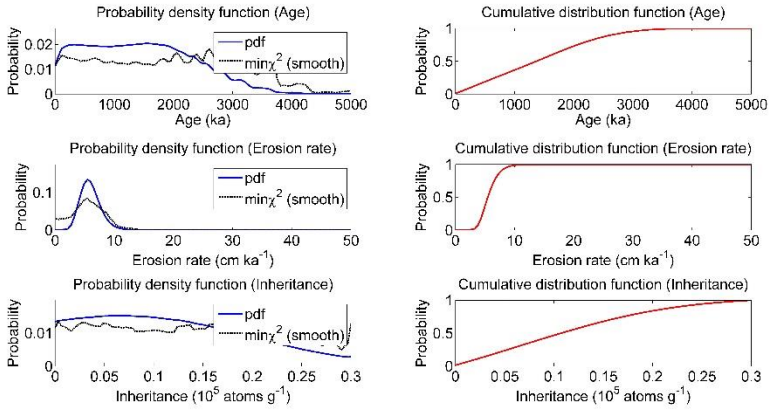

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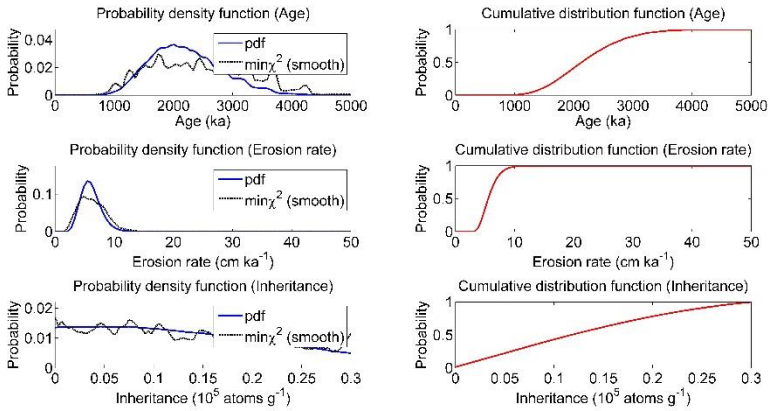
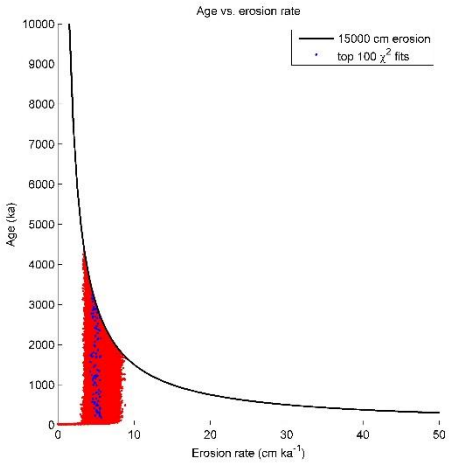


Fig. DR20 Probability density and cumulative distribution functions for the 3σ age, erosion rate and inheritance solution spaces for ^{10}Be depth-profile from Stadlerberg. Solid black line indicates the lowest chi-square value. A: 0-150 m net erosion; B: -10-150 m net erosion; C: 100-150 m net erosion.

A



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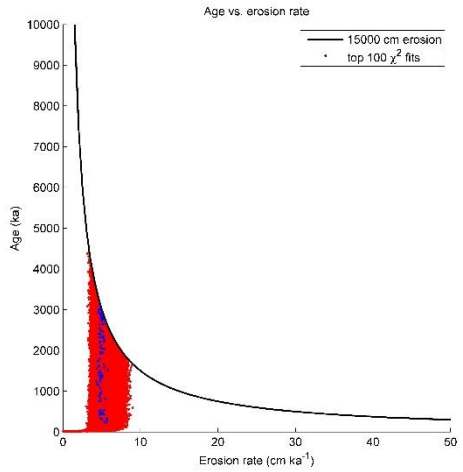

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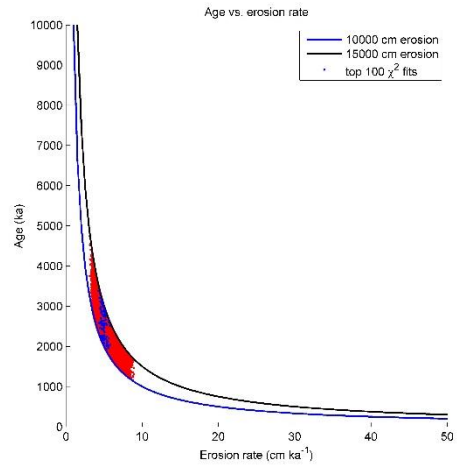

Fig. DR21 Age versus erosion rate plot for the Stadlerberg ^{10}Be depth profile. A: 0-150 m net erosion; B: -10-150 m net erosion; C: 100-150 m net erosion.

TABLE DR1. MAJOR AND TRACE ELEMENT DATA (DETERMINED BY XRAL. ONTARIO, CANADA) OF THE SAMPLES FROM RECHBERG

Sample name	SiO_2 (wt.%)	Al_2O_3 (wt.%)	Fe_2O_3 (wt.%)	MnO (wt.%)	MgO (wt.%)	CaO (wt.%)	Na_2O (wt.%)	K_2O (wt.%)	TiO_2 (wt.%)	P_2O_5 (wt.%)	Sm (ppm)	Gd (ppm)	U (ppm)	Th (ppm)
SCHW-DP-1b*	47.76	2.19	1.11	0.04	0.96	24.82	0.29	0.53	0.10	0.04	1.30	1.40	0.80	1.60
SCHW-DP-2	58.26	2.30	1.46	0.04	0.43	20.21	0.34	0.72	0.08	0.03	1.00	1.00	0.50	1.50
SCHW-DP-3b*	59.42	2.55	1.67	0.04	1.38	18.05	0.41	0.62	0.12	0.01	1.30	1.40	0.90	1.70
SCHW-DP-4b*	44.49	2.10	1.32	0.03	1.27	26.68	0.33	0.47	0.10	0.04	1.10	1.10	0.70	1.60
SCHW-DP-5	70.00	2.48	1.86	0.04	0.59	13.16	0.38	0.66	0.10	0.02	1.20	1.10	0.60	1.60
Average	55.99	2.32	1.48	0.04	0.93	20.58	0.35	0.60	0.10	0.03	1.18	1.20	0.70	1.60

*samples that were resampled.

TABLE DR2. INPUT PARAMETERS FOR THE 10BE MONTE CARLO AGE SIMULATIONS FOR THE SAMPLES IN ÄNGI, RECHBERG, IRCHEL STEIG ANDWILEMER IRCHEL (HIDY ET AL., 2010)

Parameter	Ängi			Rechberg			Irchel Steig		
Latitude (degree)	47.560			47.634			47.536		
Longitude (degree)	8.191			8.359			8.615		
Altitude (m)	475			433			675		
Strike (degree)	0			0			0		
Dip (degree)	0			0			0		
Shielding correction factor	1			1			1		
Cover correction factor	1			1			1		
Uncertainty of ^{10}Be Half-life (%)	1			1			1		
Local spallogenic production rate (at.g^{-1}.a^{-1})	5.62			5.38			7.05		
Error in local spallogenic production rate (at.g^{-1}.a^{-1})	± 0.30 (2σ)			± 0.30 (2σ)			± 0.30 (2σ)		
Error in total production rate (%)	5			5			5		
Density (g.cm^{-3})	1.8 - 2.6			1.8 - 2.6			1.8 - 2.6		
Number of profiles	100'000			100'000			100'000		
Depth of muon fit (m)	155			35			168		
Total erosion threshold (cm)	0 - 15,000	-1000 - 15,000	10,000 - 15,000	0 - 2800	-1000 - 2800	1000 - 2800	0 - 16,000	-1000 - 16,000	10,000 - 16,000
Confidence level (σ)	2			3			2		
Age (a)	0 - 5,000,000			0 - 5,000,000			0 - 5,000,000		
Erosion rate (cm.ka^{-1})	0 - 50			0 - 50			0 - 50		
Inheritance (at.g^{-1})	0 - 30,000			0 - 30,000			0 - 30,000		
Attenuation length (g.cm^{-2})	160 ± 5			160 ± 5			160 ± 5		

Parameter	Wilemer Irchel			Mandach (Akçar et al. 2014)			Stadlerberg (Calude et al. 2017)		
Latitude (degree)	47.545			47.554			47.533		
Longitude (degree)	8.606			8.187			8.446		
Altitude (m)	678			507			610		
Strike (degree)	0			0			0		
Dip (degree)	0			0			0		
Shielding correction factor	1			1			1		
Cover correction factor	1			1			1		
Uncertainty of ^{10}Be Half-life (%)	1			1			1		
Local spallogenic production rate (at.g^{-1}.a^{-1})	7.05			5.88			7.18		
Error in local spallogenic production rate (at.g^{-1}.a^{-1})	± 0.30 (2σ)			± 0.30 (2σ)			± 0.30 (2σ)		
Error in total production rate (%)	5			5			5		
Density (g.cm^{-3})	2.2 - 2.6			1.8 - 2.6			1.8 - 2.6		
Number of profiles	100'000			100'000			100'000		
Depth of muon fit (m)	157			158			156		
Total erosion threshold (cm)	0 - 15,000	-1000 - 15,000	10,000 - 15,000	0 - 15,000	-1000 - 15,000	10,000 - 15,000	0 - 15,000	-1000 - 15,000	10,000 - 15,000
Confidence level (σ)	4			3			3		
Age (a)	0 - 5,000,000			0 - 5,000,000			0 - 5,000,000		
Erosion rate (cm.ka^{-1})	0 - 50			0 - 50			0 - 50		
Inheritance (at.g^{-1})	0 - 30,000			0 - 30,000			0 - 30,000		
Attenuation length (g.cm^{-2})	160 ± 5			160 ± 5			160 ± 5		

Note: A half-live of 1.387 ± 0.012 Ma for 10Be (Chmeleff et al., 2010; Korschinek et al., 2010) is considered for the calculations. Local spallogenic production rate is calculated with the CRONUS-Earth exposure age calculator (http://hess.ess.washington.edu/math/; v. 2.2; Balco et al., 2008 and update from v. 2.1 to v. 2.2 published by Balco in October 2009) and constant production rate Lal (1991)/Stone (2000) scaling model using the NENA (Balco et al., 2009) production rate calibration dataset.

TABLE DR3. INPUT PARAMETERS FOR THE ^{36}CL MONTE CARLO AGE SIMULATIONS OF THE SAMPLES IN RECHBERG

Parameter	Value
Latitude (degree)	47.634
Longitude (degree)	8.359
Altitude (m)	433
Strike (degree)	0
Dip (degree)	0
Shielding correction factor	1
Cover correction factor	1
Density (g/cm^3)	1.8 - 2.6
Depth of muon fit (m)	20
Scaling scheme (Balco et al., 2008)	St
Spallogenic production rates (at/g/a) from:	
- Ca (Stone et al., 1996)	48.8 ± 3.4
- K (Evans et al., 1997)	170 ± 27
- Ti (Fink et al., 2000)	13 ± 3
- Fe (Stone et al., 2005)	1.9 ± 0.2
Production rate of epithermal neutrons (g air)$^{-1}$ a^{-1} (Alfimov and Ivy-Ochs, 2009)	760 ± 150
Muogenic production rate error (%)	5
Attenuation length (g/cm^2):	
- fast neutrons	160 ± 8
- epithermal neutrons	3.13 ± 0.25
- thermal neutrons	15.48 ± 1.1
Uncertainty of ^{36}Cl half-life (%)	5
Age (a)	0 - 1,000,000
Net erosion (cm)	0 - 1,300
Erosion rate (cm/ka)	0 - 10
Inheritance (at/g)	0 - 400,000
Confidence interval (σ)	4
Number of profiles	100,000

Note: A half-live (3.013 ± 0.015) x 10^5 a (Lederer and Shirley, 1978) is considered for the calculations

TABLE DR4. OUTPUT VALUES FROM THE DEPTH PROFILE MODELLING FOR THE SITES ÄNGI, IRCHEL STEIG, WILEMER IRCHEL AND RECHBERG

	Age (ka)	Inheritance (10^4 atoms/g)	Erosion rate (cm/ka)	Age (ka)	Inheritance (10^4 atoms/g)	Erosion rate (cm/ka)	**Age (ka)**	**Inheritance (10^4 atoms/g)**	**Erosion rate (cm/ka)**
Ängi ^{10}Be	net erosion: 0 - 15000 cm			net erosion: -1000 - 15000 cm			**net erosion: 10000 - 15000 cm**		
Mean	434	0.56	17.32	435	0.56	17.32	**729**	**0.49**	**17.55**
Median	429	0.55	17.12	430	0.55	17.14	**720**	**0.49**	**17.27**
Mode	6	0.57	16.50	6	0.56	16.39	**690**	**0.52**	**15.92**
Minimum χ^2	48	0.85	11.55	54	0.82	12.86	**1010**	**0.77**	**12.77**
Maximum	1271	1.27	28.85	1247	1.26	27.87	**1324**	**1.34**	**28.04**
Minimum	4	0.00	0.00	4	0.00	0.00	**370**	**0.00**	**11.00**
Bayesian most probable	435	0.62	16.85	435	0.59	17.92	**598**	**0.49**	**17.93**
Bayesian 2-sigma upper	932	1.14	31.81	927	1.14	31.80	**2010**	**1.09**	**32.44**
Bayesian 2-sigma lower	0	0.04	11.58	0	0.04	11.59	**322**	**0.02**	**12.77**
Irchel Steig ^{10}Be	net erosion: 0 - 14000 cm			net erosion: -1000 - 14000 cm			**net erosion: 10000 - 16000 cm**		
Mean	414	1.71	24.57	414	1.72	24.57	**630**	**1.80**	**24.72**
Median	351	1.75	22.46	350	1.75	22.43	**572**	**1.83**	**22.62**
Mode	324	1.84	17.51	327	1.83	15.72	**377**	**1.91**	**18.13**
Minimum χ^2	374	1.19	16.74	873	1.40	13.81	**693**	**1.45**	**16.87**
Maximum	2031	2.98	50.00	2028	2.98	50.00	**2066**	**3.00**	**50.00**
Minimum	2	0.23	0.06	2	0.34	0.01	**201**	**0.02**	**6.59**
Bayesian most probable	326	1.83	15.76	326	1.83	14.13	**380**	**1.89**	**14.67**
Bayesian 2-sigma upper	1397	2.20	47.55	1398	2.20	47.53	**1612**	**2.29**	**47.47**
Bayesian 2-sigma lower	0.00	0.81	7.66	0.00	0.82	7.69	**178**	**0.78**	**8.17**
Wilemer Irchel ^{10}Be	net erosion: 0 - 15000 cm			net erosion: -1000 - 15000 cm			**net erosion: 10000 - 15000 cm**		
Mean	1032	1.16	4.20	1034	1.16	4.20	**2828**	**1.13**	**4.50**
Median	462	1.14	4.37	472	1.14	4.37	**2821**	**1.00**	**4.51**
Mode	26	1.12	4.44	23	1.05	4.55	**2748**	**0.24**	**4.52**
Minimum χ^2	20	2.21	0.59	55	1.91	2.99	**2914**	**2.34**	**3.66**
Maximum	4442	3.00	5.98	4366	3.00	6.05	**4597**	**3.00**	**5.81**
Minimum	13	0.00	0.00	13	0.00	0.00	**1782**	**0.00**	**3.15**
Bayesian most probable	54	1.17	5.43	54	1.04	5.43	**1794**	**0.88**	**5.43**
Bayesian 2-sigma upper	3101	2.85	14.48	3097	2.85	14.48	**3420**	**2.90**	**14.08**
Bayesian 2-sigma lower	6	0.03	3.13	6	0.03	3.14	**794**	**0.03**	**3.62**
Rechberg ^{10}Be	net erosion: 0 - 2800 cm			net erosion: -1000 - 2800 cm			**net erosion: 1000 - 2800 cm**		
Mean	527	1.19	3.10	527	1.19	3.10	**602**	**1.10**	**3.40**
Median	505	1.22	3.00	506	1.22	3.01	**577**	**1.14**	**3.25**
Mode	393	1.52	2.74	486	1.38	2.74	**541**	**1.46**	**2.77**
Minimum χ^2	660	0.49	3.72	555	0.69	3.66	**503**	**0.67**	**3.66**
Maximum	1684	2.88	7.27	1693	2.81	7.18	**1678**	**2.54**	**7.10**
Minimum	35	0.00	0.00	43	0.00	0.00	**159**	**0.00**	**1.15**
Bayesian most probable	380	1.86	2.72	380	1.86	2.72	**435**	**1.63**	**3.26**
Bayesian 2-sigma upper	1092	2.90	6.84	1095	2.90	6.84	**1125**	**2.86**	**7.11**
Bayesian 2-sigma lower	37	0.08	0.56	37	0.08	0.56	**170**	**0.06**	**1.39**
Rechberg ^{36}Cl							**net erosion: 0 - 1300 cm**		
Mean							**213**	**13.64**	**4.32**
Median							**205**	**13.50**	**4.21**
Mode							**183**	**13.70**	**3.77**
Minimum χ^2							**188**	**10.30**	**6.69**
Maximum							**762**	**40.00**	**9.86**
Minimum							**14**	**0.82**	**0.21**
Mandach ^{10}Be	net erosion: 0 - 15000 cm			net erosion: -1000 - 15000 cm			**net erosion: 10000 - 15000 cm**		
Mean	379	0.45	12.68	379	0.45	12.67	**895**	**0.30**	**14.59**
Median	277	0.42	12.78	279	0.42	12.75	**862**	**0.27**	**14.47**
Mode	16	0.30	12.42	18	0.29	12.78	**793**	**0.16**	**13.50**
Minimum χ^2	10	0.99	1.36	9	0.99	0.61	**959**	**1.00**	**14.27**
Maximum	1995	1.38	26.15	2038	1.38	26.77	**2150**	**1.43**	**26.97**
Minimum	5	0.00	0.00	5	0.00	0.00	**407**	**0.00**	**6.74**
Bayesian most probable	54	0.75	13.59	54	0.72	13.59	**652**	**0.72**	**13.59**
Bayesian 2-sigma upper	1206	1.28	44.93	1203	1.28	44.92	**1396**	**1.29**	**45.81**
Bayesian 2-sigma lower	0.00	0.01	5.31	0.00	0.01	5.28	**224**	**0.00**	**8.98**
Stadlerberg ^{10}Be	net erosion: 0 - 15000 cm			net erosion: -1000 - 15000 cm			**net erosion: 10000 - 15000 cm**		
Mean	1492	0.80	5.32	1497	0.79	5.32	**2436**	**0.91**	**5.34**
Median	1453	0.69	5.20	1460	0.68	5.20	**2403**	**0.76**	**5.20**
Mode	388	0.47	4.79	763	0.25	4.90	**2369**	**0.05**	**4.96**
Minimum χ^2	813	0.97	5.18	2928	1.47	4.54	**2866**	**1.91**	**4.76**
Maximum	4328	3.00	8.94	4419	3.00	9.00	**4743**	**3.00**	**8.93**
Minimum	13	0.00	0.01	13	0.00	0.01	**1153**	**0.00**	**3.13**
Bayesian most probable	1576	0.78	5.43	1576	0.65	5.43	**2174**	**0.72**	**5.43**
Bayesian 2-sigma upper	3265	2.76	9.49	3263	2.75	9.50	**3552**	**2.85**	**9.49**
Bayesian 2-sigma lower	40	0.02	3.29	40	0.02	3.29	**1172**	**0.02**	**3.46**

Note: Statistics are shown for erosion rate; however, since constraint was placed on net erosion they cannot be used to report a value for erosion rate (after Hidy et al., 2010). Mandach and Stadlerberg depth profiles were remodeled after Akçar et al. (2014) and Claude et al. (2017), respectively.

TABLE DR5. RESULTS OF ISOCHRON BURIAL AGE SIMULATION
FOR IRCHEL HÜTZ AND IRCHEL STEIG

	Sample name	Measured ^{10}Be (10^3 atoms/g)	Measured ^{26}Al (10^3 atoms/g)	Inherited ^{10}Be concentration (10^3 atoms/g)	^{10}Be linearization factor	Linearized 10Be (10^3 atoms/g)	Age (Ma)
Irchel Hütz							
	IRCH-1	7.91 ± 1.27	3.66 ± 0.40	2.09	0.9994	7.84 ± 1.27	
	IRCH-5	7.49 ± 0.92	5.00 ± 0.39	1.72	0.9970	7.44 ± 0.92	0.6 ± 0.1 Ma (ratio 6.75)
	IRCH-6	7.29 ± 1.09	4.51 ± 0.41	1.49	0.9968	7.23 ± 1.09	**0.9 ± 0.4 Ma (ratio 7.6 ± 0.8)**
	IRCH-8	7.43 ± 1.13	4.17 ± 0.48	1.62	1.0000	7.37 ± 1.13	1.1 ± 0.1 Ma (ratio 8.4)
	IRCH-9	12.06 ± 1.18	6.17 ± 0.52	6.25	0.9994	11.99 ± 1.18	
Irchel Steig							
	IRCH-10	9.49 ± 1.22	74.32 ± 6.68	1.84	0.9998	9.50 ± 1.22	
	IRCH-11	7.63 ± 1.08	64.48 ± 6.08	0.00	1.0000	7.64 ± 1.08	
	IRCH-13	9.98 ± 1.23	72.04 ± 6.20	2.33	0.9998	10.00 ± 1.23	
	IRCH-14	8.41 ± 1.36	67.49 ± 5.13	0.75	0.9999	8.42 ± 1.36	0.7 ± 0.2 Ma (ratio 6.75)
	IRCH-16	14.17 ± 1.54	78.13 ± 6.54	6.48	0.9993	14.18 ± 1.54	**0.9 ± 0.4 Ma (ratio 7.6 ± 0.8)**
	IRCH-17	12.75 ± 1.36	106.74 ± 6.83	5.08	0.9995	12.75 ± 1.36	1.1 ± 0.2 Ma (ratio 8.4)
	IRCH-20	13.24 ± 1.43	97.86 ± 7.63	5.57	0.9994	13.25 ± 1.43	
	IRCH-21	27.35 ± 2.35	145.99 ± 9.34	19.57	0.9980	27.32 ± 2.35	
	IRCH-22	13.95 ± 1.60	100.26 ± 6.52	6.26	0.9994	13.96 ± 1.60	