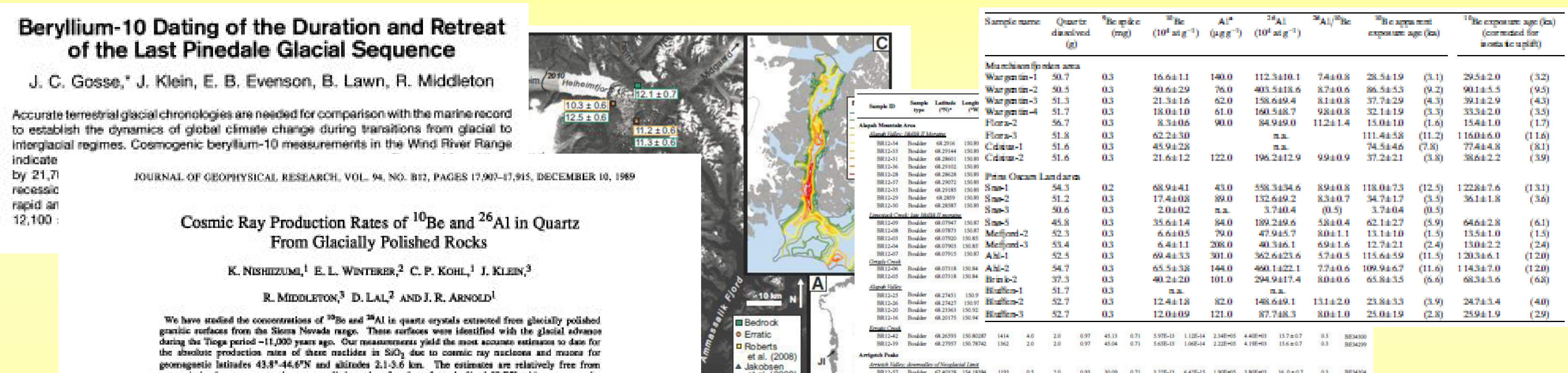
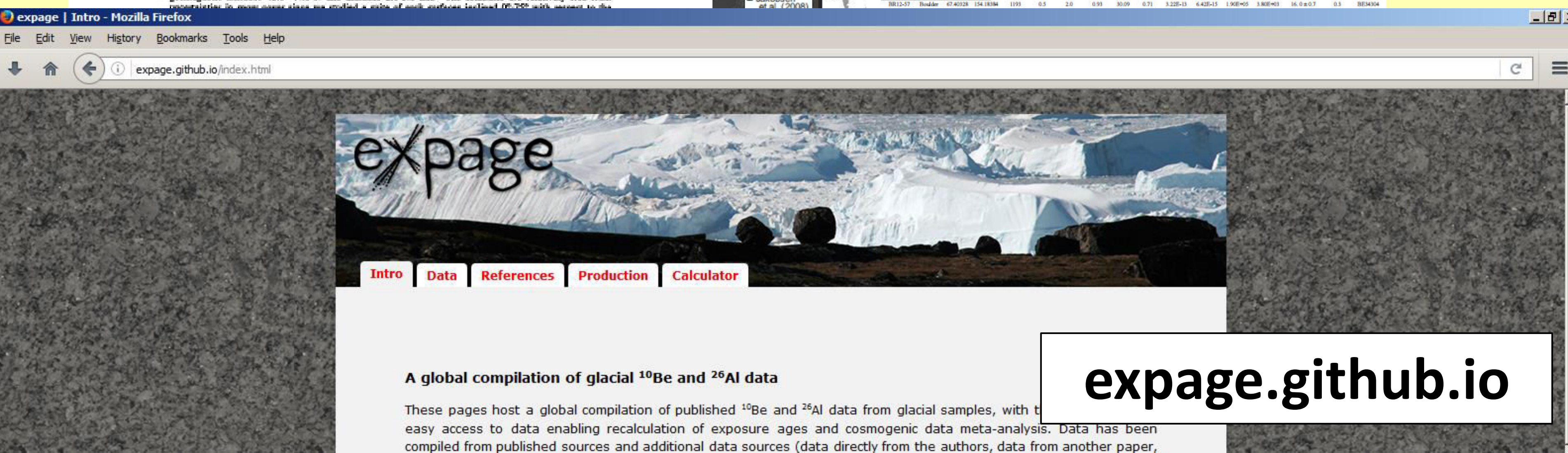
A global compilation of glacial ^{10}Be and ^{26}Al exposure age data

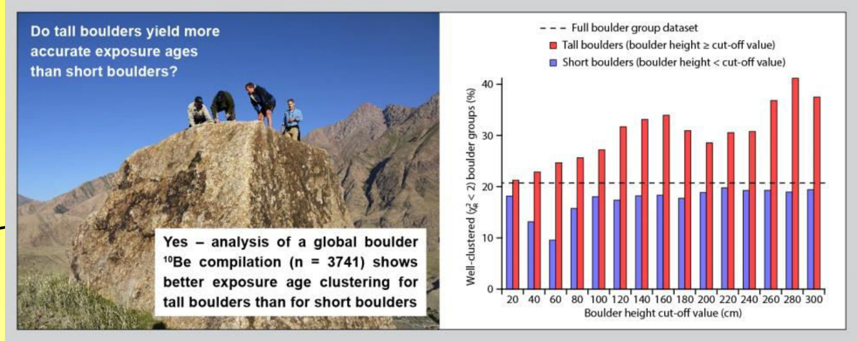
Jakob Heyman



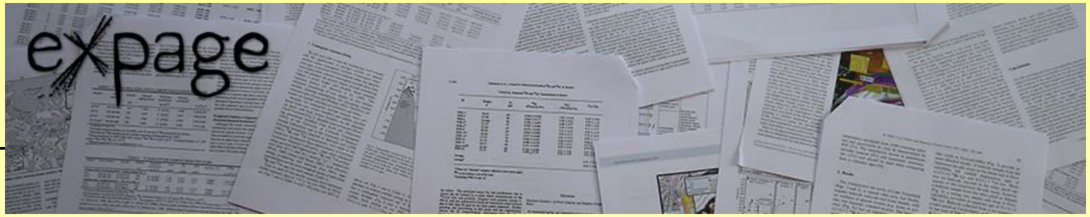


expage.github.io

Outline



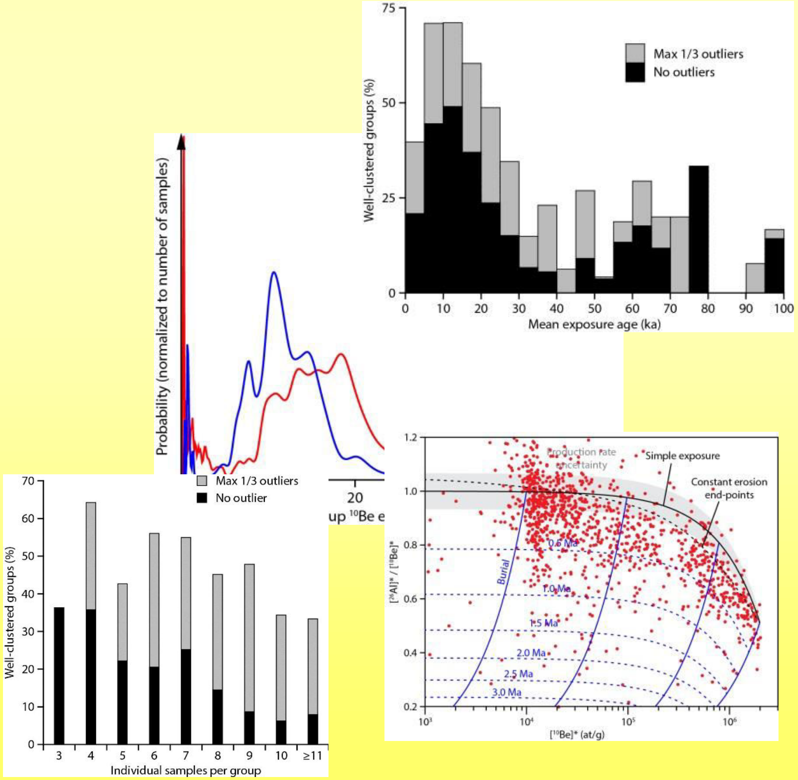
Motivation



The compilation

Analysis

- Scatter / clustering
- Well-clustered ages
- ^{26}Al / ^{10}Be burial dating
- How many samples to collect?



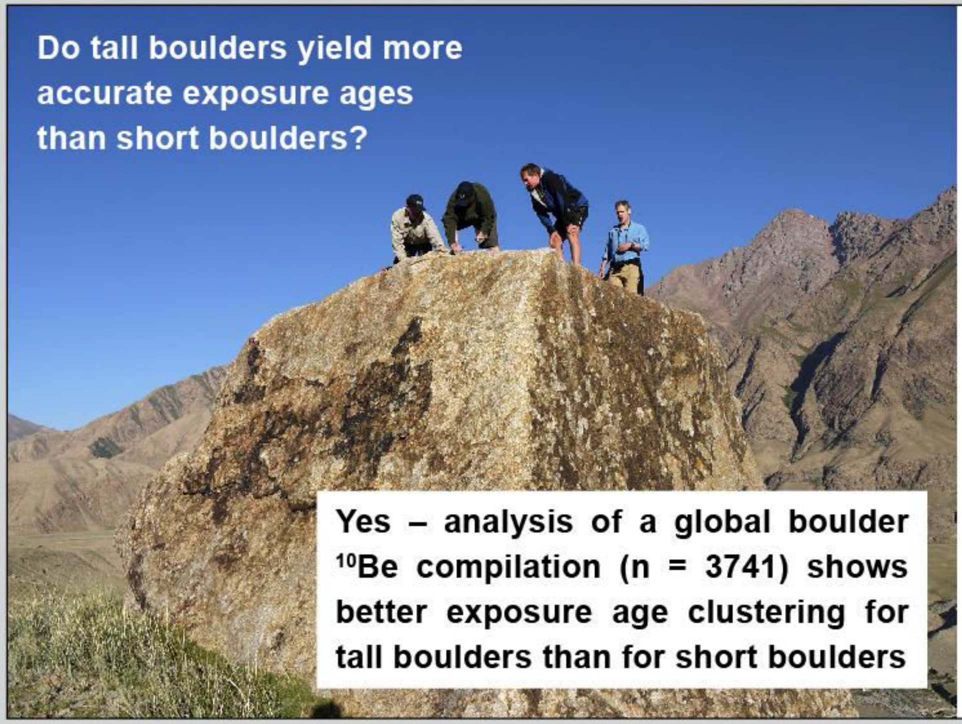
Motivation 1

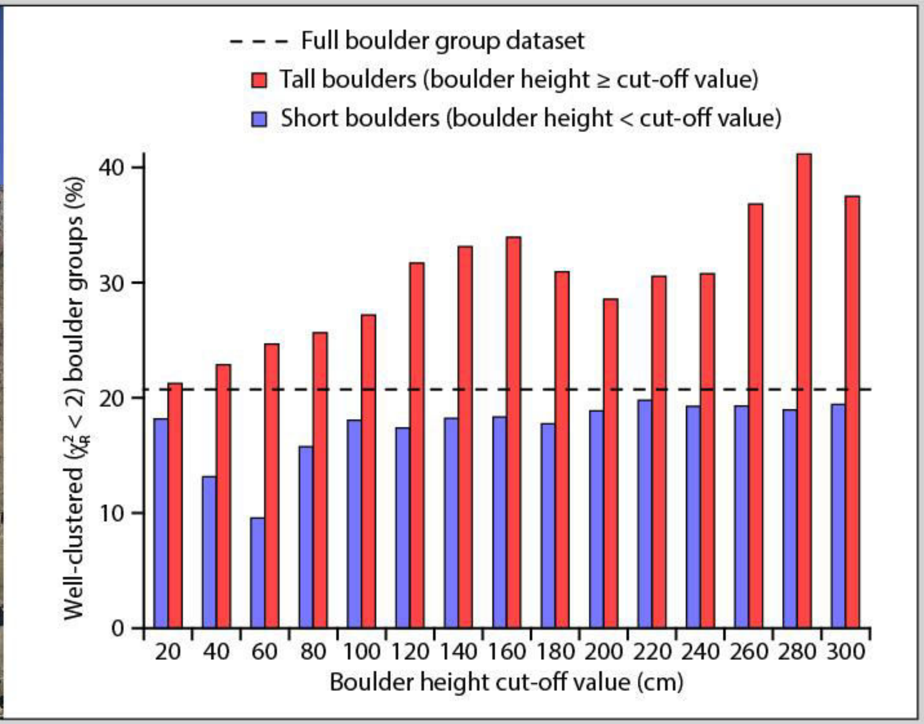
Enable easy recalculation of glacial exposure ages

Publication	Sample-type	Surface-ID	Group-ID	Sample	Lat(DD)	Long(DD)	Elev(masl)	Thickn(cm)	Density(g/cm3)	Shield	10Be-conc(at/g)	10Be-unc(at/g)	10Be-std	26Al-conc(at/g)	26Al-unc(at/g)	26Al-std	Sampl-year	Publ-10-age(yr)	Publ-10-unc(yr)	Publ-26-age(yr)	Publ-26-unc(yr)	10Be-age(yr)	10-ext-unc(yr)	10-int-unc(yr)	26Al-age(yr)	26-ext-unc(yr)	26-int-unc(yr)	Extra-publ
Heyman et al. (2011)	pebbles	Heym2011-1	Heym2011-A	TB-05-051	34.108167	97.645933	4780	2	2.7	1	2863124	73331	KNSTD	0	0	0	2005	30361	2677	-	-	31421	1577	811	-	-	-	-
Heyman et al. (2011)	boulder	Heym2011-2	Heym2011-B	TB-05-018	34.268533	97.858433	4716	1	2.7	1	4581447	117445	KNSTD	0	0	0	2005	46517	4119	-	-	47536	2396	1233	-	-	-	-
Heyman et al. (2011)	boulder	Heym2011-3	Heym2011-B	TB-05-019	34.268817	97.865417	4683	1	2.7	1	8701361	222951	KNSTD	0	0	0	2005	92334	8271	-	-	94973	4845	2492	-	-	-	-
Heyman et al. (2011)	boulder	Heym2011-4	Heym2011-C	TB-05-048	33.989310	97.449230	4576	1	2.7	1	1095381	61254	KNSTD	0	0	0	2005	13559	1369	-	-	15234	1076	855	-	-	-	-
Heyman et al. (2011)	boulder	Heym2011-5	Heym2011-C	TB-05-049	33.986667	97.449050	4573	1	2.7	1	926127	26858	KNSTD	0	0	0	2005	11495	1021	-	-	13085	678	381	-	-	-	-
Heyman et al. (2011)	boulder	Heym2011-6	Heym2011-C	TB-05-050	33.986183	97.448350	4576	1	2.7	1	1520856	60700	KNSTD	0	0	0	2005	18459	1719	-	-	20168	1185	809	-	-	-	-
Heyman et al. (2011)	pebbles	Heym2011-7	Heym2011-C	TB-07-29	33.987889	97.448472	4574	2	2.7	1	4734112	118571	07KNSTD	0	0	0	2007	59242	5252	-	-	60826	3058	1547	-	-	-	-
Heyman et al. (2011)	boulder	Heym2011-8	Heym2011-D	TB-06-01	34.599056	97.984639	4259	5	2.7	1	3290490	119237	07KNSTD	0	0	0	2006	47302	4365	-	-	49259	2793	1807	-	-	-	-
Heyman et al. (2011)	boulder	Heym2011-9	Heym2011-D	TB-06-02	34.596500	97.986861	4264	5	2.7	1	4126823	111897	07KNSTD	0	0	0	2006	60660	5418	-	-	62517	3213	1722	-	-	-	-
Heyman et al. (2011)	boulder	Heym2011-10	Heym2011-D	TB-06-37	34.599222	97.994611	4256	3	2.7	1	2353618	97376	07KNSTD	0	0	0	2006	34795	3277	-	-	36112	2167	1508	-	-	-	-
Heyman et al. (2011)	boulder	Heym2011-11	Heym2011-D	TB-07-125	34.604917	98.015056	4248	5	2.7	1	4020038	143384	07KNSTD	0	0	0	2007	59514	5495	-	-	61494	3475	2227	-	-	-	-
Heyman et al. (2011)	pebbles	Heym2011-12	Heym2011-D	TB-07-12	34.596139	97.986250	4266	2	2.7	1	2082644	90767	07KNSTD	0	0	0	2007	30781	2927	-	-	32264	1985	1418	-	-	-	-
Heyman et al. (2011)	boulder	Heym2011-13	Heym2011-E	TB-06-16	34.526389	97.987194	4332	4	2.7	1	2917059	61565	07KNSTD	0	0	0	2006	40691	3548	-	-	41936	2019	894	-	-	-	-
Heyman et al. (2011)	boulder	Heym2011-14	Heym2011-E	TB-06-17	34.525778	97.987528	4332	4	2.7	1	3688936	138929	07KNSTD	0	0	0	2006	51136	4753	-	-	53383	3081	2037	-	-	-	-
Heyman et al. (2011)	pebbles	Heym2011-15	Heym2011-E	TB-07-13	34.526139	97.986944	4331	2	2.7	1	2471948	115493	07KNSTD	0	0	0	2007	34964	3381	-	-	36211	2313	1707	-	-	-	-
Heyman et al. (2011)	boulder	Heym2011-16	Heym2011-F	TB-06-05	33.991861	97.430472	4593	4	2.7	1	2698316	123372	07KNSTD	0	0	0	2006	34743	3342	-	-	35779	2259	1651	-	-	-	-
Heyman et al. (2011)	boulder	Heym2011-17	Heym2011-F	TB-06-07	33.989556	97.429667	4590	5	2.7	1	1294833	47593	07KNSTD	0	0	0	2006	17887	1642	-	-	19635	1112	725	-	-	-	-
Heyman et al. (2011)	pebbles	Heym2011-18	Heym2011-F	TB-07-30	33.991917	97.430500	4589	2	2.7	1	5649820	230123	07KNSTD	0	0	0	2007	69949	6626	-	-	71734	4311	2975	-	-	-	-
Heyman et al. (2011)	boulder	Heym2011-19	Heym2011-G	TB-06-46	34.153528	98.019028	4573	3	2.7	1	3387206	77434	07KNSTD	0	0	0	2006	41823	3666	-	-	42845	2098	990	-	-	-	-
Heyman et al. (2011)	boulder	Heym2011-20	Heym2011-G	TB-06-47	34.155389	98.020194	4583	4	2.7	1	3982840	105727	07KNSTD	0	0	0	2006	49049	4359	-	-	50715	2583	1363	-	-	-	-
Heyman et al. (2011)	boulder	Heym2011-21	Heym2011-G	TB-06-48	34.156972	98.020333	4592	3	2.7	1	6421993	185987	07KNSTD	0	0	0	2006	79903	7219	-	-	82714	4358	2446	-	-	-	-
Heyman et al. (2011)	boulder	Heym2011-22	Heym2011-H	TB-06-31	34.511556	97.740750	4456	4	2.7	1	3509687	69298	07KNSTD	0	0	0	2006	45540	3961	-	-	46766	2227	934	-	-	-	-
Heyman et al. (2011)	boulder	Heym2011-23	Heym2011-H	TB-06-32	34.513444	97.740722	4451	4	2.7	1	7095024	233596	07KNSTD	0	0	0	2006	94727	8724	-	-	97717	5401	3297	-	-	-	-

Motivation 2

Enable meta-analysis using a comprehensive dataset





Heyman et al. (2016)

Compilation work

- **Searching** (Journals, Google Scholar, reference lists…)
- **Copy-paste, copy-paste, copy-paste…**
- **Correcting mistakes**
- **Emails**
- **Assumptions**
- **Recalculation**

```
Abramowski et al. (2006)
Latitudes and longitudes based on map figures and Google Earth.
Sample density assumed to be 2.65 g/cm3.
10Be standard assumed to be S555.
Sampling year assumed to be 2002 (based on Abramowski 2004).

Ackert et al. (2007)
Sample density assumed to be 2.65 g/cm3.
10Be concentration derived from Ackert et al. (2011).
10Be standard traced via CRONUS calculator to 07KNSTD.
Sampling year based on sample names.
```

DATA COMMENTS

Included data

1. Primary publication
2. Sample type
3. Surface ID
4. Group ID
5. Sample name

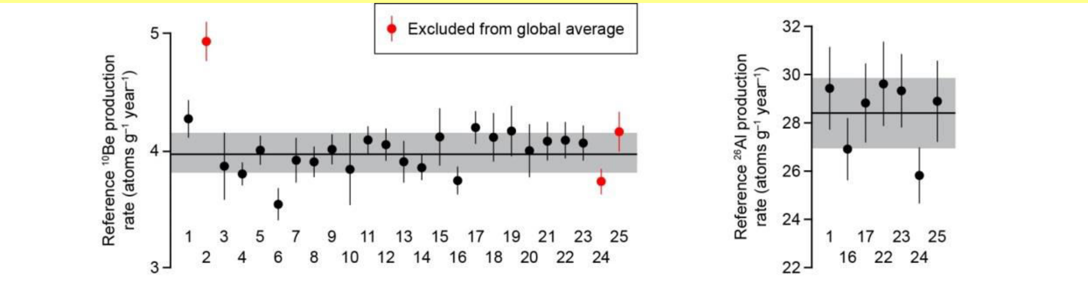
For recalculation

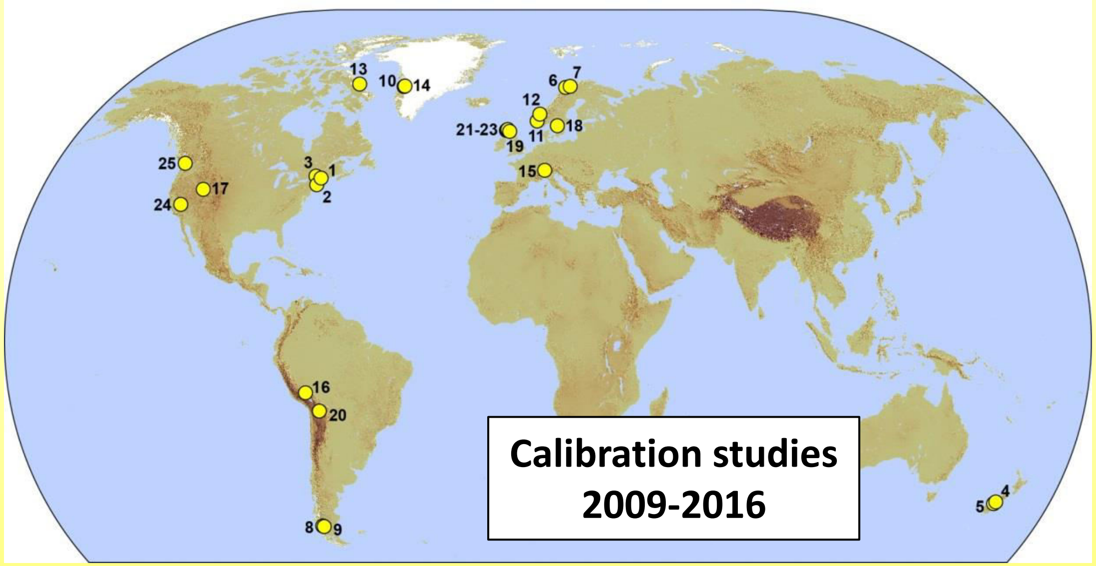
6. Latitude
7. Longitude
8. Elevation
9. Sample thickness
10. Sample density
11. Shielding
12. ^{10}Be concentration
13. ^{10}Be uncertainty
14. ^{10}Be standard
15. ^{26}Al concentration
16. ^{26}Al uncertainty
17. ^{26}Al standard
18. Sampling year
19. Publ ^{10}Be exp age
20. Publ ^{10}Be exp age unc
21. Publ ^{26}Al exp age
22. Publ ^{26}Al exp age unc

Recalculated ages

23. Recalc ^{10}Be exp age
24. ^{10}Be external unc
25. ^{10}Be internal unc
26. Recalc ^{26}Al exp age
27. ^{26}Al external unc
28. ^{26}Al internal unc
29. Extra publication

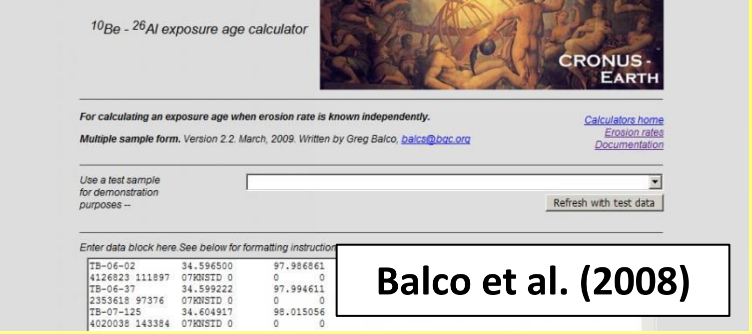
Recalculation



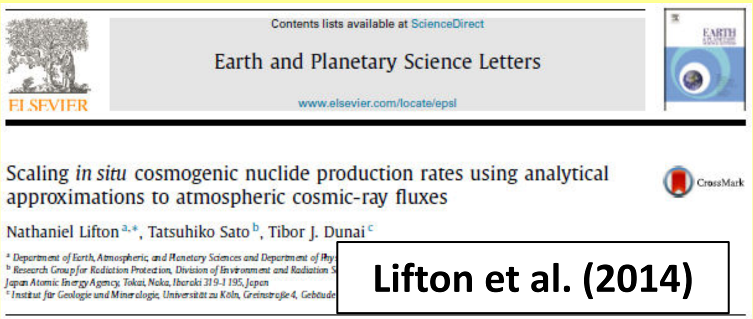


Calibration studies 2009-2016

expage.github.io/calculator



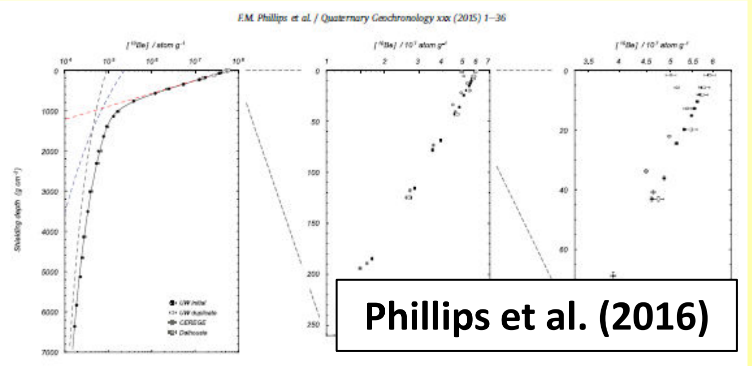
Balco et al. (2008)


Contents lists available at ScienceDirect
Earth and Planetary Science Letters
www.elsevier.com/locate/epsl
ELSEVIER

Scaling *in situ* cosmogenic nuclide production rates using analytical approximations to atmospheric cosmic-ray fluxes

Nathaniel Lifton[a,*], Tatsuhiko Sato[b], Tibor J. Dunai[c]

Lifton et al. (2014)



Phillips et al. (2016)

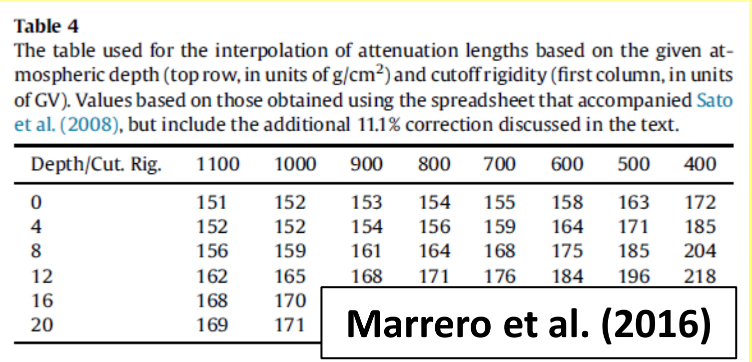


Table 4
The table used for the interpolation of attenuation lengths based on the given atmospheric depth (top row, in units of g/cm^2) and cutoff rigidity (first column, in units of GV). Values based on those obtained using the spreadsheet that accompanied Sato et al. (2008), but include the additional 11.1% correction discussed in the text.

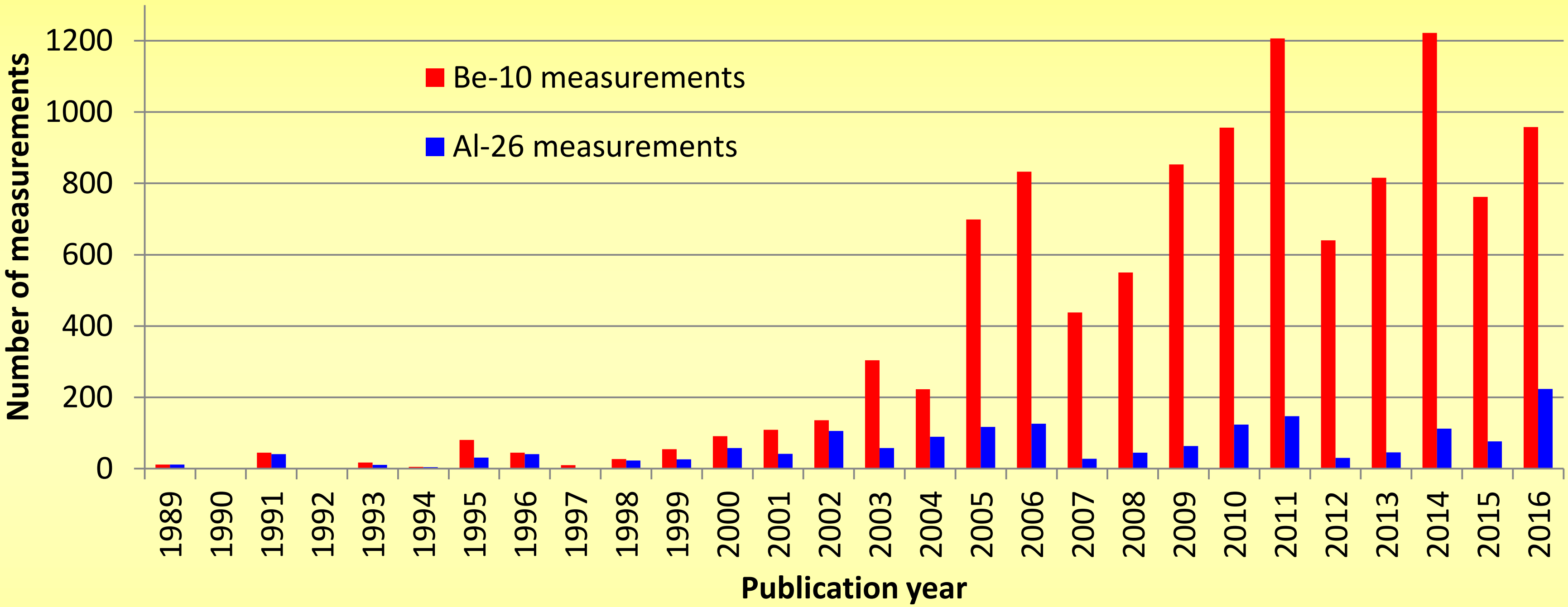
Depth/Cut. Rig.	1100	1000	900	800	700	600	500	400
0	151	152	153	154	155	158	163	172
4	152	152	154	156	159	164	171	185
8	156	159	161	164	168	175	185	204
12	162	165	168	171	176	184	196	218
16	168	170						
20	169	171						

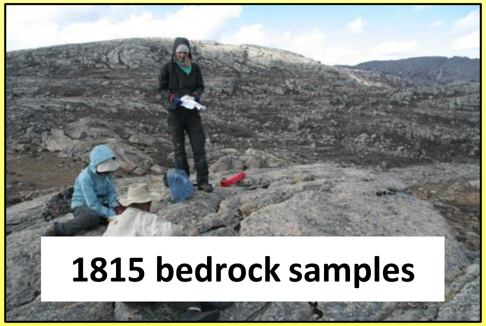
Marrero et al. (2016)

Data from 527 primary publications

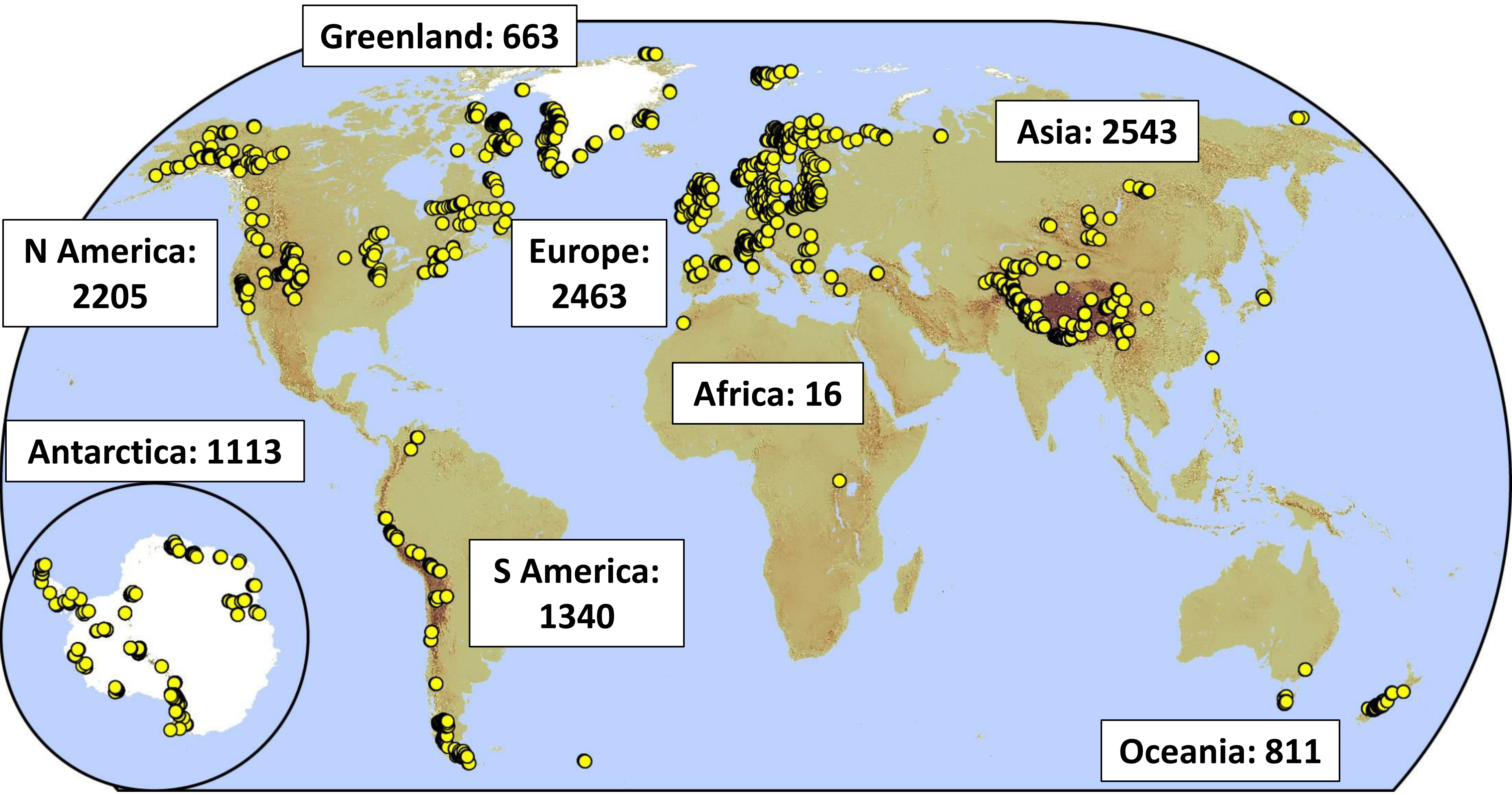
^{10}Be: **11 093** measurements

^{26}Al : **1 683** measurements





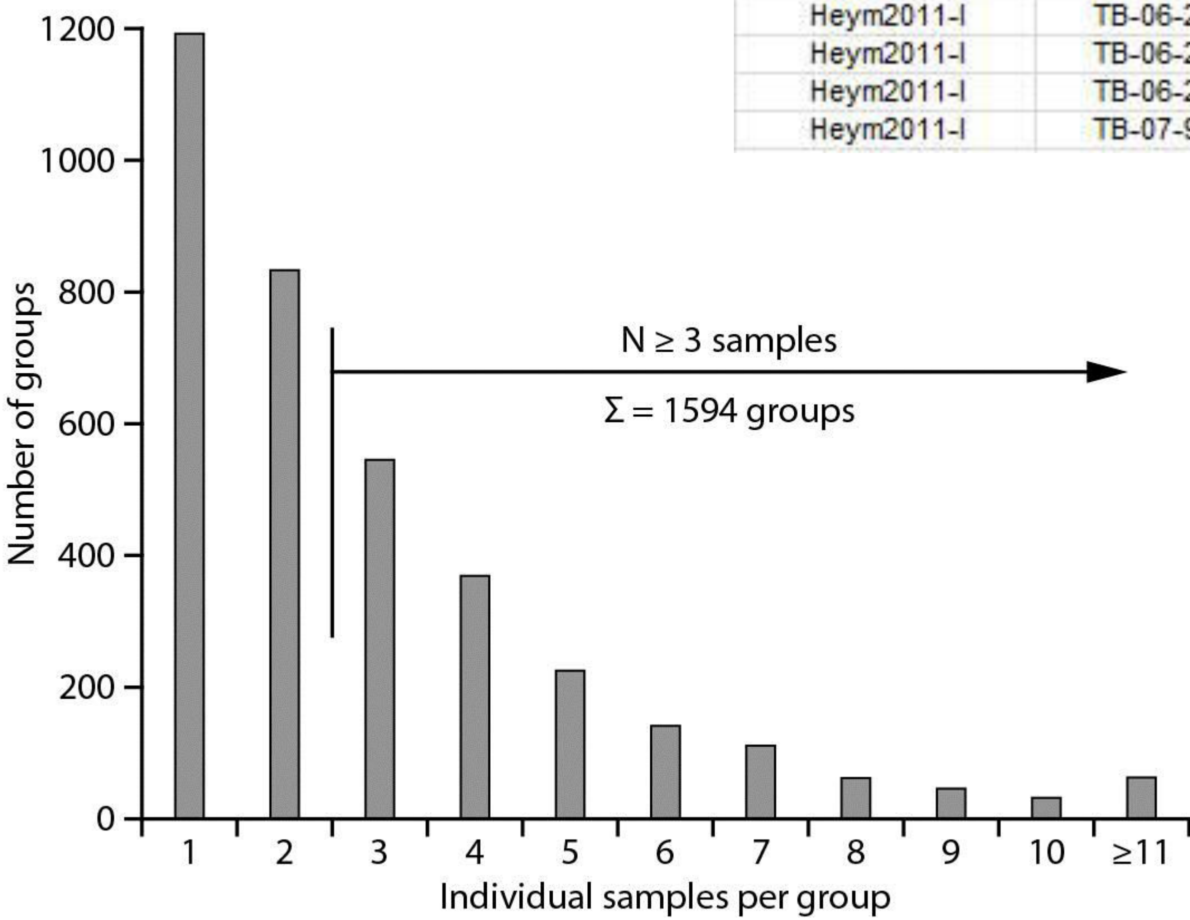
Spatial distribution

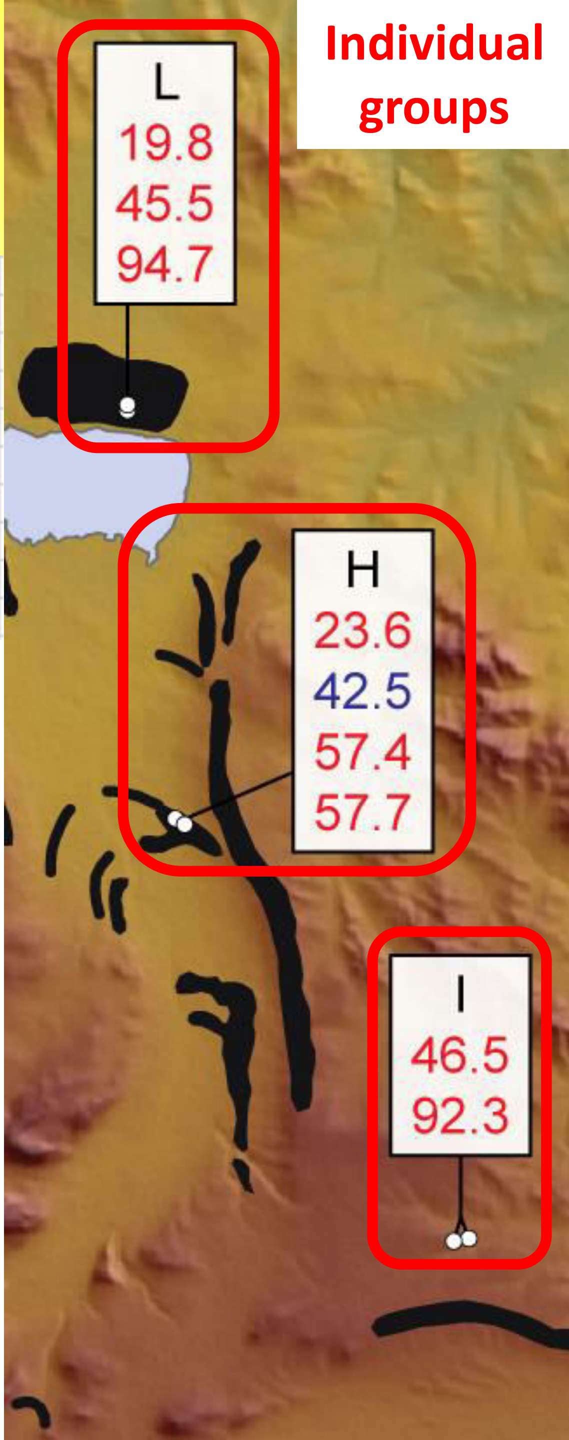


All samples ordered in groups

One group = one deglaciation age

Heym2011-G	TB-06-46
Heym2011-G	TB-06-47
Heym2011-G	TB-06-48
Heym2011-H	TB-06-31
Heym2011-H	TB-06-32
Heym2011-H	TB-06-33
Heym2011-I	TB-06-25
Heym2011-I	TB-06-26
Heym2011-I	TB-06-27
Heym2011-I	TB-07-90



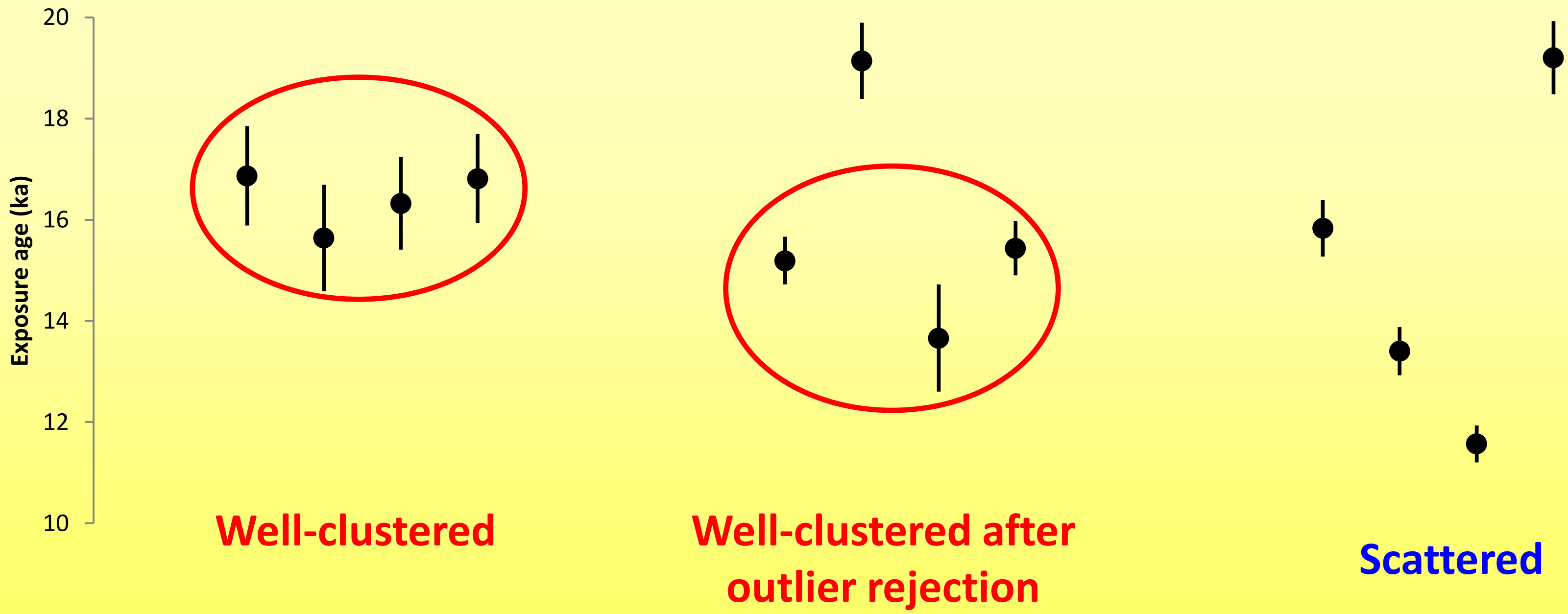


Group exposure age clustering

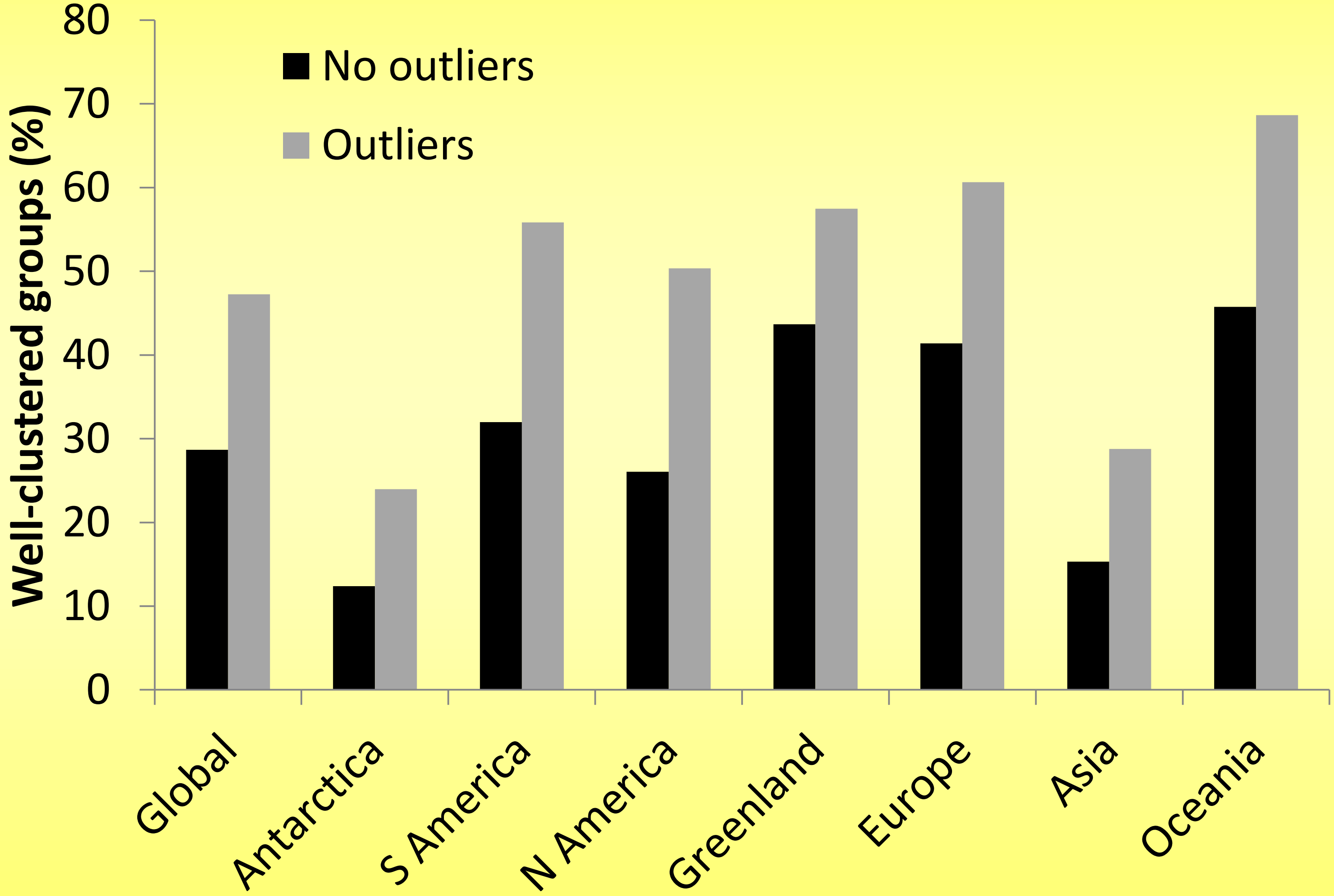
Scattered: Chi-square analysis P-value < 0.05

Well-clustered: Chi-square analysis P-value > 0.05

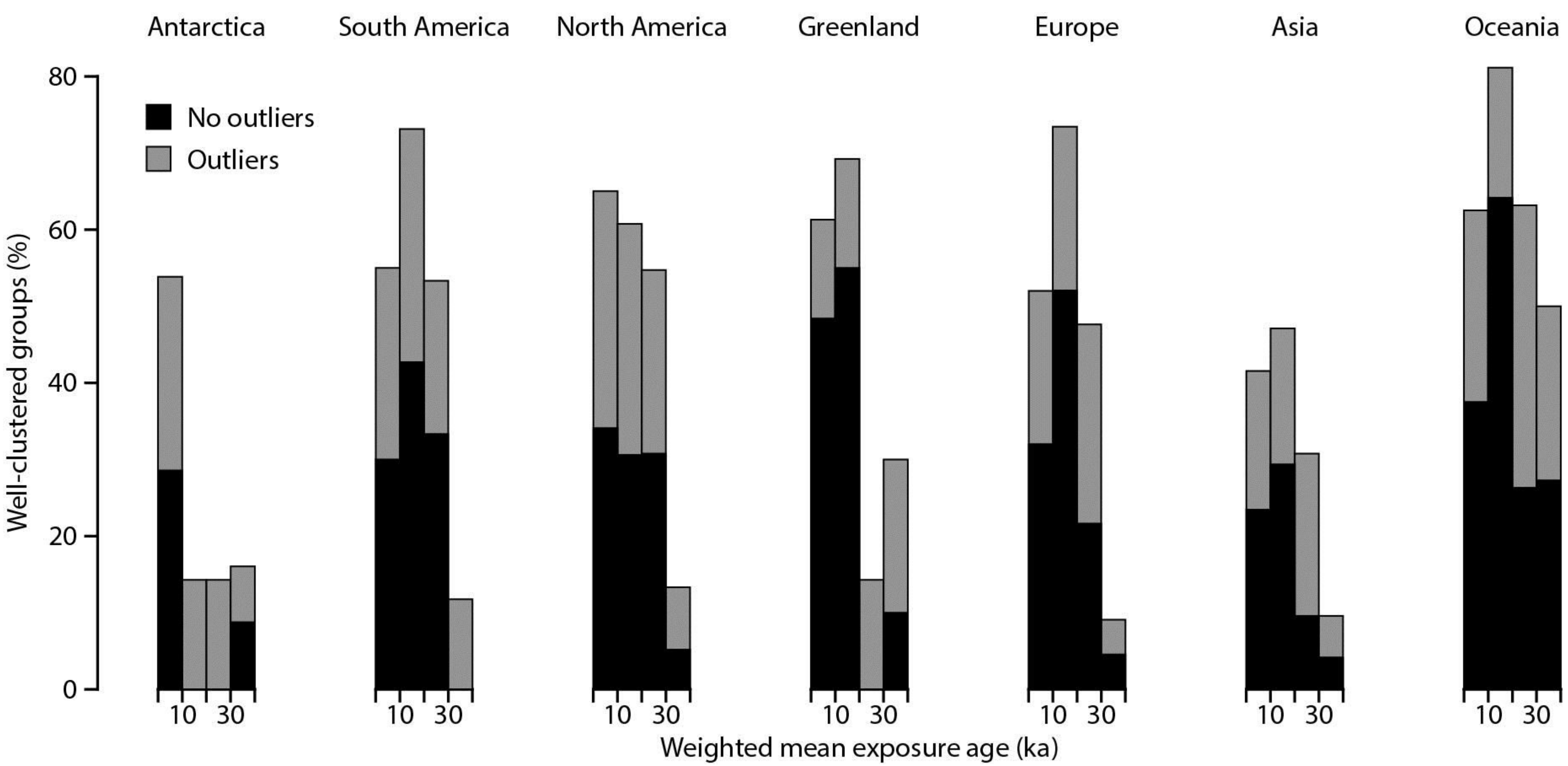
Outlier rejection: max 1/3 still requiring at least 3 samples



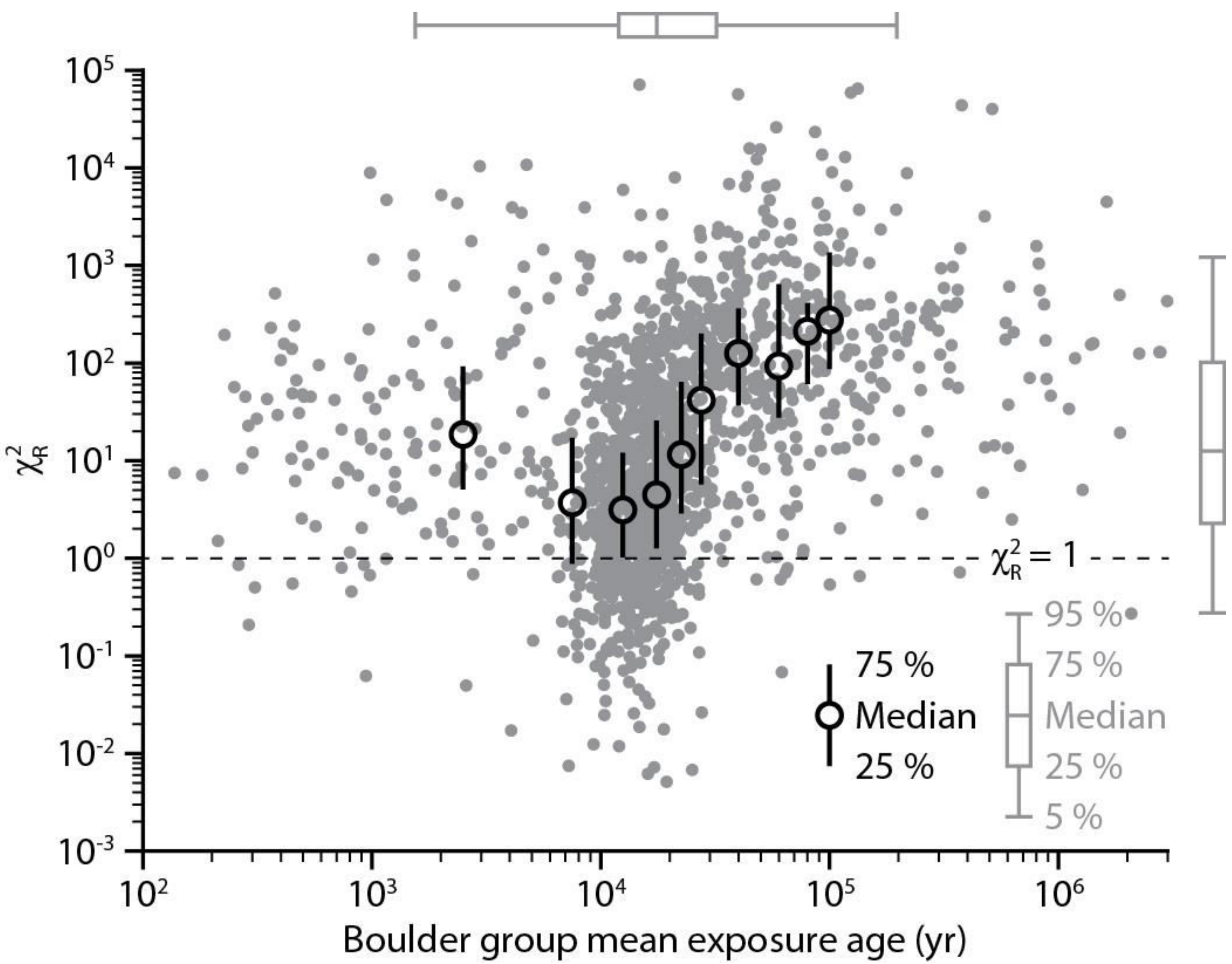
How common is well-clustered data?



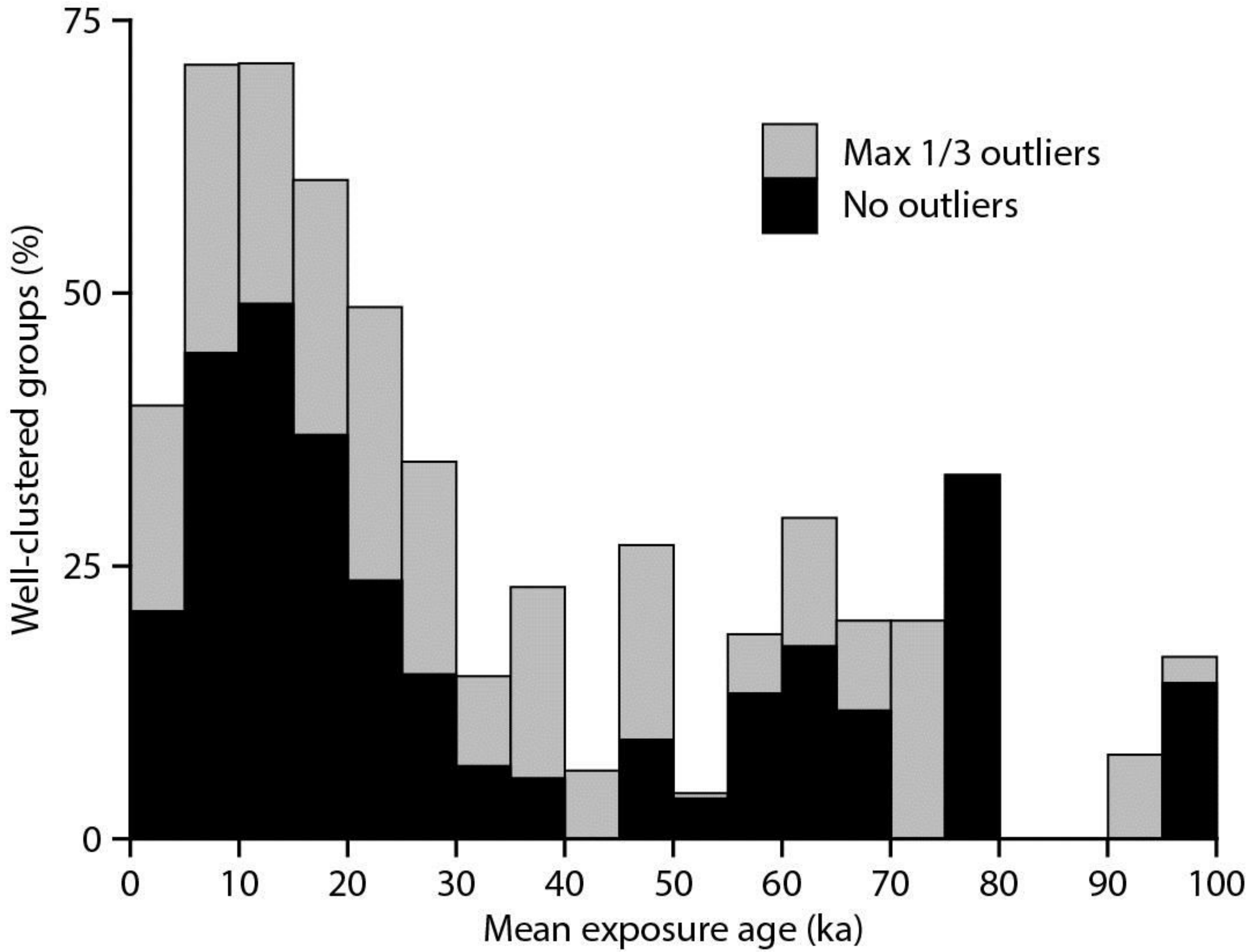
Clustering against mean age



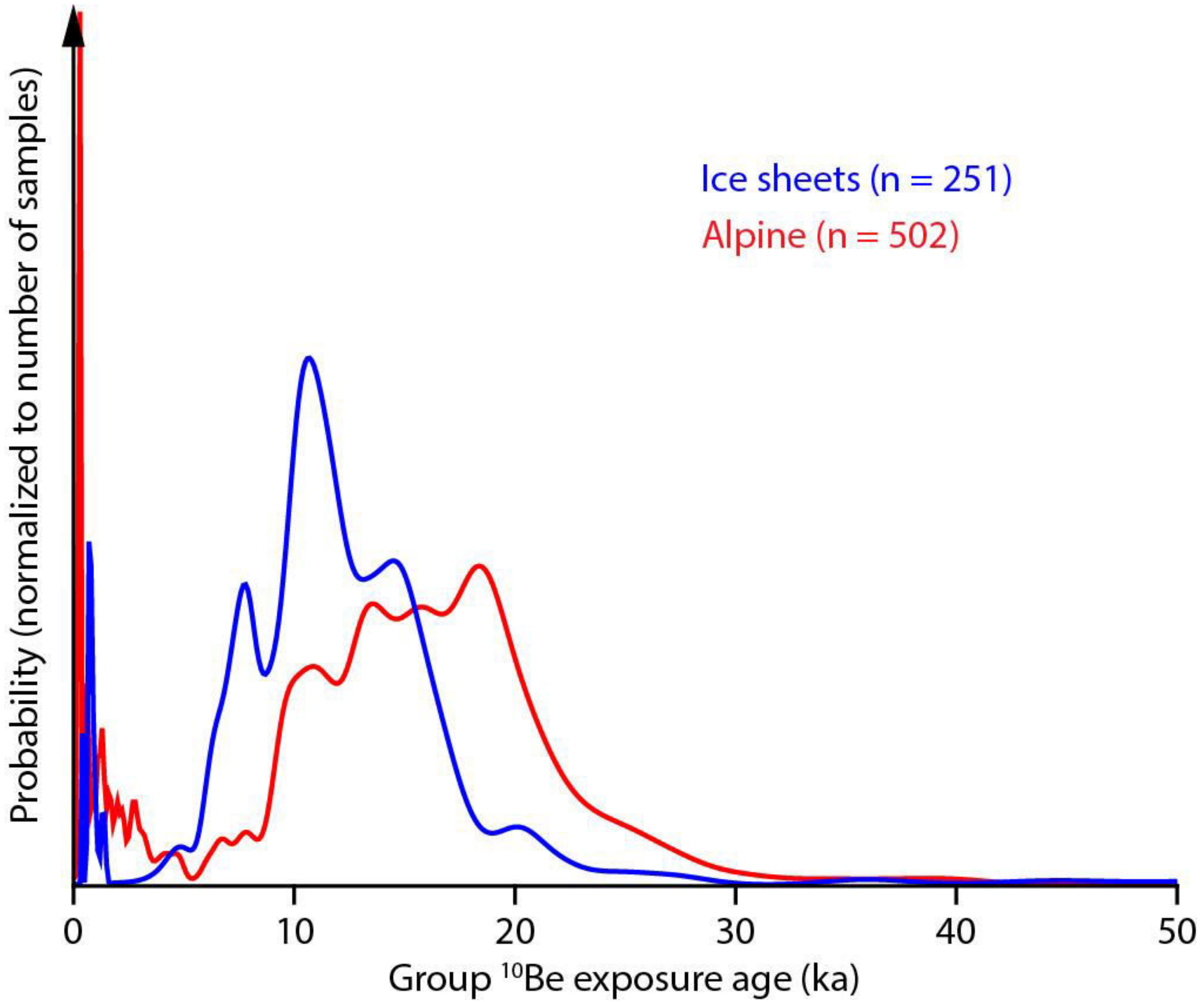
Clustering/scatter against mean age



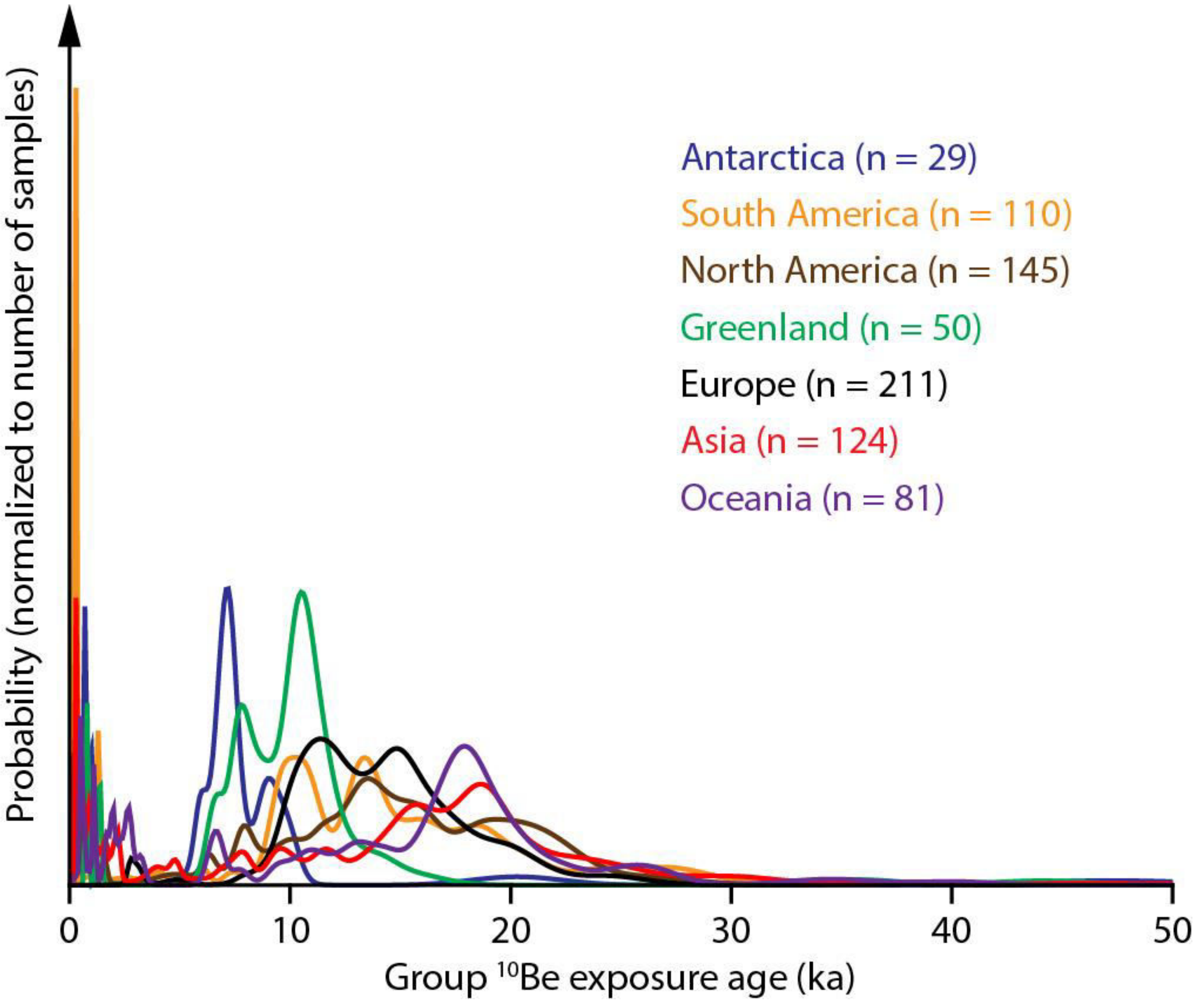
Clustering against mean age



Well-clustered group ages

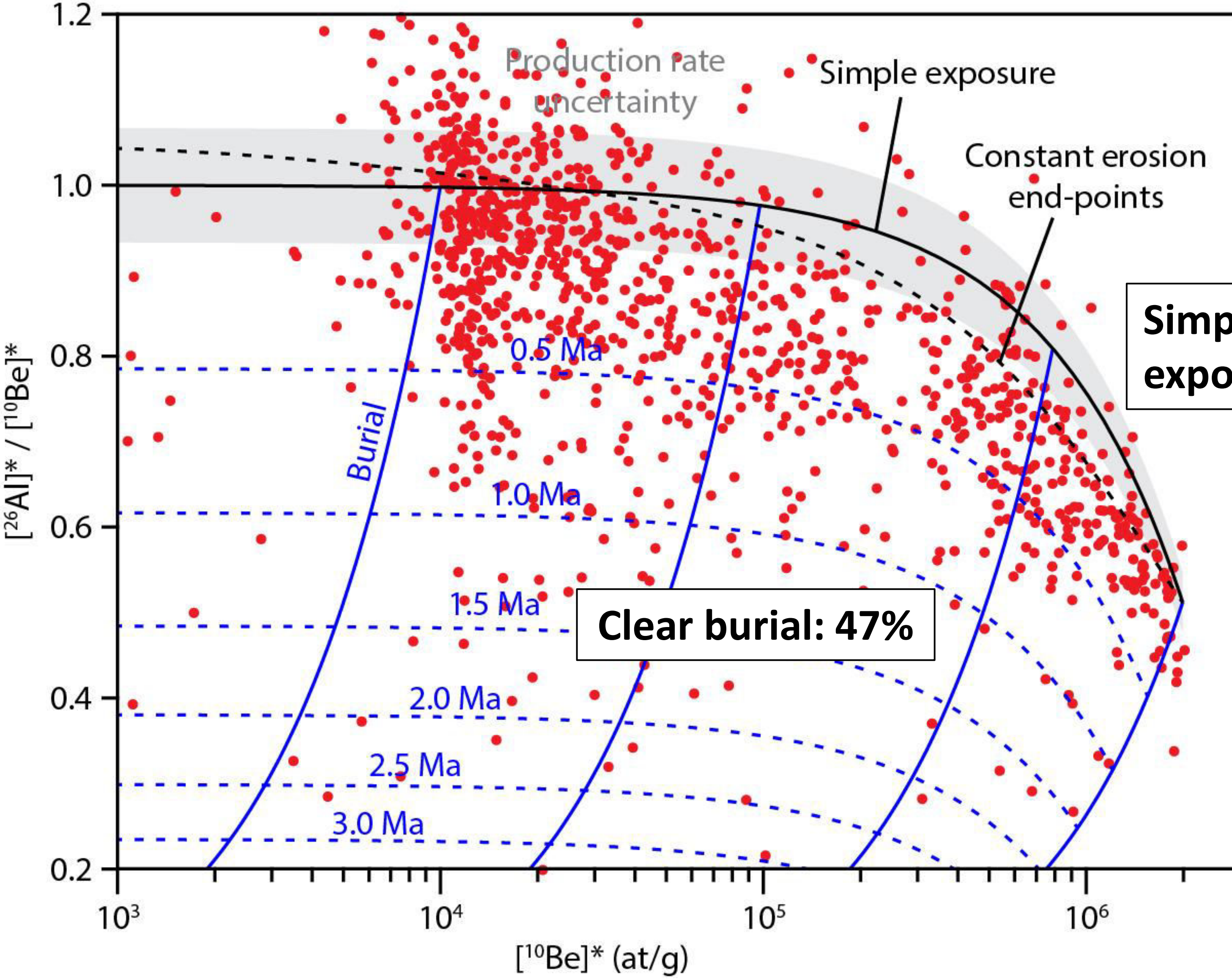


Well-clustered group ages



ICE SHEETS

Forbidden zone: 6%

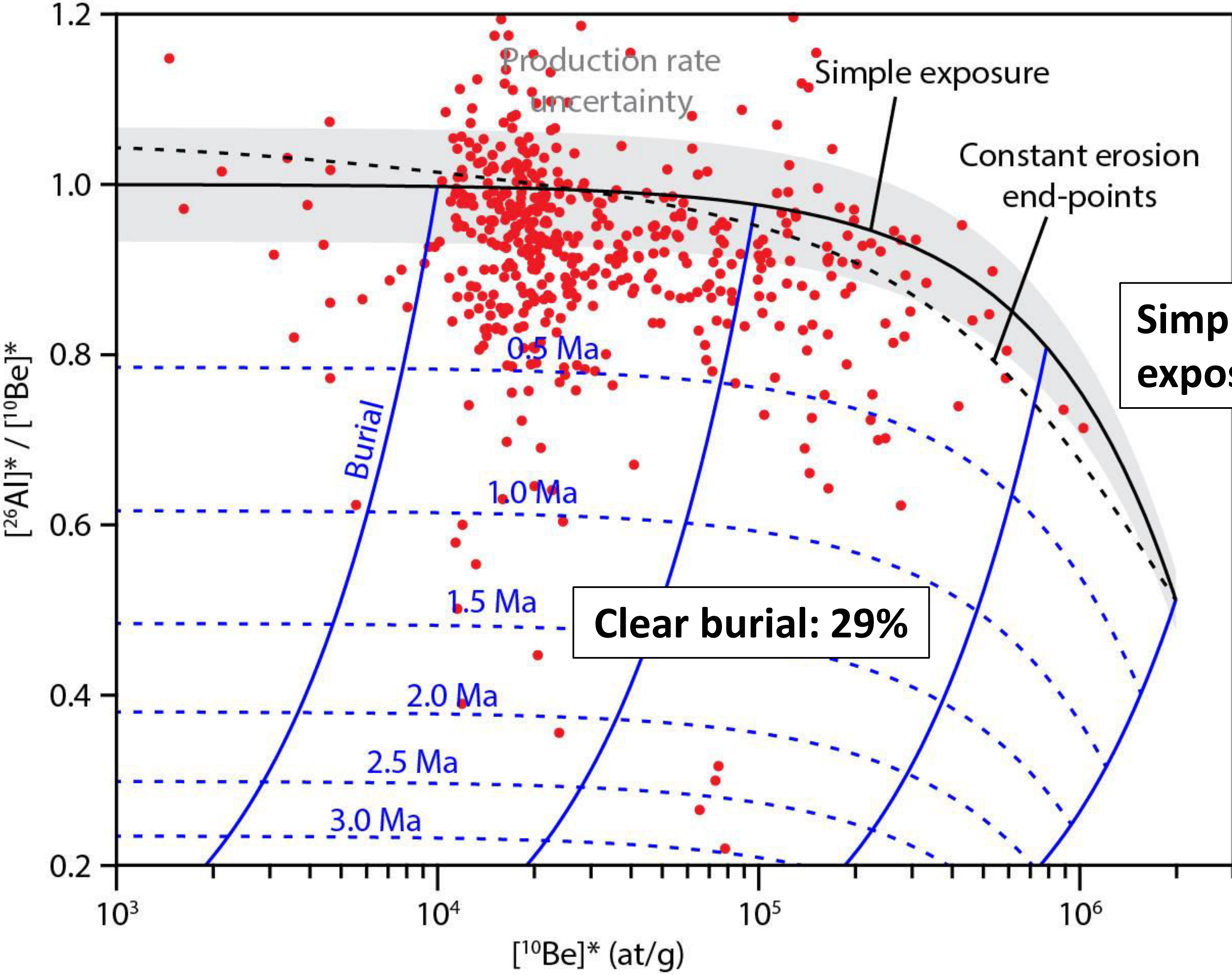


Simple exposure: 47%

Clear burial: 47%

ALPINE

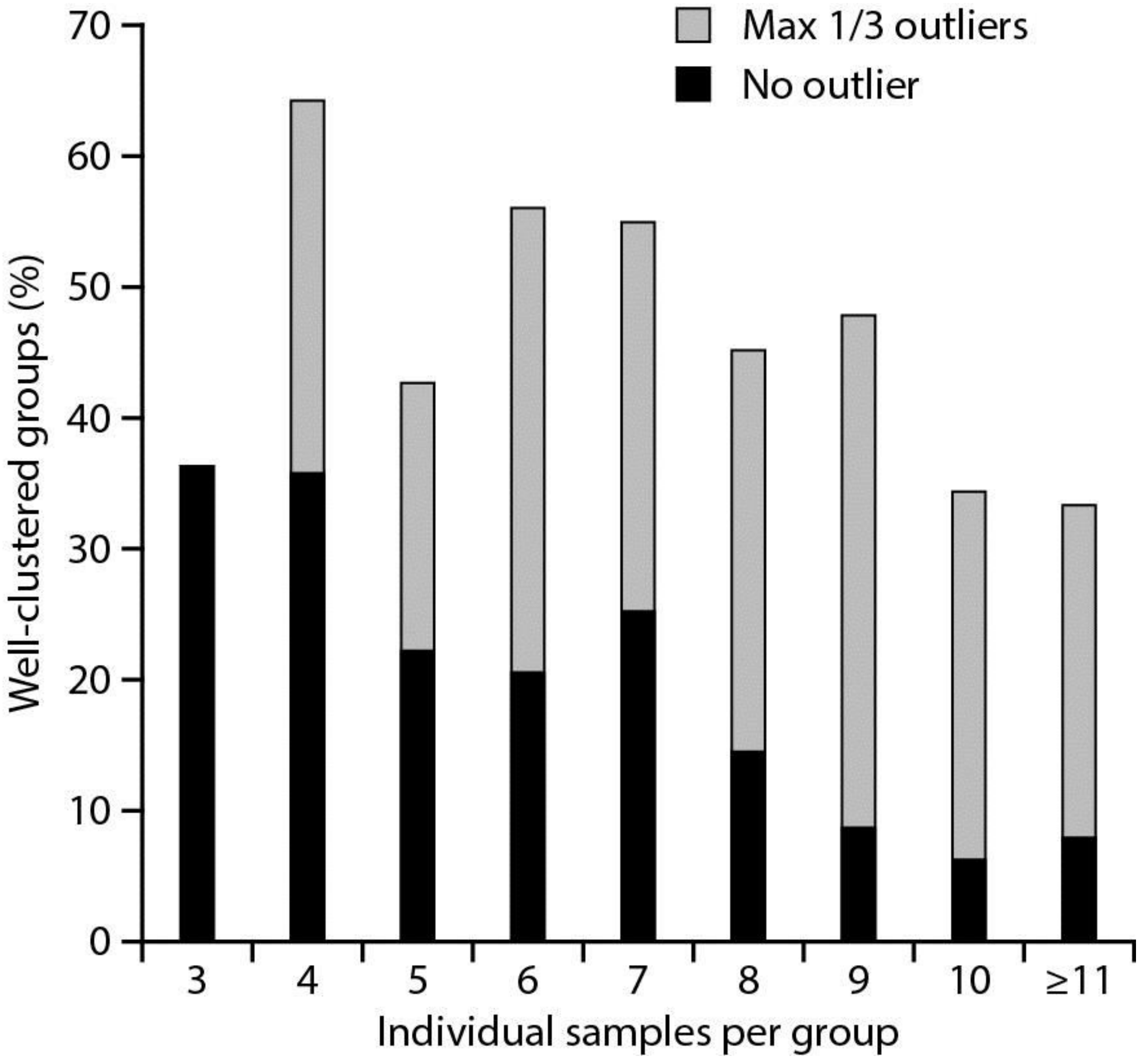
Forbidden zone: 6%



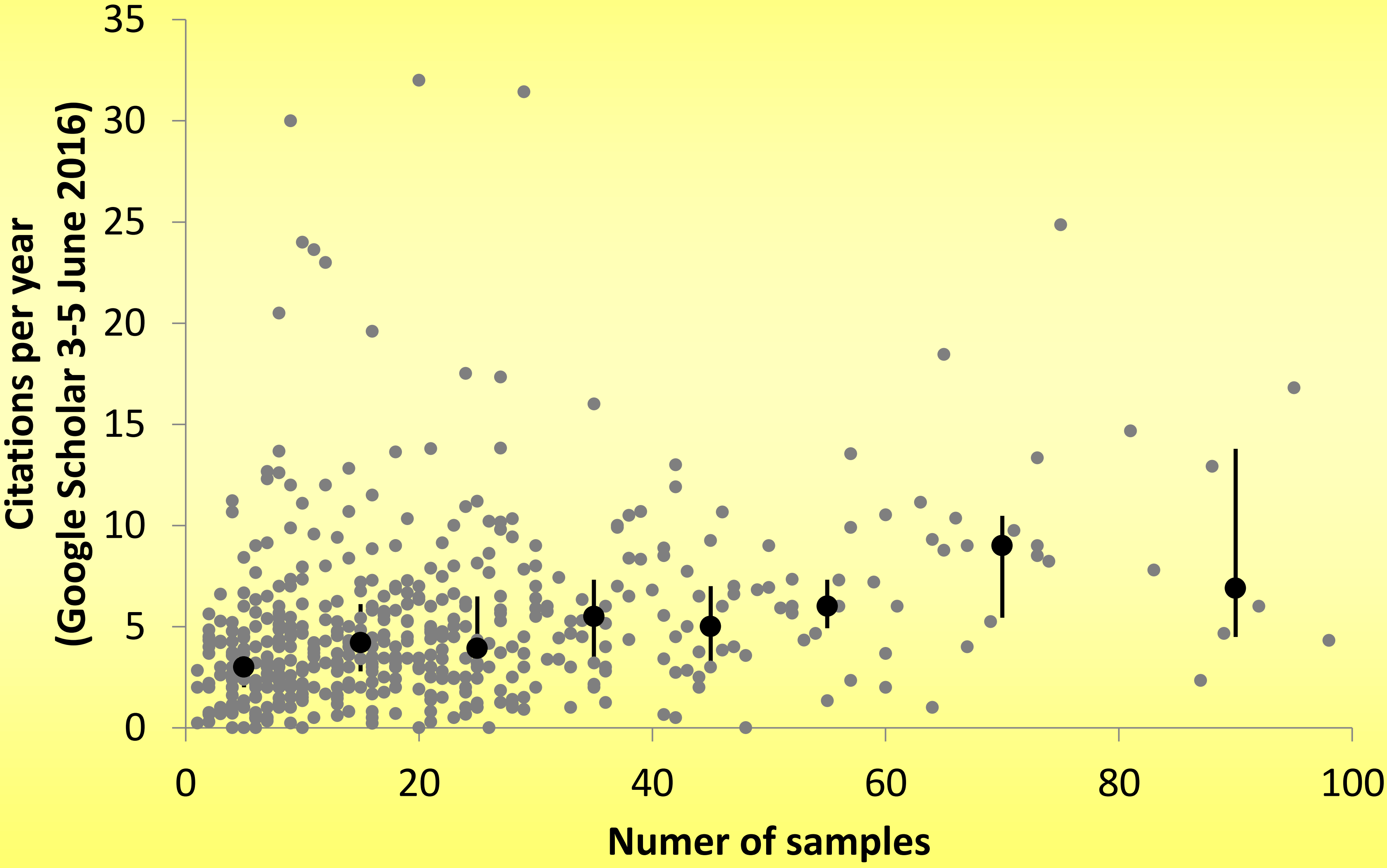
Simple exposure: 65%

Clear burial: 29%

How many samples per site?



How many samples per publication?



expage.github.io

A global compilation of glacial ^{10}Be and ^{26}Al data

These pages host a global compilation of published ^{10}Be and ^{26}Al data from glacial samples, with the aim of allowing easy access to data enabling recalculation of exposure ages and cosmogenic data meta-analysis. Data has been compiled from published sources and additional data sources (data directly from the authors, data from another paper, assumptions etc) are recorded.

If you find mistakes in the data or if you have more correct / new data: jakob.heyman@gu.se

---

Data description

The exposure age data is presented in tab-delimited text files with the following 29 columns:

1. **Publication** – Primary publication presenting the data with enough detail to enable recalculation.
2. **Sample type** – Type of sample such as boulder, bedrock, cobble, pebbles...
3. **Surface ID** – Identifier to keep track of repeat measurements of single samples and closely spaced samples from single surfaces.
4. **Group ID** – Identifier to keep track of groups of samples derived from single sites with one deglaciation age.
5. **Sample name** – From the original publication.
6. **Latitude** – Sample latitude in WGS-84 datum (DD).
7. **Longitude** – Sample longitude in WGS-84 datum (DD).

Thank you!