

Supporting Information for

PSVM: A global database for the Miocene indicating elevated paleosecular variation relative to the last 10 Myrs.

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Text S1 Serial Correlation:

When lava flows erupt rapidly, multiple stacked flows might represent the same snapshot of the Earth's magnetic field. In a PSV study, this serial correlation (SC) can produce overrepresentation of short time periods leading to underestimation of the VGP dispersion associated with the secular variation (Biggin et al., 2008). To check for serial correlation in the studies, a common true mean direction (CTMD) test is commonly used (Tauxe, 2010; Watson, 1956). For this test, the individually measured directions per sample are needed which are often not provided in the literature. To overcome this problem, bootstrapped parametric sampling (creating a possible set of sample level directions to create the mean-direction given, with the known number of samples, with the known k value, Tauxe et al., 1991) was performed for every site mean after which the Watson test of randomness was performed on every two stacked sites. This process was repeated 10000 times to compensate for the randomness of parametric sampling. Whenever two or three sites were serially correlated, the site(s) with a higher α_{95} value was (were) ignored in the SC corrected database (PSVM^{SC}). When 4 sites or more were stacked and serially correlated, the bottom and top site were included and the middle sites ignored. In total 301 sites (21%) were excluded from PSVM^{SC}. This sequence was repeated for each database with different applied selection criteria (k and n) as discussed in the previous section.

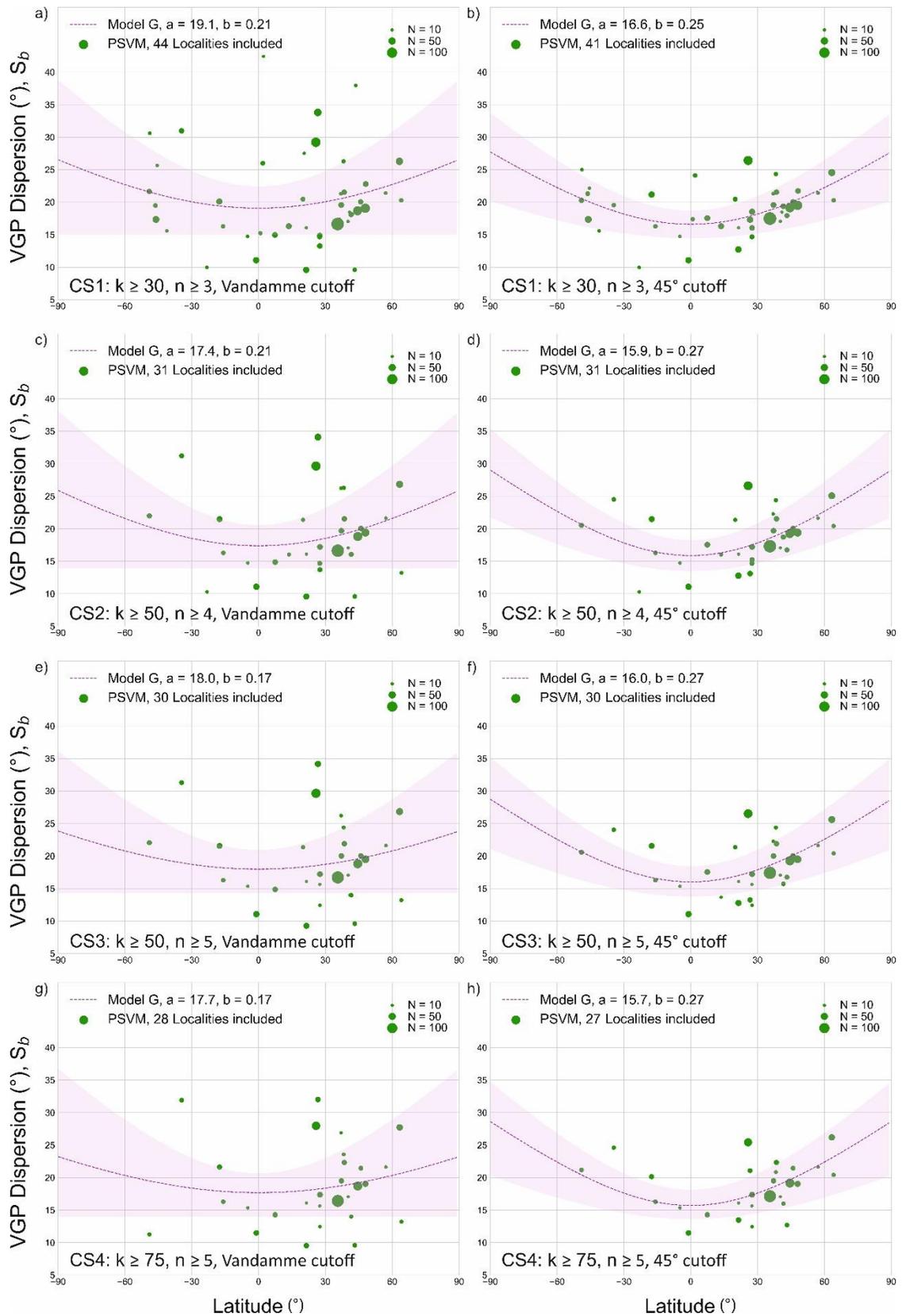


Figure S1. VGP dispersion versus latitude per locality in PSVM with different selection criteria (CS 1 to 4 in the main manuscript and Table S1) and cut-offs. Green dots represent the localities from PSVM and their size represents the number of sites included in that locality (N). The pink dashed line represents the Model G prediction for this specific situation and the pink shaded area represents the 95% confidence bounds on that Model G prediction. Subfigures a and b show PSVM with selection criteria set 1 (CS1). Subfigures c and d show subset CS2. Subfigures e and f show subset CS3 and subfigures g and h show subset CS4. Subfigures a, c, e and g show VGP dispersion with a Vandamme cut-off (1994), where subfigures b, d, f and h show the VGP dispersion with a 45° cut-off.

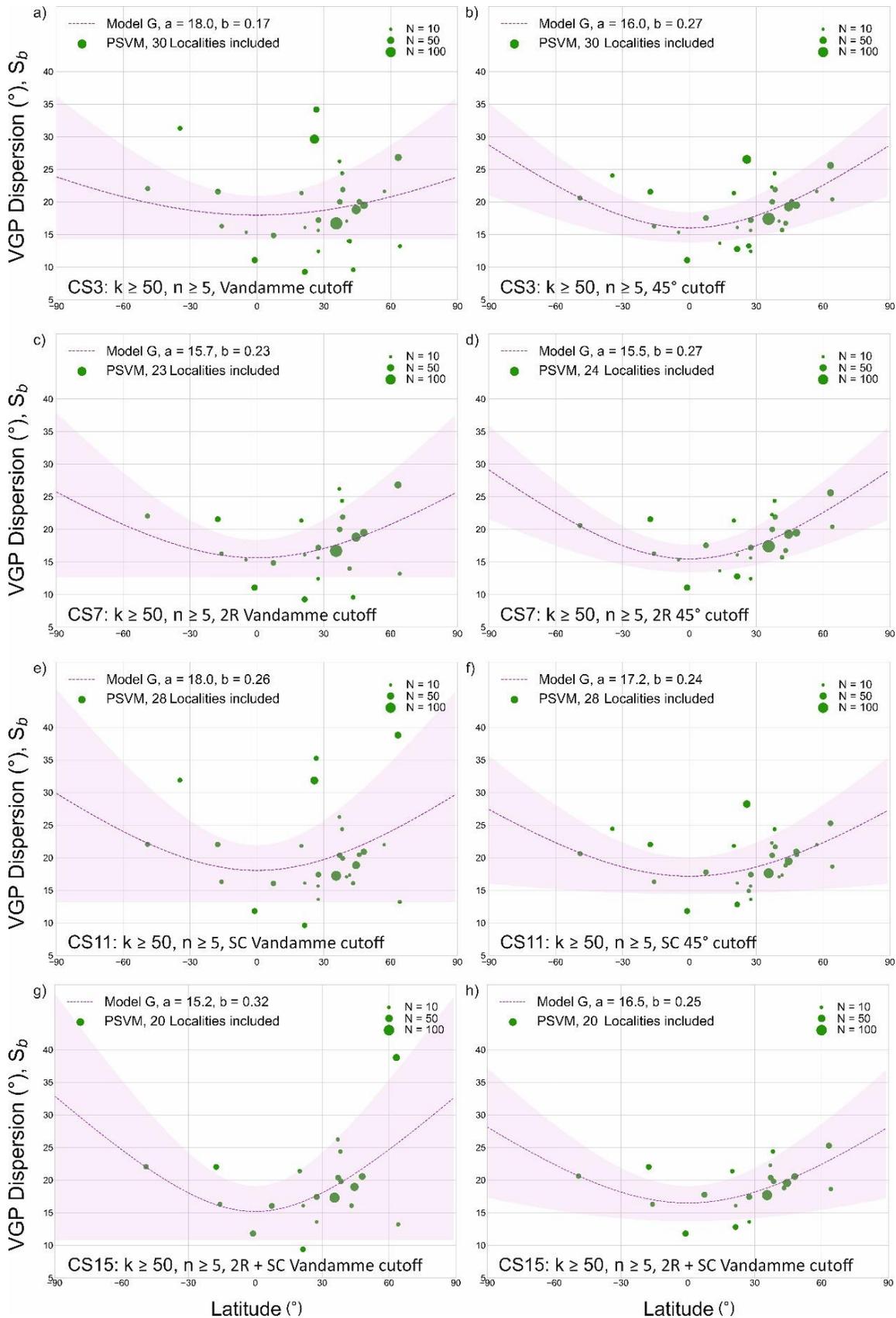


Figure S2. VGP dispersion versus latitude per locality in PSVM with different selection criteria (CS3, 7, 11, 15 in the main manuscript and Table S1) and cut-offs. Green dots represent the localities from PSVM and their size represents the number of sites included in that locality (N). The pink dashed line represents the Model G prediction for this specific situation and the pink shaded area represents the 95% confidence bounds on that Model G prediction. All of the subfigures show different variations of PSVM with $k \geq 50$ and $n \geq 5$. Subfigures a and b show PSVM (CS3), c and d show PSVM^{2R} (CS7). Subfigures e and f show PSVM^{SC} (CS11) and subfigures g and h show PSVM^{SC-2R} (CS15). Subfigures a, c, e and g show VGP dispersion with a Vandamme cut-off (1994), where subfigures b, d, f and h show the VGP dispersion with a 45° cutoff.

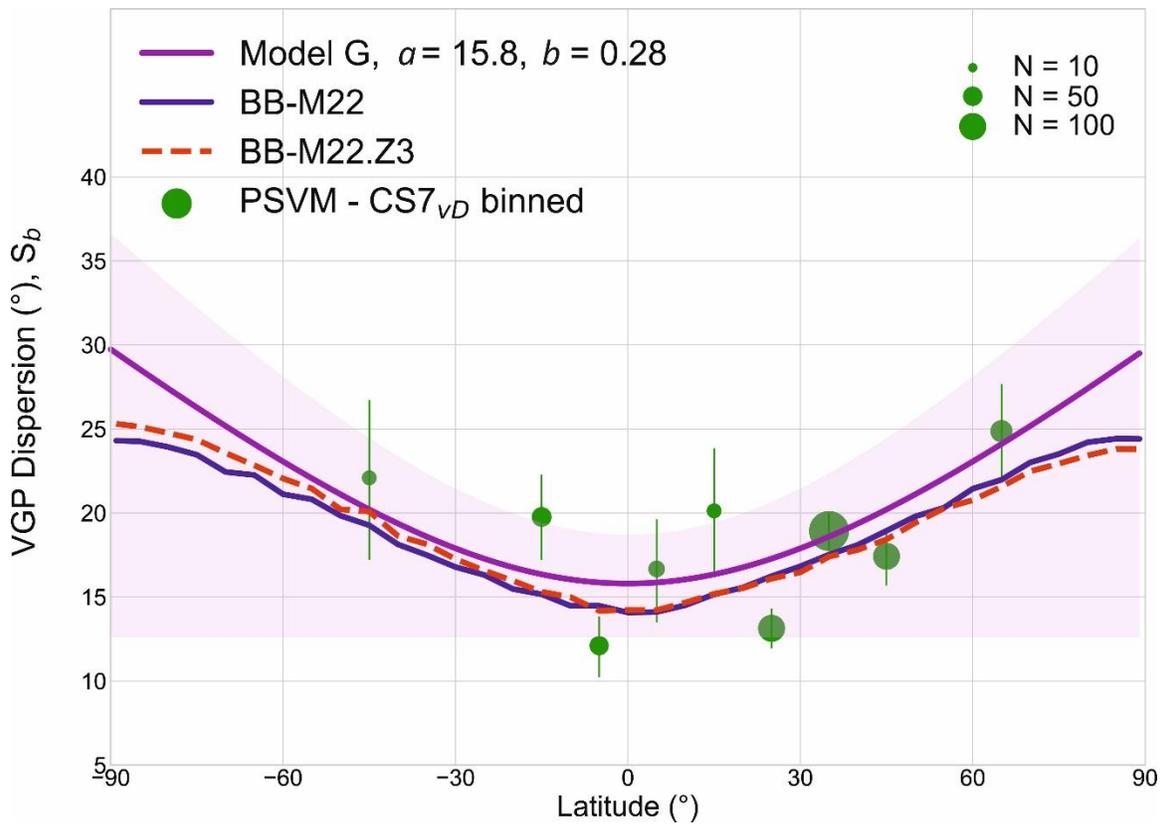


Figure S3. VGP dispersion versus latitude per 10° latitude bin in PSVM (CS7_{vD}, excluding locality #8 due to local block rotation). Green dots represent the bins from PSVM with their error margin, and the size of the dot represents the number of sites included in that bin (N). The pink dashed line represents the Model G prediction for this specific situation and the pink shaded area represents 95% confidence bounds on that Model G prediction. The blue line and red dashed line represent the predictions from BB-M22 and BB-M22.Z3 based on the PSVM localities (main text).

PSVM subset:	Selection Criteria				<i>Vandamme cut-off</i>		<i>45° cut-off</i>	
	<i>n</i>	<i>k</i>	2R	SC	<i>a</i> values	<i>b</i> values	<i>a</i> values	<i>b</i> values
CS1	≥ 3	> 30	N	N	19.1 +3.3/-4.1	0.21 +0.15/-0.20	16.6 +2.1/-2.2	0.25 +0.07/-0.09
CS2	≥ 4	> 50	N	N	17.4 +3.3/-3.4	0.21 +0.14/-0.21	15.9 +2.4/-2.3	0.27 +0.07/-0.08
CS3	≥ 5	> 50	N	N	18.0 +3.0/-3.7	0.17 +0.15/-0.17	16.0 +2.4/-2.2	0.27 +0.07/-0.09
CS4	≥ 5	> 75	N	N	17.7 +2.9/-3.7	0.17 +0.17/-0.17	15.7 +2.4/-2.1	0.27 +0.06/-0.10
CS5	≥ 3	> 30	Y	N	18.3 +3.4/-4.0	0.19 +0.15/-0.19	16.7 +2.0/-2.1	0.25 +0.07/-0.09
CS6	≥ 4	> 50	Y	N	15.7 +2.5/-2.7	0.23 +0.14/-0.23	15.8 +2.0/-2.0	0.27 +0.07/-0.08
CS7	≥ 5	> 50	Y	N	15.7 +2.7/-3.0	0.23 +0.14/-0.23	15.5 +2.2/-2.1	0.27 +0.07/-0.09
CS8	≥ 5	> 75	Y	N	15.3 +2.5/-2.9	0.20 +0.15/-0.20	14.4 +1.9/-1.8	0.28 +0.06/-0.09
CS9	≥ 3	> 30	N	Y	19.5 +3.9/-4.7	0.29 +0.17/-0.28	17.3 +2.2/-2.3	0.24 +0.08/-0.11
CS10	≥ 4	> 50	N	Y	17.7 +4.1/-4.5	0.29 +0.18/-0.29	17.2 +2.7/-2.4	0.24 +0.08/-0.13
CS11	≥ 5	> 50	N	Y	18.0 +3.9/-4.8	0.26 +0.18/-0.26	17.2 +2.9/-2.7	0.24 +0.16/-0.09
CS12	≥ 5	> 75	N	Y	17.5 +4.0/-4.5	0.26 +0.18/-0.25	16.6 +2.9/-2.5	0.25 +0.08/-0.14
CS13	≥ 3	> 30	Y	Y	18.5 +4.0/-4.6	0.28 +0.17/-0.28	17.2 +2.1/-2.2	0.25 +0.09/-0.11
CS14	≥ 4	> 50	Y	Y	15.1 +3.4/-3.6	0.34 +0.17/-0.34	16.3 +2.0/-2.1	0.26 +0.09/-0.10
CS15	≥ 5	> 50	Y	Y	15.2 +3.9/-4.4	0.32 +0.17/-0.32	16.5 +2.6/-2.8	0.25 +0.10/-0.14
CS16	≥ 5	> 75	Y	Y	14.6 +3.9/-4.3	0.30 +0.17/-0.30	14.9 +2.4/-2.2	0.27 +0.08/-0.12

Table S1. The different PSVM selection criteria subsets (CS) and their criteria and the Model G fit *a* and *b* parameters for the different applied cut-offs, with their bootstrap uncertainty values. *n* = minimum number of samples per site, *k* is the Fisher precision parameter (Fisher, 1953), 2R and SC give information if the criteria of at least 2 reversals (2R) or correction for serial correlation (SC) have been applied. The subsets in bold are those analyzed in the main manuscript and shown in Figure S1 and S2 of this Supplementary Information file.

Table S2. PSVM – CS7_{VD}. Locality is the locality number as in Table 1 of the main text. Lat and Long are the average paleolatitude of the locality. N is the number of sites included after the Vandamme cut-off (Vandamme, 1994) was applied. Dec and Inc are the average declination and inclination of the locality. S is the VGP dispersion for that locality with its upper and lower limit. ΔI is the inclination anomaly of that locality with its error. For locality #8, the inclination anomaly is not given as this locality experienced a local block rotation and it's not certain that it has not moved latitudinally. This locality was excluded from any analysis concerning inclination anomaly.

Locality	Lat (°)	Long (°)	N	Dec (°)	Inc (°)	S (°)	ΔI (°)
1	63.3	344.1	49	6.9	72.9	26.8 +2.9/-3.2	-3.0 ± 1.9
2	64.1	343.9	15	18.4	77.4	13.2 +3.6/-4.0	1.0 ± 1.5
6	48.0	245.3	56	359.3	60.0	19.5 +2.5/-2.6	-5.7 ± 1.7
8	44.5	244.1	80	13.9	56.3	18.8 +2.1/-2.2	-
9	43.2	114.6	20	355.5	57.2	9.6 +3.0/-3.5	-4.8 ± 1.3
10	41.6	107.9	19	12.2	60.8	14.0 +2.4/-2.6	0.2 ± 1.7
14	38.2	248.3	16	351.4	51.7	24.4 +5.3/-6.0	-5.9 ± 4.4
15	38.5	137.3	28	6.9	50.5	21.9 +4.0/-4.3	-7.3 ± 2.7
16	37.0	128.7	13	2.7	55.0	26.2 +7.4/-7.6	-1.4 ± 4.9
17	37.2	133.2	30	8.2	47.5	20.0 +3.9/-4.2	-9.1 ± 3.2
18	35.6	248.9	145	354.8	48.2	16.7 +1.3/-1.3	-6.8 ± 1.0
19	27.5	344.9	12	352.1	41.8	12.4 +3.3/-4.0	-4.4 ± 3.3
20	27.5	342.3	10	0.5	38.4	15.6 +3.8/-4.6	-7.7 ± 4.1
23	27.5	249.7	32	352.2	43.2	17.2 +3.1/-3.2	-3.0 ± 2.3
24	21.5	258.2	10	0.2	35.2	16.1 +4.3/-4.5	-3.0 ± 4.5
25	21.4	258.3	34	351.8	29.8	9.3 +1.7/-1.8	-8.3 ± 1.3
27	20.0	263.1	17	344.6	36.0	21.4 +4.3/-4.6	0.0 ± 4.3
29	7.4	36.8	30	0.5	8.0	14.9 +2.8/-3.0	-6.6 ± 2.6
33	-1.0	5.1	38	358.0	-6.1	11.1 +1.9/-2.0	-4.0 ± 1.8
34	-4.8	328.0	11	358.4	-17.2	15.4 +3.7/-4.2	-7.5 ± 5.2
35	-15.9	286.1	20	353.8	-33.2	16.3 +3.0/-3.3	-3.6 ± 3.1
36	-17.6	352.0	33	356.8	-20.2	21.6 +3.4/-3.6	12.1 ± 3.7
44	-49.0	67.2	25	5.8	-61.2	22.1 +4.9/-5.5	5.4 ± 2.4

Table S3. PSVM – CS7_{VD} in 10° latitude bins. Bin is the latitude range of the 10° latitude bin. N is the number of sites included after the Vandamme cut-off (Vandamme, 1994) was applied. Dec and Inc are the average declination and inclination of the bin. S is the VGP dispersion for that bin with its upper and lower limit. ΔI is the inclination anomaly of that bin with its error. Locality #8 was excluded from this analysis as it experienced a local block rotation and cannot be combined with other localities from the same latitude bin.

Bin	N	Dec (°)	Inc (°)	S (°)	ΔI (°)
-50° – -40°	28	3.2	-61.3	22.0 +4.6/-4.9	2.1 ± 2.4
-20° – -10°	52	356.5	-26.1	19.8 +2.5/-2.6	2.1 ± 2.5
-10° – 0°	49	358.1	-8.5	12.1 +1.7/-1.8	1.4 ± 1.8
0° – 10°	36	359.6	7.5	16.7 +3.0/-3.2	-2.4 ± 2.8
10° – 20°	28	349.9	26.3	20.1 +3.7/-3.9	-1.9 ± 3.5
20° – 30°	100	354.1	36.1	13.1 +1.1/-1.2	-6.9 ± 1.1
30° – 40°	225	358.1	50.1	18.9 +1.1/-1.1	-4.3 ± 0.9
40° – 50°	99	359.9	59.6	17.4 +1.7/-1.7	-3.8 ± 1.0
60° – 70°	66	8.2	75.3	24.9 +2.8/-2.9	-1.6 ± 1.4

Data Set S1. PSVM.

This file contains all the data in PSVM, with different tabs for different selection criteria. In PSVM Studies, the different localities and studies are presented with their numbers and average Latitude (Lat), Longitude (Long), Paleolatitude (Mlat), Paleolongitude (Mlong), Age in Ma, Number of sites (N), Number of sites after correction for serial correlation (N_SC), whether the locality contains 2 reversals (2R) and whether it is included for the Inclination anomaly analyses (IA). The country of the locality is given in Location, and then the year and authors are presented (same as Table 1 in main text).

In the PSVM_CS1 tab the sites are given separately. 'Site_ID' is the individual number each site has, 'Site' is the name of the site given in the study itself. 'age' is the age in Ma. 'Locality' gives the locality number and 'StudyNr' gives the study number. 'Lat_ave' and 'Long_ave' give the average paleolatitude and paleolongitude for the locality respectively. 'site_lat' and 'Site_Lon' give the precise latitude and longitude of the site, and 'model_lat' and 'model_lon' give the corrected paleolatitude and paleolongitude for that site. 'plate' gives the abbreviation for the tectonic plate on which the site is located. 'dec' and 'inc' give the result for that site in declination and inclination. 'Ndir' gives the number of samples used for that result. 'kdir' gives the k value from that result. 'alpha95' gives the α_{95} value for that result. 'Polarity' gives N for normal polarity, R for Reverse polarity and T for Transitional polarity. 'Dec_norm' and 'Inc_norm' give the declination and inclination for that result after being normalized to normal polarity. 'Model_vgp_lat' and 'model_vgp_lon' give the latitude and longitude for the virtual geomagnetic pole calculated from the directional result and paleolatitude and paleolongitude from that site. 'location' and 'PSVM_location' give the country and more specific location of the locality and 'reference' gives the first author and year of publication.

The other tabs have the same headings, and represent the different subsets (CS2 – CS16) for the different selection criteria. The final two tabs are of CS1 but with only normal or reversed data, respectively.