**Supporting information for**

Lead isotopic constraints on the provenance of Antarctic dust and relevant atmospheric circulation patterns prior to the Mid-Brunhes Event (~430 kyr ago)

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**Summary**

There are 14 pages in this Supplementary Information including 2 tables and 7 figures.

Table S1. Data obtained from 40 depth intervals from 2,973.9 (age of 572,800 yr B.P.) to 3189.45 m (age of 801,590 yr B.P.). The depths and estimated ages given in the table are the depth and age for the top of the samples. Uncertainties in the isotope ratios are for 95% confidence intervals.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| No. | Depth (m) | Age (years BP) | δD (‰) | Concentration (pg/g) | | 206Pb/207Pb | ± | 208Pb/207Pb | ± | 206Pb/204Pb | ± | Pb/Ba (by wt.) | dust Pb (%) |
| Pb | Ba |
| 1 | 2973.91 | 572,800 | -403 | 1.01 | 19.7 | 1.1945 | 0.0032 | 2.4674 | 0.0044 | 18.49 | 0.19 | 0.05 | 58.5 |
| 2 | 2974.08 | 572,900 | -403 | 0.45 | 8.8 | 1.1945 | 0.0034 | 2.4729 | 0.0057 | 18.43 | 0.23 | 0.05 | 58.1 |
| 3 | 2985.07 | 576,765 | -404 | 0.72 | 15.0 | 1.1975 | 0.0028 | 2.4703 | 0.0049 | 18.52 | 0.15 | 0.05 | 62.3 |
| 4 | 2990.35 | 578,965 | -398 | 0.83 | 15.4 | 1.1874 | 0.0028 | 2.4618 | 0.0050 | 18.25 | 0.21 | 0.05 | 55.6 |
| 5 | 2995.92 | 581,610 | -415 | 1.31 | 39.5 | 1.1995 | 0.0024 | 2.4729 | 0.0041 | 18.73 | 0.14 | 0.03 | 90.3 |
| 6 | 3001.41 | 585,975 | -424 | 2.14 | 38.4 | 1.1853 | 0.0027 | 2.4556 | 0.0047 | 18.09 | 0.20 | 0.06 | 53.8 |
| 7 | 3001.58 | 586,225 | -424 | 0.97 | 20.5 | 1.1959 | 0.0033 | 2.4744 | 0.0051 | 18.43 | 0.20 | 0.05 | 63.6 |
| 8 | 3012.41 | 597,180 | -432 | 6.81 | 122.3 | 1.1975 | 0.0021 | 2.4674 | 0.0032 | 18.51 | 0.13 | 0.06 | 53.9 |
| 9 | 3012.58 | 597,510 | -432 | 4.30 | 81.5 | 1.1970 | 0.0022 | 2.4696 | 0.0041 | 18.59 | 0.13 | 0.05 | 56.8 |
| 10 | 3023.35 | 610,680 | -401 | 0.46 | 5.0 | 1.1824 | 0.0032 | 2.4663 | 0.0055 | 18.39 | 0.17 | 0.09 | 32.4 |
| 11 | 3034.35 | 622,895 | -405 | 2.21 | 72.4 | 1.1958 | 0.0027 | 2.4644 | 0.0047 | 18.47 | 0.12 | 0.03 | 98.1 |
| 12 | 3040.13 | 631,365 | -438 | 3.84 | 100.1 | 1.2021 | 0.0022 | 2.4743 | 0.0048 | 18.67 | 0.13 | 0.04 | 78.1 |
| 13 | 3045.42 | 644,485 | -433 | 8.63 | 161.9 | 1.1955 | 0.0024 | 2.4686 | 0.0040 | 18.50 | 0.10 | 0.05 | 56.3 |
| 14 | 3056.48 | 662,800 | -437 | 19.05 | 297.1 | 1.2041 | 0.0018 | 2.4686 | 0.0037 | 18.68 | 0.08 | 0.06 | 46.8 |
| 15 | 3056.61 | 663,290 | -437 | 16.99 | 311.0 | 1.2004 | 0.0020 | 2.4661 | 0.0040 | 18.40 | 0.13 | 0.06 | 54.9 |
| 16 | 3072.92 | 682,755 | -425 | 3.54 | 40.4 | 1.1845 | 0.0026 | 2.4576 | 0.0045 | 18.26 | 0.20 | 0.09 | 34.2 |
| 17 | 3073.08 | 682,990 | -425 | 2.93 | 48.7 | 1.2011 | 0.0023 | 2.4763 | 0.0037 | 18.68 | 0.13 | 0.06 | 49.9 |
| 18 | 3078.35 | 687,730 | -417 | 1.94 | 32.7 | 1.1964 | 0.0019 | 2.4667 | 0.0035 | 18.61 | 0.10 | 0.06 | 50.5 |
| 19 | 3083.85 | 691,890 | -411 | 1.23 | 15.0 | 1.2047 | 0.0034 | 2.4636 | 0.0061 | 18.40 | 0.22 | 0.08 | 36.5 |
| 20 | 3089.42 | 695,620 | -403 | 3.54 | 11.4 | 1.2332 | 0.0032 | 2.4902 | 0.0047 | 19.10 | 0.17 | 0.31 | 9.7 |
| 21 | 3089.59 | 695,785 | -403 | 1.63 | 6.7 | 1.2000 | 0.0030 | 2.4693 | 0.0047 | 18.57 | 0.18 | 0.24 | 12.4 |
| 22 | 3094.92 | 699,080 | -405 | 1.33 | 21.0 | 1.2119 | 0.0036 | 2.4748 | 0.0045 | 18.54 | 0.23 | 0.06 | 47.2 |
| 23 | 3095.09 | 699,240 | -405 | 2.15 | 9.9 | 1.2086 | 0.0029 | 2.4703 | 0.0043 | 18.71 | 0.18 | 0.22 | 13.8 |
| 24 | 3100.42 | 702,580 | -408 | 0.84 | 9.5 | 1.1907 | 0.0023 | 2.4658 | 0.0035 | 18.50 | 0.16 | 0.09 | 33.8 |
| 25 | 3100.57 | 702,740 | -408 | 13.21 | 13.0 | 1.1900 | 0.0022 | 2.4579 | 0.0042 | 18.57 | 0.11 | 1.02 | 2.9 |
| 26 | 3106.08 | 706,315 | -407 | 0.70 | 14.5 | 1.2044 | 0.0024 | 2.4767 | 0.0046 | 18.75 | 0.13 | 0.05 | 62.1 |
| 27 | 3111.35 | 711,860 | -412 | 6.97 | 171.4 | 1.2299 | 0.0020 | 2.4853 | 0.0033 | 19.16 | 0.09 | 0.04 | 73.8 |
| 28 | 3122.35 | 721,290 | -438 | 9.90 | 88.3 | 1.2259 | 0.0017 | 2.4751 | 0.0032 | 19.15 | 0.08 | 0.11 | 26.8 |
| 29 | 3127.85 | 727,415 | -422 | 4.06 | 36.3 | 1.2307 | 0.0024 | 2.4939 | 0.0037 | 19.20 | 0.13 | 0.11 | 26.9 |
| 30 | 3133.45 | 732,980 | -412 | 1.27 | 30.7 | 1.2013 | 0.0020 | 2.4765 | 0.0032 | 18.64 | 0.11 | 0.04 | 72.8 |
| 31 | 3133.60 | 733,260 | -412 | 2.11 | 31.9 | 1.2137 | 0.0022 | 2.4766 | 0.0035 | 19.01 | 0.11 | 0.07 | 45.2 |
| 32 | 3139.95 | 739,730 | -439 | 17.07 | 453.1 | 1.1965 | 0.0020 | 2.4713 | 0.0034 | 18.67 | 0.09 | 0.04 | 79.6 |
| 33 | 3145.45 | 746,495 | -439 | 7.52 | 143.6 | 1.2108 | 0.0022 | 2.4742 | 0.0039 | 18.82 | 0.10 | 0.05 | 57.3 |
| 34 | 3149.85 | 751,860 | -439 | 8.64 | 177.8 | 1.1973 | 0.0018 | 2.4704 | 0.0034 | 18.64 | 0.08 | 0.05 | 61.8 |
| 35 | 3156.45 | 759,970 | -429 | 1.96 | 37.0 | 1.1990 | 0.0023 | 2.4758 | 0.0038 | 18.72 | 0.12 | 0.05 | 56.8 |
| 36 | 3160.85 | 765,820 | -420 | 2.54 | 25.6 | 1.1877 | 0.0021 | 2.4642 | 0.0033 | 18.57 | 0.13 | 0.10 | 30.3 |
| 37 | 3165.32 | 771,640 | -415 | 0.89 | 25.9 | 1.1986 | 0.0041 | 2.4725 | 0.0052 | 18.64 | 0.24 | 0.03 | 87.1 |
| 38 | 3172.95 | 781,015 | -403 | 0.49 | 10.7 | 1.2110 | 0.0032 | 2.4849 | 0.0053 | 18.83 | 0.16 | 0.05 | 66.3 |
| 39 | 3178.52 | 786,950 | -396 | 1.09 | 12.9 | 1.2013 | 0.0067 | 2.4747 | 0.0089 | 18.63 | 0.38 | 0.09 | 35.3 |
| 40 | 3189.45 | 801,590 | -441 | 107.98 | 626.8 | 1.2295 | 0.0015 | 2.4749 | 0.0024 | 19.25 | 0.05 | 0.17 | 17.4 |
| All periods | | Mean | | 6.9 | 85 | 1.2022 |  | 2.4715 |  | 18.64 |  | 0.10 | 50.3 |
| Min-Max | | 0.45-108 | 5.0-627 | 1.1824-1.2332 |  | 2.4556-2.4939 |  | 18.09-19.25 |  | 0.03-1.02 | 2.9-98.1 |
| Glacials (δD < –405‰) | | Mean | | 9.3 | 114 | 1.2025 |  | 2.4712 |  | 18.67 |  | 0.10 | 52.2 |
| Min-Max | | 0.70-108 | 9.5-627 | 1.1845-1.2307 |  | 2.4556-2.4939 |  | 18.09-19.25 |  | 0.03-1.02 | 2.9-90.3 |
| Interglacials (δD > –405‰) | | Mean | | 1.3 | 17 | 1.2015 |  | 2.4723 |  | 18.58 |  | 0.11 | 45.8 |
| Min-Max | | 0.45-3.54 | 5.0-72.4 | 1.1824-1.2332 |  | 2.4618-2.4902 |  | 18.25-19.10 |  | 0.03-0.31 | 9.7-98.1 |

Table S2. Statistical summary (mean ± standard deviation, SD) of Pb isotope ratios. The dust dominant and non-dust dominant Pb isotopes are separated according to the glacial and interglacial periods between the post-MBE and pre-MBE intervals. The post-MBE data are from Vallelonga et al. (2010). The number of samples is given in parentheses. Four pre-MBE samples (nos. 20, 28, 29, 40) were excluded in the calculation to avoid bias because they are outside the general trend of the pre-MBE non-dust dominant isotopic compositions (see text).

|  |  |  |
| --- | --- | --- |
| Samples | 206Pb/207Pb | 208Pb/207Pb |
| Post-MBE glacial dust-dominant (n=39) | 1.2050 ± 0.0090 | 2.4731 ± 0.0108 |
| Post-MBE interglacial dust-dominant (n=13) | 1.2049 ± 0.0126 | 2.4801 ± 0.0138 |
| Post-MBE glacial non-dust dominant (n=21) | 1.2311 ± 0.0160 | 2.4877 ± 0.0127 |
| Post-MBE interglacial non-dust dominant (n=1) | 1.2240 | 2.4793 |
| Pre-MBE glacial dust dominant (n=9) | 1.2028 ± 0.0105 | 2.4749 ± 0.0045 |
| Pre-MBE interglacial dust dominant (n=3) | 1.2014 ± 0.0083 | 2.4732 ± 0.0105 |
| Pre-MBE glacial non-dust dominant (n=16) | 1.1974 ± 0.0085 | 2.4672 ± 0.0065 |
| Pre-MBE interglacial non-dust dominant (n=8) | 1.1976 ± 0.0100 | 2.4697 ± 0.0045 |



Figure S1. Scatter plots of Pb and Ba concentrations versus dust fluxes (Lambert et al., 2008) in the pre-MBE EDC ice core samples. Two lines with Pearson’s correlation coefficients (*r*) that are significant at the *p* < 0.01 level are fit to the data, the solid line being the least squares line for Pb concentrations (solid circles) and the dashed line for Ba concentrations (open circles). The extreme values of Pb and Ba concentration in the deepest ice at 3,189.45 m (sample no. 40, ~801 kyr B.P., MIS 20) was excluded (see text). All uncertainties are 95% confidence intervals.



Figure S2. Scatter plots of Pb concentrations versus Ba concentrations in the pre-MBE EDC ice core samples. Two lines with Pearson’s correlation coefficients (*r*) are fit to the data, the solid line being the least squares line for data with δD values below –420‰ (solid circles) and the dashed line for data with δD values above –420‰ (open circles). The extreme values of Pb and Ba concentrations in the deepest ice at 3,189.45 m (sample no. 40, ~801 kyr B.P., MIS 20) were excluded (see text). All uncertainties are 95% confidence intervals.



Figure S3. Changes in Pb concentrations as a function of the deuterium content (expressed in delta per mil) in the pre-MBE EDC ice core samples. The numbers in parentheses represent sample numbers in Table S1. All uncertainties are 95% confidence intervals.

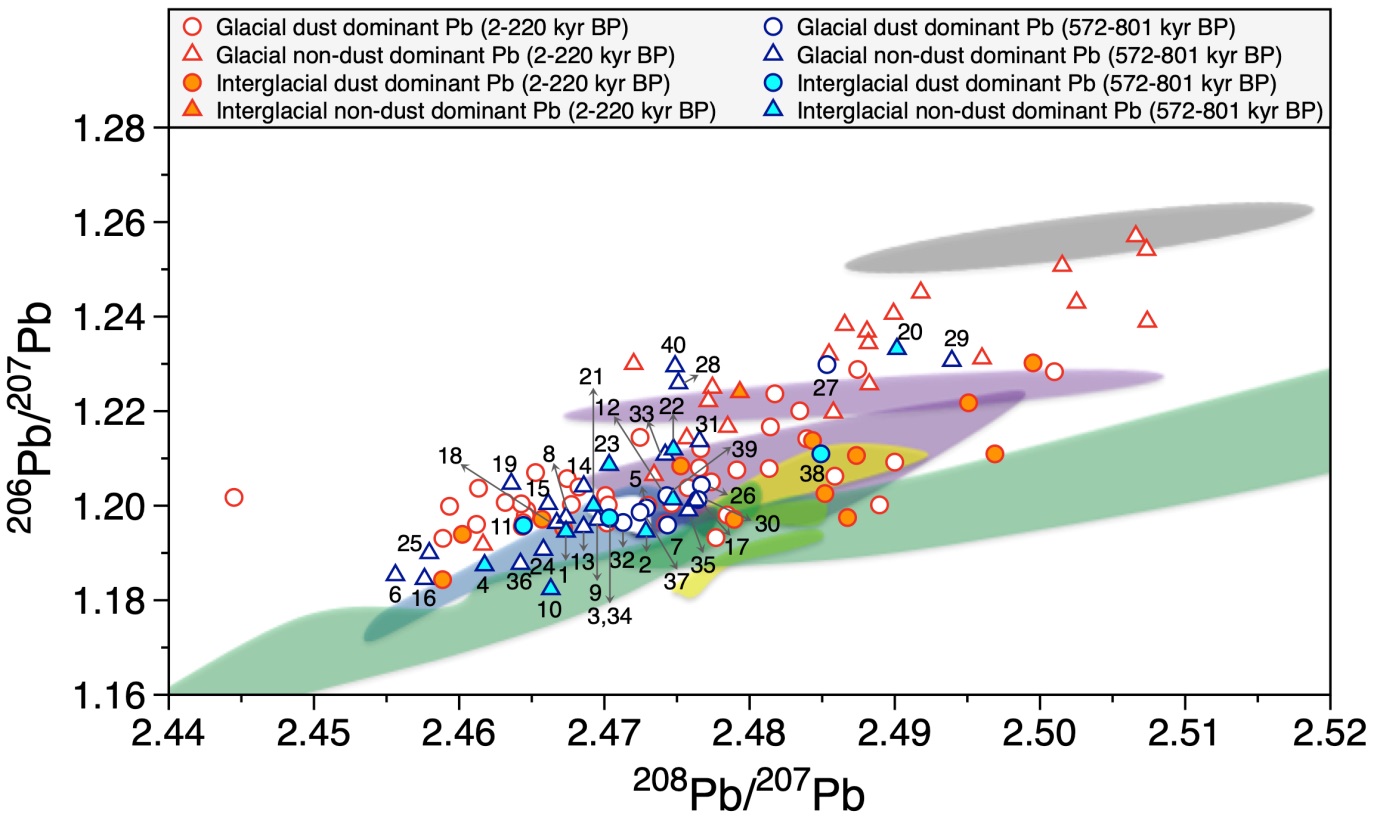


Figure S4. A plot of the 208Pb/207Pb versus 206Pb/207Pb in the EDC ice core samples showing the identification numbers of pre-MBE samples in Table S1. All uncertainties are 95% confidence intervals.

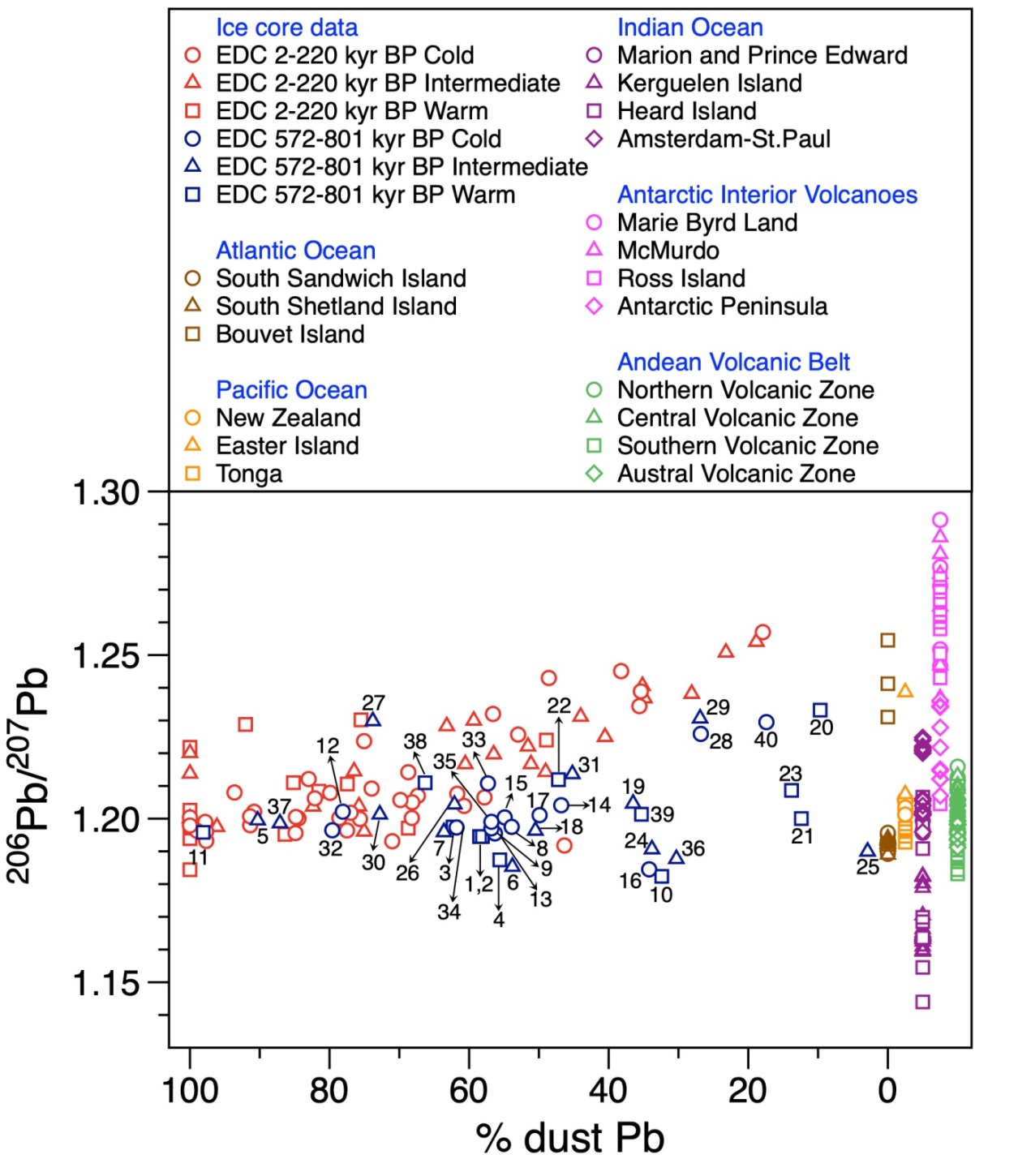


Figure S5. Comparison of 206Pb/207Pb ratios between the pre- MBE and post-MBE intervals as a function of dust fraction of Pb showing the identification numbers of pre-MBE samples in Table S1. The end-members of volcanic 206Pb/207Pb ratios for the potential volcanic sources come from published literature: Marie Byrd Land (Hart et al., 1997), McMurdo volcanics (Rocholl et al., 1995), Ross Island basanitoids (Sun and Hanson, 1975), Antarctic Peninsula basalts (Hole et al., 1993), South American volcanoes (Harmon et al., 1984; Stern and Kilian, 1996), South Sandwich Island (Barreiro, 1983), Bouvet Island (Sun, 1980), South Shetland Island (Lee et al., 2008), Marion and Prince Edward (le Roex et al., 2012), Kerguelen Island (Weis et al., 1998), Heard Island (Barling et al., 1994), Amsterdam-St.Paul (Doucet et al., 2004), New Zealand (McCulloch et al., 1994), and Easter Island and Tonga (Sun, 1980).

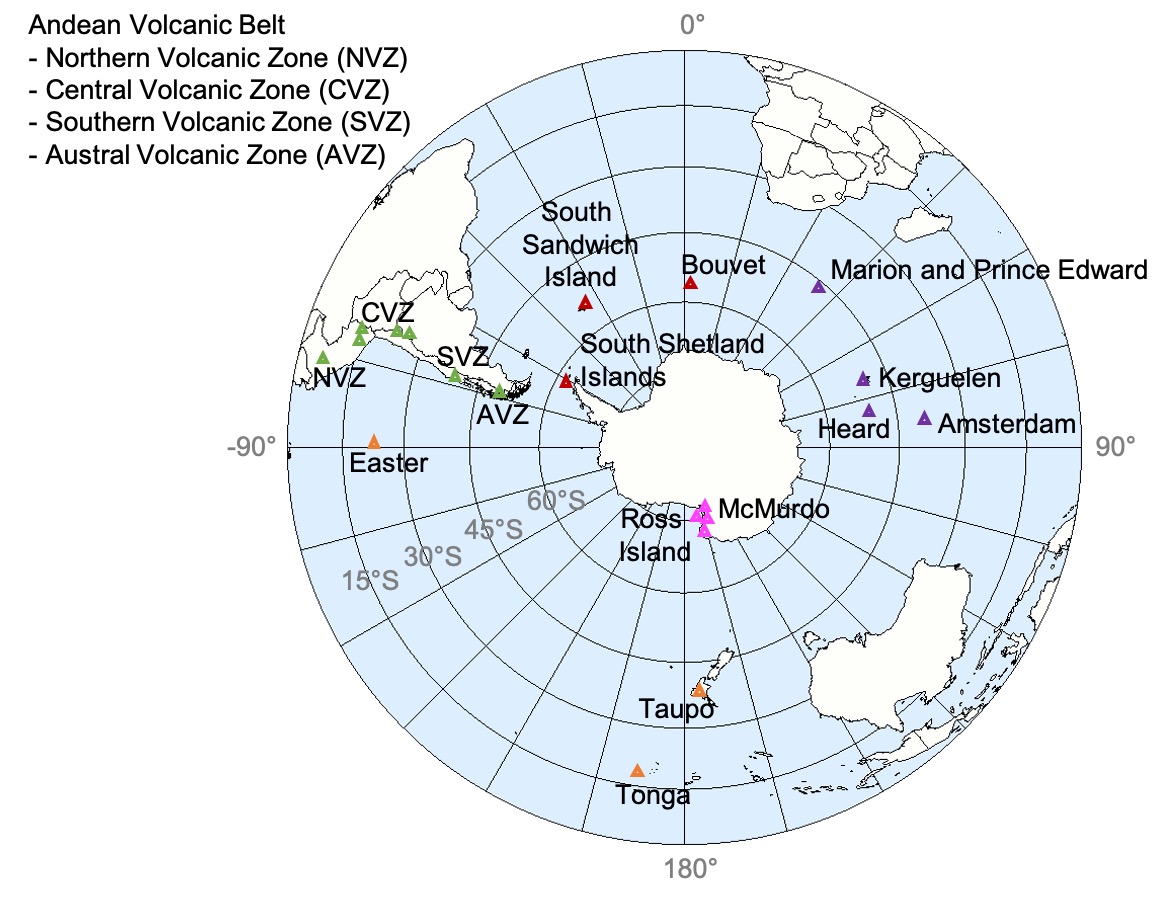


Figure S6. Location map for Antarctic and extra-Antarctic volcanoes mentioned in the text. The base map is ‘Southern Hemisphere of Earth (Lambert Azimuthal projection)’ by Sean Baker licensed under CC BY 2.

텍스트, 지도이(가) 표시된 사진

자동 생성된 설명Figure S7. Changes in Pb and Ba concentrations and 206Pb/207Pb ratios (open circles) as a function of radius in two sections: (a) depth of 2973.91 m (572.8 kyr B.P.), MIS 15.1 interglacial; (b) depth of 3056.48 m (662.8 kyr B.P.), MIS 14 glacial. Two different values are given for concentrations and isotope ratios in the innermost part because the inner cores were divided into two consecutive 20 cm long parts. The error bars of the 206Pb/207Pb ratios are 95% confidence intervals.

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