## Supplementary Material to *"Orbital control on the timing of oceanic anoxia in the Late Cretaceous"*

### Supplementary Table 1: Complete $^{40}Ar/^{39}Ar$ results

Sample 91-O-03, J: 0.0207634 ± 0.0000127 (1σ), D/amu: 1.00 ± 0.0002 (1σ), MSWD = 0.69
Single sanidine fusions, Ages relative to 28.201 Ma Fish Canyon sanidine (Kuiper et al., 2008)

| File | $^{40}Ar$ (moles) | $^{40}Ar$ ($10^{-15}$ V) | ± 1σ$_{40}$ ($10^{-15}$ V) | $^{39}Ar$ ($10^{-15}$ V) | ±1σ$_{39}$ ($10^{-15}$ V) | $^{38}Ar$ ($10^{-15}$ V) | ± 1σ$_{38}$ ($10^{-15}$ V) | $^{37}Ar$ ($10^{-15}$ V) | ± 1σ$_{37}$ ($10^{-15}$ V) | $^{36}Ar$ ($10^{-15}$ V) | ± 1σ$_{36}$ ($10^{-15}$ V) | %$^{40}Ar^*$ | $^{40}Ar^*/^{39}Ar_K$ ± 2σ | Age (Ma) | ± 2σ (Ma) | K/Ca | Outliers |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BG2538 | 2.688E-15 | 0.455488 | 0.000598 | 0.173046 | 0.000268 | 0.002121 | 0.000020 | 0.001465 | 0.000167 | 0.000017 | 0.000006 | 98.87 | 2.602509 | 0.02323 | 96.33 | ± 0.84 | 50.8 | |
| BG2540 | 1.513E-15 | 0.256400 | 0.000567 | 0.098068 | 0.000224 | 0.001175 | 0.000019 | 0.001086 | 0.000159 | 0.000009 | 0.000006 | 99.02 | 2.588839 | 0.03975 | 95.84 | ± 1.43 | 38.8 | |
| BG2541 | 3.716E-15 | 0.629596 | 0.000618 | 0.240421 | 0.000296 | 0.002879 | 0.000025 | 0.001621 | 0.000183 | 0.000021 | 0.000006 | 98.99 | 2.592404 | 0.01653 | 95.97 | ± 0.60 | 63.8 | |
| BG2543 | 1.923E-15 | 0.325774 | 0.000582 | 0.125257 | 0.000245 | 0.001508 | 0.000022 | 0.000840 | 0.000168 | 0.000019 | 0.000006 | 98.24 | 2.555077 | 0.03117 | 94.62 | ± 1.13 | 64.1 | < 98.5% 40Ar |
| BG2544 | 2.152E-15 | 0.364594 | 0.000623 | 0.139133 | 0.000257 | 0.001626 | 0.000020 | 0.001099 | 0.000187 | 0.000010 | 0.000006 | 99.15 | 2.598308 | 0.02828 | 96.18 | ± 1.02 | 54.4 | |
| BG2546 | 2.952E-15 | 0.500217 | 0.000615 | 0.191081 | 0.000240 | 0.002271 | 0.000024 | 0.001465 | 0.000171 | 0.000016 | 0.000006 | 99.03 | 2.592507 | 0.02113 | 95.97 | ± 0.76 | 56.1 | |
| BG2547 | 1.457E-15 | 0.246878 | 0.000561 | 0.094100 | 0.000221 | 0.001160 | 0.000014 | 0.000801 | 0.000172 | 0.000008 | 0.000006 | 99.10 | 2.599921 | 0.04078 | 96.24 | ± 1.47 | 50.5 | |
| BG2549 | 2.939E-15 | 0.497890 | 0.000627 | 0.190952 | 0.000248 | 0.002331 | 0.000020 | 0.001266 | 0.000172 | 0.000007 | 0.000006 | 99.61 | 2.597166 | 0.02073 | 96.14 | ± 0.75 | 64.9 | |
| BG2550 | 2.535E-15 | 0.429545 | 0.000614 | 0.163874 | 0.000244 | 0.001953 | 0.000021 | 0.001768 | 0.000169 | 0.000011 | 0.000006 | 99.23 | 2.600931 | 0.02412 | 96.28 | ± 0.87 | 39.9 | |
| BG2552 | 1.700E-15 | 0.288101 | 0.000584 | 0.109420 | 0.000227 | 0.001293 | 0.000017 | 0.001118 | 0.000190 | 0.000016 | 0.000006 | 98.40 | 2.590863 | 0.03509 | 95.91 | ± 1.27 | 42.1 | < 98.5% 40Ar |
| BG2555 | 2.418E-15 | 0.409718 | 0.000592 | 0.156706 | 0.000225 | 0.001849 | 0.000017 | 0.001257 | 0.000153 | 0.000010 | 0.000006 | 99.26 | 2.595314 | 0.02439 | 96.07 | ± 0.88 | 53.6 | |
| BG2556 | 2.673E-15 | 0.452928 | 0.000609 | 0.173626 | 0.000257 | 0.002080 | 0.000025 | 0.001284 | 0.000162 | 0.000007 | 0.000006 | 99.55 | 2.596947 | 0.02221 | 96.13 | ± 0.80 | 58.2 | |
| BG2558 | 2.125E-15 | 0.360015 | 0.000576 | 0.136902 | 0.000237 | 0.001651 | 0.000023 | 0.000973 | 0.000191 | 0.000017 | 0.000006 | 98.57 | 2.592119 | 0.02865 | 95.96 | ± 1.03 | 60.5 | |
| BG2559 | 2.424E-15 | 0.410644 | 0.000637 | 0.155942 | 0.000254 | 0.001895 | 0.000024 | 0.001459 | 0.000172 | 0.000008 | 0.000006 | 99.45 | 2.618752 | 0.02516 | 96.92 | ± 0.91 | 46.0 | |
| BG2561 | 1.965E-15 | 0.332994 | 0.000575 | 0.127580 | 0.000257 | 0.001537 | 0.000027 | 0.001137 | 0.000159 | 0.000000 | 0.000006 | 99.96 | 2.609120 | 0.03105 | 96.57 | ± 1.12 | 48.2 | |
| BG2562 | 1.962E-15 | 0.332400 | 0.000579 | 0.127720 | 0.000243 | 0.001504 | 0.000018 | 0.001202 | 0.000168 | 0.000009 | 0.000006 | 99.23 | 2.582635 | 0.03006 | 95.62 | ± 1.08 | 45.7 | |
| BG2565 | 2.799E-15 | 0.474318 | 0.000595 | 0.181702 | 0.000294 | 0.002173 | 0.000027 | 0.001605 | 0.000166 | 0.000011 | 0.000006 | 99.30 | 2.592148 | 0.02166 | 95.96 | ± 0.78 | 48.7 | |
| BG2567 | 2.447E-15 | 0.414686 | 0.000593 | 0.156068 | 0.000259 | 0.001893 | 0.000022 | 0.001004 | 0.000189 | 0.000023 | 0.000006 | 98.38 | 2.614099 | 0.02576 | 96.75 | ± 0.93 | 66.9 | < 98.5% 40Ar |
| BG2568 | 3.073E-15 | 0.520647 | 0.000594 | 0.198725 | 0.000278 | 0.002450 | 0.000026 | 0.001661 | 0.000167 | 0.000006 | 0.000006 | 99.66 | 2.610987 | 0.02016 | 96.64 | ± 0.73 | 51.4 | |
| BG2570 | 2.071E-15 | 0.350955 | 0.000574 | 0.134345 | 0.000246 | 0.001637 | 0.000021 | 0.000813 | 0.000171 | 0.000008 | 0.000006 | 99.35 | 2.595250 | 0.02920 | 96.07 | ± 1.05 | 71.0 | |
| BG2571 | 2.002E-15 | 0.339143 | 0.000577 | 0.129811 | 0.000240 | 0.001553 | 0.000019 | 0.000877 | 0.000149 | 0.000007 | 0.000006 | 99.37 | 2.596017 | 0.03003 | 96.10 | ± 1.08 | 63.6 | |
| BG2573 | 2.735E-15 | 0.463406 | 0.000591 | 0.176698 | 0.000259 | 0.002172 | 0.000025 | 0.001557 | 0.000174 | 0.000010 | 0.000006 | 99.37 | 2.606031 | 0.02223 | 96.46 | ± 0.80 | 48.8 | |
| BG2574 | 2.371E-15 | 0.401755 | 0.000591 | 0.153758 | 0.000245 | 0.001873 | 0.000022 | 0.000927 | 0.000176 | 0.000002 | 0.000006 | 99.88 | 2.609848 | 0.02535 | 96.60 | ± 0.91 | 71.3 | |
| BG2576 | 2.199E-15 | 0.372670 | 0.000581 | 0.142847 | 0.000264 | 0.001763 | 0.000020 | 0.001095 | 0.000168 | 0.000007 | 0.000006 | 99.46 | 2.594743 | 0.02714 | 96.05 | ± 0.98 | 56.1 | |
| BG2577 | 1.935E-15 | 0.327913 | 0.000558 | 0.125206 | 0.000251 | 0.001521 | 0.000019 | 0.000989 | 0.000166 | 0.000002 | 0.000006 | 99.83 | 2.614620 | 0.03075 | 96.77 | ± 1.11 | 54.4 | |
| BG2579 | 1.732E-15 | 0.293406 | 0.000568 | 0.112215 | 0.000214 | 0.001345 | 0.000023 | 0.000902 | 0.000177 | 0.000003 | 0.000006 | 99.68 | 2.606365 | 0.03485 | 96.47 | ± 1.26 | 53.5 | |
| BG2580 | 1.724E-15 | 0.292050 | 0.000569 | 0.111667 | 0.000234 | 0.001335 | 0.000017 | 0.000895 | 0.000165 | 0.000004 | 0.000006 | 99.64 | 2.605889 | 0.03511 | 96.46 | ± 1.27 | 53.6 | |
| BG2582 | 1.892E-15 | 0.320504 | 0.000371 | 0.122576 | 0.000181 | 0.001475 | 0.000016 | 0.000906 | 0.000158 | 0.000001 | 0.000004 | 99.90 | 2.612138 | 0.02046 | 96.68 | ± 0.74 | 58.2 | |
| BG2585 | 1.836E-15 | 0.311041 | 0.000333 | 0.118229 | 0.000217 | 0.001459 | 0.000022 | 0.000872 | 0.000142 | 0.000004 | 0.000004 | 99.61 | 2.620656 | 0.02362 | 96.99 | ± 0.85 | 58.3 | |
| BG2588 | 1.557E-15 | 0.263847 | 0.000344 | 0.100811 | 0.000137 | 0.001190 | 0.000017 | 0.000593 | 0.000144 | 0.000007 | 0.000004 | 99.23 | 2.597069 | 0.02743 | 96.14 | ± 0.99 | 73.1 | |
| BG2589 | 2.238E-15 | 0.379144 | 0.000410 | 0.143448 | 0.000196 | 0.001735 | 0.000020 | 0.001102 | 0.000135 | 0.000020 | 0.000004 | 98.42 | 2.601440 | 0.01771 | 96.30 | ± 0.64 | 56.0 | < 98.5% 40Ar |
| BG2591 | 1.347E-15 | 0.228257 | 0.000379 | 0.087467 | 0.000145 | 0.001030 | 0.000013 | 0.000871 | 0.000137 | 0.000014 | 0.000004 | 98.21 | 2.562801 | 0.02766 | 94.90 | ± 1.00 | 43.2 | < 98.5% 40Ar |
| BG2592 | 1.699E-15 | 0.287944 | 0.000362 | 0.110065 | 0.000164 | 0.001350 | 0.000017 | 0.001010 | 0.000141 | 0.000007 | 0.000004 | 99.27 | 2.596988 | 0.02143 | 96.14 | ± 0.77 | 46.8 | |
| BG2594 | 1.411E-15 | 0.239135 | 0.000364 | 0.091782 | 0.000126 | 0.001122 | 0.000019 | 0.000817 | 0.000133 | 0.000002 | 0.000004 | 99.72 | 2.598287 | 0.02574 | 96.18 | ± 0.93 | 48.3 | |
| BG2595 | 1.337E-15 | 0.226515 | 0.000347 | 0.086378 | 0.000143 | 0.001056 | 0.000019 | 0.000487 | 0.000142 | 0.000003 | 0.000004 | 99.65 | 2.613206 | 0.02703 | 96.72 | ± 0.97 | 76.2 | |
| BG2597 | 1.697E-15 | 0.287521 | 0.000348 | 0.109701 | 0.000161 | 0.001331 | 0.000021 | 0.000811 | 0.000139 | 0.000019 | 0.000003 | 98.05 | 2.569814 | 0.02111 | 95.16 | ± 0.76 | 58.2 | < 98.5% 40Ar |
| BG2598 | 1.764E-15 | 0.298867 | 0.000385 | 0.114184 | 0.000151 | 0.001370 | 0.000020 | 0.000656 | 0.000158 | 0.000011 | 0.000004 | 98.93 | 2.589375 | 0.02192 | 95.86 | ± 0.79 | 74.9 | |
| BG2600 | 1.410E-15 | 0.238883 | 0.000350 | 0.090732 | 0.000121 | 0.001113 | 0.000018 | 0.000970 | 0.000158 | 0.000021 | 0.000004 | 97.39 | 2.564202 | 0.02644 | 94.95 | ± 0.95 | 40.2 | < 98.5% 40Ar |
| BG2601 | 1.063E-15 | 0.180108 | 0.000332 | 0.068258 | 0.000134 | 0.000847 | 0.000016 | 0.000327 | 0.000144 | 0.000015 | 0.000004 | 97.50 | 2.572580 | 0.03526 | 95.25 | ± 1.27 | 89.6 | < 98.5% 40Ar |
| BG2926 | 3.465E-15 | 0.587096 | 0.000442 | 0.224134 | 0.000225 | 0.002679 | 0.000023 | 0.001883 | 0.000210 | 0.000019 | 0.000003 | 99.04 | 2.594313 | 0.01123 | 96.04 | ± 0.41 | 51.2 | |
| BG2928 | 3.049E-15 | 0.516641 | 0.000417 | 0.198197 | 0.000226 | 0.002344 | 0.000030 | 0.001483 | 0.000186 | 0.000009 | 0.000003 | 99.48 | 2.593281 | 0.01231 | 96.00 | ± 0.44 | 57.5 | |
| BG2929 | 3.308E-15 | 0.560569 | 0.000469 | 0.210814 | 0.000212 | 0.002477 | 0.000027 | 0.001500 | 0.000180 | 0.000055 | 0.000004 | 97.09 | 2.581662 | 0.01281 | 95.58 | ± 0.46 | 60.4 | < 98.5% 40Ar |
| BG2931 | 3.553E-15 | 0.601924 | 0.000568 | 0.230144 | 0.000284 | 0.002794 | 0.000026 | 0.001907 | 0.000188 | 0.000006 | 0.000004 | 99.72 | 2.608160 | 0.01313 | 96.54 | ± 0.47 | 51.9 | |
| BG2932 | 2.471E-15 | 0.418739 | 0.000497 | 0.158816 | 0.000236 | 0.001889 | 0.000022 | 0.001746 | 0.000196 | 0.000015 | 0.000004 | 98.99 | 2.609934 | 0.01890 | 96.60 | ± 0.68 | 39.1 | |
| BG2934 | 2.576E-15 | 0.436471 | 0.000538 | 0.167862 | 0.000238 | 0.002053 | 0.000018 | 0.001028 | 0.000178 | 0.000007 | 0.000004 | 99.55 | 2.588466 | 0.01789 | 95.83 | ± 0.65 | 70.2 | |
| BG2935 | 3.511E-15 | 0.594817 | 0.000540 | 0.215834 | 0.000254 | 0.002616 | 0.000025 | 0.001278 | 0.000184 | 0.000016 | 0.000005 | 99.18 | 2.733345 | 0.01695 | 101.05 | ± 0.61 | 72.6 | xenocryst |
| BG2937 | 2.357E-15 | 0.399345 | 0.000473 | 0.152211 | 0.000260 | 0.001789 | 0.000025 | 0.001554 | 0.000187 | 0.000023 | 0.000004 | 98.27 | 2.578292 | 0.01978 | 95.46 | ± 0.71 | 42.1 | < 98.5% 40Ar |
| BG2938 | 2.430E-15 | 0.411701 | 0.000530 | 0.158137 | 0.000285 | 0.001904 | 0.000020 | 0.001058 | 0.000186 | 0.000022 | 0.000004 | 98.42 | 2.562437 | 0.01885 | 94.89 | ± 0.68 | 64.3 | < 98.5% 40Ar |
| BG2940 | 2.695E-15 | 0.456622 | 0.000522 | 0.176042 | 0.000231 | 0.002112 | 0.000021 | 0.001030 | 0.000179 | 0.000006 | 0.000004 | 99.61 | 2.583644 | 0.01585 | 95.65 | ± 0.57 | 73.5 | |
| BG2941 | 2.960E-15 | 0.501440 | 0.000575 | 0.192708 | 0.000218 | 0.002276 | 0.000018 | 0.001395 | 0.000170 | 0.000003 | 0.000004 | 99.85 | 2.598098 | 0.01501 | 96.18 | ± 0.54 | 59.4 | |
| BG2943 | 3.064E-15 | 0.519164 | 0.000535 | 0.198481 | 0.000251 | 0.002418 | 0.000027 | 0.001542 | 0.000197 | 0.000010 | 0.000004 | 99.44 | 2.600966 | 0.01495 | 96.28 | ± 0.54 | 55.4 | |
| BG2946 | 2.542E-15 | 0.430646 | 0.000530 | 0.164530 | 0.000226 | 0.001992 | 0.000021 | 0.001714 | 0.000188 | 0.000009 | 0.000004 | 99.40 | 2.601626 | 0.01785 | 96.30 | ± 0.64 | 41.3 | |
| BG2947 | 3.105E-15 | 0.526018 | 0.000568 | 0.201033 | 0.000225 | 0.002425 | 0.000030 | 0.001689 | 0.000208 | 0.000012 | 0.000004 | 99.35 | 2.599547 | 0.01549 | 96.23 | ± 0.56 | 51.2 | |
| Weighted mean age (41 of 53): | | | | | | | | | | | | | | 96.21 | 0.11 | analytical uncert. only | | |
| | | | | | | | | | | | | | | **96.21** | **±0.16** | analytical uncert. with J error | | |
| | | | | | | | | | | | | | | 96.21 | 0.36 | total uncertainty | | |

Data from neutron fluence montor crystals of Fish Canyon Sanidine (FCs)
Mass discrimination D/amu: 1.001 ± 0.0002 (1σ), MSWD = 0.54

| File | $^{40}Ar$ (moles) | $^{40}Ar$ (Volts) | ± 1σ$_{40}$ (Volts) | $^{39}Ar$ (Volts) | ±1σ$_{39}$ (Volts) | $^{38}Ar$ (Volts) | ± 1σ$_{38}$ (Volts) | $^{37}Ar$ (Volts) | ± 1σ$_{37}$ (Volts) | $^{36}Ar$ (Volts) | ± 1σ$_{36}$ (Volts) | %$^{40}Ar^*$ | $^{40}Ar^*/^{39}Ar_K$ ± 1σ | J | ± 2σ | K/Ca | Outliers |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BF9104 | 2.076E-14 | 3.516720 | 0.035443 | 4.506578 | 0.007733 | 0.054688 | 0.000146 | 0.047081 | 0.000361 | 0.000534 | 0.000010 | 95.55 | 0.745621 | 0.00368 | 0.0208222 | ± 0.000103 | 41.2 | |
| BF9105 | 3.523E-14 | 5.969541 | 0.065522 | 7.937673 | 0.007861 | 0.095540 | 0.000194 | 0.052232 | 0.000355 | 0.000098 | 0.000011 | 99.51 | 0.748368 | 0.00217 | 0.0207458 | ± 0.000060 | 65.3 | |
| BF9107 | 1.589E-14 | 2.692941 | 0.009360 | 3.501108 | 0.007627 | 0.042670 | 0.000133 | 0.025957 | 0.000213 | 0.000186 | 0.000009 | 97.96 | 0.753503 | 0.00470 | 0.0206044 | ± 0.000128 | 58.0 | X |
| BF9108 | 1.992E-14 | 3.374348 | 0.010170 | 4.352846 | 0.007726 | 0.053111 | 0.000156 | 0.030149 | 0.000246 | 0.000403 | 0.000011 | 96.48 | 0.747884 | 0.00388 | 0.0207592 | ± 0.000108 | 62.1 | |
| BF9110 | 3.659E-14 | 6.200087 | 0.023474 | 7.815288 | 0.007829 | 0.096371 | 0.000197 | 0.053106 | 0.000371 | 0.001171 | 0.000018 | 94.42 | 0.749049 | 0.00246 | 0.0207269 | ± 0.000068 | 63.3 | |
| BF9111 | 3.092E-14 | 5.239527 | 0.022662 | 6.879092 | 0.007779 | 0.083495 | 0.000171 | 0.052370 | 0.000376 | 0.000305 | 0.000009 | 98.29 | 0.748620 | 0.00243 | 0.0207388 | ± 0.000067 | 56.5 | |
| BF9113 | 4.077E-14 | 6.908084 | 0.031763 | 9.150692 | 0.007918 | 0.110224 | 0.000199 | 0.061748 | 0.000436 | 0.000243 | 0.000011 | 98.96 | 0.747067 | 0.00189 | 0.0207819 | ± 0.000053 | 63.7 | |
| BF9114 | 1.539E-14 | 2.607770 | 0.010494 | 3.410169 | 0.007620 | 0.041550 | 0.000130 | 0.023712 | 0.000198 | 0.000203 | 0.000012 | 97.70 | 0.747091 | 0.00500 | 0.0207813 | ± 0.000139 | 61.8 | |
| BF9116 | 3.215E-14 | 5.446513 | 0.006841 | 7.137932 | 0.007863 | 0.086544 | 0.000190 | 0.049738 | 0.000378 | 0.000388 | 0.000011 | 97.89 | 0.746976 | 0.00241 | 0.0207845 | ± 0.000067 | 61.7 | |
| BF9117 | 1.006E-14 | 1.704794 | 0.001443 | 2.201945 | 0.007545 | 0.026468 | 0.000122 | 0.028470 | 0.000207 | 0.000206 | 0.000010 | 96.49 | 0.747027 | 0.00742 | 0.0207830 | ± 0.000206 | 33.3 | |
| Weighted mean (9 of 10): | | | | | | | | | | | | | | 0.0207634 ± 0.000025 | | | | |

The values in this table represent blank, discrimination, and decay ($^{37}Ar$ and $^{39}Ar$) corrected values.

| Atmospheric argon ratios | | |
|---|---|---|
| $^{40}Ar/^{36}Ar$ | 295.5 ± 0.5 | Steiger & Jäger (1977) |
| $^{38}Ar/^{36}Ar$ | 0.1880 ± 0.0003 | Nier (1950) |

| Interfering isotope production ratios | | |
|---|---|---|
| $(^{40}Ar/^{39}Ar)_K$ | $(5.4 \pm 1.4) \times 10^{-4}$ | Jicha and Brown (2013) |
| $(^{38}Ar/^{39}Ar)_K$ | $(1.210 \pm 0.002) \times 10^{-2}$ | Jicha and Brown (2013) |
| $(^{39}Ar/^{37}Ar)_{Ca}$ | $(6.95 \pm 0.09) \times 10^{-4}$ | Renne et al. (2013) |
| $(^{38}Ar/^{37}Ar)_{Ca}$ | $(1.96 \pm 0.08) \times 10^{-5}$ | Renne et al. (2013) |
| $(^{36}Ar/^{37}Ar)_{Ca}$ | $(2.65 \pm 0.022) \times 10^{-4}$ | Renne et al. (2013) |

| Decay constants | | |
|---|---|---|
| $l_{40Ar}$ | $(0.580 \pm 0.014) \times 10^{-10}$ $a^{-1}$ | Min et al. (2000) |
| $l_B$- | $(4.884 \pm 0.099) \times 10^{-10}$ $a^{-1}$ | Min et al. (2000) |
| $^{39}Ar$ | $(2.58 \pm 0.03) \times 10^{-3}$ $a^{-1}$ | Stoenner et al. (1965) |
| $^{37}Ar$ | $(5.4300 \pm 0.0063) \times 10^{-2}$ $a^{-1}$ | Renne & Norman (2001) |
| $^{36}Cl$ $l_B$ | $(2.35 \pm 0.02) \times 10^{-6}$ $a^{-1}$ | Endt (1998) |

All lithologic, geophysical, and stable isotope data will be made available in the Pangaea database (http://www.pangaea.de/).