Supplemental material to

Geochemical indications for the Paleocene-Eocene Thermal Maximum (PETM) and Eocene Thermal Maximum 2 (ETM-2) hyperthermals in terrestrial sediments of the Canadian Arctic

by

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Supplemental Material

**Figure S1:** Comparison of most depleted δ13C values of selected records of early Eocene hyperthermals in terrestrial or terrestrial to shallow marine settings.

**Figure S2:** Age of volcanic ash layer MA-1 including graphical representation of error ranges in relation to astronomically calibrated age of the I-1 hyperthermal (all hyperthermal ages according to the current astronomical timescale of the Ypresian by Westerhold et al., 2017).

**Table S1:** Bulk coal carbon isotope data as δ13C (VPDB, ‰) of late Paleocene outcrop at eastern shore of Stenkul Fiord.

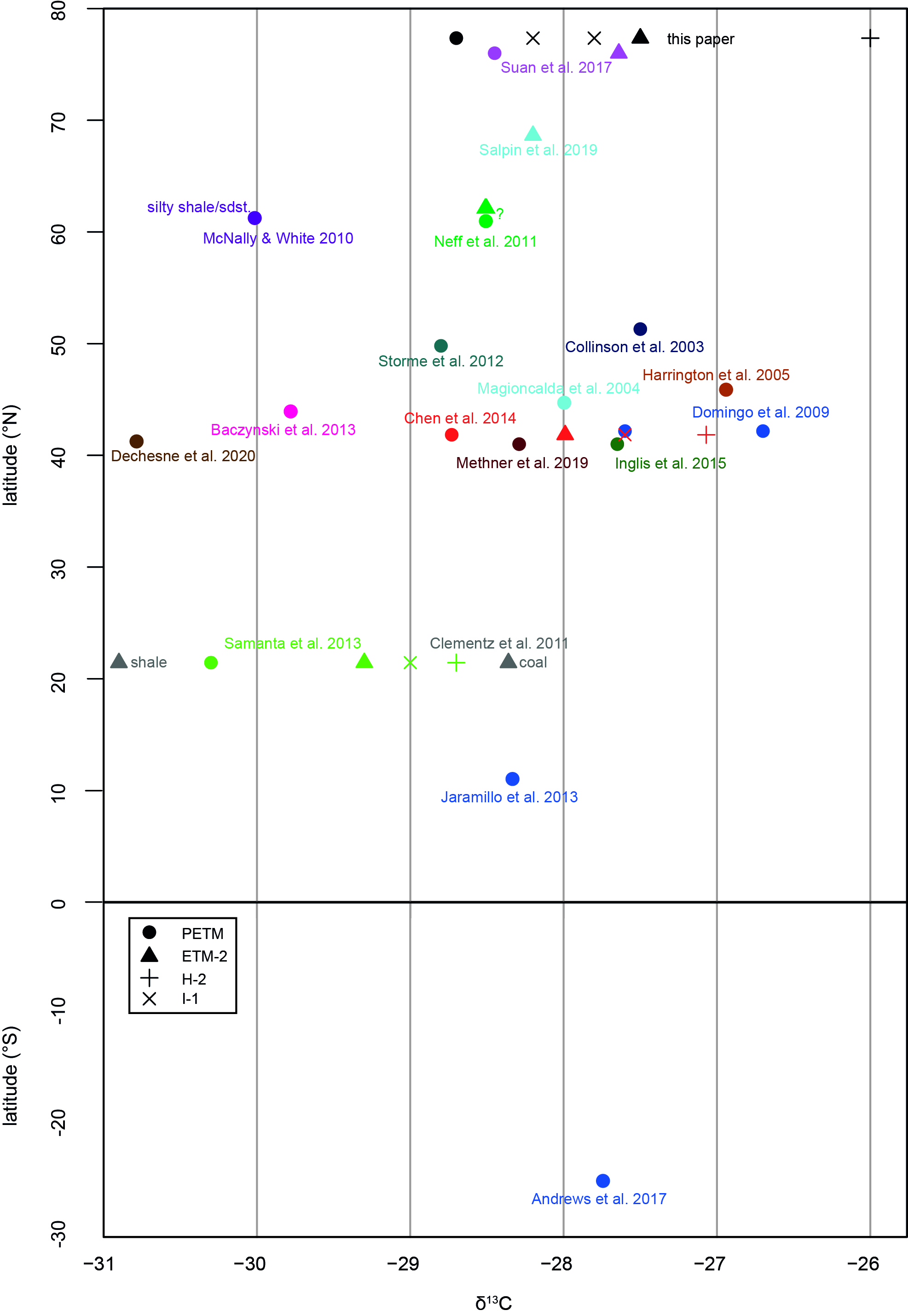
**Table S2:** Organic carbon content (Corg weight %) and bulk coal carbon isotope data as δ13C (VPDB, ‰) of the coal seam at outcrop LR17-030 with volcanic-ash layer MA-1 therein.

**Table S3:** Organic carbon content (Corg weight %), bulk carbon isotope data as δ13C (VPDB, ‰), and δ13C *n*-C31 (VPDB, in ‰) of the Stenkul Fiord section.

**Table S4:** Thicknesses of clastic intervals of the Stenkul Fiord section (except white quartz sandstone).

**Table S5:** Results of three individual U-Pb zircon analyses (ID-TIMS) from samples of volcanic ash layer MA-1.

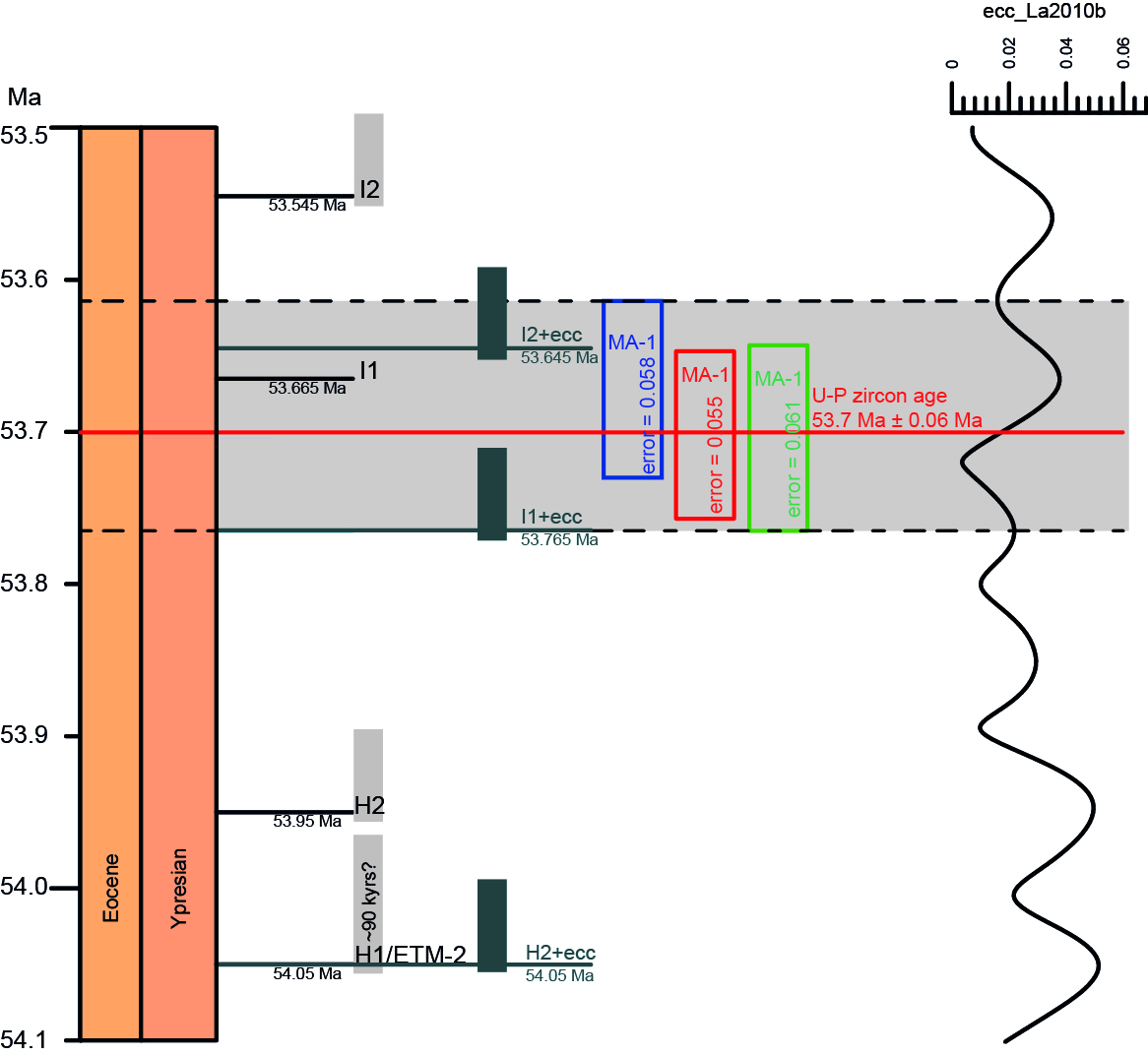
**Figure S1:**



**Figure S1:** The latitude (in degrees) is given with respect to the modern position, which in general has only slightly changed since the Paleogene. Dots indicate PETM, triangles ETM-2, crosses H-2, and x-symbols I-1 δ13C values. All values were measured in coals or organic-rich sediments, except those from Magioncalda et al. (2004), Domingo et al. (2009), McNally and White (2010), Baczynski et al. (2013), Jaramillo et al. (2013), Andrews et al. (2017), and Salpin et al. (2019), which were measured as bulk carbon from more clastic (fluvial system) deposits. The two contrasting values from Clementz et al. (2011) are from a shale and the closest coal seam in the section, respectively (eventual facies dependency is unclear). Negative carbon isotope excursion in Neff et al. (2011) likely indicates one of the larger hyperthermal events PETM/ETM-2/ETM-3 in the Chickaloon Formation. The respective hyperthermal events of the different references are color coded; see reference list at the end of supplemental file for complete citations.

All values together indicate considerable differences in their *absolute δ13C values* for individual hyperthermal events. Typically, the recorded δ13C values depend on the completeness of the respective stratigraphic record and/or sampling bias. According to Diefendorf et al. (2010) and Kohn (2010), who analyzed carbon isotope compositions of C3 plants, an increase in δ13C generally correlates with decreasing mean annual precipitation (MAP), which may explain differences between geographic areas.

**Figure S2:**



**Figure S2:** Age of volcanic ash layer MA-1 including graphical representation of error ranges (horizontal grey field with analytical error of the three samples, see table S5) in relation to astronomically calibrated age of the I-1 hyperthermal. All hyperthermal ages according to the current astronomical timescale of the Ypresian by Westerhold et al. (2017). The vertical grey boxes indicate assumed durations of ~70 kyrs for the H and I hyperthermal events and ~90 kyrs for the ETM-2 hyperthermal event, respectively.

The positions of I and H hyperthermal events are hypothetically shifted +100 kyrs (i.e., ~one eccentricity cycle, simplification / not correlated to eccentricity curve), represented by blue vertical rectangles). The scenario keeps the position of the hypothetically older I-1 hyperthermal in range of the U-Pb zircon age of 53.7 Ma ± 0.06 Ma. The hypothetically older I-1 hyperthermal touches the error limit of the zircon age. This suggests an interpretation of the negative carbon isotope excursion occurring ca. 56 cm above the ash layer MA-1 as hyperthermal I-2 to become more likely, but our preferred interpretation as hyperthermal event I-1 remains possible.

Table S1. bulk coal carbon isotope data as δ13C (VPDB, ‰) of late paleocene outcrop at eastern shore of stenkul fiord

|  |  |  |  |
| --- | --- | --- | --- |
| No. | Sample identification | Corg weight % | δ13C (VPDB) ‰ |
| 32 | LR17-043\_32 | 50.2 | -25.5 |
| 31 | LR17-043\_31 | 48.7 | -25,3 |
| 30 | LR17-043\_30 | 47.3 | -25,3 |
| 29 | LR17-043\_29 | 51.2 | -25,3 |
| 28 | LR17-043\_28 | 55.1 | -25.6 |
| 27 | LR17-043\_27 | 56.6 | -25.4 |
| 26 | LR17-043\_26 | 25.7 | -25.6 |
| 25 | LR17-043\_25 | 29.9 | -25.1 |
| 24 | LR17-043\_24 | 55.3 | -25.9 |
| 23 | LR17-043\_23 | 28.3 | -24.7 |
| 22 | LR17-043\_22 | 30.7 | -26.2 |
| 21 | LR17-043\_21 | 29.4 | -26.5 |
| 20 | LR17-043\_20 | 24.9 | -25.2 |
| 19 | LR17-043\_19 | 34.3 | -24.9 |
| 18 | LR17-043\_18 | 51.0 | -24.8 |
| 17 | LR17-043\_17 | 46.4 | -25.1 |
| 16 | LR17-043\_16 | 50.6 | -25.8 |
| 15 | LR17-043\_15 | 47.2 | -25.1 |
| 14 | LR17-043\_14 | 52.8 | -25.3 |
| 13 | LR17-043\_13 | 58.2 | -24.6 |
| 12 | LR17-043\_12 | 53.6 | -25.2 |
| 11 | LR17-043\_11 | 32.2 | -25.2 |
| 10 | LR17-043\_10 | 51.3 | -26.1 |
| 9 | LR17-043\_9 | 53.3 | -25.8 |
| 8 | LR17-043\_8 | 36.2 | -25.6 |
| 7 | LR17-043\_7 | 33.7 | -26.3 |
| 6 | LR17-043\_6 | 31.2 | -26.3 |
| 5 | LR17-043\_5 | 50.1 | -24.5 |
| 4 | LR17-043\_4 | 58.2 | -24.0 |
| 3 | LR17-043\_3 | 13.2 | -27.8 |
| 2 | LR17-043\_2 | 29.8 | -26.3 |
| 1 | LR17-043\_1 | 50.1 | -25.3 |
| *Notes:* Base of late Paleocene section is located at position LR17-043 (latitude N 77.34815, longitude W 83.44457), situated ca. 2.5 km to the east of the early Eocene section at Stenkul Fiord. Own unpublished data, from a comparable fluvial to fluvio-deltaic depositional setting. Late Paleocene age based on palynology (section CR-83-10 of Riediger, 1985; Riediger and Bustin, 1987; and Kalkreuth et al., 1996). Samples are from coals and organic-rich sediments. Mean value = -25.5 ‰ (± 0.7 ‰), median value =-25.3 ‰. The values range between -27.8 ‰ to 24.0 ‰. Subtracting 1 σ standard deviation from the average value results in a value of -26.2 ‰, used as an orientation to identify relevant early Eocene carbon isotope excursions. | | | |

Table S2. Organic carbon content (Corg, weight %) and bulk coal carbon isotope data as δ13C (VPDB, ‰) of the coal seam at outcrop LR17-030 with volcanic-ash layer MA-1 therein

|  |  |  |  |
| --- | --- | --- | --- |
| No. | sample identification | Corg weight % | δ13C (VPDB) ‰ |
| 42 | LR17\_30\_124\_127 | 48.0 | -24.2 |
| 41 | LR17\_30\_121\_124 | 49.3 | -26.5 |
| 40 | LR17\_30\_118\_121 | 44.8 | -27.0 |
| 39 | LR17\_30\_115\_118 | 48.0 | -26.5 |
| 38 | LR17\_30\_112\_115 | 31.9 | -26.3 |
| 37 | LR17\_30\_109\_112 | 29.5 | -27.0 |
| 36 | LR17\_30\_106\_109 | 33.4 | -27.1 |
| 35 | LR17\_30\_103\_106 | 36.1 | -26.3 |
| 34 | LR17\_30\_100\_103 | 16.8 | -27.1 |
| 33 | LR17\_30\_97\_100 | 16.9 | -27.4 |
| 32 | LR17\_30\_94\_97 | 13.2 | -27.2 |
| 31 | LR17\_30\_91\_94 | 50.0 | -28.2 |
| 30 | LR17\_30\_88\_91 | 26.5 | -27.0 |
| 29 | LR17\_30\_85\_88 | 38.4 | -26.4 |
| 28 | LR17\_30\_82\_85 | 29.5 | -26.7 |
| 27 | LR17\_30\_79\_82 | 27.6 | -26.5 |
| 26 | LR17\_30\_76\_79 | 2.97 | -26.9 |
| 25 | LR17\_30\_73\_76 | 5.56 | -26.3 |
| 24 | LR17\_30\_70\_73 | 48.2 | -25.7 |
| 23 | LR17\_30\_67\_70 | 44.6 | -25.8 |
| 22 | LR17\_30\_64\_67 | 42.8 | -26.1 |
| 21 | LR17\_30\_61\_64 | 46.8 | -26.0 |
| 20 | LR17\_30\_58\_61 | 41.7 | -26.6 |
| 19 | LR17\_30\_55\_58 | 45.9 | -26.6 |
| 18 | LR17\_30\_52\_55 | 47.5 | -26.5 |
| 17 | LR17\_30\_49\_52 | 48.2 | -25.9 |
| 16 | LR17\_30\_46\_49 | 52.0 | -26.0 |
| 15 | LR17\_30\_43\_46 | 51.4 | -25.3 |
| 14 | LR17\_30\_40\_43 | 42.2 | -26.0 |
| 13 | LR17\_30\_37\_40 | 54.3 | -26.0 |
| 12 | LR17\_30\_34\_37 | 47.8 | -25.7 |
| 11 | LR17\_30\_31\_34 | 53.5 | -25.3 |
| 10 | LR17\_30\_28\_31 | 50.3 | -25.8 |
| 9 | LR17\_30\_25\_28 | 48.8 | -26.0 |
| 8 | LR17\_30\_22\_25 | 50.0 | -26.3 |
| 7 | LR17\_30\_19\_22 | 41.0 | -26.8 |
| 6 | LR17\_30\_16\_19 | 37.8 | -26.0 |
| 5 | LR17\_30\_13\_16 | 36.1 | -25.7 |
| 4 | LR17\_30\_10\_13 | 55.4 | -26.9 |
| 3 | LR17\_30\_7\_10 | 54.2 | -25.1 |
| 2 | LR17\_30\_4\_7 | 54.6 | -25.1 |
| 1 | LR17\_30\_1\_4 | 55.4 | -26.0 |
| *Notes:* Volcanic ash layer MA-1 occurs between samples 11 and 12. The interval 10 cm above the volcanic ash layer comprises samples 14 to 18 (*n* = 5). See text for discussion. | | | |

Table S3. Organic carbon content (Corg, weight %), bulk carbon isotope data as δ13C (VPDB, ‰), and δ13C *n*-C31 (VPDB, ‰) of the Stenkul Fiord section

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| No. | meter in section | material if other than coal | sample identification | Corg weight % | δ 13C (VPDB) ‰ | δ13C *n*-C31  (VPDB) ‰ |
| 125 | 176.10 | plant remain | LR17-020\_12300 | 47.40 | -27.9 |  |
| 124 | 175.50 | plant remain | P16 | N.D.\* | -25.9 |  |
| 123 | 173.60 | plant remain | LR17-020\_12050 | 52.10 | -26.4 |  |
| 122 | 163.30 | plant remain | LR17-020\_11020 | 5.45 | -26.7 |  |
| 121 | 162.60 | plant remain | LR17-020\_10950 | 54.80 | -25.4 |  |
| 120 | 158.60 | plant remain | LR17-020\_10550 | 46.20 | -23.6 |  |
| 119 | 157.10 | plant remain | LR17-020\_10400 | 48.40 | -24.1 |  |
| 118 | 152.10 | plant remain | LR17-020\_9900 | 49.40 | -24.5 |  |
| 117 | 145.60 | coal particles | LR17-020\_9250 | 40.80 | -25.7 |  |
| 116 | 144.10 | plant remains | LR17-020\_9100 | N.D.\* | -22.0 |  |
| 115 | 143.10 | plant remain | LR17-020\_9000 | 49.00 | -23.5 |  |
| 114 | 142.10 | plant remain | LR17-020\_8900 | 48.80 | -22.6 |  |
| 113 | 140.60 | plant remain | LR17-020\_8750 | 48.80 | -21.5 |  |
| 112 | 138.60 | plant remain | LR17-020\_8550 | 46.30 | -22.4 |  |
| 111 | 135.60 | plant remain | LR17-020\_8250 | 48.00 | -22.7 |  |
| 110 | 135.10 |  | LR17-020\_8200 | 54.10 | -25.8 |  |
| 109 | 135.00 |  | P15 | N.D.\* | -25.6 |  |
| 108 | 134.80 |  | LR17-020\_8150 | 47.80 | -25.2 |  |
| 107 | 134.60 |  | P14 | N.D.\* | -25.1 |  |
| 106 | 134.50 |  | LR17-020\_8100 | 37.10 | -25.6 |  |
| 105 | 134.20 |  | LR17-020\_8050 | 41.40 | -25.5 |  |
| 104 | 133.90 |  | LR17-020\_8000 | N.D.\* | -23.7 |  |
| 103 | 133.60 |  | LR17-020\_7950 | 10.80 | -24.6 |  |
| 102 | 133.30 |  | LR17-020\_7900 | 44.30 | -23.9 |  |
| 101 | 133.10 |  | P13 | N.D.\* | -23.5 |  |
| 100 | 133.00 |  | P12 | N.D.\* | -23.6 |  |
| 99 | 133.00 |  | LR17-020\_7850 | 27.30 | -25.0 |  |
| 98 | 132.60 |  | LR17-020\_7800 | 19.10 | -24.1 |  |
| 97 | 132.10 |  | LR17-020\_7750 | 23.80 | -24.7 |  |
| 96 | 131.60 |  | LR17-020\_7700 | 26.80 | -26.3 |  |
| 95 | 131.10 |  | LR17-020\_7650 | 31.50 | -26.0 |  |
| 94 | 130.60 |  | LR17-020\_7600 | 47.70 | -26.4 |  |
| 93 | 130.50 |  | LR17-020\_7550 | 47.40 | -25.4 |  |
| 92 | 129.10 |  | P11 | N.D.\* | -25.5 |  |
| 91 | 122.60 |  | LR17-020\_6750 | 21.60 | -24.6 |  |
| 90 | 120.10 |  | LR17-020\_6500 | N.D.\* | -23.5 |  |
| 89 | 118.00 |  | P10 | N.D.\* | -23.5 |  |
| 88 | 117.60 |  | LR17-020\_6250 | 41.80 | -24.7 |  |
| 87 | 117.10 |  | LR17-020\_6200 | 34.90 | -24.5 |  |
| 86 | 116.60 |  | LR17-020\_6150 | 46.80 | -24.2 |  |
| 85 | 116.10 |  | LR17-020\_6100 | 46.50 | -24.4 |  |
| 84 | 113.40 |  | LR17-020\_5820 | 47.30 | -24.3 |  |
| 83 | 113.20 |  | LR17-020\_5800 | 45.70 | -26.4 |  |
| 82 | 113.00 |  | P09 | N.D.\* | -26.0 |  |
| 81 | 112.70 |  | LR17-020\_5750 | 45.30 | -25.5 |  |
| 80 | 110.20 |  | LR17-020\_5500 | 46.80 | -23.7 |  |
| 79 | 107.70 |  | LR17-020\_5250 | 47.50 | -27.8 |  |
| 78 | 107.20 |  | LR17-020\_5200 | 42.30 | -26.7 |  |
| 77 | 106.80 |  | LR17-020\_5160 | 35.50 | -26.0 | -32.2 |
| 76 | 106.60 |  | P08 | N.D.\* | -25.5 |  |
| 75 | 94.20 |  | LR17-020\_3900 | 43.00 | -22.5 |  |
| 74 | 92.70 |  | LR17-020\_3750 | 48.10 | -24.4 |  |
| 73 | 91.00 |  | LR17-020\_3600 | 47.90 | -25.5 |  |
| 72 | 90.70 |  | LR17-020\_3570 | 35.70 | -26.0 |  |
| 71 | 90.50 |  | P07 | N.D.\* | -25.6 |  |
| 70 | 86.60 |  | LR17-020\_3500 | 39.90 | -25.3 |  |
| 69 | 84.62 |  | LR17-020\_2950 | 44.10 | -27.5 |  |
| 68 | 83.50 |  | LR17-020\_2800 | 45.60 | -27.5 | -31.0 |
| 67 | 80.50 |  | LR17-020\_2500 | 39.80 | -27.1 |  |
| 66 | 80.00 |  | LR17-020\_2450 | 46.20 | -26.5 | -33.1 |
| 65 | 79.75 |  | P06 | N.D.\* | -26.2 |  |
| 64 | 78.50 |  | LR17-020\_2300 | 50.80 | -27.0 |  |
| 63 | 78.00 |  | LR17-020\_2250 | N.D.\* | -26.2 | -32.7 |
| 62 | 77.75 |  | P05 | N.D.\* | -26.3 |  |
| 61 | 77.50 |  | LR17-020\_2200 | 48.10 | -25.9 |  |
| 60 | 77.00 |  | LR17-020\_2150 | N.D.\* | -25.0 |  |
| 59 | 76.50 |  | LR17-020\_2100 | 55.00 | -25.6 |  |
| 58 | 75.70 |  | LR17-020\_2050 | 48.50 | -24.7 | -31.4 |
| 57 | 74.80 |  | LR17-020\_1960 | 45.50 | -24.8 |  |
| 56 | 74.75 |  | LR17-020\_1955 | 28.70 | -25.4 | -32,2 |
| 55 | 74.70 |  | LR17-020\_1950 | 42.50 | -25.5 |  |
| 54 | 74.20 |  | P04 | N.D.\* | -26.5 |  |
| 53 | 73.85 |  | LR17-020\_1865 | N.D.\* | -25.3 | -31.6 |
| 52 | 73.50 |  | LR17-020\_1850 | N.D.\* | -22.5 | -29.8 |
| 51 | 73.00 |  | P03 | N.D.\* | -24.7 |  |
| 50 | 72.70 |  | LR17-020\_1770 | 38.90 | -25.8 |  |
| 49 | 70.50 |  | LR17-020\_1550 | N.D.\* | -24.1 |  |
| 48 | 69.50 |  | LR17-020\_1450 | N.D.\* | -25.6 | -31.8 |
| 47 | 67.40 |  | LR17-020\_1240 | 49.60 | -25.7 |  |
| 46 | 67.00 |  | LR17-020\_1200 | 43.00 | -24.7 |  |
| 45 | 66.75 |  | LR17-020\_1175 | N.D.\* | -25.1 | -32.2 |
| 44 | 66.50 |  | LR17-020\_1150 | 34.00 | -24.9 |  |
| 43 | 65.30 |  | LR17-020\_1030 | 48.10 | -25.7 |  |
| 42 | 65.00 |  | LR17-020\_1000 | 37.80 | -24.5 | -30.7 |
| 41 | 64.80 |  | LR17-020\_980 | N.D.\* | -23.1 |  |
| 40 | 64.10 |  | P02 | N.D.\* | -23.9 |  |
| 39 | 64.00 |  | LR17-020\_900 | N.D.\* | -25.0 |  |
| 38 | 62.60 |  | LR17-020\_750 | N.D.\* | -26.6 | -30.6 |
| 37 | 60.95 |  | LR17-020\_595 | 28.20 | -25.5 |  |
| 36 | 59.10 | coal particles | LR17-020\_400 | 28.20 | -24.9 |  |
| 35 | 57.10 | coal particles | LR17-020\_200 | 35.90 | -24.3 |  |
| 34 | 56.10 | coal particles | LR17-020\_100 | 32.20 | -22.8 |  |
| 33 | 55.10 |  | LR17-020\_0 | 52.10 | -26.8 | -33.2 |
| 32 | 54.70 |  | P01 | N.D.\* | -25.5 |  |
| 31 | 54.30 |  | LR17-011\_80 | 47.50 | -25.3 |  |
| 30 | 49.30 | argillaceous sandst., dark color | LR17-011\_below | N.D.\* | -25.3 |  |
| 29 | 36.30 | argillaceous sandst., dark color | LR17-010\_above | 37.50 | -25.4 |  |
| 28 | 33.30 |  | LR17-010\_150 | 51.00 | -28.2 | -34.0 |
| 27 | 32.55 |  | LR17-010\_75 | 52.20 | -27.7 | -33.7 |
| 26 | 31.80 |  | LR17-010\_0 | N.D.\* | -27.6 |  |
| 25 | 29.55 | argillaceous sandst., dark color | LR17-009 middle | N.D.\* | -26.7 | -32.6 |
| 24 | 27.30 |  | LR17-009\_550 | 43.80 | -25.8 |  |
| 23 | 26.80 |  | LR17-009\_500 | 48.70 | -26.7 | -33.9 |
| 22 | 25.80 |  | LR17-009\_400 | 26.00 | -27.9 |  |
| 21 | 24.80 |  | LR17-009\_300 | 37.50 | -27.2 | -34.5 |
| 20 | 23.80 |  | LR17-009\_200 | 51.20 | -27.8 |  |
| 19 | 22.80 |  | LR17-009\_100 | N.D.\* | -27.5 | -32.8 |
| 18 | 21.80 |  | LR17-009\_0 | 40.00 | -28.7 |  |
| 17 | 19.55 | argillaceous sandst., dark color | LR-008 middle | 33.40 | -23.5 | -32.1 |
| 16 | 16.30 |  | LR17-008\_450 | 41.70 | -26.8 |  |
| 15 | 15.80 |  | LR17-008\_400 | 51.70 | -26.8 | -35.1 |
| 14 | 14.80 |  | LR17-008\_300 | 41.10 | -26.8 |  |
| 13 | 13.80 |  | LR17-008\_200 | 50.90 | -27.5 | -34.1 |
| 12 | 12.80 |  | LR17-008\_100 | 42.80 | -27.5 |  |
| 11 | 11.80 |  | LR17-008\_0 | 47.00 | -26.9 | -33.7 |
| 10 | 10.80 | argillaceous sandst., dark color | LR17-007 middle | N.D.\* | -27.3 |  |
| 9 | 9.55 |  | LR17-007\_525 | N.D.\* | -26.0 | -33.8 |
| 8 | 8.30 |  | LR17-007\_400 | 47.80 | -26.3 |  |
| 7 | 7.30 |  | LR17-007\_300 | 41.90 | -26.2 | -33.7 |
| 6 | 6.30 |  | LR17-007\_200 | 39.00 | -27.8 |  |
| 5 | 5.30 |  | LR17-007\_100 | 54.80 | -27.2 | -34.0 |
| 4 | 4.30 |  | LR17-007\_0 | 49.20 | -28.1 |  |
| 3 | 1.80 |  | LR17-006\_80 | 31.60 | -27.7 | -33.6 |
| 2 | 1.40 |  | LR17-006\_40 | 46.30 | -27.9 |  |
| 1 | 1.00 |  | LR17-006\_0 | 44.70 | -25.1 | -33.3 |
| *Notes:* Base of section is located at position LR17-006, cf. Table 2).  \*N.D. = not determined. | | | | | | |

Table S4: Thicknesses of clastic intervals of the stenkul fiord section (except White Quartz sandstone)

|  |  |  |  |
| --- | --- | --- | --- |
| No. | Lithology | Thickness (m) | x 0.55 |
| 35 | sandstone (inserted) | 3.00 | 1.65 |
| 34 | sandstone (inserted) | 3.00 | 1.65 |
| 33 | sandstone (inserted) | 3.00 | 1.65 |
| 32 | sandstone | 3.00 | 1.65 |
| 31 | siltstone / mudstone | 0.40 | 0.22 |
| 30 | sandstone | 1.88 | 1.03 |
| 29 | siltstone / mudstone | 0.05 | 0.03 |
| 28 | sandstone | 0.57 | 0.31 |
| 27 | siltstone / mudstone | 1.00 | 0.55 |
| 26 | siltstone / mudstone | 2.40 | 1.32 |
| 25 | sandstone | 0.50 | 0.28 |
| 24 | siltstone / mudstone | 0.20 | 0.11 |
| 23 | siltstone / mudstone | 1.50 | 0.83 |
| 22 | siltstone / mudstone | 1.00 | 0.55 |
| 21 | sandstone | 0.10 | 0.06 |
| 20 | sandstone | 0.10 | 0.06 |
| 19 | siltstone / mudstone | 0.25 | 0.14 |
| 18 | sandstone | 0.10 | 0.06 |
| 17 | siltstone / mudstone | 1.00 | 0.55 |
| 16 | sandstone | 1.50 | 0.83 |
| 15 | siltstone / mudstone | 2.00 | 1.10 |
| 14 | siltstone / mudstone | 0.50 | 0.28 |
| 13 | siltstone / mudstone | 1.50 | 0.83 |
| 12 | siltstone / mudstone | 0.65 | 0.36 |
| 11 | sandstone | 3.00 | 1.65 |
| 10 | sandstone (inserted) | 4.20 | 2.31 |
| 9 | sandstone (inserted) | 4.20 | 2.31 |
| 8 | sandstone (inserted) | 4.20 | 2.31 |
| 7 | sandstone (inserted) | 4.20 | 2.31 |
| 6 | sandstone (inserted) | 4.20 | 2.31 |
| 5 | sandstone | 4.50 | 2.48 |
| 4 | sandstone | 5.50 | 3.03 |
| 3 | sandstone | 2.25 | 1.24 |
| 2 | sandstone | 2.50 | 1.38 |
| 1 | sandstone | 1.00 | 0.55 |
| *Notes:* sandstone (inserted) indicates estimated unit thicknesses replacing undifferentiated intervals of 21 (no. 6-10) and 9 (no. 33-35) meters, respectively. Column x 0.55 indicates the correction factor of Fielding and Crane (1987) to calculate channel depth from total thickness of a clastic body. The mean value of all clastic body thicknesses is 2.4 m (including overlooked multistory units and including the undifferentiated intervals of 9 meters and 21 meters, see above). The median value of the same data set is 1 m. Including differentiated sand bodies of 9 and 21 m in artificial subunits (respective thickness oriented at the thickest measured sand bodies below the undifferentiated units), results in an average value of 1.97 m and a median of 1.5 m. Applying the correction factor of Fielding and Crane (1987) results in a mean value of 1.09 m. | | | |

Table S5: Results of Three individual U-Pb zircon analyses (ID-TIMS) From Samples of volcanic ash layer MA-1

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Sample | Wtd. mean age (Ma)  (analytical uncertainty) | n | MSWD | Probability fit |
| CASE16-P08/SF14-17 | 53.704 ± 0.061 | 4 | 0.53 | 0.6601 |
| CASE16-ASH2 | 53.702 ± 0.055 | 4 | 1.51 | 0.2093 |
| CASE12-019 | 53.672 ± 0.058 | 5 | 1.40 | 0.2325 |
| *Notes:* From von Gosen et al. (2019) for additional details of the individual ID-TIMS measurements, see there. | | | | |

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