# *Supplementary Material*



**Supplementary Figure 1.** Fraction modern (Fm) of 14C and total nitrogen to total organic carbon (TN/TOC) ratio for particulate organic carbon (POC) and streambank sediments along the ~12 km transect on the Peel Plateau. Symbols with a black stroke represent headwall (active layer, Holocene permafrost, headwall debris) and scar zone sediments and scar zone POC within retrogressive thaw slump (RTS) FM3. Ranges for biospheric POC (green shape) and petrogenic POC (black rectangle) according to Hilton et al. (2015).

**Supplementary Table 1.** Coordinates of sampling sites on the Peel Plateau, Canada.

|  |  |  |
| --- | --- | --- |
| Sampling site | Latitude | Longitude |
| Thaw slump FM3 | W135.27302 | N67.25547 |
| Thaw slump FM2 | W135.23171 | N67.25703 |
| T1 | W135.27570 | N67.25491 |
| T2 | W135.27286 | N67.25346 |
| T3 | W135.26504 | N67.25173 |
| T4 | W135.26022 | N67.25185 |
| T5 | W135.24760 | N67.25430 |
| T6 | W135.23941 | N67.25789 |
| T7 | W135.23569 | N67.25997 |
| T8 | W135.20425 | N67.27359 |
| T9 | W135.20473 | N67.27393 |
| T10 | W135.17557 | N67.29484 |
| T11 | W135.13873 | N67.32426 |
| T12a | W135.11501 | N67.32733 |
| T12b | W135.12213 | N67.32703 |
| T12c | W135.12160 | N67.32732 |
| B1 (FM2 outflow) | W135.23171 | N67.25703 |
| N1 (unimpacted stream) | W135.26022 | N67.25185 |
| N2 (unimpacted stream) | W135.20374 | N67.27362 |
| S1 (Stony Creek) | W134.98360 | N67.39076 |
| P1 (Peel River) | W134.87656 | N67.33857 |

**Supplementary Table 2.** Total suspended solids (TSS) and stable water isotopes (δ18O, δ2H) in the scar zone of retrogressive thaw slumps (RTS) FM3 and FM2, sampling site B1 and unimpacted streams N1-N2, and along the ~12 km transect (sampling sites T1-T12) on the Peel Plateau.

|  |  |  |  |
| --- | --- | --- | --- |
| Sampling site | TSS (mg L-1) | δ18O (‰) | δ2H (‰) |
| Scar zone 2, FM3 | 158 | -21.72 | -174.4 |
| T1 | 31407 | -23.95 | -195.0 |
| T2 | 11925 | -25.45 | -204.9 |
| T3 | 8617 | -21.35 | -165.7 |
| T4 | 6818 | -22.57 | -181.1 |
| T5 | 631 | -22.45 | -179.4 |
| T6 | 55.9 | -20.88 | -165.1 |
| T7 | 5385 | -20.22 | -155.8 |
| T8 | 4958 | -20.11 | -155.4 |
| T9 | 9247 | -20.07 | -154.9 |
| T10 | 4550 | -20.33 | -158.8 |
| T11 | 1757 | -20.14 | -155.3 |
| T12a | 1430 | -20.16 | -155.1 |
| T12b | 1724 | -20.1 | -154.8 |
| T12c | 902 | -20.19 | -155.2 |
| N1 | 41.2 | -20.54 | -157.4 |
| N2 | 28.6 | -19.80 | -153.5 |
| B1 | 492900 | n/a | n/a |
| Scar zone 1, FM2 | 251095 | -24.45 | -195.7 |
| Scar zone 2, FM2 | 648800 | -21.49 | -172.3 |

**Supplementary Table 3**. Total organic carbon (TOC) , δ13C, total nitrogen (TN) and molar TOC:TN ratio for active layer, headwall debris, Holocene permafrost of retrogressive thaw slump (RTS) FM3, and scar zone sediments within RTS features FM3 and FM2, and for streambank sediments along the ~12 km transect on the Peel Plateau. Sediments within RTS feature FM3 (active layer, Holocene permafrost and headwall debris) and sediment samples B1 and T1 are previously reported in Bröder et al. (2021).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Sampling site | TOC (%) | δ13C (‰) | TN (%) | TOC:TN |
| In slump FM3 | Active layer 1 | 9.21 | -26.28 | 0.63 | 14.5 |
| Active layer 2 | 3.98 | -26.23 | 0.35 | 11.4 |
| Headwall debris | 1.46 | -26.80 | 0.13 | 11.1 |
| Holocene permafrost | 1.31 | -26.40 | 0.13 | 10.0 |
| Scar zone 1 | 2.34 | -26.44 | 0.17 | 13.9 |
| Scar zone 2 | 1.84 | -28.21 | 0.15 | 12.1 |
| Scar zone 3 | 1.77 | -26.45 | 0.14 | 12.6 |
| Transect | T1 | 1.38 | -26.90 | 0.12 | 11.1 |
| T2 | 1.42 | -26.55 | 0.13 | 10.8 |
| T4 | 1.01 | -26.67 | 0.09 | 11.3 |
| T5 | 1.67 | -26.58 | 0.12 | 13.7 |
| T6 | 1.24 | -26.19 | 0.11 | 11.7 |
| T7 | 0.74 | -26.86 | 0.06 | 13.0 |
| T8 | 0.61 | -26.81 | 0.05 | 11.7 |
| T9 | 0.75 | -26.78 | 0.06 | 11.8 |
| T10 | 0.82 | -27.08 | 0.07 | 12.3 |
| T11 | 1.13 | -26.62 | 0.08 | 14.3 |
| FM2 | B1 | 1.23 | -26.47 | 0.09 | 14.2 |
| Scar zone 1 | 1.11 | -26.60 | 0.09 | 12.5 |
| Scar zone 2 | 1.16 | -26.67 | 0.09 | 12.5 |

**Supplementary Table 4.** Particulate organic carbon (POC) and dissolved organic carbon (DOC) concentrations, δ13C for POC and DOC for scar zone sediments within retrogressive thaw slumps (RTS) FM3 and FM2, transect samples, sample B1 and unimpacted streams N1-N2. Also shown are total nitrogen (TN) and molar total organic carbon (TOC) to TN ratio (TOC:TN) for suspended particulate matter (SPM).

|  |  |  |
| --- | --- | --- |
| Sampling site | SPM | DOC |
| **POC (mg L-1)** | **δ13C (‰)** | **TN (mg L-1)** | **TOC:TN** | **DOC (mg L-1)** | **δ13C (‰)** |
| Scar zone 2, FM3 | 6.27 | -26.50 | 0.52 | 12.1 | 18.16 | -25.77 |
| T1 | 570 | -26.63 | 54.3 | 10.5 | 8.68 | -26.02 |
| T2 | 249 | -26.49 | 20.9 | 12 | 13.16 | -25.99 |
| T3 | 203 | -26.50 | 16.3 | 12.5 | 13.32 | -26.16 |
| T4 | 138 | -26.35 | 11.3 | 12.2 | 14.34 | -26.15 |
| T5 | 21.3 | -26.29 | 1.49 | 14.3 | 14.78 | -25.91 |
| T6 | 1.75 | -26.43 | 0.16 | 11.2 | 12.45 | -25.46 |
| T7 | 98.3 | -26.50 | 6.35 | 15.5 | 8.97 | -27.29 |
| T8 | 111 | -26.49 | 7.67 | 14.5 | 8.80 | -27.80 |
| T9 | 182 | -26.49 | 12.7 | 14.4 | 9.70 | -27.12 |
| T10 | 81.2 | -26.60 | 5.89 | 13.8 | 11.77 | -28.04 |
| T11 | 44.3 | -26.49 | 3.20 | 13.8 | 13.57 | -28.23 |
| T12a | 34.0 | -26.49 | 2.47 | 13.8 | 10.38 | -27.83 |
| T12b | 38.9 | -26.55 | 2.77 | 14.1 | 12.65 | -27.80 |
| T12c | 20.8 | -26.38 | 1.49 | 14 | 5.13 | -27.18 |
| N1 | 1.65 | -26.37 | 0.14 | 12.2 | 14.22 | -26.36 |
| N2 | 1.00 | -26.54 | 0.09 | 11.5 | 13.59 | -27.8 |
| B1 | 8073 | -26.48 | 528 | 15.3 | 6.07 | -26.22 |
| Scar zone 1, FM2 | 3897 | -26.31 | 261 | 14.9 | 3.20 | -24.73 |
| Scar zone 2, FM2 | 8878 | -26.47 | 599 | 14.8 | 3.56 | -25.92 |

**Supplementary Table 5.** The 14C data with fraction modern (Fm), Δ14C (‰) and ETH identification codes for sediments and particulate organic carbon (POC) within retrogressive thaw slumps (RTS) FM3 and FM2, and along the ~12 km transect on the Peel Plateau. The sediment samples within RTS feature FM3 (active layer, Holocene permafrost and headwall debris) and sediment samples B1 and T1 are previously reported in Bröder et al. (2021).

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | POC | Sediment OC |
|  | **Sampling site** | **ETH code** | **Fm** | **Error (%)** | **Δ14C (‰)** | **ETH code** | **Fm** | **Error (%)** | **Δ14C (‰)** |
| In slump FM2 | Scar zone 1 | 85552.1.1 | 0.04 | 3.79 | -959 | n/a | n/a | n/a | n/a |
| Scar zone 2 | 87968.1.1 | 0.08 | 2.57 | -919 | 85540.1.1 | 0.10 | 2.34 | -900 |
| B1 | 87967.1.1 | 0.17 | 1.81 | -835 | 85530.1.1 | 0.15 | 1.94 | -846 |
| In slump FM3 | Active layer 1 | n/a | n/a | n/a | n/a | 92483.1.1 | 0.36 | 1.32 | -640 |
| Active layer 2 | n/a | n/a | n/a | n/a | 85600.1.1 | 0.29 | 1.37 | -711 |
| Headwall debris | n/a | n/a | n/a | n/a | 85596.1.1 | 0.04 | 3.42 | -958 |
| Permafrost | n/a | n/a | n/a | n/a | 87970.1.1 | 0.03 | 4.71 | -974 |
| Scar zone 1 | n/a | n/a | n/a | n/a | 85546.1.1 | 0.24 | 1.56 | -758 |
| Scar zone 2 | 86949.1.1 | 0.42 | 3.83 | -579 | 85557.1.1 | 0.12 | 2.18 | -882 |
| Scar zone 3 | n/a | n/a | n/a | n/a | 85571.1.1 | 0.19 | 1.74 | -814 |
| Transect | T1 | 86955.1.1 | n/a | n/a | n/a | 85542.1.1 | 0.05 | 3.26 | -948 |
| T2 | 86956.1.1 | 0.07 | 29.1 | -934 | 85531.1.1 | 0.10 | 2.49 | -903 |
| T3 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| T4 | 86958.1.1 | 0.05 | 40 | -952 | 85534.1.1 | 0.13 | 2.10 | -874 |
| T5 | 86959.1.1 | 0.15 | 13.2 | -856 | 85536.1.1 | 0.18 | 1.73 | -823 |
| T6 | 86960.1.1 | 0.30 | 6.66 | -699 | 85535.1.1 | 0.12 | 2.07 | -881 |
| T7 | 86954.1.1 | 0.07 | 30.4 | -934 | 85567.1.1 | 0.07 | 2.88 | -935 |
| T8 | 86952.1.1 | 0.11 | 17.7 | -894 | 85566.1.1 | 0.16 | 1.87 | -845 |
| T9 | 86953.1.1 | 0.11 | 17.6 | -893 | 85565.1.1 | 0.14 | 2.01 | -858 |
| T10 | 86951.1.1 | 0.10 | 18.9 | -903 | 85556.1.1 | 0.18 | 1.76 | -820 |
| T11 | 86950.1.1 | 0.14 | 13.7 | -866 | 85549.1.1 | 0.26 | 1.51 | -747 |
| T12a | 86965.1.1 | 0.17 | 10.3 | -828 | n/a | n/a | n/a | n/a |
| T12b | 86966.1.1 | 0.20 | 9.2 | -806 | n/a | n/a | n/a | n/a |
| T12c | 86964.1.1 | 0.16 | 11.4 | -839 | n/a | n/a | n/a | n/a |
|  | N1 | 86944.1.1 | 0.32 | 15.1 | -680 | n/a | n/a | n/a | n/a |
| N2 | 86941.1.1 | 0.51 | 4.15 | -495 | n/a | n/a | n/a | n/a |
| S1 | 86967.1.1 | 0.19 | 18.2 | -810 | 85550.1.1 | 0.58 | 1.07 | -429 |
| P1\* | 86963.1.1 | 0.26 | 6.46 | -740 | 54637.1.1 | n/a | n/a | -810 |
| \*Sediment data from Vonk et al. (2015). |  |  |  |

**Supplementary Table 6.** Data from pyrolysis-gas chromatography-mass spectrometry. The results are given as relative amounts of the compound group to all identified compound groups in each sample, not as absolute amounts. The targeted compound groups shown are aromatics (toluene, ethylbenzene, naphthalene), phenols (phenol, 2-methylphenol, 3-methylphenol and 4-methylpehenol), lignin markers (guaiacol, creosol and 4-ethylguaiacol), nitrogen (N) - containing compounds (pyridine, 2-methylpyridine and benzonitrile), polysaccharides (3-furaldehyde, furfural, 5-methylfurfural) and alkanes (carbon chain lengths C9-14). The sediments within retrogressive thaw slump (RTS) FM3 active layer, Holocene permafrost and headwall debris) and streambank sediment sample T1 are previously reported in Bröder et al. (2021).

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Sampling site** | **Aromatics (%)** | **Polysaccharides (%)** | **Lignin (%)** | **Phenols (%)** | **N containing compounds (%)** | **Alkanes (%)** |
| **Sediment** | Active layer 1 | 42.8 | 19.2 | 1.4 | 22.7 | 9.1 | 4.9 |
| Active layer 2 | 35.0 | 9.0 | 6.0 | 35.0 | 7.3 | 7.6 |
| Holocene permafrost | 67.3 | 0.2 | 0 | 17.3 | 3.7 | 11.6 |
| Headwall debris | 79.6 | 0 | 0 | 6.6 | 3.7 | 10.1 |
| Scar zone 1 | 66.8 | 1.4 | 0 | 19.5 | 3.7 | 8.5 |
| Scar zone 2 | 65.9 | 0.9 | 0 | 16.5 | 10.8 | 5.8 |
| Scar zone 3 | 63.1 | 1.5 | 0 | 21.5 | 8.2 | 5.7 |
| T1 | 68.7 | 0 | 0 | 19.1 | 4.2 | 8.0 |
| T2 | 71.8 | 0.6 | 0 | 10.0 | 9.6 | 8.0 |
| T4 | 80.0 | 0.3 | 0 | 2.7 | 6.9 | 10.1 |
| T5 | 51.3 | 0 | 0 | 36.8 | 4.4 | 7.3 |
| T6 | 80.3 | 0.4 | 0 | 6.6 | 3.8 | 9.0 |
| T7 | 87.1 | 0 | 0 | 0 | 0 | 12.9 |
| T9 | 88.1 | 0 | 0 | 0 | 0 | 12.0 |
| T10 | 77.5 | 0.8 | 0 | 6.0 | 5.5 | 10.1 |
| T11 | 73.1 | 0 | 0 | 8.9 | 7.5 | 10.6 |
| Stony creek | 47.5 | 2.8 | 2.0 | 38.9 | 5.4 | 3.5 |
| Peel fresh bank\* | 81.3 | 0 | 0 | 2.0 | 5.0 | 11.7 |
| Peel upper bank\* | 72.0 | 0 | 0 | 12.5 | 6.7 | 9.6 |
| **POC** | T1 | 57.6 | 0.2 | 0 | 28.8 | 6.8 | 6.6 |
| T3 | 64.1 | 0.7 | 0 | 19.1 | 7.5 | 8.7 |
| T5 | 60.5 | 0.7 | 0 | 20.1 | 13.1 | 5.6 |
| T7 | 78.7 | 0 | 0 | 15.4 | 1.8 | 4.1 |
| T9 | 73.5 | 1.3 | 0 | 9.7 | 2.4 | 13.1 |
| T10 | 75.9 | 0 | 0 | 8.7 | 1.9 | 13.6 |
| T12a | 68.5 | 2.1 | 0 | 17.0 | 3.8 | 8.7 |
| T12c | 69.6 | 2.2 | 0 | 17.4 | 2.4 | 8.4 |
| Stony creek | 61.0 | 1.1 | 0 | 21.3 | 8.2 | 8.3 |

\*Sediments sampled in 2011 by J. Vonk (data not published before).

**Supplementary Table 7**. Lipid biomarker (*n*-alkane and *n*-alkanoic acid) concentrations (ug g-1 OC and ug m-2) for high molecular weight (HMW, carbon chain lengths C27-33 for *n*-alkanes and C24-32 for *n*-alkanoic acids) and low molecular weight (LMW, carbon chain lengths C17-19 for *n*-alkanes and C16-18 for *n*-alkanoic acids), Carbon preference index\* (CPI) for sediments within retrogressive thaw slump (RTS) FM3 (active layer, Holocene permafrost, headwall debris and scar zone) and along the ~12 km transect on the Peel Plateau. The sediments within RTS feature FM3 (active layer, Holocene permafrost and headwall debris) and sediment samples B1 and T1 are same samples as those reported in Bröder et al. (2021), but were extracted separately for this manuscript.

|  |  |  |  |
| --- | --- | --- | --- |
|  | Sediment | *n*-alkanes | *n*-alkanoic acids |
| **Sampling site** | **HMWC27-33**ug g-1 OC | **LMWC17-19**ug g-1 OC | **HMWC27-33**ug m-2 | **LMWC17-19**ug m-2 | **CPI** | **HMWC24-32**ug g-1 OC | **LMWC16-18**ug g-1 OC | **HMWC24-32**ug m-2 | **LMWC16-18**ug m-2 | **CPI\*** |
| In slump FM3 | Active layer 1 | 246 | 10.32 | 0.47 | 0.02 | 7.56 | 3491 | 1273 | 6.62 | 2.41 | 5.66 |
| Active layer 2 | 362 | 10.74 | 0.31 | 0.01 | 6.10 | 5504 | 2349 | 4.71 | 2.01 | 4.73 |
| Holocene permafrost | 94.4 | 19.34 | 0.06 | 0.01 | 8.05 | 628 | 192 | 0.43 | 0.13 | 5.74 |
| Headwall debris | 2041 | 357 | 1.12 | 0.20 | 4.14 | 461 | 157 | 0.25 | 0.09 | 5.36 |
| Scar zone 1 | 396 | 39.6 | 0.58 | 0.06 | 6.53 | 1343 | 677 | 1.96 | 0.98 | 5.06 |
| Scar zone 2 | 384 | 46.8 | 0.23 | 0.03 | 6.07 | 842 | 627 | 1.50 | 0.92 | 5.39 |
| Transect | T1 | 118 | 40.6 | 0.06 | 0.02 | 5.26 | 276 | 476 | 0.15 | 0.25 | 5.98 |
| T2 | 104 | 30.9 | 0.06 | 0.02 | 5.10 | 380 | 505 | 0.20 | 0.27 | 4.57 |
| T4 | 152 | 25.6 | 0.09 | 0.01 | 4.47 | 77.2 | 179 | 0.04 | 0.10 | 4.00 |
| T5 | 132 | 24.2 | 0.11 | 0.02 | 6.82 | 24.2 | 33.2 | 0.02 | 0.03 | 5.05 |
| T6 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| T7 | 123 | 64.4 | 0.11 | 0.06 | 2.11 | 236 | 212 | 0.21 | 0.19 | 5.20 |
| T8 | 203 | 152 | 0.11 | 0.08 | 1.83 | 23.1 | 173 | 0.01 | 0.09 | 2.97 |
| T9 | 104 | 92.5 | 0.05 | 0.04 | 1.84 | 81.8 | 105 | 0.04 | 0.05 | 4.31 |
| T10 | 169 | 95.9 | 0.12 | 0.07 | 2.67 | 136 | 221 | 0.09 | 0.15 | 4.31 |
| T11 | 154 | 46.3 | 0.14 | 0.04 | 3.32 | 465 | 525 | 0.41 | 0.46 | 4.63 |

 \*CPI is defined as $\frac{1}{2}\sum\_{}^{}(X\_{i}+X\_{i+2}+..+X\_{n})/\sum\_{}^{}(X\_{i-1}+X\_{i+1}+..+X\_{n-1})+\frac{1}{2}\sum\_{}^{}(X\_{i}+X\_{i+2}+..+X\_{n})/\sum\_{}^{}(X\_{i+1}+X\_{i+3}+..+X\_{n+1})$, where X is concentration.

**Supplementary Table 8.** Lipid biomarker (*n*-alkane and *n*-alkanoic acid) concentrations (ug g-1 OC and ug m-2) for high molecular weight (HMW, carbon chain lengths C27-33 for *n*-alkanes and C24-32 for *n*-alkanoic acids) and low molecular weight (LMW, carbon chain lengths C17-19 for *n*-alkanes and C16-18 for *n*-alkanoic acids), Carbon preference index\* (CPI) for particulate organic carbon (POC) along the ~12 km transect on the Peel Plateau.

|  |  |  |
| --- | --- | --- |
| POC | *n*-alkanes | *n*-alkanoic acids |
| Sampling site | **HMWC27-33**µg g-1 OC | **LMWC17-19**µg g-1 OC | **HMWC27-33**µg m-2 | **LMWC17-19**µg m-2 | **CPI** | **HMWC24-32**µg g-1 OC | **LMWC16-18**µg g-1 OC | **HMWC24-32**µg m-2 | **LMWC16-18**µg m-2 | **CPI\*** |
| T1 | 57.3 | 21.9 | 0.05 | 0.02 | 4.30 | 375 | 330 | 0.35 | 0.31 | 4.61 |
| T2 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| T3 | 173 | 32.3 | 0.11 | 0.02 | 6.52 | 1133 | 1078 | 0.75 | 0.71 | 5.80 |
| T4 | 190 | 43.5 | 0.11 | 0.02 | 6.21 | 319 | 1065 | 0.18 | 0.60 | 5.73 |
| T5 | 131 | 62.3 | n/a | n/a | 3.48 | 88.2 | 722 | n/a | n/a | 3.57 |
| T6 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| T7 | 133 | 41.9 | n/a | n/a | 3.56 | 149 | 323 | n/a | n/a | 5.14 |
| T8 | 346 | 78.8 | 0.35 | 0.08 | 4.19 | 326 | 755 | 0.33 | 0.77 | 5.39 |
| T9 | 121 | 28.7 | n/a | n/a | 4.54 | 449 | 493 | n/a | n/a | 4.52 |
| T10 | 234 | 45.8 | 0.19 | 0.04 | 6.59 | 273 | 810 | 0.22 | 0.66 | 4.16 |
| T11 | 207 | 38.0 | 0.18 | 0.03 | 5.29 | 182 | 578 | 0.16 | 0.51 | 4.32 |
| T12 | 182 | 28.4 | n/a | n/a | 8.48 | 812 | 1448 | n/a | n/a | 4.55 |

 \*CPI is defined as $\frac{1}{2}\sum\_{}^{}(X\_{i}+X\_{i+2}+..+X\_{n})/\sum\_{}^{}(X\_{i-1}+X\_{i+1}+..+X\_{n-1})+\frac{1}{2}\sum\_{}^{}(X\_{i}+X\_{i+2}+..+X\_{n})/\sum\_{}^{}(X\_{i+1}+X\_{i+3}+..+X\_{n+1}) $, where X is concentration.

**References**

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