**Supplementary Information for**

**Incubation experiments characterize turbid glacier plumes as a major source of Mn and Co, and a minor source of Fe and Si, to seawater**

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**Table S1. Analysis results of certified reference materials**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **CRMs** |  | **dFe** | **dMn** | **dCo** |
|  | **unit: nM** | | |
| GSC112 | certified | 1.54±0.115 | 2.18±0.075 | n/a |
| measured | 1.49±0.063 (n=13) | 2.18±0.057 (n=14) | 0.099±0.004 (n=14) |
| NASS-7 | certified | 6.28±0.466 | 13.6±1.092 | 0.248±0.024 |
| measured | 5.97±0.298 (n=15) | 14.0±0.689 (n=15) | 0.246±0.006 (n=15) |
| CASS-6 | certified | 27.4±2.15 | 39.7±2.18 | 1.12±0.088 |
| measured | 25.8±0.695 (n=16) | 37.8±0.976 (n=16) | 1.08±0.029 (n=16) |
| SLEW-3 | certified | 10.2±1.06 | 29.3±4.00 | 0.713±0.170 |
| measured | 10.7±0.309 (n=8) | 31.2±0.600 (n=9) | 0.799±0.014 (n=9) |
|  |  | **LPFea** | **LPMnb** | **LPCob** |
|  |  | **unit: a, mg/g dry sediment; b, μg/g dry sediment** | | |
| BCR-414 | certified | n/a | n/a | n/a |
| measured | 0.251±0.010 (n=5) | 246±3.95 (n=5) | 0.666±0.010 (n=5) |
| PACS-3 | certified | n/a | n/a | n/a |
| measured | 3.94±0.081 (n=6) | 26.0±1.20 (n=6) | 1.51±0.367 (n=6) |

Note: dFe, dissolved Fe; LPFe, labile particulate Fe; n/a, not applicable; n, number of analyses.

**Table S2. Compilation of literature reported fractional solubilities and fluxes of metals released from other particle sources (e.g. aerosol and volcanic ash) in seawater**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Types** | **Solubility definition** | **Fe** | **Mn** | **Co** | **Si** | **References** |
| Aerosol | Fractional solubility, leaching in seawater for 10 min, 15.3-42 mg/L, % soluble | 0.066±0.039 | 28±12 | 17±10 | n/d | Mackey et al., 2015 |
| Aerosol | Fractional solubility, leaching in seawater for 7 days, 15.3-42 mg/L, % soluble | 0.044±0.022 | 38±15 | 17±7 | n/d | Mackey et al., 2015 |
| Aerosol | Fractional solubility, leaching in seawater, % soluble | n/d | 50-104 | 29-58 | n/d | Fishwick et al., 2018 |
| Biogenic-Silicate-rich sediment collected at 150 m depth | Overall solubility of initial particulate stocks over incubation of 423 days in seawater at a sediment load of ~5 mg/L, % soluble | 0.40±0.04 | +1.06±0.42a | n/d | 9.23±0.20 | Cheize et al., 2019 |
| Calcite-rich sediment collected at 530 m depth | Overall solubility of initial particulate stocks over incubation of 423 days in seawater at a sediment load of ~5 mg/L, % soluble | 0.11±0.01 | 30.0±2.9 | n/d | 8.30±0.64 | Cheize et al., 2019 |
| Calcite-rich sediment collected at 530 m depth | Overall solubility of initial particulate stocks over incubation of 423 days in seawater at a sediment load of ~5 mg/L, % soluble | 0.11±0.01 | 30.0±2.9 | n/d | 8.30±0.64 | Cheize et al., 2019 |
| Volcano Hekla, 2000 | Initial dissolution flux in seawater, 5 g ash in a plug flow-through reactor, nmol/g/hour | 37000 | 1700 | n/d | n/d | Frogner et al., 2001 |
| Volcano Galeras, 2005 | Fluxes of metals released, 5 g ash in a plug flow-through reactor, leaching in seawater for 8 h, nmol/g | 30 | 645 | 18 | n/d | Jones and Gislason, 2008 |
| Volcano Montserrat, 2003 | 60 | 535 | 4 | n/d |
| Volcano Hekla, 2000 | 8005 | 820 | 5.5 | n/d |
| Volcano Santiaguito, 1998 | 30 | 50 | 0.5 | n/d |
| Volcano Arenal, 1993 | Fluxes of metals released, leaching in seawater for 15 min, 2.67 g/L, nmol/g | 2.1 | 17.4 | 0.1 | n/d | Hoffmann et al., 2012 |
| Volcano Popocatepetl, 2000 | 7 | 29.5 | 0.4 | n/d |
| Volcano Rabaul-Tavurvur, 2002 | 5.7 | 69.5 | 1 | n/d |
| Volcano Sakura-jima, 2007 | 83.2 | 1299 | 33 | n/d |
| Volcano Calbuco, 2015 | Fluxes of metals released, leaching in seawater for 10 min, nmol/g | 53-1200 | 47-68 | 0.7-17 | n/d | Vergara-Jara et al., 2021 |
| Biogenic-Silicate-rich sediment collected at 150 m depth | Mean dissolution rate over incubation of 423 days at a sediment load of ~5 mg/L, pmol/L/d for Fe and Mn and nmol/L/d for Si | 7.77±0.61 | -0.40±0.18a | n/d | 11.62±2.75 | Cheize et al., 2019 |
| Biogenic-Silicate-rich sediment collected at 150 m depth | Overall solubility of initial particulate stocks over incubation of 423 days at a sediment load of ~5 mg/L, % | 0.40±0.04 | +1.06±0.42a | n/d | 9.23±0.20 | Cheize et al., 2019 |
| Calcite-rich sediment collected at 530 m depth | Mean dissolution rate over incubation of 423 days at a sediment load of ~5 mg/L, pmol/L/d for Fe and Mn and nmol/L/d for Si | 1.74±0.18 | 17.0±3.23 | n/d | 6.26±1.28 | Cheize et al., 2019 |
| Calcite-rich sediment collected at 530 m depth | Overall solubility of initial particulate stocks over incubation of 423 days at a sediment load of ~5 mg/L, % | 0.11±0.01 | 30.0±2.9 | n/d | 8.30±0.64 | Cheize et al., 2019 |
| Basalt collected at 3350 m depth | Mean dissolution rate over incubation of 423 days at a sediment load of ~5 mg/L, pmol/L/d for Fe and Mn and nmol/L/d for Si | 2.57±0.16 | 0.09±0.19 | n/d | 0.33±0.11 | Cheize et al., 2019 |
| Basalt collected at 3350 m depth | Overall solubility of initial particulate stocks over incubation of 423 days at a sediment load of ~5 mg/L, % | 0.015±0.001 | 0.28±0.10 | n/d | 0.33±0.04 | Cheize et al., 2019 |
| Glacier/Iceberg/Fjord sediment | Fractional solubility\*, leaching in seawater for 24 h, 20-500 mg/L, % soluble | 0.040-0.46 | 0.31-13.7 | 1.84-9.23 | n/d | This study |
| Initial release flux#, 20-500 mg/L, nmol/g | 0.73-70.6 (24.4, 18.6) | 1.50-174 (52.7, 13.7) | 0.06-2.40 (0.84, 0.65) | n/d |
| Fluxes of metals released§, leaching in seawater for 24 h, 20-500 mg/L, nmol/g | 4.90-107 | 6.46-203 | 0.37-4.20 | n/d |
| Fluxes of Si released, leaching in seawater for 24 h, 20-500 mg/L, nmol/L/d |  |  |  | -0.52-2.34 |  |

Note: a A decrease of dissolved Mn in seawater and an enrichment of particulate Mn on particles over the incubation course. n/d no data.

\* Fractional solubility herein refers to the ratio of seawater soluble metals content to labile particulate metals content (Table 2 in the main text), as the total particulate metal content was not determined in this study.

# The numbers are ranked as range (average, median).

§ Data units were converted to nmol/g to facilitate comparison within the table. Refer to Table 2 in the main text for details.



Figure S1. Sediment-seawater incubation experiment conducted under light and dark conditions. Bottles were shaken thoroughly every several hours and positions changed randomly to avoid possible differences in light intensity within the chamber.



Figure S2. Measured concentrations of dissolved Fe, Mn, Co and Si in seawater over 24 hours incubation at varying sediment loads(Experiment SSIE1). Data of light and dark treatments are shown with hollow and solid symbols, respectively. Note the differences in the scale and unit of Y axes.



Figure S3. The change in observed concentrations of dissolved Fe, Mn, Co and Si relative to control groups in seawater over 24 hours incubation at varying sediment loads(Experiment SSIE1). Boxes show the upper and lower quartiles of each group, the horizontal line denotes the median and the square inside the box denotes the mean. Whiskers and crosses at the ends of each box show the minimum, maximum, 1st and 99th percentiles of each dataset. Dots overlapped with boxes show the data. Note the differences in the scale and unit of Y axes.



Figure S4. Release flux of Fe, Mn, Co and Si in seawater over 24 hours incubation at varying sediment loads(Experiment SSIE1). Data of light and dark treatments are shown with hollow and solid symbols, respectively. Note the differences in the scale and unit of Y axes.



Figure S5. Measured concentrations of dissolved Fe, Mn, Co and Si in the control groups over up to 21 days incubation (Experiment SSIE2). Note the differences in the scale and unit of Y axes.



Figure S6. The change in observed concentrations of dissolved Fe, Mn, Co and Si relative to control groups in seawater over up to 21 days incubation (Experiment SSIE2). The data were grouped by sampling timepoint, sample label, sediment loads (low: ca. 50 mg/L, high: ca. 200 mg/L) or light conditions. Boxes show the upper and lower quartiles of each group, with the horizontal line showing the median and the square inside the box showing the mean. The whiskers and crosses at the ends of each box show the minimum, maximum, 1st and 99th percentiles of each dataset. Dots overlapped with boxes show the data. Note the differences in the scale and unit of Y axes.



Figure S7. Measured concentrations of dissolved Fe, Mn, Co and Si in the control groups over 8 days incubation (Experiment SSIE3). Note the differences in the scale and unit of Y axes.



Figure S8. The change in observed concentrations of dissolved Fe, Mn, Co and Si relative to control groups in seawater over 8 days incubation (Experiment SSIE3). Boxes show the upper and lower quartiles of each group, with the horizontal line showing the median and the square inside the box showing the mean. The whiskers and crosses at the ends of each box show the minimum, maximum, 1st and 99th percentiles of each dataset. Dots overlapped with boxes show the data. Note the differences in the scale and unit of Y axes.



Figure S9. Prior estimates of the dissolved Fe, Mn, Co and Si flux around Greenland reported to date are compared to the fluxes expected to be released from suspended particles based on work herein. Values taken from Hawkings et al., 2017, 2020, Krause et al., 2021, and Krisch et al., 2022. n/d no data. Note the log scale on the y axes.

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