

Motivation

The iron (Fe) limited Southern Ocean accounts for **20 % of the global annual phytoplankton production**^[1]. **Phytoplankton blooms** occur downstream (north) of **South Georgia** and there is limited knowledge of the **Fe sources** (e.g., benthic Fe fluxes, meltwater,...) that fuel these blooms. **Stable iron isotopes** ($\delta^{56}\text{Fe}$) in the sediments as well as the water column are a useful tool for identifying and **tracing Fe sources and reaction pathways**.

Aim of the study

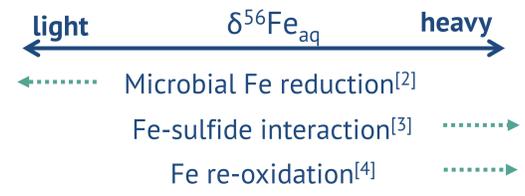
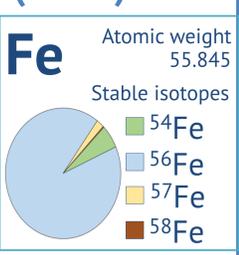
- Assess whether benthic Fe fluxes, potentially most relevant source, can be traced based on **pore-water Fe isotope** ($\delta^{56}\text{Fe}_{\text{aq}}$) values.
- Examine the **seawater $\delta^{56}\text{Fe}_{\text{aq}}$** signal across ice-proximal to ice-distal sites to constrain the sources of Fe.

Material and Methods

Seawater sampling: Trace metal Clean CTD (Conductivity, Temperature, Depth): 18 water samples
Parameters: dissolved Fe (dFe), seawater $\delta^{56}\text{Fe}_{\text{aq}}$ values, nutrients, ...
Sediment sampling: 5 MUC (multiple corer) cores and 2 handheld gravity cores
Parameters: Total organic carbon (TOC), ^{210}Pb age model, pore-water $\delta^{56}\text{Fe}_{\text{aq}}$ values, nutrients, ...

Stable Fe Isotopes ($\delta^{56}\text{Fe}$)

- Redox processes cause fractionation of $\delta^{56}\text{Fe}$, which is reflected in the resulting $\delta^{56}\text{Fe}$ values.
- Seawater $\delta^{56}\text{Fe}_{\text{aq}}$ can be used to trace Fe sources in the water column.
- Variations in pore-water $\delta^{56}\text{Fe}_{\text{aq}}$ arise from the fractionation of dissolved $\delta^{56}\text{Fe}$ by a variety of processes:



Sediment:

- Flux weighted average benthic $\delta^{56}\text{Fe}_{\text{aq}}$ signature: -2.05 ± 1.04 ‰.
- Low benthic Fe fluxes in our study area are a consequence of **processes** that fractionate into **different directions**: (1) sluggish **microbial Fe reduction**, (2) **interaction** between dissolved Fe and hydrogen sulfide and (3) **re-oxidation** of dissolved Fe.

Seawater:

- Lower seawater dFe conc. in Cumberland Bay (~6 nM) compared to King Haakon Bay (Fig. 1).
- Close to glacier: light seawater $\delta^{56}\text{Fe}_{\text{aq}}$ signature possibly a subglacial meltwater signal (salinity ~27 psu) → brownish meltwater.
- Heavier $\delta^{56}\text{Fe}_{\text{aq}}$ signatures of -0.19 ‰ (close to crustal signature ~ 0 ‰) probably due to lithogenic input → low primary productivity as a result of higher turbidity.

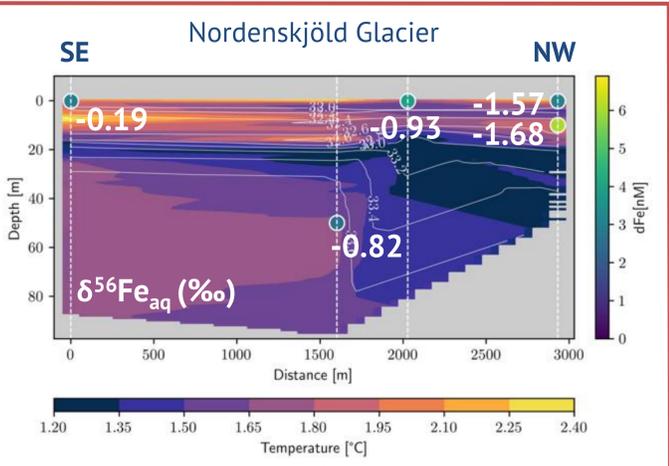
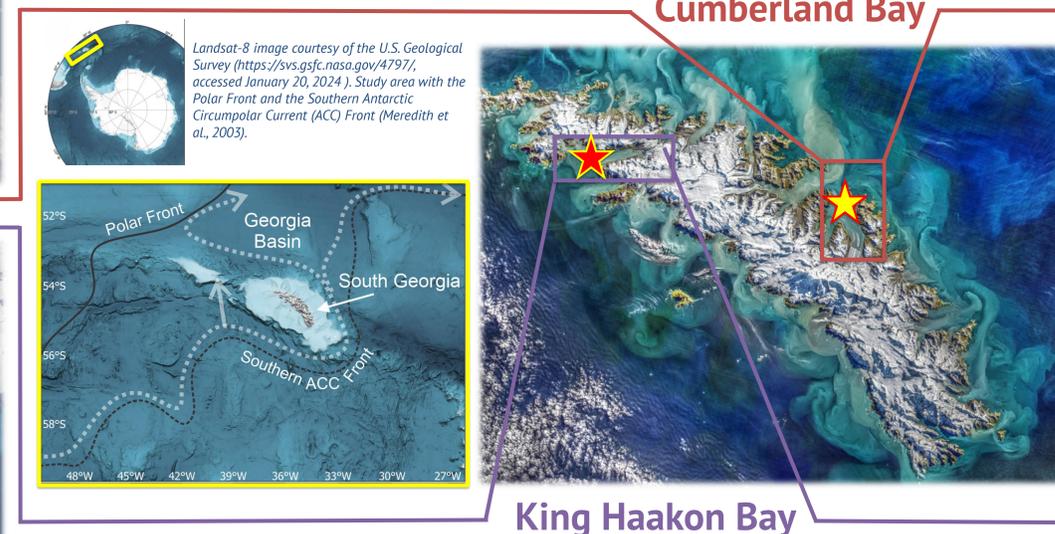
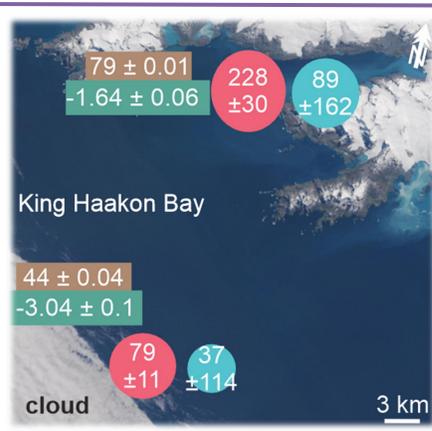


Fig. 1. Water column temperature (°C) and dFe conc. (nM) across Nordenskjöld Glacier in Cumberland Bay (distance to glacier 0.5 km) showing seawater $\delta^{56}\text{Fe}_{\text{aq}}$ values. Samples and handheld CTD were obtained during zodiac trips.



Sediment:

- Flux weighted average benthic $\delta^{56}\text{Fe}$ signature: -2.96 ± 0.21 ‰.
- Generally higher benthic Fe fluxes accompanied by high organic carbon accumulation rates (MAR_{TOC}) (Fig. 3).

Seawater:

- Generally higher dFe conc. in KHB up to 12 nM.
- A relatively heavy surface $\delta^{56}\text{Fe}$ (-0.16 ‰) coincides with high chlorophyll conc. ($2.29 \mu\text{g/L}$) and primary production ($55 \text{ mgCm}^{-3} \text{ d}^{-1}$)^[5], consistent with preferential biological uptake of lighter Fe isotopes.
- Clean CTD station at ice-distal site: light $\delta^{56}\text{Fe}$ values ranging from -1.3 to -1 ‰ indicates benthic input from reducing sediments. In line with higher benthic Fe fluxes.

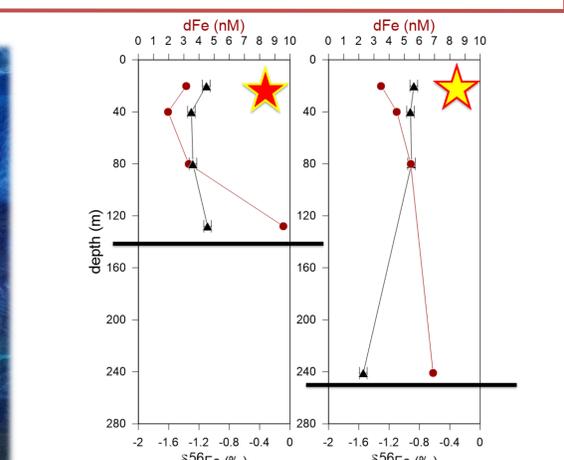
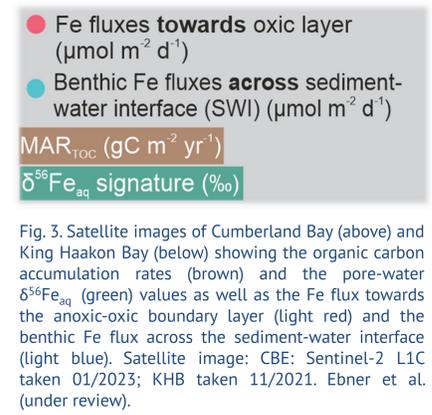


Fig. 2. Clean-CTD depth profiles: showing the dissolved Fe concentration (filtered < 0.45 μm) and the corresponding seawater $\delta^{56}\text{Fe}$ signatures. Left: King Haakon Bay. Right: Cumberland Bay. Black line indicates the seafloor. 2SD is given as the 2SD of the isotope ratio over 25 consecutive measurement cycles.



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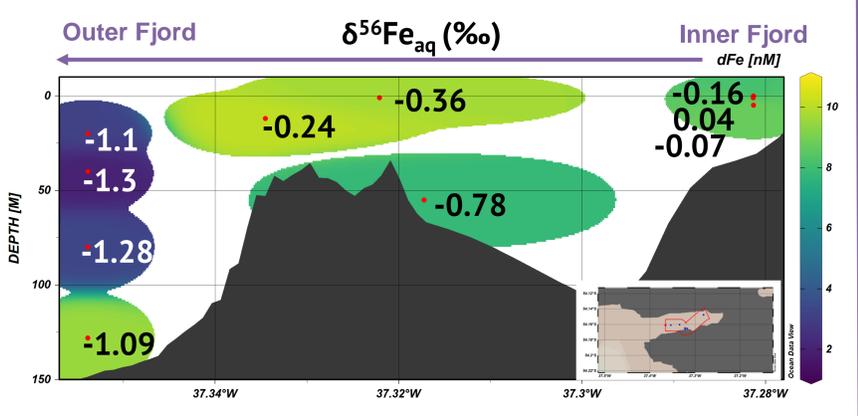


Fig. 4. Water profile showing the dissolved Fe concentrations and the corresponding seawater $\delta^{56}\text{Fe}_{\text{aq}}$ signatures from the inner to the outer fjord at King Haakon Bay. Exact location is given in the bottom right corner of the profile.

Conclusions

- Primary driver of high benthic Fe fluxes: **organic carbon accumulation rates**.
- Link between pore-water $\delta^{56}\text{Fe}_{\text{aq}}$ and benthic Fe fluxes:**
 - Low flux sites** → broader pore-water $\delta^{56}\text{Fe}_{\text{aq}}$ range (-3.94 ± 0.14 ‰ to -0.98 ± 0.11 ‰)
 - High flux sites** → narrower pore-water $\delta^{56}\text{Fe}_{\text{aq}}$ range (-3.14 ± 0.02 ‰ and -1.64 ± 0.06 ‰)
- Important to consider: **depositional regime** and the **abiotic and biotic processes** in fjord sediments and on the shelf, when interpreting the **seawater $\delta^{56}\text{Fe}_{\text{aq}}$ signatures!**
- Generally, light **seawater $\delta^{56}\text{Fe}_{\text{aq}}$** signatures (from -0.07 to -1.68 ‰) are associated with reducing conditions.

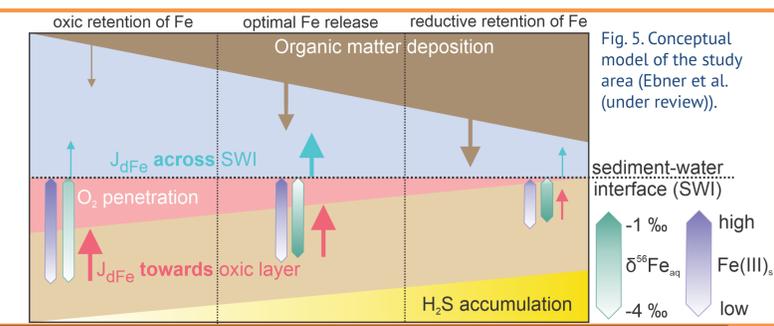


Fig. 5. Conceptual model of the study area (Ebner et al. (under review)).