Abstract # 9610

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Marine ice – a sleeping iron giant in the Southern Ocean?

1. The Situation

We know today that the Polar Southern Ocean (PSO) is a region with one of the highest concentrations of the macro-nutrients nitrate and phosphate, but lacks micronutrients such as Fe and Mn limiting the productivity[1]. However, we do find patches of high productivity all around the continent, in particular in front of the larger ice sheets (fig. 1). These patches of high productivity make the PSO a key location for the carbon uptake[2]. Yet, we do not really know where the fuel, i.e. the micronutrients, for such productivity hot spots comes from.

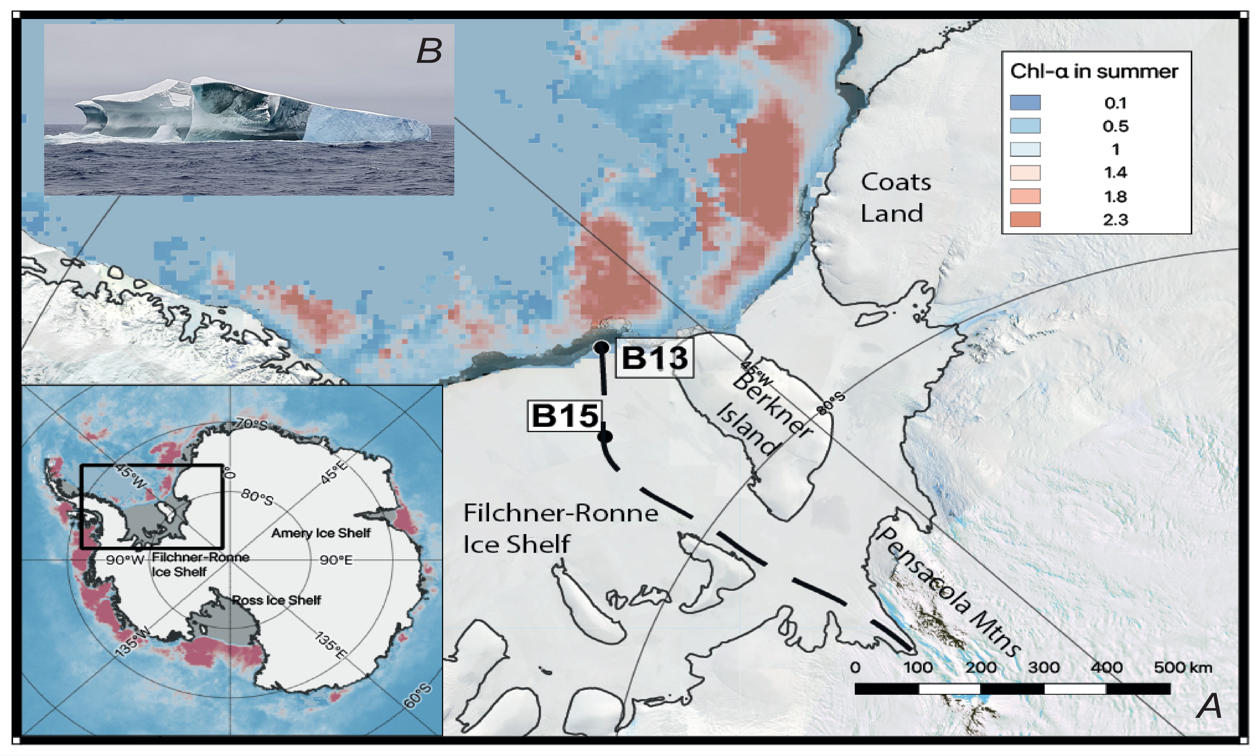

Figure 1: (A) Location of the two MI cores B13 and B15 from Filchner-Ronne Ice Shelf at the of sampling on today's ice shelf configuration. The dashed line illustrates the ice flow line of B13, adapted from Oerter et al. (1992)[10]. Red-Blue colour scale represents the average summer chlorophyll-alpha concentration at sea surface from 2002 to 2016 in mg/m³ (Raymond et al., 2017)[11]. (B) Photgraph of a green iceberg taken during F/S Polarstern expedition PS129, courtesy of Andreas Becker.

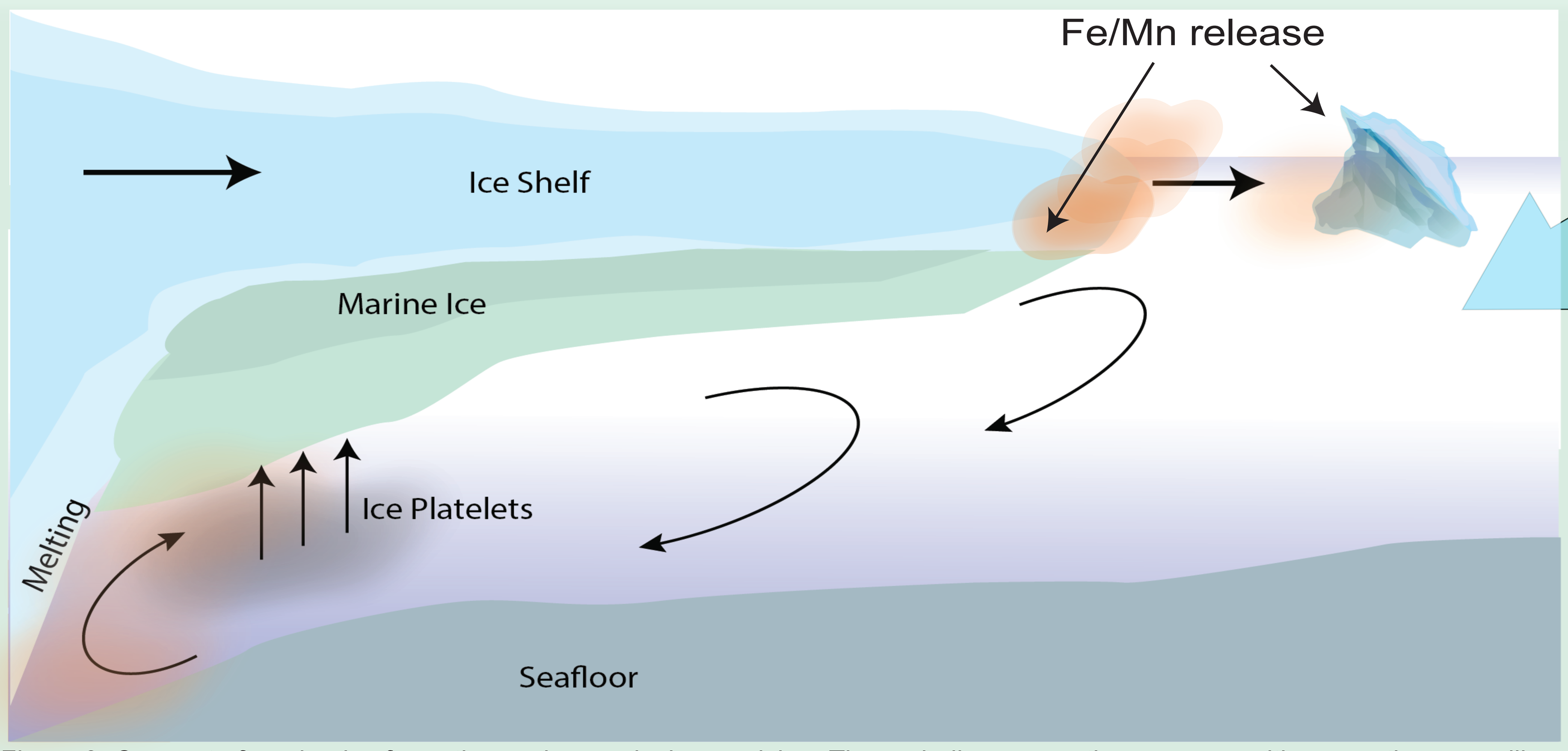

Figure 2: Concept of marine ice formation and green iceberg calving. Thermohaline convection causes melting near the groundling line. This leads to the formation of ice platelets ascending through the water column, while they scavenge particles. These ice platelets accumulate underneath the continental ice shelf and form a layer of marine ice. The locations of ice cores B13 and B15 are for illustration purposes only and are not to scale. Adapted from Kipfstuhl et al. (1992)[12].

2. The Hypothesis

There are indications for a potentially neglected source of micronutrients all around Antarctica, which is also the origin of "green icebergs" - marine ice. It has been stated until only recently that its greenish colour is derived from organic compounds trapped in the ice[3]. This study has shown that organic material must be much higher concentrated to produce this green colour. However, there are now strong indications that this green appearance is due to FeOOH particles instead[4,5].

The process (fig. 2) behind forming marine ice starts near the grounding line of large ice shelfs where sub-ice shelf water induces partial melting of meteoric shelf ice. This parcel of water is buoyant and can form small ice platelets during ascent and scavenge marine and terrestrial particles. These platelets accumulate underneath the ice shelf and become compact bubble-free marine ice. During this process, trace metals, such as Fe and Mn, in dissolved and particulate form become incapsulated in marine ice. Basal melting and iceberg calving could then release large amounts of Fe and Mn to trigger plankton blooms.

3. The Approach

We have access to 2 ice cores recovered in the early 90's from a large marine ice deposition underneath the Filchner-Ronne Ice Shelf. Until now, there is no geochemical data extracted from these cores and knowledge of geochemical composition, in particular that of Fe, Mn, Fe isotopes and other terrestrial tracers can help us to evaluate marine ice as a potential significant source for micronutrients for the PSO.

We determine particulate and dissolved trace metal content using a combination of seaFAST (SP2, ESI) ICP-OES (iCAP-7400, ThermoFisher), Sector-Field ICPMS (Element2, ThermoFisher) and MC-ICPMS (Nu-Plasma2, Nu-instruments). Mineral phases of particles are determined by µ-XRD (KIT).

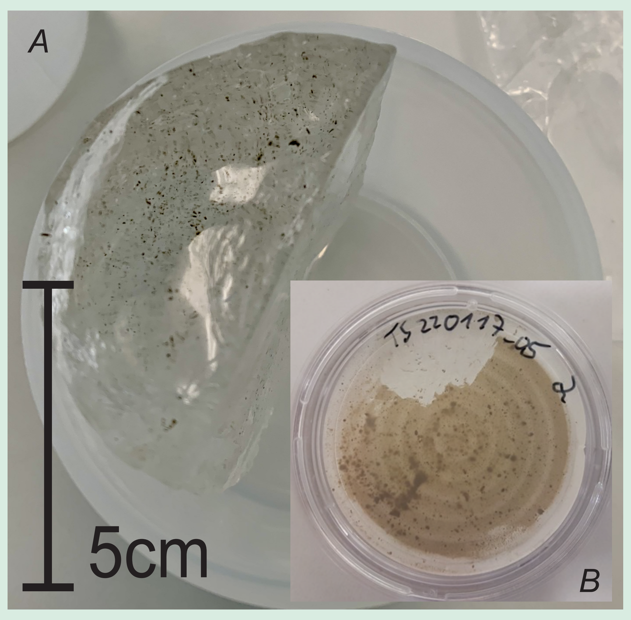

Figure 3: (A) Typical sub-sample from MI core B13 containing visible particles. This sample is from close to the transition of meteoric ice. (B) Filtered material from a different sub-sample containing fine grained (<2µm) particles, sticking together in larger (>10µm) aggregates.

4. Results and Discussion

Dissolved concentrations of Fe and Mn (dFe and dMn) are up to 390 and 150 nmol/kg, respectively (fig. 4A). The enrichment factors (EF) compared to Southern Ocean seawater[6] for dFe are as high as 1600 with median of close to 365. EF-dMn are on average 410. Other dissolved trace elements, such as YREE, do not show significant enrichement in MI. Normalised to PAAS[7], dYREE show a small enrichment in MREE (MREE bulge, fig. 5), which could give indication of dissolution of Fe and Mn oxides and associated release of scavenged YREE. Most dYREE are found depleted relative to PSO seawater[6] (fig. 4B), suggesting that dYREE are mostly present from scavenged seawater composition, whereas the high dMn and dFe appear to have sources from mineral dissolution.

Particulate ratios of Fe/Al and Fe/Ti match those of upper continental crust (UCC[8]) and additional Nd-isotopes of εNd* = -6.8 to -7.4 indicate one single source for the particles in MI (fig. 6), whereas Mn/Al (and Mn/Ti, not shown) are below 60% of UCC ratios. This suggests a depletion of pMn, e.g. by MnO dissolution which could explain MREE bulge. The high dFe concentration are therefore porbably the result of crustal material being dissolved whereas Mn is primarly released from Mn-oxides.

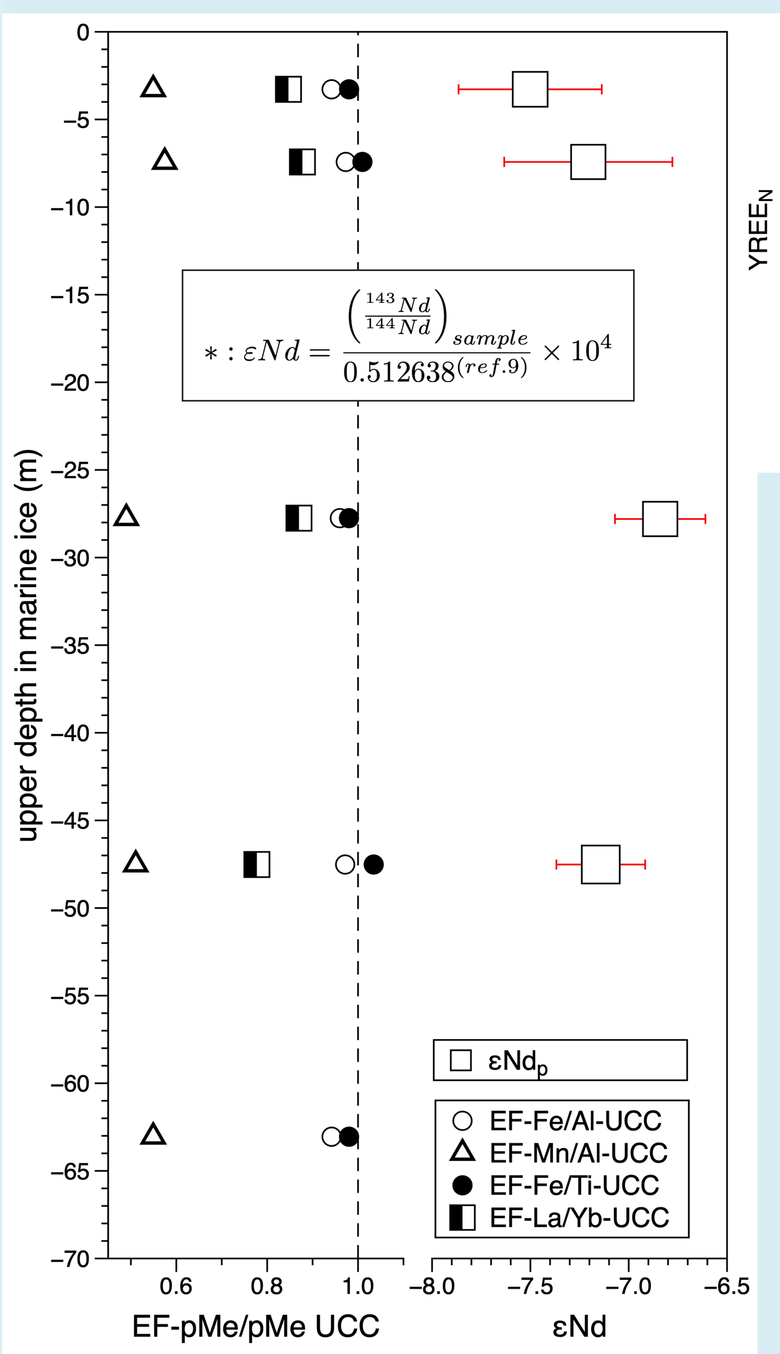

Figure 6: Enrichment factors (EF) for selected element ratios compared to Upper Continental Crust vlaues[8]. Fe/Al and Fe/Ti suggest an UCC like source of the particles. The source appears to be of a single origin, as indicated by the invariant Nd-isotope composition (expressed in εNd).*

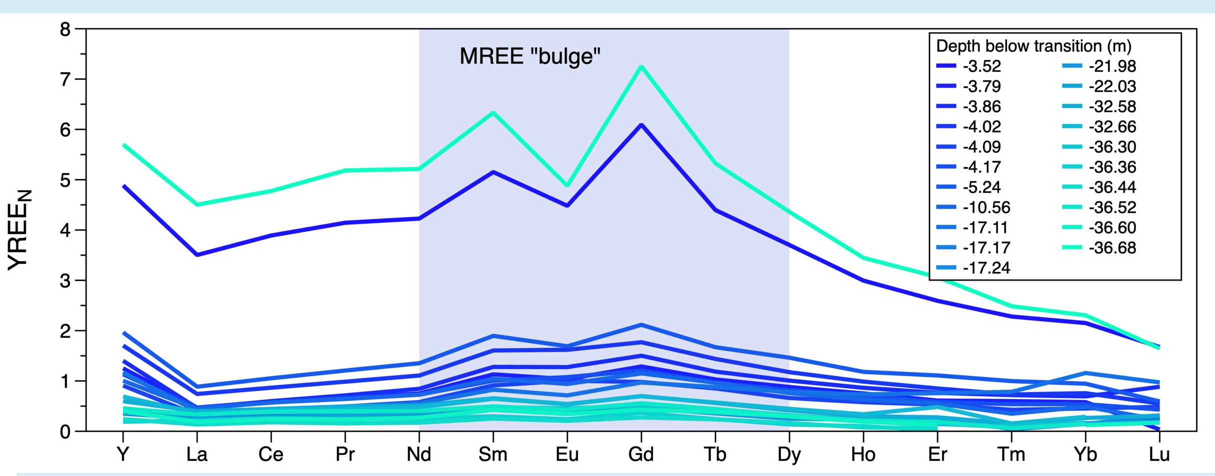

Figure 5: Dissolved Yttrium and Lanthanide (dYREE) concentrations normalised to Post-Archaean-Average-Shale (PAAS[7]) showing a light enrichment in middle REE (MREE „bulge"). This bulge could suggest release from previously scavenged YREE.

5. Conclusions

- Marine Ice shows orders of magnitude higher dissolved Fe and Mn compared to Southern Ocean seawater
- Other trace elements, such as dYREE are not enriched suggesting secondary release from previous scavenging
- Particulate data suggest that Fe is of continental origin, while Mn could be derived from secondary mineral phase such as Mn-oxides
- Nd isotopes and Fe/Al ratios suggest one single source for the particulate material in marine ice

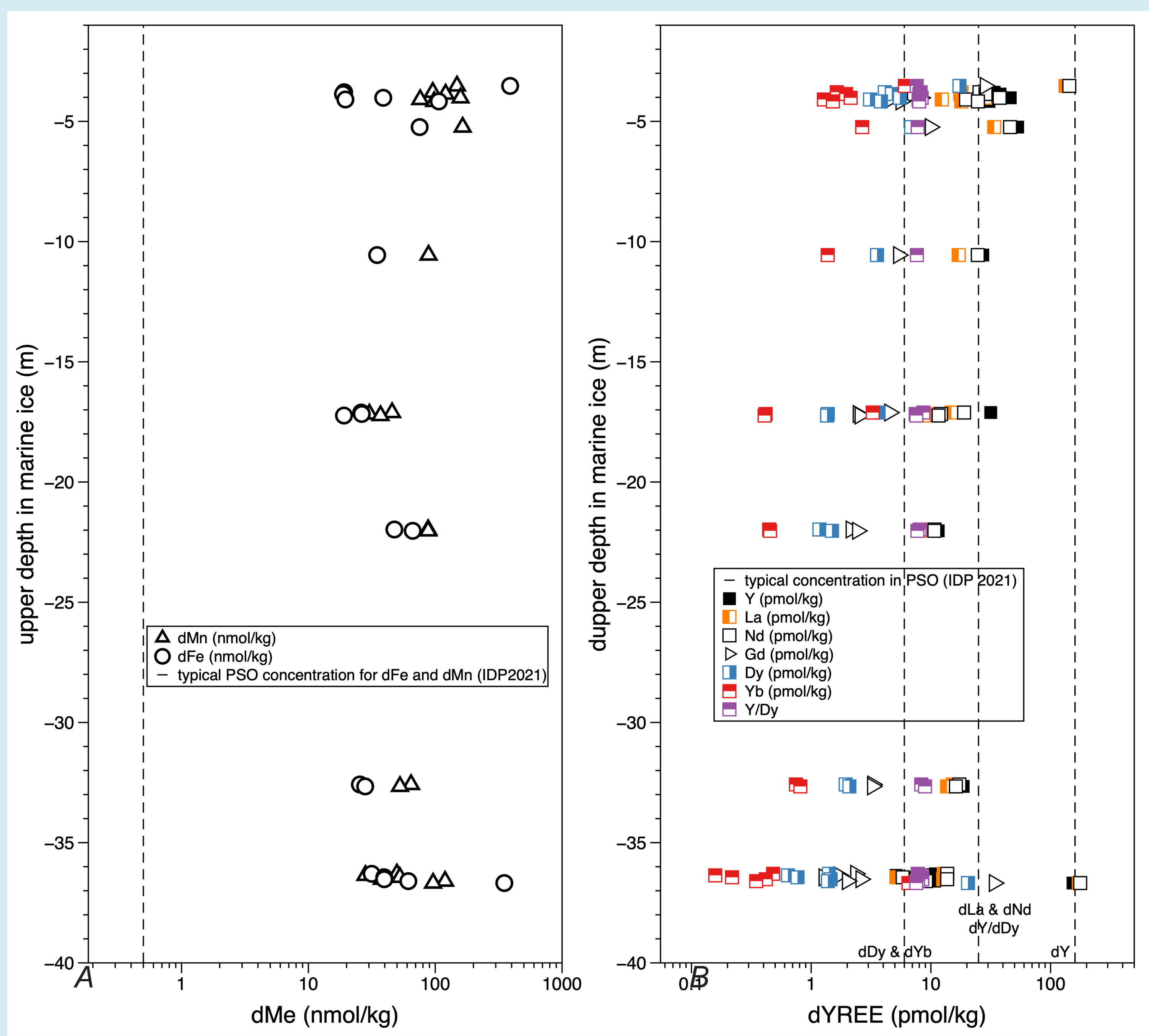

Figure 4 (A): Dissolved Fe and Mn (dFe, dMn) show orders of magnitude higher concentrations compared to Southen Ocean seawater throughout the length of the core.
(B): Most dissolved YREE are depleted relative to Southern Ocean seawater suggesting a scavengend source from marine YREE in marine ice. Constant Y/Dy could suggest a single source of dYREE and that fractionation is only minor. In contrast to dFe nd dMn, dYREE show a slight decreasing trend with core depth.

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