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 productivity1. However, we do find patches of high productivity all over the continent, in particular in front of the larger ice shelves (fig. 1). These patches of high productivity make the PSO a key location for the carbon uptake2. Yet, we do not really know where the fuel, i.e. the micronutrients, for such productivity hot spots comes from.

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 ice3. 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 instead4,5.

The process (fig. 2) behind forming marine ice starts near the grounding line of large ice shelves where sub-ice shelf water interacts and forms a layer of marine 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 incorporated 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 the chemical composition, in particular that of Fe, Mn, Fe isotope and other terestrial tracers can help us to evaluate marine ice as a potential significant source for micronutrients in the PSO.

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

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 seawater6 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 enrichment in MI. Normalized to PAAS7, 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 seawater8, 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/Mn and Fe/Al match those of upper crustal material (UCCT)9,10 and additional Nd-isotopes of Nd* are not enriched suggesting a scavenged source from marine YREE in marine ice. Constant Y/Dy could suggest a single source of dYREE and that Nd isotopes and Fe/Mn ratios suggest one single source for the particulate material in marine ice.

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/Mn ratios suggest one single source for the particulate material in marine ice.