Fertilizing the Southern Ocean:

Using the Mount Brown South ice core to extend the Heard Island volcanic record

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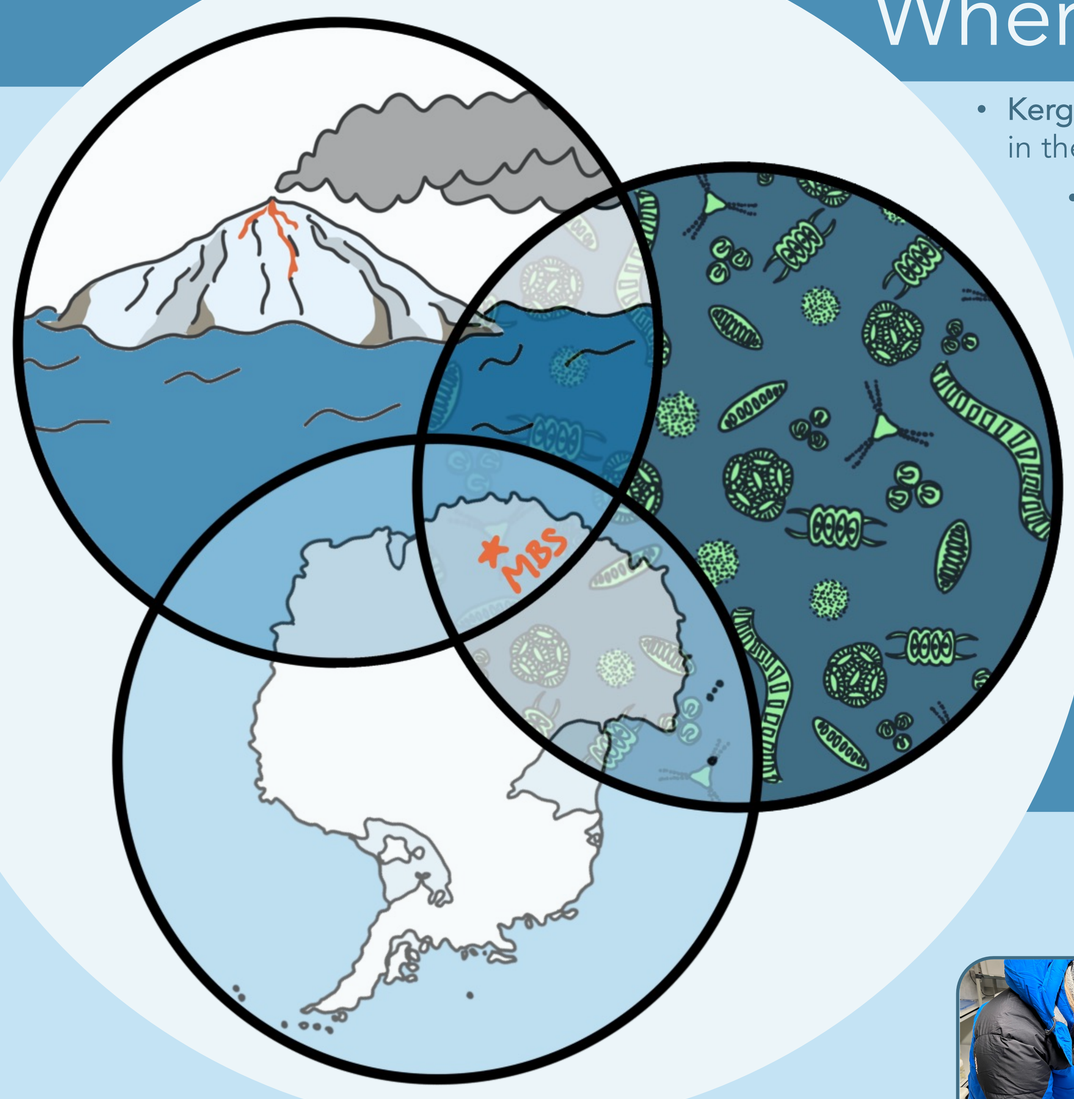
Background

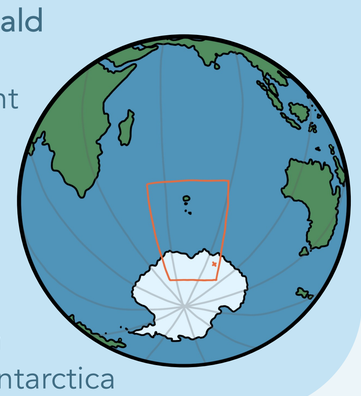
Southern Ocean biological productivity is iron limited, but the Kerguelen Plateau region, around Heard and McDonald Islands (HIMI) is home to substantial annual phytoplankton blooms[1,2]. The volcanoes on HIMI have poorly observed eruption histories[3].

- Could ash (cryptotephra) from HIMI be preserved in East Antarctic Ice?
- Could HIMI volcanic fallout be a source of bioavailable iron for the Kerguelen Plateau region?



Where in the world?

- **Kerguelen Plateau:** Large Igneous Provence in the Southern Indian Ocean
- **Heard and McDonald Islands (HIMI):** Approx. equidistant from Madagascar and Western Australia
- **Mount Brown South (MBS):** Ice core site in coastal East Antarctica



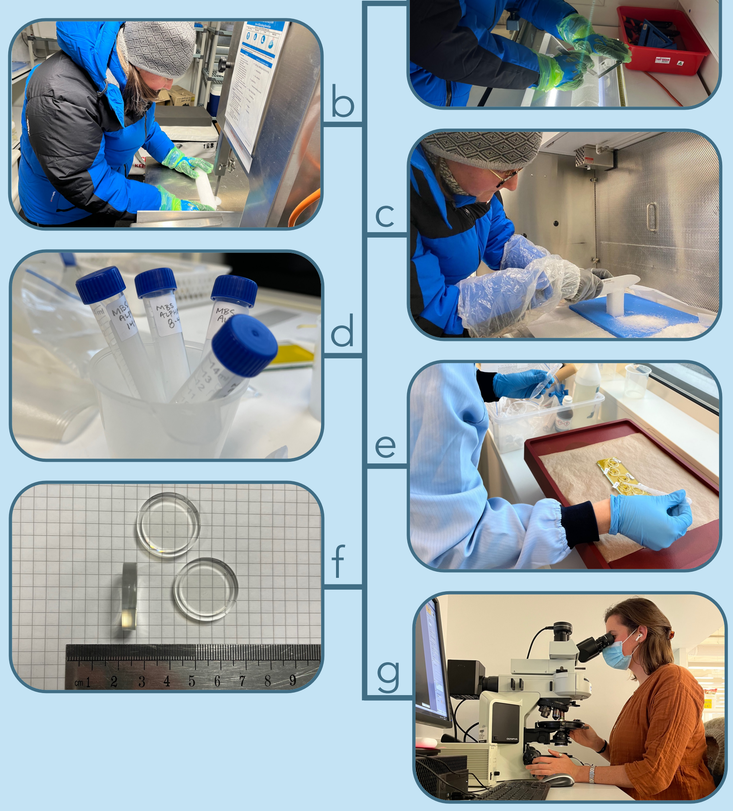
Sampling plan

- Sampling depths selected based on:
  - Existing Heard Island volcanic record (Fox, et al., 2021)
  - HYSPLIT air parcel trajectories
  - MBS CFA and discrete chemistry data
- Preliminary samples obtained from the MBS Main Core, outer edge pieces, ~15cm sampling resolution.
- Main core samples inspected using optical microscope, and depth ranges selected for subsequent high-resolution sampling from MBS Alpha core, ~5cm sampling resolution.
- MBS Alpha core samples were prioritized based on tephra quantities found in MBS Main core samples.

Sample selection

Month	Month	Year	Decimal Date	MBS Main depth	MBS Charlie depth
'January'	1	1983	1983.04	17.83	17.68
'January'	1	1985	1985.04	16.71	16.54
'October-November'	10	1985	1985.79	16.18	16.20
October-November'	11	1985	1985.88	16.12	16.15
'December'	12	1986	1986.96	15.55	15.47
'Jan	1	1987	1987.04	15.50	15.43
'Jan	1	1992	1992.04	13.01	13.07
'Jan		2000	2000.04	8.90	9.03
'Oc				8.50	8.58
Oc					8.53
Fe					
'F					8.33
'January			2002.04		7.77
'January			2004.04	6.40	6.66
'February'			2007		6.1
'February'			2007		8
'May'	5		2007		9
'April'	4	2009			12
'February'	2	2010	2010.13		78
'July 2012-January'	7	2012	2012.54		4.69
'July 2012-January'	8	2012	2012.63		2.65
'July 2012-January'	9	2012	2012.71		2.60
'July 2012-January'	10	2012	2012.79		2.56
		2012	2012.88		2.51
		2012	2012.96		2.47
		2013	2013.04		2.42
		2013	2013.63		2.18
		2015	2015.46		1.41
		2016	2016.04		1.02
		2016	2016.13		0.99
		2016	2016.21		0.95
		2017	2017.13		0.51

Methods



a. The ice core is measured out according to the sampling plan.
b. The ice core is cut into ~5 cm samples.
c. The outer edges of each sample are removed using a ceramic blade
d. The ice samples are melted and centrifuged to concentrate any microparticles present.
e. Concentrated sample material is pipetted onto an ultra-flat adhesive surface and evaporated.
f. Dry sample material is sealed in epoxy resin and polished to expose grains.
g. Samples are inspected using a petrographic microscope in preparation for further analysis.

Results

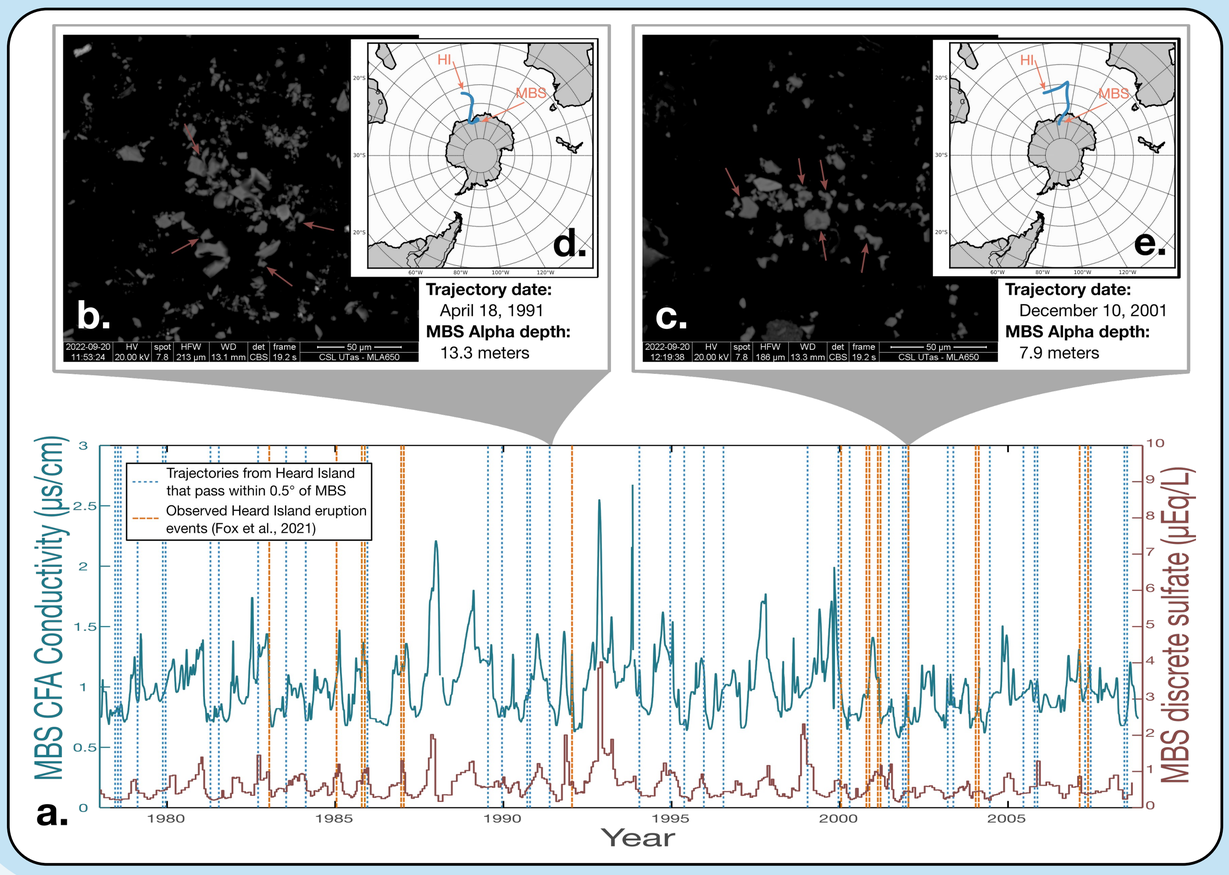


Figure 1:
a. 30 years of continuous flow analysis (CFA) conductivity record (blue, left axis) and discrete sulfate chemistry (dark red, right axis) from the Mount Brown South Main Core (69.111°S, 86.312°E). Blue dotted vertical lines indicate the dates of HYSPLIT air parcel trajectories originating from Heard Island that pass within 0.5° of MBS. Orange dashed vertical lines indicate recorded Heard Island eruption events (from Fox, et al., 2021).

b. & c. Examples of backscatter electron (BSE) images showing microparticles contained in MBS Alpha core samples from the indicated depths. Red arrows indicate grains that show characteristic scanning electron microscopy/energy dispersive spectroscopy (SEM-EDS) spectra matching that expected of volcanic glasses.

d. & e. Maps showing HYSPLIT trajectories passing from HI to MBS with the corresponding MBS Alpha sample depths.

Key findings

- HYSPLIT air parcel trajectory modeling confirms that favorable transport from Heard Island to Mount Brown South occurs on the order of days.
- Preliminary SEM-EDS analysis using Advanced Mineral Analysis and Characterization System (AMICS, Bruker) automated mineralogy shows that microparticles displaying spectra characteristic of volcanic glasses are present in the MBS Alpha core samples.

Up next

- BSE imaging with AMICS and electron microprobe analysis for mineral characterization of full suite of MBS Alpha core samples.
- Synchrotron analysis for:
  - X-ray fluorescence microscopy for characterization of smallest shards
  - X-ray absorption near edge spectroscopy for iron content and bioavailability analysis.
- Correlation analysis with existing satellite chlorophyll records from the Kerguelen Plateau.

1. Blain, S et al. 2001, 'A biogeochemical study of the island mass effect in the context of the iron hypothesis: Kerguelen Islands, Southern Ocean', *Deep-sea research. Part I, Oceanographic research papers*, vol. 48, no. 1, pp. 163–187.
2. Wojtasiewicz, B et al. 2019, 'Factors Controlling the Lack of Phytoplankton Biomass in Naturally Iron Fertilized Waters Near Heard and McDonald Islands in the Southern Ocean', *Frontiers in Marine Science*, vol. 6.
3. Fox, JM et al. 2021, 'Construction of an intraplate island volcano: The volcanic history of Heard Island', *Bulletin of Volcanology*, vol. 83, no. 5, p. 37.