Antarctic Science Bursary Report
Provenance of Aeolian Dust Deposited in McMurdo Sound, SW Ross Sea

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Project description

Aeolian dust is a source of soluble iron (Fe), which is the limiting nutrient required for phytoplankton growth in high nutrient low chlorophyll (HNLC) regions of the world's ocean including the Southern Ocean.[1-5] This 'iron fertilisation' of the ocean results in vast phytoplankton blooms that alter the food web and have the potential to export particulate carbon to the deep ocean.[6] Each summer the Fe-limited waters of McMurdo Sound, in the south-western (SW) Ross Sea, bloom with phytoplankton.[7-8] This phenomenon is thought to be stimulated by the addition of soluble Fe. An importance source of soluble Fe is aeolian dust from local and global sources.[e.g. 9] The solubility of Fe is influenced by several parameters including dust flux, particle size distribution and provenance.[e.g. 10-13] Aspects of this biogeochemical cycle have been addressed for the first time by analysing the physical and geochemical properties of the aeolian dust accumulating on sea ice, deposited and trapped in coastal snow and ice in the McMurdo Sound region[14].

An important control on Fe solubility is dust provenance.[e.g. 9-12] The geochemical fingerprint of remote dust deposited on the Antarctic plateau shows it originates from arid regions in Patagonia and Australia,[15-18] but contribution from exposed Antarctic sources is likely for sites located on the margin of the ice sheet.[19] Global 'background dust' is characterized by its fine grain size (mode <5 μm) and modern mass accumulation rates of 0.001-0.02 g m^{-2} yr^{-1}.[20-24] In contrast, the debris bands on the McMurdo Ice Shelf represent the most significant local dust source in Antarctica and contributes ~1.5 g m^{-2} yr^{-1} of aeolian dust to SW Ross Sea (Fig. 1).[14]

There are two local potential source areas (PSAs) in McMurdo Sound (a western source: McMurdo Dry Valleys and a southern source: McMurdo Volcanic Group) each with a distinctive geochemical fingerprint. The combination of different isotopic signatures ($^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$) is extremely useful in tracing PSAs because different geographic provenances can be discriminated by variations in radiogenic isotopes of mantle derived (basaltic rocks, tephra and soils derived from them, weathered and eroded mafic particles) or crustal (soils, sediments) derived sediments.[25] This bursary was used to determine the Sr and Nd isotopic signature of McMurdo Sound dust and compare the results with the isotopic signature of local PSAs.

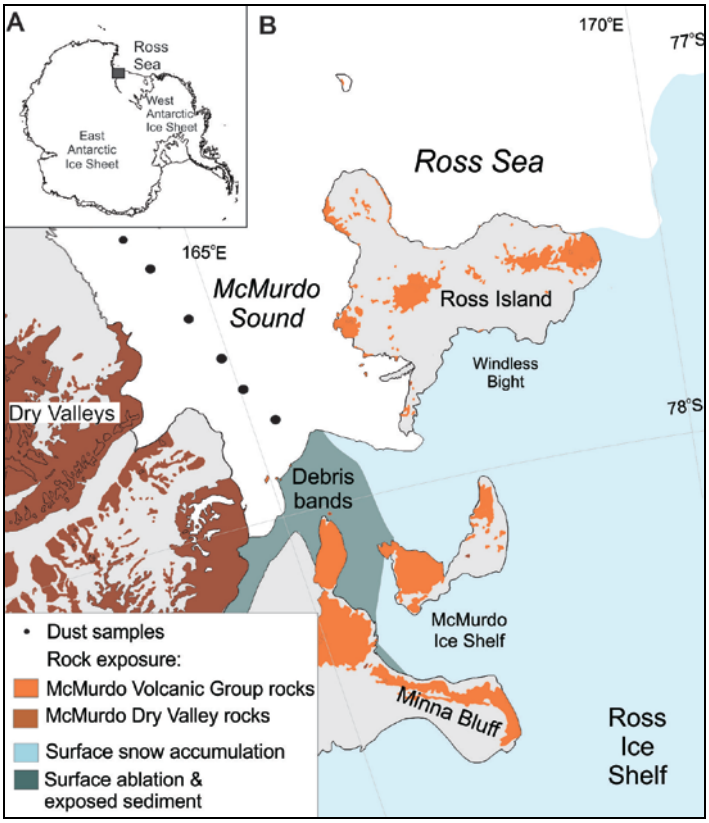

Fig. 1: A) Map of Antarctica showing location of McMurdo Sound. B) Map of McMurdo Sound showing the north-south transect of dust samples on the sea ice and potential source areas.

Method

Dust sample digestion and separation of and Nd and Sr using ion exchange chromatography[26] was carried out at the Laboratory for Isotope Geology at the Swedish Museum of Natural History, Stockholm under clean conditions in a class 100 laminar flow hood. The samples were spiked with ^{150}Nd and ^{84}Sr for isotope dilution determination of the concentrations and analysed on a Thermo Scientific TRITON thermal ionisation mass-spectrometer (TIMS). Reproducibility of the ^{143}Nd/^{144}Nd and ^{87}Sr/^{86}Sr ratios is 50 ppm and 40 ppm respectively. The total column yield for the Nd and Sr separation exceed 95 %. The total blank concentrations, including dissolution, chemical separation and mass spectrometry, was <10 pg for Nd and <80 pg for Sr.

Results and discussion

The Sr and Nd isotopic ratios of aeolian dust in McMurdo Sound are reported in Fig. 2 and compared with PSA samples from Delmonte et al.[19, 27] The large particle size and high dust flux suggest transport distance is limited and therefore only local PSAs are considered. Sedimentological evidence points to the debris bands as the most important source of dust in the McMurdo Sound region.[14] The additional isotopic analyses confirm dust accumulating on the sea ice is locally-derived. This data is used to investigate the relative contribution of the two dust sources in McMurdo Sound by considering the samples as a mixture between two end members: McMurdo Dry Valleys and McMurdo Volcanic Group (Figs. 1 and 2). Overall, the Sr isotopic ratios for McMurdo Sound PSAs range between 0.703< ^{87}Sr/^{86}Sr <0.714 while εNd(0) ranges between (6< εNd(0) >-13). Assuming these two end members, it is observed that the dust samples are included within the mixing field: the isotopic signature (0.705331< ^{87}Sr/^{86}Sr <0.7091465 and -1.1< εNd(0) >3.45) lies on the mixing line between the two isotopically distinct end members. Within the narrow range of isotopic ratios of McMurdo Sound dust, there is a small change in the ^{87}Sr/^{86}Sr and ^{143}Nd/^{144}Nd composition of the dust along the south-north transect (Fig. 1). As the dust is transported north from the debris bands the composition moves along the mixing line from the

McMurdo Volcanic Group towards the Dry Valleys. This gradient in mixing is consistent with the exponential decrease in dust flux downwind from the debris bands and the local meteorology.

The narrow range of isotopic ratios has implications for supply of Fe to the SW Ross Sea. A previous study observed that there is little variability in Fe solubility[14] along the north-south transect in Fig. 1 and the homogenous composition of the dust can thus explain this. Given that total Fe content and particle size do not influence Fe solubility[14], it can be concluded that dust provenance is the major control on Fe solubility in McMurdo Sound. This conclusion is consistent with studies from other regions.[e.g.28]

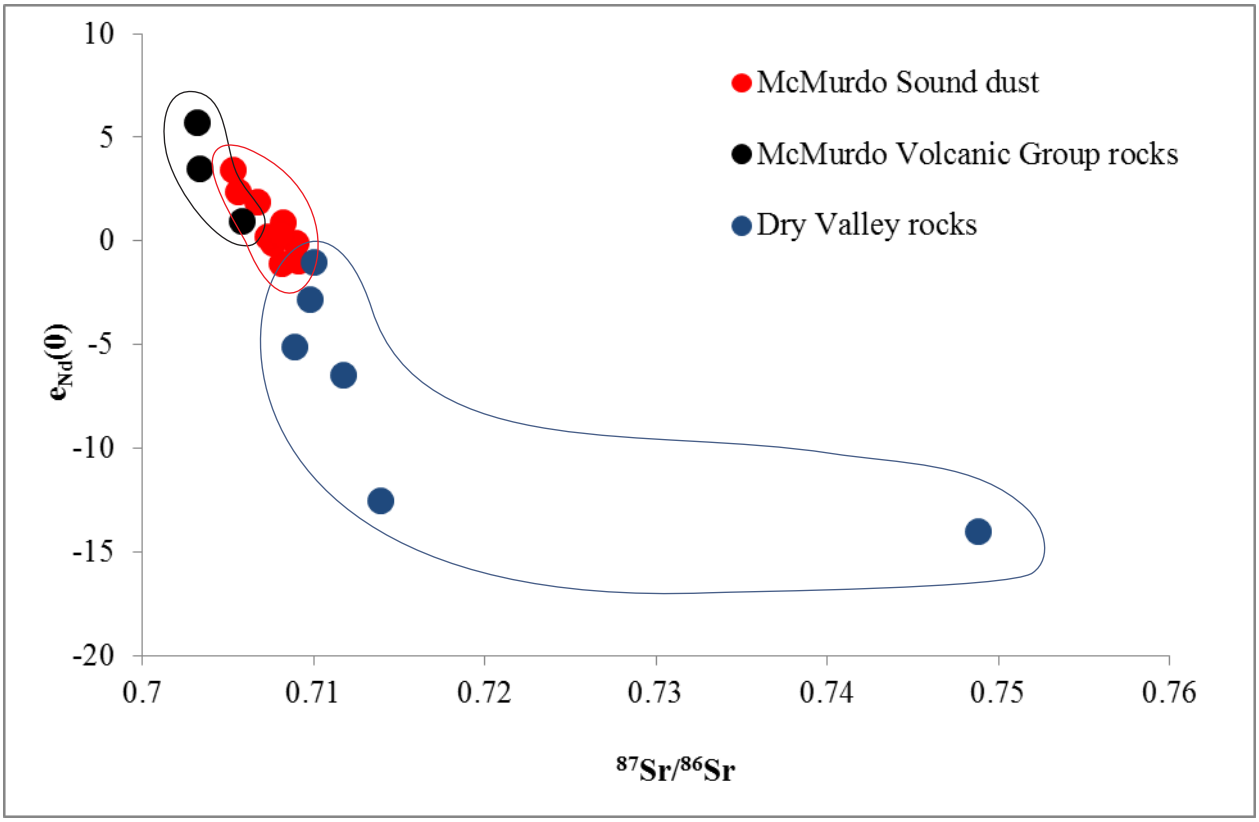

Fig. 1: Isotopic composition of McMurdo Sound dust (red circles) compared with PSA samples from Delmonte et al. [20, 28]

Conclusion and future work

Local dust accumulating on McMurdo Sound sea ice is derived from exposed areas of unconsolidated sediment. The isotopic signature of McMurdo Sound dust lies between two isotopically distinct PSAs in the sound and thus is a mixture of these two sources. The isotopic composition of McMurdo Sound dust falls within a narrow range ($0.705331 < {}^{87}Sr/{}^{86}Sr < 0.7091465$ and $-1.1 < \varepsilon Nd(0) > 3.45$). This homogenous composition can explain the constant Fe solubility of the dust samples along a north-south transect. If this local dust is transported beyond McMurdo Sound and further north into the Ross Sea, Fe supplied from the local dust can be quantified from the known Fe solubility. Samples from Roosevelt Island, on the eastern side of the Ross Ice Shelf, will be analysed for $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ isotopic ratios to determine how far north locally derived dust is transported into the Ross Sea. The broader implications of this research are to determine the influence of the dust source on Fe solubility in McMurdo Sound and to quantify the area in which the dust is potentially bio-available for phytoplankton growth in the Ross Sea, a critical region of carbon sequestration.

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