Enhanced enrichment of metals in fresh precipitation on Ross Ice Shelf

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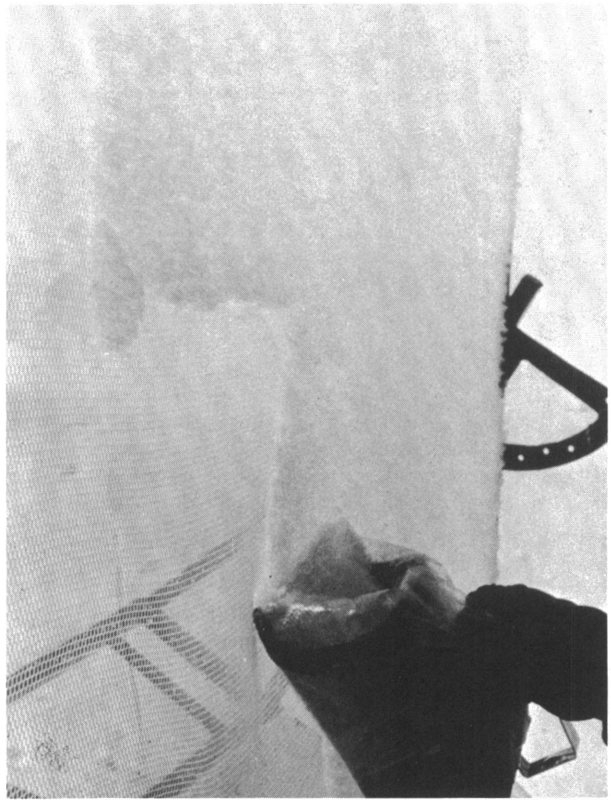
During the austral summers of 1974–75 and 1976–77, we collected snow and firn samples at several locations on the Ross Ice Shelf (see figure 1 in Warburton, Molenar, and Anderson, 1979) and fresh precipitation samples at some of the same sites (C–7, RISP–BC, and J–9). Using flameless atomic absorption spectrophotometry techniques, we determined the concentrations of sodium (Na), manganese (Mn), and silver (Ag) in the snow and fresh precipitation.

Sheets of nylon net were used to collect the samples of fresh falling snow during storms and of rime and hoar during periods of supercooled fog. Before leaving the United States, we cleaned the nylon nets by a series of leachings in analytical grade solutions of nitric acid. This treatment was followed by several rinses and leachings in doubly distilled, de-ionized water. All the equipment was then sealed in polyethylene bags for transport to the Antarctic.

Once a sufficient quantity of ice had accumulated, a sample was taken from the nets with a special scoop fitted with a new, clean, plastic sample bag. The samples were then stored in tightly sealed polyethylene bags and kept frozen until they could be analyzed. Figure 1 shows ice accumulation on the net and the method of removing it for analysis.



Fog deposition ice on nylon net collector at RISP–BC site, Ross Ice Shelf.

The results, shown in the accompanying table, demonstrate that enhanced enrichment occurs on the Ross Ice Shelf in two specific precipitation types: (1) diffu-

Table 1. Enhanced heavy metal enrichment in fresh precipitation—Ross Ice Shelf

Location and Distance from Ice Front and Collection Time		OBSERVED CONCENTRATIONS			OBSERVED RATIOS		*CALCULATED ENRICHMENTS	
		Na ppb	Mn ppb	Ag ppb	Mn/Na	Ag/Na	E(Mn)	E(Ag)
Seawater		10^7	10	2×10^{-1}	10^{-6}	2×10^{-8}	—	—
Ice Shelf C-7								
70 km (Fog Dep.)		237		5.2×10^{-3}		2.2×10^{-5}		10^3
Ice Shelf BC								
450 km (Fog Dep.)		47		9.5×10^{-3}		2.0×10^{-4}		10×10^3
Ice Shelf J–9: 11/14/76								
Sample No.	Collection Time							
10	1000 hrs.	50	71×10^{-2}	8.3×10^{-3}	142×10^{-4}	170×10^{-6}	1.4×10^4	8.5×10^3
11	1815 hrs.	55	55	5.4	100	100	1.0×10^4	5.0×10^3
12	1845 hrs.	42	39	5.0	93	119	0.9×10^4	5.9×10^3
13	1915 hrs.	32	36	4.4	113	138	1.1×10^4	6.9×10^3
14	1945 hrs.	18	13	6.0	72	334	0.7×10^4	16.7×10^3
15	2015 hrs.	10	19	4.0	190	400	1.9×10^4	20.0×10^3
16	2045 hrs.	8	9	5.0	113	625	1.1×10^4	31.2×10^3
17	2115 hrs.	6	10	4.5	167	750	1.7×10^4	37.5×10^3
18	2145 hrs.	12	5	12.5	42	1040	0.4×10^4	52.0×10^3
19	2215 hrs.	11	25	2.2	227	200	2.3×10^4	10.0×10^3
20	2250 hrs.	11	12	3.0	109	273	1.1×10^4	13.6×10^3
21	2310 hrs.	21	12	4.2	57	200	0.6×10^4	10.0×10^3

sional deposition from supercooled fogs (Linkletter and Warburton, 1976), and (2) fresh snowfall in light wind conditions.

These enhanced factors are greater than those seen in samples of snow and firn collected from shallow pits (not more than two meters deep) at the same locations (compare with tables 1 and 2 of Warburton, Molenar, and Anderson, 1979). The general accumulation includes dry fallout, as well as rime and hoar deposition from fogs and precipitation from large snow storms.

For fog deposition and precipitation, the manganese enrichment factors are 15 to 100 times greater than firn values and the silver enrichment factors are 5 to 50 times greater than firn values at the same locations. The iron values for these samples have not yet been determined. The fog deposition and precipitation samples were collected at about 30-minute intervals in low shear stress conditions and therefore probably occurred under conditions when the sea surface close to the ice front was calm.

Not only are the enrichment factors enhanced but quite marked variations occur as a function of time throughout the precipitation period. As shown in figures 2, 3, and 4, the sodium and manganese concentrations follow the same general trend as a function of time, whereas the silver concentrations behave quite differently, suggesting that the latter may have different origins.

Thus, our investigations are showing that more enhanced enrichment occurs in fresh precipitation, by quite large factors, than in samples of general accumulation for the same locations. Because the occurrences of these precipitation types vary temporally and geographically, it has become apparent that the shear stress conditions in the near-surface boundary layer need to be considered in studies of snow and ice chemistry, particularly in polar regions where the chemical composition of permanent snow and ice fields are being investigated for evidence of climatic change and of glaciological behavior and origins of chemical constituents.

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References

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Heavy metal enrichment in antarctic snow and firn

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During the austral summers of 1971–72, 1974–75 and 1976–77, snow and firn samples were collected at Amundsen-Scott (South Pole) Station, Byrd Station, and several locations on the Ross Ice Shelf (see figure 1). Flameless atomic absorption spectrophotometry techniques were employed to determine the concentrations of sodium (Na), manganese (Mn), iron (Fe), and silver (Ag), in the snow and firn.

The Ross Ice Shelf in particular has proved to be an excellent region for the study of atmospheric chemical processes. Cyclonic storm systems originating in the Southern Ocean often move in across the shelf, penetrating to the mountains and beyond. These storms and other large-scale air mass motions carry aerosols, particulates, and hydrometeors inland, enabling them to be precipitated onto the shelf. The ice shelf also is a region much affected by katabatic winds flowing from the Antarctic plateau. These winds could be responsible for bringing aerosol material onto the shelf from nonmarine sources, particularly from the Transantarctic Mountains and from high-pressure subsidence air masses containing both stratospheric and tropospheric components.

Samples of the snowpack on the ice shelf were taken from 2-meter pits dug at the sites shown on the accompanying map. The samples of snow and firn from Byrd Station and South Pole Station were collected by augering horizontally into the walls of existing and new snow pits, using a SIPRE auger with either a specially cleaned stainless steel core barrel or, in cases where the snow was not compacted, a polyethylene plastic scoop. In all cases, sampling equipment and the individuals doing the sampling were covered with polyethylene sheeting. Cores were allowed to slide from the auger into polyethylene containers, which were then sealed immediately. All chemical analyses were conducted in the clean room facilities of the Desert Research Institute (Reno, Nevada).

Table 1 shows the results obtained for silver, manganese, and iron for four sites on the Ross Ice Shelf varying in distance from 70 to 600 kilometers from the ice front. Elemental concentrations in snow samples taken from near-surface snow pits are compared with the sodium concentrations for the same samples. The enrichment factors E(Ag), E(Mn) and E(Fe) have been determined using the standard equation.

The enrichment factors are numerically large and increase with distance from the ice front. The ratio of Mn/Fe is fairly constant at all sites and approximates the crustal ratio of 0.02 (see table 2). On the other hand, the