

Isotopic and related studies of Antarctic ice samples

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Abstract. The ice samples obtained from Dakshin Gangotri, Antarctica show the presence of nuclear debris, attributed mainly to French nuclear explosions. Cosmogenic ^7Be occurs at levels of 30 dpm/L. The vertical profile of δD in 6 m long drill core ranges between -130 and -180‰ compared to Standard Mean Ocean Water (SMOW). No systematic change with depth is seen. Small amounts of dust obtained by filtering melt water show presence of metallic spherules. Absence of elements characteristic of meteoritic or cometary debris suggests that most of them are of volcanic or industrial origin.

Keywords. Antarctica; radioactive fallout; isotopic composition; spherules.

1. Introduction

Surface and drill core samples of ice were collected from Dakshin Gangotri, Antarctica by the first Indian expedition to Antarctica during January–February 1982. These samples were brought back in frozen condition to Goa and then transported to the Physical Research Laboratory. A series of scientific experiments were carried out to characterise these samples. These included measurements of radioisotopes ^{210}Pb , cosmogenic ^7Be and bomb produced ^{137}Cs , stable isotopes D/H and analysis of particulate matter.

2. Sample description

Two bulk and two shallow ice core samples were used for the present study. The bulk samples called ANB and ANC were approximately 20 and 10 l of ice respectively. The two drill core samples consisted of several 20–50 cm sections of about 5 cm diameter going to 6 and 4 m depth respectively. One of the sections 2/5/C of core 2 is shown in figure 1, while it was being dissected for isotopic analysis. The samples from known depths were melted and analysed using standard techniques.

3. Results and discussion

3.1 *Natural and bomb-produced radioactivity in surface and core samples*

Measurements of ^7Be and ^{137}Cs in some samples have been made using gamma-ray spectroscopy with HPGe detector located in a 10 cm thick lead shield. The charac-

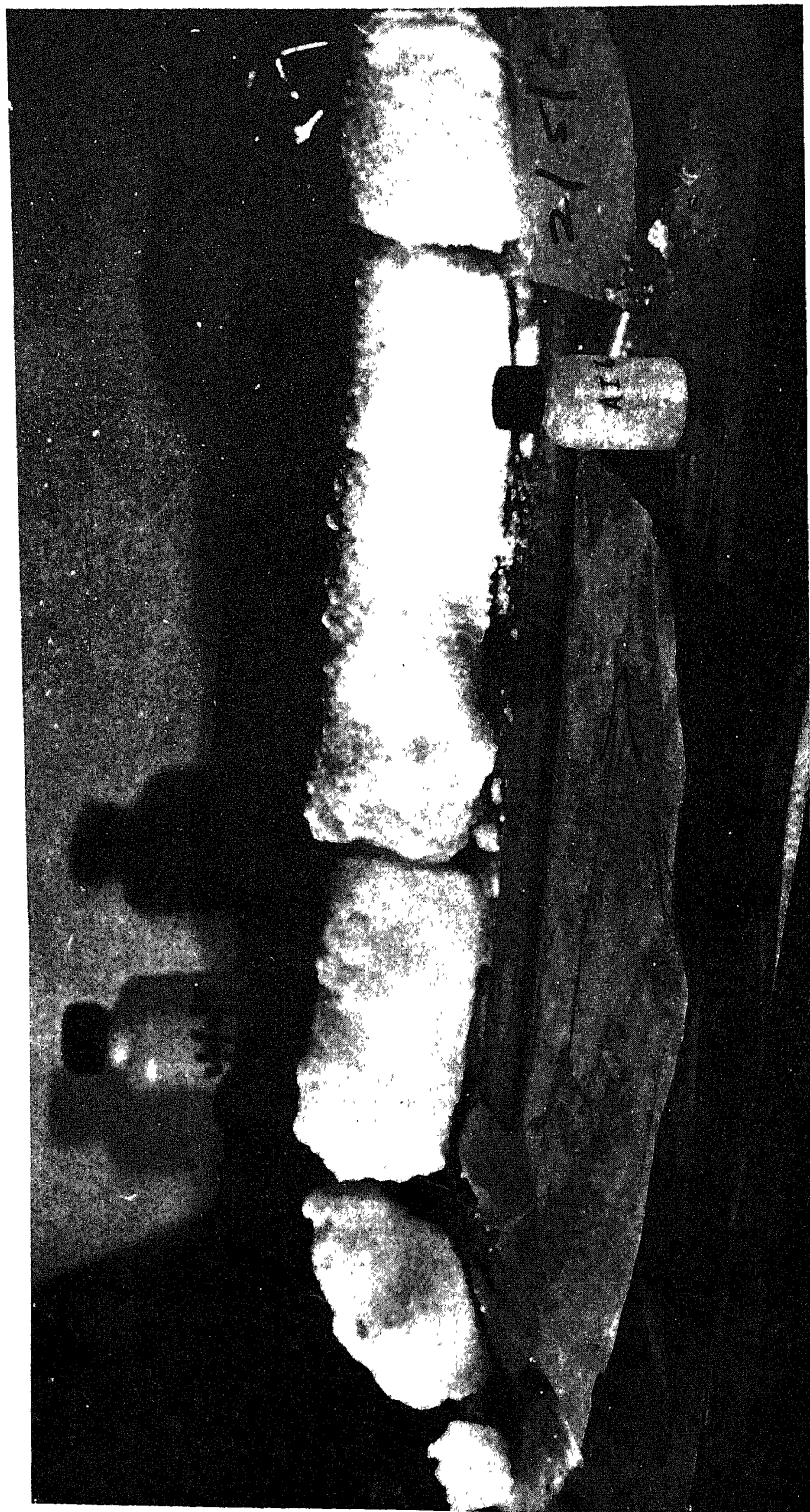


Figure 1. Samples of core 2 S C being taken for stable isotope and chemical analysis

teristics of the detector background and efficiency etc were described earlier (Bhandari *et al* 1982). The results are summarised in table 1. Corrected for decay to the time of collection, the ^7Be activity roughly corresponds to 15–30 dpm/L as expected for natural fallout in Polar region. The ^{137}Cs activity measured in section 2/6/a is 0.6 ± 0.2 dpm/L.

There have been several atmospheric nuclear tests in the past few years (SIPRI 1980). The radioactive fallout due to bomb-produced activities in Antarctica samples can be attributed to the French nuclear explosions conducted at Muraroa atoll in South Pacific. The presence of ^7Be and ^{137}Cs suggests that the ice samples at Dakshin Gangotri are young and represent fresh precipitation. The ^{210}Pb value of 3.17 dpm/L is consistent with the expected fall-out level.

3.2 Isotopic composition of water

The isotopic composition of hydrogen has been measured in several samples from the 6 m core using a micromass stable isotope mass-spectrometer. Figure 2 shows δD variations with depth. The δD values range between -130‰ (in the surface sample ANC) and -180‰ in core samples. The reproducibility and the precision of the measurements are better than 2‰ . There is no systematic change seen with depth. The δD values are similar to those reported for King Baudouin base ($78^\circ 26' \text{S}$, $24^\circ 19' \text{E}$) (Piccitto *et al* 1960) but significantly higher than that at south pole (Epstein *et al* 1965). The data show depletion of δD towards poles as expected from the precipitation temperatures and suggest a mean annual surface air temperature of about -10°C based on the empirical relationship established for precipitations in near Polar region (Dansgaard 1964).

Table 1. Natural and bomb produced radioactivity in surface and core samples.

Sample	Sample Volume (L)	Date of counting	^7Be	^{137}Cs	^{210}Pb
			(dpm/L)		
ANB-3	7.2	13.3.82	7 ± 0.4	0.06 ± 0.03	—
ANC	4.5	23.5.82	7.6 ± 2.1	0.8 ± 0.2	—
2/6/a	0.91	15.3.82	—	0.6 ± 0.2	—
2/1/b	0.485	7.3.83	—	—	3.17 ± 0.36

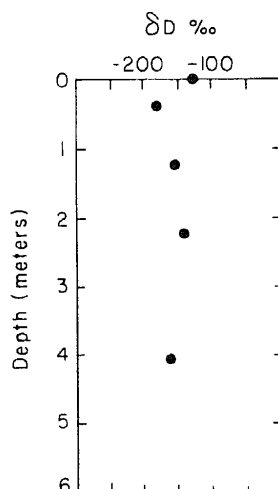


Figure 2. δD concentration with depth.

3.3 Chemical analysis of spherules

The melt water (4.5 l) obtained from bulk ice sample ANC was filtered on millipore papers in a clean room and the particles were examined under a microscope. A core sample from sample 2/6 was also similarly studied. The dust showed presence of some spherules which were quantitatively separated. The majority of the spherules obtained were smooth, black, shining and perfectly spherical in shape. Some of these had less lustre and rough or pitted surface. These spherules might be from any one of the three sources *viz.* cosmic, volcanic and industrial (Bhandari *et al* 1968; King and Wagstaff 1981; Wagstaff and King 1981; Blanchard *et al* 1980). Some of these spherules are hollow suggesting volcanic origin. The size frequency distribution is shown in figure 3. Most of the spherules lie in the range of 40 to 100 μm . Some of the spherules were mounted on Al-disc using double sided tape and coated with Au-Pd for SEM studies. Surface structure of a spherule is shown in figure 4. The chemical analysis of the spherules obtained by a Kevex Si(li) detector attached to the SEM is given in table 2. Absence of Ni which is characteristic of meteoritic iron in any of the spherules studied indicates that none may be definitely extra-terrestrial in origin. However, some authors (King and Wagstaff 1981) consider FeS and FeO spheres as extra-terrestrial. In such a case five of the 35 spherules which are compositionally magnetite could be assigned to extra-terrestrial category. Other spherules with Si-Mn-Fe composition might also be extra-terrestrial in origin. Some other particles having compositions Si-Al-S and Si-S-Ti-Cr-Fe seem to be volcanic in origin. Compositions of most of the other spherules having varying compositions and combinations of Al-Si-Ca-Ti-Mn-Fe-K-Mg also indicate volcanic origin or these might be terrestrial contaminants.

The identification and collection of interplanetary dust is an important problem and

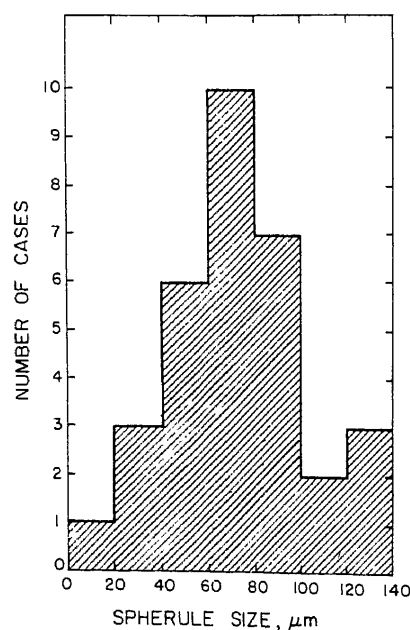


Figure 3. Size frequency distribution of spherules.

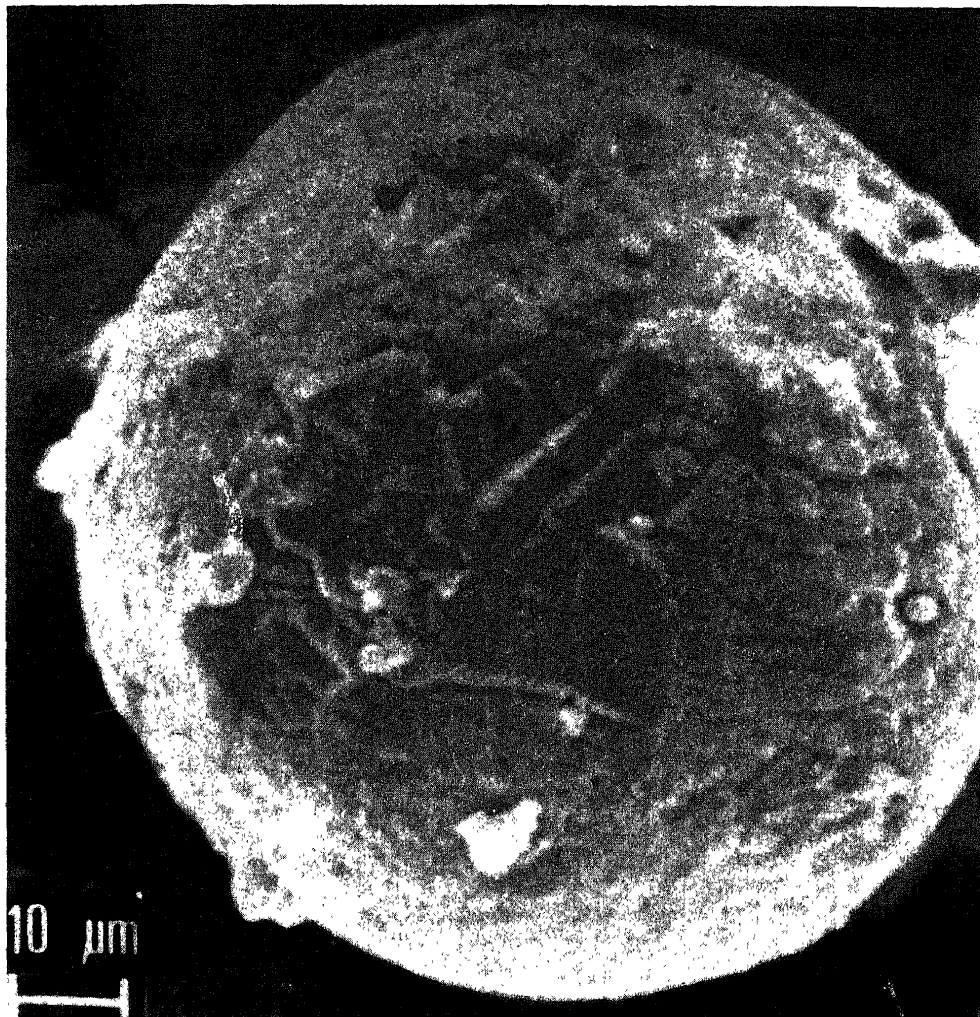


Figure 4. SEM microphotograph of a spherule type 2 from the bulk ice sample showing surface structures.

considerable efforts have been made to collect the dust in the stratosphere by balloons (Bhandari *et al* 1968), aircrafts (Blanchard *et al* 1980) etc. Antarctic ice presents a simple opportunity of collecting the interplanetary dust since the terrestrial contamination is minimum there (King and Wagstaff 1981). Although the present results are not unambiguous, if a clean collection is carefully planned, significant amounts of interplanetary dust can be collected from Antarctic ice.

Acknowledgements

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Table 2. Chemical type of spherules and their frequency.

Type	Elements present	Number of spherules
1	Si	1
2	Fe	5
3	Si, Fe(++)	2
4	Mn, Fe(++)	1
5	Si, Mn, Fe(++)	1
6	Si, Ti, Fe(++)	2
7	Si, Al, S(++)	1
8	Al, Ti, Fe(++)	1
9	Ti, Mn, Fe(++)	2
10	Si, Ti, Mn, Fe(++)	5
11	Si, Al, Mn, Fe(++)	1
12	Si, Al, Ti, Fe(++)	1
13	Al, Ti, Mn, Fe(++)	2
14	Ca, Ti(++), Mn, Fe(++)	1
15	Si, Al, Ti, Mn, Fe(++)	3
16	Si, S(++), Ti(+), Cr, Fe	1
17	Si, Ca, Ti, Mn, Fe(++)	1
18	Si, Al, Cl, Mn, Fe(++), Ti	1
19	Si, Al, Ca, Ti(++), Mn, Fe(++)	1
20	Si, Al, Mg, Ti(++), Ca, K, Mn, Fe(++)	1
21	Si(++), Mg, Al, Ca, Ti(++), Mn, Fe	1

(++) indicates the major signal. For types 19 and 21 Ti signal > Fe.

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