Glaciological Studies During the First Indian Antarctic Expedition

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ABSTRACT

A large number of horizontal, tilted and overturned icebergs were observed during the First Indian Expedition to Antarctica. Their estimated thickness trend from a few metres to over 200 m. Examination of the pack ice and the ice shelf around the base camp indicated the altitude of the latter as 44 m. Experiments using carbon black gave average results of ice melting as 35.8 mm/day (19.7 mm water equivalent). Average natural melting was observed as2.6 mm/day (1.4 mm w. cqv.). Studies of the ice core samples show the presence of nuclear debris. Cosmogenic 7Be occurs at levels of 30 dpm/L. The vertical profile of D in the 6 m long core range between - 130 to - 180‰. No systematic trend 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 suggest that most of them are of volcanic or industrial origin.

The work carried out during the First Antarctica Expedition included the following:

1. Nature of icebergs sighted during the voyage.
2. Observations on the calving processes, wind erosion and general glaciological features.
3. Measurement of ice melt and its artificial augmentation.
4. Study of ice cores.

ICE BERGS

The first ice berg was noticed on the way to Antarctica at 58°50'S.: 45°20'E. On first of January 1982 a very large ice berg which extended upwards for 85 m was seen at 59° 10.3' S : 45°01.8'E. Considering the specific gravity of Antarctic ice as 0.6 the total average thickness of the ice would be around 170 m. In case the average specific gravity of a thick ice glacier is about 0.72, the average thickness would have been much larger i.e. 212 m. The ice berg had floated away to about 11° of latitude towards north from its breaking point. A majority of ice bergs were horizontal, a few were tilted, and all of these were of lesser thickness than the one mentioned above. The very small sized floating ice was not too easy to notice but was observed on many occasions.

The following are the locations of major icebergs along the way in and on the way out.

	On the way in		On the way out	
1.	58°50'S	45°20'E(H)	57°32'S	29°87'E
2.	59°10.3'S	45°01.8'E(H)	59°00'S	27°30'E (H) (H) (H)
3.	59°52.6'S	44°35.4'E (H) (T)	61°38'S	24°44'E
4.	60°36'S	44°09.5'E(H)	61°45'S	24°35'E (O) (H)
5.	61°21.7'S	44°44.2'E(H) (H) (T)	62°01'S	24°17'E
6.	62°07'S	43°16'E (H)	62°25'S	23°38'E (H)(H)
7.	62°51'S	42°45'E(H) (H)	62°37'S	23°33'E(H)
8-	63°37'S	42°13.6'E (H)	68°01.3'S	13°40'E
9.	64°22.3'S	41°44'E(T)		
10.	65°06'S	41°15'E(H) (H)		
11.	65°52.4'S	40°41'E(H) (H) (H)		
12.	66°38'S	40°11.8'E (H)		

Note: (H) = Horizontal, (T) = Tilted and(O) = overturned.
In some locations more than one iceberg was observed.

In addition there were several icebergs in the calm blue waters between the coast and the pack ice in the landing area (69°59'S 11°54'E). These formed a very long, deceptive looking front about 10 km off the present coast line. These were most probably and effectively stopped from drifting further afield by an underwater rise. The water at the rise was about 100-150 m deep while further inside it was 150-200 m deep. Most of the ice bergs here were horizontal but some were tilted and a few seemed to have suffered

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erosion on the top face loosing their tabular character altogether. These icebergs belonged obviously to more than one generation and had drifted to shallower zone and accummulated in a manner somewhat akin to the pack ice to provide a scene of intense grandeour and beauty.

PACK ICE

0The pack ice is formed of thinner tabular ice masses which are several metres across and generally 1-3 m thick. Near the junction of the pack ice and water individual ice floes are separated by water and are of relatively small size. Away from the water's edge the ice floes are packed more tightly and the water between them is frozen near the surface. The pack ice then assumes the character of a unified sheet with major cracks (sometimes sealed by refreezing of water or by ice slush) developed due to the swell of underlying water. There are many potholes in the floes, which appear to be work of seals and perhaps penguins who use the ice platform for basking and diving for fish through these holes. Quite a significant population of seals and penguins live on the pack ice. Certain patches within the pack ice have more water and provide open space for the passage of ships. Often these are enclosed patches with more firmly packed ice around. Sometimes these may join to provide 'leads'. These were useful for finding a way through the pack ice area for achieving the landing.

ICE SHELF

The ice shelf formed a continuous ice cliff at its junction with sea. As it is continuously breaking off, often facilitated by long tensional cracks in the ice shelf, into large angular blocks, it has many bays of different sizes. The bays are also frozen but with ice only 1-3 m thick which breaks and floats off during the summer adding to the pack ice offshore. The tensional cracks extend 1-2 km into the ice shelf but become open and wide near the water's edge, with thinner ice at the bottom, sort of 'gullies' leading to the ocean. The ice shelf which is a flat table land, about 50m above sea level except for domes where it rides basement highs, sloped gently towards the water edge for about half a kilometre and then more abruptly it seems to arch towards the water for a few metres so that its lip is only 3-5 m above the water. Where it is broken, the recently arched part is missing and the cliff has a sharper edge and stand out higher. Often the 'arched' ice edge is already separating from the main ice mass by a continuously widening crevasse or a series of crevasses. The altitude of the ice shelf was 44 m near the camp (69°59'12" S; 11°55'09"E).

Wind erosion on the ice shelf is fairly strong and long grooves several centimetres deep and tens of centimetre across are etched ubiquitously on it. Melt water channels are as a rule absent from the ice shelf but were seen well developed into a drainage system in the area adjoining the slopes of the "Oasis Mountain". This indicated running surface melt in this area for at least several years during the summer months. The drainage is towards the junction of ice shelf with the 'Oasis' slopes where obviously it finds its passage (underground ?) to the sea below. Surface water in this tract is a common feature hindering movement of tracked vehicles during the summer months. It seems to be related to excessive melting in this area and may, if it continues long enough, lead to eventual detachment of the floating ice from the continental glacier/ice cover.

Photographic evidence of the various features described above and the various stages of calving of the ice shelf were collected and will be reported later. This area deserves greater attention for detailed glaciological studies.

MELTING RATES OF ICE ON ANTARCTIC ICE SHELF AND EXPERIMENTS IN AUGMENTATION OF MELT

The melting rate of ice was measured near the Camp on the ice shelf with the help of a network of stakes fixed in the ice. A contiguous plot, with a similar network of stakes, was treated with carbon black sprinkled uniformly by hand to record (i) the increase in absorption of short wave solar radiation and (ii) the increase thereby of the melting rate of ice. Air temperature, wind velocity and cloudiness were measured along with the stake readings. The data are presented in Fig. 1 and Tables I & II.

TABLE 1

Radiations, in Langley/Min

Date	Time(IST)	Direct	Global	Reflected (Ice)	Albedo	Reflected (Treated ice)	Albedo
11.1.82	0830	0.913	0.192	- 0.173	90.1%	—	---
	1130	0.985	0.519	0.433			
	1430	1.196	0.721	0.558			
	1730	1.260	0.769	0.654			
	1930	1.276	0.692	0.481			
" 12.1.82	1130	— .	0.308	0.288			
	1430	—	0.538	0.461			
	1730	—	0.615	0.500			
	2210	—	0.269	0.231			
13.1.82	1200	1.107	0.461	0.442	95.9	0.221	*473*
	1430	1.236	0.702	0.529		0.298	
	1730	1.171	0.644	0.548		0.260	
	2030	1.204	0.567	0.385		0.279	
14.1.82	1030	—	0.154	0.135		0.115	
	1200	—	0.269	0.211		0.173	
	1430	—	0.423	0.327		0.240	
	16.00	—	0.461	0.365		0.288	
	1730	—	0.442	0.356		0.250	
	2030		0.221	0.183		0.135	
15.1.82	1130		0.211	0.163		0.135	
	1230	—	0.231	0.183		0.115	
	1430	—	0.346	0.269		0.192	
	1730	—	0.471	0.375		0.231	
	1830	—	0.538	0.433		0.279	
	1930	—	0.452-	0.356		0.202	
	2030		0.240	0.202		0.115	
16.1.82	1530	0.547	0.634	0.490		0.260	
	1730	—	0.481	0.404		0.250	
	1850	—	0.481	0.385		0.250	
	2030	—	0.346	0.231		0.135	
	2200	—	0.250	0.192		0.135	
	2330	0.388	0.231	0.183		0.106	
17.1.82	0100	0.695	0.202	0.135		0.087	
	0830	—	0.115	0.106		0.058	
	1130	—	0.211	0.163		0.125	
	1230	—	0.269	0.240		0.154	
	1430	—	0.481	0.404		0.231	
	1330	—	0.606	0.433		0.288	
	2030	—	0.423	0.346		0.192	
	2200	1.001	0.442	0.336		0.192	
	2330	0.969	0.221	0.183		0.106	
18.1.82	0515	0.315	0.038	0.029		0.019	
	0830	0.695	0.250	0.231		0.154	
	1130	—	0.231	0:173		0.115	
	1300	1.002	0.577	0.452		0.250	
	1400	1.155	0.586	0.500		0.317	

TABLE 2

Meteorological observation at base station, Antarctica

Date	Time IST	D. B. °C	W.B. °C	Wind Speed/ Dir. km/hr.	Cloudiness Fraction of 8 octa	snow surface Temp. °C
11	0830	—6.2	—	05/145	1	—
	1130	—3.8	—	10/120	2	—
	1420	0.0	+ 0.5 W.F.	18/120	2	—
	1730	—1.7	+ 0.2W.F.	24/120	1	—
	1930	—0.5	0.0 W.F.	25/110	1	—
12	1130	—1.5	+ 0.5 W.F.	08/135	7	—
	1430	—0.9	—1.4	10/120	7	—
	1730	—0.8	—1.2	10/120	6	—
	2210	+ 1.0	0.4	Calm	7	—
13	1200	—2.7	—2.4	Calm	1	—2.0
	1430	+ 0.7	+ 0.5	Calm	1	
	1730	—0.1	+ 0.5 W.F.	Calm	1	
	2030	+ 0.5	+ 0.3	08/260	2	—
14	1030	—2.7	+ 0.5 W.F.	06/330	7	—
	1200	—3.1	—2.8 W.F.	06/030	8	—2.7
	1430	—2.1	—1.8 W.F.	08/070	8	—1.8
	1730	—2.5	—1.7 W.F.	18/090	8	—2.0
	2030	—2.2	+ 0.5 W.F.	14/090	8	—
15	1130	—3.8	+ 0.5 W.F.	12/120	7	—
	1430	—2.8	—0.5 W.F.	12/120	7	—0.3
	1730	—1.2	—0.2 W.F.	14/120	7	—
	2030	—0.5	—0.7 W.F.	18/135	7	—
16	1530	+ 0.8	+ 0.5	Calm	6	+ 0.8
	1730	+ 2.5	+ 1.2	08/250	6	+ 0.8
	2030	0.0	—1.2	05/250	5	—
	2330	—2.2	—2.4 W.F.	Calm	3	—
17	0830	—5.5	—5.8 W.F.	Calm	6	—5.2
	1130	—2.8	—3.0 W.F.	Calm	6	—2.3
	1430	0.0	—1.7	Calm	7	—
	1730	1.0	—0.87	Calm	6	—
	2030	0.5	—0.8	04/260	6	—
	2330	—2.0	—2.6 W.F.	04/225	1	—
18	0515	—7.0	—6.2 W.F.	10/250	0	—
	0830	—1.0	—1.2 W.F.	18/260	5	—
	1130	—1.5	—2.1 W.F.	18/260	5	—
	1430	—0.1	—1.2	18/250	3	

W. F. — Water Freezed.

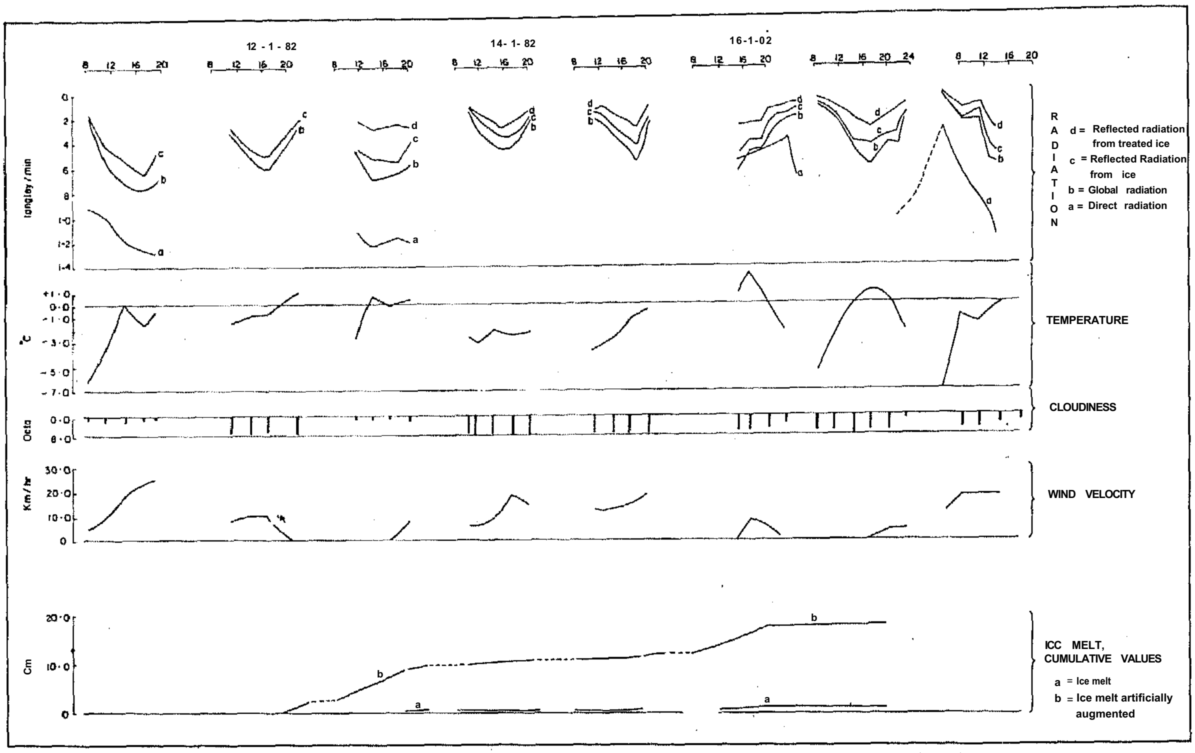

Fig. 1 : Artificial augmentation of melting rate of ice and related meteorological parameters at the case camp, Antarctic ice shelt.

Wooden stakes were inserted at 5 m intervals so that these are located at the centre of a square with five metre long sides. A plot covering three rows of four stakes was treated moderately with carbon black and an untreated area with two rows of four stakes each served as a 'test plot'. The melting at each stake was recorded after about twenty four hours. The data are given in Table 3. The sky was clear to begin with but became cloudy later with short periods of clear sky. It snowed lightly during the night of 13-14 Jan. '82 and a layer of about 2 mm snow was recorded. The wind often brought the snow on to the plots and this was more evident near the edges of the treated plot and was responsible for negative readings (accumulation) on some stakes. During cloudy periods the artificial augmentation was low but increased dramatically when the sun came out for any length of time.

TABLE 3

Reading ofstake net-work (in mm)

Stake No.	12.1.82.	13.1.	14.1.	15.1.	16.1.	17.1.82.	
A —1	0.0	8	9.5	12.5	18.5	19.5	
2	0.0	8	10.5	10.7	17.5	18.1	
3	0.0	8	8.0	8.7	12.8	13.0	
B —1	0.0	9	10.5	10.6	18.8	20.2	*Treated*
2	0.0	8	7.5	7.5	19.0	20.0	*plot of*
3	0.0	9	11.0	13.5	14.0	14.5	*ice*
4 .	0.0	10	13.0	13.0	17.5	18.2	

TABLE 3 (Contd.)

Stake No.	12.1.82	13.1	14.1	15.1	16.1	17.1.82.	
c — 1	0.0	9	9.75	10.75	15.0	15.2	
2	0.0	7	11.0	11.5	20.5	21.4	Treated
3	0.0	8	8.3	10.5	16.5	16.8	plot of ice
4	0.0	10	12.5	12.8	16.5	16.8	
a. 1	0.0	1.0	0.5	1.0	0.4	0.4	
2	0.0	0.5	0.5	0.7	0.6	0.6	
3	0.0	0.2	0.3	0.7	1.4	1.4	Untreated
4	0.0	0.4	0.6	0.5	1.4	1.4	plot of ice
b. 1	0.0	0.5	0.2	0.2	0.7	0.7	
2	0.0	0.2	0.2	0.2	0.7	0.7	
3	0.0	0.5	0.2	0.5	0.9	0.9	
4	0.0	0.2	0.4	0.4	1.9	1.9	

The following are the average daily melt/figures on the two plots.

12-13.1.82		13-14.1.82		14-15.1.82		15-16.1.82		16-17.1.82	
85.4	4.5	18.6	1.3	10.2	1.0	58.2	6.0	6.4	—

(figures in mm)

The variation from one day to the next, as may be seen above, is substantial. In the treated plot, the ice became highly porous and fragile and its surface very uneven after the first 24 hrs. The w. eq. of melt on subsequent days was therefore difficult to work out for day to day comparison. The ice density in the area varies from 0.55 to 0.57 down to 60 cm depth. The top 20-22 cm was wet and crystalline (2 mm crystal size) showing more refrozen layers while the lower part was granular ice with fewer refrozen ice layers. As will be clear from Table 3 the melting rates recorded at different stakes were not uniform, because of the factors mentioned above. The total average natural melting for five days of observation was 12.9 mm i.e. about 2.6 mm/day (1.4 mm of w. eq.) while the total average melting in the treated plot for the same five days was 178.8 mm i.e. about 35.8 mm/day (19.7 mm of w.eq.). The maximum total melting (214 mm) was recorded by stake No. C 2 and minimum (130 mm) by stake No. A 3.

The effect of darkening the glacier surface to augment ice melt in Antarctica is more striking than in the Himalayas. Considering that the total annual precipitation in Antarctica is less than a metre the melting by darkened surfaces has very large possibilities of melting off several years accumulation in one summer.

The melt water did not flow away in any channel but appeared to percolate downwards into ice itself and may have refrozen in the lower colder ice strata.

PRELIMINARY RESULTS OF SCIENTIFIC STUDIES OF ANTARCTIC ICE SAMPLES

A hand-held ice coring auger was used for obtaining ice-core samples from shallow depths. Two samples were obtained, one (4m length) from near the camp (69°59'12"S; 11°55'09"E) and the second (6m length) about 8 km of the Camp on Lazarev Ice Shelf, Antarctica.

These were packed in convenient lengths in alkathene tubing and stored aboard ship in a deep freeze. The ice in some sections was granular, sand like or powdery and was difficult to preserve along with core at relative position. Special tubings will be necessary for taking care of this problem in future.

Stratigraphic and age determination studies are important to find out the accumulation rates and past variaton in these, isotopic composition of oxygen and deuterium can be used for deciphering the temperatures of precipitation. Chemical composition of ice and the study of dust/debris in ice yield important environmental data. The present effort constitutes preliminary investigations on some of the above problems.

Surface and drill core samples of ice were collected during Jan-Feb. 1982. These samples were brought back in frozen condition to Goa and then transported to the Physical Research Laboratory, Ahmedabad. A series of scientific experiments were carried out on these samples. Some preliminary results obtained so far are discussed here.

Two bulk and two core samples were available for the present study. The bulk samples called ANB and ANC were approximately 20 and 10 litres of ice respectively. The two core samples consisted of several 20-50 cm sections of about 5 cm diameter going to 6 and 4 metres depth respectively. These are labelled as Core 1 and 2 respectively. One of the sections 2/5/C of Core 2 is shown in Plate 1 while it was being dissected for isotopic and chemical analysis.

Part of the samples were taken for various studies and the remaining samples have been preserved at about-10°C for future work.

The following studies are being carried out on these samples:

(i) Natural and bomb produced radioactivity in surface and core samples.
(ii) Search for extraterrestrial and volcanic spherules.
(iii) Isotopic composition of Oxygen and Deuterium.
(iv) Feasibility of dating Antarctic dust by thermoluminescence.
(v) Chemical composition of surface and core ice.

Natural and Bomb produced radioactivity in surface and core samples

In order to understand the accumulation and flow pattern of ice, it is planned to measure cosmic ray produced ^{10}Be, natural ^{210}Pb and bomb produced ^{137}Cs in surface and core samples. The peak deposition in core samples may correspond to individual explosions and can provide accumulation rates. Measurement of ^{10}Be and ^{137}Cs in some samples have been completed and summarised in Table 4. These measurements were made by a Hewlett Packard Germanium detector. The characteristics of this detector is described in detail elsewhere (Bhandari *et al.* 1982). The ^{10}Be activity, corrected for decay to the time of collection, roughly correspond to 15-30 dpm/L as expected for natural fallout in polar regions. The ^{137}Cs activity measured'in section 2/6/a is 0.6 ± 0.2 dpm/L. Its stratigraphy in core samples still remains to be measured.

Search for cosmic spherules

Cosmic dust particles constitute an important category of extraterrestrial material, although their identification on the earth is difficult because of large abundance of terrestrial material. Studies of these particles help us in understanding meteoroid ablation products, cometary dust and micrometeorite flux on the earth. Collection of such particles from the atmosphere has been difficult because of terrestrial contamination (Bhandari *et. al.* 1968). Recently it has been possible to collect such particles by flying aeroplanes at very high altitudes (~ 60,000 ft.) in the stratosphere. Brownlee and co-workers at Washington

University, Seattle have done pioneering work in this field and NASA is collecting such particles regularly. The Antarctic surface and ice core samples provide us with an alternative opportunity for collecting such particles as the problem of terrestrial contamination is minimised. This approach has been adopted in the past and recently King and co-workers at University of Houston, Texas, suggested that one should be able to see the cometary dust particle from a particular comet by examining specific ice cores from Antarctica. Keeping the above in view, we attempted to search for such particles in bulk ice sample from Antarctica brought during the First Indian Expedition. The procedure adopted is briefly described below.

TABLE 4

Natural and bomb produced radioactivity in surface and core samples.

Sample No.	Sample Volume (Litre)	Date of counting	^{10}Be (dpm/L)	^{137}Cs (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

Plate 1: Samples of core 2/5/c being taken for isotope and chemical analysis.

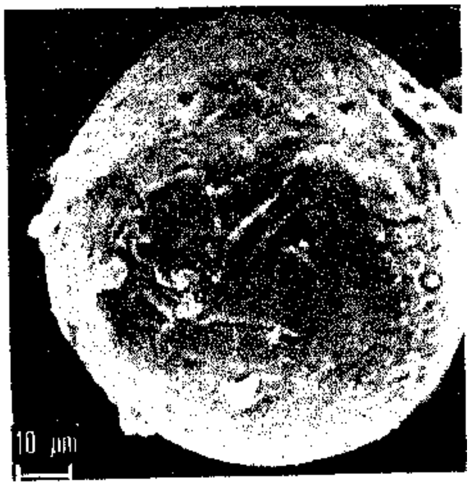

Plate 2 : SEM microphotographs showing surface structure of a type 2 spherule from the bulk ice sample.

As a preliminary investigation we took a chunk of visibly clean ice sample and allowed it to melt in a clean beaker in a semi-clean room. As terrestrial contamination is most serious in such studies we did our utmost to avoid it, although the conditions were far from satisfactory. The melted water (4.5 1) was filtered on millipore papers which after drying were examined under a microscope. A core sample from sample 2/6 was also studied in a similar way. Instead of studying all particles we confined this study to spherules only which, if extraterrestrial in origin, are meteoroid ablation products. The majority of the spherules are smooth, black, shining and perfectly spherical in shape. Some of these have less lustre and rough or pitted surface. Other spherules are hollow suggesting a volcanic origin. A typical spherule is shown in

Plate 2 suggesting volcanic origin. These spherules were mounted on A1-disc using double sided tape and coated with Au—Pd for Scanning Electron Microscope (SEM) studies.

The size frequency distribution is shown in Fig. 2. Most of the spherules lie in the range of 40µm to 100µm. These spherules may be from any one of the three sources viz. cosmic, volcanic and terrestrial (industrial). The qualitative chemical composition indicating the elements present is given in Table 5. Absence of Ni in all the spherules studied indicates that these may not be of extraterrestrial origin. However some authors consider (King *et al.* 1982) that Fe-S and Fe-O spheres are extraterrestrial. In which case five such spherules which are compositionally magnetite could be tentatively assigned to the extraterrestrial category. Another spherule with Si-Mn-Fe composition might also be extraterrestrial in origin. Some other particles having compositions of Si-A1-S and Si-S-Ti-Cr-Fe seem to be volcanic in origin. Compositions of most of the other spherules having varying combinations of Al-Si-Ca-Ti-Mn-Fe-K-Mg also indicate volcanic origin or these might be terrestrial contaminants. Thus out of 30 spherules about 6 particles have some possibility of being extraterrestrial in origin.

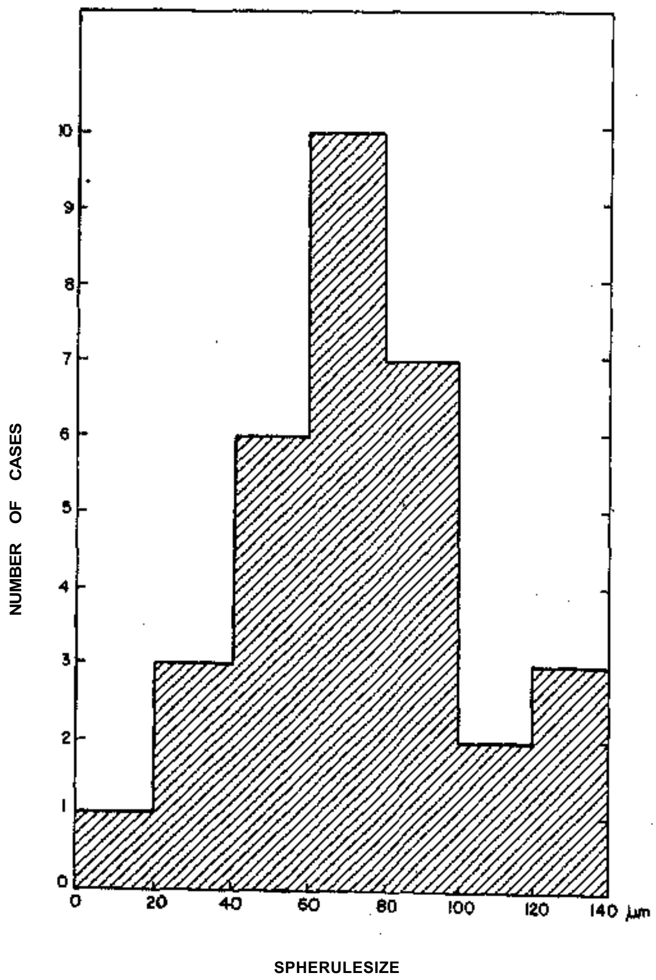

Fig. 2 : **Size distribution (µm) of cosmic spherules**

TABLE 5

Elemental composition of spherules and their frequency

Type	Elements present	Number of spherules	Remarks
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,A1,S(++)	1	
8	A1,Ti,Fe(++)	1	
9	Ti, Mn, Fe (+ +)	2	
10	Si,Ti,Mn,Fe(++)	5	
11	Si,A1,Mn,Fe(++)	1	
12	Si,A1,Ti,Fe(++)	1	
13	A1, Ti, Mn, Fe (+ +)	2	
14	Ca,Ti, (++),Mn,Fe(++)	1	
15	Si, A1, Ti, Mn, Fe (+ +)	3	
16	Si,S(++),Ti(+),Cr,Fe	1	
17	Si,Ca,Ti,Mn,Fe(++)	1	
18	Si,A1,Cl,Mn,Fe(++),Ti	1	
19	Si,A1,Ca,Ti,(++),Mn,Fe(++)	1	Ti signal > Fe
20	Si,A1.Mg,Ti(++),Ca,K,Mn,Fe(++)	1	
21	Si(++),Mg,A1,Ca,Ti(++),Mn,Fe	1	Ti signal > Fe

(+ +) indicates the major signal.

Isotopic composition of water

The isotopic composition of hydrogen has been measured in several samples from the 6 metre core using stable isotope mass spectrometer. Fig. 3 shows δD variation with depth. The δD values range between — 130‰ (in the surface sample ANC) to - 180‰ in core samples. There is no systematic trend seen with depth. The δD values are similar to those reported for King Baudouin base (78°26' S, 24°19' E) (Picciotto *et al.* 1960) but are significantly higher than the values found at South Pole (Epstein *et al.* 1965).

Thermoluminescence studies

Dust separated from the two Bulk samples was studied for thermoluminescence (T.L.). The natural T.L. levels in both the samples are about 1000 rads, much smaller than the geologic T.L. values. Using new techniques developed to determine sedimentary T.L. after its sun bleaching during windborne transport before deposition in the ice matrix, we find values of ~ 400 rads. Because of the small amount of sample available, more detailed studies could not be undertaken. But from the data it appears that the age of the ice can be determined from this value if annual T.L. dose rate is known.

It is hoped that on future expeditions larger (10^3 liters) samples under controlled conditions could be collected for T.L. studies and surface dose rate at the site can be measured which will enable us to date the samples. It should be possible to melt the samples at the site and filter through millipore filters to obtain 10-20 mg of dust from different depths of the polar ice cap.

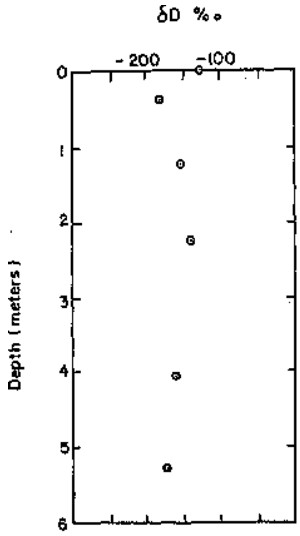

Fig. 3 .- δD profile in the ice-core samples

OTHER STUDIES

We also plan to measure the ionic composition of the ice samples. The chemical analysis could not be undertaken so far because the abundance of ions present is much below the present A. A.S. detection limit in almost all the cases. Special sampling and analytical techniques are planned, which in due course should enable these measurements to be made.

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