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GLACIOLOGICAL STUDIES DURING THE EXPEDITION

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ABSTRACT

Geological studies on shelf ice, polar ice tongue and icebergs were carried out on a routine basis as part of a long term programme of these elements. Some variations in the accumulation/ablation pattern over shelf ice are noticed during 1999 austral summer. A near steady state of recession of the snout of Dakshin Gangotri Glacier is indicated. The monitoring of icebergs in southern ocean was carried out between 45° and 70° south latitude on way to Antarctica and also during return voyage. The observations revealed that the maximum concentration of icebergs lies in two distinct zones separated by a less frequented area.

INTRODUCTION

The dynamics of ice shelves surrounding the Antarctic continent has a global significance particularly in connection with global warming, climatic circulation and changes on global sea level. A warming trend has been observed in retreat of ice shelves to a variable degree in different areas of the continent. This has kindled the interest of glaciologists world over in the dynamics of ice shelves surrounding the Antarctic continent. Keeping this in view Geological Survey of India is continuously monitoring the ice shelf in the Indian sector since the first Indian Antarctic Expedition. The studies carried out during the XVIII expedition involved

1. Monitoring of icebergs during onward and return journey.
2. Accumulation on the ice shelfthrough a network of stakes.
3. Glaciological studies along the shelf margin.
4. Monitoring of snout of Dakshin - Gangotri glacier.

Pattern Icebergs in the Indian sector

Icebergs constitute one of the important physical forms of ice around the Antarctic continent. The occurrence and distribution of icebergs influence the sea-water temperature which regulates the ocean circulation and indirectly affect global climate. Thus long term iceberg monitoring gives significant clues to monitor changes in global climate. Geological Survey of India has been monitoring the icebergs in the Indian

sector since 1985 under the International Iceberg Monitoring Programme. Observations on the occurrence, location, size and shape of the icebergs encountered along the onward and return journey are made following the guidelines prescribed by Norwegian Polar Research Institute. Table no.1 gives the details of observations made during the present expedition.

Table 1 Details of icebergs observed during XVIII Indian Antarctic Expedition.

Journey	Total no. of ice bergs	Size					Distribution (S latitude)			
		< 50m	50m to 200 m	200m to 500m	500m to 1km	>1km	50° to 55°	50° to 60°	60° to 65°	65° to 70°
Onward	213	32	65	74	32	to	1	35	88	89
Return	447	57	183	145	60	2	0	29	65	353

First iceberg was sighted on 5th Jan 1999 at 53° 51.06S latitude and 32° 24'.21 E longitude. The icebergs encountered during the expedition are calved from the shelf ice under the influence of dynamic ice-flow processes operating in the shelf region. Two well defined zones of concentration of icebergs were observed with a distinct iceberg free area in between (Fig la). The northern zone occurs between 57°S and 64°S while the southern zone lies between 67'S and 70°S. As soon as they are generated the icebergs start moving westward due to the Antarctic coastal current. This journey reverses at the convergence zone and the icebergs start drifting east due to the Southern Ocean Current (Fig lb).

Icebergs vary in size from few meters to few km in length. About 8/9th portion of the iceberg remains submerged below the water level and the remaining projects above. Most of the icebergs project 15 to 30 m above the water line. The size usually decreases away from the coast mainly due to melting and disintegration of the iceberg. Icebergs near the coast are usually tabular having flat tops and vertical walls (Fig. 2). Away from the coast, weathered icebergs showing varied shapes are more common (Fig. 3 and 4), Occasionally uneven in tilted icebergs, melting, wave erosion and wind cutting may destabilize an iceberg resulting in tilted icebergs.

Snow accumulation and ablation on ice shelf.

Antarctic ice shelves, covering an area of about 1.3-million sq.km act as an exoskeleton of the main continent. They not only protect but also bind and shape the continental ice sheet. Ice shelves are extension of continental ice, which is floating over the sea after crossing the main land. Ice shelves are floating slabs of land ice that

rise and fall with the ocean tide. The critical boundaries of an ice shelf are the grounding tine or hinge, where the glacier or ice sheet begins to float and the ice front where the shelf disintegrates in to ice bergs. There is a constant balance between processes adding to the volume of ice like ice flow from the continent, snow fall, bottom freezing and processes leading to loss of ice, like bottom melting and the calving of ice bergs. The stability of ice shelf rests on maintaining this equilibrium. Average annual precipitation on the Antarctic continent is less than 50 cm/yr. of water equivalent making it one of the driest regions on the Earth.

Measurement of snow/ice accumulation and/or ablation on ice shelf is an integral part of glaciological studies carried out by GSI. While eight stakes put in the earlier expeditions were completely buried and the rest of the stakes were at the verge of getting buried. It necessitated installing new stakes. A new network of stakes was fixed on 24th February 1999, during XVIII Expedition (1998-99). The present site is located near Dakshin Gangotri station (now buried) on the shelf ice. It is about 100m southwest of 'Sankalp" living module. The present site is selected in such a way that monitoring of stakes becomes convenient. It is 20 km away from the coastline in Indian bay region of Lazarev Ice Shelf area. A total of 16 wooden stakes were fixed in a rectangular pattern. The coordinates of stake no. 1 are 70^0 04.730'S Latitude and 12"00.320'E longitude at an altitude of 180ft above msl. The plot of stakes network covers an area of 2250 sq.m. Stakes have been fixed on an almost flat surface, free from any obstacle. The stakes were fixed by drilling a hole using hand auger up to a depth of 2ft and packing by snow. Pouring water to allow firm grip reinforced the stakes by freezing. Then stakes were numbered in spiral pattern, as shown in the layout (Fig 5), for future reference.

The exposed height of the stakes were recorded and are given in Table no. 2.

Table 2 New stake network as on 24th February 1999.

Stake No.	Exposed height (in cm)	Stake No.	Exposed height (in cm)
1	269	9	254
2	251	10	242
3	268	11	250
4	264	12	253
5	263	13	251
6	249	14	250
7	267	15	256
8	248	16	248

The observations were also made using the network of stakes fixed during the XV IAE and are presented in table 3.. Earlier studies have indicated a strong temporal (seasonal) bias in accumulation/ablation with higher accumulation and precipitation during polar summer (2.2gm/sqcm/month) and lesser (0.89gm/sqcm/month) during winter. The average annual accumulation was 18.71gm/sqcm during a period of four years i.e. Mar1990-94 (Beg et al,1997). A net yearly accumulation of 66.5cm of snow was recorded during Mar-96 to Mar-97 amounting to a net rise of 2.2cm in the shelf surface (Chaturvedi et al, 1999). On the basis of exposed height of the stakes the existing surface looks like the one given in fig 6. A net accumulation of 190cm has been recorded during the years 1996 to 1999 with maximum accumulation in the area north of Sankalp/porta cabin.

Table 3 Net accumulation/ablation in m [w.r.t. Feb 1996].

STAKE No.	Mar-96	Mar-97	Feb-98	Feb-99
1	0.000	-0.010	1.410	1.970
2	-0.030	-0.030	1.280	1.930
3	-0.020	-0.040	1.180	1.850
4	-0.020	-0.030		
5	-0.030	-0.030	1.160	2.000
6	-0.020	-0.040	1.180	1.890
7	-0.010	-0.020	1.240	1.760
8	0.000		1.300	1.960
9	-0.010	-0.010		
10	-0.020		1.360	1.900
11	-0.010			
12	0.000	-0.010	1.350	1.880
13	-0.020	-0.010	1.340	1.840
14	-0.030	-0.040	1.440	2.090
15	-0.010	-0.040		
16	-0.020	-0.040	1.160	1.890
17	-0.010	0.010	1.250	1.950
18	0.000	0.020		
19	-0.020	-0.030		
20	-0.040	-0.030	1.210	1.960
21	-0.010	-0.030	1.240	1.850
22	-0.010	-0.020		
23	-0.030	-0.020	1.290	1.920
24	0.000	-0.020	1.220	1.880
25	-0.030	-0.030	1.160	1.840

MONITORING OF SNOUT OF DAKHIN GANGOTRI GLACIER.

The ice sheet of Antarctica covers about 12 million sqkm and is a prominent feature of the continent. The complex interaction between atmospheric circulation and this large ice sheet plays a key role in modulating global climate. The status of the precise mass balance of the Antarctic ice sheet is difficult to calculate exactly due to the vastness of the sheet, which restricts adequate number of observations. Nevertheless, significant trends in the climate changes and their future implications can be made using local mass balance input. Thus, Geological Survey of India is continuously monitoring the changes in the Dakshin Gangotri Glacier snout (70°45'20"3 latitude; 10°35'05" E longitude) overriding the Schirmacher Oasis from south, since 1985 (Fig 7).

The Antarctic ice sheet is in a dynamic state. The ice flows from the centre of the ice cap towards the edge and flow lines converge in to main streams. The flow pattern is domal in shape. Drainage from the East Antarctic Ice Sheet is divergent primarily towards the coast. This combined with ablation due to melting at the surface and calving of the tongue may be responsible for the retreat of the DG glacier tongue.

The glacier tongue has shown continuous recession since 1983 with maximum area vacated at its northern flank. The area vacated by the receding tongue over 3 yearly periods between 1986-89 and 1989-92 has been calculated to the order of 2600 sq. and 2520 sq.m respectively. This movement of the glacier varies in magnitude and direction with time (Ravindra et al, 1994). An overall recession of 7m has been observed in the polar front during the decade 1983-1993, correspondingly, the area of the proglacial lake presented an increase of 550 sq.m. (Asthana et al., 1996). The outline surface of the snout is the result of essentially two dynamic processes, viz: advance and retreat. During the polar winter, the glacier advances northward due to accelerated flow regime. There is differential movement of the bottom layers and top layers leading to a bulging outward of the surface layers. Due to this transverse cracks develop on the surface and finally calving/gravitational collapse of ice blocks occurs. This results in a net retreat of the glacier front. The recession is further enhanced by melting during the summer months. An average annual recession of 105cm has been recorded during the period from 1996-97 (Chaturvedi et al., 1999.).

During the 18th expedition, the DG snout was surveyed with the help of Survey of India team in the month of Feb. 1999. The surveying was done with the help of E D M using the permanent survey stations 'G' and 'H' as well as the 15 reference points marked close to the periphery of the snout. All the measurement details along with the reference points are given in Table - 4.

Table-4

Reference point	Distance from Snout (in metres)		Retreat (in metres)
	Feb.1996	Feb.1999	
1	2.0	Covered	-
2	4.50	Covered	-
3	1.0	2.2	1.2
4	2.0	3.4	1.4
4A	2.00	2.85	0.85
4B	2.60	3.0	0.40
5A	1.20	1.92	0.72
5B	1.20	2.60	1.40
6	1.50	1.96	0.46
7	1.50	3.84	2.34
8	5.0	6.2	1.20
9	2.0	5.56	3.56
10	4.0	4.47	0.47
11	2.0	3.71	1.71
12	3.5	6.68	3.18
13	1.0	4.26	126
14	1.50	Covered	-
15	6.50	Covered	-

The present outline of the snout with respect to that of 1996 has been shown in Fig.8. Reference points 1 to 8 are on the eastern wall of the snout whereas points 9 to 15 are on the northern wall of the glacier. Observation shows that there is a differential recession along the periphery of the snout. The eastern side has recorded lesser recession as compared to the northern flank. The retreat thus recorded varies from minimum 0.40 metre to a maximum of 3.56 metres during a span of three years.

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References

1. Asthana, R. Gaur, M.P. and Chaturvedi, A. (1996) Notes on pattern of snow accu mulation/ablation on ice shelf and secular movement of Dakshin Gangotri glacier snout in central Dronning Maud Land, E. Antarctica. Rep XII IAE, D O D Tech. Publ.No. 10, PP 111-122.

2. Beg,M.J., Chaturvedi,A., D'Souza,M.J. and Asthana.R. (1997): Fluctuations in the surface profile of a part of ice shelf in Central Dronning Maud Land, E. Antarctica. Sci. Rep. XIII IAE, D O D Tech. Publ.No.] l,pp 221-226.

3. Chaturvedi,A., Amar Singh and Beg,M.J. (1999): Trend of depositional patterns on the ice shelf near Dakshin Gangotri Station. Sci. Rep. XV IAE, D O D Tech. Publ. no.13,pp313-320.

4. Chaturvedi, A., Amar Singh; Gaur, M.P., Krishnamurthy, K.V. and Beg, M.J. (1999). A confirmation of Polar Glacial Recession by monitoring the snout of Dakshin Gangotri Glacier in Schirmacher Range. Rep. XV I IAE, D O D Tech. Publ. No. 13 PP 321-335.

5. Ravindra, R., Dey, A., Beg, M.J. and KauL M.K. (1994) Observation on the snow accumulation/ablation over shelf and continental ice in parts of central Dronning Maud Land,E.Antarctica.Rep. IX IAE, DODTech.Publ.No. 6,PP 227-238.

EXPLANATION TO THE FIGURES

Fig. No.

1 .a. Zones of icebergs observed along the cruise line.

1 .b. Details of icebergs sighted during the expedition.

2 A large tabular iceberg drifting in open water.

3. Pyramidal iceberg with sharp crest and pinnacles.

4. Tabular iceberg under influence of wind and wave erosion.

5. Lay-out of stakes network fixed during the expeditions.

6. Shelf ice surface in 1999 Austral Summer (March, 1996 as base).

7. A view of the Dakshin Gangotri glacier snout.

8. Present outline of the snout delineated with respect to the 1996 margin. Arrow indicating net retreat in the snout margin.

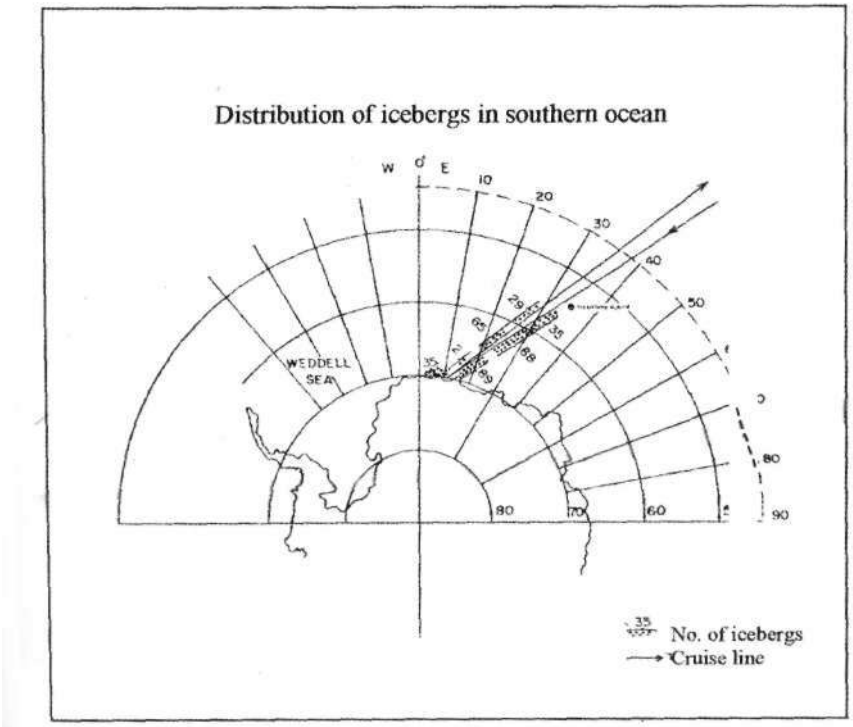


Fig 1a. Zones of icebergs observed along the cruise line.

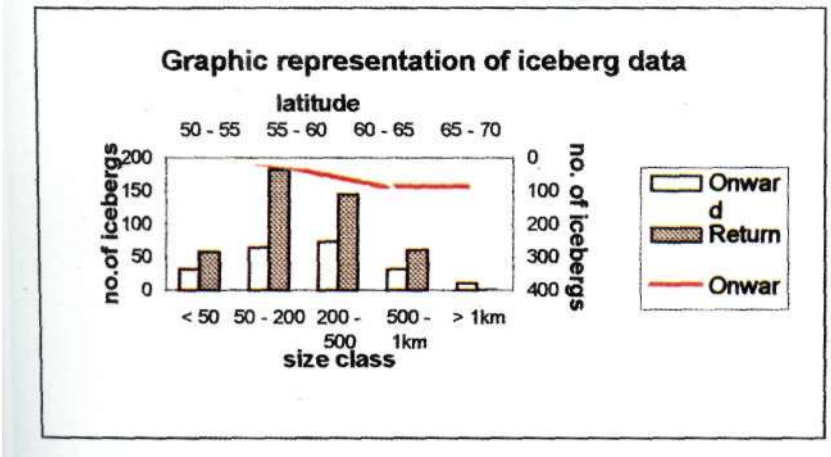


Fig 1b. Details of icebergs sighted during the expedition

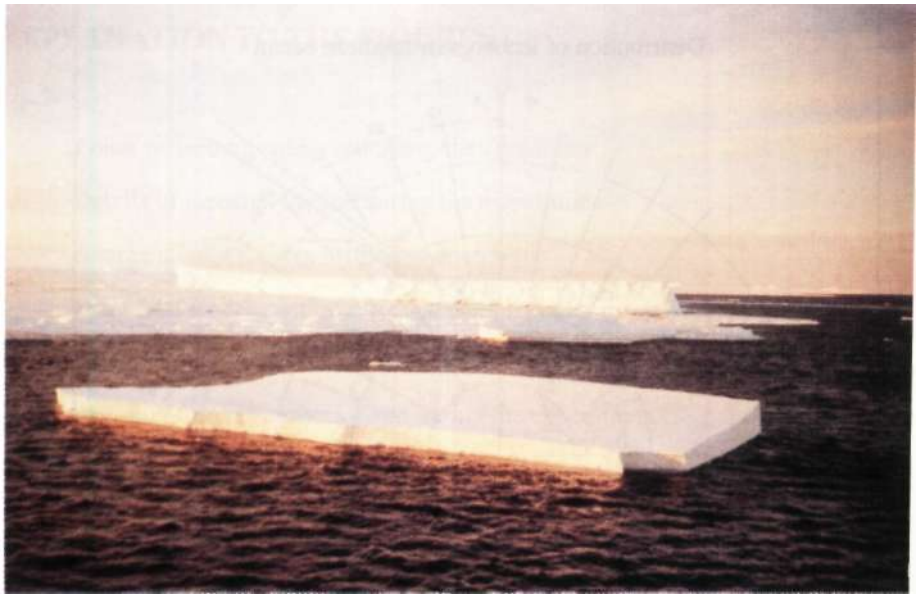


Fig.2

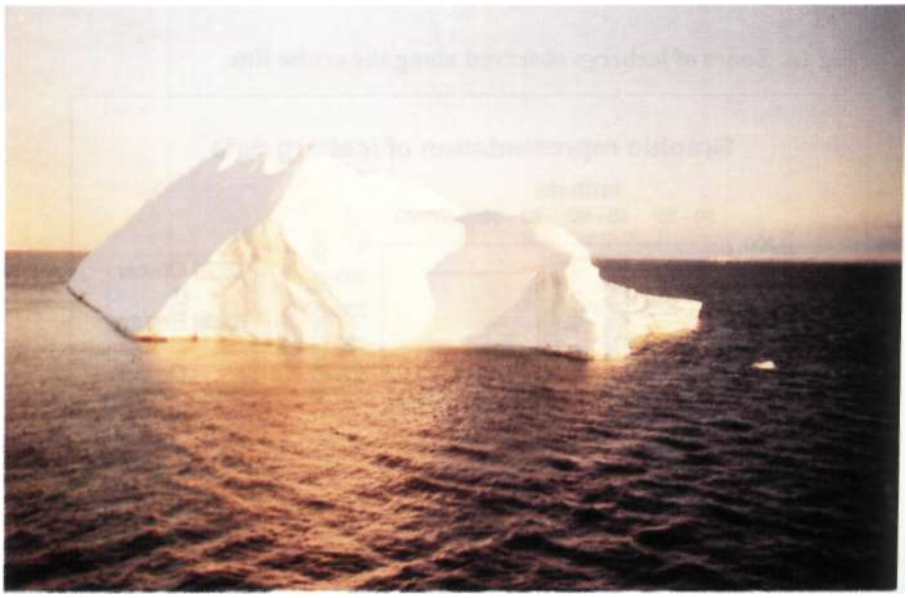


Fig. 3

Glaciological studies.

Fig.4.

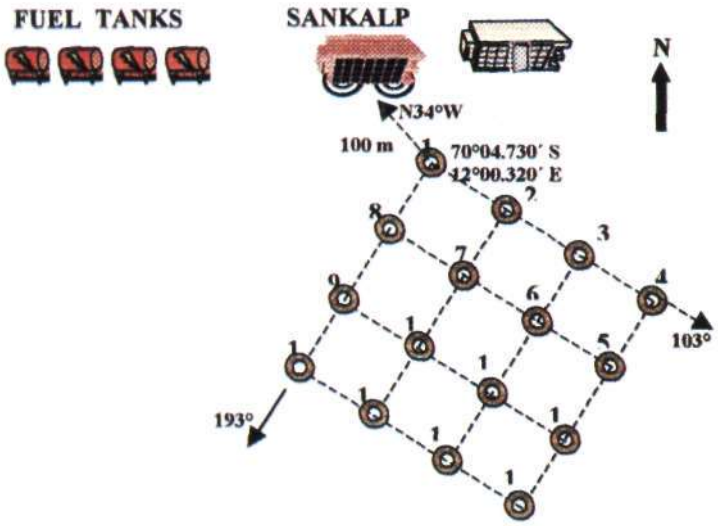


Fig 5. Layout of stakes network fixed during the expedition

Fig. 5

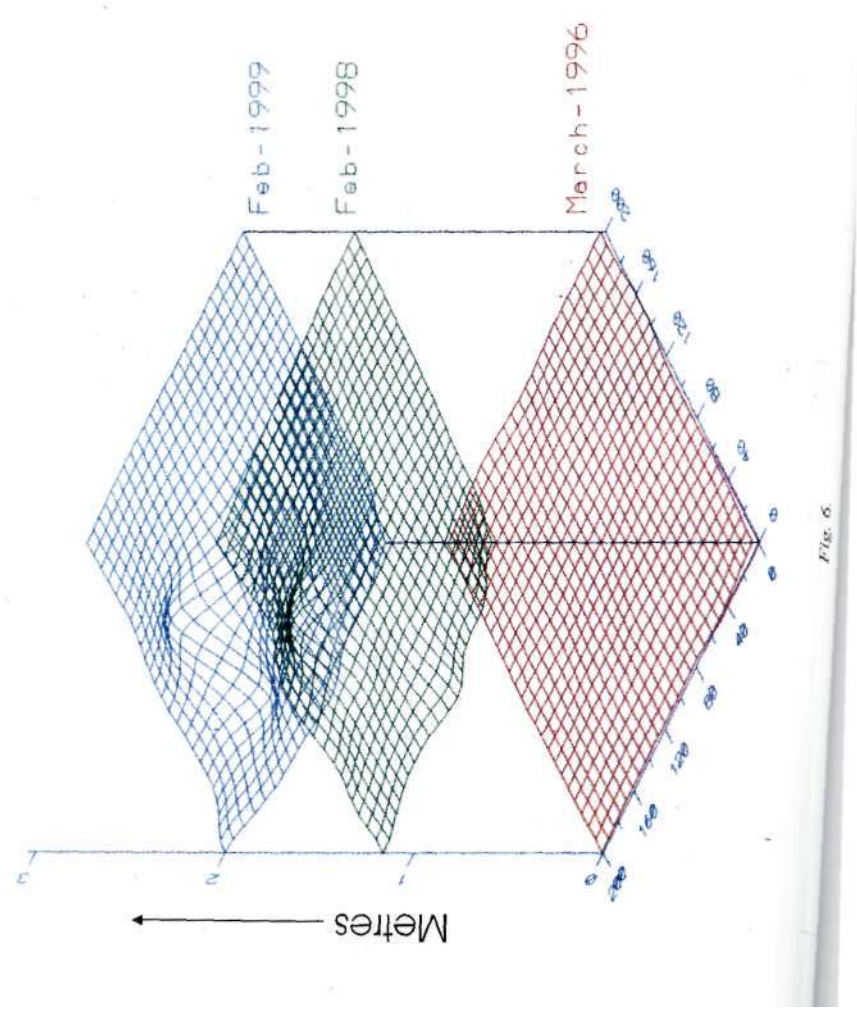
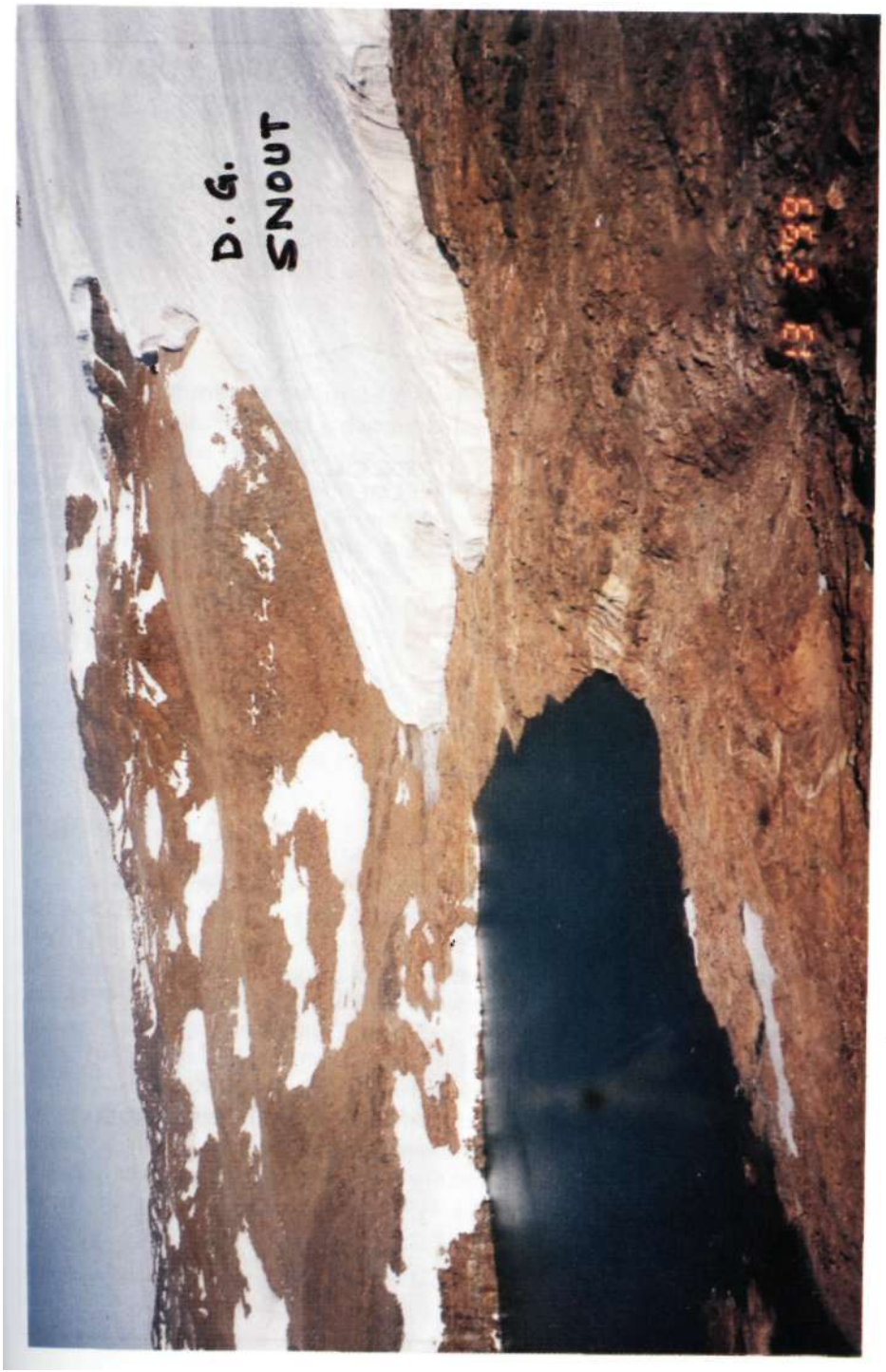


Fig. 6.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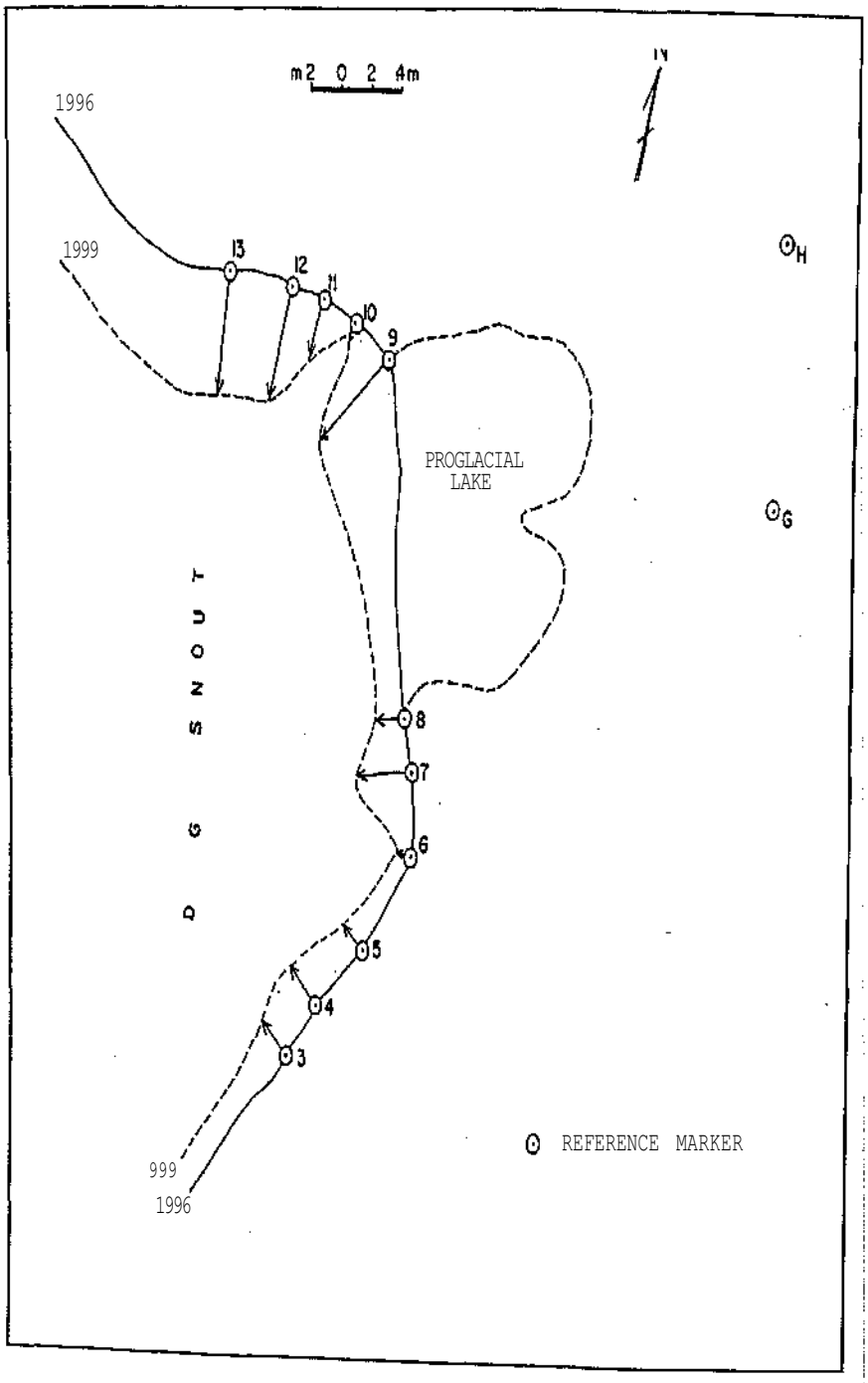
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