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First Attempt at Motorised Ice Core Drilling during the Antarctic Summer Season

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OBJECTIVES

In the 22nd Indian Antarctic Expedition, year 2002-03, GSI had sent **a** two-member team for Ice Core drilling work. For the first time, this was to be attempted during the summer season, as all the earlier operations of motorised Ice Core drilling were confined to the wintering period of previous expeditions. Moreover, the existing drilling machine was extensively upgraded by the suppliers in Japan, and this was to be the first field trial of various new sub-systems of the machine.

Additionally, another complementary work was planned. In the 15th expedition, about 160 m of Ice Core was generated from two boreholes. Since, at that time, no facility was available in India for the analysis of Ice Cores, it was decided to preserve this core in a frozen condition in Antarctica itself. This entire core was properly packed and lowered in an abandoned 'Hangar building' near old Dakshin Gangotri (DG) station on the Ice shelf. Over the years, this Hangar building was buried by wind-borne snow accumulations and was lost. It was a challenging task to locate this buried structure in the vast flat plains of the Ice shelf, then to precisely find out the entrance-shaft and finally to try to retrieve all the Ice Core. Thus, the assignments were as follows:

A. Transportation, positioning, assembling and installation of the new drilling machine at a suitable field site.
B. Test Drilling of the first borehole during the polar summer season and raising of ice core samples for the upcoming Ice-Lab **in** NCAOR.
C. Locating buried and lost DG station structures on the Ice shelf **and** retrieval of 160 m of Ice Core from DG Hangar building.

TRANSPORTATION & ASSEMBLING OF THE DRILLING MACHINE

The GSI team had carried out an initial testing of the machine at NCAOR in Goa during October 2002. This was done on ice-slabs ordered from the market! After a successful trial, each part of the drill was carefully labeled and packed for transportation. The drill was shipped to Cape Town in South Africa in a"cargo container and then loaded on to the expedition vessel.

At Antarctica in January 2003, the drill boxes were opened, taken out to the ship-deck and prepared as portable smaller under-slung loads for the helicopters. These loads were airlifted to Maitri station. It is worth mentioning here that the wooden box containing the mast of the drilling-rig was huge and unwieldy, but the helicopter pilots prepared a special double hook, added some additional loads to stabilize swinging mast, and transported it efficiently as an under-slung load.

At Maitri station, all these boxes were loaded in a container and with the help of a crane this container was mounted on a sledge. A field site was identified near Tallaksenvarden nunatak at 70° 51.383' South latitude and 11° 32.180' East longitude. This site was selected because in the 20^{lh} expedition, i.e. in 2001, a GPR-profile of Veteheia-Tallaksenvarden cross-section was given by WIHG. The container-sledge was towed to the field site by a snowmobile. In addition to the drilling container, one mobile camping module and one mobile generator unit were also positioned at this site. Four barrels of Aviation Turbine Fuel (ATF) were dropped at the drill site by helicopters.

In February 2003, the GSI team shifted to the camp. The altitude of the drill site was 680 m above the msl. Heavy loads like the winch-drum were opened up and earned out manually from the container. The drilling rig was installed. The assembling and fine-tuning of each sub-system of the machine took two days, and finally, the drill was ready for testing.

TEST DRILLING

Since there was no drilling shelter, the work had to be carried out in the open. At first, drilling was tried during the daytime. Though the working temperatures were cold enough, ranging from -7°C to -10°C during the day, the exposed drill barrels were getting heated up by the sunlight. This resulted in frequent jamming of both the barrels due to melting and refreezing of snow chips between them. The barrels could only be separated by taking them inside a heated chamber and melting the snow-bind. In the absence of any drilling shelter, this problem proved insurmountable and day-time drilling trials had to be given up.

After this, drilling was attempted during the night time. In February and March, the sun dips to lower angles and the time-slot available between dusk to dawn gradually increases from 4 hours to 8 hours. The machine worked better due to absence of direct sunlight and colder temperatures, ranging from -15° C to -20° C.

However, a new problem was encountered. Every day, around the time of sunset, cold katabatic (gravity) winds started blowing and continued till the sunrise. The force of the wind ranged from 50 to 70 km per hour and it always carried a heavy snow-drift. The working conditions at the drilling camp are shown in **Photo-1.** Besides exposing the field personnel to low wind-chill temperatures (up to -40° C), this snow drift was getting inside all the drilling accessories and panels.

Photo-1: The usual working conditions in the Drilling Camp

Since it was impossible to cover all the equipment against these heavy winds, all the control panels and accessories were shifted inside the drill-container. Now one person manned the control units sitting inside the container, while the other person stood out in the open, facing the winds and snow-drift, handling the drilling-rig. This difficulty was also solved by working in rotation. Thus, all the drilling work was carried out successfully during the night time only, amid heavy winds and snow drift.

Some other problems were also encountered during the test-drilling. The first was intermittent malfunctioning of the Winch Control Unit. Due to this, many times the motorized winch stopped working, while the drill was at the bottom of the borehole. Then it had to be lifted up manually, consuming a lot of effort and working time in those difficult field-conditions. At the end of the season, this malfunctioning unit was transported back to India for repairs. The other major problem was failure of the locking mechanism between the outer and inner drill-barrels. This interrupted the operations completely. It became necessary to fly-in a specialized kit from Maitri station to repair the defect. The vast practical experience of the second author in mechanical engineering was quite handy in diagnosing and repairing this delicate breakdown.

In addition to the daily snow-drift generated by the katabatic winds, two severe blizzards were also faced by the camping team. Each lasted for about four days and the wind speed exceeded 160 km per hour. The resultant snow-drift was so strong, that the team was confined to the living module only.

Fhotu-2. A view of Ice Core output before labelling and packing

DRILLING OUTPUT

The day-to-day progress of the drilling work, along with the details of sample-rolls, is given in Table-1. The core recovery was nearly 100%. The interruptions are caused by bad weather and mechanical problems. A view of the generated Ice Core, before labeling and numbering, is seen in **Photo-2.**

Table 1—Day-to-day Output of Ice Core Drilling Work

Date 2003	Roll Number	from cm	to cm	Roll length in cm	Total length in meters
12-Feb	R-l	0	50	50	0.50
12-Feb	R-2	50	100	50	1.00
12-Feb	R-3	100	152	52	1.52
12-Feb	R-4	152	202	50	2.02
12-Feb	R-5	202	249	47	2.49
12-Feb	R-6	249	299	50	2.99
12-Feb	R-7	299	311	12	3.11
12-Feb	R-8	311	361	50	3.61
12-Feb	R-9	361	410	49	4.10
12-Feb	R-10	410	459	49	4.59
12-Feb	R-ll	459	506	47	5.06
12-Feb	R-12	506	559	53	5.59
12-Feb	R-13	559	612	53	6.12
12-Feb	R-14	612	647	35	6.47
13-Feb	R-15	647	680	33	6.80
13-Feb	R-16	680	710	30	7.10
14-Feb	R-17	710	738	28	7.38
14-Feb	R-18	738	791	53	7.91
14-Feb	R-19	791	841	50	8.41
14-Feb	R-20	841	895	54	8.95
14-Feb	R-21	895	939	44	9.39
14-Feb	R-22	939	984	45	9.84
14-Feb	R-23	984	1036	52	10.36

(Contd.)

Table 1—Contd.

14-Feb	R-24	1036	1089	53	10.89
14-Feb	R-25	1089	1143	54	11.43
14-Feb	R-26	1143	1191	48	11.91
14-Feb	R-27	1191	1236	45	12.36
14-Feb	R-28	1236	1289	53	12.89
14-Feb	R-29	1289	1343	54	13.43
14-Feb	R-30	1343	1392	49	13.92
14-Feb	R-31	1392	1400	8	14.00
14-Feb	R-32	1400	1446	46	14.46
14-Feb	R-33	1446	1499	53	14.99
14-Feb	R-34	1499	1553	54	15.53
14-Feb	R-35	1553	1601	48	16.01
22-Feb	R-36	1601	1625	24	16.25
22-Feb	R-37	1625	1670	45	16.70
22-Feb	R-38	1670	1702	32	17.02
22-Feb	R-39	1702	1730	28	17.30
22-Feb	R-40	1730	1781	51	17.81
22-Feb	R-41	1781	1826	45	18.26
22-Feb	R-42	1826	1876	50	18.76
22-Feb	R-43	1876	1906	30	19.06
22-Feb	R-44	1906	1935	29	19.35
22-Feb	R-45	1935	1972	37	19.72
22-Feb	R-46	1972	1992	20	19.92
22-Feb	R-47	1992	2035	43	20.35
22-Feb	R-48	2035	2073	38	20.73
22-Feb	R-49	2073	2116	43	21.16
22-Feb	R-50	2116	2157	41	21.57
22-Feb	R-51	2157	2201	44	22.01
22-Feb	R-52	2201	2246	45	22.46
22-Feb	R-53	2246	2282	36	22.82

Table 1—Contd.

22-Feb	R-54	2282	2322	40	23.22
22-Feb	R-55	2322	2361	39	23.61
22-Feb	R-56	2361	2395	34	23.95
22-Feb	R-57	2395	2429	34	24.29
22-Feb	R-58	2429	2467	38	24.67
22-Feb	R-59	2467	2511	44	25.11
22-Feb	R-60	2511	2549	38	25.49
23-Feb	R-61	2549	2586	37	25.86
24-Feb	R-62	2586	2629	43	26.29
24-Feb	R-63	2629	2671	42	26.71
24-Feb	R-64	2671	2699	28	26.99
24-Feb	R-65	2699	2746	47	27.46
24-Feb	R-66	2746	2780	34	27.80
24-Feb	R-67	2780	2813	33	28.13
24-Feb	R-68	2813	2862	49	28.62
24-Feb	R-69	2862	2896	34	28.96
24-Feb	R-70	2896	2940	44	29.40
24-Feb	R-71	2940	2979	39	29.79
24-Feb	R-72	2979	3015	36	30.15
24-Feb	R-73	3015	3046	31	30.46
24-Feb	R-74	3046	3095	49	30.95
24-Feb	R-75	3095	3115	20	31.15
24-Feb	R-76	3115	3163	48	31.63
24-Feb	R-77	3163	3184	21	31.84
24-Feb	R-78	3184	3223	39	32.23
24-Feb	R-79	3223	3243	20	32.43
24-Feb	R-80	3243	3287	44	32.87
24-Feb	R-81	3287	3313	26	33.13
24-Feb	R-82	3313	3367	54	33.67
24-Feb	R-83	3367	3399	32	33.99

(Contd.)

Table 1—Contd.

25-Feb	R-84	3399	3445	46	34.45
25-Feb	R-85	3445	3488	43	34.88
25-Feb	R-86	3488	3537	49	35.37
25-Feb	R-87	3537	3585	48	35.85
25-Feb	R-88	3585	3638	53	36.38
25-Feb	R-89	3638	3687	49	36.87
25-Feb	R-90	3687	3720	33	37.20
25-Feb	R-9 1	3720	3737	17	37.37
25-Feb	R-92	3737	3784	47	37.84
25-Feb	R-93	3784	3834	50	38.34
25-Feb	R-94	3834	3864	30	38.64
25-Feb	R-95	3864	3912	48	39.12
25-Feb	R-96	3912	3938	26	39.38
25-Feb	R-97	3938	3982	44	39.82
25-Feb	R-98	3982	4035	53	40.35
25-Feb	R-99	4035	4056	21	40.56
25-Feb	R-100	4056	4101	45	41.01
25-Feb	R-101	4101	4141	40	41.41
26-Feb	R-102	4141	4193	52	41.93
26-Feb	R-103	4193	4245	52	42.45
26-Feb	R-104	4245	4292	47	42.92
26-Feb	R-105	4292	4343	51	43.43
26-Feb	R-106	4343	4359	16	43.59
26-Feb	R-107	4359	4411	52	44.11
26-Feb	R-108	4411	4463	52	44.63
26-Feb	R-109	4463	4513	50	45.13
26-Feb	R-110	45 1 3	4538	25	45.38
26-Feb	R-111	4538	4589	51	45.89
26-Feb	R-112	4589	4624	35	46.24
26-Feb	R-113	4624	4674	50	4*.74

(Contd.)

Table 1—Contd.

26-Feb	R-114	4674	4723	49	47.23
26-Feb	R-115	4723	4758	35	47.58
26-Feb	R-116	4758	4783	25	47.83
27-Feb	R-117	4783	4836	53	48.36
27-Feb	R-118	4836	4866	30	48.66
27-Feb	R-119	4866	4908	42	49.08
27-Feb	R-120	4908	4961	53	49.61
27-Feb	R-121	4961	4991	30	49.91
27-Feb	R-122	4991	5041	50	50.41
27-Feb	R-123	5041	5075	34	50.75
2-Mar	TL-1	5075	5122	47	51.22
3-Mar	TL-2	5122	5172	50	51.72
3-Mar	TL-3	5172	5232	60	52.32
3-Mar	TL-4	5232	5281	49	52.81
4-Mar	TL-5	5281	5331	50	53.31
4-Mar	TL-6	5331	5381	50	53.81
4-Mar	TL-7	5381	5431	50	54.31
Second Borehole					
8-Mar	TL-8	0	95	95	55.26
8-Mar	TL-9	95	144	49	55.75
8-Mar	TL-10	144	222	78	56.53
8-Mar	TL-11	222	308	86	57.39
8-Mar	TL-12	308	373	65	58.04
8-Mar	TL-13	373	450	77	58.81
8-Mar	TL-14	450	538	88	59.69
9-Mar	TL-15	538	620	82	60.51
9-Mar	TL-16	620	709	89	61.40
9-Mar	TL-17	709	788	79	62-19

In the first borehole, ice cores were raised up to a depth of 50.75 m. This marked the successful completion of the test drilling of the new machine.

After this, drilling was confined to the darkest period of the night for collecting ice samples for TL-dating work. About 3.5 m of TL-samples were generated from the bottom of the first borehole. Then this borehole was closed at a depth of 54.31m.

To collect some baseline samples, a second borehole was started just one meter away from the first one. In this, surface-level ice samples were generated for TL-dating. Again, this work was also confined to the darkest period of the night only. About 7.8 m length of TL-samples were raised from the second borehole. Thus, a total of 62.19 m of ice cores were generated during the summer season. The first borehole of 54.31 m depth was also utilized by scientists from Bhopal University for VLF-logging for Whistler-studies. VLF-data of two days' duration were collected from this borehole.

All the ice cores were cut into samples averaging 50 cm length. These were packed in double polyethylene rolls, labeled, covered with plastic food-wraps to secure the labeling and stacked in baskets. Each basket thus carried about 5 m of core, weighing around 40 kg. These baskets were airlifted under-slung by the helicopters and transported to containerised walk-in deep freezers of the ship. From Cape Town, these were shipped as frozen cargo to the Ice-Lab in NCAOR at Goa.

RETRIEVAL OF ICE CORE FROM DG HANGAR BUILDING

In the year 1997, 160 m Ice Core of the 15th expedition was packed in about 160 plastic baskets and lowered into a buried structure on the Ice shelf, called DG-Hangar. Even at that time, the floor of this building was 12 m below the shelf-surface and the top of the entrance shaft in the roof of the building was about one metre above the ground. During the intervening five years, even this roof shaft was buried, and thus, this Hangar building, along with the entire core, was practically lost in a white monotonous snow-desert.

This year, Dr Rajib Sinharay, a scientist from CWPRS-Pune, participated in the expedition and he carried a Ground Penetrating Radar (GPR) with him. The GSI team, along with Sh Ajay Dhar of IIG, took GPR-traverses with him for a detailed imaging of the sub-surface area at Dakshin Gangotri Ice shelf **(Photo-3).** The spacing between the traverses was gradually narrowed down, till a likely target zone was zeroed upon for locating the entrance shaft of the Hangar. A snow-vehicle with a front blade was engaged to remove the snow cover from this zone. After a day of extensive digging by the vehicle, the entrance shaft was finally located, about 2 m below the

Photo-3: GPR-traverses for locating the buried 'Hangar' building

surface **(Photo-4).** Though the ice core was found to be perfectly preserved, the Hangar building was found getting crushed by the movement of the Ice Sheet. On 17th March 2003, a large day-long operation was organized **(Photo-5),** which involved coordinated action of vehicles, ropes, pulleys, lighting, human-chains and helicopters. By the end of the day, the entire lot of 160 baskets of Ice core was shifted to the containerised walk-in freezers of the ship for transportation to India.

CONCLUSIONS AND RECOMMENDATIONS

1. The attempt to carry out Ice Core Drilling during the polar summer season was successful and the new sub-systems of the drilling machine have been tested.
2. In order to optimize the utilization of time during the short polar summer, it is necessary to have a Mobile Drilling Shelter, housing the machine inside, so that the work can be carried out at any time of the day. The designs for mobile drilling shelter have already been submitted to NCAOR by the GSI. In the absence of a shelter, as in the present conditions, the drilling operations are confined to the available hours of dusk and night time only.

Photo-4: The entrance shaft in the roof of the buried building

Photo-5: Retrieval of Ice Core from the buried building by a 'human-chain'

3. The lower the temperature, the better is the performance of the drilling machine. So by moving deeper inside the continent, into the mountain chains and the polar plateau, the output can be enhanced during the summer season.
4. Due to the absence of ECM or DEP type of field-logging equipment, a lot of information was missed in the field. These loggers should be part of the drilling accessories.
5. A mobile sledge-mounted generator (30 KVA) was borrowed from the convoy-team and it was vital for the drilling operations. The small field-genset (4.5 KVA) provided with the drilling equipment was insufficient to take up various tasks. The drilling team should have an ear-marked sledge-mounted generator for working in the interior parts of the continental glaciers.
6. The shipment of the Ice Core samples from Cape Town (South Africa) to Goa (India) has taken almost six months. The proper preservation of the Ice Core during this long transportation period is difficult to supervise. It is suggested that the Ice Core should be booked as a "Priority Frozen Cargo", so that it arrives at the Lab in Goa within two weeks of shipping from Cape Town.

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