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A New Approach for Bathymetric Survey in Antarctic Lake: A pilot study

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ABSTRACT

In order to assess the feasibility of carrying out the underwater geophysical survey in Antarctic lakes, a pilot study of the bathymetric survey in Priyadarshini Lake was launched using 'HydroBox'-a portable high resolution shallow water echo sounder, during the Silver Jubilee Indian Scientific Expedition to Antarctica (2005-2006). Shoreline demarcation of Priyadarshini lake was carried out by fixing a total of 104 closely spaced geodetic positions using Global Positioning System (GPS) while moving on the lake shoreline.Bathymetry survey of the lake along 1800 line meter was carried out and the data in digital and analogue forms were recorded.The data was processed and bathymetric map with three-dimensional view of the lake was prepared using ArcMap (version 9.2) software in the Geographical Information System environment.The analysis of the bathymetric map of the lake revealed an undulating lake floor with maximum water depth of 5.9 m recorded in the north-eastern part of the surveyed area of the lake. The bathymetric map of the lake further reveals comparatively steep slope towards the northwest portion of the lake with an average gradient of 1:22.

INTRODUCTION

The lake sedimentsof Antarctica have preserved a long history of climatic changes of this region. However, in order to retrieve the long sediment cores for high resolution paleoclimatic studies, the detailed information of water depths, lakefloor topography, sediments nature, etc., is very important. Such information can be retrieved through indirect methods using under water geophysical survey such as bathymetric and sub-bottom profiling. While the bathymetric profiling system (Echosounder) provides accurate water depths and topographic profiles of the floor of lake, shallow penetration high-resolution seismic systems (Sub-bottom profiler) provide an estimation of the distribution, thickness and stratigraphy of the sediments on or below the lake floor. These information assume significance for identifying ideal site for retrieving the long sediment cores from the lake (Chaturvedi and Khare, 2005). In view of this, during the Silver Jubilee Indian Scientific Expedition to Antarctica, a pilot project was launched to carry out detailed bathymetric and sub-bottom profiler survey and to prepare bathymetric and isopach map of the Antarctic lakes in order to identify the suitable locations to retrieve long sediment cores from these lakes to study paleoclimatic history recorded in subsurface sediments.

Carrying out the geophysical survey of Antarctic lakes in highly unpredictable and harsh climatic condition was a challenging task in itself. Adventuring in near freezing Antarctic lakes on a small boat with sophisticated and sensitive equipment posed a formidable task while acquiring data. However, as a modest beginning, the Priyadarshini lake, the largest and one of the deepest lake of Schirmacher Oasis, was selected for the pilot study. This paper presents details of acquisition, processing and interpretation of bathymetric survey of the Priyadarshini lake of Antarctica.

Study Area

The Schirmacher oasis in Antarctica is interspersed with more than hundred lakes (Ravindra et al., 2001). The permanent Indian Antarctic Station "MAITRI" is situated near the Priyadarshini lake in the Schirmacher Oasis in Antarctica. Priyadarshini lake, trending ENE-WSW direction, is one of the deepest lake in the Schirmacher Oasis (Figures 1a &1b). The Oasis presents a bed rock area elongated in a narrow strip around 17 km long and 3 km wide in west-northwest to east-southeast. Its relief is typically hillocky with the absolute marks up to 228 m. The general topography of the oasis is undulating with gentle sloping. The plain regions are covered with glacial moraine debris. The ice cover on the lake persists, in winter however, the ice melts in same lake during summer. Climate in the oasis is predominantly of continental characteristics. Much of the oasis area is characterized by the absence of continuous ice cover not only in summer but also in winter. The lake is perennially fed by the melting of the polar ice that stands all along the southern margin of the oasis as a fortress and drain out into smaller lakes in the north and finally onto vast ice shelf extending tens of kilometres up to the polynya. Sediments of the lake, therefore, archive the climate history of this lake and are vital for paleoclimatic reconstruction.

Fig. 1a: A panoramic view of Priyadarshini lake – the study area near Indian Antarctic Station "Maitri"

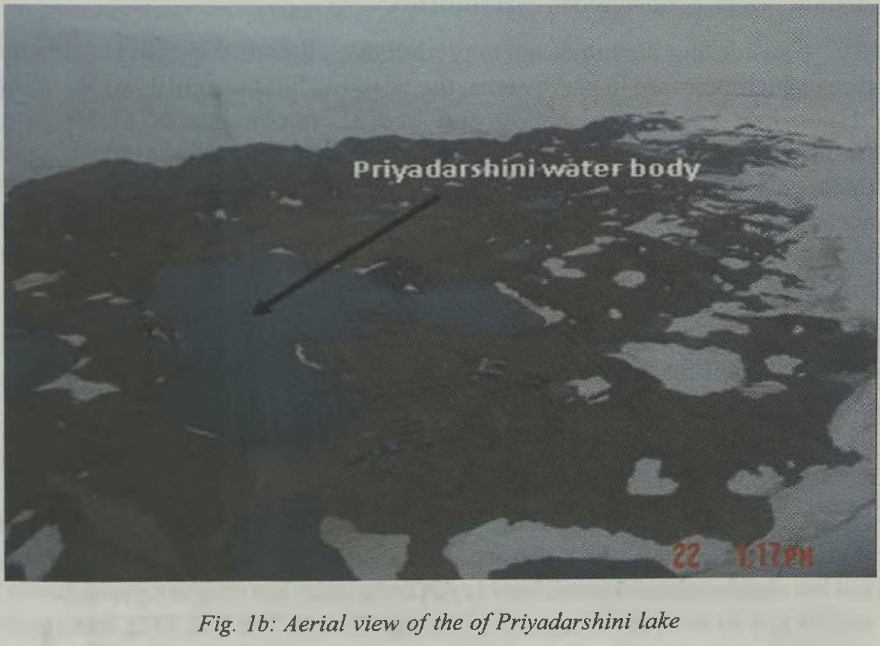

Fig. 1b: Aerial view of the of Priyadarshini lake

OBJECTIVE

As a beginning, the bathymetry survey was undertaken to determine water depth and sea floor topography to help define morphology of the lake floor.

Lake Shoreline Demarcation

Prior to the start of the bathymetric survey, the demarcation of the lake shoreline of the Priyadarshini Lake was carried out using hand held 'Etrax Garmin Global Positioning System (GPS)'. Study area being near to the polar region, the GPS system was receiving maximum satellite channels with high accuracy in the study area. The accuracy of the system was further confirmed with the Survey of India's established permanent control point near the lake. A total of 104 closely spaced geodetic positions were taken while moving on the Lake Shoreline all around the shore (Table 1) and boundary map of the lake was prepared. Once the demarcation of the shoreline of the lake was completed, the preparation for the bathymetric survey of the lake was initiated.

Bathymetry Survey

Bathymetry survey was carried out using a portable high resolution shallow water echosounder - 'HydroBox'.

Considering the harsh and unpredictable climatic conditions, and near freezing temperature in survey area, the portable light weight echo sounding "HydroBox" was very handy and useful. It consists of underwater 'transducer' unit for transmitting and receiving the acoustic signals, and a deck unit for signal processing and data recording along with other accessory. The system was interfaced with GPS for continuous position recording during the survey. The essential unit of the system utilized for the survey is as follows:

1. Transducer – 33 KHz & 210 KHz
2. Dual frequency signal processing unit – HydroBox
3. Online data recording device – Laptop
4. Global Positioning System – handheld Garmin GPS
5. Power source- DC 12 V Battery.

In order to calibrate the echosounder, bar check in the lake was carried out from the solid platform of the Water Pump House, as carrying out bar check onboard small boat is not only risky but may not yield desired results due to excess rolling and pitching of boat. The 210 kHz transducer was deployed vertically 20 cm below water level. After proper connections,

Table 1—Geodetic coordinates of the shoreline of Priyadarshini Lake

Sr. No.	Latitude (°S)	Longitude (°E)	Sr. No.	Latitude (°S)	Longitude (°E)
1.	70°45’52.7”	11°44’6.0”	28.	70°45’53.0”	11°44’43.3”
2.	70°45’52.0”	11°44’6.1”	29.	70°45’52.4”	11°44’45.5”
3.	70°45’52.6”	11°44’7.7”	30.	70°45’52.1”	11°44’48.1”
4.	70°45’54.2”	11°44’9.6”	31.	70°45’51.1”	11°44’50.1”
5.	70°45’54.6”	11°44’13.9”	32.	70°45’50.1”	11°44’49.3”
6.	70°45’53.7”	11°44’17.7”	33.	70°45’48.2”	11°44’49.5”
7.	70°45’53.3”	11°44’21.0”	34.	70°45’47.9”	11°44’53.4”
8.	70°45’53.3”	11°44’22.7”	35.	70°45’47.7”	11°44’56.7”
9.	70°45’53.7”	11°44’23.1”	36.	70°45’47.4”	11°45’0.3”
10.	70°45’54.3”	11°44’22.3”	37.	70°45’46.0”	11°45’3.3”
11.	70°45’55.7”	11°44’19.0”	38.	70°45’45.1”	11°44’59.0”
12.	70°45’55.7”	11°44’19.0”	39.	70°45’44.8”	11°44’58.3”
13.	70°45’56.5”	11°44’18.1”	40.	70°45’43.2”	11°44’53.0”
14.	70°45’57.1”	11°44’16.6”	41.	70°45’43.1”	11°44’50.6”
15.	70°45’59.0”	11°44’13.8”	42.	70°45’42.7”	11°44’49.0”
16.	70°46’1.5”	11°44’15.8”	43.	70°45’41.8”	11°44’47.2”
17.	70°46’2.4”	11°44’17.8”	44.	70°45’,40.0”	11°44’44.1”
18.	70°46’3.6”	11°44’25.8”	45.	70°45’39.9”	11°44’42.7”
19.	70°46’3.5”	11°44’27.8”	46.	70°45.’40.0”	11°44’38.0”
20.	70°46’2.9”	11°44’30.5”	47.	70°45’40.”0	11°44’33.6”
21.	70°45’59.4”	11°44’46.4”	48.	70°45’39.8”	11°44’30.4”
22.	70°45’57.5”	11°44’44.5”	49.	70°45.’41.0”	11°44’22.5”
23.	70°45’56.8”	11°44’40.4”	50.	70°45’41.5”	11°44’19.1”
24.	70°45’55.9”	11°44’38.0”	51.	70°45’41.4”	11°44’17.2”
25.	70°45’54.4”	11°44’38.9”	52.	70°45’41.3”	11°44’13.9”
26.	70°45’53.6”	11°44’39.7”	53.	70°45’40.7”	11°44’11.8”
27.	70°45’53.0”	11°44’43.3”	54.	70°45’39.0”	11°44’6.6”

(Contd...)

Table 1— Contd.

Sr. No.	Latituide (°S)	Longitude (°E)	Sr. No.	Latituide (°S)	Longitude (°E)
55.	70°45'39.5"	11°44'1.8"	80.	70°45'54.8"	11°43'33.7"
56.	70°45'40.2"	11°44'2.0"	81.	70°45'55.0"	11°43'35.0"
57.	70°45'41.2"	11°44'2.2"	82.	70°45'55.1"	11°43'35.9"
58.	70°45'42.3"	11°44'3.8"	83.	70°45'55.2"	11°43'36.7"
59.	70°45'42.6"	11°44'6.2"	84.	70°45'55.2"	11°43'37.6"
60.	70°45'43.2"	11°44'7.9"	85.	70°45'55.4"	11°43'39.1"
61.	70°45'43.7"	11°44'8.6"	86.	70°45'55.3"	11°43'42.4"
62.	70°45'44.1"	11°44'8.1"	87.	70°45'55.1"	11°43'46.4"
63.	70°45'44.6"	11°44'3.8"	88.	70°45'54.9"	11°43'47.5"
64.	70°45'44.1"	11°44'1.5"	89.	70°45'54.5"	11°43'48.8"
65.	70°45'43.8"	11°43'56.5"	90.	70°45'54.1"	11°43'50.6"
66.	70°45'45.2"	11°43'52.6"	91.	70°45'52.9"	11°43'52.9"
67.	70°45'46.5"	11°43'49.5"	92.	70°45'51.8"	11°43'55.5"
68.	70°45'46.7"	11°43'46.1"	93.	70°45'51.2"	11°44'2.3"
69.	70°45'46.5"	11°43'42.6"	94.	70°45'51.0"	11°44'3.9"
70.	70°45'46.6"	11°43'39.5"	95.	70°45'51.1"	11°44'4.4"
71.	70°45'46.8"	11°43'37.7"	96.	70°45'51.5"	11°44'5.4"
72.	70°45'46.9"	11°43'35.4"	97.	70°45'51.7"	11°44'5.8"
73.	70°45'47.6"	11°43'31.8"	98.	70°45'51.8"	11°44'5.9"
74.	70°45'48.7"	11°43'29.4"	99.	70°45'51.9"	11°44'6.4"
75.	70°45'49.8"	11°43'28.1"	100.	70°45'52.2"	11°44'7.2"
76.	70°45'51.2"	11°43'25.0"	101.	70°45'53.2"	11°44'8.5"
77.	70°45'52.3"	11°43'24.8"	102.	70°45'53.7"	11°44'9.0"
78.	70°45'53.8"	11°43'27.1"	103.	70°45'55.7"	11°44'3.6"
79.	70°45'54.5"	11°43'31.8"	104.	70°45'55.7"	11°44'3.6"

the system was set on with 12V DC power. The HydroBox software system was set on and after necessary software setting, command was given to the transducer. Once the transducer started pinging, the system was put in recording mode. An iron plate bar was lowered in water right below the transducer with the help of graduated rope and reflections were recorded. This procedure was repeated by lowering the plate bar below the transducer at every 0.5 m fixed depth intervals and setting the accurate depth by adjusting speed of the acoustic wave. The same procedure was repeated while hauling up the plate bar. With the repeated procedure, the speed of the acoustic wave was finally set as 1405 m/s. Finally, the transducer was lowered 20 cm below the surface water and firmly fixed vertically on the side of the boat with the support of strong aluminium rod in order to avoid

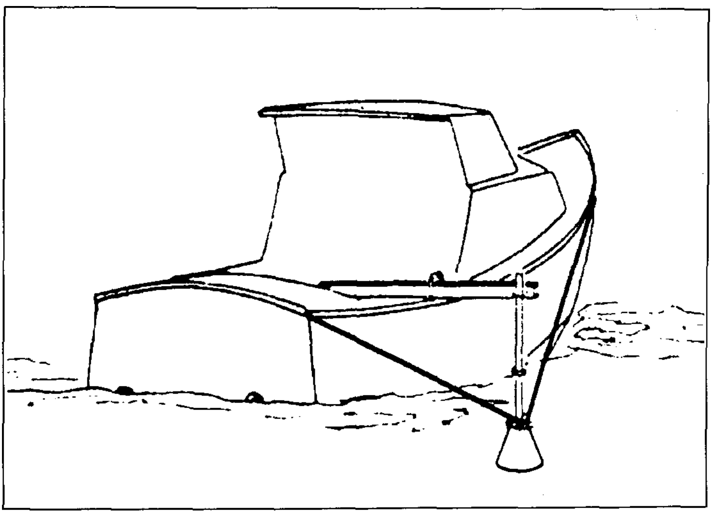

Fig. 2: Schematic diagram of HydroBox Operation on board mechanised boat

movement of transducer during survey (Figure 2). The GPS interfaced with the laptop were set on transducer for recording the continuous position. The system was set on and survey started. Under windy conditions, many a time survey had to be abandoned as the water used to splash in the boat risking the safety of equipment and personnel onboard. The logistic constraint was also another reason during survey. Finally on February 10, 2006 during fair weather and calm sea condition (wind speed <3 knots) the survey along pre-determined tracks were carried out and bathymetric profiling data in digital and analogue mode were recorded. The speed of the boat was maintained around 3 knots throughout the survey. The fixed marking interval was set at every 1 minute in automatic mode; however, manual fixing and annotation were also made at the end and start of the lines and at striking points, whenever required.

RESULTS AND DISCUSSION

The lake shoreline boundary map of the Priyadarshini Lake was prepared using 104 GPS points (Figure 3). During the bathymetric survey,

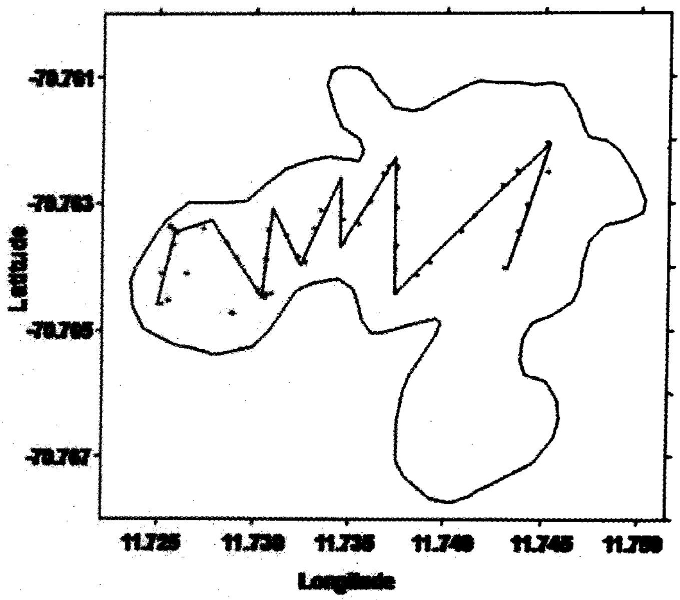

Fig. 3: Shoreline boundary map and bathymetric survey track in Priyadarshini Lake

a total of 1800 line meter of continuous bathymetric profiling data (Figure 4) in digital and analogue forms were acquired (Chaturvedi and Khare, 2006; Chaturvedi et al., 2006). It may be mentioned here that maintaining a straight survey line was very difficult due to high wind speed and presence of underwater large boulders and many time survey had to be abandoned even during fair weather condition due to various other reasons such as high wind speed, rapid discharge of computer battery, etc. In spite of our best efforts, small portion of the south-eastern side of the lake remained unsurveyed. The depth data for small portion of the un-surveyed area of the lake were taken from the published literature of Ingole and Parulekar (1990) who collected depth value of the lake by spot sounding using the conventional string rope. All the bathymetric profiling data were

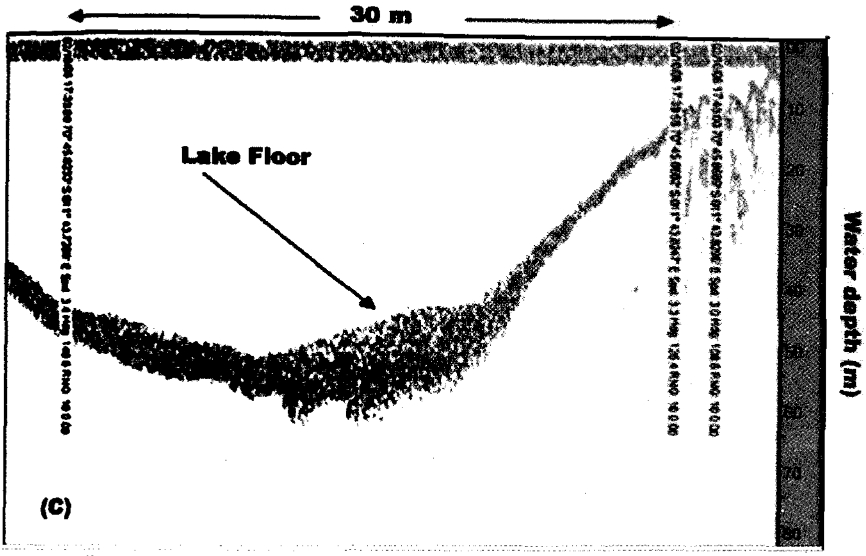

Fig. 4: Examples of bathymetric profiles recorded by using 'HydroBox'

taken in Geographical Information System Environment and a comprehensive bathymetric map in three-dimensional view was prepared using ArcMap version 9.2 computer software (Figure 5). The analysis of the bathymetric map of the lake revealed an undulating lake floor with the

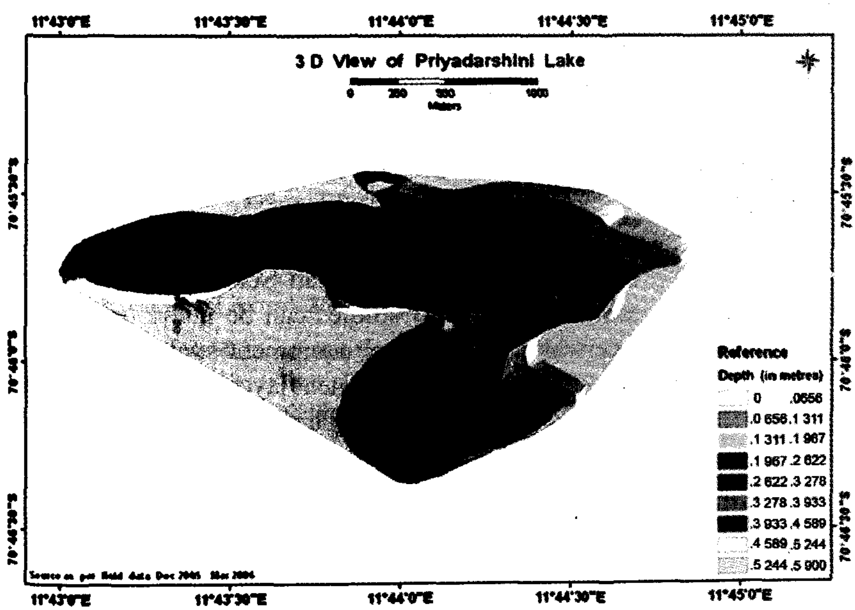

Fig. 5: Three-dimensional view of the bathymetric map of Priyadarshini Lake

maximum water depth of 5.9 meters recorded in the north-eastern part of the surveyed area of the lake. The eastern and western portion of the lake is deeper with (more than 5 meter of water depth) compared to other parts of the lake. Similarly the bathymetric map of the lake reveals comparatively steep slope towards the northwest portion of the lake with an average gradient of 1:22. The data of present survey was further utilised to analyse the various morphometric features of the lake (Khare et al., 2008). The experience gained during the pilot study of the bathymetric survey in Antarctic lake and lesson learned during survey (Chaturvedi et al., 2009) has developed the confidence and will help to prepare well for such studies in future in an inhospitable, unpredictable and near freezing climatic conditions of Antarctica. The bathymetric data of the lake collected in the present study once integrated with the sub-bottom profiler data will provide detailed information of the sub surface features of this lake that will help in identifying suitable locations to retrieve long sediment cores for paleoclimatic study.

CONCLUSIONS

A three-dimensional bathymetric map of the Priyadarshini Lake was prepared from the data collected during the survey using ArcMap (version 9.2) software in the Geographical Information System Environment. The study reveal an undulating lake floor with the maximum water depth of 5.9 meters in the north-eastern part of the surveyed area of the lake with comparatively steep slope towards the northwest portion of the lake with an average gradient of 1:22. The eastern and western portion of the lake is deeper with more than 5 meter of water depth compare to other parts of the lake.

The successful completion of our pilot study of the bathymetric survey of Antarctic lake during Silver Jubilee Indian Scientific Expedition to Antarctica is the testimony that such studies can be taken up in futures along with other underwater geophysical equipment such as sub-bottom profiler, to characterize the subsurface sediment layers of the lake to select suitable locations for sediment coring to study history of the Earth's climate.

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