Seabed morphology of the Approach Channel of Larsemann Hills, Prydz Bay, East Antarctica

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Seabed topography of the Approach Channel to the Larsemann Hills in the Prydz Bay is important to understand the Prydz Bay drainage basin and interlinkage between its major topographic features. As India proposes to establish her third permanent station in Larsemann Hills, East Antarctica, the access to the site by safe navigation of vessels necessitated a bathymetric survey of the Approach Channel. The survey was divided into two blocks, a part of the Prydz Bay (latitudes 69°10′S to 69°22′S, longitudes 75°45′E to 76°15′E) and the Larsemann Hill Approach Channel (latitudes 69°22.00′S to 69°25.14′S, longitudes 76°04.00′E to 76°16.00′E). A total area of 55 km in length and 19 km in width was covered with 155 lines-km bathymetric data which was collected by deploying a boat-mounted shallow water multibeam echosounder system. Hull mounted multibeam system of *R. V. Akademik Boris Petrov* was used for the survey of the Prydz Bay and a total of about 410 lines-km of bathymetric data was collected.

The survey area is a part of the Svenner Channel and maximum depth in the Prydz Bay was found to be 800 m. The maximum depth in the Approach Channel was found as 450 m. The area has variable morphological features and interlinks the Four Ladies Bank, Amery Ice Shelf and Amery Depression. Results indicate the glacial erosion in the channel. The Larsemann Hills Approach Channel was found to be in the depth range of 25–450 m, with a safe navigational passage up to the NE–SW boundary of the Larsemann Hills.

Keywords: Antarctica, glacial erosion, Larsemann Hills, seabed topography, Swath bathymetry.

Introduction

THE Prydz Bay is an embayment along the Antarctic margin between 66°E and 79°E. It is bounded on the southwestern side by the Amery Ice Shelf, on the southeast by the Ingrid Christensen Coast and by Mac. Robertson Land to the west, ending in Cape Darnley (Figure 1). The Laresmann Hills (69°20′S to 69°30′S lat., 75°55′E to 76°30′E long.), named after Laresmann Christensen, is an ice-free coastal oasis fringing the Prydz Bay, located approximately midway between the eastern extremity of the Amery Ice Shelf and the southern boundary of the Vestfold Hills.

There are two main peninsulas on the two extremities of the Larsemann Hills, viz. the Broknes and the Stornes peninsulas. Between these two, there are number of islands of varying dimensions and some unnamed promontories. Westwards, the Clemence Fjord separates Broknes Peninsula from Stinear Peninsula and Fisher Island (Figure 1). The area north and westwards is marked by a number of islands, viz. Harley, Easther, Breadloaf, Butler, Betts, McLeod, Jeason, Solomon and Sandercock Islands.

India proposes to establish a third permanent station at Larsemann Hills in East Antarctica in a place having geological links to Indian mainland in the geological history. The feasibility study and the site identification was carried out during the 23rd IAE by Task Force and a special expedition to the Larsemann Hills and the Southern Ocean was launched onboard *R. V. Akademik Boris Petrov* in the austral summer 2006.

In the Prydz Bay some scattered depth soundings are available but no multibeam data and no seabed topography or contour maps are available. The Larsemann Hills area is uncharted and it is connected with the open sea through a passage between McLeod and Sandercock Islands. Bathymetry data provide the seabed topography which helps to understand the local tectonic setting of the channel and identify a safe navigation passage.

Material and methods

The Reson 8101-ER side-mounted system was used for the Larsemann Hills Channel and the Prydz Bay was surveyed by the vessel-mounted Atlas Hydrosweep DS 2 system.

Prydz Bay survey

The Hydrosweep DS2 system was designed to cover a large sector of 120° by a fan of 59 or 240 Pre-Formed Beams (PFBs). It can measure the depth from 10 to 11,000 m and operates with a sonar frequency[1] of 15.5 kHz. All the 59 PFBs, covering each 2.3°, form the sonar swath with an apex angle of 90°. Thus, the centre lines of adjacent PFBs are about 1.53° apart and due to this fixed PFB angle, the footprint size changes with

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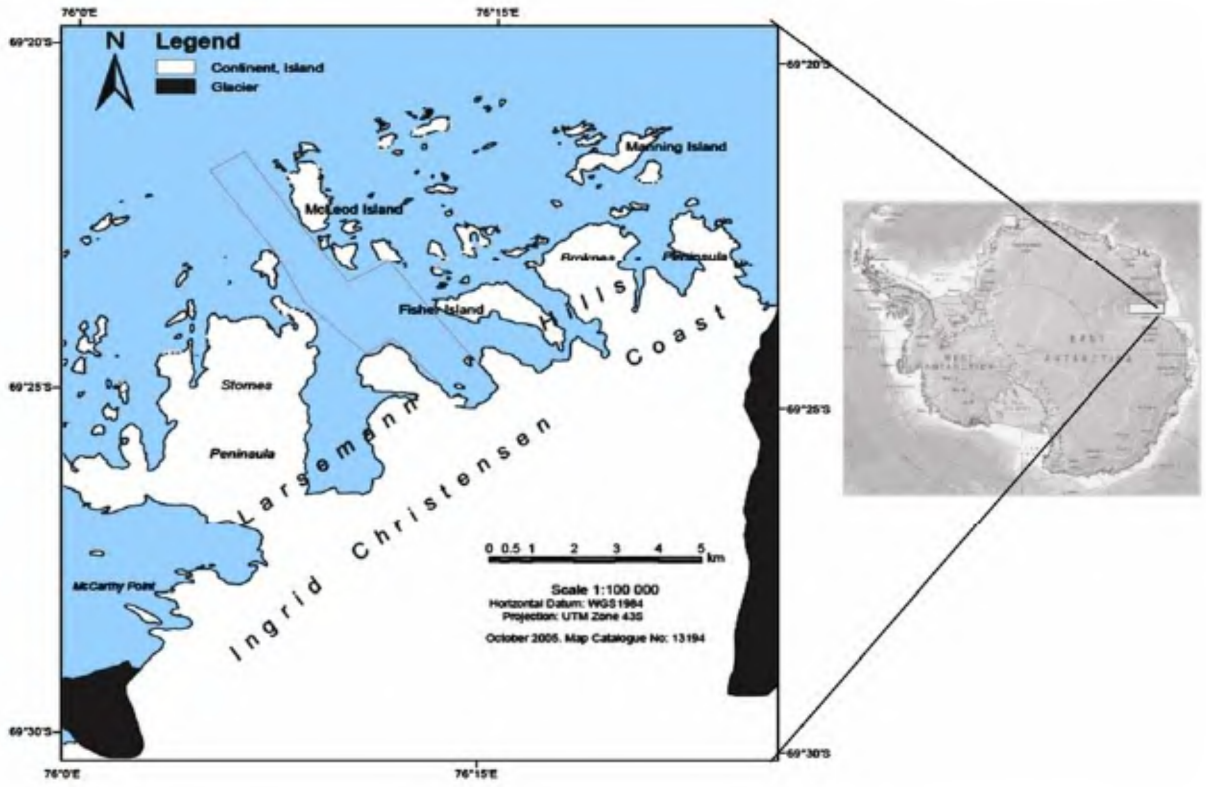

Figure 1. Location map of the study area: Larsemann Hills, Prydz Bay, East Antarctica[12].

Table 1. System specification of the Atlas Hydrosweep DS2 system

Technical specifications	Depth range	10–11,000 m
	Frequency of operation	15.5 kHz
	No. of beams	59 hard beams, 240 (with HDBE)
Swath width	Water depth	Coverage
	10–4700 m	120° (3.7× water depth)
	4700–8000 m	90° (2× water depth)
	Up to 11,000 m	60° (1.5× water depth)
Depth resolution	0.1 m	For 10–999 m water depth
	1 m	For > 999 m water depth
Roll/pitch/heave compensation	Roll angle	± 10° (for 120° survey mode)
		± 20° (for 90° survey mode)
	Pitch angle	± 10°
	Heave	± 5 m

depth and is approximately 4% of the water depth near the centre beam and 7% at the outer beams[2].

The system mainly comprises transceiver cabinets, signal processor cabinet, DGPS receiver, motion sensor, gyro, sound velocity sensors, and control, processing and navigational units. The SVP-20 (Navitronic Systems AS) sound velocity profilers onboard *Akademik Boris Petrov* were used to obtain the sound velocity profile for the Prydz Bay survey. SVP-20 can be operated in deep water up to the maximum depth of 1000 m with a resolution of 0.1 m/s and an accuracy of ± 0.3 m/s. System specifications of Hydrosweep DS 2 system are given in Table 1.

Larsemann Hill Approach Channel survey

The Reson SeaBat 8101-ER system was used to carry out the bathymetric survey of the approach channel of Larsemann Hills. The system was pole mounted to the starboard side of the 7.9 m × 2 m fibreglass boat. The required power supply was made available with the portable generator. The SeaBat 8101 ER is a 240 kHz multibeam system that measures relative water depths across a 150° swath, consisting of 101 individual 1.5° × 1.5° beams. The main features of the equipment are shown in Table 2.

The System Reson 8101 was designed to measure the maximum depth of 320 m of IHO standards and in

Figure 2. Reson SeaBat 8101-ER transducers in different modes: ***a***, on deck; ***b***, mounted on boat and ***c***, Underwater.

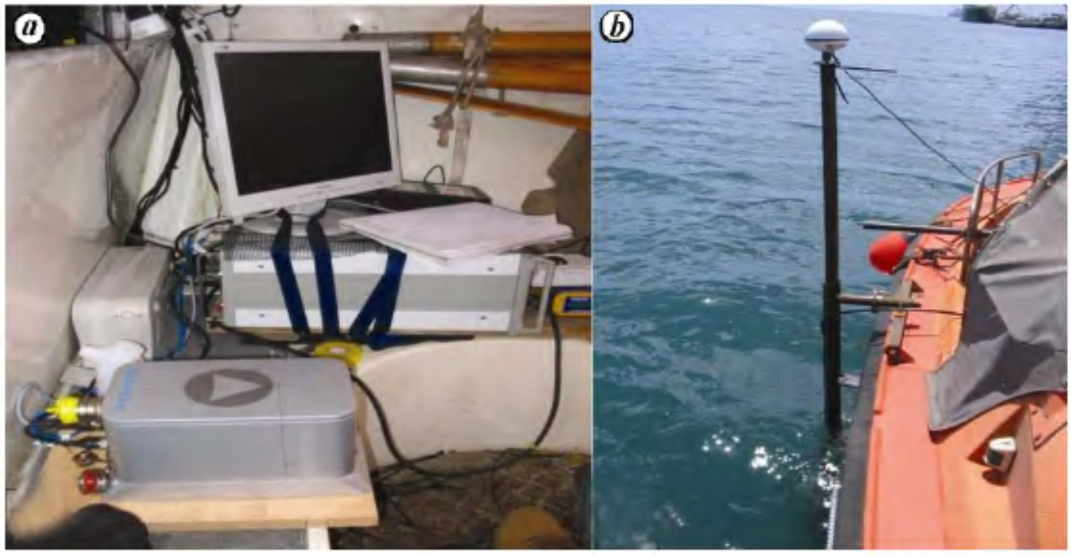

Figure 3. ***a***, Reson SeaBat-8101 ER control unit and Ixsea Octans; ***b***, Trimble GPS.

Table 2. System features of the Reson SeaBat 8101 ER multibeam echosounder

System features	Details
Sonar operating frequency	240 kHz
Power requirements	24–28VDC, 2A Peak
Operating temperature	– 5° to + 40°C
Maximum pinging rate	40
Number of beams	101, Centred 1.5° apart
Sector coverage	150°

Table 3. Seafloor coverage with the water depth of the Reson SeaBat 8101 ER system

Depth (m)	Coverage (× water depth)
1–70	7.4
70–100	4.2
100–150	2.7
150–200	1.8
200–250	1.6
250–300	1.3

8101-ER depth increases to 450 m (Figure 2). The maximum seafloor coverage with the depths are given in Table 3.

An Ixsea Octans gyrocompass and integrated motion sensor (Figure 3) was used to provide true heading in addition to heave, pitch and roll correctors in NEMA and TSS HDT formats. The octans generates attitude data in three axes (roll, pitch and heading). The dynamic heading accuracy was ∀0.2E and dynamic accuracy for roll and pitch was ∀0.01E. Heave measurements maintained an accuracy of 5 cm or 5% of the measured vertical displacement. The heave period was automatically compensated for by the firm ware for periods between 0.03 and 40 s.

SVP-15 (Reson) sound velocity profiler was taken on the survey boat for the Larsemann Hills channel survey. The SVP was calibrated at the manufacturer's facility before arrival and has high precision absolute sound velocity measuring probes, using direct sounding technology. This SVP can be operated up to the maximum depth of 200 m with a resolution of 0.1 m/s and an accuracy of ± 0.25 m/s.

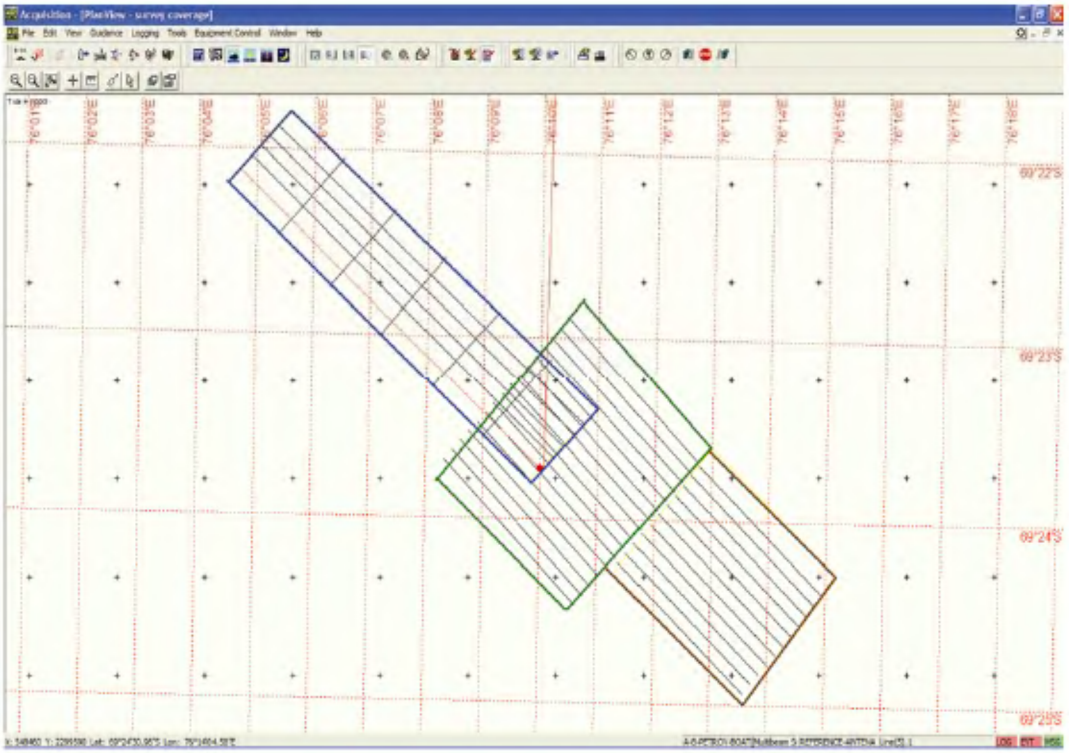

Figure 4. Survey plan of the Larsemann Hills Approach Channel.

Survey plan and data collection

The Larsemann Hills Approach Channel was divided into three blocks to carry out the bathymetric survey (Figure 4). The survey was carried out in the channel region 76:04:00E to 76:16:00E; 69:25:14S to 69:22:00S. The survey line spacing was made 135 m with 40% overlap. The tracks have been negotiated to achieve near 100% coverage. The survey lines were planned along the approach channel to minimize the depth variation in the survey lines.

Survey operations were conducted at a speed between 4.0 and 5.0 knots. Survey tracks were maintained and tracks were negotiated due to the grounded and floating icebergs, katabatic winds and rock outcrops in the channel to achieve full coverage of the area.

The 155 line-km bathymetric data was logged digitally into the Laptop computer supplied with the Multibeam Reson 8101. The data acquisitions were made with PDS2000 Ver. 1.2 software and position, heading and motion input were taken by the GPS (Trimble) and Ixsea Octans systems.

The outer region of the channel, Prydz Bay (75:45:00E to 76:15:00E; 69:10:00S to 69:22:00S) has been surveyed by Atlas Hydrosweep DS 2 system. The survey lines were made at distance of 350 m to cover the area with approximate 15% overlap. Total 410 line-km data were collected on the computer by using Hydro Map online software. During the survey, casts of Sound Velocity Profiler (SVP) were taken at 4 hourly intervals.

Data processing and presentation

The bathymetric data collected from the Larsemann Hills Approach Channel were processed with PDS 2000 software, whereas Atlas Hydrosweep DS2 data collected from the Prydz Bay were processed with HYDROMAP Offline and MB-System software[3]. The sound velocity profiles obtained from SVPs were matched occasionally with the CTD data, as a counter check, and were found to be comparable[4].

The data sets and offset values were analysed to remove data outliers[5]. The cleaned multibeam data form the basis for modelling the seafloor topography and a Digital Terrain Model (DTM) was generated. The seabed topographic map/bathymetric contour map and mesh polt of the Prydz Bay are shown in Figures 5 and 6 respectively. Seabed topography of the Larsemann Hills Channel was plotted at 25 m contour interval on the 1 : 10000 scale. The seabed topographic map/bathymetric contour map and mesh polt of the Larsemann Hills Approach Channel are shown in Figures 7 and 8 respectively.

Results and discussion

The regional setting and major bathymetric features of the Prydz Bay are shown in Figure 9. The Prydz Bay forms the terminus of the Lambert glacier–Amery Ice Shelf drainage system, which drains about 14% of the ice drainage from the East Antarctica Ice Sheet[6,7]. The major bathymetric features of the Prydz Bay include the

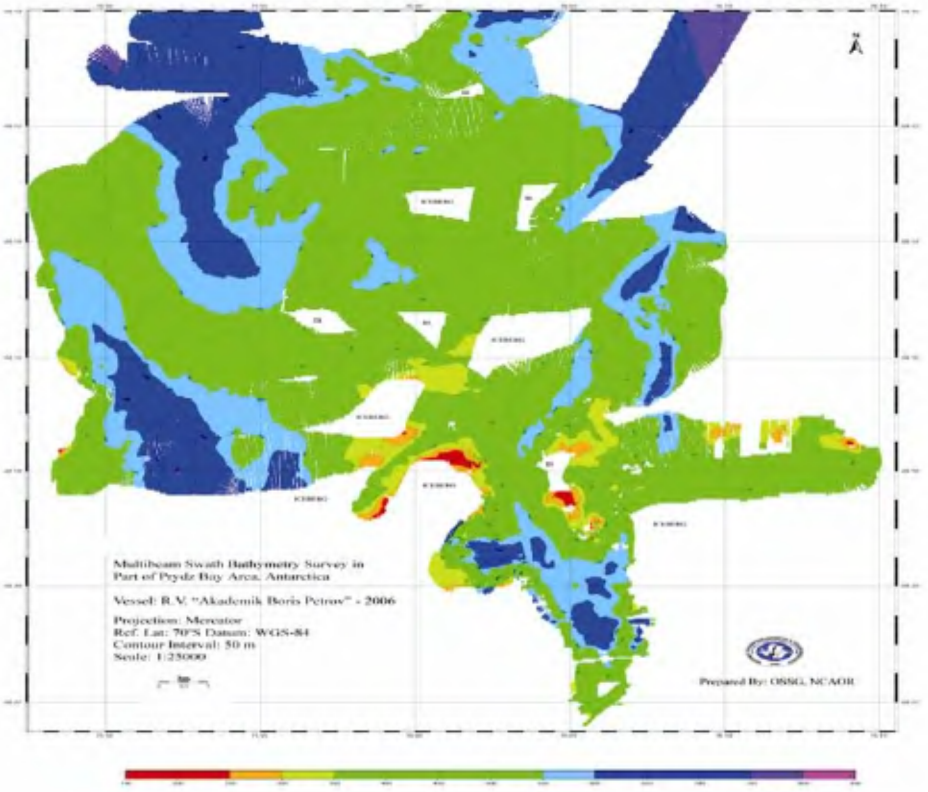

Figure 5. Seabed topography map of Prydz Bay, East Antarctica.

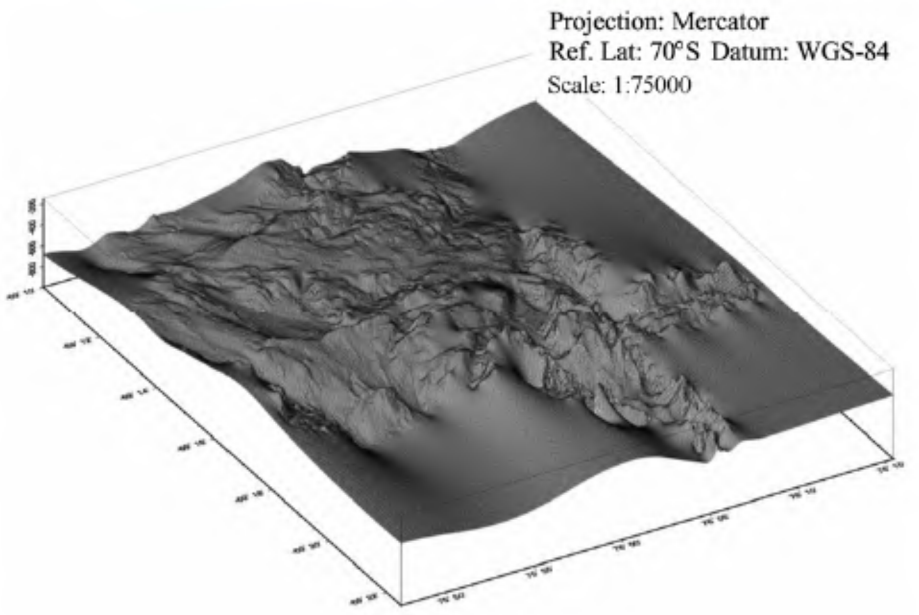

Figure 6. Mesh plot of the Prydz Bay, East Antarctica.

Lambert Deep, Amery Depression, Prydz Channel, Nella Rim and Fram Bank[8,9]. The Prydz Bay is typical of the Antarctic shelf with the deepest area (~1200 m) near the front of the Amery Ice Shelf in the Amery Depression[10]. On the eastern side of the Prydz Bay, the sea floor shoals to depth of 100–200 m on Four Ladies Bank which is separated from the Ingrid Christensen Coast by a series of connected troughs and saddles known as the Svenner Channel. The Svenner Channel also separates the Amery Depression and Ingrid Christensen Coast. The Amery

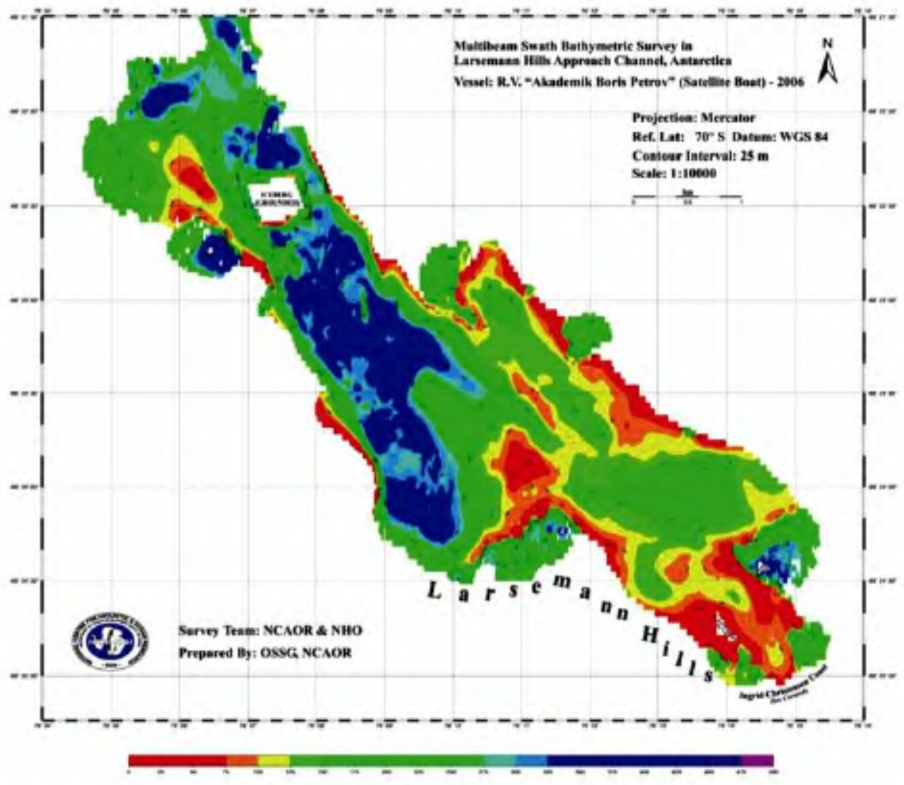

Figure 7. Seabed topography map of Larsemann Hills Approch Channel.

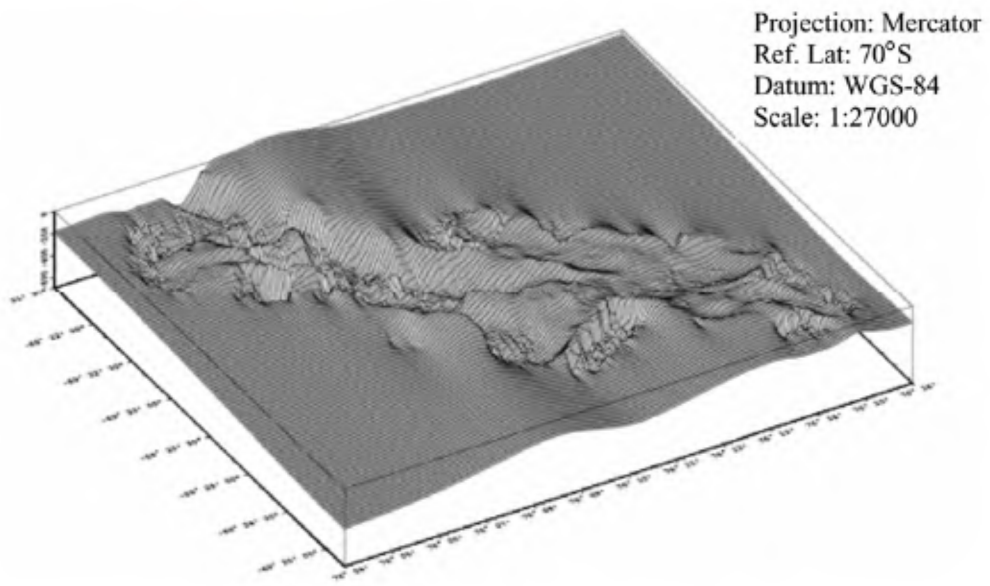

Figure 8. Mesh plot of the Larsemann Hills Approach Channel.

Depression is the link to the shelf edge by the Prydz Channel. The Prydz Channel has depths from 500 m at the shelf end and 700 m at the channel side[10].

In the study area a part of the Svenner Channel, a depth of 800 m was found in the North Eastern part. The minimum depth was found to be 250 m in the south of the area which is connected to the Larsemann Hills Approach Channel. In general the sea end area is deeper and depth varies from 450 m to 800 m. Many deep regions are found in the study area and the main deep zone is associated with the western margin of the area. The narrow deep zone connecting the Larsemann Hills Approach Channel is the main passage for the movement of icebergs. A number of icebergs are found in the area and one

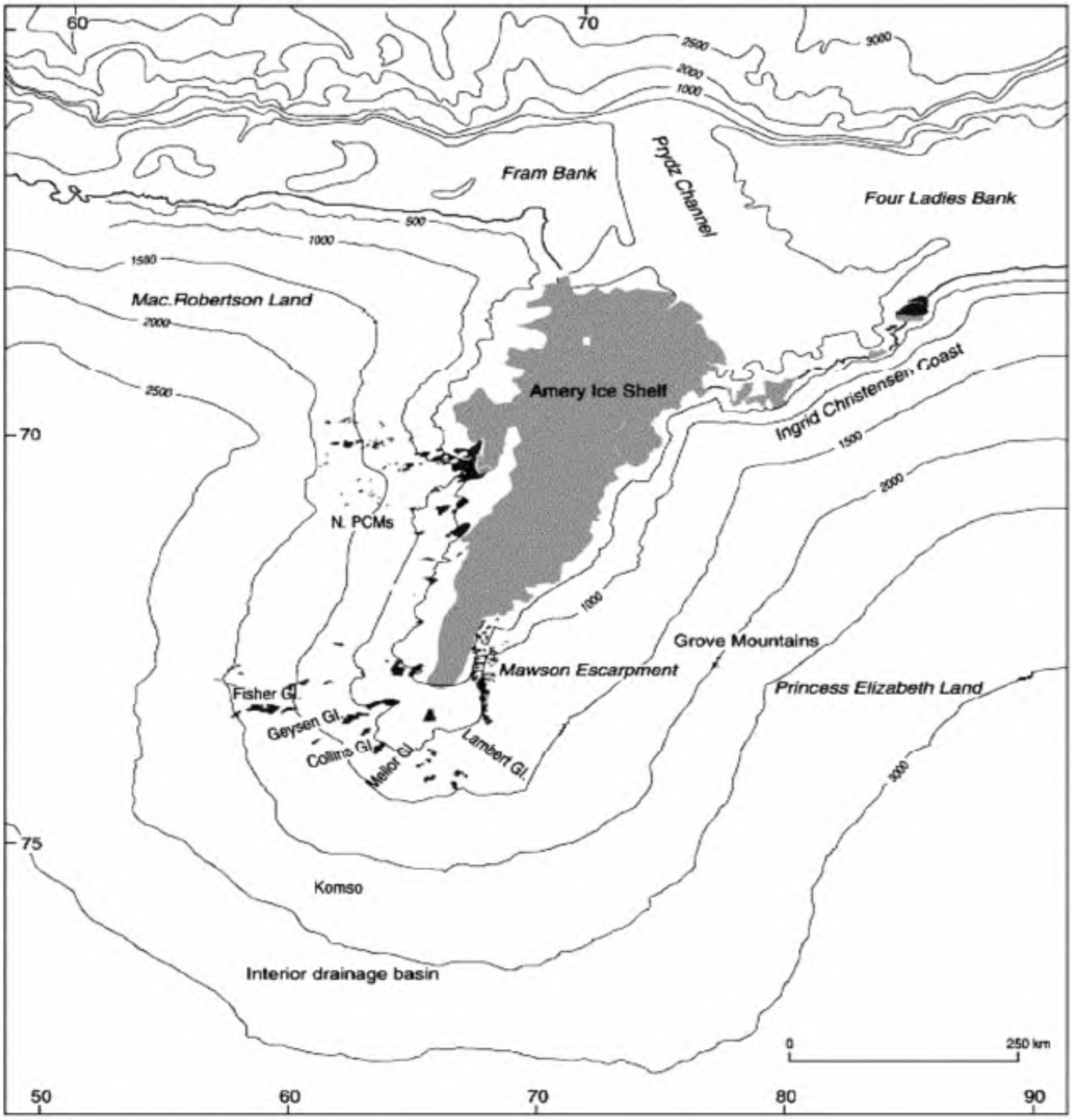

Figure 9. Regional setting and major bathymetric features of the Prydz Bay[10].

grounded iceberg was found at the mouth of the Approach Channel.

The Larsemann Hills Approach Channel is confined between the elongated boundaries of many islands, with depths varying from 25 m to 450 m. The maximum depth, 450 m, is found in the upper part of the western boundary of the Approach Channel. The Approach Channel was found to be long, wide, steep sloped from its mouth to the NE–SW boundary of the Larsemann Hills and subsequently it was shallower with gently slopped side boundaries and associated with rock outcrops.

In the deeper part of the channel from the mouth to the Larsemann Hills, the normal depth was from 200 m to 425 m. However the one shallow zone of 50 m depth along the western boundary and another NE–SW shallow region of depth 175 m to 250 m connected with the shallow zone were found in this deeper part of the channel. In the shallow region of the channel the depth varied from 25 m to 325 m, with the normal depths of 75 to 225 m. The higher depth, 325 m, in the shallow zone is found to be close to the Ingrid Christensen Coast.

Water depths up to 1000 m were reported along the Ingrid Christensen Coast of the Svenner Channel[11]. The normal depth of 600–700 m of Amery Depression was reported for the front of Amery Ice Shelf, which reaches 1400 m in several closed depressions in the southwestern corner of the Bay. In the study area the maximum depth was found to be 800 m along the sea end towards the Amery Depression. The regional and bathymetric setting of the study area falls in the Svenner Channel where the maximum depth is reported as 1000 m. The Svenner Channel separates the Four Ladies Bank in the east of the study area where the depth is shallow 100–200 m, and in the east it runs up to the Amery Ice Shelf where the depth is higher, 1400 m. The study area is between the shallower and deeper regions. The maximum depth in the Larsemann Hills Approach Channel in one place is recorded as 450 m which is the maximum detection limit of the instruments, may be possibly deeper. Steep channel boundary along the islands indicates the glacial movement and heavy glacial erosion along the coast and steep continental slope. The shallow inner channel bounded by the gently sloped boundaries may be due to the surrounding islands, which restrict the glacial movement and erosion along the coast.

Conclusion

The bathymetric survey provides the detailed topographic pictures of the seabed of the uncharted area of Larsemann Hills. The map will be helpful for further studies and understanding the Svenner Channel. The map can be utilized for safe navigation purposes, construction of the jetty and other logistical purposes for establishing the 3rd Indian permanent station in Antarctica.

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