SUBMARINE TOPOGRAPHY OF THE CENTRAL PART OF LÜTZOW-HOLM BAY AND AROUND ONGUL ISLANDS, ANTARCTICA

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Abstract: The drowned glacial trough formed when the ice sheet expanded in the past exists in the central part of Lützow-Holm Bay. The trough extends north-south and joins the drowned glacial troughs off the Honnör Glacier and off the Telen Glacier, and also joins the Shirase Glacier probably. This trough suggests the existence of a major geologic structural zone which seems to extend from the Shirase Glacier to the eastern margin of Gunnerus Bank. The continental shelf west of the trough is 200–300 m deeper than that east of the trough.

The submarine topography around the Ongul Islands also reflects the geologic structure. The trends of geomorphic features fit the foliation and jointing of gneissic basement rocks. Preglacial landform in the vicinity of the Ongul Islands had been gentle in relief like a peneplain. It was glaciated during a period of expansion of the ice sheet and was divided into several islands.

1. Introduction

The continental shelf extends up to 70 km off the Prince Olav Coast. The shelf break, at a depth of about 400 m, extends straight and in pararell with the Prince Olav Coast, and it deepens over 600 m off Lützow-Holm Bay. The rather deep bottom of 500 to 600 m enters the bay towards the south. In the middle of Lützow-Holm Bay, the depression over 600 m deep is found and appears to be the glacial trough off the Shirase Glacier (YOSHIDA *et al*., 1964; FUJIWARA, 1971).

The submarine topography in an extent of 30 km off the Sôya Coast and several conspicuous drowned glacial troughs off the present glaciers have been clarified by surveys from the 9th Japanese Antarctic Research Expedition (JARE–9) (1968) to JARE–16 (1975) (Fig. 1; FUJIWARA, 1971; MORIWAKI, 1975; OMOTO, 1976b and HAYASHI, unpublished).

The author sounded in the central part of Lützow-Holm Bay and clarified the existence of the depressions and their cross profiles. He sounded also densely the submarine topography around the Ongul Islands, in the austral winter of 1977. This survey was suported by Messrs. TERAI, YAMAKAWA and YOSHIDA who were the members of JARE–18. The author would like to express his hearty thanks to them. He wishes to extend his thanks to Prof. Torao YOSHIKAWA of the University of Tokyo

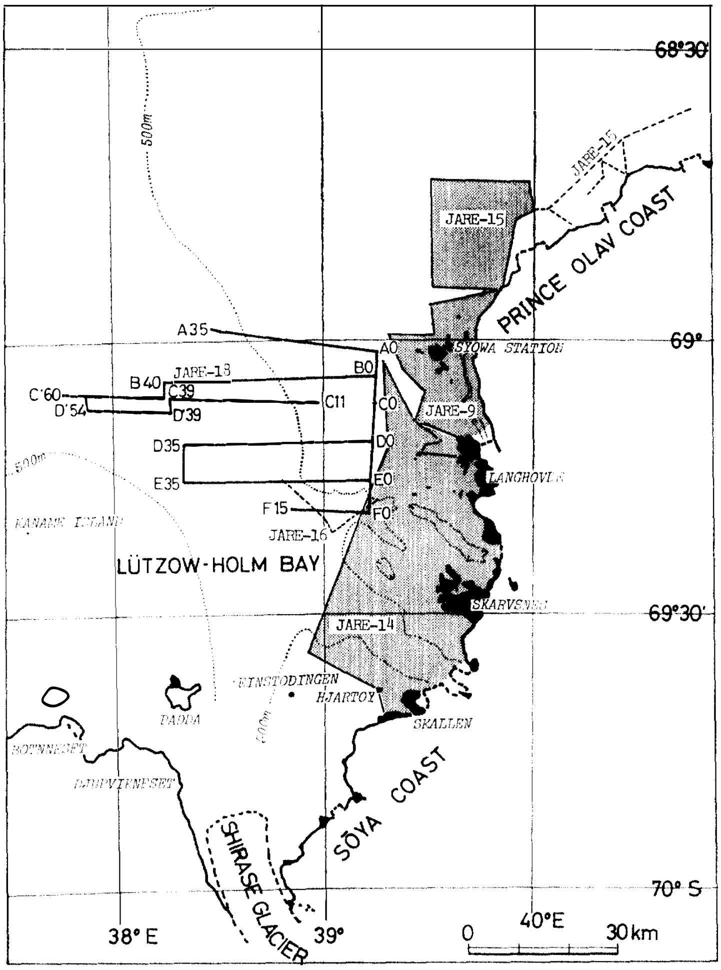

Fig. 1. Surveyed area in Lützow-Holm Bay.

and Prof. Yoshio YOSHIDA of National Institute of Polar Research who read critically the final draft of this paper.

2. Instruments

New echo-sounder GS-3-22-3 (Oki Kaiyo Electronics, Ltd.) was remodeled for the use in the Antarctic environment of severe climatic and mechanical conditions (Fig. 2). The main body (transmitting, receiving and recording) of the echo-sounder is put in the box which has an electric heater and receives warm air from the defroster of the snow vehicle. The warm air system is more effective. Two types of instruments (transducers), one for use on the ice surface and the other for use under ice, are of the same styles as those of NSL-1300 echo-sounder (YOSHIDA, 1969).

Drilling and sampling equipments and bathymetric instruments except the main

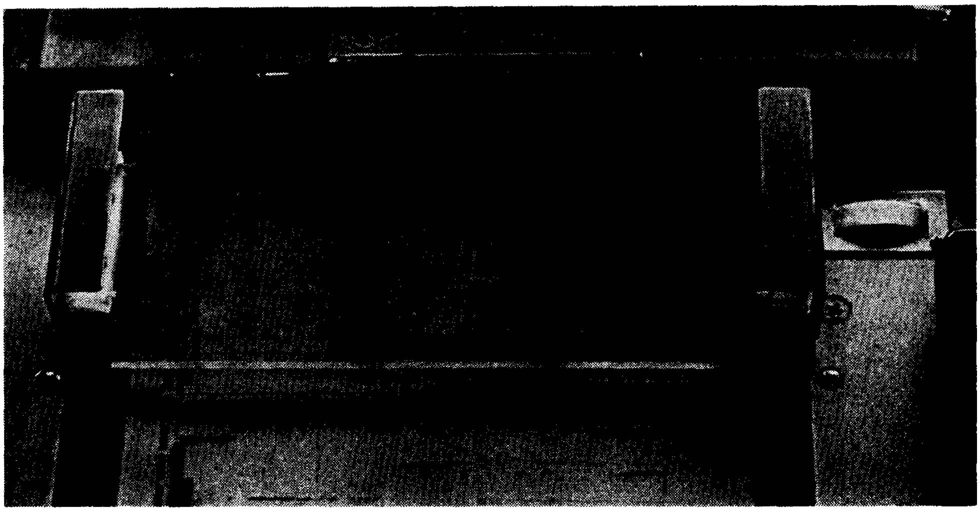

Fig. 2. GS-3 echo-sounder and several records of sounding.

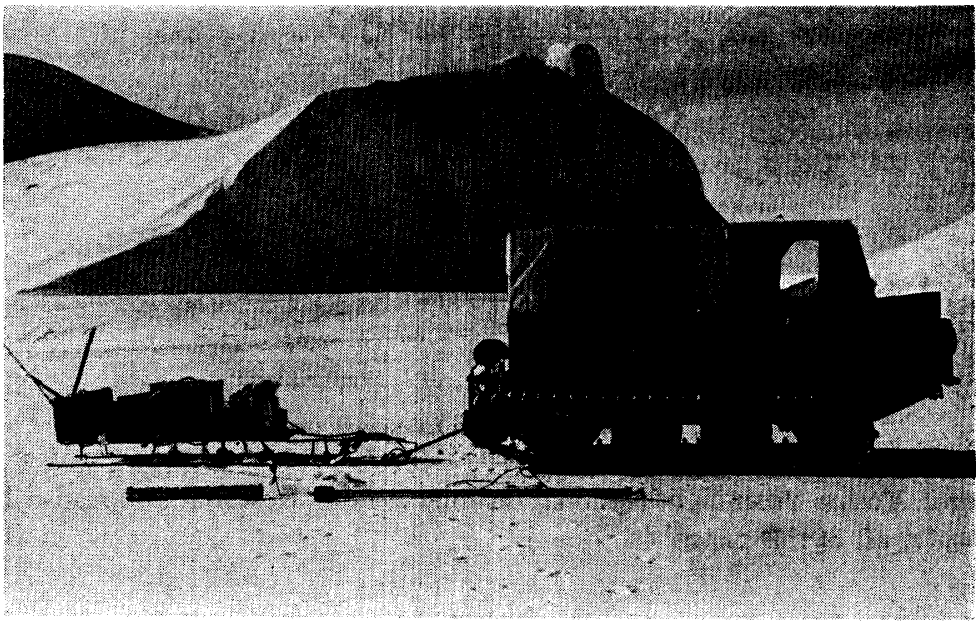

Fig. 3. The float type snow vehicle and the light sledge using skis made by Mr. TERAI (N.I.P.R.). The bit of ice auger and the 'under-ice' type transducer of echo-sounder are on this side.

body of echo-sounder were mounted on the wooden sledge, which was trailed by an ordinary snow vehicle (MORIWAKI, 1975) until October. After November the light sledge mounting bathymetric instruments was trailed by a float type snow vehicle (Fig. 3).

The correction of sounding values due to water temperature and salinity is omitted in this paper. Depth obtained by echo-sounding becomes smaller than that by wire-sounding with increase in depth (Table 1). It is difficult to determine which gives better values. The discussion of the topography under consideration is based on echo-sounding data.

Table 1. Comparison of echo-sounding values with wire-sounding values.

	a) Echo-sounding	b) Wire-sounding	b/a
YOSHIDA, Y. (1969)	93.5 m*	95.5 m	1.021
FUJIWARA, K. (1971)	47.0 m*	47.7 m	1.015
	197.0 m*	200.5 m	1.018
MORIWAKI, K.	62.5 m**	62.5 m	1.000
	398 m**	412 m	1.035

* NSL-1300, ** GS-3

3. Submarine Topography of the Central Part of Lützow-Holm Bay

3.1. Position of sounding

The survey was carried out at 1-km intervals in the east-west direction and at a distance of 5–7 km apart in the north-south direction (Fig. 1). Positions of base points, A0, B0, etc., and lines of sounding were determined by triangulation connected with geodetic stations on East Ongul Island (Hatinosu Peak), Benten Island and Ongulkalven (Table 2). A survey line was kept on the extension of the line connecting two or more flags. In this method, errors of straightness of survey lines remained less than 5 cm per 1-km. Distance was measured with the distancemeter of the snow vehicle. The distancemeter was examined on the 500 m straight course established with the measuring tape. In spite of this method, the error in location determination seems to amount to 1-km near the west end of the survey lines.

3.2. Operation of sounding

The surveyed area is shown in Fig. 1. It partly overlaps the areas surveyed by JARE–14 and JARE–16.

In 1977, the spacious open water was formed to the west of the Ongul Islands in late March, and extended into the Ongul Strait in late April. The new sea ice west and south of the Ongul Islands was broken and carried away by several blizzards. Finally it began to grow at the beginning of July (MORIWAKI, 1978). The survey ultimately began at the end of September owing to the delayed freezing of sea water and the bad weather in September. Westward extension of the survey was interrupted by a vast hummocked ice zone to the west of stations A35, B40 and C′60. 246 points of sounding were obtained by November 14th when the sounding came to a close due to the worsened condition of sea ice. Most of echo-sounding were car-

Table 2. Some examples of triangulation using Wild T2 theodolite.

Point of observation	Object	° ′ ″
Benten Island	Hatinosu Peak*	0 0 0
	A0	253 56 16
	Mt. Tyôtô	60 12 46
	Skjegget (Peak)	86 51 40
	Ongulkalven*	356 12 24
A0	Hatinosu Peak*	0 0 0
	Ongulkalven *1	3 1 44
	Ongulkalven *2	3 49 11
	Mt. Tyôtô	53 50 0
	Benten Island*	66 35 18
	Skjegget (Peak)	78 58 45
	Base line (B0)	99 26 38
	A2	194 24 15
B0	Base line (A0)	0 0 0
	Benten Island*	15 48 14
	Hatinosu Peak*?	62 27 5
	Mt. Tyôtô	124 43 56
	Rumpa (Island)	136 29 34
	Skjegget (Peak)	157 16 36
	B1	265 28 46

Point of observation	Object	° ′ ″
D0	Base line (C0)	0 0 0
	Benten Island*	3 23 9
	Rumpa (Island)	51 56 11
	Mt. Tyôtô	88 0 17
	Skjegget (Peak)	146 52 26
	Base line (E0)	179 28 28
	D1	265 42 1
D35	D34	0 0 0
	Skjegget (Peak)	27 26 30
	E35	91 37 3
E35	D35	0 0 0
	E34	88 22 43
	Mt. Heitô?	89 17 6
	Skjegget (Peak)	108 52 1
F0	Base line (E0)	0 0 0
	Rumpa (Island)	20 1 44
	Mt. Tyôtô	51 13 34
	Breidvågnipa (Peak)	100 50 36
	Skjegget (Peak)	125 34 32
	Skallevikhalsen	171 3 37
	F1	270 1 41

* geodesic station

ried out by using the 'under ice type' transducer after the sea ice was drilled with the improved SIPRE ice auger (OMOTO, 1976b). Sea ice 60–130 cm thick was easy to drill.

Core sampling of sea bottom was attempted at station E 20, but was unsuccessful because of a wire breakage.

3.3. Results of survey

The features of submarine topography of the central and eastern parts of Lützow-Holm Bay are as follows (Figs. 4, 5 and 12):

1) The depression of the central part of Lützow-Holm Bay joins the drowned glacial troughs off the Honnör Glacier and off the Telen Glacier, which were discovered by OMOTO (1976b). This north-south trending depression seems to join the trough of the Shirase Glacier (YOSHIDA *et al.*, 1964), and to extend to the east of Gun-

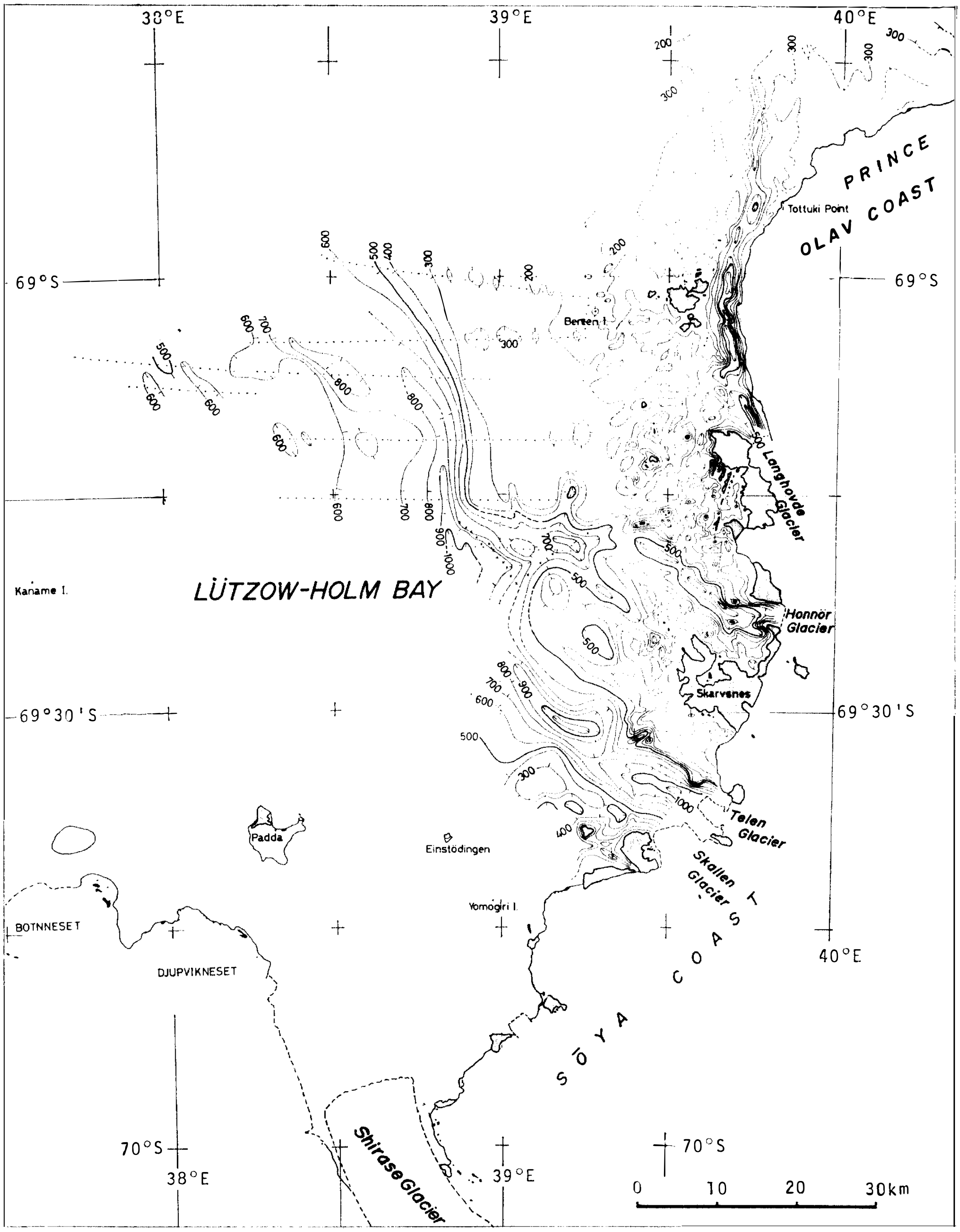

Fig. 4. Bathymetric chart of the eastern part of Lützow-Holm Bay compiled by MORIWAKI, *who made use of charts and data of* FUJIWARA *(1971),* MORIWAKI *(1975),* OMOTO *(1976 b) and M.* HAYASHI *(unpublished). · Position of sounding by K.* MORIWAKI *(JARE-18). × Position of sounding by M.* HAYASHI *(JARE-16).*

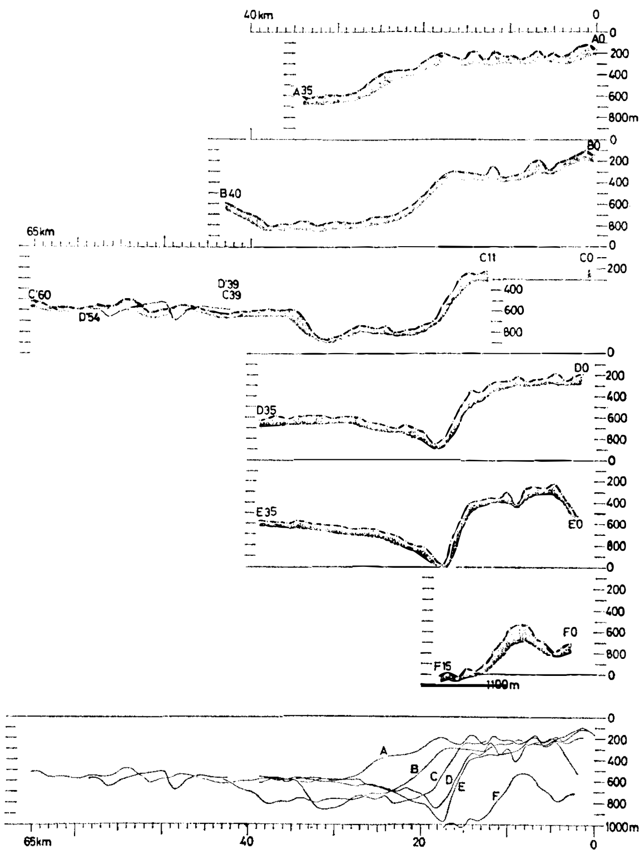

Fig. 5. Profiles of submarine topography of the central part of Lützow-Holm Bay, shown in Fig. 2 and Fig. 3. · Position of sounding.

nerus Bank.

2) The depression has an undulating longitudinal profile with a landward gradient (YOSHIDA *et al.*, 1964).

3) The bottom of the depression becomes wider from south to north, and the deeper part of it seems to be divided into two parts by a rise between stations C21 and C26 near 69°07′S in latitude.

4) Cross profiles of the depression are asymmetrical, being steeper on its east side.

5) The west-facing valley wall extends in the direction of north or NNW over 30 km from 69°15′S. It is steep especially between 69°07′S and 69°15′S, where it has an inclination of 8 to 11 degrees.

6) The sea floor depth is conspicuously different between the two sides of the depression. The depth of the sea floor on the east side of the depression is shallower than 300 m, whereas that on the west side is 500–600 m (YOSHIDA *et al.*, 1964; Fig. 12). In Sulzberger Bay, east of the Ross Sea, LEPLEY (1964) inferred that such

difference of the sea floor depth represents the difference of resistance of rocks to erosion or block movement along a fault zone marked by depressions. In the present case, however, the reason of the difference has not been clarified yet.

7) The sea floor east of the depression has a hillocky topography with the relative height of about 100 m. On the other hand, the floor west of it seems to be flat or slightly undulating. However, there is not enough data of the sea floor west of the depression. This sea floor may be a part of an extremely broad depression which is not recognized yet in our survey.

Facts of 1) and 2) suggest that the depression of the central part of Lützow-Holm Bay is a glacial trough like the drowned fjords off Wilkes Land (GRINNELL, 1971). It was formed by glaciation when the ice sheet expanded in the past. It is undoubtful that some outlet glaciers on the Sôya Coast flowed into this glacial trough, forming a large ice stream in the past. FUJIWARA (1971) suggested that the Langhovde Glacier branched away into three ice streams on the north side of Langhovde. It seems that the southernmost one among them and a ice flow through Langhovde (ISHIKAWA, 1974) flowed into the glacial trough off the Honnör Glacier, and then into the larger trough of central Lützow-Holm Bay (Fig. 12).

It has been discussed from some examples that glacial troughs on the continental shelf around Antarctica were developed under the control of the bedrock structure (YOSHIDA *et al.*, 1964; LEPLEY, 1964; CAMERON, 1965; FUJIWARA, 1971; NEETHLING, 1972; MORIWAKI, 1975; OMOTO, 1976a). The view that a glacial trough is developed along a pre-existing fluvial valley has been described by CAMERON (1965) and FUJIWARA (1971). However, the view not yet supported by positive evidence. Characteristics of 1) and 5) suggest that a SSE–NNW geological structure exists in Lützow-Holm Bay, and the trough was formed by glaciation along this structure, for instance an estimated fault which divides geology of the area into the Ongul group and the Skallen group (YOSHIDA, 1978). The distinct shelf break extends more than 400 km in parallel with the Prince Olav Coast from 48°E to the mouth of Lützow-Holm Bay. However, it becomes obscure west of the line connecting the eastern margin of Gunnerus Bank to the Shirase Glacier (YOSHIDA *et al.*, 1964). This line is inferred to be a major structural zone trending SSE–NNW. On the other hand, in the Mizuho Plateau, inland of Antarctica, a subglacial trough which seems to join the Shirase glacial trough was found in the vicinity of 71°S, 43°E by radar echo-sounding (OMOTO, 1976a; SHIMIZU *et al.*, 1978). Taking into account the effect of spatial fading and erroneous echoes caused by the large-scale undulation of the bedrock, MAE (1978) reanalyzed the radar echo data to obtain bedrock topography. He concluded that the subglacial trough exists, but is not so deep as was reported by NARUSE and YOKOYAMA (1975).

The above-mentioned situations suggest that there is a major structural zone trending SSE–NNW and/or SE–NW and connecting the eastern margin of Gunnerus Bank to the Shirase Glacier and its upstream subglacial trough in the vicinity of

71°S, 43°E.

The geophysical survey of the sea bottom, for instance by sparker or by air gun, is desired in the future for clarification of the development of submarine topography of Lützow-Holm Bay.

4. Submarine Topography around the Ongul Islands

4.1. Position of sounding

Survey flags were set at 100 m intervals along two north-south baselines at both margins of the sounding area. East-west lines determined with a hand-carried compass from these flagged positions were marked at 100 m intervals to make a grid of survey points. Many of the survey points were checked by triangulation from the land, and it is considered that survey points were located within an error of 3 m (MORIWAKI, 1975; Fig. 9).

4.2. Operation of sounding

Survey started in July 1977 in the sea to the east off West Ongul Island where freezing of sea water commenced earlier than in other water. In this sea, as a broad hummocked ice zone including several icebergs extended from Pollholmen to Teöya, setting of survey lines and sounding were so hard that the operation could not be carried out efficiently (Figs. 6 and 7). Since new ice in the sea to the west off West

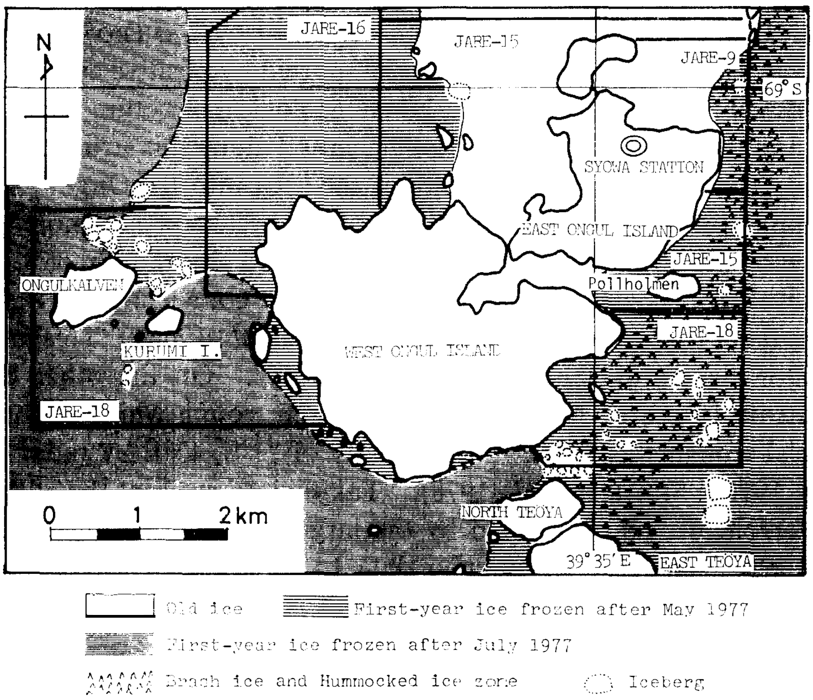

Fig. 6. Surveyed area and situation of sea ice around the Ongul Islands in the austral winter of 1977.

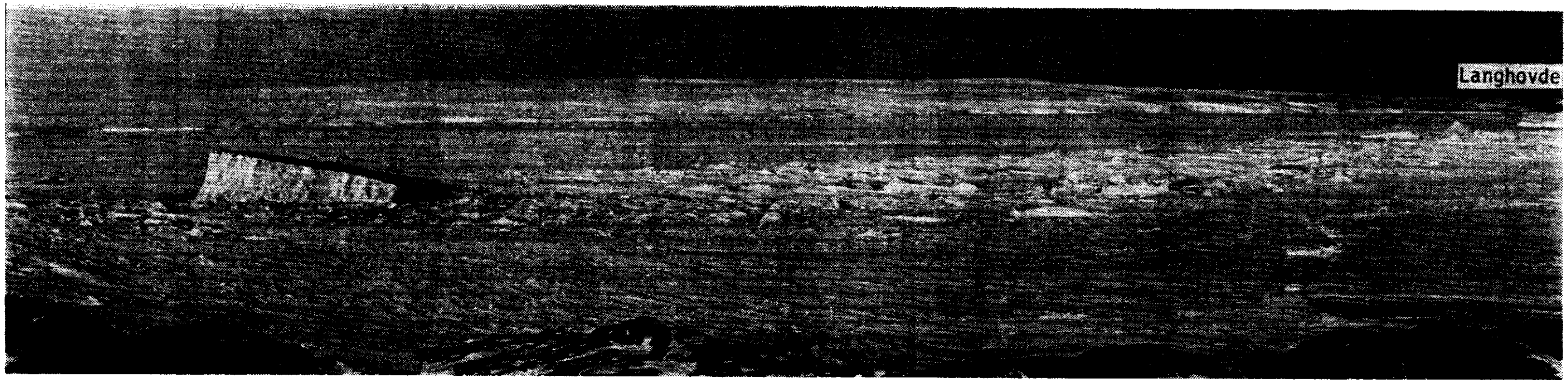

Fig. 7. Sea ice east of West Ongul Island viewed from Pollholmen (July 7, 1977).

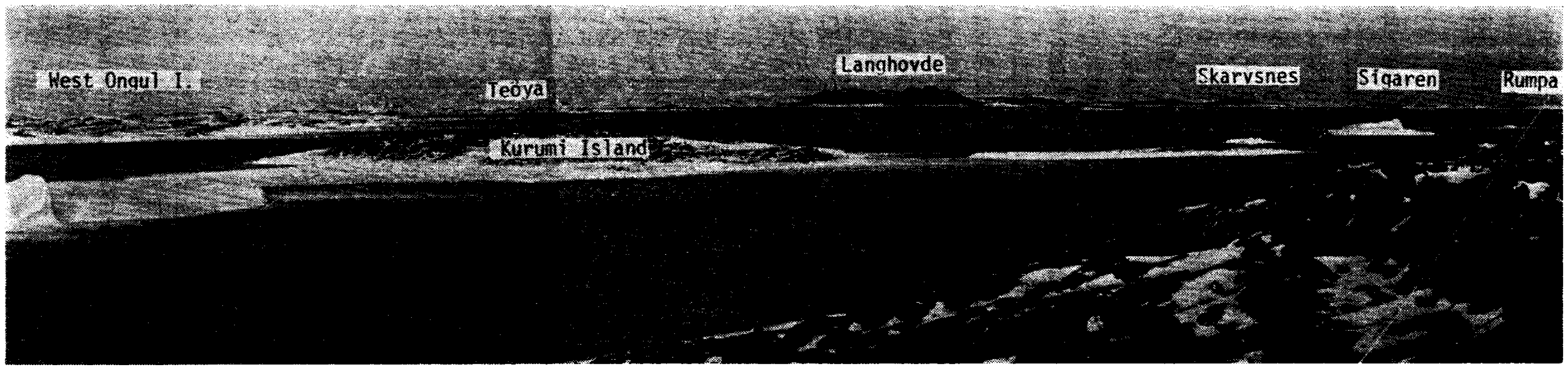

Fig. 8. Sea ice southwest of West Ongul Island viewed from Ongulkalven (July 17, 1977).

Ongul Island became stable after September, survey was done in this area, where sea ice was so flat and thin, 60–100 cm thick, that sounding progressed speedily (Fig. 8). 859 points of sounding were established by December 12th.

4.3. Results of survey

The submarine topography around the Ongul Islands reflects the geologic structure as has been already indicated by FUJIWARA (1971) and MORIWAKI (1975). A narrow and long trough between West Ongul Island and Ongulkalven (Island) joins northward to the north-south trough located to the northwest of West Ongul Island which has been reported by HAYASHI (1977), and it is inferred to be a glacial trough along the strike of foliation of the gneissic basement rocks. This trough also probably joins southward to one of the three troughs branching from the trough off the Langhovde Glacier (FUJIWARA, 1971; Fig. 12), and it seems to have been excavated by south-to-north moving ice.

As topographic features of the islands, such as rises and depressions along the strike of the foliation, trend in the direction of NNE–SSW near Ongulkalven, and change gradually to the N–S direction in the west and north of West Ongul Island and then to NNW–SSE in the east of West Ongul Island. Relief features arranged E–W and/or NE–SW, which intersect the N–S relief features rectangularly and/or diago-

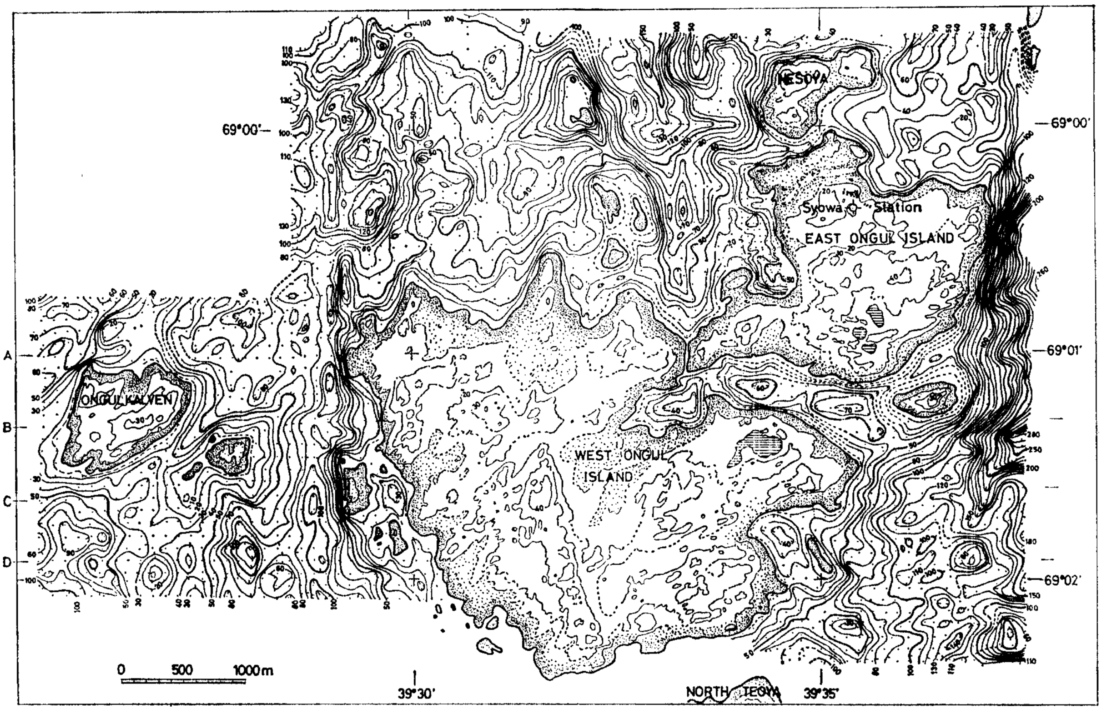

Fig. 9. Bathymetric chart around East Ongul Island, West Ongul Island and Ongulkalven compiled by MORIWAKI, who made use of charts and data of FUJIWARA (1971), MORIWAKI (1975) and HAYASHI (1977). (· position of sounding).

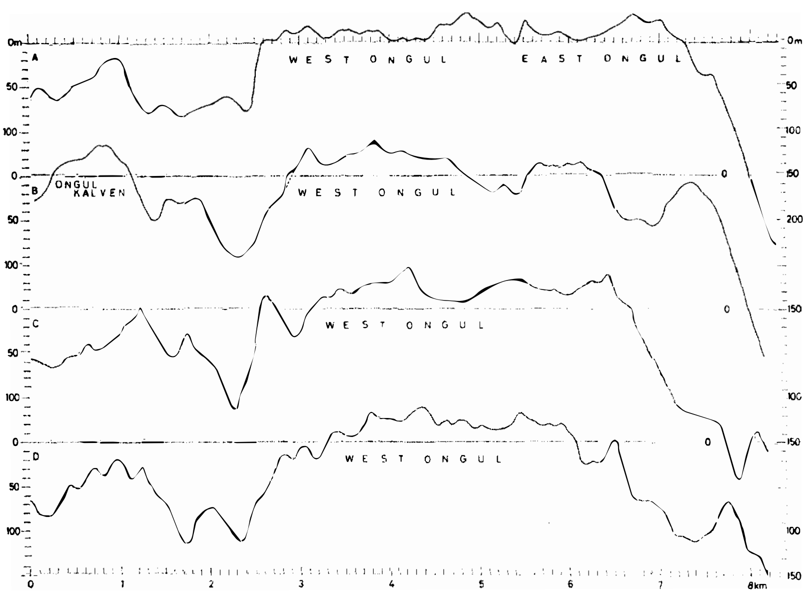

Fig. 10. W-E profiles of topography around the Ongul Islands, shown in Fig. 9.

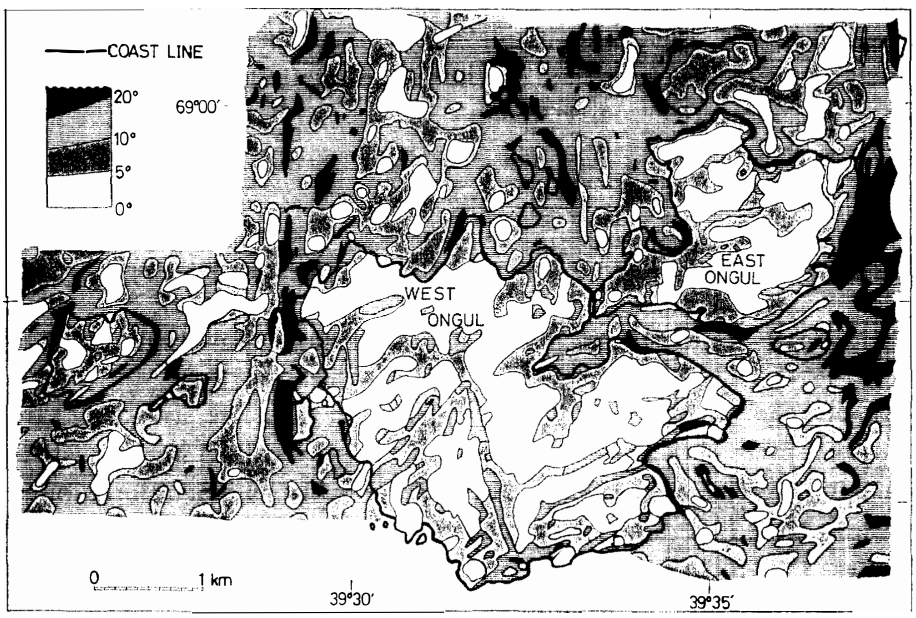

Fig. 11. Slope classification map around East Ongul Island, West Ongul Island and Ongulkalven.

nally, coincide in trend with the direction of the joint system in the basement rocks (YANAI *et al.*, 1974a, 1974b, 1975a, 1975b). Such arrangements of topographic features are somewhat obscure in the east of West Ongul Island, where relief features seem to be controlled more plainly by the joint system than by the strike of foliation of basement rocks.

A relatively flat and shallow floor (less than 200 m deep) extending north and NNW of the Ongul Islands is believed to be the remains of a preglacial peneplain (FUJIWARA, 1971; Fig. 12). An extremely flat and low relief landform of the Ongul Islands is found distinctly in a distant view (KOAZE, 1963; MORIWAKI, 1976), and their low relief landform is shown in Figs. 10 and 11. Such a low relief landform seems to be the remains of the undulating preglacial peneplain. It is inferred that a gently undulating preglacial landform was transformed into a jagged relief feature composed of depressions and troughs of various sizes by glaciation in a 'glacial epoch' which terminated at least 30000 yrs. B. P. on the Sôya Coast and the Prince Olav Coast (MEGURO *et al.*, 1964; YOSHIDA, 1971, 1977; OMOTO, 1977). Conspicuous depressions and troughs separated several islands with transgression after glaciation (Figs. 9 and 10).

There is a break of slope between submarine and subaerial topographies on East Ongul Island and West Ongul Island. The slope above sea level is gentle, while that under water is steep (FUJIWARA, 1971; MORIWAKI, 1975; Figs. 10 and 11). Such a break is not so conspicuous on small islands like Ongulkalven, where a flat area is very narrow or absent. If depressions and troughs which separate several islands were glaciated, the above-mentioned topographic discontinuity must have been formed by processes other than glaciation on the upper part of glaciated topography near the shore after deglaciation.

5. Summary

The geomorphological map of the eastern part of Lützow-Holm Bay is shown in Fig. 12.

1) The north-south depression of the central Lützow-Holm Bay joins the troughs off the Honnör Glacier, Telen Glacier, Shirase Glacier and others. It is the drowned glacial trough which was formed by a large ice stream fed by several outlet glaciers on the Sôya Coast when the ice sheet expanded in the past.

2) This huge glacial trough was formed probably by glaciation along a major geological structure like a fault. The geographical position and features of this trough suggest that there is the SSE–NNW and/or SE–NW major structural zones connecting the eastern margin of Gunnerus Bank to the Shirase Glacier.

3) The depth of the sea floor is different between the two sides of the central trough by more than 200 m. The depth of the sea floor on the east side is shallower than 300 m, whereas that on the west side seems to be 500–600 m. The reason of the difference is not known yet.

4) It was reconfirmed by the survey of JARE-18 that the submarine topography around the Ongul Islands reflects the geologic structure of the gneissic basement rocks.

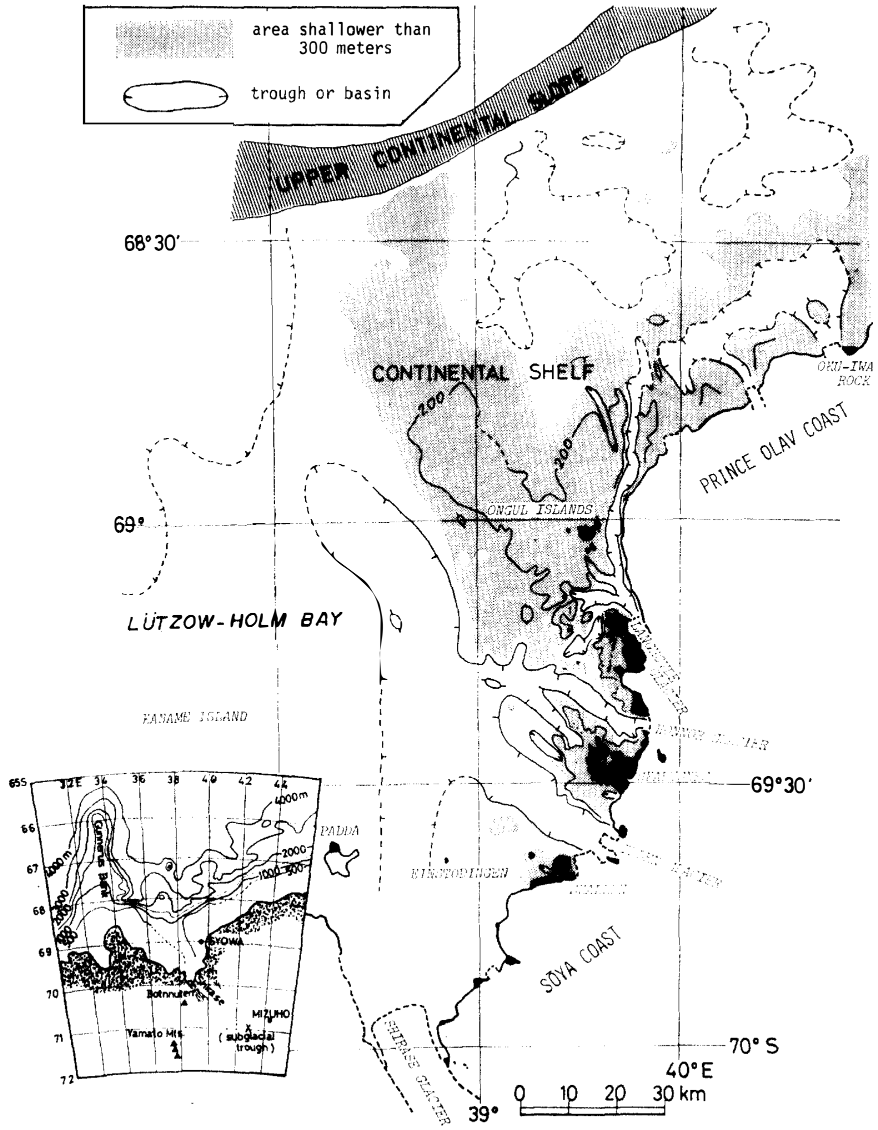

Fig. 12. Geomorphological map of the continental shelf near Syowa Station.

5) The relatively flat landform of the Ongul Islands originated from the gentle relief like a peneplain. Such gentle relief was glaciated and was divided into several islands when the ice sheet expanded in the past.

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