Proc. NIPR Symp. Antarct. Geosci., 1, 41–47, 1987

A PRELIMINARY SURVEY BY A SEISMIC PROFILING ACROSS THE GUNNERUS RIDGE OFF THE RIISER-LARSEN PENINSULA, ANTARCTICA

Kiichi MORIWAKI, Norikazu MATSUOKA and Yoshio YOSHIDA

National Institute of Polar Research, 9–10, Kaga 1-chome, Itabashi-ku, Tokyo 173

Abstract: The following conclusion can be drawn from the interpretation of sparker sonic prospecting records obtained on the Gunnerus Ridge, off the Riiser-Larsen Peninsula, East Antarctica. 1) The Gunnerus Ridge may be a horst composed of a continental crust, 2) a graben-like depression lies to the east of the ridge, and it seems to be connected with the inferred fault system in the central part of Lützow-Holm Bay, 3) topography or sediments on the ridge appear not to have been deformed by glaciation, suggesting that the maximum expansion of the past ice sheet might not have reached so far as 67°45′S in latitude on the Gunnerus Ridge 725 m in present depth.

1. Introduction

The Gunnerus Ridge forms an outstanding spur projecting into the Indian Ocean from the roughly circular continental margin of East Antarctica. It is located in 32°–35°E longitude and 66°–68°30′S latitude. Its southern part shallows toward south and is called Gunnerus Bank. The ridge is bounded by steep slopes on its eastern and western sides. Particularly, from the topographic characteristics the eastern slope may be regarded as a western edge of the major structural zone trending SSE-NNW and extending towards the Shirase Glacier (MORIWAKI, 1979), which is one of the most rapidly flowing ice streams in Antarctica (FUJII, 1981). The ridge is also expect to provide some information regarding the extent of the past expanded ice sheet (FUJIWARA, 1971; YOSHIDA and MAE, 1978). On the other hand, gravels of shale, sandy shale and sandstone were dredged by R/V UMITAKA MARU at two stations 730 m (69°49.5′S, 33°02′E) and 790 m (67°48.5′S, 33°41′E) deep respectively on the Gunnerus Ridge in 1957 (Fig. 1). These gravels are inferred to have been derived from Neogene rocks, because they contain fossils of Neogene foraminifera (NIINO, 1958), though no Tertiary rock is known on land in the vicinity of the Gunnerus Ridge.

In relation to these problems a preliminary sonic prospecting was carried out by a 4.5 kJ sparker across the Gunnerus Ridge on board the icebreaker SHIRASE in the 27th Japanese Antarctic Research Expedition (1986). The result and its interpretation briefly reported here.

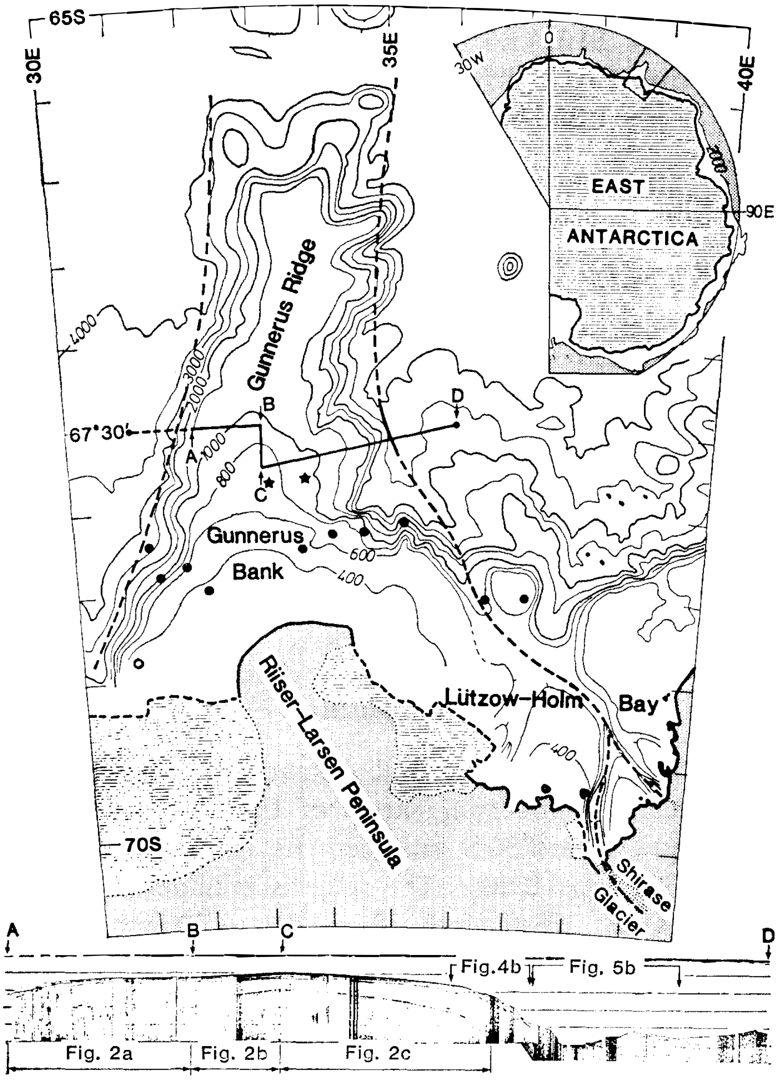

Fig. 1. Submarine topography around the Gunnerus Ridge (modified from GEBCO 5·18, 1980) showing the location of sparker profiling, the traces of inferred faults and the former dredged stations (star: by R/V UMITAKA MARU (NIINO, 1958); solid circle: R/S SÔYA (SHOJI and SATO, 1959); open circle: by R/S SÔYA (SATO, 1964)).

2. Track of Seismic Profiling

Tracks of seismic profiling were approximately an E-W line along 67°30′S latitude and partially an N-S line along 33°E longitude, which ran roughly along the northern outer edge of a pack ice zone off the Riiser-Larsen Peninsula in the survey period (18–20 February 1986). Total length of the surveyed line was about 245 km. We failed, however, in obtaining reflection from the sea bottom on its western 38 km line (Fig. 1).

3. Seismic Profiling and Interpretation

The Gunnerus Ridge rises abruptly from a surrounding abyssal plain 3800–4000 m

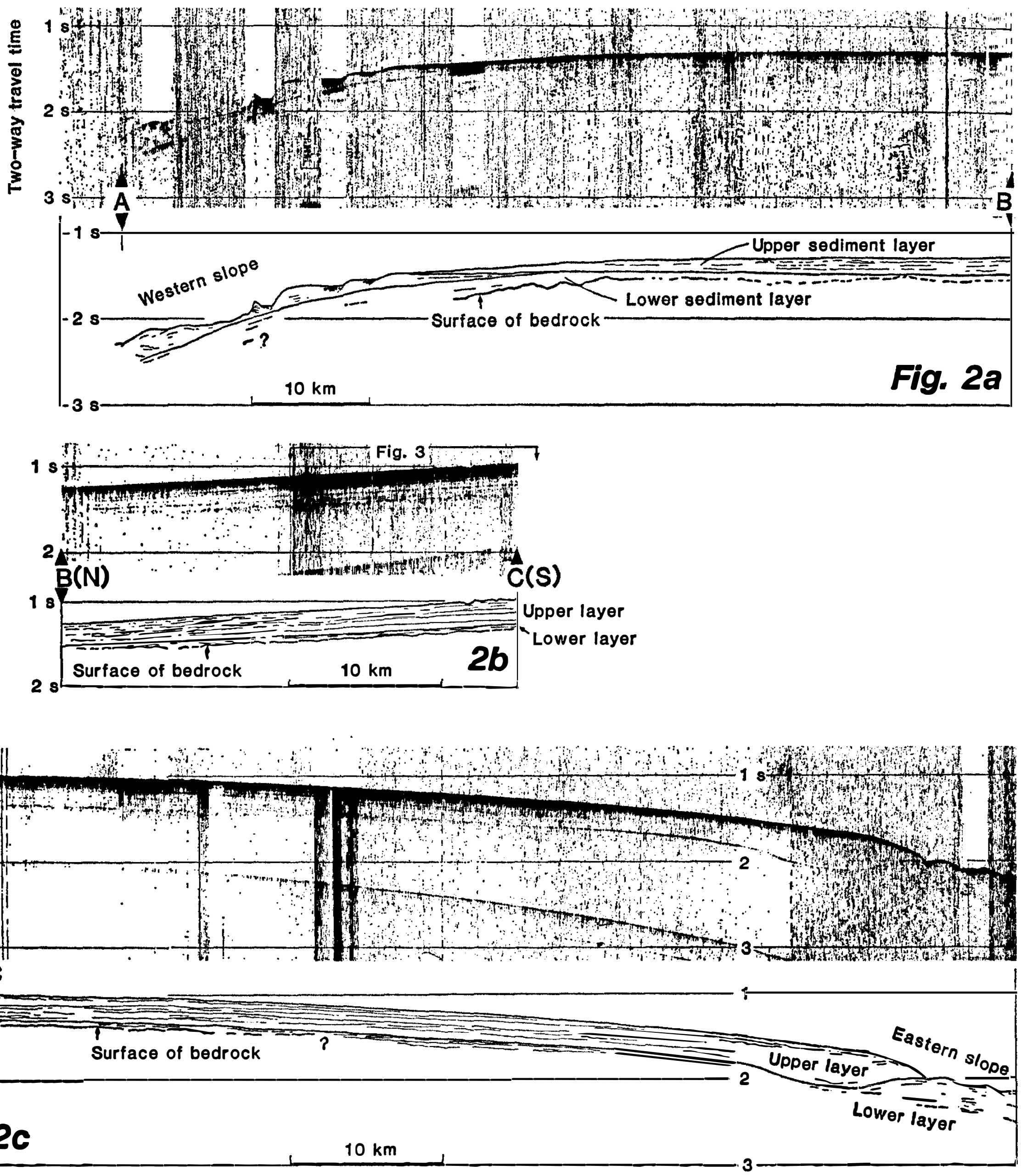

Fig. 2. Sparker profiles and interpreted sections of the Gunnerus Ridge shown in Fig. 1.

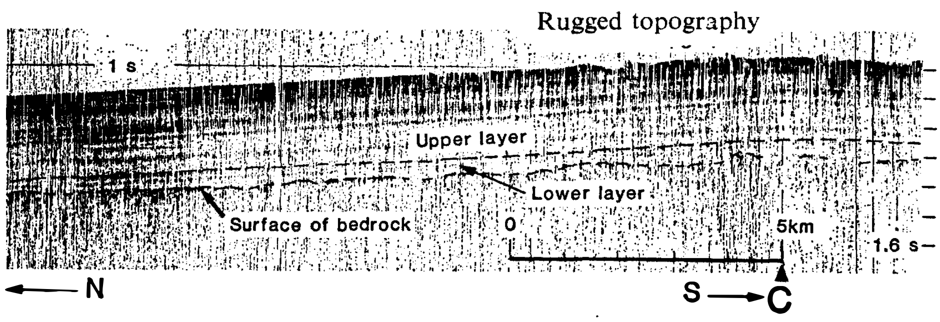

Fig. 3. A sparker profile of the flat top and the rugged topography of the Gunnerus Ridge.

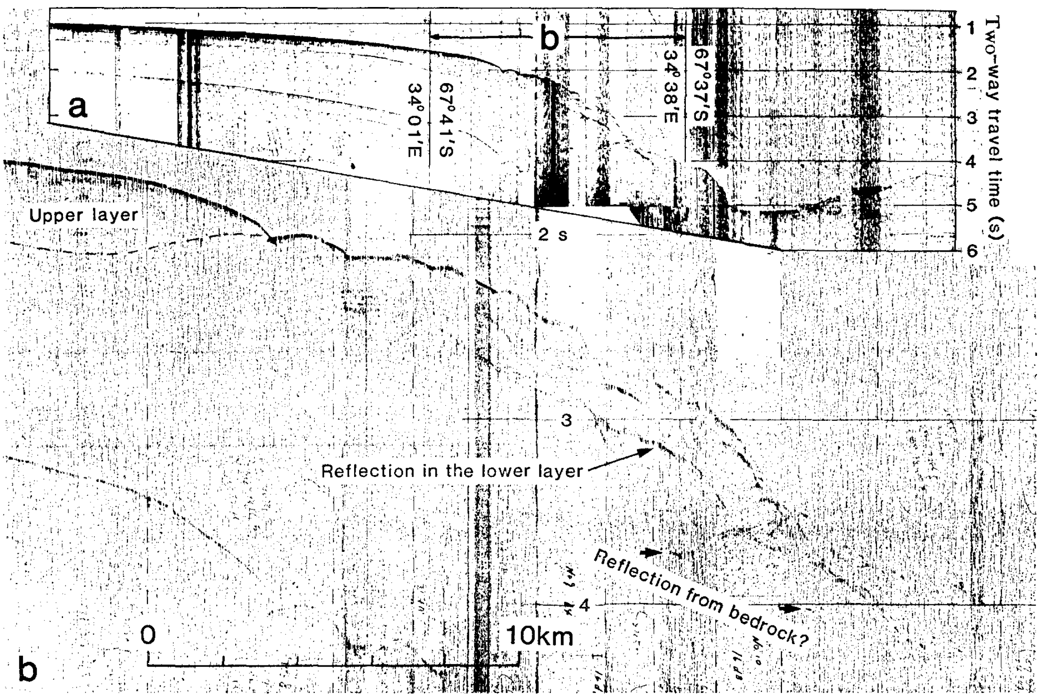

Fig. 4. A sparker profile of the eastern slope of the Gunnerus Ridge.

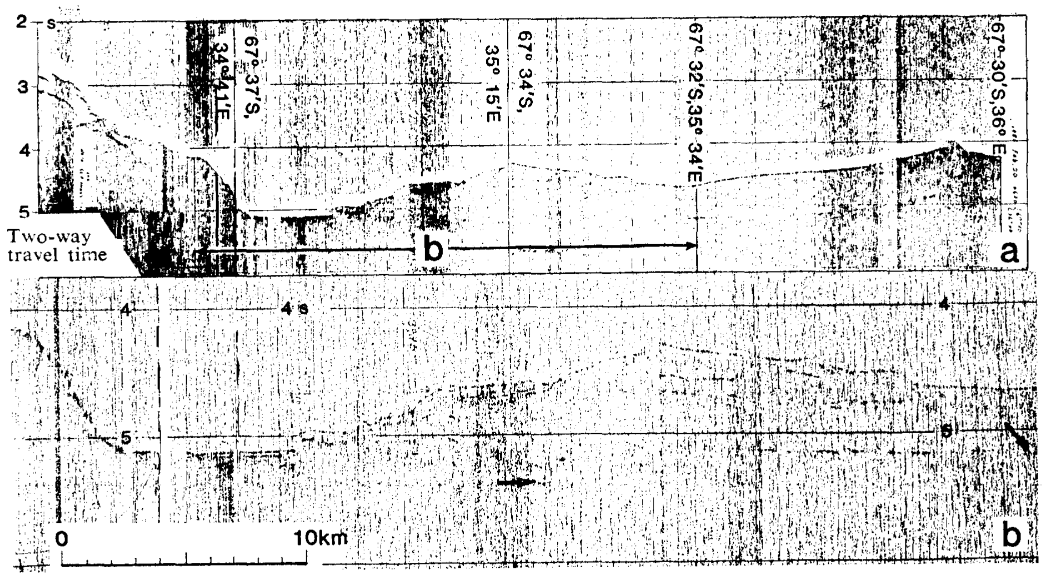

Fig. 5. A sparker profile east of the Gunnerus Ridge.

deep and has a broad and remarkably flat top 750–1200 m deep along the survey line. This protuberance is composed of the high seismic velocity (5.8 km/s) bedrock (SAKI *et al.*, 1987), which is covered by sediments of constant thickness (two-way travel time: 0.3–0.4 s) in the area of the top of the ridge (Figs. 2, 3). The sediments show horizontally stratified structure. Many angular gravels were dredged from the south of the present surveyed area on the Gunnerus Ridge (SHOJI and SATO, 1959; SATO, 1964; Fig. 1). These facts suggest that these sediments are not basal tills brought by the past expanded ice sheet but glaciomarine deposits brought by icebergs (SATO, 1964). The sediments are probably divided into two units of sediment layers by a strong reflector (Fig. 2). The upper layer clearly shows a horizontally stratified structure and becomes thinner to the west. Furthermore, it was not deposited on both eastern and western slopes of the ridge. The surface topography of the upper layer is very smooth except the southernmost part of the line B-C, where a rugged topography exists (Fig. 3). The rugged topography seems to have been formed in the upper layer by some erosional action. However, it seems to be too deep in water depth and too large on spatial scale to be iceberg plough marks (DREWRY, 1986). The origin of its topography is not clear at present.

The lower layer is recognized throughout this survey line. It is probably subdivided into two or more parts on the western and the eastern slopes of the Gunnerus Ridge (Figs. 4, 6). The lower layer seems to bury a gentle relief of the bedrock on the top of the ridge but it is very thin there (Figs. 2, 3). Difference in sedimentary areas between the upper and the lower layers seems to be caused by conspicuous change in sedimentary environment such as formation of a circum-Antarctic current. Bedrock surface of the top of the ridge forms a rather flat plane without any trough. This suggests that the bedrock surface had been an old erosional continental shelf and the area had not been affected by glacial erosion.

Beam trawling for marine biological investigation in JARE-27 at the depth of 955 m on the surveyed line also yielded angular gravel specimens. However, all of them are of crystalline rock and no Tertiary sedimentary rock gravel was found.

The eastern slope (1200–3800 m deep) of the Gunnerus Ridge is covered with the lower sediment layer and forms a step-like topography (Fig. 4). Absence of the upper layer means that the eastern slope has been exposed in erosional environment after sedimentation of the lower layer. It is possible that the step-like topography was formed by current erosion. Thickness of sediments is not known because any clear reflection from bedrock surface could not be obtained by the present survey. However, it is a fact that there are irregular strong reflectors in the sediments. Such deformed structure of the sediment layer was probably caused by tectonic movement.

To the east of the foot of the eastern slope, a depression approximately 10 km wide and a gentle rise located further eastward were found (Fig. 5). The rise seems to be composed of sediments because they appear to have obscure bedding planes. The depression between the rise and the Gunnerus Ridge has a remarkably flat surface of sedimentary origin, and its sediment shows a horizontal sedimentary structure at least in the upper part of it. Though the depth of basement is not clear, the origin of this depression is inferred to be a tectonic depression and it seems to have been buried by sediments without disturbance until recently.

The western slope of the Gunnerus Ridge deepens abruptly from the depth of 1100 m but its lower part deeper than 1600 m is not clear because reflection from the sea bottom was not obtained. The western slope is covered with the lower sediment layer and forms also a step-like topography. There is a strong reflector in the sediments at least on the upper part of the western slope. This reflector seems to be not deformed. Therefore, the step-like topography was probably formed by current erosion and/or sliding of sediments upper than the reflector (Fig. 6). The steep western

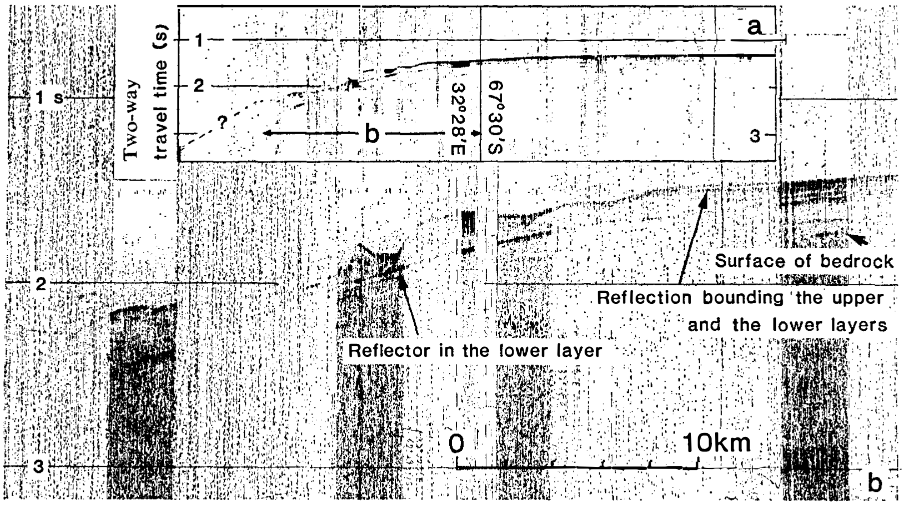

Fig. 6. A sparker profile of the upper part of the western slope of the Gunnerus Ridge.

slope seems to be of tectonic origin (SAKI *et al.*, 1987), though evidence of it was not obtained by the present survey.

In Lützow-Holm Bay southeast of the Gunnerus Ridge submarine glacial troughs develop on the continental shelf. The central trough which constitutes the lower reaches of two troughs off the Shirase and the Tellen Glaciers divides the sea floor into the western and the eastern parts. The former is 300 m deeper than the latter. These troughs are inferred to have been greatly affected by faulting. Abrupt change in direction of the outer margin of the continental shelf is conspicuous at the mouth of Lützow-Holm Bay. These facts, together with the embayment of the bay itself, may suggest that the Lützow-Holm Bay region is situated on one of major tectonic zones in East Antarctica (MORIWAKI and YOSHIDA, 1983). The graven-like depression at the foot of the eastern slope of the Gunnerus Ridge is located on a line extending from one of the inferred faults in Lützow-Holm Bay (Fig. 1). Therefore, the formation of the Gunnerus Ridge might have been closely related to the crustal movement which had influenced the formation of the major topography of Lützow-Holm Bay.

4. Concluding Remarks

(1) The Gunnerus Ridge may be composed of continental crust extending toward north from the Riiser-Larsen Peninsula. It seems to be a part of submerged continent and to be a horst bounded by faults on its eastern and western sides. Therefore, the ridge must be taken into consideration for the reconstruction model of the Indian Ocean sector of Gondowanaland (*e.g.* KATZ, 1978).

(2) The graven-like depression in the east of the Gunnerus Ridge seems to be connected with the inferred faults indicated by deep troughs in the central part of Lützow-Holm Bay, the Shirase and the Tellen Glaciers. This fact confirms to some extent the presence of large scale faulting in the Lützow-Holm Bay region (MORIWAKI and YOSHIDA, 1983).

(3) There is no evidence that the ice sheet advanced as far north as 67°45'S

latitude (725 m deep) on the Gunnerus Ridge even during the past maximum ice sheet expansion.

Acknowledgments

The present authors express their hearty gratitude to the members of the summer party of JARE-27 and the crew of icebreaker SHIRASE. They are also deeply indebted to Dr. H. KAGAMI, Ocean Research Institute, the University of Tokyo, for his critical reading of the manuscript.

References

DREWRY, D. (1986): Glacial Geologic Processes. London, Edward Arnold, 276 p.

FUJII, Y. (1981): Aerophotographic interpretation of surface features and an estimation of ice discharge at the outlet of the Shirase drainage basin, Antarctica. Nankyoku Shiryô (Antarct. Rec.), **72**, 1–15.

FUJIWARA, K. (1971): Ryutsuo·Horumu Wan ni okeru sokushin to hyôshoku tairiku-dana no chikei (Soundings and submarine topography of the glaciated continental shelf in Lützow-Holm Bay, East Antarctica). Nankyoku Shiryô (Antarct. Rec.), **41**, 81–103.

KATZ, M. B. (1978): Sri Lanka in Gondowanaland and the evolution of the Indian Ocean. Geol. Mag., **115**, 237–316.

MORIWAKI, K. (1979): Submarine topography of the central part of Lützow-Holm Bay and around Ongul Islands, Antarctica. Mem. Natl Inst. Polar Res., Spec. Issue, **14**, 194–209.

MORIWAKI, K. and YOSHIDA, Y. (1983): Submarine topography of Lützow-Holm Bay, Antarctica. Mem. Natl Inst. Polar Res., Spec. Issue, **28**, 247–258.

NIINO, H. (1958): Nankyoku Purinsu Hararudo Kukku Misaki oki no teishitsu (On the bottom deposits of the sea around Cape Cook, Prins Harald Coast, Antarctic region). Tokyo Suisan Daigaku Tokubetsu Kenkyû Hôkoku (J. Tokyo Univ. Fish., Spec. Ed.), **1**, 250–257.

SAKI, T., TAMURA, Y., TOKUHASHI, S., KODATO, T., MIZUKOSHI, I. and AMANO, H. (1987): Preliminary report of geological and geophysical surveys off Queen Maud Land, East Antarctica. Proc. NIPR Symp. Antarct. Geosci., **1**, 23–40.

SATO, T. (1964): Submarine topography and several bottom sediments around Prince Olav and Prince Harald Coasts, Antarctica. Nankyoku Shiryô (Antarct. Rec.), **21**, 1–11.

SHOJI, D. and SATO, T. (1959): Nankyoku no teishitsu—Sono ryûdo bunseki (On the bottom sediment dredged by the second Japanese Antarctic Exploration. Especially on the grain size analysis). Nankyoku Shiryô (Antarct. Rec.), **7**, 39–49.

YOSHIDA, Y. and MAE, S. (1978): Some information on topographic features and the characteristics of the ice sheet around the Yamato Mountains. Mem. Natl Inst. Polar Res., Spec. Issue, **8**, 93–100.

(Received March 3, 1987; Revised manuscript received April 20, 1987)