SEA GRAVITY MEASUREMENTS IN THE ANTARCTIC REGIONS DURING THE 22ND AND 23RD JAPANESE ANTARCTIC RESEARCH EXPEDITIONS

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Abstract: Sea gravity measurements on board the icebreaker FUJI in the Antarctic regions were conducted in the 23rd Japanese Antarctic Research Expedition (JARE-23). They are the second intensive measurements following the work of JARE-22.

Cruise tracks of JARE-22 and -23 have some crossing points in the Antarctic regions. Gravity data at the crossing points were used to calibrate outputs of the sea gravity meter NIPRORI.

The icebreaker FUJI entered Amundsen Bay for the first time during the cruise of JARE-23. Detailed sea gravity survey in the bay revealed a significant, local free-air gravity low down to −70 mgal in the area.

1. Introduction

Gravity data in the Antarctic regions are still insufficient today, though they are necessary for knowing global gravity, geoid and tectonics of Antarctica. The icebreaker FUJI is possibly the only Japanese vessel which can be sent regularly to Syowa Station in the Antarctic regions by the Japanese Antarctic Research Expedition every year to transport research expedition parties. Therefore, we can conduct sea gravity measurements on board the icebreaker on her round trip cruise, and expect that gravity data will be accumulated year by year. During the 22nd Japanese Antarctic Research Expedition (JARE-22) from 1980 to 1981, the first sea gravity measurements in the Antarctic region were carried out (KASUGA *et al.*, 1982a). The measurements were conducted also during JARE-23, from 1981 to 1982. In this paper, we report the results of gravity measurements conducted in both JARE-22 and -23.

2. Outline of the Cruise

The tracks of the icebreaker FUJI south of 40°S during JARE-22 and -23 are shown in Fig. 1. In both cruises the icebreaker left Tokyo on 25 November, calling at Fremantle, Australia from 11 to 16 December, and reached the edge of the sea ice north of Syowa Station on 2 January of the following year in JARE-22 and 4 January in JARE-23. On the way back from Syowa Station, she visited Molodezhnaya Station of USSR and left the station on 17 February in JARE-22 and 16 February in JARE-23. The next port of call was Port Louis, Mauritius where she stayed from 11 to 17 March, and then visited Singapore to stay from 1 to 8 April. The date she returned to Tokyo was 20 April. These dates were the same for both JARE-22 and -23.

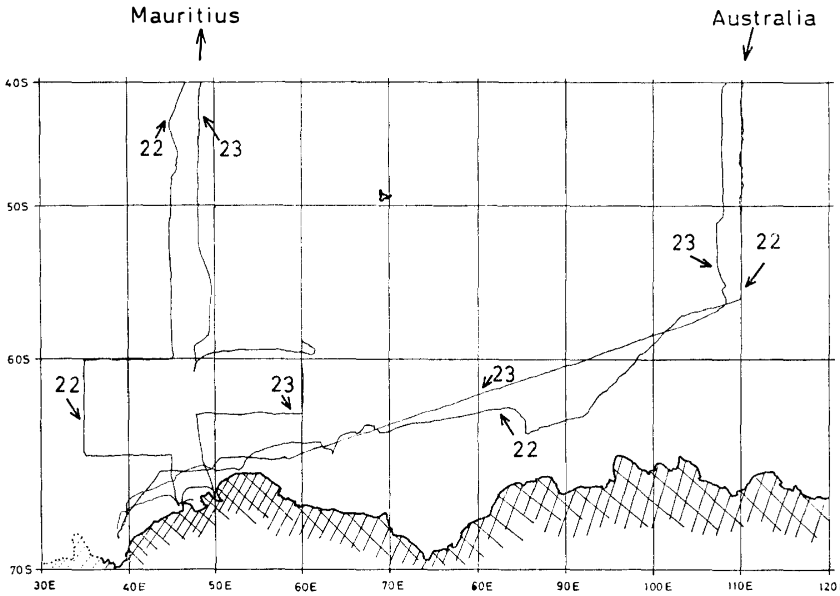


Fig. 1. The tracks of the icebreaker FUJI south of 40°S during JARE-22 and -23.

At the quays of Tokyo, Fremantle, Port Louis, and Singapore we measured gravity by means of a LaCoste & Romberg land gravity meter, whose uncertainty of readings was less than $\pm 30\ \mu$gal. We failed to make another calibration point on the ice sheet about 100 cm thick, where we estimated the accuracy of the gravity measurement to be 5 mgal because of vibrations of the ice sheet.

At Tokyo (in JARE-22 and -23) and Singapore (only in JARE-22) we brought the LaCoste & Romberg gravity meter to the gravity base station to calibrate it. We brought it also to the gravity base station at Syowa Station for calibration. Assuming that scale factors of the meter given from the LaCoste & Romberg Inc. were reliable, we estimated drifts of the land gravity meter by comparing the obtained values with those previously given at the stations. The estimated drift rates of the land gravity meter were 0.3 mgal/month during JARE-22 and 1.0 mgal/month during JARE-23.

The sea gravity meter NIPRORI on board has characteristics which can be expressed by,

$$g = A \cdot q + B + C \cdot \exp(-d/T),$$

(KASUGA *et al.*, 1982a) where g is a gravity value in mgal, q an output of the sea gravity meter in volts and d the days elapsed since the icebreaker departed from Tokyo.

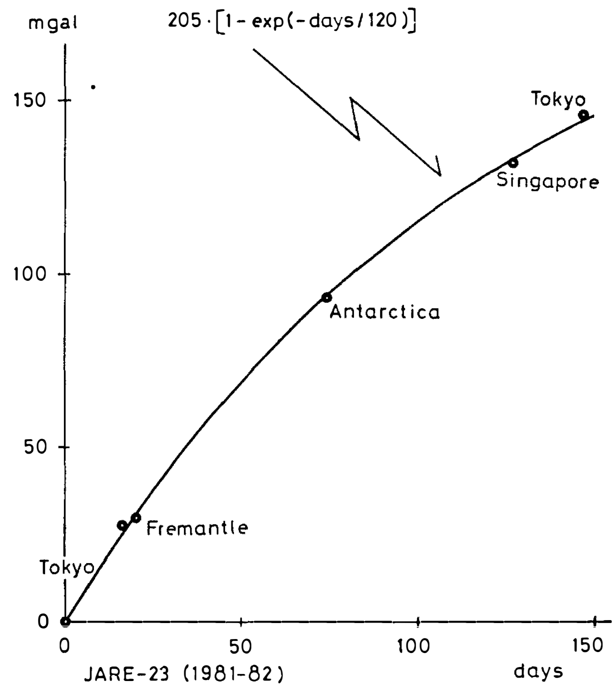


Fig. 2. Drift of the sea gravity meter NIPRORI during JARE-23. The abscissa indicates days elapsed, d, since the icebreaker departed from Tokyo. The ordinate indicates meter's drift in mgal. The curve written in the figure is obtained from C·(1−exp(−d/T)), where a drift amplitude C=205 mgal and a drift time constant T=120 days.

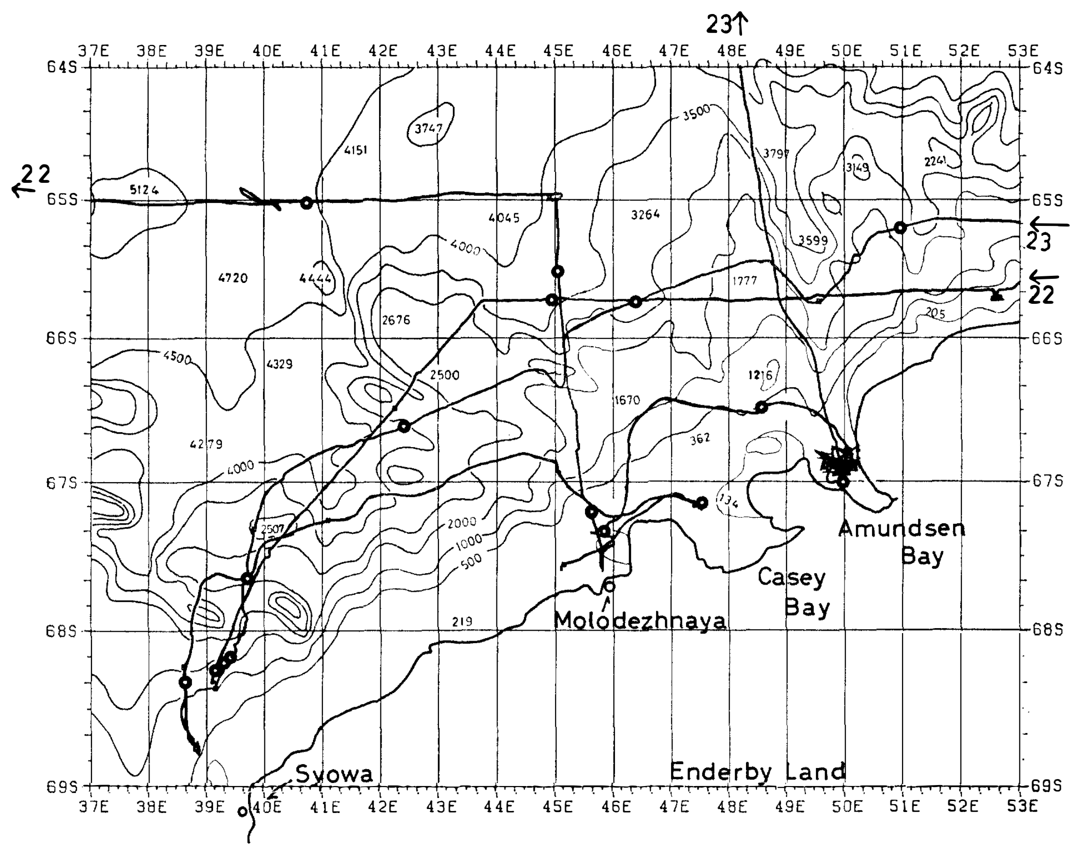
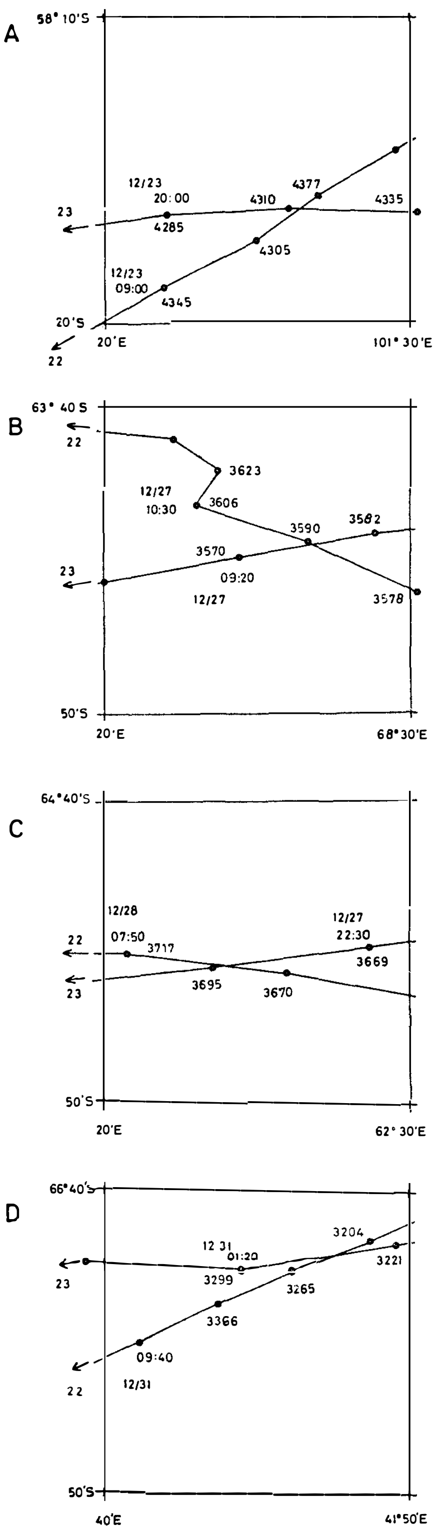
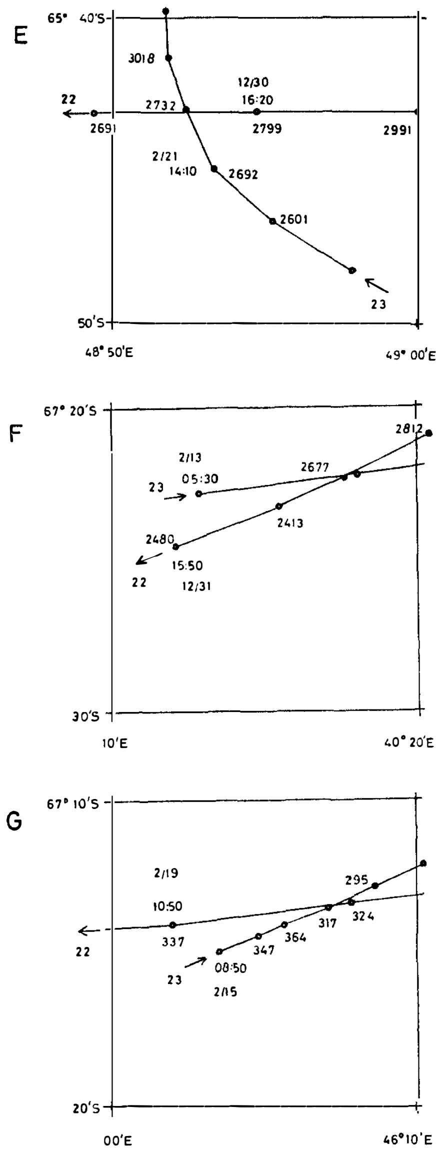


Fig. 3. Detailed cruise tracks in JARE-22 and -23 off the Enderby Land of Antarctica. There are some crossing points between tracks of JARE-22 and -23.





	JARE-22	JARE-23	△
A	981790.6	981776.1	+14.5
B	982216.7	982225.4	-8.7
C	982283.8	982273.8	+10.0
D	982424.3	982427.9	-3.6
E	982357.4	982352.6	+4.8
F	982498.7	982496.3	+2.4
G	982475.2	982480.4	-5.2

(mgal)

P2202 J
03 J
P2302 E
03 E

Fig. 4. The crossing points are shown from A to F, where lines marked by 22 and 23 are the tracks of JARE-22 and -23, respectively. Positions of the icebreaker plotted every ten minutes are shown by circles, and time in UT and bathymetry near the spots in meters are indicated. Differences between gravity values obtained in JARE-23 and revised values for JARE-22 are shown in a table in the figure.

Gravity values, g, measured by the land gravity meter at quays were used to determine a coefficient, A, a drift amplitude, C, a drift time constant, T, and a constant, B. The drift of the sea gravity meter during JARE-23 is shown in Fig. 2, where the abscissa indicates days elapsed and the ordinates does meter's drift in mgal. The curve in Fig. 2 shows $C \cdot (1-\exp(-d/T))$ with $C=205$ mgal and $T=120$ days. The drift rate was much reduced compared with C = 523 mgal and $T=120$ days for the case of JARE-22 (KASUGA *et al.*, 1982a). The drift amplitude of JARE-23 became almost one third of that of JARE-22.

Detailed cruise tracks in JARE-22 and -23 off the Enderby Land, Antarctica are shown in Fig. 3. The bathymetric map in the figure is redrawn after Atlas Okeanov (MINISTERSTVA OBORONY, 1977). There are some crossing points between cruise tracks of JARE-22 and -23. In the Antarctic regions we did not have calibration points for the sea gravity meter except for the point on the ice sheet, and we used gravity measurements at the crossing points to calibrate the meter. Assuming that gravity values obtained during JARE-23 when the drift was much smaller, were true, we revised values for JARE-22. Revised gravity values for JARE-22 obtained in this way show values 5 to 6 mgal smaller than those presented in the previous paper (KASUGA *et al.*, 1982a, b) for the part of the tracks on the way to Antarctica, and almost the same on the way back. In Fig. 4, the crossing points are shown from A to G, where lines marked by 22 show the tracks of JARE-22 and those marked by 23 the tracks of JARE-23. Positions of the icebreaker are shown by open circles with every ten minutes, and time in UT and bathymetry near the spots in meters are indicated. Differences between gravity values obtained by JARE-23 and those by JARE-22 are shown in the lower part of the figure. Large differences at A and C can be considered as the errors in Eotvös correction which were calculated using satellite fixes obtained from a Navy Navigation Satellite System receiver on board. Uncertainty of the obtained sea gravity values during JARE-22 and -23 is thought to be 15 mgal in the worst case.

3. Discussion

Figures 5 and 6 show cruise tracks, profiles of gravity anomalies and bathymetry across the Gaussberg Plateau and the Lena Bank, respectively. In Fig. 5a or 6a, the cruise tracks indicated by 22 and 23 give those of JARE-22 and -23, respectively, drawn over the bathymetric map after Atlas Okeanov (MINISTERSTVA OBORONY, 1977). The arrow marks indicate direction in which the icebreaker proceeded. Circles on the lines mark midnight in UT. Profiles of (b) and (c) in each figure show bathymetry in meters, free-air gravity anomaly in mgal, and simple Bouguer gravity anomaly in mgal from the lower to the upper, respectively. The abscissa of each profile shows the length of ship's track. Vertical lines mark intervals of every six hours, where the corresponding time is given every twelve hours in UT. Numbers attached to be bottom of the profiles indicate month and day as, for example, 1225 reads December 25.

The Gaussberg Plateau in Fig. 5 is a southern part of the much larger plateau extending to Kerguelen Island at about 49°S in latitude and 70°E in longitude. As seen in Fig. 5a of the case of JARE-22 and -23, the icebreaker passed the southern and northern sides of the plateau, respectively. Changes of free-air anomalies on the

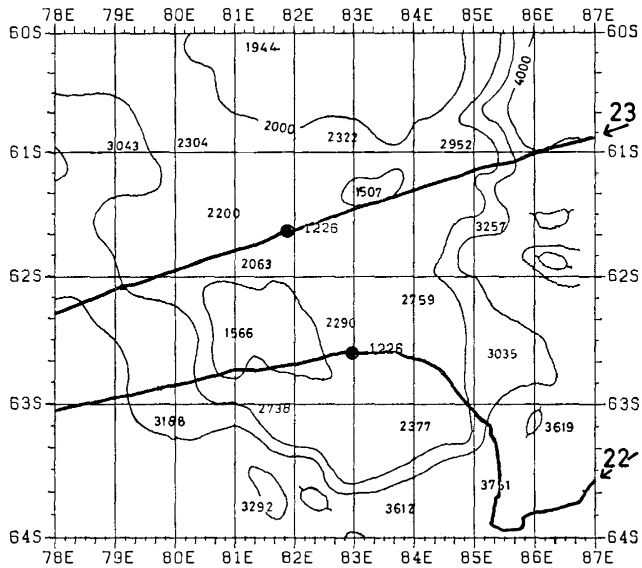


Fig. 5a. Cruise tracks across the Gaussberg Plateau. Lines marked by 22 and 23 indicate tracks of JARE-22 and -23, respectively. The arrow marks indicate the direction in which the icebreaker proceeded. Circles on the lines mark midnight in UT.

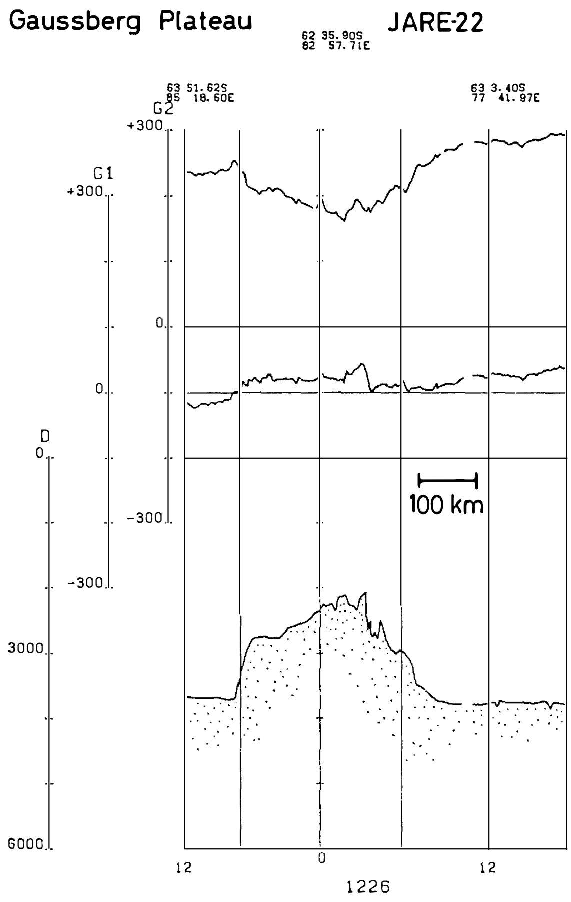


Fig. 5b.

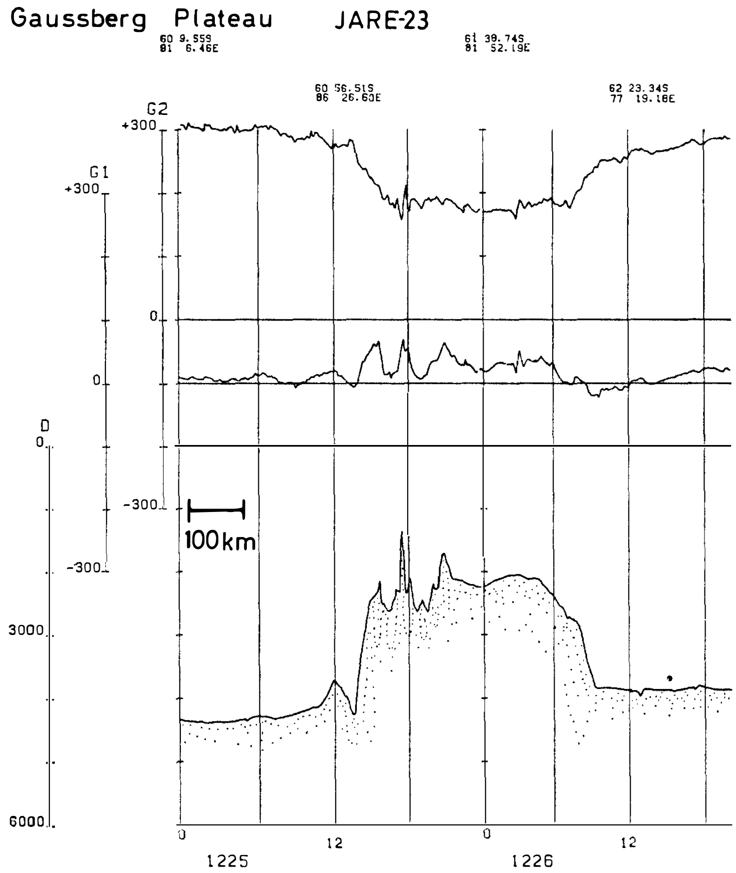


Fig. 5c.

Figs. 5b and 5c. Profiles of bathymetry in meters, free-air anomaly in mgal, and simple Bouguer gravity anomaly in mgal from the lower to the upper. The abscissa shows the length of ship's track. Vertical lines mark intervals of every six hours, where the corresponding time is given every twelve hours in UT. Numbers attached to the bottom of the profiles indicate month and day as, for example, 1228 reads December 28. (b) is the profile across the Gaussberg Plateau obtained during JARE-22 and (c) is that obtained during JARE-23.

plateau are not very distinguished as a whole, but small scale changes with an amplitude of 50 mgal and a wavelength of about 50 km can be recognized in good correspondence to bathymetric notches, especially for profiles of JARE-23.

As seen in Fig. 6a, in the case of JARE-22 the icebreaker ran across the Lena Bank, but in the case of JARE-23 she ran across the unnamed bank which is located 200 km west of the Lena Bank. A positive peak of free-air anomaly up to +130 mgal at the center of the Lena Bank and gravity lows at its foot can be seen in Fig. 6b. A topographic sink at the top of the bank reflects clearly on the free-air anomaly. A large rise at the center of the bathymetric profile in Fig. 6c is the unnamed paired banks. Maximum free-air anomaly of +70 mgal and +140 mgal correspond to each bank. The smaller peak beside the main bank shows a gravity high of +30 mgal in the regional gravity low of −40 mgal. Gravity low of −30 mgal can be also recognized at the other side of the bank. Existence of these gravity lows implies that there is a low density layer at a greater depth.

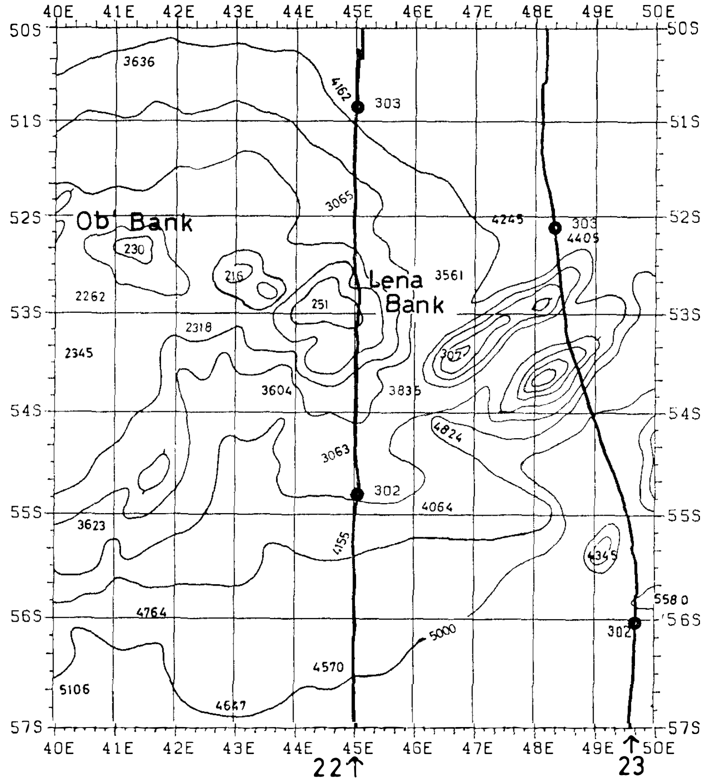


Fig. 6a. Cruise tracks near the Lena Bank.

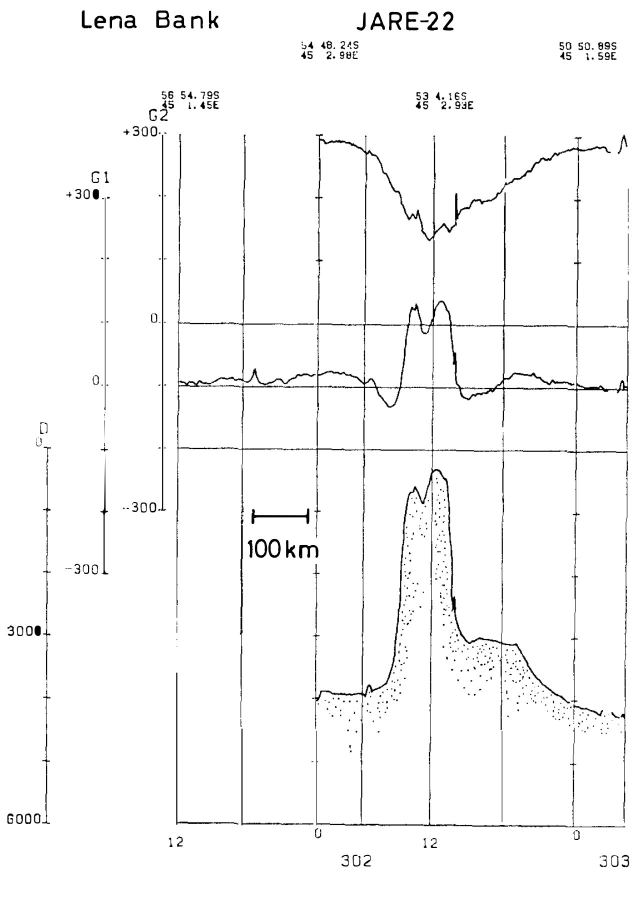


Fig. 6b. Profiles across the Lena Bank obtained during JARE-22.

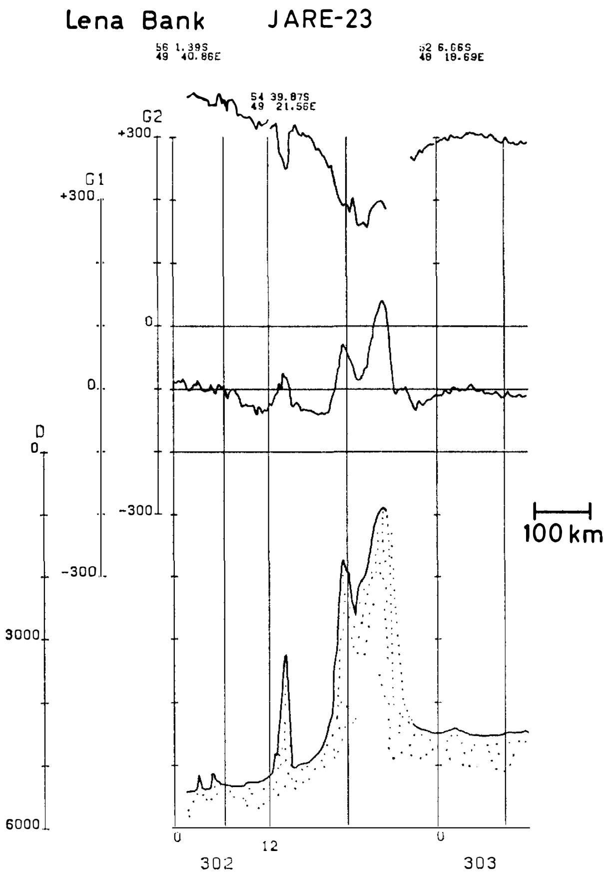


Fig. 6c. Profiles across the unknown bank which is located 200 km west of the Lena Bank, obtained during JARE-23.

Figure 7 shows profiles obtained off the Enderby Land of Antarctica during JARE-23. The profiles are complicated because the icebreaker went in and out of the continental shelves and bays. The icebreaker of JARE-23 went into Amundsen Bay for the first time. Her tracks inside the bay are shown in Fig. 8a. Amundsen Bay is located at the foot of the Mt. Riiser-Larsen where the oldest rocks of an age 4.0×10^9 yr were found by the USSR Antarctic Research Expedition. Figures 8b and 8c show preliminary maps of bathymetry and free-air anomaly, respectively, which were obtained by the surveys along tracks in Fig. 8a. Although restricted to the entrance of Amundsen Bay, a gravity low can be recognized in the greater part of the bay, as seen in the map of free-air anomaly. This gravity low may become lower in the area further inside the bay. Taking bathymetry which may become deeper than 1000 m in the inner part of the bay into consideration, it is inferred that a glaciated large valley is hidden in the bay.

4. Conclusion

The sea gravity measurements in the Antarctic region were successfully conducted during JARE-22 and -23. The number of the measurements necessary for the dis-

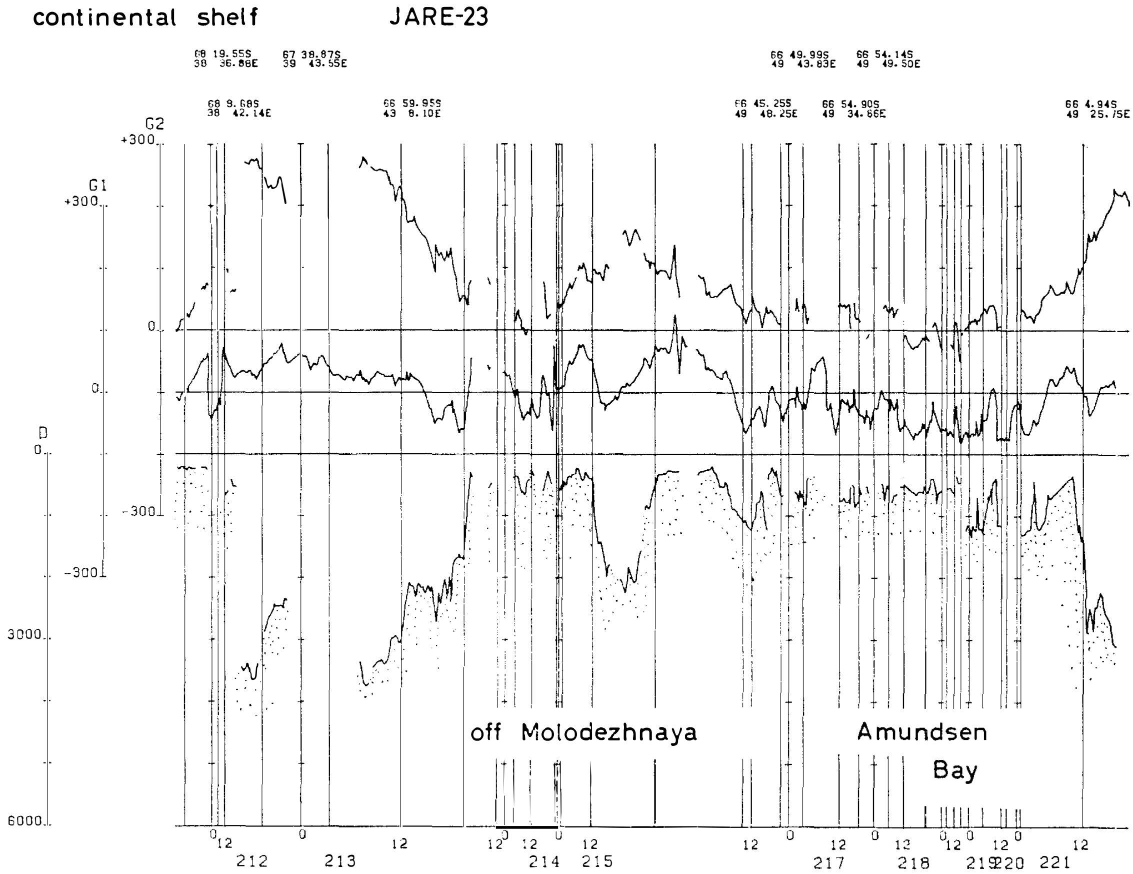


Fig. 7. Profiles of bathmetry and gravity anomalies off the Enderby Land obtained during JARE-23. Notations in this figure are the same as those in (b) and (c) of Figs. 5 and 6.

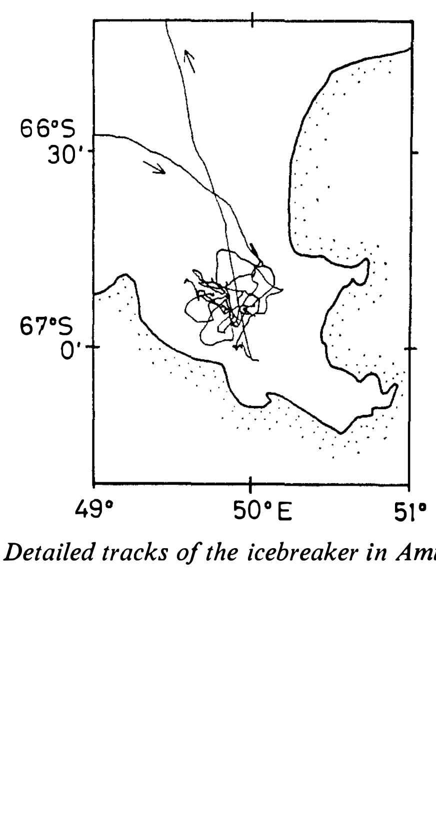


Fig. 8a. Detailed tracks of the icebreaker in Amundsen Bay.

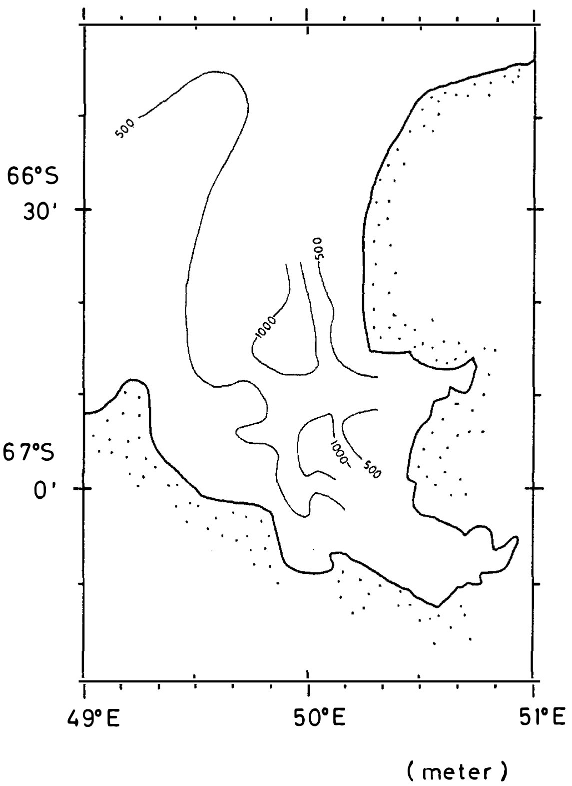


Fig. 8b. Preliminary map of bathymetry.

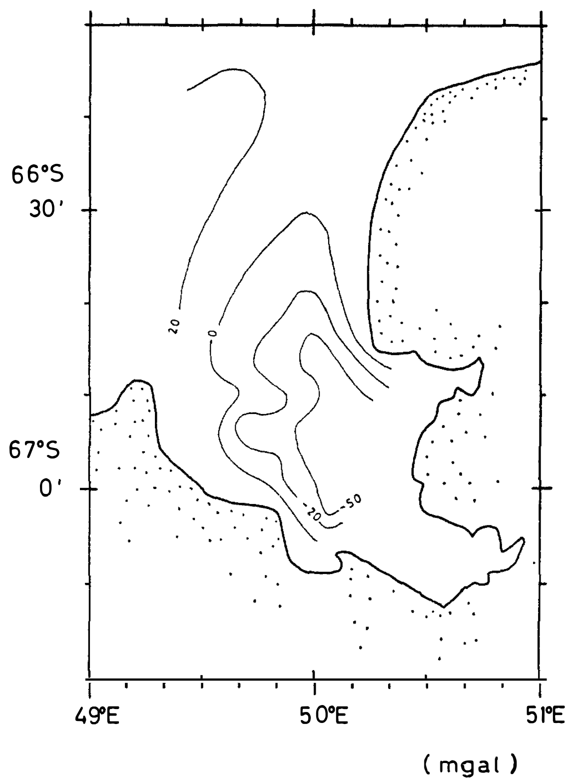


Fig. 8c. Preliminary map of free-air gravity anomaly.

Figs. 8a–c. These maps were obtained by survey along the tracks Fig. 8a. The basic topographical map used here is taken after Karta Zemli Enderby, SSSR (1977).

cussion of the sub-bottom structures and the continental shelves, however, is too small in comparison with the area surveyed. An important conclusion from this study is that, as far as Antarctica is concerned, further accumulation of data is the only clue to disclose the mystery of the area. The icebreaker FUJI will retire in April 1983 and a new icebreaker SHIRASE which is twice as large as FUJI will go into commission of the Japanese Antarctic Research Expedition program in November 1983. SHIRASE will provide much more reliable sea gravity data because she is better equipped with regard to navigational aids and other devices.

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