Polar Geosci., **14**, 226–234, 2001

Gravity observations along the traverse routes from Syowa Station to Dome Fuji Station, East Antarctica

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Abstract: In polar regions, there are relatively sparse geophysical and geodetic data for the severe environment. This paper presents the result of gravity observations obtained along the traverse routes from Syowa Station to Dome Fuji Station, East Antarctica. The obtained gravity values were determined within the accuracy of 1 mgal. Gravity values should be available to examine gravity changes for each station. The Bouguer gravity anomalies calculated show the large negative anomaly trending inland toward Dome Fuji, in the southern most observation area, at about −200 mgal. This indicates that the Bouguer gravity anomalies express the depth of the Moho discontinuity, that is, thickening of the crust inland, which in turn suggests that the depth of the Moho discontinuity around Dome Fuji Station is about 45 km.

key words: gravimeter, gravity change, Bouguer gravity anomaly, inland, Moho discontinuity

1. Introduction

Several geophysical and geodetic observations were carried out by members of the 38th Japanese Antarctic Research Expedition (JARE-38) wintering party during 1996–1998 (*e.g.*, Kanao and Higashi, 1999). In particular, gravity measurements were carried out in the field around Syowa Station (ϕ=69.0°S, λ=39.6°E, H=20 m) as often as opportunity allowed. Gravity surveys in the inland of Antarctica had previously been carried out by several JARE parties (*e.g.*, Yanai and Kakinuma, 1971; Nagao and Kaminuma, 1988; Kamiyama *et al.*, 1994b).

In the spring of 1997 we carried out a trip to Dome Fuji Station (ϕ=77.3°S, λ=39.7°E, H=3800 m), 1000 km inland from Syowa Station which is on Ongul Island, in order to support the wintering team at that station. Taking this opportunity, we performed gravity measurements on the route. The traverse route and gravity measurement points are shown in Fig. 1.

2. Gravity measurements

Gravity measurements along the Dome Fuji traverse route were carried out using a LaCoste & Romberg gravimeter (G-680) at 10–20 km intervals. The gravimeter was

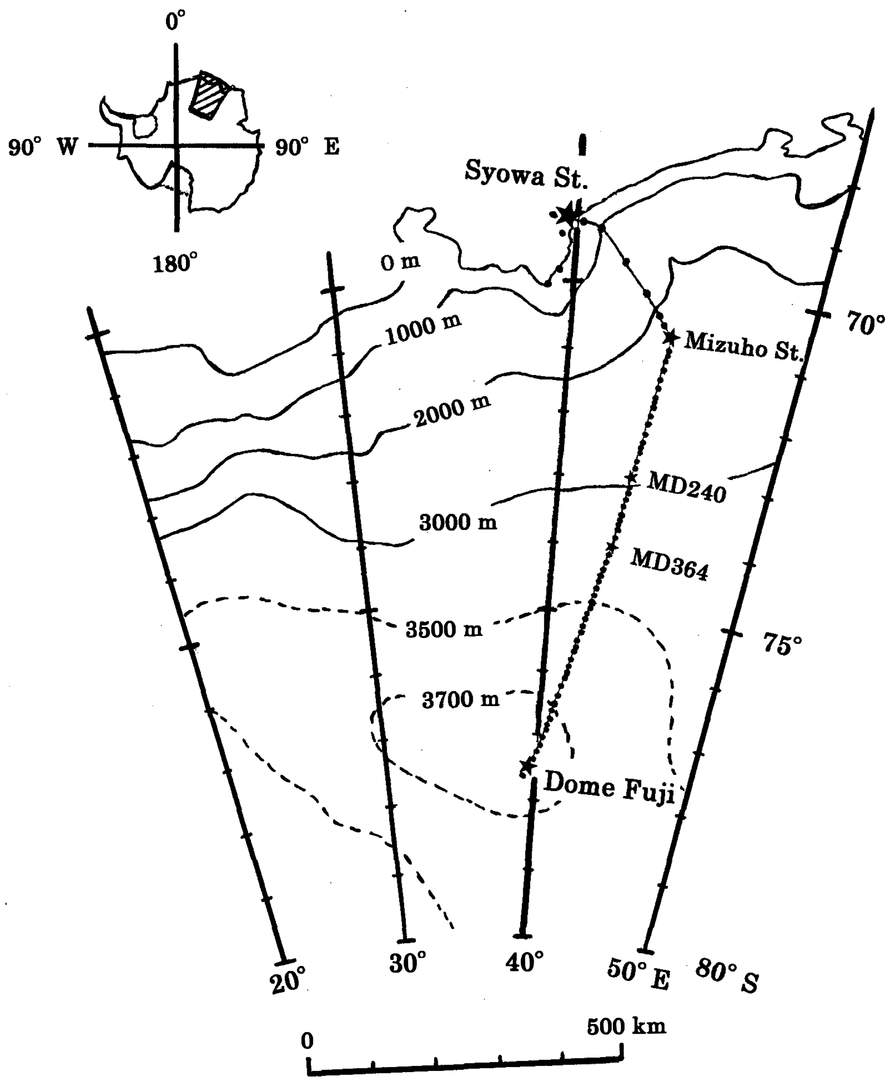

Fig. 1. The traverse route from Syowa Station to Dome Fuji Station. Closed circles show gravity measurement points.

carried by an oversnow vehicle carefully to protect it from shocks. The gravimeter battery was always supplied from the vehicles', therefore, interruptions of power supply and cooling down of the gravimeter did not occur during the trip. In order to evaluate instrumental drift and sudden jumps, the measurements were made at the same stations as often as possible both going and returning.

Each station datum such as position, height and ice thickness had been determined by JARE-33 in 1992 (Kamiyama *et al.*, 1994a). Surface elevation and bedrock topography of measured stations (67 points) are shown in Fig. 2. Bedrock height (surface elevation–ice thickness) was not determined by the radio echo sounding system for 6 points.

The gravity values at each station were calculated from the gravity value at Syowa Station (IAGBN; see Fig. 3a), which was obtained with an FG5 absolute gravimeter as follows (Kaminuma *et al.*, 1997):

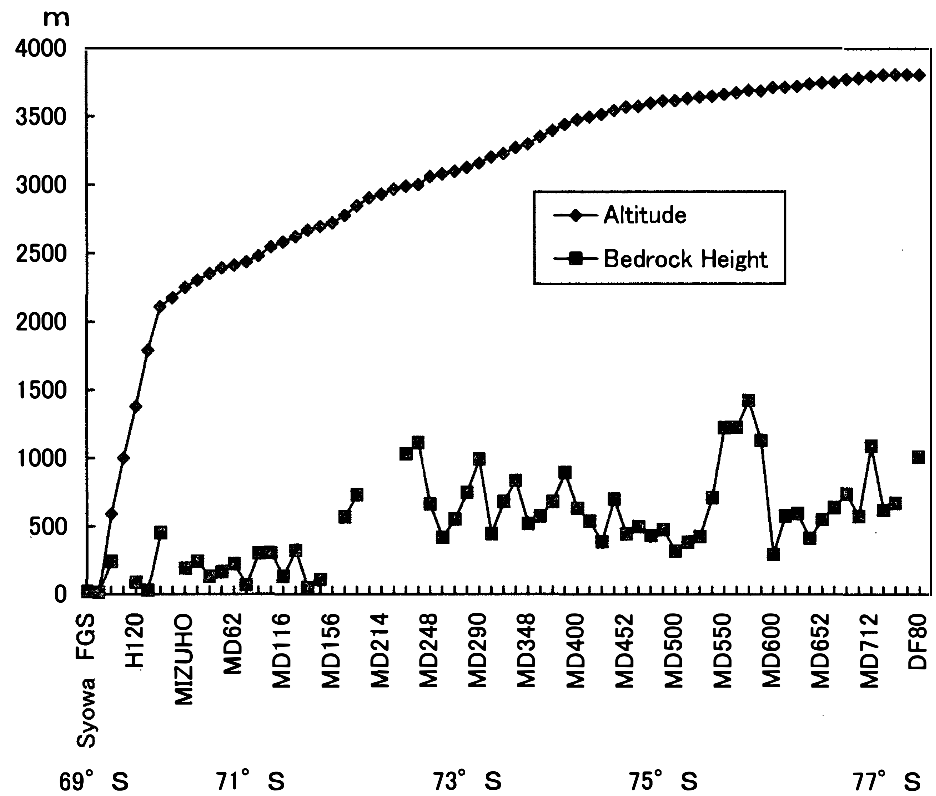

Fig. 2. Surface elevation and bedrock topography along the traverse routes (after Kamiyama et al., 1994a).

$$g_{\mathrm{Syowa}} = 982524.327 \text{ mgal},$$

where 1 mgal=10^{-5} m/s^2.

The drift rate throughout the measurement period (49 days) was +0.26 mgal/day, and sudden jumps occurred two times, +9.15 mgal and +2.09 mgal, respectively. It was estimated that the gravity values at each station were determined within an accuracy of 1 mgal. Figure 3b shows an example of the gravity measurement at DF80 at the southern most point in this observation. At the same points we will be able to perform gravity measurement again. Therefore, if gravity changes greater than 1 mgal occur, perhaps due to ice flow, it will be possible to detect this at each station, in the future. The obtained gravity values are shown in Appendix 1.

3. Bouguer gravity anomalies

Bouguer gravity anomalies (g") were calculated from the following equation:

$$g" = g_{\mathrm{obs}} - \gamma + 0.3086H - 2\pi G\ \{\rho_1(H-h) + \rho_2 h\},$$

where g_{obs} is the gravity value corrected for drift, sudden jumps and earth tide, γ is normal gravity, H is the surface height, h is the bedrock height, ρ_1 is the ice density (0.90 g/cm^3), ρ_2 is the bedrock density (2.67 g/cm^3 for the averaged continental crust) and the vertical gradient of gravity is assumed to be 0.3086 mgal/m. The error of the calculated Bouguer gravity anomaly will become about 10 mgal due to the uncertainty of

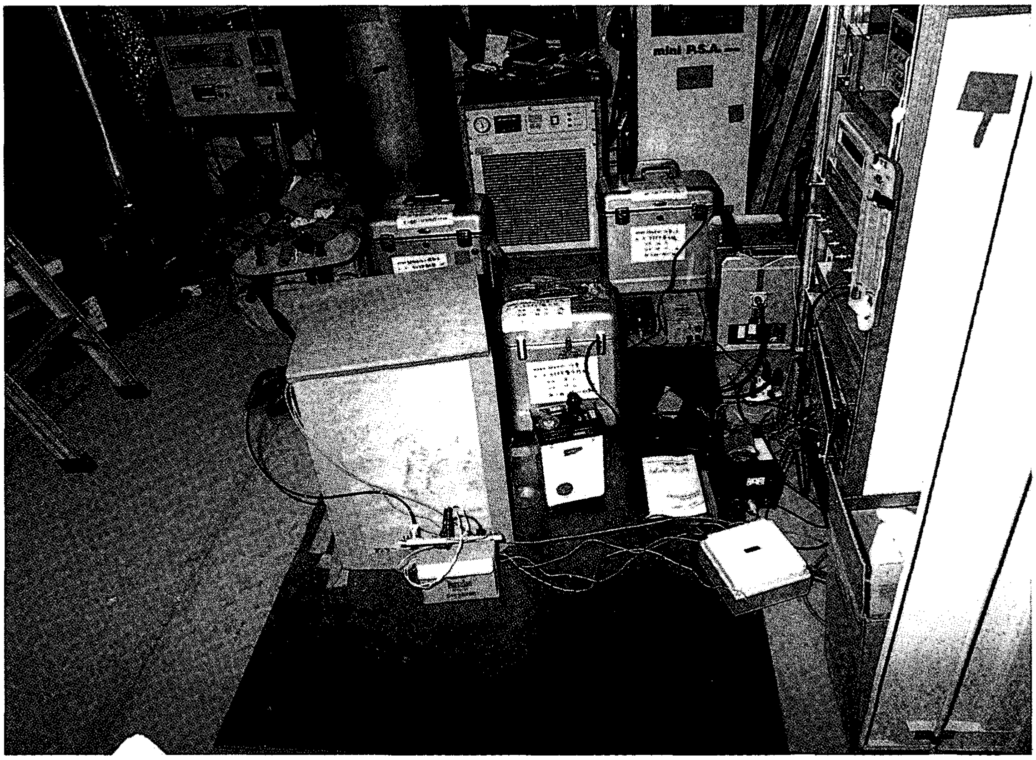

Fig. 3a. Gravity measurement at the International Absolute Gravity Basestation Network, (IAGBN) Syowa Station, in the Gravity Observation Hut.

Fig. 3b. Snapshot of the gravity measurement at point DF80. GPS observation was also carried out at this point.

the surface height and ice thickness (Kamiyama *et al.*, 1994a). The results are shown in Fig. 4 and Appendix 1.

As shown in Fig. 4, Bouguer gravity anomalies decreases from the coast (Syowa Station) inland (Dome Fuji Station), suggesting thickening of the crust. Figure 5 gives the regression relationship between Bouguer gravity anomalies and bedrock height. The

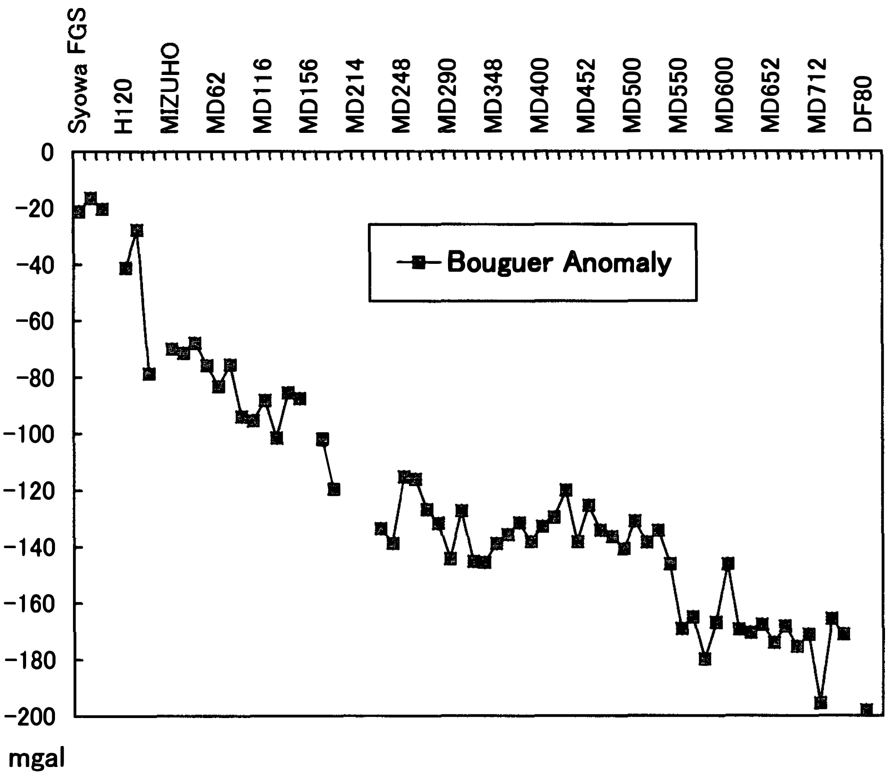

Fig. 4. Bouguer gravity anomalies along the traverse routes.

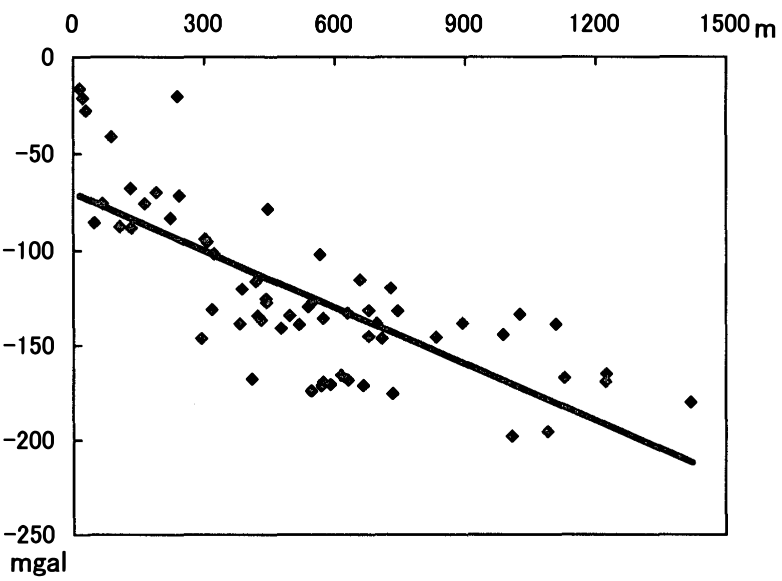

Fig. 5. Regression relationship between Bouguer gravity anomalies and bedrock height.

obtained value is about −0.1 mgal/m, indicating isostatic equilibrium.

According to Ikami *et al.* (1984), the depth of the Moho discontinuity from explosion seismic experiments was determined as about 40 km around Mizuho Station (ϕ=70.7°S, λ=44.3°E, H=2300 m, $g''_{\mathrm{Mizuho}}=-70$ mgal). We calculated the crust thickness at Dome Fuji Station (d_{Dome}) from the following equation:

$$d_{\mathrm{Dome}} - d_{\mathrm{Mizuho}} = -(g''_{\mathrm{Dome}} - g''_{\mathrm{Mizuho}}) / 2\pi G(\rho_{\mathrm{m}} - \rho_{\mathrm{c}}),$$

where ρ_{m} is the density of the upper mantle (3.27 g/cm^3), and ρ_{c} is the density of the crust (2.67 g/cm^3) (*e.g.*, Heiskanen and Moritz, 1967, p. 135). This suggests that the depth of the Moho discontinuity is about 45 km around Dome Fuji Station.

The mean thickness of the Moho discontinuity was found to be about 40–45 km in East Antarctica and about 30 km in West Antarctica from the results of explosion seismic experiments (Bentley, 1983). Furthermore, comparing with the results of previous surveys (Yanai and Kakinuma, 1971; Kanao *et al.*, 1994), the obtained results were approximately consistent for the Moho discontinuity beneath the Dome Fuji area.

4. Concluding remarks

Gravity observations were carried out in the inland of East Antarctica. The gravity values of 67 points were determined within the accuracy of 1 mgal. The obtained values will make it possible to examine gravity changes which might, for example, result from ice flow. The calculated Bouguer gravity anomaly ground data show thickening of the crust inland in isostatic equilibrium. This suggests that the depth of the Moho discontinuity around Dome Fuji Station, which is located about 1000 km from the coast, is about 45 km.

Acknowledgments

We express our sincere thanks to the all members of JARE-38 and especially Messrs. N. Kizu, S. Takeuchi, Y. Sekiguchi, M. Tanaka, T. Koseki and K. Kitada for their help on the trip to Dome Fuji Station. We would like to thank Drs. K. Nawa and T. Kudo for their critical reading of the manuscript and useful suggestions for its improvement.

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(Received March 29, 2001; Revised manuscript accepted May 24, 2001)

Appendix 1. Results of the gravity observations along the traverse routes from Syowa Station to Dome Fuji Station.

Station name	Latitude (deg. min.)	Longitude (deg. min.)	Altitude (m)	Gravity value (mgal)	Bouguer anomaly (mgal)
Syowa FGS	69 00.5 S	39 35.7 E	21.49	982524.327	-21
Tottuki BM	68 54.7	39 49.7	15.0	982524.44	-16
S16	69 01.8	40 03.2	591	982388.6	-20
H120	69 21.9	41 30.5	1378	982163.4	-41
H264	69 53.3	42 43.8	1789	982092.3	-28
Z50	70 22.1	43 44.6	2109	982013.8	-79
Z78	70 30.1	43 59.0	2173	981970.0	---
MIZUHO	70 42.0	44 17.4	2250	981983.8	-70
MD18	70 55.0	44 11.6	2303	981984.2	-71
MD32	71 02.5	44 09.4	2351	981973.5	-68
MD52	71 13.2	44 05.8	2394	981966.3	-76
MD62	71 18.6	44 04.0	2413	981963.0	-83
MD70	71 22.9	44 02.6	2437	981956.6	-76
MD86	71 31.5	43 59.7	2481	981951.5	-94
MD106	71 42.2	43 55.9	2546	981942.6	-95
MD116	71 47.6	43 54.1	2583	981931.7	-88
MD130	71 55.1	43 51.4	2622	981928.6	-102
MD140	72 02.4	43 49.6	2669	981918.2	-85
MD148	72 04.7	43 48.0	2697	981914.8	-88
MD156	72 09.0	43 46.6	2724	981911.5	---
MD174	72 18.7	43 42.8	2777	981925.3	-102
MD192	72 28.3	43 39.2	2849	981908.6	-120
MD204	72 34.8	43 36.8	2905	981891.4	---
MD214	72 40.1	43 34.4	2931	981897.0	---
MD226	72 46.6	43 31.7	2967	981887.5	---
MD236	72 51.9	43 29.8	2989	981899.2	-134
MD240	72 54.0	43 28.3	3001	981898.6	-139
MD248	72 58.3	43 26.7	3059	981876.6	-115
MD258	73 03.7	43 24.3	3078	981857.4	-116
MD270	73 10.1	43 21.4	3099	981856.0	-127
MD280	73 15.5	43 19.0	3125	981863.1	-132
MD290	73 20.9	43 16.6	3159	981863.9	-144
MD300	73 26.2	43 14.1	3203	981833.0	-127
MD316	73 34.7	43 10.2	3228	981832.6	-145
MD332	73 43.3	43 06.3	3272	981838.8	-146
MD348	73 51.9	43 03.0	3298	981822.2	-139
MD364	74 00.5	42 59.8	3353	981821.5	-136
MD376	74 07.0	42 56.4	3399	981826.3	-131
MD388	74 13.4	42 51.6	3444	981828.4	-138
MD400	74 19.9	42 45.5	3480	981809.6	-133
MD414	74 27.4	42 39.6	3498	981807.0	-130
MD426	74 34.0	42 34.8	3517	981805.4	-120
MD440	74 41.7	42 29.0	3547	981808.0	-138

Appendix 1. Continued

Station name	Latitude (deg. min.)	Longitude (deg. min.)	Altitude (m)	Gravity value (mgal)	Bouguer anomaly (mgal)
MD452	74 48.2 S	42 23.7 E	3572	981800.1	−125
MD464	74 54.6	42 19.0	3576	981799.1	−134
MD484	75 05.3	42 07.8	3601	981793.3	−137
MD498	75 12.9	42 01.7	3615	981794.2	−141
MD500	75 13.9	42 00.7	3618	981792.3	−131
MD512	75 20.4	41 54.6	3632	981790.6	−139
MD522	75 25.7	41 48.4	3643	981798.8	−134
MD534	75 32.0	41 41.8	3648	981811.4	−146
MD550	75 40.6	41 32.2	3663	981828.9	−169
MD560	75 45.8	41 26.4	3675	981833.7	−165
MD572	75 52.3	41 19.3	3693	981833.2	−180
MD584	75 58.6	41 12.1	3688	981830.1	−167
MD600	76 07.2	41 01.7	3713	981788.2	−146
MD616	76 15.8	40 52.5	3715	981791.5	−169
MD620	76 18.0	40 49.9	3722	981791.3	−171
MD636	76 26.7	40 40.1	3741	981781.6	−168
MD652	76 35.3	40 30.8	3748	981789.3	−174
MD668	76 43.9	40 21.2	3754	981805.7	−168
MD682	76 51.4	40 11.9	3776	981805.2	−175
MD694	76 57.9	40 04.8	3782	981800.0	−171
MD712	77 07.7	39 53.9	3799	981816.0	−195
MD726	77 15.3	39 45.5	3807	981813.5	−166
MD734	77 19.6	39 40.5	3809	981814.3	−171
DOME	77 19.0	39 42.2	3810	981815.6	---
DF80	77 22.4	39 36.8	3807	981814.8	−198

Note: Gravimeter (G-680), Investigator(T. HIGASHI)