GRAVITY ANOMALIES AND BEDROCK RELIEF IN MIZUHO PLATEAU

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Abstract: Distributional maps of free-air and Bouguer anomalies of gravity are presented, compiled from the data obtained by the oversnow traverses during the period from 1969 to 1974 over Mizuho Plateau, East Antarctica. Considerably large positive free-air anomalies were found in the region between Syowa Station and Mizuho Camp, while large negative anomalies were found to the southwest of Sandercock Nunataks. The existence of a large-scale bedrock rise is suggested in the former region, namely 43°–45°E in 69°45′S, whereas a large-scale subglacial trough in the latter, namely 48°–52°E in 69°30′S. The distribution of Bouguer anomaly also showed irregular patterns in these regions. The value of Bouguer anomaly decreases in general with the increase of the surface elevation at a rate of about −40 mgal per 1000 m.

1. Data Reduction

Measurements of gravity were carried out by using a LaCoste and Romberg Model G gravity meter (No. G183) in 1969–1971 and 1973–1974 at a total of 972 stations along the oversnow traverse routes of the 10th, 11th, and 14th Japanese Antarctic Research Expedition (JARE) in Mizuho Plateau. Gravity values were calculated from the observed values *in situ* on the basis of the absolute value determined by the G.S.I. pendulum apparatus at Syowa Station (HARADA *et al.*, 1963). The gravity value at Syowa Station adopted in this paper is 982539.4 mgal in the Potsdom system value, while the IGSN71 value there is 982525.6 mgal (SUZUKI, 1976). Table 1 summarizes the routes, years and parties of measurements on gravity, position, elevation and ice thickness used in this

Table 1. Notes of data used for calculations.

Item	Route	Observation year	Party of measurement	Source
Gravity	Routes S, A, B, C	1969–70	JARE-10	YOSHIDA and YOSHIMURA, 1972
	Routes H, M, Z	1973–74	JARE-14	ABE, 1975
	Routes W, X, Y	1970–71	JARE-11	YOSHIDA and YOSHIMURA, 1972
Position and elevation	Route S	1968–71	JARE-9, -10, -11	SHIMIZU *et al.*, 1972
	Routes A, B, C	1969–70	JARE-10	SHIMIZU *et al.*, 1972
	Routes H, M, Z	1973–74	JARE-14	NARUSE and YOKOYAMA, 1975
	Routes W, X, Y	1970–71	JARE-11	SHIMIZU *et al.*, 1972
Ice thickness	All routes	1969–71	JARE-10, -11	SHIMIZU *et al.*, 1972

paper to calculate gravity anomalies. Explanations of the traverse routes are given by SHIMIZU (1978) and in Fig. A at the end of this volume. In addition to the data referred to in Table 1, the gravity values and the ice thicknesses obtained in 1973–1974 by JARE-14 (ABE, 1975; NARUSE and YOKOYAMA, 1975) were also used to supplement the data along Routes S, H, Z, X, C, B and A.

The amount of drift of the instrument was distributed over the traverse routes according to the time elapsed. Corrections for earth tides and topographic conditions were not made. The observed gravity value g (mgal) at each measuring station was subjected firstly to the free-air reduction; namely, the value g was reduced to mean sea level by using only the elevation h (m) of the station, as follows:

$$g_0 = g + 0.3086h. \qquad (1)$$

The value g_0 was subjected secondly to the Bouguer reduction; namely, the effect of mass which existed between the surface of the ice sheet and the geoid was eliminated by using the elevation h (m) and the ice thickness I (m) at the station obtained by radio echo sounding, assuming the density of ice and of the bedrock as 0.9 g/cm^3 and 2.67 g/cm^3 respectively, as follows:

$$g_0'' = g_0 - 0.1119h + 0.0742I. \qquad (2)$$

The standard gravity value γ_0 (mgal) at each station in the latitude of ϕ (degree) was calculated by the following equation:

$$\gamma_0 = 978049(1 + 0.0052884 \sin^2 \phi - 0.0000059 \sin^2 2\phi). \qquad (3)$$

The free-air anomaly Δg_0 (mgal) and Bouguer anomaly $\Delta g_0''$ (mgal) of each station were obtained from the difference between g_0 and γ_0, and g_0'' and γ_0 respectively, as follows:

$$\Delta g_0 = g_0 - \gamma_0 = g + 0.3086h - \gamma_0, \qquad (4)$$

$$\Delta g_0'' = g_0'' - \gamma_0 = g + 0.1967h + 0.0742I - \gamma_0. \qquad (5)$$

It is considered generally that the algebraically large value of the free-air anomaly Δg_0 indicates the rise of the bedrock relief, the small value the depression of bedrock; while the algebraically large value of the Bouguer anomaly $\Delta g_0''$ indicates the existence of the larger mass beneath the geoid.

2. Distribution of Free-Air Anomalies

A contour map of free-air anomalies over Mizuho Plateau is shown in Fig. 1. The contour lines are marked for every 20 mgal. The maximum error involved in the value of free-air anomaly is estimated to reach 23 mgal, supposing that the error involved in the surface elevation is 3% for the area up to 2500 m in elevation.

One can notice the following remarkable results on free-air anomalies in Fig. 1.

(a) Largest positive anomalies exceeding 150 mgal along a route from M29 (69°42′S, 44°11′E), to M54 (69°38′S, 43°20′E).

(b) Positive anomalies larger than 100 mgal around the region of A001 (71°47′S, 36°12′E).

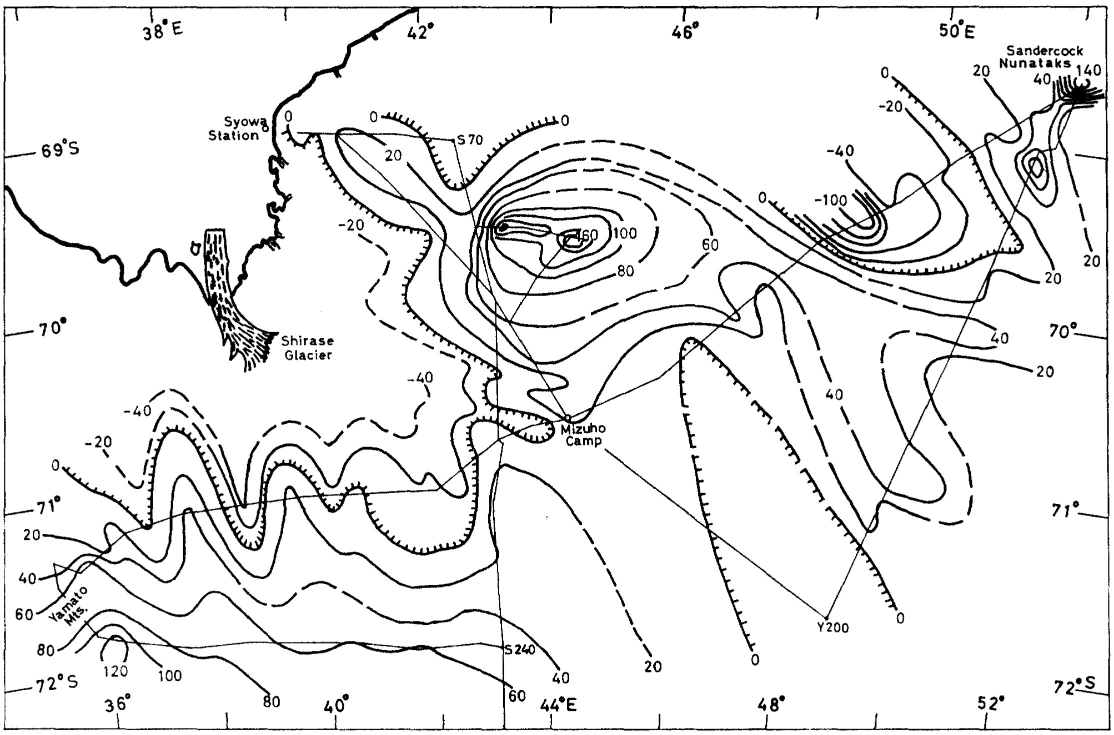

Fig. 1. A contour map of the free-air anomaly (unit: mgal) over Mizuho Plateau. Fine solid lines indicate the oversnow traverse routes where the gravity measurements were made at intervals of 2 or 5 km. The number of points at which free-air anomalies were obtained is 972.

(c) Large positive anomalies of about 100 mgal in the vicinity of W00 (68°37′S, 52°06′E).

(d) Large negative anomalies along a route from W25 (69°05′S, 50°25′E) to W51 (69°39′S, 48°25′E), showing the minimum value less than −100 mgal at W45 (69°31′S, 48°59′E), and a slight negative value near Y460 (69°31′S, 51°09′E).

(e) Small negative anomalies more or less than −10 mgal around the region of Y200 (71°46′S, 48°56′E).

(f) Small or slight negative anomalies discretely along Routes C, X, S and H, that are:

1) C25 (71°10′S, 36°50′E)—C28 (71°08′S, 36°58′E),
2) C53 (71°07′S, 38°18′E)—C66 (71°06′S, 38°59′E),
3) C86 (71°06′S, 40°04′E)—C95 (71°06′S, 40°35′E),
4) C99 (71°06′S, 40°49′E)—C140 (70°54′S, 42°47′E),
5) X5 (70°43′S, 44°00′E)—X17 (70°47′S, 43°16′E),
6) S158 (70°38′S, 43°06′E)—S163 (70°43′S, 43°07′E),
7) S145 (70°25′S, 43°06′E)—S149 (70°29′S, 43°06′E),
8) S61 (69°05′S, 42°04′E)—S86 (69°24′S, 42°39′E),
9) H189 (69°37′S, 42°05′E)—H194 (69°38′S, 42°08′E).

3. Bedrock Relief Deduced from Free-Air Anomaly

From eqs. (4) and (5), we get

$$\begin{aligned}\Delta g_0 &= 0.1119h - 0.0742I + \Delta g_0'' \\ &= 0.0377h + 0.0742B + \Delta g_0'' \\ &\simeq 0.0377(h+2B) + \Delta g_0'',\end{aligned} \tag{6}$$

where B (m) is the bedrock elevation, that is (h-I). Supposing the Bouguer anomaly $\Delta g_0''$ had a constant value throughout a limited locality, the difference of the free-air anomaly Δg_0 among stations there would be strongly reflected by the difference of the bedrock elevation according to the relation in eq. (6): the effect of the change of 10 m in the surface elevation amounts to 0.38 mgal, while that of 10 m in the bedrock elevation 0.75 mgal. Furthermore, the surface elevation does not vary considerably compared with the bedrock elevation in the limited locality, as shown by SHIMIZU *et al.* (1978). Consequently, the distribution of free-air anomaly can be considered to show not the absolute but the relative elevation of the subglacial relief. Also one must keep in mind that the gravity results yield only an average ice thickness giving rise to anomalies to a distance equivalent to ice depth, in contrast to a seismic measurement which determines the ice thickness at a point. The bedrock profiles obtained from the gravity are somewhat smoothed and the method does not pick out minor irregularities.

The positive free-air anomaly, therefore, can be regarded as due to the effect of the large-scale rise of the bedrock relief; on the other hand, the negative anomaly as due to the effect of the large-scale depression of the same.

The results of anomalies mentioned in (a) to (f) in Section 2, are interpreted as follows:

(a) Moraine bands on the ice sheet surface were discovered in 1970 (YOSHIDA *et al.*, 1971), and ice mounds of 100–150 m in height from the level of the surrounding ice surface were briefly surveyed first in 1973 (NARUSE, 1975), in this region. Supposing the Bouguer anomaly was −50 mgal, the ice thickness at M30 near the ice mounds would be 230 m. It seems undoubted that subglacial mountains exist in the region.

(b) In the vicinity of the Yamato Mountains; numerous nunataks exist, and the subglacial surface around them can be considered to rise in general.

(c) In the vicinity of the Sandercock Nunataks, the same situation as the above is found.

(d) The existence of a large distinct subglacial trough running from southeast to northwest is inferred.

(e) The existence of the depression of the bedrock over a large-scale area is inferred.

(f) The existence of a large number of subglacial troughs extending from the inland area to the coastal region is inferred. Taking into account also the divides of the drainage basins (SHIMIZU *et al.,* 1978), the five troughs 2), 3), 4), 5)–6), and 7) run towards the Shirase Glacier; a trough 8) runs towards the northern coast of Syowa Station; a trough 9) runs towards the Sôya Coast.

4. Distribution of Bouguer Anomalies

A contour map of Bouguer anomalies over Mizuho Plateau for every 20 mgal is shown in Fig. 2. An error involved in the value of anomaly is estimated as about 20 mgal, assuming that the error in the surface elevation is 3% and the error in the ice thickness is 5% for the area up to 2500 m in elevation. It is revealed, however, that the obtained values of Bouguer anomalies are widely scattered in magnitude from station to station. In order to illustrate the general tendency of Bouguer anomaly, the contour lines are smoothed out considerably.

It is noted in Fig. 2 that the value of Bouguer anomaly tends to decrease in general with the increase of the surface elevation at a rate of about −40 mgal/1000 m. Assuming the density of ice and of the bedrock as 0.9 g/cm^3 and 2.67 g/cm^3 respectively, the above decreasing rate corresponds to about −110 mgal/1000 m on the ice-free land, the value is close to −100 mgal/1000 m

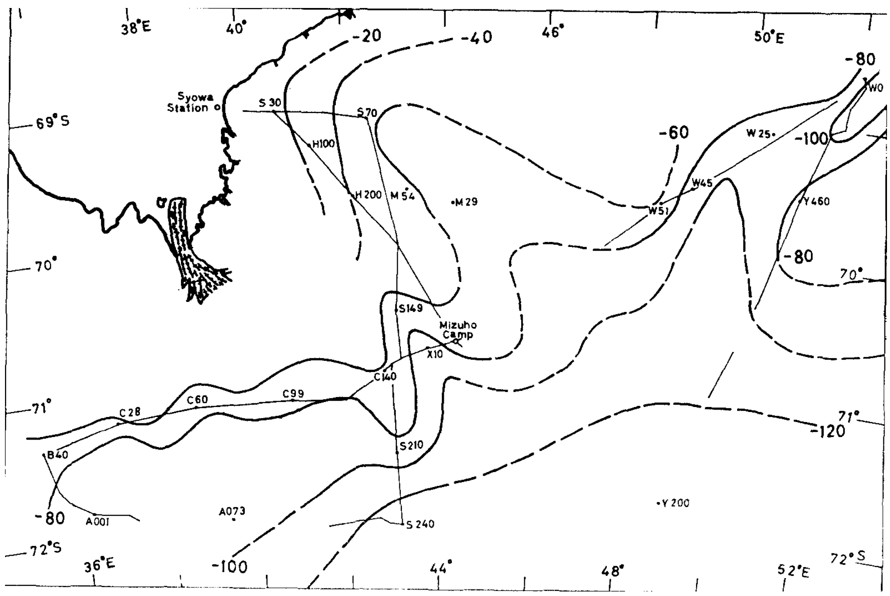

Fig. 2. A contour map of the Bouguer anomaly (unit: mgal) over Mizuho Plateau.
The number of points at which Bouguer anomalies were obtained is 265 along the routes indicated by thin solid lines.

obtained on the global continent. It follows that isostasy holds approximately over Mizuho Plateau.

Detailed discussion on Bouguer anomalies cannot be given here for the lack of data of ice thicknesses.

5. Concluding Remarks

Occasionally, a remarkable difference in the value of ice thickness by radio echo soundings at a station was found between the results in 1969–1970 and in 1973–1974 (SHIMIZU *et al.*, 1972; NARUSE and YOKOYAMA, 1975). This was caused by the interpretation of the multiple echoes, and has not been solved yet. Although the gravity measurement is an indirect method to determine the ice thickness, this method becomes advantageous in a case in which the general relief of the bedrock is wanted, because the measured gravity value at a station shows the mean value in an area around the station. The main purpose of this paper was to try to look over the general subglacial topography from the distribution of free-air anomalies. Calculation of ice thickness on the basis of the gravity value and Bouguer anomaly was not made because of the lack of confidence in the assumed Bouguer anomaly especially in the inland regions.

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