GRAVITY SURVEY ALONG THE L- AND AB-ROUTES, EAST DRONNING MAUD LAND, ANTARCTICA

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1. Introduction

Gravity surveys in Mizuho Plateau, East Antarctica, have been carried out by many field parties of the Japanese Antarctic Research Expedition (JARE) since 1968. More than 1000 gravity data were collected by the field traverse parties of JARE-9, -10, -11, -14, -22, -23, -24 and -26 (Yanai and Kakinuma, 1971; Yoshida and Yoshimura, 1972; Abe, 1975; Kaminuma and Nagao, 1984; Nagao and Kaminuma, 1988). There are yet comparatively small number of gravity data in East Dronning Maud Land.

2. Measurements by JARE-28

In 1987, gravity measurements along the L-route and AB-route in East Dronning Maud Land were carried out using a LaCoste-Romberg G-805 gravity meter during the field programs of JARE-28 as part of the Sør Rondane Mountains expedition project. The traverse route is shown in Fig. 1. The measurements were made by dividing the routes into four segments, and outline of the measurements is summarized in Table 1. The traverse

route almost coincides with 24°E meridian of a 150 km distance from L0 point to AB37 point through Asuka Station nearby L121 point. The measurements were carried out basically at every 1 km interval. The reference point of the measurements was the Seal Rock No. 26-01 gravity mark (Fig. 2); the gravity connection between the above mark and the Earth Science Laboratory (ESL) reference mark of Syowa Station had already been made in January 2, 1986 by Fukuda (1986), and was repeated by K. Shibuya in January 2, 1988 as noted in Table 1. The drift rate of the G-805 gravity meter throughout the measurement period was 0.32 μgal/h (1 μgal = 10^{-8} m/s^2) and the standard deviation of the residuals after the least-squares fitting procedure of the solution was 102.1 μgal as summarized in the lower part of Table 1.

3. Determination of Station Coordinates

Satellite Doppler positio ning was conducted at several selected points (L0, L47.5, L66, L90, Asuka Station, and Seal Rock), and the results were summarized in this data report (Shibuya, 1999). Navigational data such as azimuth and distance from one station to a neighboring station were obtained with a hand-bearing compass and an odometer of an over-snow vehicle, and latitudes and longitudes of non-satellite Doppler stations were estimated from an interpolation method.

As for heights above sea level of the satellite Doppler stations described above, the EGM96 model (Lemoine et al., 1997) geoid height was calculated and subtracted from the observed ellipsoidal height to obtain the height above sea level (surface elevation). Because height differences between neighboring gravity stations were obtained by a barometric altimeter, heights above sea level of the non-satellite Doppler stations can also be adjusted in

order that the successively attained height at the next satellite Doppler station by an iterative interpolation method to be consistent with the observed height.

With a combined use of satellite Doppler translocation and one-frequency GPS relative positioning, the elevation of the No. 25-01 geodetic mark at the Seal Rock was estimated to be 974.6 m above sea level within the standard error of 2 m (Shibuya et al., 1999).

4. Adjustment of the Observed Gravity Data to the International Absolute Gravity Basestation Network Syowa Station Standard Value

Gravity measurements in the Japanese Antarctic research area were previously referred to the value at the pier mark of the ESL of Syowa Station (Kaminuma et al., 1984) as

$$g_{ESL,old} = 982523.75 \text{ mgal}, \quad (1)$$

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

In 1994, absolute gravity meter observations were made using an FG5 gravity meter at the International Absolute Gravity Basestation Network Syowa Station (IAGBN-A #0417 by Boedecker and Fritzer, 1986). The gravity standard value was determined to be 982524.327 mgal with an accuracy of 15 μgal (Kaminuma and Tsukahara, 1996). Together with a gravity difference of -0.276 mgal between the ESL mark and the IAGBN mark, gravity standard value at the ESL pier mark can be updated to

$$g_{ESL,new} = 982524.051 \text{ mgal}. \quad (2)$$

Therefore we can apply the following equation in order to adjust each gravity data obtained at the traverse route station to this new standard:

$$g_{new} = g_{obs} + 0.301 \text{ mgal}. \quad (3)$$

5. Free-air Reduction

After Nagao and Kaminuma (1988), we calculate the normal gravity value γ from the equation of Gravity Formula 1967:

$$\gamma = (A\,GE\cos^2\phi + B\,GP\sin^2\phi)/(A^2\cos^2\phi + B^2\sin^2\phi)^{1/2} \quad (4)$$

where

A	= 6378.14 km	equatorial radius of the Earth
B	= A(1−1.0/298.257)	polar radius of the Earth
GE	= 978031.846 mgal	gravity value at the equator
GP	= 983217.728 mgal	gravity value at the pole
ϕ	: geodetic latitude.	

Free-air gravity anomaly $\Delta g_{0'}$ in this report was calculated from the following equation

$$\Delta g_{0'} = g_{new} - \gamma + 0.3089\,H + 0.87 - 0.0000965\,H, \quad (5)$$

where g_{new} is each observed gravity value in mgal by eq. (3) which was corrected for the instrumental drift and the earth tide at each station, H the height above sea level in meters, and a term 0.87−0.0000965H stands for atmospheric correction. Because of high latitudes (around 71°S), the vertical gradient of normal gravity is slightly larger (0.3089 mgal/m in eq. (5)) than the usually adopted value of 0.3086 mgal/m at mid-latitudes.

Although ice thickness data at each route point was not available yet, radio-echo sounding profile obtained with a Pilatus PC-6 aircraft (National Institute of Polar Research, 1989) indicated coincidence of bedrock height with sea level for the most part of the traverse route, and Bouguer gravity anomaly was calculated by assuming that the ice thickness IC (in meters) is equal to the surface elevation H:

$$\Delta g_{0''} = \Delta g_{0'} - 0.0419\ \rho_2\,IC, \quad (6)$$

where ρ_2 is the density of ice (0.90 g/cm^3).

6. Results and Accuracy

Table 2 summarizes the obtained results, where column 1 shows station name, column 2 indicates observed gravity value g_{new} which was adjusted to the IAGBN Syowa Station standard value, column 3 the free-air gravity anomaly, column 4 the Bouguer gravity anomaly, columns 5-6 the latitude and the longitude respectively, and column 7 the height above sea level.

As for an observation error, 0.1 mgal standard deviation of the overall residuals may indicate a total error of within 0.2 mgal including the reading error of the G-805 gravity meter. Probable positioning error of 10 m for latitudinal direction may result in 10 μgal error in the calculated normal gravity value. As for the error of the height above sea level, 2-3 m uncertainty must be considered at each station with a resultant 0.6-0.9 mgal uncertainty in the free-air reduction. Together with the uncertainty of 15 μgal at the IAGBN gravity station standard value, an overall error of 1 mgal may be allocated to the free-air gravity anomalies listed in Table 2.

As shown in Fig. 3, there seems to be a bell-shaped free-air gravity anomaly high around L0 point (e.g. Shibuya et al., 1991). From L20 point towards inland, the free-air gravity anomaly decreases with a trend of roughly -0.8 mgal/km, suggesting possible thickening of the crust.

7. Around Asuka Station

Table 3 summarizes similar results of the gravity data obtained at station facilities and temporarily installed seismic stations (Shibuya and Sakai, 1989) around Asuka Station and Seal Rock nearby L120 point. Although it is too early to draw any free-air anomaly contours around Asuka Station, plots of Table 3 data may indicate rise of bedrock topography from south towards north, and that the anomaly pattern becomes complex around

Asuka Station.

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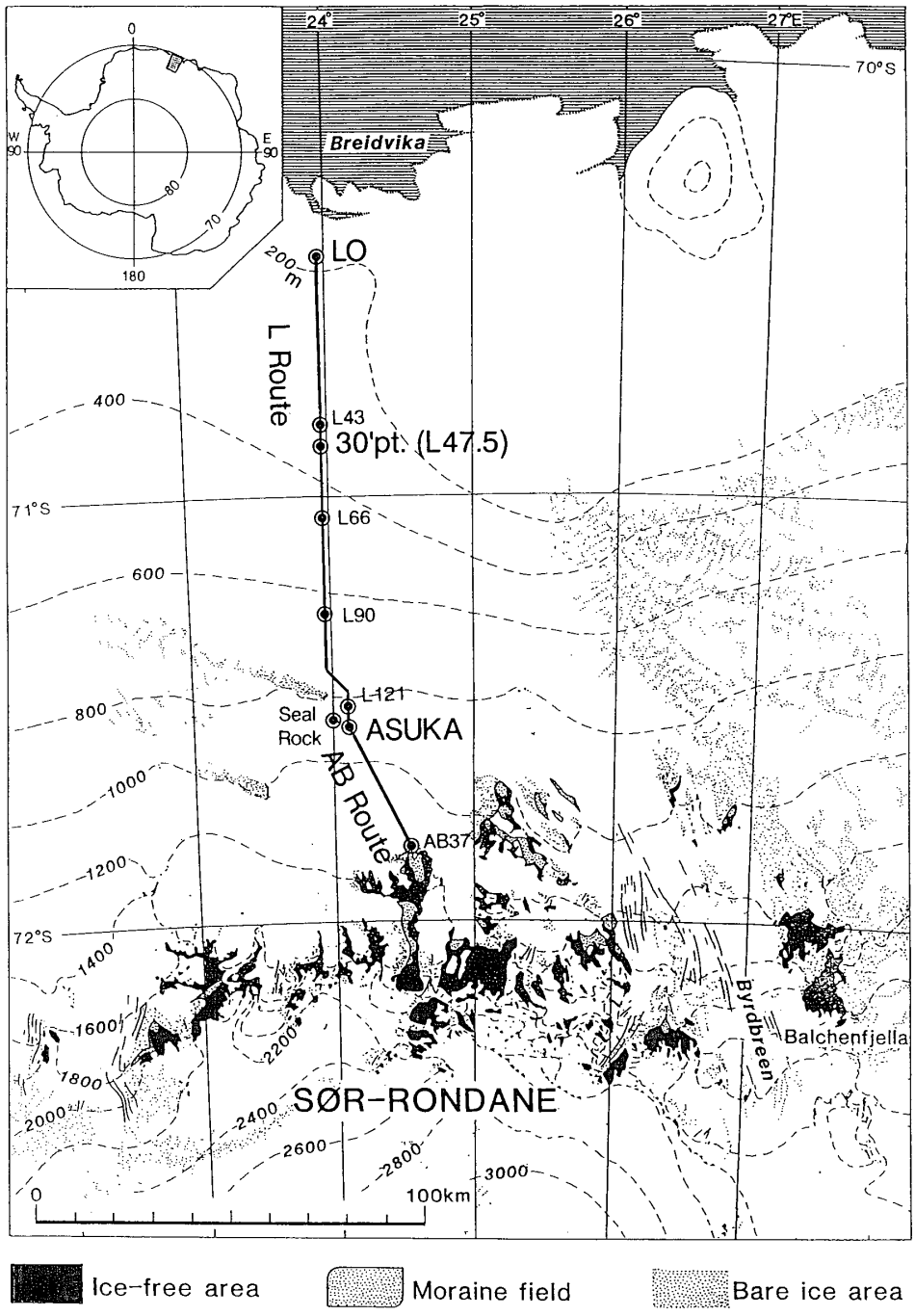

Fig. 1. Sketch of L- and AB-routes from Breid Bay to the tip of the Sør Rondane Mountains along 24°E. Gravity measurements were made at every 1 km interval. Dot circles indicate satellite Doppler stations whose positions were summarized in Shibuya (1999) in another part of this report.

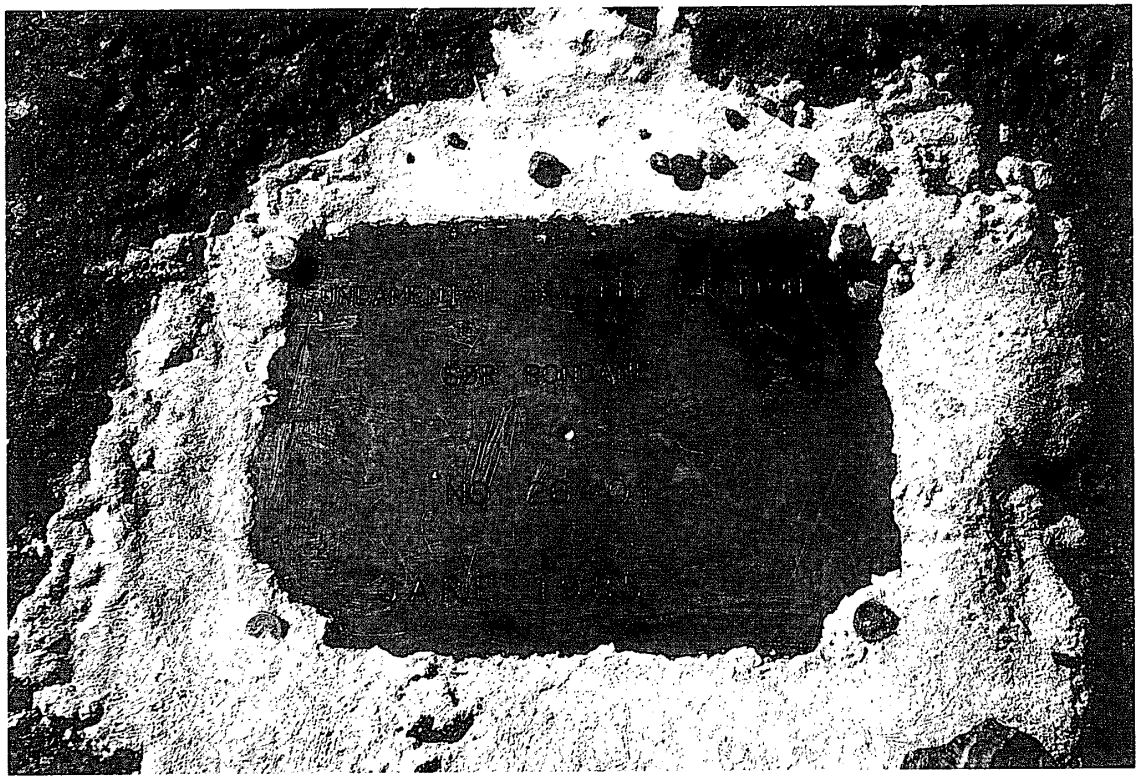

Fig. 2. No. 26-01 gravity station mark installed at Seal Rock.

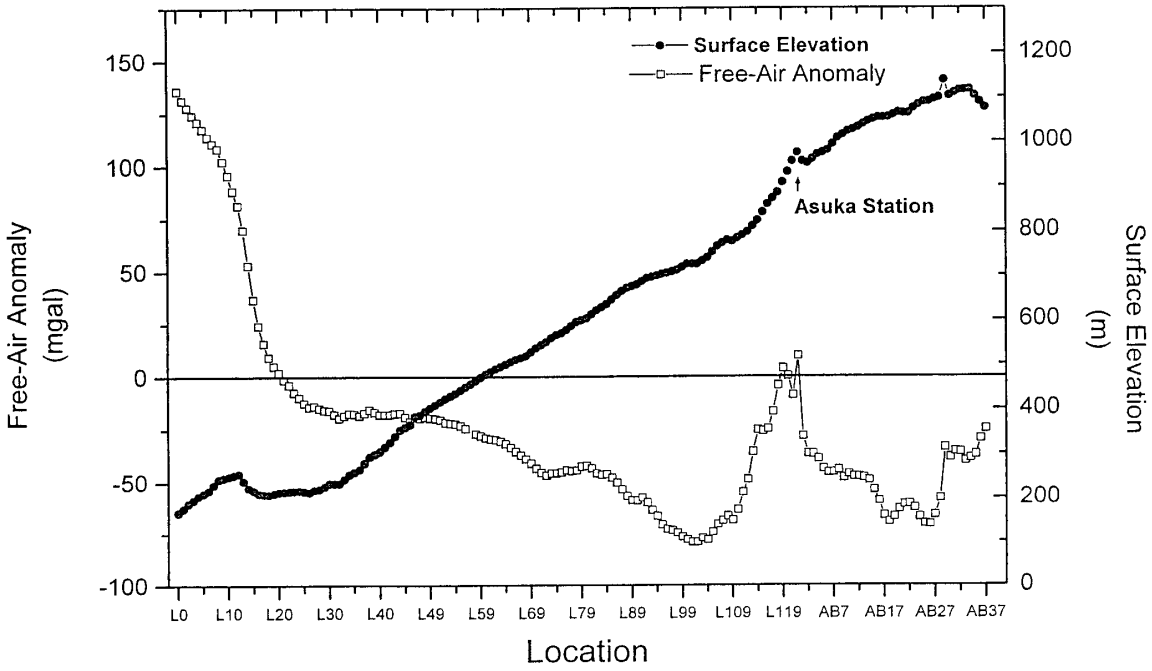

Fig. 3. Surface elevation data (solid circles) determined from satellite Doppler positioning data and barometric data along the L- and AB-routes. Open boxes indicate free-air gravity anomalies listed in Table 2.

Table 1. Outline of the gravity survey along the L- and AB-routes

Day of Measurement in 1987	Segment	Vehicle	Party Member
(1) Dec 14-15	Asuka - AB37	SM513 SM512	Shibuya, Ariga, Oomoto Takagi, Mori
(2) Dec 17	Asuka - L121 - L90 - Seal Rock - Asuka	SM513	Shibuya, Ayukawa
(3) Dec 25	L90 - L43	SM513	Shibuya, Tomita
(4)* Dec 28-29	L43 - L0	SM512 SM513	Shibuya, Takagi, Takahashi, Oosaka Sakai, Tomita, Nozaki

* On January 2, 1988, G-805 was carried back to Syowa Station by icebreaker "Shirase" and the observed gravity values were connected to the standard value at the ESL gravity mark.

Observer	Kazuo Shibuya
Gravity Meter	LaCoste-Romberg G-805
Number of Measurement	205 sets: 3 readings consists 1 set for (1), and 1 reading for other 3 sets.
Number of Stations	167
Drift of the Gravity Meter	0.32 μgal /h
Standard Error of the Residual	102. 1 μgal

Table 2. Results of the measurements by JARE-28 along L- and AB-routes.

Station Name	Gravity value (mgal)	Free-air (mgal)	Bouguer (mgal)	Lati-tude (degree)	Longi-tude (degree)	Alti-tude (m)
L0	982718.143	135.94	129.60	-70.454	23.890	168.0
L1	982711.396	131.45	124.78	-70.463	23.890	177.0
L2	982705.124	128.06	120.98	-70.472	23.890	188.0
L3	982699.459	124.30	116.91	-70.482	23.891	196.0
L4	982694.106	121.27	113.54	-70.490	23.891	205.0
L5	982689.305	117.75	109.79	-70.500	23.891	211.0
L6	982683.739	113.89	105.67	-70.508	23.892	218.0
L7	982677.206	110.86	102.15	-70.517	23.892	231.0
L8	982671.308	108.40	99.20	-70.527	23.892	244.0
L9	982664.860	102.43	93.11	-70.535	23.893	247.0
L10	982657.953	95.87	86.45	-70.545	23.893	250.0
L11	982650.063	88.45	78.91	-70.553	23.894	253.0
L12	982642.846	81.65	72.00	-70.562	23.894	256.0
L13	982636.750	70.04	60.99	-70.572	23.894	240.0
L14	982625.339	53.23	44.79	-70.580	23.896	224.0
L15	982611.455	36.93	28.71	-70.590	23.898	218.0
L16	982601.536	24.39	16.43	-70.598	23.898	211.0
L17	982594.265	15.93	8.05	-70.608	23.898	209.0
L18	982588.470	9.32	1.47	-70.617	23.899	208.0
L19	982583.873	5.08	-2.88	-70.627	23.899	211.0
L20	982580.320	2.00	-6.07	-70.635	23.899	214.0
L21	982577.124	-1.34	-9.45	-70.643	23.901	215.0
L22	982574.921	-3.81	-11.95	-70.653	23.901	216.0
L23	982571.529	-7.40	-15.58	-70.662	23.901	217.0
L24	982569.432	-9.76	-17.98	-70.672	23.901	218.0
L25	982567.832	-12.43	-20.57	-70.680	23.903	216.0
L26	982566.977	-14.35	-22.42	-70.688	23.903	214.0
L27	982566.520	-13.83	-22.09	-70.698	23.903	219.0
L28	982565.252	-14.99	-23.33	-70.707	23.904	221.0
L29	982563.142	-15.82	-24.38	-70.717	23.904	227.0
L30	982561.179	-16.07	-24.89	-70.725	23.904	234.0
L31	982559.898	-17.80	-26.63	-70.733	23.906	234.0
L32	982558.577	-19.69	-28.51	-70.743	23.906	234.0
L33	982557.258	-18.43	-27.63	-70.752	23.906	244.0
L34	982555.744	-17.42	-27.00	-70.762	23.906	254.0
L35	982554.138	-17.62	-27.43	-70.770	23.907	260.0

L36	982551.938	-18.42	-28.45	-70.778	23.908	266.0
L37	982549.428	-17.17	-27.73	-70.788	23.908	280.0
L38	982547.119	-15.67	-26.75	-70.797	23.909	294.0
L39	982544.690	-16.80	-28.12	-70.807	23.909	300.0
L40	982542.172	-17.92	-29.46	-70.815	23.910	306.0
L41	982539.522	-17.93	-29.85	-70.823	23.912	316.0
L42	982536.975	-17.95	-30.25	-70.833	23.912	326.0
L43	982533.655	-17.46	-30.28	-70.842	23.913	340.0
L44	982530.085	-17.15	-30.50	-70.850	23.914	354.0
L45	982526.866	-19.08	-32.66	-70.860	23.914	360.0
L46	982523.325	-21.22	-35.02	-70.868	23.915	366.0
L47	982520.129	-19.36	-33.84	-70.877	23.916	384.0
L47.5	982519.155	-19.69	-34.28	-70.882	23.916	387.0
L48	982517.274	-19.07	-34.00	-70.887	23.916	396.0
L49	982515.048	-19.58	-34.78	-70.895	23.916	403.0
L50	982513.205	-19.83	-35.29	-70.905	23.916	410.0
L51	982510.980	-20.34	-36.06	-70.913	23.916	417.0
L52	982507.949	-21.71	-37.70	-70.922	23.916	424.0
L53	982506.376	-21.99	-38.21	-70.932	23.915	430.0
L54	982504.603	-22.36	-38.80	-70.940	23.915	436.0
L55	982502.173	-23.19	-39.89	-70.950	23.915	443.0
L56	982499.113	-24.53	-41.50	-70.958	23.915	450.0
L57	----------	------	------	-70.967	23.916	457.0
L58	982493.377	-27.01	-44.51	-70.977	23.918	464.0
L59	982490.711	-27.96	-45.72	-70.985	23.918	471.0
L60	982488.039	-28.92	-46.94	-70.993	23.920	478.0
L61	982486.162	-29.50	-47.75	-71.003	23.921	484.0
L62	982484.518	-29.80	-48.27	-71.012	23.923	490.0
L63	982482.694	-30.52	-49.19	-71.020	23.924	495.0
L64	982480.339	-31.78	-50.63	-71.028	23.924	500.0
L65	982477.310	-33.51	-52.59	-71.038	23.925	506.0
L66	982474.426	-35.41	-54.68	-71.048	23.927	511.0
L67	982471.990	-37.06	-56.48	-71.056	23.927	515.0
L68	982469.404	-38.91	-58.48	-71.065	23.929	519.0
L69	982465.086	-40.89	-60.80	-71.073	23.931	528.0
L70	982460.384	-43.37	-63.62	-71.083	23.931	537.0
L71	982456.656	-45.44	-65.95	-71.092	23.931	544.0
L72	982453.608	-46.77	-67.55	-71.100	23.931	551.0
L73	982452.452	-45.70	-66.82	-71.110	23.929	560.0
L74	982450.857	-45.58	-66.96	-71.118	23.929	567.0
L75	982450.644	-45.12	-66.65	-71.128	23.927	571.0
L76	982449.898	-44.20	-66.00	-71.137	23.927	578.0
L77	982447.132	-44.63	-66.77	-71.145	23.927	587.0

L78	982445.240	-44.30	-66.77	-71.155	23.929	596.0
L79	982446.158	-42.59	-65.21	-71.163	23.929	600.0
L80	982445.793	-42.27	-65.05	-71.173	23.931	604.0
L81	982442.372	-43.41	-66.53	-71.182	23.933	613.0
L82	982437.698	-45.75	-69.21	-71.190	23.933	622.0
L83	982435.354	-46.49	-70.21	-71.200	23.935	629.0
L84	982433.976	-46.14	-70.13	-71.208	23.935	636.0
L85	982429.605	-47.98	-72.34	-71.218	23.937	646.0
L86	982424.728	-50.27	-75.00	-71.227	23.937	656.0
L87	982419.139	-53.52	-78.60	-71.235	23.939	665.0
L88	982414.167	-56.88	-82.22	-71.245	23.939	672.0
L89	982411.349	-58.91	-84.40	-71.253	23.941	676.0
L90	982410.499	-59.02	-84.66	-71.262	23.941	680.0
L91	982410.259	-57.65	-83.55	-71.272	23.941	687.0
L92	982406.202	-59.98	-86.16	-71.280	23.942	694.0
L93	982402.095	-63.61	-89.89	-71.288	23.942	697.0
L94	982398.879	-66.45	-92.84	-71.298	23.942	700.0
L95	982394.253	-70.64	-97.15	-71.307	23.943	703.0
L96	982391.575	-72.84	-99.46	-71.315	23.943	706.0
L97	982390.564	-73.47	-100.21	-71.325	23.943	709.0
L98	982388.901	-74.65	-101.50	-71.333	23.943	712.0
L99	982385.353	-76.58	-103.70	-71.343	23.945	719.0
L100	982382.341	-77.93	-105.31	-71.352	23.945	726.0
L101	982381.505	-79.21	-106.58	-71.360	23.957	726.0
L102	982381.975	-79.12	-106.50	-71.367	23.968	726.0
L103	982382.186	-77.19	-104.83	-71.375	23.978	733.0
L104	982380.565	-78.02	-105.93	-71.400	23.990	740.0
L105	982379.742	-74.28	-102.67	-71.390	24.002	753.0
L106	982380.018	-70.43	-99.31	-71.398	24.013	766.0
L107	982379.948	-68.72	-97.87	-71.405	24.025	773.0
L108	982380.481	-66.46	-95.88	-71.413	24.035	780.0
L109	982379.904	-68.46	-97.76	-71.422	24.047	777.0
L110	982383.089	-63.44	-93.01	-71.428	24.058	784.0
L111	982389.958	-54.96	-84.79	-71.438	24.065	791.0
L112	982394.405	-48.84	-78.93	-71.447	24.070	798.0
L113	982404.013	-35.66	-66.24	-71.455	24.077	811.0
L114	982410.743	-25.35	-56.42	-71.463	24.083	824.0
L115	982405.212	-25.81	-57.56	-71.472	24.090	842.0
L116	982401.037	-24.87	-57.30	-71.480	24.095	860.0
L117	982405.739	-16.69	-49.62	-71.490	24.102	873.0
L118	982414.617	-4.24	-37.65	-71.498	24.108	886.0
L119	982416.057	3.81	-30.46	-71.507	24.113	909.0
L120	982405.879	0.25	-34.90	-71.516	24.120	932.0

L121	982389.853	-8.85	-44.91	-71.525	24.126	956.0
SEAL	982402.817	9.97	-26.77	-71.525	24.065	974.0
AB1	982371.305	-28.22	-64.27	-71.540	24.133	956.0
AB2	982364.779	-36.42	-72.32	-71.548	24.145	952.0
AB3	982362.212	-36.59	-72.83	-71.555	24.155	961.0
AB4	982357.261	-38.89	-75.50	-71.563	24.167	971.0
AB5	982351.744	-43.66	-80.43	-71.572	24.177	975.0
AB6	982348.852	-45.44	-82.40	-71.580	24.188	980.0
AB7	982345.154	-45.25	-82.73	-71.588	24.198	994.0
AB8	982342.512	-44.06	-82.07	-71.597	24.210	1008.0
AB9	982336.839	-48.00	-86.28	-71.605	24.220	1015.0
AB10	982336.752	-46.05	-84.63	-71.613	24.232	1023.0
AB11	982334.626	-47.33	-86.05	-71.620	24.242	1027.0
AB12	982333.380	-47.46	-86.38	-71.628	24.253	1032.0
AB13	982331.236	-47.93	-87.11	-71.637	24.263	1039.0
AB14	982328.351	-49.09	-88.53	-71.645	24.275	1046.0
AB15	982322.902	-53.74	-93.33	-71.653	24.285	1050.0
AB16	982316.725	-59.17	-98.91	-71.662	24.297	1054.0
AB17	982310.097	-66.23	-105.98	-71.670	24.307	1054.0
AB18	982306.831	-69.19	-108.97	-71.670	24.318	1055.0
AB19	982308.144	-66.76	-106.74	-71.678	24.328	1060.0
AB20	982310.690	-63.05	-103.21	-71.685	24.342	1065.0
AB21	982313.690	-60.79	-100.92	-71.693	24.352	1064.0
AB22	982314.530	-60.44	-100.56	-71.702	24.363	1064.0
AB23	982309.450	-62.56	-103.09	-71.710	24.373	1075.0
AB24	982303.083	-66.89	-107.73	-71.718	24.385	1083.0
AB25	982298.489	-70.11	-111.18	-71.727	24.397	1089.0
AB26	982298.295	-70.43	-111.53	-71.735	24.407	1090.0
AB27	982301.717	-65.84	-107.13	-71.742	24.418	1095.0
AB28	982308.899	-57.86	-99.30	-71.750	24.428	1099.0
AB29	982321.357	-33.78	-76.70	-71.758	24.440	1138.0
AB30	982328.084	-38.35	-79.95	-71.767	24.450	1103.0
AB31	982329.494	-35.52	-77.34	-71.775	24.462	1109.0
AB32	982327.798	-35.80	-77.84	-71.783	24.472	1115.0
AB33	982323.820	-39.95	-82.04	-71.792	24.483	1116.0
AB34	982325.209	-38.69	-80.81	-71.800	24.493	1117.0
AB35	982331.619	-36.98	-78.57	-71.807	24.503	1103.0
AB36	982343.777	-29.57	-70.64	-71.815	24.515	1089.0
AB37	982352.837	-24.96	-65.54	-71.823	24.527	1076.0

Table 3. Results of the measurements by JARE-28 around Asuka Station.

Station Name	Gravity value (mgal)	Free-air (mgal)	Bouguer (mgal)	Lati-tude (degree)	Longi-tude (degree)	Alti-tude (m)
SYOKU	982380.998	-15.80	-52.08	-71.524	24.129	962.0
KANSOK	982385.150	-11.40	-47.71	-71.525	24.129	963.0
FLUX	982381.032	-17.68	-53.73	-71.525	24.131	956.0
WIND	982384.079	-14.63	-50.68	-71.525	24.130	956.0
POLE	982384.544	-14.11	-50.16	-71.524	24.130	956.0
ULF	982381.155	-17.55	-53.60	-71.525	24.131	956.0
ST1	982378.096	-20.83	-56.88	-71.529	24.130	956.0
ST3	982378.226	-20.81	-56.86	-71.531	24.130	956.0
ST4	982374.305	-24.73	-60.78	-71.531	24.123	956.0
ST5	982368.602	-30.49	-66.54	-71.532	24.137	956.0
ST6	982371.119	-27.97	-64.02	-71.532	24.130	956.0
ST7	982366.773	-32.43	-68.48	-71.534	24.130	956.0
ST9	982368.910	-30.40	-66.45	-71.536	24.123	956.0
ST10	982366.816	-32.49	-68.54	-71.536	24.130	956.0
ST11	982363.072	-36.45	-72.51	-71.540	24.137	956.0
ST12	982364.717	-34.81	-70.86	-71.540	24.130	956.0

As for station names SYOKU through ULF, they are abbreviated from the hut names and sensor locations which are concentrated around the KANSOKU (observation) hut. As for station names ST1 through ST12, they are seismic stations temporarily installed to the south of Asuka Station, and their locations are indicated in Shibuya and Sakai (1989).