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A GRAVITY SURVEY ON ASO CALDERA KYUSHU DISTRICT, JAPAN (II)

By

Akira KUBOTERA, Norihiko SUMITOMO, Hirokazu TAZIMA*
and Sadakutu IZUTUYA*

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Abstract

A gravity survey at 292 points in an area of about 1700 km^2 over the Aso volcanic region was made by using Worden and LaCost & Lomberg geodetic gravimeters from 1964 to 1966.

Bouguer gravity anomalies over this area are characterized by a strong negative anomaly on the Aso caldera and positive anomalies on the south-western flank of somma of the Aso caldera.

The gravity low of the Aso caldera shows characteristic feature of the "low anomaly type caldera" as is pointed out by Yokoyama.

On the south-western flank of the somma of the Aso caldera, the oldest formation consists of semi-shist (Sanbagawa System) and outcrop of basalt is also being found by geological surveys. The gravity high which reaches to 22 mgal at the center coincides with the distribution of basaltic formation. It reveals, therefore, the high density of material such as basaltic or metamorphic rocks.

The underground structure of the Aso caldera was computed from the observed gravity data by using the sin x/x method.

For the computations, models of basement layer and overlying layer, reasonable density contrast between two layers and the depth of datum-plane were assumed. Thus, several models were obtained which are, however, the first approximated ones.

1. Introduction

The gravity survey on Aso caldera was made at 95 points from 1964 to 1965 and the observed results were reported in our previous paper (Kubotera and Sumitomo, [1965]). From 1965 to 1966 another gravity survey was made over Aso and Kuju volcanic regions, the central part of Kyushu Island of Japan. This survey was carried out as one of the branch projects of "Combined Aeromagnetic Gravity Studies of Caldera in Japan" in which the members of the Faculty of Science of the Kyoto University and the Earthquake Research Institute of Tokyo University take part.

* Earthquake Research Institute, University of Tokyo.

A discussion will be made in this paper on the gravimetric feature of the Aso caldera, using the above mentioned data of two gravity surveys.

2. Observation and corrections

Observation

Two types of gravimeter, Worden Gravimeter No. 127 and LaCoste & Romberg Geodetic Gravimeter G 34 were used. Most of the measurements were made on bench marks and triangulation points of the 3 rd and 4 th order and on spot heights. The elevations are acculately measured on these points. The railway platforms or the spots on the road where heights are known other favourable observation points. Also supplementarily added in our observation points are the spots where heights are determined from aerophotographs or topographical maps.

The gravity values at a total of 292 points were measured over the Aso caldera during two surveys. All the observation points are shown in Fig. 1.

The gravity data obtained by the Geographical Survey Institute on the bench marks in 1954 are also compatible with the present values if terrain corrections, which have been neglected in the published data, are made. Also a gravity survey was made on Kumamoto plane in 1960 by the Geological Survey Institute (Chujō [1961]) and data from this is also added.

As a result the number of gravity stations amount to 308 over Aso caldera, which gives an average density of one station per 6 sq. km.

Standard looping methods were used to take measurements and all the observed gravity values were reduced to the value determined at the local pendulum station at Kumamoto University in Kumamoto City (Fujii et al. [1964]).

Correction

The vertical gradient of gravity: $\partial g/\partial z$ was assumed to be 0.3086 mgal/m for the free air reduction. For terrain corrections the simplified method derived by Hagiwara [1965, 1968] was applied. The two cases of density for the earth crust, $D=2.67\,gr/cm^3$ and $D=2.30\,gr/cm^3$ respectively, were calculated by making terrain and Bouguer corrections. The international formula was used to obtain the normal gravity value.

3. Bouguer anomaly

The iso-anomaly contours of the Bouguer anomaly are shown with 5 mgal intervals in Fig. 1. This corresponds to the case of $D=2.67\,gr/cm^3$. In the case of $D=2.30\,gr/cm^3$, the Bouguer anomaly map shows similar patterns of the case of $D=2.67\,gr/cm^3$.

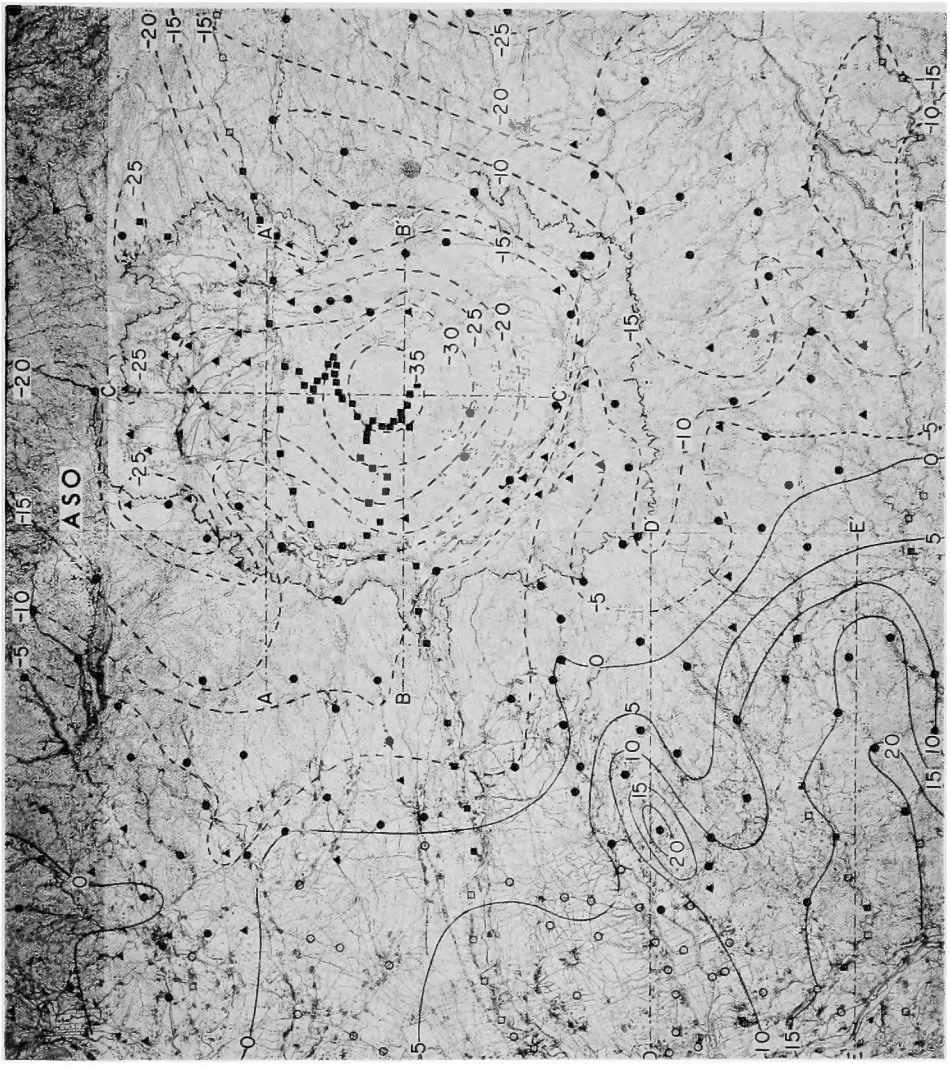

Fig. 1. Distribution of the gravity stations and Bouguer anomalies. (unit mgal)

■ denote bench mark.
▲ denote triangulation point.
● denote another station.
□ denote bench marks for Geographical Survey Institute.
○ denote gravity stations for Geological Survey Institute.

A complete picture of the gravity anomalies spread over the Aso caldera was obtained from the above mentioned two gravity surveys.

The Bouguer anomalies over this area are characterized by a strong negative anomaly on the Aso caldera and positive anomalies on the south-western flank of somma of the Aso caldera.

Negative anomaly over the Aso caldera

When compared with the neighbouring area, the gravity value lowers rapidly toward the interior of the caldera with a maximum gradient of 5.4 mgal/km amounting to -20 mgal at the center. It exhibits a typical feature of "low anomaly type caldera" supporting Yokoyama's discussions [1963]. The rough sketch of this picture can also be understood from a previous survey map by two of the present authors (Kubotera and Sumitomo, [1965]).

The Bouguer anomaly map over the Aso caldera is in conformity with its topography except at the north-eastern edge where the flank of the caldera gradually merges in the Kuju volcano group. The pattern of the Bouguer anomaly over this area suggests that the Aso caldera is structurally linked with the Kuju volcano group.

Positive anomalies on the south-western flank of somma of the Aso caldera

A region where the positive gravity anomalies amount to $+22$ mgal (in case when $D=2.67\,gr/cm^3$ is assumed) has been found on the south-western flank of somma of the Aso caldera. A detailed geological survey of this area by H. Matsumoto [1963] disclosed outcrops of basalt. According to his investigations, the oldest formation in this area consists of semishist which is one of the typical metamorphic rocks in Japan belonging to Sanbagawa System. The southern part of this system is connected to the Mifune group (Cretaceous Age) by a fault. The serpentines are found to have intruded along the boundary between these formations. The basaltic rocks are found to be of two types: one is as a dyke rock cutting through the serpentine mass, the other is as volcanic neck which is called Gongenyama.

A comparison between gravimetric and geological studies clearly shows that centers of gravity high in this region corresponed to the outcrop of the basaltic formation. It is clear, therefore, that the high gravity of the south-western flank of somma of the Aso caldera is a reflexion of exceptionally thin deposits of volcanic material on a base rock with a high density such as basaltic or metamorphic formations.

This inferrence is also supported by a magnetic survey which showed an anomalous pattern on this region (Blank et al., [1966]).

4. Underground structure over the Aso caldera

The well known $\sin x/x$ method (Tomoda and Aki [1955]) was used to compute the possible model of the underground structure over the Aso caldera from the observed gravity anomalies. For the computation, Bouguer gravity anomalies were determined at square grid points of 1 km meshes from the obseved gravity

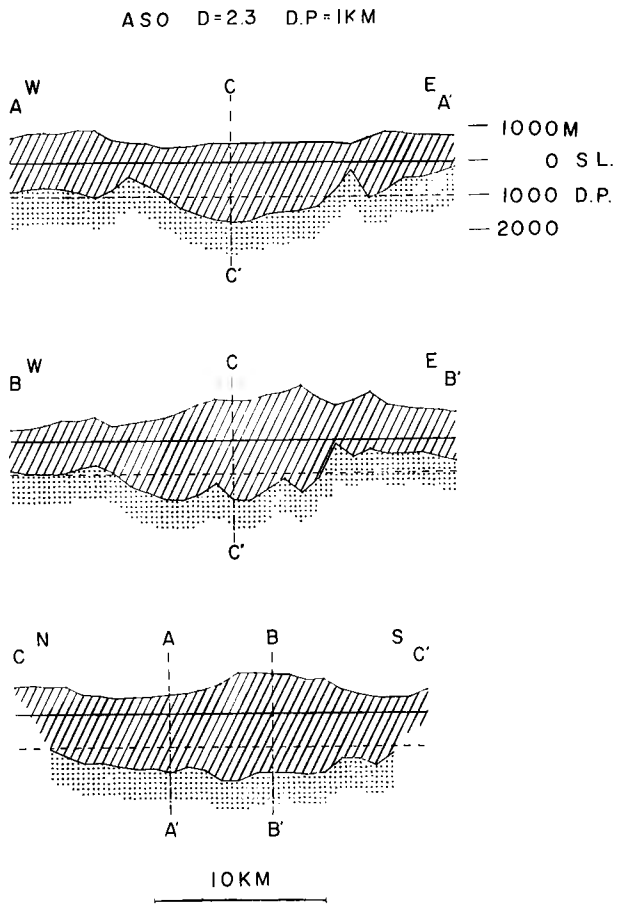

Fig. 2. Estimated profiles along the sections AA′, BB′ and CC′.
S. L. : Sea level D. P. : Datum plane

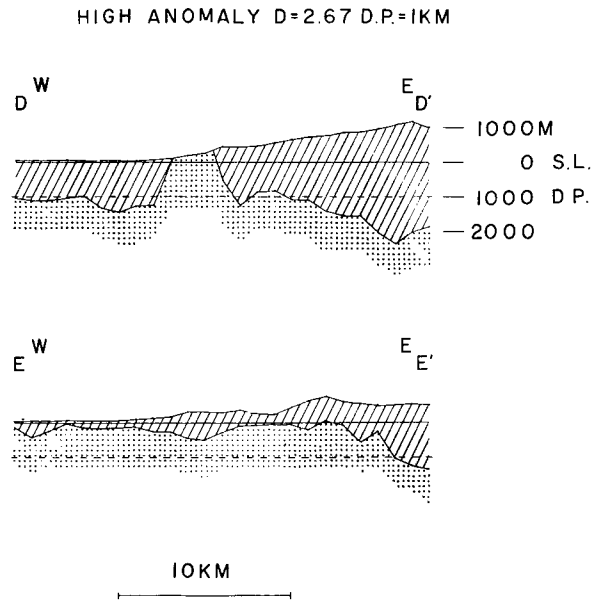

Fig. 3. Estimated profiles along the sections DD′ and EE′.

anomalies.

The unique solution of the underground structure are not determined from gravimetric observations, therefore the following assumptions were used. The underground structure consists of basement layer and overlying layer of which the material covered in the region over the Aso caldera. The most of low density materials are of volcanic origin. Reasonable density contrast between them and the depth of datum-plane on which the mass responsible for the gravity anomalies is assumed to be condensed were choosen as follows:

Density	Density Contrast	Depth of Datum-Plane	No.
D	ΔD	D. P.	
2.3	0.5	0.8 km	1
		1.0	2
		1.2	3
	0.6	0.8	4
		1.0	5
		1.2	6
2.67	0.3	1.0	7
	0.4	0.8	8
		1.0	9
		1.2	10

In this way several underground models were computed. Fig. 2 shows the estimated profile along the section AA′, BB′ (E−W) and CC′ (N−S) crossing the center of the Aso caldera for the assumption No. 2. The estimated profile along the section DD′ and EE′ crossing the center of high anomalous region on the south western flank of the Aso caldera is shown in Fig. 3 for the assumption No. 9.

These models are first approximated ones. It is necessary to combine seismological or geological information of the subsurface of the Aso caldera, in order to determine reasonable models.

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References

Blank, H. R. Jr., S. Aramaki and K. Ono, 1966 ; Aeromagnetic surveys of Kuttyaro and Aso caldera regions, Japan. Bull. Vocanol., Tome XXIX.

Chūjō, J., 1961 ; Gravitational survey of Kumamoto district in Kyushu, Bull. Geol. Survey Japan, Vol. **12**, (in Japanese).

Fujii, Y., S. Kogure, T. Saito, K. Inoue and I. Murata, 1965 ; On the reading accuracy and the scale factor reliability for the LaCoste and Romberg geodetic gravimenter G-29, J. Geod. Soc. Japan, Vol. **10**, (in Japanese).

Hagiwara, Y., 1967 ; Analyses of gravity values in Japan. Bull. Earth. Res. Inst. Vol. 45,

Kubotera, A. and N. Sumitomo, 1965 ; A gravity survey on Aso caldera Kyushu district Japan (I), Spec. Cont. Geophy. Inst. Kyoto Univ., **5**,

Matsumoto, H., 1963 ; Petrological study on rocks from Aso volcano, Kumamoto Jour. Seience. Ser. B. Sec. I. Geology Vl Vol. **5**,

Rikitake, T., H. Tajima, S. Izutuya, Y. Hagiwara, K. Kawada and Y. Sasai, 1965 ; Gravimetric and Geomagnetic sutdies of Onikobe area, Bull. Earthq. Res. Inst., Vol. 43,

Tomoda, Y. and K. Aki, 1955 ; Use of the function sin x/x in gravity problems, Proc. Japan. Acad., Vol. 31,

Yokoyama, I., 1963 ; Gravity anomaly on the Aso caldera, Geophysical Paper Dedicted to Prof. K. Sassa.

Yokoyama, I., 1963 ; Structure of caldera and gravity anomaly, Bull. Volcanol., Tome XXVI.