Detailed Gravity Anomaly Map in and around the Japanese Islands

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1. Introduction-- History

Detailed gravity anomaly map over wide areas is thought to be useful to understand and to analyze underground structure in geothermal fields.

Gravity measurements in and around the Japanese Islands were started from a century ago. In 1899, Dr. H. Nagaoka connected the absolute gravity in Potsdam with Tokyo by using Sterneck pendulum. Until 1915, more than 100 gravity stations were settled over the Japanese islands. In early period of gravimetrical studies, the measurement of gravity itself was one of important physical studies.

The first gravity measurement in oceanic area was carried out off Sanriku district, around the Japan trench axis, in 1932 by Dr. M. Matsuyama. A submarine and a Vening Meinesz type pendulum were employed for the measurements.

After the second world war, gravity measurements by using spring type gravimeters increased rapidly. In 1954, gravity measurements at the second order leveling stations along national roads were performed by Dr. C. Tsuboi and his colleague by using Wordon gravimeter and number of measurement points was 4,500. In 1969, Geographical Survey Institute (G. S. I.), completed the precise gravity measurements one round all over Japan by using North American gravimeters and the G. S. I. type pendulums. Measured data were increased in about 10,000 points. Their gravity anomaly maps showed already complicated pattern of the anomaly reflecting complicated geological structures of the Japanese Islands. However, gravity stations were still restricted only along national roads and then wide vacant spaces were remained inside of them. Furthermore, many of national roads are running along faults or geological boundaries, it is obvious that many of gravity stations were situated in geologically singular locations. Geological structures in Japan are so complicated as those extensions are ordinarily limited within tens of kilometer, sparse gravity stations may not give real information on subsurface structures.

Gravity measurements over oceans were started by Dr. Y. Tomoda, inventing a new precise surface ship gravimeter. Hydrographic department of Maritime Safety Agency is also performing gravity measurements particularly over continental shelves around Japan.

In parallel with these nation-wide gravity measurements, detailed local gravimetries for geophysical exploration were also carried out in various economically potential areas by Geological Survey of Japan, Metal and Mining Agency and other exploration companies and institutions.

2. Digital compilation --- Data sources and data processing.

As mentioned previously, gravity stations in Japan were so heterogeneously distributed as somewhere only aligned along main roads and somewhere densely distributed in narrow regions. To improve these situation, we started gravity measurements not only in flat areas but also in ragged mountain areas. Digital compilation of gravity data was also started with help of many institutions and organizations. They kindly offered unpublished data files as a form of printed matter or computer readable media. Total number of data is about 500,000 points, 80,000 points are on land and the others are on ocean. Mean density of the gravity stations is about 25 points/100km^2

After various data checking and data processing, all data are unified as if they measured by one institution. Gravity system is followed by the International Gravity Standardization Net 1971 (IGSN 71). Density (ρ) for the Bouguer correction is assumed to be 2.67 gr/cm^3. The Bouguer anomaly ($\Delta g''$) is calculated by

$$\Delta g'' = g - \gamma + Atm + 0.3086\, h - 2\pi G \rho h + Tr \qquad (1)$$

where, g is absolute gravity, γ is normal gravity, Atm is atmospheric correction, G is universal gravity constant, h is altitude, and Tr is terrain correction term. The terrain correction term was calculated by using digital topographic data prepared by G. S. I., which grid interval is about 500 m (Kono and Kubo, 1982). The accuracy is estimated within 10 % of it's value.

3. Bouguer anomaly map.

Randomly distributed observed data were converted into grid data, which grid size is about 2 km and a contour map was produced by employing an automatic contouring technique. Accuracy of the grid data is evaluated within 1 mgal. Fig.1 shows a part of the Bouguer anomaly map of the Japanese Islands and it's environs thus produced. The original map is 1 in 1 million in scale and covers area from 30°N to 47°N and from 127°E to 148°E. The contour interval is 2 mgals.

The map shows complicated anomaly pattern. Strong positive anomalies over the outer belt (Pacific Ocean side), and strong negative anomalies over the central part of Honshu and over the Hiroshima district are already recognized in older gravity anomaly maps. Our new map shows more detailed pattern of anomalies and strengthens contrast between locally positive and negative anomalies. For example, the large gravity change between Northeastern and Central Japan clearly appeared in the new map, which boundary is traceable from Chosi (Pacific ocean side) to Naoetsu (Japan sea side).

Strong positive anomalies over the outer belt partly come from the gravity attraction caused by the subducting Pacific and Philippine sea plates, because the plates are denser than the asthenosphere. We are computing to separate the anomalies into subducting slab and crustal contribution parts.

At present, it is difficult to give comments for geothermal areas from the gravity anomaly point of view, but the map will be useful to understand basic features of geothermal fields in Japan.

References

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Fig. 1 A part (northern part of Central Japan) of the Bouguer anomaly map in and around the Japanese Islands . The map is drawn based on 500,000 observations. The original map is 1:1,000,000 and covers area from 30°N to 47°N and from 127°E to 148°E. The contour interval is 2 mgals.