ON SECULAR CHANGE OF GRAVITY

BY

Tokio ICHINOHE, Ichiro NAKAGAWA and Norihiko SUMITOMO

1. Introduction

The value of gravity acceleration at any fixed point on the earth's surface is dependent on three factors, namely gravitational attraction by the earth's mass, centrifugal force originated from the earth's rotation, and tidal force by some celestial bodies. These three factors are the functions of many physical quantities, namely universal constant of gravitation, mass of the earth, radius of the earth, angular velocity of the earth's rotation, mass of the celestial bodies, distance of the celestial bodies from the earth, zenith distance of the celestial bodies, and the like, each and all being variable in the long run. Comparatively rapid and periodic variation of the last two of these quantities causes periodic variation in tidal force, which has been particularly investigated by many researchers in relation to the problems on oceanic or earth tides since the times of Newton. On the contrary, gravity change due to the other quantities, which is called secular change of gravity in this article, is so slow and minute that we have little observational data to support its existence, though it must surely exist, especially in case that subterranean mass distribution were changed to a certain degree.

Under these circumstances, expecting to find any clue to the investigation on secular change of gravity and taking the recent development of highly sensitive and portable gravimeters into account, the authors already made first series of gravity surveys, consisting of four repeated gravity measurements, at one hundred and sixty stations in the Kinki District during four years from 1950 to 1953. Observed results of the first series of gravity surveys were already published, and it was pointed out that somewhat noticeable gravity increases had been found in the western shore region of Lake Biwa.

In a period from July 24 to August 1, 1962, the same kind of gravity survey, for the first measurement in the second series, was made at fifty nine stations in the Kinki District to compare the observed gravity values with those of the first series. Some noteworthy results obtained by the survey and some considerations on the results will be briefly described in the following.

2. Observed results of the survey

Location of the observation stations of the present survey is shown in Fig. 1. In most stations, the gravimeter was set at the entirely same position as former survey by the help of old photographs. In the rest stations where it was impossible by various reasons, suitable height corrections were applied to the observed values. The gravimeter used in the present survey was the Worden gravimeter No. 127 belonging to the Geological Institute of Kyoto University. In addition to this, the Askania Gs-11 gravimeter No. 111 was also used at the stations from Kyoto to Hikone and Imazu. The gravity value at the Geophysical Institute of Kyoto University was adopted as standard, being assumed to be unchanged, throughout both series of gravity surveys.

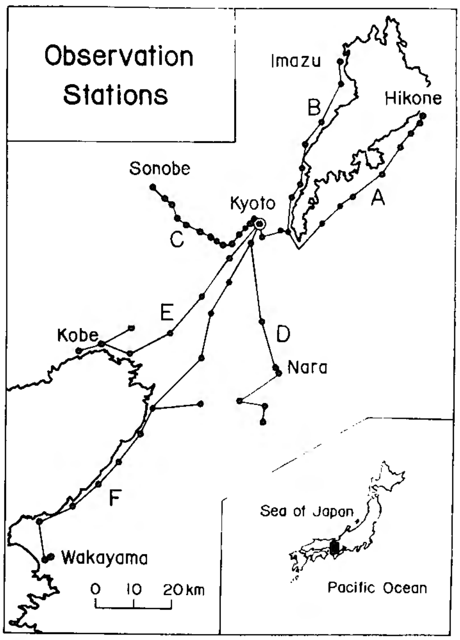

Fig. 1 Location of the observation stations. *A*, *B*, *C*, *D*, *E*, and *F* represent the survey routes.

Observed gravity values at each station were reduced by tide and drift corrections. Though drift correction for gravimetric observations includes many troublesome problems, in the present case the correction was carried out under an assumption that drift had kept a uniform speed during one closing measurement. Some discussions will be made later as to whether that assumption was correct or not. For the scale constants of the gravimeters the values given by the makers were formally adopted. In the investigation on secular change of gravity, the scale constant of gravimeter is of vital importance, especially in case that successive surveys were made with the different types of gravimeters. Actually the first series of surveys were made with a North American gravimeter and the second series with Worden and Askania gravimeters as described above. If there were any difference between the two scale constants of the North American gravimeter and the Worden one, some apparent gravity change should be found even if the fact were not so.

For the purpose of examining the possibility of such a case, the following measures were adopted: taking the gravity value at the base station (Geophysical Institute of Kyoto University) as the coordinate origin, the gravity difference between each station and the base station as the abscissa, and plotting the difference between the gravity value of the present survey and that of the former one at each station as the ordinate, as shown in Fig. 2. For the former gravity values those of the survey in 1952 were adopted by some reasons. In Fig. 2, it will be

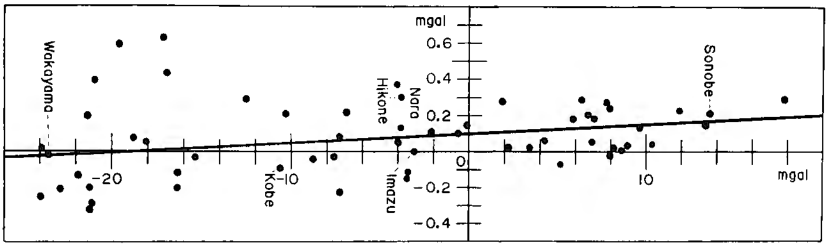

Fig. 2 The abscissa represents the gravity difference between each station and the base station, the ordinate the difference between the gravity value of the present survey and that of the former one at each station.

found that all the plotted points distribute nearly along a straight line with some gradient. It will be reasonable to regard this tendency as originated from not real gravity change but the difference between the scale constants of the gravimeters used. From the gradient of this line the difference between the scale constants of the two gravimeters is determined to be about 0.5 per cent. In the figure, it will be also found that the line doesn't pass across the origin but the ordinate axis at the point of 0.096 mgal, which indicates apparent gravity change of 0.096 mgal at the base station. Such a paradoxical occurrence, contrary to our assumption that the gravity value at the base station were invariable, is considered to be originated from the imperfectness in the connection of the gravity values at the present and former base stations, for in the present survey the gravity reference station of the new Geophysical Institute was adopted as the base station and in the former survey the basement room of the old Geophysical Institute. Considering the above-mentioned conditions, the deviations of all the plotted points from the line are considered to be utilizable for further discussions on gravity change. These deviations are graphically shown in Fig. 3, in which the abscissa represents the distance of each observation station from the base station along the route. In the next section, some discussions will be made concerning the question whether the gravity changes shown in Fig. 3 surely indicate the real gravity change or merely some instrumental or observational errors.

3. Discussion on the observed results

In Fig. 3, it will be noteworthy that some regularities are found on the gravity

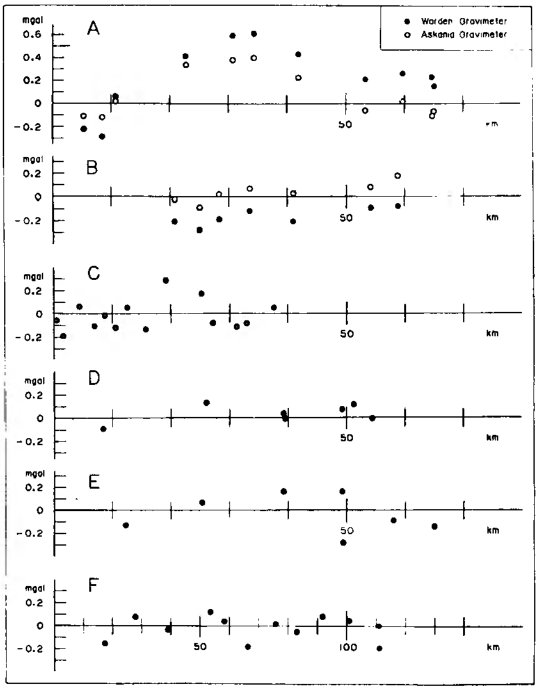

Fig. 3 Gravity change in each survey route. The abscissa represents the distance of each observation station from the base station.

changes in the routes A, B, and E, especially in the routes A and B it appears quite similarly on the both observed results by the Worden and Askania gravimeters. If it were merely originated from some instrumental or observational errors, it will be natural to attribute its origin, first of all, to the irregularity in the drift speed of the gravimeter used. If the drift speed were irregular, contrary to our assumption that drift had kept a uniform speed during one closing measurement, such gravity changes as observed in Fig. 3 should appear as the natural results of data analysis even if the fact were not so. It may be the change of temperature what produces the most effect on the irregularity of drift speed. But it was proved by the observations of weather stations that the atmospheric temperature of the days had been neither remarkably high nor low. It is also possible that intense solar radiation of the days might affect the drift speed. In this case, however, it is very strange that the two different types of gravimeters were affected by solar radiation in the quite same way, though it is not necessarily impossible. There may be the case that the upheaval or subsidence of the ground, as the results of the displacement of the observation stations, produced apparent gravity changes. But it is impossible that there has occurred during the last ten years so great ground subsidence that produced such gravity changes as shown in Fig. 3. There may be supposed the case that the change of underground water level produced some effects on gravity value. But it is also impossible in the present case, because it needs the change of water level reaching to about 25 metres to produce such gravity changes.

Considering the above-mentioned conditions, it ought to be taken into account that the gravity changes shown in Fig. 3 possibly represent real gravity changes caused by the change of subterranean mass distribution. If it be so, is there any immediate evidence to confirm the change of subterranean mass distribution? We have, much to our regret, little evidence about it. Bouguer anomaly alone, however, gives us important informations on it. From the tectonic point of view, the routes A, B, and E are situated in the regions of negative Bouguer anomaly, especially the route A of the eastern shore of Lake Biwa is situated in the region of extremely negative anomaly. Furthermore, that region is considered to be in isostatically unstable state. It is naturally speculated that in such an unstable region subterranean substances may change their distribution to recover a stable state. According to an informal report of the Geographical Survey Institute, an erosion is in progress at the bottom of Lake Biwa. Further according to unpublished data of the Kinki Regional Construction Bureau, the water level of Lake Biwa continued to rise during the last ten years, though it hasn't so importance in the present case because it is largely governed by artificial conditions. There are other evidential phenomena to confirm the progress of erosion of Lake Biwa.

From the above-mentioned situations, it is considered to be not impossible that some crustal changes are in progress in the region of Lake Biwa, and for this cause gravity changes have occurred. Assuming tentatively that the crust with a thickness of 40 kilometres uniformly changed its density, the amount of density change to produce such gravity changes as observed in the route A is estimated to be 0.04～0.15 per cent; and assuming the spherical region with a radius of 20 kilometres, it is estimated to be 0.12～0.45 per cent.

4. Summary

Summarizing the preceding descriptions, some gravity changes were observed in the regions of negative Bouguer anomaly, especially in the eastern shore region of Lake Biwa rather prominent gravity increases were observed. But, many questions were deferred to be solved as to whether the observed gravity changes were real gravity changes or apparent ones caused by any instrumental or observational errors. For the solution of these questions, generally speaking, for the investigation of the problem on secular change of gravity, it is considered to be indispensable to use portable gravimeters in combination with other measuring apparatus, for instance suitable gravity variometers and gravity pendulums. Astronomical observations on the change of plumb-line will give us some important informations on this problem.