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STUDY ON CHANGE OF GRAVITY WITH TIME
PART II. REPEATED GRAVITY SURVEYS IN THE KINKI DISTRICT

BY

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ABSTRACT

Gravity surveys with a portable gravimeter of the North American type were made repeatedly four times during 1950–1953 at about one hundred and sixty points in the Kinki District as a preliminary study on the problem of probable secular variation in gravity. In this article some important conditions, which are considered to be noteworthy for the future development of the investigation of secular variation of gravity, comprise the main discussion as deduced from the data of the present surveys. It should be mentioned that, in the present surveys, some remarkable secular variations in gravity, though not without some uncertainty, were observed in the western shore region of Lake Biwa and the City of Ōsaka.

1. Introduction

The value of gravity acceleration at any fixed point on the earth is dependent on three factors: attraction by the earth's mass, centrifugal force caused by the rotation of the earth, and attraction by the celestial bodies. The latter has already been dealt with in the first Part of the present investigation as the tidal variation of gravity. In the present article the non-periodic variation of gravity, if it exists, caused by changes in the first two factors will be investigated by repeated gravity surveys at many points within a small area.

The non-periodic variation in gravity of short duration (sudden change) or long duration (secular variation) may be caused by the following changes: upheaval and sinking of the ground, effusion of volcanic lava, change of groundwater level, displacement of oceanic water mass, change of atmospheric state, orogenic movements, epeirogenetic movements, and, generally speaking, a change in the geoidal figure caused by displacement or mass changes on the surface or in the interior of the earth. And, moreover, sudden or secular changes of the earth's rotation speed would theoretically affect the gravity value, though in a minute order of magnitude, and could be detected in the future course of fine observation of gravity changes.

In former times, a comparison was made of the gravity values measured at intervals of some fourty years at four stations in India, and changes in gravity of from 27 mgal to 103 mgal were found. But it is questionable as to whether such changes may have been caused by a real change in gravity or attributable to some observational and instrumental errors (**1**). Absolute measurements of gravity were made at Washington, U. S. A., in 1936, and at Teddington, England, in 1939, and these values were referred to the absolute value determined at Potsdam, Germany, in 1906. B. C. Browne and E. C. Bullard (**2**) discussed the problem of difference in the absolute values of gravity at the three stations of Potsdam, Washington, and Teddington, and concluded that the value at Potsdam should reasonably be corrected to -17 mgal in magnitude. In the treatment by Browne and Bullard it was assumed *a priori* that the gravity value at Potsdam had been invariable during the period of thirty years from 1906 to 1936. It is not unthinkable that a part, if not the whole, of the discrepancy in the absolute values of gravity might be attributable to some secular variation at Potsdam. On this point a re-measurement of the absolute value of gravity at Potsdam is most earnestly hoped for towards the development of the research in the secular variation of gravity.

On the other hand, the recent development of a highly sensitive and portable gravimeter has greatly facilitated the quick and precise relative measurement of gravity over large survey areas. The world-wide surveys of gravity with the Worden Gravimeter made by G. P. Woollard (**3**) is an epochmaking step in the research field of gravity, as evidenced by his precise relative measurement of gravity at thirty-three pendulum stations and one hundred and twenty-five gravity stations connecting all continents of the world in the relatively short period of three months, the measurements hitherto having been made under non-uniformity with different instruments and at different times. But the changes deduced from the results of Woollard's surveys and old values should not be considered as directly attributable to any actual secular variation, because the old values were obtained by different instrumtnts and with varying accuracies from those of Woollard. It is expected that, the problem of the secular variation of gravity on a world-wide basis will be developed by the repetition of such surveys as Woollard's in successive decades.

At the Meeting of the International Gravimetric Comission at Paris in 1953, it was resolved and recommended that the selection of a network of some thirty "first order" international gravity stations be established all over the world, with frequent and efficient connection between the first international stations for each other and between the first international stations and the national reference stations. The completion of such a program would certainly make a great contribution to the advancement of research in geoidal figure and in world-wide secular variation of gravity.

Setting the phenomena of world-wide scope aside, the non-periodic variation of gravity of local or regional character observed in this country will be mentioned. Previously, the secular change in the rate of speed of the Riefler-clock in the Tokyo Astronomical Observatory was examined by M. Ishimoto and K. Tuzi (**4**) in connection with the occurrence of the Great Earthquake near Tokyo on September, 1, 1923. Assuming that the whole change of rate of the Riefler-clock would be caused only by a gravity change, the gravity value at Tokyo might have change 10 mgal before the earthquake occurrence. But this problem remains undetermined, as indicated by C. Tsuboi's study, for the relation between the clock rate and gravity change is not so simple as above assumed. After the occurrence of the strong earthquake on December 26, 1949, at Imaichi, 7 km distant from Nikkō, in Tochigi Prefecture, it was found by K. Iida, M. Hayakawa, and K. Katayose (**5**) that the gravity value at Imaichi had decreased by the amount of 0.15 mgal compared with that at Nikkō during three months after the earthquake occurrence. The change of gravity at the area of Volcano Mihara in Ōshima of Izu Islands was also observed by the same members above mentioned (**6**) at the time of violent eruption in 1950. This report is reasonably appreciated since an abundant effusion of lava may cause a local deformation in the gravitational field. The results above described are considered to be quite accurate since the gravimeter used in both cases was of the North American type whose sensitivity is enough to detect such a degree of gravity change and instrumental drift is estimated to be exceedingly small. On December 21, 1946, the Great Nankaidō Earthquake occurred at the area 50 km offshore in the open sea southward of the Kii Peninsula. This destructive earthquake of a magnitude of 8.2 (Pas.) brought about great damage by Tsunami along the neighbouring harbours, and, moreover, an upheaval and sinking of the ground exceeding the amount of 1 meter in the region of the southern part of Kii Peninsula and the south-eastern part of Shikoku. Referring to this earthquake the plumb-line deviation was re-surveyed by T. Okuda (**7**) at thirteen points around the epicentral region, and it was ascertained that the large secular change of the plumb-line occurred during several years from the old epoch (1939–1946) to the new epoch (1947–1950), whose amount reaches nearly 4 seconds angle in the maximum. The above result means, in other words, a local change of geoid in the epicentral region and consequently a local change in gravity intensity. Really the change of gravity at several points in the southern part of Kii Peninsula was observed by N. Kumagai (not yet published) with the Meinesz' gravity pendulum, amounting to several milligals. These observations throw some light upon the little known field of secular variation of gravity and suggest a method of future research. In connection with these phenomena a gravity survey along the lines of precise levels throughout Japan with a Worden Gravimeter has recently been accomplished by C. Tsuboi (**8**). This precise survey of dense net not only revealed the fine subterranean structure in Japan but also will certainly make a great contribution to the future study on the secular variation of gravity when these values are compared with those which will be observed after one or two decades.

Concerning the problem of crustal deformation, the concurrent observations of self-recording by the highly sensitive gravimeter with the tiltmeter and the extensometer of high quality have been operated under the auspices of our Geophysical Institute, Kyoto University, since 1951 at several points in the Kinki District. As already described in the preceding paper, the highly sensitive station gravimeter is unsuitable for the study of secular variation of gravity owing to its enormously large drift of zero position. But it will certainly promise the possibility of detecting sudden changes in gravity because of its high sensitivity. On the secular variations in gravity at these stations, the precise and frequently repeated relative measurements of gravity with the pendulum will commence early in 1956. Parallel to this series of observations, the frequent repetition of dense net gravimetric surveys in the Kinki District with the highly sensitive (0.09104 mgal/div. with the negligibly small drift of 0.05 mgal/day) portable North American Gravimeter was planned by Profs. K. Sassa and K. Iida for the purpose of determining the fine subterranean structure of the Kinki District and of obtaining profitable data for the study of secular variation of gravity. Four surveys have been made from 1950 to 1953 at 160 points near Kyoto and Ōsaka by the operators, K. Iida, M. Hayakawa, Y. Kotani, T. Sugiyama, and the writer. In the present article the observational data and results of the four surveys will be reported by the writer by permission of the planners and operators, confining the subject mainly to the problem of time variation in gravity.

2. Results of surveys

Present series of gravity surveys were originally planned to investigate the following three points:

(a) To investigate the fine subterranean structure of the Kinki District by applying the precise and dense gravity surveys to a relatively small area, complemented with the knowledge obtained from the analyses of seismic waves in near earthquakes.

(b) To estimate the amount of secular variation in gravity, if any, and to find a fitting method for its investigation by applying the ruled and frequent repeated surveys to one and the same area.

(c) To obtain useful data for investigating the phenomenon of ground-subsidence, in particular, in the area of Ōsaka City from both sides of the distribution mode of gravity anomlies and its time variation.

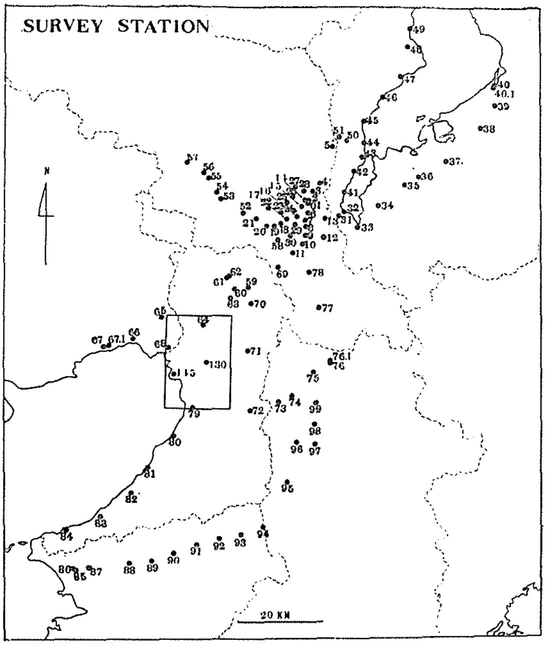

Fig. 1a. Survey stations in the Kinki District (near Kyoto, Ōsaka, Kōbe, Nara, and Wakayama)

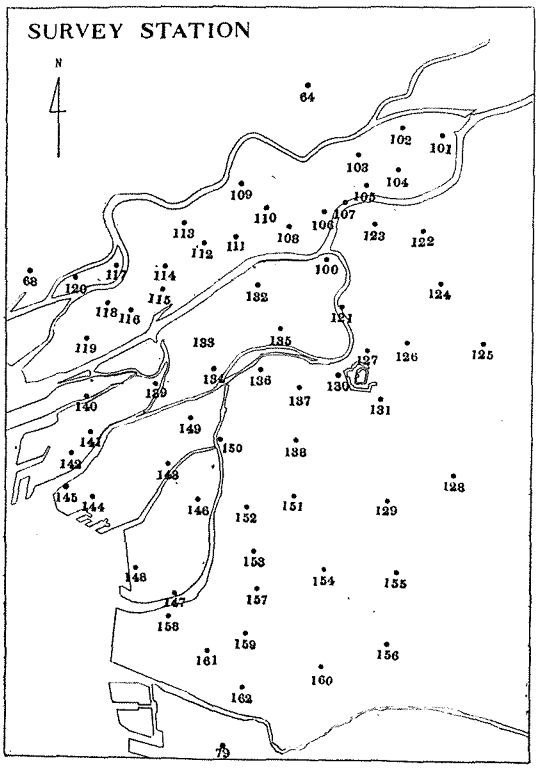

Fig. 1b. Survey stations in Ōsaka City

The survey stations are shown in Fig. 1, and the instrument used is the North American Gravimeter AG–1, 108, belonging to the Geological Survey of Japan, and whose construction and function can be obtained by referring to the article by T. Matsuda (**9**). The four surveys were made in the periods of December, 1950 (I); December, 1951–January, 1952 (II); November–December, 1952 (III); and December, 1953 (IV). The materials obtained in surveys I and II and corrected for both effects of "drift" and "tidal force" have already been published by K. Sassa and K. Iida (**10**). In the present paper the materials of all four surveys are tabulated at the end of the article, and it should be remarked that the gravity values in the table are listed in the figure of 0.1 mgal for the sake of assurance, though the instrument is designed to measure and read in the figure of 0.01 mgal. By the analysis of data obtained in survey I some problems were treated by the writer (**11**), and the Bouguer anomalies calculated in that treatment are again shown in Fig. 2, which well coincides with that derived independently from a different survey made by C. Tsuboi (**8**). Of the data of survey II some detailed discussions were made on the problem of ground-subsidence in the area of

Ōsaka City referring to the distribution mode of the Bouguer anomalies in that area, and some considerations were applied to the difference of gravity values at the re-measured places in surveys I and II. Two papers on survey III were read at the Annual Meeting of the Seismological Society of Japan at Kanazawa on May, 1953, but they are not yet printed. In the following section the problems on the time variation in gravity and its observational degree of reliability are discussed mainly by analyzing all materials obtained from the present four gravity surveys from 1950 to 1953 in the Kinki Ditrict.

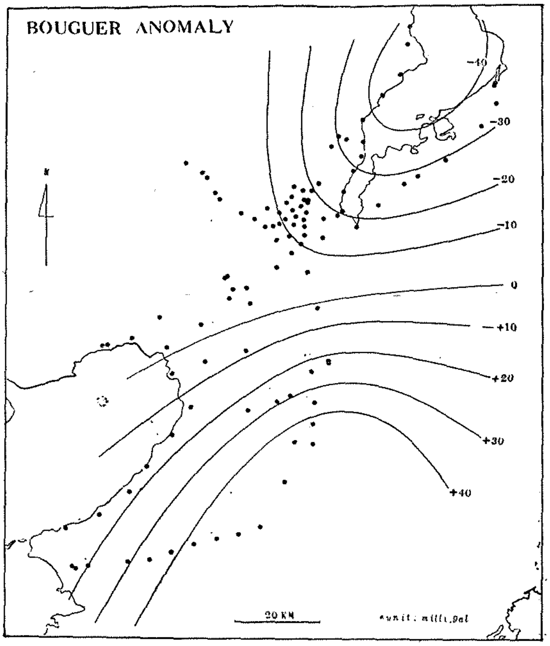

Fig. 2. Bouguer anomaly in the Kinki District

3. Observed secular variation of gravity

The stations surveyed in the present series of four gravity surveys amounted to about one hundred and sixty in all, and among them about sixty stations are situated in the area of Ōsaka City. Consequently, it is convenient to treat the observed materials by separating those of the Ōsaka area from those of the remaining area. As seen in the table at the end, the observed values at any place in each survey differ greatly from each other. An essential problem in the present article is whether these variations may be correctly interpreted as secular change in gravity or whether they were caused by some instrumental or observational error. On this point, for the purpose of examining whether there is any systematic variation of the measured gravity in any region or not, the amounts of change in gravity are graphically shown by the survey route in Fig. 3. As shown in this figure, considerable amount of variation in the measured gravity values are found in some periods, but it is generally difficult to find any route of systematic change throughout all four surveys. Only route B, from Kyoto (station-number, 0) to Imazu (station-number, 49), namely the western shore region of Lake Biwa, is somewhat worth noticing, because of the increase in gravity values at all stations along this route during 1950 to 1952. As this area is just in the region of large negative Bouguer anomlies with steep gradient, it is speculatively interesting to imagine some connection between the amount of secular variation in gravity and the steepness of distribution in gravity anomalies. But it is questionable as to whether the changes shown in Fig. 3 depend upon real gravity changes or some instrumental and observational errors, for only two surveys were made in this route. The solution of this sort of problem by the repetition of gravity surveys in the succeeding decade or century is greatly to be desired.

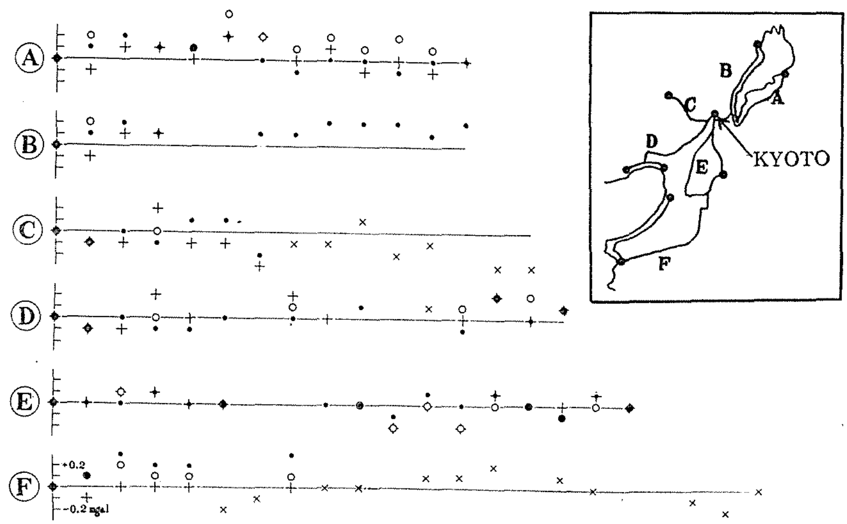

Fig. 3

○ : Difference between surveys I–II
● : " " " I–III
+ : " " " I–IV
× : " " " III–IV
A : Station numbers, 0, 13, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 40.1
B : " " , 0, 13, 31, 32, 41, 42, 43, 44, 45, 46, 47, 48, 49,
C : " " , 0, 14, 15, 16, 17, 18, 19, 20, 21, 52, 53, 54, 55, 56, 57
D : " " , 0, 14, 15, 16, 29, 30, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67
E : " " , 0, 6, 7, 8, 9, 10, 11, 69, 70, 71, 72, 73, 74, 75, 76, 76.1, 77, 78
F : " " , 0, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99

Concerning the data of Ōsaka City, the observed materials in surveys II, III, and IV will be analyzed, because the survey stations were only two points in survey I. In Figs. 4 and 5, the difference between the gravity values observed in surveys II and III, and in surveys III and IV are plotted respectively. And the amount of ground-subsidence measured in Ōsaka City are also shown in Fig. 6 for comparison with Figs. 4 and 5. From these three figures it is generally understood that the places of large ground-subsidence well coincide with those of large increases in gravity, excepting the case in the small north-western part of City. Ground-subsidence certainly causes an increase of gravity value owing to the approach of the survey

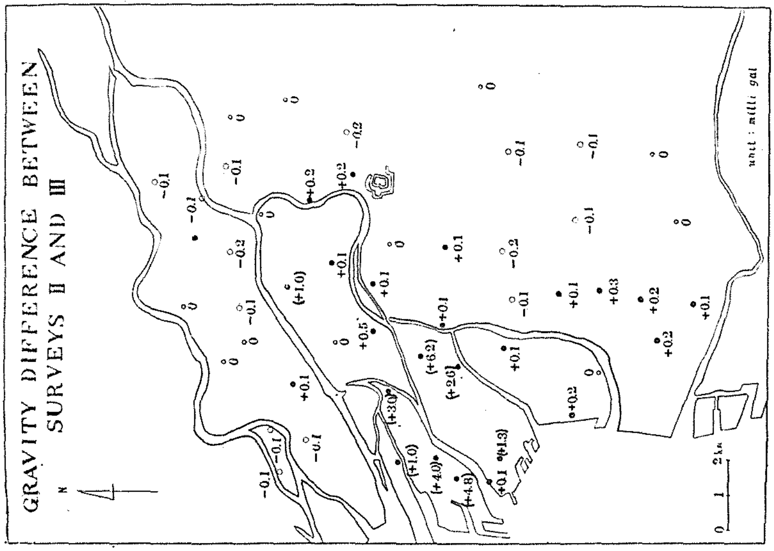

Fig. 4. Cravity difference in Ōsaka City.

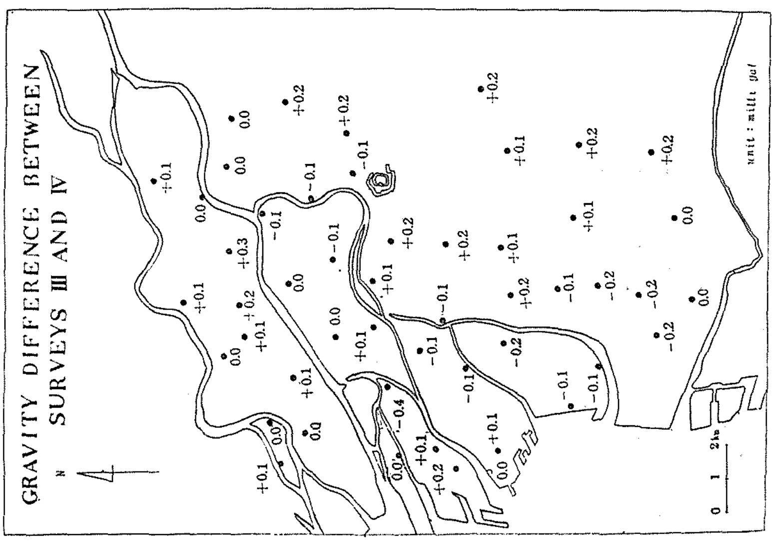

Fig. 5. Gravity difference in Ōsaka City

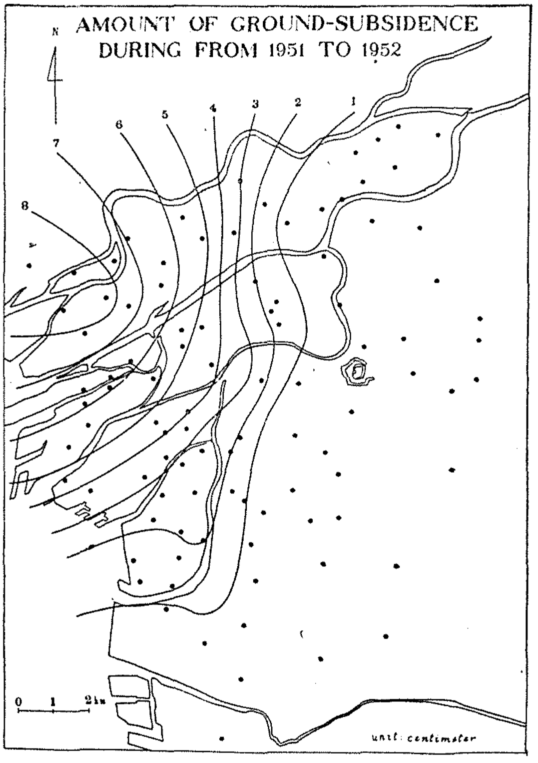

Fig. 6. Ground-subsidence in Ōsaka City

station, though small, to the centre of the earth, but, in the case of Ōsaka City, special note should be made of amount of gravity increase. Namely, the maximum subsidence in this case amounted to nearly 10 cm, and consequently the gravity increase by this subsidence was calculated as nearly 0.03 mgal, which is exceedingly small compared with those observed in the present survey, as seen in Figs. 4 and 5. Therefore, if the observed increase in gravity in Ōsaka City is assumed as the real phenomenon, the ground-subsidence would cause the increase of effective density in the subterranean layer which generally contains a great deal of underground-water. And, on the other hand, it has been previously discussed (**12**) that the places of large ground-subsidence generally coincide with the places of negative Bouguer anomalies in gravity in the area of Ōsaka City. Combining this and the above argument, it can be said that, phenomenologically, the gravity value increased largely at the places of negative Bouguer anomalies in Ōsaka City. This relation resembles, in appearance, that discussed in the case of the western shore region of Lake Biwa. But, under practical considerations, the gravity variation of 1 mgal would necessitate a density variation of 0.05 gr/cm^3 in the subterranean layer of 500 m thickness, or 0.24 gr/cm^3 in the layer of 100 m, and these amounts of density variation are generally unthinkable excepting in an unusual instance. Besides, the places of large ground-subsidence are generally on sandy and weak ground where the amplitude of the micro-tremors of the ground excited by various sources is enormously large compared with those of ordinary firm ground. As it is reasonably supposed that the large micro-tremors of ground would greatly disturb the reading of the portable gravimeter, the large change of gravity at the places of large ground-subsidence deduced from the gravity surveys in Ōsaka City may partly be attributable to the erroneous observation of gravity on the weak and restless ground. Especially, anomalously large changes shown in Fig. 4 may perhaps be interpreted as derived from the observational errors in survey in 1951. On the contrary, the gravity change shown in Fig. 5 is considered to be trustworthy, and this problem on the relation between the ground-subsidence and the change in gravity could be solved by applying the repeated survey of gravity and levelling to the restricted small area of large ground-subsidence.

In the above discussions the following three essential points are naturally assumed:

(a) All values of gravity in the present four surveys are referred to that at the gravity base station of Kyoto, in the old Astronomical Institute, Kyoto University, and the gravity value at the reference station was assumed to have suffered no change during the period of the successive surveys.

(b) In the application of correction for drift to the measured values, the amount of drift was assumed to be in a linear rate with time in any closing circuit of survey.

(c) The sensitivity of the gravimeter was assumed to have remained constant throughout the period of all the surveys.

Regarding the first supposition, as all gravity measurements made in the world are generally so-called relative measurements, any point should tentatively be adopted as a reference station of no change in the treatment of the relative time variation of gravity in the event that there is no base station of absolute measurement as reference. In the case of the present survey, therefore, the absolute amount of gravity variation, if it exists, is undetectable, and it must be noticed that that which is detectable in the present surveys is the time variation of gravity difference between any of the stations and the old Astronomical Institute of Kyoto University. As to the second supposition, this problem is considered to be an extremely essential point for the investigation of the phenomenon of time variation in gravity, perhaps of an exceedingly minute amount, if it exists, by a highly sensitive but labile survey gravimeter. The North American Gravimeter used in the present surveys is somewhat troublesome in the point of artificial heating for regulating the temperature in the equipment, but its rate of drift is extremely small (roughly estimated as 0.05 mgal per day, during the period of the present surveys). As the main spring of the North American Gravimeter, made of an isoelastic alloy, contains in itself a large internal stress in the manufacturing process of the La Coste-winding, only three years' guarantee is generally provided for the stability of the spring. But the Gravimeter AG-1, 108, used has been satisfactory in the points of its sensitivity and small drift since its import in 1949 to the present, its cause being supposed to be partly attributable to the continuous temperature-regulation and the gravity mass-clamping in every time, though cumbersome in manipulation. The Worden Gravimeter, on the contrary, the spring and other principal parts of the instrument being made of fused silica, needs no heating and clamping. But in spite of its easy manipulation, the Worden Gravimeter belonging to the Geological Institude, Kyoto University, by which the tidal variation of gravity was observed at several stations in the Kinki District by the writer (**13**), showed a large amount of drift about 0.6 mgal per day and moreover a non-linear rate of drift even in the course of continuous reading at one station. Therefore, in the study on the time variation of gravity, a strict examination has to be made as to whether the rate of drift of the used gravimeter maintains the linearity or not.

Regarding the third postulation, the calibration of the sensitivity of the instrument has frequently been made by comparing the gravity value at the basement with that at the roof of the building of the Geological Survey. From these measurements the scale-constant of the instrument was confirmed to have been practically invariable during the past several years, but it needs to be ascertained in other ways as to whether the scale-constant is invariable or not with time in wider ranges as well. On this point it will be checked, as one way of discrimination, by the following procedure; taking the base station (old Astronomical Institute, Kyoto University) as the coordinate origin, and the difference of gravity value between any station and the base station as the abscissa, and plotting the change of gravity during surveys I to II, I to III, and I to IV at the corresponding stations as the ordinate, the diagram as shown in Fig. 7 is obtained. When at any time there happens to be a variation in the gravimeter's scale-constant, even if there is no time variation of gravity at any station, all points thus plotted would range on three straight lines passing through the coordinate origin and producing some angles with the abscissa-axis respectively. And if the rate of change of scale-constant with time is constant from year to year, the three straight lines thus obtained for each difference in surveys I–II, I–III, and I–IV would pass the coordinate origin with angles increasing at a uniform rate to the abscissa-axis. But

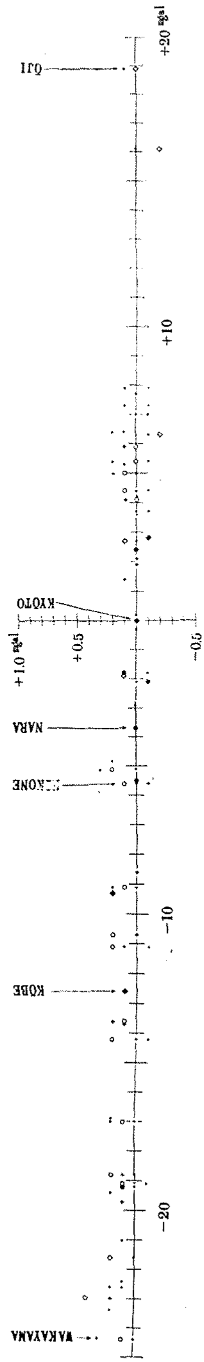

Fig. 7

○ : Difference between surveys I–II
● : " " " I–III
+ : " " " I–IV

as seen in Fig. 7, such a tendency is never systematically observed, and, therefore, the scale-constant in the present instrument is considered to have been approximately invariable throughout the whole survey period.

4. Summary

The results of the present surveys of gravity repeatedly operated during the period of 1950–1953 in the Kinki District may be summarized as follows:

1. The change of gravity value in the order of magnitude of 0.1–0.2 mgal in every survey compared with those of the preceding year were observed at a majority of the observation stations. But there were generally no systematic changes of gravity value at the stations in any region excepting the cases in the western shore region of Lake Biwa and Ōsaka City. The apparent changes of gravity value obtained in the present surveys may be attributed mainly to instrumental and observational errors, and this type of investigation for secular variation of gravity is considered to necessitate an assistant named "time" of several decades or centuries for the complete solution of the problem.
2. In the area of the western shore of Lake Biwa, all stations showed a somewhat increasing variation in measured values. If this increase is assumed to be an increase in real gravity value, it provides an interesting speculation on the relation between the time variation of gravity and the area of steep gradient in the Bouguer anomalies of gravity. But its reality should also be ascertained by the repetition of gravity surveys in the future.
3. In Ōsaka City, the tendency was observed that the gravity value increased in the area of markedly large ground-subsidence. The amount of these increases in gravity is not adequately covered by the change of station level and needs to be explained by some another unknown procedure through which both the phenomena of gravity variation and the deformation of weak ground are connected. This problem is also an interesting research item which should be solved by applying the same gravity survey to other area of large ground-subsidence.

In conclusion, the result derived from the present series of gravity surveys is, in a word, that the secular variation in gravity, if it exists, is very minute in quantity, and the errors caused by the instrument, observation, and other unknown sources are far larger than the quantity in question. Nevertheless, the study on the secular variation of gravity should be advanced by reducing the instrumental and observational errors as far as possible, and on the other hand, by spending long series of surveys over several decades or even centuries. The phenomenon of gravity change with time is certainly an attractive and essential research item in geodesy and seismology, especially in regions greatly disturbed by such crustal deformation and strong seismic activity as found in this country. In our institute, the study on the time variation of gravity is scheduled to be operated by the combined observation with the extremely highly sensitive station gravimeter, frequently checked by the gravity pendulum, along with frequently repeated surveys with the portable gravimeter of high sensitivity and small drift. Finally, it is earnestly hoped that the values of gravity listed in the table at the end of this paper and the various remarks above described may serve, to a certain degree, for the future development of study on the periodic and non-periodic variation of gravity with time.

Acknowledgements

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Description of survey stations

Number

0. Kyoto University, Cellar of the old Astronomical Institute, Gravity base station, on floor (not on stone base).
1. " " , Geophysical Institute, Basement room by the side of stairs, on floor.
1.1. " " , Geophysical Institute, at roof.
2. " " , Geological Institute, International fundamental gravity station, on floor (not on stone base).
3. Kyoto City, Yama-bana trifurcate road, on road of 1 meter east from the guide post of "Daikokuten-michi".
4. " " , Yase, on road near the west edge of Saitō bridge.
5. " " , Kode-ishi trifurcate road, on road in front of a small shrine.
6. " " , Gion-ishidan-shita, on road in front of the stone pillar of the Yasaka shrine.
7. " " , Hon-machi hachi-chōme, B. M. 216. 1.
8. " " , Fushimi-inari, B.M.
9. " " , Fujino-mori, B.M. 217. 1.
10. " " , Momoyama, B.M.
11. " " , Bank of Uji river, B.M.
12. " " , Daigo, on road in front of the gate of Sampō-in.
13. " " , Yamashina, B.M. 214. 1.
14. " " , De-machi, B.M. 241.
15. " " , Kyoto Palace, T.P.
16. " " , In front of the west gate of Honkoku-ji, B.M.
17. " " , Senshō-ji-chō, B.M.
18. " " , Katsura, B.M. 1298.
19. " " , Kataki-bara, B.M. 1297.
20. " " , Tsuka-hara, B.M. 1296.
21. " " , Oino-saka ridge, B.M. 1293.
22. " " , Saga, on road near the north edge of the Togetsu bridge.
23. " " , Uzumasa, T.P.
24. " " , Intersecting point of Sanjō street and Sembon avenue, on ground in front of 40 cm from the monument stone of "Shōgaku-in".
25. " " , North gate of Myōshin-ji, on road in front of 1 meter from the monument stone of "Sakuma Shōzan".
26. " " , Rentai-ji, on pavement in front of 2 meters from the name post of "Rentai-ji".
27. " " , Ōmiya primary school, on ground between the gate pillars.

28. Kyoto City, Minami-shiba-chō trifurcate road, on road in front of the police box.
29. " " , near Rajō-mon stop of the city tram, on pavement in front of 3 meters from the name post of "Kanzeon bosatsu".
30. " " , Tōno-mori, T.P.
31. Ōtsu City, Ōsaka-yama Observatory of Kyoto University, on ground near the entrance of tunnel.
32. " " , Izumi chō, B.M. J. 213.
33. " " , Seta bridge, B.M. 211.
34. Shiga Prefecture, Kusatsu Town, on road in front of Minami dental hospital.
35. " " , Yasu Town, B.M. 207.
36. " " , Shino-hara Village, B.M. 206. 1. (new : on concrete block).
37. " " , Musa Village, B.M. 204.
38. " " , Hie Village, B.M. 201. 1.
39. " " , Takamiya Town, B.M. 200.
40. Hikone City, Hikone Castle, on ground in front of 2 meters from the monument stone of "Enjō Kendō" (new : inside of palisade).
41. 1. " " , Hikone Municipal Office, on ground in front of 1.5 meters from the right hand pillar of porch.
41. Ōtsu City, Karasaki, B.M. 1302.
42. " " , Okoto, B.M. 1305.
43. Shiga Prefecture, Katada Town, B.M. 1307. (new : near side of B.M.).
44. " " , Wani Village, B.M. 1309.
45. " " , Kido Village, B.M. 1312.
46. " " , Komatsu Village, Kita Komatu, Kino-shita shrine, on road in front of 1 meter from the name post of "Kino-shita Shrine"
47. " " , Takashima Town, B.M. 1320.
48. " " , Aiba Village, Kumanomoto, Intersecting point, on road in south-western corner.
49. " " , Imazu Town, B.M. 1326.
50. " " , Ikatachi Village, Kami-ryūge, Fukujuzen-ji, on ground in front of 40cm from the stone steps.
51. " " , Ikatachi Village, Tochū trifurcate road, on road.
52. Kyoto Prefecture, Shino Village, B.M. 1292.
53. " " , Ōi Village, Namikawa, Namikawa station, on concrete block in railway near crossing.
54. " " , Chiyokawa Village, B.M. 1287.
55. " " , Yagi Town, Ōyabu, B.M. 1285.
56. " " , Yagi Town, Yoshitomi, B.M. (new : Yoshitomi primary school, on stepping-stone in front of the gate).
57. " " , Sonobe Town, B.M. 1281.
58. " " , Mukou Town, Mukou shrine, on ground in front of stone steps.
59. Takatsuki City, B.M.
60. Ōsaka Prefecture, Tonda Town, Intersecting point of so-called industrial road, on road near B.M. of Ōsaka Prefecture.
61. Takatsuki City, Abuyama Seismological Observatory of Kyoto University, Basement room, on stone base.
61. 0. " " , " " , Basement.
63. 1. " " , " " , First floor.
61. 2. " " , " " , Second floor.
61. 3. " " , " " , Third floor.

61.4. Takatsuki City, Abuyama Seismological Observatory of Kyoto University, Fourth floor.
61.5. " " , " " , Fifth floor.
61.6. " " , " " , Sixth floor.
62. " " , " " , Pumping room.
63. Ibaraki City, Tobushi, B.M. 225.
64. Suita City, Tarumi, B.M. 411.
65. Itami City, Koya, B.M. 464.
66. Nishinomiya City, B.M.
67. Kōbe City, Mikage chō, on pavement in front of Higashi-nada police station.
67.1. " " , Uosaki chō, Nada high school, in the porch.
68. Amagasaki City, Amagasaki high school, on ground in front of the porch.
69. Kyoto Prefecture, Yahata Town, South edge of Gokō bridge, on road in front of the guide post.
70. Hirakata City, South edge of Hirakata bridge, on road in front of the stone pillar.
71. Ōsaka Prefecture, Suminodō Town, Suminodō primary school, on ground in front of 1 meter from the name post.
72. " " , Kashihara Town, Ichimura, on road in front of 2 meters from the monument stone of "Hatanaka Ō".
73. Nara Prefecture, Ōji Town, B.M. 1388.
74. " " , Ikaruga Town, Hōryū-ji, on stepping stone in front of the south gate.
75. " " , Kōriyama Town, B.M. 1395.
76. Nara City, Sanjō street, B.M. 1398.
76.1. " " , Nara Gakugei University, on ground in front of the assembly hall.
77. Kyoto prefecture, Ide Village, East edge of the Tamamizu bridge, Intersecting point on bank, at north-eastern corner.
78. Uji City, Ōkubo, Intersecting point, on road near the guide post.
79. Sakai City, Ayano chō, B.M. J. 246.
80. Ōsaka Prefecture, Takaishi Town, Town office, on ground between the gate pillars.
81. Kishiwada City, B.M. 255.
82. Izumi-sano City, Ichiba, B.M. 259.
83. Ōsaka Prefecture, Ozaki Town, intersecting point, on stone block near a solitary pine-tree.
84. " " , Tan-nowa Village, Izumisaki middle school, on ground between the gate pillars.
85. Wakayama City, Nakanoshima primary school, at a small room by the side of assembly hall.
86. " " , Hon-machi, B.M. J. 273.
87. Wakayama prefecture, Nishi-wasa Village, Hachikenya, B.M. J. 271.
88. " " , Iwade Town, B.M. 1582.
89. " " , Tanaka Village, Kurotsuchi, B.M. 1579.
90. 4 " , Nade Town, B.M. 1576.
91. " " , Ōtani Village, Shin-zaika, Bank near B.M., on concrete block of a small shrine.
92. " " , Kōyaguchi Town, B.M. 1570.
93. " " , Hashimoto Town, B.M.
94. " " , Suda Village, Matsuchi, on road near the east edge of Ryōgoku bridge.
95. Nara Prefecture, Katsuragi Village, Kotono, at porch of the ruin of isolation hospital.
96. Yamato-takada City, on concrete block by the side of monument stone of "The Emperor Meiji"
97. Nara Prefecture, Yagi Town, Ebisu shrine, on stone base of left hand lantern.
98. " " , Tawaramoto Town, Tsushima shrine, on stone base of the monument

of "Kokui Senyō".
99. Nara Prefecture, Nikaidō Village, Kizuki shrine, at the middle of the dancing-platform.
100. Ōsaka City, Ōyodo ku, Nagara Nakadōri, B.M. J. 229.
101. Higashi Yodogawa ku, Kita Ōmichi chō, Ōsumi shrine, O.B.M. N. 1. (*)
102. " " , Komatsu Nakadōri, Sennen-ji, O,B.M. N .2.
103. " " , Shimo Shinjō chō, B.M. 228.
104. " " , Toyosato Samban chō, Teisembō, O.B.M. N. 4.
105. " " , Toyosato Sugahara chō, O.B.M. N. 5.
106. " " , Shibajima chō, Shibajima shrine, O.B.M. N. 6.
107. " " , Shibajima chō, B.M. 228. 1.
108. " " , Minamikata chō, Shōfuku-ji, O.B.M. N. 8.
109. " " , Mikuni Hon-machi, Mikuni primary school, O.B.M. N. 12.
110. " " , Nishi chō, Kōyō-ji, O.B.M. N. 13.
111. " " , Jūso Higashino chō, Jūso primary school, O.B.M. N. 14.
112. " " , Motoimasato, Hakuaisha kindergarten, O.B.M. N. 16.
113. " " , Mitsuya Nakadōri, Renshō-ji, O.B.M. N. 17.
114. Nishi Yodogawa ku, Nozato chō, Tanaka laboratory, O.B.M. N. 20.
115. " " , Nozato chō, Nozato Sumiyoshi shrine, O.B.M. N. 22.
116. " " , Himejima chō, Himejima shrine, B.M. 10696.
117. " " , Tsukuta chō, Ichi chōme, O.B.M. N. 24.
118. " " , Ōwada chō, Ōwada Higashi primary school, O.B.M. N. 25.
119. " " , Ōno chō, Sumiyoshi shrine, O.B.M. N. 26.
120. " " , Tsukuta chō, B.M. 10697.
121. Miyakojima ku, Nakano chō, B.M. 229. 1.
122. Asahi ku, Ōmiya chō, Ōmiya shrine, O.B.M. E. 2.
123. " " , Akagawa chō, Jōhoku primary school, O.B.M. E. 3.
124. Jōtō ku, Sekime chō, Police school, O.B.M. E. 6.
125. " " , Hanaten chō, B.M. 10746.
126. " " , Shin Kita chō, B.M. 10747.
127. Miyakojima ku, Aioi chō, B.M. J. 232.
128. Ikuno ku, Ōtomo chō, Koji primary school, O.B.M. E. 20.
129. " " , Katsuyama dōri, Ōsaka Meteorological Observatory, B.M. near well.
129. 1. " " , " " , " " " , B.M. in garden.
129. 2. " " , " " , " " " , Seismograph room.
130. Higashi ku, Ōtemaeno chō, Staff's hall of Ōsaka Prefecture, at porch.
131. " " , Morinomiya Higashino chō, Labourer's hall of Ōsaka City, in front of the stone steps.
131. 1. " " , " " " , Hikarino-ma in the third floor.
132. Ōyodo ku, Nakatsu Hon dōri, Nakatsu primary school, O.B.M. M. 8.
133. Fukushima ku, Ebie chō, Nippon Medicine Co., O.B.M. M. 16.
134. " " , Tamakawa chō, Ebisu shrine, O.B.M. M. 13.
135. Kita ku, Sonezaki kami ni chōme, Tsuyu-tenjin shrine, O.B.M. M. 18.
136. Nishi ku, Edobori minami dōri, Nishi Semba primary school, O.B.M. M. 23.
137. Higashi ku, Hon-machi ni chōme, north-eastern corner, O.B.M. M. 27.
138. Minami ku, North edge of Nippon bridge, O.B.M. M. 40.
139. Konohana ku, Shikanjima Ōdōri, Donkai-in, O.B.M. W. 2.
140. " " , Hideno chō, Senshū-ji, O.B.M. W. 10.
141. " " , Shimaya chō, Sumitomo Metal Co., O.B.M. W. 13.
142. " " , Sakurajima Kitano chō, Hitachi shipyard, O.B.M. W. 18.
143. Minato ku, Ichioka Hama dōri, Ichioka commercial high school, O.B.M. W. 27.

144. Minato ku, Yawataya Motomachi, Harbour works section of Ōsaka City, at lowest step of the stairs. (new: in lawn graden in front of the building).
145. 〃 〃, Tempōzan, T.P.
146. Taishō ku, Minami Izuo chō, Izuo Higashi primary school, O.B.M. W. 33.
147. 〃 〃, Funa chō, Nakayama Steel Co. O.B.M. W. 38.
148. 〃 〃, Tsuruhama dōri, Harbour works section of Ōsaka City, O.B.M. W. 40.
149. Nishi ku, Kujō dōri, Kujō small park, O.B.M. W. 45.
150. 〃 〃, Nishi Dōtonbori dōri, B.M. 235. 2.
151. Naniwa ku, Ebisu chō, B.M. 235.
152. Nishinari ku, Nakabiraki chō, Nakabiraki primary school, O.B.M. S. 3.
153. 〃 〃, Tachibana dōri, Tachibana primary school, O.B.M. S. 7.
154. Abeno ku, Hannan chō, Abeno high school, O.B.M. S. 11.
155. Higashi Sumiyoshi ku, Kuizen chō, Ikuwa primary school, O.B.M. S. 12.
156. 〃 〃 〃, Yuzato chō, Minami Kudara primary school, O.B.M. S. 15.
157. Nishinari ku, Tabata dōri, O.B.M. S. 20.
158. Sumiyoshi ku, Shibaya chō, Fujinagata shipyard, O.B.M. S. 22.
159. Nishinari ku, Kohama Nakano chō, Kohama primary school, O.B.M. S. 24.
160. Sumiyoshi ku, Higashi Nagai chō, Nagai primary school, O.B.M. S. 27.
161. 〃 〃, Minami kagaya chō, Sumiyoshi park, O.B.M. S. 34.
162. 〃 〃, Adachi chō, B.M. 245.

(*) O.B.M.: Abbreviation of bench mark made by Ōsaka City

Table

Station number	Latitude (N)	Longitude (E)	Elevation (m) *1	Bouguer anomaly (mgal) *2	Survey I		Survey II			Survey III				Survey IV			
					Correction to elevation (m) *3	g (gal) *4	Correction to elevation (m)	g (gal)	Difference I–II (mgal)	Correction to elevation (m)	g (gal)	Difference II–III (mgal)	Difference I–III (mgal)	g (gal)	Difference III–IV (mgal)	Difference II–IV (mgal)	Difference I–IV (mgal)
0	35°01.′40	135°46.′93	55	−11.6	—	979.7230	—	979.7230	0.0	—	979.7230	0.0	0.0	979.7230	0.0	0.0	0.0
1	35°01.′39	135°46.′93	55.6	—	—	.7228	—	.7228	0.0	—	.7228	0.0	0.0	.7228	0.0	0.0	0.0
1.1	″	″	55.6+13.67	—	—	.7189	—	—	—	—	—	—	—	—	—	—	—
2	35°01.′56	135°47.′18	—	—	—	.7208	—	—	—	—	.7210	—	+0.2	.7208	−0.2	—	0.0
3	35°02.′84	135°47.′56	—	—	—	.7199	—	—	—	—	.7199	—	0.0	—	—	—	—
4	35°03.′80	135°48.′62	—	—	—	.7046	—	—	—	—	—	—	—	—	—	—	—
5	35°08.′57	135°50.′59	—	—	—	.6802	—	—	—	—	—	—	—	—	—	—	—
6	35°00.′03	135°46.′82	—	—	—	.7249	—	—	—	—	.7249	—	0.0	.7249	0.0	—	0.0
7	34°59.′00	135°46.′38	31.50	−11.3	−0.20	.7255	−0.20	.7256	+0.1	—	.7255	−0.1	0.0	.7256	+0.1	0.0	+0.1
8	34°57.′95	135°46.′43	32.22	−11.0	−0.10	.7242	—	—	—	—	.7243	—	+0.1	.7243	0.0	—	+0.1
9	34°56.′89	135°46.′41	30.04	− 9.5	−0.15	.7247	—	—	—	—	.7247	—	0.0	.7247	0.0	—	0.0
10	34°55.′98	135°46.′08	26.73	− 8.0	−0.20	.7256	−0.20	.7256	0.0	—	.7256	0.0	0.0	.7256	0.0	0.0	0.0
11	34°54.′80	135°44.′51	16.39	− 6.8	−0.10	.7272	—	—	—	—	—	—	—	—	—	—	—
12	34°56.′93	135°49.′30	—	—	—	.7197	—	—	—	—	—	—	—	—	—	—	—
13	34°59.′28	135°49.′37	62.94	−11.8	(+0.20)*5	.7177	(−0.20)	.7179	+0.2	—	.7178	−0.1	+0.1	.7176	−0.2	−0.3	−0.1
14	35°01.′62	135°46.′37	53.74	− 9.8	−0.30	.7256	−0.37	.7255	−0.1	—	.7255	0.0	−0.1	.7255	0.0	0.0	−0.1
15	35°00.′92	135°45.′90	46.10	− 9.8	−0.10	.7265	—	—	—	—	.7265	—	0.0	.7264	−0.1	—	−0.1
16	34°59.′40	135°45.′13	23.75	−10.9	−0.20	.7282	−0.14	.7282	0.0	—	.7281	−0.1	−0.1	.7284	+0.3	+0.2	+0.2
17	34°59.′17	135°43.′62	21.70	− 9.2	−0.25	.7301	—	—	—	—	.7302	—	+0.1	.7300	−0.2	—	−0.1
18	34°58.′65	135°42.′73	21.97	− 7.7	(+0.20)	.7307	—	—	—	—	.7308	—	+0.1	.7306	−0.2	—	−0.1
19	34°58.′30	135°41.′71	32.9	− 6.2	(+0.20)	.7292	—	—	—	—	.7294	—	+0.2	.7293	−0.1	—	+0.1
20	34°58.′21	135°40.′44	78.93	—	—	—	—	—	—	—	.7250	—	—	.7249	−0.1	—	—
21	34°59.′29	135°36.′78	193.70	—	—	—	—	—	—	—	.7051	—	—	.7050	−0.1	—	—
22	35°00.′64	135°40.′83	—	—	—	(.7339)	—	—	—	—	(.7344)	—	(+0.5)	—	—	—	—
23	35°00.′05	135°42.′59	33.9	− 6.5	−0.15	.7309	—	—	—	—	.7313	—	+0.4	—	—	—	—
24	35°00.′34	135°44.′71	—	—	—	.7287	—	—	—	—	.7286	—	−0.1	.7287	+0.1	—	0.0
25	35°01.′37	135°43.′52	—	—	—	.7281	—	—	—	—	.7282	—	+0.1	—	—	—	—
26	35°02.′06	135°44.′52	—	—	—	.7228	—	—	—	—	.7230	—	+0.2	—	—	—	—
27	35°03.′34	135°44.′94	—	—	—	.7225	—	—	—	—	.7225	—	0.0	—	—	—	—
28	35°02.′88	135°46.′19	—	—	—	.7230	—	—	—	—	.7232	—	+0.2	—	—	—	0.0
29	34°58.′56	135°44.′79	—	—	—	.7298	—	—	—	—	.7297	—	−0.1	.7298	+0.1	—	—
30	34°57.′00	135°44.′21	20.2	− 5.7	−0.15	.7305	—	—	—	—	.7305	—	0.0	—	—	—	—
31	34°59.′81	135°51.′63	—	—	—	.7002	—	—	—	—	.7004	—	+0.2	.7003	−0.1	—	+0.1
32	35°00.′14	135°52.′40	91.01	−21.6	(+0.20)	.7031	—	—	—	—	.7032	—	+0.1	.7032	0.0	—	+0.1
33	34°58.′19	135°54.′50	88.69	−19.2	−0.25	.7036	−0.25	.7037	+0.1	—	.7037	0.0	+0.1	.7036	−0.1	−0.1	0.0
34	35°00.′81	135°57.′75	—	—	—	.6998	—	.7002	+0.4	—	.7000	−0.2	+0.2	.7000	0.0	−0.2	+0.2
35	35°03.′64	136°01.′41	99.86	−27.0	−0.15	.7012	−0.15	.7014	+0.2	—	.7012	−0.2	0.0	.7014	+0.2	0.0	+0.2
36	35°04.′60	136°03.′61	102.44	−25.3	−0.20	.7037	−0.20	.7038	+0.1	.7036	.7036	−0.2	−0.1	.7037	+0.1	−0.1	0.0
37	35°06.′67	136°07.′94	100.60	−28.4	−0.20	.7040	−0.20	.7042	+0.2	(new in III)	.7040	−0.2	0.0	.7041	+0.1	−0.1	+0.1
38	35°11.′02	136°13.′33	100.00	−38.7	−0.15	.6998	−0.15	.6999	+0.1	—	.6998	−0.1	0.0	.6997	−0.1	−0.2	−0.1
39	35°13.′82	136°15.′47	104.73	−32.8	−0.25	.7086	−0.25	.7088	+0.2	—	.7085	−0.3	−0.1	.7086	+0.1	−0.2	0.0
40	35°16.′44	136°15.′57	—	(−32.0)	—	.7172	—	.7173	+0.1	.7172	.7172	−0.1	0.0	.7171	−0.1	−0.2	−0.1
40.1	35°16.′16	136°15.′29	—	—	—	.7142	—	—	—	(new in III)	.7142	—	0.0	.7142	0.0	—	0.0
41	35°02.′65	135°52.′56	87.03	—	—	—	—	—	—	0.0	.6960	—	—	—	—	—	—
42	35°05.′30	135°53.′82	87.41	—	—	—	—	—	—	+0.24	.6976	—	—	—	—	—	—
43	35°07.′26	135°55.′25	88.04	−35.3	−0.40	.7004	—	—	—	.7004	.7005	—	+0.1	—	—	—	—
44	35°09.′18	135°55.′44	98.21	−35.5	−0.15	.7002	—	—	—	(new in III)	.7003	—	+0.1	—	—	—	—
45	35°11.′76	135°55.′42	104.55	−36.3	−0.30	.6994	—	—	—	—	.6996	—	+0.2	—	—	—	—
46	35°14.′84	135°58.′39	—	—	—	.7059	—	—	—	—	.7061	—	+0.2	—	—	—	—
47	35°17.′71	136°00.′96	87.15	−46.9	−0.05	.7034	—	—	—	—	.7036	—	+0.2	—	—	—	—
48	35°21.′43	136°01.′96	—	—	—	.7146	—	—	—	—	.7147	—	+0.1	—	—	—	—
49	35°23.′80	136°02.′32	87.42	−41.3	−0.15	.7180	—	—	—	—	.7182	—	+0.2	—	—	—	—
50	35°09.′39	135°52.′84	—	—	—	.6907	—	—	—	—	—	—	—	—	—	—	—
51	35°09.′83	135°51.′70	—	—	—	.6774	—	—	—	—	—	—	—	—	—	—	—
52	34°59.′88	135°36.′82	116.85	—	—	—	—	—	—	−0.28	.7169	—	—	.7170	+0.1	—	—
53	35°01.′67	135°33.′46	—	—	—	—	—	—	—	—	.7230	—	—	.7228	−0.2	—	—
54	35°02.′57	135°32.′84	100.64	—	—	—	—	—	—	−0.18	.7235	—	—	.7234	−0.1	—	—
55	35°04.′51	135°31.′52	110.32	—	—	—	—	—	—	−0.30	.7282	—	—	—	—	—	—
56	35°05.′08	135°30.′83	112.83	—	—	—	—	—	—	.7312	.7316	—	—	.7313	−0.3	—	—
57	35°06.′48	135°28.′20	131.03	—	—	—	—	—	—	(new in IV)	.7347	—	—	.7344	−0.3	—	—
58	34°56.′50	135°42.′13	—	—	—	.7299	—	—	—	—	—	—	—	—	—	—	—
59	34°50.′41	135°37.′68	7.64	− 2.3	−0.20	.7278	−0.24	.7279	+0.1	—	.7278	−0.1	0.0	.7280	+0.2	+0.1	+0.2
60	34°50.′24	135°35.′53	—	—	—	.7262	—	—	—	—	—	—	—	.7262	—	—	0.0
61	34°51.′56	135°34.′40	200+ 0.28	—	—	.7016	—	—	—	—	—	—	—	—	—	—	—
61.0	″	″	200+ 0.00	—	—	.7018	—	—	—	—	.7019	—	+0.1	—	—	—	—
61.1	″	″	200+ 3.23	—	—	.7008	—	—	—	—	—	—	—	—	—	—	—
61.2	″	″	200+ 6.84	—	—	.6996	—	—	—	—	.6996	—	0.0	—	—	—	—
61.3	″	″	200+10.55	—	—	.6983	—	—	—	—	—	—	—	—	—	—	—
61.4	″	″	200+14.61	—	—	.6970	—	—	—	—	.6970	—	0.0	—	—	—	—
61.5	″	″	200+22.81	—	—	.6942	—	—	—	—	—	—	—	—	—	—	—
61.6	″	″	200+29.11	—	—	.6921	—	—	—	—	.6921	—	0.0	—	—	—	—
62	34°51.′65	135°34.′51	—	—	—	.7106	—	—	—	—	—	—	—	—	—	—	—
63	34°49.′10	135°34.′91	10.33	—	—	—	—	—	—	−0.05	.7265	—	—	.7266	+0.1	—	—
64	34°45.′65	135°30.′69	9.03	+ 4.1	(+0.20)	.7272	−0.20	.7273	+0.1	—	.7271	−0.2	−0.1	.7272	+0.1	−0.1	0.0
65	34°46.′74	135°24.′28	21.15	− 8.5	−0.30	.7135	−0.27	.7137	+0.2	—	.7137	0.0	+0.2	.7137	0.0	0.0	+0.2
66	34°43.′84	135°20.′09	—	—	—	.7121	—	.7123	+0.2	—	.7121	−0.2	0.0	.7121	0.0	−0.2	0.0
67	34°42.′86	135°15.′62	—	(− 6.4)	—	.7102	—	.7103	+0.1	—	.7103	0.0	+0.1	.7103	0.0	0.0	+0.1
67.1	34°42.′97	135°16.′26	—	—	—	—	—	.7074	—	—	.7074	0.0	—	.7074	0.0	0.0	—
68	34°42.′68	135°25.′41	—	—	—	.7092	—	.7093	+0.1	—	.7094	+0.1	+0.2	.7094	0.0	+0.1	+0.2
69	34°53.′04	135°42.′16	—	—	—	.7293	—	—	—	—	—	—	—	—	—	—	—
70	34°48.′49	135°38.′24	—	—	—	.7270	—	—	—	—	.7270	—	0.0	—	—	—	—
71	34°42.′36	135°37.′60	—	—	—	.7173	—	.7173	0.0	—	.7173	0.0	0.0	—	—	0.0	—
72	34°34.′68	135°37.′80	—	—	—	.7291	—	.7289	−0.2	—	.7290	+0.1	−0.1	.7289	−0.1	0.0	−0.2
73	34°35.′75	135°42.′17	35.87	+38.8	−0.05	.7417	−0.05	.7417	0.0	—	.7418	+0.1	+0.1	.7417	−0.1	0.0	0.0
74	34°36.′58	135°44.′23	—	—	—	.7389	—	.7387	−0.2	—	.7389	+0.2	0.0	.7387	−0.2	0.0	−0.2
75	34°39.′50	135°47.′48	56.81	+23.0	−0.15	.7269	−0.15	.7269	0.0	—	.7270	+0.1	+0.1	.7270	0.0	+0.1	+0.1
76	34°40.′76	135°50.′19	98.48	+23.1	−0.15	.7191	−0.15	.7191	0.0	—	.7191	0.0	0.0	—	—	—	—
76.1	34°40.′95	135°50.′20	—	—	—	.7207	—	.7206	−0.1	—	.7206	0.0	−0.1	.7207	+0.1	+0.1	0.0
77	34°47.′75	135°48.′36	—	—	—	.7287	—	.7287	0.0	—	.7288	+0.1	+0.1	.7288	0.0	+0.1	+0.1
78	34°52.′35	135°46.′95	—	—	—	.7252	—	.7252	0.0	—	.7252	0.0	0.0	.7252	0.0	0.0	0.0
79	34°35.′02	135°29.′06	3.52	+11.4	(+0.20)	.7210	+0.15	.7211	+0.1	—	.7211	0.0	+0.1	.7209	−0.2	−0.2	−0.1
80	34°31.′51	135°26.′14	—	—	—	.7177	—	.7179	+0.2	—	.7180	+0.1	+0.3	.7177	−0.3	−0.2	0.0
81	34°27.′36	135°22.′24	3.26	+14.9	−0.20	.7137	−0.14	.7138	+0.1	—	.7139	+0.1	+0.2	.7137	−0.2	−0.1	0.0
82	34°24.′07	135°19.′50	18.38	+15.1	−0.20	.7058	−0.20	.7059	+0.1	—	.7060	+0.1	+0.2	.7058	−0.2	−0.1	0.0
83	34°21.′13	135°14.′91	—	—	—	—	—	—	—	—	.7024	—	—	.7022	−0.2	—	—
84	34°19.′26	135°09.′81	—	—	—	—	—	—	—	—	.6974	—	—	.6973	−0.1	—	—
85	34°14.′22	135°11.′28	—	(+17.9)	—	.6984	—	.6985	+0.1	—	.6987	+0.2	+0.3	.6984	−0.3	−0.1	0.0
86	34°14.′32	135°10.′61	2.74	—	—	—	—	—	—	−0.02	.6978	—	—	.6978	0.0	—	—
87	34°14.′54	135°13.′12	5.79	—	—	—	—	—	—	−0.25	.7028	—	—	.7028	0.0	—	—
88	34°15.′00	135°19.′33	22.97	—	—	—	—	—	—	−0.20	.7120	—	—	—	—	—	—
89	34°15.′45	135°22.′87	40.21	—	—	—	—	—	—	−0.22	.7061	—	—	.7062	+0.1	—	—
90	34°16.′29	135°26.′21	58.22	—	—	—	—	—	—	−0.15	.7043	—	—	.7045	+0.1	—	—
91	34°17.′37	135°29.′62	—	—	—	—	—	—	—	—	.7003	—	—	.7005	+0.2	—	—
92	34°18.′10	135°33.′08	67.87	—	—	—	—	—	—	−0.45	(.7000)	—	—	(.7011)	(+1.1)	—	—
93	34°18.′75	135°36.′51	84.84	—	—	—	—	—	—	−0.42	.7006	—	—	.7007	+0.1	—	—
94	34°19.′80	135°39.′75	—	—	—	—	—	—	—	—	.6955	—	—	.6955	0.0	—	—
95	34°25.′54	135°43.′40	—	—	—	—	—	—	—	—	—	—	—	.6970	—	—	—
96	34°30.′62	135°44.′88	—	—	—	—	—	—	—	—	—	—	—	.7307	—	—	—
97	34°30.′54	135°47.′83	—	—	—	—	—	—	—	—	(.7261)	—	—	(.7251)	(−1.0)	—	—
98	34°32.′97	135°47.′73	—	—	—	—	—	—	—	—	.7345	—	—	.7343	−0.2	—	—
99	34°35.′70	135°48.′00	—	—	—	—	—	—	—	—	.7330	—	—	.7330	0.0	—	—
100	34°42.′85	135°31.′08	4.2146	+ 4.9	—	—	0.0	.7254	—	—	.7254	0.0	—	.7253	−0.1	−0.1	—
101	34°44.′85	135°33.′22	5.4157	+ 2.2	—	—	+0.20	.7250	—	—	—	—	—	—	—	—	—
102	34°45.′03	135°32.′47	5.5086	+ 4.5	—	—	+0.08	.7277	—	—	—	—	—	—	—	—	—
103	34°44.′57	135°31.′65	3.6198	+ 5.5	—	—	−0.10	.7285	—	—	.7284	−0.1	—	.7285	+0.1	0.0	—
104	34°44.′30	135°31.′43	3.4582	+ 4.6	—	—	+0.10	.7272	—	—	—	—	—	—	—	—	—
105	34°44.′15	135°31.′68	2.9874	+ 5.9	—	—	+0.09	.7284	—	—	—	—	—	—	—	—	—
106	34°43.′65	135°31.′00	4.5787	+ 5.8	—	—	+0.20	.7271	—	—	—	—	—	—	—	—	—
107	34°43.′77	135°31.′37	10.3654	+ 6.1	—	—	−0.10	.7265	—	—	.7264	−0.1	—	.7264	0.0	−0.1	—
108	34°43.′40	135°30.′37	3.3339	− 2.0	—	—	+0.06	.7194	—	—	.7192	−0.2	—	.7195	+0.3	+0.1	—
109	34°44.′10	135°29.′50	2.4332	− 8.2	—	—	+0.13	.7144	—	—	.7144	0.0	—	.7145	+0.1	+0.1	—
110	34°43.′65	135°30.′02	2.5552	− 5.6	—	—	+0.09	.7163	—	—	—	—	—	—	—	—	—
111	34°43.′23	135°29.′33	1.7706	− 8.2	—	—	+0.18	.7133	—	—	.7132	−0.1	—	.7134	+0.2	+0.1	—
112	34°43.′13	135°28.′73	1.2730	− 9.4	—	—	+0.80	.7119	—	—	.7119	0.0	—	.7120	+0.1	+0.1	—
113	34°43.′45	135°28.′32	2.4875	−10.1	—	—	+0.26	.7114	—	—	.7114	0.0	—	.7114	0.0	0.0	—
114	34°42.′77	135°27.′97	1.7371	−10.1	—	—	+0.15	.7108	—	—	—	—	—	—	—	—	—
115	34°42.′43	135°27.′88	1.8791	− 9.6	—	—	+0.13	.7107	—	—	.7108	+0.1	—	.7109	+0.1	+0.2	—
116	34°42.′07	135°27.′33	1.2154	− 9.2	—	—	−0.02	.7108	—	—	—	—	—	—	—	—	—
117	34°42.′78	135°27.′03	2.3946	−10.1	—	—	+0.50	.7103	—	—	.7102	−0.1	—	.7102	0.0	−0.1	—
118	34°42.′17	135°26.′87	0.5545	− 9.5	—	—	+0.10	.7107	—	—	.7106	−0.1	—	.7106	0.0	−0.1	—
119	34°41.′62	135°26.′52	1.6246	− 8.8	—	—	0.0	.7105	—	—	—	—	—	—	—	—	—
120	34°42.′53	135°26.′30	0.8954	−10.3	—	—	+0.15	.7104	—	—	.7103	−0.1	—	.7104	+0.1	0.0	—
121	34°42.′13	135°31.′35	7.4058	+ 6.4	—	—	−0.10	.7252	—	—	.7254	+0.2	—	.7253	−0.1	+0.1	—
122	34°43.′32	135°32.′87	3.6701	+ 3.7	—	—	+0.21	.7249	—	—	.7249	0.0	—	.7249	0.0	0.0	—
123	34°43.′42	135°31.′97	3.1932	+ 6.0	—	—	+0.02	.7275	—	—	.7274	−0.1	—	.7274	0.0	−0.1	—
124	34°42.′53	135°33.′17	2.4647	+ 3.1	—	—	+0.19	.7234	—	—	.7234	0.0	—	.7236	+0.2	+0.2	—
125	34°41.′53	135°34.′02	4.1267	+ 0.5	—	—	+0.01	.7191	—	—	—	—	—	—	—	—	—
126	34°41.′55	135°32.′58	3.7462	+ 5.1	—	—	+0.04	.7238	—	—	.7236	−0.2	—	.7238	+0.2	0.0	—
127	34°41.′45	135°31.′82	4.6135	+ 6.3	—	—	+0.18	.7247	—	—	.7249	+0.2	—	.7248	−0.1	+0.1	—
128	34°39.′43	135°33.′52	4.0270	+ 2.1	—	—	+0.12	.7178	—	—	.7178	0.0	—	.7180	+0.2	+0.2	—
129	34°39.′03	135°32.′38	—	—	—	—	−0.14	.7183	—	—	.7182	−0.1	—	.7183	+0.1	0.0	—
129.1	″	″	—	—	—	—	−0.12	.7184	—	—	—	—	—	.7183	—	−0.1	—
129.2	″	″	—	—	—	—	—	.7186	—	—	—	—	—	—	—	—	—
130	34°41.′00	135°31.′28	—	—	—	.7209	—	.7210	+0.1	—	.7210	0.0	+0.1	.7210	0.0	0.0	+0.1
131	34°40.′63	135°32.′08	—	—	—	—	—	.7230	—	—	.7228	−0.2	—	.7230	+0.2	0.0	—
131.1	″	″	—	—	—	—	—	.7208	—	—	—	—	—	—	—	—	—
132	34°42.′45	135°29.′72	2.0817	(− 7.2)	—	—	+0.07	(.7131)	—	—	.7141	(+1.0)	—	.7141	0.0	(+1.0)	—
133	34°41.′70	135°28.′67	1.6020	− 7.8	—	—	+0.07	.7116	—	—	.7116	0.0	—	.7116	0.0	0.0	—
134	34°41.′12	135°28.′88	1.9294	− 7.1	—	—	+0.17	.7114	—	—	.7119	+0.5	—	.7120	+0.1	+0.6	—
135	34°41.′78	135°30.′20	3.6558	− 3.6	—	—	+0.25	.7153	—	—	.7154	+0.1	—	.7153	−0.1	0.0	—
136	34°41.′12	135°29.′80	3.5417	− 4.8	—	—	+0.11	.7134	—	—	.7135	+0.1	—	.7136	+0.1	+0.2	—
137	34°40.′82	135°30.′57	5.3261	+ 0.7	—	—	+0.29	.7178	—	—	.7178	0.0	—	.7180	+0.2	+0.2	—
138	34°39.′98	135°30.′55	5.4836	+ 2.8	—	—	+0.19	.7189	—	—	.7190	+0.1	—	.7192	+0.2	+0.3	—
139	34°40.′85	135°27.′82	2.2406	(− 9.2)	—	—	+0.18	(.7089)	—	—	.7119	(+3.0)	—	.7115	−0.4	(−2.6)	—
140	34°40.′67	135°26.′52	1.2391	(− 8.0)	—	—	+0.15	(.7100)	—	—	.7110	(+1.0)	—	.7110	0.0	(+1.0)	—
141	34°40.′08	135°26.′55	1.1240	(−10.1)	—	—	−0.10	(.7072)	—	—	.7112	(+4.0)	—	.7113	+0.1	(+4.1)	—
142	34°39.′77	135°26.′22	1.4845	(−10.7)	—	—	+0.40	(.7059)	—	—	.7107	(+4.8)	—	.7109	+0.2	(+5.0)	—
143	34°39.′60	135°28.′03	1.0047	(− 6.5)	—	—	+0.17	(.7100)	—	—	.7126	(+2.6)	—	.7125	−0.1	(+2.5)	—
144	34°39.′08	135°26.′55	—	—	—	—	—	(.7096)	—	.7104	.7109	(+1.3)	—	.7110	+0.1	(+1.4)	—
145	34°39.′30	135°26.′10	7.2	—	0.0	.7091	−0.10	(.7079)	(−1.2)	(new in IV)	.7092	(+1.3)	+0.1	.7092	0.0	(+1.3)	+0.1
146	34°39.′05	135°28.′63	1.1721	− 2.6	—	—	+0.19	.7132	—	—	.7133	+0.1	—	.7131	−0.2	−0.1	—
147	34°37.′53	135°28.′20	2.3837	+ 0.7	—	—	+0.12	.7140	—	—	.7140	0.0	—	.7139	−0.1	−0.1	—
148	34°37.′93	135°27.′38	2.6361	− 2.2	—	—	−0.10	.7117	—	—	.7119	+0.2	—	.7118	−0.1	+0.1	—
149	34°40.′35	135°28.′45	0.8776	(−11.3)	—	—	+0.23	(.7062)	—	—	.7124	(+6.2)	—	.7123	−0.1	(+6.1)	—
150	34°39.′97	135°29.′05	1.9051	− 3.4	—	—	+0.27	.7133	—	—	.7134	+0.1	—	.7133	−0.1	+0.0	—
151	34°39.′12	135°30.′52	3.6837	+ 3.6	—	—	+0.44	.7189	—	—	.7187	−0.2	—	.7188	+0.1	−0.1	—
152	34°38.′92	135°29.′58	2.0960	+ 1.3	—	—	+0.35	.7154	—	—	.7153	−0.1	—	.7155	+0.2	+0.1	—
153	34°38.′18	135°29.′67	3.1724	+ 2.3	—	—	+0.26	.7162	—	—	.7163	+0.1	—	.7162	−0.1	0.0	—
154	34°37.′97	135°31.′03	14.6970	+ 5.5	—	—	+0.64	.7164	—	—	.7163	−0.1	—	.7164	+0.1	0.0	—
155	34°37.′88	135°32.′45	5.6525	+ 4.8	—	—	+0.06	.7179	—	—	.7178	−0.1	—	.7180	+0.2	+0.1	—
156	34°36.′68	135°32.′30	7.3821	+ 8.1	—	—	+0.15	.7191	—	—	.7191	0.0	—	.7193	+0.2	+0.2	—
157	34°37.′58	135°29.′73	3.6278	+ 4.0	—	—	+0.27	.7170	—	—	.7173	+0.3	—	.7171	−0.2	+0.1	—
158	34°37.′20	135°28.′10	3.0514	+ 1.4	—	—	+0.13	.7142	—	—	—	—	—	—	—	—	—
159	34°36.′88	135°29.′53	3.2631	+ 6.6	—	—	+0.35	.7187	—	—	.7189	+0.2	—	.7187	−0.2	0.0	—
160	34°36.′37	135°31.′02	12.8134	+10.2	—	—	+0.01	.7196	—	—	.7196	0.0	—	.7196	0.0	0.0	—
161	34°36.′58	135°28.′92	2.9724	+ 5.4	—	—	−0.01	.7173	—	—	.7175	+0.2	—	.7173	−0.2	0.0	—
162	34°36.′08	135°29.′52	3.6134	+ 9.7	—	—	+0.25	.7207	—	—	.7208	+0.1	—	.7208	0.0	+0.1	—

Notices on Table

*1. Elevations of the stations of from No. 0 to No. 99 are obtained from the map published by the Geographical Survey Institute, and those of from No. 100 to No. 162 are referred to the results of precise levelling (O.P. is adopted as reference level) made by the Bureau of Planning of Ōsaka Municipal Office in 1951.

*2. The international formula is adopted as the reference gravity formula.

*3. This column means the elevation difference between the top of bench mark and the lower end of the gravimeter stand.

*4. The calculation of the absolute value of gravity at each station is based on the assumption that the absolute gravity value at the old Astronomical Institute of Kyoto University is 979.7230 gal and this value is invariable with time.

*5. All values in bracket are considered to be uncertain.