Serial No. 246

DEPARTMENT OF COMMERCE

U. S. COAST AND GEODETIC SURVEY

E. LESTER JONES, DIRECTOR

ISOSTATIC INVESTIGATIONS AND DATA FOR GRAVITY STATIONS IN THE UNITED STATES ESTABLISHED SINCE 1915

By

WILLIAM BOWIE

CHIEF OF DIVISION OF GEODESY, U. S. COAST AND GEODETIC SURVEY

Special Publication No. 99

QB
275
.U35
no.99

PRICE 25 CENTS (paper cover)

Sold only by the Superintendent of Documents, Government Printing Office, Washington, D. C.

WASHINGTON
GOVERNMENT PRINTING OFFICE
1924

National Oceanic and Atmospheric Administration

ERRATA NOTICE

One or more conditions of the original document may affect the quality of the image, such as:

Discolored pages
Faded or light ink
Binding intrudes into the text

This has been a co-operative project between the NOAA Central Library and the Climate Database Modernization Program, National Climate Data Center (NCDC). To view the original document, please contact the NOAA Central Library in Silver Spring, MD at (301) 713-2607 x124 or www.reference@nodc.noaa.gov.

LASON
Imaging Contractor
12200 Kiln Court
Beltsville, MD 20704-1387
January 1, 2006

Blank page retained for pagination

CONTENTS.

	Page.
Introduction	1

Part I.—ISOSTATIC INVESTIGATIONS.

Abnormal densities in earth's crust disclosed by geodetic data	3
Shape and size of the earth	4
Relation between spheroid and geoid	5
Effect of isostasy on geoid surface	7
Effect of reduction for isostatic compensation on derived size of spheroid	7
Gravity formulas of 1912 and 1917	8
Helmert formula of 1915	9
Proposed form of gravity formula	10
Some problems of isostasy	10
Illustration of isostasy	12
Density of material between earth's surface and depth of compensation	13
Topography compensates abnormal density in isostatic shell	14
Reliability of geodetic data	14
Reliability of computation of isostatic compensation	15
Distribution of compensation	15
Uniform distribution vertically	15
Horizontal distribution	16
Datum used for computing the effect of topography and compensation	17
Completeness of compensation	18
Determination of the depth of isostatic compensation	19
Relation of gravity anomalies to topography	22
Relation of gravity anomalies to areas of erosion and sedimentation	23
Prediction as a test of the theory of isostasy	23
Gravity observations over the Arctic Ocean	24
Relation of gravity anomalies to deviations from normal densities in local materials	24
Geologic formation at gravity stations	29
Relation of gravity anomalies to effusive and intrusive geological formations	30
Gravity anomalies near the Pacific coast of the United States	31
Isostasy in high latitudes	33
Size of topographic feature which may not be compensated	34
Relation between the size of the topographic feature which is compensated and the size of the block of the earth's crust independently in equilibrium	35
Stations selected to test effect of abnormal densities on gravity	36
Computation of effect of local deviations of density on gravity	37
Relation of depths of compensation, horizontal flow, and equal pressure	39
Effect of temperature on depth of horizontal flow	39
Effect of the theory of isostasy on geological theories	39
Probable causes of vertical movements	40
Isostasy a geological problem	42
Uplift of mountains	42
Folding in parallel ridges	45
Subsidence of areas of sedimentation	46
Periodic uplift and subsidence	46
Direction of overthrusts	47
Isostatic equilibrium of delta areas	47
Effect of isostatic adjustment on surface configuration	50
Effect of isostatic adjustment on surface configuration near areas of erosion and sedimentation	51
Zone of horizontal movement	53

Part II.—GRAVITY DETERMINATIONS. Page.
Abstracts of results 55
Methods of observing 55
Explanation of tables 56
Principal facts for gravity stations established since 1915 58
Anomalies by the isostatic, Bouguer, and free-air reductions 59
Mean elevations and corrections for topography and isostatic compensation, separate zones 61
Pendulum observations and reductions 72
Summary of standardization periods of pendulums at base station, Washington, D. C 86
Descriptions of stations 86
Index of stations 91

ILLUSTRATIONS.

Fig. 1. Relation of geoid and spheroid 5
Fig. 2. An illustration of isostasy 13
Fig. 3. (Omitted.)
Fig. 4. Gravity stations near Seattle, Wash 20
Fig. 5. Gravity stations at Damon Mound, Tex 21
Fig. 6. Gravity stations near Compton, Calif 21
Fig. 7. (Omitted.)
Fig. 8. Group of gravity stations in Wisconsin and Minnesota 27
Fig. 9. Group of gravity stations in Maryland and West Virginia 30
Fig. 10. Group of gravity stations in New Jersey 30
Fig. 11. Group of gravity stations in Wyoming and South Dakota 31
Fig. 12. Gravity stations near Denver, Colo 31
Fig. 13. Gravity stations in northeastern Kansas 32
Fig. 14. Group of gravity stations in southern Oklahoma 35
Fig. 15. Gravity stations at Saline, Tex 35
Fig. 16. Gravity stations near Austin, Tex 36
Fig. 17. Attraction of cylindrical masses 37
Fig. 18. Attraction of indefinite disks 38
Fig. 19. Relative sizes of masses of different forms having equal attractive effects 38
Fig. 20. Earth movements required to cause mountains by lateral thrust 44
Fig. 21. Nile Delta 48
Fig. 22. Profile of Nile Delta 48
Fig. 23. Niger Delta 49
Fig. 24. Profile of Niger Delta 49
Fig. 25. Gravity stations on Mississippi Delta 50
Fig. 26. Location and isostatic anomalies of gravity stations in the United States 56

ISOSTATIC INVESTIGATIONS AND DATA FOR GRAVITY STATIONS IN THE UNITED STATES ESTABLISHED SINCE 1915.

By WILLIAM BOWIE, *Chief of the Division of Geodesy, U. S. Coast and Geodetic Survey.*

INTRODUCTION.

In the investigations of isostasy carried on by the U. S. Coast and Geodetic Survey deflections of the vertical and values of gravity have been used. Reports on these investigations have been made from time to time as they have progressed.

The first two reports were the Figure of the Earth and Isostasy from Measurements in the United States, and Supplementary Investigation in 1909 of the Figure of the Earth and Isostasy. These were followed by Special Publication No. 10, Effect of Topography and Isostatic Compensation upon the Intensity of Gravity; Special Publication No. 12, same title as No. 10 (second paper); and Special Publication No. 40, Investigations of Gravity and Isostasy.

In addition to the reports of the Coast and Geodetic Survey, some phases of the investigations have been dealt with by the author in papers which have appeared in scientific journals. The principal ones of these are:

Our present knowledge of isostasy from geodetic data, July–August, 1917, Journal of Geology.
Some geological conclusions from geodetic data, Proceedings of the National Academy of Sciences, January, 1921.
The relation of isostasy to uplift and subsidence, American Journal of Science, July, 1921.
The theory of isostasy—A geological problem, Bulletin of the Geological Society of America, June 30, 1922.
The earth's crust and isostasy, Geographical Review, October, 1922.
The yielding of the earth's crust, Annual Report of the Smithsonian Institution for 1921.

Although the theory of isostasy had to be considered by the Coast and Geodetic Survey in connection with its geodetic work in order to eliminate, or at least reduce in size, the deflections of the vertical and the gravity anomalies, it was soon found that the importance of this interesting subject was of a more general nature. In fact, there are many problems of geophysics, including geology, in which isostasy must play an important part. The writer has endeavored to show the relation between isostasy and certain geophysical and geological phenomena and processes in the papers referred to above.

In this report it is believed advisable to have each of the geophysical or geological phases of the investigations treated more or less fully under a separate heading. This is to enable the reader to get a clearer word picture of each of the several subjects without having to read through the whole text. This way of treating the various questions involves an occasional restatement of some of the facts disclosed by the investigations, but this seems to be inevitable if we are not to sacrifice clearness for brevity.

It should be understood by the reader that the processes involved in the establishment or maintenance of isostatic equilibriun can not explain the formation of a mountain system or, in fact, any major change in elevation of the earth's crust. It should be remembered, however, that any large active region of the earth's crust undoubtedly remains in isostatic equilibrium during uplift or subsidence.

One of the most important geological conclusions from the isostatic investigations seems to be that the predominating movement involved in the formation of a mountain system is vertical and results from the expansion of the material of the earth's crust beneath the affected area.

Part I of this report is devoted to a discussion of the geodetic data used in the isostatic investigations and the conclusions resulting from these investigations. In Part II of the report are given the gravity data which have been accumulated in the United States since the publication of Special Publication No. 40. These two volumes contain all available data except for several stations in New Mexico and Colorado occupied during the season of 1922. Owing to an accident to the gravity apparatus it will be necessary to reoccupy one or more of those stations before definite values can be assigned to them.

In the investigation covered by Special Publication No. 40, 42 gravity stations established in Canada by the Dominion Observatory at Ottawa were used. This added much to the value of the results of the investigation. The data for the Canadian stations appeared in publications of the Dominion Observatory, Vol. II, No. 10, 1915, and Vol. III, No. 9, 1918.

One of the important results of recent isostatic investigations has been the discovery that the greater part of the larger gravity anomalies and deflections of the vertical are probably due to the presence of abnormally light or heavy material close to the geodetic stations, and therefore do not indicate the degree to which blocks of the earth's crust may depart from isostatic equilibriun. It is very desirable that many gravity stations be established in the United States in critical areas in order to study more in detail the equilibrium of the crust.

There is needed very badly an apparatus which will enable an observer to obtain the value of gravity with much less time and cost than is involved in using the pendulum apparatus. The pendulums give very accurate results, but the equipment is heavy and about four stations per month are as many as can be occupied. The geophysical laboratory of the Carnegie Institution of Washington is now at work upon a new form of gravity apparatus which the director of that laboratory hopes and believes will give the requisite accuracy with a very short period of observations. Prof. A. A. Michelson, of the University of Chicago, has also designed a new form of gravity apparatus which is now (February, 1924) being constructed under his supervision. It is expected to give the value of gravity to one part in one million. A sketch of the apparatus furnished by Professor Michelson shows a long horizontal quartz beam cemented to a glass base. To the free end of the beam is attached a silvered glass. Variations in the depression of this glass under different values of gravity are measured by a special form of interferometer in which a divided ray of light undergoes multiple reflection, thus increasing the sensitiveness of the instrument.

It is hoped that the time may not be far distant when an apparatus will be available for making gravity observations at sea. It is desirable that the uncertainty of such observations should not be very much larger than those on land. The average gravity anomaly on land is about 20 parts in 1,000,000, and it seems desirable that the uncertainty in the work at sea should not be greater than about one-half of that amount.

The writer wishes to express his appreciation of the assistance rendered him by C. H. Swick, mathematician of the division of geodesy of the Coast and Geodetic Survey, who has had direct charge of all of the office computations of the observations for standardization of the pendulums at the base station and those made at the field stations for which data are given in this report. He also has had direct charge of the computations of the effect of topography and compensation on the value of gravity and has assisted the author in the editing of the manuscript of this paper. The observers who made the observations at the base station and at the field stations were trained by him in gravity work. Mr. Swick is the author of the manual for gravity observations and computations, entitled "Modern Methods for Measuring the Intensity of Gravity," U. S. Coast and Geodetic Survey Special Publication No. 69.

The author also acknowledges the assistance rendered by W. D. Lambert, mathematician of the U. S. Coast and Geodetic Survey, in criticising certain parts of the text. He wishes to express appreciation of the excellent work done by the several observers in the field and by the mathematicians who assisted Mr. Swick in the computations.

Part I.—ISOSTATIC INVESTIGATIONS.

ABNORMAL DENSITIES IN EARTH'S CRUST DISCLOSED BY GEODETIC DATA.

The geodesist has found that the water surface of the earth approximates a spheroid—a mathematical surface. In order that it may be so the densities must be approximately the same throughout any given shell of the earth. We do not know the law of change of density with the depth, but we do know that the average density of the earth is about 5.5 times that of water.

Although the geodetic measurements, based upon triangulation, and the astronomic observations used in deriving the shape and size of the earth have been made over land areas, yet the gravity observations made on islands and also on the oceans by Hecker, Briggs, Duffield, and Nansen show conclusively that the shape derived from land observations is practically correct for water areas.

If there were no irregularities of the surface of the solid earth, the water would stand at a uniform depth over the whole earth. (See p. 17.) Then the plumb line would at all places be normal to the spheroid or mathematical surface, and the value of gravity would be the same for points having the same latitude both north and south of the equator. The value of gravity would increase uniformly north and south of the equator due to changes in the mass attraction of the spheroid and to changes in the centrifugal force.

The surface of the earth instead of being a regular mathematical one is irregular; but we find that the surfaces of the oceans and the imaginary sea level continued under land areas do form a surface closely approximating the spheroidal one we should have were there no irregularities.

For any large area the plumb line will, on an average, be normal to the spheroid; also the values of gravity along a given parallel of latitude will be very nearly the same after applying corrections for the elevations of the stations above the geoid or sea-level surface. The value of gravity necessarily decreases as we increase the distance from the center of attraction of the earth. Geodesists have made searching investigations to learn the cause or causes of the deviations from normal directions of the plumb line and of the variations of gravity along any parallel of latitude.

It was soon realized that the land masses above sea level and the deficiencies in density of the water in ocean basins as compared with equal volumes of surface rock would cause irregularities; but corrections applied for the effects of these excesses and deficiencies of mass still left irregularities. There is some additional cause for these irregularities in the geodetic data. It must be in the outer portion of the earth, for stations, both deflection and gravity, only short distances apart are affected differently. If the cause were deep seated, such, for instance, as variation in the density distribution 1,000 miles below the surface, then all the geodetic data for an area—say, 300 miles square—would be affected by nearly the same amount. This we do not find. The logical assumption is that there are abnormal densities of materials in the outer portions of the earth.

The geodesists have made computations on the theory that at some depth below sea level the pressure for a unit area will be the same regardless of the character of the earth's surface above. On this assumption the density of the outer material of the earth would be less under a high portion of the surface than under a low one. The computations have confirmed the assumption (the theory of isostasy) to a remarkable degree. They have shown that at least the greater portion of the abnormal densities exist in the outer 100 kilometers (60 miles) of the earth.

These isostatic computations have reduced the anomalies in the geodetic data to from one-seventh to one-tenth of what they would be if there were no such irregularities as the theory of isostasy postulates. The small anomalies which now remain may be due to lack of uniformity in the distribution of the abnormal density and to deviation from uniform pressure on the imaginary surface, but probably they are mostly due to very abnormal densities of materials close to the geodetic stations.

The significant facts relating to isostasy are: The sea-level surface of the earth is very nearly a spheroid; the distribution of density with depth is about the same along all radii of the earth; the irregularities in the directions of the plumb line and in gravity values are due to causes near the earth's surface; and these irregularities are largely due to the uneven surface of the earth and deviations from normal densities in the earth's materials extending to a distance of the order of magnitude of 100 kilometers (about 60 miles) below sea level.

SHAPE AND SIZE OF THE EARTH.

If the earth were not rotating and its materials were homogeneous with respect to depth—that is, if at any depth there were uniform densities around the whole earth and if the material were plastic—the actual surface of the earth would be a true sphere. This condition would be brought about by the attraction on each other of the particles composing the earth. The earth, however, is rotating and, due to the centrifugal force, the surface of the ideal earth mentioned above would be a mathematical figure called a spheroid of revolution.[1]

As a matter of fact the earth's surface is irregular, due to the heterogeneous densities in the crust and to a degree of viscosity, at least in the outer mass, which resists the tendency of the material to arrange itself in strata each with a uniform density. If the earth's materials were highly plastic, the mountains would flatten and their materials would spread over the continents, while the materials of the continents would flow out to the oceans and all irregularities in the earth's surface would disappear. The water of the oceans would then spread out over the whole earth and have the same depth at all places. This is not strictly true, for equipotential surfaces at different altitudes are not parallel, but the deviation is extremely small.

If sea-level canals were cut into the existing land areas of the earth, the surface of the waters of the oceans and of those connecting sea-level canals would form a figure of equilibrium very closely approximating a spheriod of revolution. The deviation of this imaginary surface from the mean spheroid of revolution would be a maximum of possibly 100 meters. The maximum deviations would occur under great mountain masses, such as the Andes, the Himalayas, and the Rockies.

The fundamental problem of the geodesists is to determine the shape and size of the sea-level surface of the earth. This can be done only by making astronomic observations and connecting the astronomic stations by accurate measurements over the earth's surface by means of triangulation or direct measurements. The shape, but not the size, can also be obtained from gravity measurements. Triangulation has been carried on in most of the countries of the earth for the purpose of controlling surveys and maps and for locating boundary lines between nations and political subdivisions of nations. This triangulation and the connected astronomic stations have been used extensively in determining the figure of the earth, but it has been found that this determination was not as simple a matter as, theoretically, it should be.

If the earth were not rotating and if there were no other disturbing influence, all that would be necessary in determining the figure of the earth would be to observe the astronomic latitudes at two widely separated points on a meridian and then obtain by triangulation or direct measurement the distance between these two places. A certain difference in latitude in degrees, minutes, and seconds and a certain distance between the two stations would be obtained. The measured distance would bear the same relation to the circumference of the earth as the angular distance between the two stations would bear to 360°. From these data the circumference of the earth could be computed and therefore its diameter. On account of the fact that

[1] See F. Tisserand, Traité de Mécanique Céleste, Vol. II, Chaps. VI, VII, XIII, XV, and XVIII.

the earth is a spheroid and not a sphere the problem is not quite so simple, but if there were no irregularities of the surface and no deviations from normal density at any depth, the problem still would be an easy one to solve. It would only be necessary to have three or more astronomic stations along a meridian with measurements between them. With these data the elements of the ellipse, which is the meridional section of the spheroid, could be computed.

The confusion which arose in the early attempt to derive the figure of the earth from astronomic observations and triangulation was due to the presence of marked differences of elevation within or near the area where the measurements were made. About 65 years ago, in the determination of a figure of the earth from triangulation and astronomic observations in India, it was found that the length of a degree of latitude varied greatly from place to place. The suggestion was offered that this was caused by the attraction of mountain masses and plateaus on the plumb line to which all astronomic observations must be referred. When corrections were applied to the astronomic observations in order to allow for the attractive effect of the land masses and for the effect of the deficiency of mass in the ocean basins, it was found that deviations of an opposite sign resulted. The conclusion was then reached that there are deficiencies of material under mountains and excesses under the oceans which also affect the astronomic observations and to a certain extent neutralize the attraction of the mountains and the lack of attraction of the oceans. This conclusion was well received by geodesists and geologists and was frequently mentioned in literature on geophysical and geological questions. One of the early investigators of this matter of the deficiency of material under continental and mountain masses and the excess under oceans was C. E. Dutton, of the U. S. Geological Survey. In an article entitled "On Some of the Greater Problems of Physical Geology,"[2] which was read before the Philosophical Society of Washington on April 27, 1889, he gave the name "isostasy" to this balancing of topography by deficiency or excess of mass below sea level.

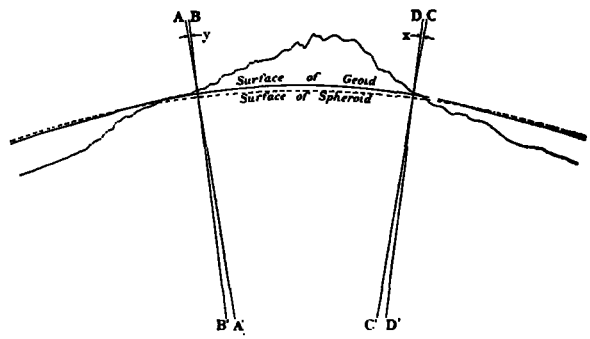

FIG. 1.—Relation of geoid and spheroid.

Under an island the geoid will have an upward bulge with relation to the spheroid. The lines AA' and CC' are normal to the geoid and the lines BB' and DD' are normal to the spheroid. The angle between each pair of normals is the deflection of the vertical at that point.

RELATION BETWEEN SPHEROID AND GEOID.

The geoid is the form which would be taken by the surface of the oceans undisturbed by meteorological conditions and the tidal forces of the sun and moon. If sea-level canals were extended over the continents, the average position of the surface of the water in them would coincide with the geoid. The water surface over the oceans and in the continental canals would at all places be at right angles to the plumb line or resultant direction of the attractive force exerted by the earth's materials, including the water of the oceans, combined with the centrifugal force due to the earth's rotation.

Owing to the irregular surface of the earth the geoid surface is irregular. It inclines upward from the oceans toward the continents and large islands. (See fig. 1.) Within a continent it inclines upward from a valley toward a plateau or mountain.

It is impracticable to obtain equations for the surface of the geoid, due to lack of data. Besides, if sufficient data were available, and equations were derived, it would not be convenient to make use of the geoid in the computations for the geographical positions of objects; but it is practicable to derive a mathematical surface, a spheroid, which will be a close approach to the geoid. For the area used in computing the spheroid the geoid surface will extend above the spheroid in some places and fall below it in others.

[2] Bull. Phil. Soc. of Washington, Vol. XI, 1892, pp. 51-64.

The shape of the earth has been derived many times from data obtained in various parts of the earth's surface. The values agree in showing that the earth has a form which deviates but very little from a spheroid. Various dimensions of the earth and the flattening, or relation of the equatorial radius to the polar semidiameter, are given in many books and reports on geodetic subjects.[3]

In the investigations reported on in The Figure of the Earth and Isostasy, it was shown that the total range of the geoid surface below and above the spheroid for those portions of the United States considered is 37¾ meters, about 124 feet. It may be assumed that for this area the actual maximum deviation of the geoid from the spheroid is only one-half this amount, or 19 meters (about 62 feet).

The area of the United States is about 3,000,000 square miles and that of the globe is about 197,000,000 square miles. It would not be justifiable to predict that no greater deviation of the geoid and spheroid surfaces will be found in other areas, yet what is found in the United States is a good indication of what may exist elsewhere. It is probable that the geoid is above the spheroid by as much as 100 meters under great mountain masses like the Himalayas and the Andes.

The deflections of the vertical are derived from the differences between astronomic and geodetic latitudes and longitudes. These deflections enable us to compute the inclination of the geoid surface to that of the spheroid. It is well known that the plumb line, to which astronomic observations are referred, is deflected toward land masses and away from large bodies of water. Notable examples of this are found on the island of Porto Rico and in Turkestan. In the former the plumb lines at Ponce and at San Juan are drawn together 56 seconds, corresponding to a distance of about 1 mile on the earth. These two places are only 33 miles apart in the north and south direction. Deep water lies both to the north and south of this island.

The other notable deflection of the vertical is in a valley in Turkestan. The distance between two astronomic stations which are connected by triangulation is 65 miles in the north and south direction. The plumb lines at these two stations are drawn away from each other by 76 seconds, corresponding to almost 1½ miles on the earth. To the north and south of the valley are mountains which cause the disturbance.

The method employed in computing the deviation of the geoid from the spheroid is set forth on pages 57–65 of The Figure of the Earth and Isostasy. If the deflection of the vertical or tilting of the geoid surface is 20 seconds of arc at a station where the geoid and spheroid surfaces intersect, and should this tilting continue without change for 40 miles, the two surfaces at the latter place would be 20 feet apart. The two sides of an angle of one second deviate 1 foot at 40 miles.

Along an arc of triangulation there are usually many stations at which the deflection of the vertical has been determined. Therefore, the variations of the geoid surface can be computed. A simple method is to assume that the tilting of the geoid at a station continues one-half the way to the next deflection station.

Let it be assumed that in an arc of triangulation there are a number of deflection stations exactly 40 miles apart. Let the stations be numbered 1 to 10 and let the midway points be numbered the same as the preceding station with the letter "a" added. In the second column of the table following are given deflections of the vertical. Let it be assumed that the plus deflections indicate a tilt upward of the geoid surface in the direction of the increase in the

[3] Among these are (1) John F. Hayford, The Figure of the Earth and Isostasy from Measurements in the United States, U. S. Coast and Geodetic Survey; (2) John F. Hayford, Supplementary Investigation in 1909 of the Figure of the Earth and Isostasy, U. S. Coast and Geodetic Survey; (3) William Bowie, Special Publication No. 40, Investigations of Gravity and Isostasy, U. S. Coast and Geodetic Survey; (4) R. S. Woodward, Smithsonian Geographical Tables; (5) F. R. Helmert, Theorieen der Höheren Geodäsie; (6) Arthur D. Butterfield, A History of the Determination of the Figure of the Earth from Arc Measurements. Worcester, Mass., 1906; (7) Mansfield Merriman, The Figure of the Earth, New York, 1881; (8) Capt. (now Col.) G. Perrier, La Figure de la Terre—les Grandes Opérations Géodésiques in Revue de Géographie Annuelle. Tome II, 1908.

numbers. The changes in the distance between the geoid and spheroid surfaces are shown in the fourth column, and the accumulated change is shown in the last column:

Station.	Deflection.	Change between surfaces.		Accumulated change between surfaces.		Station.	Deflection.	Change between surfaces.		Accumulated change between surfaces.	
		From station, to station.	Amount.	At station.	Amount.			From station, to station.	Amount.	At station.	Amount.
			Feet.		*Feet.*				*Feet.*		*Feet.*
1	+4	.....	.....	1	0	6	+18	5a — 6	+9	6	71
		1 — 1a	+2					6 — 6a	+9		
2	+8	1a — 2	+4	2	6	7	−10	6a — 7	−5	7	75
		2 — 2a	+4					7 — 7a	−5		
3	+12	2a — 3	+6	3	16	8	0	7a — 8	0	8	70
		3 — 3a	+6					8 — 8a	0		
4	+16	3a — 4	+8	4	30	9	+20	8a — 9	+10	9	80
		4 — 4a	+8					9 — 9a	+10		
5	+24	4a — 5	+12	5	50	10	+40	9a — 10	+20	10	110
		5 — 5a	+12								

EFFECT OF ISOSTASY ON GEOID SURFACE.

The effect of a mountain mass in tilting the geoid is greatly lessened by the isostatic equilibrium of the earth's crust. As blocks of the earth's crust of equal cross section have very nearly the same mass, the density of the material of a block under a mountain mass will be less than normal. The deficiency of matter under a mountain area tends to nullify the effect of the mountain mass on the tilt of the geoid surface. Close to the mountain the mountain's effect greatly predominates, but at a distance of about 140 miles the effect of the isostatic compensation (deficiency of matter under the mountain) will almost offset that of the mountain. At this distance the effect of the mountain is reduced 90 per cent. This is a very important point, and it makes necessary a revision of some old estimates of the extent to which continents, with their high land, tilt up the geoid surface.

It has been held that the geoid must be much below the spheroid out in the oceans, but this probably is not true. At a short distance from the coast the effect of the land masses will be offset by the isostatic compensation, and only the irregular configuration of the bottom will vary the relative positions of the geoid and spheroid surfaces.

The effect of the continental shelf may be large, but, as in the case of land masses above sea level, it will be offset by the deficiency of density in the material of the block under the shelf, as compared with the density of the material of the crust under the deeper water.

From a consideration of all the evidence, we may conclude that the deviation of the geoid from the spheroid is probably not more than 100 meters over a great ocean "deep," and that the area affected by such a deviation is quite limited in extent. Over land areas the deviation may be as much as 100 meters under some of the great mountain systems. It will be seen that, as compared with the smooth mathematical surface of the spheroid (the mean surface), the geoid has bumps and hollows of moderate sizes. If there were no isostatic equilibrium in the earth's crust, the bumps and hollows on the geoid might be from 30 to 40 times greater. Considering the insignificant size of the deviations of the geoid from the spheroid we can readily understand that such deviations are not factors in dynamic and structural geology.

EFFECT OF REDUCTION FOR ISOSTATIC COMPENSATION ON DERIVED SIZE OF SPHEROID.

The computed spheroid, which approximates the mean sea-level surface of the earth, depends on the astronomic and geodetic observations at what are called deflection stations. The plumb line is always at right angles to the geoid surface, and therefore a deflection of the vertical is a measure of the rate at which the geoid surface departs from the mean surface or spheroid.

Let us start at the Atlantic coast in the United States at approximately 39° latitude and work westward. If we assume that the spheroid and geoid coincide at this coast, then, under the Appalachian mountains, the geoid will be above the spheroid. This is due to the fact that the Appalachian mass attracts the plumb line and causes the geoid surface to incline upward

towards the mountain. Beyond the Appalachian system the geoid will tend to approach the spheroid surface because the topographic attraction is greater to the eastward than to the westward. The two surfaces will probably come nearest to each other under the plains of the Mississippi River. West of that river the resultant topographic attraction is toward the westward and the geoid will necessarily be gradually raised above the spheroid. This raising of the geoid will increase until the Rocky Mountains are reached, where it will be a maximum. Then there will be a lessening of the distance between the surfaces just to the westward of the Rockies, and through the western part of the country this distance will increase and decrease as the mountain masses are approached and passed. It is probable that the geoid surface at the Pacific coast will still be somewhat above the spheroid.

If corrections are applied to the astronomic observations for the effect of topography and isostatic compensation, the corrected direction of the vertical will be very nearly normal to the mean surface of the earth. In consequence of this method of computation the humps or ridges of the geoid would be smoothed out, and the computed spheroidal surface would be a mean of this smoothed-out geoid, rather than of the actual one. The final outcome of this process would be to make the smoothed-out geoid surface for the United States a few meters, probably not over 10 or 20, closer to the center of the earth than the average distance of the actual geoid surface. We are considering land areas only, for it is only on these that we have geodetic data from which to compute the spheroid.

The only way to derive from triangulation and astronomic observations the mathematical surface or spheroid for the whole geoid would be to have connected triangulation over all the earth. This is not possible, because the great land areas are separated by large bodies of water across which geodetic measurements can not be made. It is very probable that the process of eliminating the local deviations of the geoid caused by the attraction of the topography and compensation for the area of the United States has enabled us to obtain a spheroid which represents the mean surface of the earth very much closer than if we attempted to compute the mean spheroid from the actual uncorrected geoidal surface.

It is worthy of note that the Hayford spheroids, derived from United States data only, have dimensions which are greater than the most reliable of the previously derived spheroids. In the derivation of the other spheroids isostatic compensation was not considered, but it was by Hayford. If in an area used in deriving a spheroid the central portions have much higher elevations than the margins, and if the effect of topography and isostatic compensation is not considered, the dimensions of the spheroid will be less than when the area has its greater elevations near the margins.

It is believed that, if the isostatic method were applied in the computation of the spheroid in each of a number of large separated areas, the derived spheroids would have a very close agreement. It seems equally certain that they would differ considerably if derived by the older methods.

GRAVITY FORMULAS OF 1912 AND 1917.

In the gravity investigations of which Special Publication No. 12 is a report, a new gravity formula was derived which appeared to agree more closely with the conditions in the United States than did the Helmert formula of 1901. The new formula is (see p. 25, Special Publication No. 12):

$$\gamma_0 = 978.038\ (1 + 0.005304 \sin^2 \phi - 0.000007 \sin^2 2\phi)$$

As the second term of this formula agreed so closely with that of the Helmert formula, the Helmert value was adopted, thus making what is referred to as the Coast and Geodetic 1912 formula (Bowie formula No. 1), which is as follows:

$$\gamma_0 = 978.038\ (1 + 0.005302 \sin^2 \phi - 0.000007 \sin^2 2\phi)$$

The "isostatic anomalies" are derived from the use of this formula. It is the basis of the isostatic anomalies in Special Publications Nos. 12 and 40, and also in this publication.

In the gravity investigations covered by Special Publication No. 40, a gravity formula was derived from 348 stations of the United States and other countries. It is—

$$\gamma_0 = 978.039\ (1 + 0.005294 \sin^2 \phi - 0.000007 \sin^2 2\phi)$$

This, the 1917 formula (Bowie formula No. 2), is very nearly the same as the 1912 formula derived from stations in the United States alone. The two do not differ enough to warrant its use in making the gravity reductions in this publication. It is probable that there will be available many more gravity data in the near future from which, in conjunction with data now existing, a gravity formula can be derived which will be so near the truth that all gravity results can be reduced by it when making isostatic investigations. By holding to the 1912 formula the data given in this report are comparable with similar data in Special Publications Nos. 10, 12, and 40.

HELMERT FORMULA OF 1915.

In 1915 Helmert derived the following formula: [4]

$$g_0 = 978.052\ [1 + 0.005285 \sin^2 \phi - 0.000007 \sin^2 2\phi + 0.000018 \cos^2\phi \cos 2(\lambda + 17°)]$$

in which ϕ, as usual, is the geographic latitude and λ is the longitude from Greenwich, east longitude being positive. The formula corresponds to a spheroid with three unequal axes, the shorter equatorial axis being in longitude 73° east from Greenwich and the longer, which exceeds the shorter by 230 meters, in longitude 17° west of Greenwich. The reciprocal of the mean polar flattening is 296.7 ± 0.4. The mean value of gravity over the sphere is 979.771 dynes. The formula is based upon 410 stations in all parts of the world selected for being neither too near to the coast nor to mountainous regions and upon certain coast stations which were given reduced weight.

The coefficient of $\sin^2 2\phi$ is based on the theoretical calculations of Darwin and Wiechert.[5] It corresponds to a spheroid of revolution in hydrostatic equilibrium. This spheroid is not an exact ellipsoid of revolution, but in latitude 45° is depressed about 3 meters below a concentric ellipsoid of revolution having its equatorial and polar axes coincident in length and direction with those of the spheroid.

The coast stations were used in determining all other constants except the first one, which from coast stations alone had the special value of 978.068 dynes. The precise number of coast stations is not given. The formula, when the first coefficient is used as 978.052, represents gravity reduced by the free-air method for stations in the interior and not in mountainous regions.

This formula of Helmert is somewhat different from the Coast and Geodetic Survey formulas of 1912 and of 1917, both in the value of gravity at the equator, namely, 978.052, and in the value of the second term 0.005285. As Helmert did not apply the theory of isostasy in deriving his formula, it will not be used in this publication.

There are 134 stations in the United States, not on the coast and not in mountainous regions, treated in Special Publication No. 40. (See pp. 64 and 65 of that paper.) The mean free-air anomaly with regard to sign for those stations is +0.012 dyne. It is noteworthy that this is within 0.002 of being the difference between the first terms of Helmert's formula of 1915 and of the 1912 formula of the Coast and Geodetic Survey.

Helmert derived his longitude terms from stations which were not reduced for the effect of topography and compensation, nor was any account taken of the decided effect of recent sedimentary matter on the value of gravity. The writer believes that the effect of all local influences should be eliminated from the gravity data before using them for the determination of the shape of the earth. If each coast station were affected by the same amount, then we

[4] Sitzungsberichte der Königlich Preussischen Akademie der Wissenschaften, No. 41 (1915), p. 676, entitled "Neue Formeln für den Verlauf der Schwerkraft im Meeresniveau beim Festlande."

[5] G. H. Darwin. "The theory of the figure of the earth carried to the second order of small quantities." Month. Not. Roy. Astr. Soc. 60 (1900), p. 82. Also Scientific Papers, Vol. III, p. 78.

E. Wiechert. "Ueber die Massenvertheilung im Innern der Erde." Nachr. v. d. Kön. Ges. d. Wiss. zu Göttingen. Math.-phys. Kl. 1897, 221.

would be justified in using uncorrected values of gravity for the derivation of the longitude terms, but an inspection of coast stations clearly indicates local disturbances. Island stations differ from main coast stations.

PROPOSED FORM OF GRAVITY FORMULA.

The complete gravity formula really should be of the form

$$g_0 = g\ (1 + C_1 \sin^2 \phi - C_2 \sin^2 2\phi) + H + T + C_t + D,$$

where g_0 is the value sought, g the gravity at sea level at the equator, C_1 and C_2 are constants, ϕ the latitude of the station, H the correction for elevation of the station above sea level, T the correction for topography, C_t the correction for isostatic compensation, and D the correction for abnormal densities in the material close to the station. The last correction can not be derived with any great certainty, because the volume and shape of the extra light or heavy matter can not be accurately determined. The correction H is negative for all stations above sea level, while the corrections T, C_t, and D may be positive or negative.

A careful consideration of the literature on the subject of gravity reductions will convince one that the gravity anomalies based upon a gravity formula which considers the sea-level surface as an ellipsoid of revolution are functions of the reduction for topography and compensation and to a certain extent of the geological formation on which the station is located. In brief, a gravity anomaly is caused, to a large extent, by something local, and probably not by the earth's figure having three unequal axes instead of two.

SOME PROBLEMS OF ISOSTASY.

The theory of isostasy postulates that at some imaginary surface below sea level and concentric with it the pressure on equal areas is the same throughout. To what extent is this theory true and what is the minimum cross section of the column above this surface that will be in equilibrium? There have been advocates of the theory that the unit column has a very small cross section. Others maintain that the cross section must be equivalent to the area of the United States or a large part of it.

Other problems connected with the theory are: What is the limiting depth within which the compensating deficiencies take place, how is the deficiency (or excess) of density distributed with respect to depth, and is this deficiency directly under the topographic feature or is it regionally distributed?

The first comprehensive investigation of the theory of isostasy was made at the U. S. Coast and Geodetic Survey by Dr. John F. Hayford when he was in charge of the geodetic work of that bureau. His results are contained in publications [6] of the Coast and Geodetic Survey and in articles in the scientific press.

Many facts in regard to the distribution of material in the outer portion of the earth may be ascertained by a study of geodetic data. Some of the fundamental principles involved in this work are outlined below.

Let us consider the method employed in determining the figure of the earth; that is, by the combination of astronomic stations and triangulation. For simplicity let us assume that there is only one mountain mass affecting the station, and that this mass is an extra load on the earth. The astronomic station is affected by the mountain mass and, in consequence, the plumb line will be deflected toward the mountain. Its direction depends upon the relative attractions of the rest of the earth and of the mountain.

It will be readily seen that the actual water surface of the earth formed by the oceans and the imaginary sea-level canals, mentioned earlier, will be tilted upward toward the mountain. The direction of the plumb line to which all astronomic observations must be referred will be normal to the water surface and not to the mean or mathematical surface.

It may be thought that if we compute and apply a correction to the astronomical observations to account for the attractive effect of the mountain we would obtain a direction of the

[6] John F. Hayford, Figure of the Earth and Isostasy from Measurements in the United States, and Supplementary Investigation in 1909 of the Figure of the Earth and Isostasy, U. S. Coast and Geodetic Survey.

plumb line at the astronomic station normal to the mathematical surface, but this is not the case. After applying a correction for the mountain's attraction the corrected direction of the plumb line will be deflected away from the mountain. It would appear, therefore, that this correction to the astronomic observation is too great. If we now assume that the mountain mass affecting the particular astronomic station under discussion is compensated by a deficiency of mass in the column of the earth's crust under it equal in amount to the mountain and compute its effect on the astronomic station, we shall obtain another correction of the opposite sign to that due to the attraction of the mountain mass. If this second correction is also applied to the astronomic observations, the corrected direction of the plumb line will be nearly, if not exactly, normal to the mean surface of the earth.

Instead of a single mountain mass affecting the direction of the plumb line at a station we have many such masses, as well as the other continental material and the deficiency of matter in the ocean basins. For each station the resultant effect of all disturbing masses out to about 2,500 miles and of their compensation is determined. The combined effect of the more distant topography and its compensation is negligible.

The methods used in making these computations are described very clearly and fully in Figure of the Earth and Isostasy from Measurements in the United States, mentioned previously, and need not be treated in this paper.

Hayford in his investigations in the determination of the figure of the earth assumed that there is uniform distribution of compensating masses with respect to depth, that the compensating masses are directly under the masses which are above sea level, and that the compensation extends to a uniform depth. He also computed the effect on the astronomic stations of the compensation distributed to various depths. In his first publication [7] on the result of his investigations Hayford derived the value of 113.7 kilometers as the most probable depth of compensation. In his second paper [8] he derived the most probable depth as 122.2 kilometers.

These depths were obtained by a study of the outstanding differences between the latitudes, longitudes, and azimuths secured by triangulation and those resulting from the astronomic observations. The computed depth on this assumed hypothesis of uniform distribution will probably be changed somewhat in any area when additional data are used, and it will no doubt be different in different large areas. It is equally true that the uniform distribution of the compensation is not a demonstrable fact but a logical assumption by the mathematician to facilitate the computations.

The depth found by Hayford is in each of his investigations the one which most nearly eliminates the deviations of the plumb line from the normal to the mean surface of the earth. It is an average depth for the whole group of stations.

Let us consider the depth of compensation and the distribution of material. If we make an assumption with regard to the distribution of material and that assumption applies to all astronomical stations in every part of the world with equal exactness and causes the resulting deflections of the vertical to be almost entirely eliminated, then we can safely conclude that, although this assumption may be artifical and somewhat different from the actual state of affairs, at the same time it is a very close approximation to the truth.

A number of assumptions can be made with regard to the manner in which the compensating deficiency or excess of material is distributed with respect to the depth. First, it may be assumed that the distribution is uniform; second, that the compensation is greatest in the outer portion of the earth, gradually decreasing to zero at lower depths; third, that the compensation is small near the surface, gradually increasing to a maximum at a reasonable depth below sea level and then gradually decreasing to zero; fourth, that the compensation is confined to a zone of certain thickness—say, 10 or 20 miles—and that this zone is at different depths below the surface. Combinations of these various distributions may also be assumed.

The writer believes that, regardless of how the compensation is actually distributed, the only logical distribution to assume is one which will have the center of attraction of the com-

[7] Figure of the Earth and Isostasy from Measurements in the United States.
[8] Supplementary investigation in 1909 of the Figure of the Earth and Isostasy.

pensation somewhere between 30 and 50 kilometers below sea level.[9] This opinion of the writer has been strengthened by a statement by Col. Sidney G. Burrard, former superintendent of the Trigonometrical Survey of India. In an article appearing in The Geographical Journal, London, July, 1920, page 51, he made the statement that:

> The attraction at the surface of this uniform distribution (down to 70 miles) is nearly the same as the attraction of a compensation which is all concentrated at 25 miles deep (approximately 40 kilometers).

If we should plot curves representing various methods of distributing the isostatic compensation with respect to depth, with the center of attraction at or close to 40 kilometers, we should find that the average of all the possible assumptions would be approximately uniform distribution. It may be said that the method of distribution, if it is a rational one, has very little effect on the fundamental conclusions reached from investigations in isostasy. This is due to inherent difficulties in evaluating the depth of compensation and the distribution of the compensating material. There are heterogeneous densities, at least near the outer portion of the earth, which in some cases materially affect the direction of the plumb line and prevent a rigid mathematical determination of the depth and the distribution of compensation horizontally and vertically.

Before Doctor Hayford severed his connection with the Coast and Geodetic Survey he and the writer began investigations in the subject of the effect of isostatic compensation on the intensity of gravity. These studies were carried on by Doctor Hayford and the writer in cooperation for a few years after the former left the Coast and Geodetic Survey and later by the writer alone. The results have appeared in publications of the Coast and Geodetic Survey and in scientific journals.[10]

The investigations of the effect of isostatic compensation on the intensity of gravity have led to practically the same conclusions that were reached from a study of the effect of isostatic compensation on the deflection of the plumb line. The most probable depth of compensation, if the compensation is assumed to be uniformly distributed with respect to depth, was found by the writer to be approximately 96 kilometers. This value is the mean of the one determined from observations made at gravity stations in mountain regions, 95 kilometers, and the value 97 kilometers derived from deflection investigations by Hayford also for stations in mountain regions. It is believed 95 kilometers is the strongest value obtainable from the existing gravity data in the United States, because the determination was very much more sensitive than a determination in regions of low relief or for the whole country.

There is one very important mathematical principle involved in the gravity work, namely, that the attraction on a particle by a plate of material of uniform density and of limited uniform thickness but of large horizontal dimensions is independent of the distance that the particle may be from the plate. It is readily seen that for reasonable distances of the particle above the plate the same principle would practically hold if the plate has limited horizontal dimensions. This is very interesting, as it shows that for a plateau—say, 5,000 feet in elevation and 1,000 miles in diameter—the attractive effect of the material above sea level is approximately the same as the negative effect of the isostatic compensation. The same principle applies to a coastal plain with an elevation of only a few hundred feet above sea level. It is evident that the observed value of gravity on an extended plateau or plain should be nearly normal if a state of isostasy exists, and therefore the effect of the compensation will be approximately the same regardless of how far the deficiency extends below sea level and how it is distributed, provided it is not extended so far as to make the depth of compensation no longer small in comparison with the horizontal extent of the plateau or plain. It is for this reason that a depth of compensation computed from gravity observations in a flat region will have great uncertainty.

ILLUSTRATION OF ISOSTASY.

It is difficult at times for one to visualize the isostatic condition of the earth's crust. It may help somewhat to consider a simple illustration. Let us take equal masses of a number of differ-

[9] "Our present knowledge of isostasy from geodetic evidence," July-August (1917) Journal of Geology, p. 437.
[10] See especially U. S. Coast and Geodetic Survey Special Publications Nos. 10, 12, and 40.

ent metals having different densities but none greater than that of mercury. Have the several masses of metal cast into prisms of the same cross section. All the prisms will have the same mass and the same cross section, but they will differ in length inversely as their densities. If we should place these prisms in a vessel partly filled with mercury, one alongside of the other, we should find that as each prism has the same mass, the same cross section, and will displace the same amount of mercury, the lower bases of the several prisms will be in the same plane. The upper surfaces of the prisms will project different amounts, thus forming a very irregular surface. (See fig. 2.) The lower surfaces of the prisms define what may be called the depth of compensation. Now, suppose we should, in imagination, cut the earth's crust into blocks by vertical planes and let the bases of these blocks be 60 miles below sea level and each 100 miles square or, if preferred, some larger or smaller square. Let it also be supposed there is no resistance to the vertical movement of a block with relation to the adjacent blocks by reason of friction or other causes. According to the theory of isostasy each of the truncated pyramids will have the same mass, each will have the same area of its base, but the lengths of these figures will vary considerably. Therefore, the average density of the matter in each truncated pyramid will be a function of the length of the block. We may express the above relations by a simple equation:

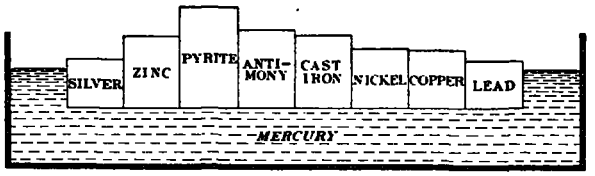

FIG. 2.—An illustration of isostasy.

$$VD = C \text{ (a constant)}.$$

That is, if the volume, V, of one of the blocks under consideration is greater than normal, the density, D, of the material in it must be less than normal. If the volume is less than normal, the density will be greater.

Now, suppose the truncated pyramids of the earth were placed in a liquid or very plastic substance of somewhat greater density than the earth's crust. The lower bases of the blocks would form a smooth surface, while the tops of the blocks would form an irregular surface. The blocks would project amounts inversely proportional to the density of the material in them.

Although the isostatic balance of the earth's crust is nearly perfect, it is somewhat misleading to speak of the percentage of the completeness of the isostatic compensation. We may, however, safely express as a percentage the reduction of the deflection of the vertical and the gravity anomalies by the application of the theory of isostasy.

It has been shown and stated that the application of the theory of isostasy has reduced the deflections of the vertical to 10 per cent of what they are on the theory that the earth is rigid, and, similarly, has reduced the values of the gravity anomalies to from 10 to 15 per cent of what they would be if the earth were considered rigid.

DENSITY OF MATERIAL BETWEEN EARTH'S SURFACE AND DEPTH OF COMPENSATION.

There has been much confusion as to just what is the stand of the geodesists in regard to densities in the earth's crust. In isostatic investigations there is no need to use a numerical value for the average density of the materials of the earth's crust for any block. What is attempted is to weigh by indirect methods the differences in mass or deviations from the normal average density of the various imaginary blocks into which the crust may be divided. For instance, if D is the average density of the crust under the coastal plains, then the theory of isostasy postulates that the average density of the material of the crust under the land masses is less than D and under the oceans is greater than D.

There are certain normal or average densities for the various zones or layers of material below sea level, and geodesists are concerned simply with the deviation from these unknown normal densities. It is generally accepted that the density of the earth increases with the depth, but

† 322696 O—41——2

it is readily seen that, as far as the computation of the effect of isostatic compensation is concerned, only the deviations from the unknown normal density need be considered.

The whole theory of isostasy is based on the idea that the mean density of a unit column of the earth's crust times its volume is a constant, and therefore that the mean density of these columns of the same cross section, all extending to a certain depth below sea level, will vary inversely as the volume. Consequently, under a mountain mass the column will be longer, the volume greater, and the density less than normal; under the coastal plain the density and volume will be normal; and under an ocean the column will be shorter, the volume less, and the density greater than normal. From the geodetic evidence we must conclude that these conditions are substantially true. The minimum area of the cross section of the column that may be independently in equilibrium is not known, but it is very probably less than 200 miles square, and it may be less than 100 miles square.

TOPOGRAPHY COMPENSATES ABNORMAL DENSITY IN ISOSTATIC SHELL.

The Geographical Journal for July, 1920, contains a paper on isostasy read by Colonel Burrard before the Royal Geographic Society.[11] In the general discussion at the end of the paper is a statement by R. D. Oldham in which he emphasizes the importance of stating clearly whether mountains are compensated by the deficiency of material in the columns under them or whether they are the compensation of the light material in the columns under them. It is the writer's belief that a mountain mass is the result of the lighter material in the column under it, rather than that the deficiency of density in the column is due to the mountain mass. Likewise, the oceans compensate the excess of density under them. It is true that in America geodesists have spoken of compensating deficiency of material under the continents and compensating excess of material under the oceans as the result of the presence of the continental mass above mean sea level in the one case and of the ocean volume with deficient density in the second case. However, the writer wishes to go on record as being in favor of the theory that the mountains and the oceans are the result of the deficiency and excess of density, respectively, in the columns under them.

The writer believes that it will be most convenient to continue to speak of the compensation of land masses and the deficiency of the mass in the oceans, but, with the explanation given above, the reader will not be misled into believing that the isostasist holds that the continents and oceans are the causes and the "isostatic compensation" the effect.

RELIABILITY OF GEODETIC DATA.

There has been doubt in the minds of many geologists and geodesists as to the reliability of the data used in the isostatic investigations and of the conclusions that have been reached. The isostatic investigations involve both observations and computations. The observations are accurate beyond doubt; in fact, they are more accurate than are necessary in carrying on the investigations. For instance, it is quite certain that the error of an observed deflection of the vertical is seldom greater than 0.″5 of latitude or longitude, and the error of an observed intensity of gravity is seldom greater than 0.003 or 0.004 dyne. We may conclude, therefore, that the observed data are correct. They are accurate physical measurements.

The method used in computing the effect of topography on the deflections of the vertical and the accuracy of the computations are discussed in much detail in Dr. Hayford's books [12] on the figure of the earth and isostasy already referred to. The accuracy of the computed topographic effects as applied in the gravity reductions is discussed fully in Special Publication No. 10.[13] It is not necessary to quote from these publications, since they are readily available to any one who wishes to study in detail the question of the accuracy of the topographic corrections. The writer believes that he is justified in stating that these topographic corrections can be accepted as reliable and accurate.

[11] "A brief review of the evidence on which the theory of isostasy is based," The Geographical Journal, July, 1920.

[12] See footnote on p. 10.

[13] John F. Hayford and William Bowie, Effect of Topography and Isostatic Compensation upon the Intensity of Gravity, Spec. Pub. No. 10, U. S. Coast and Geodetic Survey, 1912.

If we accept the statement that the observations and the computed topographic corrections to the deflections of the vertical and to the intensity of gravity are correct to the required degree of accuracy, then there is left only the question of the reliability of the isostatic corrections.

RELIABILITY OF COMPUTATION OF ISOSTATIC COMPENSATION.

When geodetic measurements were corrected for the visible land masses and the deficiency of material in the oceans, there were outstanding differences that showed decided relations to the character of the topography in the vicinity of the various stations. Isostasy was the theory advanced to explain the presence of these outstanding differences. In order to make the computations to test the theory of isostasy, some simple method had to be adopted. The most logical method seems to be the one used first by Hayford and since by others working in the geodetic field. The method is based on the assumptions that isostasy is complete; that the compensation is directly under the topographic feature, whether land or water; that the compensation is uniformly distributed vertically; and that it extends from the surface of the earth to a uniform depth below sea level.

Computations were made on this theory to obtain the effect of the isostatic compensation on the deflection of the vertical and on the intensity of gravity. The computations were made, first, for a number of deflection stations in the United States, then for several in India, and later for gravity stations in the United States, Canada, Europe, and Asia.

The corrections for isostatic compensation as thus computed were applied to the deflections of the vertical and to the values of gravity with the remarkable result that for the area of the United States deflection anomalies were on an average reduced to 10 per cent of what they would be if there were no isostatic compensation and the average gravity anomaly to from 10 to 15 per cent of what it would be on the rigid-earth hypothesis. These results indicate very clearly that the United States, both as a whole and locally, is in practically complete isostatic adjustment.

Now, the question arises, How can we justify the adoption of the methods employed in distributing the isostatic compensation? That is the crux of the whole discussion in the subject of isostasy. If we can prove to the satisfaction of all that these methods are justified, then the conclusions resulting from the computations will carry great weight.

The only evidence that we can offer as to the reliability of the computation of the effects of the compensation is that the mathematical part of the work is accurate. If we are correct in assuming that the compensation is complete, that it is directly under the topographic feature, that it is limited within a certain depth, and that it is uniformly distributed vertically, then the numerical results of the attraction of the compensation of any feature on the plumb line and on the pendulum are accurate; but it may be argued that the method of distribution is illogical. This may be true, but the computations on this theory of the distribution has practically eliminated the anomalies at gravity stations and at deflection stations, reducing them to from one-seventh to one-tenth of what they would have been if there had been no compensation whatever. When it is remembered that this method of distributing the compensation has given equally satisfactory results in the several countries in different parts of the earth, we must assume that it is a most satisfactory basis for our investigation.

DISTRIBUTION OF COMPENSATION.

UNIFORM DISTRIBUTION VERTICALLY.

The uniform distribution of the compensation seems to be a stumbling block to the acceptance of the theory of isostasy. In fact, the greatest effort of some writers in criticizing the theory is put forth to show how illogical are the assumptions postulated by the geodesist in making the computations for the isostatic compensation. It is believed that, if the fundamental facts, which can not be questioned, are accepted and the attention is concentrated on the variation of densities in the outer portion of the earth—say, to a depth of 60 or 70 miles—there will be less confusion on the subject.

It is more logical to think that the compensation is distributed through a long column rather than through a very short one or through a very short section of a column, say, 5, 10, or 20 miles in length. In a small volume it would require a rather decided decrease or increase from normal densities, especially in columns under high mountains or deep oceans. We might assume that the compensation is nearly all confined to a certain part of the column with other parts receiving much smaller amounts, but the computations show that no matter how the compensation is assumed to be distributed its center of gravity must be approximately 40 kilometers below sea level in order that the computed corrections may reduce the gravity and deflection anomalies to the extent that they are reduced by the uniform distribution.

Burrard has remarked as follows on Hayford's method of distributing the compensation: "He assumed uniform distribution in depth in order to facilitate computations." It is thus seen that Burrard does not consider that uniform distribution extending to a definite depth was believed in rigidly by Hayford.

HORIZONTAL DISTRIBUTION.

The distribution of the compensation horizontally with relation to the topographic features has received attention from those geologists who hold that the earth's material is very rigid and capable of withstanding great loads. It has also received the attention of geodesists who have computed the effect of several horizontal distributions of the compensation of topographic features. It can not be said that any very definite conclusions have been reached in this matter, as from the nature of the case mathematical treatment can not give very accurate results. At the same time the evidence is all in favor of limiting the horizontal distribution within a reasonably short distance. When the compensation is distributed horizontally to a distance of 100 miles in all directions, the gravity anomalies become more discordant than when distributed close to the feature.[14]

It is difficult to see why a plain 100 miles from a mountain should help bear the mountain mass. The mountain mass is not picked up bodily and placed on the earth's crust, but it is formed from the crust, and whatever caused the uplift acted locally rather than regionally. Of course, no one would hold that all of the compensation of a single mountain peak or ridge is located directly under it and confined within the base of the mountain peak or ridge. The compensation naturally extends out some distance, but that it extends for hundreds of miles around each large topographic feature is beyond the possibilities. Such an assumption would certainly cause the computed anomalies to be large. We may infer from the geodetic data available that the compensation is distributed locally under the topographic feature or to a distance not greater than about 100 miles in all directions.

McMillan made the statement that:

> From a purely mathematical point of view any set of a finite number of observations of the intensity and direction of gravity can be satisfied not approximately but exactly in infinitely many ways by a proper distribution of the density in the earth.

This statement is justified mathematically, but any distribution of the densities that would exactly eliminate the anomalies of the deflections of the vertical and of the intensity of gravity but that would not be general in its application would be so artificial as not to be reasonable. The writer believes that the only hypothesis that will carry weight is one that will be very general in its application. We can not assume one depth of compensation for one station or a general group of stations, another for a second group of stations, and so on through the list, nor can we assume different distributions of densities horizontally and vertically for different stations or groups of stations. This would be merely guesswork, for no one can really tell with certainty what variations there are in the isostatic shell of the earth, except in so far as they may be indicated by borings and by the exposed rocks. McMillan is correct in saying that any general system that applies uniformly can be used only as a first approximation to the actual situation, and that "depth of compensation" and size of the "areas of compensation"

[14] William Bowie, Investigations of Gravity and Isostasy, U. S. Coast and Geodetic Survey Special Publication No. 40, and "Our present knowledge of isostasy from geodetic evidence," Journal of Geology, July-August, 1917.

depend for their successful determination on the vastly more difficult matter of second and higher approximations, and that these approximations can be obtained, if at all, only by a very much more dense net of observations. McMillan also thought it quite likely that the observations themselves would have to be still further refined.

We must remember that the first approximation eliminates nearly all of the anomalies, and the second and higher approximations are needed only to perfect the details. They are not necessary in the establishment of the theory of isostasy. The first approximation has done this.

The isostatic method used by Hayford, Burrard, and the writer, and accepted by many others, is certainly correct in its general principles and is a long step in advance in geophysical science. It is probable that the exact depth of the compensation and the exact area over which the compensation of a feature is distributed can never be determined with mathematical precision even for local areas. There will always be an error in the result, the size of which can not be determined. The writer believes that further refinement of the observations is unnecessary, because the outstanding anomalies in deflection and gravity work are large in comparison with the probable errors of the observational data. The deflection and gravity data are undoubtedly sufficiently accurate for all studies connected with isostatic compensation.

We are certainly justified in holding that isostasy has been proved beyond a reasonable doubt. In the words of Col. E. H. Hills, when discussing Colonel Burrard's paper:[15]

> It seems to me that Colonel Burrard put the matter very clearly and proved his case, and what I should like now is for the geologists to tell us—which I have never yet heard a geologist do—how this condition of compensation really arises.

DATUM USED FOR COMPUTING THE EFFECT OF TOPOGRAPHY AND COMPENSATION.

It has been held that errors have been made in the isostatic reductions as a result of having adopted mean sea level as the datum for computing the topographic and compensation corrections instead of having adopted some other plane of reference as, for instance, the bottom of the ocean or the bottom of the sedimentary rocks. It may be well to point out here that there would be slight changes in some of the gravity anomalies if the datum plane were changed from sea level to some other depth, say several miles below.

The same reasoning that we used above, in connection with the distribution of isostatic compensation vertically and its effect on the intensity of gravity and the deflection of the vertical, will apply equally well to this question of the datum plane. With mean sea level as the plane, the average density of the material in the columns which are under the coastal plains with practically no elevation is assumed to be normal, and the density of the material under the oceans is greater than normal and under the continents less than normal. We can just as readily use a datum plane below sea level, even at a depth equal to the greatest depth of the ocean. Then we should have to assume that the material in the column under the deepest part of the ocean had normal density and that all other columns had abnormally light density. Which is more logical, to assume densities lighter than normal in practically all of the outer portion of the earth or to assume that the density is less than normal for a part and greater than normal for the remainder?

In an article [16] on the hypotheses of isostasy Prof. W. D. McMillan favored the depth of 9,000 feet below the present sea level as the datum to which all of the computations should be referred in treating the effect of topography and isostatic compensation. This is the depth, according to McMillan, to which the earth would be covered with water "if the solid portion of the earth were altogether lacking in rigidity and if the concentric layers were homogeneous in density."

Possibly this depth of 9,000 feet would be a more logical one than mean sea level, but mean sea level is something that we can use in a practical way. It is the surface of the water of the

[15] "A brief review of the evidence upon which the theory of isostasy is based," Geographical Journal, London, July, 1920, p. 55.
[16] Journal of Geology, February-March, 1917.

oceans, and elevations on land can be easily referred to it. As a matter of fact, any equipotential surface of the earth or above it could be used as the datum for the computation of the effect of topography and isostatic compensation, but it is believed that the results would be the same as those obtained by the use of mean sea level as the datum.

COMPLETENESS OF COMPENSATION.

McMillan states:

> From the fact that the hypothesis of isostasy reduced the sum of the residuals from 65.434 to 8.013, or by approximately 90 per cent, and from the fact that the average elevation of the United States is about 2,500 feet, Hayford concluded that the average departure from complete isostasy in the United States is equal to about 250 feet of rocks.

On pages 164–166 of The Figure of the Earth and Isostasy from Measurements in the United States Hayford discusses the subject of the degree of completeness of compensation and in a table shows the mean of the topographic deflections without regard to sign for each of 10 groups of deflection stations. This table also shows the mean residual of solution *G*, the one which he adopted as the most probable. Except for one group the mean residual is only about one-tenth the value of the mean topographic deflection. For one group of 53 stations of the 507 deflection stations the mean residual is 42 per cent of the mean topographic deflection. The stations of this group are in Michigan, Minnesota, and Wisconsin, an area of low relief, but one known to have abnormally dense material at various places which would have rather large effect on the deflection of the vertical. It is impossible to compute what the effect of these dense rocks is in each case, because it is not known to what vertical depth they extend.

For the 507 stations considered in the United States the mean topographic deflection is 32.″26 while the mean isostatic residual is 3.″04. It is seen that the mean residual is only 9.4 per cent of the mean topographic deflection.

Hayford stated his conclusion from the evidence presented as follows:

> For the United States and adjacent areas it is safe to conclude from the evidence just summarized that the isostatic compensation is so nearly complete on an average that the deflections of the vertical are thereby reduced to less than one-tenth of the mean values which they would have if no isostatic compensation existed. One may properly characterize the isostatic compensation as departing on an average less than one-tenth from completeness of perfection.

Had the depth of 9,000 feet below mean sea level been adopted as a datum plane the residuals would undoubtedly have been almost the same as they are with mean sea level as the plane, and certainly the topographic deflections would have been almost the same. With 9,000 feet more material to consider in the topographic computations, there would be as much added material on one side of the station as on the opposite side, and the resultant effect of the added material would be zero. Similarly, the effect of the isostatic compensation of this 9,000-foot layer would be symmetrical with respect to the station, and its resultant would be zero. The same is true in regard to ocean areas in so far as the effect on the deflection of the vertical is concerned.

Although it would not affect the topographic corrections to the deflections of the vertical, this change of datum plane from mean sea level to 9,000 feet below would affect the topographic corrections as applied to the intensity of gravity. All of the 9,000 feet of material between mean sea level and the new datum would have a downward pull on the pendulum, and therefore the effect of this topography would all be of one sign.

This change of datum, however, would also increase the compensation effect. There would be an additional deficiency of material below the 9,000-foot depth to balance the additional topography. The effect of this additional compensation would largely neutralize the effect of the additional topography. The gravity anomalies would, therefore, be practically the same as those we now get. They would, however, be very much smaller in proportion to the greater topographic corrections, and instead of being 10 or 15 per cent of the effect of the topography would be only approximately 3 or 4 per cent of this greater topographic effect.

It is questionable whether Hayford was justified from his deflection investigations in saying that isostatic compensation departs, on an average, less than 10 per cent from completeness or perfection. He would have been justified, however, in saying that the isostatic residuals

are only 10 per cent of what they would have been if there were no isostatic compensation. It does not seem possible to interpret this great reduction in the deflections of the vertical in terms of matter. On this point McMillan is justified in questioning Hayford's statement that isostasy in the United States is approximately 90 per cent complete. McMillan shows that, if the 9,000-foot level had been used as the datum for the computations, then the average elevation of the United States, with reference to that datum, would be 11,500 feet and the average departure from complete isostasy on the 10 per cent basis would be 1,150 feet.

It does seem, however, that we are justified in saying that, for the area of the United States, the unit columns for any one of the areas considered by Hayford have, on an average, within 10 per cent of the topography above sea level, the same amount of material as the columns with normal densities, a unit column at the seacoast with the elevation of the surface of the column at mean sea level being assumed to have normal volume and densities. This statement appears to be in accordance with the facts and is entirely independent of the datum used for the computations of the effect of topography and isostatic compensation. It avoids the question raised by McMillan as to what would be the percentage of completeness of isostatic compensation if we should lower the datum surface to 9,000 feet or to some other distance below sea level.

It must be admitted that mean sea level is an arbitrary datum for isostatic computations, but McMillan's depth of 9,000 feet below mean sea level is not entirely logical. The writer believes [17] that the most logical datum is one which, after all of the water of the oceans has been condensed to the normal surface densities of the solid material of the earth, approximately 2.7, has as much volume above it, occupied by material, as below this surface, unoccupied.

After all is said in favor of one or the other plane of reference we find that it makes very little difference in our conclusions in regard to the theory of isostasy what datum is used. All that we are striving for is to learn what is the condition of the material in what Willis has very aptly called the "isostatic shell." Mean sea level is as good as any other reference surface, and it has the great advantage that all elevations shown on maps and the depths of the oceans are referred to it.

In the isostatic investigations an attempt is made to weigh by indirect methods the differences in mass between different parts of the earth's crust, each part having the same cross section at sea level. These derived differences will be the same regardless of the datum used.

DETERMINATION OF THE DEPTH OF ISOSTATIC COMPENSATION.

The theory of isostasy postulates a depth within which the compensation takes place. If a state of isostatic equilibrium exists, then there must be a limit to the outer materials of the earth which are in a state of stress due to the unequal elevations of the earth's surface.

Henry S. Washington has made a distinction between the "depth of compensation" as derived from geodetic data and the depth at which loads on equal areas are the same. The latter he calls the "isopiestic depth." The two depths are not necessarily the same unless we should define the "depth of compensation" as that one to which the deepest compensation extends.

It is probable that the compensation in some blocks of the earth's crust extends to a greater depth than in others. It is impossible to determine the depth of compensation for each topographic feature of limited extent, as the deflections of the vertical and the gravity anomalies are undoubtedly due, in part, to other causes than the depth to which the compensation extends. Some of these other causes are: The way in which the compensation is distributed horizontally with respect to the feature; the way the compensation is distributed vertically, whether uniformly or irregularly; the deviations from normal densities of the materials within a few miles of the surface; the degree to which the region may deviate from the perfect isostatic state; deviations of the densities of the material of the topographic feature from that used in the reductions; and, lastly, though negligible, the errors of the geodetic

[17] This view was advanced to the writer by W. D. Lambert, mathematician of the U. S. Coast and Geodetic Survey.

observations. It may be readily seen that this array of causes of uncertainty makes the depth of compensation derived for a small area of doubtful value.

The depth of compensation resulting from investigations by the U. S. Coast and Geodetic Survey is based upon a consideration of the deflection stations and the gravity stations over extensive areas. An average value has thus been derived for each class of geodetic data.

In his second report on the figure of the earth and isostasy[18] Hayford used all deflection stations available at the time in the United States. His value of the depth of compensation was 122.2 kilometers.

The writer derived two values for the depth of compensation by using, first, all the gravity stations in the United States, and, second, only those in mountainous regions. The first depth is 60 kilometers and the second 95 kilometers. Hayford also obtained a depth of 97 kilometers from deflection stations in mountainous regions, but he did not consider this value as reliable as the larger one of 122.2 kilometers.

As the depth of compensation derived from mountain gravity stations was 95 kilometers and Hayford's corresponding depth was 97 kilometers, the writer has adopted the mean of 96 kilometers as the most probable depth.[19]

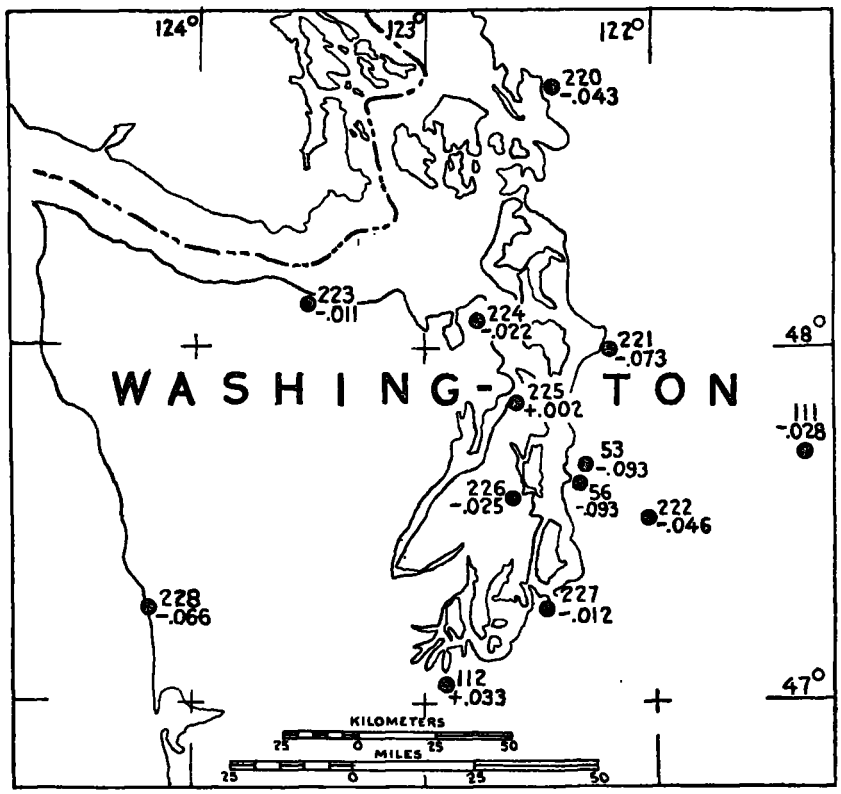

FIG. 4.—Gravity stations near Seattle, Wash.

Why, it may be asked, should a value for the depth of compensation derived from a small amount of data be considered more reliable than from a much greater amount? A careful consideration of the conditions will show why the value derived from stations in regions of considerable elevation is more reliable.

Aside from the local causes of deflection and gravity anomalies enumerated above there are the following causes having a general or regional effect: (1) Errors in the assumed figure of the earth for deflection anomalies and in the shape of the earth for the gravity anomalies; (2) error in the value of gravity at the equator as used in the computations; and (3) regional deviations from the condition of perfect equilibrium.

The effect of each of the first two general or regional causes of deflection and gravity anomalies can be eliminated. The effect of the third general cause and that of each of the numerous local causes are present in the remaining anomalies which are used in deriving the depth of compensation.

Let us consider some of the large gravity anomalies. At Seattle (see fig. 4) the anomaly is −0.093 dyne, while the elevation of the station is only 190 feet. At a gravity station just 20 miles west of Seattle the anomaly is −0.025 dyne. At a station about 25 miles northwest of Seattle the anomaly is +0.002 dyne. The great differences in these anomalies are certainly

[18] Supplementary investigation in 1909 of the figure of the earth and isostasy, 1910.
[19] See U. S. Coast and Geodetic Survey Special Publication No. 40, p. 133.

due to local causes close to the surface and not to an erroneous distribution of the compensation. There is practically no topography to be compensated.

There are two gravity stations on or near Damon Mound, Tex. (Nos. 311 and 313, in the table on p. 58), which are only 7 miles apart, and their anomalies differ by 0.045 dyne. (See fig. 5.) The elevation of these stations is less than 70 feet, and they are on a coastal plain. It is certain that here the cause of the large difference in the anomalies is local and near the surface.

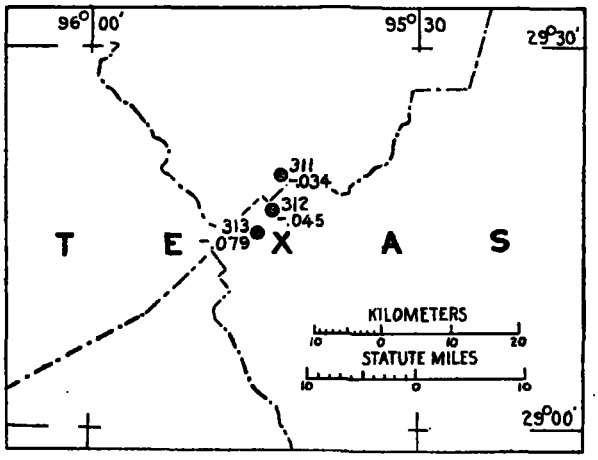

FIG. 5.—Gravity stations at Damon Mound, Tex.

The anomaly at Compton, Calif., is −0.050 dyne, while at Long Beach, only 8 miles distant, the anomaly is −0.022 dyne. (See fig. 6.) The difference is 0.028 dyne. Here, again, the cause of the anomalies is local and high in the crust, for the elevations of the stations are less than 70 feet, and no distribution of the compensation of so small an amount of topography close to the stations could affect the anomalies materially. Many other cases could be cited, and we must consider the evidence given under the heading "The relation of gravity anomalies to deviations from normal densities in local materials," pages 24 to 33. It is shown there that the abnormally light material of the Cenozoic formations is the cause of at least a part of the anomalies at gravity stations on that formation. The elevations of the gravity stations on that formation are all small. It is impossible to greatly reduce the anomalies at the Cenozoic stations by using a different depth of compensation

Now, let us consider the gravity stations at high elevations. Here there is a great amount of topography with a corresponding amount of compensation. Even though a part of an anomaly may be due to the local causes near the surface, a change in the depth of compensation will have a decided effect on the size and sign of the anomaly. For instance, the anomalies at Pikes Peak for no compensation, and for depths of 42.6, 85.3, 127.9, and 184.6 kilometers are, respectively, −0.204, +0.057, +0.032, +0.019, and +0.006 dyne. For the Seattle station the anomaly for no compensation is −0.111 dyne, while it is −0.093 dyne for 113 kilometers. The Pikes Peak anomaly varies as the depth of compensation is changed, while there is practically no change in the anomaly at Seattle.

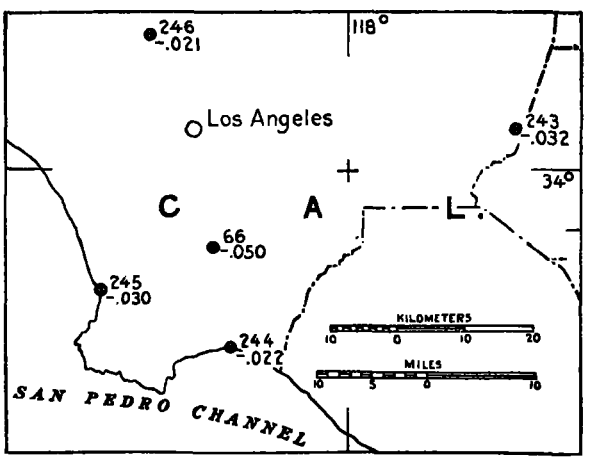

FIG. 6.—Gravity stations near Compton, Calif.

It is readily seen from the above discussion that a depth of compensation obtained from gravity data at low stations only would be indeterminate, while a depth derived from a combination of low and high stations will be much in error. To obtain any depth of a high degree of probability from the gravity data, we must use only gravity stations in high regions with irregular surfaces.

Even gravity stations on an extensive high plateau are not suitable for this purpose, for a change in the depth of compensation does not materially change the anomaly. This is due to the fact that a given mass of very great horizontal extent and of uniform density and thickness will exert the same attractive force on a particle (the gravity pendulum for instance), regardless of the distance of the particle from the surface of the material, provided this distance is much less than the horizontal dimensions of the mass. This same principle holds should

the same mass be expanded to occupy a greater volume. (See fig. 18.) The problem of obtaining a depth of compensation from only plateau stations is thus indeterminate. The more extensive the plateau and the more uniform its elevation the more indeterminate the problem. Take, for instance, the anomaly at station Wallace, Kans., No. 41 of the table on page 103, of Special Publication No. 40. The anomaly does not change when the depth of compensation is changed from 42.6 to 184.6 kilometers.

It is reasonable to assume that the depth of compensation which enables us to obtain the smallest gravity and deflection of the vertical anomalies in mountainous regions is the most probable one. The depth of 96 kilometers, which is the mean of the depths derived from deflection and gravity data at mountain stations in the United States, accomplishes this and is the one believed to be the best now available. It is hoped that data may soon be available in other countries when a new depth may be computed. With more data the depth obtained will, of course, have greater probability.

What does the "depth of compensation" mean? On the theory that the compensation is complete, is distributed uniformly with respect to depth, and is distributed within a limited distance horizontally from the topographic features or directly under them, then the derived depth of compensation is the average distance below sea level to which the compensation of the whole region considered extends. This depth may not be correct for any other extensive region, though it seems reasonable to infer that it will be.

As the "depth of compensation" derived from geodetic data is the average depth to which the isostatic compensation extends, it must be true that the isopiestic depth, or the one at which pressures are equal, is somewhat greater. The difference in these depths is not known, but it probably is not great.

It should be noted here that although 96 kilometers is now considered the best value for the depth of compensation, the value of 113.7 kilometers was used in computing the isostatic anomalies in this publication, as in previous gravity publications. As the use of the more recent value of the depth of compensation would change the anomalies by only very small amounts it seemed desirable to compute the anomalies on the same basis as those in previous publications.

RELATION OF GRAVITY ANOMALIES TO TOPOGRAPHY.

If the earth were rigid with land masses as overloads on the crust and with the deficiencies of mass in the oceans as underloads, the gravity anomalies on this theory would be the same as the attractive effect of the masses above sea level, diminished by the negative attractive effect of the ocean deficiencies of mass.

The isostatic gravity anomalies are, on an average, only 15 per cent of what the anomalies would be if the earth were considered rigid. This is the most important fact resulting from the isostatic investigations, for it shows that the earth's crust is very nearly in complete isostatic adjustment.

In the Bouguer method of reducing gravity data no account is taken of the isostatic compensation. The average and maximum Bouguer and isostatic anomalies in the United States are given in the following table:[20]

	Number of stations or groups.	Average without regard to sign.	Average with regard to sign.	Maximum.
		Dyne.	*Dyne.*	*Dyne.*
Bouguer anomalies	296	0.048	−0.036	0.229
Isostatic anomalies	296	.021	−.006	.093

Of the 296 anomalies 208 of the Bouguer are negative and 87 are positive, but of the isostatic 168 are negative and 126 positive. The average Bouguer anomaly with regard to sign is −0.036, but the isostatic is only −0.006. This is strong evidence in favor of the theory of isostasy.

[20] Each of four groups of stations were treated as a single station by taking the mean anomaly for the group.

A very severe test of the theory of isostasy is given by the relation of the anomalies to the elevations of the stations. This test shows whether the anomalies are different for the various topographic conditions. In the following table are given the average Bouguer and isostatic anomalies in the United States for various elevations:

Elevation in meters.	Number of stations or groups.	Average Bouguer anomalies.		Average isostatic anomalies.	
		Without regard to sign.	With regard to sign.	Without regard to sign.	With regard to sign.
		Dyne.	*Dyne.*	*Dyne.*	*Dyne.*
0 to 400	213	0.027	−0.010	0.022	−0.010
401 to 800	32	.039	−.037	.018	+.011
801 to 1,200	16	.104	−.104	.022	−.004
1,201 to 1,600	15	.128	−.128	.022	+.010
Over 1,600	20	.184	−.184	.014	+.003

We find very nearly the same values for the average isostatic anomalies for the five groups of elevations. On the other hand, the Bouguer anomalies have a very definite relation in size and sign to the elevation. This test is strongly in favor of the isostatic theory.

RELATION OF GRAVITY ANOMALIES TO AREAS OF EROSION AND SEDIMENTATION.

There seems to be no relation between the size and sign of the isostatic gravity anomalies and areas of erosion. There may, of course, be areas of erosion in which gravity anomalies tend to be of one sign, but in such areas the anomalies are comparatively small and there is no general relation whatever that can be discovered.

On the other hand, there is a decided relation between the areas of recent deposition and the gravity anomalies, and in this group of areas is included all of the Cenozoic formation. For some years it was believed that there was a definite relation between the isostatic gravity anomalies and the margins of continents due, in some way, to conditions existing along the coast that did not obtain in the interior. It was later found that a very simple explanation could be made of these coastal anomalies, namely, that the material along the margins of the continents is mostly of recent formation with density from 10 to 20 per cent less than normal. This light material, nearly all below sea level and immediately below the gravity stations, has an attractive force which is less than that of material of normal density. This explanation was advanced by the writer in Coast and Geodetic Survey Special Publication No. 40 and has been accepted by other geodesists, notably Col. Sir Sidney Burrard, former superintendent of the Trigonometrical Survey of India.

In a recent publication [21] by Colonel Burrard, entitled "Investigations of Isostasy in Himalayan and Neighbouring Regions," he gives the results of certain computations made to show the effect of a volume of light material close to a gravity station and to show what amount of sedimentary material would be required in the vicinity of gravity stations on the Indo-Gangetic plain to account for the deficient force of gravity at nearly all the stations on that plain. As a result of his investigations Colonel Burrard concludes that the column under the Indo-Gangetic plain is probably in isostatic equilibrium, and that the abnormally small values of gravity are due almost entirely to the presence of the Cenozoic material close to the surface.

We may safely conclude that the rather decided relation between the areas of deposition and the gravity anomalies can be explained by the presence of lighter material, and that the negative gravity anomalies on the Cenozoic formation are not indications of departures from the isostatic condition.

PREDICTION AS A TEST OF THE THEORY OF ISOSTASY.

In a recent article,[22] entitled "A brief review of the evidence on which the theory of isostasy is based," Colonel Burrard brings out a number of interesting points in connection with the subject. He shows how the isostatic method of reducing gravity observations for topography

[21] Professional Paper No. 17, Trigonometrical Survey of India.
[22] The Geographic Journal, Royal Geographic Society, London, July 1920, p. 47.

and compensation enables one to predict with considerable accuracy the value of gravity at any particular station, and he shows that this can not be done by any other method.

If we can predict the value of a deflection of the vertical or the value of gravity at a station and find when the observations are made, a difference between the predicted and observed values, or an anomaly, only 10 or 15 per cent as large, on an average, as it would have been if the prediction had been made with the rigid-earth theory, then we may say that we have arrived at a theory that is workable and reasonable. The methods adopted by the geodesists can stand the test of prediction. Some other method not yet formulated may do equally well, but it can not depart materially from the one now in use.

GRAVITY OBSERVATIONS OVER THE ARCTIC OCEAN.

The North Polar Expedition of 1893–96, under Dr. Fridtjof Nansen, determined the value of gravity at 10 places on the Arctic Ocean. Observations at these stations were made while the ship was frozen in the ice, with the half-second pendulum of modern type and according to approved methods, except that the pendulums were in no case swung for more than 45 minutes for each of from one to seven determinations at a station. No local time observations were made for the control of the rates of the chronometers which were used to get the period of the pendulums.

It is probable that there are actual errors of from 0.020 to 0.050 dyne in the values of gravity given in the published results,[23] owing to the difficult conditions under which the observations were made. At the same time the mean value of the gravity anomalies for Nansen's 10 stations over the Arctic is only −0.037 dyne and the mean without regard to sign is only 0.048 dyne. No isostatic reduction was possible for these stations, as the configuration of the bottom of the Arctic Ocean is not known. It is probable, however, that the isostatic reduction would not change the values materially, provided the bottom of the ocean, under the points where the gravity observations were made, is comparatively level. On the other hand, if the ocean bottom is very irregular, the isostatic reduction might make a change of as much as 0.050 dyne. The mean value of the gravity anomalies for the Nansen stations would seem to indicate that the earth's crust under the portion of the Arctic over which the observations were made is in isostatic equilibrium to a marked degree.

The computed and the observed values of gravity in the Arctic indicate also that the Coast and Geodetic Survey gravity formula applies to high latitudes. This formula is given in U. S. Coast and Geodetic Survey Special Publication No. 40, Investigations of Gravity and Isostasy, page 134.

RELATION OF GRAVITY ANOMALIES TO DEVIATIONS FROM NORMAL DENSITIES IN LOCAL MATERIALS.

A well-defined relation between gravity anomalies and the densities of materials near gravity stations on certain geologic formations was recognized some time ago. The first mention of this, so far as the author is informed, is contained in Special Publication No. 10 of the U. S. Coast and Geodetic Survey.[24]

In the study of the possible relations existing between the gravity anomalies and geologic formations it was found that there existed a strong tendency of the anomalies at pre-Cambrian stations to be positive in sign and for the anomalies at Cenozoic stations to be negative. In the above report it was said:

> The evidence of correlation between the prevailing signs of new method (isostatic) anomalies and the geologic formations on which the stations stand which has here been set forth is weak in certain respects. It deals with present surface geology only, as seen in large areas on a small-scale geologic map. A thorough study of the evidence should deal with past as well as present surface geology, should deal with the subsurface geology taking into account as far as possible the thickness of the strata of various formations, and possibly also the details of the geology in the immediate vicinity of the station should be considered.

[23] The North Polar Expedition, Memoir 8, vol. 2, p. 69.

[24] J. F. Hayford and William Bowie, The Effect of Topography and Isostatic Compensation upon the Intensity of Gravity, 1912.

Nevertheless, it is believed that further evidence will support the generalization now made for the United States that at stations in pre-Cambrian areas gravity tends to be in excess and at stations in Cenozoic areas tends to be in defect. The first case corresponds to excess of mass or under compensation of topography for all land stations, and the second case to defect of mass or overcompensation of topography for all land stations.

In general, pre-Cambrian formations are of greater density than Cenozoic formations. Hence, the correlation noted is of the character to be expected if one considers that surface densities—that is, the density of masses near the station— have more influence over gravity at the station than the density of masses lying deeper and therefore farther from the station.

It was also stated:

Measured in terms of strata of normal density the excess of mass in pre-Cambrian areas corresponds on an average to a stratum somewhat more than 600 feet thick and the defect of mass in the Cenozoic areas to a stratum somewhat less than 400 feet thick.

While the authors of Special Publication No. 10 detected the relation of the gravity anomalies to the Cenozoic and pre-Cambrian formations, they did not fully realize at the time that the anomalies might be explained by deviations from normal densities in the local material. The following extract from page 121 of Special Publication No. 10 would indicate that they felt the anomalies were probably due to local deviations from a perfect isostatic condition:

Attention has been concentrated in the preceding paragraphs on the departures from perfect isostatic compensation, partly to ascertain how close an agreement there is between the evidence from the two kinds of observations, partly because these departures, slight as they are, may furnish a basis for future studies of the process of isostatic readjustment, and partly for the purpose of ascertaining whether they indicate any systematic errors in the processes of logic and computation used. This concentration of the attention on the departures must not be allowed to obscure the fact that the most significant thing about them is their smallness. Though the average elevation in the United States above sea level is 2,500 feet, the departures from complete compensation as measured by the gravity anomalies are represented by strata of which the maximum thickness is 3,200 feet, corresponding to the defect of gravity at Seattle, and of which the average thickness is only 570 feet.

In Special Publication No. 12[25] which appeared shortly after Special Publication No. 10, the author called attention to the fact that the anomalies at Cenozoic and pre-Cambrian stations tended to be systematic in sign. It was realized that the cause might not be altogether a departure from the perfect state of isostatic equilibrium. The following is quoted from page 21 of Special Publication No. 12:

In general, the rocks of the oldest formations have greater densities than 2.67, the adopted mean value for the surface density of the earth, and this fact may lead one to conclude that the gravity should be greater on these formations; but it will appear on reflection that these can not be merely surface phenomena.

Let it be assumed that the pressure at the depth of 113.7 kilometers under a station of the oldest formations is normal (that is, the crust is in a state of perfect isostasy), and let it be assumed that the average anomaly with regard to sign of +0.024 is caused by an erroneous assumption regarding the surface density. Then, if the formation considered extends 19 kilometers in every direction from the station and to a depth of 1,000 feet, an increase in density of 2.06 would be necessary to cause an anomaly of +0.024. With the same radius but a depth of 10,000 feet the necessary increase of density would be 0.20.

The maximum anomaly in the oldest formation is +0.052, and this could be caused by an increase in density of 0.43 in a disk of material about the station with a radius of 19 kilometers and a depth of 10,000 feet.

To cause the maximum negative anomaly of −0.093 at Seattle would require a decrease of density of 0.82 in the material of a disk 10,000 feet thick and a radius of 19 kilometers directly under the station.

From the considerations stated above it seems probable that the excesses and deficiencies of mass which cause the largest of the anomalies can not be surface phenomena alone, and that such excesses and defects must extend through depths at least as great as 15,000 feet. There is no conclusive evidence from gravity observations to indicate whether the anomalies of the average size are caused by difference between the actual and the assumed density of the earth's surface material near the station or whether such anomalies are caused by an actual departure from a state of complete isostasy.

Views similar to those expressed in the preceding paragraph are contained in an article published in 1912.[26]

While making the investigations reported in U. S. Coast and Geodetic Survey Special Publication No. 40 the author reached the conclusion that a gravity anomaly does not necessarily indicate a local departure from the perfect isostatic state, but that the anomaly may

[25] William Bowie, Effect of Topography and Isostatic Compensation upon the Intensity of Gravity, Second Paper, 1912.

[26] William Bowie, "Some relations between gravity anomalies and the geologic formation in the United States," American Journal of Science, March, 1912.

be due to the deviations from normal density in the material close to the affected stations. As this publication may not be readily available to the reader, it seems desirable to make the following quotations from it:

Under the heading "Anomalies in pre-Cambrian formations," on pages 72 and 74, are these paragraphs:

If the density of the upper strata of the earth's crust for large distances (horizontal) from the stations is above normal, then the effect of this greater density, which will tend to increase the gravity, will be offset by the opposite effect of the compensating deficiency of density in the deeper crust. This is due to the fact that the effect of a certain amount of material in the form of a disk of infinite horizontal extent is the same on a unit mass of matter whether the unit mass is immediately above the surface of the attracting matter or at an indefinite distance above it. Therefore, if we should have a stratum or mass of pre-Cambrian material of density 2.90 at the earth's surface directly under the station and of great or infinite extent horizontally it would have the same attractive effect on the unit mass as if this matter were distributed through a great vertical distance but had the same horizontal extent. Therefore, if the dense material at the surface were compensated for by a deficiency of density in the lower crust, the positive effect of the former would be exactly counter-balanced by the negative effect of the compensation. Hence, we should not expect a decided positive anomaly at a pre-Cambrian gravity station should the formation be of uniform thickness and of great horizontal dimensions. This statement is based upon the assumption, which may be substantially true, that the area in question is in a state of perfect isostatic equilibrium at the depth of compensation.

If, however, the area of denser material is limited in horizontal extent, then the effect of the added material, being inversely proportional to the square of its distance from the attracted unit mass, will be greater than the negative effective of the compensation. Therefore, if there is a compensating lack of density in the lower crust, the resultant effect will be positive and we should have a positive gravity anomaly. The size of the anomaly will depend upon the thickness of the stratum of pre-Cambrian rock, its density, its horizontal extent, and the vertical location of the compensation.

It should be borne in mind that in making the gravity reductions no numerical values are given for the densities in the earth's crust below sea level. It is assumed that the densities in the crust under the coastal plane at sea level for the various strata are normal, and that these densities are modified by the isostatic compensation under the topography of the interior of the continents and under the oceans. It is only the deviations from the normal densities in the crust below sea level which are considered in these investigations.

If there were many gravity stations on and near a limited area of pre-Cambrian formation, it might be possible to estimate from the results the approximate limits of the space within which the densities were above normal; but it must be borne in mind that the problem of determining exactly the space or spaces within which there are abnormal densities which might cause the anomalies is not susceptible of mathematical solution. This is because there are too many unknowns which would enter into any equations used and arbitrary assumptions would have to be made. Of course, the problem can be treated mathematically and with greater numbers of stations in any given area the truth can be more closely approximated.

It seems to be evident that the anomalies are not due simply to an assumed erroneous density of the mass above sea level, for at a number of pre-Cambrian stations the elevation above sea level is less than 1,500 feet, and the maximum effect of a change in the density of 10 per cent in that mass would be only 0.005 dyne. The cause of the anomaly must, therefore, be located to a large extent below sea level in nearly all cases.

It is no doubt true that the deep-seated rocks have densities comparable with those of the pre-Cambrian rocks seen at the surface, but the cause of the anomaly at pre-Cambrian stations seems to be due largely to the dense rock protruding through the materials of the upper crust which are of less density.

The author does not mean to state that the whole of any anomaly is due to the geological formation, for there is probably in many cases a local lack of perfect isostasy which may produce deviations from the normal gravity.

It is a noteworthy fact that the pre-Cambrian stations in the United States show an excess of gravity in general, and that they are on areas which have been subjected to erosive action for geological ages. We may conclude that as erosion has taken place there has been a rising of the areas due probably to isostatic adjustment.

The following paragraphs are from pages 76 and 77 of Special Publication No. 40, under the heading "Anomalies on Cenozoic Formations":

If the Cenozoic formation of small density is small in horizontal dimensions, and if there is perfect local isostasy, the effect of the light material in the upper crust and near the surface would be much greater than the opposite effect of the compensating increase in density in the lower crust. The cause of the large Cenozoic anomalies must be local, for there are decided differences in the size of the anomalies at pairs of stations which are comparatively close togther.

It appears from the evidence above that we may gain from the negative anomalies of the Cenozoic formations some idea of the depth of the Cenozoic material at a station, and where there are many stations in any given locality of Cenozoic formation we may get an approximation to the horizonal limits of the affected spaces. For instance, it is reasonable to conclude that if the Virginia Beach anomaly is caused by a thick stratum of material of light density, and that if this stratum extends to Crisfield, it is considerably thinner at the latter station. The reasoning employed in the discussion of pre-Cambrian anomalies on pages 72 to 74 (quoted above) would indicate that the large Cenozoic anomalies must be due largely to local causes, if it is assumed that an area under investigation is in a state of perfect isostatic equilibrium.

There is evidently a definite relation between the coasts and the gravity anomaly, but it may be due to the presence of Cenozoic materials which extend along practically all of the coasts. The cause of the difference in the size of the anomalies at different stations may be due to the varying thickness of the material and the varying horizontal dimensions of thick and thin strata.

That the Cenozoic areas are undercompensated, as the negative anomalies might indicate, does not seem to be true, for the reason that these areas are areas of deposition in recent times, and the areas have probably been sinking during the time when materials were accumulating on them. This deposition of material would lead one to suppose that the crust under such areas is heavier than normal. Undercompensation therefore appears to be improbable. The writer is aware that there may be even in areas of heavy deposition sections which are undercompensated, but this would be due to conditions existing before deposition began.

In Special Publication No. 40 data for 73 gravity stations in India are used. Of these 8 are on pre-Cambrian and 31 on Cenozoic formations. For many years the negative gravity anomalies at stations in India had been considered as indicating a lack of isostatic adjustment, but the author felt that another interpretation could be given, as is indicated by the following extracts from page 82 of Special Publication No. 40:

Many of the Cenozoic stations in India are in areas to which great quantities of material have been carried from the Himalaya Mountains. It is probable that the larger Cenozoic anomalies are above portions of the crust where the recent material is thick and of limited horizontal extent.

It has been held by some geodesists in India[27] that there is probably a rift in the earth's crust where the large, negative anomalies exist. The evidence at hand makes it possible to account for the anomalies by the Cenozoic formation in the affected area.

Of course, it is probable that in India, as in other countries, there are local, and in some areas regional, departures from a state of perfect isostasy, but as evidence in the form of gravity stations accumulates the theory of isostasy is given added strength.

The summaries on pages 72 and 81 (Special Publication No. 40), which gives evidence for stations in the United States and in India, respectively, point strongly to rather definite relations between the sign of the anomaly and the surface geology at the station. This relation may be due to variation from the normal density for strata in the upper crust, these abnormal densities being compensated for by a counterbalancing change in density occurring in the lower crust, possibly to the depth of compensation.

The views of the author regarding the gravity anomalies in India attracted the attention of Colonel Burrard, who was then superintendent of the Trigonometrical Survey of India, and he made a very careful investigation of the effect of local deviations in density on the values of gravity.[28]

Having in mind the probable effect of local conditions of density on the gravity anomalies, additional gravity stations were established by the Coast and Geodetic Survey near the stations at Minneapolis, Minn.; Seattle, Wash.; and Compton, Calif.

The station at Minneapolis is on Paleozoic surface material and has an anomaly of +0.059 dyne. Only one larger positive anomaly has been found in the United States. The stations on the Paleozoic formation do not in general have excessively large anomalies.

Figure 8 shows the locations of the stations near Minneapolis and their anomalies. Additional data regarding them may be found in Special Publication No. 40.

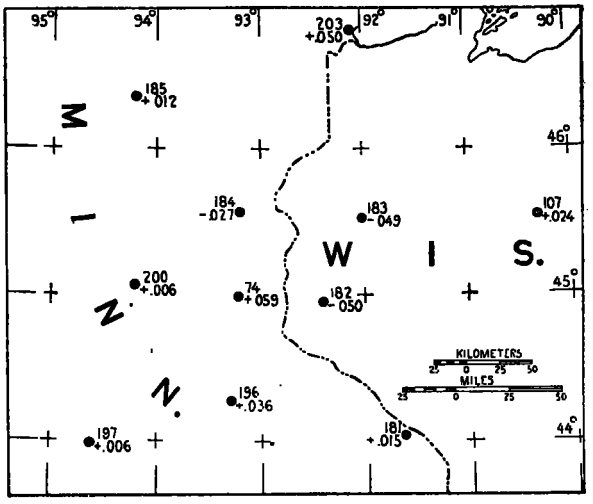

FIG. 8.—Group of gravity stations in Wisconsin and Minnesota.

The anomalies clearly indicate a cause which is local and in the outer portion of the crust. If the cause were a regional departure from the isostatic state there could not be such great differences in the anomalies at stations so close together, and if the cause were deep-seated the anomalies would be of the same sign and of like size.

[27] Col. Sir Sidney Burrard, On the Origin of the Himalaya Mountains, Survey of India. Prof. Paper No. 12, p. 5.

[28] Col. Sir Sidney Burrard, Investigations of Isostasy in Himalayan and Neighboring Regions, Survey of India. Prof. Paper No. 17, Dehra Dun, 1918.

The station at Compton, Calif., has an anomaly of −0.050 dyne, while the anomaly at station No. 244, about 10 miles to the south, is −0.022 dyne. At station No. 245, only 11 miles west of Compton, the anomaly is −0.030 dyne. The stations surrounding Compton are shown in Figure 6.

The Seattle (Wash.) stations, each with a gravity anomaly of −0.093 dyne, have attracted the attention of geophysicists and geologists. These anomalies were first discussed in Special Publication No. 10.[29] The authors of that report believed that these very large anomalies indicated a decided departure of the surrounding region from the isostatic state. In order to localize the disturbed area, a number of stations were established near Seattle. They are shown with their anomalies in Figure 4.

The noteworthy fact in connection with these stations is that at station No. 225, only 25 miles northwest from Seattle, the anomaly is +0.002 dyne. The anomalies at this group of stations indicate clearly that the abnormal densities extend along the eastern shore of Puget Sound, and that to the west the disturbance is slight or nonexistent. The abnormal densities must be near the surface, for otherwise the anomalies at stations close together could not be so different in size. At Olympia the anomaly is +0.033 dyne, which indicates that the cause of the negative anomalies of the stations along the eastern shore of Puget Sound does not extend so far south. The Puget Sound area has been subject to recent sedimentation, and the light density of the sediments is probably the cause of the negative anomalies.

The large anomalies near Minneapolis, Minn., Compton, Calif., and Seattle, Wash., can be explained by the presence of abnormal densities near the stations, and we do not have to resort to a lack of isostatic equilibrium. The author has discussed this subject at some length in recent papers.[30]

Burrard has asked how lighter material can take the place of heavier material in areas of sedimentation. The answer seems to be that it does so only to a certain extent. It is the writer's opinion that there is a down warping due to a contraction of the materials in the block of the earth's crust independent of the sediments. This contraction must continue during sedimentation in order that the block may remain in isostatic equilibrium. The sediments will push the original material down, and a mass equal to that of the sediments will move laterally from the lower end of the column, but it will be of a smaller volume than that of the sediments. Hence, if there were no increase in the density of the original material the sediments would soon be piled up so high that deposition would cease. This matter is discussed by the author in the two papers referred to in the footnote below.

---

[29] See footnote on p. 24.

[30] "The relation of isostasy to uplift and subsidence," American Journal of Science, July, 1921; "The earth's crust and isostasy," The Geographic Review, October, 1922.

GEOLOGIC FORMATION AT GRAVITY STATIONS.

There are given in the following table the geologic formation and the anomaly for each of 78 new stations or groups of stations in the United States. Similar tables are given in Special Publication No. 40 for 218 stations in the United States and for others in Canada and India:

Geologic formations and anomalies for 78 stations or groups in the United States.

Formation and station number.	Isostatic anomaly.	Formation and station number.	Isostatic anomaly.	Formation and station number.	Isostatic anomaly.
Pre-Cambrian formation:	*Dyne.*	Mesozoic formation—Continued.	*Dyne.*	Cenozoic formation—Continued	*Dyne.*
269	+0.042	309	−0.003	250	−0.081
272	+.046	310	−.012	251	−.037
276	+.022			252	−.029
300	+.020	Cenozoic formation:			
		220	−.043	253	−.030
Paleozoic formation:		221	−.073	255	−.050
234	+.010	222	−.046	257	−.029
260	−.006	223	−.011	271	−.008
261	+.004	224	−.022	277	−.030
262	+.010				
263	+.007	225	+.002	278	−.032
		226	−.025	279	−.018
264	−.004	227	−.012	280	+.019
296	−.024	228	−.066	281	+.014
297	−.038	229	−.007	282	+.012
298	−.022				
299	−.032	230	+.027	283	−.026
		231	+.009	284	+.002
301	+.063	232	+.008	285	−.022
302	−.008	233	+.005	286	−.014
{303	+.010}	235	.000		
{304	+.019}			{306	+.003}
{305	−.011}	236	−.012	{307	−.002}
		238	−.048	{308	+.007}
Mesozoic formation:		240	−.031	{311	−.034}
237	−.042	241	−.014	{312	−.045}
259	−.032	242	−.053	{313	−.079}
265	−.038				
266	−.020	243	−.032	Intrusive formation, 258	−.019
267	−.018	{244	−.022}		
		{245	−.030}	Unclassified:	
268	+.009	246	−.021	239	−.028
270	+.029	247	−.030	254	−.030
273	−.014			256	−.019
274	−.020	248	−.039		
275	−.006	249	−.062		

NOTE.—Each of the four groups, indicated by braces, was used as a single station by taking the mean anomaly for the group in obtaining the summaries below. The two Seattle stations were also treated as a group for the second summary on page 30.

A summary of the data of the above table is given below. One of the stations has a zero anomaly

Summary.

Geologic formation.	Number of stations—			Mean anomaly—	
	With plus anomalies.	With minus anomalies.	Total.	With regard to sign.	Without regard to sign.
				Dyne.	*Dyne.*
Pre-Cambrian	4	0	4	+0.032	0.032
Paleozoic	6	7	13	−.003	.018
Mesozoic	2	10	12	−.014	.020
Cenozoic	10	34	45	−.023	.027
Intrusive	0	1	1	−.019	.019
Unclassified	0	3	3	−.026	.026
Total and mean	22	55	78	−.015	.025

There is given below a general summary for all of the stations used in this and the previous report.

Summary for all gravity stations in the United States.

Geologic formation.	Number of stations—			Mean anomaly—	
	With plus anomalies.	With minus anomalies.	Total.	With regard to sign.	Without regard to sign.
				Dyne.	*Dyne.*
Pre-Cambrian	16	2	18	+0.022	0.025
Paleozoic	29	56	85	−.010	.021
Mesozoic	27	21	48	+.003	.018
Cenozoic	32	66	100	−.014	.023
Intrusive	2	6	8	−.014	.023
Effusive	2	6	8	−.005	.015
Unclassified	18	11	29	+.006	.022
Total and mean	126	168	296	−.006	.021

The added data in the preceding table and summaries strengthen the conclusions stated in Special Publication No. 40. Undoubtedly, there is a very definite relation in size and sign between the anomalies and the pre-Cambrian and Cenozoic formations.

Of the 127 stations having anomalies greater than the average, 0.021 dyne, 44 are on Cenozoic and 10 on pre-Cambrian. There are 32 stations having anomalies greater than 0.040 dyne, and 17 of these are on the Cenozoic and 4 on pre-Cambrian. The 8 largest negative anomalies are on the Cenozoic.

It is possible that there is a definite relation in sign between the Paleozoic anomalies and the geologic formation, for the summary shows 56 negative and only 29 positive anomalies on the

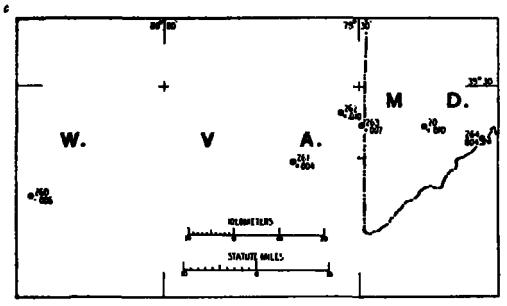

FIG. 9.—Group of gravity stations in Maryland and West Virginia.

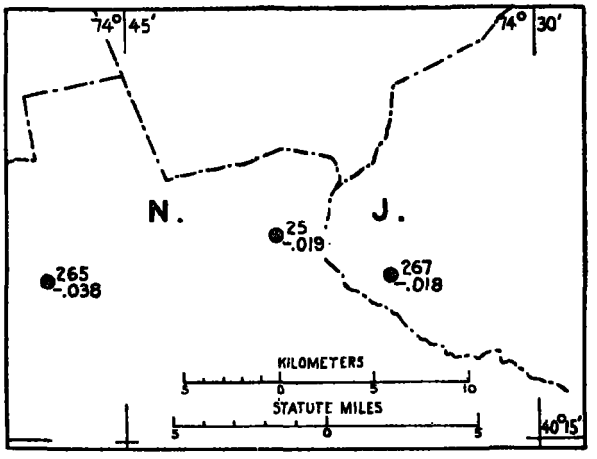

FIG. 10.—Group of gravity stations in New Jersey.

Paleozoic. Further gravity data may show whether or not the tendency toward negative anomalies will persist. There is no great deviation from normal densities in the Paleozoic materials such as are found in the Cenozoic and pre-Cambrian.

RELATION OF GRAVITY ANOMALIES TO EFFUSIVE AND INTRUSIVE GEOLOGICAL FORMATIONS.

There are only 16 stations in the United States on the intrusive and effusive formations, but it is interesting to note that 12 of them have negative anomalies. No definite conclusions should be drawn from so few data but it is significant that the anomalies indicate that the density of the crust under these stations is no greater than normal, and that a rather high degree of isostatic equilibrium exists. It is probable that as the earth's crust is solid and the earth itself has the rigidity of steel there is no great volume of liquid material from which effusive and intrusive rocks come to the surface. The outflow of material through fissures and through volcanic

vents are probably incidental to the expansion of the material of the earth's crust during the process of uplift. (See pp. 42 and 51.)

The intrusive and effusive material may come from a zone that is considerably above the depth of compensation. If this is so, the mere pouring out of deep-seated material at the surface of the earth does not increase the mass of the earth block extending to the depth of compensation. If a very deep-seated material—that is, material below the earth's crust—could be forced up in the liquid or plastic state through the earth's crust, then this would certainly indicate a crust too weak to have maintained mountain masses and adjacent low plains for geological ages.

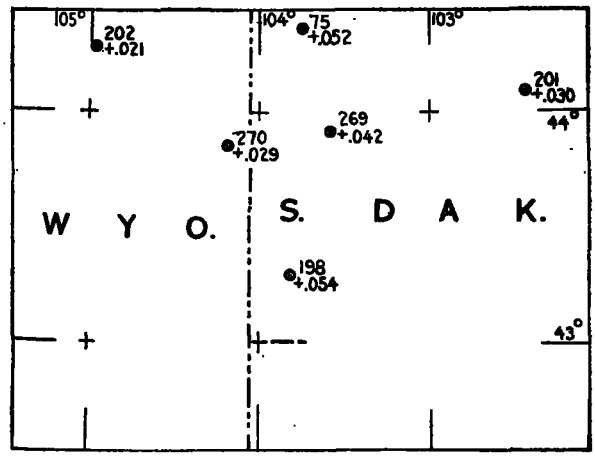

FIG. 11.—Group of gravity stations in Wyoming and South Dakota.

The processes involved in expanding a column under an area that has been subject to heavy sedimentation into one of uplift, which is considerably longer, may well be adequate to cause the outpouring of material. It is certain that the isostatic balance of the blocks of the earth's crust of the magnitude of 100 miles square must not be greatly disturbed in any processes that cause great changes in the elevation of the surface. Therefore, when a mountain mass such as we have on the island of Hawaii is formed by volcanic action, we must assume that this mass of material is due to the expansion of the material of the earth's crust. If it were not so, there would be the anomalous condition of a very weak earth's crust standing up under a tremendous overload.[30a] It is possible that where the resistance to the upward movement is very great, sufficient heat is developed to cause a lowering of the rigidity of the magmatic material. If the resistance to lengthening of a column of the earth's crust by decrease in density is sufficiently low, then an arching up of the area over the column might occur without evidences of vulcanism. The degree of vulcanism that is present in any particular region may be a function of the resistance to the expansion of the material of the earth's crust below.

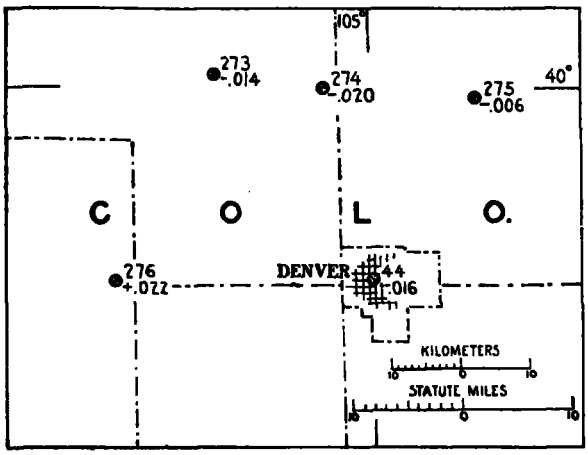

FIG. 12.—Gravity stations near Denver, Colo.

GRAVITY ANOMALIES NEAR THE PACIFIC COAST OF THE UNITED STATES.

For a number of years explanations have been sought for the anomalies, by the old methods of reduction, at gravity stations which are close to the continental coasts and especially where there is deep water very close to the coasts. The investigations in gravity and isostasy made by the Coast and Geodetic Survey prior to 1916 indicated that the whole of California, except a very small section in the southeastern part of the State, has a deficiency in gravity, but the gravity anomaly map showing this condition was constructed from only five stations in California.

[30a] The large positive anomalies in Hawaii do not indicate overloads but are undoubtedly due to the large densities of the rocks (about 3.00) as compared with the density 2.67 used in the computations. See H. S. Washington, "The density of the earth as calculated from the densities of Mauna Kea and Haleakala," Jour. Washington Acad. Sc., vol. 13, No. 21, Dec. 19, 1923, pp. 453-456.

Owing to the geological importance of the area of California, on account of the existence of active seismic regions, it was decided to make a rather intensive gravimetric survey over it. In the year 1916, 25 stations were established in that State, all of them within 90 miles of the coast and 12 of them within 5 miles of the coast.

At the time these stations were established it was not realized how intimately associated are the gravity anomalies and the geological formation. In consequence, we have the situation that all of the gravity stations in California except six are located on the Cenozoic formation. This formation, as is well known, is composed largely of materials which have densities somewhat less than 2.67, the normal surface density used in the isostatic investigations. It has been shown in Special Publication No. 40, and is shown in this publication, that the presence of light material close to a gravity station, but extending below sea level, will have a tendency to cause negative gravity anomalies even though the block of the earth's surface under the area in question may be in isostatic equilibrium. All of the new stations in California have negative anomalies.

A number of gravity stations in California were located as close to the San Andreas fault as practicable, in order to learn whether there could be found any relation between the fault and the gravity anomalies. As far as the writer can see, there is no relation whatever between the two. It is practically impossible to differentiate the several causes of gravity anomalies, at least where the anomalies are small. In order that gravimetric surveys may throw light on the cause of seismic disturbances, the stations should be closely grouped. It is the writer's belief that the negative anomalies of the California stations, most of which are located on the Cenozoic formation, do not indicate that the crust under the State, as a whole, is out of isostatic equilibrium. If the negative anomalies should be given their apparent interpretation—that is, that they indicate a lightness of the earth's crust in the region in question—then on an average the crust under the State would have a deficiency of mass equivalent to a disk of material of normal surface density, say 2.7, and 900 feet in thickness. The attraction of such a disk at a station near its surface would be 0.031 dyne, the average gravity anomaly for the State.

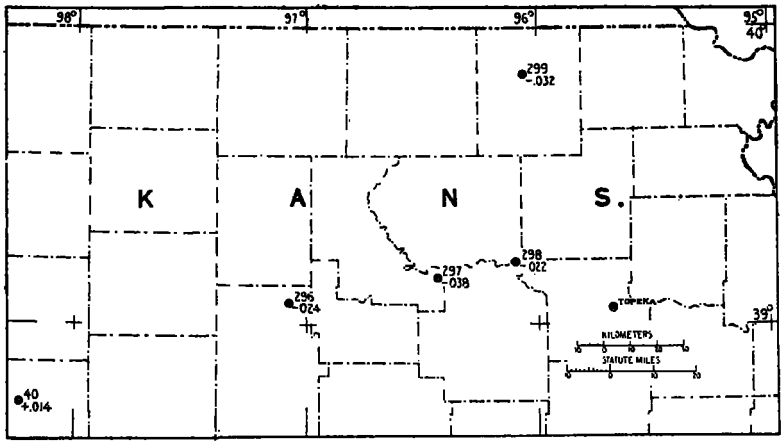

FIG. 13.—Gravity stations in northeastern Kansas.

As the gravity stations are practically all on the Cenozoic formation, it is rather improbable that there is an actual deficiency in density of the earth's crust under California. It seems more probable that the seismic disturbances in California are merely incidental to deformation of the crust resulting from either an uplift due to expansion of the crust below or to uplift in response to isostatic adjustment following erosion.

It may be possible to resume gravity observations in California in the not distant future and to establish stations on other formations than the Cenozoic. It seems especially desirable that a number of stations be located on the large area covered by the intrusive formation and on the outcrops of the pre-Cambrian.

Six new stations were established in western Oregon in 1916. Of these three are immediately on the coast and the others are inland at distances of from 50 to 60 miles from the coast. Five of the stations are on Cenozoic formation and one on Palaeozoic. Five of the stations have positive anomalies and one negative, but the positive anomalies in four cases are less than half the size of the average anomaly without regard to sign and the other one is only 0.027 dyne

The writer can not see any relation between the geological formation in western Oregon and the gravity anomalies except that, as in other places, if the anomalies on Cenozoic formations are positive they are, in all cases, quite small. In the United States and Canada the largest positive Cenozoic anomaly is 0.036 dyne.

Nine new stations were established in 1916 in the State of Washington, largely around the Puget Sound region. The object was to localize, as far as possible, the cause of the very large negative anomaly existing at each of two gravity stations at Seattle. The anomalies at these stations, each −0.093 dyne, are the largest isostatic gravity anomalies in the United States or Canada as far as existing data show. All of the new stations established in the State of Washington are on Cenozoic formations and, as usual, the anomalies are either negative or, if positive, very small in amount. At one of the new stations the anomaly is +0.002 dyne, but at all the other stations the anomalies are negative. The anomalies at the Puget Sound stations are discussed on pages 20 and 28.

The existing geodetic data seem to indicate very clearly that the earth's crust is in a more perfect state of isostatic equilibrium than even the most sanguine isostasist believed a few years ago. The large gravity anomalies which had been used by Barrell and others to prove that the earth's crust was in places far from a state of isostatic equilibrium may be logically explained by the presence of very light or very heavy material close to the stations. If the cause of the anomaly were deep-seated, there could not be such great differences as actually occur in the gravity anomalies and in the deflections of the vertical at stations which are close together.

It is believed that the preponderance of negative gravity anomalies at stations along the western coast of the United States is due almost entirely to the fact that nearly all the stations are located on Cenozoic formations with densities less than the normal surface densities. These anomalies have no relation, apparently, to the structure of the continental area and of the area under water near the coast.

ISOSTASY IN HIGH LATITUDES.[31]

A recent book covering researches by Fridtjof Nansen[51a] leads to the conclusion that the earth's crust yields to the loading and unloading by ice. His views are summarized in the following excerpts from his book:

> The fact, proved by the strandflat and by the raised shore lines, that the coast of Norway has been depressed during the last glacial period and has again in post glacial time risen to a level slightly higher than the level it had before the subsidence, while the upheaval of the land is not yet completed in the central and Baltic regions of the depressed area, which after the retreat of the ice was covered by a thick layer of sea, seems to me to form convincing evidence of the correctness of the theory that it was the load of the ice which caused the depression of the crust and the unloading which caused its upheaval. I do not think that serious objections can be any longer raised against this theory.
>
> It seems to me that the more one studies the whole process of the late-glacial and postglacial subsidence and upheaval of Fenno-Scandia, and the related crustal movements in the surrounding regions, in all their details, the more one must be convinced that these movements are isostatic. One will find that the theory of isostasy gives a simple and natural explanation of almost all phenomena and even of many details which may seem startling at the first glance.
>
> It has also been maintained that great disturbances over extensive areas are necessary to start the crustal movements for adjustment of isostasy, and such movements will occur, as a rule, only during periods of special mobility of the earth's crust and within certain specially mobile regions. As far as I can judge, the late-glacial and postglacial vertical movements of Fenno-Scandia and surrounding regions, and especially the movements of the Norwegian coast and the present position of its strandflat, conclusively disprove the correctness of views such as these. They indicate that the earth's crust in the course of time approaches its level of perfect isostatic equilibrium much more closely than even the most extreme advocates (like Hayford) of perfect isostasy have considered to be possible.
>
> We may, therefore, infer that the earth's crust is on the whole very responsive to disturbances of its equilibrium and has a great ability to reestablish it. After a sufficient time it will attain its level of isostasy at least within some few meters.
>
> It is a general tendency of the lithosphere to readjust its isostasy after disturbances and in the course of time to approach its average level of isostatic equilibrium within some few meters at least. The isostatic movements of the lithosphere are not limited to especially mobile regions nor to periods of special crustal mobility.

---

[31] While this publication was in press an article was received which gave the results for 9 new gravity stations in Canada, the one farthest north being in latitude 67° 27′ (A. H. Miller, "Gravity results in the Mackenzie Basin," Jour. Royal Astron. Soc. Canada, Vol. XVII, No. 9–10, Nov.–Dec., 1923). The average isostatic anomalies with and without regard to sign for the 9 stations are −0.003 dyne and 0.010 dyne, respectively.

[51a] The Strandflat and Isostasy," I Kommission Hos Jacob Dybwad, Kristiania, 1922.

While Nansen drew his conclusions from physiographic evidence, his deductions and conclusions are in general accord with those arrived at by the geodesist who has used geodetic data.

SIZE OF TOPOGRAPHIC FEATURE WHICH MAY NOT BE COMPENSATED.

While some may still doubt the existence of the isostatic condition of the earth's crust, the accumulated accurate data obtained from direct observations and measurements all point to a high degree of isostatic adjustment even for moderately small areas. Certainly a topographic feature of the order of magnitude of 20 miles radius and 3,000 feet in thickness is at least partly compensated. Apparently the cross section of the block of the crust which may escape compensation is dependent upon the amount of material on it which is above sea level. A mountain or plateau block with an elevation of, say, 10,000 feet will probably be in balance for a smaller cross section than one in low ground with an average elevation of a few hundred or a thousand feet. Of course, one must distinguish between the horizontal dimensions of a block of topography which may be compensated and the horizontal dimensions of an earth block which may be in equilibrium independently of surrounding blocks. If the topographic feature is in equilibrium then the gravity anomaly should be affected by ignoring in the reductions the compensation of the feature.

The effect of ignoring the compensation for topography extending 17.9 miles and 36.5 miles from each of 42 gravity stations in the United States at elevations greater than 1,000 meters (about 3,300 feet) is shown in the following table. The stations are numbered the same as elsewhere in this publication and in Special Publications Nos. 10, 12, and 40:

Effect on gravity anomalies of the compensation for inner zones.

Number and name of station.	Elevation *H*.	Isostatic anomaly.	Cor. to discard comp. out to and including		Anomalies with isostatic comp. omitted to	
			Zone L (17.9 mi.).	Zone M (36.5 mi.).	Zone L.	Zone M.
	Meters.	*Dyne.*	*Dyne.*	*Dyne.*	*Dyne.*	*Dyne.*
41. Wallace, Kans	1,005	−0.012	−0.027	−0.048	−0.039	−0.060
42. Colorado Springs, Colo	1,841	−.007	−.054	−.094	−.061	−.101
43. Pikes Peak, Colo	4,293	+.021	−.070	−.113	−.049	−.092
44. Denver, Colo	1,638	−.016	−.038	−.076	−.054	−.092
45. Gunnison, Colo	2,340	+.020	−.063	−.120	−.043	−.100
46. Grand Junction, Colo	1,398	+.024	−.041	−.082	−.017	−.058
47. Green River, Utah	1,243	−.021	−.033	−.067	−.054	−.058
48. Pleasant Valley Junction, Utah	2,191	+.004	−.060	−.103	−.056	−.099
49. Salt Lake City, Utah	1,322	+.010	−.040	−.075	−.030	−.065
50. Grand Canyon, Wyo	2,386	−.002	−.061	−.108	−.063	−.110
51. Norris Geyser Basin, Wyo	2,276	+.021	−.059	−.104	−.038	−.083
52. Lower Geyser Basin, Wyo	2,200	−.001	−.058	−.103	−.059	−.104
55. Mount Hamilton, Calif	1,282	−.003	−.014	−.017	−.017	−.020
63. El Paso, Tex	1,146	+.007	−.030	−.054	−.023	−.047
64. Nogales, Ariz	1,181	−.050	−.029	−.046	−.079	−.096
67. Goldfield, Nev	1,716	−.013	−.043	−.074	−.056	−.087
68. Yavapai, Ariz	2,179	+.001	−.045	−.080	−.044	−.079
70. Gallup, N. Mex	1,990	−.013	−.053	−.095	−.066	−.108
71. Las Vegas, N. Mex	1,960	+.003	−.053	−.094	−.050	−.091
75. Lead, S. Dak	1,590	+.052	−.038	−.064	+.014	−.012
81. Sisson, Calif	1,048	−.010	−.033	−.058	−.043	−.068
82. Rock Springs, Wyo	1,910	+.013	−.052	−.093	−.039	−.080
98. Alpine, Tex	1,359	+.021	−.034	−.061	−.013	−.040
99. Farwell, Tex	1,259	−.016	−.030	−.055	−.046	−.071
102. Cloudland, Tenn	1,890	+.004	−.025	−.039	−.021	−.035
109. Sheridan, Wyo	1,150	+.032	−.032	−.068	−.000	−.036
110. Boulder, Mont	1,493	−.015	−.046	−.077	−.061	−.092
114. Truckee, Calif	1,805	−.028	−.051	−.085	−.079	−.113
115. Winnemucca, Nev	1,311	−.009	−.032	−.062	−.041	−.071
116. Ely, Nev	1,962	−.021	−.055	−.094	−.076	−.115
117. Guernsey, Wyo	1,322	+.036	−.031	−.062	+.005	−.026
195. Lander, Wyo	1,635	+.019	−.047	−.090	−.028	−.071
198. Edgemont, S. Dak	1,066	+.054	−.028	−.052	+.026	+.002
202. Moorecroft, Wyo	1,295	+.021	−.031	−.058	−.010	−.037
269. Hill City, S. Dak	1,518	+.042	−.040	−.067	+.002	−.025
270. Newcastle, Wyo	1,328	+.029	−.035	−.064	−.006	−.035
271. Bridgeport, Nebr	1,114	−.008	−.029	−.053	−.037	−.061
272. Buford, Wyo	2,396	+.046	−.057	−.100	−.011	−.054
273. Boulder, Colo	1,630	−.014	−.048	−.092	−.062	−.106
274. Lafayette, Colo	1,595	−.020	−.040	−.081	−.060	−.101
275. Brighton, Colo	1,511	−.006	−.038	−.073	−.044	−.079
276. Idaho Springs, Colo	2,303	+.022	−.068	−.120	−.046	−.098
Mean with regard to sign		+0.005	−0.043	−0.077	−0.037	−0.072
Mean without regard to sign		0.019			0.040	0.072

The significance of the data presented in this table can not be ignored. They strengthen the conclusions derived from consideration of Bouguer anomalies given in Coast and Geodetic Survey Special Publication No. 40. In the Bouguer reduction of gravity stations no account is taken of the effect of isostatic compensation.

Referring to the above table it is seen that while the mean isostatic anomaly with regard to sign is +0.005 dyne, the mean anomaly when ignoring the compensation of the topography out to 17.9 miles is −0.037 dyne and to 36.5 miles is −0.072 dyne. The means without regard to sign for the three kinds of anomalies are, respectively, 0.019, 0.040, and 0.072 dyne. Only seven of the isostatic anomalies are over 0.030 dyne. The anomalies resulting from the ignoring of compensation for the topography out to 17.9 miles have 28 values of 0.030 dyne or greater and out to 36.5 miles have 37 values of 0.030 dyne or greater.

The data given in the table show clearly a definite relation between the gravity anomalies and the topography when the isostatic compensation of even small amounts of topography are ignored. One of the strong features of the isostatic anomalies is that there is no apparent relation between their size and sign and the elevation of the gravity stations.

In the above table there are 22 positive and 20 negative isostatic anomalies, but only 4 of the 42 anomalies are positive when the compensation of the topography out to 17.9 miles is

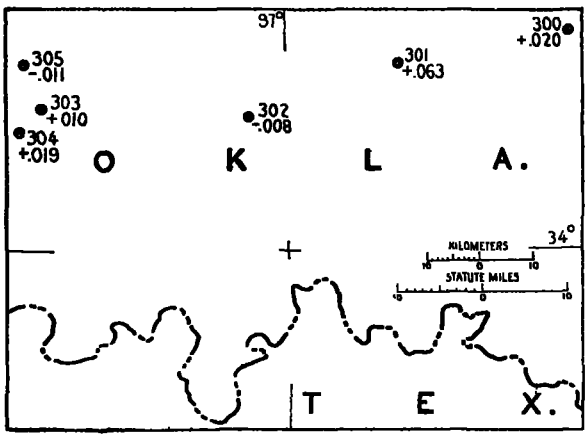

FIG. 14.—Group of gravity stations in southern Oklahoma.

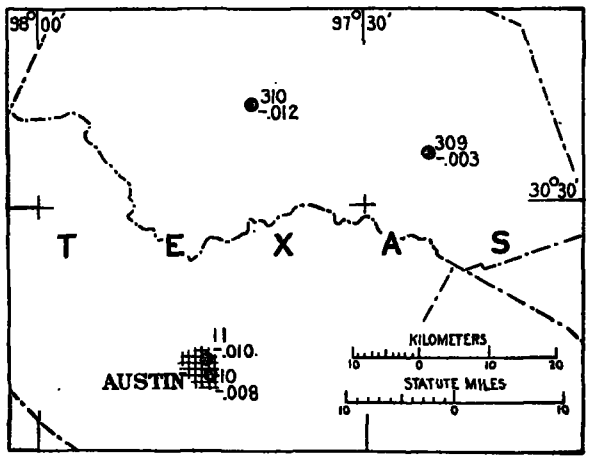

FIG. 15.—Gravity stations at Saline, Tex.

ignored, and only 1 of the 42 anomalies is positive when the compensation of the topography out to 36.5 miles is ignored and that one is only 0.002 dyne.

The isostatic reduction greatly reduces, and in fact practically eliminates, the difference between the computed and observed values of gravity, regardless of the elevations of the stations and the geographic location of the area. It has been found effective in the United States, Canada, and India, where the method has been extensively used. The method has also been applied to a small number of gravity stations in Europe with excellent results.

RELATION BETWEEN THE SIZE OF THE TOPOGRAPHIC FEATURE WHICH IS COMPENSATED AND THE SIZE OF THE BLOCK OF THE EARTH'S CRUST INDEPENDENTLY IN EQUILIBRIUM.

The discussion above of the data of the table on page 34 gives a rather definite idea of the size of a topographic feature which does not escape isostatic compensation, but it does not give any clear idea as to the minimum cross section of the earth crust block which may be independently in equilibrium. It is probable that the compensation of a single mountain peak, or a group of peaks, or a single ridge is not all in the blocks directly under these features. The compensation probably extends horizontally to a moderate distance from the features.

The horizontal distribution of compensation was treated at some length in Coast and Geodetic Survey Special Publication No. 40, pages 85 to 92, under the heading "Regional versus local distribution of compensation." The conclusion was reached that local distribution of the compensation is nearer the truth than regional distribution to a distance of 100 miles from

the topographic features. There was no evidence in favor of local distribution over regional distribution out to a distance of about 40 miles from a feature. Tests were not made for regional distribution for any distance between 40 and 100 miles. Nansen in discussing the strandflat of Norway holds:

> These facts indicate that considerable isostatic movements may take place within areas no more than a few hundred kilometers wide, and probably even much smaller.[32]

The minimum size of the block of the earth's crust which may be in isostatic equilibrium can not be derived, at least with a high degree of accuracy, by the geodetic methods which have been employed in isostatic investigations. The variation in the size of the gravity anomaly for a moderate change in the distribution of the compensation is of the order of magnitude of the effect of variations in the densities of the materials composing the crust. This makes it difficult if not impossible to evaluate the effect of different horizontal distributions of the compensation to moderate distances from topographic features. This problem seems to be one for the geologist and geophysicist rather than for the geodesist.

STATIONS SELECTED TO TEST EFFECT OF ABNORMAL DENSITIES ON GRAVITY.

The results of the studies in isostasy, the increase in the number of gravity stations, and the conclusion that some at least of the gravity anomalies are due to abnormal densities in the earth's material near the stations, made it desirable to conduct experiments in regions where the densities of materials are known from borings or from field observations of exposed geologic strata.

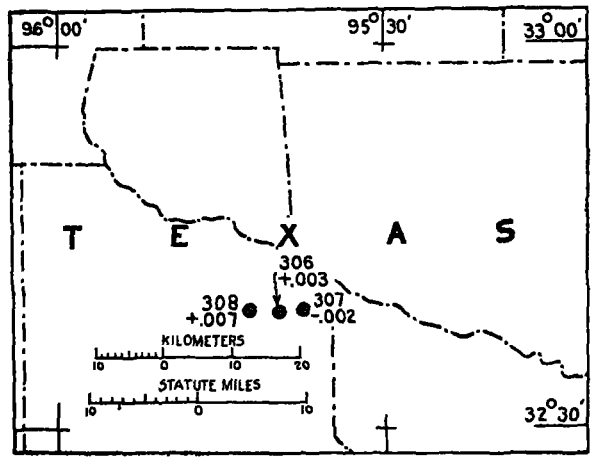

FIG. 16.—Gravity stations near Austin, Tex.

At the request of the Director of the Geological Survey, observers of the U. S. Coast and Geodetic Survey were assigned to the determination of the intensity of gravity at a number of stations selected by Dr. David White, then chief geologist of the Geological Survey. Dr. White is making a study of the relation of the gravity anomalies and densities of materials at these stations and will publish the results of his findings. It is probable that as a result of this work the pendulum may be found to be of value in certain branches of economic geology. The names of the stations especially selected by Dr. White, with their geographic location and their anomalies, are given in the following table:

Gravity stations selected by United States Geological Survey.

Number and name of station.	Latitude φ.		Longitude λ.		Isostatic anomaly.	Number and name of station.	Latitude φ.		Longitude λ.		Isostatic anomaly
	°	′	°	′	*Dyne.*		°	′	°	′	*Dyne.*
260. Clarksburg, W. Va.	39	16.8	80	20.3	−0.006	297. Zeandale, Kans.	39	09.7	96	25.6	−0.038
261. Rowlesburg, W. Va.	39	20.8	79	40.2	+.004	298. Doyle Well, Kans.	39	12.5	96	05.2	−.022
262. Terra Alta, W. Va.	39	26.9	79	32.9	+.010	299. Seneca Well, Kans.	39	50.4	96	03.6	−.032
263. Corinth, W. Va.	39	25.6	79	29.4	+.007	300. Wapanucka, Okla.	34	22.1	96	25.5	+.020
264. Kitzmiller, Md.	39	23.6	79	10.4	−.004	301. Troy, Okla.	34	19.6	96	46.6	+.063
265. Pennington, N. J.	40	20.0	74	47.6	−.038	302. Idle Wilde, Okla.	34	13.3	97	07.0	−.008
266. Glen Ridge, N. J.	40	48.1	74	12.2	−.020	303. Lowery, Okla.	34	14.1	97	30.8	+.010
267. Plainsboro, N. J.	40	20.0	74	35.8	−.018	304. Carter, Okla.	34	11.4	97	32.6	+.019
269. Hill City, S. Dak.	43	55.9	103	34.1	+.042	305. Busby, Okla.	34	18.3	97	31.6	−.011
270. Newcastle, Wyo.	43	51.4	104	11.8	+.029	306. Saline No. 1, Tex.	32	38.6	95	39.6	+.003
271. Bridgeport, Nebr.	41	40.1	103	05.9	−.008	307. Saline No. 2, Tex.	32	38.6	95	37.0	−.002
272. Buford, Wyo.	41	07.4	105	18.3	+.046	308. Saline No. 3, Tex.	32	38.6	95	42.2	+.007
273. Boulder, Colo.	40	01.2	105	16.6	−.014	309. Taylor, Tex.	30	34.1	97	24.5	−.008
274. Lafayette, Colo.	39	59.8	105	05.2	−.020	310. Georgetown, Tex.	30	38.0	97	40.1	−.012
275. Brighton, Colo.	39	59.3	104	48.9	−.006	311. Damon No. 1, Tex.	29	19.5	95	42.7	−.034
276. Idaho Springs, Colo.	39	44.6	105	31.1	+.022	312. Damon No. 2, Tex.	29	17.0	95	43.7	−.045
296. Wilkins Well, Kans.	39	04.4	97	04.5	−.024	313. Damon No. 3, Tex.	29	15.5	95	45.2	−.079

[32] Fridtjof Nansen, "The strandflat and isostasy," I Kommission Hos Jacob Dybwad, Kristiania, 1922.

Complete data for these stations are given in Part II of this report. The location of many of these stations and the way in which they are grouped are shown in Figures 9 to 16, inclusive.

COMPUTATION OF EFFECT OF LOCAL DEVIATIONS OF DENSITY ON GRAVITY.

Tables have appeared in U. S. Coast and Geodetic Survey Special Publications Nos. 10, 12, and 40, and in Professional Paper No. 17 of the Survey of India, by which one can compute the effect of certain masses on the value of gravity. An extension of these tables is given below:

Attraction of cylindrical blocks.

[Station at center of upper surface. Density=1.]

Depth of block.	Radius of block in miles.														
	½	1	1½	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½
Feet.	*Dyne.*	*Dyne.*	*Dyne.*	*Dyne.*	*Dyne.*	*Dyne.*	*Dyne.*	*Dyne.*	*Dyne.*	*Dyne.*	*Dyne.*	*Dyne.*	*Dyne.*	*Dyne.*	*Dyne.*
1,000	0.010	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.013	0.013	0.013	0.013	0.013	0.013	0.013
2,000	.017	.021	.022	.023	.024	.024	.024	.025	.025	.025	.025	.025	.025	.025	.025
3,000	.021	.028	.031	.033	.034	.035	.035	.036	.036	.036	.036	.037	.037	.037	.037
4,000	.024	.034	.039	.042	.044	.045	.046	.046	.047	.047	.048	.048	.048	.048	.049
5,000	.025	.038	.045	.050	.052	.054	.055	.056	.057	.058	.058	.059	.059	.060	.060
6,000	.027	.042	.051	.056	.060	.062	.064	.066	.067	.068	.069	.070	.070	.071	.071
7,000	.028	.045	.056	.063	.067	.071	.073	.075	.077	.078	.079	.080	.080	.081	.082
8,000	.028	.047	.060	.068	.074	.078	.081	.084	.086	.087	.088	.090	.091	.091	.092
9,000	.029	.049	.063	.073	.080	.085	.089	.092	.094	.096	.098	.099	.100	.101	.102
10,000	.029	.051	.066	.077	.085	.091	.095	.099	.102	.104	.106	.108	.110	.111	.112
12,000	.030	.053	.071	.084	.094	.102	.108	.113	.117	.120	.123	.125	.127	.129	.130
14,000	.031	.055	.075	.090	.102	.111	.119	.125	.130	.134	.138	.141	.144	.146	.148
16,000	.031	.057	.078	.094	.108	.119	.128	.135	.142	.147	.152	.156	.159	.162	.165
18,000	.031	.058	.080	.098	.113	.126	.136	.145	.153	.159	.165	.169	.173	.177	.180
20,000	.032	.059	.082	.102	.118	.132	.144	.154	.162	.170	.176	.182	.187	.191	.195
25,000	.032	.060	.086	.108	.126	.143	.158	.170	.182	.191	.200	.208	.215	.221	.226
30,000	.032	.062	.088	.112	.133	.152	.169	.184	.198	.210	.221	.231	.239	.247	.255

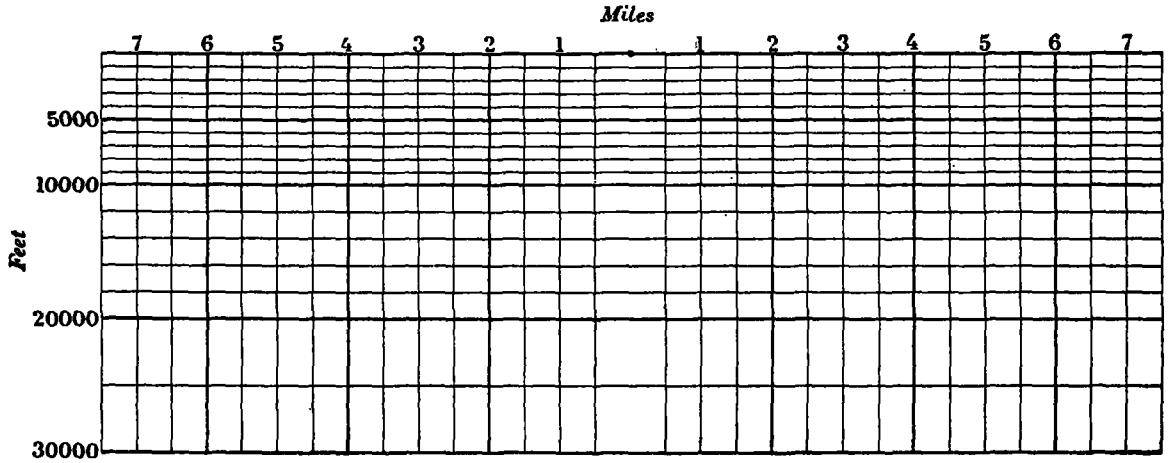

FIG. 17.—Attraction of cylindrical masses.

The use of the above table is facilitated by Figure 17. The horizontal distances from the station, shown as a dot at the center of the top line, are in miles and the depths are in feet. The values of the attraction given in the table are in dynes. One one-thousandth of a dyne corresponds to one part in one million of the earth's attraction. The density of the material was taken as unity in computing the table. In order to get the attraction for a mass of greater density, say 2.65, simply multiply the tabular value by this number. If the effect in any volume of an excess or deficiency in density is desired, multiply the excess or deficiency by the tabular value for that volume. For instance, if the excess is 0.24 and the tabular value is 0.015, the attraction is +0.004 dyne. With a deficiency of density the result will be minus. Several examples of the use of the table and diagram are given below.

What is the effect of a deficiency in density of 0.45 in a cylinder 1 mile in radius, 5,000 feet in length, with the upper end 3,000 feet below the station? From the table it is found that the effect of a column 8,000 feet in length and 1 mile in radius is 0.047. Also for a column 3,000 feet in length and 1 mile in radius the effect is 0.028. The difference between the two, 0.019, multiplied by 0.45, is the effect sought. This equals 0.009 dyne.

What is the effect of a deficiency of density of 0.35 in a cylinder 10,000 feet long and 2 miles in diameter, with its top at the surface and its axis 3 miles from the station? The value sought can not be gotten directly from the table, but we can obtain it by an indirect method.

The attraction of a cylinder 4 miles in radius and 10,000 feet long, with top at the surface of the earth, is 0.099 dyne. Similarly, for a cylinder 2 miles in radius and 10,000 feet long the attraction is 0.77 dyne. The difference between the attractive effects is 0.022 dyne.

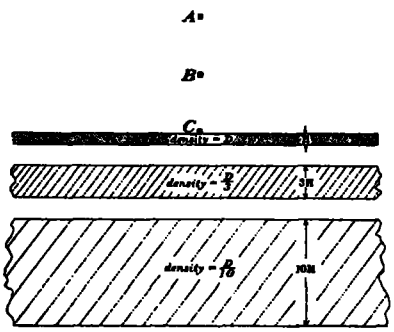

FIG. 18.—Attraction of indefinite disks.

The area of the cross section of the hollow cylinder is 37.7 square miles. The area of a circle 2 miles in diameter is 3.1 square miles. Therefore, the ratio, 3.1 divided by 37.7, multiplied by 0.022 dyne, the attraction of the hollow cylinder, will give the attraction of the cylinder 2 miles in radius, which equals 0.0018 dyne. Now, multiply this by 0.35, the deficiency of density, and the answer is 0.0006 dyne.

Let the conditions be as in the above problem except that the top of the cylinder is 5,000 feet below the surface. First, we find the value of a cylinder 4 miles in radius and 15,000 feet in length with its top at the surface. The value is 0.130 dyne. From this subtract the effect of a cylinder 4 miles in radius and 5,000 feet in length, 0.056 dyne. The difference is 0.074 dyne. Next, take the value from the table for a cylinder 2 miles in radius and 15,000 feet in length, 0.092 dyne. From this subtract 0.050 dyne, the value for a cylinder 2 miles in radius and 5,000 feet in length. The difference is 0.042 dyne. Subtract 0.042 dyne from 0.074 dyne and we get 0.032 dyne, which is the value of the effect of a hollow cylinder with inner radius 2 miles and outer radius 4 miles, 10,000 feet in length with its top 5,000 feet below the surface. As in the previous problem, multiply the ratio of the area of the circle 2 miles in diameter to that of the cross section of the hollow cylinder, 3.1 over 37.7, by 0.032 dyne, and we have 0.0027 dyne as the attraction of the cylinder for unit density. Then multiply 0.0027 dyne by 0.35, the deficiency of density, and we get 0.0009 dyne, the value sought.

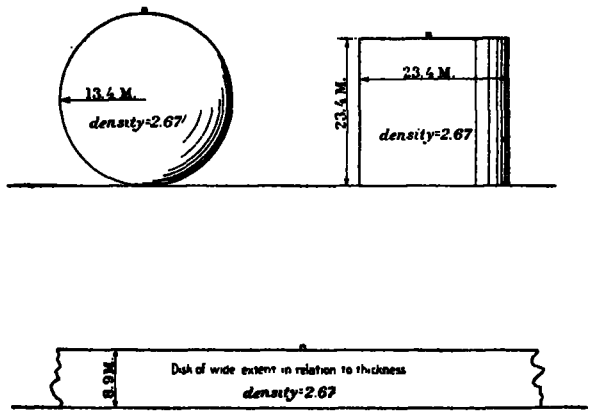

FIG. 19.—Relative sizes of masses of different forms having equal attractive effects.

It is readily seen that from the table one can obtain the value of the attraction of masses of various dimensions situated in different positions from the station. For a sphere or cube an equal volume of the hollow cylinder can be used with sufficient accuracy.

Should the table not be comprehensive enough it may be readily extended. The formula for the attraction in dynes of a right cylinder on a unit mass (1 gram) located outside the mass but on its axis is

$$2\pi K\delta\left\{\sqrt{c^2+h^2}-\sqrt{c^2+(h+t)^2}+t\right\}$$

in which K is the gravitation constant, δ is the density of the material, c is the radius of the cylinder, t is the length of the element of the cylinder, and h is the distance from the attracted mass to the nearest end of the cylinder. The value of K may be taken as 6673 (10^{-11}).[33]

[33] See U. S. Coast and Geodetic Survey Special Publication No. 10, 1912, pp. 13 and 17.

If it is desired to know what excess or deficiency from normal density in a given volume of material situated in a certain position with relation to the station would cause a certain gravity anomaly proceed as follows: From the table and diagram obtain the effect of the same volume of material of unit density, then divide the anomaly by the value obtained to get the desired excess or deficiency in density. For instance, if the tabular value is 0.015 dyne and the anomaly is 0.010, the density sought will be 0.67. It will be plus for a positive anomaly and minus for a negative anomaly.

RELATION OF DEPTHS OF COMPENSATION, HORIZONTAL FLOW, AND EQUAL PRESSURE.

In isostatic investigations it has been assumed that the compensation under topographic features, such as a mountain system or a continent, extended to the depth at which the material changes from a solid capable of resisting horizontal stresses to a solid which is plastic to horizontal stresses. It is certain that the compensation must be above this depth, but it is very improbable that it always or even often extends exactly to that depth.

The lowest depth at which the material loses its power of resistance to horizontal flow should really be called the depth of equal pressure rather than the depth of compensation. If the compensation does not extend to the plastic depth for each block of the crust, then the computed depth, approximately 60 miles, which we get from the isostatic investigations does not coincide exactly with the depth at which pressures exerted by the blocks are equal.

The compensation under a mountain mass is caused by an expansion of the underlying column which, before the uplift began, was a column under a sedimentary area. If the expansion of this column under the sedimentary area extended all the way to the depth of equal pressure and if the expansion were uniform throughout the column, then the depth of compensation would coincide with the depth at which flow may take place horizontally, but for any given feature it may be that the expansion is only to a depth somewhat above the depth of equal pressure. As the compensation is the cause of the surface elevation, it may be that the change of density does not take place throughout the whole depth of the isostatic shell.

In spite of what has been said above we must conclude that there is only one way to determine, with any degree of accuracy, the depth to which the compensation extends; that is, by making use of the geodetic data in the form of deflections of the vertical and the intensity of gravity. The depth of compensation may be different at different places, but in no event will it extend below the depth of flow and on the average is probably not very far above it.

EFFECT OF TEMPERATURE ON DEPTH OF HORIZONTAL FLOW.

The depth at which a change from resistance to yielding takes place in the material of the earth depends on the physical characteristics or conditions at that depth. It is probable that the physical conditions at a depth of from 50 to 100 miles below sea level make the resistance of the material to flow considerably different from that near the surface. The resistance undoubtedly would be the same at any particular depth around the whole earth if the chemical composition of the rocks were the same throughout each layer and if the temperature and pressure were approximately the same; but it is reasonable to suppose that the geoisotherms are not at uniform distances below sea level. It is quite certain that they are somewhat lower than normal below areas of sedimentation and are elevated under areas of erosion. They may have different depths under oceans than under continents.

It seems probable that the chemical composition of the material near the upper limit of the plastic matter is nearly the same around the earth. If it should be decidedly different in different places, then we should expect the resistance to flow to be different also. Two different materials of the same temperature may have very different strength or plasticity.

EFFECT OF THE THEORY OF ISOSTASY ON GEOLOGICAL THEORIES.

The results of geodetic investigations indicate that the outer portion of the earth is in a condition of hydrostatic equilibrium at some depth of the order of magnitude of 60 miles below

sea level. Each of the blocks of the earth's crust, possibly of the order of magnitude of 100 miles square, exerts very nearly the same pressure on the horizontal surface below sea level called the depth of equal pressure. A logical conclusion from the fact that the earth's crust is now everywhere in isostatic equilibrium is that it has been in this condition for geological ages past.

If we assume the conditions outlined in the paragraph above, we find that some very important geological conclusions must result. Elevated areas are not extra loads on the earth's crust or isostatic shell. It would appear, therefore, that as the columns are in equilibrium now and were in equilibrium in the past material was not brought to the elevated areas and placed on the blocks of the earth's isostatic shell under them to form the high ground. Areas of sedimentation from which mountain masses are formed are found to be in isostatic equilibrium and mountain areas are also; therefore, the forces which uplift mountains are not horizontal. If they were horizontal, there would be extra loads on the blocks of the isostatic shell, but the geodetic data furnish evidence that the mountains are not extra loads and therefore must be caused by vertical forces which do not bring extra material into the column. These vertical forces expand the material of the original column sufficiently to change the elevation of the surface.

If mountain areas are raised by swelling the material in the columns, then there need be no disturbance of surrounding columns, except as these surrounding columns yield to shearing resistance and the friction of the upmoving material. It is probable that as the mountain column moves upward the material of the surrounding blocks is to a certain extent dragged along with it, thus causing more or less an upward movement of the area surrounding or to the side of the uplifted area. The extent of the upward movement in the outside areas is undoubtedly quite small in comparison with the uplift of the mountain.

In nearly all mountain areas there have been horizontal movements which have caused crushing, faulting, folding, overfolds, underthrusts and overthrusts, but it is believed that these may be only incidents to the vertical movement caused by the expansion of the material in the column. Mountain masses usually occupy rather broad and long bases, and such areas appear ample in extent to allow horizontal movements to develop as incidents to uplift from vertical forces. There is much evidence in mountain areas that horizontal movements are very local in their extent, and this is in harmony with the vertical uplift theory but out of harmony with the theory that the mountain masses are formed by regionally acting horizontal forces.

PROBABLE CAUSES OF VERTICAL MOVEMENTS.

If the theory is correct that mountains are caused by the expansion of the material of the isostatic column or block below them, what causes the expansion to take place? There must be a change in the density of the elevated column, for the column was shorter before uplift began, and there is the best of evidence that all large sections of the isostatic shell are in equilibrium.

It is probable that the cause of the expansion of the material of a column under an area of sedimentation is the previous depression of the column during sedimentation. There is evidence that deposits as thick as 30,000 feet or more may occur. Let us assume there was a thickness of 30,000 feet of deposits over an area such as the one now occupied by the Himalayan mountains. The sediments were probably all deposited at or very close to sea level, and this indicates that as the sediments were laid down the block or column under them was pushed down deeper into the earth. As the subsidence of the block took place no doubt the material below its lower end moved off horizontally to reestablish or tend to reestablish the balance between the sedimentary area and the area or areas of erosion. All of the material of the column below the sediments was pushed down, say, 6 miles. A change of depth of 6 miles must result in every particle of the column being heated to a temperature much higher than before subsidence began, perhaps several hundred degrees. It is not known, of course, what the temperature gradient is throughout the earth's crust, but undoubtedly a low zone is much hotter than one some distance above it.

It is possible that as each element of the crustal material sank down during sedimentation it did not immediately assume the temperature of the new depth attained by it.[34] When it did assume the new temperature, chemical or physical action or a combination of these might have occurred to change the volume of the material. The material at any point in the subsiding column was under greater pressure than obtained before subsidence began but was also at a higher temperature. It is possible that the increase in temperature more than offset the increase in pressure and brought about the expansion necessary to elevate the surface.

We have evidence that mountain masses which existed in the past have been base-leveled and the areas are now at a very low elevation or even below sea level. On the theory that vertical forces cause action within the isostatic shell, what can be the cause of a subsidence of an area that was once high above the sea level?

While a mountain area or any land area is being eroded material is brought into the lower part of the column to reestablish the isostatic equilibrium. This tends to maintain the average elevation of the area of erosion, but the material that is brought into the base of the column or block under the area of erosion is probably somewhat denser than the material that is eroded from the surface. It is a reasonable assumption that the material that flows into the base of the column is at least 10 per cent denser than the eroded matter. Therefore, when 1,000 feet of material is eroded from an area we should expect only about 900 feet of material to be brought into the base of the column, and as a result the surface would be 100 feet lower than before the erosion began. In order to lower a mountain mass 5,000 feet by this process, it would be necessary to erode about 50,000 feet from the mountain area.

Let it be assumed that 30,000 feet of material has been eroded from a mountain area, and that the surface is 3,000 feet lower than it was at the time that the erosion began. This amount of subsidence is not sufficient to lower the surface of a great mountain range to sea level. There may be another cause for the lowering which, working together with the one previously outlined, would cause the total subsidence of which we have evidence.

As the isostatic adjustment takes place in the columns or blocks under an area of erosion, every particle of the block is elevated by the amount of the thickness of the material brought into the column to restore the isostatic adjustment. When 30,000 feet of material has been eroded from the mountain area, then approximately 27,000 feet of material has come into the column under the eroded area, thus lifting all parts of the column approximately 5 miles. Each particle of the column has, therefore, been carried upward, to a zone that has a normal temperature much less than the zone in which it was before the erosion began. It is probable that the difference in temperature for a difference in depth of 5 miles is several hundred degrees. As the material assumes the temperature of its new zone some chemical or physical action probably results from the change in temperature and makes the material assume a greater density with a resulting contraction of the column and a lowering of the surface even below sea level. In the last stages of base leveling there would be operating simultaneously erosion, isostatic adjustment, and contraction.

Apparently, therefore, sedimentation alone is not the primary cause of the sinking of the earth's surface. Sedimentary material placed on the earth, where there is not an independent subsidence, would soon elevate the surface of the area in question to such an extent that further sedimentation would cease. When the earth's crust yields under an added load, material just below the column probably moves horizontally toward areas of erosion. The material that moves from the base of the column is probably from 10 to 20 per cent denser than the material that is deposited at its upper surface. Suppose 5,000 feet of sediments were deposited on an area and that the earth's crust were so weak as to permit of a perfect hydrostatic adjustment of the column, thus causing an equal mass of material to flow from the base. If the material leaving the base of the column were 20 per cent denser than the sediments, we should expect the original column to be shortened by only 4,167 feet, and the surface of the sediments would be elevated 833 feet above the original level before sedimentation began.

[34] See "Notes on Isostasy," by C. E. Van Orstrand, which forms an appendix to an article entitled "Building of the Southern Rocky Mountains," by Willis T. Lee. Bulletin of the Geological Society of America, June 30, 1923.

It is known that where heavy sedimentation has taken place the sediments have all been deposited at a rather low elevation. We may, therefore, conclude that there has been an actual subsidence of the base on which sediments were deposited independent of the subsidence due to the weight of the sediments. It is possible that the process by which a mountain area becomes base leveled and even carried down below the sea level may be the determining factor in deciding where new sedimentation shall occur. In this discussion of sedimentation it is assumed, of course, that we are dealing with areas where very heavy sedimentation is occurring, such as in the Indo-Gangetic plain and like places.

It has been suggested above that the cause of changes in density might be the decided changes in temperature under an area undergoing sedimentation and under an area where great erosion is taking place. That there has been a change in density in the materials of the block of the isostatic shell between the time the block was subject to sedimentation and the time it was subject to erosion is beyond question. If there are not different densities in columns whose surfaces have different elevations, then the whole theory of isostasy fails. If there are different densities, and there is no reason to doubt it, then we might well accept as a working hypothesis this process of change in density as the cause of the uplift. Investigations and tests will show whether it is sound or must be abandoned.

ISOSTASY, A GEOLOGICAL PROBLEM.

It is believed that the theory that the expansion of a column is the cause of mountain formation will be far easier to defend than has been the theory that mountains are formed by regionally acting horizontal thrusts and horizontal movement of material in the crust.

Some of the great outstanding problems in geology may have some light thrown on them by careful analysis of the results of the isostatic investigations. It is probable that earthquakes and volcanoes are incidents to the changes in elevation of the surface of the earth, due to the processes involved in the isostatic adjustment or to the changes in density in the earth's crust. Dr. H. S. Washington has been investigating the relation of the densities of igneous rocks as derived from chemical analyses to the elevation at which they are found, and it is possible that his researches combined with consideration of the isostatic data may throw some light on the question of the stability of continents and oceans throughout geological times.

Isostasy has really become more of a geological than a geodetic problem, and it is only due to the fact that the geodesist had material at hand which was being used in the determination of the figure of the earth that he was able to undertake investigations in the theory of isostasy on a much greater scale than has been done by the geologist. It is reasonably certain that there can be very little further progress in isostatic investigations unless the geological phases of the question are carefully and fully considered.

UPLIFT OF MOUNTAINS.

The results of isostatic studies in the United States and in India have led to the rather definite conclusion that light material of the Cenozoic formation is the cause of the negative gravity anomalies at stations located on that formation. In the United States we have 100 gravity stations on the Cenozoic formation, and 66 of these have negative anomalies.

It is hardly possible that in any column that has been subject to heavy sedimentation for a geological period the amount of material is subnormal. It is more logical to conclude that there is more material in the column than normal, because the column has been sinking under the added load. After the sedimentation ceases the area may be raised into a mountain mass. In fact, this has often occurred. The question immediately arises as to how a mountain can be formed in a column which is already normal in the amount of mass or has possibly more than the normal mass.

Studies of the gravity results and of the deflection of the vertical show that mountain masses are in a high state of equilibrium. Therefore, if a mountain mass has been formed over a column which was subjected previously to heavy sedimentation, it can not be an extra load on the column.

If the mountain mass is not an extra load, then it could not have been brought from some other area to the one it now occupies. In other words, it could not have been transferred horizontally to its present position. If the mountain mass is not an extra load, it could not have been caused by lateral thrusts operating in the earth's isostatic shell and extending far, horizontally, beyond the mountain area. If the mountain mass is not an extra load, was not transported to its present position, and was not caused by lateral thrust acting regionally, then it must be due to local causes.

The only local cause that seems to be a reasonable one is a change in density in the column under the mountain. There must have been expansion due to some process going on locally in the isostatic shell. Just what this action is we do not know, nor does it seem possible to find out, for we can not reproduce at the surface the conditions that exist far below. But there seems to be no doubt that some changes in density have occurred.

The mountain mass is not a permanent feature on the face of the earth, as is shown by the fact that on most mountains evidence is found that the material was at some time at or below sea level. There seems also to be geological evidence that some areas that are now low in elevation were at one time occupied by mountain systems. This indicates an oscillation of the earth's surface, a rising and falling to the extent of many thousands of feet. Since areas that were once low and are now very greatly elevated or that were once high and are now low are still in isostatic equilibrium, there must have been a change in the density of the column with the change in height of its surface.

It is not known just how these changes have been brought about, but it is certain that the base of sedimentary material which was once approximately at sea level has in some cases been depressed several miles. On the assumption that the temperature increases with the depth, each part of the greater portion of the column under the area of heavy sedimentation has been depressed into a zone that was much hotter than the zone from which it came. This movement of material from one vertical zone to another which is much hotter may start chemical or physical action and cause the material to change its density.

It is probable that the isogeotherms do not maintain their normal depth with the depression of the material under an area of sedimentation. They may be depressed with the material, and after sedimentation has ceased they may rise to their normal position. If this is the case, all of the material of the depressed column would finally become hotter than formerly, and this change of temperature might be enough to cause physical or chemical action resulting in expansion.

There is abundant evidence that there have been horizontal forces at work to distort the sedimentary strata in a mountain area, and we have evidence of overthrusts or underthrusts which extend for a number of miles. This, on first thought, might lead one to conclude that the mountain formation could not have been the result of vertically acting forces. However, the base of a mountain system is usually quite large. The Appalachian system is approximately 200 miles wide on an average. This appears to be a sufficiently large area to permit the development of horizontal movements incidental to the uplift. It seems reasonable to suppose that when the sedimentary material is laid down the area of sedimentation is depressed different amounts in different parts due to the fact that some parts are more heavily sedimented than others. This irregular subsidence might cause the subsequent uplift to take place in different sections of the area affected at different rates and at different times. Distortion of the strata of the sedimentary material must occur whenever a local area is uplifted with the surrounding regions quiescent. The uplifted material probably follows the line of least resistance, and inclined and even horizontal movements will develop, at least near the surface.

There is evidence that much material of the earth has been uplifted without distortion of the strata. The strata of the great plateaus of the west are practically horizontal, and these strata extend for many miles. These plateaus are not the result of horizontal thrusts. They have been found to be in a state of nearly perfect isostatic equilibrium, and therefore their materials are not extra loads on the earth's isostatic shell. If they are not extra loads, then there must have been changes in the densities of the columns under them if the material forming

them was deposited at or below sea level. The column under a sedimentary area will not have less than normal mass before the uplift begins.

Although he was an advocate of only regional isostasy, Barrell recognized the necessity for having a decrease of density under the Colorado plateaus in order to account for their uplift. In Part I, Strength of the Earth's Crust, Journal of Geology, January–February, 1914, page 35, he makes the following statement:

> There are difficulties, however, in using ancient base leveled surfaces now upwarped as measures of the previous stress. It is known that a region like the Colorado plateau, which now stands markedly high, tended to lie near sea level from the beginning of the Paleozoic to the end of the Mesozoic. Presumably a decrease of density within the zone of isostatic compensation has taken place here during the Cenozoic and the uplift has accompanied or followed the internal change.

There seems to be no reason to doubt the theory that mountain masses and plateaus have been uplifted as a result of decrease in the density in the column below them and not by horizontal thrusts developed in great areas beyond the limits of the uplifted material. The theory that a mountain system has been caused by lateral thrusts originating from a distance supposes a very anomalous condition. The theory implies that the earth's crust is competent

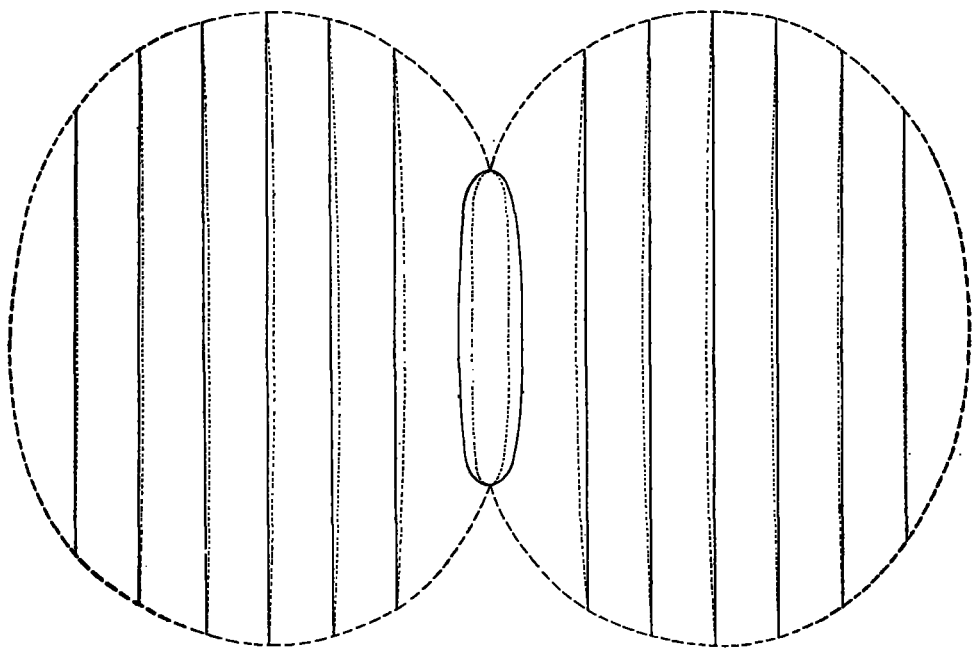

FIG. 20.—Earth movements required to cause mountains by lateral thrust.

to carry thrusts that would squeeze up mountains and plateaus and at the same time that it is so weak that it can undergo the distortion incident to the movement causing the uplift. To be concrete, the Appalachian system is supposed by many to occupy an area that is many miles narrower than the area occupied by the material before the uplift began. Let us assume that the amount of contraction is 20 miles. If the regional horizontal thrust theory is correct, this means that some of the material in the areas beyond moved toward the mountain area as much as 10 miles, or one-half of the shortening of the width of the base of the mountains, assuming that movement occurred from both sides. If we should consider a number of imaginary straight lines a few miles apart parallel to the axis of the mountains to have been drawn on the earth's surface before the movement began, then each of these lines would become bowed during the mountain formation to the extent of making the centers of at least the near ones 10 miles distant from the positions occupied originally. (See fig. 20.)

This, it seems, is an inconceivable situation because no structure that is so weak as to be distorted to this extent could possibly transmit the stresses necessary to hoist the mountains.

From an engineering standpoint we can not conceive of horizontal movements originating outside of the area occupied by the mountains as the cause of mountain uplift. It seems illogical to suppose that the necessary forces could have originated in vast areas which were quiescent, apparently, at the time that the mountain masses were formed. Tremendous forces are required to throw up a mountain mass, and these forces must be developed in some way. The advocates of the theory of regional horizontal thrusts may advance the idea that the earth has contracted and that this has caused the crust or isostatic shell to buckle and thus cause mountain masses, but, if such contraction has occurred, it would be more logical to conclude that the isostatic shell has simply become thicker as the radius of the earth has decreased. This thickening might have occurred locally wherever the radius was shortened, or if the radius were shortened throughout the whole earth then the whole lithosphere or isostatic shell might have become thicker. There must be tremendous friction between the isostatic shell and the material below the shell, and it is hardly possible that the isostatic shell would move over the nucleus and cause some portion of the shell far removed from the forces to rise up as mountains.

Of course, the advocate of the theory of horizontal thrusts has the support of the fact that material below the shell must move from the vicinity of a block of the shell undergoing sedimentation toward one that is being unloaded. This must be taking place all the time in order to maintain the isostatic equilibrium of the areas of sedimentation and areas of erosion. To what extent this flow of material differs from the flow that would be necessary to cause a mountain mass is not known, but if the earth's material has an undertow which keeps the isostatic equilibrium in a high state of perfection the isostatic shell must be quite weak and therefore incapable of accumulating stresses and exerting thrusts of great magnitude. The isostatic flow seems to be a movement which is more or less free. It may not be a hydrostatic flow, but it produces the same results as if it were.[35]

The theory of isostasy is based on the idea of the existence of lighter than normal material under elevated areas, and this theory is widely accepted to-day, but that the changing from normal to subnormal density caused the uplift, independently of the action of regionally acting horizontal forces, is an idea which has not met with the favor that it appears to deserve.

In an interesting and valuable paper entitled "Building of the Southern Rocky Mountains,"[36] Willis T. Lee made a quantitative test of the vertical uplift of mountains. He concludes his paper with the following paragraph:

> In conclusion, two critical considerations may be emphasized: First, changes in density due to flow of heat are slow and they usually oppose crustal movement, halting and finally reversing it. Second, a column of rock made light by increased temperature and decreased density may rise as the top is eroded away, in the manner illustrated by ice, which rises in water as the upper part is melted. Because of the tendency of the column of rock to behave as a floating mass the rise is not restricted to the mere expansion of the mass. A search for cause of the building of the southern Rockies fails to reveal evidence of lateral thrust of sufficient magnitude to account for them by crustal shortening. Field observations indicate that they were formed chiefly by vertical uplift. Considering available sources of information, local forces acting within the crust beneath these mountains seem competent to build them without calling on forces originating at a great distance.

FOLDING IN PARALLEL RIDGES.

It is very difficult to conceive of a disk of viscous material buckling in parallel ridges from regional lateral pressure through surface strata. If a disk were subjected to excessive lateral stresses, it would undoubtedly fail along some one line, and further exertion of the pressures would exaggerate this initial failure. It is inconceivable that the disk would fail in such a way as to make its surface corrugated. We have in some cases parallel ridges in the form of foothills skirting the main ridge of a mountain. If these ridges were caused by lateral pressure, exerted from regions far beyond the base of the mountain mass, it is difficult to see how these

[35] Bailey Willis in a recent article advanced a theory as to the way in which the isostatic flow may take place. See "Discoidal structure of the lithosphere," Bulletin of Geological Society of America, June 30, 1920.

[36] Presented at the annual meeting of the Geological Society of America. Published in Bulletin of Geological Society of America, June 30, 1923.

parallel ridges, often rather symmetrical in character, could be brought about. If one of these ridges were formed by the regional lateral thrust, we should expect it to be increased by continued pressure rather than that the thrusts carried through this distorted area would cause the uplift of additional ridges beyond the first one. If the earth's outer strata were strong enough to throw up mountain masses, then they would certainly be too strong to buckle locally into these low parallel ridges. Again, if the earth's crust were so yielding as to permit the formation of these low ridges, then it would certainly be too weak to throw up the high mountain masses or to maintain them as extra loads on the earth. It seems probable that the folded parallel ridges are caused by horizontal thrusts and movements of a local character.

SUBSIDENCE OF AREAS OF SEDIMENTATION.

Heavy sedimentation sometimes occurs in an inland area where the surface of the sedimentary material remains at approximately the same elevation as the former elevation of the base on which the sediments are laid. The fact that this is true in the Indo-Gangetic plain made it difficult to explain some of the geodetic data collected in that region.

In Burrard's recent paper [37] he discusses at some length this question of the elevation of the surface of the sediments in the Indo-Gangetic plain. After arriving at the conclusion that the gravity anomalies, nearly all of a negative character in this region, are an indication of a condition of isostasy, he asks how large amounts, 40,000 feet, more or less, of sedimentary material of low density can take the place of an equal volume of material of greater density which flows from the base of the earth block under the sediments.

This is an important problem which can not be explained except on the assumption that the material below the sediments has increased in density during the sedimentation. If the column were in isostatic equilibrium when sedimentation started, then after the sediments were deposited it could not have less material in it than normal for the column would not sink if it were lighter than normal.

If the only activity in the column were one to perfect the isostatic balance as sedimentation proceeded, then there would be a gradual rising of the surface of the sedimentary area as the light material was deposited, until sedimentation ceased. This is due to the fact that the sediments are lighter than the material flowing out at the bottom of the column, and therefore the column would subside into the earth only about 80 or 90 per cent of the thickness of the sediments. The remaining thickness of the sediments would stand above the original level. For instance, 10,000 feet of sediments would cause the column to sink approximately 8,000 feet into the earth and 2,000 feet would stand out if the difference in the densities of the materials at the two ends of the column were 20 per cent. But this is not the case in the Indo-Gangetic plain, and we must conclude that the material in the column under the sediments has increased in density. The cause of this increase in density is, of course, not known, but it may have been due to some chemical or physical action other than the ordinary thermal contraction. Whether all of the shrinking of the column and increase in the density of material occurred during the sedimentary period or whether some of the change took place before sedimentation started is also unknown, but probably some of the change took place before sedimentation started and decided the area in which sedimentation occurred. In order that the condition of isostasy may exist there must be increases and decreases of density in the isostatic shell. An increase in density must have occurred under the Indo-Gangetic plain.

PERIODIC UPLIFT AND SUBSIDENCE.

After a mountain has become base leveled by the processes of erosion, isostatic adjustment, and shrinking, the surface of the column may be brought below sea level or at least much lower than the surrounding country and the area may be subjected to very heavy sedimentation. After this sedimentation has progressed to such an extent that the new material is tens of thousands of feet thick the area may again become one of uplift. This process of lowering and

[37] Investigations of Isostasy in Himalayan and Neighboring Regions, Professional Paper No. 17, Trigonometrical Survey of India, Dehra Dun, 1917.

uplift may occur a number of times in the same region. The Alps is a case where the area has been several times below sea level and a like number of times a mountain region. A discussion of this process is given in a paper by the author entitled "The earth's crust and isostasy," which appeared in the Geographical Review, Vol. XII, No. 4, October, 1922.

DIRECTION OF OVERTHRUSTS.

Much has been written about the extent to which overthrusts or underthrusts have occurred in mountainous areas, but the direction of thrusts with relation to the axis of a mountain system has not been carefully considered. If mountains are caused by regional horizontal movements, then the thrusts should evidently be toward the axis of the mountains.

If the mountain masses are caused by vertical uplift due to an expansion of the material in the column under the area affected, the thrusts should ordinarily be away from the center or axis of the mountain system toward the edges. There might be areas, however, in which the maximum upward movement occurred near the edges of the mountain mass and this might cause a thrust toward the center of the area rather than toward the edges. This might occur when the greatest thickness of sediments existed near the margins of the affected area. (See p. 50.) The profiles of mountain ranges should be studied carefully to see what are the directions of the overthrusts or underthrusts.[38]

ISOSTATIC EQUILIBRIUM OF DELTA AREAS.

The first part of a series of papers by Joseph Barrell, entitled "The strength of the earth's crust," in the Journal of Geology, Vol. XXII, 1914, deals with geological tests of the limits of strength of the outer portion of the earth's material. In the introduction Barrel states:

> The capacity of the outer crust to resist vertical stresses is an important field in the theory of dynamical and structural geology. On the one hand, it is known that the larger segments, those of continental and oceanic proportions, rest to a large degree in isostatic equilibrium, the subcrust of the continental areas being lighter than that of the oceanic areas in proportion to the regional elevation. On the other hand, the minor features, those which enter into the composition of the landscape, are known to have been sculptured by external forces and are to be explained, therefore, as sustained by reason of the rigidity of the crust.
>
> Between these two extremes in magnitude of terrestrial relief lie mountain ranges, plateaus, and basins, made in part by tangential forces modified by erosion and sedimentation. To what extent can these constructional and destructional forces work in opposition to those other forces which by producing vertical movement make for isostatic equilibrium?

Barrell discusses the evidence used by the geologists and the isostasists in arriving at their conclusions in regard to the strength of the earth's crust and its ability to carry extra loads. He lays particular stress on the presence of great volumes of sedimentary material at the mouths of large rivers as evidence of the strength of the earth's crust. He shows that the best two of the existing deltas for making the test of the strength of the earth's crust are those of the Nile and the Niger.

Barrell's Figure 1 (fig. 21 in this volume) shows clearly that there has been a filling up of space at the mouth of the Nile which was once occupied by water. Similarly, Barrell's Figure 3 (our fig. 23) indicates a filling in by deposits at the mouth of the Niger. Figures 22 and 24 copied from Barrell give vertical sections through the deltas of the Nile and the Niger, respectively.

Barrell computes from these cross sections and the areas shown on the charts the load added to the earth's crust in the form of sediment. In the case of the Nile the volume is computed as 89,000 cubic kilometers (21,300 cubic miles) which, after accounting for the weight of the water that originally occupied the space, is equivalent to 50,000 cubic kilometers (12,000 cubic miles) of rock on the land.

In the case of the Niger delta the volume of sediments is 217,000 cubic kilometers (52,000 cubic miles) which, after allowing for the water displaced, is equivalent to 120,000 cubic kilometers (29,000 cubic miles) of rock on the land.

[38] A. C. Lawson is of the opinion that thrusts occur in most cases as underthrusts rather than overthrusts. See article by him on Isostatic Compensation Considered as a Cause of Thrusting, Bull. Geol. Soc. of Amer., June 30, 1922.

After discussing the geology of the coasts of Africa and the probability (in his estimation) that the deltas under consideration are extra loads on the earth's crust, Barrell concludes his Chapter I with the following words:

> These deltas point toward a measure of crustal rigidity capable of sustaining to a large degree the downward strains due to the piling up and overthrusting of mountains built by tangential forces or those resulting from the load of sediments in areas of deposition or those upward strains produced by the erosion of the plateaus previously uplifted toward isostatic equilibrium. A final conclusion must, however, await a further discussion in the later parts.

In the remainder of Barrell's series of papers he deals with many phases of structural and dynamic geology and the theory of isostasy, but he does not modify the conclusions quoted above that the earth's crust is able to carry without yielding the mass represented by a large delta. Barrell may have erred in arriving at his conclusion that the earth is able to withstand the load of a mountain mass if it is able to hold up a river delta, but was he not also wrong in his conclusions regarding river deltas?

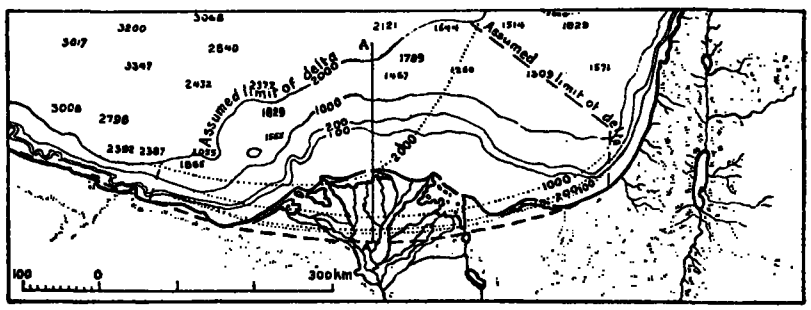

FIG. 21.—Nile Delta.

The maximum depth of the sediments in the delta of the Niger down to the former ocean bottom level is about 3,000 meters (approximately 10,000 feet). The density of this material is probably not more than 2.40. The density of the sea water which occupied the space now occupied by the sediments was slightly over 1. Therefore, we may assume that the weight of the water displaced corresponds to 40 per cent of the material deposited, and that the other 60 per cent is an extra load. Therefore, according to Barrell, there is an overload on the earth's crust amounting to about 6,000 feet of deposits.

We can explain the presence of this 6,000 feet of added material by the theory of isostasy if we assume that much more material has been deposited at the mouth of the Niger than the 10,000 feet. We have abundant evidence that tens of thousands of feet of sediments have been deposited in some localities, and why might there not be more than the 10,000 feet in the Niger delta?

A sinking of the base of the sediments occurs in most areas of sedimentation. This certainly occurred during the sedimentation of the areas occupied by the Appalachian, Himalayan, and other mountain systems. The sinking of the base is due mostly to the isostatic adjustment of the column which is undergoing sedimentation.

The average density of the material of the earth's outer strata—say, for a few miles below sea level—may be assumed to be approximately 3.00. The sedimentary material deposited by the Niger probably has a density of about 2.40. Therefore, the density of the material just below the base of the deposits is 0.60, or 25 per cent greater than the density of the sediments. Assume that the difference is only 20 per cent and also assume that as the sediments are deposited isostatic adjustment takes place. Then, ignoring the water, if 1,000 feet of sediments are deposited, 800 feet of this will sink below the former level of the base of the sediments and 200 feet will stand above the original position of the base. On this basis the delta of the Niger would require a total depth of sediments below the original position of the base of 24,000 feet to bring the surface to the top of the water and give the 6,000 feet of added material in the space once occupied by the water. This, with the 10,000 feet above the base, makes a total depth of the deposits of 34,000 feet. This is not believed to be an excessive depth. In India in the Indo-Gangetic plain the recent sediments are believed to be somewhat more than 40,000 feet in certain parts of the area.

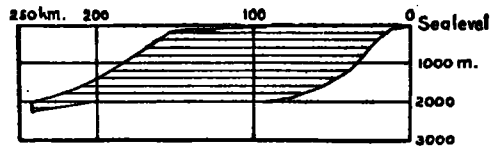

FIG. 22.—Profile of Nile Delta.

With regard to the Nile Delta, Barrell figures that there is a maximum depth of the deposits of approximately 7,000 feet. By the method of computation used above for the Niger Delta we find that the amount of water displaced by the sediments is equivalent to the weight 2,800 feet of the sediments. This leaves 4,200 feet of sediments as an excess load above the sedimentary base on Barrell's theory that the sediments are an overload.

On the theory that the base of the sediments sinks, due to the isostatic adjustment, it would be necessary to lower the base of sediments about 17,000 feet in order to give the 4,200 feet of added material in the space once occupied by the water. This, with the 7,000 feet above the base, makes a total depth of the deposits of 24,000 feet. This is not large in comparison with the depth of sediments in many places of the earth. The above reasoning is justified if the materials deposited in the form of deltas at the mouths of rivers and in the water just beyond the exposed deltas are found to be in isostatic equilibrium.

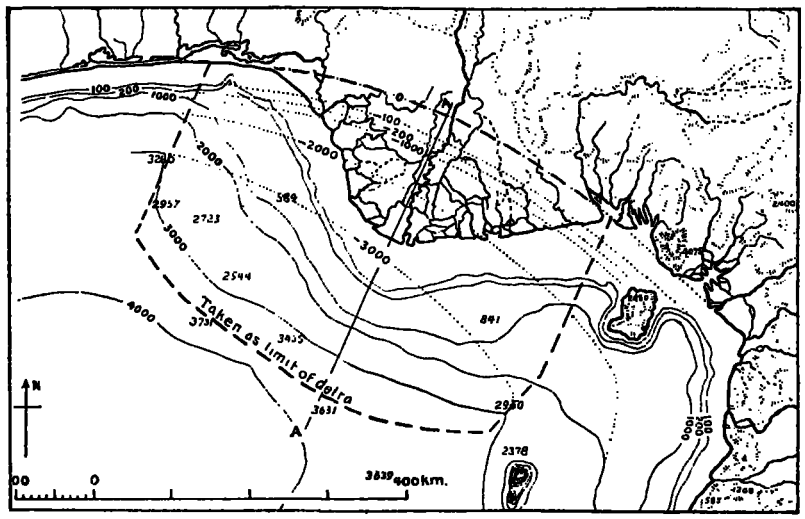

FIG. 23.—Niger Delta.

We are fortunate in having a number of gravity stations on or near the Mississippi River Delta. There are eight of these stations. (See fig. 25.) Although the mass of the Mississippi River Delta does not show on a hydrographic chart as distinctly as do those of the Nile and Niger, yet the river has carried material quite far out into the Gulf of Mexico, and the depth of the deposits must be considerable.

If the block of the isostatic shell under the delta was in equilibrium before deposition began, then certainly the added material is an extra load unless some subsidence of the block has taken place. On the assumption that the delta material is an extra load we should find positive anomalies at the gravity stations on the delta, the sizes of the anomalies being in proportion to the depth of the delta material.

Instead of finding decided positive anomalies at the eight stations on or near the delta, we find that only four of the stations have positive anomalies of 0.012, 0.014, 0.019 and 0.002 dyne. All of these positive anomalies are smaller than the average anomaly without regard to sign for the 304 gravity stations of the United States. The other four delta stations have negative anomalies of 0.018, 0.026, 0.013 and 0.032 dyne. Three of these anomalies are larger than the average for all in the United States. The average of the eight anomalies with regard to sign is -0.007. Surely, if the delta is an extra load the pendulum observations would not give an average negative anomaly at these delta stations.

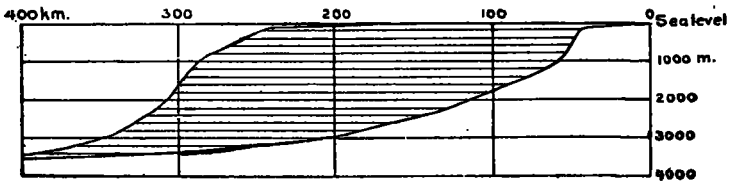

FIG. 24.—Profile of Niger Delta.

It is believed that the positive anomalies on the delta at the three stations near the mouth of the river may be due to local accumulation of material which has not yet been isostatically balanced. On the other hand, the presence of extra light material close to the station is the probable cause of the negative anomalies, and the columns under these negative stations are probably in isostatic equilibrium. That the anomalies are due to local causes which are located

near the surface is indicated by the difference in the anomalies at stations 279 and 280 which are at the mouths of the river. The difference in these anomalies is 0.037 dyne and the distance between the stations is only about 12 miles. It is certain that if the cause of either of the two anomalies in question were deep seated in the earth's crust the effect on the two stations would be almost the same.

It is rather difficult to analyze the gravity anomalies on the Mississippi Delta in such a way as to give a logical explanation of the size and sign of each of them. It is much safer to use the whole group of stations as a single unit in drawing conclusions. Since the average anomaly of the whole group is −0.007 dyne, we are evidently justified in concluding that the block of the isostatic shell directly under the Delta of the Mississippi is very nearly in isostatic equilibrium and that the delta material has been compensated for by a movement of material from the base of the block.

It is unfortunate that there are no gravity stations on such deltas as the Nile and the Niger to test the degree of isostatic equilibrium which exists in the earth's crust under them. This matter is of such great interest it is hoped gravity stations will be established on these deltas in the not distant future.

EFFECT OF ISOSTATIC ADJUSTMENT ON SURFACE CONFIGURATION.

It would be a difficult task to work out in detail the effect of isostatic adjustment (the movement of material below the crust from areas of sedimentation toward areas of erosion) on the surface configuration of the earth. It is undoubtedly true that as a block of the earth's crust sinks under a load of sediments there is much distortion of the lower sedimentary strata as well as of the material on which the sediments are laid. When enormous depths of sediments are laid on an area, the sediments are apt to be placed in an irregular way. Take, for instance, the Indo-Gangetic plain, all of which is above sea level, which receives material eroded from the Himalayan Mountains. This material is not laid down in concentric strata but is, no doubt, deposited, first in one place and then in another. Owing to the irregular manner in which the deposits are made, the subsidence is probably a rather local phenomenon which takes place under the area being loaded while the other portions of the plain remain inactive. After sediments have elevated the surface of a portion of an area a certain amount they are probably deflected to some other place, perhaps a hundred miles or more away.

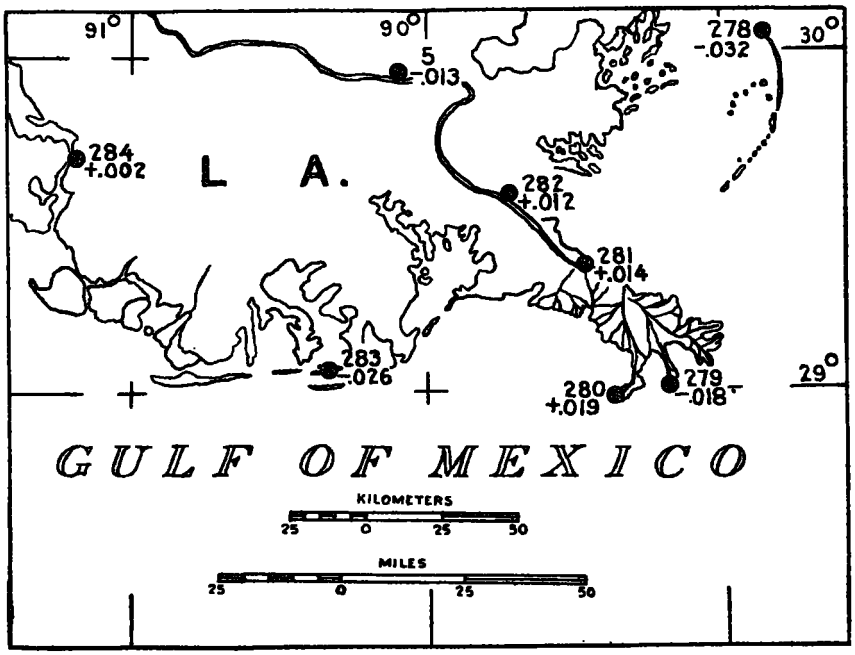

FIG. 25.—Gravity stations on Mississippi Delta.

During the process of subsidence of an area under sedimentation there must be distortion, especially near the margins of the sedimentary region. In the process of uplift following the subsidence there must be additional distortion of the strata because of the fact that the area does not all move upward at the same rate and at the same time. Probably, as in the case of

subsidence, one portion of the area undergoes uplift while the remainder is quiescent. This irregularity in the time and place of uplift, together with the distortions that occurred with the subsidence, might cause considerable change in the form of the strata and result in much of the folding that is seen in mountain areas. Undoubtedly the distortions due to subsidence and uplift have much to do with the forms of the surface of mountain areas. Besides, much of the buried material, which is later exposed after erosion, is distorted by the upward movement resulting from the isostatic adjustment.

We can not believe that every small topographic feature such as a small mountain valley, an individual peak, or a hillside, is in isostatic equilibrium independently of the surrounding region. In order to permit isostatic adjustment directly under the very limited area, the material in the isostatic shell would have to be almost entirely without rigidity or strength. Suppose a small mountain valley should fill up to the extent of a few hundred feet. If isostatic adjustment took place, the whole column under that small valley, down to the depth of compensation, would have to be lowered, thus making a small amount of overload overcome the resistance to shear along the sides of the column. The materials of the crust resist the stress differences due to the irregular surface, and hence they must have sufficient strength to maintain a small load such as a few hundred feet of sediments in a small mountain valley. If the earth's material were very plastic, then individual mountain peaks and ridges would flatten out into the surrounding valleys and plains. This, we know, does not occur.

There are two processes involved in mountain uplift. One is the original movement which can not be due to any isostatic adjustment, as no material is brought into the column and therefore the isostatic balance is not disturbed during the movement. This uplift must be due to the expansion of the material in the earth's crust under the area of sedimentation. After the uplift has begun and erosion has started the isostatic adjustment comes into play and the configuration of the area subsequent to the erosion will be more or less modified by the adjustment. These two movements, one the original elevation of the mountain due to expansion and the other the isostatic uplift, have an influence on the configuration of the earth's surface. It is probable, and in fact it seems certain, that the exposure of igneous rocks in an old mountain mass is due to the continued uplift of the area to maintain the isostatic balance as erosion takes place.

The theory of isostasy enables us to reach a reasonable explanation of the phenomenon of erosion to the extent of tens of thousands of feet from a mountain area, say 5,000 or 10,000 feet in height originally. As material is eroded from the surface other material enters the base of the isostatic column under the area of erosion, and the average elevation of the area will be lowered very slowly.

It is probable that an area of very light material is lowered much more rapidly by erosion than one of very heavy material. This may be at least a partial explanation of the maintenance of the elevation of the pre-Cambrian areas. The material of the pre-Cambrian formation has a density probably 10 per cent greater than the average density of surface rocks, and it may be that the material entering at the base of the column is very little denser than that eroded from the surface. The density at the base of the isostatic columns is not known, of course, but it is probably not very much greater than the densities of the pre-Cambrian materials.

EFFECT OF ISOSTATIC ADJUSTMENT ON SURFACE CONFIGURATION NEAR AREAS OF EROSION AND SEDIMENTATION.

If we consider an area of deposition and try to visualize the method by which the isostatic adjustment takes place, we find a very complicated situation. Let us suppose that 100 feet of sediment has been deposited over an area comparable in size with the Mississippi Delta. This deposit, if placed on the area in a very short time, will make the column under it heavier than contiguous columns of equal cross section. The stress difference will be from the sedimentary column toward the surrounding columns, and if the material is sufficiently yielding the balance will be restored by a flowing out of material from the vicinity of the lower part of the sedimentary column.

Let us suppose that the sedimentary column has been brought into equilibrium with the surrounding columns. Then, these columns combined will be out of equilibrium with the columns that are outside of the limited area that we have been considering. If the stress differences are beyond the power of resistence of the material at or below the base of the columns, there will be a flow from the central columns toward these outer ones. This process no doubt will cause local oscillations of the earth's crust incident to the establishment of the isostatic equilibrium between adjacent blocks of the isostatic shell. It is possible that there is a sort of wave motion in the isostatic shell, tending to reestablish isostatic equilibrium between the area of deposition and the area of erosion, which may be 1,000 miles or more away.

We certainly can not expect material to flow from below the base of a column that has been subject to sedimentation straight back toward the area from which the material was eroded, or without affecting the elevation of the intervening area. As the flow of material progresses from the area of sedimentation toward areas of erosion there will undoubtedly be first a rising and then a settling back to the normal elevation of the surface of the intermediate portion of the isostatic shell.

If an elevated region and the surrounding blocks of the isostatic shell are in equilibrium to start with, then as erosion from the high area takes place a stress difference from the surrounding region toward the area from which material is being removed will be developed. When the stress difference has accumulated to a sufficient extent the surrounding region will sink in order to bring it into equilibrium with the eroded area. This process will cause a stress difference between the areas still farther out and the central area which will tend to bring the two into equilibrium. Whether there will be any actual vertical movement responding to these stresses will depend on the magnitude of the stress difference and the resistance of the material of the isostatic shell. It will be seen that this is the reverse of the process which tends to operate around areas undergoing sedimentation. The movement of material below the isostatic shell to restore isostatic equilibrium will not be a simple one along straight lines from under the area of sedimentation back to that of erosion.

In his book, "The Strandflat and Isostasy,"[39] Nansen discussed the vertical movement which would probably occur adjacent to an area covered by an ice cap. He says in part:

> Let us try to imagine what would happen if the crust be gradually pressed down by an increasing ice cap, provided that the conditions are fairly hydrostatic at a certain depth under the earth's surface.
>
> Supposing the ice cap begins to be formed in the central area of an extensive region like Fenno-Scandia, the load of the ice cap will press the crust down in this central area and in a zone surrounding it the crust will be pressed up and will there form a kind of concentric wave. As, however, this wave will not represent a state of equilibrium, it will gradually extend outward and will be flattened down as it becomes wider and wider.
>
> If, now, the ice cap increases in thickness and in extent, the crust will continue to be pressed down and the surrounding upheaval wave will increase somewhat in height while it will be moved outward by the advance of the ice cap.
>
> The depression of the crust will continue a long time after the ice cap has ceased to increase and will only very slowly and asymptotically approach its level of isostatic equilibrium. The wave of upheaval surrounding the depressed area will continue to widen, and the real level of isostatic equilbrium will not be fully reached before this surrounding wave is entirely flattened out and the depression of the ice-covered area is fully compensated for by the upheaval of the floor of the ocean, but this is a state which is never reached.

Nansen discusses vertical movements of the surface as the ice cap diminishes in area and volume, and then says:

> It seems to be that a development, as here indicated, agrees well with what we know about the late-glacial and post-glacial crustal movements which probably have taken place in Fenno-Scandia and the surrounding regions.

There is a decided difference in the situation discussed by Nansen and that due to erosion and deposition of material. In the first case, the accumulation of material in the form of an ice cap is much more rapid than that due to ordinary sedimentation. The stress differences in the first case might assume large dimensions owing to the slowness of the material of the isostatic shell in yielding to rapidly accumulated stresses, but with ordinary sedimentation the stresses would accumulate gradually and probably would be relieved before they could reach the magnitude of those that would occur under and near an ice cap.

---

[39] Fridtjof Nansen, "The Strandflat and Isostasy," I Kommission Hos Jacob Dybwad, Khristiania, Norway, 1922.

ZONE OF HORIZONTAL MOVEMENT.

One of the most important phases of isostasy from a geological standpoint is the question of the depth at which the isostatic flow or adjustment takes place. Barrell, in the "Strength of the Earth's Crust," Part VI (Journal of Geology, October-November, 1914, p. 681) argues in favor of a zone of weakness below the isostatic shell, which he calls the asthenosphere, in which the isostatic movement horizontally takes place. Willis agrees with Barrell that the isostatic movement horizontally takes place below the isostatic shell.[40] The writer feels that Barrell's and Willis's views that the movement is below the shell are reasonable and justifiable.

If the earth's crust were weak enough to permit isostatic adjustment to take place comparatively near the surface then the material would probably be so weak that masses of different densities would tend to flatten out and to adjust themselves in strata, each having a uniform density. The heavy material under the oceans would move under the continents and the light material of the continents would move out over the ocean floor. The heavy material under a broad plain would move under the adjacent mountain area and the material under the mountains would overflow the denser material of the plains. This, as we have found from the studies of the deflections of the vertical and the gravity observations, has not taken place. We have denser material under the plains and lighter material under the mountains, and this condition tends to remain so. We must conclude that in the column down to the lower limit of compensation the material is of sufficient viscosity to resist the stresses tending to cause the transference of material horizontally due to different densities.

There is no doubt that isostatic adjustment takes place, and therefore there must be a zone within which horizontal movement occurs. Since, for the reasons stated above, this movement could not take place within the isostatic shell, it is logical to conclude that the movement is in what Barrell terms the asthenosphere or zone of weakness. Barrell's diagram, on page 681 of "Strength of the Earth's Crust," referred to above, would indicate that he believed the thickness of the asthenosphere to be several times the thickness of the isostatic shell. Undoubtedly, the zone of weakness may be of considerable thickness and may extend to the earth's center, but it is more reasonable to believe that the isostatic adjustment takes place within a short distance of the isostatic shell.

In order to visualize the problem, let us suppose that we have a mountain mass of 100 square miles in cross section and an adjacent plateau of the same area 3,000 feet lower than the average elevation of the mountain. It can be readily shown that if these two columns are in isostatic equilibrium, then at any depth below sea level but above the depth of compensation the pressure on an imaginary horizontal surface will be greater for the mountain block or column than for the plateau column. At a depth of 5,000 feet below the surface of the plateau column the pressure would be that of 5,000 feet of material, but on the same surface under the mountain the pressure would be that of 8,000 feet of material. The stress difference at the depth in question would tend to cause a movement from the mountain column toward the plateau column.

If we assume that the depth of compensation is 60 miles below the surface of the plateau column, then at a depth of 30 miles, half way from the surface to the depth of compensation, we should expect the deficiency of density due to the isostatic compensation of the mountain column to counterbalance 1,500 feet of the 3,000 feet at the top of the mountain column, and the weight on this surface at a depth of 30 miles would be greater for the mountain column than for the plateau column due to the remaining 1,500 feet of material. The stress difference would still be acting from the mountain column toward the plateau column. At a depth of 45 miles below the surface the stress difference would be the equivalent of the weight of 750 feet of material and would still be from the mountain column toward the plateau column. It can be seen from the above that if the isostatic compensation is uniformly distributed there will not be a zero stress difference between the mountain and the plateau columns until the depth of compensation is reached, approximately 60 miles below sea level.

[40] Bailey Willis, Discoidal Structure of the Lithosphere. Bulletin of the Geological Society of America, June 30, 1920, p. 251.

Suppose some material is eroded from the mountain area and deposited on the plateau column. The stress difference at the depth of compensation will then act in a direction from the plateau column toward the mountain column. There will be a surface somewhere above the depth of compensation at which the pressure of the lightened mountain column will exactly balance that of the plateau column which has been increased by the weight of the eroded matter. If 100 feet of material, on an average, is eroded from the mountain column and placed on the plateau column, we should expect the surface at which the two columns will exert equal weight to be 56 miles below the surface or 4 miles above the depth of compensation. Below this surface the stress difference will be from the plateau column toward the mountain column, and if this stress difference is great enough to overcome the resistance of the material a flow will take place from the plateau column toward the mountain column tending to bring the two columns into equilibrium again at the depth of compensation.

It is probable that this flow actually takes place below the depth of compensation because of the fact that the material below the depth limiting the compensation must differ from the material above in rigidity or viscosity. The fact that we have a depth of compensation implies a plastic material below it, and there is no reason why this material should not flow rather than the material above, which is rigid enough to maintain its position in spite of different densities in adjacent columns.

If the depth of compensation is above the depth of equal pressure (see p. 39) the problem outlined above and its solution should be slightly modified, but the general principles and conclusions would be unaltered.

In the above illustration two blocks of the isostatic shell have been used which have very small difference in elevation and which are adjacent to each other. As a rule, we may expect the area of erosion to be quite distant from the area within which the deposition of the eroded material occurs. In the case of the Mississippi River drainage basin the mountains from which much of the material comes are more than a thousand miles from the mouth of the river at which a great proportion of the eroded material is deposited. Of course, there is no well defined area from which this material is eroded. There is a large zone of erosion rather than a small limited area.

Part II.—GRAVITY DETERMINATIONS.

ABSTRACTS OF RESULTS.

At the beginning of the year 1916, 219 gravity determinations of precise accuracy had been made in the United States. The results for these stations are given in Special Publication No. 40. Observations at 94 additional stations have since been made. Abstracts of the observations at 85 of these new stations and at the base station at Washington, D. C., are given in the following pages. Descriptions of the stations are also given. (See pp. 86–90).

Stations Nos. 287 to 296 have not been finally computed. These nine stations were occupied in 1922 by a party making wireless longitude determinations and latitude observations in Wisconsin, New Mexico, and Colorado. When the pendulums were restandardized at the end of this season's work, the periods obtained differed by considerable amounts from those obtained at the beginning of the season. As all six pendulums tested showed nearly the same discrepancies, it was concluded that the trouble must be with the receiver or other auxiliary apparatus rather than with the pendulums themselves. A long but unsuccessful series of observations was made at the base station in an attempt to locate the cause of the discrepancies. It was finally decided that the preseason standardization must have been at fault. It will be necessary to reoccupy several of the stations before the final results of that season's work can be computed.

The Coast and Geodetic Survey has two complete sets of gravity apparatus of the modern type, to each of which has recently been added a set of invar pendulums. One set of apparatus was sent to the Philippines in 1921 for some special work at Manila and was not available for use here for the 1922 season. As it was desired to have two gravity parties in the field, a set of apparatus belonging to Cornell University was borrowed from Dr. D. S. Kimball, dean of engineering of that university. The bronze pendulums of the Cornell set were not sent to the field as it was desired to make use of the new invar pendulums, but all of the auxiliary apparatus of the Cornell set was used at the nine stations mentioned above.

Beginning with station No. 277, the first station of the 1921 field season, all determinations of gravity have been made with the new invar pendulums. The reliability of these pendulums has been tested at several stations by means of duplicate determinations with the old bronze pendulums. The new pendulums have been found entirely satisfactory. The probable errors obtained with them under adverse observing conditions are no larger than those obtained with the bronze pendulums under much better conditions.

A solenoid is used with which to demagnetize the invar pendulums and to keep the magnetic effect on the pendulum periods small enough to be negligible. The pendulums are tested for magnetism before and after use at each station. For this purpose a compass declinometer equipped with two horizontal arms from which the pendulums may be suspended at known distances from the needle is used. The pendulums seldom need to be demagnetized, as a deflection of the needle of 3° at a distance of 15 centimeters is considered an allowable limit, and the deflection found is seldom greater than 2°.

METHODS OF OBSERVING.

The methods used in making gravity observations are explained fully in U. S. Coast and Geodetic Survey Special Publication No. 69, entitled "Modern Methods for Measuring the Intensity of Gravity," of which C. H. Swick, mathematician, is the author.

With the exception of 7 stations on and near the Mississippi Delta, the chronometer rates for all gravity determinations considered in this publication have been obtained from time signals sent out from the Naval Observatory at Washington, D. C., either by wire or wireless or

from the Naval Observatory at Mare Island, Calif., by wire. During the 1922 field season wireless signals were used for the first time for gravity work. They were recorded on a chronograph by means of a special radio receiving apparatus designed and constructed by Drs. E. A. Eckhardt and J. C. Karcher, of the Bureau of Standards. The same type of recording apparatus has been used also on longitude work and has given very satisfactory results on both classes of work.

Two 12-hour swings per day are now generally used instead of the three 8-hour swings as formerly. During the season of 1922, however, both the noon and 10 p. m. signals were recorded at many of the stations, and the day was divided into one 10-hour swing and two 7-hour swings. This gave two independent determinations of gravity for each day's observations and was therefore a very efficient method.

When gravity observations are made with invar pendulums and wireless signals are used for obtaining the chronometer rates, it is possible without excessive cost to observe the value of gravity at almost any desired location even though it be in an open field a long distance from a telegraph station and where no constant temperature room is available. The antenna for the wireless receiving set may be stretched between trees, or if the station is in an open field the 50-foot collapsible poles carried with the outfit are set up and guyed and the antenna stretched. Since even large changes in temperature have only a slight effect on the period of an invar pendulum, the apparatus is often set up in a canvas tent.

The collapsible aluminum tripod, designed as a support for the latitude instrument, has been used at many of the recent stations as a substitute for a pier on which to support the receiver. The legs of the tripod are placed on pieces of wood or rock buried about a foot below the surface of the ground and the earth is tamped in around the legs. The flexure correction is from two to four times the average correction obtained when the instrument is mounted on a concrete pier or floor. Owing to the difficulty in making determinations of large flexures and possibly to more uncertainty in the values than is desirable, it is believed the use of these tripods should not be continued.

During the 1922 season both gravity parties used motor trucks for transportation. This resulted in a saving of both time and money, as many of the stations were at long distances from the nearest railroad stations.

EXPLANATION OF TABLES.

The arrangement of the various tables in this publication is practically the same as in Special Publication No. 40. The table of Principal Facts on page 58 has an additional column giving the isostatic anomaly, but otherwise it corresponds exactly to the table in No. 40.

It should be noted that the theoretical gravity at sea level, γ_0, is computed by the Helmert formula of 1901[1] both as a matter of convenience and to make the table correspond to the tables in previous gravity publications. The column headed $g-g_0$ gives, therefore, the gravity anomaly based on the Helmert formula. The isostatic anomalies are obtained by applying a correction of -0.008 dyne to the values in the "$g-g_0$" column. This correction reduces the anomalies to what they would be if the 1912 formula were used in computing the theoretical gravity at sea level. (See p. 8.) This correction also happens to represent about the average difference between the Helmert formula and the formula given on page 134 of Special Publication No. 40 for the latitude of the United States.

The correction in dynes for elevation of station was computed by the formula

$$C=-0.0003086H,$$

in which H is the elevation in meters. It should be carefully noted that with the sign as given this is the reduction from sea level to the level of the station, a correction to the theoretical value, not to the observed value. This correction takes account of the increased distance of the station from the attracting mass, as if the station were in the air and there were no irregularities in the earth's surface (or topography).

[1] Helmert's formula of 1901 for the Potsdam system is as follows: $\gamma_0=978.030\,(1+0.005302\sin^2\phi-0.000007\sin^2 2\phi)$. (See U. S. Coast and Geodetic Survey Special Publication No. 40, p. 49.)

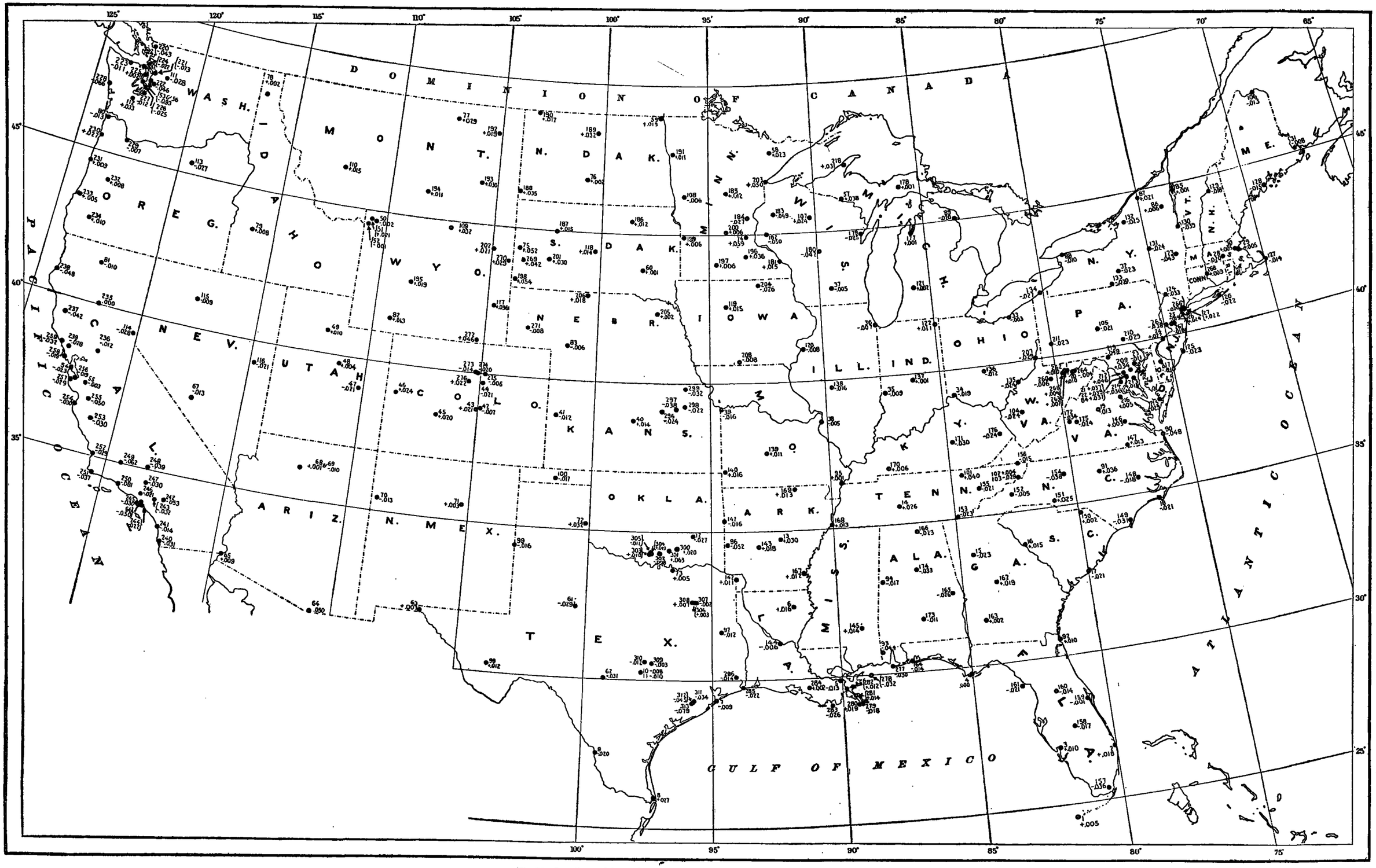

Fig. 26.—Location and isostatic anomalies of gravity stations in the United States.

The corrections for topography and compensation by the isostatic method were computed with the reduction tables shown on pages 30 to 47 of Special Publication No. 10, except that the corrected table for Zone C on page 10 of Special Publication No. 40 was used. The resultant effect of the topography and compensation was applied as a correction to the theoretical value of gravity at sea level as was done with the correction for elevation. These corrections are often applied to the observed values, and the results are compared with the theoretical value of gravity at sea level. The method employed in this publication and also in Special Publications Nos. 10, 12, and 40 seems to be the more logical one.

The observed values in the column headed "*g*" depend upon relative determinations with the half-second pendulums and are based on 980.112 dynes as the value of gravity at the base station at the Coast and Geodetic Survey office in Washington. This value depends upon the absolute determination of the value of gravity at Potsdam,[2] Germany, and upon the adjustment of the net of base stations throughout the world.[3] The observations used in the adjustment to connect Washington with stations in Europe were made by G. R. Putnam in 1900.[4]

The table on page 59, giving the anomalies by the three different methods of computation, is the same as the table on page 59 of Special Publication No. 40. The table of pendulum observations and reductions on pages 72 to 85 correspond exactly to that in Special Publication No. 40, except that the probable errors are computed a little differently, as explained below.

In the interval between time determinations there are usually 2 and sometimes 3 or more swings of the pendulum, calling a swing the interval of from 8 to 12 hours between the time the pendulum is started to oscillate and the time it is stopped and started anew. Due to the irregular rate of the chronometer with which the pendulum is compared by the method of coincidences, the results of the different swings may have considerable range, but the mean of the swings between consecutive time determinations gives an accurate independent determination of gravity. The probable errors were, therefore, computed by using the means of the swings between time determinations instead of the individual swings. For stations Nos. 220 to 286 and 296 the value of *g* for each individual swing has been computed. For the remaining stations the mean periods of the pendulums between consecutive time determinations have been used in computing the values of *g*. In either case, however, the mean values of *g* between consecutive time determinations were used in computing the probable errors.

In the third column of the table is given the number of the pendulum used for each swing. Pendulums numbered A4, A5, A6, B4, B5, and B6 are bronze pendulums, and those numbered A7, A8, A9, B7, B8, and B9 are invar pendulums. Observations with pendulums A7, A8, and A9 are not given in the table, as these pendulums were used for the first time at the nine stations mentioned on page 55, which have not yet been computed. The bronze and invar pendulums may usually be distinguished in the table by the size of the temperature correction in the fifteenth column as well as by the number of the pendulum. The temperature correction for the bronze pendulums is always quite large unless the temperature given in the tenth column is close to the standard of 15° C.

[2] Prof. F. Kuhnen und Prof. Dr. Ph. Furtwängler, Bestimmung der absoluten Grösse der Schwerkraft zu Potsdam mit Reversionspendeln, p. 380.

[3] See Comptes Rendus l'Association Géodesique Internationale, Vol. III, 1911, E. Borass, pp. 25 and 244.

[4] G. R. Putnam, Determination of Relative Value of Gravity in Europe and the United States in 1900, Appendix 5, Coast and Geodetic Survey Report, 1901, pp. 354-355.

Principal facts for gravity stations established since 1915.

Number and name of station.	Latitude ϕ.		Longitude λ.		Elevation.	Theoretical gravity γ_0.	Correction for— Elevation.	Correction for— Topography and compensation.	Computed gravity g_c.	Observed gravity g.	$g-g_c$.	Isostatic anomaly.
	°	′	°	′	*Meters.*	*Dynes.*	*Dyne.*	*Dyne.*	*Dynes.*	*Dynes.*	*Dyne.*	*Dyne.*
220. Bellingham, Wash	48	45.1	122	28.6	20	980.955	−0.006	−0.030	980.919	980.884	−0.035	−0.043
221. Everett, Wash	47	58.6	122	12.5	41	980.885	−.013	−.026	980.846	980.781	−.065	−.073
222. Issaquah, Wash	47	31.6	122	02.2	39	980.844	−.012	−.031	980.801	980.763	−.038	−.046
223. Port Angeles, Wash	48	07.0	123	25.9	24	980.898	−.007	−.013	980.878	980.875	−.003	−.011
224. Port Townsend, Wash	48	06.8	122	45.6	30	980.897	−.009	−.016	980.872	980.858	−.014	−.022
225. Port Gamble, Wash	47	51.3	122	35.1	17	980.874	−.005	−.021	980.848	980.858	+.010	+.002
226. Bremerton, Wash	47	34.4	122	37.8	6	980.849	−.002	−.020	980.827	980.810	−.017	−.025
227. Tacoma, Wash	47	15.2	122	26.3	26	980.820	−.008	−.020	980.792	980.788	−.004	−.012
228. Moclips, Wash	47	14.6	124	13.4	8	980.819	−.002	+.011	980.828	980.770	−.058	−.066
229. Portland, Oreg	45	31.4	122	40.7	8	980.663	−.002	−.016	980.645	980.646	+.001	−.007
230. Tillamook, Oreg	45	27.4	123	50.6	5	980.657	−.002	+.010	980.665	980.700	+.035	+.027
231. Newport, Oreg	44	38.2	124	03.3	48	980.583	−.015	+.016	980.584	980.601	+.017	+.009
232. Eugene, Oreg	44	02.7	123	05.6	129	980.529	−.040	−.015	980.474	980.490	+.016	+.008
233. Marshfield, Oreg	43	22.0	124	13.4	24	980.468	−.007	+.018	980.479	980.492	+.013	+.005
234. Glendale, Oreg	42	44.2	123	25.8	434	980.411	−.134	+.007	980.284	980.302	+.018	+.010
235. Tehama, Calif	40	01.6	122	07.2	65	980.168	−.020	−.034	980.114	980.122	+.008	.000
236. Sacramento, Calif	38	34.8	121	29.8	7	980.040	−.002	−.016	980.022	980.018	−.004	−.012
237. Willits, Calif	39	24.9	123	22	420	980.114	−.130	+.057	980.041	980.007	−.034	−.042
238. Eureka, Calif	40	48.2	124	09.7	12	980.237	−.004	+.027	980.260	980.220	−.040	−.048
239. Santa Rosa, Calif	38	26.4	122	43.0	48	980.028	−.015	+.028	980.041	980.021	−.020	−.028
240. San Diego, Calif	32	42.8	117	09.9	7	979.539	−.002	+.014	979.551	979.528	−.023	−.031
241. Oceanside, Calif	33	11.6	117	22.5	39	979.578	−.012	+.008	979.574	979.568	−.006	−.014
242. Highland, Calif	34	07.5	117	12.5	393	979.656	−.121	−.014	979.521	979.476	−.045	−.053
243. Pomona, Calif	34	03.2	117	45.2	258	979.650	−.080	.000	979.570	979.546	−.024	−.032
244. Long Beach, Calif	33	46.3	118	11.6	8	979.627	−.002	+.005	979.630	979.616	−.014	−.022
245. Redondo Beach, Calif	33	50.6	118	23.3	23	979.633	−.007	+.011	979.637	979.615	−.022	−.030
246. Burbank, Calif	34	11.1	118	18.9	187	979.662	−.058	−.001	979.603	979.590	−.013	−.021
247. Palmdale, Calif	34	35	118	08	808	979.695	−.249	+.038	979.484	979.462	−.022	−.030
248. Mojave, Calif	35	03.2	118	10.4	838	979.734	−.259	+.027	979.502	979.471	−.031	−.039
249. Maricopa, Calif	35	03.8	119	24.0	257	979.735	−.079	−.002	979.654	979.600	−.054	−.062
250. Ventura, Calif	34	16.8	119	17.6	24	979.670	−.007	+.006	979.669	979.596	−.073	−.081
251. Concepcion, Calif	34	26.9	120	28.3	65	979.684	−.020	+.050	979.714	979.685	−.029	−.037
252. Avila, Calif	35	10.6	120	43.9	13	979.745	−.004	+.032	979.773	979.752	−.021	−.029
253. San Lucas, Calif	36	07.8	121	01.2	122	979.827	−.038	+.020	979.809	979.787	−.022	−.030
254. Monterey, Calif	36	36.0	121	53.8	6	979.867	−.002	+.047	979.912	979.890	−.022	−.030
255. Hollister, Calif	36	51.1	121	24	88	979.889	−.027	+.017	979.879	979.837	−.042	−.050
256. Palo Alto, Calif	37	26.6	122	09.7	15	979.940	−.005	+.030	979.965	979.954	−.011	−.019
257. San Gregorio, Calif	37	19.4	122	23.3	16	979.930	−.005	+.046	979.971	979.950	−.021	−.029
258. Point Reyes Station, Calif	38	04.0	122	48.7	8	979.995	−.002	+.042	980.035	980.024	−.011	−.019
259. Duncans Mills, Calif	38	27.3	123	03.8	7	980.029	−.002	+.036	980.063	980.039	−.024	−.032
260. Clarksburg, W. Va	39	16.8	80	20.3	306	980.102	−.094	−.002	980.006	980.008	+.002	−.006
261. Rowlesburg, W. Va	39	20.8	79	40.2	421	980.108	−.130	+.003	979.981	979.993	+.012	+.004
262. Terra Alta, W. Va	39	26.9	79	32.9	790	980.117	−.244	+.040	979.913	979.931	+.018	+.010
263. Corinth, W. Va	39	25.6	79	29.4	751	980.115	−.232	+.038	979.921	979.936	+.015	+.007
264. Kitzmiller, Md	39	23.6	79	10.4	493	980.112	−.152	+.011	979.971	979.975	+.004	−.004
265. Pennington, N. J	40	20.0	74	47.6	56	980.196	−.017	+.014	980.193	980.163	−.030	−.038
266. Glen Ridge, N. J	40	48.1	74	12.2	58	980.237	−.018	+.011	980.230	980.218	−.012	−.020
267. Plainsboro, N. J	40	20.0	74	35.8	26	980.196	−.008	+.012	980.200	980.190	−.010	−.018
268. Hartford, Conn	41	44.8	72	41.8	37	980.322	−.011	+.008	980.319	980.336	+.017	+.009
269. Hill City, S. Dak	43	55.9	103	34.1	1,518	980.519	−.468	+.035	980.086	980.136	+.050	+.042
270. Newcastle, Wyo	43	51.4	104	11.8	1,328	980.512	−.410	+.003	980.105	980.142	+.037	+.029
271. Bridgeport, Nebr	41	40.1	103	05.9	1,114	980.315	−.344	−.005	979.966	979.966	.000	−.008
272. Buford, Wyo	41	07.4	105	18.3	2,396	980.266	−.739	+.049	979.576	979.630	+.054	+.046
273. Boulder, Colo	40	01.2	105	16.6	1,630	980.168	−.503	−.038	979.627	979.621	−.006	−.014
274. Lafayette, Colo	39	59.8	105	05.2	1,595	980.166	−.492	−.025	979.649	979.637	−.012	−.020
275. Brighton, Colo	39	59.3	104	48.9	1,511	980.165	−.466	−.022	979.677	979.679	+.002	−.006
276. Idaho Springs, Colo	39	44.6	105	31.1	2,303	980.143	−.711	−.004	979.428	979.458	+.030	+.022
277. Fort Morgan, Ala	30	13.8	88	01.2	2	979.339	−.001	+.016	979.354	979.332	−.022	−.030
278. Chandeleur Island, La	30	02.8	88	52.3	2	979.325	−.001	+.015	979.339	979.315	−.024	−.032
279. Port Eads, La	29	01.0	89	09.8	2	979.245	−.001	+.034	979.278	979.268	−.010	−.018
280. Burrwood, La	28	58.0	89	22.8	2	979.241	−.001	+.031	979.271	979.298	+.027	+.019
281. Fort St. Philip, La	29	21.8	89	27.9	2	979.271	−.001	+.022	979.292	979.314	+.022	+.014
282. Pointe a la Hache, La	29	34.7	89	47.7	2	979.288	−.001	+.017	979.304	979.324	+.020	+.012
283. Timbalier Island, La	29	02.8	90	21.3	2	979.248	−.001	+.020	979.267	979.249	−.018	−.026
284. Morgan City, La	29	41.7	91	12.5	2	979.297	−.001	+.012	979.308	979.318	+.010	+.002
285. Sabine, Tex	29	43.4	93	52.0	3	979.299	−.001	+.007	979.305	979.291	−.014	−.022
286. Beaumont, Tex	30	05.2	94	06.0	6	979.328	−.002	+.005	979.331	979.325	−.006	−.014
296. Wilkins Well, Kans	39	04.4	97	04.5	355	980.084	−.110	−.007	979.967	979.951	−.016	−.024
297. Zeandale, Kans	39	09.7	96	25.6	312	980.092	−.096	−.007	979.989	979.959	−.030	−.038
298. Doyle Well, Kans	39	12.5	96	05.2	275	980.096	−.085	−.010	980.001	979.987	−.014	−.022
299. Seneca Well, Kans	39	50.4	96	03.6	351	980.152	−.108	−.001	980.043	980.019	−.024	−.032

Principal facts for gravity stations established since 1915—Continued.

Number and name of station.	Latitude ϕ.	Longitude λ.	Elevation.	Theoretical gravity γ_0.	Correction for— Elevation.	Correction for— Topography and compensation.	Computed gravity g_0.	Observed gravity g.	$g-g_0$.	Isostatic anomaly.
	° ′	° ′	*Meters.*	*Dynes.*	*Dyne.*	*Dyne.*	*Dynes.*	*Dynes.*	*Dyne.*	*Dyne.*
300. Wapanucka, Okla	34 22.1	96 25.5	202	979.677	−.062	−.003	979.612	979.640	+.028	+.020
301. Troy, Okla	34 19.6	96 46.6	281	979.673	−.087	+.001	979.587	979.658	+.071	+.063
302. Idle Wilde, Okla	34 13.3	97 07.0	261	979.665	−.081	−.001	979.583	979.583	.000	−.008
303. Lowery, Okla	34 14.1	97 30.8	295	979.666	−.091	−.001	979.574	979.592	+.018	+.010
304. Carter, Okla	34 11.4	97 32.6	281	979.662	−.087	−.002	979.573	979.600	+.027	+.019
305. Busby, Okla	34 18.3	97 31.6	327	979.672	−.101	+.001	979.572	979.569	−.003	−.011
306. Saline No. 1, Tex	32 38.6	95 39.6	114	979.533	−.035	−.001	979.497	979.508	+.011	+.003
307. Saline No. 2, Tex	32 38.6	95 37.0	125	979.533	−.039	.000	979.494	979.500	+.006	−.002
308. Saline No. 3, Tex	32 38.6	95 42.2	144	979.533	−.044	+.001	979.490	979.505	+.015	+.007
309. Taylor, Tex	30 34.1	97 24.5	178	979.366	−.055	+.002	979.313	979.318	+.005	−.003
310. Georgetown, Tex	30 38.0	97 40.1	231	979.371	−.071	+.002	979.302	979.298	−.004	−.012
311. Damon No. 1, Tex	29 19.5	95 42.7	20	979.268	−.006	+.005	979.267	979.241	−.026	−.034
312. Damon No. 2, Tex	29 17.0	95 43.7	44	979.265	−.014	+.008	979.259	979.222	−.037	−.045
313. Damon No. 3, Tex	29 15.5	95 45.2	18	979.264	−.006	+.006	979.264	979.193	−.071	−.079

Anomalies by the isostatic, Bouguer, and free-air reductions.

Number and name of station.	Elevation H.	Theoretical gravity γ_0.	Observed gravity g.	Correction to g for— Elevation.	Correction to g for— Topography to Zone O.	Observed gravity reduced by— Bouguer method, g_0''.	Observed gravity reduced by— Free-air method, g_0.	Anomaly. Isostatic.	Anomaly. Bouguer $g_0''-\gamma_0$.	Anomaly. Free air $g_0-\gamma_0$.
	Meters.	*Dynes.*	*Dynes.*	*Dyne.*	*Dyne.*	*Dynes.*	*Dynes.*	*Dyne.*	*Dyne.*	*Dyne.*
220. Bellingham, Wash	20	980.955	980.884	+0.006	−0.002	980.888	980.890	−0.043	−0.067	−0.065
221. Everett, Wash	41	980.885	980.781	+.013	−.005	980.789	980.794	−.073	−.096	−.091
222. Issaquah, Wash	39	980.844	980.763	+.012	−.004	980.771	980.775	−.046	−.073	−.069
223. Port Angeles, Wash	24	980.898	980.875	+.007	−.002	980.880	980.882	−.011	−.018	−.016
224. Port Townsend, Wash	30	980.897	980.858	+.009	−.003	980.864	980.867	−.022	−.033	−.030
225. Port Gamble, Wash	17	980.874	980.858	+.005	−.002	980.861	980.863	+.002	−.013	−.011
226. Bremerton, Wash	6	980.849	980.810	+.002	−.001	980.811	980.812	−.025	−.038	−.037
227. Tacoma, Wash	26	980.820	980.788	+.008	−.003	980.793	980.796	−.012	−.027	−.024
228. Moclips, Wash	8	980.819	980.770	+.002	−.001	980.771	980.772	−.066	−.048	−.047
229. Portland, Oreg	8	980.663	980.646	+.002	−.001	980.647	980.648	−.007	−.016	−.015
230. Tillamook, Oreg	5	980.657	980.700	+.002	.000	980.702	980.702	+.027	+.045	+.045
231. Newport, Oreg	48	980.583	980.601	+.015	−.005	980.611	980.616	+.009	+.028	+.033
232. Eugene, Oreg	129	980.529	980.490	+.040	−.014	980.516	980.530	+.008	−.013	+.001
233. Marshfield, Oreg	24	980.468	980.492	+.007	−.002	980.497	980.499	+.005	+.029	+.031
234. Glendale, Oreg	434	980.411	980.302	+.134	−.044	980.392	980.436	+.010	−.019	+.025
235. Tehama, Calif	65	980.168	980.122	+.020	−.007	980.135	980.142	.000	−.033	−.026
236. Sacramento, Calif	7	980.040	980.018	+.002	−.001	980.019	980.020	−.012	−.021	−.020
237. Willits, Calif	420	980.114	980.007	+.130	−.047	980.090	980.137	−.042	−.024	+.023
238. Eureka, Calif	12	980.237	980.220	+.004	−.001	980.223	980.224	−.048	−.014	−.013
239. Santa Rosa, Calif	48	980.028	980.021	+.015	−.006	980.030	980.036	−.028	+.002	+.008
240. San Diego, Calif	7	979.539	979.528	+.002	−.001	979.529	979.530	−.031	−.010	−.009
241. Oceanside, Calif	39	979.578	979.568	+.012	−.004	979.576	979.580	−.014	−.002	+.002
242. Highland, Calif	393	979.656	979.476	+.121	−.040	979.557	979.597	−.053	−.099	−.059
243. Pomona, Calif	258	979.650	979.546	+.080	−.026	979.600	979.626	−.032	−.050	−.024
244. Long Beach, Calif	8	979.627	979.616	+.002	−.001	979.617	979.618	−.022	−.010	−.009
245. Redondo Beach, Calif	23	979.633	979.615	+.007	−.002	979.620	979.622	−.030	−.013	−.011
246. Burbank, Calif	187	979.662	979.590	+.058	−.020	979.628	979.648	−.021	−.034	−.014
247. Palmdale, Calif	808	979.695	979.462	+.249	−.087	979.624	979.711	−.030	−.071	+.016
248. Mojave, Calif	838	979.734	979.471	+.259	−.092	979.638	979.730	−.039	−.096	−.004
249. Maricopa, Calif	257	979.735	979.600	+.079	−.026	979.653	979.679	−.062	−.082	−.056
250. Ventura, Calif	24	979.670	979.596	+.007	−.001	979.602	979.603	−.081	−.068	−.067
251. Concepcion, Calif	65	979.684	979.685	+.020	−.003	979.702	979.705	−.037	+.018	+.021
252. Avila, Calif	13	979.745	979.752	+.004	−.001	979.755	979.756	−.029	+.010	+.011
253. San Lucas, Calif	122	979.827	979.787	+.038	−.016	979.809	979.825	−.030	−.018	−.002
254. Monterey, Calif	6	979.867	979.890	+.002	.000	979.892	979.892	−.030	+.025	+.025
255. Hollister, Calif	88	979.889	979.837	+.027	−.010	979.854	979.864	−.050	−.035	−.025
256. Palo Alto, Calif	15	979.940	979.954	+.005	−.002	979.957	979.959	−.019	+.017	+.019
257. San Gregorio, Calif	16	979.930	979.950	+.005	−.002	979.953	979.955	−.029	+.023	+.025
258. Point Reyes Sta., Calif	8	979.995	980.024	+.002	−.001	980.025	980.026	−.019	+.030	+.031
259. Duncans Mills, Calif	7	980.029	980.039	+.002	.000	980.041	980.041	−.032	+.012	+.012
260. Clarksburg, W. Va	306	980.102	980.008	+.094	−.034	980.068	980.102	−.006	−.034	.000
261. Rowlesburg, W. Va	421	980.108	979.993	+.130	−.044	980.079	980.123	+.004	−.029	+.015
262. Terra Alta, W. Va	790	980.117	979.931	+.244	−.082	980.093	980.175	+.010	−.024	+.058
263. Corinth, W. Va	751	980.115	979.936	+.232	−.082	980.086	980.168	+.007	−.029	+.053
264. Kitzmiller, Md	493	980.112	979.975	+.152	−.051	980.076	980.127	−.004	−.036	+.015

Anomalies by the isostatic, Bouguer, and free-air reductions—Continued.

Number and name of station.	Elevation H.	Theoretical gravity γ_0.	Observed gravity g.	Correction to g for— Elevation.	Correction to g for— Topography to Zone O.	Observed gravity reduced by— Bouguer method, g_0''.	Observed gravity reduced by— Free-air method, g_0.	Anomaly. Isostatic.	Anomaly. Bouguer $g_0''-\gamma_0$.	Anomaly. Free air $g_0-\gamma_0$.
	Meters.	*Dynes.*	*Dynes.*	*Dyne.*	*Dyne.*	*Dynes.*	*Dynes.*	*Dyne.*	*Dyne.*	*Dyne.*
265. Pennington, N. J	56	980.196	980.163	+.017	−.007	980.173	980.180	−.038	−.023	−.016
266. Glen Ridge, N. J	58	980.237	980.218	+.018	−.007	980.229	980.236	−.020	−.008	−.001
267. Plainsboro, N. J	26	980.196	980.190	+.008	−.003	980.195	980.198	−.018	−.001	+.002
268. Hartford, Conn	37	980.322	980.336	+.011	−.004	980.343	980.347	+.009	+.021	+.025
269. Hill City, S. Dak	1,518	980.519	980.136	+.468	−.169	980.435	980.604	+.042	−.084	+.085
270. Newcastle, Wyo	1,328	980.512	980.142	+.410	−.143	980.409	980.552	+.029	−.103	+.040
271. Bridgeport, Nebr	1,114	980.315	979.966	+.344	−.125	980.185	980.310	−.008	−.130	−.005
272. Buford, Wyo	2,396	980.266	979.630	+.739	−.262	980.107	980.369	+.046	−.159	+.103
273. Boulder, Colo	1,630	980.168	979.621	+.503	−.179	979.945	980.124	−.014	−.223	−.044
274. Lafayette, Colo	1,595	980.166	979.637	+.492	−.176	979.953	980.129	−.020	−.213	−.037
275. Brighton, Colo	1,511	980.165	979.679	+.466	−.168	979.977	980.145	−.006	−.188	−.020
276. Idaho Springs, Colo	2,303	980.143	979.458	+.711	−.245	979.924	980.169	+.022	−.219	+.026
277. Fort Morgan, Ala	2	979.339	979.332	+.001	−.001	979.332	979.333	−.030	−.007	−.006
278. Chandeleur Island, La	2	979.325	979.315	+.001	.000	979.316	979.316	−.032	−.009	−.009
279. Port Eads, La	2	979.245	979.268	+.001	.000	979.269	979.269	−.018	+.024	+.024
280. Burrwood, La	2	979.241	979.298	+.001	.000	979.299	979.299	+.019	+.058	+.058
281. Fort St. Philip, La	2	979.271	979.314	+.001	.000	979.315	979.315	+.014	+.044	+.044
282. Pointe a la Hache, La	2	979.288	979.324	+.001	.000	979.325	979.325	+.012	+.037	+.037
283. Timbalier Island, La	2	979.248	979.249	+.001	.000	979.250	979.250	−.026	+.002	+.002
284. Morgan City, La	2	979.297	979.318	+.001	.000	979.319	979.319	+.002	+.022	+.022
285. Sabine, Tex	3	979.299	979.291	+.001	.000	979.292	979.292	−.022	−.007	−.007
286. Beaumont, Tex	6	979.328	979.325	+.002	−.001	979.326	979.327	−.014	−.002	−.001
296. Wilkins Well, Kans	355	980.084	979.951	+.110	−.037	980.024	980.061	−.024	−.060	−.023
297. Zeandale, Kans	312	980.092	979.959	+.096	−.032	980.023	980.055	−.038	−.069	−.037
298. Doyle Well, Kans	275	980.096	979.987	+.085	−.028	980.044	980.072	−.022	−.052	−.024
299. Seneca Well, Kans	351	980.152	980.019	+.108	−.038	980.089	980.127	−.032	−.063	−.025
300. Wapanucka, Okla	202	979.677	979.640	+.062	−.021	979.681	979.702	+.020	+.004	+.025
301. Troy, Okla	281	979.673	979.658	+.087	−.028	979.717	979.745	+.063	+.044	+.072
302. Idle Wilde, Okla	261	979.665	979.583	+.081	−.026	979.638	979.664	−.008	−.027	−.001
303. Lowery, Okla	295	979.666	979.592	+.091	−.029	979.654	979.683	+.010	−.012	+.017
304. Carter, Okla	281	979.662	979.600	+.087	−.028	979.659	979.687	+.019	−.003	+.025
305. Busby, Okla	327	979.672	979.569	+.101	−.033	979.637	979.670	−.011	−.035	−.002
306. Saline No. 1, Tex	114	979.533	979.508	+.035	−.012	979.531	979.543	+.003	−.002	+.010
307. Saline No. 2, Tex	125	979.533	979.500	+.039	−.013	979.526	979.539	−.002	−.007	+.006
308. Saline No. 3, Tex	144	979.533	979.505	+.044	−.015	979.534	979.549	+.007	+.001	+.016
309. Taylor, Tex	178	979.366	979.318	+.055	−.019	979.354	979.373	−.003	−.012	+.007
310. Georgetown, Tex	231	979.371	979.298	+.071	−.023	979.346	979.369	−.012	−.025	−.002
311. Damon No. 1, Tex	20	979.268	979.241	+.006	−.002	979.245	979.247	−.034	−.023	−.021
312. Damon No. 2, Tex	44	979.265	979.222	+.014	−.005	979.231	979.236	−.045	−.034	−.029
313. Damon No. 3, Tex	18	979.264	979.193	+.006	−.002	979.197	979.199	−.079	−.067	−.065
Mean with regard to sign								−.015	−.032	.000
Mean without regard to sign								.025	.045	.027
All stations, U. S.:										
Mean with regard to sign								−.006	−.035	+.009
Mean without regard to sign								.021	.048	.026

NOTE.—Each of the four groups, indicated by a brace, was used as a single station, by taking the mean of the group, in computing the mean anomalies at the foot of the table. The two Seattle stations were also treated as a group in computing the second set of means.

Mean elevations and corrections for topography and isostatic compensation, separate zones.

Zone.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.
	Bellingham, Wash., No. 220.				Everett, Wash., No. 221.				Issaquah, Wash., No. 222.				Port Angeles, Wash., No. 223.			
A	65	+2	0	+2	135	+2	0	+2	128	+2	0	+2	80	+2	0	+2
B	70	+16	0	+16	141	+32	0	+32	130	+28	0	+28	70	+18	0	+18
C	70	+4	0	+4	138	+8	0	+8	116	+5	0	+5	72	+3	0	+3
D	61	+1	0	+1	128	+6	0	+6	107	+2	0	+2	82	0	0	0
E	90	0	0	0	84	0	0	0	250	+4	−1	+3	65	0	0	0
F	137	0	0	0	93	0	0	0	488	−1	−2	−3	41	0	0	0
G	178	0	−1	−1	57	0	0	0	668	−3	−2	−5	67	0	0	0
H	204	0	−1	−1	64	0	0	0	622	0	−3	−3	12	0	0	0
I	260	0	−2	−2	103	0	−1	−1	472	0	−4	−4	−8	0	0	0
J	213	0	−2	−2	113	0	−1	−1	369	0	−4	−4	7	0	0	0
K	331	0	−7	−7	192	0	−3	−3	328	0	−5	−5	133	0	−2	−2
L	131	0	−3	−3	135	0	−3	−3	409	0	−10	−10	1,098	0	−31	−31
M	581	0	−36	−36	690	0	−42	−42	936	0	−55	−55	1,160	0	−69	−69
N	1,111	0	−57	−57	1,736	+1	−89	−88	2,134	+4	−111	−107	317	0	−16	−16
O	2,363	0	−119	−119	1,966	0	−99	−99	1,986	0	−100	−100	427	0	−22	−22
18				−24				−16				−12				−15
17				−19				−14				−12				−15
16				−20				−15				−10				−11
15				−19				−12				−11				−6
14				−16				−10				−13				−3
13				−20				−26				−23				−10
12				−19				−19				−13				−6
11				−4				−8				−8				−2
10				0				0				0				+1
9				+5				+4				+4				+5
8				+11				+10				+9				+10
7				+6				+6				+6				+6
6				+7				+7				+7				+7
5				+8				+8				+8				+8
4				+7				+7				+7				+7
3				+3				+3				+3				+3
2				+3				+3				+3				+3
1				+1				+1				+1				+1
Total				−295				−260				−314				−134
	Port Townsend, Wash., No. 224.				Port Gamble, Wash., No. 225.				Bremerton, Wash., No. 226.				Tacoma, Wash., No. 227.			
A	100	+2	0	+2	56	+2	0	+2	21	+2	0	+2	85	+2	0	+2
B	100	+22	0	+22	55	+14	0	+14	28	+7	0	+7	92	+22	0	+22
C	79	+3	0	+3	59	+2	0	+2	32	0	0	0	77	+2	0	+2
D	67	+1	0	+1	24	0	0	0	42	0	0	0	100	+3	0	+3
E	47	0	0	0	9	0	0	0	38	0	0	0	110	+2	0	+2
F	16	0	0	0	3	0	0	0	38	0	0	0	121	0	0	0
G	44	0	0	0	44	0	0	0	44	0	0	0	123	0	0	0
H	19	0	0	0	101	0	0	0	92	0	0	0	95	0	0	0
I	10	0	0	0	64	0	0	0	136	0	−1	−1	154	0	0	0
J	−12	0	0	0	−3	−1	0	−1	162	0	−2	−2	122	0	−1	−1
K	−4	0	0	0	3	0	0	0	57	0	−1	−1	138	0	−2	−2
L	99	0	−2	−2	144	0	−3	−3	80	0	−2	−2	221	0	−5	−5
M	436	0	−28	−28	699	0	−42	−42	700	+1	−41	−40	330	0	−19	−19
N	962	0	−49	−49	1,163	0	−60	−60	1,083	0	−56	−56	1,656	0	−85	−85
O	1,370	0	−69	−69	1,522	0	−77	−77	1,347	0	−68	−68	1,634	0	−82	−82
18				−16				−17				−14				−11
17				−12				−14				−10				−11
16				−12				−8				−8				−8
15				−7				−3				−8				−8
14				−6				−8				−9				−9
13				−18				−20				−18				−18
12				−14				−16				−14				−15
11				−5				−6				−6				−6
10				0				0				+1				+2
9				+4				+4				+4				+4
8				+10				+10				+10				+10
7				+6				+6				+6				+6
6				+7				+7				+7				+7
5				+8				+8				+8				+8
4				+7				+7				+7				+7
3				+3				+3				+3				+3
2				+3				+3				+3				+3
1				+1				+1				+1				+1
Total				−161				−208				−198				−198

Mean elevations and corrections for topography and isostatic compensation, separate zones—Continued.

Zone.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.
	Moclips, Wash., No. 228.				Portland, Oreg., No. 229.				Tillamook, Oreg., No. 230.				Newport, Oreg., No. 231.			
A	26	+2	0	+2	26	+2	0	+2	15	+2	0	+2	157	+2	0	+2
B	25	+6	0	+6	30	+8	0	+8	15	0	0	0	154	+32	0	+32
C	26	0	0	0	45	0	0	0	15	0	0	0	145	+10	0	+10
D	18	0	0	0	46	0	0	0	15	0	0	0	142	+6	0	+6
E	20	0	0	0	44	0	0	0	25	0	0	0	52	0	0	0
F	15	0	0	0	112	0	0	0	50	0	0	0	59	0	0	0
G	11	0	0	0	220	0	−1	−1	75	0	0	0	69	0	0	0
H	11	0	0	0	312	0	−1	−1	125	0	0	0	60	0	0	0
I	6	0	0	0	240	0	−2	−2	175	0	−1	−1	121	0	−1	−1
J	7	0	0	0	145	0	−2	−2	131	0	−1	−1	133	0	−1	−1
K	1	0	0	0	168	0	−3	−3	457	0	−7	−7	148	0	−2	−2
L	61	0	−1	−1	233	0	−6	−6	569	0	−14	−14	180	0	−4	−4
M	206	0	−12	−12	618	0	−36	−36	346	0	−20	−20	425	0	−25	−25
N	148	0	−8	−8	1,594	+1	−82	−81	−194	0	+10	+10	162	0	+7	+7
O	−717	0	+36	+36	1,123	0	−57	−57	−513	0	+26	+26	466	0	+24	+24
18				+10				−7				+2				+3
17				+10				−4				+6				+2
16				+8				−4				+6				+6
15				+6				−5				+9				+10
14				+4				−4				+7				+8
13				0				−13				+5				+11
12				−3				−5				+4				+7
11				−2				−2				+6				+10
10				+2				+5				+7				+7
9				+4				+7				+6				+6
8				+9				+12				+11				+11
7				+6				+7				+7				+7
6				+7				+7				+7				+7
5				+8				+8				+8				+8
4				+7				+7				+7				+7
3				+3				+3				+3				+3
2				+3				+3				+3				+3
1				+1				+1				+1				+1
Total				+106				−163				+100				+165
	Eugene, Oreg., No. 232.				Marshfield, Oreg., No. 233.				Glendale, Oreg., No. 234.				Tehama, Calif., No. 235.			
A	422	+2	0	+2	79	+2	0	+2	1,424	+2	0	+2	214	+2	0	+2
B	422	+56	0	+56	80	+17	0	+17	1,425	+64	0	+64	214	+40	0	+40
C	422	+48	0	+48	70	+3	0	+3	1,429	+120	0	+120	212	+18	0	+18
D	420	+19	0	+19	56	0	0	0	1,431	+133	−2	+131	208	+6	0	+6
E	430	+8	−1	+7	102	0	0	0	1,591	+79	−4	+75	206	0	0	0
F	437	+1	−1	0	118	0	0	0	1,815	+31	−5	+26	206	+1	−1	0
G	503	+2	−2	0	113	0	0	0	2,038	0	−7	+7	225	+1	−1	0
H	566	0	−3	−3	112	0	−1	−1	2,025	+5	−10	−5	240	0	−1	−1
I	602	0	−5	−5	158	0	−1	−1	2,120	+7	−17	−10	267	0	−2	−2
J	685	+1	−8	−7	237	0	−3	−3	1,975	0	−22	−22	333	0	−4	−4
K	752	0	−12	−12	295	0	−5	−5	2,175	−5	−35	−40	500	0	−8	−8
L	775	0	−19	−19	312	0	−7	−7	1,808	0	−43	−43	793	0	−19	−19
M	1,379	−4	−81	−85	378	0	−22	−22	1,850	0	−109	−109	1,580	−2	−93	−95
N	1,866	+2	−95	−93	−228	0	+12	+12	2,144	0	−110	−110	3,069	+3	−157	−154
O	2,189	0	−110	−110	−827	0	+42	+42	1,908	0	−96	−96	2,989	0	−151	−151
18				−9				+6				−11				−26
17				−9				+6				−8				−22
16				−5				+6				−4				−16
15				−3				+6				−1				−10
14				−1				+8				+2				−4
13				−2				+17				+8				+4
12				+3				+13				+10				+12
11				+6				+16				+13				+15
10				+7				+9				+9				+11
9				+7				+7				+7				+9
8				+12				+12				+12				+14
7				+8				+8				+8				+9
6				+8				+8				+8				+8
5				+9				+9				+9				+9
4				+8				+8				+8				+8
3				+4				+4				+4				+4
2				+4				+4				+4				+4
1				+1				+1				+1				+1
Total				−154				+185				+69				−338

Mean elevations and corrections for topography and isostatic compensation, separate zones—Continued.

Zone.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.
	Sacramento, Calif., No. 236.				Willitts, Calif., No. 237.				Eureka, Calif., No. 238.				Santa Rosa, Calif., No. 239.			
A	24	+2	0	+2	1,378	+2	0	+2	38	+2	0	+2	159	+2	0	+2
B	24	+4	0	+4	1,378	+64	0	+64	39	+11	0	+11	163	+36	0	+36
C	24	0	0	0	1,378	+124	0	+124	38	0	0	0	163	+12	0	+12
D	21	0	0	0	1,378	+134	−2	+132	32	0	0	0	158	+6	0	+6
E	18	0	0	0	1,378	+75	−3	+72	25	0	0	0	156	0	0	0
F	21	0	0	0	1,378	+34	−4	+30	19	0	0	0	154	0	0	0
G	20	0	0	0	1,378	+17	−5	+12	20	0	0	0	180	+1	−1	0
H	21	0	0	0	1,378	+7	−7	0	24	0	0	0	247	+1	−1	0
I	20	0	0	0	1,860	+15	−15	0	21	0	0	0	390	+1	−3	−2
J	27	0	0	0	1,662	0	−19	−19	134	0	−2	−2	490	0	−5	−5
K	42	0	−1	−1	1,640	0	−26	−26	134	0	−2	−2	692	−2	−11	−13
L	76	0	−2	−2	1,888	0	−45	−45	223	0	−5	−5	645	0	−15	−15
M	339	0	−20	−20	1,257	0	−74	−74	227	0	−13	−13	576	0	−34	−34
N	1,128	0	−58	−58	508	+1	−26	−25	−427	+1	+22	+23	152	0	−8	−8
O	2,579	0	−130	−130	−1,448	0	+73	+73	−457	0	+23	+23	−1,282	0	+65	+65
18				−28				+17				+13				+18
17				−22				+17				+13				+16
16				−14				+17				+13				+13
15				−6				+20				+17				+17
14				−4				+19				+18				+16
13				+4				+32				+34				+26
12				+14				+25				+24				+23
11				+16				+21				+21				+21
10				+11				+14				+14				+14
9				+9				+9				+9				+10
8				+14				+13				+12				+14
7				+10				+9				+9				+10
6				+9				+8				+8				+9
5				+9				+9				+9				+9
4				+8				+8				+8				+8
3				+5				+4				+4				+5
2				+4				+4				+4				+4
1				+1				+1				+1				+1
Total				−165				+567				+268				+278
	San Diego, Calif., No. 240.				Oceanside, Calif., No. 241.				Highland, Calif., No. 242.				Pomona, Calif., No. 243.			
A	22	+2	0	+2	127	+2	0	+2	1,288	+2	0	+2	847	+2	0	+2
B	24	+6	0	+6	129	+28	0	+28	1,294	+64	0	+64	847	+60	0	+60
C	24	0	0	0	119	+5	0	+5	1,296	+116	0	+116	848	+92	0	+92
D	17	0	0	0	94	+2	0	+2	1,292	+119	−1	+118	848	+67	−1	+66
E	24	0	0	0	75	0	0	0	1,300	+67	−3	+64	852	+30	−2	+28
F	50	0	0	0	52	0	0	0	1,312	+27	−4	+23	859	+13	−3	+10
G	65	0	0	0	51	0	0	0	1,418	+10	−5	+5	879	+3	−3	0
H	95	0	0	0	44	0	0	0	1,672	+6	−8	−2	969	+5	−5	0
I	87	0	−1	−1	−8	0	0	0	1,895	+3	−15	−12	994	+6	−8	−2
J	108	0	−1	−1	−53	0	0	0	2,403	+1	−27	−26	1,122	0	−12	−12
K	177	0	−3	−3	−73	0	0	0	3,190	−9	−51	−60	1,400	−5	−22	−27
L	128	0	−3	−3	31	0	−1	−1	3,371	−3	−81	−84	1,877	−5	−45	−50
M	48	−2	−3	−5	275	0	−16	−16	3,436	−2	−202	−204	2,104	−3	−123	−126
N	167	0	−9	−9	713	0	−36	−36	2,112	0	−108	−108	1,710	0	−88	−88
O	15	0	−1	−1	740	0	−37	−37	1,465	0	−74	−74	1.103	0	−55	−55
18				−3				−3				−11				−7
17				+1				0				−10				−5
16				+4				+2				−10				−5
15				+9				+6				−12				+1
14				+13				+9				−10				+3
13				+25				+20				−4				+10
12				+13				+11				+5				+9
11				+8				+7				+6				+7
10				+10				+11				+9				+11
9				+11				+11				+10				+11
8				+17				+17				+15				+16
7				+10				+10				+10				+10
6				+9				+9				+9				+9
5				+9				+9				+9				+9
4				+8				+8				+8				+8
3				+5				+5				+5				+5
2				+4				+4				+4				+4
1				+1				+1				+1				+1
Total				+139				+84				−144				−5

Mean elevations and corrections for topography and isostatic compensation, separate zones—Continued.

Zone.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.
	Long Beach, Calif., No. 244.				Redondo Beach, Calif., No. 245.				Burbank, Calif., No. 246.				Palmdale, Calif., No. 247.			
A	27	+2	0	+2	76	+2	0	+2	612	+2	0	+2	2,651	+2	0	+2
B	35	+4	0	+4	81	+17	0	+17	615	+56	0	+56	2,655	+68	0	+68
C	35	0	0	0	88	+3	0	+3	615	+72	0	+72	2,655	+150	0	+150
D	35	0	0	0	76	0	0	0	623	+45	−1	+44	2,653	+222	−3	+219
E	26	0	0	0	61	0	0	0	650	+18	−2	+16	2,649	+195	−6	+189
F	12	0	0	0	47	0	0	0	695	+12	−2	+10	2,645	+108	−8	+100
G	10	0	0	0	29	0	0	0	867	+1	−3	−2	2,600	+51	−9	+42
H	22	0	0	0	23	0	0	0	1,156	0	−6	−6	2,600	+36	−12	+24
I	15	0	0	0	81	0	−1	−1	1,066	+4	−9	−5	2,650	+21	−21	0
J	24	0	0	0	71	0	−1	−1	1,239	0	−14	−14	2,650	+13	−29	−16
K	29	0	−1	−1	−237	0	+4	+4	1,361	−8	−22	−30	3,140	−3	−50	−53
L	−235	0	+5	+5	−376	0	+9	+9	1,785	−2	−43	−45	3,208	0	−77	−77
M	103	0	−6	−6	−11	0	+1	+1	1,636	−3	−96	−99	2,771	+3	−163	−160
N	610	0	−31	−31	474	0	−23	−23	1,250	+1	−64	−63	2,125	+1	−109	−108
O	1,186	0	−59	−59	848	0	−42	−42	1,226	0	−62	−62	1,645	0	−83	−83
18				−5				−5				−8				−9
17				−3				−1				−8				−9
16				+3				+3				−5				−8
15				+5				+8				+4				0
14				+7				+7				+11				+1
13				+17				+18				+16				+7
12				+15				+15				+13				+8
11				+9				+10				+10				+8
10				+11				+11				+12				+11
9				+12				+12				+11				+10
8				+16				+16				+16				+15
7				+11				+11				+10				+10
6				+9				+9				+9				+9
5				+9				+9				+9				+9
4				+8				+8				+8				+8
3				+5				+5				+5				+5
2				+4				+4				+4				+4
1				+1				+1				+1				+1
Total				+48				+110				−9				+377
	Mojave, Calif., No. 248.				Maricopa, Calif., No. 249.				Ventura, Calif., No. 250.				Concepcion, Calif., No. 251.			
A	2,750	+2	0	+2	842	+2	0	+2	78	+2	0	+2	213	+2	0	+2
B	2,758	+68	0	+68	850	+59	0	+59	102	+12	0	+12	167	+30	0	+30
C	2,758	+150	0	+150	852	+91	0	+91	109	+1	0	+1	46	+2	0	+2
D	2,761	+228	−3	+225	850	+66	−1	+65	153	−1	0	−1	25	+1	0	+1
E	2,775	+215	−7	+208	869	+30	−2	+28	124	−1	0	−1	6	0	0	0
F	2,788	+118	−8	+110	880	+14	−3	+11	140	0	0	0	−2	0	0	0
G	2,804	+60	−10	+50	910	+3	−3	0	221	+1	−1	0	−15	0	0	0
H	2,845	+36	−14	+22	1,048	+5	−5	0	275	+1	−1	0	49	0	0	0
I	2,940	+26	−24	+2	1,258	+2	−10	−8	293	+2	−2	0	54	0	0	0
J	3,091	+19	−35	−16	1,572	−3	−18	−21	376	0	−2	−2	26	0	0	0
K	3,388	−3	−54	−57	1,704	−10	−27	−37	338	−1	−5	−6	−68	0	+1	+1
L	3,258	0	−78	−78	2,017	0	−48	−48	756	−5	−18	−23	−238	0	+6	+6
M	3,179	+4	−187	−183	2,352	−4	−138	−142	962	−4	−57	−61	−177	0	+10	+10
N	2,894	+2	−148	−146	1,631	0	−84	−84	826	0	−42	−42	−728	−2	+37	+35
O	2,400	0	−121	−121	1,114	0	−56	−56	325	0	−16	−16	−2,100	0	+106	+106
18				−18				−11				+6				+27
17				−16				−9				+8				+28
16				−15				−4				+4				+27
15				−5				+4				+12				+26
14				−4				+9				+17				+24
13				−1				+17				+27				+42
12				+6				+14				+18				+24
11				+7				+14				+15				+22
10				+11				+12				+13				+13
9				+10				+10				+10				+10
8				+15				+16				+16				+17
7				+10				+10				+10				+10
6				+9				+9				+9				+9
5				+9				+9				+9				+9
4				+8				+8				+8				+8
3				+5				+5				+5				+5
2				+4				+4				+4				+4
1				+1				+1				+1				+1
Total				+272				−22				+55				+499

Mean elevations and corrections for topography and isostatic compensation, separate zones—Continued.

Zone.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.
	Avila, Calif., No. 252.				San Lucas, Calif., No. 253.				Monterey, Calif., No. 254.				Hollister, Calif., No. 255.			
A	44	+2	0	+2	400	+2	0	+2	19	+2	0	+2	288	+2	0	+2
B	48	+8	0	+8	402	+56	0	+56	33	+10	0	+10	288	+48	0	+48
C	40	0	0	0	407	+49	0	+49	40	0	0	0	288	+30	0	+30
D	18	0	0	0	412	+18	0	+18	58	+2	0	+2	295	+12	0	+12
E	106	−1	0	−1	420	+9	−1	+8	98	+1	0	+1	300	+8	−1	+7
F	119	0	0	0	432	+1	−1	0	173	+1	−1	0	325	+1	−1	0
G	228	0	−2	−2	494	+2	−2	0	228	+1	−1	0	350	+1	−1	0
H	334	0	−3	−3	568	0	−3	−3	204	0	−1	−1	375	0	−2	−2
I	315	−2	−3	−5	648	−2	−5	−7	101	0	−1	−1	375	0	−3	−3
J	247	0	−3	−3	900	+5	−10	−5	91	0	−1	−1	794	+3	−9	−6
K	242	0	−5	−5	1,185	+16	−19	−23	−516	−2	+8	+6	1,118	−7	−18	−25
L	576	−1	−14	−15	1,448	0	−35	−35	−502	−2	+12	+10	1,142	0	−27	−27
M	321	0	−19	−19	1,550	0	−91	−91	−689	−6	+40	+34	1,033	0	−61	−61
N	159	0	−8	−8	300	0	−15	−15	−839	−4	+43	+39	281	0	−14	−14
O	−1,672	0	+84	+84	−1,018	0	+51	+51	−2,016	0	+102	+102	−704	0	+35	+35
18				+25				+16				+26				+8
17				+26				+9				+26				+5
16				+24				+2				+24				+1
15				+19				+5				+15				+3
14				+25				+11				+12				+9
13				+35				+31				+33				+26
12				+23				+20				+25				+19
11				+22				+20				+22				+20
10				+13				+14				+15				+15
9				+10				+10				+10				+10
8				+17				+16				+16				+15
7				+10				+10				+10				+10
6				+9				+9				+9				+9
5				+9				+9				+9				+9
4				+8				+8				+8				+8
3				+5				+5				+5				+5
2				+4				+4				+4				+4
1				+1				+1				+1				+1
Total				+318				+205				+473				+173
	Palo Alto, Calif., No. 256.				San Gregoria, Calif., No. 257.				Point Reyes Station, Calif., No. 258.				Duncan Mills, Calif., No. 259.			
A	48	+2	0	+2	54	+2	0	+2	26	+2	0	+2	24	+2	0	+2
B	50	+12	0	+12	49	+14	0	+14	26	+6	0	+6	25	+6	0	+6
C	52	+2	0	+2	48	0	0	0	26	0	0	0	42	0	0	0
D	53	0	0	0	76	0	0	0	40	0	0	0	193	−7	0	−7
E	51	0	0	0	156	0	0	0	100	0	0	0	200	+2	0	+2
F	47	0	0	0	245	+1	−1	0	150	0	0	0	250	+1	−1	0
G	60	0	0	0	215	+1	−1	0	200	+1	−1	0	300	0	−1	−1
H	91	0	0	0	235	0	−1	−1	344	+1	−2	−1	388	0	−2	−2
I	126	0	0	0	327	0	−3	−3	335	0	−3	−3	419	−1	−3	−4
J	379	+4	−4	0	475	+2	−5	−3	262	0	−3	−3	314	+1	−4	−3
K	570	−3	−9	−12	460	0	−7	−7	208	0	−3	−3	434	0	−7	−7
L	463	0	−11	−11	370	0	−9	−9	53	0	−1	−1	336	0	−8	−8
M	351	0	−21	−21	−258	0	+15	+15	−23	0	+1	+1	410	0	−24	−24
N	−587	0	+30	+30	−1,209	−2	+62	+60	−797	−2	+41	+39	−635	−2	+33	+31
O	−1,300	0	+66	+66	−2,167	0	+109	+109	−2,085	0	+105	+105	−1,982	0	+100	+100
18				+22				+28				+29				+26
17				+19				+28				+26				+27
16				+14				+25				+21				+21
15				+12				+24				+20				+18
14				+11				+19				+20				+20
13				+25				+31				+32				+34
12				+22				+26				+25				+26
11				+21				+21				+22				+22
10				+14				+14				+14				+15
9				+10				+10				+10				+10
8				+15				+15				+14				+14
7				+10				+10				+10				+10
6				+9				+9				+9				+9
5				+9				+9				+9				+9
4				+8				+8				+8				+8
3				+5				+5				+5				+5
2				+4				+4				+4				+4
1				+1				+1				+1				+1
Total				+299				+464				+421				+364

Mean elevations and corrections for topography and isostatic compensation, separate zones—Continued.

Zone.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.
	Clarksburg, W. Va., No. 260.				Rowlesburg, W. Va., No. 261.				Terra Alta, W. Va., No. 262.				Corinth, W. Va., No. 263.			
A	1,005	+2	0	+2	1,381	+2	0	+2	2,591	+2	0	+2	2,463	+2	0	+2
B	1,002	+64	0	+64	1,382	+64	0	+64	2,597	+61	0	+61	2,460	+68	0	+68
C	979	+102	0	+102	1,384	+120	0	+120	2,610	+143	0	+143	2,450	+144	0	+144
D	971	+81	−1	+80	1,532	+124	−2	+122	2,533	+213	−3	+210	2,478	+212	−3	+209
E	1,045	+49	−3	+46	1,737	+74	−4	+70	2,506	+186	−6	+180	2,542	+182	−6	+176
F	1,078	+21	−3	+18	1,900	+33	−6	+27	2,545	+107	−8	+99	2,563	+103	−8	+95
G	1,108	+4	−4	0	2,062	+12	−7	+5	2,527	+48	−9	+39	2,577	+46	−9	+37
H	1,175	+6	−6	0	2,078	−2	−10	−12	2,528	+28	−12	+16	2,606	+32	−13	+19
I	1,132	+9	−9	0	2,073	+1	−17	−16	2,456	+22	−20	+2	2,555	+20	−20	0
J	1,203	0	−13	−13	2,191	+9	−25	−16	2,309	+14	−26	−12	2,503	+12	−28	−16
K	1,245	0	−20	−20	2,141	−2	−34	−36	2,302	0	−36	−36	2,402	+1	−38	−37
L	1,300	0	−31	−31	2,262	0	−54	−54	2,272	0	−54	−54	2,277	0	−55	−55
M	1,572	0	−92	−92	1,478	0	−87	−87	1,800	0	−104	−104	2,100	+2	−123	−121
N	1,906	0	−98	−98	1,828	0	−94	−94	1,784	0	−90	−90	1,778	0	−91	−91
O	1,503	0	−76	−76	1,484	0	−75	−75	1,557	0	−77	−77	1,391	0	−70	−70
18				−14				−12				−12				−12
17				−13				−12				−12				−11
16				−11				−12				−9				−9
15				−10				−8				−8				−8
14				−9				−8				−8				−8
13				−12				−11				−11				−11
12				0				+1				+1				+1
11				+5				+7				+7				+7
10				+11				+12				+12				+12
9				+8				+10				+10				+10
8				+9				+10				+10				+10
7				+5				+5				+5				+5
6				+6				+6				+6				+6
5				+8				+8				+8				+8
4				+7				+7				+7				+7
3				+6				+6				+6				+6
2				+3				+3				+3				+3
1				+1				+1				+1				+1
Total				−18				+33				+395				+377
	Kitzmiller, Md., No. 264.				Pennington, N. J., No. 265.				Glen Ridge, N. J., No. 266.				Plainsboro, N. J., No. 267.			
A	1,617	+2	0	+2	185	+2	0	+2	191	+2	0	+2	86	+2	0	+2
B	1,618	+68	0	+68	188	+40	0	+40	185	+38	0	+38	81	+20	0	+20
C	1,627	+128	0	+128	182	+14	0	+14	179	+14	0	+14	80	+4	0	+4
D	1,612	+146	−2	+144	188	+10	0	+10	188	+6	0	+6	82	+5	0	+5
E	1,575	+91	−4	+87	175	0	0	0	166	+3	0	+3	77	0	0	0
F	1,710	+47	−5	+42	183	+1	−1	0	205	+1	−1	0	89	0	0	0
G	1,938	+20	−7	+13	224	+1	−1	0	239	+1	−1	0	89	0	0	0
H	2,078	+7	−10	−3	225	+1	−1	0	258	+1	−1	0	89	0	0	0
I	2,502	+3	−20	−17	205	0	−1	−1	286	0	−2	−2	123	0	−1	−1
J	2,315	0	−24	−24	185	0	−1	−1	170	0	−2	−2	152	0	−1	−1
K	2,193	−2	−34	−38	170	0	−2	−2	174	0	−3	−3	156	0	−1	−1
L	2,156	0	−50	−50	194	0	−4	−4	262	0	−6	−6	152	0	−3	−3
M	1,836	−2	−106	−108	177	0	−8	−8	374	0	−21	−21	127	0	−6	−6
N	1,853	0	−94	−94	326	0	−14	−14	335	0	−16	−16	249	0	−11	−11
O	1,348	0	−68	−68	356	0	−15	−15	488	0	−24	−24	319	0	−14	−14
18				−10				−4				−4				−4
17				−10				−4				−5				−4
16				−10				−5				−5				−4
15				−8				−2				0				0
14				−8				+1				+2				+2
13				−10				+12				+12				+14
12				+3				+19				+21				+20
11				+8				+21				+20				+21
10				+13				+16				+15				+16
9				+10				+11				+11				+11
8				+10				+14				+15				+14
7				+5				+6				+6				+6
6				+6				+6				+6				+6
5				+8				+6				+6				+6
4				+7				+6				+6				+6
3				+6				+6				+6				+6
2				+3				+4				+4				+4
1				+1				+1				+1				+1
Total				+106				+135				+106				+115

Mean elevations and corrections for topography and isostatic compensation, separate zones—Continued.

Zone.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.
	Hartford, Conn., No. 268.				Hill City, S. Dak., No. 269.				Newcastle, Wyo., No. 270.				Bridgeport, Nebr., No. 271.			
A	123	+2	0	+2	4,981	+2	0	+2	4,356	+2	0	+2	3,656	+2	0	+2
B	125	+28	0	+28	4,978	+68	0	+68	4,358	+68	0	+68	3,659	+68	0	+68
C	124	+6	0	+6	4,984	+160	0	+160	4,377	+156	0	+156	3,660	+156	0	+156
D	112	+6	0	+6	4,984	+300	−6	+294	4,387	+281	−5	+276	3,668	+262	−4	+258
E	90	0	0	0	5,038	+372	−12	+360	4,344	+333	−10	+323	3,672	+289	−9	+280
F	82	0	0	0	5,240	+279	−16	+263	4,430	+227	−13	+214	3,678	+181	−11	+170
G	99	0	0	0	5,292	+165	−19	+146	4,496	+123	−16	+107	3,690	+97	−13	+84
H	106	0	−1	−1	5,337	+114	−26	+88	4,489	+78	−22	+56	3,723	+58	−18	+40
I	129	0	−1	−1	5,700	+85	−46	+39	4,472	+59	−36	+23	3,771	+50	−30	+20
J	211	0	−2	−2	5,719	+56	−64	−8	4,472	+37	−50	−13	3,818	+27	−43	−16
K	275	0	−4	−4	5,475	+39	−88	−49	4,670	+27	−75	−48	3,952	+23	−63	−40
L	492	0	−12	−12	5,302	+27	−127	−100	4,954	+23	−119	−96	4,064	+25	−97	−72
M	371	0	−21	−21	4,471	+24	−263	−239	5,071	+12	−298	−286	4,149	+11	−244	−233
N	525	0	−26	−26	3,622	−1	−185	−186	4,450	0	−228	−228	4,169	0	−213	−213
O	464	0	−23	−23	3,779	0	−190	−190	3,986	0	−201	−201	4,236	0	−214	−214
18				−6				−37				−38				−41
17				−4				−35				−39				−42
16				−5				−37				−43				−46
15				+1				−40				−48				−49
14				+2				−41				−43				−44
13				+13				−63				−67				−72
12				+20				−38				−39				−41
11				+22				−30				−31				−30
10				+17				−19				−20				−20
9				+12				−6				−6				−5
8				+16				+8				+3				+4
7				+6				+6				+6				+7
6				+6				+9				+9				+9
5				+6				+10				+10				+10
4				+6				+7				+7				+8
3				+6				+4				+4				+5
2				+4				+3				+3				+3
1				+1				+1				+1				+1
Total				+75				+346				+27				−53
	Buford, Wyo., No. 272.				Boulder, Colo., No. 273.				Lafayette, Colo., No. 274.				Brighton, Colo., No. 275.			
A	7,860	+2	0	+2	5,346	+2	0	+2	5,231	+2	0	+2	4,957	+2	0	+2
B	7,863	+68	0	+68	5,350	+68	0	+68	5,234	+68	0	+68	4,972	+62	0	+62
C	7,862	+160	0	+160	5,352	+160	0	+160	5,231	+160	0	+160	4,965	+160	0	+160
D	7,860	+339	−9	+330	5,357	+306	−6	+300	5,225	+300	−6	+294	4,990	+300	−6	+294
E	7,828	+491	−19	+472	5,374	+397	−13	+384	5,234	+389	−13	+376	5,012	+372	−12	+360
F	7,828	+453	−23	+430	5,410	+305	−16	+289	5,210	+297	−16	+281	5,007	+275	−15	+260
G	7,842	+316	−28	+288	5,642	+185	−20	+165	5,229	+151	−19	+132	5,017	+160	−18	+142
H	7,841	+242	−38	+204	5,860	+122	−28	+94	5,223	+121	−25	+96	5,022	+107	−24	+83
I	7,845	+202	−63	+139	6,121	+93	−49	+44	5,230	+94	−42	+52	5,055	+80	−40	+40
J	7,709	+115	−86	+29	6,353	+54	−71	−17	5,297	+59	−59	0	5,091	+57	−57	0
K	7,629	+90	−122	−32	6,701	+34	−107	−73	5,424	+46	−87	−41	5,140	+42	−82	−40
L	7,433	+59	−178	−119	7,156	+26	−172	−146	5,773	+28	−138	−110	5,179	+28	−124	−96
M	7,400	+61	−435	−374	7,407	+16	−436	−420	6,821	+25	−401	−376	6,000	+17	−352	−335
N	6,838	+12	−349	−337	7,881	+4	−403	−399	7,456	+5	−382	−377	6,869	+5	−352	−347
O	6,582	+11	−332	−321	7,593	+18	−383	−365	7,347	+19	−370	−351	7,357	+17	−371	−354
18				−63				−73				−68				−66
17				−63				−69				−68				−65
16				−62				−65				−65				−66
15				−61				−62				−63				−63
14				−58				−61				−62				−61
13				−88				−86				−85				−83
12				−49				−49				−48				−48
11				−32				−31				−31				−30
10				−19				−18				−18				−17
9				−2				−1				0				0
8				+7				+9				+9				+9
7				+7				+7				+7				+7
6				+9				+9				+9				+9
5				+10				+10				+10				+10
4				+8				+8				+8				+8
3				+5				+5				+5				+5
2				+3				+3				+3				+3
1				+1				+1				+1				+1
Total				+492				−377				−250				−216

Mean elevations and corrections for topography and isostatic compensation, separate zones—Continued.

Zone.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.
	Idaho Springs, Colo., No. 276.				Fort Morgan, Ala., No. 277.				Chandeleur Island, La., No. 278.				Port Eads, La., No. 279.			
A	7,556	+2	0	+2	8	+2	0	+2	0	0	0	0	3	+1	0	+1
B	7,565	+64	0	+64	20	+4	0	+4	0	0	0	0	−3	0	0	0
C	7,625	+157	0	+157	19	0	0	0	0	0	0	0	−12	−1	0	−1
D	7,800	+320	−9	+311	1	0	0	0	−1	0	0	0	−4	0	0	0
E	7,975	+477	−19	+458	−8	0	0	0	−4	0	0	0	−3	0	0	0
F	8,195	+435	−25	+410	−12	0	0	0	−10	0	0	0	−1	0	0	0
G	8,446	+291	−30	+261	−9	0	0	0	−13	0	0	0	−2	0	0	0
H	8,628	+223	−41	+182	−11	0	0	0	−17	0	0	0	−6	0	0	0
I	8,892	+174	−71	+103	−12	0	0	0	−17	0	0	0	−26	0	0	0
J	9,181	+101	−103	−2	−16	0	0	0	−17	0	0	0	−53	0	+1	+1
K	9,770	+66	−156	−90	−17	0	0	0	−17	0	0	0	−87	0	+1	+1
L	9,233	+53	−222	−169	−19	0	0	0	−16	0	0	0	−162	0	+4	+4
M	8,821	+47	−519	−472	−23	0	+1	+1	−15	0	+1	+1	−469	0	+28	+28
N	8,275	+17	−424	−407	−19	0	+1	+1	−7	0	0	0	−876	0	+45	+45
O	7,921	+21	−399	−378	−295	0	+15	+15	−214	0	+11	+11	−1,283	0	+62	+62
18				−72				+5				+5				+14
17				−70				+6				+8				+16
16				−66				+6				+6				+17
15				−65				+8				+7				+17
14				−63				+9				+11				+18
13				−87				+18				+23				+35
12				−49				+16				+17				+21
11				−31				+8				+6				+5
10				−17				+7				+4				+1
9				0				+3				+3				+1
8				+9				+6				+6				+7
7				+7				+7				+7				+7
6				+9				+9				+9				+9
5				+10				+10				+10				+10
4				+8				+8				+8				+8
3				+6				+6				+6				+6
2				+3				+3				+3				+2
1				+1				+1				+1				+1
Total				−38				+159				+151				+336
	Burrwood, La., No. 280.				Fort St. Philip, La., No. 281.				Pointe a la Hache, La., No. 282.				Timbalier Island, La., No. 283.			
A	5	+1	0	+1	6	+1	0	+1	6	+1	0	+1	0	0	0	0
B	1	0	0	0	6	0	0	0	6	0	0	0	0	0	0	0
C	−6	0	0	0	0	0	0	0	6	−1	0	−1	0	0	0	0
D	−6	0	0	0	−14	0	0	0	−27	0	0	0	−1	0	0	0
E	−6	0	0	0	−14	0	0	0	−16	0	0	0	−1	0	0	0
F	−3	0	0	0	−9	0	0	0	−4	0	0	0	−3	0	0	0
G	−3	0	0	0	−6	0	0	0	−4	0	0	0	−4	0	0	0
H	−6	0	0	0	−4	0	0	0	−2	0	0	0	−7	0	0	0
I	−26	0	0	0	−3	0	0	0	−1	0	0	0	−9	0	0	0
J	−54	0	+1	+1	−2	0	0	0	−2	0	0	0	−12	0	0	0
K	−80	0	+1	+1	−3	0	0	0	−1	0	0	0	−15	0	0	0
L	−100	0	+2	+2	−4	0	0	0	0	0	0	0	−18	0	0	0
M	−288	0	+17	+17	−18	0	+1	+1	−6	0	0	0	−29	0	+2	+2
N	−767	0	+39	+39	−180	0	+9	+9	−19	0	+1	+1	−76	0	+4	+4
O	−1,096	0	+55	+55	−616	0	+31	+31	−258	0	+13	+13	−433	0	+22	+22
18				+13				+11				+6				+8
17				+15				+12				+7				+12
16				+16				+13				+10				+16
15				+19				+14				+12				+17
14				+20				+16				+16				+19
13				+35				+30				+26				+30
12				+21				+19				+19				+18
11				+5				+5				+6				+4
10				+1				+2				+2				0
9				+1				+2				0				+1
8				+7				+6				+6				+7
7				+7				+7				+7				+7
6				+9				+9				+9				+9
5				+10				+10				+10				+10
4				+8				+8				+8				+8
3				+6				+6				+6				+6
2				+2				+3				+2				+2
1				+1				+1				+1				+1
Total				+312				+216				+167				+203

Mean elevations and corrections for topography and isostatic compensation, separate zones—Continued.

Zone.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.
	Morgan City, La., No. 284.				Sabine, Tex., No. 285.				Beaumont, Tex., No. 286.				Wilkins Well, Kans., No. 296.			
A	5	+1	0	+1	8	+2	0	+2	20	+2	0	+2	1,166	+2	0	+2
B	4	0	0	0	8	0	0	0	20	+4	0	+4	1,165	+64	0	+64
C	4	0	0	0	8	0	0	0	20	0	0	0	1,168	+112	0	+112
D	3	0	0	0	−3	0	0	0	20	0	0	0	1,164	+104	−1	+103
E	−2	0	0	0	−1	0	0	0	13	0	0	0	1,170	+53	−3	+50
F	3	0	0	0	−1	0	0	0	16	0	0	0	1,194	+20	−4	+16
G	4	0	0	0	−1	0	0	0	25	0	0	0	1,206	+2	−4	−2
H	4	0	0	0	−1	0	0	0	23	0	0	0	1,214	+3	−6	−3
I	2	0	0	0	−2	0	0	0	24	0	0	0	1,246	+11	−10	+1
J	3	0	0	0	−3	0	0	0	29	0	0	0	1,257	0	−14	−14
K	4	0	0	0	−6	0	0	0	34	0	−1	−1	1,225	0	−20	−20
L	4	0	0	0	−6	0	0	0	21	0	−1	−1	1,246	0	−30	−30
M	2	0	0	0	−6	0	0	0	34	0	−2	−2	1,329	0	−78	−78
N	1	0	0	0	4	0	0	0	42	0	−2	−2	1,362	0	−70	−70
O	−2	0	0	0	20	0	−1	−1	70	0	−4	−4	1,418	0	−71	−71
18				+1				−1				−1				−14
17				+1				−1				−1				−15
16				+4				0				−1				−15
15				+7				+2				−1				−15
14				+12				+4				+2				−17
13				+21				+9				+6				−39
12				+18				+6				+4				−23
11				+5				0				−1				−20
10				+1				−3				−4				−14
9				−1				0				0				−5
8				+6				+7				+6				+1
7				+7				+8				+8				+7
6				+10				+10				+10				+9
5				+10				+10				+10				+10
4				+8				+9				+9				+7
3				+6				+6				+6				+4
2				+3				+2				+2				+4
1				+1				+1				+1				+1
Total				+121				+70				+51				−74
	Zeandale, Kans., No. 297.				Doyle Well, Kans., No. 298.				Seneca Well, Kans., No. 299.				Wapanucka, Okla., No. 300.			
A	1,020	+2	0	+2	900	+2	0	+2	1,150	+2	0	+2	660	+2	0	+2
B	1,020	+64	0	+64	902	+64	0	+64	1,150	+68	0	+68	660	+60	0	+60
C	1,020	+104	0	+104	913	+95	0	+95	1,148	+110	0	+110	658	+76	0	+76
D	1,020	+86	−1	+85	952	+70	−1	+69	1,176	+102	−1	+101	657	+48	−1	+47
E	1,057	+41	−3	+38	950	+33	−2	+31	1,171	+51	−3	+48	675	+18	−2	+16
F	1,068	+19	−3	+16	952	+13	−3	+10	1,195	+20	−4	+16	665	+10	−2	+8
G	1,081	0	−4	−4	971	0	−3	−3	1,230	+5	−4	+1	675	0	−2	−2
H	1,103	0	−5	−5	978	0	−5	−5	1,249	+6	−6	0	667	0	−3	−3
I	1,133	+3	−9	−6	1,004	0	−8	−8	1,280	+12	−10	+2	677	0	−5	−5
J	1,157	0	−13	−13	1,045	0	−12	−12	1,302	0	−15	−15	692	0	−8	−8
K	1,172	0	−19	−19	1,089	0	−17	−17	1,299	0	−21	−21	724	0	−12	−12
L	1,188	0	−29	−29	1,129	0	−27	−27	1,296	0	−31	−31	731	0	−18	−18
M	1,221	0	−72	−72	1,173	0	−69	−69	1,166	0	−69	−69	779	0	−46	−46
N	1,195	0	−61	−61	1,216	0	−62	−62	1,120	0	−57	−57	784	0	−40	−40
O	1,237	0	−62	−62	1,189	0	−60	−60	1,205	0	−61	−61	820	0	−41	−41
18				−12				−13				−13				−8
17				−13				−13				−13				−9
16				−13				−12				−13				−9
15				−13				−13				−13				−10
14				−14				−14				−14				−11
13				−32				−30				−30				−19
12				−19				−18				−18				−14
11				−16				−16				−17				−12
10				−14				−14				−14				−12
9				−6				−6				−6				−4
8				+1				+1				+1				+2
7				+8				+8				+8				+8
6				+9				+9				+9				+9
5				+11				+11				+11				+11
4				+7				+7				+7				+8
3				+5				+5				+5				+5
2				+3				+3				+3				+3
1				+1				+1				+1				+1
Total				−69				−96				−12				−27

Mean elevations and corrections for topography and isostatic compensation, separate zones—Continued.

Zone.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.
	Troy, Okla., No. 301.				Idle Wilde, Okla., No. 302.				Lowery, Okla., No. 303.				Carter, Okla., No. 304.			
A	918	+2	0	+2	853	+2	0	+2	967	+2	0	+2	920	+2	0	+2
B	918	+64	0	+64	858	+60	0	+60	967	+64	0	+64	920	+64	0	+64
C	918	+96	0	+96	855	+92	0	+92	963	+100	0	+100	920	+96	0	+96
D	918	+73	−1	+72	857	+66	−1	+65	948	+77	−1	+76	920	+72	−1	+71
E	908	+31	−2	+29	842	+29	−2	+27	944	+36	−2	+34	920	+33	−2	+31
F	903	+10	−3	+7	821	+10	−2	+8	959	+10	−3	+7	917	+10	−3	+7
G	908	0	−3	−3	804	0	−3	−3	949	0	−3	−3	918	0	−3	−3
H	895	0	−4	−4	823	0	−4	−4	957	0	−5	−5	925	0	−4	−4
I	914	0	−7	−7	835	0	−7	−7	944	0	−8	−8	922	0	−7	−7
J	903	0	−10	−10	832	0	−9	−9	949	0	−11	−11	921	0	−10	−10
K	880	0	−14	−14	836	0	−13	−13	932	0	−15	−15	924	0	−15	−15
L	895	0	−21	−21	886	0	−21	−21				−23	896	0	−22	−22
M	796	0	−47	−47	825	0	−49	−49				−52	843	0	−50	−50
N	794	0	−41	−41	853	0	−44	−44				−49	956	0	−49	−49
O	841	0	−42	−42	877	0	−44	−44				−49	954	0	−48	−48
18				−8				−9				−10				−10
17				−9				−10				−11				−11
16				−10				−10				−11				−11
15				−11				−12				−13				−13
14				−11				−12				−14				−14
13				−22				−24				−26				−27
12				−15				−15				−16				−16
11				−13				−13				−13				−13
10				−13				−13				−13				−13
9				−3				−2				−2				−2
8				+3				+4				+4				+4
7				+8				+8				+8				+8
6				+9				+9				+9				+9
5				+11				+11				+11				+11
4				+8				+8				+8				+8
3				+5				+5				+5				+5
2				+3				+3				+3				+3
1				+1				+1				+1				+1
Total				+14				−11				−12				−18
	Busby, Okla., No. 305.				Saline No. 1, Tex., No. 306.				Saline No. 2, Tex., No. 307.				Saline No. 3, Tex., No. 308.			
A	1,070	+2	0	+2	369	+2	0	+2	408	+2	0	+2	468	+2	0	+2
B	1,070	+64	0	+64	369	+52	0	+52	397	+56	0	+56	461	+56	0	+56
C	1,068	+108	0	+108	372	+44	0	+44	390	+47	0	+47	465	+56	0	+56
D	1,047	+90	−1	+89	380	+18	0	+18	400	+18	0	+18	470	+26	−1	+25
E	1,032	+47	−2	+45	402	+8	−1	+7	425	+8	−1	+7	470	+10	−1	+9
F	1,023	+16	−3	+13	422	0	−1	−1	436	0	−1	−1	471	0	−1	−1
G	1,017	0	−4	−4	452	0	−2	−2	435	0	−2	−2	458	0	−2	−2
H	1,014	0	−5	−5	450	0	−2	−2	450	0	−2	−2	470	0	−2	−2
I	986	0	−8	−8	500	0	−4	−4	500	0	−4	−4	500	0	−4	−4
J	970	0	−11	−11	500	0	−6	−6	500	0	−6	−6	500	0	−6	−6
K	960	0	−15	−15				−8				−9	492	0	−8	−8
L				−24				−12				−12	496	0	−12	−12
M				−54				−29				−27	504	0	−30	−30
N				−51				−26				−28	491	0	−25	−25
O				−51				−26				−27	489	0	−25	−25
18				−11				−6				−6				−6
17				−12				−6				−6				−6
16				−12				−6				−6				−6
15				−14				−6				−5				−6
14				−15				−5				−5				−5
13				−27				−12				−11				−12
12				−16				−8				−7				−8
11				−13				−8				−7				−8
10				−13				−10				−9				−10
9				−2				−2				−2				−2
8				+4				+4				+4				+4
7				+8				+8				+8				+8
6				+9				+9				+10				+9
5				+11				+11				+10				+11
4				+8				+8				+8				+8
3				+5				+5				+6				+5
2				+3				+3				+2				+3
1				+1				+1				+1				+1
Total				+12				−13				−3				+13

Mean elevations and corrections for topography and isostatic compensation, separate zones—Continued.

Zone.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.
	Taylor, Tex., No. 309.				Georgetown, Tex., No. 310.				Damon No. 1, Tex., No. 311.			
A	581	+2	0	+2	755	+2	0	+2	62	+2	0	+2
B	585	+56	0	+56	750	+60	0	+60	62	+16	0	+16
C	584	+70	0	+70	748	+84	0	+84	62	+2	0	+2
D	580	+40	−1	+39	744	+54	−1	+53	60	0	0	0
E	552	+16	−1	+15	720	+19	−2	+17	60	0	0	0
F	562	+2	−2	0	729	+10	−2	+8	69	0	0	0
G	588	0	−2	−2	759	0	−3	−3	76	0	0	0
H	601	0	−3	−3	784	0	−4	−4	78	0	0	0
I	612	0	−5	−5	776	0	−6	−6	82	0	−1	−1
J	558	0	−6	−6	777	0	−9	−9				−2
K	575	0	−9	−9	815	0	−13	−13				−2
L	595	0	−14	−14	802	0	−19	−19				−3
M	593	0	−35	−35	721	0	−42	−42				−5
N	669	0	−34	−34	825	0	−42	−42				−5
O	723	0	−36	−36	827	0	−42	−42				−6
18				−8				−9				−1
17				−8				−9				0
16				−7				−8				+1
15				−7				−8				+2
14				−7				−8				+3
13				−12				−14				+2
12				−9				−10				0
11				−7				−8				−3
10				−10				−10				−7
9				+1				+1				+1
8				+7				+7				+7
7				+9				+9				+8
6				+10				+10				+10
5				+10				+10				+10
4				+9				+9				+9
3				+6				+6				+6
2				+2				+2				+2
1				+1				+1				+1
Total				+18				+15				+47

Zone.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.	Elev. in feet.	Topog.	Comp.	Topog. and Comp.
	Damon No. 2, Tex., No. 312.				Damon No. 3, Tex., No. 313.			
A	142	+2	0	+2	58	+2	0	+2
B	142	+32	0	+32	58	+16	0	+16
C	142	+8	0	+8	58	+2	0	+2
D	147	+6	0	+6	60	0	0	0
E	125	0	0	0	66	0	0	0
F	95	0	0	0	82	0	0	0
G	82	0	0	0	86	0	0	0
H	74	0	0	0	72	0	0	0
I	70	0	−1	−1	59	0	0	0
J				−1	57	0	−1	−1
K				−1	60	0	−1	−1
L				−2	68	0	−2	−2
M				−4	72	0	−4	−4
N				−4	58	0	−3	−3
O				−5	82	0	−4	−4
18				−1				−1
17				0				0
16				+1				+1
15				+2				+2
14				+3				+3
13				+2				+2
12				0				0
11				−3				−3
10				−7				−7
9				+1				+1
8				+7				+7
7				+8				+8
6				+10				+10
5				+10				+10
4				+9				+9
3				+6				+6
2				+2				+2
1				+1				+1
Total				+81				+56

Pendulum observations and reductions.

Station and observer.	Swing No.	Pendulum.	Position.	Date.	Coincidence interval. Chronometer No. 1828.	Coincidence interval. Chronometer No. 1838.	Total arc. Initial.	Total arc. Final.	Temperature.	Pressure.	Period uncorrected. Chronometer No. 1828.	Period uncorrected. Chronometer No. 1838.	Corrections (seventh decimal place). Arc.	Temperature.	Pressure.	Rate. Chronometer No. 1828.	Rate. Chronometer No. 1838.	Flexure.	Period corrected. Chronometer No. 1828.	Period corrected. Chronometer No. 1838.	Period corrected. Mean.	g.	Mean g.
				1916.	s.	s.	mm.	mm.	°C.	mm.	s.	s.							s.	s.	s.	Dynes.	Dynes.
Washington, D. C., Coast and Geodetic Survey Office, C. L. Garner.	1	A4	D	June 23	285.36	309.76	7.9	1.7	20.18	63	0.5008776	0.5008084	−17	−217	+1	−171	+522	−13	0.5008359	0.5008360	0.5008360	.....	
	2	A4	D	June 24	283.17	307.53	8.3	1.9	20.29	62	.5008844	.5008142	−20	−222	+2	−171	+522	−13	.5008420	.5008411	.5008416	.....	
	3	A5	D	June 26	353.38	395.86	8.1	1.8	20.85	57	.5007084	.5006323	−18	−245	+7	−188	+581	−13	.5006627	.5006635	.5006631	.....	
	4	A5	D	June 27	352.83	395.30	8.0	1.8	20.95	62	.5007095	.5006332	−18	−249	+2	−188	+581	−13	.5006629	.5006635	.5006632	.....	
	5	A5	D	....do	352.43	395.58	7.9	1.7	21.08	60	.5007103	.5006328	−17	−255	+4	−188	+581	−13	.5006634	.5006628	.5006631	.....	
	6	A5	D	June 28	351.60	394.78	8.0	1.6	21.18	69	.5007121	.5006340	−17	−259	−4	−188	+581	−13	.5006640	.5006628	.5006634	.....	
	7	A6	D	....do	368.98	416.54	8.0	1.9	21.38	61	.5006784	.5006009	−18	−267	+3	−201	+580	−13	.5006288	.5006294	.5006291	.....	
	8	A6	D	June 29	367.82	415.94	7.9	1.6	21.48	67	.5006806	.5006018	−17	−272	−3	−201	+580	−13	.5006300	.5006293	.5006296	.....	
No. 220, Bellingham, Wash., C. L. Garner.	1	A4	D	July 19	371.88	415.79	7.7	1.9	18.06	58	.5006731	.5006020	−17	−128	+6	−160	+547	−9	.5006423	.5006419	.5006421	980.882	
	2	A4	D	July 20	372.78	416.53	7.9	1.7	17.82	60	.5006715	.5006009	−17	−118	+4	−160	+547	−9	.5006415	.5006416	.5006416	980.884	
	3	A4	D	....do	373.15	417.24	8.0	1.7	17.75	60	.5006709	.5005999	−17	−115	+4	−158	+557	−9	.5006414	.5006419	.5006416	980.884	980.884 ±0.000
	4	A4	D	July 21	372.57	417.18	8.1	1.9	17.72	61	.5006719	.5006000	−18	−114	+3	−158	+557	−9	.5006423	.5006419	.5006421	980.882	
	5	A5	D	....do	505.60	588.02	7.9	2.0	17.76	55	.5004949	.5004255	−19	−116	+8	−160	+538	−9	.5004653	.5004657	.5004655	980.886	
	6	A5	D	July 22	505.06	588.50	7.9	1.7	17.66	56	.5004954	.5004252	−17	−111	+7	−160	+538	−9	.5004664	.5004660	.5004662	980.883	
No. 221, Everett, Wash., C. L. Garner.	1	A6	D	July 25	510.23	601.56	7.9	1.8	17.45	60	.5004904	.5004159	−18	−103	+4	−200	+543	−8	.5004579	.5004577	.5004578	980.783	
	2	A6	D	July 26	508.26	598.20	7.9	1.8	17.81	62	.5004923	.5004183	−18	−118	+2	−200	+543	−8	.5004581	.5004584	.5004582	980.782	
	3	A6	D	....do	513.49	602.34	7.9	1.6	17.21	62	.5004873	.5004154	−17	−93	+2	−156	+553	−8	.5004601	.5004591	.5004596	980.776	980.781 ±0.002
	4	A6	D	July 27	516.05	602.96	8.0	1.8	16.66	62	.5004849	.5004149	−18	−70	+2	−156	+553	−8	.5004599	.5004608	.5004604	980.773	
	5	A5	D	....do	486.94	560.40	7.9	1.7	16.25	60	.5005140	.5004465	−17	−52	+3	−163	+513	−8	.5004903	.5004904	.5004904	980.788	
	6	A5	D	July 28	486.68	560.57	8.0	1.7	15.96	61	.5005142	.5004463	−17	−40	+2	−163	+513	−8	.5004916	.5004913	.5004914	980.784	
No. 222, Issaquah, Wash., C. L. Garner.	1	A4	D	Aug. 1	356.50	403.34	7.9	1.9	16.98	60	.5007022	.5006206	−18	−83	+4	−194	+619	−8	.5006723	.5006720	.5006722	980.763	
	2	A4	D	Aug. 2	356.56	403.27	7.9	1.7	16.81	62	.5007021	.5006207	−17	−76	+2	−194	+619	−8	.5006728	.5006727	.5006728	980.761	
	3	A4	D	....do	357.50	402.82	7.9	1.7	16.67	63	.5007003	.5006214	−17	−70	0	−185	+603	−8	.5006723	.5006722	.5006722	980.763	980.763 ±0.000
	4	A4	D	Aug. 3	357.57	402.84	8.1	1.6	16.64	64	.5007002	.5006214	−17	−69	0	−185	+603	−8	.5006723	.5006723	.5006723	980.763	
	5	A5	D	....do	478.32	560.32	7.9	1.8	16.79	59	.5005232	.5004465	−18	−75	+4	−172	+593	−8	.5004963	.5004961	.5004962	980.765	
	6	A5	D	Aug. 4	478.85	560.48	8.0	1.8	16.56	60	.5005226	.5004464	−18	−65	+3	−172	+593	−8	.5004966	.5004969	.5004968	980.763	
No. 223, Port Angeles, Wash., C. L. Garner.	1	A5	D	Aug. 9	498.22	588.48	8.0	1.7	17.39	58	.5005023	.5004252	−17	−100	+5	−217	+548	−9	.5004685	.5004679	.5004682	980.875	
	2	A5	D	Aug. 10	497.78	586.48	8.0	1.8	17.39	59	.5005027	.5004266	−18	−100	+5	−217	+548	−9	.5004688	.5004692	.5004690	980.872	
	3	A5	D	....do	497.08	584.70	8.0	1.8	17.36	59	.5005034	.5004279	−18	−99	+5	−234	+530	−9	.5004679	.5004688	.5004684	980.874	
	4	A5	D	Aug. 11	495.80	585.82	7.8	1.8	17.32	59	.5005047	.5004271	−17	−97	+4	−234	+530	−9	.5004694	.5004682	.5004688	980.873	980.875 ±0.000
	5	A6	D	....do	531.93	633.88	7.9	1.6	17.48	65	.5004705	.5003947	−17	−104	−1	−234	+530	−9	.5004340	.5004346	.5004343	980.876	
	6	A6	D	Aug. 12	531.78	635.28	8.0	1.8	17.49	58	.5004706	.5003938	−18	−104	+6	−234	+530	−9	.5004347	.5004343	.5004345	980.875	
	7	A6	D	....do	533.50	634.80	7.9	1.8	17.54	58	.5004690	.5003941	−18	−106	+6	−235	+527	−9	.5004328	.5004341	.5004334	980.879	
	8	A6	D	Aug. 13	530.28	634.44	7.8	1.7	17.64	58	.5004719	.5003943	−17	−111	+6	−235	+527	−9	.5004353	.5004339	.5004346	980.874	
No. 224, Port Townsend, Wash., C. L. Garner.	1	A6	D	Aug. 18	548.60	640.85	7.9	1.5	14.52	61	.5004561	.5003904	−16	+20	+2	−179	+467	−7	.5004381	.5004370	.5004376	980.863	
	2	A6	D	Aug. 19	550.80	640.84	7.9	1.4	14.14	61	.5004543	.5003904	−15	+36	+2	−179	+467	−7	.5004380	.5004387	.5004384	980.860	
	3	A6	D	....do	551.60	640.71	8.1	1.6	13.91	61	.5004536	.5003905	−17	+46	+2	−180	+461	−7	.5004380	.5004390	.5004385	980.859	
	4	A6	D	Aug. 20	550.56	640.38	7.9	1.6	13.89	61	.5004545	.5003907	−17	+47	+2	−180	+461	−7	.5004390	.5004393	.5004392	980.857	980.858 ±0.001
	5	A4	D	....do	376.82	417.52	8.1	1.8	14.04	58	.5006644	.5005995	−18	+40	+5	−180	+461	−7	.5006484	.5006476	.5006480	980.858	
	6	A4	D	Aug. 21	376.07	416.60	8.0	1.8	14.12	60	.5006657	.5006008	−18	+37	+3	−180	+461	−7	.5006492	.5006484	.5006488	980.855	
	7	A4	D	....do	375.98	416.70	8.1	1.8	14.30	60	.5006658	.5006007	−18	+29	+3	−187	+471	−7	.5006478	.5006485	.5006482	980.858	
	8	A4	D	Aug. 22	374.86	416.34	8.1	1.8	14.56	60	.5006678	.5006012	−18	+18	+3	−187	+471	−7	.5006487	.5006479	.5006483	980.857	
No. 225, Port Gamble, Wash., C. L. Garner.	1	A4	D	Aug. 24	362.95	409.60	8.0	1.7	19.29	62	.5006898	.5006111	−17	−180	+2	−215	+571	−11	.5006477	.5006476	.5006476	980.860	
	2	A4	D	Aug. 25	362.62	409.47	8.0	1.6	19.11	63	.5006904	.5006113	−17	−172	+1	−215	+571	−11	.5006490	.5006485	.5006488	980.855	
	3	A4	D	....do	363.94	409.88	8.1	1.6	18.93	64	.5006879	.5006106	−17	−165	0	−215	+556	−11	.5006471	.5006469	.5006470	980.862	980.858 ±0.001
	4	A4	D	Aug. 26	364.00	409.92	8.0	1.6	18.78	64	.5006878	.5006106	−17	−158	0	−215	+556	−11	.5006477	.5006476	.5006476	980.860	
	5	A5	D	....do	491.84	575.40	8.0	1.5	18.54	63	.5005088	.5004349	−16	−148	+1	−188	+564	−11	.5004726	.5004739	.5004732	980.856	
	6	A5	D	Aug. 27	489.94	576.24	8.0	1.6	18.78	61	.5005108	.5004342	−17	−158	+3	−188	+564	−11	.5004737	.5004723	.5004730	980.857	

No. 226, Bremerton, Wash., C. L. Garner.	1	A5	D	Aug. 30.....	476.50	559.17	7.8	1.6	18.05	68	.5005252	.5004475	−16	−128	−4	−241	+534	−11	.5004852	.5004850	.5004851	980.809		
	2	A5	D	Aug. 31.....	478.48	561.38	7.9	1.7	17.79	58	.5005230	.5004457	−17	−117	+6	−241	+534	−11	.5004850	.5004852	.5004851	980.809		
	3	A5	D	.....do.....	477.77	561.80	8.0	1.6	17.55	59	.5005238	.5004454	−17	−107	+5	−253	+537	−11	.5004855	.5004861	.5004858	980.806	980.810	
	4	A5	D	Sept. 1.....	475.56	560.12	8.0	1.6	18.48	60	.5005262	.5004467	−17	−146	+4	−253	+537	−11	.5004839	.5004834	.5004836	980.815	±0.000	
	5	A6	D	.....do.....	508.62	606.00	7.7	1.7	18.66	60	.5004920	.5004129	−16	−153	+4	−230	+558	−11	.5004514	.5004511	.5004512	980.809		
	6	A6	D	Sept. 2.....	508.75	605.44	7.9	1.7	18.68	63	.5004918	.5004132	−17	−154	+1	−230	+558	−11	.5004507	.5004509	.5004508	980.811		
No. 227, Tacoma, Wash., C. L. Garner.	1	A6	D	Sept. 7.....	497.95	592.96	7.9	1.7	19.55	63	.5005026	.5004219	−17	−191	+1	−237	+573	−9	.5004573	.5004576	.5004574	980.785		
	2	A6	D	Sept. 8.....	498.44	594.85	7.9	1.5	19.48	66	.5005021	.5004206	−16	−188	−1	−237	+573	−9	.5004570	.5004565	.5004568	980.787		
	3	A6	D	.....do.....	501.74	592.93	7.9	1.7	19.33	60	.5004988	.5004220	−17	−181	+4	−204	+553	−9	.5004581	.5004570	.5004576	980.784	980.788	
	4	A6	D	Sept. 9.....	504.34	593.72	7.8	1.7	19.28	61	.5004962	.5004214	−17	−179	+3	−204	+553	−9	.5004556	.5004565	.5004560	980.791	±0.001	
	5	A4	D	.....do.....	357.42	395.52	8.0	1.6	19.21	62	.5007005	.5006329	−17	−176	+2	−162	+531	−9	.5006643	.5006660	.5006652	980.791		
	6	A4	D	Sept. 10.....	356.54	396.59	8.0	1.8	19.11	58	.5007021	.5006312	−18	−172	+6	−162	+531	−9	.5006666	.5006650	.5006658	980.789		
No. 228, Moclips, Wash., C. L. Garner.	1	A4	D	Sept. 13.....	358.01	395.60	8.0	1.7	15.95	56	.5006993	.5006328	−17	−40	+7	−199	+424	−12	.5006732	.5006690	.5006711	980.768		
	2	A4	D	Sept. 14.....	361.53	395.08	8.0	1.9	15.28	57	.5006924	.5006336	−18	−12	+6	−199	+424	−12	.5006689	.5006724	.5006706	980.770		
	3	A4	D	.....do.....	362.78	395.77	8.0	1.8	15.41	59	.5006900	.5006325	−18	−17	+4	−152	+412	−12	.5006705	.5006694	.5006700	980.772	980.770	
	4	A4	D	Sept. 15.....	362.95	394.69	8.0	1.8	15.31	60	.5006898	.5006342	−18	−13	+3	−152	+412	−12	.5006706	.5006714	.5006710	980.768	±0.001	
	5	A5	D	.....do.....	487.14	547.86	8.0	1.8	15.45	58	.5005138	.5004567	−18	−19	+5	−151	+398	−12	.5004943	.5004921	.5004932	980.777		
	6	A5	D	Sept. 16.....	488.00	544.09	8.0	1.8	15.08	60	.5005128	.5004599	−18	−3	+3	−151	+398	−12	.5004947	.5004967	.5004957	980.767		
No. 229, Portland, Oreg., C. L. Garner.	1	A5	D	Sept. 19.....	444.44	505.15	8.1	1.6	17.94	61	.5005632	.5004954	−17	−123	+3	−213	+453	−8	.5005274	.5005262	.5005268	980.646		
	2	A5	D	Sept. 20.....	445.34	504.16	7.8	1.6	18.01	63	.5005620	.5004963	−16	−126	+1	−213	+453	−8	.5005258	.5005267	.5005262	980.648		
	3	A5	D	.....do.....	445.92	504.64	8.0	1.6	18.13	60	.5005613	.5004959	−17	−131	+4	−191	+466	−8	.5005270	.5005273	.5005272	980.644	980.646	
	4	A5	D	Sept. 21.....	444.94	504.26	8.0	1.8	18.25	60	.5005625	.5004962	−18	−136	+4	−191	+466	−8	.5005276	.5005270	.5005273	980.643	±0.001	
	5	A6	D	.....do.....	474.63	539.26	7.9	1.6	18.53	58	.5005273	.5004640	−17	−148	+6	−180	+454	−8	.5004926	.5004927	.5004926	980.647		
	6	A6	D	Sept. 22.....	474.07	539.02	7.9	1.6	18.68	60	.5005279	.5004642	−17	−154	+4	−180	+454	−8	.5004924	.5004921	.5004922	980.649		
No. 230, Tillamook, Oreg., C. L. Garner.	1	A6	D	Sept. 26.....	484.84	569.84	7.8	1.7	18.15	59	.5005162	.5004391	−17	−132	+5	−206	+531	−8	.5004804	.5004770	.5004787	980.701		
	2	A6	D	Sept. 27.....	488.28	566.02	8.0	1.6	17.74	60	.5005125	.5004421	−17	−115	+4	−206	+531	−8	.5004783	.5004816	.5004800	980.697		
	3	A6	D	.....do.....	495.38	566.38	7.9	1.6	17.46	60	.5005051	.5004418	−17	−103	+4	−139	+500	−8	.5004788	.5004794	.5004791	980.700	980.700	
	4	A6	D	Sept. 28.....	495.02	567.34	7.8	1.6	17.44	61	.5005056	.5004410	−16	−102	+3	−139	+500	−8	.5004794	.5004787	.5004790	980.701	±0.000	
	5	A4	D	.....do.....	350.62	383.68	8.0	1.9	17.50	58	.5007141	.5006524	−18	−105	+5	−145	+484	−8	.5006870	.5006882	.5006876	980.703		
	6	A4	D	Sept. 29.....	349.58	383.90	8.0	1.6	17.49	60	.5007161	.5006521	−17	−104	+4	−145	+484	−8	.5006891	.5006880	.5006886	980.699		
No. 231, Newport, Oreg., C. L. Garner.	1	A4	D	Oct. 3.....	338.96	377.47	8.0	1.8	17.38	56	.5007387	.5006632	−18	−100	+7	−128	+596	−8	.5007140	.5007109	.5007124	980.606		
	2	A4	D	Oct. 4.....	340.34	375.78	8.0	1.6	17.02	58	.5007356	.5006661	−17	−85	+6	−128	+596	−8	.5007124	.5007153	.5007138	980.600		
	3	A4	D	.....do.....	339.85	374.28	8.1	1.6	17.45	59	.5007367	.5006688	−17	−103	+5	−105	+554	−8	.5007139	.5007119	.5007129	980.604	980.601	
	4	A4	D	Oct. 5.....	340.28	372.58	8.0	1.8	17.34	60	.5007357	.5006719	−18	−98	+4	−105	+554	−8	.5007132	.5007153	.5007142	980.599	±0.001	
	5	A5	D	.....do.....	441.02	500.53	7.6	1.6	18.46	62	.5005675	.5005000	−16	−145	+2	−116	+541	−8	.5005392	.5005374	.5005383	980.600		
	6	A5	D	Oct. 6.....	441.64	497.82	7.7	1.6	18.55	64	.5005667	.5005027	−16	−149	0	−116	+541	−8	.5005378	.5005395	.5005386	980.599		
No. 232, Eugene, Oreg., C. L. Garner.	1	A5	D	Oct. 10.....	427.60	479.76	7.6	1.8	14.37	57	.5005853	.5005216	−17	+26	+6	−180	+450	−10	.5005678	.5005671	.5005674	980.487		
	2	A5	D	Oct. 11.....	428.26	479.46	7.9	1.7	14.34	57	.5005844	.5005219	−17	+28	+6	−180	+450	−10	.5005671	.5005676	.5005674	980.487		
	3	A5	D	.....do.....	428.77	479.82	8.0	1.8	14.24	58	.5005837	.5005215	−18	+32	+5	−187	+439	−10	.5005659	.5005663	.5005661	980.491	980.490	
	4	A5	D	Oct. 12.....	428.04	479.97	8.0	1.7	14.16	58	.5005848	.5005214	−17	+35	+5	−187	+439	−10	.5005674	.5005666	.5005670	980.488	±0.001	
	5	A6	D	.....do.....	458.94	513.33	7.9	1.7	13.93	59	.5005453	.5004875	−17	+45	+4	−164	+426	−10	.5005311	.5005323	.5005317	980.494		
	6	A6	D	Oct. 13.....	458.07	514.57	7.9	1.5	13.70	60	.5005463	.5004863	−16	+54	+3	−164	+426	−10	.5005330	.5005320	.5005325	980.491		
No. 233, Marshfield, Oreg., C. L. Garner.	1	A6	D	Oct. 17.....	448.81	514.50	7.9	1.8	16.73	60	.5005576	.5004864	−18	−72	+4	−140	+551	−9	.5005341	.5005320	.5005330	980.489		
	2	A6	D	Oct. 18.....	454.90	517.65	8.0	1.5	15.84	63	.5005502	.5004834	−16	−35	0	−140	+551	−9	.5005302	.5005325	.5005314	980.495		
	3	A6	D	.....do.....	453.26	516.12	7.8	1.9	16.20	56	.5005522	.5004849	−17	−50	+7	−123	+537	−9	.5005330	.5005317	.5005324	980.491	980.492	
	4	A6	D	Oct. 19.....	452.85	513.29	7.9	1.7	16.42	57	.5005527	.5004875	−17	−59	+6	−123	+537	−9	.5005325	.5005333	.5005329	980.489	±0.001	
	5	A4	D	.....do.....	329.50	358.38	7.9	1.8	16.07	60	.5007599	.5006985	−18	−45	+4	−126	+485	−9	.5007405	.5007402	.5007404	980.496		
	6	A4	D	Oct. 20.....	330.05	358.82	8.0	1.7	15.64	61	.5007586	.5006977	−17	−27	+2	−126	+485	−9	.5007409	.5007411	.5007410	980.494		
No. 234, Glendale, Oreg., C. L. Garner.	1	A4	D	Oct. 25.....	313.08	334.43	7.9	1.9	12.97	57	.5007998	.5007486	−18	+85	+5	−145	+384	−8	.5007917	.5007934	.5007926	980.292		
	2	A4	D	Oct. 26.....	313.80	337.15	7.9	1.7	12.97	59	.5007980	.5007426	−17	+85	+4	−145	+384	−8	.5007899	.5007874	.5007886	980.308		
	3	A4	D	.....do.....	313.82	335.98	8.0	1.7	13.11	60	.5007979	.5007452	−17	+79	+3	−146	+391	−8	.5007890	.5007900	.5007895	980.304		
	4	A4	D	Oct. 27.....	313.02	336.04	7.9	1.7	13.36	61	.5007999	.5007450	−17	+69	+2	−146	+391	−8	.5007899	.5007887	.5007893	980.305	980.302	
	5	A5	D	.....do.....	402.95	439.42	7.9	1.7	13.35	56	.5006212	.5005696	−17	+69	+6	−113	+336	−8	.5006149	.5006132	.5006140	980.304	±0.001	
	6	A5	D	Oct. 28.....	403.50	437.56	7.9	1.7	13.19	56	.5006204	.5005720	−17	+76	+6	−113	+386	−8	.5006148	.5006163	.5006156	980.297		
	7	A5	D	.....do.....	404.06	436.44	8.0	1.7	13.12	57	.5006195	.5005735	−17	+79	+6	−113	+340	−8	.5006142	.5006135	.5006138	980.305		
	8	A5	D	Oct. 29.....	404.50	435.60	7.9	1.7	12.91	57	.5006188	.5005746	−17	+88	+6	−113	+340	−8	.5006144	.5006155	.5006150	980.300		
No. 235, Tehama..... Calif., C. L. Garner.	1	A5	D	Nov. 1.....	368.52	400.36	7.9	1.8	15.69	62	.5006794	.5006252	−18	−29	+1	−148	+404	−9	.5006591	.5006601	.5006596	980.125		
	2	A5	D	Nov. 2.....	366.82	399.72	7.9	1.6	15.84	64	.5006825	.5006262	−17	−35	−1	−148	+404	−9	.5006615	.5006604	.5006610	980.119		
	3	A5	D	.....do.....	367.64	400.10	7.7	1.7	15.82	59	.5006809	.5006256	−16	−34	+4	−141	+408	−9	.5006613	.5006609	.5006611	980.119	980.122	
	4	A5	D	Nov. 3.....	367.58	399.54	8.0	1.8	15.80	59	.5006810	.5006265	−18	−34	+4	−141	+408	−9	.5006612	.5006616	.5006614	980.118	±0.001	
	5	A6	D	.....do.....	386.92	422.28	8.0	1.7	15.80	61	.5006470	.5005927	−17	−34	+2	−166	+392	−9	.5006246	.5006261	.5006254	980.127		
	6	A6	D	Nov. 4.....	385.63	423.02	7.7	1.7	15.91	62	.5006491	.5005917	−16	−38	+1	−166	+392	−9	.5006263	.5006247	.5006255	980.126		

Pendulum observations and reductions—Continued.

Station and observer.	Swing No.	Pendulum.	Position.	Date.	Coincidence interval. Chronometer No. 1828.	Coincidence interval. Chronometer No. 1838.	Total arc. Initial.	Total arc. Final.	Temperature.	Pressure.	Period uncorrected. Chronometer No. 1828.	Period uncorrected. Chronometer No. 1838.	Corrections (seventh decimal place). Arc.	Corrections. Temperature.	Corrections. Pressure.	Corrections. Rate. Chronometer No. 1828.	Corrections. Rate. Chronometer No. 1838.	Corrections. Flexure.	Period corrected. Chronometer No. 1828.	Period corrected. Chronometer No. 1838.	Period corrected. Mean.	g.	Mean g.
				1916.	s.	s.	mm.	mm.	°C.	mm.	s.	s.							s.	s.	s.	Dynes.	Dynes.
No. 236, Sacramento, Calif., C. L. Garner.	1	A6	D	Nov. 7	361.25	397.38	7.7	1.8	20.23	60	0.5006930	0.5006299	−17	−219	+4	−157	+482	−10	0.5006531	0.5006539	0.5006535	980.017	
	2	A6	D	Nov. 8	360.48	397.55	7.9	1.7	20.38	63	.5006944	.5006296	−17	−225	+1	−157	+482	−10	.5006536	.5006527	.5006532	980.018	
	3	A6	D	.....do	359.98	397.27	7.9	1.8	20.82	58	.5006954	.5006301	−18	−244	+6	−156	+507	−10	.6006532	.5006542	.5006537	980.016	980.018 ±0.001
	4	A6	D	Nov. 9	358.32	396.46	7.9	1.7	21.26	60	.5006987	.5006314	−17	−262	+4	−156	+507	−10	.5006546	.5006536	.5006541	980.014	
	5	A4	D	.....do	275.64	297.08	8.0	1.6	21.68	64	.5009086	.5008430	−17	−280	0	−163	+494	−10	.5008616	.5008617	.5008616	980.022	
	6	A4	D	Nov. 10	275.43	296.82	8.1	1.6	21.79	57	.5009093	.5008436	−17	−285	+7	−163	+494	−10	.5008625	.5008625	.5008625	980.019	
No. 237, Willits, Calif., C. L. Garner.	1	A4	D	Nov. 12	287.14	302.45	7.8	2.2	11.86	57	.5008722	.5008280	−19	+132	+5	−183	+264	−10	.5008647	.5008652	.5008650	980.009	
	2	A4	D	Nov. 13	287.63	303.40	8.0	1.6	11.63	58	.5008707	.5008253	−17	+141	+4	−183	+264	−10	.5008642	.5008635	.5008638	980.014	
	3	A4	D	.....do	287.96	304.64	7.9	1.7	11.28	59	.5008697	.5008220	−17	+156	+3	−165	+327	−10	.5008664	.5008679	.5008672	980.000	980.007 ±0.002
	4	A4	D	Nov. 14	288.44	306.43	8.0	1.6	11.19	60	.5008683	.5008172	−17	+160	+2	−165	+327	−10	.5008653	.5008634	.5008644	980.011	
	5	A5	D	.....do	361.31	387.92	7.8	1.7	11.03	59	.5006929	.5006453	−17	+166	+3	−158	+307	−10	.5006913	.5006902	.5006908	980.003	
	6	A5	D	Nov. 15	362.10	387.47	8.0	1.6	10.97	60	.5006914	.5006460	−17	+169	+2	−158	+307	−10	.5006900	.5006911	.5006906	980.004	
No. 238, Eureka, Calif., C. L. Garner.	1	A5	D	Nov. 18	379.44	418.84	8.0	1.6	15.72	60	.5006597	.5005976	−17	−30	+3	−191	+434	−8	.5006354	.5006358	.5006356	980.219	
	2	A5	D	Nov. 19	378.86	418.90	8.0	1.6	15.52	61	.5006608	.5005975	−17	−22	+2	−191	+434	−8	.5006372	.5006364	.5006368	980.215	
	3	A5	D	.....do	380.26	419.56	8.0	1.7	15.27	63	.5006583	.5005966	−17	−11	0	−211	+422	−8	.5006336	.5006352	.5006344	980.224	980.220 ±0.001
	4	A5	D	Nov. 20	378.42	419.54	8.0	1.8	15.28	64	.5006616	.5005966	−18	−12	0	−211	+422	−8	.5006367	.5006350	.5006358	980.218	
	5	A6	D	.....do	398.97	445.42	7.8	1.6	15.57	62	.5006274	.5005619	−16	−24	+1	−217	+442	−8	.5006010	.5006014	.5006012	980.222	
	6	A6	D	Nov. 21	399.06	446.02	7.8	1.6	15.54	63	.5006273	.5005612	−16	−23	0	−217	+442	−8	.5006009	.5006007	.5006008	980.223	
No. 239, Santa Rosa, Calif., C. L. Garner.	1	A6	D	Nov. 23	367.04	406.58	7.9	1.6	16.79	60	.5006820	.5006156	−17	−75	+4	−198	+464	−9	.5006525	.5006523	.5006524	980.021	
	2	A6	D	Nov. 24	366.96	406.34	8.0	1.5	16.53	62	.5006822	.5006160	−16	−64	+2	−198	+464	−9	.5006537	.5006537	.5006537	980.016	
	3	A6	D	.....do	366.98	406.78	8.0	1.6	16.58	60	.5006821	.5006153	−17	−66	+3	−215	+460	−9	.5006517	.5006524	.5006520	980.023	980.021 ±0.001
	4	A6	D	Nov. 25	366.20	407.03	8.0	1.6	16.60	61	.5006836	.5006150	−17	−67	+3	−215	+460	−9	.5006531	.5006520	.5006526	980.020	
	5	A4	D	.....do	280.21	302.70	8.0	1.8	16.82	61	.5008938	.5008273	−18	−76	+3	−227	+439	−9	.5008611	.5008612	.5008612	980.024	
	6	A4	D	Nov. 26	279.43	301.96	8.0	1.8	17.17	63	.5008963	.5008293	−18	−91	+1	−227	+439	−9	.5008619	.5008615	.5008617	980.022	
				1917.	1818	1842					1818	1842				1818	1842		1818	1842			
Washington, D. C., Coast and Geodetic Survey Office, C. L. Garner.	1	A4	D	Jan. 15	325.88	314.11	7.9	1.7	8.40	56	.5007683	.5007972	−17	+277	+5	+428	+159	−10	.5008366	.5008386	.5008376	.....	
	2	A4	D	Jan. 16	324.76	314.74	7.8	1.8	8.24	57	.5007710	.5007956	−17	+283	+5	+428	+159	−10	.5008399	.5008376	.5008388	.....	
	3	A5	D	.....do	422.94	403.40	7.9	1.7	8.18	56	.5005918	.5006205	−17	+286	+5	+432	+161	−10	.5006614	.5006630	.5006622	.....	
	4	A5	D	Jan. 17	421.70	404.23	7.7	1.6	8.09	57	.5005935	.5006192	−16	+290	+4	+432	+161	−10	.5006635	.5006621	.5006628	.....	
	5	A6	D	.....do	449.82	427.34	7.8	1.4	8.08	59	.5005564	.5005857	−15	+290	+3	+432	+156	−10	.5006264	.5006281	.5006272	.....	
	6	A6	D	Jan. 18	445.85	426.14	8.0	1.7	8.13	60	.5005614	.5005874	−17	+288	+2	+432	+156	−10	.5006309	.5006293	.5006301	.....	
				1916.	1828	1838					1828	1838				1828	1838		1828	1838			
Washington, D. C., Coast and Geodetic Survey Office, Max Steinberg.	1	B6	D	June 15	337.11	366.99	7.7	2.0	21.26	54	.5007427	.5006821	−18	−262	+10	−144	+460	−13	.5007000	.5006998	.5006999	.....	
	2	B6	D	June 16	337.12	367.03	7.7	1.8	20.90	56	.5007427	.5006820	−17	−247	+9	−144	+460	−13	.5007015	.5007012	.5007014	.....	
	3	B6	D	.....do	337.44	366.76	8.1	2.0	20.70	57	.5007420	.5006826	−19	−239	+7	−166	+463	−13	.5006990	.5007025	.5007008	.....	
	4	B6	D	June 17	336.26	369.02	7.8	1.7	20.67	58	.5007446	.5006784	−17	−238	+6	−166	+463	−13	.5007018	.5006985	.5007002	.....	
	5	B4	D	June 19	287.40	311.05	7.9	1.8	20.72	60	.5008714	.5008050	−18	−240	+4	−164	+508	−13	.5008283	.5008291	.5008287	.....	
	6	B4	D	June 20	286.58	310.85	8.1	1.8	21.18	61	.5008739	.5008056	−18	−259	+3	−164	+508	−13	.5008288	.5008277	.5008282	.....	
	7	B5	D	.....do	328.51	359.60	8.0	1.7	21.28	56	.5007622	.5006962	−17	−263	+8	−146	+522	−13	.5007191	.5007199	.5007195	.....	
	8	B5	D	June 21	328.18	360.22	8.0	1.8	21.12	57	.5007629	.5006950	−18	−257	+7	−146	+522	−13	.5007202	.5007191	.5007196	.....	
					1818	1842					1818	1842				1818	1842		1818	1842			
No. 240, San Diego, Calif., Max Steinberg.	1	B4	D	July 19	251.54	251.40	8.0	1.4	19.60	58	.5009958	.5009964	−16	−193	+6	+19	+26	−10	.5009764	.5009777	.5009770	979.532	
	2	B4	D	July 20	250.78	251.37	8.1	1.9	19.48	60	.5009989	.5009965	−19	−188	+4	+19	+26	−10	.5009795	.5009778	.5009786	979.526	
	3	B4	D	.....do	251.26	251.10	8.7	1.8	19.48	60	.5009970	.5009976	−20	−188	+4	+8	+19	−10	.5009764	.5009781	.5009772	979.531	979.528 ±0.001
	4	B4	D	July 21	250.80	251.54	8.0	1.9	19.50	61	.5009988	.5009958	−18	−189	+3	+8	+19	−10	.5009782	.5009763	.5009772	979.531	
	5	B5	D	.....do	281.68	282.15	8.0	2.0	19.70	59	.5008892	.5008877	−19	−197	+5	+22	+41	−10	.5008693	.5008697	.5008695	979.528	
	6	B5	D	July 22	281.07	281.87	8.0	1.9	19.72	60	.5008911	.5008885	−18	−198	+4	+22	+41	−10	.5008711	.5008704	.5008708	979.523	

No. 241, Oceanside, Calif., Max Steinberg.	1	B5	D	July 27	282.34	283.99	8.2	1.8	20.42	60	.5008870	.5008818	−19	−227	+4	−26	+26	−12	.5008590	.5008590	.5008590	979.570		
	2	B5	D	July 28	281.66	283.48	8.2	1.8	20.44	61	.5008892	.5008835	−19	−223	+3	−26	+26	−12	.5008610	.5008605	.5008608	979.563		
	3	B5	D	do	282.41	283.84	8.2	1.8	20.59	62	.5008868	.5008823	−19	−234	+2	−26	+26	−12	.5008579	.5008586	.5008582	979.573		
	4	B5	D	July 29	281.39	283.27	8.3	1.9	20.87	55	.5008900	.5008841	−20	−246	+9	−26	+26	−12	.5008605	.5008598	.5008602	979.565		
	5	B5	D	do	281.82	283.26	8.3	1.8	21.03	56	.5008836	.5008841	−19	−253	+9	−20	+34	−12	.5008591	.5008600	.5008596	979.567	979.568 ±0.001	
	6	B5	D	July 30	280.84	282.90	8.2	2.0	21.20	56	.5008918	.5008853	−20	−260	+8	−20	+34	−12	.5008614	.5008603	.5008608	979.563		
	7	B6	D	do	287.24	289.02	8.5	1.8	21.35	62	.5008719	.5008664	−20	−266	+2	−45	+28	−12	.5008378	.5008396	.5008387	979.574		
	8	B6	D	July 31	286.03	288.81	8.1	1.8	21.30	63	.5008756	.5008672	−18	−264	+1	−45	+28	−12	.5008418	.5008407	.5008412	979.565		
	9	B6	D	do	286.59	288.98	8.0	1.9	21.33	63	.5008738	.5008666	−19	−265	+1	−45	+28	−12	.5008398	.5008399	.5008398	979.570		
	10	B6	D	Aug. 1	285.95	288.58	8.1	1.8	21.43	63	.5008759	.5008679	−18	−269	+1	−45	+28	−12	.5008416	.5008409	.5008412	979.565		
No. 242, Highland, Calif., Max Steinberg.	1	B6	D	Aug. 3	274.25	277.18	8.1	1.6	23.98	65	.5009132	.5009036	−17	−376	0	−101	−2	−11	.5008627	.5008630	.5008628	979.480		
	2	B6	D	Aug. 4	274.19	277.30	8.6	2.0	23.81	56	.5009134	.5009032	−21	−369	+8	−101	−2	−11	.5008640	.5008637	.5008638	979.476		
	3	B6	D	do	275.24	278.10	8.4	1.9	23.68	57	.5009100	.5009006	−20	−364	+8	−75	+11	−11	.5008638	.5008630	.5008634	979.477		
	4	B6	D	Aug. 5	275.00	277.96	8.3	2.0	23.51	57	.5009108	.5009010	−20	−357	+7	−75	+11	−11	.5008652	.5008640	.5008646	979.473		
	5	B4	D	do	242.10	243.89	8.3	1.8	23.24	59	.5010348	.5010271	−19	−345	+6	−75	+11	−11	.5009904	.5009913	.5009908	979.478	979.476 ±0.001	
	6	B4	D	Aug. 6	241.81	244.00	8.1	1.8	22.99	62	.5010361	.5010267	−18	−335	+3	−75	+11	−11	.5009925	.5009917	.5009921	979.473		
	7	B4	D	do	242.89	244.54	8.3	1.8	22.73	62	.5010314	.5010244	−19	−324	+3	−75	+11	−11	.5009888	.5009904	.5009896	979.482		
	8	B4	D	Aug. 7	242.08	244.16	8.2	1.8	22.88	62	.5010349	.5010260	−18	−330	+3	−75	+11	−11	.5009918	.5009915	.5009916	979.475		
	9	B4	D	do	242.58	244.49	8.2	1.7	22.93	62	.5010327	.5010246	−18	−332	+3	−69	+20	−11	.5009900	.5009908	.5009904	979.479		
	10	B4	D	Aug. 8	242.22	244.53	8.0	1.7	22.68	62	.5010342	.5010245	−17	−322	+3	−69	+20	−11	.5009926	.5009918	.5009922	979.472		
No. 243, Pomona, Calif., Max Steinberg.	1	B4	D	Aug. 10	246.74	248.28	8.4	1.8	23.20	62	.5010152	.5010090	−19	−344	+3	−68	+7	−12	.5009712	.5009725	.5009718	979.552		
	2	B4	D	Aug. 11	246.18	248.27	8.3	1.8	23.07	64	.5010176	.5010090	−19	−338	+1	−68	+7	−12	.5009740	.5009729	.5009734	979.546		
	3	B4	D	do	247.24	248.62	8.3	1.8	22.90	65	.5010132	.5010076	−19	−331	0	−57	+9	−12	.5009713	.5009723	.5009718	979.552		
	4	B4	D	Aug. 12	246.26	248.18	8.4	1.9	22.84	65	.5010173	.5010094	−19	−329	0	−57	+9	−12	.5009756	.5009743	.5009750	979.540	979.546 ±0.004	
	5	B5	D	do	276.80	277.60	8.6	1.8	22.87	58	.5009048	.5009022	−20	−330	+6	−50	−11	−12	.5008642	.5008655	.5008648	979.547		
	6	B5	D	Aug. 13	275.73	277.65	8.6	1.8	22.80	62	.5009083	.5009020	−20	−327	+3	−50	−11	−12	.5008677	.5008653	.5008665	979.540		
	7	B5	D	do	277.38	277.78	8.5	1.8	22.70	63	.5009030	.5009017	−20	−323	+2	−50	−11	−12	.5008627	.5008653	.5008640	979.550		
	8	B5	D	Aug. 14	276.14	277.78	8.4	1.8	22.66	65	.5009070	.5009017	−19	−321	0	−50	−11	−12	.5008668	.5008654	.5008661	979.542		
No. 244, Long Beach, Calif., Max Steinberg.	1	B5	D	Aug. 16	285.39	285.72	8.4	1.7	20.74	59	.5008775	.5008765	−18	−240	+5	−55	−32	−10	.5008457	.5008470	.5008464	979.619		
	2	B5	D	Aug. 17	284.68	285.93	8.5	1.9	20.64	59	.5008798	.5008759	−20	−236	+5	−55	−32	−10	.5008482	.5008466	.5008474	979.615		
	3	B5	D	do	285.68	286.09	8.4	1.8	20.58	59	.5008767	.5008754	−19	−234	+5	−35	−17	−10	.5008474	.5008479	.5008476	979.614	979.616 ±0.001	
	4	B5	D	Aug. 18	285.12	285.88	8.3	1.9	20.68	59	.5008783	.5008761	−19	−238	+5	−35	−17	−10	.5008486	.5008482	.5008484	979.611		
	5	B6	D	do	291.61	292.40	8.4	1.7	20.79	56	.5008588	.5008564	−18	−242	+8	−60	−23	−10	.5008266	.5008279	.5008272	979.619		
	6	B6	D	Aug. 19	290.86	292.62	8.4	1.8	20.68	57	.5008610	.5008558	−19	−238	+7	−60	−23	−10	.5008290	.5008275	.5008282	979.615		
No. 245, Redondo Beach, Calif., Max Steinberg.	1	B6	D	Aug. 23	292.89	291.83	8.5	1.8	20.12	63	.5008550	.5008581	−20	−217	+1	−33	−48	−10	.5008271	.5008287	.5008279	979.616		
	2	B6	D	Aug. 24	291.77	291.63	8.5	1.9	20.24	64	.5008583	.5008587	−20	−219	0	−33	−48	−10	.5008301	.5008290	.5008296	979.610		
	3	B4	D	do	254.43	254.52	8.1	1.8	20.31	60	.5009845	.5009841	−18	−223	+4	−47	−23	−10	.5009551	.5009571	.5009561	979.613	979.615 ±0.001	
	4	B4	D	Aug. 25	253.72	254.88	8.1	1.7	20.40	62	.5009873	.5009828	−17	−226	+2	−47	−23	−10	.5009575	.5009554	.5009564	979.612		
	5	B4	D	do	254.72	254.74	8.2	1.8	20.40	62	.5009834	.5009833	−19	−226	+2	−36	−27	−10	.5009545	.5009553	.5009549	979.618		
	6	B4	D	Aug. 26	254.66	255.08	8.1	1.7	20.38	62	.5009837	.5009820	−17	−226	+2	−36	−27	−10	.5009550	.5009542	.5009546	979.619		
No. 246, Burbank, Calif., Max Steinberg.	1	B4	D	Aug. 29	249.76	251.15	8.1	1.7	22.34	62	.5010030	.5009974	−17	−308	+3	−96	−28	−11	.5009601	.5009613	.5009607	979.595		
	2	B4	D	Aug. 30	248.90	250.90	8.4	1.9	22.30	63	.5010064	.5009984	−19	−306	+2	−96	−28	−11	.5009634	.5009622	.5009628	979.587		
	3	B4	D	do	250.02	251.42	8.2	1.8	22.17	63	.5010019	.5009963	−19	−300	+2	−79	−14	−11	.5009612	.5009621	.5009616	979.592	979.590 ±0.001	
	4	B4	D	Aug. 31	249.30	251.24	8.1	1.9	22.11	63	.5010048	.5009971	−18	−298	+2	−79	−14	−11	.5009644	.5009632	.5009638	979.583		
	5	B5	D	do	280.37	281.80	8.5	1.8	21.96	62	.5008933	.5008887	−20	−292	+2	−89	−33	−11	.5008523	.5008533	.5008528	979.594		
	6	B5	D	Sept. 1	279.72	281.78	8.4	1.7	21.81	64	.5008953	.5008888	−18	−285	+1	−89	−33	−11	.5008551	.5008542	.5008546	979.587		
No. 247, Palmdale, Calif., Max Steinberg.	1	B5	D	Sept. 5	266.21	269.84	8.2	1.7	23.49	63	.5009409	.5009282	−18	−356	+2	−167	−20	−13	.5008857	.5008877	.5008867	979.461		
	2	B5	D	Sept. 6	265.58	270.40	8.1	1.8	23.52	67	.5009431	.5009263	−18	−357	−2	−167	−20	−13	.5008874	.5008853	.5008864	979.462		
	3	B5	D	do	266.54	270.32	8.4	1.8	23.58	56	.5009397	.5009265	−19	−360	+8	−151	−16	−13	.5008862	.5008865	.5008864	979.462	979.462 ±0.001	
	4	B5	D	Sept. 7	265.86	269.90	8.3	1.9	23.67	61	.5009421	.5009280	−19	−363	+4	−151	−16	−13	.5008879	.5008873	.5008876	979.458		
	5	B6	D	do	272.05	275.77	8.2	1.7	23.69	62	.5009206	.5009082	−18	−364	+3	−148	−23	−13	.5008666	.5008667	.5008666	979.465		
	6	B6	D	Sept. 8	272.14	275.78	8.2	1.9	23.59	54	.5009203	.5009082	−19	−360	+10	−148	−23	−13	.5008673	.5008677	.5008675	979.462		
No. 248, Mojave, Calif., Max Steinberg.	1	B6	D	Sept. 12	272.53	278.79	8.2	1.7	23.89	58	.5009190	.5008983	−18	−372	+6	−160	+79	−17	.5008829	.5008861	.5008845	979.473		
	2	B6	D	Sept. 13	271.60	279.68	8.5	1.9	23.89	58	.5009222	.5008955	−20	−372	+6	−160	+79	−17	.5008859	.5008831	.5008845	979.473		
	3	B6	D	do	272.76	280.82	8.3	1.7	23.80	58	.5009182	.5008918	−18	−369	+6	−141	+122	−17	.5008843	.5008842	.5008842	979.474	979.471 ±0.001	
	4	B6	D	Sept. 14	271.96	280.06	8.4	1.9	23.96	59	.5009210	.5008942	−19	−375	+6	−141	+122	−17	.5008864	.5008859	.5008862	979.467		
	5	B4	D	do	239.14	245.28	8.3	1.6	24.19	60	.5010476	.5010213	−18	−385	+5	−147	+127	−17	.5009914	.5009925	.5009920	979.473		
	6	B4	D	Sept. 15	238.14	244.72	8.1	1.7	24.45	65	.5010520	.5010237	−17	−396	0	−147	+127	−17	.5009943	.5009934	.5009938	979.466		
No. 249, Maricopa, Calif., Max Steinberg.	1	B4	D	Sept. 20	246.63	249.44	8.2	1.7	25.58	61	.5010157	.5010042	−18	−443	+4	−99	+22	−11	.5009590	.5009596	.5009593	979.601		
	2	B4	D	Sept. 21	246.02	249.10	8.3	1.9	25.81	62	.5010182	.5010056	−20	−453	+3	−99	+22	−11	.5009602	.5009597	.5009600	979.598		
	3	B4	D	do	246.66	249.15	8.4	1.8	25.85	63	.5010156	.5010054	−19	−455	+2	−88	+20	−11	.5009585	.5009591	.5009588	979.603	979.600 ±0.600	
	4	B4	D	Sept. 22	246.19	249.12	8.2	1.9	25.75	63	.5010175	.5010055	−19	−450	+2	−88	+20	−11	.5009609	.5009597	.5009603	979.597		
	5	B5	D	do	276.26	279.40	8.6	1.7	25.55	60	.5009066	.5008964	−19	−442	+5	−90	+14	−11	.5008509	.5008511	.5008510	979.601		
	6	B5	D	Sept. 23	275.91	279.15	8.4	1.8	25.46	63	.5009078	.5008972	−19	−438	+2	−90	+14	−11	.5008522	.5008520	.5008521	979.597		

Pendulum observations and reductions—Continued.

Station and observer.	Swing No.	Pendulum.	Position.	Date.	Coincidence interval. Chronometer No. 1818.	Coincidence interval. Chronometer No. 1842.	Total arc. Initial.	Total arc. Final.	Temperature.	Pressure.	Period uncorrected. Chronometer No. 1818.	Period uncorrected. Chronometer No. 1842.	Corrections (seventh decimal place). Arc.	Temperature.	Pressure.	Rate. Chronometer No. 1818.	Rate. Chronometer No. 1842.	Flexure.	Period corrected. Chronometer No. 1818.	Period corrected. Chronometer No. 1842.	Period corrected. Mean.	g.	Mean g.
				1916.	s.	s.	mm.	mm.	°C.	mm.	s.	s.							s.	s.	s.	Dynes.	Dynes.
No. 250, Ventura, Calif., Max Steinberg.	1	B5	D	Sept. 26	284.62	286.42	8.2	1.7	19.94	56	0.5008799	0.5008743	−18	−207	+8	−79	+6	−9	0.5008494	0.5008523	0.5008508	979.601	
	2	B5	D	Sept. 27	283.00	286.87	8.4	1.8	19.94	58	.5008850	.5008730	−19	−207	+6	−79	+6	−9	.5008542	.5008507	.5008524	979.595	
	3	B5	D	do	284.61	285.98	8.4	1.8	19.92	58	.5008800	.5008758	−19	−206	+6	−45	0	−9	.5008527	.5008530	.5008528	979.594	979.596 ±0.001
	4	B5	D	Sept. 28	284.25	285.84	8.3	1.9	19.90	59	.5008810	.5008762	−20	−205	+5	−45	0	−9	.5008536	.5008533	.5008534	979.592	
	5	B6	D	do	290.86	291.77	8.3	1.7	19.88	61	.5008610	.5008583	−18	−204	+3	−63	−27	−9	.5008319	.5008328	.5008324	979.599	
	6	B6	D	Sept. 29	290.12	291.60	8.3	1.7	19.88	64	.5008632	.5008588	−18	−204	0	−63	−27	−9	.5008338	.5008330	.5008334	979.595	
No. 251, Concepcion, Calif., Max Steinberg.	1	B6	D	Oct. 2	304.60	305.68	8.4	1.7	16.78	58	.5008221	.5008192	−18	−75	+5	−24	+8	−11	.5008098	.5008101	.5008100	979.686	
	2	B6	D	Oct. 3	304.14	305.60	8.2	1.8	16.39	58	.5008233	.5008194	−19	−58	+5	−24	+8	−11	.5008126	.5008119	.5008122	979.678	
	3	B6	D	do	306.32	307.61	8.3	1.7	15.98	58	.5008175	.5008141	−18	−41	+5	−32	−1	−11	.5008078	.5008075	.5008076	979.696	979.685 ±0.002
	4	B6	D	Oct. 4	305.34	306.50	8.2	2.0	15.90	58	.5008201	.5008170	−20	−38	+5	−32	−1	−11	.5008105	.5008105	.5008105	979.685	
	5	B4	D	do	265.04	264.42	8.0	1.6	15.92	62	.5009450	.5009472	−17	−39	+1	−16	−18	−11	.5009368	.5009388	.5009378	979.685	
	6	B4	D	Oct. 5	264.05	264.44	8.0	1.7	15.92	63	.5009486	.5009472	−17	−39	0	−16	−18	−11	.5009403	.5009387	.5009395	979.679	
No. 252, Avila, Calif., Max Steinberg.	1	B4	D	Oct. 9	271.38	272.05	8.2	1.6	15.32	61	.5009229	.5009207	−18	−13	+2	−19	+12	−16	.5009165	.5009174	.5009170	979.766	(Reject.)
	2	B4	D	Oct. 10	270.72	271.82	8.3	1.5	15.38	61	.5009252	.5009214	−17	−16	+2	−19	+12	−16	.5009186	.5009179	.5009182	979.762	(Reject.)
	3	B4	D	do	269.98	270.98	8.2	1.6	15.82	62	.5009277	.5009243	−18	−34	+1	−25	+19	−16	.5009185	.5009195	.5009190	979.759	
	4	B4	D	Oct. 11	269.04	270.53	8.2	1.6	16.07	63	.5009310	.5009258	−18	−45	0	−25	+19	−16	.5009206	.5009198	.5009202	979.754	
	5	B5	D	do	303.97	305.41	8.5	1.8	16.36	63	.5008238	.5008199	−20	−57	0	−22	+22	−16	.5008123	.5008128	.5008126	979.751	
	6	B5	D	Oct. 12	303.96	305.84	8.5	1.6	16.21	67	.5008238	.5008188	−19	−51	−3	−22	+22	−16	.5008127	.5008121	.5008124	979.752	979.752 ±0.001
	7	B6	D	do	309.90	311.59	8.1	2.4	16.73	60	.5008080	.5008036	−21	−72	+4	−46	−1	−16	.5007929	.5007930	.5007930	979.753	
	8	B6	D	Oct. 13	309.85	311.30	8.6	1.8	16.71	63	.5008082	.5008044	−20	−72	+1	−46	−1	−16	.5007929	.5007936	.5007932	979.752	
	9	B4	D	do	268.38	269.13	8.2	2.0	16.66	55	.5009333	.5009307	−20	−70	+8	−24	+5	−16	.5009211	.5009214	.5009212	979.750	
	10	B4	D	Oct. 14	268.32	269.21	8.2	1.8	16.60	56	.5009334	.5009304	−19	−67	+7	−24	+5	−16	.5009215	.5009214	.5009214	979.749	
No. 253, San Lucas, Calif., Max Steinberg.	1	B5	D	Oct. 17	311.49	312.14	8.3	1.9	14.27	59	.5008039	.5008022	−19	+31	+4	−21	+9	−10	.5008024	.5008037	.5008030	979.789	
	2	B5	D	Oct. 18	310.46	311.82	8.5	1.8	14.40	59	.5008065	.5008030	−20	+25	+4	−21	+9	−10	.5008043	.5008038	.5008040	979.785	
	3	B5	D	do	311.52	312.48	8.3	1.8	14.23	60	.5008038	.5008013	−19	+32	+3	−18	+16	−10	.5008026	.5008035	.5008030	979.789	979.787 ±0.000
	4	B5	D	Oct. 19	310.82	312.42	8.5	1.8	14.18	60	.5008056	.5008015	−20	+34	+3	−18	+16	−10	.5008045	.5008038	.5008042	979.784	
	5	B6	D	do	319.60	320.50	8.2	1.9	13.92	57	.5007834	.5007812	−19	+45	+6	−34	+12	−10	.5007822	.5007846	.5007834	979.791	
	6	B6	D	Oct. 20	317.66	320.56	8.5	1.8	13.96	57	.5007882	.5007811	−20	+44	+6	−34	+12	−10	.5007868	.5007843	.5007856	979.782	
No. 254, Monterey, Calif., Max Steinberg.	1	B6	D	Oct. 23	341.34	330.45	8.2	1.8	14.98	63	.5007335	.5007577	−19	+1	0	+256	+25	−7	.5007566	.5007577	.5007572	979.893	
	2	B6	D	Oct. 24	340.04	330.16	8.2	1.8	14.90	65	.5007363	.5007584	−19	+4	−2	+256	+25	−7	.5007595	.5007585	.5007590	979.886	
	3	B6	D	do	342.08	330.32	8.4	1.8	14.77	60	.5007319	.5007580	−19	+10	+3	+256	+13	−7	.5007562	.5007580	.5007571	979.893	
	4	B6	D	Oct. 25	340.61	330.38	8.2	1.9	14.74	60	.5007351	.5007578	−19	+11	+3	+256	+13	−7	.5007595	.5007579	.5007587	979.887	979.890 ±0.001
	5	B4	D	do	291.44	283.30	8.0	1.7	14.68	58	.5008593	.5008840	−17	+13	+5	+248	+27	−7	.5008835	.5008861	.5008848	979.892	
	6	B4	D	Oct. 26	289.82	283.38	8.0	1.8	14.67	59	.5008641	.5008838	−18	+14	+4	+248	+27	−7	.5008882	.5008858	.5008870	979.884	
	7	B4	D	do	291.59	283.36	8.2	1.8	14.66	59	.5008588	.5008838	−19	+14	+4	+246	+24	−7	.5008826	.5008854	.5008840	979.895	
	8	B4	D	Oct. 27	289.54	283.23	8.2	1.8	14.95	59	.5008649	.5008842	−19	+2	+4	+246	+24	−7	.5008875	.5008846	.5008860	979.888	
No. 255, Hollister, Calif., Max Steinberg.	1	B4	D	Oct. 31	285.24	277.88	8.4	1.8	16.16	61	.5008780	.5009013	−19	−49	+2	+256	+46	−6	.5008964	.5008987	.5008976	979.843	
	2	B4	D	Nov. 1	283.58	277.64	8.4	1.8	16.20	61	.5008832	.5009021	−19	−50	+2	+256	+46	−6	.5009015	.5008994	.5009004	979.832	
	3	B4	D	do	284.82	278.14	8.4	1.8	16.26	61	.5008793	.5009004	−19	−53	+2	+248	+47	−6	.5008965	.5008975	.5008970	979.845	979.837 ±0.001
	4	B4	D	Nov. 2	283.48	277.54	8.4	2.0	16.28	61	.5008835	.5009024	−20	−54	+2	+248	+47	−6	.5009005	.5008993	.5008999	979.834	
	5	B5	D	do	324.13	315.13	8.5	1.8	16.39	60	.5007725	.5007946	−20	−58	+3	+260	+53	−6	.5007904	.5007918	.5007911	979.835	
	6	B5	D	Nov. 3	323.13	315.30	8.6	1.9	16.37	61	.5007749	.5007942	−20	−57	+2	+260	+53	−6	.5007928	.5007914	.5007921	979.832	

32296 O—41——6

No. 256, Palo Alto, Calif., Max Steinberg.	1	B5	D	Nov. 6	336.96	327.14	8.4	1.7	16.57	59	.5007430	.5007654	−18	−66	+4	+255	+38	−10	.5007595	.5007602	.5007598	979.958	979.954 ±0.001
	2	B5	D	Nov. 7	336.45	327.00	8.2	1.8	16.34	59	.5007442	.5007657	−19	−56	+4	+255	+38	−10	.5007616	.5007614	.5007615	979.951	
	3	B5	D	...do...	338.70	328.31	8.2	1.7	15.97	59	.5007392	.5007627	−18	−41	+4	+264	+43	−10	.5007591	.5007605	.5007598	979.958	
	4	B5	D	Nov. 8	337.51	328.38	8.3	1.9	15.95	60	.5007418	.5007625	−19	−40	+3	+264	+43	−10	.5007616	.5007602	.5007609	979.953	
	5	B6	D	...do...	346.42	335.95	8.4	1.8	16.25	61	.5007227	.5007453	−19	−52	+2	+246	+47	−10	.5007394	.5007421	.5007408	979.957	
	6	B6	D	Nov. 9	343.75	335.73	8.2	1.9	16.43	61	.5007283	.5007457	−19	−60	+2	+246	+47	−10	.5007442	.5007417	.5007430	979.948	
	7	B6	D	...do...	345.32	335.80	8.3	1.8	16.53	61	.5007250	.5007456	−19	−64	+2	+245	+39	−10	.5007404	.5007404	.5007404	979.959	
	8	B6	D	Nov. 10	344.28	334.82	8.2	1.9	16.62	61	.5007272	.5007478	−19	−68	+2	+245	+39	−10	.5007422	.5007422	.5007422	979.952	
No. 257, San Gregorio, Calif., Max Steinberg.	1	B6	D	Nov. 14	363.44	349.89	7.1	1.6	9.83	60	.5006888	.5007155	−14	+217	+2	+348	+89	−9	.5007432	.5007440	.5007436	979.946	979.950 ±0.001
	2	B6	D	Nov. 15	362.26	349.49	8.4	1.8	10.36	61	.5006911	.5007163	−19	+195	+1	+348	+89	−9	.5007427	.5007420	.5007424	979.951	
	3	B6	D	...do...	363.03	348.63	8.6	1.8	10.47	62	.5006896	.5007181	−20	+190	+1	+383	+93	−9	.5007441	.5007436	.5007438	979.945	
	4	B6	D	Nov. 16	365.00	350.28	8.4	1.9	10.32	62	.5006859	.5007147	−19	+196	0	+383	+93	−9	.5007410	.5007408	.5007409	979.957	
	5	B4	D	...do...	307.88	297.16	8.1	1.6	9.89	60	.5008133	.5008427	−17	+214	+2	+379	+108	−9	.5008702	.5008725	.5008714	979.945	
	6	B4	D	Nov. 17	307.47	298.21	8.2	1.8	10.03	62	.5008144	.5008398	−19	+208	0	+379	+108	−9	.5008703	.5008686	.5008694	979.953	
No. 258, Point Reyes Station, Calif., Max Steinberg.	1	B4	D	Nov. 19	315.18	305.01	8.3	1.9	9.74	61	.5007945	.5008210	−19	+220	+1	+379	+117	−9	.5008517	.5008520	.5008518	980.022	980.024 ±0.000
	2	B4	D	Nov. 20	315.93	305.90	8.4	1.8	9.48	64	.5007925	.5008186	−19	+231	−2	+379	+117	−9	.5008505	.5008504	.5008504	980.027	
	3	B4	D	...do...	317.90	305.73	8.3	1.8	9.09	56	.5007876	.5008190	−19	+248	+6	+406	+102	−9	.5008508	.5008518	.5008513	980.024	
	4	B4	D	Nov. 21	317.73	306.44	8.3	2.0	9.06	57	.5007880	.5008172	−20	+249	+5	+406	+102	−9	.5008511	.5008499	.5008505	980.027	
	5	B5	D	...do...	368.78	352.96	8.4	1.7	8.96	59	.5006788	.5007093	−18	+253	+3	+393	+109	−9	.5007410	.5007431	.5007420	980.027	
	6	B5	D	Nov. 22	365.16	351.56	8.6	1.8	9.57	62	.5006856	.5007122	−20	+228	0	+393	+109	−9	.5007448	.5007430	.5007439	980.020	
No. 259, Duncans Mills, Calif., Max Steinberg.	1	B5	D	Nov. 25	374.10	358.15	8.1	1.8	7.53	59	.5006692	.5006990	−18	+313	+3	+375	+110	−11	.5007354	.5007387	.5007370	980.047	980.039 ±0.000
	2	B5	D	Nov. 26	367.02	354.89	8.2	1.8	8.73	61	.5006821	.5007054	−19	+263	+1	+375	+110	−11	.5007430	.5007398	.5007414	980.030	
	3	B5	D	...do...	364.76	351.56	8.2	1.8	10.16	64	.5006863	.5007122	−19	+203	−2	+371	+99	−11	.5007405	.5007392	.5007398	980.036	
	4	B5	D	Nov. 27	365.60	352.56	8.3	1.9	10.24	65	.5006847	.5007101	−19	+199	−3	+371	+99	−11	.5007384	.5007366	.5007375	980.045	
	5	B6	D	...do...	378.32	361.79	8.2	1.8	9.63	58	.5006617	.5006919	−19	+225	+4	+371	+99	−11	.5007187	.5007217	.5007202	980.038	
	6	B6	D	Nov. 28	377.10	362.34	8.2	1.8	9.80	61	.5006638	.5006909	−19	+218	+1	+371	+99	−11	.5007198	.5007197	.5007198	980.040	
	7	B6	D	...do...	379.64	364.16	8.2	1.8	9.39	61	.5006594	.5006875	−19	+235	+1	+437	+145	−11	.5007237	.5007226	.5007232	980.026	
	8	B6	D	Nov. 29	385.97	368.70	8.2	1.8	8.43	62	.5006486	.5006790	−19	+275	0	+437	+145	−11	.5007168	.5007180	.5007174	980.049	
				1917.																			
Washington, D. C., Coast and Geodetic Survey Office, Max Steinberg.	1	B4	D	Jan. 15	329.95	317.87	7.6	1.6	8.33	59	.5007588	.5007877	−16	+279	+3	+428	+159	−10	.5008272	.5008292	.5008282	....	
	2	B4	D	Jan. 16	328.67	318.39	8.0	1.8	8.05	60	.5007618	.5007864	−18	+291	+2	+428	+159	−10	.5008311	.5008288	.5008300	....	
	3	B5	D	...do...	385.57	369.28	7.8	1.8	7.89	59	.5006493	.5006779	−17	+298	+3	+432	+161	−10	.5007199	.5007214	.5007206	....	
	4	B5	D	Jan. 17	384.52	369.95	7.8	1.7	7.80	61	.5006510	.5006767	−17	+302	+1	+432	+161	−10	.5007218	.5007204	.5007211	....	
	5	B6	D	...do...	397.83	380.15	7.9	1.6	7.74	62	.5006292	.5006585	−17	+304	0	+432	+156	−10	.5007001	.5007018	.5007010	....	
	6	B6	D	Jan. 18	394.40	378.90	8.1	1.4	7.83	73	.5006347	.5006607	−15	+300	−11	+432	+156	−10	.5007043	.5007027	.5007035	....	
	7	B6	D	...do...	395.46	378.34	8.0	1.6	8.00	63	.5006330	.5006617	−17	+293	−1	+403	+133	−10	.5006998	.5007015	.5007006	....	
	8	B6	D	Jan. 19	392.10	377.17	8.1	1.6	8.37	58	.5006384	.5006637	−17	+278	+4	+403	+133	−10	.5007042	.5007025	.5007034	....	
	9	B6	D	Jan. 22	391.83	376.10	8.0	1.6	9.02	59	.5006388	.5006656	−17	+251	+3	+389	+144	−10	.5007004	.5007027	.5007016	....	
	10	B6	D	Jan. 23	388.73	375.83	7.8	1.7	9.38	58	.5006439	.5006661	−17	+235	+4	+389	+144	−10	.5007040	.5007017	.5007028	....	
Do.[1]	1	B4	D	Feb. 28	328.31	315.48	7.8	1.7	9.37	63	.5007627	.5007937	−17	+236	−1	+433	+143	−9	.5008269	.5008289	.5008279	....	
	2	B4	D	Mar. 1	330.82	319.41	8.0	1.7	7.46	63	.5007569	.5007840	−17	+316	−1	+433	+143	−9	.5008291	.5008272	.5008282	....	
	3	B4	D	...do...	333.66	320.16	8.0	1.8	6.75	63	.5007504	.5007821	−18	+346	−1	+455	+146	−9	.5008277	.5008285	.5008281	....	
	4	B4	D	Mar. 2	333.31	320.58	8.0	1.8	6.44	63	.5007512	.5007810	−18	+358	−2	+455	+146	−9	.5008296	.5008285	.5008290	....	
	5	B5	D	...do...	387.71	368.96	8.2	1.7	6.39	64	.5006457	.5006785	−18	+360	−3	+469	+153	−9	.5007256	.5007268	.5007262	....	
	6	B5	D	Mar. 3	387.34	370.03	8.0	1.7	6.05	66	.5006462	.5006765	−17	+374	−5	+469	+153	−9	.5007274	.5007261	.5007268	....	
	7	B5	D	...do...	390.14	371.26	8.1	1.9	5.78	60	.5006416	.5006743	−19	+406	+1	+474	+161	−9	.5007269	.5007283	.5007276	....	
	8	B5	D	Mar. 4	388.75	371.50	8.3	1.7	5.62	61	.5006439	.5006738	−18	+413	0	+474	+161	−9	.5007299	.5007285	.5007292	....	
	9	B6	D	...do...	402.08	382.74	8.0	1.8	5.76	60	.5006225	.5006540	−18	+384	+1	+467	+162	−9	.5007050	.5007060	.5007055	....	
	10	B6	D	Mar. 5	400.56	382.50	8.0	1.6	5.85	63	.5006249	.5006544	−16	+380	−2	+467	+162	−9	.5007069	.5007059	.5007064	....	
	11	B6	D	...do...	401.82	381.96	8.2	1.7	5.85	65	.5006230	.5006554	−18	+380	−4	+458	+152	−9	.5007037	.5007055	.5007046	....	
	12	B6	D	Mar. 6	398.68	381.10	8.2	1.6	6.00	67	.5006278	.5006569	−17	+374	−6	+458	+152	−9	.5007078	.5007063	.5007070	....	
	13	B6	D	Mar. 8	339.78	332.70	8.3	2.0	26.99	57	.5007368	.5007526	−20	−498	+8	+186	+53	−9	.5007035	.5007060	.5007048	....	
	14	B6	D	Mar. 9	338.52	333.51	8.3	1.9	26.67	57	.5007396	.5007508	−20	−484	+8	+186	+53	−9	.5007077	.5007056	.5007066	....	
	15	B6	D	...do...	340.79	333.69	8.2	1.9	26.74	58	.5007346	.5007503	−19	−488	+7	+192	+66	−9	.5007029	.5007060	.5007044	....	
	16	B6	D	Mar. 10	337.50	333.22	8.2	1.9	26.91	59	.5007418	.5007514	−19	−494	+6	+192	+66	−9	.5007094	.5007064	.5007079	....	
	17	B4	D	Mar. 12	284.92	281.87	8.0	2.0	32.81	58	.5008789	.5008885	−19	−746	+9	+247	+156	−9	.5008271	.5008276	.5008274	....	
	18	B4	D	Mar. 13	283.68	280.94	8.0	2.0	33.02	60	.5008829	.5008915	−19	−755	+7	+247	+156	−9	.5008300	.5008295	.5008298	....	
	19	B4	D	...do...	286.25	281.84	8.0	2.0	31.96	62	.5008749	.5008886	−19	−710	+4	+242	+119	−9	.5008257	.5008271	.5008264	....	
	20	B4	D	Mar. 14	285.93	282.40	7.8	1.8	31.05	66	.5008759	.5008868	−17	−672	+1	+242	+119	−9	.5008304	.5008290	.5008297	....	
	21	B5	D	...do...	326.49	319.69	8.2	1.8	30.27	66	.5007669	.5007832	−19	−638	+1	+246	+97	−9	.5007250	.5007264	.5007257	....	
	22	B5	D	Mar. 15	325.21	319.68	8.2	1.6	30.19	74	.5007699	.5007832	−17	−635	−7	+246	+97	−9	.5007277	.5007261	.5007269	....	
	23	B5	D	...do...	326.23	320.09	8.4	2.0	30.48	60	.5007675	.5007822	−20	−647	+6	+236	+115	−9	.5007241	.5007267	.5007254	....	
	24	B5	D	Mar. 16	323.57	319.51	8.3	1.8	30.86	66	.5007739	.5007837	−19	−663	+1	+236	+115	−9	.5007285	.5007262	.5007274	....	

[1] This series of 24 swings was made for the purpose of redetermining the temperature coefficients of the three B bronze pendulums. A similar series of observations was made for the three A bronze pendulums at the same time. The new coefficients thus determined have been used *in the reductions of all gravity stations occupied after this date.* (See p. 76 of Special Publication No. 69.) The standardization periods of the B pendulums, used in computing the work of the following season, were obtained from this same series of observations by taking the mean of the 8 swings with each pendulum. Due to the war the pendulums were not restandardized at the close of the field season, and therefore stations Nos. 260 to 268 depend upon this one standardization only.

Pendulum observations and reductions—Continued.

Station and observer.	Swing No.	Pendulum.	Position.	Date.	Coincidence interval. Chronometer No. 1818.	Coincidence interval. Chronometer No. 1842.	Total arc. Initial.	Total arc. Final.	Temperature.	Pressure.	Period uncorrected. Chronometer No. 1818.	Period uncorrected. Chronometer No. 1842.	Corrections (seventh decimal place). Arc.	Temperature.	Pressure.	Rate. Chronometer No. 1818.	Rate. Chronometer No. 1842.	Flexure.	Period corrected. Chronometer No. 1818.	Period corrected. Chronometer No. 1842.	Period corrected. Mean.	g.	Mean g.
				1917.	s.	s.	mm.	mm.	°C.	mm.	s.	s.							s.	s.	s.	Dynes.	Dynes.
No. 260, Clarksburg, W. Va., Max Steinberg.	1	B4	D	Apr. 18	295.53	287.72	7.9	1.9	18.62	50	0.5008474	0.5008704	−19	−152	+13	+226	+9	−14	0.5008528	0.5008541	0.5008534	980.014	
	2	B4	D	Apr. 19	293.37	286.42	7.8	1.6	18.94	76	.5008536	.5008743	−16	−165	−11	+226	+9	−14	.5008556	.5008546	.5008551	980.007	
	3	B5	D	do	334.37	325.17	7.9	2.0	19.20	48	.5007488	.5007700	−19	−176	+15	+220	+21	−14	.5007514	.5007527	.5007520	980.010	980.008
	4	B5	D	Apr. 20	333.36	325.14	8.1	1.8	19.13	54	.5007511	.5007701	−18	−173	+10	+220	+21	−14	.5007536	.5007527	.5007532	980.005	±0.001
	5	B5	D	do	334.33	324.69	8.0	1.9	19.13	54	.5007489	.5007711	−18	−173	+10	+220	+35	−14	.5007514	.5007551	.5007532	980.005	
	6	B5	D	Apr. 21	332.74	326.26	8.0	1.7	19.12	62	.5007525	.5007674	−17	−172	+3	+220	+35	−14	.5007545	.5007509	.5007527	980.007	
No. 261, Rowlesburg, W. Va., Max Steinberg.	1	B5	D	Apr. 24	338.85	328.89	7.9	1.9	16.26	57	.5007389	.5007613	−19	−52	+6	+244	+51	−12	.5007556	.5007587	.5007572	979.990	
	2	B5	D	Apr. 25	339.03	331.76	8.0	1.9	15.74	58	.5007385	.5007547	−19	−31	+5	+244	+51	−12	.5007572	.5007541	.5007556	979.996	
	3	B6	D	do	350.21	339.57	7.9	1.8	15.38	64	.5007149	.5007373	−18	−16	−1	+248	+52	−12	.5007350	.5007378	.5007364	979.992	979.993
	4	B6	D	Apr. 26	349.07	341.14	8.0	1.7	15.48	65	.5007173	.5007339	−17	−20	−2	+248	+52	−12	.5007370	.5007340	.5007355	979.996	±0.001
	5	B6	D	do	349.87	340.12	8.0	1.8	15.46	61	.5007156	.5007361	−18	−19	+2	+261	+56	−12	.5007370	.5007370	.5007370	979.990	
	6	B6	D	Apr. 27	351.76	341.76	8.0	1.7	14.82	61	.5007117	.5007326	−17	+7	+2	+261	+56	−12	.5007358	.5007362	.5007360	979.994	
No. 262, Terra Alta, W. Va., Max Steinberg.	1	B6	D	Apr. 30	345.56	335.72	7.9	1.7	13.39	59	.5007245	.5007458	−17	+67	+4	+227	+38	−12	.5007514	.5007538	.5007526	979.929	
	2	B6	D	May 1	342.29	334.59	8.1	1.7	14.23	68	.5007314	.5007483	−17	+32	−5	+227	+38	−12	.5007539	.5007519	.5007529	979.928	
	3	B4	D	do	294.98	288.53	7.8	1.8	13.86	61	.5008490	.5008680	−17	+48	+2	+232	+49	−12	.5008743	.5008750	.5008746	979.930	
	4	B4	D	May 2	295.78	288.96	7.8	1.4	12.98	75	.5008466	.5008667	−15	+85	−12	+232	+49	−12	.5008744	.5008762	.5008753	979.928	979.931
	5	B4	D	do	297.02	290.36	7.9	2.0	12.83	48	.5008431	.5008625	−19	+91	+14	+232	+49	−12	.5008737	.5008748	.5008742	979.932	±0.001
	6	B4	D	May 3	296.31	291.13	7.8	1.7	12.64	58	.5008452	.5008602	−17	+99	+4	+232	+49	−12	.5008758	.5008725	.5008742	979.932	
	7	B4	D	do	296.67	289.87	7.8	1.9	12.70	60	.5008441	.5008640	−18	+96	+3	+216	+35	−12	.5008726	.5008744	.5008735	979.935	
	8	B4	D	May 4	295.77	290.01	7.9	1.6	12.93	62	.5008467	.5008636	−16	+87	+1	+216	+35	−12	.5008743	.5008731	.5008737	979.934	
No. 263, Corinth, W. Va., Max Steinberg.	1	B4	D	May 7	309.30	299.12	8.0	1.9	7.75	59	.5008096	.5008372	−18	+304	+3	+350	+80	−14	.5008721	.5008727	.5008724	979.939	
	2	B4	D	May 8	308.52	298.89	8.0	1.8	7.89	59	.5008116	.5008378	−18	+298	+3	+350	+80	−14	.5008735	.5008727	.5008731	979.936	
	3	B5	D	do	353.52	339.64	8.1	1.8	7.92	60	.5007082	.5007371	−18	+296	+2	+355	+78	−14	.5007703	.5007715	.5007709	979.935	979.936
	4	B5	D	May 9	352.48	339.83	8.2	1.6	7.91	62	.5007102	.5007367	−18	+296	0	+355	+78	−14	.5007721	.5007709	.5007715	979.933	±0.001
	5	B5	D	do	353.30	339.98	8.1	1.8	7.90	61	.5007086	.5007364	−18	+297	+1	+355	+84	−14	.5007707	.5007714	.5007710	979.935	
	6	B5	D	May 10	353.59	340.89	8.2	1.6	7.65	62	.5007080	.5007344	−18	+307	0	+355	+84	−14	.5007710	.5007703	.5007706	979.937	
No. 264, Kitzmiller, Md., Max Steinberg.	1	B5	D	May 14	354.57	341.38	8.2	1.7	9.54	60	.5007061	.5007334	−18	+228	+2	+338	+68	−10	.5007601	.5007604	.5007602	979.977	
	2	B5	D	May 15	353.76	340.92	8.0	1.7	9.60	59	.5007077	.5007344	−17	+226	+3	+338	+68	−10	.5007617	.5007614	.5007616	979.973	
	3	B6	D	do	363.97	349.67	8.3	1.9	9.85	61	.5006879	.5007160	−20	+214	+1	+321	+56	−10	.5007385	.5007401	.5007393	979.981	
	4	B6	D	May 16	361.87	349.63	8.0	1.7	9.90	59	.5006918	.5007160	−17	+212	+3	+321	+56	−10	.5007427	.5007404	.5007416	979.972	979.975
	5	B6	D	do	362.86	348.95	8.2	1.9	9.97	63	.5006899	.5007175	−20	+209	−1	+321	+56	−10	.5007398	.5007409	.5007404	979.977	±0.001
	6	B6	D	May 17	360.74	347.88	8.0	1.7	10.30	60	.5006940	.5007196	−17	+195	+2	+321	+56	−10	.5007431	.5007422	.5007426	979.968	
	7	B6	D	do	360.64	347.82	7.9	1.8	10.69	60	.5006942	.5007198	−18	+179	+2	+307	+51	−10	.5007402	.5007402	.5007402	979.978	
	8	B6	D	May 18	359.37	346.70	8.0	1.7	11.01	59	.5006967	.5007221	−17	+166	+3	+307	+51	−10	.5007416	.5007414	.5007415	979.973	
No. 265, Pennington, N. J., Max Steinberg.	1	B6	D	May 23	377.12	362.87	8.0	1.6	13.95	59	.5006638	.5006899	−17	+44	+4	+269	+13	−13	.5006925	.5006930	.5006928	980.163	
	2	B6	D	May 24	377.17	363.35	8.0	1.7	13.70	59	.5006637	.5006890	−17	+54	+4	+269	+13	−13	.5006934	.5006931	.5006932	980.162	
	3	B4	D	do	319.94	309.14	7.3	1.7	13.37	64	.5007826	.5008100	−15	+68	−1	+264	+21	−13	.5008129	.5008160	.5008144	980.166	980.163
	4	B4	D	May 25	318.24	309.78	8.1	1.5	13.11	70	.5007868	.5008083	−16	+79	−7	+264	+21	−13	.5008175	.5008147	.5008161	980.159	±0.001
	5	B4	D	do	320.92	310.58	7.8	1.8	12.80	60	.5007902	.5008062	−17	+92	+3	+263	+24	−13	.5008130	.5008151	.5008140	980.168	
	6	B4	D	May 26	319.31	310.64	8.2	1.7	12.64	63	.5007842	.5008061	−18	+99	0	+263	+24	−13	.5008173	.5008153	.5008163	980.158	
No. 266, Glen Ridge, N. J., Max Steinberg.	1	B4	D	May 29	320.11	311.36	8.1	1.8	15.56	56	.5007822	.5008042	−18	−23	+6	+228	+26	−11	.5008004	.5008022	.5008013	980.218	
	2	B4	D	May 30	319.52	312.10	8.1	1.8	15.68	57	.5007836	.5008023	−18	−28	+6	+228	+26	−11	.5008013	.5007998	.5008006	980.220	
	3	B5	D	do	368.32	357.38	8.2	1.9	15.70	61	.5006797	.5007005	−19	−29	+2	+225	+39	−11	.5006965	.5006987	.5006976	980.222	980.218
	4	B5	D	May 31	365.56	356.94	8.4	1.7	15.88	62	.5006848	.5007014	−18	−37	+1	+225	+39	−11	.5007008	.5006988	.5006998	980.214	±0.001
	5	B5	D	do	367.50	355.97	8.1	1.8	16.04	63	.5006812	.5007033	−18	−43	0	+230	+30	−11	.5006970	.5006991	.5006980	980.221	
	6	B5	D	June 1	365.22	355.71	8.3	1.8	16.30	63	.5006855	.5007038	−19	−54	0	+230	+30	−11	.5007001	.5006984	.5006992	980.216	

No. 267, Plainsboro, N. J., Max Steinberg.	1	B5	D	June 6.....	.....	348.37	8.2	1.7	17.55	58	.....	.5007187	−18	−107	+5	.....	+6	−14	.....	.5007059	.....	980.190	
	2	B5	D	June 7.....	.....	349.02	8.1	1.8	17.24	59	.....	.5007174	−18	−94	+5	.....	+6	−14	.....	.5007059	.....	980.190	
	3	B5	D	.....do.....	360.98	350.04	8.0	2.0	16.99	59	.5006935	.5007152	−19	−83	+5	+221	+13	−14	.5007045	.5007054	.5007050	980.193	980.190
	4	B5	D	June 8.....	359.75	349.64	8.0	1.9	16.91	59	.5006959	.5007160	−18	−80	+5	+221	+13	−14	.5007073	.5007066	.5007070	980.186	±0.001
	5	B6	D	.....do.....	372.20	359.74	8.0	1.9	16.90	61	.5006726	.5006959	−18	−79	+3	+224	+7	−14	.5006842	.5006858	.5006850	980.194	
	6	B6	D	June 9.....	370.60	359.77	8.1	1.8	16.83	62	.5006755	.5006959	−18	−76	+2	+224	+7	−14	.5006873	.5006860	.5006866	980.188	
No. 268, Hartford, Conn., Max Steinberg.	1	B6	D	June 13.....	387.38	375.42	8.0	1.8	18.57	56	.5006462	.5006669	−18	−148	+8	+193	−9	−12	.5006485	.5006490	.5006488	980.335	
	2	B6	D	June 14.....	386.75	375.14	8.0	1.9	18.60	57	.5006472	.5006673	−19	−149	+7	+193	−9	−12	.5006492	.5006491	.5006492	980.335	
	3	B4	D	.....do.....	325.64	317.00	8.1	1.9	18.78	61	.5007689	.5007899	−19	−158	+3	+187	−7	−12	.5007690	.5007706	.5007698	980.341	980.336
	4	B4	D	June 15.....	324.18	316.82	7.9	1.8	18.69	62	.5007724	.5007903	−18	−154	+2	+187	−7	−12	.5007729	.5007714	.5007722	980.331	±0.001
	5	B4	D	.....do.....	326.39	317.66	7.8	1.9	18.41	62	.5007671	.5007882	−18	−143	+2	+189	−1	−12	.5007689	.5007710	.5007700	980.340	
	6	B4	D	June 16.....	324.90	317.92	7.8	1.5	18.35	63	.5007706	.5007876	−16	−140	+1	+189	−1	−12	.5007728	.5007708	.5007718	980.333	
				1919.	1842	1836					1842	1836				1842	1836		1842	1836			
Washington, D. C., Coast and Geodetic Survey Office, E. W. Eickelberg.	1	A4	D	Sept. 2.....	290.70	288.21	7.8	1.6	22.10	59	.5008615	.5008690	−16	−293	+5	+102	+30	−10	.5008403	.5008406	.5008404	.....	
	2	A4	D	Sept. 3.....	290.69	288.24	7.8	1.5	22.03	62	.5008615	.5008689	−16	−290	+2	+102	+30	−10	.5008403	.5008405	.5008404	.....	
	3	A5	D	Sept. 4.....	363.33	358.46	7.9	1.6	21.65	56	.5006890	.5006984	−17	−278	+8	+127	+36	−10	.5006720	.5006723	.5006722	.....	
	4	A5	D	Sept. 5.....	363.00	358.33	7.8	1.7	21.70	59	.5006897	.5006986	−17	−280	+5	+127	+36	−10	.5006722	.5006720	.5006721	.....	
	5	A6	D	.....do.....	381.16	376.82	7.9	1.7	21.88	64	.5006568	.5006644	−17	−288	+10	+107	+31	−10	.5006370	.5006370	.5006370	.....	
	6	A6	D	Sept. 6.....	381.16	376.86	7.6	1.6	21.99	58	.5006568	.5006643	−16	−292	+6	+107	+31	−10	.5006363	.5006362	.5006362	.....	
					1836	1842					1836	1842				1836	1842		1836	1842			
No. 269, Hill City, S. Dak., E. W. Eickelberg.	1	A4	D	Oct. 10.....	323.42	327.48	7.7	1.7	3.97	52	.5007742	.5007646	−16	+456	+9	+136	+229	−9	.5008318	.5008315	.5008316	980.151	
	2	A4	D	Oct. 11.....	322.65	327.34	8.2	1.9	3.85	56	.5007760	.5007649	−19	+460	+5	+136	+229	−9	.5008333	.5008315	.5008324	980.148	
	3	A4	D	.....do.....	321.36	324.20	7.8	1.7	4.22	56	.5007792	.5007723	−17	+445	+5	+136	+229	−9	.5008352	.5008376	.5008364	980.133	
	4	A4	D	Oct. 12.....	320.80	323.74	7.9	1.5	4.45	61	.5007805	.5007734	−16	+436	0	+136	+229	−9	.5008352	.5008374	.5008363	980.133	
	5	A4	D	.....do.....	320.80	324.03	7.8	1.8	4.62	49	.5007805	.5007727	−17	+429	+12	+136	+229	−9	.5008356	.5008371	.5008364	980.133	
	6	A4	D	Oct. 13.....	318.76	323.18	7.7	1.7	5.06	52	.5007855	.5007748	−16	+411	+9	+136	+229	−9	.5008386	.5008372	.5008379	980.127	
	7	A4	D	.....do.....	318.08	322.46	7.9	1.8	5.53	56	.5007872	.5007765	−18	+391	+5	+136	+229	−9	.5008377	.5008363	.5008370	980.130	980.136
	8	A4	D	Oct. 14.....	316.76	321.31	7.9	1.7	5.96	60	.5007905	.5007793	−17	+373	+1	+136	+229	−9	.5008389	.5008370	.5008380	980.126	±0.001
	9	A4	D	.....do.....	316.14	320.64	7.8	1.9	6.44	50	.5007920	.5007809	−18	+354	+11	+106	+218	−9	.5008364	.5008365	.5008364	980.133	
	10	A4	D	Oct. 15.....	316.44	320.92	7.6	1.7	6.56	52	.5007913	.5007802	−16	+349	+9	+106	+218	−9	.5008352	.5008353	.5008352	980.137	
	11	A5	D	.....do.....	403.66	409.46	8.0	2.1	6.39	53	.5006201	.5006113	−20	+360	+8	+143	+225	−9	.5006683	.5006677	.5006680	980.130	
	12	A5	D	Oct. 16.....	407.54	412.81	7.7	1.7	5.83	56	.5006142	.5006064	−16	+383	+5	+143	+225	−9	.5006648	.5006652	.5006650	980.142	
	13	A6	D	.....do.....	436.06	439.74	8.1	1.9	4.93	50	.5005739	.5005692	−18	+421	+10	+154	+206	−9	.5006297	.5006302	.5006300	980.141	
	14	A6	D	Oct. 17.....	435.84	440.18	7.8	1.7	4.86	53	.5005742	.5005686	−17	+424	+8	+154	+206	−9	.5006302	.5006298	.5006300	980.141	
No. 270, Newcastle, Wyo., E. W. Eickelberg.	1	A4	D	Oct. 20.....	296.57	301.74	7.7	1.7	16.85	60	.5008444	.5008299	−16	−76	+4	+6	+145	−12	.5008350	.5008344	.5008347	980.139	
	2	A4	D	Oct. 21.....	296.50	301.39	7.7	1.7	17.02	62	.5008446	.5008308	−16	−83	+2	+6	+145	−12	.5008343	.5008344	.5008344	980.141	
	3	A5	D	.....do.....	368.68	376.88	7.6	1.7	17.49	54	.5006790	.5006642	−16	−104	+9	−4	+159	−12	.5006663	.5006678	.5006670	980.134	980.142
	4	A5	D	Oct. 22.....	368.32	376.18	7.7	1.7	17.83	58	.5006797	.5006654	−16	−118	+6	−4	+159	−12	.5006653	.5006673	.5006663	980.137	±0.002
	5	A6	D	.....do.....	389.20	401.43	7.7	1.6	18.03	50	.5006432	.5006235	−16	−127	+13	−4	+159	−12	.5006286	.5006252	.5006269	980.153	
	6	A6	D	Oct. 23.....	389.02	399.48	7.7	1.7	18.25	52	.5006435	.5006266	−16	−136	+11	−4	+159	−12	.5006278	.5006272	.5006275	980.151	
No. 271, Bridgeport, Nebr., E. W. Eickelberg.	1	A4	D	Oct. 28.....	296.59	302.00	8.4	2.0	7.74	61	.5008443	.5008292	−20	+300	+1	+156	+192	−8	.5008872	.5008757	.5008814	979.956	
	2	A4	D	Oct. 29.....	294.58	299.97	8.0	1.6	9.01	65	.5008501	.5008348	−17	+247	−3	+156	+192	−8	.5008876	.5008759	.5008818	979.955	
	3	A4	D	.....do.....	298.13	298.39	7.7	1.7	9.38	51	.5008400	.5008392	−16	+232	+11	+156	+192	−8	.5008775	.5008803	.5008789	979.967	
	4	A4	D	Oct. 30.....	297.04	297.66	7.9	1.8	9.76	52	.5008431	.5008413	−18	+216	+10	+156	+192	−8	.5008787	.5008805	.5008796	979.963	979.966
	5	A4	D	.....do.....	298.54	296.90	7.9	1.9	10.12	52	.5008388	.5008434	−19	+202	+10	+156	+192	−8	.5008729	.5008811	.5008770	979.974	±0.002
	6	A4	D	Oct. 31.....	298.54	296.80	7.7	1.7	10.33	53	.5008388	.5008437	−16	+193	+9	+156	+192	−8	.5008722	.5008807	.5008764	979.975	
	7	A5	D	.....do.....	372.73	371.52	7.7	1.8	10.24	57	.5006716	.5006738	−17	+199	+5	+205	+178	−8	.5007100	.5007095	.5007098	979.966	
	8	A5	D	Nov. 1.....	373.89	372.07	7.8	1.7	10.01	57	.5006695	.5006729	−17	+209	+5	+205	+178	−8	.5007089	.5007096	.5007092	979.969	
					1818	1836					1818	1836				1818	1836		1818	1836			
No. 272, Buford, Wyo., E. W. Eickelberg.	1	A5	D	Nov. 5.....	326.58	325.18	7.9	1.7	9.70	60	.5007667	.5007699	−17	+222	+2	+92	+68	−10	.5007956	.5007964	.5007960	979.629	
	2	A5	D	Nov. 6.....	326.44	325.32	7.6	1.6	9.78	63	.5007670	.5007697	−16	+218	−1	+92	+68	−10	.5007953	.5007956	.5007954	979.632	
	3	A6	D	.....do.....	345.20	342.79	8.0	2.0	9.51	54	.5007253	.5007304	−19	+229	+8	+141	+92	−10	.5007602	.5007604	.5007603	979.631	979.630
	4	A6	D	Nov. 7.....	345.06	342.85	8.0	1.7	9.41	58	.5007256	.5007302	−17	+234	+4	+141	+92	−10	.5007608	.5007605	.5007606	979.630	±0.000
	5	A6	D	.....do.....	346.98	342.58	7.8	1.7	9.42	62	.5007215	.5007308	−17	+233	0	+179	+97	−10	.5007600	.5007611	.5007606	979.630	
	6	A6	D	Nov. 8.....	346.63	342.86	8.1	1.7	9.40	64	.5007222	.5007302	−18	+234	−2	+179	+97	−10	.5007605	.5007603	.5007604	979.631	
No. 273, Boulder, Colo., E. W. Eickelberg.	1	A6	D	Nov. 12.....	328.36	327.56	7.7	1.7	17.37	66	.5007625	.5007644	−16	−99	−2	+72	+55	−15	.5007565	.5007567	.5007566	979.645	Reject.
	2	A6	D	Nov. 13.....	328.00	327.30	7.8	1.7	17.60	58	.5007634	.5007650	−17	−109	+6	+72	+55	−15	.5007571	.5007570	.5007570	979.644	
	3	A4	D	.... do.....	257.90	258.07	8.2	2.0	17.87	52	.5009712	.5009706	−20	−119	+11	+90	+107	−15	.5009659	.5009670	.5009664	979.624	
	4	A4	D	Nov. 14.....	256.60	257.29	8.0	1.8	18.35	57	.5009762	.5009735	−18	−138	+6	+90	+107	−15	.5009687	.5009677	.5009682	979.617	979.621
	5	A4	D	.....do.....	255.42	257.46	8.0	1.8	18.53	61	.5009807	.5009729	−18	−146	+3	+28	+106	−15	.5009659	.5009659	.5009659	979.626	±0.002
	6	A4	D	Nov. 15.....	254.34	256.44	7.9	1.7	18.87	66	.5009848	.5009768	−17	−160	−1	+28	+106	−15	.5009683	.5009681	.5009682	979.617	

Pendulum observations and reductions—Continued.

Station and observer.	Swing No.	Pendulum.	Position.	Date.	Coincidence interval. Chronometer No. 1818.	Coincidence interval. Chronometer No. 1836.	Total arc. Initial.	Total arc. Final.	Temperature.	Pressure.	Period uncorrected. Chronometer No. 1818.	Period uncorrected. Chronometer No. 1836.	Corrections (seventh decimal place). Arc.	Temperature.	Pressure.	Rate. Chronometer No. 1818.	Rate. Chronometer No. 1836.	Flexure.	Period corrected. Chronometer No. 1818.	Period corrected. Chronometer No. 1836.	Period corrected. Mean.	g.	Mean g.
				1919.	s.	s.	mm.	mm.	°C.	mm.	s.	s.							s.	s.	s.	Dynes.	Dynes.
No. 274, Lafayette, Colo., E. W. Eickelberg.	1	A4	D	Nov. 18.....	273.20	271.68	7.8	2.0	9.22	59	0.5009168	0.5009219	−18	+239	+3	+245	+201	−11	0.5009626	0.5009633	0.5009630	979.637	979.637 ±0.001
	2	A4	D	Nov. 19.....	272.42	271.32	8.0	1.7	9.34	61	.5009194	.5009231	−17	+234	−1	+245	+201	−11	.5009644	.5009637	.5009640	979.633	
	3	A5	D	.....do.....	335.63	333.65	7.8	1.8	9.22	56	.5007459	.5007504	−17	+242	+6	+247	+199	−11	.5007926	.5007923	.5007924	979.643	
	4	A5	D	Nov. 20.....	333.42	331.28	7.9	1.8	9.63	60	.5007510	.5007558	−18	+224	+2	+247	+199	−11	.5007954	.5007954	.5007954	979.632	
	5	A5	D	.....do.....	334.96	330.75	7.6	1.8	9.84	51	.5007475	.5007570	−17	+216	+11	+262	+172	−11	.5007936	.5007941	.5007938	979.638	
	6	A5	D	Nov. 21.....	335.58	331.78	8.1	1.9	9.50	53	.5007461	.5007546	−19	+230	+9	+262	+172	−11	.5007932	.5007927	.5007930	979.641	
No. 275, Brighton, Colo., E. W. Eickelberg.	1	A5	D	Nov. 24.....	332.45	.....	8.1	1.7	10.46	61	.5007531	.....	−17	+190	+1	+147	.....	−11	.5007841	.....	.....	979.676	979.679 ±0.001
	2	A5	D	Nov. 25.....	333.18	.....	8.0	1.8	10.46	56	.5007514	.....	−18	+190	+6	+147	.....	−11	.5007828	.....	.....	979.681	
	3	A5	D	.....do.....	335.58	329.58	7.7	1.6	10.27	62	.5007461	.5007597	−16	+198	0	+195	+60	−11	.5007827	.5007828	.5007828	979.681	
	4	A5	D	Nov. 26.....	335.42	329.62	7.9	1.7	9.85	67	.5007465	.5007596	−17	+215	−5	+195	+60	−11	.5007842	.5007838	.5007840	979.676	
	5	A6	D	.....do.....	357.75	350.94	7.4	1.7	8.43	58	.5006998	.5007134	−16	+275	+3	+251	+116	−11	.5007500	.5007501	.5007500	979.671	
	6	A6	D	Nov. 27.....	361.66	354.73	7.6	1.6	6.95	65	.5006922	.5007057	−16	+336	−3	+251	+116	−11	.5007479	.5007479	.5007479	979.679	
	7	A6	D	.....do.....	364.58	357.37	7.9	1.6	5.72	73	.5006866	.5007006	−17	+388	−11	+251	+116	−11	.5007466	.5007471	.5007468	979.684	
	8	A6	D	Nov. 28.....	367.23	360.27	7.5	1.6	4.93	58	.5006817	.5006949	−16	+421	+2	+251	+116	−11	.5007464	.5007461	.5007462	979.685	
No. 276, Idaho Springs, Colo., E. W. Eickelberg.	1	A6	D	Dec. 1.....	329.92	329.08	8.2	1.9	7.32	59	.5007589	.5007608	−19	+321	+3	+190	+164	−9	.5008075	.5008068	.5008072	979.447	979.458 ±0.001
	2	A6	D	Dec. 2.....	333.07	331.88	8.0	1.8	6.89	68	.5007517	.5007544	−18	+339	−6	+190	+164	−9	.5008013	.5008014	.5008014	979.470	
	3	A4	D	.....do.....	259.95	259.24	7.9	1.8	7.60	58	.5009636	.5009662	−18	+306	+4	+178	+155	−9	.5010097	.5010100	.5010098	979.454	
	4	A4	D	Dec. 3.....	259.51	259.10	8.0	1.7	7.92	68	.5009653	.5009668	−17	+292	−6	+178	+155	−9	.5010091	.5010083	.5010087	979.458	
	5	A4	D	.....do.....	259.26	256.86	8.1	1.8	8.41	55	.5009662	.5009752	−18	+272	+6	+171	+89	−9	.5010084	.5010092	.5010088	979.458	
	6	A4	D	Dec. 4.....	257.98	256.06	7.8	1.6	9.17	66	.5009710	.5009783	−16	+241	−4	+171	+89	−9	.5010093	.5010084	.5010088	979.458	
	7	A5	D	.....do.....	310.04	306.22	8.1	1.9	10.15	58	.5008077	.5008177	−19	+203	+4	+139	+43	−9	.5008395	.5008399	.5008397	979.458	
	8	A5	D	Dec. 5.....	309.17	305.80	8.0	1.6	10.61	71	.5008099	.5008189	−17	+184	−8	+139	+43	−9	.5008388	.5008382	.5008385	979.463	
				1920.																			
Washington, D. C., Coast and Geodetic Survey Office, E. W. Eickelberg.	1	A5	D	Jan. 27.....	408.54	411.82	8.0	1.8	5.85	59	.5006127	.5006078	−18	+382	+2	+249	+292	−9	.5006733	.5006727	.5006730	.....	
	2	A5	D	Jan. 28.....	407.59	410.28	8.1	1.7	6.38	56	.5006141	.5006101	−18	+360	+5	+249	+292	−9	.5006728	.5006731	.5006730	.....	
	3	A4	D	Mar. 16.....	303.27	298.29	7.9	1.6	14.96	58	.5008257	.5008395	−17	+2	+5	+182	+51	−14	.5008415	.5008422	.5008418	.....	
	4	A4	D	Mar. 17.....	301.70	297.32	8.2	1.8	15.30	58	.5008300	.5008422	−19	−12	+5	+182	+51	−14	.5008442	.5008433	.5008438	.....	
	5	A6	D	.....do.....	400.41	392.46	8.0	1.8	15.84	54	.5006252	.5006378	−18	−35	+9	+185	+63	−14	.5006379	.5006383	.5006381	.....	
	6	A6	D	Mar. 18.....	400.61	393.00	8.0	1.7	15.79	54	.5006248	.5006369	−17	−33	+8	+185	+63	−14	.5006377	.5006376	.5006376	.....	
				1921.	1824						1824					1824			1824				
Washington, D. C., Coast and Geodetic Survey Office, G. D. Cowie.[2]	1	B7	D	Aug. 4.....	280.42	280.52	8.5	2.3	23.88	56	.5008931	.5008928	−23	−25	+8	−11	−10	−11	.5008869	.5008867	.5008868	.....	
	2	B7	D	Aug. 5.....	280.58	280.56	8.9	2.0	23.70	57	.5008926	.5008927	−22	−24	+6	−11	−10	−11	.5008864	.5008866	.5008865	.....	
	3	B9	D	.....do.....	314.84	314.61	8.0	2.4	23.60	55	.5007953	.5007959	−21	−24	+7	+2	−7	−11	.5007906	.5007903	.5007904	.....	
	4	B9	D	Aug. 6.....	315.08	314.70	8.4	1.8	23.42	57	.5007947	.5007957	−20	−24	+6	+2	−7	−11	.5007900	.5007901	.5007900	.....	
	5	B8	D	Aug. 8.....	302.74	303.52	8.7	2.1	23.58	68	.5008272	.5008250	−22	−24	−3	−21	+6	−11	.5008191	.5008196	.5008194	.....	
	6	B8	D	Aug. 9.....	302.89	304.00	8.8	1.9	23.50	60	.5008267	.5008237	−21	−24	+4	−21	+6	−11	.5008194	.5008191	.5008192	.....	
No. 277, Fort Morgan, Ala., G. D. Cowie.	1	A6	D	Sept. 5.....	279.18	278.94	10.0	2.6	29.47	51	.5008971	.5008979	−31	−605	+14	+36	+24	−12	.5008373	.5008369	.5008371	979.330	979.332 ±0.001
	2	A6	D	Sept. 6.....	279.68	279.26	8.8	2.2	29.47	55	.5008955	.5008968	−23	−605	+10	+36	+24	−12	.5008361	.5008362	.5008362	979.334	
	3	A4	D	.....do.....	227.84	227.72	7.4	1.8	29.50	50	.5010997	.5011003	−16	−599	+15	+46	+40	−12	.5010431	.5010431	.5010431	979.327	
	4	A4	D	Sept. 7.....	227.94	227.79	7.8	1.8	29.52	56	.5010992	.5010998	−17	−600	+9	+46	+40	−12	.5010418	.5010418	.5010418	979.332	
	5	B9	D	.....do.....	252.36	252.04	7.4	2.0	29.52	62	.5009926	.5009938	−17	−41	+3	+45	+33	−12	.5009904	.5009904	.5009904	979.328	
	6	B9	D	Sept. 8.....	252.50	252.27	7.8	2.0	29.52	58	.5009921	.5009929	−18	−41	+7	+45	+33	−12	.5009902	.5009898	.5009900	979.329	
	7	B8	D	.....do.....	245.76	245.28	7.9	2.3	29.52	59	.5010194	.5010213	−21	−41	+6	+53	+33	−12	.5010179	.5010178	.5010178	979.334	
	8	B8	D	Sept. 9.....	245.60	245.12	8.2	2.0	29.52	64	.5010200	.5010220	−20	−41	+2	+53	+33	−12	.5010182	.5010182	.5010182	979.333	
	9	B7	D	.....do.....	230.74	230.34	8.2	1.6	29.52	59	.5010858	.5010877	−18	−41	+6	+50	+30	−12	.5010843	.5010842	.5010842	979.338	
	10	B7	D	Sept. 10.....	230.44	230.02	7.4	1.9	29.57	67	.5010872	.5010892	−17	−41	−1	+50	+30	−12	.5010851	.5010851	.5010851	979.334	

					2490	1824					2490	1824				2490	1824		2490	1824				
No. 278, Chandeleur Island, La., G. D. Cowie.	1	B7	D	Sept. 16.....	234.66	229.45	5.7	1.9	29.24	51	.5010677	.5010920	−12	−40	+12	+270	+47	−26	.5010881	.5010901	.5010891	979.319		
	2	B7	D	Sept. 17.....	233.77	229.48	8.1	2.8	28.83	53	.5010717	.5010918	−24	−39	+11	+270	+47	−26	.5010909	.5010887	.5010898	979.316		
	3	B8	D	.....do.....	250.44	244.34	7.9	1.7	28.51	48	.5010002	.5010252	−17	−38	+14	+295	+54	−26	.5010230	.5010239	.5010234	979.313	979.315	
	4	B8	D	Sept. 18.....	250.13	244.36	8.3	2.3	28.76	54	.5010015	.5010252	−22	−38	+10	+295	+54	−26	.5010234	.5010230	.5010232	979.313	±0.001	
	5	B9	D	.....do.....	256.73	250.88	7.6	1.3	28.19	54	.5009757	.5009985	−14	−37	+10	+270	+36	−26	.5009960	.5009953	.5009956	979.308		
	6	B9	D	Sept. 19.....	257.37	251.16	7.5	2.4	28.09	62	.5009732	.5009974	−20	−37	+4	+270	+36	−26	.5009923	.5009931	.5009927	979.319		
					1824	1841					1824	1841				1824	1841		1824	1841				
No. 279, Port Eads, La., G. D. Cowie.	1	B7	D	Sept. 25.....	226.08	224.47	8.0	1.3	29.76	69	.5011083	.5011162	−15	−41	−2	+40	−39	−23	.5011042	.5011042	.5011042	979.260		
	2	B7	D	Sept. 26.....	226.74	225.11	7.8	1.7	28.81	61	.5011050	.5011132	−17	−39	+4	+40	−39	−23	.5011015	.5011018	.5011016	979.270		
	3	B8	D	.....do.....	241.64	238.60	8.0	1.2	28.46	53	.5010367	.5010500	−14	−38	+11	+64	−56	−23	.5010367	.5010380	.5010374	979.258	979.268	
	4	B8	D	Sept. 27.....	242.46	240.12	8.6	2.7	29.46	58	.5010333	.5010433	−25	−40	+7	+64	−56	−23	.5010316	.5010296	.5010306	979.285	±0.001	
	5	B7	D	.....do.....	226.74	224.78	7.8	1.3	29.63	57	.5011050	.5011147	−15	−41	+7	+61	−18	−23	.5011039	.5011057	.5011048	979.257		
	6	B7	D	Sept. 28.....	227.49	225.96	7.9	1.1	29.91	61	.5011014	.5011088	−14	−42	+5	+61	−18	−23	.5011001	.5010996	.5010998	979.277		
No. 280, Burrwood, La., G. D. Cowie.	1	B9	D	Oct. 1.....	248.08	245.58	7.6	1.7	25.34	54	.5010098	.5010201	−16	−29	+10	−7	−98	−55	.5010001	.5010013	.5010007	979.288		
	2	B9	D	Oct. 2.....	248.26	246.16	8.1	2.9	27.27	61	.5010091	.5010177	−24	−34	+4	−7	−98	−55	.5009975	.5009970	.5009972	979.301		
	3	B8	D	.....do.....	241.26	239.66	8.0	1.5	27.91	55	.5010384	.5010454	−16	−36	+9	+6	−87	−55	.5010292	.5010269	.5010280	979.295		
	4	B8	D	Oct. 3.....	242.12	239.50	8.0	1.7	26.66	60	.5010347	.5010460	−17	−33	+5	+6	−87	−55	.5010253	.5010273	.5010263	979.301	979.298	
	5	B7	D	.....do.....	226.50	225.04	7.5	1.6	25.12	59	.5011062	.5011134	−16	−28	+5	−20	−118	−55	.5010948	.5010922	.5010935	979.302	±0.001	
	6	B7	D	Oct. 4.....	227.06	224.62	8.4	1.7	22.84	62	.5011035	.5011155	−19	−22	+2	−20	−118	−55	.5010921	.5010943	.5010932	979.303		
	7	B9	D	.....do.....	248.58	244.86	7.8	1.5	20.53	63	.5010078	.5010231	−16	−15	+1	+7	−147	−55	.5010000	.5009999	.5010000	979.290		
	8	B9	D	Oct. 5.....	249.02	245.27	8.0	2.0	21.55	75	.5010059	.5010214	−19	−18	−8	+7	−147	−55	.5009966	.5009967	.5009966	979.303		
No. 281, Fort St. Philip, La., G. D. Cowie.	1	B9	D	Oct. 8.....	251.86	247.62	8.0	1.6	22.11	54	.5009946	.5010116	−17	−20	+9	+35	−131	−7	.5009946	.5009950	.5009948	979.311		
	2	B9	D	Oct. 9.....	251.47	247.49	8.3	2.7	23.17	60	.5009961	.5010122	−24	−23	+4	+35	−131	−7	.5009946	.5009941	.5009944	979.312		
	3	A5	D	.....do.....	272.68	267.10	10.0	1.6	24.54	87	.5009185	.5009377	−24	−399	−20	+43	−150	−7	.5008778	.5008777	.5008778	979.311	979.314	
	4	A5	D	Oct. 10.....	273.14	267.46	8.0	1.6	25.22	65	.5009170	.5009365	−17	−427	0	+43	−150	−7	.5008762	.5008764	.5008763	979.317	±0.001	
	5	B8	D	.....do.....	245.08	240.16	8.4	1.9	25.57	54	.5010222	.5010432	−20	−30	+10	+15	−163	−7	.5010190	.5010222	.5010206	979.323		
	6	B8	D	Oct. 11.....	243.14	239.94	8.3	2.4	25.54	59	.5010303	.5010441	−22	−30	+5	+15	−163	−7	.5010264	.5010224	.5010244	979.309		
No. 282, Pointe a la Hache, La., G. D. Cowie.	1	B7	D	Oct. 16.....	230.24	225.89	7.7	1.9	22.64	59	.5010882	.5011092	−17	−21	+5	+42	−177	−9	.5010882	.5010873	.5010878	979.324		
	2	B7	D	Oct. 17.....	230.52	225.86	7.1	1.7	22.47	60	.5010869	.5011093	−15	−21	+4	+42	−177	−9	.5010870	.5010875	.5010872	979.326		
	3	B7	D	.....do.....	230.18	225.61	7.6	1.8	22.50	61	.5010885	.5011106	−17	−21	+3	+42	−177	−9	.5010883	.5010885	.5010884	979.322		
	4	B7	D	Oct. 18.....	229.98	225.46	8.1	2.3	22.60	62	.5010894	.5011113	−21	−21	+3	+42	−177	−9	.5010888	.5010888	.5010888	979.320	979.324	
	5	A6	D	.....do.....	289.22	283.70	8.1	1.7	22.47	52	.5008659	.5008828	−18	−312	+12	+22	−161	−9	.5008354	.5008340	.5008347	979.340	±0.002	
	6	A6	D	Oct. 19.....	288.68	281.88	6.9	1.4	22.34	56	.5008676	.5008885	−13	−307	+8	+22	−161	−9	.5008377	.5008403	.5008390	979.323		
	7	B8	D	.....do.....	245.00	239.88	7.7	1.7	22.57	80	.5010225	.5010444	−16	−21	−12	+48	−173	−9	.5010215	.5010213	.5010214	979.320		
	8	B8	D	Oct. 20.....	244.98	239.79	8.4	1.7	22.50	78	.5010226	.5010448	−19	−21	−10	+48	−173	−9	.5010215	.5010216	.5010216	979.319		
No. 283, Timbalier Island, La., G. D. Cowie.	1	B7	D	Oct. 27.....	225.88	223.08	8.0	2.4	25.94	45	.5011092	.5011232	−21	−31	+17	+20	−104	−29	.5011048	.5011064	.5011056	979.254		
	2	B7	D	Oct. 28.....	225.25	223.14	8.2	2.3	25.57	47	.5011124	.5011229	−22	−30	+15	+20	−104	−29	.5011078	.5011059	.5011068	979.249		
	3	B8	D	.....do.....	.....	237.92	8.5	0.6	24.47	52	.....	.5010530	−12	−27	+11	.....	−127	−29	.....	.5010346	.....	979.269	979.249	
	4	B8	D	Oct. 29.....	.....	236.45	8.5	1.7	22.57	55	.....	.5010596	−19	−21	+8	.....	−127	−29	.....	.5010408	.....	979.245	±0.002	
	5	B9	D	.....do.....	247.78	241.92	8.0	3.5	19.93	58	.5010110	.5010355	−28	−14	+5	+71	−169	−29	.5010115	.5010120	.5010118	979.244		
	6	B9	D	Oct. 30.....	247.96	241.82	8.1	2.4	19.81	62	.5010103	.5010360	−22	−13	+3	+71	−169	−29	.5010113	.5010130	.5010122	979.243		
No. 284, Morgan City, La., G. D. Cowie.	1	B7	D	Nov. 5.....	230.96	226.08	8.1	2.0	18.09	59	.5010848	.5011083	−20	−9	+4	+84	−162	−8	.5010899	.5010888	.5010894	979.318		
	2	B7	D	Nov. 6.....	230.88	225.92	7.6	2.0	19.01	68	.5010852	.5011090	−18	−11	−3	+84	−162	−8	.5010896	.5010888	.5010892	979.319		
	3	B7	D	.....do.....	230.85	225.50	7.6	1.4	19.53	74	.5010853	.5011111	−14	−13	−8	+84	−162	−8	.5010894	.5010906	.5010900	979.317		
	4	B7	D	Nov. 7.....	230.88	225.34	7.7	1.8	20.03	79	.5010852	.5011119	−17	−14	−12	+84	−162	−8	.5010885	.5010906	.5010896	979.315	979.318	
	5	B8	D	.....do.....	246.09	240.22	7.9	1.0	20.55	76	.5010179	.5010429	−13	−16	−10	+86	−166	−8	.5010218	.5010216	.5010217	979.319	±0.001	
	6	B8	D	Nov. 8.....	246.36	240.30	8.6	1.5	20.83	65	.5010169	.5010425	−18	−16	0	+86	−166	−8	.5010213	.5010217	.5010215	979.320		
	7	B9	D	.....do.....	253.45	247.14	8.5	1.9	20.93	60	.5009883	.5010136	−20	−17	+4	+101	−160	−8	.5009943	.5009935	.5009939	979.314		
	8	B9	D	Nov. 9.....	253.82	247.16	7.8	1.6	20.75	68	.5009869	.5010136	−16	−16	−3	+101	−160	−8	.5009927	.5009933	.5009930	979.318		
No. 285, Sabine, Tex., G. D. Cowie.	1	B7	D	Nov. 25.....	228.00	224.74	7.9	1.6	21.65	73	.5010989	.5011149	−17	−19	−6	+83	−77	−50	.5010980	.5010980	.5010980	979.284		
	2	B7	D	Nov. 26.....	228.18	224.94	7.4	1.1	20.18	74	.5010980	.5011139	−13	−15	−9	+83	−77	−50	.5010976	.5010975	.5010976	979.286		
	3	B8	D	.....do.....	243.08	239.42	8.2	1.3	20.23	75	.5010306	.5010464	−16	−15	−9	+85	−92	−50	.5010301	.5010282	.5010292	979.290	979.291	
	4	B8	D	Nov. 27.....	243.50	239.68	8.3	1.1	20.63	78	.5010288	.5010453	−15	−16	−11	+85	−92	−50	.5010281	.5010269	.5010275	979.296	±0.002	
	5	B8	D	.....do.....	242.94	238.98	7.5	1.7	18.42	77	.5010312	.5010483	−16	−10	−10	+85	−92	−50	.5010311	.5010305	.5010308	979.284		
	6	B8	D	Nov. 28.....	244.96	239.99	8.7	1.5	14.23	74	.5010227	.5010438	−19	+2	−9	+85	−92	−50	.5010236	.5010270	.5010253	979.305		

[1] Pendulums B7, B8 and B9 are of invar.

Pendulum observations and reductions—Continued.

Station and observer.	Swing No.	Pendulum.	Position.	Date.	Coincidence interval. Chronometer No. 1824.	Coincidence interval. Chronometer No. 1841.	Total arc. Initial.	Total arc. Final.	Temperature.	Pressure.	Period uncorrected. Chronometer No. 1824.	Period uncorrected. Chronometer No. 1841.	Corrections (seventh decimal place). Arc.	Temperature.	Pressure.	Rate. Chronometer No. 1824.	Rate. Chronometer No. 1841.	Flexure.	Period corrected. Chronometer No. 1824.	Period corrected. Chronometer No. 1841.	Period corrected. Mean.	g.	Mean g.
				1921.	s.	s.	mm.	mm.	°C.	mm.	s.	s.							s.	s.	s.	Dynes.	Dynes.
No. 286, Beaumont, Tex., G. D. Cowie.	1	B7	D	Nov. 14	231.36	226.98	8.5	1.1	23.32	66	0.5010829	0.5011039	−16	−23	−1	+79	−127	−8	0.5010860	0.5010864	0.5010862	979.330	
	2	B7	D	Nov. 15	231.43	226.92	8.4	1.3	23.47	71	.5010826	.5011041	−16	−24	−4	+79	−127	−8	.5010853	.5010862	.5010858	979.332	
	3	B7	D	do	230.92	226.84	8.4	1.4	23.72	74	.5010850	.5011045	−17	−24	−8	+79	−127	−8	.5010872	.5010861	.5010866	979.328	
	4	B7	D	Nov. 16	230.44	226.60	8.6	1.3	23.92	78	.5010872	.5011057	−17	−25	−10	+79	−127	−8	.5010891	.5010870	.5010880	979.323	
	5	B8	D	do	246.14	241.84	9.0	1.8	24.10	58	.5010177	.5010359	−21	−25	+5	+73	−95	−8	.5010201	.5010215	.5010208	979.323	
	6	B8	D	Nov. 17	246.07	241.88	8.2	2.5	24.20	64	.5010180	.5010357	−23	−26	+1	+73	−95	−8	.5010197	.5010206	.5010202	979.325	
	7	B8	D	do	245.78	241.85	8.8	2.0	24.24	66	.5010193	.5010358	−22	−26	−1	+73	−95	−8	.5010209	.5010206	.5010208	979.323	
	8	B8	D	Nov. 18	245.68	242.14	8.0	1.7	24.27	68	.5010197	.5010346	−17	−26	−2	+73	−95	−8	.5010217	.5010198	.5010208	979.323	979.325 ±0.001
	9	B9	D	do	252.54	248.80	8.1	2.0	24.37	67	.5009919	.5010068	−20	−26	−1	+56	−93	−8	.5009920	.5009920	.5009920	979.322	
	10	B9	D	Nov. 19	252.54	248.87	7.8	1.9	23.00	71	.5009919	.5010065	−18	−22	−5	+56	−93	−8	.5009922	.5009919	.5009920	979.322	
	11	A4	D	do	234.66	231.48	8.5	1.6	20.91	63	.5010677	.5010823	−19	−244	+1	+51	−133	−8	.5010458	.5010420	.5010439	979.324	
	12	A4	D	Nov. 20	235.28	231.78	8.4	1.3	20.28	68	.5010648	.5010809	−16	−218	−3	+51	−133	−8	.5010454	.5010431	.5010442	979.323	
	13	A4	D	do	236.45	231.98	7.8	1.1	19.83	70	.5010596	.5010800	−14	−199	−5	+51	−133	−8	.5010421	.5010441	.5010431	979.327	
	14	A4	D	Nov. 21	236.18	231.43	8.1	1.3	20.01	72	.5010608	.5010826	−16	−207	−7	+51	−133	−8	.5010421	.5010455	.5010438	979.325	
	15	A6	D	do	291.11	283.55	7.1	1.2	21.65	70	.5008603	.5008832	−12	−278	−5	+94	−140	−8	.5008394	.5008389	.5008392	979.322	
	16	A6	D	Nov. 22	289.84	282.31	7.9	1.4	22.91	75	.5008641	.5008872	−15	−331	−8	+94	−140	−8	.5008373	.5008370	.5008372	979.330	
				1922.																			
Washington, D. C., Coast and Geodetic Survey Office, G. D. Cowie.	1	A5	D	Jan. 10	365.20	352.50	8.7	1.7	20.08	61	.5006855	.5007102	−20	−212	+3	+105	−140	−10	.5006721	.5006723	.5006722	.....	
	2	A5	D	Jan. 11	363.64	351.29	9.0	1.4	20.28	65	.5006884	.5007127	−19	−221	−1	+105	−140	−10	.5006738	.5006736	.5006737	.....	
	3	A6	D	do	382.44	368.80	8.9	1.8	21.18	53	.5006545	.5006788	−21	−258	+11	+105	−134	−10	.5006372	.5006376	.5006374	.....	
	4	A6	D	Jan. 12	382.57	369.38	8.2	2.0	21.18	56	.5006543	.5006777	−20	−258	+8	+105	−134	−10	.5006368	.5006363	.5006366	.....	
	5	A4	D	do	291.52	283.57	8.8	2.2	21.08	49	.5008590	.5008832	−23	−251	+15	+105	−130	−10	.5008426	.5008433	.5008430	.....	
	6	A4	D	Jan. 13	292.10	284.45	8.8	1.7	20.80	56	.5008573	.5008804	−20	−240	+8	+105	−130	−10	.5008416	.5008412	.5008414	.....	
	7	B7	D	do	285.34	277.72	8.2	2.4	20.02	53	.5008768	.5009018	−22	−14	+10	+123	−115	−10	.5008855	.5008867	.5008861	.....	
	8	B7	D	Jan. 14	285.54	278.06	8.0	1.8	19.65	58	.5008771	.5009007	−18	−13	+5	+123	−115	−10	.5008858	.5008856	.5008857	.....	
	9	B8	D	Jan. 16	308.92	300.20	8.2	1.8	19.60	50	.5008106	.5008342	−19	−13	+12	+110	−114	−10	.5008186	.5008198	.5008192	.....	
	10	B8	D	Jan. 17	308.46	300.02	7.0	1.2	19.50	74	.5008118	.5008346	−12	−13	−8	+110	−114	−10	.5008185	.5008189	.5008187	.....	
	11	B9	D	Jan. 18	320.74	311.23	7.8	1.6	19.22	44	.5007807	.5008045	−16	−12	+17	+107	−127	−10	.5007893	.5007897	.5007895	.....	
	12	B9	D	Jan. 19	319.82	310.56	8.3	1.6	19.70	60	.5007829	.5008063	−18	−13	+4	+107	−127	−10	.5007899	.5007899	.5007899	.....	
Washington, D. C., Coast and Geodetic Survey Office, F. E. Joekel.	1	A5	D	May 22	351.90	344.68	6.9	1.7	24.35	42	.5007114	.5007263	−14	−391	+22	+17	−132	−20	.5006728	.5006728	.5006728	.....	
	2	A5	D	May 23	351.66	344.39	7.5	1.9	24.50	42	.5007119	.5007270	−17	−397	+21	+17	−132	−20	.5006723	.5006725	.5006724	.....	
	3	A6	D	do	369.88	361.39	6.7	1.3	24.68	45	.5006768	.5006927	−12	−405	+19	+23	−136	−20	.5006373	.5006373	.5006373	.....	
	4	A6	D	May 24	370.21	361.78	7.5	1.5	24.70	47	.5006762	.5006919	−15	−405	+17	+23	−136	−20	.5006362	.5006360	.5006361	.....	
	5	A4	D	do	284.51	278.36	8.3	1.9	24.70	42	.5008803	.5008997	−19	−401	+22	+46	−149	−20	.5008431	.5008430	.5008430	.....	
	6	A4	D	May 25	284.96	278.82	7.7	1.8	24.70	44	.5008788	.5008982	−17	−401	+20	+46	−149	−20	.5008416	.5008415	.5008416	.....	
	7	B9	D	do	316.43	309.76	7.0	2.0	24.65	43	.5007913	.5008084	−16	−27	+19	+35	−138	−20	.5007904	.5007902	.5007903	.....	
	8	B9	D	May 26	316.95	310.14	6.6	1.9	24.85	46	.5007900	.5008074	−14	−28	+16	+35	−138	−20	.5007889	.5007890	.5007890	.....	
	9	B8	D	do	305.82	299.42	7.8	2.2	25.08	40	.5008188	.5008363	−19	−28	+21	+48	−122	−20	.5008190	.5008195	.5008192	.....	
	10	B8	D	May 27	306.13	299.98	7.4	2.1	25.10	43	.5008180	.5008348	−18	−28	+19	+48	−122	−20	.5008181	.5008179	.5008180	.....	
	11	B7	D	do	282.76	277.52	7.2	1.9	24.85	46	.5008857	.5009024	−16	−28	+16	+52	−115	−20	.5008861	.5008861	.5008861	.....	
	12	B7	D	May 28	283.00	277.78	6.3	1.7	24.52	49	.5008850	.5009017	−12	−27	+13	+52	−115	−20	.5008856	.5008856	.5008856	.....	
					2490						2490					2490			2490				
No. 293, Wilkins Well, Kans., F. E. Joekel.	1	B9	D	July 18	309.26	294.13	7.8	1.6	23.90	48	.5008097	.5008514	−16	−25	+14	+303	−119	−36	.5008337	.5008332	.5008334	979.941	
	2	B9	D	July 19	311.34	295.38	8.7	1.9	23.38	56	.5008043	.5008478	−21	−24	+7	+303	−119	−36	.5008272	.5008285	.5008278	979.964	
	3	B9	D	do	310.41	294.74	7.1	1.9	24.58	64	.5008067	.5008497	−16	−27	+1	+382	−115	−36	.5008371	.5008304	.5008338	979.940	
	4	B9	D	July 20	314.22	293.76	8.9	1.3	24.68	76	.5007969	.5008525	−18	−27	−8	+382	−115	−36	.5008262	.5008321	.5008292	979.958	979.951 ±0.001
	5	B9	D	do	315.50	295.92	8.1	2.1	25.57	58	.5007936	.5008462	−20	−30	+6	+464	−80	−36	.5008320	.5008302	.5008311	979.951	
	6	B8	D	July 21	299.68	284.77	6.8	2.8	26.52	59	.5008356	.5008795	−19	−32	+6	+297	−107	−36	.5008572	.5008607	.5008590	979.955	
	7	B8	D	do	297.90	285.09	6.4	2.4	26.02	62	.5008406	.5008784	−16	−31	+4	+297	−107	−36	.5008624	.5008598	.5008611	979.946	

No. 297, Zeandale (Bard Well), Kans., F. E. Joekel.	1	A6	D	July 29.....	357.45	335.30	7.7	2.1	27.85	58	.5007004	.5007467	−19	−537	+8	+333	−130	−57	.5006732	.5006732	.5006732	979.968		
	2	A6	D	July 30.....	354.14	335.61	7.0	2.1	27.61	58	.5007069	.5007460	−16	−528	+7	+253	−129	−57	.5006728	.5006737				
	3	A6	D	.....do.....	354.62	336.81	6.3	2.3	26.69	58	.5007060	.5007434	−15	−489	+7	+253	−129	−57	.5006759	.5006751	.5006744	979.963		
	4	A4	D	.....do.....	276.60	264.06	6.9	1.8	26.57	63	.5009055	.5009486	−15	−478	+3	+296	−135	−57	.5008804	.5008804	.5008804	979.959		
	5	A4	D	July 31.....	274.93	264.08	7.8	2.4	26.17	64	.5009110	.5009485	−20	−461	+1	+220	−138	−57	.5008793	.5008810				
	6	A4	D	.....do.....	275.69	265.73	6.2	2.2	25.03	65	.5009084	.5009426	−14	−414	0	+220	−138	−57	.5008819	.5008803	.5008806	979.958	979.959 ±0.002	
	[3] 8	B7	D	Aug. 2.....	275.24	263.96	6.8	1.8	27.41	64	.5009100	.5009489	−14	−35	+1	+252	−128	−57	.5009247	.5009256				
	9	B7	D	.....do.....	273.66	263.20	8.0	2.2	27.56	66	.5009152	.5009517	−20	−35	0	+252	−128	−57	.5009292	.5009277	.5009268	979.953		
	10	B8	D	.....do.....	299.32	284.16	7.5	2.6	27.21	61	.5008366	.5008813	−21	−34	+4	+313	−126	−57	.5008571	.5008579	.5008575	979.960		
	11	B8	D	Aug. 3.....	296.41	284.28	7.0	2.2	27.24	65	.5008449	.5008810	−17	−34	+1	+235	−119	−57	.5008577	.5008584				
	12	B8	D	.....do.....	294.62	283.00	7.7	2.2	26.86	65	.5008500	.5008850	−19	−33	+1	+235	−119	−57	.5008627	.5008623	.5008603	979.949		
No. 298, Doyle Well, Kans., F. E. Joekel.	1	B9	D	Aug. 11.....	316.53	302.75	6.4	1.6	26.18	58	.5007910	.5008272	−12	−31	+7	+375	+20	−32	.5008217	.5008224	.5008220	979.986		
	2	B9	D	Aug. 12.....	310.63	300.14	6.6	2.2	26.96	58	.5008061	.5008343	−16	−33	+7	+221	−42	−32	.5008208	.5008227				
	3	B9	D	.....do.....	309.34	300.54	6.2	2.2	25.72	58	.5008095	.5008332	−14	−30	+6	+221	−42	−32	.5008246	.5008220	.5008226	979.984		
	4	B7	D	Aug. 14.....	278.09	271.84	8.4	2.1	26.67	61	.5009006	.5009214	−22	−33	+4	+262	+55	−32	.5009185	.5009186	.5009186	979.984		
	5	B7	D	Aug. 15.....	276.48	270.36	7.3	2.5	26.42	63	.5009059	.5009264	−19	−32	+2	+207	+6	−32	.5009185	.5009189				
	6	B7	D	.....do.....	276.57	270.39	7.7	2.5	24.97	63	.5009056	.5009263	−21	−28	+1	+207	+6	−32	.5009183	.5009189	.5009186	979.984	979.987 ±0.001	
	7	A4	D	.....do.....	280.35	273.48	7.6	1.0	26.92	61	.5008934	.5009159	−12	−492	+4	+265	+72	−32	.5008667	.5008699				
	8	A4	D	Aug. 16.....	278.93	274.06	8.0	0.6	25.99	63	.5008979	.5009139	−11	−454	+3	+265	+72	−32	.5008750	.5008717	.5008708	979.996		
	9	A5	D	.....do.....	348.63	330.42	8.4	1.8	26.94	59	.5007181	.5007578	−20	−499	+6	+392	+16	−32	.5007028	.5007049	.5007038	979.990		
	10	A5	D	Aug. 17.....	341.22	327.89	8.0	2.4	27.36	60	.5007338	.5007636	−21	−517	+5	+230	−25	−32	.5007003	.5007046	.5007047	979.986		
	11	A5	D	.....do.....	340.40	331.13	7.4	2.2	25.65	61	.5007355	.5007561	−18	−445	+4	+230	−25	−32	.5007004	.5007045				
No. 299, Seneca Well, Kans., F. E. Joekel.	1	B9	D	Aug. 26.....	308.57	305.88	6.6	2.0	24.32	56	.5008115	.5008187	−15	−26	+8	+112	+50	−56	.5008138	.5008148	.5008144	980.016		
	2	B9	D	.....do.....	308.02	305.96	7.6	2.4	21.98	62	.5008130	.5008184	−20	−20	+2	+112	+50	−56	.5008148	.5008140				
	3	B9	D	.....do.....	309.40	305.38	7.8	1.8	22.35	68	.5008093	.5008200	−17	−21	−2	+166	+51	−56	.5008163	.5008155	.5008159	980.010		
	4	B8	D	Aug. 27.....	296.42	295.50	8.6	2.8	21.20	62	.5008448	.5008475	−27	−17	+2	+96	+63	−56	.5008446	.5008440	.5008427	980.018		
	5	B8	D	.....do.....	298.20	296.80	7.2	2.8	18.65	63	.5008398	.5008437	−21	−10	+1	+96	+63	−56	.5008408	.5008414				
	6	B8	D	.....do.....	303.09	296.96	8.2	2.0	22.31	65	.5008262	.5008433	−20	−20	0	+259	+93	−56	.5008425	.5008430	.5008428	980.018		
	7	B7	D	Aug. 28.....	277.12	274.18	7.8	3.0	24.08	62	.5009037	.5009135	−24	−25	+3	+166	+78	−56	.5009101	.5009111	.5009105	980.016	980.019 ±0.001	
	8	B7	D	.....do.....	277.12	274.71	7.3	2.2	23.12	64	.5009037	.5009118	−18	−23	+1	+166	+78	−56	.5009107	.5009100				
	9	B7	D	.....do.....	282.72	276.23	6.9	1.6	26.94	68	.5008858	.5009067	−14	−33	−1	+343	+138	−56	.5009097	.5009101	.5009099	980.019		
	10	A4	D	Aug. 29.....	279.68	273.96	8.1	1.3	28.82	66	.5008955	.5009142	−16	−571	0	+259	+116	−56	.5008571	.5008615	.5008634	980.025		
	11	A4	D	Aug. 30.....	276.99	274.10	7.7	1.3	27.68	75	.5009042	.5009138	−14	−524	−8	+259	+116	−56	.5008699	.5008652				
	12	A5	D	.....do.....	343.86	336.00	7.9	1.9	27.90	66	.5007281	.5007452	−18	−539	0	+283	+119	−56	.5006951	.5006958	.5006954	980.023		
	13	A5	D	Aug. 31.....	339.13	333.89	7.5	2.1	28.32	69	.5007382	.5007498	−18	−557	−3	+191	+91	−56	.5006939	.5006955	.5006942	980.027		
	14	A5	D	.....do.....	341.71	337.78	8.3	2.4	26.62	75	.5007327	.5007412	−22	−486	−8	+191	+91	−56	.5006946	.5006931				
No. 300, Wapanucka, Okla., F. E. Joekel.	1	B7	D	Sept. 11.....	253.66	247.16	6.9	1.9	19.07	57	.5009876	.5010136	−15	−11	+6	+244	−14	−32	.5010068	.5010070	.5010069	979.639		
	2	B7	D	Sept. 12.....	251.70	247.14	7.7	2.7	19.10	58	.5009952	.5010136	−22	−11	+5	+161	+2	−32	.5010053	.5010078	.5010065	979.641		
	3	B7	D	.....do.....	251.24	248.04	7.3	2.3	17.15	58	.5009970	.5010099	−18	−6	+4	+161	+2	−32	.5010079	.5010049			979.640 ±0.000	
	4	B8	D	.....do.....	272.92	265.63	7.9	1.8	19.05	62	.5009177	.5009429	−18	−11	+2	+269	+22	−32	.5009387	.5009392	.5009390	979.641		
	5	B8	D	Sept. 13.....	273.48	265.03	7.8	2.7	20.82	64	.5009159	.5009451	−22	−16	+1	+278	+12	−32	.5009368	.5009394	.5009391	979.641		
	6	B8	D	.....do.....	271.72	265.14	8.9	3.3	19.15	66	.5009217	.5009447	−31	−12	−1	+278	+12	−32	.5009419	.5009383				
No. 301, Troy, Okla., F. E. Joekel.	1	B9	D	Sept. 17.....	280.50	274.36	6.6	5.0	21.92	53	.5008929	.5009129	−30	−19	+9	+199	+23	−33	.5009055	.5009079	.5009067	979.655	(Weighted) 979.658 ±0.001	
	[4] 3	B9	D	Sept. 18.....	284.14	276.17	6.3	0.7	24.00	56	.5008814	.5009069	−8	−25	+7	+288	+37	−33	.5009043	.5009047	.5009045	979.663		
	4	B9	D	.....do.....	280.08	275.24	6.3	4.3	21.62	58	.5008942	.5009100	−25	−19	+6	+213	+46	−33	.5009084	.5009075	.5009080	979.650		
	5	B7	D	.....do.....	254.35	249.75	8.9	2.1	27.86	65	.5009848	.5010030	−23	−36	+1	+267	+89	−33	.5010024	.5010028	.5010026	979.656		
	6	B7	D	Sept. 19.....	256.40	249.38	8.9	1.7	24.00	49	.5009769	.5010045	−20	−25	+13	+315	+43	−33	.5010019	.5010023	.5010021	979.658		
No. 302, Idle Wilde, Okla, F. E. Joekel.	1	B9	D	Sept. 22.....	277.42	269.42	7.8	2.0	22.65	56	.5009028	.5009296	−18	−21	+7	+302	+30	−42	.5009256	.5009252	.5009254	979.582		
	2	B9	D	Sept. 23.....	274.32	269.18	9.0	3.6	22.25	59	.5009130	.5009305	−34	−20	+5	+195	+20	−42	.5009234	.5009254	.5009252	979.582		
	3	B9	D	.....do.....	273.52	269.51	8.2	3.6	21.12	59	.5009157	.5009294	−30	−17	+5	+195	+20	−42	.5009268	.5009250			979.583 ±0.001	
	4	B9	D	.....do.....	276.02	269.77	7.8	2.0	22.60	61	.5009073	.5009284	−18	−21	+3	+259	+50	−42	.5009254	.5009256	.5009255	979.581		
	5	B8	D	Sept. 25.....	268.41	261.86	8.8	3.3	23.40	51	.5009332	.5009566	−31	−24	+11	+263	+48	−42	.5009509	.5009528	.5009528	979.587		
	6	B8	D	.....do.....	267.62	262.20	7.5	3.1	21.55	53	.5009359	.5009553	−24	−18	+9	+263	+48	−42	.5009547	.5009526				

[3] Swing No. 7 was rejected.
[4] Swing No. 2 rejected. Due to special time signals swings Nos. 1 and 4 are only about two and one-half hours in duration.

Pendulum observations and reductions—Continued.

Station and observer.	Swing No.	Pendulum.	Position.	Date.	Coincidence interval. Chronometer No. 2490.	Coincidence interval. Chronometer No. 1841.	Total arc. Initial.	Total arc. Final.	Temperature.	Pressure.	Period uncorrected. Chronometer No. 2490.	Period uncorrected. Chronometer No. 1841.	Corrections (seventh decimal place). Arc.	Corrections. Temperature.	Corrections. Pressure.	Corrections. Rate. Chronometer No. 490.	Corrections. Rate. Chronometer No. 1841.	Corrections. Flexure.	Period corrected. Chronometer No. 2490.	Period corrected. Chronometer No. 1841.	Period corrected. Mean.	g.	Mean g.
				1922.	s.	s.	mm.	mm.	°C.	mm.	s.	s.							s.	s.	s.	Dynes.	Dynes.
No. 303, Lowery, Okla., F. E. Joekel.	1	B7	D	Sept. 29.....	252.24	253.48	6.4	1.6	29.46	62	0.5009930	0.5009882	−12	−40	+4	+292	+387	−48	0.5010126	0.5010173	0.5010190	979.594	979.592 ±0.001
	2	B7	D	Sept. 30.....	249.07	252.88	7.4	1.4	25.50	63	.5010057	.5009906	−14	−29	+2	+292	+387	−48	.5010260	.5010204			
	3	B7	D	.....do.....	253.42	253.60	8.4	2.2	26.00	65	.5009884	.5009878	−22	−31	+1	+392	+403	−48	.5010176	.5010181	.5010178	979.596	
	4	B8	D	Oct. 1.....	268.42	271.56	7.8	2.9	26.22	58	.5009331	.5009223	−23	−31	+7	+241	+367	−48	.5009477	.5009495			
	5	B8	D	.....do.....	266.88	270.91	7.8	1.9	23.92	60	.5009385	.5009246	−17	−25	+4	+241	+367	−48	.5009540	.5009527	.5009524	979.589	
	6	B8	D	.....do.....	266.04	270.06	8.2	3.3	22.50	62	.5009415	.5009274	−28	−21	+3	+241	+367	−48	.5009562	.5009547			
	7	B8	D	Oct. 2.....	265.74	270.10	7.8	2.8	21.50	62	.5009425	.5009273	−23	−18	+3	+183	+343	−48	.5009522	.5009530	.5009526	979.588	
	8	B8	D	.....do.....	265.54	270.18	8.4	2.9	20.28	62	.5009432	.5009271	−26	−15	+2	+183	+343	−48	.5009528	.5009527			
No. 304, Carter, Okla., F. E. Joekel.	1	B9	D	Oct. 8.....	275.80	280.31	7.4	1.9	15.68	65	.5009061	.5008935	−17	−2	−1	+191	+335	−40	.5009212	.5009210	.5009211	979.599	979.600 ±0.001
	2	B9	D	Oct. 9.....	273.77	279.99	7.9	3.4	15.25	68	.5009149	.5008944	−26	−1	−3	+142	+352	−40	.5009221	.5009226	.5009214	979.597	
	3	B9	D	.....do.....	274.30	280.98	7.9	3.4	12.65	68	.5009131	.5008914	−26	+7	−5	+142	+352	−40	.5009209	.5009202			
	4	B7	D	.....do.....	250.21	253.36	8.1	1.7	16.74	61	.5010012	.5009887	−18	−5	+2	+209	+343	−40	.5010160	.5010169	.5010164	979.602	
	5	B7	D	Oct. 10.....	247.64	253.54	7.7	2.1	17.05	64	.5010115	.5009880	−19	−6	0	+111	+363	−40	.5010161	.5010178	.5010167	979.601	
	6	B7	D	.....do.....	247.40	254.25	8.4	2.4	13.95	64	.5010126	.5009852	−23	+3	−1	+111	+363	−40	.5010176	.5010154			
No. 305, Busby, Okla., F. E. Joekel.	1	B9	D	Oct. 13.....	273.80	279.34	7.6	3.0	21.05	55	.5009148	.5008966	−23	−17	+8	+184	+380	−26	.5009274	.5009288	.5009287	979.569	979.569 ±0.001
	2	B9	D	.....do.....	273.17	279.46	8.0	3.0	18.98	56	.5009169	.5008962	−25	−11	+7	+184	+380	−26	.5009298	.5009287			
	3	B9	D	.....do.....	275.30	279.42	8.0	2.0	20.50	58	.5009098	.5008963	−19	−15	+5	+241	+383	−26	.5009284	.5009291	.5009288	979.568	
	[5]6	B8	D	Oct. 14.....	267.07	271.34	7.7	1.9	23.60	61	.5009378	.5009230	−17	−24	+3	+255	+402	−26	.5009569	.5009568	.5009568	979.571	
No. 306, Saline No. 1, Tex., F. E. Joekel.	1	B7	D	Oct. 28.....	245.42	247.12	7.7	1.7	19.66	54	.5010207	.5010137	−16	−13	+8	+253	+328	−38	.5010401	.5010406	.5010404	979.508	979.508 ±0.001
	2	B7	D	Oct. 29.....	241.70	247.57	6.7	1.7	18.02	56	.5010365	.5010118	−14	−8	+6	+81	+337	−38	.5010392	.5010401	.5010393	979.513	
	3	B7	D	.....do.....	241.82	248.34	6.7	2.3	14.38	55	.5010360	.5010087	−16	+2	+7	+81	+337	−38	.5010396	.5010379			
	4	B8	D	.....do.....	264.90	264.54	8.0	2.0	21.72	56	.5009455	.5009468	−19	−19	+7	+336	+342	−38	.5009722	.5009741	.5009732	979.507	
	5	B8	D	Oct. 30.....	260.42	264.56	7.2	2.8	20.30	58	.5009618	.5009468	−21	−15	+6	+155	+338	−38	.5009705	.5009738	.5009734	979.506	
	6	B8	D	.....do.....	259.12	265.10	7.3	2.4	16.80	58	.5009667	.5009448	−19	−5	+5	+155	+338	−38	.5009765	.5009729			
No. 307, Saline No. 2, Tex., F. E. Joekel.	1	B9	D	Nov. 3.....	265.46	272.99	8.0	1.4	20.03	43	.5009436	.5009174	−15	−14	+17	+96	+357	−50	.5009470	.5009469	.5009470	979.497	979.500 ±0.001
	2	B9	D	.....do.....	271.13	273.43	7.0	1.5	21.38	46	.5009233	.5009160	−13	−18	+15	+270	+358	−50	.5009442	.5009452			
	3	B9	D	Nov. 4.....	268.14	272.95	8.3	1.7	21.40	48	.5009341	.5009176	−18	−18	+14	+270	+358	−50	.5009539	.5009462	.5009462	979.500	
	4	B9	D	.....do.....	271.68	272.02	9.4	3.0	21.70	48	.5009219	.5009207	−31	−19	+13	+270	+358	−50	.5009402	.5009478			
	5	B7	D	Nov. 5.....	242.13	245.77	8.5	3.3	23.65	61	.5010346	.5010193	−29	−24	+3	+155	+312	−50	.5010401	.5010405	.5010424	979.500	
	6	B7	D	.....do.....	241.25	245.27	7.3	1.9	23.15	64	.5010384	.5010214	−16	−23	+1	+155	+312	−50	.5010451	.5010438			
	7	B7	D	.....do.....	243.93	245.33	7.6	1.9	21.95	64	.5010270	.5010211	−17	−19	+1	+228	+294	−50	.5010413	.5010420	.5010416	979.503	
No. 308, Saline No. 3, Tex., F. E. Joekel.	1	B8	D	Nov. 7.....	259.02	264.55	7.3	1.3	22.72	63	.5009670	.5009468	−13	−22	+2	+148	+360	−55	.5009730	.5009740	.5009735	979.506	979.505 ±0.001
	2	B8	D	Nov. 8.....	259.20	264.34	7.8	2.3	16.55	64	.5009664	.5009475	−20	−4	0	+170	+361	−55	.5009755	.5009757	.5009732	979.507	
	3	B8	D	.....do.....	260.58	266.14	7.1	2.1	13.95	64	.5009613	.5009411	−17	+3	−1	+170	+361	−55	.5009713	.5009702			
	4	B9	D	.....do.....	268.46	271.79	7.5	1.2	18.26	63	.5009330	.5009215	−13	−9	0	+192	+348	−55	.5009445	.5009486	.5009454	979.503	
	5	B9	D	Nov. 9.....	267.92	273.66	8.8	1.4	15.70	65	.5009348	.5009152	−18	−2	−1	+192	+348	−55	.5009464	.5009424			
No. 309, Taylor, Tex., F. E. Joekel.	1	B7	D	Nov. 22.....	232.24	236.86	9.0	3.8	13.45	53	.5010788	.5010577	−35	+4	+9	+128	+356	−12	.5010882	.5010899	.5010888	979.319	979.318 ±0.001
	2	B7	D	.....do.....	232.37	237.76	6.4	3.0	12.10	54	.5010782	.5010537	−19	+8	+8	+128	+356	−12	.5010895	.5010878			
	3	B7	D	.....do.....	232.92	237.23	8.2	2.3	13.15	55	.5010756	.5010560	−22	+5	+7	+152	+350	−12	.5010886	.5010888	.5010887	979.319	
	4	B8	D	Nov. 23.....	248.14	252.40	8.5	4.1	14.20	54	.5010095	.5009925	−34	+2	+8	+165	+346	−12	.5010224	.5010235			
	5	B8	D	.....do.....	248.13	253.14	7.8	3.6	13.55	54	.5010096	.5009895	−28	+4	+8	+165	+346	−12	.5010233	.5010213	.5010222	979.316	
	6	B8	D	.....do.....	248.82	253.32	7.0	2.0	14.90	55	.5010067	.5009888	−16	0	+7	+165	+346	−12	.5010211	.5010213			

No. 310, Georgetown, Tex., F. E. Joekel.	1	B9	D	Nov. 25.....	252.75	258.32	8.4	1.9	16.95	60	.5009911	.5009696	−20	−5	+3	+159	+316	−13	.5010035	.5009977	.5009984	979.296	979.298 ±0.001
	2	B9	D	Nov. 26.....	255.23	257.92	8.7	1.6	17.45	62	.5009815	.5009711	−19	−7	+1	+159	+316	−13	.5009936	.5009989			
	3	B7	D	.....do.....	231.07	234.85	8.5	2.0	17.65	61	.5010842	.5010668	−21	−7	+2	+163	+309	−13	.5010966	.5010938	.5010932	979.302	
	4	B7	D	Nov. 27.....	232.51	235.04	8.5	1.7	18.45	63	.5010776	.5010659	−19	−10	+1	+163	+309	−13	.5010898	.5010927			
	5	B8	D	.....do.....	246.47	250.78	9.1	1.8	19.45	64	.5010164	.5009989	−22	−12	0	+187	+330	−13	.5010304	.5010272	.5010266	979.298	
	6	B8	D	Nov. 28.....	248.32	251.03	8.9	1.8	19.60	66	.5010088	.5009979	−21	−13	−1	+187	+330	−13	.5010227	.5010261			
	7	A5	D	.....do.....	232.86	238.69	8.3	1.3	19.15	59	.5008854	.5008675	−16	−173	+5	+198	+328	−13	.5008855	.5008806	.5008813	979.295	
	8	A5	D	Nov. 29.....	285.10	287.93	7.0	1.2	19.40	63	.5008784	.5008698	−12	−184	+1	+198	+328	−13	.5008774	.5008818			
	9	A6	D	.....do.....	294.66	300.31	7.2	1.2	20.75	57	.5008499	.5008339	−12	−240	+7	+193	+330	−13	.5008434	.5008411	.5008446	979.297	
	10	A6	D	Nov. 30.....	293.04	296.98	7.4	1.5	21.20	60	.5008546	.5008432	−15	−259	+5	+193	+330	−13	.5008457	.5008480			
No. 311, Damon No. 1, Tex., F. E. Joekel.	1	B7	D	Dec. 16.....	228.66	232.36	7.0	2.5	16.20	50	.5010957	.5010782	−18	−3	+11	+167	+379	−56	.5011058	.5011095	.5011090	979.240	979.241 ±0.002
	2	B7	D	.....do.....	227.42	232.62	7.3	2.7	14.05	51	.5011017	.5010770	−20	+3	+10	+167	+379	−56	.5011121	.5011086			
	3	B7	D	.....do.....	227.30	232.29	7.1	2.7	17.05	56	.5011023	.5010786	−20	−6	+6	+124	+359	−56	.5011071	.5011069	.5011070	979.248	
	4	B8	D	Dec. 17.....	242.92	246.69	7.7	3.0	18.95	53	.5010313	.5010154	−24	−11	+9	+155	+344	−56	.5010386	.5010416	.5010415	979.240	
	5	B8	D	.....do.....	241.90	246.98	6.8	2.4	16.50	56	.5010356	.5010143	−17	−4	+7	+155	+344	−56	.5010441	.5010417			
	6	B8	D	.....do.....	242.30	246.94	6.8	1.8	17.10	58	.5010339	.5010144	−14	−6	+4	+161	+357	−56	.5010428	.5010429	.5010428	979.235	
No. 312, Damon No. 2, Tex., F. E. Joekel.	1	B9	D	Dec. 19.....	250.83	252.21	7.3	1.9	11.10	55	.5009987	.5009933	−16	+11	+6	+237	+287	−41	.5010184	.5010180	.5010182	979.219	979.222 ±0.001
	2	B9	D	Dec. 20.....	247.76	252.50	7.3	2.7	11.45	56	.5010111	.5009921	−20	+10	+6	+100	+295	−41	.5010166	.5010171	.5010171	979.223	
	3	B9	D	.....do.....	247.33	252.42	8.3	3.1	9.70	58	.5010129	.5009924	−27	+15	+3	+100	+295	−41	.5010179	.5010169			
	4	B7	D	.....do.....	229.50	229.86	7.1	1.8	13.00	57	.5010917	.5010900	−15	+6	+5	+253	+283	−41	.5011125	.5011138	.5011132	979.223	
	5	B7	D	Dec. 21.....	226.48	229.32	9.1	3.3	14.95	61	.5011063	.5010926	−32	0	+2	+126	+288	−41	.5011118	.5011143	.5011130	979.224	
	6	B7	D	.....do.....	226.32	230.24	7.1	2.9	11.65	62	.5011071	.5010882	−21	+9	0	+126	+288	−41	.5011144	.5011117			
No. 313, Damon No. 3, Tex., F. E. Joekel.	1	B9	D	Dec. 28.....	247.10	254.92	7.4	2.0	12.65	51	.5010138	.5009826	−17	+7	+10	+129	+471	−30	.5010237	.5010267	.5010254	979.191	979.193 ±0.001
	2	B9	D	.....do.....	246.44	255.96	6.6	2.0	9.05	51	.5010165	.5009786	−15	+17	+9	+129	+471	−30	.5010275	.5010238			
	3	B9	D	.....do.....	246.60	253.86	8.4	1.8	11.20	52	.5010159	.5009868	−20	+11	+9	+116	+413	−30	.5010245	.5010251	.5010248	979.193	
	4	B8	D	Dec. 29.....	240.24	247.56	9.0	2.9	11.60	54	.5010428	.5010119	−29	+10	+7	+144	+466	−30	.5010530	.5010543	.5010525	979.197	
	5	B8	D	.....do.....	240.72	248.62	9.0	2.5	8.40	55	.5010407	.5010076	−27	+18	+6	+144	+466	−30	.5010518	.5010509			
	6	B8	D	.....do.....	240.72	246.66	7.0	1.0	12.65	58	.5010407	.5010156	−11	+7	+4	+169	+417	−30	.5010546	.5010543	.5010544	979.190	
				1923.	211	220	[a]				211	220				211	220		211	220			
Washington, D. C., Coast and Geodetic Survey Office, G. D. Cowie.	1	B7	D	Jan. 29.....	294.90	290.13	7.6	2.4	19.67	35	.5008492	.5008632	−20	−13	+24	+397	+234	−15	.5008865	.5008842	.5008854	.....	
	2	B7	D	Jan. 30.....	295.25	288.66	7.0	2.4	19.70	37	.5008482	.5008676	−18	−13	+22	+397	+234	−15	.5008855	.5008886	.5008870	.....	
	3	B8	D	.....do.....	319.20	316.16	8.7	2.5	19.70	44	.5007844	.5007920	−25	−13	+17	+382	+282	−15	.5008190	.5008166	.5008178	.....	
	4	B8	D	Jan. 31.....	319.38	314.34	8.4	2.4	19.70	46	.5007840	.5007966	−23	−13	+15	+382	+282	−15	.5008186	.5008212	.5008199	.....	
	5	B9	D	.....do.....	332.74	327.58	8.2	2.5	19.67	43	.5007525	.5007643	−23	−13	+17	+415	+274	−15	.5007906	.5007883	.5007894	.....	
	6	B9	D	Feb. 1.....	333.34	326.02	8.5	2.4	19.60	45	.5007511	.5007680	−23	−13	+16	+415	+274	−15	.5007891	.5007919	.5007905	.....	
	7	A4	D	.....do.....	303.38	299.84	9.0	2.1	19.75	40	.5008254	.5008352	−24	−196	+23	+371	+259	−15	.5008413	.5008399	.5008406	.....	
	8	A4	D	Feb. 2.....	303.64	299.06	9.5	2.3	19.85	44	.5008247	.5008373	−26	−200	+19	+371	+259	−15	.5008396	.5008410	.5008403	.....	
	9	A5	D	.....do.....	381.20	374.93	9.2	1.8	20.02	44	.5006567	.5006677	−23	−210	+19	+381	+240	−15	.5006719	.5006688	.5006704	.....	
	10	A5	D	Feb. 3.....	379.49	369.41	8.9	2.2	20.40	46	.5006596	.5006777	−24	−226	+17	+381	+240	−15	.5006729	.5006769	.5006749	.....	
	11	A6	D	.....do.....	401.13	394.86	7.8	1.5	20.81	39	.5006240	.5006339	−16	−243	+24	+374	+259	−15	.5006364	.5006348	.5006356	.....	
	12	A6	D	Feb. 4.....	401.02	392.64	7.7	2.0	20.80	41	.5006242	.5006375	−18	−242	+22	+374	+259	−15	.5006363	.5006381	.5006372	.....	

[a] Swings Nos. 4 and 5 were rejected.

Summary of standardization periods of pendulums at base station, Washington, D. C.

Date.	Mean periods.									Observer.
	Bronze pendulums.						Invar pendulums.			
	A4	A5	A6	B4	B5	B6	B7	B8	B9	
	s.	s.	s.	s.	s.	s.	s.	s.	s.	
June, 1916	0.5008388	0.5006632	0.5006294							C. L. Garner.
January, 1917	.5008382	.5006625	.5006287							Do.
June, 1916				0.5008285	0.5007196	0.5007005				Max Steinberg.
January, 1917				.5008291	.5007209	.5007021				Do.
Mean [1]	.5008385	.5006628	.5006290	.5008288	.5007202	.5007013				
February–March, 1917				.5008283	.5007269	.5007059				Do.
September, 1919	.5008404	.5006721	.5006366							E. W. Eickelberg.
January, 1920	.5008428	.5006730	.5006379							Do.
August, 1921							0.5008866	0.5008193	0.5007902	G. D. Cowie.
January, 1922	.5008422	.5006730	.5006370				.5008859	.5008190	.5007897	Do.
May, 1922	.5008423	.5006726	.5006367				.5008858	.5008186	.5007896	F. E. Joekel.
January, 1923	.5008404	.5006726	.5006364				.5008862	.5008188	.5007900	G. D. Cowie.
Mean	.5008416	.5006727	.5006369				.5008861	.5008189	.5007899	

[1] Between the standardizations of January and February–March, 1917, a rivet was inserted in each bronze pendulum to make the connection between bob and stem more rigid. This caused small changes in the standardization periods.

DESCRIPTIONS OF STATIONS.

The following descriptions are given in sufficient detail to enable one to find the locations of the stations within a few feet horizontally and within a foot or two vertically in each case. It is not necessary to preserve the exact spot at which the pendulums were swung, as the variation of gravity in a distance of a few feet is too small to be detected with the present type of gravity apparatus.

The support used for the receiver is given at the end of each description. At a large number of the stations the receiver was mounted on a concrete floor with only a brick or small concrete block under each footplate. These bricks or blocks were necessary to give room for the bottom piece of the felt-and-leather case used to protect the receiver against temperature variations. A concrete floor makes a very satisfactory support for the instrument, and if a station is located in a town it is almost always possible to find a cellar or basement with a concrete floor that can be used for a pendulum room. At several of the recent stations the receiver was mounted on an aluminum tripod partly embedded in the ground. (See p. 56).

If it is desired to know the name of the observer who established the station, the alphabetical index of stations on page 91 should be consulted.

No. 220, Bellingham, Wash. (1916).—Federal Building, engineer's room in the south end of the basement. The receiver was mounted with a small concrete block under each footplate cemented to the concrete floor.

No. 221, Everett, Wash. (1916).—Post office at corner of Colby and Wall Streets, north basement room. The receiver was mounted with a small concrete block under each footplate cemented to the concrete floor.

No. 222, Issaquah, Wash. (1916).—Public-school building, coal room. The receiver was mounted with a small concrete block under each footplate cemented to the concrete floor.

No. 223, Port Angeles, Wash. (1916).—Clallam County courthouse on Lincoln Street between Third and Fourth Streets, northernmost basement room. The receiver was mounted with a small concrete block under each footplate cemented to the concrete floor.

No. 224, Port Townsend, Wash. (1916).—Federal Building on Harrison and Washington Streets, northwest basement room. The receiver was mounted with a small concrete block under each footplate cemented to the conerete floor.

No. 225, Port Gamble, Wash. (1916).—Hotel Puget annex, southeast corner of storeroom under and just to the left of the entrance. The receiver was mounted with a small concrete block under each footplate cemented to the concrete floor.

No. 226, Bremerton, Wash. (1916).—Smith graded school on Park Avenue and Evergreen Street, about 1 mile northwest of the boat landings, southwest basement room. The receiver was mounted with a small concrete block under each footplate cemented to the concrete floor.

No. 227, Tacoma, Wash. (1916).—Federal Building on A Avenue between Eleventh and Twelfth Streets, storeroom in north end of basement. The receiver was mounted with a small concrete block under each footplate cemented to the concrete floor.

No. 228, Moclips, Wash. (1916).—Public-school building, south part of furnace room. The receiver was mounted with a small concrete block under each footplate cemented to the concrete floor.

No. 229, Portland, Oreg. (1916).—Customhouse on Park Avenue and Davis Street, northwest basement room formerly used for coal and wood. The receiver was mounted with a small concrete block under each footplate cemented to the concrete floor.

No. 230, Tillamook, Oreg. (1916).—Tillamook Hotel, southwest basement room. The receiver was mounted with a small concrete block under each footplate cemented to the concrete floor.

No. 231, Newport, Oreg. (1916).—High school, center room in south side of basement. The receiver was mounted with a small concrete block under each footplate cemented to the concrete floor.

No. 232, Eugene, Oreg. (1916).—Junior High School on Olive Street near Fourteenth Avenue, southeast basement room. The receiver was mounted with a small concrete block under each footplate cemented to the concrete floor.

No. 233, Marshfield, Oreg. (1916).—High School at the head of Hall Street, small basement room adjoining and directly north of furnace. The receiver was mounted with a small concrete block under each footplate cemented to the concrete floor.

No. 234, Glendale, Oreg. (1916).—Concrete building belonging to B. S. Radcliff, about 100 meters south of railroad station, southeast room. The receiver was mounted with a small concrete block under each footplate cemented to the concrete floor.

No. 235, Tehama, Calif. (1916).—West store of Clark Building belonging to Henry Clark. The receiver was mounted with a small concrete block under each footplate cemented to the concrete floor.

No. 236, Sacramento, Calif. (1916).—Post office, small storeroom in basement directly east of furnace room. The receiver was mounted with a small concrete block under each footplate cemented to the concrete floor.

No. 237, Willits, Calif. (1916).—Concrete building belonging to H. C. Mohn, about 75 meters south of Hotel Willits, west end of north storeroom. The receiver was mounted with a small concrete block under each footplate cemented to the concrete floor.

No. 238, Eureka, Calif. (1916).—Federal Building and post office, storeroom in center of north side of basement west of the main lobby entrance to the basement. The receiver was mounted with a small concrete block under each footplate cemented to the concrete floor.

No. 239, Santa Rosa, Calif. (1916).—Post office, northwest basement room. The receiver was mounted with a small concrete block under each footplate cemented to the concrete floor.

No. 240, San Diego, Calif. (1916).—Post office on F and Union Streets, corner of the passage leading from the boiler room to the northeast room of the basement, near the door to the latter room. The receiver was mounted with a brick under each footplate cemented to the concrete floor.

No. 241, Oceanside, Calif. (1916).—Carlsbad Union High School, a one-story concrete building on Horn and First Streets, west corner of the boiler room in the basement. The receiver was mounted with a brick under each footplate cemented to the concrete floor.

No. 242, Highland, Calif. (1916).—Congregational Church, center of small furnace room at the center of the east side of the basement. The receiver was mounted with a brick under each footplate cemented to the concrete floor.

No. 243, Pomona, Calif. (1916).—City Hall, furnace room in southwest corner of building. The receiver was mounted with a brick under each footplate cemented to the concrete floor.

No. 244, Long Beach, Calif. (1916).—Post office on Pine Avenue between Fifth and Sixth Streets, southeast corner of northeast basement room. The receiver was mounted with a brick under each footplate cemented to the concrete floor.

No. 245, Redondo Beach, Calif. (1916).—Union High School, small room under the main stairway of the northwest wing. The receiver was mounted with a brick under each footplate cemented to the concrete floor.

No. 246, Burbank, Calif. (1916).—Union High School on Second and Cypress Streets, small basement room adjacent to the southeast side of the furnace. The receiver was mounted with a brick under each footplate cemented to the concrete floor.

No. 247, Palmdale, Calif. (1916).—C. C. Moore's general store, about 200 feet east-southeast of the Southern Pacific Railroad Station, small cellar under southeast corner of store. The receiver was mounted with a brick under each footplate cemented to the concrete floor.

No. 248, Mojave, Calif. (1916).—A. Asher's general store, 100 feet east of the north end of the Southern Pacific Railroad Station, cellar. The receiver was mounted on a brick pier with a brick under each footplate cemented to the pier.

No. 249, Maricopa, Calif. (1916).—Bank of Maricopa, east side of basement just north of the vault support. The receiver was mounted with a brick under each footplate cemented to the concrete floor.

No. 250, Ventura, Calif. (1916).—Ventura County courthouse, northeast corner of basement. The receiver was mounted with a brick under each footplate cemented to the concrete floor.

No. 251, Concepcion, Calif. (1916).—Light keeper's residence, cellar under northwest end. The receiver was mounted with a brick under each footplate cemented to the concrete floor.

No. 252, Avila, Calif. (1916).—House occupied by Charles Stuart, north end of cellar. The house is on a slope, and although the south end of cellar floor is flush with ground the north end is 10 feet below surface. The receiver was mounted with a brick under each footplate cemented to the concrete floor.

No. 253, San Lucas, Calif. (1916).—Pleasant View Hotel opposite Southern Pacific Railroad Station, south end of basement. The receiver was mounted with a brick under each footplate cemented to the concrete floor.

No. 254, Monterey, Calif. (1916).—Volunteer fire house, small sub-basement cut out of solid rock. The receiver was monnted with a brick under each footplate cemented to the concrete floor.

No. 255, Hollister, Calif. (1916).—Hall of Records Building of San Benito County, vault in basement. The receiver was mounted with a brick under each footplate cemented to the concrete floor.

No. 256, Palo Alto, Calif. (1916).—Post office, north corner of basement. The receiver was mounted with a brick under each footplate cemented to the concrete floor.

No. 257, San Gregorio, Calif. (1916).—San Gregorio Hotel pump house, a small two-story building surmounted by a tank and windmill about 400 feet west of the hotel, northwest end of room. The receiver was mounted with a brick under each footplate cemented to the concrete floor.

No. 258, Point Reyes Station, Calif. (1916).—Grandi Co. Building, south end of basement. The receiver was mounted with a brick under each footplate cemented to the concrete floor.

No. 259, Duncans Mills, Calif. (1916).—Garage belonging to Doctor Raynes of the Orchard Hotel. The receiver was mounted with a brick under each footplate cemented to the concrete floor.

No. 260, Clarksburg, W. Va. (1917).—Post office at corner of Pike and South Third Streets, center of small basement room under the stairway leading from the north entrance to the basement. The receiver was mounted with a brick under each footplate cemented to the brick floor.

No. 261, Rowlesburg, W. Va. (1917).—High school, northwest corner of physics laboratory in northeast corner of basement. The receiver was mounted with a brick under each footplate cemented to the concrete floor.

No. 262, Terra Alta, W. Va. (1917).—Brick grammar school, near foot of stairway leading from main entrance to boys' toilet in basement. The receiver was mounted with a brick under each footplate cemented to the concrete floor.

No. 263, Corinth, W. Va. (1917).—Residence of S. K. Elsey, about 250 feet south of the Baltimore & Ohio Railroad tracks and 700 feet northwest of the station, cellar. The receiver was mounted on a brick pier with a brick under each footplate cemented to the top of the pier.

No. 264, Kitzmiller, Md. (1917).—Methodist church, west corner of basement. The receiver was mounted with a brick under each footplate cemented to the concrete floor.

No. 265, Pennington, N. J. (1917).—Residence of Mrs. M. E. Knowles at 124 North Main Street, small room in northeast corner of cellar. The receiver was mounted with a brick under each footplate cemented to the concrete floor.

No. 266, Glen Ridge, N. J. (1917).—High school, center of room on the south or Bloomfield Avenue side of the basement just south of the boys' toilet. The receiver was mounted with a brick under each footplate cemented to the concrete floor.

No. 267, Plainsboro, N. J. (1917).—Residence of Louis B. Okeson, immediately west of the Okeson garage, center of south room of cellar. The receiver was mounted with a brick under each footplate cemented to the concrete floor.

No. 268, Hartford, Conn. (1917).—Jarvis laboratory of Trinity College, room in basement immediately west of the Public Utilities Commission room. The receiver was mounted on the north one of two similar brick piers which are capped with massive flat stones. A brick was placed under each footplate and cemented to the top of the pier.

No. 269, Hill City, S. Dak. (1919).—Town jail, a brick building 12 feet square about 550 feet south of the Chicago, Burlington & Quincy Railroad Station. The receiver was mounted with a brick under each footplate cemented to the concrete floor.

No. 270, Newcastle, Wyo. (1919).—County courthouse, hallway in basement between county agriculture agent's room and coal room. The receiver was mounted with a brick under each footplate cemented to the concrete floor.

No. 271, Bridgeport, Nebr. (1919).—Post office, northeast corner. The receiver was mounted with a brick under each footplate cemented to the concrete floor.

No. 272, Buford, Wyo. (1919).—Residence of C. H. Sargent, maintainer on the local section of the Union Pacific Railroad, northwest corner of cellar. The receiver was mounted with a brick under each footplate cemented to the concrete floor.

No. 273, Boulder, Colo. (1919).—Mountain States Telegraph & Telephone Co.'s Building, northwest corner of south room of basement. The receiver was mounted with a brick under each footplate cemented to the concrete floor.

No. 274, Lafayette, Colo. (1919).—Baptist church on Cleveland Street and Roosevelt Avenue, southwest corner of basement. The receiver was mounted with a brick under each footplate cemented to the concrete floor.

No. 275, Brighton, Colo. (1919).—(Name of building not stated in description.) The station is in the basement under the northeast corner of the building. The receiver was mounted with a brick under each footplate cemented to the concrete floor.

No. 276, Idaho Springs, Colo. (1919).—Manual Training Building, at the corner of Colorado Avenue and Fourteenth Street, northeast corner of small room in basement just south of the stairway. The receiver was mounted with a brick under each footplate cemented to the concrete floor.

No. 277, Fort Morgan, Ala. (1921).—Powder magazine room, southwest corner, just west of the west gun of Battery Duportail and south of the ammunition hoist. The receiver was mounted with a brick under each footplate cemented to the concrete floor.

No. 278. Chandeleur Island, La. (1921).—Boathouse of the U. S. Light House Engineers at Chandeleur Light Station, about 70 meters south of the lighthouse. The boathouse is supported on piles which are in water at high tide. The receiver was mounted with a brick under each footplate cemented to the wooden floor.

No. 279, Port Eads, La. (1921).—Longitude observing tent on fill back of the first quarters up the river from the power plant and about 300 feet from the river. The receiver was mounted on a pile, the southwest one of four used as anchors for the wireless pole, which is about 150 feet to the eastward.

No. 280, Burrwood, La. (1921).—Tent in the middle of a small field south of the water tank and 55 feet southeast of a bunk house. The receiver was mounted on an aluminum tripod partly embedded in the ground.

No. 281, Fort St. Philip, La. (1921).—Magazine about 150 feet northwest of the end of the trestle leading to the dock and near the southwest one of two small gun positions, the farthest west of all the gun positions at the fort. The receiver was mounted with a brick under each footplate cemented to the concrete floor.

No. 282, Pointe a la Hache, La. (1921).—Parish jail, a brick building at the rear of the courthouse, about 250 feet from the levee, southeast corner of the lower northwest cell. The receiver was mounted with a brick under each footplate cemented to the concrete floor.

No. 283, Timbalier Island, La. (1921).—Main dwelling house of the dismantled 1906 light station at the east end of the island, southeast corner of the west room. The house is supported on posts and has heavy plank floors. The receiver was mounted with a brick under each footplate cemented to the wooden floor.

No. 284. Morgan City, La. (1921).——City hall, small room between the office of the city engineer and the sleeping quarters of the firemen. The receiver was mounted with a brick under each footplate cemented to the concrete floor.

No. 285, Sabine, Tex. (1921).—Longitude observing tent in an open field about 40 meters due east of the northeast corner of the Southern Pacific Railroad Station. The receiver was mounted on an aluminum tripod set on large stones sunk 1½ feet in the ground.

No. 286, Beaumont, Tex. (1921).—Post office, small alcove in basement between the boiler room and the rest room at the north corner of the basement. The receiver was mounted with a brick under each footplate cemented to the concrete floor.

Nos. 287 to 295, inclusive, have not been finally computed. (See p. 55.)

No. 296, Wilkins Well, Kans. (1922).—Tent at an abandoned oil well of the same name about 15 miles northwest of Junction City, about one-fourth mile northeast of Swartz's farm and one-fourth mile southeast of Jones's farm, in the NE. ¼ sec. 26, T.11 S., R. 3 E., in a cultivated field owned by Mr. Wilkins, about 200 feet east of the road leading from Sutphen Mill toward Clay Center. The receiver was mounted on a 12 by 14 inch oak beam 12 feet long solidly embedded in the earth.

No. 297, Zeandale (Bard Well), Kans. (1922).—Schoolhouse in T. 10 S., R. 9 E., about one-eighth mile north of Bard Well, northeast anteroom. The receiver was mounted on the wooden floor.

No. 298, Doyle Well, Kans. (1922).—Tent about 1½ miles from the town of St. Marys, across the road from the Doyle farmhouse, in SW. ¼ sec. 4, T. 10 S., R. 12 E., in a pasture 150 feet south of Doyle's well, which was drilled by J. J. Crawford, of Toronto, Ohio. The receiver was mounted on a concrete pier flush with the ground.

No. 299, Seneca Well, Kans. (1922).—Tent at the northeast edge of the town of Seneca, across the road from the residence of Mr. Voss, about 50 feet south of the old well casing and 75 feet southeast of the corner of a barbed-wire fence. The receiver was mounted on an aluminum tripod partly embedded in the ground.

No. 300, Wapanucka, Okla. 1922).—Tent across the street from the Harris Hotel, in the northwest corner of a square occupied by the buildings of an abandoned lumber yard, between the office building on the north side of the square and the shed on the west side. The receiver was mounted on an aluminum tripod partly embedded in the ground.

No. 301, Troy, Okla. (1922).—Abandoned gin on the east side of the railroad track just south of the main road crossing. The receiver was mounted on the oak beams, 14 inches square, which form the base of the gin press.

No. 302, Idle Wilde, Okla. (1922).—Residence of E. J. Cruce, Idle Wilde Dairy, about 4 miles north of Ardmore, in sec. 8, T. 4 S., R. 2 E., basement. The receiver was mounted on an aluminum tripod partly embedded in the ground.

No. 303, Lowery, Okla. (1922).—Tent in SE. ¼ sec. 4, T. 4 S., R. 3 W., 150 feet west of Pure Oil Co. pump house, 100 feet northeast of Lowery well No. 29 (abandoned) and 75 feet from well No. 30. The receiver was mounted on an aluminum tripod partly embedded in the ground.

No. 304, Carter, Okla. (1922).—Tent in SE. ¼ sec. 19, T. 4 S., R. 3 W., on the Carter Oil Co. tank farm 3 miles south of Dundee, 150 feet northeast of farm manager's house, about 50 feet from center of road and 25 feet from fire wall of tank farm. The receiver was mounted on an aluminum tripod partly embedded in the ground.

No. 305, Busby, Okla. (1922).—Tent in SW. ¼ sec. 9, T. 3 S., R. 3W., on land owned by Mollie C. Busby, about 200 feet northwest of her house, in the corner of a barbed-wire fence just outside the garden. The receiver was mounted on an aluminum tripod partly embedded in the ground.

No. 306, Saline No. 1, Tex. (1922).—Tent about ¾ mile south of Grand Saline on the road leading south from the Texas & Pacific Railway Depot. The station is in a pasture owned by W. P. Robertson, of Grand Saline, about 400 feet from the road, 600 feet northeast of a white house, and 75 feet south of a barbed-wire fence, near the bank of a small run. The receiver was mounted on an aluminum tripod partly embedded in the ground.

No. 307, Saline No. 2, Tex. (1922).—Tent about 2¾ miles east of Grand Saline, on the road to Mineola and 2½ miles directly east of Saline No. 1, on a well-defined hill back of a farmhouse and barn, about 50 feet north of the north-

east corner of a cow lot and 15 feet northwest of a large oak tree. The property is owned by W. P. Robertson, of Grand Saline, and rented by Moseley. The receiver was mounted on an aluminum tripod partly embedded in the ground.

No. 308, Saline No. 3, Tex. (1922).—Tent about 2½ miles directly west of Saline No. 1. To reach station from Grand Saline follow Terrell Road as far as the 2-mile sign, turn to the left across railroad and proceed about ¾ mile, then turn to the right and follow road about ½ mile to a farmhouse on the left. The station is in a pasture east of a cotton field about 600 feet east of the house and near the bank of a small run. The receiver was mounted on an aluminum tripod partly embedded in the ground.

No. 309, Taylor, Tex. (1922).—City Hall, southwest corner of a room in the basement used as a washroom by the firemen, the second room from the basement entrance on the south. The receiver was mounted on the concrete floor.

No. 310, Georgetown, Tex. (1922).—Science Building of Southwestern University, southeast corner of a room used as a radio laboratory in the southeast corner of the building. The receiver was mounted on the concrete floor.

No. 311, Damon No. 1, Tex. (1922).—Country schoolhouse known as Bethel School in the east corner of the north quarter of section 116 of the H. and T. C. Survey, near the center of the northeast wall in the main schoolroom. The receiver was mounted on the floor.

No. 312, Damon No. 2, Tex. (1922).—Barn shed on Mulchay place just back of the ranch house occupied by Mr. Rhoades. The receiver was mounted on an aluminum tripod partly embedded in the earth.

No. 313, Damon No. 3, Tex. (1922).—Tent, in marshy pasture, about 1,000 feet directly south of the west corner of the 100-acre plot belonging to James Ptak. The receiver was mounted on an aluminum tripod partly embedded in the earth.

INDEX OF STATIONS.

Name of station.	No. of station.	Observer.	Year observed.	Description.	Abstract.
				Page.	*Page.*
Avila, Calif.	252	Max Steinberg	1916	87	76
Beaumont, Tex.	286	G. D. Cowie	1921	89	82
Bellingham, Wash.	220	C. L. Garner	1916	86	72
Boulder, Colo.	273	E. W. Eickelberg	1919	88	79
Bremerton, Wash.	226	C. L. Garner	1916	86	73
Bridgeport, Nebr.	271	E. W. Eickelberg	1919	88	79
Brighton, Colo.	275	do	1919	88	80
Buford, Wyo.	272	do	1919	88	79
Burbank, Calif.	246	Max Steinberg	1916	87	75
Burrwood, La.	280	G. D. Cowie	1921	89	81
Busby, Okla.	305	F. E. Joekel	1922	89	84
Carter, Okla.	304	do	1922	89	84
Chandeleur Island, La.	278	G. D. Cowie	1921	89	81
Clarksburg, W. Va.	260	Max Steinberg	1917	88	78
Concepcion, Calif.	251	do	1916	87	76
Corinth, W. Va.	263	do	1917	88	78
Damon No. 1, Tex.	311	F. E. Joekel	1922	90	85
Damon No. 2, Tex.	312	do	1922	90	85
Damon No. 3, Tex.	313	do	1922	90	85
Doyle Well, Kans.	298	do	1922	89	83
Duncans Mills, Calif.	259	Max Steinberg	1916	88	77
Eugene, Oreg.	232	C. L. Garner	1916	87	73
Eureka, Calif.	238	do	1916	87	74
Everett, Wash.	221	do	1916	86	72
Fort Morgan, Ala.	277	G. D. Cowie	1921	88	80
Fort St. Philip, La.	281	do	1921	89	81
Georgetown, Tex.	310	F. E. Joekel	1922	90	85
Glen Ridge, N. J.	266	Max Steinberg	1917	88	78
Glendale, Oreg.	234	C. L. Garner	1916	87	73
Hartford, Conn.	268	Max Steinberg	1917	88	79
Highland, Calif.	242	do	1916	87	75
Hill City, S. Dak.	269	E. W. Eickelberg	1919	88	79
Hollister, Calif.	255	Max Steinberg	1916	88	76
Idaho Springs, Colo.	276	E. W. Eickelberg	1919	88	80
Idle Wilde, Okla.	302	F. E. Joekel	1922	89	83
Issaquah, Wash.	222	C. L. Garner	1916	86	72
Kitzmiller, Md.	264	Max Steinberg	1917	88	78
Lafayette, Colo.	274	E. W. Eickelberg	1919	88	80
Long Beach, Calif.	244	Max Steinberg	1916	87	75
Lowery, Okla.	303	F. E. Joekel	1922	89	84
Maricopa, Calif.	249	Max Steinberg	1916	87	75
Marshfield, Oreg.	233	C. L. Garner	1916	87	73
Moclips, Wash.	228	C. L. Garner	1916	87	73
Mojave, Calif.	248	Max Steinberg	1916	87	75
Monterey, Calif.	254	do	1916	88	76
Morgan City, La.	284	G. D. Cowie	1921	89	81
Newcastle, Wyo.	270	E. W. Eickelberg	1919	88	79
Newport, Oreg.	231	C. L. Garner	1916	87	73
Oceanside, Calif.	241	Max Steinberg	1916	87	75
Palmdale, Calif.	247	do	1916	87	75
Palo Alto, Calif.	256	do	1916	88	77
Pennington, N. J.	265	do	1917	88	78
Plainsboro, N. J.	267	do	1917	88	79
Point Reyes Station, Calif.	258	do	1916	88	77
Pointe a la Hache, La.	282	G. D. Cowie	1921	89	81
Pomona, Calif.	243	Max Steinberg	1916	87	75
Port Angeles, Wash.	223	C. L. Garner	1916	86	72
Port Eads, La.	279	G. D. Cowie	1921	89	81
Port Gamble, Wash.	225	C. L. Garner	1916	86	72
Port Townsend, Wash	224	do	1916	86	72
Portland, Oreg.	229	do	1916	87	73
Redondo Beach, Calif.	245	Max Steinberg	1916	87	75
Rowlesburg, W. Va.	261	do	1917	88	78
Sabine, Tex.	285	G. D. Cowie	1921	89	81
Sacramento, Calif.	236	C. L. Garner	1916	87	74
Saline No. 1, Tex.	306	F. E. Joekel	1922	89	84
Saline No. 2, Tex.	307	do	1922	89	84
Saline No. 3, Tex.	308	do	1922	90	84
San Diego, Calif.	240	Max Steinberg	1916	87	74
San Gregorio, Calif.	257	do	1916	88	77
San Lucas, Calif.	253	do	1916	88	76
Santa Rosa, Calif.	239	C. L. Garner	1916	87	74
Seneca Well, Kans.	299	F. E. Joekel	1922	89	83
Tacoma, Wash.	227	C. L. Garner	1916	86	73
Taylor, Tex.	309	F. E. Joekel	1922	90	84
Tehama, Calif.	235	C. L. Garner	1916	87	73
Terra Alta, W. Va.	262	Max Steinberg	1917	88	78
Tillamook, Oreg.	230	C. L. Garner	1916	87	73
Timbalier Island, La.	283	G. D. Cowie	1921	89	81
Troy, Okla.	301	F. E. Joekel	1922	89	83
Ventura, Calif.	250	Max Steinberg	1916	87	76
Wapanucka, Okla.	300	F. E. Joekel	1922	89	83
Wilkins Well, Kans.	296	do	1922	89	82
Willits, Calif.	237	C. L. Garner	1916	87	74
Zeandale, Kans.	297	F. E. Joekel	1922	89	83

O