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U. S. COAST AND GEODETIC SURVEY
E. LESTER JONES, DIRECTOR

COMPARISON OF OLD AND NEW TRIANGULATION IN CALIFORNIA

BY

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ILLUSTRATIONS

COMPARISON OF OLD AND NEW TRIANGULATION IN CALIFORNIA

By WILLIAM BOWIE, *Chief, Division of Geodesy, United States Coast and Geodetic Survey*

INTRODUCTION

This is the third report made by the Coast and Geodetic Survey on the testing by triangulation of earth movements in California. The first one appeared as Appendix 3 of 1907, just after the 1906 earthquake. The second was entitled "Earth Movements in California," Special Publication No. 106, and was printed in 1924.

The present report enables one to draw very much more definite and accurate conclusions regarding earth movements in this region of seismic activity, owing to the availability of a stronger base from which to make the computation and adjustment of the triangulations to be compared. This base, or the basic data, resulted from the readjustment of the triangulation net of the western part of the country. The present report supersedes Special Publication No. 106. The conclusions arrived at in the latter were found to have been based on insufficient evidence.

The writer wishes to acknowledge the valuable assistance he has received from a number of the mathematicians of the division of Geodesy of the Coast and Geodetic Survey in carrying out the investigations and in preparing this report. He wishes especially to mention Dr. O. S. Adams, who had charge of the readjustment of the triangulation of the western half of the country and of the arcs in California; G. L. Fentress, who made the actual adjustments of the California arcs; and C. H. Swick, who edited this manuscript and supervised the preparation of the sketches. Much credit is due Clem L. Garner, F. W. Hough, and William Mussetter, the engineers who had charge of the field work of reobserving these arcs. The results obtained by them are of a high degree of excellence.

CHAPTER 1.—GENERAL STATEMENT

The United States Coast and Geodetic Survey began the reoccupation of triangulation stations in California in 1922, but it is only now that the final results secured can be made available in definite form. This is owing to the fact that the readjustment of the triangulation net of the western half of the United States had to be made before the California triangulation, executed 30 years or more ago, could be accurately compared with the work done during the past six years.

Where statements are made in this report to the effect that certain stations have or have not moved it should be understood that the time interval involved extends from the completion of the first triangulation which was prior to 1900 to that of the second triangulation which was executed between 1922 and 1925. The only exception is for the triangulation across southern California to the eastward of stations Cuyamaca and San Jacinto which was first executed in 1910 and 1911.

FIXED POSITIONS AT ENDS OF CALIFORNIA ARC

It can now be definitely stated that there has been no perceptible horizontal movement of the ground at those stations extending from Monticello and Vaca, in longitude approximately 122°, eastward to Carson Sink, in longitude 118° 15′. It can also be stated that there is no definite indication of horizontal shifting of the ground at the stations from San Jacinto and Cuyamaca to Kofa, in longitude 114° 10′. This means that Mount Lola, Round Top, Pine Hill, Marysville Butte, Vaca, and Monticello have not changed in their horizontal positions with respect to Carson Sink nor have San Jacinto, Cuyamaca, American, and Butte changed with relation to Kofa. These are significant facts, since they enable us to assume that San Jacinto and Cuyamaca on the south and Round Top and Mount Lola on the north are unmoved points.

CHANGES IN POSITIONS IN SOUTHERN CALIFORNIA

When we compare the old and new geographic positions of triangulation stations based on these four fixed points we were led to the conclusion that there have been no earth movements of detectable size between San Jacinto and Cuyamaca at the south and Castle Mount and Santa Lucia to the northward. The changes in the geographic positions from the old to the new triangulation, with stations San Jacinto, Cuyamaca, Mount Lola, and Round Top held fixed, are shown in Figure 2. The positions of the fixed points result from the readjustment of the net of the western half of the country, in which is included the triangulation of California executed during the past few years. These positions of the fixed points were then used as the basis for the adjustment of the old arc of triangulation executed 30 years or more ago. From the evidence shown in Figure 2, the definite conclusion was drawn that no earth movements occurred

at stations between Lospe-Tepusquet and San Jacinto-Cuyamaca. Lospe and Tepusquet are two stations at the western end of the arc of triangulation which extends eastward across California and into Nevada. (See fig. 4.) Since they are at a junction of two arcs of the triangulation net, their positions resulting from the general adjustment are very strong.

An inspection of Figure 2 indicates very definitely that there has been a gradual change in geographic positions of the triangulation stations from Lospe and Tepusquet to the vicinity of Castro and San Fernando. The shifts have been to the southward. Then from the latter two stations there is a gradual diminution of the changes in geographic positions until San Jacinto and Cuyamaca are reached. The maximum change in position for the stations to the south of Lospe and Tepusquet, if these stations are held fixed, is 3.6 feet, which occurs at station San Fernando. This station is nearly 100 miles (about 500,000 feet) east-southeast of Tepusquet, the nearest one of the points held fixed in the adjustment. The change in position is only about 1 part in 140,000 of the distance between these two stations. This change can easily be accounted for by the accumulation of accidental errors of triangulation.

Having this evidence, it was decided to make an adjustment of the old arc based on the new positions for Lospe-Tepusquet and San Jacinto-Cuyamaca. The changes in positions resulting from this adjustment are shown in Figure 6.

It would seem (see fig. 6) that there have been no earth movements of any great amount for stations Rocky Butte, San Luis, and San Jose with respect to Lospe and Tepusquet. The change in geographic position at Rocky Butte is about 2¾ feet, but that station is nearly 60 miles (or about 300,000 feet) from Lospe, and the change in position is approximately 1 part in 100,000 of the distance between the two stations. Of course, it can not be said definitely that there has been no actual earth movement at Rocky Butte with respect to stations Lospe and Tepusquet, but it would seem that the change in position is quite within the expected errors of triangulation. The subject of errors of triangulation will be discussed later in this report.

Discrepancies as proportional parts

Discrepancy, feet	Length of line, in miles							
	10	15	20	25	30	35	40	50
1	52,800	79,200	105,600	132,000	158,400	184,800	211,200	264,000
2	26,400	39,600	52,800	66,000	79,200	92,400	105,600	132,000
3	17,600	26,400	35,200	44,000	52,800	61,600	70,400	88,000
4	13,200	19,800	26,400	33,000	39,600	46,200	52,800	66,000
5	10,560	15,840	21,120	26,400	31,680	36,960	42,240	52,800
6	8,800	13,200	17,600	22,000	26,400	30,800	35,200	44,000
7	7,543	11,314	15,086	18,857	22,629	26,400	30,171	37,714
8	6,600	9,900	13,200	16,500	19,800	23,100	26,400	33,000
9	5,867	8,800	11,733	14,667	17,600	20,533	23,467	29,333
10	5,280	7,920	10,560	13,200	15,840	18,480	21,120	26,400
11	4,800	7,200	9,600	12,000	14,400	16,800	19,200	24,000

Discrepancies as proportional parts—Continued

Discrepancy, feet	Length of line, in miles						
	60	70	80	90	100	110	120
1	316,800	369,600	422,400	475,200	528,000	580,800	633,600
2	158,400	184,800	211,200	237,600	264,000	290,400	316,800
3	105,600	123,200	140,800	158,400	176,000	193,600	211,200
4	79,200	92,400	105,600	118,800	132,000	145,200	158,400
5	63,360	73,920	84,480	95,040	105,600	116,160	126,720
6	52,800	61,600	70,400	79,200	88,000	96,800	105,600
7	45,257	52,800	60,343	67,886	75,429	82,971	90,514
8	39,600	46,200	52,800	59,400	66,000	72,600	79,200
9	35,200	41,067	46,933	52,800	58,667	64,533	70,400
10	31,680	36,960	42,240	47,520	52,800	58,080	63,360
11	28,800	33,600	38,400	43,200	48,000	52,800	57,600

CHANGES IN POSITIONS IN NORTHERN HALF OF CALIFORNIA ARC

The changes in geographic positions between Mount Lola and Round Top to the north and Lospe and Tepusquet to the south (see fig. 6) lead to the conclusion that there had been no earth movement at stations Mount Helena, Monticello, Marysville Butte, and Pine Hill between the date of the old triangulation and that of the new. It was therefore decided that an adjustment of the old work should be made, based on the new positions of stations Mount Helena and Monticello to the north and Lospe and Tepusquet to the south. The results of this adjustment are shown in Figure 7. The changes in geographic positions thus obtained between the old and the new triangulations furnish the basis for the greater part of the report. Necessarily those triangulation stations which remained unchanged but which are nearest to those where actual earth movement is indicated or suspected are the ones which furnish the best means of comparison of the old and the new work. Where the distances are small between the stations which have not suffered from earth movements and those that have, then the relative effect of accidental errors of triangulation on the geographic positions is minimized. It is essential that we eliminate, as far as possible, the triangulation errors in order that we may know, at least approximately, what have been the changes due to actual earth movements.

It is impossible to make a physical measurement without some error, and, therefore, the arrows shown in Figures 2, 3, 6, 7, and 8, although indicating the changes in geographic positions of the triangulation stations, do not truly represent earth movements. The triangulation errors are combined with the actual earth movements in the differences in geographic positions shown in the figures. The analyses of the triangulation errors made in this report will, it is hoped, enable the reader to arrive at correct conclusions as to which stations have actually moved and the probable extent of the movements.

The changes in geographic positions of the triangulation stations between Castle Mount and Ross Mountain are so large as to make it seem practically certain that earth movement has occurred at some of the stations involved. It can not be said that each one of the stations has been subject to actual earth movement, but it is evident, when pairs of stations are considered, that there has been some distortion of the earth's surface.

Of course, every one is familiar with the fact that much distortion of the earth's surface close to the San Andreas fault occurred during

the earthquake of 1906. This report does not deal with the extent of the local movements but it is an attempt to discover to what extent horizontal movements of the surface occurred at points used as triangulation stations which are at varying distances from the active fault line. If first-order triangulation stations had, prior to 1906, been established close to the fault and at gradually increasing distances from it, then a reoccupation of those stations would enable one to determine the extent of the deformation of the earth's surface, in a horizontal sense, resulting from the 1906 earthquake. There were in existence, before 1906, a number of stations of third-order triangulation close to the fault line in the vicinity of San Francisco Bay and to the northward. The positions of some of these stations were redetermined in 1906 (see Appendix 3, report for 1907, Coast and Geodetic Survey). Third-order triangulation, as is well known, furnishes the lengths of triangle sides within about 1 part in 10,000 of the lengths. This accuracy is only about one-tenth that of the first-order triangulation which is the basis of this report. It is hoped, however, that it will be possible before very long to make computations and adjustments of the third-order triangulation in question with a view to learning whether the data involved will throw any light on the question of how far from a fault line or zone the earth's surface is liable to be shifted during an earthquake.

An inspection of Figure 7 indicates that there has been a definite south or southeast drift of stations Ross Mountain, Mount Hamilton, Loma Prieta, Santa Ana, and Hepsedam. Sierra Morena has moved to the northwest and Point Reyes Lighthouse has moved to the north. The most noticeable case of relative earth movement occurs for the pair of stations Ross Mountain and Point Reyes Lighthouse. There the shifts in position are about 10.4 feet northward for Point Reyes Lighthouse and slightly more than 3.5 feet southward for Ross Mountain. The relative movement of these two stations is about 14 feet.

CHANGES IN POSITIONS IN POINT ARENA SPUR

A scheme of triangulation extends from Mount Helena, Ross Mountain, and Marysville Butte to Mount Sanhedrin and Snow Mountain West, thence southwestward to the vicinity of Point Arena. The new triangulation in this section starts from Marysville Butte, Mount Helena, and Ross Mountain and hence is based upon a strong connection. In the old work, however, the original connection was made with the line Mount Helena to Ross Mountain and was a comparatively weak connection. In 1904, when the arc extending northward to Puget Sound was started, the angle at Marysville Butte between Mount Helena and Snow Mountain West was observed, as was also that at Snow Mountain West between Marysville Butte and Mount Helena. Since the angle at Mount Helena, between Snow Mountain West and Marysville Butte was determined by the original work, this gave a closed triangle involving those three stations.

In order to test whether or not Snow Mountain West has moved with respect to Marysville Butte and Mount Helena, both this old triangle and the triangle of 1925 were closed by applying in each case one-third of the closing correction of the triangle to each angle. The position of Snow Mountain West was then computed from the posi-

tions of Marysville Butte and Mount Helena as fixed by the western adjustment, using both the old triangle and the 1925 triangle.

The spherical angles in this triangle, after the closing corrections have been applied, are as follows:

	New			Old	New minus old
	°	′	″	″	″
Snow Mountain West	69	11	10.10	11.32	−1.22
Marysville Butte	53	27	02.35	00.75	+1.60
Mount Helena	57	22	03.19	03.57	−0.38

These differences in the angles are no more than could be expected in the triangulation, and they indicate quite clearly that Snow Mountain West has not moved with respect to Marysville Butte and Mount Helena.

The two positions of Snow Mountain West as computed through the two triangles differ in latitude by 0.″021 (or 0.65 meter) and in longitude by 0.″002 (or 0.05 meter), and the total difference in position is 0.65 meter (or 2.1 feet). This is only about 1 part in 128,000 of the distance from Marysville Butte and only about 1 part in 122,000 of the distance from Mount Helena. It is within the limits of what could be expected in triangulation. We are thus led to the conclusion that Snow Mountain West has not moved in relation to these two stations.

With this fact established, it was decided to hold the line Mount Helena to Snow Mountain West as fixed by the western net adjustment and to compute both the old and the new work of the Point Arena spur from this fixed line in order to obtain a comparison of the positions. The results of this computation are shown in Figure 8, and the comparison of angles is shown in the table on page 29.

The changes in position for Mount Sanhedrin, Two Rock, Paxton, and Cleland are very small. The changes at stations Fisher, Cold Spring, Dunn, Clark, and Lane, however, are such as to indicate definite earth movements. The change at Cold Spring is 2.7 feet and at Lane 7.4 feet. Although the change at Cold Spring is not very large the station is only 14 miles from Paxton, and the ratio of the changes at those two stations to the distance between them is 1: 30,000, which is greater than might be expected from the triangulation errors. All of these five stations at which the changes in position are large are close to the San Andreas fault. Station Lane is within a mile of the fault of 1906. The change at each of these five stations is to the southeastward, which agrees in direction with the changes in position at Ross Mountain and other stations to the southward which are on the eastern side of the fault.

The remainder of this report is devoted to the detailed data and their analyses on which the conclusions set forth in this general statement are based. The geographic positions of the several triangulation stations involved in the California studies are given in the table on page 37. These positions will enable one to plot the stations on maps showing geological formations and the locations of the active fault zones.

CHAPTER 2.—TEST BY TRIANGULATION OF STABILITY OF THE EARTH'S SURFACE IN CALIFORNIA

In chapter 1 there are given, in brief outline, the conclusions which may be drawn from a comparison of the geographic positions of stations in California. The comparison is between the triangulation executed 30 years or more ago and that executed between the years 1922 and 1925. In this chapter will be described the methods used in the field and in the office in securing the data.

Whenever a severe earthquake occurs on land, a movement of the earth's surface close to the fault zone may be noted on the ground. The land may move vertically or horizontally or in both directions. These movements will affect the elevations of bench marks and the geographic positions of triangulation stations located within the active area. The question of how far from an active fault zone the vertical and horizontal movements occur is an important one to the student of seismology. Some hold that the affected area is quite local, confined to within a few miles of the active fault, while others believe that the whole region surrounding the earthquake center is in movement. It is evident that to settle this very interesting and important question the geophysicists must have some definite measurements. It is also important that they should know whether there are earth movements of measurable amounts prior to the actual breaking of the ground that causes an earthquake.

In order that light may be thrown on these matters, the United States Coast and Geodetic Survey has, for the past six years, cooperated with the advisory committee in seismology of the Carnegie Institution of Washington, of which committee Dr. Arthur L. Day, director of the geophysical laboratory of that institution, is chairman. Doctor Day presented the plan of determining earth movements in California to Col. E. Lester Jones, Director of the United States Coast and Geodetic Survey, with the result that the latter asked for and was granted by Congress an appropriation of $15,000 for the fiscal year ended June 30, 1923, with which to begin a study of the problem. An appropriation has been made for each year since that time, the amount now being $10,000.

TEST MADE AFTER EARTHQUAKE OF 1906

Soon after the earthquake of 1906 observers of the Coast and Geodetic Survey reoccupied a number of old triangulation stations established in the vicinity of San Francisco Bay many years before. Angles were reobserved and positions were redetermined for the several stations involved. A report on the work appeared as Appendix 3 of the report of the Coast and Geodetic Survey for 1907. The authors of this publication were John F. Hayford, at that time in charge of the geodetic division of the United States Coast and Geodetic Survey, and A. L. Baldwin, chief mathematician of that division.

Hayford and Baldwin held fixed the geographic positions of the stations Mount Diablo, Mocho, and Santa Ana and determined the changes from the old to the 1906–7 geographic positions. Their computation involved a few of the same stations as does the present paper and, in addition, quite a number of subsidiary or third-order stations located in San Francisco Bay and along the outer coast.

Hayford and Baldwin were somewhat handicapped by not having the positions for the main-scheme triangulation stations that are now available as a result of the readjustment of the triangulation net of the western half of the country. It is inevitable, therefore, that the changes in geographic positions shown by their investigations should not correspond to those given in the present paper.

It is probable that the results given in this paper will furnish the basis for further determinations of geographic positions along the coast of California. It is hoped that opportunity will be presented for combining the observations made in 1906–7 at the subsidiary stations mentioned above with the triangulation data for the main-scheme stations secured between the years 1922 and 1925, in order to get fuller information regarding changes in geographic positions at those Hayford-Baldwin stations which lie close to the San Andreas fault. The amount of work involved in making the necessary computations and adjustments will prevent this being done for some time to come.

NEW TEST MADE IN 1922–1928

In conferences between Doctor Day and officials of the United States Coast and Geodetic Survey it was decided that a readjustment of the old triangulation should be made from stations Mount Lola and Round Top on the Sierra Nevadas in approximate latitude 39° and longitude 120°, westward to the coast and then along the coast to stations San Jacinto and Cuyamaca, which are comparatively near the coast in southern California. (See fig. 1.)

It is fortunate that several years ago in charting the coasts and in making a connection between the Atlantic and Pacific coasts by triangulation, a net of first-order stations was established along the coast of California and along the thirty-ninth parallel of latitude. It is also fortunate that these stations, established between the years 1855 and 1899, were substantially marked or monumented. Every one of the main-scheme stations of the old triangulation except Forty Acre Opening was recovered during the triangulation operations of 1922–25. At stations Rocky Butte and Chaffee the monuments had been broken, but the observer in charge of the new work, Floyd W. Hough, reported that the new station on Rocky Butte was certainly within 3 or 4 inches of the old station and that at station Chaffee "A new station was established as near as possible to the old one, and it is believed to be not more than 4 inches away from the old station." We may assume that all the stations except Forty Acre Opening were exactly recovered.

The first field work undertaken in carrying out the cooperative plan between the Coast and Geodetic Survey and the advisory committee in seismology of the Carnegie Institution was the reoccupation of the triangulation stations from Mount Lola and Round Top westward to the coast and southeastward to stations Lospe and Tepusquet, approximately in latitude 35°. Next the work was extended northward

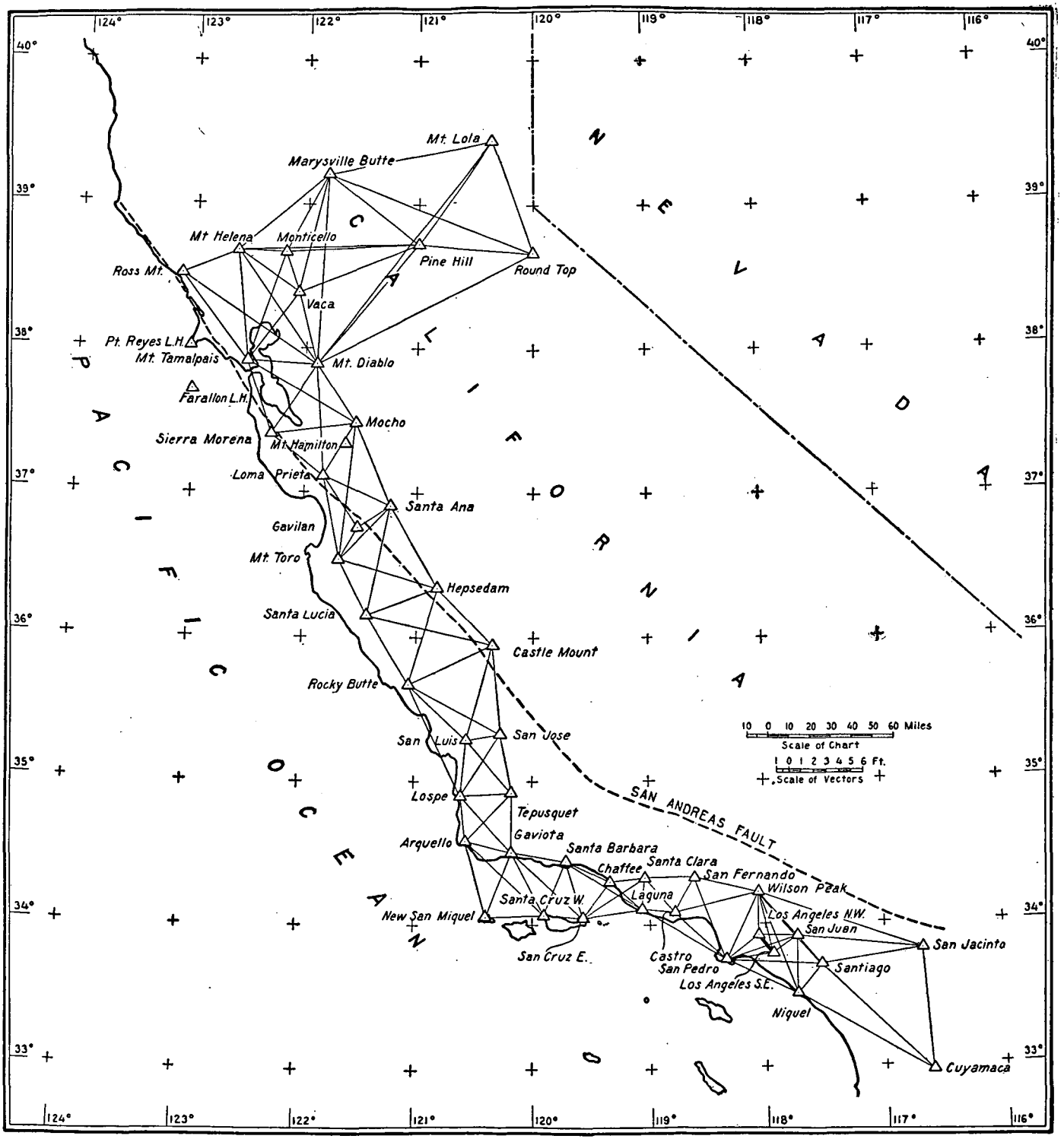

FIG. 1.—*California triangulation and San Andreas fault line*

from stations San Jacinto and Cuyamaca at the south to stations Chaffee and Laguna, in longitude approximately 119° 15′. There remained a small gap between stations Lospe and Tepusquet and stations Chaffee and Laguna that had to wait until the succeeding season.

PRELIMINARY REPORT

The interest in the results of this California work was so great that a preliminary report was made by the author, which appeared in 1924 as Special Publication No. 106 of the United States Coast and Geodetic Survey, under the title "Earth Movements in California." That publication gave the changes in geographic positions resulting from the new triangulation. The only points held fixed in the adjustment of the northern part of the new work were Mount Lola and Round Top, and there were no checks in azimuth and length at stations Lospe and Tepusquet at the end of the arc.

A comparison of the old and the new positions in this northern part indicated some very great changes in geographic positions which were apparently larger than could be accounted for by the errors of triangulation alone. On the other hand, the new triangulation from San Jacinto and Cuyamaca westward to Chaffee and Laguna did not disclose any very great changes in geographic positions.

Later the new triangulation was extended across the gap from Lospe and Tepusquet to Chaffee and Laguna. When this had been done the indications were that the very large changes reported in Special Publication No. 106, amounting to approximately 24 feet as a maximum at stations Tepusquet and Lospe, must have been due largely to accumulated errors of triangulation and not to actual earth movements. It was not possible, however, at the time this gap was spanned to separate the effect of errors of triangulation and of actual earth movements. This had to wait till the results of the readjustment of the triangulation net of the western half of the United States were available.

TEST OF FIXED POSITIONS

After the triangulation had been completed from Mount Lola and Round Top to San Jacinto and Cuyamaca, it was thought best by the chairman of the advisory committee in seismology of the Carnegie Institution of Washington and the officials of the Coast and Geodetic Survey to extend the new triangulation to the eastward from both ends. The new work would indicate whether there had been earth movements to the eastward of Mount Lola and Round Top, the stations held fixed at the north, and of San Jacinto and Cuyamaca, those held fixed at the south. This was considered of such importance that the triangulation to the eastward of Mount Lola and Round Top was extended to station Carson Sink, in approximate latitude 39° 35′ and longitude 118° 15′, a distance of approximately 110 miles from Mount Lola. The triangulation to the eastward of Cuyamaca and San Jacinto was extended to station Kofa, in approximate latitude 33° 20′ and longitude 114° 05′, a distance of approximately 155 miles from Cuyamaca.

The changes in geographic positions of the triangulation stations to the eastward of Mount Lola and Round Top are shown in Figure 3.

It is remarkable that the changes at Mount Como, Mount Grant, and Carson Sink are each less than 1 foot and that the change in position at Pah Rah is slightly less than 2½ feet. These changes are so small that they come well within the limits of accuracy which may be expected in triangulation. There is no indication whatever of any relative earth movements of these stations. We may, therefore, assume that Mount Lola and Round Top have not changed their positions since the first triangulation observations were made at them about 50 years ago.

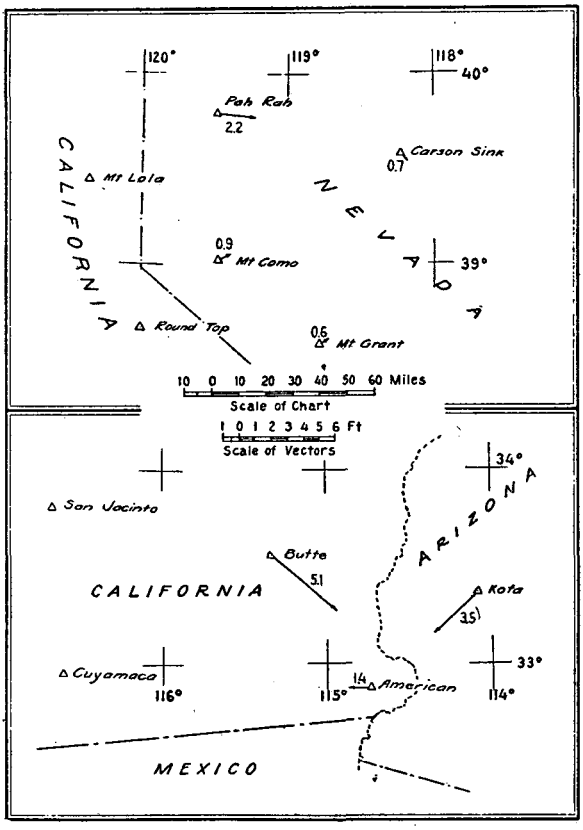

FIG. 3.—*Changes of positions to the eastward of the fixed ends of the California arc*

With regard to the work to the eastward of San Jacinto and Cuyamaca, we note that the change in geographic position at station American (see fig. 3) is less than 1½ feet, although American is 108 miles distant from Cuyamaca. The ratio of this change to the distance between that station and Cuyamaca is so small that it may be asserted that the change is due to triangulation uncertainties. With regard to Kofa, the change in geographic position is about 3½ feet and the distance from that station to Cuyamaca is more than 150 miles, or approximately 800,000 feet. The ratio is less than 1 part in 200,000, and therefore this change at Kofa can be considered as having been caused by errors of triangulation.

With regard to station Butte, there is some uncertainty as to whether or not the change of position, amounting to slightly more than 5 feet, is entirely due to errors of triangulation. The distance from Butte to San Jacinto is 79 miles (or approximately 420,000 feet), and the ratio of the change to the distance is about 1 part in 80,000. This ratio is small, and the change of position is probably due to errors of triangulation alone. When the changes at Butte and Kofa are compared it is found that the relative change in position is approximately 6½ feet. The distance between them is about 75 miles, or approxi-

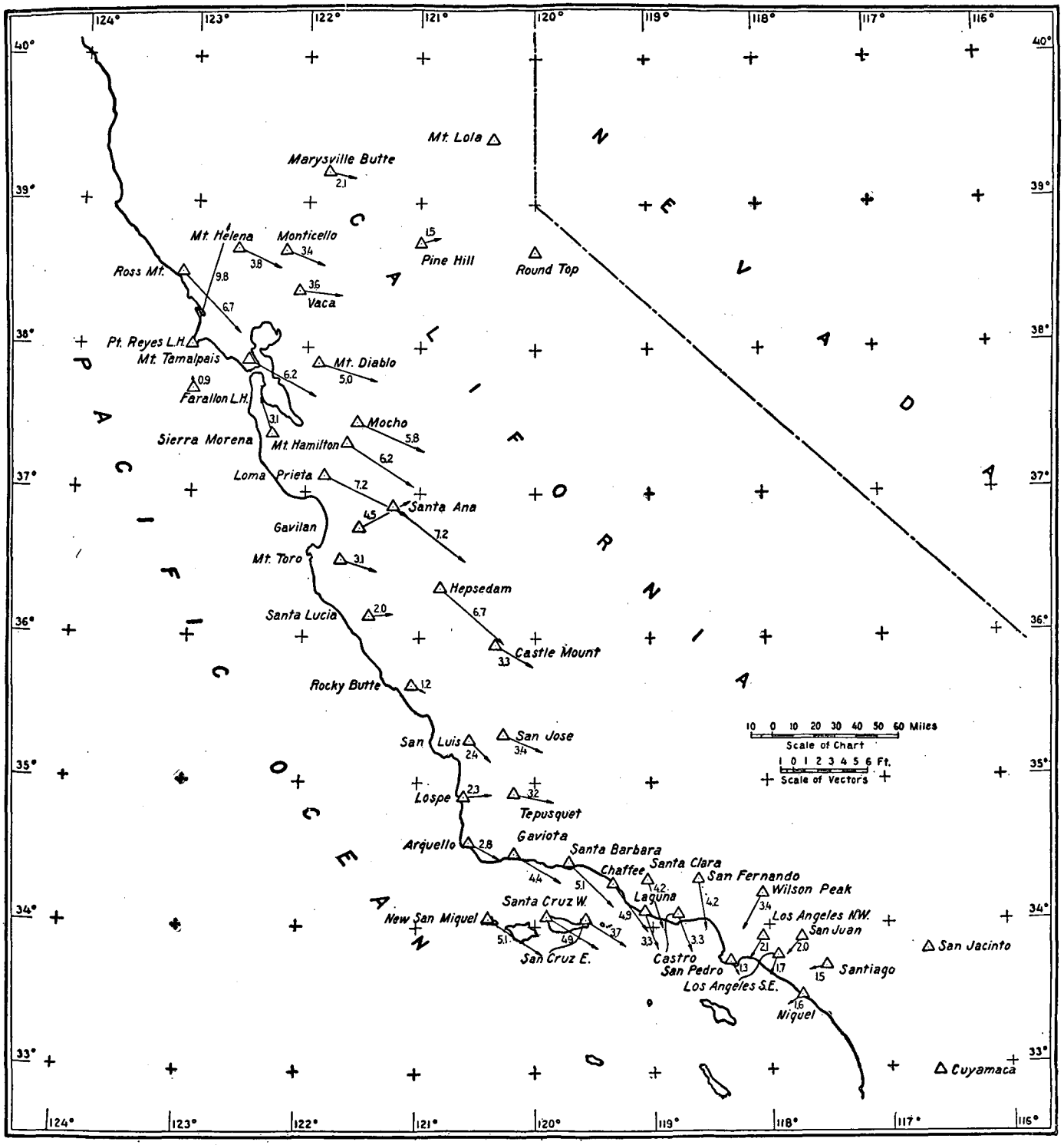

FIG. 2.—*Changes of positions of triangulation stations in California as determined by holding fixed the two ends of arc only*

6600°-28. (Face p. 10.)

mately 400,000 feet. The ratio is therefore approximately 1 part in 60,000. Both of these last two ratios are quite small, though they are larger than the ratios of the corrections to lengths of the various sections as obtained in the readjustment of the western triangulation net. The latter were seldom greater than 1 part in 150,000. It must be remembered that stations Cuyamaca, San Jacinto, Butte, and American are in a single quadrilateral. In such a figure it is improbable that the length of a line between any two of the triangulation stations is known with certainty within 1 part in 50,000. The above ratios are smaller than this.

In the new triangulation Kofa, Butte, and American form one triangle, and in this triangle the angle at Kofa was not reobserved. We seem to be justified from the above evidence and analysis of the data to conclude that there is no clear indication of earth movement at station Butte. We may therefore assume that there has been no earth movement to the eastward of stations Cuyamaca and San Jacinto.

It would seem from an analysis of the differences between the old and the new angles, together with the changes in geographic positions at the stations to the eastward of Mount Lola and Round Top, and of Cuyamaca and San Jacinto, that we are justified in assuming or concluding that Mount Lola and Round Top have not changed their positions relative to San Jacinto and Cuyamaca. We also seem to be justified in assuming that none of these stations have changed in absolute position with respect to the triangulation net of the whole country.

EXTENSION OF SPUR TO POINT ARENA

In 1925 the new triangulation was extended northward from Ross Mountain, Mount Helena, and Marysville Butte to Mount Sanhedrin and then down to Point Arena Lighthouse and to the Ukiah latitude station. This was done partly with funds of the Coast and Geodetic Survey and partly with money furnished by the Carnegie Institution of Washington.

All of the stations shown in Figure 8 had been established previous to 1905 by the Coast and Geodetic Survey. Unfortunately, Point Arena Lighthouse, whose position had been determined in the old triangulation, was moved in 1908, so that the original station could not be recovered.

Station Forty-Acre Opening probably was not exactly recovered by the 1925 party. The station was marked originally by a shallow drill hole in outcropping rock. This rock was found rather badly disintegrated in 1925. The observer discovered a slight depression that might have been the old station, but he was not absolutely sure. It is well, therefore, to consider that station Forty-Acre Opening was not recovered.

The Ukiah latitude station had not been included in the old triangulation scheme, and hence it is not possible to learn whether any earth movement occurred there during the 1906 earthquake or at other times in the past. It was included, however, in the new scheme, so that, at any time in the future, new triangulation can be used to determine whether or not the station has shifted in position. Its position is as follows: Latitude, 39° 08′ 14.″496; longitude, 123° 12′ 38.″127.

The triangulation to the northward of Ross Mountain and Mount Helena is of first-order accuracy, except from stations Fisher and Cold Spring to Point Arena Lighthouse which was third order in accuracy.

CHAPTER 3.—DISCUSSION OF FIRST-ORDER TRIANGULATION

METHODS EMPLOYED ON CALIFORNIA TRIANGULATION

The specifications for first-order triangulation require that the average closing errors of the triangles—that is, the deviation of the sum of the three observed angles from 180° plus the spherical excess of the triangle—must not be more than about 1 second and that the individual closing errors must seldom exceed 3 seconds. Both the old and new work in California conform to these requirements. Although the specifications for the old work in California were not as definite as those now in use, nevertheless the results were of high accuracy and conform in general to present-day standards. The old triangulation depended for the control of the lengths of triangle sides on bases measured in the vicinity of Los Angeles and Palo Alto, Calif., and Salt Lake City, Utah.

In the execution of the new work it was decided to strive for even greater accuracy than is usually obtained in first-order triangulation. The observing at each station was done on at least two nights instead of one, and double the usual number of observations were made. The average closing errors of the triangles in both the old and the new work were satisfactory.

It may be said that as great accuracy as may be desired can be obtained from triangulation. To secure this extreme accuracy, however, a tremendous effort would have to be made, and the cost in time and money would be great. The most exact measuring of this kind that has been done in the United States was that involved in the measurement of a base line and the determination by triangulation of the distance between San Antonio Peak and Mount Wilson in southern California for the use of Dr. A. A. Michelson in determining the velocity of light. The uncertainty in the distance between those two peaks, approximately 22 miles apart, as furnished to him by this bureau was not greater than 0.2 foot.

In ordinary first-order triangulation, frequently spoken of as precise or primary, the procedure is to measure base lines along an arc at intervals of approximately 200 or 300 miles, depending on the length of the triangle sides, and to measure the horizontal angles of each of the triangles involved in the net. The base measurement is done with two or more invar tapes, and check measurements are made to insure against blunders. The probable error of the length of a base line is usually about 1 part in 1,000,000, and the actual error is seldom greater than 1 part in 300,000. Such an accuracy means that a base 10 miles long is not in error by more than 0.2 foot. The base measurement is reduced to sea level in order that the computations of the triangulation may be referred to a mathematical surface rather than to the irregular one which constitutes the actual surface of the earth.

The measurement of the horizontal angles of the triangles is made with theodolites of the greatest precision. The theodolite is similar to an engineer's transit, but the workmanship is very much more perfect, the horizontal circle is larger, the graduations are made with greater accuracy, and the reading of the scale during the observations is made with micrometer microscopes.

In triangulation of first order 32 pointings are made on each of the stations contiguous to the station that is being occupied by the observer. The mean of these observations for any one station is taken as the measure of the direction to that station. In making the computations the observations are treated in pairs, and the mean of each pair (one observation made with the telescope direct and the other with it in the reverse position) is considered as a single determination. The average deviation of a single determination from the mean of all of the determinations of a direction is about two seconds. The maximum allowable deviation is only four seconds.

The effect of errors in the angle measurements is largely eliminated by the methods employed and by making a number of repetitions. There remains, however, one error having a considerable effect that is rather difficult to eliminate, namely, what we call lateral refraction. Where a line between two stations passes close to a mountain or hillside or over a valley where there is a decided vertical movement of air during the period of the observations, the line may be deviated sidewise a second of arc or more. This is a systematic or constant error that is not indicated by a variation in the individual measurements of a direction. Its presence can not be detected until the three angles of the triangle in which this line occurs have been measured and their sum compared with the theoretical sum, which is 180° plus the spherical excess of the triangle.

The great accuracy required in first-order triangulation may be better understood if one realizes that at a distance of 40 miles from the observer the sides of an angle of 1 second diverge only 1 foot. For other distances the divergence is in the same proportion, of course; that is, at 20 miles the divergence of a 1-second angle is ½ foot and at 100 miles it is 2½ feet. It is well to keep these values in mind when considering the effect of unavoidable errors in triangulation measurements on the geographic positions of the stations.

LAPLACE AZIMUTHS

In spite of the great accuracy with which horizontal angle measurements are made, there is always present a tendency for an arc of triangulation to swerve to the right or left of the direction of progress. This swerving may be, and probably is, due to meteorological conditions. It is nearly always greater than can be accounted for by the accidental errors in the angle observations.

To overcome this swerving of an arc of triangulation from its true direction the Coast and Geodetic Survey employs what are called Laplace azimuths. The use of these azimuths has marked a great step forward in the adjustment of arcs and nets of triangulation. A Laplace azimuth is one which is derived from astronomic observations on Polaris by applying a correction for the tilting of the meridian with respect to the spheroid.

It is well known to all who are engaged on triangulation that astronomic latitudes, longitudes, and azimuths are affected by what are termed "deflections of the vertical." Triangulation computations must be made on the spheroid, the mathematical surface that most nearly coincides with the geoid or sea-level surface. The sea-level surface is at all places at right angles to the direction of gravity, but the direction of gravity is influenced by near-by mountain masses or even large hills. A near-by valley has a similar effect on the plumb line but in a negative sense. At points along the coast the plumb line is drawn out of the normal to the spheroid owing to the mass above sea level on the continental side and the deficiency of mass in the waters of the ocean on the opposite side.

It is possible to determine the deflection of the vertical or the tilting of the meridian by comparing the astronomic latitudes and longitudes with geodetic latitudes and longitudes determined by triangulation. The astronomic latitudes and longitudes can be observed with such accuracy that redeterminations of the values will generally show an agreement with the original ones of about 15 feet in latitude and about 40 feet in longitude. The geodetic latitudes and longitudes can be determined with an accuracy that compares with that of the astronomic observations. When the astronomic latitudes and longitudes are compared with the geodetic values it is sometimes found that they differ as much as 20 or 30 seconds (corresponding to a half mile or more in linear measure) in extreme cases and that the agreement is very seldom less than 2 seconds. Two seconds in latitude is approximately 200 feet, and two seconds in longitude in latitude 39° is approximately 170 feet.

For a Laplace station azimuth observations are made on Polaris at a triangulation station whose astronomic longitude has also been determined. The amount the vertical is deflected is obtained by comparing the two values of the longitude, and a correction is then applied to the azimuth observations to make them conform to the values which would be obtained if the horizontal circle of the theodolite could be placed in a plane tangent to the mathematical spheroid at the point of observation. In other words, the Laplace azimuth obtained by the above process is merely the observed astronomic azimuth corrected for the tilting of the meridian.

ACCURACY OF TRIANGULATION AS DISCLOSED BY THE READJUSTMENT OF THE NET IN WESTERN UNITED STATES

The triangulation of the Coast and Geodetic Survey, done prior to 1908, had been adjusted in long arcs across the country without the use of Laplace azimuths. At about that time it was realized that Laplace azimuths are an essential part of triangulation, but the network of the United States was then so far from completion that it was not thought necessary to disturb the geographic positions of the arcs previously adjusted. As new arcs were measured they were made to fit between the old ones, and since the discrepancies involved in the loops or arcs were not excessive, it was believed that no readjustment of the old work would be needed. This opinion, however, was later found to be erroneous when the triangulation had become greatly extended. As the large loops were divided by new arcs it became increasingly difficult to fit the new into the old arcs, and

very large corrections had to be applied to the new work. This led to the conclusion that the whole western half of the triangulation net of the United States should be readjusted in order that all arcs forming a circuit should take their proportionate share of the closing error of the loop.

For a long time it was not thought feasible, although very desirable, to make this readjustment because, by the old methods (now held to be classical), the work involved might be something like 50 to 75 years of computing for one expert mathematician. It might have taken 25 or 30 years to complete the work, since only a few mathematicians could have been employed on the scheme at the same time. Fortunately, a method was devised at the office of the Coast and Geodetic Survey [1] which makes it possible to adjust a triangulation net over large areas in a short time and with a relatively small amount of effort. A dozen or more mathematicians were able to work simultaneously on the western net, and in 15 months the readjustment was completed in so far as obtaining the most probable positions of the junction points of the various arcs in the net was concerned.

The method used in making this readjustment is described in Serial No. 350, which appeared in 1926. The preliminary results of the adjustment are contained in Special Publication No. 134, Geodetic Operations in the United States, January 1, 1924, to December 31, 1926, which was issued in 1927.

This readjustment really served many purposes, but the immediate one was to furnish a more reliable datum on which to base the triangulation of western Canada and Alaska. This was accomplished by obtaining the most probable positions for triangulation stations in northwestern Washington from which computations could be carried through an arc of triangulation extending along the coast of British Columbia and through southeastern Alaska.

In using the new method, the first step was to determine the most probable value for the length and azimuth of a line at each junction of the arcs of triangulation. Each of the various arcs was then adjusted between the junction points by holding fixed the lengths and azimuths of the junction lines and any bases and Laplace azimuths along the arc. Then, starting at Meades Ranch, the station used in defining the North American datum, geographic positions were computed through the various arcs and the discrepancies at the different junction points were obtained. With these data the method of least squares was used to determine the most probable values for the latitude and longitude of a selected station at each junction point of the system. The intermediate arcs were then fitted in between the junction stations.

Figures 4 and 5 show the great accuracy that exists in the triangulation of the western half of the country when the lengths and azimuths are controlled by an adequate number of base lines and Laplace azimuths. It will be noticed in Figure 4 that for the 16 loops of triangulation in the net the average closure of a loop is about 1 part in 435,000 and that there are only two loops that have closing errors greater than 1 part in 200,000.

[1] Serial No. 350, Report on the Readjustment of the First-Order Triangulation Net of the Western Part of the United States, by O. S. Adams.

In Figure 5 are given the corrections which were applied to the several sections in order to make the loops, of which the sections form parts, close exactly. The first number is the correction to the

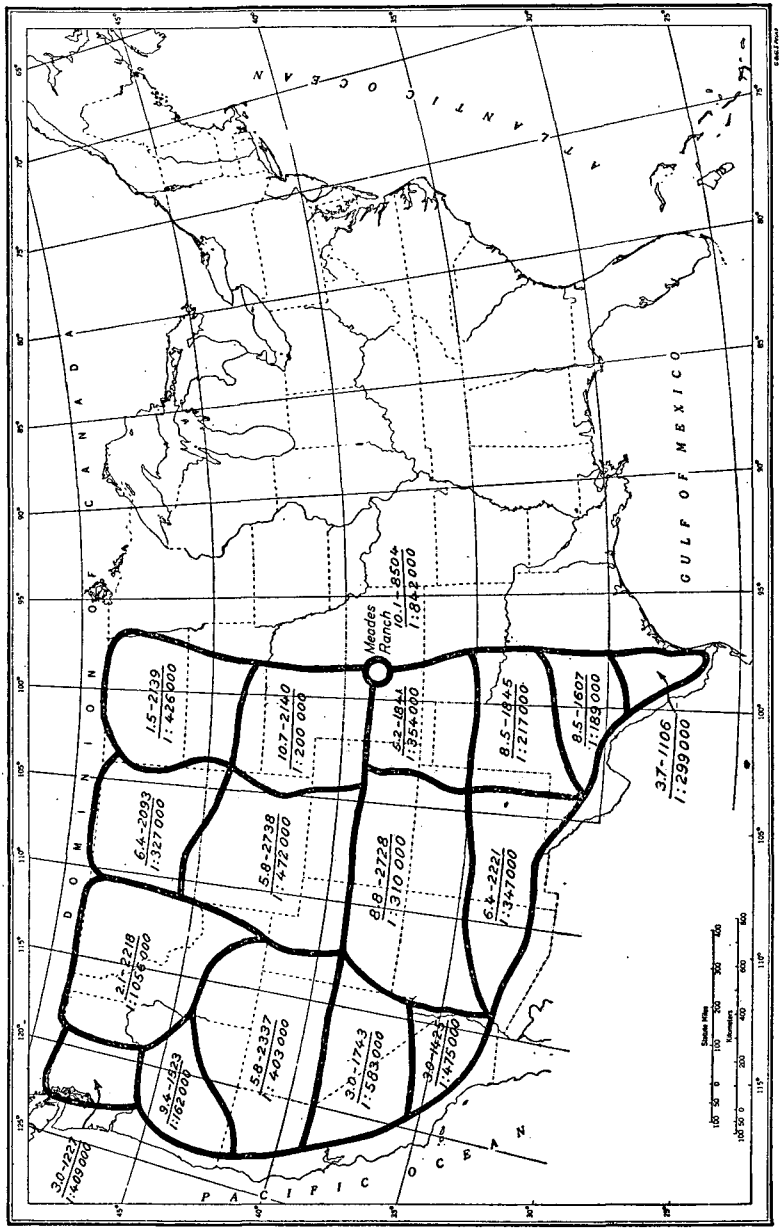

FIG. 4.—*Loop closures resulting from the readjustment of the western half of the United States*

For each loop the first number above the line is the total closure in meters and the second number the approximate length of the loop in kilometers. Below the line is the approximate proportional part of the whole circuit represented by the closure

latitude in meters, the second is the correction to the longitude in meters, and the third is the total correction in geographic position in meters. On the opposite side of the line is given the ratio the correction to the position bears to the length of the section.

It will be noticed that the average correction to a section is about 1 part in 300,000. Only 15 of the 42 sections have corrections greater than 1 part in 200,000, and the largest correction is 1 part in 120,000.

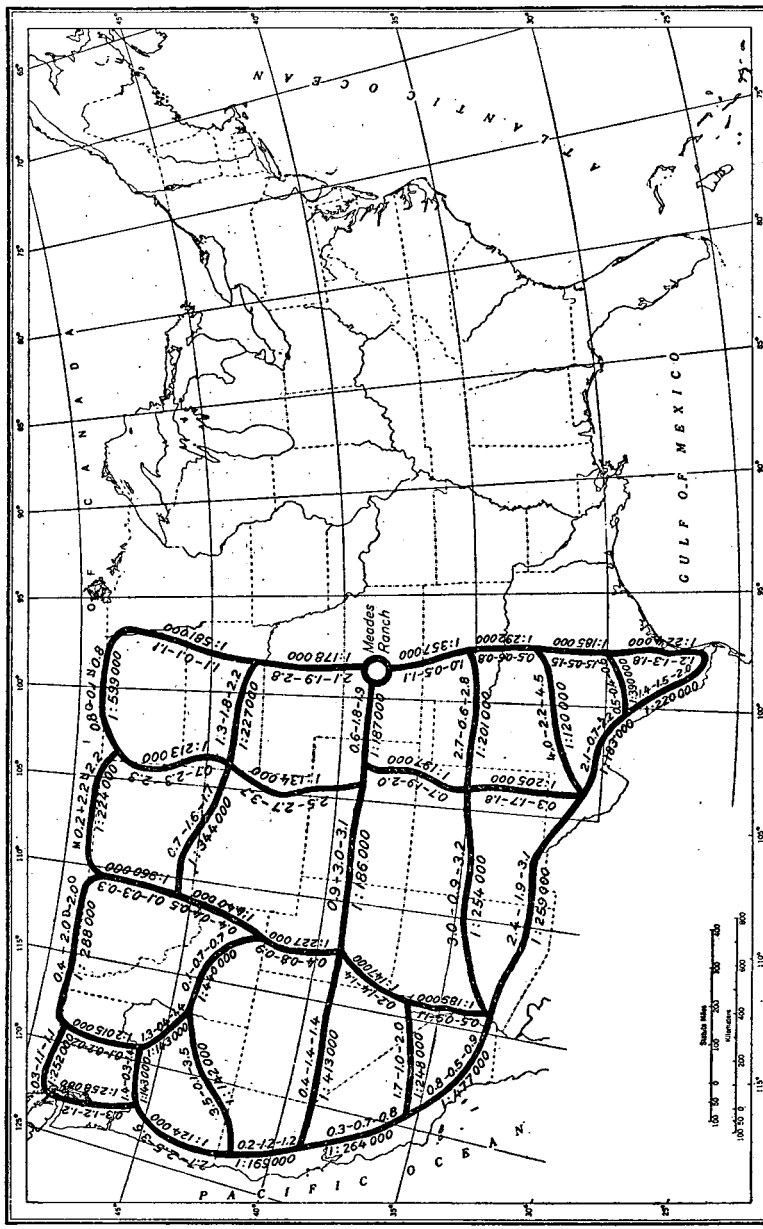

FIG. 5.—*Section closures in western half of the United States resulting from apportionment of loop closures*

For each section the first number above the line is the closure of latitude in meters, the second number the closure in longitude in meters, and the third number the total closure in meters. Below the line is the approximate proportional part of the length of the section represented by the total closure

The data given on Figures 4 and 5 show that the accumulated error in an arc of triangulation which has been adjusted into a net is, in the majority of cases, smaller than 1 part in 200,000 of the distance from

the starting point. One part in 200,000 is equivalent to about 1 inch in 3 miles, 1 foot in 40 miles, or 2½ feet in 100 miles. Of course, on an occasional arc the error may be greater than this.

When an arc is started from two stations whose geographic positions, distance apart, and azimuth of the line between them are held fixed, but there are no Laplace azimuths or base lines along the arc to control it, then the positions computed through the triangulation may be in error by an amount much greater than 1 part in 200,000. This was evidently the case with the first computation of the arc extending from Mount Lola and Round Top southward to the stations Arguello and Gaviota, shown in Figure 1 of this publication, and in Figure 3 of Special Publication No. 106. The distance of the center of the line joining Arguello and Gaviota from a point midway between Mount Lola and Round Top through the axis of the triangulation is about 400 miles. The error to be expected in the geographic position through such a distance where no base line or Laplace azimuth was used might be of the order of 20 or 30 feet. The actual difference in geographic position found at Gaviota was 24 feet or 1 part in 88,000 of the distance and that at Arguello was 22 feet. As stated in Special Publication No. 106, a careful inspection of the observations, made both prior to 1900 and during recent years at the various triangulation stations involved, failed to disclose any blunder that might cause the large changes in geographic positions. There must have been a bunching of accidental errors of triangulation which caused the rather large rate of accumulation of change in geographic position from stations Mount Toro and Santa Ana to Arguello and Gaviota and which resulted in the large changes in position at the latter two points.

Having in mind the accuracy obtained in extending arcs of triangulation across country, as indicated by the closing errors of the loops of triangulation in the western half of the United States, and the corrections which had to be applied to the several sections, we are now in a better position to decide whether the differences in geographic positions found at triangulation stations in California are due to earth movements or to accidental errors of triangulation.

It is believed that, as a working rule, we may assume that the distance in a quadrilateral between any two of the stations forming it should be correct within 1 part in 75,000. An exception to this would be the case of a short line of a quadrilateral opposite a very small angle. When a triangulation has been reobserved over the same stations, an error in a line of 1 part in 75,000, but of the opposite sign to what it was in the original work, might result in a difference in the lengths as determined by the old and the new triangulation of about 1 part in 40,000. Therefore, if the ratio of the change in geographic positions between two stations of a quadrilateral to the distance between those stations is less than 1 part in 40,000, we may assume that the relative change in position is likely to have been caused by the unavoidable errors of triangulation.

Judging from the small corrections to the sections of the triangulation net of the western half of the country as determined in the readjustment, we may conclude that for properly adjusted triangulation the uncertainty, due to triangulation errors, of the geographic position of one triangulation station with respect to that of another which is several quadrilaterals away should seldom be greater than about 1 part in 150,000. Where triangulation is reobserved over the same stations,

the ratio of the differences in geographic positions for two stations as determined by the old and the new work should not be greater than 1 part in 75,000 of the distance between the stations. This is the maximum limit which should seldom be exceeded. Where two stations are widely separated—say, 200 miles or more—their relative changes in geographic position from errors of triangulation alone should seldom exceed 1 part in 100,000 of the distance between the stations.

ACCURACY OF ANGLE MEASUREMENTS IN FIRST-ORDER TRIANGULATION

Prior to the work done in California the Coast and Geodetic Survey had no extensive data in regard to the agreement to be expected in redeterminations of triangulation angles. The California data enables us to form a rather clear idea of what agreement to expect where the stations apparently have not changed their geographic positions.

In another part of this report evidence is presented (p. 44) to show that probably Monticello, Mount Helena, and Vaca have not shifted in geographic positions with respect to Mount Lola and Round Top. (See fig. 6.) Evidence is also presented (p. 35) which indicates that there have been no earth movements for the stations from Mount Lola and Round Top to Carson Sink. (See fig. 3.)

Between Mount Helena and Monticello on the west and Mount Grant and Carson Sink on the east there are 90 angles. Of these angles, 78 have changes less than 1 second, 11 show changes between 1 and 2 seconds, and only one has a change greater than 2 seconds. This maximum change is 2.65 seconds.

For the 14 angles between Cuyamaca and San Jacinto on the west and Kofa on the east 7 have changes less than 1 second, 5 have changes between 1 and 2 seconds, and only 2 have changes greater than 2 seconds. Only three have changes greater than 1.5 seconds. The maximum difference between an old and a new angle is 2.21 seconds.

It has been shown elsewhere in this report (p. 36) that the changes in geographic positions between stations Lospe and Tepusquet on the north and San Jacinto and Cuyamaca on the south are so small that they may be due entirely to the errors in triangulation. No actual earth movements are evident at these stations. In this arc of triangulation there are 150 angles. The changes between the old and the new angles are less than 1 second for 105 angles, between 1 and 2 seconds for 42 angles, and between 2 and 3 seconds for 3 of the angles. The maximum correction to an angle is 2.66 seconds, and the next smaller is 2.39 seconds.

This distribution of the differences between the old and the new angles seems to follow closely the law of distribution of accidental errors. It would appear that these errors are really accidental, as the average of the closing errors of the triangles is only about 1 second and the maximum closing error is seldom more than 3 seconds. As previously stated, the closing error of a triangle is the difference between 180° and the sum of the three observed angles less the spherical excess. The correction for spherical excess is to take account of the fact that the observed angles are spherical rather than plane.

Since for the 254 angles under consideration there are only 6 with changes greater than 2 seconds, we may safely conclude that any difference between an old and a new angle that is greater than 3 seconds is an indication of actual earth movement at one or more of the stations of the triangle of which the angle considered is a part. It might even be reasonably assumed that any difference between an old and a new angle of 2.4 seconds is an indication of earth movement, since there were only two angles of the 254 considered that have changes greater than that amount. It is possible that some of the differences as small as 2 seconds may be actually due to earth movements rather than to accidental errors of observation, but there seems to be no method of differentiating the effects of the two causes. It may be said, however, that those stations having changes as great as 2 seconds should be reoccupied in the future to learn whether or not any progressive changes are occurring in the angles.

CHAPTER 4.—ANALYSES AND INTERPRETATION OF ANGLE CHANGES IN CALIFORNIA TRIANGULATION

ANGLE CHANGES IN NORTHERN HALF OF CALIFORNIA ARC

If we assume that any change of 3 seconds in an angle is a definite indication of earth movement, we find, in considering the triangles from Mount Helena and Monticello on the north toward Lospe and Tepusquet at the south, that no angles changed more than 2 seconds until the triangle is reached which involves stations Sierra Morena, Mount Tamalpais, and Mount Diablo. In this triangle the new angle at Sierra Morena is 3.44 seconds larger than the old one, that at Mount Tamalpais is 5.21 seconds larger, and that at Mount Diablo is 8.65 seconds smaller than the old one. In the triangle involving stations Mocho, Sierra Morena, and Mount Tamalpais the new angle at Mocho is 5.86 seconds smaller, at Mount Tamalpais 3.76 seconds larger, and at Sierra Morena 2.10 seconds larger than the old ones. In the triangle formed by the stations Mocho, Sierra Morena, and Mount Diablo the new angle at Mocho is 5.48 seconds smaller than the old one, the angle at Sierra Morena remains practically the same, and the new angle at Mount Diablo is larger than the old one by 6.82 seconds. The three triangles mentioned above surely indicate an earth movement, and the movement seems to have been at station Sierra Morena, since this station is in each of the three triangles. There is no change greater than 1.83 seconds in the triangle Mocho, Mount Tamalpais, and Mount Diablo.

In the triangle Loma Prieta, Sierra Morena, and Mount Diablo the angle at Loma Prieta has changed very little, but at Sierra Morena it has decreased 7.18 seconds, and at Mount Diablo it has increased 8.41 seconds. In the triangle Loma Prieta, Sierra Morena, and Mocho the angle at the first station has decreased only 1.85 seconds, but at the second station the angle has decreased 5.84 seconds, and at the third station it has increased 7.69 seconds. Here again the two triangles involve Sierra Morena. This station surely must have moved with respect to the other stations involved in the triangles.

The greatest change in the triangle Loma Prieta, Mount Diablo, and Mocho is only 2.21 seconds, so it is difficult to tell whether any relative earth movement has occurred among those stations. The ratio of the relative change at Mount Diablo and Loma Prieta to the distance between those two stations is 1 part in 70,000.

In the triangle Santa Ana, Loma Prieta, and Mocho there is an increase of 3.10 seconds in the Loma Prieta angle and a decrease of 2.36 seconds in the Mocho angle. There has evidently been a small amount of earth movement in one or more of these three stations.

In the triangle Mount Toro, Loma Prieta, and Mocho there has been an increase in the Loma Prieta angle of 4.32 seconds and a decrease in the Mocho angle of 3.43 seconds. In the triangle Mount Toro, Loma Prieta, and Santa Ana the angle at Mount Toro has

increased 2.63 seconds and the angle at Santa Ana has decreased 3.85 seconds. The angle at Loma Prieta changed only 1.22 seconds. In the triangle Mount Toro, Mocho, and Santa Ana the angle at Mount Toro has increased 3.52 seconds, and at Santa Ana it has decreased 4.59 seconds. The angle at Mocho has changed about 1 second. Mount Toro is the only station that is common to these three triangles, and the indications are that it is the station which has moved with respect to the others. Of course, it may be that Mount Toro has remained fixed while all of the other stations have moved with respect to it, but there is no direct evidence in the angles to show what stations actually moved.

Some information in regard to Mount Toro may be obtained from a consideration of the three triangles involving the station Gavilan. That station was not one of the main-scheme stations in the old work but a supplementary one. In the triangle involving Gavilan, Santa Ana, and Mount Toro the angle at Gavilan has decreased 12.80 seconds, the one at Santa Ana has increased 7.89 seconds, and the one at Mount Toro has increased 4.91 seconds. In the triangle involving Gavilan, Mount Toro, and Loma Prieta the only angle that changed more than 2.4 seconds is the one at Loma Prieta, which increased 3.76 seconds. In the triangle Gavilan, Loma Prieta, and Santa Ana the angle at Gavilan has increased 14.18 seconds, the one at Loma Prieta has decreased 2.52 seconds, and the one at Santa Ana has decreased 11.66 seconds. Mount Toro is in two of these triangles, each of which has had decided changes in the angles. There has undoubtedly been relative movement between Gavilan and Mount Toro. Gavilan has also changed position decidedly with respect to Loma Prieta and Santa Ana, as is indicated by the changes in the angles of the third triangle mentioned above.

Comparison of angles, new and old triangulation

CUYAMACA-SAN JACINTO TO KOFA

Number of triangle	Stations	Spherical angles				Differences, new-old
		New			Old	
		°	′	″	″	″
1	Butte	42	54	59.35	60.45	−1.10
	Cuyamaca	63	33	13.10	10.89	+2.21
	San Jacinto	73	32	17.40	18.51	−1.11
2	American	27	22	46.58	46.36	+0.22
	Cuyamaca	96	45	26.94	26.90	+0.04
	San Jacinto	55	52	28.80	29.06	−0.26
3	American	51	07	49.65	47.98	+1.67
	Cuyamaca	33	12	13.81	16.01	−2.20
	Butte	95	40	29.41	28.88	+0.53
4	American	23	45	03.07	01.62	+1.45
	San Jacinto	17	39	48.57	49.45	−0.88
	Butte	138	35	28.76	29.33	−0.57
5	Kofa	52	38	49.35	49.99	−0.64
	American	83	15	38.40	39.24	−0.84
	Butte	44	05	52.45	50.97	+1.48

Comparison of angles, new and old triangulation—Continued

LOSPE-TEPUSQUET TO SAN JACINTO-CUYAMACA

Number of triangle	Stations	Spherical angles				Differences, new-old
		New			Old	
		°	′	″	″	″
1	Gaviota	41	55	59.05	60.82	−1.77
	Lospe	52	04	21.92	21.57	+0.35
	Tepusquet	85	59	43.44	42.02	+1.42
2	Arguello	50	01	59.54	60.29	−0.75
	Lospe	86	03	07.92	07.66	+0.26
	Tepusquet	43	54	55.92	55.43	+0.49
3	Arguello	111	45	07.99	07.01	+0.98
	Lospe	33	58	46.00	46.09	−0.09
	Gaviota	34	16	08.84	09.73	−0.89
4	Arguello	61	43	08.45	06.72	+1.73
	Tepusquet	42	04	47.52	46.59	+0.93
	Gaviota	76	12	07.89	10.55	−2.66
5	New San Miguel	33	30	00.47	00.26	+0.21
	Arguello	59	59	37.39	39.78	−2.39
	Gaviota	86	30	26.87	24.69	+2.18
6	Santa Cruz, west	48	37	22.88	22.65	+0.23
	New San Miguel	99	52	58.55	57.76	+0.79
	Arguello	31	29	45.35	46.37	−1.02
7	Santa Cruz, west	66	19	05.38	05.50	−0.12
	New San Miguel	66	22	58.08	57.50	+0.58
	Gaviota	47	18	02.01	02.47	−0.46
8	Santa Cruz, west	17	41	42.50	42.85	−0.35
	Arguello	28	29	52.04	53.41	−1.37
	Gaviota	133	48	28.88	27.16	+1.72
9	Santa Barbara	76	48	04.59	03.25	+1.34
	Santa Cruz, west	55	18	31.86	31.20	+0.66
	Gaviota	47	53	28.22	30.22	−2.00
10	Santa Cruz, east	36	51	00.41	00.02	+0.39
	Santa Cruz, west	121	55	22.41	22.00	+0.41
	Gaviota	21	13	41.00	41.80	−0.80
11	Santa Cruz, east	66	41	42.44	41.93	+0.51
	Santa Cruz, west	66	36	50.55	50.80	−0.25
	Santa Barbara	46	41	30.15	30.41	−0.26
12	Santa Cruz, east	29	50	42.03	41.91	+0.12
	Gaviota	26	39	47.22	48.42	−1.20
	Santa Barbara	123	29	34.74	33.66	+1.08
13	Chaffee	69	47	58.07	58.77	−0.70
	Santa Cruz, east	57	52	58.21	56.81	+1.40
	Santa Barbara	52	19	06.80	07.50	−0.70
14	Laguna	36	09	08.59	08.64	−0.05
	Santa Cruz, east	102	06	58.01	57.50	+0.51
	Santa Barbara	41	43	58.16	58.62	−0.46
15	Laguna	48	17	58.30	58.11	+0.19
	Santa Cruz, east	44	13	59.80	60.69	−0.89
	Chaffee	87	28	04.77	04.07	+0.70
16	Laguna	12	08	49.71	49.47	+0.24
	Santa Barbara	10	35	08.64	08.88	−0.24
	Chaffee	157	16	02.84	02.84	0.00
17	Santa Clara	52	41	44.50	44.89	−0.39
	Laguna	102	51	31.35	31.07	+0.28
	Santa Cruz, east	24	26	46.94	46.83	+0.11
18	Santa Clara	78	32	07.39	08.77	−1.38
	Laguna	54	33	33.05	32.96	+0.09
	Chaffee	46	54	21.19	19.90	+1.29
19	Santa Clara	25	50	22.89	23.88	−0.99
	Santa Cruz, east	19	47	12.86	13.86	−1.00
	Chaffee	134	22	25.96	23.97	+1.99

Comparison of angles, new and old triangulation—Continued

LOSPE-TEPUSQUET TO SAN JACINTO-CUYAMACA—Continued

Number of triangle	Stations	Spherical angles			Differences, new-old
		New		Old	
		° ′ ″		″	″
20	Castro	43 05 42.25		42.87	−0.62
	Laguna	89 55 33.21		34.37	−1.16
	Santa Clara	46 58 46.13		44.35	+1.78
21	San Fernando	57 15 59.02		58.93	+0.09
	Castro	73 18 21.39		20.41	+0.98
	Santa Clara	49 25 42.35		43.42	−1.07
22	Wilson Peak	26 11 24.40		24.57	−0.17
	Castro	44 46 21.46		22.50	−1.04
	San Fernando	109 02 18.06		16.85	+1.21
23	San Pedro	11 16 24.49		24.60	−0.11
	Laguna	25 03 50.02		51.20	−1.18
	Castro	143 39 47.68		46.39	+1.29
24	San Pedro	27 04 26.53		26.30	+0.23
	Castro	99 56 08.68		10.33	−1.65
	San Fernando	52 59 29.28		27.86	+1.42
25	San Pedro	73 11 41.06		41.26	−0.20
	Castro	55 09 47.21		47.83	−0.62
	Wilson Peak	51 38 39.75		38.93	+0.82
26	San Pedro	46 07 14.53		14.96	−0.43
	San Fernando	56 02 48.78		48.99	−0.21
	Wilson Peak	77 50 04.14		03.50	+0.64
27	Northwest Base	125 41 32.82		33.29	−0.47
	San Pedro	27 57 56.34		55.67	+0.67
	Wilson Peak	26 20 33.09		33.29	−0.20
28	Southeast Base	60 35 30.36		32.29	−1.93
	San Pedro	28 21 15.90		14.95	+0.95
	Northwest Base	91 03 15.17		14.19	+0.98
29	Southeast Base	85 01 13.31		15.07	−1.76
	San Pedro	56 19 12.24		10.62	+1.62
	Wilson Peak	38 39 39.03		38.89	+0.14
30	Southeast Base	24 25 42.95		42.78	+0.17
	Northwest Base	143 15 12.01		12.52	−0.51
	Wilson Peak	12 19 05.94		05.60	+0.34
31	San Juan	16 54 51.49		50.85	+0.64
	Southeast Base	152 32 14.01		15.21	−1.20
	San Pedro	10 32 55.50		54.94	+0.56
32	San Juan	36 20 17.73		17.58	+0.15
	Southeast Base	91 56 43.65		42.92	+0.73
	Northwest Base	51 42 59.65		60.53	−0.88
33	San Juan	84 26 21.15		21.69	−0.54
	Southeast Base	67 31 00.70		00.14	+0.56
	Wilson Peak	28 02 40.82		40.84	−0.02
34	San Juan	19 25 26.24		26.73	−0.49
	San Pedro	17 48 20.40		20.01	+0.39
	Northwest Base	142 46 14.82		14.72	+0.10
35	San Juan	67 31 29.66		30.84	−1.18
	San Pedro	45 46 16.74		15.68	+1.06
	Wilson Peak	66 42 19.85		19.73	+0.12
36	San Juan	48 06 03.42		04.11	−0.69
	Northwest Base	91 32 12.36		11.99	+0.37
	Wilson Peak	40 21 46.76		46.44	+0.32
37	Santiago	46 50 42.55		43.42	−0.87
	San Pedro	21 33 24.03		24.47	−0.44
	San Juan	111 35 57.48		56.17	+1.31
38	Santiago	46 18 46.57		47.37	−0.80
	San Pedro	67 19 40.77		40.15	+0.62
	Wilson Peak	66 21 42.92		42.74	+0.18

Comparison of angles, new and old triangulation—Continued

LOSPE-TEPUSQUET TO SAN JACINTO-CUYAMACA—Continued

Number of triangle	Stations	Spherical angles				Differences, new-old
		New			Old	
		°	′	″	″	″
39	Santiago	0	31	55.98	56.05	−0.07
	Wilson Peak	0	20	36.93	36.99	−0.06
	San Juan	179	07	27.14	27.01	+0.13
40	Niguel	44	01	10.30	11.53	−1.23
	San Pedro	89	14	30.77	28.94	+1.83
	Wilson Peak	46	44	28.13	28.73	−0.60
41	Niguel	105	04	22.03	23.67	−1.64
	San Pedro	21	54	50.00	48.79	+1.21
	Santiago	53	00	52.32	51.89	+0.43
42	Niguel	61	03	11.73	12.14	−0.41
	Wilson Peak	19	37	14.79	14.01	+0.78
	Santiago	99	19	38.89	39.26	−0.37
43	Niguel	64	28	06.28	06.81	−0.53
	San Pedro	43	28	14.03	13.26	+0.77
	San Juan	72	03	45.98	46.22	−0.24
44	Niguel	20	26	55.98	55.28	+0.70
	Wilson Peak	19	57	51.72	51.00	+0.72
	San Juan	139	35	15.64	17.06	−1.42
45	Niguel	40	36	15.75	16.86	−1.11
	San Juan	39	32	11.50	09.95	+1.55
	Santiago	99	51	34.87	35.31	−0.44
46	San Jacinto	14	45	27.76	28.87	−1.11
	Santiago	121	21	19.38	17.65	+1.73
	San Juan	43	53	17.97	18.59	−0.62
47	San Jacinto	28	00	55.17	56.73	−1.56
	Santiago	121	53	15.36	13.70	+1.66
	Wilson Peak	30	06	02.41	02.51	−0.10
48	San Jacinto	13	15	27.41	27.86	−0.45
	San Juan	136	59	14.89	14.40	+0.49
	Wilson Peak	29	45	25.48	25.52	−0.04
49	Cuyamaca	13	33	27.34	27.18	+0.16
	Niguel	80	23	42.69	42.49	+0.20
	Santiago	86	02	58.79	59.15	−0.36
50	Cuyamaca	41	17	37.49	36.62	+0.87
	Santiago	52	44	06.96	07.89	−0.93
	San Jacinto	85	58	35.13	35.07	+0.06

MOUNT HELENA-MONTICELLO TO MOUNT GRANT-CARSON SINK

1	Mount Diablo	20	20	00.56	00.82	−0.26
	Mount Helena	19	56	16.97	16.44	+0.53
	Vaca	139	43	47.87	48.14	−0.27
2	Mount Diablo	38	40	31.22	31.70	−0.48
	Mount Helena	94	28	45.94	45.47	+0.47
	Marysville Butte	46	51	08.01	08.00	+0.01
3	Mount Diablo	18	20	30.66	30.88	−0.22
	Vaca	150	48	18.87	18.89	−0.02
	Marysville Butte	10	51	17.16	16.92	+0.24
4	Vaca	39	31	32.67	32.60	+0.07
	Mount Helena	33	17	27.15	27.73	−0.58
	Monticello	107	11	03.29	02.78	+0.51
5	Vaca	69	27	53.26	52.97	+0.29
	Mount Helena	74	32	28.97	29.03	−0.06
	Marysville Butte	35	59	50.85	51.08	−0.23
6	Mount Diablo	34	26	00.78	00.93	−0.15
	Marysville Butte	105	01	29.93	30.66	−0.73
	Mount Lola	40	34	15.50	14.62	+0.88

Comparison of angles, new and old triangulation—Continued

MOUNT HELENA-MONTICELLO TO MOUNT GRANT-CARSON SINK—Continued

Number of triangle	Stations	Spherical angles				Differences, new-old
		New			Old	
		°	′	″	″	″
7	Mount Diablo	58	51	33.29	33.28	+0.01
	Marysville Butte	72	53	42.29	43.54	−1.25
	Round Top	48	15	44.74	43.50	+1.24
8	Mount Helena	3	32	06.11	05.67	+0.44
	Pine Hill	1	18	12.46	12.29	+0.17
	Monticello	175	09	42.30	42.91	−0.61
9	Mount Helena	36	49	33.26	33.40	−0.14
	Pine Hill	19	44	52.85	52.79	+0.06
	Vaca	123	25	46.50	46.42	+0.08
10	Mount Helena	56	45	50.23	49.84	+0.39
	Pine Hill	47	00	42.26	41.31	+0.95
	Mount Diablo	76	14	00.24	01.58	−1.34
11	Monticello	77	39	14.41	14.31	+0.10
	Pine Hill	18	26	40.39	40.50	−0.11
	Vaca	83	54	13.83	13.82	+0.01
12	Monticello	78	07	24.48	24.25	+0.23
	Pine Hill	45	42	29.80	29.02	+0.78
	Mount Diablo	56	10	29.13	30.14	−1.01
13	Marysville Butte	32	07	47.64	47.12	+0.52
	Mount Lola	99	28	10.02	10.46	−0.44
	Round Top	48	24	31.53	31.61	−0.08
14	Pine Hill	172	51	48.57	46.98	+1.59
	Mount Diablo	3	07	28.24	28.95	−0.71
	Mount Lola	4	00	46.92	47.80	−0.88
15	Pine Hill	59	39	48.86	47.80	+1.06
	Mount Lola	54	54	07.60	08.04	−0.44
	Round Top	65	26	21.69	22.31	−0.62
16	Pine Hill	127	28	22.57	25.22	−2.65
	Round Top	31	13	54.58	52.80	+1.78
	Mount Diablo	21	18	04.27	03.40	+0.87
17	Mount Lola	58	54	54.52	55.19	−0.67
	Round Top	96	40	16.27	15.23	+1.04
	Mount Diablo	24	25	32.51	32.88	−0.37
18	Pine Hill	27	15	49.41	48.52	+0.89
	Mount Diablo	55	53	59.68	00.76	−1.08
	Vaca	96	50	25.63	25.44	+0.19
19	Marysville Butte	21	54	10.53	10.50	+0.03
	Monticello	116	50	53.61	54.16	+0.45
	Mount Helena	41	15	01.82	01.30	−0.48
20	Marysville Butte	14	05	40.32	40.58	−0.26
	Vaca	29	56	20.59	20.37	+0.22
	Monticello	135	58	03.10	03.06	+0.04
21	Mount Diablo	20	03	31.11	31.44	−0.33
	Mount Helena	53	13	44.12	44.17	−0.05
	Monticello	106	42	53.22	52.84	+0.38
22	Mount Diablo	0	16	29.45	29.38	+0.07
	Monticello	0	28	10.07	09.94	+0.13
	Vaca	179	15	20.54	20.74	−0.20
23	Mount Diablo	18	37	00.11	00.26	−0.15
	Monticello	136	26	13.17	13.00	+0.17
	Marysville Butte	24	56	57.48	57.50	−0.02
24	Mount Lola	39	12	28.64	28.23	+0.41
	Mount Como	71	46	22.32	23.25	−0.73
	Round Top	69	01	21.92	21.60	+0.32
25	Mount Lola	58	23	31.72	33.11	−1.39
	Pah Rah	62	37	05.66	05.66	0
	Mount Como	58	59	39.33	37.94	+1.39

Comparison of angles, new and old triangulation—Continued

MOUNT HELENA-MONTICELLO TO MOUNT GRANT-CARSON SINK—Continued

Number of triangle	Stations	Spherical angles				Differences, new-old
		New			Old	
		°	′	″	″	″
26	Round Top	46	21	05.52	05.87	−0.35
	Mount Como	99	15	12.88	12.88	0
	Mount Grant	34	23	53.38	53.03	+0.35
27	Mount Como	129	58	45.27	45.94	−0.67
	Pah Rah	23	39	57.38	56.96	+0.42
	Mount Grant	26	21	30.31	30.06	+0.25
28	Pah Rah	54	15	20.68	20.48	+0.20
	Carson Sink	79	30	33.45	33.23	+0.22
	Mount Grant	46	14	39.09	39.51	−0.42
29	Mount Como	70	37	39.33	39.35	−0.02
	Carson Sink	36	46	34.26	34.08	+0.18
	Mount Grant	72	36	09.40	09.56	−0.16
30	Carson Sink	42	43	59.19	59.16	+0.03
	Mount Como	59	21	05.94	06.59	−0.65
	Pah Rah	77	55	18.06	17.44	+0.62

MOUNT HELENA-MONTICELLO TO LOSPE-TEPUSQUET

1	Vaca	39	31	32.67	32.81	−0.14
	Mount Helena	33	17	27.15	28.02	−0.87
	Monticello	107	11	03.29	02.28	+1.01
2	Mount Tamalpais	43	53	25.78	27.50	−1.72
	Mount Helena	53	40	13.30	13.46	−0.16
	Vaca	82	26	30.73	28.85	+1.88
3	Mount Tamalpais	18	23	18.28	19.42	−1.14
	Monticello	39	38	43.14	43.74	−0.60
	Vaca	121	58	03.40	01.66	+1.74
4	Mount Tamalpais	96	28	25.12	25.51	−0.39
	Mount Helena	33	43	56.33	56.94	−0.61
	Mount Diablo	49	47	51.13	50.13	+1.00
5	Mount Diablo	70	07	51.69	51.16	+0.53
	Mount Tamalpais	52	34	59.34	58.01	+1.33
	Vaca	57	17	17.14	19.00	−1.86
6	Mount Diablo	20	20	00.56	01.03	−0.47
	Mount Helena	19	56	16.97	16.52	+0.45
	Vaca	139	43	47.87	47.85	+0.02
7	Mount Diablo	0	16	29.45	29.42	+0.03
	Monticello	0	28	10.07	09.98	+0.09
	Vaca	179	15	20.54	20.66	−0.12
8	Mount Diablo	69	51	22.24	21.74	+0.50
	Mount Tamalpais	70	58	17.62	17.43	+0.19
	Monticello	39	10	33.07	33.76	−0.69
9	Mount Diablo	20	03	31.11	31.61	−0.50
	Mount Helena	53	13	44.12	44.54	−0.42
	Monticello	106	42	53.22	52.30	+0.92
10	Mount Tamalpais	25	30	07.50	08.08	−0.58
	Mount Helena	86	57	40.45	41.48	−1.03
	Monticello	67	32	20.15	18.54	+1.61
11	Sierra Morena	57	27	13.28	09.84	+3.44
	Mount Tamalpais	61	37	34.62	29.41	+5.21
	Mount Diablo	60	55	20.50	29.15	−8.65
12	Mocho	34	50	14.64	20.50	−5.86
	Sierra Morena	107	20	18.44	16.34	+2.10
	Mount Tamalpais	37	49	37.06	33.30	+3.76
13	Mocho	61	06	28.56	34.04	−5.48
	Sierra Morena	49	53	05.16	06.50	−1.34
	Mount Diablo	69	00	34.46	27.64	+6.82

Comparison of angles, new and old triangulation—Continued

MOUNT HELENA-MONTICELLO TO LOSPE-TEPUSQUET—Continued

Number of triangle	Stations	Spherical angles				Differences, new-old
		New			Old	
		°	′	″	″	″
14	Mocho	26	16	13.92	13.54	+0.38
	Mount Tamalpais	23	47	57.56	56.11	+1.45
	Mount Diablo	129	55	54.96	56.79	−1.83
15	Loma Prieta	46	51	45.26	46.49	−1.23
	Sierra Morena	95	13	41.44	48.62	−7.18
	Mount Diablo	37	54	41.71	33.30	+8.41
16	Loma Prieta	83	02	48.66	50.51	−1.85
	Sierra Morena	45	20	36.28	42.12	−5.84
	Mocho	51	36	41.47	33.78	+7.69
17	Loma Prieta	36	11	03.40	04.02	−0.62
	Mount Diablo	31	05	52.75	54.34	−1.59
	Mocho	112	43	10.03	07.82	+2.21
18	Santa Ana	42	50	13.86	14.60	−0.74
	Loma Prieta	80	33	25.10	22.00	+3.10
	Mocho	56	36	28.13	30.49	−2.36
19	Mount Toro	20	22	09.60	10.49	−0.89
	Loma Prieta	130	00	06.38	02.06	+4.32
	Mocho	29	37	50.39	53.82	−3.43
20	Mount Toro	56	18	34.73	32.10	+2.63
	Loma Prieta	49	26	41.28	40.06	+1.22
	Santa Ana	74	14	51.75	55.60	−3.85
21	Mount Toro	35	56	25.13	21.61	+3.52
	Mocho	26	58	37.74	36.67	+1.07
	Santa Ana	117	05	05.61	10.20	−4.59
22	Hepsedam	42	17	42.02	43.39	−1.37
	Mount Toro	69	40	40.73	43.52	−2.79
	Santa Ana	68	01	46.77	42.61	+4.16
23	Santa Lucia	33	07	20.32	17.53	+2.79
	Mount Toro	119	21	00.70	05.19	−4.49
	Santa Ana	27	31	44.41	42.71	+1.70
24	Santa Lucia	92	30	29.71	24.55	+5.16
	Mount Toro	49	40	19.97	21.67	−1.70
	Hepsedam	37	49	16.86	20.32	−3.46
25	Santa Lucia	59	23	09.39	07.02	+2.37
	Santa Ana	40	29	02.36	59.90	+2.46
	Hepsedam	80	07	58.88	03.71	−4.83
26	Rocky Butte	47	32	32.84	29.91	+2.93
	Santa Lucia	78	04	23.14	27.94	−4.80
	Hepsedam	54	23	12.80	10.93	+1.87
27	Castle Mount	38	25	06.53	06.90	−0.37
	Rocky Butte	95	58	37.32	37.07	+0.25
	Santa Lucia	45	36	27.46	27.34	+0.12
28	Castle Mount	68	40	55.05	56.79	−1.74
	Rocky Butte	48	26	04.48	07.16	−2.68
	Hepsedam	62	53	10.71	06.29	+4.42
29	Castle Mount	30	15	48.52	49.89	−1.37
	Santa Lucia	32	27	55.68	60.60	−4.92
	Hepsedam	117	16	23.51	17.22	+6.29
30	San Jose	56	02	57.36	57.12	+0.24
	Rocky Butte	53	28	12.88	14.87	−1.99
	Castle Mount	70	28	61.70	59.95	+1.75
31	San Luis	61	30	42.31	41.56	+0.75
	Rocky Butte	68	40	49.66	51.05	−1.39
	Castle Mount	49	48	38.62	37.98	+0.64
32	San Luis	127	19	34.40	35.24	−0.84
	Rocky Butte	15	12	36.78	36.18	+0.60
	San Jose	37	27	52.21	51.97	+0.24

Comparison of angles, new and old triangulation—Continued

MOUNT HELENA-MONTICELLO TO LOSPE-TEPUSQUET—Continued

Number of triangle	Stations	Spherical angles: New			Spherical angles: Old	Differences, new-old
		°	′	″	″	″
33	San Luis	65	48	52.09	53.68	−1.59
	Castle Mount	20	40	23.08	21.97	+1.11
	San Jose	93	30	49.57	49.09	+0.48
34	Lospe	31	00	49.29	49.24	+0.05
	Rocky Butte	20	42	28.09	29.64	−1.55
	San Luis	128	16	47.94	46.44	+1.50
35	Lospe	58	46	51.74	49.32	+2.42
	Rocky Butte	35	55	04.87	05.82	−0.95
	San Jose	85	18	14.93	16.40	−1.47
36	Lospe	27	46	02.45	00.08	+2.37
	San Luis	104	23	37.66	38.32	−0.66
	San Jose	47	50	22.72	24.43	−1.71
37	Tepusquet	52	43	04.67	07.58	−2.91
	Lospe	81	45	03.65	01.99	+1.66
	San Luis	45	31	55.81	54.56	+1.25
38	Tepusquet	83	03	56.93	57.73	−0.80
	Lospe	53	59	01.20	01.91	−0.71
	San Jose	42	57	06.28	04.77	+1.51
39	Tepusquet	30	20	52.26	50.15	+2.11
	San Luis	58	51	41.85	43.76	−1.91
	San Jose	90	47	29.00	29.20	−0.20
40	Ross Mountain	56	15	43.83	40.73	+3.10
	Mount Helena	102	52	42.84	46.94	−4.10
	Mount Diablo	20	51	45.63	44.63	+1.00
41	Ross Mountain	77	51	16.41	13.22	+3.19
	Mount Helena	69	08	46.51	50.00	−3.49
	Mount Tamalpais	33	00	06.14	05.84	+0.30
42	Ross Mountain	21	35	32.58	32.49	+0.09
	Mount Diablo	28	56	05.50	05.50	0
	Mount Tamalpais	129	28	31.26	31.35	−0.09
43	Mount Hamilton	62	35	23.59	16.14	+7.45
	Loma Prieta	85	49	24.68	26.54	−1.86
	Sierra Morena	31	35	15.92	21.51	−5.59
44	Mount Hamilton	172	05	23.69	23.57	+0.12
	Loma Prieta	2	46	36.02	35.92	+0.10
	Mocho	5	08	00.47	00.69	−0.22
45	Mount Hamilton	109	30	00.10	07.43	−7.33
	Sierra Morena	13	45	20.36	20.32	+0.04
	Mocho	56	44	41.94	34.65	+7.29
46	Gavilan	140	26	08.51	21.31	−12.80
	Santa Ana	18	22	65.42	57.53	+7.89
	Mount Toro	21	09	47.39	42.48	+4.91
47	Gavilan	126	31	51.04	52.42	−1.38
	Mount Toro	35	08	47.34	49.72	−2.38
	Loma Prieta	18	19	24.28	20.52	+3.76
48	Gavilan	93	01	60.45	46.27	+14.18
	Loma Prieta	31	07	17.00	19.52	−2.52
	Santa Ana	55	50	46.33	57.99	−11.66

MOUNT HELENA-ROSS MOUNTAIN TO POINT ARENA

1	Snow Mountain West	25	57	00.26	01.96	−1.70
	Mount Helena	105	16	27.71	24.31	+3.40
	Ross Mountain	48	46	40.98	42.68	−1.70
2	Mount Sanhedrin	38	55	09.69	09.76	−0.07
	Snow Mountain West	125	58	36.81	37.74	−0.93
	Mount Helena	15	06	18.85	17.85	+1.00

Comparison of angles, new and old triangulation—Continued

MOUNT HELENA-ROSS MOUNTAIN TO POINT ARENA—Continued

Number of triangle	Stations	Spherical angles				Differences, new-old
		New			Old	
		°	′	″	″	″
3	Mount Sanhedrin	63	11	47.98	49.50	−1.52
	Snow Mountain West	100	01	36.55	35.78	+0.77
	Ross Mountain	16	46	43.83	43.08	+0.75
4	Mount Sanhedrin	24	16	38.29	39.74	−1.45
	Mount Helena	90	10	08.86	06.46	+2.40
	Ross Mountain	65	33	24.81	25.76	−0.95
5	Cold Spring	25	10	21.06	19.22	+1.84
	Mount Sanhedrin	96	10	49.40	52.48	−3.08
	Snow Mountain West	58	38	55.01	53.77	+1.24
6	Cold Spring	82	50	23.79	20.93	+2.86
	Mount Sanhedrin	57	15	39.71	42.72	−3.01
	Mount Helena	39	54	10.90	10.75	+0.15
7	Cold Spring	57	40	02.73	01.71	+1.02
	Snow Mountain West	67	19	41.80	43.97	−2.17
	Mount Helena	55	00	29.75	28.60	+1.15
8	Two Rock	129	46	20.77	23.55	−2.78
	Mount Sanhedrin	26	27	00.97	59.64	+1.33
	Cold Spring	23	46	40.85	39.40	+1.45
9	Paxton	100	00	36.00	32.78	+3.22
	Cold Spring	45	17	35.48	37.07	−1.59
	Two Rock	34	41	50.05	51.68	−1.63
10	Paxton	148	21	56.76	52.14	+4.62
	Cold Spring	21	30	54.63	57.67	−3.04
	Mount Sanhedrin	10	07	09.97	11.55	−1.58
11	Paxton	48	21	20.76	19.36	+1.40
	Two Rock	95	04	30.72	31.88	−1.16
	Mount Sanhedrin	36	34	10.94	11.18	−0.24
12	Fisher	51	36	07.81	07.83	−0.02
	Two Rock	45	06	20.14	23.53	−3.39
	Paxton	83	17	33.79	30.38	+3.41
13	Fisher	110	53	50.39	42.96	+7.43
	Two Rock	10	24	30.09	31.85	−1.76
	Cold Spring	58	41	40.13	45.80	−5.67
14	Fisher	59	17	42.58	35.13	+7.45
	Paxton	16	43	02.21	02.40	−0.19
	Cold Spring	103	59	15.61	22.87	−7.26
15	Cleland	88	01	39.30	36.6	+2.7
	Paxton	82	58	48.96	53.1	−4.2
	Sanhedrin	8	59	32.58	31.1	+1.5
16	Clark	45	33	47.21	45.1	+2.1
	Fisher	74	30	41.42	56.0	−14.6
	Cold Spring	59	55	31.53	19.1	+12.4
17	Dunn	43	53	56.41	49.9	+6.5
	Fisher	87	57	55.67	72.5	−16.8
	Cold Spring	48	07	08.07	57.7	+10.4
18	Dunn	110	21	54.96	41.1	+13.9
	Fisher	13	27	14.25	16.5	−2.3
	Clark	56	10	50.83	62.4	−11.6
19	Dunn	66	27	58.55	51.2	+7.4
	Cold Spring	11	47	23.46	21.3	+2.2
	Clark	101	44	38.04	47.6	−9.6
20	Lane	20	26	35.90	25.6	+10.3
	Dunn	118	12	27.66	54.2	−26.5
	Clark	41	20	56.46	40.2	+16.3

In the triangle Hepsedam, Mount Toro, and Santa Ana one angle has decreased 2.79 seconds, another has increased 4.16 seconds, and the third has changed less than 1.5 seconds. In the triangle Santa Lucia, Mount Toro, and Santa Ana the angle at the first station has increased 2.79 seconds, at the second it has decreased 4.49 seconds, and at the third it has increased 1.70 seconds. In the triangle Santa Ana, Mount Toro, and Hepsedam one of the angles increased 5.16 seconds, another decreased 3.46 seconds, and the third changed less than 2 seconds. In the triangle Santa Lucia, Santa Ana, and Hepsedam the changes in the angles were 2.37 seconds, 2.46 seconds, and 4.83 seconds. The four stations in the quadrilateral involving the above four triangles have had some relative movements. It will be noticed from Figure 7 that the positions of Santa Ana and Hepsedam have shifted to the southeastward about the same amount, and that the changes in position at Mount Toro and Santa Lucia are in the same general direction but much smaller than at Santa Ana and Hepsedam.

Another quadrilateral involves the four stations Santa Lucia, Hepsedam, Castle Mount, and Rocky Butte. The largest change in an angle of the triangle Santa Lucia, Castle Mount, and Rocky Butte is only 0.37 second. This is a clear indication that there has been no relative earth movement involving those stations. On the other hand, in the three triangles of which Hepsedam is one of the stations the angles have changed various amounts up to 6.29 seconds. Six of the nine angles involved have changed more than 2 seconds. This seems to be a clear case of earth movement either at Hepsedam or at all of the three stations Santa Lucia, Rocky Butte, and Castle Mount. It seems more logical to conclude that Hepsedam has moved than that the other three have, especially as Castle Mount is on the same side of the San Andreas fault as Hepsedam, while Santa Lucia and Rocky Butte are on the opposite side. Any movement on one side of that fault would most likely have been in the opposite direction to that on the other side.

The next quadrilateral to the south involves the stations Rocky Butte, Castle Mount, San Jose, and San Luis. In this there are only three angles which have changes greater than 1.5 seconds. One is the angle at Rocky Butte between San Jose and Castle Mount, where the change is 1.99 seconds; another is the one at Castle Mount between San Jose and Rocky Butte, where the change is 1.75 seconds; and the third is at San Luis between Castle Mount and San Jose, where the change is 1.59 seconds. The small changes in the angles of this quadrilateral indicate that there has been no decided relative earth movement.

The last quadrilateral in the arc between Mount Helena and Monticello at the north and Lospe and Tepusquet at the south involves stations San Luis, San Jose, Lospe, and Tepusquet. There are only 3 of the 12 angles involved in this quadrilateral which have changed more than 2 seconds. The maximum change is 2.91 seconds at Tepusquet, between Lospe and San Luis. This change is somewhat more than one might expect, but there is no definite indication of any relative movement among the stations involved.

There are three triangles by which Ross Mountain is connected with stations Mount Helena, Mount Diablo, and Mount Tamalpais. In the triangle Ross Mountain, Mount Helena, and Mount Diablo one

angle has increased 3.10 seconds, another has decreased 4.10 seconds, and the third has changed only 1 second. In the triangle Ross Mountain, Mount Helena, and Mount Tamalpais one angle has increased 3.19 seconds, another has decreased 3.49 seconds, and the third angle has changed less than a second. In the triangle Ross Mountain, Mount Diablo, and Mount Tamalpais the changes are all less than a second. In the triangle involving Mount Tamalpais, Mount Helena, and Mount Diablo (see p. 27) the greatest change in an angle is only 1 second. If we consider these various triangles, we are led to the conclusion that Ross Mountain has moved with respect to the other three stations.

Mount Hamilton is a supplemental station which has been connected by means of three triangles with stations Loma Prieta, Sierra Morena, and Mocho. In the triangle Mount Hamilton, Loma Prieta, and Sierra Morena one angle has increased 7.45 seconds, another has decreased 5.59 seconds, and the third has changed less than 2 seconds. In the triangle involving Mount Hamilton, Loma Prieta, and Mocho, which has two very small angles, the changes are in no case greater than 0.30 second. In the triangle involving Mount Hamilton, Sierra Morena, and Mocho one of the angles has decreased 7.33 seconds, another has increased 7.29 seconds, and the third has had practically no change. It seems reasonable to conclude from the evidence furnished by these triangles and from the changes shown in Figure 7 that Sierra Morena has moved with respect to Mount Hamilton but that Mount Hamilton has not moved with respect to Mocho and Loma Prieta.

We may summarize the evidence and conclusions regarding earth movements between stations Mount Helena and Monticello to the northward and Lospe and Tepusquet to the southward, as follows: From the angle changes no actual earth movements are indicated at stations Vaca, Mount Tamalpais, Mount Diablo, and Mocho. There is a decided earth movement indicated by the angles for Sierra Morena and probably also for Loma Prieta. Gavilan has surely changed in position with respect to the stations surrounding it. Mount Hamilton has changed its geographic position in the same general direction as stations Mocho and Loma Prieta, but there is no indication that the change of position at Mount Hamilton is due to earth movement. If it has changed with respect to Mount Helena and Monticello to the north and Lospe and Tepusquet to the south, the change is quite small.

The indications are that Santa Ana and Hepsedam have changed in position as a result of earth movements. This is also true of station Gavilan, since it has been shown that the position of Mocho has not changed from earth movements. Gavilan is only 50 miles from Mocho, and the change in position at Mocho is about 4 feet. It is seen from the angles at stations to the north of Mocho that no decided earth movements at Mocho are indicated. The change in position at Gavilan is only about 1 foot, but it is possible that the stations surrounding Gavilan are affected by errors of the triangulation to the extent of the change at Mocho. If that is true, then the change at Gavilan must have been to the northwestward rather than to the northeastward, as indicated in Figure 7.

There have undoubtedly been changes in geographic positions at stations Hepsedam and Santa Ana, but apparently no earth movements

have taken place at stations Santa Lucia, Castle Mount, Rocky Butte, San Luis, and San Jose.

There are no triangles common to both the old and the new work involving station Farallon Lighthouse, but the angles in the triangles in both the old and the new work were observed accurately. Conclusions regarding that station must be based solely on evidence furnished by the ratio of the change in geographic position to the distances to near-by stations. The change in geographic position shown in Figure 7 for Farallon Lighthouse seems to show some earth movement for that station.

No triangles were compared for station Point Reyes Lighthouse, but the change in geographic position for that station is such as to indicate positively that earth movement has occurred there.

It will be seen, then, that earth movements have occurred at Ross Mountain, Point Reyes Lighthouse, Sierra Morena, Loma Prieta, Gavilan, and Hepsedam, and that movements may have occurred also at Santa Ana and Mount Hamilton. At the latter two stations the movements were rather small, not more than about 2 feet.

ANGLE CHANGES IN POINT ARENA SPUR

In the triangle involving Mount Helena, Mount Sanhedrin, and Snow Mountain West, no one of the angles changed more than 1 second. This would seem to indicate that there has been no relative earth movement of these three stations. In the triangle formed by Snow Mountain West, Mount Helena, and Ross Mountain one angle has changed 3.4 seconds and each of the other two 1.7 seconds. These changes indicate some relative movement of the three stations involved. This, however, is not definite, since in the triangle formed by the stations Mount Sanhedrin, Snow Mountain West, and Ross Mountain there is only one of the angles which has changed more than 1 second, and that change is only 1.52 seconds. In the triangle formed by the stations Mount Sanhedrin, Mount Helena, and Ross Mountain one angle has changed 2.4 seconds, another 1.45 seconds, and the third less than 1 second.

It is very difficult to judge from the triangles involving stations Mount Sanhedrin, Snow Mountain West, Ross Mountain, and Mount Helena whether any earth movements have occurred at Mount Sanhedrin and Snow Mountain West with respect to Mount Helena. Several of the angles seem to indicate some movement, but it would be difficult, from the triangles, to tell just where the movement, if any, occurred.

The triangles formed by the stations to the westward of Mount Sanhedrin and Snow Mountain West show some rather large changes since the first work was done. For instance, in the triangle Cold Spring, Mount Sanhedrin, and Snow Mountain West there is one change of 3.08 seconds. This change is greater than may be expected from errors of triangulation. The two other angles of the triangle changed 1.84 and 1.24 seconds, respectively. In the triangle formed by the stations Cold Spring, Mount Sanhedrin, and Mount Helena one angle has changed 2.86 seconds and another 3.01 seconds. These are indications of earth movement. In the triangle Cold Spring, Snow Mountain West, and Mount Helena there is only one change greater than 2 seconds; that one is 2.17 seconds. The other changes

are approximately 1 second each. There is no definite indication in this triangle of relative earth movement. A consideration of the changes involved in these three triangles seems to indicate that some earth movement has probably occurred at Cold Spring.

Stations Two Rock and Paxton are connected by triangles with stations Mount Sanhedrin and Cold Spring. The four triangles involved have three angles that changed more than 3 seconds. The amounts of these changes are 4.62, 3.04, and 3.22 seconds. These changes are large enough to indicate some relative earth movement of the four stations. There is no clear indication as to which of the stations have remained fixed and which have moved.

Station Fisher is connected by three triangles with stations Two Rock, Paxton, and Cold Spring. Four of the angles involved have changed 7.26, 5.67, 7.45, and 7.43 seconds, respectively, and two others have changed between 3 and 4 seconds. This would seem to indicate very clearly that there has been decided relative earth movement at these four stations.

Stations Clark and Dunn are connected with stations Fisher and Cold Spring by four triangles in which there are some very large changes in the angles. In the triangle Clark, Fisher, and Cold Spring one of the angles changed 14.6 seconds and another 12.4 seconds. In the triangle Dunn, Fisher, and Cold Spring one change is 6.5 seconds, another 16.8 seconds, and the third 10.4 seconds. In the triangle Dunn, Fisher, and Clark one of the angles has changed 13.9 seconds, another 11.6 seconds, and the third 2.3 seconds. In the last triangle of the quadrilateral under discussion, which is formed by stations Dunn, Cold Spring, and Clark, one angle has changed 7.4 seconds, another 9.6 seconds, and the third 2.2 seconds. The great changes that occurred in this quadrilateral Dunn, Clark, Fisher, and Cold Spring indicate most definitely that there were earth movements. The lines in this quadrilateral are very short, the longest one being only 6.6 miles. Dunn and Clark are just to the eastward of the San Andreas fault, and it is probable that they have moved. A consideration of this and the changes in the preceding quadrilaterals point to movements also at Fisher and Cold Spring.

Station Lane, to the west of Dunn and Clark, was established by only a single triangle. The angles of this triangle have very large changes. The change at Lane is 10.3 seconds, at Dunn 26.5 seconds, and at Clark 16.3 seconds. These large changes show beyond question relative movement of the stations Lane, Dunn, and Clark. It is understood that station Lane is to the east of and very close to the San Andeas fault.

In considering the stations involved in the net to the westward of Snow Mountain West and Mount Helena, we may say quite definitely that there have been earth movements involving stations Lane, Dunn, Clark, and Fisher, and probably Cold Spring. There does not seem to be definite information to indicate any earth movements at stations Paxton, Two Rock, Cleland, and Mount Sanhedrin.

The old station Cleland and the new stations North, Forty Acre Opening, and Ukiah magnetic station were used to connect the international latitude station at Ukiah with the triangulation scheme of California. The magnetic station is close to the latitude observatory, and these two points were joined by a traverse in order to connect the observatory with the triangulation scheme. (See p. 11.)

CHAPTER 5.—ANALYSES OF CHANGES IN GEOGRAPHIC POSITIONS

If we keep in mind the accuracy which may be obtained in extending arcs of triangulation across country, as indicated by the closing errors of loops of triangulation in the western half of the United States and the corrections which were applied to the several sections of that triangulation (see p. 14), we are in a position to judge whether the changes in the positions of the triangulation stations of California are due mostly to errors of observation or to earth movements.

CHANGES TO THE EASTWARD OF THE FIXED ENDS OF CALIFORNIA ARC

When Mount Lola and Round Top were held fixed in the positions determined by the readjustment of the western half of the country, and the old and the new triangulations to the eastward were fitted to those points, the results indicated in Figure 3 were obtained. The changes in the positions of the stations involved are very slight. The largest change is at Pah Rah, 2.2 feet to the eastward. The changes at Mount Como, Mount Grant, and Carson Sink are less than 1 foot each. The distance from Pah Rah to Mount Lola is about 52 miles, and therefore the change in position at Pah Rah is only about 1 part in 125,000 of that distance. The slight changes in position for the stations under consideration are within the limits of those to be expected from the errors of even first-order triangulation. They do not indicate any actual earth movement with respect to Mount Lola and Round Top.

In Figure 3 are shown the changes in geographic positions for stations Butte, American, and Kofa, with respect to Cuyamaca and San Jacinto. The change in position at American is 1.4 feet, and its distance to Cuyamaca is 108 miles. The ratio of the change in position to the distance is about 1 part in 400,000, which is far within the limit of error to be expected in triangulation. Butte is 79 miles from San Jacinto, and the change in its position is 5.1 feet. The ratio of the change to the distance is about 1 part in 80,000, and this may be due to the accidental errors of triangulation, since Butte is in the same quadrilateral with San Jacinto. (See p. 18.) The distance between Butte and American is about 60 miles, and the relative change in geographic position between these two stations is 6.3 feet. The ratio is 1 part in 50,000, which again is within, but close to, the limit that may be expected from triangulation errors in a quadrilateral.

In the triangle American-Butte-Kofa only the angles at the first two stations were observed in the new triangulation. The new position of Kofa differs 3.5 feet from the old one. This is quite small in relation to its distance from Cuyamaca, and it is small enough with respect to the distances from American and Butte to be due to errors of triangulation. There seems to be no distinct or definite indication of any earth movement at these stations with respect to San Jacinto and Cuyamaca.

CHANGES IN CALIFORNIA ARC

An analysis of the changes in geographic positions shown in Figure 2, where Mount Lola and Round Top in the north and San Jacinto and Cuyamaca in the south were held fixed, seems to indicate rather clearly that there was no earth movement at the stations between San Luis and San Jose and the stations San Jacinto and Cuyamaca, but there is a decided indication of earth movements at some of the stations to the north of San Luis and San Jose.

Comparison of geographic positions, various adjustments

[The numbers in the second column designate the different adjustments as follows: 1. Positions resulting from the net readjustment of the western half of the United States in which the observations of 1922–1925 were used. 2. Results obtained by a readjustment of the old work holding fixed Mount Lola-Round Top and San Jacinto-Cuyamaca. 3. Results obtained by a readjustment of the old work holding fixed Mount Lola-Round Top, Lospe-Tepusquet, and San Jacinto-Cuyamaca. 4. Results obtained by a readjustment of the old work holding fixed Mount Helena-Monticello and Lospe-Tepusquet. 5. Results obtained by a readjustment of the old work holding fixed the line Mount Helena-Snow Mountain West.]

Station	Number of adjustment	Dates of observations	Latitudes, old and new	Difference in seconds	Difference in meters	Longitudes, old and new	Difference in seconds	Difference in meters	Resultant displacement in meters	Resultant displacement in feet	Direction from old position, clockwise from south
			° ′ ″			° ′ ″					° ′
Carson Sink	1	1925	39 34 59.234			118 14 04.058					
	2	1878	59.239	−0.005	−0.15	04.064	−0.006	−0.14	0.21	0.7	316 59
Mount Grant	1	1925	38 34 13.453			118 47 25.488					
	2	1878	13.450	+0.003	+0.09	25.495	−0.007	−0.17	0.19	0.6	242 06
Mount Como	1	1925	39 01 17.046			119 28 22.510					
	2	1879	17.042	+0.004	+0.12	22.520	−0.010	−0.24	0.27	0.9	243 26
Pah Rah	1	1925	39 47 40.376			119 28 23.601					
	2	1874	40.378	−0.002	−0.06	23.629	−0.028	−0.67	0.67	2.2	275 07
Mount Lola	1	1922	39 25 59.008			120 21 50.481					
	2	1876	59.008			50.481					
	3		59.008			50.481					
Round Top	1	1922	38 39 49.291			119 59 59.989					
	2	1876	49.291			59.989					
	3	1876	49.291			59.989					
Pine Hill	1	1922	38 43 10.063			120 59 21.774					
	2	1876	10.056	+0.007	+0.22	21.791	−0.017	−0.41	0.47	1.5	241 47
Marysville Butte	1	1922	39 12 21.300			121 49 10.350					
	2	1876	21.305	−0.005	−0.15	10.376	−0.026	−0.62	0.64	2.1	283 36
	3	1876	21.312	−0.012	−0.37	10.345	+0.005	+0.12	0.39	1.3	17 58
Monticello	1	1922	38 39 49.550			122 11 21.118					
	2	1880	49.561	−0.011	−0.34	21.158	−0.040	−0.97	1.03	3.4	289 19
	3	1880	49.573	−0.023	−0.71	21.123	−0.005	−0.12	0.72	2.4	350 24
	4	1880	49.550			21.118					

Comparison of geographic positions, various adjustments—Continued

Station	Number of adjustment	Dates of observations	Latitudes, old and new		Difference in seconds	Difference in meters	Longitudes, old and new		Difference in seconds	Difference in meters	Resultant displacement in meters	Resultant displacement in feet	Direction from old position, clockwise from south
			° ′	″			° ′	″					° ′
Vaca	1	1922	38 22	32.717			122 05	00.764					
	2	1880		32.720	−0.003	−0.09		00.809	−0.045	−1.09	1.09	3.6	274 43
	3	1880		32.734	−0.017	−0.52		00.775	−0.011	−0.27	0.59	1.9	332 34
	4	1880		32.710	+0.007	+0.22		00.768	−0.004	−0.10	0.24	0.8	204 27
Mount Helena	1	1922	38 40	09.971			122 37	56.604					
	2	1876		09.986	−0.015	−0.46		56.648	−0.044	−1.06	1.16	3.8	293 28
	3	1876		09.997	−0.026	−0.80		56.609	−0.005	−0.12	0.81	2.7	351 28
	4	1876		09.971				56.604					
Ross Mountain	1	1922	38 30	19.432			123 07	07.981					
	2	1891		19.479	−0.047	−1.45		08.040	−0.059	−1.43	2.04	6.7	315 24
	3	1891		19.492	−0.060	−1.85		07.996	−0.015	−0.36	1.88	6.2	348 59
	4	1891		19.467	−0.035	−1.08		07.984	−0.003	−0.07	1.08	3.5	356 14
Mount Tamalpais	1	1922	37 55	26.381			122 35	43.976					
	2	1882		26.410	−0.029	−0.89		44.044	−0.068	−1.66	1.88	6.2	298 12
	3	1882		26.429	−0.048	−1.48		44.005	−0.029	−0.71	1.64	5.4	334 22
	4	1882		26.406	−0.025	−0.77		43.993	−0.017	−0.42	0.88	2.9	331 23
Mount Diablo	1	1922	37 52	54.387			121 54	47.107					
	2	1876		54.400	−0.013	−0.40		47.167	−0.060	−1.47	1.52	5.0	285 13
	3	1876		54.419	−0.032	−0.99		47.134	−0.027	−0.66	1.19	3.9	326 19
	4	1876		54.398	−0.011	−0.34		47.127	−0.020	−0.49	0.60	2.0	304 45
Sierra Morena	1	1923	37 24	37.212			122 18	26.803					
	2	1883		37.183	+0.029	+0.89		26.790	+0.013	+0.32	0.95	3.1	160 13
	3	1883		37.205	+0.007	+0.22		26.754	+0.049	+1.21	1.23	4.0	100 18
	4	1883		37.190	+0.022	+0.68		26.743	+0.060	+1.48	1.63	5.3	114 41
Mocho	1	1923	37 28	38.609			121 33	17.529					
	2	1887		38.632	−0.023	−0.71		17.595	−0.066	−1.62	1.77	5.8	293 40
	3	1887		38.654	−0.045	−1.39		17.563	−0.034	−0.84	1.62	5.3	328 51
	4	1887		38.641	−0.032	−0.99		17.562	−0.033	−0.81	1.28	4.2	320 43
Loma Prieta	1	1923	37 06	39.818			121 50	35.130					
	2	1884		39.849	−0.031	−0.96		35.210	−0.080	−1.98	2.20	7.2	295 52
	3	1884		39.872	−0.054	−1.66		35.178	−0.048	−1.19	2.04	6.7	324 22
	4	1884		39.861	−0.043	−1.33		35.172	−0.042	−1.04	1.69	5.5	321 59
Santa Ana	1	1923	36 54	18.287			121 13	56.474					
	2	1852		18.328	−0.041	−1.26		56.546	−0.072	−1.78	2.18	7.2	305 18
	3	1852		18.351	−0.064	−1.97		56.512	−0.038	−0.94	2.18	7.2	334 29
	4	1852		18.343	−0.056	−1.73		56.512	−0.038	−0.94	1.97	6.5	331 29
Gavilan	1	1923	36 45	19.888			121 31	10.090					
	2	1852		19.868	+0.020	+0.62		10.139	−0.049	−1.22	1.37	4.5	243 04
	3	1852		19.890	−0.002	−0.06		10.105	−0.015	−0.37	0.37	1.2	279 13
	4	1852		19.882	+0.006	+0.18		10.102	−0.012	−0.30	0.35	1.1	239 02
Mount Toro	1	1923	36 31	33.661			121 36	31.019					
	2	1885		33.669	−0.008	−0.25		31.055	−0.036	−0.90	0.93	3.1	285 31
	3	1885		33.691	−0.030	−0.92		31.022	−0.003	−0.07	0.92	3.0	355 39
	4	1885		33.684	−0.023	−0.71		31.017	+0.002	+0.05	0.71	2.3	4 02
Hepsedam	1	1923	36 18	52.548			120 49	25.097					
	2	1885		52.591	−0.043	−1.32		25.159	−0.062	−1.55	2.04	6.7	310 25
	3	1885		52.611	−0.063	−1.94		25.120	−0.023	−0.57	2.02	6.6	343 38
	4	1885		52.607	−0.059	−1.82		25.121	−0.024	−0.60	1.92	6.3	341 45
Santa Lucia	1	1923	36 08	44.299			121 25	04.676					
	2	1885		44.297	+0.002	+0.06		04.700	−0.024	−0.60	0.60	2.0	264 17
	3	1885		44.317	−0.018	−0.55		04.667	+0.009	+0.23	0.60	2.0	22 42
	4	1885		44.312	−0.013	−0.40		04.663	+0.013	+0.32	0.51	1.7	38 40
Castle Mount	1	1923	35 56	20.348			120 20	21.674					
	2	1885		20.364	−0.016	−0.49		21.710	−0.036	−0.90	1.02	3.3	298 34
	3	1885		20.378	−0.030	−0.92		21.665	+0.009	+0.23	0.95	3.1	14 02
	4	1885		20.377	−0.029	−0.89		21.666	+0.008	+0.20	0.91	3.0	12 40
Rocky Butte	1	1923	35 39	55.019			121 03	30.792					
	2	1884		55.024	−0.005	−0.15		30.805	−0.013	−0.33	0.36	1.2	294 27
	3	1884		55.039	−0.020	−0.62		30.771	+0.021	+0.53	0.82	2.7	40 32
	4	1884		55.037	−0.018	−0.55		30.769	+0.023	+0.58	0.80	2.6	46 31
San Luis	1	1923	35 16	40.129			120 33	38.798					
	2	1883		40.146	−0.017	−0.52		38.819	−0.021	−0.53	0.74	2.4	314 27
	3	1883		40.152	−0.023	−0.71		38.783	+0.015	+0.38	0.81	2.7	28 09
	4	1883		40.152	−0.023	−0.71		38.783	+0.015	+0.38	0.81	2.7	28 09
San Jose	1	1923	35 18	54.700			120 16	06.941					
	2	1884		54.712	−0.012	−0.37		06.980	−0.039	−0.98	1.05	3.4	290 41
	3	1884		54.717	−0.017	−0.52		06.938	+0.003	+0.08	0.53	1.7	8 45
	4	1884		54.717	−0.017	−0.52		06.939	+0.002	+0.05	0.52	1.7	5 30

Comparison of geographic positions, various adjustments—Continued

Station	Number of adjustment	Dates of observations	Latitudes, old and new	Difference in seconds	Difference in meters	Longitudes, old and new	Difference in seconds	Difference in meters	Resultant displacement in meters	Resultant displacement in feet	Direction from old position, clockwise from south
			° ′ ″			° ′ ″					° ′
Lospe	1	1923	34 53 37.534			120 36 18.604					
	2	1875	37.532	+0.002	+0.06	18.632	−0.028	−0.71	0.71	2.3	265 10
	3	1875	37.534			18.604					
	4	1875	37.534			18.604					
Tepusquet	1	1923	34 54 36.522			120 11 08.335					
	2	1875	36.528	−0.006	−0.18	08.373	−0.038	−0.96	0.98	3.2	280 37
	3	1875	36.522			08.335					
	4	1875	36.522			08.335					
Arguello	1	1923	34 34 58.026			120 33 37.639					
	2	1875	58.039	−0.013	−0.40	37.669	−0.030	−0.76	0.86	2.8	297 46
	3	1875	58.031	−0.005	−0.15	37.638	+0.001	+0.03	0.15	0.5	11 19
Gaviota	1	1923	34 30 06.542			120 11 52.053					
	2	1873	06.565	−0.023	−0.71	52.098	−0.045	−1.15	1.35	4.4	301 41
	3	1873	06.557	−0.015	−0.46	52.064	−0.011	−0.28	0.54	1.8	328 40
New San Miguel	1	1924	34 02 22.854			120 23 08.029					
	2	1873	22.881	−0.027	−0.83	08.080	−0.051	−1.31	1.55	5.1	302 21
	3	1873	22.876	−0.022	−0.68	08.047	−0.018	−0.46	0.82	2.7	325 55
Santa Cruz West	1	1924	34 04 23.161			119 55 01.354					
	2	1861	23.185	−0.024	−0.74	01.404	−0.050	−1.28	1.48	4.9	300 02
	3	1861	23.180	−0.019	−0.59	01.373	−0.019	−0.49	0.77	2.5	320 17
Santa Barbara	1	1924	34 24 16.722			119 42 51.740					
	2	1858	16.756	−0.034	−1.05	51.784	−0.044	−1.12	1.54	5.1	313 09
	3	1858	16.748	−0.026	−0.80	51.756	−0.016	−0.41	0.90	3.0	332 52
Santa Cruz East	1	1924	34 03 17.058			119 33 49.504					
	2	1857	17.080	−0.022	−0.68	49.539	−0.035	−0.90	1.13	3.7	307 04
	3	1857	17.076	−0.018	−0.55	49.512	−0.008	−0.21	0.59	1.9	339 06
Chaffee	1	1923	34 18 02.199			119 19 47.980					
	2	1867	02.237	−0.038	−1.17	48.015	−0.035	−0.90	1.48	4.9	322 26
	3	1867	02.231	−0.032	−0.99	47.991	−0.011	−0.28	1.03	3.4	344 12
Laguna	1	1923	34 06 30.864			119 03 50.434					
	2	1857	30.895	−0.031	−0.96	50.447	−0.013	−0.33	1.02	3.3	341 02
	3	1857	30.891	−0.027	−0.83	50.427	+0.007	+0.18	0.85	2.8	12 14
Santa Clara	1	1923	34 19 32.419			119 02 17.703					
	2	1898	32.458	−0.039	−1.20	17.720	−0.017	−0.44	1.28	4.2	339 52
	3	1898	32.451	−0.032	−0.99	17.701	+0.002	+0.05	0.99	3.2	2 53
Castro	1	1923	34 05 08.468			118 47 05.133					
	2	1898	08.499	−0.031	−0.96	05.146	−0.013	−0.33	1.02	3.3	341 02
	3	1898	08.495	−0.027	−0.83	05.130	+0.003	+0.08	0.83	2.7	5 30
San Fernando	1	1923	34 19 47.213			118 36 00.199					
	2	1898	47.254	−0.041	−1.26	00.206	−0.007	−0.18	1.27	4.2	351 52
	3	1898	47.248	−0.035	−1.08	00.192	+0.007	+0.18	1.09	3.6	9 28
San Pedro	1	1923	33 44 45.871			118 20 06.075					
	2	1853	45.883	−0.012	−0.37	06.082	−0.007	−0.18	0.41	1.3	334 03
	3	1853	45.883	−0.012	−0.37	06.071	+0.004	+0.10	0.38	1.2	15 07
Wilson Peak	1	1923	34 13 25.512			118 03 38.674					
	2	1890	25.541	−0.029	−0.89	38.654	+0.020	+0.51	1.03	3.4	29 49
	3	1890	25.537	−0.025	−0.77	38.646	+0.028	+0.72	1.05	3.4	43 05
Los Angeles Northwest Base	1	1923	33 55 04.951			118 03 22.498					
	2	1889	04.969	−0.018	−0.55	22.485	+0.013	+0.33	0.64	2.1	30 58
	3	1889	04.969	−0.018	−0.55	22.477	+0.021	+0.54	0.77	2.5	44 28
Los Angeles Southeast Base	1	1923	33 47 33.962			117 56 29.020					
	2	1889	33.978	−0.016	−0.49	29.012	+0.008	+0.21	0.53	1.7	23 12
	3	1889	33.977	−0.015	−0.46	29.004	+0.016	+0.41	0.62	2.0	41 43
San Juan	1	1923	33 54 49.470			117 44 14.005					
	2	1886	49.485	−0.015	−0.46	13.990	+0.015	+0.38	0.60	2.0	39 34
	3	1886	49.484	−0.014	−0.43	13.983	+0.022	+0.57	0.71	2.3	52 58
Niguel	1	1923	33 30 44.819			117 43 59.813					
	2	1884	44.828	−0.009	−0.28	59.798	+0.015	+0.39	0.48	1.6	54 19
	3	1884	44.829	−0.010	−0.31	59.792	+0.021	+0.54	0.62	2.0	60 08
Santiago	1	1923	33 42 37.886			117 31 59.903					
	2	1899	37.889	−0.003	−0.09	59.885	+0.018	+0.46	0.47	1.5	78 56
	3	1899	37.889	−0.003	−0.09	59.880	+0.023	+0.59	0.60	2.0	81 20
San Jacinto	1	1923	33 48 52.906			116 40 42.915					
	2	1898	52.906			42.915					
	3	1898	52.906			42.915					
Cuyamaca	1	1923	32 56 48.099			116 36 21.134					
	2	1898	48.099			21.134					
	3	1898	48.099			21.134					

Comparison of geographic positions, various adjustments—Continued

Station	Number of adjustment	Dates of observations	Latitudes, old and new	Difference in seconds	Difference in meters	Longitudes, old and new	Difference in seconds	Difference in meters	Resultant displacement in meters	Resultant displacement in feet	Direction from old position, clockwise from south
			° ′ ″			° ′ ″					° ′
Butte	1	1924	33 33 40.942			115 20 38.304					
	2	1910	40.974	−0.032	−0.99	38.351	−0.047	−1.21	1.56	5.1	309 17
American	1	1924	32 51 27.317			114 45 06.974					
	2	1910	27.317	0.000	0.00	06.957	+0.017	+0.44	0.44	1.4	90 00
Kofa	1	1924	33 21 33.147			114 04 55.617					
	2	1911	33.170	−0.023	−0.71	55.586	+0.031	+0.80	1.07	3.5	48 25
Point Reyes Lighthouse	1	1922	37 59 44.450			123 01 19.363					
	2	1874	44.356	+0.094	+2.90	19.395	−0.032	−0.78	3.00	9.8	195 03
	3	1874	44.375	+0.075	+2.31	19.352	+0.011	+0.27	2.33	7.6	173 20
	4	1874	44.349	+0.101	+3.11	19.339	+0.024	+0.58	3.16	10.4	169 26
Farallon Lighthouse	1	1922	37 41 57.153			123 00 02.393					
	2	1891	57.144	+0.009	+0.28	02.391	+0.002	+0.05	0.28	0.9	169 53
	3	1891	57.165	−0.012	−0.37	02.350	+0.043	+1.05	1.11	3.6	70 35
	4	1891	57.143	+0.010	+0.31	02.332	+0.061	+1.49	1.52	5.0	101 45
Mount Hamilton, Lick Observatory dome	1	1923	37 20 30.414			121 38 30.447					
	2	1882	30.446	−0.032	−0.99	30.513	−0.066	−1.62	1.90	6.2	301 26
	3	1882	30.468	−0.054	−1.66	30.481	−0.034	−0.84	1.86	6.1	333 10
	4	1882	30.456	−0.042	−1.29	30.478	−0.031	−0.76	1.50	4.9	329 30
Snow Mountain West	1	1925	39 22 37.364			122 45 27.452					
	5	1892	37.364			27.452					
Mount Sanhedrin	1	1925	39 30 57.602			123 05 42.401					
	5	1878	57.598	+0.004	+0.12	42.376	+0.025	+0.60	0.61	2.0	101 17
Cold Spring	1	1925	39 01 20.217			123 31 19.282					
	5	1878	20.241	−0.024	−0.74	19.297	−0.015	−0.36	0.82	2.7	334 03
Two Rock	1	1925	39 21 42.397			123 26 41.828					
	5	1877	42.410	−0.013	−0.40	41.803	+0.025	+0.60	0.72	2.4	56 19
Paxton	1	1925	39 08 08.074			123 18 42.090					
	5	1877	08.080	−0.006	−0.19	42.083	+0.007	+0.17	0.25	0.8	41 49
Cleland	1	1925	39 07 00.416			123 13 54.244					
	5	1897	00.418	−0.002	−0.06	54.254	−0.010	−0.24	0.25	0.8	284 02
Fisher	1	1925	39 03 58.563			123 35 10.569					
	5	1878	58.591	−0.028	−0.86	10.591	−0.022	−0.53	1.01	3.3	328 21
Clark	1	1925	38 59 36.573			123 37 52.627					
	5	1878	36.609	−0.036	−1.11	52.673	−0.046	−1.11	1.57	5.2	315 00
Dunn	1	1925	39 00 38.813			123 38 39.502					
	5	1878	38.851	−0.038	−1.17	39.548	−0.046	−1.11	1.61	5.3	316 30
Lane	1	1925	39 00 33.443			123 41 34.376					
	5	1870	33.500	−0.057	−1.76	34.435	−0.059	−1.42	2.26	7.4	321 06

It was thought desirable to make another adjustment of the triangulation by holding fixed the positions of Lospe and Tepusquet as determined by the readjustment of the western half of the country. These two stations are close to a new base line and also are at the end of a new arc of triangulation extending eastward. The results of this adjustment, when the three pairs of stations, Mount Lola-Round Top, Lospe-Tepusquet, and San Jacinto-Cuyamaca, were held fixed, are shown in Figure 6. Here, again, the stations between Lospe and Tepusquet and San Jacinto-Cuyamaca show very moderate changes in position. The changes gradually increase from the northward until San Fernando and Wilson Peak are reached, where they amount to about 3.5 feet, then gradually decrease to 2 feet at stations Santiego and Niguel. The changes, of course, are zero at San Jacinto and Cuyamaca, since those stations were held fixed. These small changes are an indication that no earth movements have occurred at the stations involved.

Considering now the part of the arc north of Lospe and Tepusquet, we find very small changes at stations Marysville Butte, Mount Helena, Monticello, and Vaca. The change at Pine Hill was not computed, but it would doubtless be less than 1 foot. (See fig. 2.) At Marysville Butte the change in position is 1.3 feet, or 1 part in 325,000 of the distance from Mount Lola. The change in position at Mount Helena is 2.7 feet, and the distance from Mount Lola is 133 miles. The ratio is 1 part in 260,000. The changes at Monticello and Vaca are 2.4 and 1.9 feet, respectively. They are almost exactly in the same direction as the change at Mount Helena.

The adjustment of the whole California arc holding fixed Mount Lola and Round Top to the north and San Jacinto and Cuyamaca to the south indicated that there has not been any general earth movement for the area covered by the triangulation in California. To study the local changes in geographic positions, it seemed desirable to make adjustments between stations that are not at great distances apart. Of course, the stations held fixed in these more local adjustments should be those for which no earth movements are indicated by the general adjustment. As stated above the changes at Mount Helena and Monticello are very small. We are therefore justified in assuming that they have not changed in position owing to earth movement. An adjustment was made holding these two stations and Lospe and Tepusquet fixed in the positions determined by the readjustment of the net of the western part of the country. The results are shown in Figure 7.

ANALYSIS OF CHANGES IN POSITIONS WHEN LOSPE, TEPUSQUET, MOUNT HELENA AND MONTICELLO ARE HELD FIXED

The changes in geographic positions shown in Figure 7 indicate conclusively that there have been relative movements between some of the contiguous stations. It is rather difficult to determine just which one of the two stations of any pair has moved. This is due to the fact that the ratios of the shifts in geographic positions to the distances of the stations from the near end of the arc are not much larger than might be accounted for by the accumulated accidental errors of triangulation.

The change in geographic position at Mount Hamilton is about 5 feet, and the distance from Mount Helena is about 105 miles.

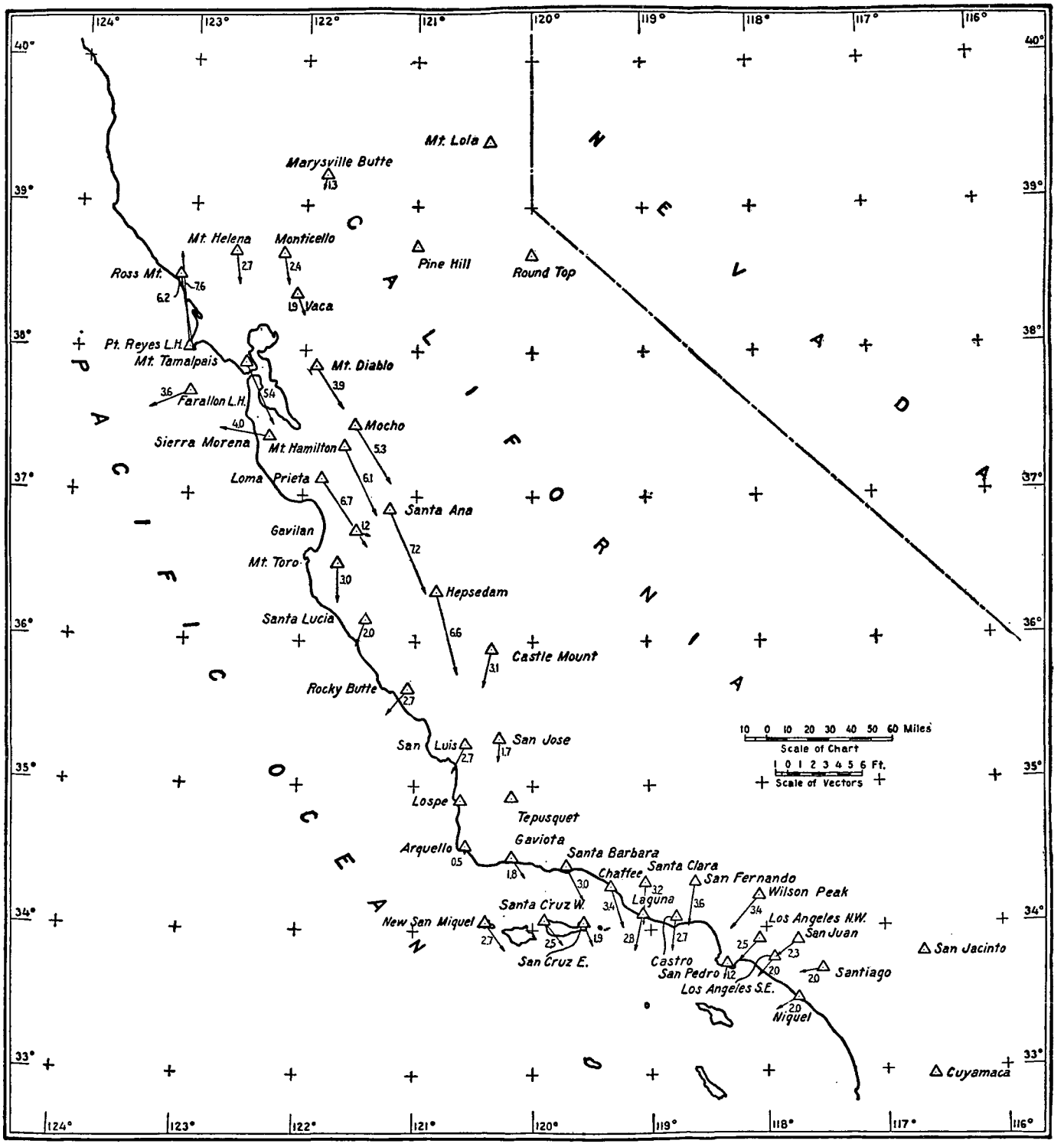

FIG. 6.—*Changes of positions of triangulation stations in California as determined by holding fixed stations Lospe and Tepusquet in addition to two ends of arc*

The ratio is 1 part in 110,000. It will be noticed that the changes in position of Mocho and Loma Prieta are practically the same as that at Mount Hamilton. If Mount Hamilton actually moved in

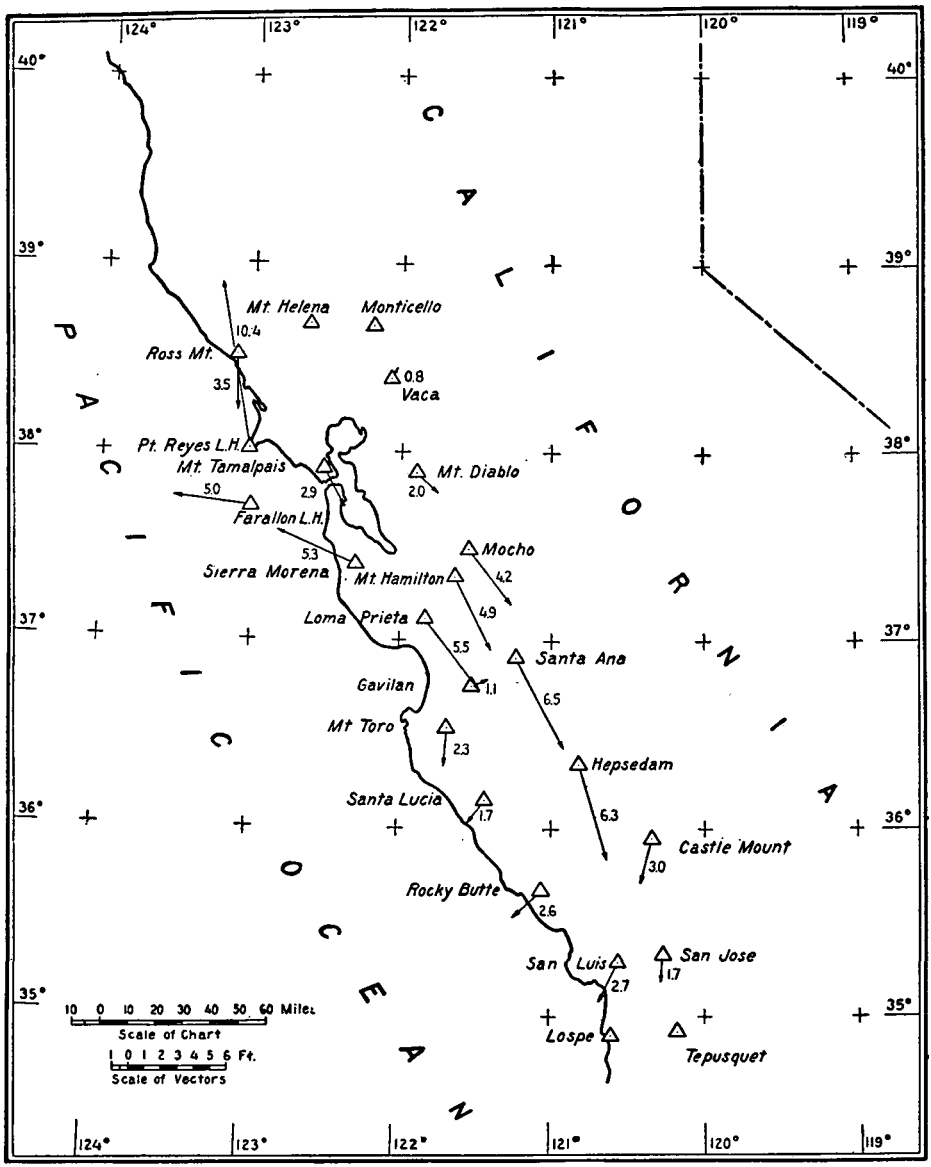

FIG. 7.—*Changes of positions in northern half of California arc as determined by holding fixed Lospe, Tepusquet, Mount Helena, and Monticello*

geographic position, then it is reasonably certain that Loma Prieta and Mocho moved with it in the same general direction and approximately the same amount. Santa Ana, just to the southward of

Mount Hamilton, has changed in geographic position about 1½ feet more than has Mount Hamilton. The distance between Santa Ana and Mount Hamilton is about 37 miles. The ratio of the relative change to the distance is less than 1 part in 100,000, and therefore it is rather difficult to say whether or not Santa Ana has moved with respect to Mount Hamilton or the other two stations mentioned above.

With regard to Hepsedam, we find that its change of position is only 0.2 foot less than the change at Santa Ana and the direction of the change is approximately the same. The distance between Santa Ana and Hepsedam is about 45 miles, and so the ratio of relative change to the distance is smaller than 1 part in 1,000,000. The relative change is most certainly due to errors of triangulation.

When we consider the relative changes in geographic position for stations Castle Mount, Mount Toro, Santa Lucia, Rocky Butte, San Luis, and San Jose, and the changes at those stations with relation to Lospe and Tepusquet, we must conclude that they come well within the limits of accuracy of triangulation. For instance, the change in position of San Luis is only 2.7 feet, and its distance from Lospe is about 27 miles. The ratio is approximately 1 part in 53,000. This is slightly more than we ordinarily expect in triangulation, but it must be remembered that San Luis is in the same quadrilateral with Lospe and Tepusquet, and, in many cases, errors as great as 1 part in 50,000 in the length of one side of a triangle with respect to that of another side of the same triangle can occur. At San Jose the change of position is only 1.7 feet, and the ratio of this change to the distance from Lospe is less than 1 part in 100,000.

A careful analysis of the changes at all of the six stations mentioned above would show that there is no clear indication of any actual relative movements of the stations of the group.

For station Gavilan, we find that the change in position is only about 1 foot. This is insignificant as compared with the distance of Gavilan from Mount Helena. The relative change of Gavilan with respect to Mount Toro, however, is about 3.2 feet, and the distance between them is only about 17 miles. The ratio is approximately 1 part in 27,000, and this would indicate some actual earth movement.

If we compare the changes at Gavilan and Santa Ana, we find a relative change in position of 6.6 feet. As the distance between them is about 19 miles, the ratio of relative movement to distance is about 1 part in 15,000 and indicates an actual relative earth movement.

Loma Prieta is about 30 miles from Gavilan, and the relative change in geographic position is approximately 5.5 feet. The ratio is about 1 part in 30,000 and again indicates a relative earth movement.

The distance between Mount Diablo and Mount Hamilton is approximately 40 miles, and the relative change in geographic positions is 3.2 feet. The ratio is less than 1 part in 60,000, which, although a slight indication of earth movement, may be due to accidental errors of triangulation. The distance between Loma Prieta and Sierra Morena is about 33 miles, and the relative change in position is nearly 11 feet. The ratio here is slightly less than 1 part in 15,000 and definitely indicates relative earth movements.

The change in geographic position at Mount Tamalpais is 2.9 feet, and its distance from Mount Helena is 52 miles. The ratio is approxi-

mately 1 part in 100,000. This does not indicate earth movement at Mount Tamalpais.

There seems to be no definite indication of relative earth movement between Mount Tamalpais and Mount Diablo. The distance between these two stations is about 37 miles, and the relative change is about 1.5 feet. The ratio is less than 1 part in 100,000.

There is strong indication of earth movements at Point Reyes Lighthouse and at Ross Mountain with respect to Mount Helena. The relative change of geographic position between Ross Mountain and Point Reyes Lighthouse is about 14 feet, and the distance is about 35 miles. The ratio is about 1 part in 13,000, which is a definite indication of relative earth movements. It seems reasonably certain that Ross Mountain has moved southward and Point Reyes Lighthouse northward.

It can be seen from the preceding discussion that it is rather difficult to arrive at a definite conclusion regarding absolute earth movements at the triangulation stations between Mount Helena and Monticello to the northward and Lospe and Tepusquet to the southward. There is some indication, however, that the group of stations involving Loma Prieta, Mount Hamilton, Mocho, Santa Ana, and Hepsedam has moved to the southeastward. This seems more likely than that stations Mount Diablo, Santa Lucia, Rocky Butte, and Castle Mount have actually moved in geographic position or that the relative changes in positions are due entirely to accidental errors of triangulation. We can say with assurance that there has been relative earth movement of the three stations Loma Prieta, Mount Hamilton, and Mocho in relation to station Sierra Morena to the northward and Gavilan to the southward, but just what the absolute movements are with respect to Mount Helena and Monticello can not be discovered from the triangulation.

There seems to be no definite evidence of earth movement at stations Vaca, Mount Diablo, and Mount Tamalpais with respect to Mount Helena and Monticello. At Farallon Lighthouse the relative change in geographic position with respect to Mount Tamalpais is 7.2 feet and the distance is 27 miles. The ratio is about 1 part in 20,000 which is an indication of relative earth movement for this pair of stations. If, as concluded above, Mount Tamalpais has not moved with respect to Mount Helena and Monticello, then Farallon Lighthouse has moved to the northwestward of the position it occupied 37 years ago.

As stated above, there has been a decided relative movement between Point Reyes Lighthouse and Ross Mountain as well as an absolute movement of those two stations with respect to Mount Helena and Monticello.

ANALYSIS OF CHANGES IN POSITION AT STATIONS OF THE POINT ARENA SPUR

The changes in geographic position for the stations of the Point Arena spur are shown in Figure 8. (See also p. 5.) The change at Mount Sanhedrin is 2 feet. Since the distance between Mount Sanhedrin and Snow Mountain West is about 20 miles, the relative change is a little more than 1 part in 50,000. The change at Two Rock is 2.4 feet, which is about 1 part in 75,000 of the distance between that station and Snow Mountain West. The changes in

position at Paxton and Cleland are each less than 1 foot. It would appear from the comparatively small changes at Mount Sanhedrin, Two Rock, Paxton, and Cleland with respect to Snow Mountain West that there probably has not been any earth movement at these stations.

When we consider the group of stations consisting of Fisher, Cold Spring, Dunn, Clark, and Lane, we find that the smallest change is for station Cold Spring, namely, 2.7 feet, to the southeastward. The maximum change is 7.4 feet, to the southeastward, for station Lane. The distance of Fisher from Paxton, the nearest station to the eastward, is about 15 miles, and the relative change is 3.2 feet. The ratio is approximately 1 part in 26,000. The relative movement between Two Rock and Paxton is only 1.4 feet, and the distance is 17 miles. The ratio is about 1 part in 65,000.

There seems to be no definite indication of earth movement at Two Rock with respect to Paxton, but there seems to have been some movement at Cold Spring with respect to Paxton. This movement is further indicated by the fact that the change of position at Fisher, which is only 4 miles from Cold Spring, is 3.3 feet, almost the same as at Cold Spring and in almost the same direction. The change of position at Clark is 5.2 feet and that at Dunn is 5.3 feet.

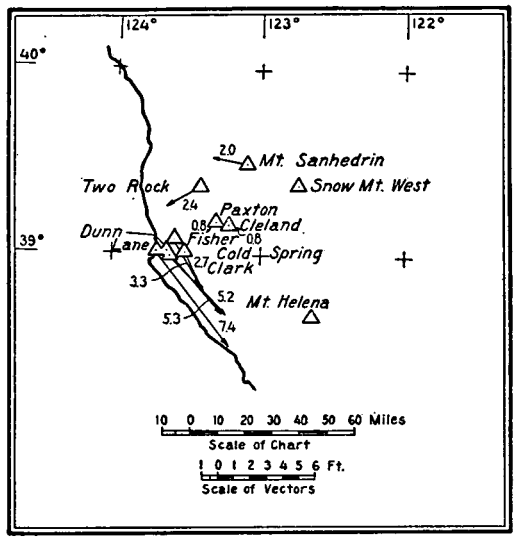

FIG. 8.—*Changes of positions on Point Arena spur*

It seems certain that there has been relative earth movement at the 10 stations from Snow Mountain West to Lane, and absolute movements seem to be indicated at stations Lane, Clark, Dunn, Fisher, and Cold Spring. As mentioned on page 6, these stations are close to the San Andreas fault. Lane is said to be within a mile of the fault and Cold Spring is only about 10 miles from it. All of these stations are to the east of the fault, and the changes in position are all to the southeastward. This agrees with the general direction of the changes at Mount Hamilton, Loma Prieta, Santa Ana, and Hepsedam, which are also to the eastward of the San Andreas fault.

SUMMARY

We may draw some definite conclusions from the investigation that has been made of the triangulation of California with a view to testing the stability of the earth's surface in the horizontal direction. There seems to have been no change in geographic positions of detectable size of Mount Lola and Round Top, approximately in latitude 39° with respect to Cuyamaca and San Jacinto, whose mean latitude

is approximately 33° 30′, and no one of these four stations seems to have changed position with respect to more inland stations of the triangulation net. No earth movements can be detected at the stations from Mount Lola and Round Top to station Carson Sink in Nevada and none at stations American and Kofa to the eastward of San Jacinto and Cuyamaca. Probably no earth movement has occurred at station Butte, which lies about 80 miles east of San Jacinto. There seems to have been no movement at the stations between Mount Helena and Mount Lola, and none at the intermediate stations from San Luis and San Jose, in latitude approximately 35° 20′, to San Jacinto and Cuyamaca. There has been no earth movement at stations Snow Mountain West, Mount Sanhedrin, Two Rock, Paxton, and Cleland, which lie to the north of parallel 39°.

There are definite indications of earth movements at stations Lane, Dunn, Clark, and probably Fisher and Cold Spring. There has been a large relative earth movement between Point Reyes Lighthouse and Ross Mountain and some absolute movement at each of them.

There have been earth movements at stations Sierra Morena, Loma Prieta, Gavilan, Santa Ana, and Hepsedam. There may have been some movement at Mocho, Mount Hamilton, and Castle Mount, but this is not absolutely certain. It is probable that there has been some movement at Farallon Lighthouse, but the movement, if any, has not been great. It seems probable, from the evidence, that there was no earth movement at station Rocky Butte. There may have been some earth movement at stations Mount Toro, and Santa Lucia, but if so, the amounts were small.

There has been no movement at station Vaca, nor is there any definite indication of earth movement at Mount Diablo. The change at Mount Tamalpais could have been caused by the unavoidable errors of triangulation, but there is a possibility of a slight movement at that station.

The comparison of the old and new triangulations of California seems to show that the largest earth movements occurred close to the fault line of the 1906 earthquake. No definite statement can be made as to how far from the fault actual movements occurred, but the available evidence indicates that stations more than 20 miles from the fault were not affected or, if so, by only slight amounts.

The trend of the changes at stations to the eastward of the fault, where earth movements are indicated, is to the southeastward. The trend of the changes at Point Reyes Lighthouse and Sierra Morena, two stations to the westward of the fault, is to the northward or northwestward. Gavilan, a station to the westward of the fault and close to it, shows very little change in position, only slightly more than 1 foot and that to the northeastward. An analysis of the angles at Gavilan and at stations near by seems to indicate, however, that Gavilan has changed more than is indicated by the arrow shown in Figure 7. This is probably due to the impossibility of separating the effects of triangulation errors and earth movements in the changes of positions at the stations surrounding Gavilan.

The results of the investigations seem to indicate that future testing of earth movements in a seismic region should probably be done by means of short arcs of triangulation of the first order extending across the fault line or zone. There should be stations close to the fault and others at varying distances up to about 25 miles to each side of

the zone to be studied. These stations could be reoccupied at certain intervals of time. The accuracy of the work, as far as base measurements and the measurement of angles are concerned, can be made great enough to detect movements that are larger than about 1 part in 50,000 of the distance between contiguous stations. This is a relative discrepancy of about 0.1 foot per mile.

It has been suggested by some investigators that monuments be placed across a fault zone exactly in a straight line and the distances between the monuments accurately determined. The alignment could then be checked from time to time and the distances remeasured. This plan is impracticable, because of the great difficulty of measuring with tapes over broken terrain such as exists along the San Andreas fault. The triangulation method is easier to put into operation, and it is believed that the results would be quite as satisfactory as if the alignment method were employed.

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