EARTHQUAKES IN THE WALKER PASS REGION, CALIFORNIA, AND THEIR RELATION TO THE TECTONICS OF THE SOUTHERN SIERRA NEVADA

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ABSTRACT

The locations and depths of earthquakes occurring in the Walker Pass Region, California, and the surrounding area have been examined for the period from January, 1934, to December, 1963. Whenever possible, least-square computer locations programs have been used to check or revise the previously determined epicenters and origin times. In most cases, epicenters determined by machine methods are within ten kilometers of those previously assigned. Accurate depths, whenever they could be calculated, were always found to be less than fifteen kilometers and usually less than ten kilometers.

The sequence of earthquakes occurring in the Walker Pass region in March, 1946, has been carefully examined. While no major shifts in epicenters were found, the depth of the main shock of this series has been revised from twenty-one kilometers to less than ten kilometers. This revision cast doubt on the assertion that the earthquake originated on the Sierra Front Fault and made it likely that the earthquake occurred on one of the northwest-southeast trending faults in the interior of the Sierra mass.

Finally, the general distribution of earthquakes furnishes no evidence for the existence of a continuous deep-lying structure traversing the southern part of the Sierra Nevada. While the possibility of the existence of such a structure has not been excluded, practically all of the evidence upon which such a speculation might be based has been removed. Any relation between activity in this region and the activity in the nearby White Wolf Fault region must instead be explained by means of a mutual transfer of strain between systems of different trend and character.

The computer programs used for the location of the earthquakes reported in this study are discussed in Appendices A and B.

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INTRODUCTION

March 15, 1946, a magnitude 6.3 earthquake occurred near Walker Pass, a region visited only infrequently by earthquakes prior to that date. This earthquake and its aftershocks were studied by Chakrabarty and Richter (1949). The conclusions drawn from that study were that the earthquake's location was somewhat west of the Sierra Fault, and that it had a depth of twenty-one kilometers. The assigned position and depth of the earthquake were cited also as evidence that the Sierra Fault in this region had a dip of seventy degrees to the west.

Six years later (July 21, 1952), a magnitude 7.6 earthquake occurred west of the Walker Pass area in the vicinity of Tehachapi. This earthquake occurred on the supposedly inactive White Wolf Fault which had been identified nearly half a century earlier, but which was thought to be dead and not likely to be the source of a major earthquake.

Many new stations were installed in the area following the Arvin-Tehachapi earthquake. Data from these stations made possible the accurate determination of hypocenters for both the 1952 earthquake there and the one of 1946 in Walker Pass. Data for a further study of the original earthquake sequence was added when the Walker Pass region itself again became active between 1955 and the present (1964).

This study was undertaken in order to clarify the relationship between the earthquake sources of 1946, 1952, and more recent date. These successive earthquakes posed a question with regard to the structure of the southern Sierra. Did they represent the seismicity of a structure not exposed on the surface which extended the trend of the White Wolf Fault across the Sierra?

Such an hypothesis would not readily be reconciled with the results obtained by Chakrabarty and Richter. However, conclusions derived from the 1952 events had already revealed the need for serious re-evaluation of the data used in the 1949 study.

SUMMARY OF EARTHQUAKE DATA SOURCES

Eighteenth century accounts of Spanish explorers provide the earliest sources of data concerning earthquakes in California. Similar data appear in more recent times both in the records maintained by military agencies and in newspaper reports. It is only since 1887 that scientifically reliable data recorded at seismographic stations have been available.

The first two such stations in California, and indeed in the United States, were established at Berkeley and at the Lick Observatory in that year. Although the seismographs that were installed there had a low magnification, they were quite capable of detecting large earthquakes. This capacity made it much less likely for large earthquakes within the state to escape notice than had been the case prior to their installation. Indeed, the value of definitive sources for origin times even at this early stage of instrumentation cannot be exaggerated. It was from this two station nucleus that a seismographic network, increasing in worth with the addition of stations and the use of increasingly sensitive instruments was expanded over the years throughout northern California.

Interest in the study of earthquakes occurring in southern California was initiated by Mr. H. O. Wood. Prompted by his enthusiasm, a cooperative program for this purpose was set up in 1921 between the Carnegie Institution of Washington and the California Institute of Technology. Under the auspices of this program, the Wood-Anderson Torsion Seismometer was developed.

The new instrument resolved previously existing problems of recording local disturbances, and coupled with the solution to the problem of accurately recording time, made possible the development of a southern California seismographic network designed to study local earthquakes.

The end of 1928 saw five stations of the net: Pasadena, Riverside, Mount Wilson, La Jolla, and Santa Barbara routinely recording earthquakes. Two more, Haiwee and Tinemaha, were installed and functioning satisfactorily by the end of September, 1929. While other stations were added to the network after 1929, the next most important one, with regard to earthquakes in the Walker Pass region, was at China Lake, which was placed in operation in July, 1949. Under the impetus of the Arvin-Tehachapi earthquake of 1952, stations were added at Woody (August, 1952) and Isabella (January, 1954). Goldstone (November, 1961), the newest station in the network, will be of value in the further study of Walker Pass seismicity by providing significant control to the southeast.

All of the stations in the southern California network are presently equipped with Benioff short period vertical seismometers. In addition, stations may have Wood-Anderson Torsion seismometers and/or strong motion equipment as well as equipment designed for the recording of teleseisms. Haiwee and Isabella added such strong motion equipment after the Arvin-Tehachapi earthquake. The lower magnification of this strong motion equipment both permits the recovery of data other than first arrival times from large events occurring in the immediate area, and provides for the separation of large, closely spaced events in the aftershock sequence. While no disturbance of major importance has occurred in southern California since the 1952 earthquake, the presence of this equipment at Haiwee and Isabella provided information concerning arrival times of secondary phases which would not otherwise have been available for the earthquakes of January and October, 1961.

METHODS FOR THE ABSOLUTE LOCATION OF EARTHQUAKES

As soon as the seismographic network for recording earthquakes in southern California was functioning, the Seismological Laboratory at Pasadena turned to the problem of establishing the velocity structure of the area covered by the net. Knowledge of the velocity structure in southern California was essential to the program's purpose of accurately locating earthquakes occurring in the area.

Initially, locations were assigned on the basis of S minus P times alone. Within four years, however, Gutenberg had completed the first study of travel times for southern California (Gutenberg, 1932), and the earthquakes were being located with reference to his structure analysis. Subsequently, he modified that original structure analysis (Gutenberg 1944, 1951). It is Gutenberg's 1951 modifications, plus others suggested by Press (1960), and the U. S. Geological Survey which forms the basis for the velocity structure concept currently used for locating earthquakes in southern California.

Up to 1962, the method by which most earthquakes in southern California were located consisted of making a first approximation regarding the earthquake's origin time from the S minus P data and calculating the distance of the focus from the stations using the travel time curves and the P minus O times. A preliminary location obtained from the intersection of the arcs thus determined was assumed. If the intersecting arcs for the preliminary location seemed to leave too great a possibility for gross error, adjustments were made to the assumed origin time. When the adjustments provided values for the P minus O times which gave the smallest circle of confusion for the intersecting arcs, a final location was assigned.

In some special cases, locations were further refined by means of calculating the distance from the focus to the stations and making intuitive adjustments to the origin time and location. This procedure was continued until the difference between the observed and calculated travel times was minimized.

Locations assigned to a few earthquakes were also reviewed by means of the least-squares method using a desk calculator. In such cases preference for data from the nearer stations, which receive the direct wave, was always recognized.

The increasing availability of digital computers has made the use of the least-square technique more practical. Programs could be constructed which would give the location by least-square solution for hypocenters in fifteen minutes (Bendix G-15D), or two seconds (IBM 7094) rather than the four hours necessary for manually carrying out the operation.

The Seismological Laboratory at Pasadena began using one such program in 1962 for the location of local earthquakes (Nordquist, 1962). Another program, using individual station corrections has also been tested (Cisternas, 1963). Both of these programs assumed a parallel plane layer structure, and although some other structures have been used, locations have been assigned principally on the basis of the structure by Press (1960).

Larger and more powerful programs for epicentral location have been written by both Cisternas and Gardner. These programs, while continuing to use the least-square technique, provide in addition a means of compensating for the varying structure found in southern California.

The locations and depths of earthquakes presented in this paper were determined by a computer program developed by the author. It provides for the possibility of solution by either a parallel plane layer or a non-parallel plane layer technique. An outline of the program and its general procedure will be found in Appendix A.

METHOD FOR THE RELATIVE LOCATION OF EARTHQUAKES

The method for the relative location of earthquakes has two major advantages. First, it can be used in an area where a knowledge of the complete structure traversed by the seismic waves is not available. Second, it can be used for shocks in which the number of data for an absolute location is inadequate. In addition, the use of relative locations makes possible the geographic grouping of large numbers of earthquakes for further study.

Known as "differencing", this method examines earthquakes in pairs. Its purpose is to locate the two earthquakes relative to one another by comparing the differences in arrival times of the shocks at the stations in the seismographic net. This is accomplished by subtracting the arrival time of one earthquake from that of the other at each station, and establishing a "difference" value between the two earthquakes for each station. These difference values are a measure both of the displacement of the two hypocenters and the difference in origin time. Therefore, the more nearly all of the differences are equal, the closer the two hypocenters are together.

In operation, the method assumes that each earthquake has a unique set of travel times to the station, and consequently that two earthquakes will have the same travel times to all of the stations if and only if they have the same focus.

However, where the difference values are constant to within three-tenths of a second, the two earthquakes are assumed to be from the same source. The plus or minus three-tenths of a second is allowed to compensate for two sources of error. One is the possibility of recording imperfections by the instruments concerned. The other is the possibility of human error in measurement. Because of the allowance for these potential errors, the same focus must be assumed for the two earthquakes since differences of focus within the three-tenths of a second would be impossible to detect.

If the difference values are not constant, that is if their range exceeds three-tenths of a second, the displacement of one hypocenter from the other can be calculated on the basis of velocities in the immediate area. When the calculated displacement of the two hypocenters from each other is found to be no more than ten kilometers, the relative displacement of the hypocenters established by the calculation is accepted as valid, and the gross paths of the seismic waves from the two hypocenters to the stations are assumed to be the same.

The most useful earthquake pairs for study, obviously, are those in which the difference values for the arrival times of the two earthquakes are constant to within plus or minus three-tenths of a second at all of the stations. In such cases, three benefits may be anticipated.

First, the two sets of data provide mutual checks for each other by which likely errors are exposed through discrepancies in the differences. If three or more earthquakes are differenced with each other, even individual errors may sometimes be found.

Second, a combination of several earthquakes can provide travel time data to more stations than a single shock occurring at any one time. Especially is this true of stations, such as the portable units used in the field after the occurrence of a major event, which are started and discontinued throughout the years. In addition, combined data can be used to compensate for stations from which data are missing due to malfunction. For example, data from Haiwee are missing for the two largest earthquakes (January 28, 1961 at 08:12 GCT and September 16, 1962 at 05:36 GCT) known to have occurred near the epicenter at 35°46'N, 118°03'W. However, since other, smaller earthquakes have occurred in that area, it is known with reasonable certainty that the travel time to Haiwee from this epicenter is near 6.6 seconds.

Third, where difference values can be shown to be constant, a means is available for discovering arrival times for the secondary phases of the event. In particular, S arrivals, usually totally lost in the larger event, can be recovered and used to aid in the location of the shock.

As the number of reliably located earthquakes increased, the well recorded data for their location has often been sufficient to establish the hypocenters for others which occurred when there were fewer seismic stations, or when those in existence were handicapped by malfunction. Differencing is what makes this possible.

Just as a computer program for the least-square method of absolute location of earthquakes has been written, so has one been written for the relative location of earthquakes by the differencing method. The program is intended to be used for those earthquakes in which the difference in location is at most only a few kilometers. An outline of the program's structure and procedure is presented in Appendix B.

METHOD OF SEARCH FOR EARTHQUAKES OCCURRING NEAR WALKER PASS

Although the first stations of southern California's seismographic net began regular recording of data in 1926, routine publication of the location of earthquakes occurring in southern California did not begin until 1934. The possibility of publication prior to that date had been impeded by shortages of personnel and financing, lack of knowledge regarding the structure and velocities of southern California, and the extra workload caused by the Long Beach earthquake of 1933.

Southern California earthquake data published since 1934 were first cataloged through 1957 onto IBM cards by Drs. C. R. Allen and Pierre St. Amand. The card catalog, updated through 1962 by the author, has had corrections, additions, and revisions in epicenters and magnitudes made to its entirety by Mr. John M. Nordquist.

With respect to earthquakes occurring in the Walker Pass region and its surrounding area, a list of all such events was first prepared by applying a computer program, developed by Mr. John M. Nordquist (1964) to the IBM card catalog. This initial list was then refined to include only those shocks having a Richter magnitude of 3.6 or greater, and prepared as a Table (1) for publication in this paper.

QUALITY OF LOCATION OF EARTHQUAKES NEAR THE WALKER PASS REGION

Walker Pass is about forty kilometers from Haiwee, Isabella, and China Lake, all of which receive the direct wave from this region as the first arrival. Because these stations are nearly equidistant from Walker Pass, the epicentral locations are excellent when data from all of them are present.

The direct wave as the first arrival is also received by the stations at Woody, Fort Tejon, Goldstone, and Tinemaha. Tinemaha is almost beyond the range at which the direct wave normally arrives first; but because of the many peculiarities of the Sierra structure, earthquakes from the Kern County region with epicentral distances as great as 170 kilometers have been found to record the direct wave as the first arrival (Richter, p 194, 1955). The remaining stations of the network normally record refracted arrivals as the first arrival from the Walker Pass region.

Between the inception of the seismographic network and 1949, only Haiwee and Tinemaha received the direct arrival from epicenters in the Walker Pass region. During that time, the essential east-west control was supplied only by Santa Barbara, which received first the refracted arrival.

The inadequacy of this east-west control by Santa Barbara is occasioned by the constant presence there of a large background noise level which obscures first arrivals, particularly those of earthquakes with magnitude less than 4.5. In addition, structural control on the path between the Walker Pass region and Santa

Barbara is not good, both because of the proximity of Santa Barbara to the coast and the thick sedimentary section there, and the position of the Walker Pass region above the deepest portion of the Sierra Nevada root. Thus, travel times from the Walker Pass region to Santa Barbara may deviate markedly from the normal travel times assumed for southern California structure.

Because the north-south control in the Walker Pass region was much better than the east-west control, the latitude of epicenters there through 1948 was much more certain than the longitude. A trivial amount of additional east-west control was provided by a portable unit taken into the region for the aftershock series of the Walker Pass earthquake of 1946. However, the concurrent failure of recording at the station at Haiwee was a serious deficiency. It was not until the installation of the station at China Lake in 1949 that the quality of east-west control for shocks occurring since that date improved and the location of epicenters in that region was markedly better. However, no important earthquakes occurred in this region, with the exception of a swarm near Little Lake in June and July of 1951, until after the stations at Woody (1952) and Isabella (1954) had been added to the net.

During the period prior to 1948, epicenters which were not in the Walker Pass region proper suffered to a lesser degree from the lack of east-west control since Haiwee could provide it. This was true for epicenters in both the Argus Mountains to the east of Haiwee and those in the interior of the Sierra block.

As epicenters approached the Garlock Fault, the stations at Pasadena and Mount Wilson which also receive the direct wave began to provide an increasing measure of east-west control. Thus, the locations of these earthquakes are somewhat better than the location of earthquakes in the Walker Pass region itself before the advent of China Lake.

The differencing technique applied to earthquakes in the Walker Pass region has been, in a few cases, exceptionally useful for the period 1936-1948, particularly for earthquakes which have occurred near the station at Haiwee and in the desert region near Brown. One or two very remarkable cases of constant difference values have appeared. In these few cases, where differencing was so successful, confidence in the accuracy of the epicenters may reach the level of that felt for those shocks recorded in more recent times with the greater number of stations.

EARTHQUAKES IN THE SOUTHERN SIERRA REGION BEFORE 1934

Since reliable knowledge concerning the frequency of the occurrence of major earthquakes in any area requires many years of accurate recording and evaluation, a chronological discussion of the earthquakes in California is necessarily hampered by the lack of such data. Historical evidence for such events can be found beginning as early as 1769, but is most charitably described as inadequate.

A search of Townley and Allen (1939) and the Earthquake History of the United States, Part II, provided the following information for shocks in the southern Sierra region. It includes a record of both those seismic events occurring before the installation of seismographs, and those recorded in the period from 1887 to 1934 when routine publication of earthquake data for southern California was begun.

The first such seismic event was reported for the Owens Valley region. It had for a source Indian recall of an earthquake occurring about eighty years before a more recent event (1872), which would, if acceptable, give us 1790 as the beginning for the historic study of seismic activity in the southern Sierra. A record of this type cannot be considered reliable in any degree. However, since numerous recent fault scarps attest to recent movements in the area, it is not necessary that any value be attached to it.

The second report applicable to the southern Sierra includes a series of earth tremors beginning in August, 1868, and continuing through September. The largest shock was reported to have occurred September 4, 1868. Epicenters for the whole series were apparently centered on the Upper Kern River.

Three years later, in July, 1871, a severe shock was felt at the Joe Walker Mine located on the east side of Walker Basin in Kern County. The mine was reported to have filled almost instantly with water as a result of the earthquake.

In the latter half of 1871 and the first three months of 1872, Owens Valley was reported as the location of another series of earthquakes. They might reasonably be considered foreshocks of the earthquake which occurred near Lone Pine, March 26, 1872, at 2:30 a.m. This earthquake is quite likely the largest which has occurred in California in historic times. Adobe houses were shattered as far away as Indian Wells, near China Lake. In Lone Pine itself, no adobe house escaped destruction. Both vertical movements as great as twenty-three feet and horizontal displacements as much as twenty feet were observed. Unfortunately, the importance of evidence regarding lateral movements was not recognized, and it has disappeared with time, leaving uncertain exactly what type of movements took place. Earthquakes which may be considered as aftershocks of this event persisted for many years.

It is from a newspaper source that information about three distinct shocks felt at Tehachapi comes for the catalog of southern

California earthquakes. They began February 13, 1890, at 2:10 a.m. and were spaced about twenty minutes apart.

Weather Bureau and press reports were also the only published information on the series of earthquakes occurring in Death Valley during October and November, 1908. However, the strongest shock of the series, that of November 4, was recorded by instruments as nearby as Berkeley and as far away as Ottawa.

Another southern Sierra earthquake occurred May 28, 1915 Its location east of Springerville in Tulare County was established by both instrumental records and the shape of the felt area. Its magnitude was closer to 5 3/4 than 6. (Dr. C.F. Richter, personal communication).

Death Valley was the site of another potentially destructive earthquake November 10, 1916. Reports from the seismograph stations at Reno, Berkeley, and Mount Hamilton provide the evidence for the location of the epicenter in the desert region of the Garlock Fault just south of the valley.

The following year, an earthquake which was felt from Little Lake on the south to a point just beyond Independence on the north occurred. A 160 foot long break in the Los Angeles aqueduct occurred on the same day, July 6, 1917, but it is not certain whether the earthquake was responsible for the break.

The next three earthquakes in the chronological catalog all touch Kern County. The first, on March 23, 1918, brought felt reports from Brown in Kern County and Little Lake in Inyo County. The second, on June 30, 1926, in the Kern River Canyon, produced shaking so severe that workmen in the area had difficulty standing. The third, on July 25, 1932, was assigned a location near the Kern River of 35°48'N, 118°32'W. This earthquake, with an origin time of 10:51 p.m. and a magnitude of 4 1/2, was recorded by instruments. However the accuracy of the assigned location may be overestimated since the recording was very incomplete.

It is probable that since 1850 every earthquake whose magnitude equaled that of the San Francisco earthquake of 1906 has been recorded. On that premise, and in view of the results of the search reported in the preceding paragraphs, it seems reasonable to assume that no major earthquake had occurred in the Walker Pass region proper. However, the fact that a major earthquake could escape notice because the area was sparsely populated is not impossible.

EARTHQUAKES LOCATED INSTRUMENTALLY IN THE WALKER PASS REGION AND SURROUNDING AREA BETWEEN JANUARY 1, 1934, AND MARCH 15, 1946

Only twenty-four earthquakes of magnitude greater than 3.5 were found in the region shown in Figure 2. Of these, only four possessed a magnitude greater than 4.4. Since earthquakes were reported to the nearest half of a magnitude unit prior to 1943, it is certain that some earthquakes with a magnitude greater than 3.5 have been missed. However, it is unlikely that many with a magnitude as great as four have been omitted.

Locations using the parallel plane layer locations program were attempted for these twenty-four earthquakes. Many converged to a solution, but the adequacy of these solutions could be questioned in almost all cases. Locations for the earthquakes in the Walker Pass region and northward were seriously affected by the poor reliability of travel times to Santa Barbara. Locations further south had the benefit of the better east-west control provided by Pasadena, Mount Wilson, and Riverside, but lacked near station control. No epicentral determinations or origin times were modified since the quality of the locations provided by the computer solution were at best only equal to the original determination of those quantities.

Many of the twenty-four earthquakes tended to fall into one of two groups. First, those earthquakes which tended to occur in swarms. Second, the earthquakes which tended to occur repeatedly from the same epicentral area. When an earthquake fell into the second group, and one of the repetitions occurred after 1949, the post-1949 location, if sufficiently well known, could establish that of the others in the group. These locations could be checked, either by direct comparison of the travel times or by use of the earthquake comparison program. However, since few of the locations obtained by such checks were of better quality than the original ones, only these few epicenters were revised.

Epicenters of earthquakes with magnitude greater than 3.8 have been plotted on Figure 2, with the exception of some occurring near the station at Haiwee. Prior to March 15, 1946, only one such earthquake occurred in the Walker Pass region proper. This earthquake, a magnitude 4, occurred on February 8, 1935, at 04:22 GCT. Examination of the arrival time data for the earthquake led to the conclusion that it actually occurred somewhat further east. Unfortunately, the arrival time data for the earthquake were not sufficiently consistent to obtain a meaningful solution from the computer program. Therefore, the original location assigned to the epicenter was not altered.

In May, 1935, the epicenter near 35°42'N, 118°22'W became active. Over fifty earthquakes above magnitude two were assigned to this epicenter. The largest occurred June 11, 1935, at 16:20 GCT. This earthquake was located relative to the earthquake of May 28, 1955 at 19:44 GCT. The location obtained was 35°42.5'N, 118°21.4'W at a depth of zero kilometers and with an origin time of 16:20:45 GCT. The May 28, 1955, earthquake was also used to establish relative locations for two later earthquakes assigned to this epicenter. One of them occurred May 3, 1936, at 14:20 GCT and the other January 19, 1937, at 23:57 GCT.

The May 3, 1936, earthquake converged to an epicentral solution near 35° 45.0' N, 118° 29.7' W at a depth of 7.2 kilometers and with an origin time of 14:21:00 GCT. However, the presence of large residuals at several key stations showed it to be unsatisfactory. The January 19, 1937, earthquake converged to an epicentral solution near 35° 40.4' N, 118° 18.6' W at a depth of 15.1 kilometers and with an origin time of 23:57:38 GCT. Since none of the locations or origin times provided by the computer program for earthquakes near the epicenter 35° 42' N, 118° 22' W seemed fundamentally of better quality than the original ones, the latter were retained.

The Haiwee region possesses a number of epicenters from which earthquakes have originated repeatedly over the years. These were labeled by H. O. Wood (p. 233, 1947) as "habitual epicenters." The earthquake which occurred on April 24, 1936, at 19:00 GCT was the first above magnitude 3.6 reported for the Haiwee region after the routine publication of southern California earthquake data began. The travel times for this earthquake, and those occurring on June 22, 1942, 22:13 GCT; June 22, 1942, 23:51 GCT; October 16, 1942, 10:07 GCT; May 30, 1943, 07:50 GCT; July 26, 1945, 10:10 GCT; and January 5, 1959, 12:36 GCT are given in Table 16.

It is apparent from an inspection of the data in Table 16 that the earthquakes are not far removed from each other. However, all attempts to relocate them by use of the earthquake comparison program were unsuccessful. Again, the probable cause of this failure was inconsistent data. A more detailed discussion of the sequence of earthquakes commencing on January 5, 1959, has been developed by Richter (1960), and the same sequence will be further examined in this paper.

On September 10, 1937, at 19:34 GCT, the first earthquake above a magnitude 3.5 was reported from the area midway between Haiwee and Walker Pass. It had a magnitude near 3.6. Other earthquakes reported from this area are given in Table 21. They include the earthquake of September 18, 1937, at 08:37 GCT; and the earthquakes of September 16, 1943, at 00:16 GCT and 07:52 GCT. The latter is the largest which occurred in this group.

Since 1952, no earthquake large enough to be well recorded at the distant stations has occurred in the area between Haiwee and Walker Pass. Several earthquakes smaller than 3.5 have occurred, but because of the lack of earthquakes suitable in size for use in the comparison program, the relocation of these earthquakes was not attempted. Although the epicenters of the larger shocks shown in Table 21 are not as accurate as might be desired, the fact that they have been assigned generally to the correct location can be shown by a comparison of the travel times appearing in the same table.

The first of the two larger shocks which occurred in the area shown in Figure 2 prior to the Walker Pass earthquakes of 1946 occurred on September 17, 1938. Attempts to find an earthquake in the immediate area for comparison purposes were unsuccessful.

The location has not, therefore, been modified in any way.

The second of the two larger shocks occurred on January 7, 1939, at 20:21 GCT. Travel times for this shock, as well as those of August 15, 1939, at 15:48 GCT; August 9, 1944, at 14:01 GCT; August 12, 1944, at 08:25 GCT; and August 13, 1944, at 06:27 GCT are given in Table 22. Locations were attempted using the comparison program, with the earthquake occurring on July 23, 1956, at 10:43 GCT as the key shock. The location of the January 7, 1939, shock was well confirmed. However, locations for the remainder are best described as, at most, fair.

Since 1934, the largest earthquake, a magnitude 4.7, reported from the Garlock Fault, occurred on July 3, 1944, at 05:38 GCT. The arrival time data for this earthquake are given in Table 23, along with the arrival time data for the earthquakes of May 11, 1945, at 00:09 GCT; and October 29, 1946, at 11:34 GCT. These earthquakes were compared against that of September 21, 1963, at 05:06 GCT. Again, none of the solutions were more satisfactory than the original epicenters, so the latter were retained.

An earthquake in the Kern River region which occurred on May 18, 1945, at 09:44 GCT, was compared against the shock of November 17, 1952, and data for the comparison are given in Table 17. The difference data indicated that the epicenters were quite close together. However, the original location was retained because the earthquake comparison program again behaved erratically due to the presence of inconsistent data resulting from the lack of east-west control for the epicenter.

All these checks of earlier data have served to confirm the fact that prior to March 15, 1946, except possibly in the region of Haiwee, there have been no major errors in the locations of the earthquakes occurring in the region shown in Figure 2. The earthquakes near Haiwee, throughout the years, have most likely occurred quite near the earthquake of January 5, 1959. However, their originally assigned locations have not been modified; because the inconsistency of the data for these shocks, which appears in Table 16, did not permit the earthquake comparison program to provide more adequate epicentral solutions.

The seismic activity, illustrated in Figure 2, prior to the earthquake of March , 1946, was distributed generally throughout the area. There was some tendency for this general distribution to concentrate near the Kern River Fault, the Garlock Fault, or the Sierra Fault near Haiwee. No known earthquake had a magnitude as large as 5.0, although three were larger than 4.6. Finally, the Walker Pass region itself, with one possible exception, was seismically quiet throughout the twelve years immediately preceding 1946.

THE MARCH 15, 1946, EARTHQUAKE AND ITS AFTERSHOCKS

The Walker Pass earthquake sequence commenced at 13:21:01 GCT with a foreshock whose magnitude was 5.5. Some twenty-eight minutes later, the main earthquake, with a magnitude of 6.3 occurred. This is the largest earthquake known to have occurred in the Walker Pass region.

A study of this earthquake and some of its aftershocks was made by Chakrabarty and Richter (1949), in which the distribution of twenty aftershocks was determined relative to the main earthquake by differences in arrival times. The results of this study, as well as the arrival times of both the initial phase and many secondary phases were published in that paper.

Locations for many of the earthquakes of the March 1946 sequence were attempted using the plane parallel layer locations program. However, the solutions had the same quality deficiencies which had previously appeared with shocks of earlier date. Therefore, the most satisfactory method of location again was by means of differencing. Since the arrival times of the various P and S phases at the stations were carefully checked by Chakrabarty, the use of differences was much more successful for this sequence of earthquakes than it was for the earlier data. Also, methods of timing had improved so much that more accurate absolute time was available at the stations.

There are three well recorded earthquakes which have occurred near or in the Walker Pass region since 1949. The first of these is the shock of July 11, 1956, at 19:22 GCT, which was so accurately recorded that it was used as the key earthquake for the relative location of the Walker Pass sequence of 1946. The second was the earthquake of October 24, 1959, at 15:35 GCT, which was inadequately recorded at Santa Barbara because the noise level there was exceptionally high and the record itself was quite faint. The third is the earthquake of January 28, 1961, at 08:12 GCT. Initially it was hoped that this earthquake had occurred at the same epicenter as the main earthquake of the 1946 sequence, and that direct comparison would be possible. This, however, did not prove to be true.

The Walker Pass sequence of 1946 was located relative to all three of the earthquakes mentioned above prior to the selection of the July 11, 1956, earthquake as the key earthquake. It was found, with a single exception, that the most consistent locations were given by comparisons with the earthquake of July 11, 1956, as the key earthquake. In all cases, except one, it was also found that the epicenters thus obtained were displaced less than five kilometers from ones determined by Chakrabarty. The one exception in both cases was the earthquake of April 16, 1946, at 10:37 GCT. This earthquake has been assigned an epicenter relative to that of the earthquake of October 24, 1959, at 15:35 GCT. The displacement of this epicenter was found to be less than three kilometers from its location as determined by Chakrabarty.

Epicenters for the 1946 sequence determined relative to either the July 11, 1956, earthquake or the October 24, 1959, earthquake are in general quite close together. In those cases where the Santa Barbara arrival time of the second key shock influenced the result, this is not true. In cases where the Santa Barbara arrival time did not influence the solution, it either was absent from the data, or the residual for Santa Barbara was so large that the program rejected the datum in computing the solution. In particular, the difference in the locations of the epicenters of the foreshock, as determined in relation to the two key shocks, was less than one kilometer. Tables 12 through 15 contain the solutions obtained by using the earthquake comparison program for the foreshock and the main shock located relative to the earthquakes of July 11, 1956, and October 24, 1959.

The origin times of these earthquakes were increased between one and two seconds over those determined by Chakrabarty. The increase was a result of the change in velocity structure from the one used by Gutenberg in 1944 to the one currently in use at the Seismological Laboratory at Pasadena.

Some aftershocks not examined by Chakrabarty were also processed and revised locations obtained. Some of these epicenters showed greater displacements than the ones which were included in his study. This occurred mainly because many of these earthquakes were assigned in a blanket manner to an epicenter at 35°42'N, 118°02'W.

One such aftershock, on March 18, 1946, at 15:50 GCT, failed to converge in any of the comparison attempts. However, inspection (see Table 20) of the differences between this earthquake and the one of July 11, 1956, at 19:22 GCT, revealed that these epicenters were quite close. The arrival times of the aftershock were somewhat obscured by another aftershock from nearly the same source which occurred only a minute earlier.

Locations of the main Walker Pass shock, its one foreshock, and many of its aftershocks are shown in Figure 3. These locations include all of the earthquakes given by Chakrabarty and Richter (1949) except one. The numbering of the shocks in Figure 3 corresponds to ones found in that paper. The one exception is the shock of February 1, 1947, at 13:30 GCT, near 35°13'N, 118°20'W, which falls outside of the limits of the figure. Shocks not listed by Chakrabarty are shown in Figure 3 by means of letter suffixes as appropriate. Detailed information regarding the particular shocks in Figure 3 may be obtained by referring to Table 1.

A nodal plane solution using the combined data of the foreshock and main earthquake of the March, 1946, sequence and the earthquake of January 28, 1961, at 08:12 GCT was reported by Ingram (Ingram et al., in press). The nodal lines obtained by Ingram were plotted as dashed lines on Figure 3. These dashed lines represent the intersection of the nodal planes with a plane perpendicular to the normal to the surface of the earth at the epicenter located ten kilometers below the focus of the earthquake. The arrows in Figure 3 give the directions of possible movement. An inspection of the figure reveals that most of the earthquakes fall in the southern quadrant of the nodal plane solution.

Attempts were made to find earthquakes occurring after 1951 which had the same epicenters as earthquakes of the 1946 sequence. These attempts were, on the whole, unsuccessful. The one outstanding exception is the earthquake of March 18, 1946, at 15:49 GCT, which has nearly the same epicenter as the earthquake of July 11, 1956, at 19:22 GCT. The data are given in Table 20. The similarity in travel times is almost beyond belief, considering that the readings were made independently and only one reading, in the latter earthquake, has been revised.

The most important single result of this portion of the study is the fact that the epicenters in the Walker Pass region, as reported by Chakrabarty and Richter (1949), do not need substantial revision. While the epicenters obtained by them may be displaced from the ones reported in this study by as much as five kilometers, the area delimited by the aftershocks remains essentially unchanged.

The result second in importance is the fact that the depths of these earthquakes do need revision. They are much less than the twenty kilometers assigned by Chakrabarty, since most have been found to be less than ten kilometers. This result is supported by evidence, to be presented later, which shows that more recently occurring earthquakes also have depths of less than ten kilometers in most cases.

A third result is the addition to the knowledge about the Walker Pass region of the fact that no earthquakes have been found to occur in the vicinity of Brown, near 35°46'N, 117°57'W, before March 18, 1946, at 15:49 GCT. This epicenter represents the greatest extension of the aftershock area in the northeast direction.

The circumstances of the first known occurrence of earthquakes near Brown were in themselves interesting. Six shocks, excluding the main shock, with magnitudes greater than five are known to have occurred in the Walker Pass sequence. Within the first twenty-four hours after the onset of the sequence, five of the six had occurred. The sixth, in the vicinity of Brown, occurred more than three days after the onset of the sequence, and was itself preceded by a foreshock and followed by aftershocks. A similar phenomenon was observed for the Arvin-Tehachapi earthquakes of 1952 (Richter, p. 192, 1955). This sequence also contained a large aftershock considerably displaced from the main shock and originating many hours after the main shock. Another similarity between the two sets of events is the fact that, in both cases, earthquakes have continued to originate from these epicenters for many years after the initial shock.

A fourth chief result is that the great majority of these earthquakes have been assigned locations south of a line drawn betwen 35°42.3'N, 118°00.2W and 35°45.3'N, 117°58.7'W. The southern terminus of this line is the epicenter for the main Walker Pass shock of March 15, 1946. Its northern terminus is the epicenter of the aftershock near Brown of March 18, 1946. Only a few earthquakes were found to be northwest of this line. However, since the north-south control for this sequence of earthquakes is far stronger than the east-west control, assignment of epicentral locations with respect to a line trending from southwest of northeast is more adequately supported than might first appear possible.

A fifth result is drawn from a comparison of the numbers of earthquakes in the Walker Pass region before and after the occurrence of the earthquakes of 1946, which shows that the area was much more quiet seismically before that date than it has ever been since. Although the 1946 aftershock sequence had terminated by 1948, earthquakes have continued to occur in the Walker Pass region with much greater frequency than ever before.

EARTHQUAKES IN THE WALKER PASS REGION AFTER THE MARCH 15, 1946, EARTHQUAKE SEQUENCE

By July, 1946, the high level of seismic activity found in the Walker Pass area during March and April of that year had greatly diminished. Two years later, the major seismic activity had pinched out almost completely, and from then until June, 1951, the largest earthquake in the Walker Pass region was a magnitude 3.6, which occurred on August 10, 1950, at 09:55 GCT.

Seismic activity in the Walker Pass region then resumed on June 25, 1951, at 19:45 GCT with a magnitude 4.6 earthquake near Brown. This earthquake was followed quickly by another of almost equal size: June 26, 1951, at 01:26 GCT with a magnitude of 4.4. During the next month, at least nine other shocks occurred near Brown. The largest of these occurred July 1, 1951, at 00:16 GCT and had a magnitude of 3.7.

These earthquakes near Brown were recorded successfully both at Haiwee and the recently installed station at China Lake. Because of the presence of the station at China Lake, east-west control was so improved that the plane parallel layer locations program was able to furnish adequate computer solutions for their hypocenters. The arrival time data for these earthquakes are given in Table 20, and the epicenters and depths provided by the computer solution are plotted in Figure 4.

The sequence of earthquakes which began on June 25, 1951, does not display the normal main shock - aftershock sequence pattern. Instead, the occurrence so close together in time of two earthquakes with nearly the same magnitude is suggestive of an earthquake swarm. The other shocks, however were smaller by about one order of magnitude. When these shocks near Brown died out, the area shown in Figure 2 experienced almost a year of seismic quiet. During that period of time no shocks of magnitude greater than 3.5 occurred in the region.

On July 21, 1952, at 11:52, just beyond the soutwest limits of Figure 2, routine seismic activity was interrupted by the Arvin-Tehachapi earthquake. Unfortunately, aftershocks of this earthquake obscured, at many of the stations, the arrival times of a shock near 35° 59'N, 117° 56'W. The latter occurred within the limits of Figure 2 only four hours after the initial Arvin-Tehachapi shock.

Arrival time data which could be recovered for this shock near Coso Junction are presented in Table 21. It is indeed regrettable that the arrival times from the epicenter near Coso Junction should be so obscured. If clear, they would have been quite useful for checking epicentral locations of shocks which occurred in the same immediate vicinity ten to twenty years earlier.

After the Arvin-Tehachapi earthquake of 1952, overall seismic activity in the Walker Pass region increased somewhat. The increased activity included four earthquakes with a magnitude greater than 3.5. They occurred in the thirty-two months between the earthquake of July 21, 1952, at 15:15 CCT, and that of May 28, 1955, 19:44 GCT, and were not concentrated in any one area, but were instead scattered throughout the area of Figure 2.

The earthquake of May 28, 1955, at 19:44 GCT, had a magnitude of 4.4, and was located at 35°32.0'N, 118°15.8'W, and occurred at a depth of 12.3 kilometers. The time, location, and depth above were supplied by the non-parallel plane layer locations program. Although data are missing for both China Lake and Isabella, it is unlikely that the location is seriously in error. Table 3 presents the epicentral solution, and Figure 2 includes the plotted location.

The location of the May 28, 1955, earthquake is of particular interest. It occurred in the seismically quiet region between Walker Pass and Caliente, the eastern terminus of activity associated with the White Wolf Fault. This earthquake is the only one with a magnitude greater than 3.9 recorded in that area since the installation of the station at China Lake in 1949. In addition, it is almost the only one recorded from that particular epicenter since the installation of the station at Isabella in 1954.

In an effort to supply the missing arrival time data at both China Lake and Isabella, a careful search was made for other earthquakes from this region. The absence of both foreshocks and aftershocks for the earthquake of May 28, 1955, made this extremely difficult. In fact, only one such earthquake was found, and it was so small that it was useless for the purpose. This dearth of aftershocks is in sharp contrast to the swarmlike numbers following the earthquakes occurring near 35°42'N, 118°22'W during 1935 and 1936. Unfortunately, at that time neither China Lake nor Isabella had been installed.

The value of being able to establish travel times for missing stations from those of other shocks is demonstrated by the earthquake of August 22, 1955, at 14:41 GCT. This earthquake with a magnitude of 3.7 occurred in Walker Pass, and was well recorded both at all of the near stations and many of the distant ones as well. The computer solution for the hypocenter is excellent. It yielded an epicenter of 35° 46.1'N, 118° 02.2'W, a depth of 7.3 kilometers, and an origin time of 14:41:20.8 GCT. This solution is displayed in Table 4, and the location plotted in Figures 2 and 7.

Because this earthquake had nearly the same epicenter as the earthquake of January 28, 1961, at 08:12 GCT, the missing arrival time at Haiwee for the latter could be supplied. It is possible to establish such missing data when, as in this case, the travel times of the two earthquakes (Table 18) are nearly identical for the nearer stations.

The earthquake of July 11, 1956, at 19:22 GCT, is an example of the value of differencing in refining previously determined epicentral locations. Although neither foreshocks nor aftershocks were recorded for the July 11, 1956, earthquake, it was most significant for this study. Not only was it perfectly recorded at all of the near stations, but in addition it was well recorded at more distant stations. Of particular importance was very clear recording of the arrival time at Santa Barbara. The value of the excellent recording at these distant stations lies in the fact that they also recorded the earthquakes occurring near this epicenter in

March 1946, and June and July, 1951.

The hypocentral solution for the July 11, 1956, earthquake is the most consistent solution obtained in this study. It yielded an epicenter of 35°46.0'N, 117°56.9'W, a depth of 12.6 kilometers, and an origin time of 19:22:06.7 GCT. The solution is given in Table 6, and the location plotted in Figures 2 and 4.

Table 20 gives the travel time data for earthquakes which have epicenters near that of the earthquake of July 11, 1956. These earthquakes have occurred over a period of ten years, and the travel times strongly indicate that they have epicenters which are very close together. This, then, is an excellent example of the "habitual epicenter" of H. O. Wood. Earthquakes from the "habitual epicenter" near 35°46'N, 117°57'W, have occurred as aftershocks of a major event (1946), as a swarm (1951), and as an isolated earthquake (1956).

After the installation of the station at China Lake, only a few earthquakes occurred in the Argus Mountains region near 35°58'N, 117°46'W, which was active in 1939 and 1944. One of the more recent earthquakes from that region occurred July 23, 1956, at 10:43 GCT. The solution is good, considering the size of the shock, and is given in Table 6. Travel times for this earthquake and those of the earlier shocks are given in Table 22.

More than a year later (October 4, 1957), a magnitude 3.8 shock occurred in the Walker Pass region itself. The plane parallel layer location solution was satisfactory, and yielded an epicenter of 35°48.1'N, 118°00.9'W, a depth of 5.7 kilometers, and an origin time of 12:00:36.9 GCT. This earthquake is of interest because it occurred farther north than any of the other earthquakes in the Walker Pass region proper. Earthquakes both before October 4, 1957, (March 1946: August, 1955) and after (October 1959: January, 1961: September, 1962) have epicenters south of that point.

The seismically quiet year of 1958 in the Walker Pass region was followed by one of greater activity. In 1958, there had been a complete absence of shocks with a magnitude greater than 3.5. In 1959, however, two important earthquake sequences occurred. The first, near Haiwee, appeared in January, 1959, and the second, in Walker Pass, during October and November, 1959.

The earthquake sequence near Haiwee (January, 1959) began with a magnitude 4.7 shock at 12:36 GCT. The solution provided by the locations program is an excellent one. It gave an epicenter of 36°09.3'N, 118°03.3'W, a depth of 2.6 kilometers, and an origin time of 12:36:02.6 GCT. The solution is given in Table 7, and the epicentral location is plotted in Figures 2 and 5.

Reference to Table 16 will demonstrate that this epicenter is near those of the shocks occurring in 1942 and 1945. In type, these latter events were a swarm with many earthquakes assigned to the same location. The 1959 earthquakes were also swarmlike in character with many of the shocks having nearly the same magnitude. Richter (1960) studied the 1959 earthquake sequence near Haiwee, and the arrival times for many of the members of that swarm may be found in his paper.

Hypocenters for six of the larger earthquakes occurring in January, 1959, have been determined by using the parallel plane layer locations program. The solution provided a series of epicenters located along a north-south trending axis as shown in Figure 5. This result confirmed Richter's conclusion that the earthquakes occurred at two epicenters displaced from each other by two minutes of latitude.

The January, 1959, earthquakes near Haiwee presented another interesting feature in that they were exceptionally shallow. The locations program found no depth greater than three kilometers for any of these earthquakes, which is the shallowest valid depth recorded for the shocks plotted in Figure 2.

The earthquake sequence in Walker Pass (October, 1959) began at 15:35 GCT, and continued for almost a month. The largest shock with a magnitude of 4.2 occurred at 15:35:15.3 GCT, on October 24, 1959. The computer solution which gave a location of 35° 44.7'N, 118° 01.4'W, and a depth of 7.4 kilometers is a good one, and is given in Table 8. For the main shock, the arrival time at China Lake was missing. However, it has been supplied by using the travel time for an aftershock occurring at 19:58 GCT on the same day.

One of the aftershocks (November 11, 1959) is of further interest. This earthquake itself was the amin shock for a subsequence of aftershocks, all within the time limits (October and November, 1959) for the main series. Again, the computer solution was a good one fitting all of the nearer stations quite well, and giving a depth of

9.7 kilometers. Table 19 gives the arrival and travel time data for the main shock in Walker Pass (October 24, 1959) and three of the larger aftershocks, including the one of November 11,1959. The locations for these earthquakes are shown in Figure 6. These locations, and others of the October-November, 1959, series place them closer to the epicenter of the 1946 earthquake in Walker Pass than any others. However, the shocks occurring in 1959 are distinctly north of those occurring in 1946.

During 1960, the Walker Pass region, and indeed all of the area shown in Figure 2, was quiet. No earthquakes of magnitude greater than 3.4 occurred. The period of quiescence was terminated January 28, 1961, by a magnitude 5.3 earthquake, the largest (as of April, 1964) which has occurred in the Walker Pass region since the 1946 sequence.

The Walker Pass earthquake of January 28, 1961, at 08:12 GCT, was assigned a location of 35°46.2'N, 118°02.9'W. The depth calculated was 5.5 kilometers, and the origin time 08:12:46.2 GCT. Unfortunately, the arrival time at Haiwee was missing for this earthquake. However, the missing data were furnished for the computer solution, shown in Table 9, by comparison of the earthquake both with its aftershocks and with the earthquake of August 22, 1955. The data for these comparisons are given in Table 18.

The location of the main shock is shown in Figures 2 and 7. The latter also includes some of the larger aftershocks. These aftershocks continued into February, 1961. They lie within quite a compact area, a phenomenon typical of many of the shocks discussed in this section, and all have depths of less than ten kilometers.

The aftershocks of the January 28, 1961, earthquake were studied by the Stanford Research Institute (Westphal, 1961). Three hundred and six events were registered by SRI during periods of intermittent recording in February, March, and May, 1961. Of these, twenty-six were both suitable for analysis and found to originate in the Walker Pass region.

In depth, the SRI group found that the earthquakes averaged eight kilometers, with the greatest being 10.4 kilometers. In location, twenty-two of the twenty-six were found by SRI to originate in the vicinity of Lamont Meadow, located about 35°48'N, 118°02'W.

Lamont Meadow is about three kilometers north of the epicenters found by using the parallel plane layer locations program. The causes of the discrepancy are not clear. Among the many possibilities, two seem most likely. One is that at Haiwee there may be local delay which would force the epicenter away from that station. The other is that epicentral control was not as good as might be desired since the temporary stations set up by SRI were all south of Lamont Meadow.

October 19, 1961, a magnitude 5.1 earthquake occurred in the region northeast of Walker Pass. The determination of the hypocenter was again excellent. The location assigned was 35°51.4'N, 117°48.3'W, the depth 6.4 kilometers, and the origin time 05:09:44.6 GCT. The solution is given in Table 10, and the location plotted in Figure 2.

For the main shock of October 19, 1961, there was only one small aftershock. Also it was preceded by only one small foreshock which occurred about eight minutes earlier. The computer solution for the foreshock yielded a depth of less than five kilometers. In this it resembles the main shock. The shallow depth of the latter is also supported by field evidence gathered by Dr. Pierre St. Amand (personal communication). Near the epicenter, he observed such effects as the displacement of heavy machinery to be much greater than might be expected for a magnitude 5.1 earthquake were it to occur at a greater depth.

Eleven months later, the relatively quiet seismicity in Walker Pass was broken by the magnitude 4.8 earthquake of September 16, 1962, at 05:36:16 GCT. Arrival and travel time data for this earthquake, which was accompanied by numerous aftershocks, are given in Table 19. Its hypocenter, at a depth of only four kilometers, is somewhat displaced from that of the January 28, 1961, earthquake. Unfortunately, the arrival time at Haiwee was lacking for both.

Chronologically, the next shock of interest recorded in the area of Figure 2 occurred September 23, 1963. The earthquake was small in magnitude, but well recorded. The solution, displayed in Table 11, gave a depth of 11.1 kilometers, an epicenter, plotted on Figure 2, of 35° 25.2' N, 117° 46.9' W, and an origin time of 05:05:59.9 GCT. The arrival and travel time data are given in Table 23, along with that of other earthquakes which have occurred in this region of the Garlock Fault.

A general summation of the seismic activity in the Walker Pass region proper between 1946 and the present (April, 1964) shows that the region has never regained the very low level of seismicity it enjoyed before the earthquake of March, 1946. Superimposed upon a low but continuous level of activity are the larger shocks (August, 1955; October, 1959; January, 1961; September, 1962). The general effect of each of these large earthquakes has been to increase the persisting shocks, both in number and magnitude.

For the same period of time, seismic activity outside of Walker Pass, but within the limits of Figure 2, decreased. The only exception to the general decrease was the region near Haiwee.

Other than activity centered at Haiwee and Walker Pass, earthquakes occurring within the bounds of Figure 2 were isolated. The characteristic feature of this isolation appears in the fact that earthquakes located away from the Sierra Fault zone tend to have many fewer aftershocks than those of equivalent magnitude which are near or on that fault zone.

DEPTHS OF EARTHQUAKES IN THE WALKER PASS REGION AND SURROUNDING AREA

The most difficult feature of hypocentral determination is establishing the focal depth of an earthquake. Prior to the construction of computer programs for the determination of hypocenters, few determinations of focal depth were made. Instead, the depth was assumed to have some standard value, and the latitude, longitude, and origin time were determined accordingly. Only in cases of special interest, or in cases where the data were exceptionally clear, was special effort expended on the question of focal depth.

One of the cases in which the data were exceptionally clear occurred for the earthquakes near Caliente, at the northeast terminus of faulting, in the Arvin-Tehachapi earthquake of 1952. Earthquakes occurring near the important epicenter of 35° 19'N, 118° 30'W had not depths of sixteen kilometers, accepted as standard at the time, (Richter, p 183, 1955), but instead had focal depths whose values were close to ten kilometers.

Focal depths of earthquakes for the region shown in Figure 2 have been cited in the discussion of individual earthquakes found in the preceding section. This section will present a discussion of earthquake depths for the several regions found within the area shown by Figure 2.

The 1959 earthquakes near Haiwee are the most favorably situated for focal depth determinations. These earthquakes are within ten kilometers of the station at Haiwee, and are surrounded by the stations at Isabella, China Lake, and Tinemaha, all of which receive the direct wave. Depths determined for the 1959 epicenters ranged from 2.5 kilometers (about 3.5 kilometers below the land surface in the vicinity of Haiwee) to about one kilometer above the land surface. Such negative depths are usually the result of slight irregularities in the arrival time at Haiwee. The two larger shocks, on January 5, 1959, and January 16, 1959, have depths of 3.5 and 1.9 kilometers respectively. It would seem valid that all of these 1959 earthquakes are within the first five kilometers of the earth's surface. They possess the shallowest depths found for earthquakes within the region shown in Figure 2. These epicenters and depths are shown in Figure 5.

The epicenter of the earthquake of October 19, 1961, at 05:09 GCT, is also in a favorable location for depth determination since it lies less than twenty kilometers west of the station at China Lake. The depth of 6.4 kilometers, determined for this shallow earthquake, was supported also by the meizoseismal evidence found by Dr. Pierre St. Amand.

Depths from the better solutions in the Walker Pass region range from four to nine kilometers, with the most satisfactory solutions giving values near seven kilometers. Here, however, no station is closer to the epicenter than about forty kilometers, although the three stations of Haiwee, China Lake, and Isabella are all almost equidistant from that epicenter. The result of this equidistant spacing is that epicentral control improves, but depth control deteriorates. Low magnification recording equipment at Haiwee and Isabella improves the situation considerably since it provides S data at these two stations. That the depths of earthquakes occurring in the Walker Pass region are near seven kilometers is also supported by the findings of the Stanford Research Institute (Westphal, p 21, 1961). The average value of aftershock depths found by their study was eight kilometers, which lies well within the four to nine kilometer range established by the better solutions from Walker Pass.

Depths of the better located earthquakes in the remaining area range between four and thirteen kilometers. Earthquakes near Brown consistently give the greatest depths. For example, the earthquake of July 11, 1956, had a depth 12.6 kilometers, and here the nearest station, China Lake, is at a distance of thirty-two kilometers.

No earthquakes with a depth of more than thirteen kilometers were found within the limits of Figure 2. The geometry of the locations program is such that focal depth determinations would become more accurate as the depth increased. Therefore, the conclusion with regard to the depth of earthquakes occurring in this region is that their focal depths are always less than fifteen and usually less than ten kilometers.

THE WALKER PASS EARTHQUAKES AND THE SIERRA FAULT

Epicenters of the earthquakes both in the Walker Pass region and near Brown lie to the west of the Sierra Fault (Trona Sheet of the Geologic Map of California). Reference to Figure 2 will demonstrate that epicenters of the earthquakes in the Walker Pass region (March, 1946; August, 1955; October, 1959; January, 1961; and September, 1962) determine a line ten kilometers west of and parallel to the Sierra Fault. The epicenters of the earthquakes near Brown are just under five kilometers west of the Sierra Fault, but do not parallel the fault itself.

Chakrabarty and Richter (p 97, 1949) asserted that it was possible for the focus of the earthquake of March 15, 1946, at 13:49 GCT to lie on the Sierra Fault. They stated that

> It lies 8 kilometers west of the Sierra front, which nearly coincides with the major Sierra Fault. With a calculated depth of 21 kilometers, this would require a dip of 70° to place the hypocenter on the fault. Such a dip would be consistent with the general curvature of the Sierra structure in this region, which is convex to the east. However, there are known active faults in the interior of the Sierra mass.

The fault geometry implicit in Chakrabarty's statement might be construed to show the Sierra Fault as a reverse one dipping west, since the Sierra mass to the west has been lifted up relative to the region east of the fault. However, this is unlikely. In addition, since the 1872 earthquake in Owens Valley had both eastward and westward facing fault scarps, (Bateman, p 485, 1961), a fault geometry might be construed from Chakrabarty's data which placed the epicenter of the 1946 earthquake on a westward dipping normal fault. This is even more unlikely.

This study has shown that depths of earthquakes in the Walker Pass region are nearer ten kilometers than twenty. Thus, in order for the 1946 earthquakes to lie on the Sierra Fault, it would have to have a dip of less than 45° to the west, which does not seem reasonable. The fact that the Sierra mass to the west is the upthrown block would then imply that the fault was a thrust fault. This is even less likely than the two alternatives mentioned in the previous paragraph. In view of these improbabilities, the evidence would seem to leave as most reasonable the inference that the hypocenters of the Walker Pass earthquakes are not on the Sierra Fault itself, but rather on faults interior to the Sierra mass.

The earthquakes near Brown are closer to the Sierra Fault, and also have greater depth. However, even here, for these earthquakes to lie on the Sierra Fault would require that the fault be a reverse one. The nodal plane analyses by Father Ingram (see page 51ff) for both the Walker Pass earthquakes and the earthquakes near Brown give essentially the same directions of motion. Thus, the more valid association of these earthquakes would again seem to be with faults, known to exist in this region, which lie in the interior of the Sierra mass.

The trend of the known faults within the Sierra mass is northwest-southeast (Engel, p 44, 1963). A similar trend persists in faults east of the mass in the southeast portion of Indian Wells Valley. Specifically, the Trona sheet shows faults in the region of the earthquakes near Brown that have a northwest-southeast trend. It also shows a fault in the Sand Canyon area with the same trend. Further data come from a set of northwest - southeast trending faults observed by the Stanford Research Institute group working in the Walker Pass region after the earthquake of January 28, 1961 (Westphal, p 8, 1961). Finally, the northwest-southeast trend of faulting here may be observed in the displacement of the offsets found on the Sierra Fault itself.

The recognition and identification of faults in the Walker Pass area by SRI was based on field observations, physiography, and aerial photographs. These faults too have a northwest - southeast trend. Since there is a northwest - southeast trend of the faults which exist within the Sierra mass and since it persists in the faults east of the mass, it seems most probable that the earthquakes in Walker Pass are associated with these faults rather than the main Sierra Fault itself.

NODAL PLANE SOLUTIONS OF EARTHQUAKES IN THE WALKER PASS REGION AND SURROUNDING AREA

The nodal lines from a number of fault plane solutions developed by Father Ingram (Ingram et al., in press) are shown in Figure 2. The sector in which dilatations were observed in shown by a "D" on that figure. Four such solutions are available for the earthquakes near Walker Pass (October 24, 1959; and January 28, 1961) and near Brown (June 25, 1951; and July 11, 1956). All show excellent agreement in the directions of the nodal lines obtained. In addition, the solutions are mechanically coherent since in all cases dilatations were observed in the northern quadrant. Therefore, the earthquakes in the Walker Pass region and those near Brown may be considered as one unit.

All of these nodal plane solutions are consistent with motion along a northwest-southeast trending fault system. Unfortunately, the question of which nodal plane actually represents the fault cannot be answered for any of the solutions. The inference that the northwest-southeast trending nodal plane is indeed the fault plane is supported by the fact that faults trending in a northwest - southeast direction are known. However, cases are recorded in which the known surface faulting did not coincide with the epicentral locations, *e. g.* the Manix Earthquakes of 1947 (Richter and Nordquist, 1951).

All four fault plane solutions for the Walker Pass region and the region near Brown have two nodal planes approximately at right angles to each other. This implies a predominance of strike slip motion. The direction of motion given by the patterns of dilatations and compressions (see Figure 3 for the earthquake of January 28, 1961) is consistent with the offsets of the Sierra Fault as shown on the Trona Sheet of the Geologic Map of California. This motion would also be consistent with that postulated by Pakiser (p 154, 1960).

Of the three remaining nodal plane solutions shown in Figure 2, two also show predominantly strike slip motion (May 28, 1955; October 19, 1961), and the other shows dip slip motion (January 5, 1959).

The earthquake of May 28, 1955, is near no major fault. However, the direction of the nodal lines, as determined, is not inconsistent with the direction of the Kern Canyon Fault. The nodal lines of the earthquake of October 19, 1961, are rotated with respect to the ones of the Walker Pass region. However, it is known that there are many north-south trending faults in that region. Therefore, the trend of the nodal lines is entirely consistent with the direction of known faulting in the region.

The nodal plane solution of the shock of January 5, 1959, is unlike any of the others in that the motion was found to be predominantly dip slip. The trend of the one nodal plane found is subparallel to the Sierra Fault structure. The direction of the motion of the fault is consistent with the upthrown block lying to the west. The nodal planes found for the aftershocks (not plotted) show components of strike slip motion. It is interesting to recall here that the earthquake of 1872 in the Owens Valley region was also reported to have both dip and strike slip components.

Thus, the nodal plane solutions all give results which are consistent with the known faults in the region. In particular, neither the solution for the earthquake of May 28, 1955, nor those for the earthquakes in Walker Pass and near Brown, give any support to an hypothesis which proposes the existence of a northeast-southwest trending structure penetrating the southern end of the Sierra Nevada on an alignment extending from or parallel to the White Wolf Fault.

TECTONIC IMPLICATIONS OF THE EARTHQUAKES IN THE WALKER PASS REGION AND SURROUNDING AREA

When the distribution of earthquakes in Figure 2 is viewed over the entire thirty year period of discussion, the fact that the earthquakes have occurred in a scatter pattern over the entire area appears. However, those epicenters which have been referred to as "habitual epicenters", or areas from which many earthquakes have originated, are located near the major faults. Thus, the earthquakes in the vicinity of Isabella (June, 1935; May, 1936) are near the Kern Canyon Fault; earthquakes in the vicinity of Haiwee are near the Sierra Fault; the earthquakes in the Walker Pass region are also near the Sierra Fault.

The earthquakes which are near the major faults tend to have many aftershocks. Those which are some distance away from the major faults tend to have many fewer aftershocks. The earthquakes of May 28, 1955, and October 19, 1961, are the best examples of the latter phenomenon. However, the earthquakes in January, 1939, and September, 1943, are examples of exceptions to it.

These "habitual epicenters" frequently have earthquakes separated from each other by long periods of time. Each earthquake has its own well defined aftershock or swarm sequence. These aftershock or swarm sequences, however, are short lived compared with the periods of time, in some cases many years, which separate the larger events.

It would seem that for this process to be perpetuated, strain would have to reaccumulate in the region. This would certainly seem to be true in the Walker Pass region. Here, the area became seismically quiet after the 1946 sequence, and only reactivated after the Arvin-Tehachapi sequence of 1952 upset the strain distribution of the region. Since that time, several distinct main shock - aftershock sequences have appeared (1959, 1961, 1962).

Other regions within the area shown in Figure 2 have remained much more quiet throughout much of the period. In particular, the region between the Sierra Fault and the Kern Canyon Fault has had a very low seismicity over the entire thirty year period. An event here, such as the earthquake of May 28, 1955, is one to be especially noted. Also, the level of activity for smaller shocks in the region is much lower than that of the rest of Figure 2. In addition, there is no alignment of epicenters through the quiet region between these two major faults that would be suggestive of any through-going, underlying structure in the southern Sierra Nevada.

Instead, the suggestion is made that the two structures, the Sierra Fault and the Kern Canyon Lineament, including the White Wolf Fault, are joined together only in that strain release on one structure affects the state of strain on the other. Thus, the 1946 earthquake sequence in the Walker Pass region relaxed the region between the Kern Canyon and Sierra faults by motion to the southeast along the northwest-trending faults in the Walker Pass region. With the strain ahead of it released, the White Wolf Fault was then able to move. Strain was released along the White Wolf such that the southern block moved northeast and up. The direction of the White

Wolf strain release thus tended to increase the strain in the Walker Pass region once again. This reaccumulated strain was then released in the earthquakes of August, 1955; October, 1959; January, 1961; and September, 1962.

CONCLUSIONS

The depths of earthquakes occurring in the Walker Pass region and surrounding areas are never greater than fifteen kilometers, and are usually not greater than ten kilometers. The shallowest known earthquakes in the region are near Haiwee; the deepest are near Brown. Accordingly, the depth of the main Walker Pass earthquake of March 15, 1946, should be revised from twenty-one kilometers (Chakrabarty and Richter, 1949) to about eight kilometers.

The Walker Pass earthquakes have most probably occurred on northwest-southeast trending faults in the Sierra mass to the west of the Sierra Fault rather than on the Sierra Fault itself. In addition, on the basis of the fault plane solutions of Father Ingram, motion along these northwest-southeast trending faults is most likely right-handed.

The region between the Sierra Fault and the Kern Canyon Fault is seismically very quiet. Therefore, while a speculative possibility that a continuous structure extends from the White Wolf Fault across the Sierra still exists, careful study of the present data removes practically all of the evidence upon which such speculation might reasonably be based.

There is no continuous connecting line of earthquake epicenters. In the light of present knowledge, this tends to confirm both (1) the absence of a through-going concealed structure penetrating the southern Sierra Nevada; and (2) the interpretation of the data in terms of a mutual transfer of strain between systems of different trend and character.

The southern Sierra, east of the extension of the Tehachapi structures associated with the 1952 earthquake, is shown to be a region of much internal complexity. It probably includes structures of several divergent trends. Interpretations of the relationship between these structures and the Sierra Front Fault must differ from those arising from the excessive depths attributed to the 1946 earthquakes by Chakrabarty and Richter.

APPENDIX A

COMPUTER PROGRAM USED FOR THE ABSOLUTE LOCATION OF LOCAL EARTHQUAKES

The presence of high speed digital computers has made possible the least-square location of hypocenters on a routine basis for the first time. Many program have been written to accomplish this purpose, such as those by Bolt(1960), Flinn (1960), and Nordquist (1962). All such programs depend fundamentally upon a means of obtaining the travel times of the seismic waves in the region under consideration. This may be done in one of two ways. The first is through the actual inclusion of tabulated travel time tables (Bolt). The second is through the calculation of the travel times from an assumed structure (Flinn, Nordquist).

An electronic computer program was developed for the Bendix G-15D computer at the Seismological Laboratory at Pasadena by Nordquist (1962). In this program travel times were computed for a structure consisting of two layers over a half-space. The structure assumed for this program was that given for the southern California region by Press (1960).

The program for the Bendix G-15D computer was further refined by Mr. Nordquist and the author. It then permitted: (1) the inclusion of the arrival times of S waves, (2) the discarding of residuals above certain specified error limits, (3) the inclusion of up to two P and two S arrival times per station, and (4) the allowance for a focus lying not only in the first, but also in the second layer.

In order to secure the benefits of greater computation speed, the locations program for the Bendix G-15D was recoded in Fortran II for the IBM 7090 computer when the latter became available for use at the California Institute of Technology. At first, there was no essential change in the logic of the program. The travel time computation employed was still the parallel plane layer computation, differing in no essential details from that described by Nordquist (1962). Later, however, provisions were added to the program to include two additional methods of travel time computation. The three methods could then be employed either separately or in any arbitrary combination.

Since the structure found in southern California is in many places very inadequately represented by the assumption of parallel plane layers, both of the additional travel time routines are attempts to compute travel times on the basis of a different assumption for the structure. The intricacy of the required computation arises from the fact that while a parallel plane structure may be defined by only three numbers for each layer (the thickness of the layer and the P and S velocities for that layer); a representation of the structure actually found in southern California involves information both as to the position of the layers and the velocity gradients to be found in each of them.

The method finally adopted for the locations program was the selection of a structure consisting of three layers over a half-space to be described by use of a rectangular grid. The values of the depths of the layers and the velocities associated with these layers totaled eighteen numbers in all for each grid point. The area covered by the grid is shown in Figure 9. Four numbers are needed to describe the position of the surface of the earth, the tops of the second and third layers, and the top of the half-space. The remaining fourteen describe the velocity structure. For each of the three layers, the P and S velocities at the top and the bottom of the layer are given. For the half-space, only the P and S velocities at the top of the half-space are given. This number of values allows velocity gradients in the x and y directions to be expressed for all of the layers and the half-space. However, velocity gradients in the z direction are permitted only in the three layers.

Data for use in the structure matrix are quite scarce. However, the more important variations in thickness are well enough established to be of considerable use in the program. The values assigned to the depth of the Mohorovicic Discontinuity and used in this program are shown in Figure 9. The velocity profile modified from Gutenberg (1951) and Press (1960) is shown in Figure 8b.

The second travel time routine allows the layers to be non-parallel, but they must still be plane. The focus may be in any layer or the half-space. This routine was programmed in order to be able to take into account the variations of crustal thickness in excess of twenty kilometers known to exist between the Sierra Nevada and the west coast of the continent, yet still maintain an execution time short enough to be widely used. A crustal profile is constructed by extracting from the structure matrix the depths of the layers below the epicenter and the station. These are then used to define the sloping layers (Figure 10).

The values of the velocities at the top and bottom of each layer and at the top of the half-space are also extracted from the structure matrix for the columns below both the station and the epicenter. In the event that the velocity in a given layer is not constant, that layer is divided into five sublayers in order to be able to approximate the curved path found in such a medium. The velocities at the station or at the epicenter are used in the manner described below.

Direct rays are calculated by an iterative process in which the ray is started from the focus toward the station. The initial direction cosines of the ray are corrected until the ray passes within one-half kilometer of the station. For the first layer (or sublayer), the velocity at the focus is used. Thereafter, the velocities of the layers associated with the station are used.

The direct ray will always exist if the velocity increases monotonically downward. However, the ray path thus calculated will cease to adequately represent the true ray in such a medium when that point is reached at which the true ray would start downward rather than upward. In such a case, the true least-time path will be one of the refracted rays transmitted along one of the layers approximating the medium with the increasing velocity gradient.

The calculation will be attempted if the velocity does not increase monotonically downward. However, in such a case, convergence is doubtful.

Reflected rays are also calculated using an iterative method on much the same basis as the direct ray. However, such rays are, of course, reflected upward from the appropriate layer. On the downward portion of the path of the reflected ray from the focus, the velocities in the layers associated with the epicenter are used. On the upward portion of the path, the velocities in the layers associated with the station are used.

Refracted rays are calculated without iteration. As in the reflected ray, velocities associated with the epicenter are used for the downward portion of the ray; velocities at the station are used for the upward portion. For that portion of the path that the ray is 'in' the refracting layer, the average of the appropriate velocities associated with the epicenter and the station are used.

The third travel time routine, still under test, permits the arbitrary variation of velocities in each of the three layers over the half-space, and the variation of the velocities in the x-y direction in the half-space. The interfaces between the layers may themselves be varied in depth. This travel time routine is slow in execution and difficulties with convergence have been experienced. Thus, this routine was not used for the location of earthquakes for this study.

When the larger earthquakes (magnitude greater than 3.8) were run on the locations program using both the parallel plane layer program and the non-parallel plane layer program, it was universally found that the smallest time residuals were obtained with the latter routine. Thus, the latter travel time routine was used to obtain the final locations for all of the larger shocks in this study, whenever possible.

Smaller earthquakes, whose arrivals were more likely to be lost at the more distant stations, were located using only the parallel plane layer travel time routine. However, since many of these smaller shocks were well recorded with both P and S arrival times at the nearer stations, these locations are also of good quality.

APPENDIX B

COMPUTER PROGRAM USED FOR THE RELATIVE LOCATION OF LOCAL EARTHQUAKES

The use of the differencing technique at the Seismological Laboratory at Pasadena has conventially been to determine differences in origin time and epicenter. This has usually been accomplished by means of a plot of the differences, expressed either as time differences or distance differences, against the azimuth of the stations from the key shock. A difference in origin time and a vector displacement of the epicenter were then computed from the plot, called a 'sine plot'.

The programming of this process has led to the realization that this technique, as far as a computer program is concerned, is in essence merely a different method of computing travel times. The established travel times of a well located shock are used to obtain the regional travel times. This is supplemented by a knowledge of the velocities in the immediate region of the hypocenters. This latter information is used to compute the change in travel times to be expected from a slight shift in the hypocenter.

More specifically, let the A_i be the arrival times at the stations, let the TT_i be the true travel times for each of the paths to the stations from the focus, and let O be the origin time. Furthermore, let the primed letters refer to a known shock and the unprimed letters refer to a shock whose location is to be established relative to that of the known shock. By taking differences, we obtain the following equation,

$$A_i - A_i' = TT_i - TT_i' + 0 - 0'. \qquad (1)$$

Note immediately that difficulty will arise over the evaluation of the differences of the travel time TT. One solution to this difficulty would be to expand the travel times TT_i about the hypocenter of the primed shock in a Taylor series. However, the difficulties in this case have only been postponed, since the appropriate partial derivatives must still be evaluated.

These partial derivatives may be evaluated by reference to some assumed structure. However, no more assumptions are involved in setting

$$TT_i - TT_i' \approx tt_i - tt_i' \qquad (2)$$

where the tt_i are the travel times evaluated with respect to some assumed structure. As an additional advantage, better account is taken of the effect of a finite displacement in epicenter than would have been taken if only the first partial derivatives of the travel time are used.

Equations (1) and (2) may now be combined to obtain a relation which can be solved. However, the combination is still non-linear. To overcome this, the tt_i may be expanded about some point $x(0)_j$ and the following relation is obtained

$$A_i - A_i' = tt(0)_i + \sum_j \frac{\partial tt(0)_i}{\partial x_j} (x_j - x(0)_j) - tt_i' + 0 - 0'. \qquad (3)$$

Two conclusions may be reached by application of equation (3). The first is that it will reduce to the difference technique formerly used if the origin point $x(0)_j$ is taken as the focus of the primed shock. It follows that

$$A_i - A_i' = \sum_j \frac{\partial tt(0)_i}{\partial x_j} (x_j - x(0)_j) + 0 - 0' \qquad (3a)$$

If only one 'iteration' is performed, there results a three dimensional generalization of the sine plot technique formerly used.

An alternative solution technique uses the fact that the time residual is usually defined as

$$r_i = A_i - tt_i - 0. \qquad (4)$$

Combining (4) with (3), there results

$$A_i = tt(0)_i + \sum_j \frac{\partial tt(0)_i}{\partial x_j} (x_j - x(0)_j)$$
$$+ 0 + r_i'. \qquad (5)$$

Here, the influence of the travel time of the known shock appears as a residual to be applied to the standard travel times calculated by a locations program. The use of equation (5) was particularly convenient since the parallel plane layer program used for the absolute location of earthquakes was quickly and conveniently adapted to its use. Additional convenience arises from the fact that the two earthquakes need not initially be assumed to have the same epicenter. Furthermore, this equation show clearly that the method is the exact equivalent of the absolute method of location of earthquakes as far as the mathematics, programming, and requirements with regard to number and position of stations are concerned. Finally, the result may be iterated to take into account the non-linearity of the travel time equations. The least-square mechanism may then be used to refine the location and to reduce the differences between the x_j and the $x(0)_j$ to the smallest possible values consistent with the application of the least square criterion.

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KEY TO HEADINGS FOR TABLE 1

YR	Year
MO	Month
DY	Day
HR	Hour
MIN	Minute
SEC	Second
LAT	Geographic latitude of the epicenter in degrees and minutes.
LONG	Longitude of the epicenter in degrees and minutes.
Q	Assigned accuracy of the epicenter, denoted by letters as follows:

A.	Exceptionally accurate
B.	Epicenter to within five kilometers, origin time to nearest second
C.	Epicenter to within fifteen kilometers, origin time to within a few seconds
D.	Very rough.

M	Richter magnitude of the earthquake
I	Index referred to a key map (see Nordquist, 1964).
DEP	Depth of the earthquake in kilometers.
O	Source of the location adopted, as listed below:

1A.	Bendix G-15D locations program
1B.	IBM 7090 locations program, modification 1
1C.	IBM 7090 locations program, modification 2
1D.	IBM 7090 locations program, modification 3
2A.	Earthquake comparison program.
8.	Graphical location by Pasadena
9.	Location from Allen - St. Amand catalog.

SO	Standard error of origin time in seconds.
SX	Standard error of X coordinate in kilometers.
SY	Standard error of Y coordinate in kilometers.
SZ	Standard error of Z coordinate in kilometers.
ID	Identification number of earthquake. See page 30.

Additional information concerning the data on these cards may be found in Nordquist (1964).

TABLE 1A

YR	MO	DY	HR	MI	SEC	LAT	LONG	Q	M	I	DEP	O	SO	SX	SY	SZ	ID
1935	2	8	4	22	-0.00	35 50.00	118 0.00	B	4.0	J 8		9					
1935	6	11	16	20	-0.00	35 42.00	118 22.00	B	4.0	J 8		9					
1936	4	24	19	0	-0.00	36 9.00	117 57.00	B	4.0	K 9		9					
1936	5	3	14	20	-0.00	35 42.00	118 22.00	C	4.0	J 8		9					
1937	1	19	23	57	-0.00	35 42.00	118 22.00	B	4.0	J 8		9					
1937	9	10	19	34	-0.00	35 58.00	117 55.00	B	4.0	K 8		9					
1937	9	18	8	37	-0.00	36 0.00	118 2.00	B	4.0	J 9		9					
1938	9	17	14	23	-0.00	35 36.00	117 39.00	B	5.0	K 8		9					
1939	1	7	20	21	-0.00	36 0.00	117 44.00	B	5.0	K 9		9					
1939	8	15	15	48	18.00	36 0.00	117 35.00	B	4.0	K 9		9					
1939	12	1	13	5	4.00	36 22.00	118 1.00	B	4.0	J 9		9					
1942	6	22	22	13	51.00	36 15.00	117 58.00	B	4.0	K 9		9					
1942	6	22	23	51	3.00	36 15.00	117 58.00	B	4.0	K 9		9					
1942	10	16	10	7	27.00	36 15.00	117 58.00	C	4.0	K 9		9					
1943	5	30	7	50	-0.00	36 8.00	117 58.00	C	4.0	K 9		9					
1943	7	10	3	12	33.00	35 44.00	118 14.00	C	4.0	J 8		9					
1943	9	16	0	16	11.00	36 1.00	117 56.00	C	4.0	K 9		9					
1943	9	16	7	52	-0.00	36 1.00	117 56.00	C	4.5	K 9		9					

TABLE 1B

YR	MO	DY	HR	MI	SEC	LAT	LONG	Q	M	I	DEP	O	SO	SX	SY	SZ	ID
1944	7	3	5	38	23.00	35 21.00	117 52.00	B	4.7	K 7		9					
1944	8	9	14	1	5.00	35 56.00	117 46.00	C	4.0	K 8		9					
1944	8	12	8	25	20.00	35 56.00	117 46.00	C	4.1	K 8		9					
1944	8	13	6	27	57.00	35 56.00	117 46.00	C	3.7	K 8		9					
1944	12	23	8	16	22.00	36 24.00	117 55.00	A	4.7	K 9		9					
1945	5	11	0	9	54.00	35 26.00	117 40.00	C	3.8	K 7		9					
1945	7	26	10	10	56.00	36 3.00	117 52.00	C	4.1	K 9		9					
1945	5	18	9	44	40.00	36 12.00	118 23.00	C	4.0	J 9		9					
1946	3	15	13	21	1.89	35 44.02	118 0.48	B	5.5	J 8	8.0	2A	0.12	0.8	0.6	1.5	1
1946	3	15	13	49	37.03	35 42.27	118 0.22	B	6.3	J 8	6.3	2A	0.46	2.9	2.0	5.7	2
1946	3	15	14	0	36.60	35 41.85	118 1.20	B	5.3	J 8	5.5	2A	2.05	4.9	3.7	18.2	3
1946	3	15	15	0	10.30	35 46.23	118 6.65	B	4.3	J 8	10.4	2A	0.31	3.0	1.5	3.4	4
1946	3	15	19	18	54.79	35 41.86	118 0.26	B	5.5	J 8	10.4	2A	0.11	0.8	0.5	1.3	5
1946	3	15	21	54	32.97	35 43.68	118 4.35	B	5.2	J 8	-2.0	2A	1.89	4.5	3.3	16.6	6
1946	3	16	1	54	18.00	35 44.00	118 2.00	C	3.8	J 8		9					
1946	3	16	9	46	19.04	35 43.44	118 3.35	B	5.0	J 8	8.9	2A	0.81	1.9	1.4	7.1	7
1946	3	16	1	59	25.00	35 44.00	118 2.00	C	3.7	J 8		9					
1946	3	16	4	7	56.00	35 44.00	118 2.00	C	3.7	J 8		9					
1946	3	16	7	53	-0.00	35 44.00	118 2.00	C	3.6	J 8		9					
1946	3	16	8	15	35.00	35 44.00	118 2.00	C	3.8	J 8		9					
1946	3	16	9	46	18.00	35 45.00	118 1.00	B	5.1	J 8		9					
1946	3	16	13	7	5.00	35 44.00	118 2.00	C	4.1	J 8		9					
1946	3	16	13	24	41.00	35 44.00	118 2.00	C	3.6	J 8		9					
1946	3	16	15	22	31.00	35 44.00	118 2.00	C	3.6	J 8		9					

TABLE 1C

YR	MO	DY	HR	MI	SEC	LAT	LONG	Q	M	I	DEP	O	SO	SX	SY	SZ	ID
1946	3	16	17	35	34.00	35 44.00	118 2.00	C	3.6	J 8		9					
1946	3	16	18	43	59.00	35 44.00	118 2.00	C	3.7	J 8		9					
1946	3	16	19	53	59.00	35 44.00	118 2.00	C	4.0	J 8		9					
1946	3	16	20	8	8.00	35 44.00	118 2.00	C	3.8	J 8		9					
1946	3	16	21	40	47.00	35 44.00	118 2.00	C	3.9	J 8		9					
1946	3	16	23	41	6.00	35 44.00	118 2.00	C	3.7	J 8		9					
1946	3	16	23	44	35.00	35 44.00	118 2.00	C	3.6	J 8		9					
1946	3	17	2	55	26.00	35 44.00	118 2.00	C	3.6	J 8		9					
1946	3	17	6	3	47.34	35 39.04	118 3.79	B	4.2	J 8	-0.7	2A	1.13	3.6	1.8	9.7	8
1946	3	17	8	16	36.00	35 44.00	118 2.00	C	4.6	J 8		9					
1946	3	17	9	4	44.00	35 44.00	118 2.00	C	3.7	J 8		9					
1946	3	17	9	24	53.00	35 44.00	118 2.00	C	3.6	J 8		9					
1946	3	17	9	38	35.00	35 44.00	118 2.00	C	3.6	J 8		9					
1946	3	17	13	32	0.00	35 44.00	118 2.00	C	3.7	J 8		9					
1946	3	17	20	53	58.00	35 44.00	118 2.00	C	3.8	J 8		9					
1946	3	17	21	8	20.00	35 44.00	118 2.00	C	3.7	J 8		9					
1946	3	17	21	18	35.00	35 44.00	118 2.00	C	4.0	J 8		9					
1946	3	18	1	15	9.00	35 44.00	118 2.00	C	4.1	J 8		9					
1946	3	18	3	0	22.00	35 44.00	118 2.00	C	4.1	J 8		9					
1946	3	18	8	58	51.00	35 44.00	118 2.00	C	3.6	J 8		9					
1946	3	18	10	5	56.06	35 41.88	118 3.25	B	4.6	J 8	6.9	2A	0.25	2.9	0.8	2.2	9
1946	3	18	15	49	26.55	35 45.26	117 58.68	B	4.6	K 8	7.5	2A	0.24	2.3	0.9	2.3	10
1946	3	18	15	50	43.00	35 44.00	118 2.00	C	5.3	J 8		9					
1946	3	18	16	3	46.00	35 44.00	118 2.00	C	4.1	J 8		9					
1946	3	18	16	54	18.00	35 44.00	118 2.00	C	3.9	J 8		9					
1946	3	18	21	12	31.00	35 44.00	118 2.00	C	3.6	J 8		9					

TABLE 1D

YR	MO	DY	HR	MI	SEC	LAT	LONG	Q	M	I	DEP	O	SO	SX	SY	SZ	ID
1946	3	19	8	15	46.00	35 44.00	118 2.00	C	3.6	J 8		9					
1946	3	19	8	45	42.58	35 39.16	118 3.81	B	3.2	J 8	8.0	2A	0.36	4.1	1.2	3.0	11
1946	3	20	4	16	37.00	35 44.00	118 2.00	C	3.7	J 8		9					
1946	3	20	8	49	22.00	35 44.00	118 2.00	C	3.6	J 8		9					
1946	3	21	19	35	4.00	35 44.00	118 2.00	C	3.7	J 8		9					
1946	3	22	4	23	20.00	35 44.00	118 2.00	C	3.8	J 8		9					
1946	3	22	10	8	33.00	35 44.00	118 2.00	C	4.1	J 8		9					
1946	3	22	12	36	10.00	35 44.00	118 2.00	C	3.9	J 8		9					
1946	3	24	2	56	46.00	35 44.00	118 2.00	C	4.4	J 8		9					
1946	3	24	5	17	28.60	35 41.26	117 53.98	B	3.5	K 8	0.7	2A	0.52	4.4	1.8	5.1	12
1946	3	24	20	0	3.74	35 40.72	118 1.77	B	4.2	J 8	0.0	2A	0.48	4.0	1.5	4.7	13
1946	3	25	11	7	29.00	35 44.00	118 2.00	C	3.6	J 8		9					
1946	3	25	23	36	46.04	35 38.96	118 3.46	B	4.2	J 8	7.6	2A	0.25	2.4	1.0	2.4	14
1946	3	26	6	7	13.00	35 44.00	118 2.00	C	4.1	J 8		9					
1946	3	26	6	33	53.00	35 44.00	118 2.00	C	3.6	J 8		9					
1946	3	26	11	50	47.00	35 44.00	118 2.00	C	3.7	J 8		9					
1946	3	26	22	39	50.00	35 44.00	118 2.00	C	3.7	J 8		9					
1946	3	27	11	17	7.00	35 44.00	118 2.00	C	3.7	J 8		9					
1946	3	28	15	26	50.00	35 44.00	118 2.00	C	3.7	J 8		9					
1946	3	29	0	44	37.00	35 44.00	118 2.00	C	3.6	J 8		9					
1946	4	4	15	44	31.00	35 42.00	118 0.00	C	3.7	J 8		9					
1946	4	7	8	28	31.00	35 42.00	118 0.00	C	3.8	J 8		9					
1946	4	9	10	17	53.00	35 42.00	118 0.00	C	3.7	J 8		9					
1946	4	11	23	35	40.00	35 42.00	118 0.00	C	3.6	J 8		9					
1946	4	12	10	34	33.84	35 41.38	117 54.31	B	3.6	K 8	3.9	2A	0.35	5.7	1.3	3.4	14A
1946	4	12	20	2	37.00	35 42.00	118 0.00	C	3.8	J 8		9					

TABLE 1E

YR	MO	DY	HR	MI	SEC	LAT	LONG	Q	M	I	DEP	O	SO	SX	SY	SZ	ID
1946	4	13	0	0	18.00	35 42.00	118 0.00	C	3.7	J 8		9					
1946	4	13	15	46	57.00	35 42.00	118 0.00	C	3.6	J 8		9					
1946	4	13	15	48	59.00	35 42.00	118 0.00	C	3.7	J 8		9					
1946	4	16	10	37	4.75	35 45.82	118 12.12	B	3.6	J 8	0.2	2A	0.47	3.2	1.5	4.5	18
1946	4	16	22	56	8.00	35 42.00	118 0.00	C	3.8	J 8		9					
1946	4	23	7	11	40.22	35 39.12	118 4.22	B	3.3	J 8	5.0	2A	0.26	2.8	0.8	2.2	15
1946	4	24	7	46	7.63	35 52.12	117 42.40	B	3.3	K 8	12.5	2A	0.86	12.3	3.3	4.4	
1946	4	27	22	37	24.38	35 44.73	117 51.74	B	3.6	K 8	10.4	2A	0.31	5.5	1.3	2.6	
1946	5	5	9	3	43.30	35 39.84	117 51.92	B	3.7	K 8	-2.0	2A	1.61	8.9	7.3	26.3	
1946	5	6	11	1	11.00	35 42.00	118 0.00	C	3.6	J 8		9					
1946	6	5	21	59	33.40	35 38.53	118 16.69	B	4.4	J 8	11.0	2A	0.44	4.5	1.4	3.9	19
1946	6	6	0	6	42.66	35 38.74	118 16.52	B	3.7	J 8	16.0	2A	0.38	4.3	1.3	3.4	19A
1946	6	10	14	4	15.03	35 48.06	117 45.49	B	3.7	K 8	14.0	2A	0.40	6.0	1.8	2.9	
1946	6	12	20	20	43.45	35 44.62	118 0.29	B	3.4	J 8	9.6	2A	0.25	4.6	1.1	2.6	
1946	7	9	3	19	1.45	35 39.35	117 58.59	B	3.8	K 8	8.5	2A	0.35	6.1	1.4	3.7	
1946	7	18	5	2	3.11	35 40.18	117 37.74	B	3.9	K 8	12.4	2A	0.12	1.6	0.5	1.2	
1946	7	22	15	19	32.26	35 46.71	117 46.46	B	4.1	K 8	1.8	2A	1.79	6.4	3.3	15.3	
1946	8	31	9	10	14.10	35 36.71	117 53.03	B	4.2	K 8	10.3	2A	0.45	6.9	1.9	4.5	20
1946	9	5	17	38	36.37	35 59.01	117 32.21	B	3.5	K 8	16.9	2A	0.75	6.8	3.3	4.3	
1946	10	4	4	32	41.00	35 2.00	117 32.00	C	3.6	K 7		9					
1946	10	29	11	34	58.00	35 25.00	117 41.00	C	3.6	K 7		9					
1947	2	1	13	30	49.72	35 12.86	118 20.06	B	3.5	J 7	9.4	2A	0.35	3.2	1.1	3.2	21
1947	2	6	17	20	41.37	35 38.83	118 3.94	B	4.6	J 8	10.1	2A	0.22	3.5	0.8	2.1	16
1947	3	1	10	40	21.50	35 39.39	118 3.67	B	3.7	J 8	6.5	2A	0.06	0.9	0.2	0.6	
1947	3	9	21	10	44.00	35 49.00	117 41.00	C	4.0	K 8		9					

TABLE 1F

YR	MO	DY	HR	MI	SEC	LAT	LONG	Q	M	I	DEP	O	SO	SX	SY	SZ	ID
1947	5	7	12	56	36.99	35 38.66	118 0.17	B	3.7	J 8	10.8	2A	0.31	5.5	1.2	3.1	
1948	2	11	3	29	28.00	36 5.00	118 48.00	B	4.6	H 9		9					
1948	5	26	19	35	13.57	35 40.14	117 57.08	B	4.1	K 8	13.7	2A	0.18	3.0	0.8	1.8	17
1948	7	26	17	50	1.71	35 35.83	118 12.18	B	4.5	J 8	10.2	2A	0.38	4.3	1.2	3.5	
1950	8	10	9	55	26.00	35 43.00	118 15.00	C	3.6	J 8		9					
1951	6	25	19	45	41.68	35 46.33	117 56.86	B	4.6	K 8	12.4	1C	0.10	0.8	0.7	1.4	
1951	6	26	1	26	39.12	35 45.67	117 57.19	B	4.4	K 8	8.1	1C	0.21	1.6	1.3	2.9	
1951	6	26	2	6	14.00	35 47.00	117 57.00	B	3.6	K 8		9					
1951	7	1	0	16	18.72	35 44.71	117 59.06	B	3.7	K 8	4.4	1C	0.14	1.6	0.5	1.3	
1952	7	21	15	51	39.00	35 59.00	117 56.00	C	3.8	K 8		9					
1952	8	29	2	51	13.00	35 56.00	117 41.00	B	3.5	K 8		9					
1952	11	17	3	20	23.16	36 3.97	118 26.43	B	3.8	J 9	-1.7	1D	0.37	1.2	1.4	4.4	
1953	3	27	20	37	10.00	35 46.00	117 59.00	B	3.6	K 8		9					
1953	5	2	11	56	50.00	35 25.00	117 52.00	C	3.8	K 7		9					
1953	7	1	22	38	8.00	35 22.00	117 47.00	B	3.5	K 7		9					
1953	8	11	18	33	59.00	35 49.00	118 23.00	B	3.8	J 8		9					
1954	1	7	16	8	35.00	35 48.00	117 38.00	B	3.6	K 8		9					
1954	5	25	10	48	23.00	35 39.00	118 31.00	B	3.8	H 8		9					
1954	11	17	7	23	57.00	36 28.00	118 0.00	C	4.1	J 9		9					

TABLE 1G

YR	MO	DY	HR	MI	SEC	LAT	LONG	Q	M	I	DEP	O	SO	SX	SY	SZ	ID
1955	05	28	19	44	20.03	35 32.05	118 15.83	B	4.5	J 8	12.3	1D	0.08	0.8	0.5	1.4	
1955	8	22	14	41	20.81	35 46.09	118 2.20	B	3.7	J 8	7.3	1D	0.18	1.3	1.2	2.7	
1956	7	11	19	22	6.72	35 45.95	117 56.89	B	4.2	K 8	12.6	1D	0.09	0.8	0.8	1.5	
1956	7	23	10	43	35.29	35 57.45	117 46.94	B	3.3	K 8	5.1	1D	0.12	1.0	1.0	1.8	
1956	9	29	18	3	6.00	35 39.00	118 28.00	B	3.6	J 8		9					
1956	10	4	20	6	35.00	35 32.00	118 21.00	B	3.9	J 8		9					
1957	1	1	9	53	40.00	35 29.00	118 21.00	B	3.6	J 7		9					
1957	3	8	13	24	57.00	35 43.00	117 30.00	B	4.0	K 8		9					
1957	10	4	12	0	37.00	35 50.00	118 2.00	B	3.9	J 8		9					
1957	12	11	4	15	12.00	35 30.00	118 20.00	B	3.7	J 8		9					
1959	01	05	12	36	2.62	36 9.31	118 3.32	B	4.7	J 9	2.6	1D	0.09	1.3	0.7	2.8	
1959	01	06	16	10	20.33	36 8.43	118 3.74	B	3.7	J 9	0.2	1D	0.11	0.7	0.7	2.1	
1959	01	11	18	54	57.76	36 9.52	118 3.05	B	3.7	J 9	-2.0	1D	0.13	0.7	0.7	2.1	
1959	01	12	12	36	5.29	36 9.37	118 3.79	B	3.9	J 9	-2.0	1D	0.15	0.8	0.9	2.4	
1959	01	16	0	10	5.33	36 7.84	118 3.58	B	4.3	J 9	1.9	1B	0.14	1.0	1.1	2.2	
1959	01	19	21	46	0.08	36 9.10	118 4.00	B	4.0	J 9	0.3	1C	0.11	0.7	0.7	1.9	
1959	06	23	06	25	35.00	36 09.00	117 58.00	B	3.8	K09		8					
1959	09	17	08	11	15.00	35 58.00	117 52.00	B	3.8	K08		8					
1959	09	27	00	21	50.00	36 02.00	117 55.00	C	3.0	K09		8					
1959	10	15	10	19	55.00	35 51.00	117 31.00	B	3.6	K08		8					
1959	10	24	15	35	15.29	35 44.68	118 1.41	B	4.2	J 8	7.4	1D	0.08	0.7	0.6	1.4	
1959	10	24	16	11	24.31	35 44.53	118 1.11	B	3.7	J 8	7.5	1C	0.15	1.0	0.8	1.4	
1959	10	24	19	58	20.14	35 44.35	118 0.45	B	3.4	J 8	4.0	1B	0.14	1.0	1.1	2.7	

TABLE 1H

YR	MO	DY	HR	MI	SEC	LAT	LONG	Q	M	I	DEP	O	SO	SX	SY	SZ	ID
1959	11	16	12	5	34.99	35 44.93	118 0.82	B	3.7	J 8	9.7	1D	0.14	1.1	1.1	2.3	
1961	01	28	8	12	46.18	35 46.69	118 2.92	B	5.3	J 8	5.5	1D	0.08	0.6	0.6	1.3	
1961	01	28	14	1	8.52	35 48.18	118 2.02	B	3.7	J 8	9.1	1D	0.24	1.6	1.8	2.3	
1961	01	28	17	2	12.20	35 46.61	118 2.99	B	3.6	J 8	7.0	1D	0.18	1.3	1.7	2.5	
1961	02	12	6	47	38.95	35 46.69	118 2.09	B	3.2	J 8	3.7	1D	0.18	1.3	1.4	3.5	
1961	02	22	7	3	1.63	35 47.15	118 3.17	B	2.8	J 8	11.5	1D	0.11	0.9	1.0	2.4	
1961	10	19	5	9	44.59	35 51.42	117 48.28	B	5.1	K 8	6.4	1D	0.06	0.4	0.5	1.0	
1961	11	18	03	18	35.96	35 23.85	117 46.37	B	4.3	K07	11.1	1A	.20	1.4	1.3	02.8	
1961	11	19	22	59	51.63	35 44.09	118 01.20	B	3.6	J08	06.1	1A	.13	1.1	1.0	02.3	
1962	03	24	03	38	18.16	35 45.73	118 01.63	B	3.7	J08	07.3	1A	.16	1.1	1.0	01.8	
1962	08	17	11	3	53.66	35 56.95	117 58.84	B	3.2	K 8	5.4	1B	0.09	0.6	0.6	1.2	
1962	09	16	5	36	15.87	35 44.33	118 3.17	B	4.8	J 8	4.0	1D	0.09	0.7	1.4	2.1	
1962	09	16	11	37	5.87	35 45.64	118 2.61	B	3.5	J 8	5.5	1B	0.25	1.7	1.5	4.9	
1962	09	19	18	50	30.66	35 48.12	118 0.76	B	3.1	J 8	6.8	1C	0.12	0.9	0.9	1.2	
1962	11	12	7	53	56.39	35 11.49	118 7.94	B	3.5	J 7	7.0	1B	0.11	1.4	0.6	1.7	
1963	04	19	3	21	9.66	35 46.33	117 59.52	B	3.6	K 8	5.4	1B	0.14	0.9	1.1	2.3	
1963	09	21	5	5	59.90	35 25.20	117 46.90	B	3.3	K 7	11.1	1D	0.21	1.7	1.3	3.4	

STATION IDENTIFIERS USED IN TABLES 2 THROUGH 23

STATION IDENTIFIER	STATION NAME	REMARKS
BAR	Barrett	
BBC	Big Bear	
BCN	Boulder City	
BRK	Berkeley	
CLC	China Lake	
DLT	Dalton	
ECC	El Centro	
FRE	Fresno	
FTC	Fort Tejon	
GSC	Goldstone	
HAI	Haiwee	
HAY	Hayfield	
IS1	Isabella	This identifier is used to denote Isabella from February 7, 1957, to June 13, 1962. During this period, the station was located at 35 39.78 N, 118 28.39 W, at an elevation of 835 meters.
ISA	Isabella	
IW1	Indian Wells	This identifier is used to denote a portable unit operated near Indian Wells from September 18, 1962, to September 19, 1962. The unit was located at 35 40.35 N, 117 52.14 W, at an elevation of 850 meters.
KRC	King Ranch	
LJC	La Jolla	
MHC	Mount Hamilton	
MWC	Mount Wilson	
OVE	Overton	
PAS	Pasadena	
PFA	Pierce Ferry	
PLM	Palomar	
PVR	Palos Verdes	
REN	Reno	
RVR	Riverside	
SBC	Santa Barbara	
SNC	San Nicolas Island	
TIN	Tinemaha	
TUC	Tucson	
VIN	Vineyard	
WDY	Woody	

NOTES FOR TABLES 2 THROUGH 15

NOTE 1. 'DELTA' is in kilometers.

NOTE 2. 'DIR' indicates that the arrival was considered to be direct by the locations program.
'RFR' indicates that the arrival was considered to be refracted by the locations program.

NOTE 3. The residual is the time residual, calculated according to the relation

RESIDUAL = ARRIVAL TIME - TRAVEL TIME - ORIGIN TIME.

NOTE 4. Phases for which the residual was greater than .75 second were not used to determine the location.

NOTE 5. The coordinate system for the location calculation is taken with the origin at 35 00 N, 118 00 W. At that point, the X axis is east, the Y axis is north, and the Z axis is downward. For further details, see Nordquist (1962).

TABLE 2

DATA FOR EARTHQUAKE OF NOVEMBER 17, 1952

LATITUDE	36 4.0 N
LONGITUDE	118 26.4 W
DEPTH	-1.7 KM
ORIGIN TIME	3 20 23.2 GCT
MAGNITUDE	3.8

STA	DELTA	PHASE	TYPE	ARRIVAL TIME	TRAVEL TIME	RESIDUAL (SEC)	P-O-DEL/8.1
HAI	45.1	P	DIR	30.7	7.4	0.1	
		S	DIR	36.0	12.8	0.0	
CLC	81.1	P	DIR	36.4	13.3	-0.1	
TIN	111.3	P	DIR	41.4	18.3	-0.0	
		S	DIR	56.8	31.6	2.0	
MWC	207.4	P	RFR	56.9	33.5	0.2	8.1
PAS	214.2	P	RFR	57.3	34.1	0.0	7.7
BBC	246.0	P	RFR	61.5	38.3	0.0	8.0
RVR	249.7	P	RFR	61.4	38.6	-0.4	7.4
PLM	333.9	P	RFR	72.0	48.7	0.1	7.6

STANDARD ERRORS

ORIGIN TIME	0.4	SEC
X COORDINATE	1.2	KM
Y COORDINATE	1.4	KM
Z COORDINATE	4.4	KM

TABLE 3

DATA FOR EARTHQUAKE OF MAY 28, 1955

LATITUDE	35 32.0 N
LONGITUDE	118 15.8 W
DEPTH	12.3 KM
ORIGIN TIME	19 44 20.0 GCT
MAGNITUDE	4.5

STA	DELTA	PHASE	TYPE	ARRIVAL TIME	TRAVEL TIME	RESIDUAL (SEC)	P-O- DEL/8.1
WDY	56.0	P	DIR	29.1	9.3	-0.2	
		S	DIR	36.1	16.1	-0.0	
HAI	72.8	P	DIR	31.8	12.0	-0.2	
		S	DIR	41.0	20.7	0.2	
FTC	93.2	P	DIR	35.4	15.3	0.1	
		S	DIR	44.9	26.4	-1.5	
KRC	136.3	P	DIR	42.6	22.2	0.4	
MWC	146.6	P	DIR	44.0	23.9	0.1	
PAS	153.9	P	DIR	45.0	25.0	-0.0	
		S	DIR	63.2	43.2	-0.1	
DLT	156.8	P	DIR	45.3	25.5	-0.2	
		S	DIR	63.8	44.1	-0.3	
TIN	168.6	P	DIR	48.2	27.4	0.7	
		S	RFR	68.0	48.1	-0.1	
SBC	179.4	P	RFR	49.1	27.5	1.6	6.9
RVR	189.2	P	RFR	49.0	29.3	-0.3	5.6
BBC	189.6	P	RFR	48.2	29.5	-1.3	4.8
PLM	273.9	P	RFR	60.3	39.5	0.8	6.5
BCN	313.8	P	RFR	64.6	44.1	0.4	5.8
BAR	348.6	P	RFR	69.2	48.4	0.7	6.1

STANDARD ERRORS

ORIGIN TIME	0.1	SEC
X COORDINATE	0.8	KM
Y COORDINATE	0.5	KM
Z COORDINATE	1.4	KM

TABLE 4

DATA FOR EARTHQUAKE OF AUGUST 22, 1955

LATITUDE	35 46.1 N
LONGITUDE	118 2.2 W
DEPTH	7.3 KM
ORIGIN TIME	14 41 20.8 GCT
MAGNITUDE	3.7

STA	DELTA	PHASE	TYPE	ARRIVAL TIME	TRAVEL TIME	RESIDUAL (SEC)	P-D-DEL/8.1
CLC	40.2	P	DIR	27.7	6.7	0.2	
HAI	41.8	P	DIR	27.6	6.9	-0.1	
		S	DIR	32.2	12.0	-0.6	
ISA	42.3	P	DIR	27.8	7.0	-0.0	
		S	DIR	32.9	12.1	-0.0	
WDY	73.7	P	DIR	32.8	12.1	-0.1	
		S	DIR	41.8	20.9	0.1	
FTC	126.2	P	DIR	41.9	20.6	0.5	
TIN	143.7	P	DIR	44.7	23.4	0.5	
		S	DIR	61.4	40.5	0.1	
KRC	162.3	P	RFR	47.4	26.6	0.0	6.5
MWC	171.3	P	RFR	47.9	27.8	-0.7	5.9
		S	RFR	69.2	48.0	0.4	
DLT	178.4	P	RFR	48.9	28.5	-0.4	6.1
PAS	180.0	P	RFR	48.2	28.6	-1.2	5.2
BBC	198.3	P	RFR	45.3	31.1	-6.6	0.0
RVR	205.9	P	RFR	52.1	31.9	-0.6	5.9
SBC	212.2	P	RFR	54.6	32.1	1.7	7.6
BCN	290.0	P	RFR	63.4	41.8	0.8	6.8

STANDARD ERRORS

ORIGIN TIME	0.2	SEC
X COORDINATE	1.3	KM
Y COORDINATE	1.2	KM
Z COORDINATE	2.7	KM

TABLE 5

DATA FOR EARTHQUAKE OF JULY 11, 1956

LATITUDE	35 45.9 N
LONGITUDE	117 56.9 W
DEPTH	12.6 KM
ORIGIN TIME	19 22 6.7 GCT
MAGNITUDE	4.2

STA	DELTA	PHASE	TYPE	ARRIVAL TIME	TRAVEL TIME	RESIDUAL (SEC)	P-O-DEL/8.1
CLC	32.5	P	DIR	12.6	5.7	0.2	
HAI	41.4	P	DIR	13.6	7.0	-0.2	
		S	DIR	18.6	12.2	-0.3	
ISA	50.0	P	DIR	15.1	8.4	0.0	
		S	DIR	21.2	14.5	0.0	
WDY	81.6	P	DIR	20.1	13.4	-0.0	
		S	DIR	29.8	23.2	-0.1	
FTC	131.1	P	DIR	28.0	21.4	-0.1	
		S	DIR	46.8	36.9	3.2	
TIN	145.1	P	DIR	30.5	23.6	0.1	
		S	DIR	47.9	40.9	0.3	
KRC	169.9	P	RFR	33.6	26.9	0.0	5.9
MWC	171.3	P	RFR	33.3	27.1	-0.5	5.4
DLT	177.3	P	RFR	34.3	27.8	-0.2	5.7
PAS	180.4	P	RFR	34.5	28.0	-0.2	5.5
BBC	193.9	P	RFR	38.4	29.9	1.7	7.7
FRE	199.7	P	RFR	38.0	29.9	1.4	6.6
RVR	203.3	P	RFR	37.4	31.0	-0.3	5.6
SBC	217.8	P	RFR	39.2	32.2	0.3	5.6
		S	RFR	68.7	55.6	6.3	
PVR	225.6	P	RFR	40.6	33.1	0.8	6.0
BCN	282.0	P	RFR	46.3	40.1	-0.6	4.8
PLM	285.4	P	RFR	47.8	40.8	0.3	5.8

STANDARD ERRORS

ORIGIN TIME	0.1	SEC
X COORDINATE	0.8	KM
Y COORDINATE	0.8	KM
Z COORDINATE	1.5	KM

TABLE 6

DATA FOR EARTHQUAKE OF JULY 23, 1956

LATITUDE	35 57.4 N
LONGITUDE	117 46.9 W
DEPTH	5.1 KM
ORIGIN TIME	10 43 35.3 GCT
MAGNITUDE	3.3

STA	DELTA	PHASE	TYPE	ARRIVAL TIME	TRAVEL TIME	RESIDUAL (SEC)	P-O-DEL/8.1
CLC	23.2	P	DIR	39.2	3.9	0.0	
HAI	25.1	P	DIR	39.3	4.2	-0.2	
ISA	71.9	P	DIR	46.9	11.7	-0.1	
		S	DIR	55.8	20.3	0.2	
TIN	128.1	P	DIR	56.5	20.9	0.3	
		S	DIR	72.7	36.1	1.3	
FTC	157.0	P	DIR	61.9	25.6	1.0	
		S	DIR	81.9	44.2	2.4	
KRC	190.9	P	RFR	67.3	30.4	1.6	8.4
		S	RFR	91.2	52.5	3.4	
MWC	194.0	P	RFR	64.8	30.8	-1.3	5.6
		S	RFR	90.4	53.3	1.8	
DLT	198.2	P	RFR	66.6	31.3	0.0	6.8
		S	RFR	92.5	54.1	3.1	
PAS	203.7	P	RFR	66.8	31.8	-0.3	6.4
		S	RFR	96.8	55.0	6.5	
RVR	221.0	P	RFR	68.5	34.1	-0.8	5.9
		S	RFR	97.6	58.9	3.4	
SBC	243.3	P	RFR	73.7	36.2	2.2	8.4
		S	RFR	104.7	62.6	6.8	
PVR	249.5	P	RFR	72.5	36.9	0.3	6.4
PLM	300.9	P	RFR	78.8	43.6	-0.1	6.4
HAY	317.5	P	RFR	81.6	45.4	1.0	7.1

STANDARD ERRORS

ORIGIN TIME	0.1	SEC
X COORDINATE	1.0	KM
Y COORDINATE	1.0	KM
Z COORDINATE	1.8	KM

TABLE 7

DATA FOR EARTHQUAKE OF JANUARY 5, 1959

LATITUDE	36	9.3 N
LONGITUDE	118	3.3 W
DEPTH		2.6 KM
ORIGIN TIME	12 36	2.6 GCT
MAGNITUDE		4.7

STA	DELTA	PHASE	TYPE	ARRIVAL TIME	TRAVEL TIME	RESIDUAL (SEC)	P-O-DEL/8.1
HAI	10.3	P	DIR	4.3	1.7	-0.1	
CLC	56.0	P	DIR	11.9	9.2	0.1	
IS1	66.4	P	DIR	13.5	10.9	0.	
TIN	101.0	P	DIR	19.3	16.5	0.2	
		S	DIR	31.1	28.6	-0.1	
KRC	178.3	P	RFR	32.0	29.4	-0.1	7.4
		S	RFR	53.0	50.9	-0.5	
MWC	214.3	P	RFR	35.9	34.0	-0.7	6.8
PAS	222.9	P	RFR	37.1	34.8	-0.3	7.0
SBC	242.7	P	RFR	41.9	36.7	2.5	9.3
RVR	247.7	P	RFR	39.8	38.0	-0.8	6.6
PVR	267.3	P	RFR	40.9	39.7	-1.4	5.3
PLM	329.4	P	RFR	50.5	47.8	0.1	7.2
BAR	405.8	P	RFR	59.8	57.0	0.2	7.1

STANDARD ERRORS

ORIGIN TIME	0.1	SEC
X COORDINATE	1.3	KM
Y COORDINATE	0.7	KM
Z COORDINATE	2.8	KM

TABLE 8

DATA FOR EARTHQUAKE OF OCTOBER 24, 1959

LATITUDE	35 44.7 N
LONGITUDE	118 1.4 W
DEPTH	7.4 KM
ORIGIN TIME	15 35 15.3 GCT
MAGNITUDE	4.2

STA	DELTA	PHASE	TYPE	ARRIVAL TIME	TRAVEL TIME	RESIDUAL (SEC)	P-O-DEL/8.1
CLC	39.5	P	DIR	21.8	6.6	-0.0	
TSI	41.8	P	DIR	22.2	6.9	-0.0	
HAI	44.2	P	DIR	22.6	7.3	0.	
		S	DIR	27.1	12.6	-0.8	
WDY	74.7	P	DIR	27.6	12.2	0.1	
		S	DIR	35.5	21.1	-0.9	
FTC	125.0	P	DIR	35.4	20.4	-0.3	
		S	DIR	50.6	35.2	0.1	
TIN	146.5	P	DIR	39.7	23.9	0.5	
		S	DIR	56.2	41.3	-0.3	
		P	DIR	39.7	23.9	0.5	
KRC	162.7	P	RFR	41.8	26.5	-0.0	6.4
PAS	177.5	P	RFR	43.4	28.2	-0.1	6.2
		S	RFR	64.1	48.8	-0.0	
RVR	203.0	P	RFR	46.0	31.5	-0.8	5.6
SBC	211.2	P	RFR	49.5	31.9	2.3	8.1
PVR	222.3	P	RFR	49.9	33.2	1.4	7.2
PLM	285.8	P	RFR	56.9	41.4	0.2	6.3
BCN	289.1	P	RFR	56.9	41.6	0.0	5.9
BAR	361.8	P	RFR	66.7	50.6	0.8	6.7

STANDARD ERRORS

ORIGIN TIME	0.1	SEC
X COORDINATE	0.7	KM
Y COORDINATE	0.6	KM
Z COORDINATE	1.4	KM

TABLE 9

DATA FOR EARTHQUAKE OF JANUARY 28, 1961

LATITUDE	35 46.7 N
LONGITUDE	118 2.9 W
DEPTH	5.5 KM
ORIGIN TIME	8 12 46.2 GCT
MAGNITUDE	5.3

STA	DELTA	PHASE	TYPE	ARRIVAL TIME	TRAVEL TIME	RESIDUAL (SEC)	P-O-DEL/8.1
IS1	40.6	P	DIR	52.8	6.7	-0.1	
		S	DIR	57.5	11.6	-0.3	
HAI	40.9	P	DIR	52.9	6.8	-0.0	
		S	DIR	57.6	11.7	-0.3	
CLC	41.2	P	DIR	53.0	6.8	0.0	
WDY	72.7	P	DIR	58.4	11.9	0.3	
FTC	126.5	P	DIR	67.2	20.6	0.4	
TIN	142.5	P	DIR	69.6	23.3	0.1	
		S	DIR	86.5	40.2	0.1	
KRC	161.6	P	RFR	72.6	26.7	-0.3	6.5
MWC	172.5	P	RFR	73.2	28.1	-1.1	5.7
PAS	181.1	P	RFR	74.2	28.9	-0.9	5.7
		S	RFR	94.4	50.0	-1.8	
FRE	191.6	P	RFR	76.7	29.7	0.8	6.9
RVR	207.3	P	RFR	77.3	32.3	-1.2	5.5
SBC	212.2	P	RFR	79.3	32.3	0.8	6.9
		S	RFR	112.1	55.8	10.1	
PVR	225.8	P	RFR	80.2	33.9	0.1	6.1
PLM	290.1	P	RFR	88.6	42.2	0.2	6.6
SNC	311.5	P	RFR	89.9	43.9	-0.2	5.3
HAY	318.6	P	RFR	90.4	45.4	-1.2	4.9
VIN	318.7	P	RFR	92.7	45.6	0.9	7.2
BAR	366.1	P	RFR	97.2	51.4	-0.3	5.8
MHC	365.3	P	RFR	97.6	51.5	-0.1	6.3
ECC	402.5	P	RFR	89.9	55.7	-12.0	-6.0
BRK	441.4	P	RFR	107.1	60.7	0.2	6.4

STANDARD ERRORS

ORIGIN TIME	0.1	SEC
X COORDINATE	0.6	KM
Y COORDINATE	0.6	KM
Z COORDINATE	1.3	KM

TABLE 10

DATA FOR EARTHQUAKE OF OCTOBER 19, 1961

LATITUDE	35 51.4 N
LONGITUDE	117 48.3 W
DEPTH	6.4 KM
ORIGIN TIME	5 9 44.6 GCT
MAGNITUDE	5.1

STA	DELTA	PHASE	TYPE	ARRIVAL TIME	TRAVEL TIME	RESIDUAL (SEC)	P-O-DEL/8.1
CLC	19.6	P	DIR	48.0	3.4	0.0	
HAI	33.8	P	DIR	50.1	5.6	-0.1	
		S	DIR	54.3	9.7	-0.0	
ISI	64.2	P	DIR	55.1	10.5	-0.0	
		S	DIR	63.0	18.2	0.2	
WDY	95.8	P	DIR	60.1	15.7	-0.2	
TIN	138.2	P	DIR	67.4	22.6	0.2	
		S	DIR	82.4	39.0	-1.2	
FTC	147.3	P	DIR	68.0	24.0	-0.6	
MWC	182.6	P	RFR	73.2	29.2	-0.6	6.1
KRC	185.3	P	RFR	74.1	29.4	0.1	6.6
PAS	192.4	P	RFR	74.2	30.2	-0.6	5.9
		S	RFR	99.7	52.2	2.9	
RVR	210.3	P	RFR	76.1	32.5	-1.0	5.5
		S	RFR	103.1	56.2	2.3	
SBC	234.3	P	RFR	80.4	34.8	1.0	6.9
		S	RFR	109.6	60.3	4.7	
PVR	238.1	P	RFR	80.7	35.3	0.8	6.7
BCN	268.4	P	RFR	104.3	39.1	20.6	26.6
HAY	310.2	P	RFR	87.4	44.2	-1.4	4.5
SNC	329.4	P	RFR	90.5	46.0	-0.1	5.2
		S	RFR	126.2	79.5	2.1	
BAR	367.3	P	RFR	95.9	51.3	-0.0	6.0
		S	RFR	143.1	88.8	9.7	
ECC	397.4	P	RFR	112.2	54.9	12.7	18.5
		S	RFR	156.7	95.0	17.1	

STANDARD ERRORS

ORIGIN TIME	0.1	SEC
X COORDINATE	0.4	KM
Y COORDINATE	0.5	KM
Z COORDINATE	1.0	KM

TABLE 11

DATA FOR EARTHQUAKE OF SEPTEMBER 21, 1963

LATITUDE	35 25.2 N
LONGITUDE	117 46.9 W
DEPTH	11.1 KM
ORIGIN TIME	5 5 59.9 GCT
MAGNITUDE	3.3

STA	DELTA	PHASE	TYPE	ARRIVAL TIME	TRAVEL TIME	RESIDUAL (SEC)	P-O-DEL/8.1
ISA	67.9	P	DIR	71.1	11.2	0.0	
HAI	81.0	P	DIR	73.5	13.3	0.3	
		S	DIR	82.8	23.0	-0.1	
GSC	89.8	P	DIR	75.9	14.7	1.3	
		S	DIR	84.1	25.4	-1.2	
FTC	118.1	P	DIR	78.9	19.3	-0.3	
		S	DIR	93.1	33.3	-0.1	
MWC	135.1	P	DIR	81.8	22.0	-0.1	
		S	DIR	98.6	38.0	0.7	
PAS	145.4	P	DIR	83.5	23.6	-0.0	
		S	DIR	99.2	40.9	-1.6	
RVR	162.5	P	RFR	85.3	25.6	-0.2	5.3
		S	RFR	104.4	44.3	0.2	
KRC	178.5	P	RFR	82.5	27.6	-5.0	0.6
TIN	185.7	P	RFR	88.6	29.5	-0.8	5.8
PLM	244.2	P	RFR	95.9	35.4	0.6	5.8
HAY	273.5	P	RFR	105.8	38.7	7.2	12.1
BAR	320.4	P	RFR	105.5	44.6	1.0	6.0

STANDARD ERRORS

ORIGIN TIME	0.2	SEC
X COORDINATE	1.7	KM
Y COORDINATE	1.3	KM
Z COORDINATE	3.4	KM

TABLE 12

DATA FOR EARTHQUAKE OF MARCH 15, 1946

LATITUDE	35 44.0 N
LONGITUDE	118 0.5 W
DEPTH	8.0 KM
ORIGIN TIME	13 21 1.9 GCT
MAGNITUDE	5.5

STA	DELTA	PHASE	TYPE	ARRIVAL TIME	TRAVEL TIME	RESIDUAL (SEC)	P-O-DEL/8.1
HAI	45.2	P	DIR	9.2	7.5	-0.	
TIN	147.9	P	RFR	26.4	23.8	-0.1	6.3
MWC	167.6	P	RFR	28.4	26.4	-0.0	5.8
PAS	176.4	P	RFR	29.6	27.4	0.0	5.9
RVR	201.4	P	RFR	32.8	30.7	0.0	6.0
SBC	211.4	P	RFR	34.1	32.0	0.1	6.1
PLM	284.1	P	RFR	43.1	41.6	-0.1	6.1
BCN	287.8	P	RFR	42.8	42.0	0.1	5.4

STANDARD ERRORS

ORIGIN TIME	0.1 SEC
X COORDINATE	0.8 KM
Y COORDINATE	0.6 KM
Z COORDINATE	1.5 KM

THIS EARTHQUAKE WAS LOCATED RELATIVE TO THE EARTHQUAKE OF JUL 11, 1956, AT 19 22 6.7 GCT. THE LATTER EARTHQUAKE WAS ASSIGNED A LOCATION OF 35 45.9 N, 117 56.9 W, AND A DEPTH OF 12.6 KM.

TABLE 13

DATA FOR EARTHQUAKE OF MARCH 15, 1946

LATITUDE	35 42.3 N
LONGITUDE	118 0.2 W
DEPTH	6.3 KM
ORIGIN TIME	13 49 37.0 GCT
MAGNITUDE	6.3

STA	DELTA	PHASE	TYPE	ARRIVAL TIME	TRAVEL TIME	RESIDUAL (SEC)	P-D-DEL/8.1
HAI	48.3	P	DIR	44.8	8.0	-0.	
TIN	151.1	P	RFR	61.9	24.4	-0.3	6.2
MWC	164.3	P	RFR	63.0	26.2	-0.3	5.7
PAS	173.2	P	RFR	64.4	27.2	-0.1	6.0
RVR	198.3	P	RFR	67.4	30.5	-0.3	5.9
SBC	209.6	P	RFR	69.6	31.9	0.5	6.7
PLM	281.0	P	RFR	78.2	41.4	0.0	6.5
BCN	287.9	P	RFR	78.4	42.2	0.4	5.8

STANDARD ERRORS

ORIGIN TIME	0.5 SEC
X COORDINATE	2.9 KM
Y COORDINATE	2.0 KM
Z COORDINATE	5.7 KM

THIS EARTHQUAKE WAS LOCATED RELATIVE TO THE EARTHQUAKE OF JUL 11, 1956, AT 19 22 6.7 GCT. THE LATTER EARTHQUAKE WAS ASSIGNED A LOCATION OF 35 45.9 N, 117 56.9 W, AND A DEPTH OF 12.6 KM.

TABLE 14

DATA FOR EARTHQUAKE OF MARCH 15, 1946

LATITUDE	35 44.2 N
LONGITUDE	117 59.9 W
DEPTH	9.8 KM
ORIGIN TIME	13 21 1.9 GCT
MAGNITUDE	5.5

STA	DELTA	PHASE	TYPE	ARRIVAL TIME	TRAVEL TIME	RESIDUAL (SEC)	P-O-DEL/8.1
HAI	44.8	P	DIR	9.2	7.5	-0.2	
TIN	147.6	P	RFR	26.4	23.6	0.2	6.3
PAS	176.8	P	RFR	29.6	27.3	-0.1	5.9
		S	RFR	49.8	47.8	-0.3	
RVR	201.6	P	RFR	32.8	30.6	0.6	6.0
SBC	212.3	P	RFR	34.1	31.9	-1.9	6.0
PLM	284.1	P	RFR	43.1	41.5	0.0	6.1
BCN	287.0	P	RFR	42.8	41.8	-0.2	5.5

STANDARD ERRORS

ORIGIN TIME	0.5	SEC
X COORDINATE	4.3	KM
Y COORDINATE	2.3	KM
Z COORDINATE	5.4	KM

THIS EARTHQUAKE WAS LOCATED RELATIVE TO THE EARTHQUAKE OF OCT 24, 1959, AT 15 35 15.3 GCT. THE LATTER EARTHQUAKE WAS ASSIGNED A LOCATION OF 35 44.7 N, 118 1.4 W, AND A DEPTH OF 7.4 KM.

TABLE 15

DATA FOR EARTHQUAKE OF MARCH 15, 1946

LATITUDE	35 42.8 N
LONGITUDE	118 0.8 W
DEPTH	7.3 KM
ORIGIN TIME	13 49 37.0 GCT
MAGNITUDE	6.3

STA	DELTA	PHASE	TYPE	ARRIVAL TIME	TRAVEL TIME	RESIDUAL (SEC)	P-O-DEL/8.1
HAI	47.5	P	DIR	44.8	7.9	-0.	
TIN	150.1	P	RFR	61.9	24.2	0.0	6.4
PAS	174.1	P	RFR	64.4	27.2	-0.2	5.9
		S	RFR	90.5	47.6	5.5	
RVR	199.4	P	RFR	67.4	30.5	0.2	5.8
SBC	209.6	P	RFR	69.6	31.8	-1.4	6.8
PLM	282.2	P	RFR	78.2	41.5	0.1	6.4
BCN	288.6	P	RFR	78.4	42.2	-0.1	5.8

STANDARD ERRORS

ORIGIN TIME	0.3	SEC
X COORDINATE	2.9	KM
Y COORDINATE	1.4	KM
Z COORDINATE	3.3	KM

THIS EARTHQUAKE WAS LOCATED RELATIVE TO THE EARTHQUAKE OF OCT 24, 1959, AT 15 35 15.3 GCT. THE LATTER EARTHQUAKE WAS ASSIGNED A LOCATION OF 35 44.7 N, 118 1.4 W, AND A DEPTH OF 7.4 KM.

NOTES FOR TABLES 16 THROUGH 23

NOTE 1. All latitudes are north, all longitudes are west, and all times are GCT.

NOTE 2. An orgin time in which the second appears as '-0. ' was given only to the nearest minute in the St. Amand-Allen catalog.

TABLE 16A

ARRIVAL AND TRAVEL TIMES FOR SHOCKS NEAR 36 09 N, 118 03 W

DATE	24 APR 36	22 JUN 42	22 JUN 42	16 OCT 42
LAT	36 9.0	36 15.0	36 15.0	36 15.0
LONG	117 57.0	117 58.0	117 58.0	117 58.0
TIME	19 0 -0.	22 13 51.0	23 51 3.0	10 7 27.0
MAG	4.0	4.0	4.0	4.0

STA		ARRT	TRVT	ARRT	TRVT	ARRT	TRVT	ARRT	TRVT
HAI	P	10.1	10.1	53.5	2.5	5.2	2.2	29.2	2.2
	S							30.7	3.7
TIN	P	26.7	26.7	67.8	16.8	19.5	16.5	44.0	17.0
	S	40.2	40.2	81.8	30.8	33.5	30.5	56.6	29.6
MWC	P	42.3	42.3	85.4	34.4	43.5	40.5	62.4	35.4
	S	70.3	70.3	110.8	59.8	69.2	66.2	89.2	62.2
PAS	P	42.9	42.9	86.6	35.6	38.4	35.4	62.2	35.2
	S	69.0	69.0	114.1	63.1	68.4	65.4	94.2	67.2
RVR	P	45.3	45.3	89.4	38.4	40.9	37.9	64.9	37.9
	S			122.2	71.2	73.5	70.5	97.7	70.7
SBC	P			91.5	40.5	43.0	40.0	66.6	39.6
	S			122.5	71.5	70.7	67.7	99.8	72.8
PLM	P							75.7	48.7

TABLE 16B

ARRIVAL AND TRAVEL TIMES FOR SHOCKS NEAR 36 09 N, 118 03 W

DATE	30 MAY 43	26 JUL 45	5 JAN 59
LAT	36 8.0	36 3.0	36 9.3
LONG	117 58.0	117 52.0	118 3.3
TIME	7 50 -0.	10 10 56.0	12 36 2.6
MAG	4.0	4.1	4.7

STA		ARRT	TRVT	ARRT	TRVT	ARRT	TRVT
HAI	P			59.4	3.4	4.3	1.7
	S			61.4	5.4		
CLC	P					11.9	9.3
IS1	P					13.5	10.9
TIN	P	73.1	73.1	76.0	20.0	19.3	16.7
	S	86.5	86.5	89.9	33.9	31.1	28.5
KRC	P					32.0	29.4
	S					53.0	50.4
MWC	P	90.3	90.3	90.7	34.7	35.9	33.3
	S	117.7	117.7	114.3	58.3		
PAS	P	95.0	95.0	92.1	36.1	37.1	34.5
	S	123.5	123.5	114.6	58.6	66.0	63.4
RVR	P	95.8	95.8	95.2	39.2	39.8	37.2
	S	124.0	124.0	121.6	65.6	71.5	68.9
SBC	P	99.9	99.9			41.9	39.3
	S	129.9	129.9			72.7	70.1
PVR	P					40.9	38.3
PLM	P	107.0	107.0			50.5	47.9
BAR	P					59.8	57.2

TABLE 17

ARRIVAL AND TRAVEL TIMES FOR SHOCKS NEAR 36 01 N, 118 23 W

DATE	18 MAY 45	17 NOV 52
LAT	36 12.0	36 4.0
LONG	118 23.0	118 26.4
TIME	9 44 40.0	3 20 23.2
MAG	4.0	3.8

STA		ARRT	TRVT	ARRT	TRVT
HAI	P	48.2	8.2	30.7	7.5
	S	56.7	16.7	36.0	12.8
CLC	P			36.4	13.2
TIN	P	58.2	18.2	41.4	18.2
	S	70.6	30.6	56.8	33.6
MWC	P	73.9	33.9	56.9	33.7
	S	97.5	57.5		
PAS	P	74.5	34.5	57.3	34.1
	S	107.0	67.0		
SBC	P	76.0	36.0		
	S	104.3	64.3		
BBC	P			61.5	38.3
RVR	P	78.5	38.5	61.4	38.2
	S	106.7	66.7		
PLM	P	89.5	49.5	72.0	48.8
LJC	S	147.2	107.2		

TABLE 18A

ARRIVAL AND TRAVEL TIMES FOR SHOCKS NEAR 36 46 N, 118 03 W

DATE	22 AUG 55	28 JAN 61	28 JAN 61	28 JAN 61
LAT	35 46.1	35 46.7	35 48.2	35 46.6
LONG	118 2.2	118 2.9	118 2.0	118 3.0
TIME	14 41 20.8	8 12 46.2	14 1 8.5	17 2 12.2
MAG	3.7	5.3	3.7	3.6

STA		ARRT	TRVT	ARRT	TRVT	ARRT	TRVT	ARRT	TRVT
CLC	P	27.7	6.9	53.0	6.8	15.6	7.1	19.1	6.9
IS1	P			52.8	6.6				
	S			57.5	11.3				
HAI	P	27.6	6.8	52.9	6.7			17.3	5.1
	S	32.2	11.4	57.6	11.4			21.9	9.7
ISA	P	27.8	7.0			15.4	6.9	18.8	6.6
	S	32.9	12.1			21.0	12.5	24.5	12.3
WDY	P	32.8	12.0	58.4	12.2	21.2	12.7	23.9	11.7
	S	41.8	21.0						
FTC	P	41.9	21.1	67.2	21.0	29.5	21.0	32.8	20.6
	S							49.0	36.8
TIN	P	44.7	23.9	69.6	23.4	31.7	23.2	35.8	23.6
	S	61.4	40.6	86.5	40.3	47.4	38.9	49.9	37.7
KRC	P	47.4	26.6	72.6	26.4	34.9	26.4	38.9	26.7
	S					54.0	45.5		
MWC	P	47.9	27.1	73.2	27.0	36.0	27.5	38.8	26.6
	S	69.2	48.4						
DLT	P	48.9	28.1						
PAS	P	48.2	27.4	74.2	28.0	36.4	27.9	40.2	28.0
	S			94.4	48.2				
FRE	P			76.7	30.5				
BBC	P	45.3	24.5						
RVR	P	52.1	31.3	77.3	31.1	40.8	32.3	43.0	30.8
SBC	P	54.6	33.8	79.3	33.1	42.2	33.7	53.2	41.0
	S							72.1	59.9
PVR	P			80.2	34.0	42.5	34.0	50.8	38.6
PLM	P			88.6	42.4	50.4	41.9	55.0	42.8
BCN	P	63.4	42.6	88.6	42.4				
SNC	P			89.9	43.7			65.9	53.7
HAY	P			90.4	44.2				
VIN	P			92.7	46.5				
BAR	P			97.2	51.0	59.8	51.3	63.5	51.3
MHC	P			97.6	51.4				
ECC	P			89.9	43.7				
BRK	P			107.1	60.9				

TABLE 18B

ARRIVAL AND TRAVEL TIMES FOR SHOCKS NEAR 36 46 N, 118 03 W

DATE	12 FEB 61	22 FEB 61	16 SEP 62	19 SEP 62
LAT	35 46.7	35 47.1	35 44.3	35 48.1
LONG	118 2.1	118 3.2	118 3.2	118 0.8
TIME	6 47 38.9	7 3 1.6	5 36 15.9	18 50 30.7
MAG	3.2	2.8	4.8	3.1

STA		ARRT	TRVT	ARRT	TRVT	ARRT	TRVT	ARRT	TRVT
IW1	P							34.0	3.3
	S							36.6	5.9
CLC	P	45.7	6.7	8.6	7.0	22.8	6.9	37.1	6.4
	S							44.1	13.4
IS1	P	46.2	7.2	8.3	6.7				
HAI	P	44.6	5.7	8.6	7.0				
	S	52.0	13.1	13.7	12.1				
ISA	P					22.3	6.4	37.8	7.1
	S					27.4	11.5		
WDY	P	50.7	11.7	13.7	12.1	28.4	12.5	43.3	12.6
	S	60.0	21.1	22.4	20.8				
FTC	P	59.9	20.9	22.8	21.2	37.0	21.1	52.4	21.7
	S	77.8	38.8	42.9	41.3			71.1	40.4
TIN	P	62.9	23.9	25.0	23.4	39.8	23.9	53.6	22.9
	S	80.0	41.1	42.2	40.6			70.8	40.1
KRC	P	65.4	26.4	28.5	26.9			57.8	27.1
	S	87.8	48.8	51.6	50.0				
MWC	P	66.4	27.4	29.0	27.4	43.4	27.5	58.7	28.0
PAS	P	67.4	28.4	32.2	30.6	44.4	28.5	59.2	28.5
RVR	P	70.5	31.6	31.9	30.3	46.9	31.0	62.3	31.6
SBC	P	74.8	35.8	39.9	38.3	50.0	34.1		
PVR	P			43.4	41.8	50.4	34.5		
PLM	P	82.9	43.9	43.8	42.2			72.8	42.1
SNC	P					61.4	45.5		
HAY	P	92.4	53.4			61.2	45.3	84.0	53.3
BAR	P	90.1	51.1	52.9	51.3	67.7	51.8	83.0	52.3
ECC	P					91.1	75.2		

TABLE 19

ARRIVAL AND TRAVEL TIMES FOR SHOCKS NEAR 35 45 N, 118 01 W

DATE		24 OCT 59		24 OCT 59		24 OCT 59		16 NOV 59	
LAT		35 44.7		35 44.5		35 44.3		35 44.9	
LONG		118 1.4		118 1.1		118 0.4		118 0.8	
TIME		15 35 15.3		16 11 24.3		19 58 20.1		12 5 35.0	
MAG		4.2		3.7		3.4		3.7	
STA		ARRT	TRVT	ARRT	TRVT	ARRT	TRVT	ARRT	TRVT
CLC	P	21.8	6.5			26.7	6.6	41.4	6.4
IS1	P	22.2	6.9			27.2	7.1	42.3	7.3
ISA	P			31.2	6.9				
	S			36.9	12.6				
HAI	P	22.6	7.3	31.7	7.4	27.5	7.4	42.2	7.2
	S	27.1	11.8	36.9	12.6	32.7	12.6		
WDY	P	27.6	12.3	36.9	12.6	32.6	12.5	47.3	12.3
	S	35.5	20.2	45.9	21.6	41.8	21.7	56.7	21.7
FTC	P	35.4	20.1	44.8	20.5	40.7	20.6	55.9	20.9
	S	50.6	35.3						
TIN	P	39.7	24.4	48.5	24.2	44.4	24.3	59.4	24.4
	S	56.2	40.9	65.8	41.5	60.2	40.1	76.9	41.9
KRC	P	41.8	26.5	50.8	26.5	46.7	26.6		
	S			68.8	44.5				
PAS	P	43.4	28.1	52.5	28.2	48.6	28.5	63.0	28.0
	S	64.1	48.8			65.6	45.5	83.4	48.4
RVR	P	46.0	30.7	55.0	30.7	51.3	31.2		
	S					75.0	54.9		
SBC	P	49.5	34.2	58.4	34.1			69.0	34.0
PVR	P	49.9	34.6	58.8	34.5	56.7	36.6	68.4	33.4
PLM	P	56.9	41.6	66.0	41.7	62.1	42.0	76.3	41.3
BCN	P	56.9	41.6	66.4	42.1	62.5	42.4		
SNC	P							79.0	44.0
HAY	P			76.0	51.7	73.5	53.4	86.8	51.8
BAR	P	66.7	51.4	75.7	51.4	71.4	51.3	86.4	51.4

TABLE 20A

ARRIVAL AND TRAVEL TIMES FOR SHOCKS NEAR 35 47 N, 117 57 W

DATE	18 MAR 46	18 MAR 46	25 JUN 51	26 JUN 51
LAT	35 45.3	35 44.0	35 46.3	35 45.7
LONG	117 58.7	118 2.0	117 56.9	117 57.2
TIME	15 49 26.5	15 50 43.0	19 45 41.7	1 26 39.1
MAG	4.6	5.3	4.6	4.4

STA		ARRT	TRVT	ARRT	TRVT	ARRT	TRVT	ARRT	TRVT
CLC	P					47.4	5.7	44.4	5.3
HAI	P	33.6	7.0	49.6	6.6	48.5	6.8	46.0	6.9
TIN	P	50.6	24.0	65.5	22.5	65.5	23.8	63.2	24.1
	S	69.1	42.5	85.0	42.0	83.1	41.4	81.2	42.1
MWC	P	53.7	27.1	69.9	26.9	68.1	26.4	66.2	27.1
	S	69.4	42.8	91.1	48.1				
PAS	P	54.7	28.1	70.5	27.5	69.4	27.7	67.2	28.1
	S	75.5	48.9	89.0	46.0	89.8	48.1	88.0	48.9
BBC	P					71.1	29.4	68.9	29.8
FRE	P	57.9	31.3			71.7	30.0	69.0	29.9
RVR	P	57.5	31.0	74.2	31.2	72.5	30.8	70.2	31.1
	S	85.7	59.1	96.4	53.4				
SBC	P					74.5	32.8	73.7	34.6
	S					102.3	60.6	100.4	61.3
BCN	P	66.7	40.1			82.8	41.1	80.6	41.5
PLM	P	68.2	41.6			83.1	41.4	80.7	41.6
OVE	P					90.7	49.0	89.3	50.2
PFA	P					92.2	50.5	89.0	49.9
TUC	P	124.9	98.3						

TABLE 20B

ARRIVAL AND TRAVEL TIMES FOR SHOCKS NEAR 35 47 N, 117 57 W

DATE	26 JUN 51	1 JUL 51	11 JUL 56
LAT	35 47.0	35 44.7	35 45.9
LONG	117 57.0	117 59.1	117 56.9
TIME	2 6 14.0	0 16 18.7	19 22 6.7
MAG	3.6	3.7	4.2

STA		ARRT	TRVT	ARRT	TRVT	ARRT	TRVT
CLC	P	19.7	5.7	24.6	5.9	12.6	5.9
HAI	P	21.6	7.6	26.0	7.3	13.6	6.9
	S	26.6	12.6	31.2	12.5	18.6	11.9
ISA	P					15.1	8.4
	S					21.2	14.5
WDY	P					20.1	13.4
	S					29.8	23.1
FTC	P					28.0	21.3
	S					46.8	40.1
TIN	P	38.4	24.4	42.9	24.2	30.5	23.8
	S	56.2	42.2	60.7	42.0	47.9	41.2
KRC	P					33.6	26.9
MWC	P	41.6	27.6	45.5	26.8	33.3	26.6
DLT	P					34.3	27.6
PAS	P	42.5	28.5	46.7	28.0	34.5	27.8
	S			64.7	46.0		
BBC	P	44.3	30.3	51.9	33.2	38.4	31.7
FRE	P					38.0	31.3
RVR	P	45.7	31.7	49.8	31.1	37.4	30.7
SBC	P	49.7	35.7	54.5	35.8	39.2	32.5
PVR	P					40.6	33.9
BCN	P					46.3	39.6
PLM	P	56.2	42.2	61.0	42.3	47.8	41.1
LJC	P			73.0	54.3		

TABLE 21A

ARRIVAL AND TRAVEL TIMES FOR SHOCKS NEAR 35 58 N, 117 58 W

DATE		10 SEP 37		18 SEP 37		16 SEP 43		16 SEP 43	
LAT		35 58.0		36 0.		36 1.0		36 1.0	
LONG		117 55.0		118 2.0		117 56.0		117 56.0	
TIME		19 34 -0.		8 37 -0.		0 16 11.0		7 52 -0.	
MAG		4.0		4.0		4.0		4.5	
STA		ARRT	TRVT	ARRT	TRVT	ARRT	TRVT	ARRT	TRVT
HAI	P	12.8	12.8	36.2	36.2	15.1	4.1	26.1	26.1
	S	16.0	16.0	39.2	39.2	17.9	6.9	28.7	28.7
TIN	P	30.1	30.1			32.3	21.3	43.0	43.0
	S	46.6	46.6			48.2	37.2	58.2	58.2
MWC	P	35.7	35.7	62.9	62.9	44.3	33.3	53.7	53.7
	S	67.0	67.0	87.9	87.9	68.9	57.9	79.4	79.4
PAS	P	41.3	41.3	62.9	62.9	44.0	33.0	54.6	54.6
	S	65.5	65.5	85.8	85.8	70.0	59.0	78.9	78.9
RVR	P	43.2	43.2			47.1	36.1	56.2	56.2
	S	73.0	73.0	95.6	95.6	66.0	55.0	85.6	85.6
SBC	P	50.0	50.0			48.8	37.8	60.1	60.1
	S	79.0	79.0			81.7	70.7	91.8	91.8
PLM	P					56.0	45.0	66.6	66.6
	S							109.3	109.3
LJC	P			86.5	86.5	67.0	56.0	71.0	71.0
	S					107.2	96.2	120.3	120.3
TUC	P							124.0	124.0

TABLE 21B

ARRIVAL AND TRAVEL TIMES FOR SHOCKS NEAR 35 58 N, 117 58 W

DATE	21 JUL 52	27 SEP 59	17 AUG 62
LAT	35 59.0	36 2.0	35 56.9
LONG	117 56.0	117 55.0	117 58.8
TIME	15 51 39.0	0 21 50.0	11 3 53.7
MAG	3.8	3.0	3.2

STA		ARRT	TRVT	ARRT	TRVT	ARRT	TRVT
HAI	P	42.0	3.0	52.9	2.9		
	S			54.9	4.9		
CLC	P	44.7	5.7	56.2	6.2	59.9	6.2
	S					72.2	18.5
IS1	P			59.9	9.9		
ISA	P					63.2	9.5
WDY	P			64.6	14.6	67.4	13.7
	S			74.8	24.8	77.2	23.5
TIN	P	59.5	20.5	70.4	20.4	74.1	20.4
	S	74.3	35.3	85.7	35.7	89.4	35.7
GSC	P					59.9	6.2
	S					15.9	-37.8
FTC	P					78.4	24.7
	S					95.3	41.6
KRC	P			80.4	30.4		
	S			99.6	49.6		
FRE	P	71.8	32.8				
MWC	P					83.4	29.7
PAS	P			83.3	33.3	84.5	30.8
	S			108.0	58.0		
BBC	P	76.0	37.0				
RVR	P	74.5	35.5			87.4	33.7
SBC	P	79.4	40.4			92.9	39.2
PVR	P					96.1	42.4
PLM	P			96.8	46.8	97.5	43.8
HAY	P			105.3	55.3		
MHC	P	89.3	50.3				
BAR	P			113.1	63.1	107.0	53.3
REN	P	111.7	72.7				

TABLE 22A

ARRIVAL AND TRAVEL TIMES FOR SHOCKS NEAR 35 58 N, 117 45 W

DATE		7 JAN 39		15 AUG 39		9 AUG 44		12 AUG 44	
LAT		36 0.		36 0.		35 56.0		35 56.0	
LONG		117 44.0		117 35.0		117 46.0		117 46.0	
TIME		20 21 -0.		15 48 18.0		14 1 5.0		8 25 20.0	
MAG		5.0		4.0		4.0		4.1	
STA		ARRT	TRVT	ARRT	TRVT	ARRT	TRVT	ARRT	TRVT
HAI	P	54.6	54.6	24.9	6.9	11.1	6.1	27.9	7.9
	S					15.4	10.4	31.4	11.4
TIN	P	70.9	70.9			28.5	23.5	43.6	23.6
	S	87.7	87.7			45.2	40.2	62.8	42.8
MWC	P	79.9	79.9	50.7	32.7	37.3	32.3	53.3	33.3
	S	107.0	107.0	77.5	59.5	63.1	58.1	75.5	55.5
FRE	P	82.6	82.6						
	S	107.0	107.0						
PAS	P	81.5	81.5	50.7	32.7	38.1	33.1	54.0	34.0
	S	110.7	110.7	80.5	62.5	62.0	57.0	78.0	58.0
RVR	P	83.4	83.4	52.2	34.2	40.1	35.1	56.0	36.0
	S					67.5	62.5	84.4	64.4
SBC	P	87.2	87.2	62.5	44.5	46.9	41.9	63.0	43.0
	S	119.0	119.0	94.5	76.5	73.2	68.2	92.7	72.7
BCN	P			59.0	41.0				
PLM	P					50.4	45.4	66.1	46.1
LJC	P			76.0	58.0	58.2	53.2	73.1	53.1
	S					102.2	97.2	117.9	97.9
BRK	P	115.3	115.3						
TUC	P					107.4	102.4	122.7	102.7

TABLE 22B

ARRIVAL AND TRAVEL TIMES FOR SHOCKS NEAR 35 58 N, 117 45 W

DATE		13 AUG 44		23 JUL 56	
LAT		35 56.0		35 57.4	
LONG		117 46.0		117 46.9	
TIME		6 27 57.0		10 43 35.3	
MAG		3.7		3.3	
STA		ARRT	TRVT	ARRT	TRVT
CLC	P			39.2	3.9
HAI	P	63.0	6.0	39.3	4.0
	S	66.8	9.8		
ISA	P			46.9	11.6
	S			55.8	20.5
TIN	P	79.8	22.8	56.5	21.2
	S			72.7	37.4
FTC	P			61.9	26.6
	S			81.9	46.6
KRC	P			67.3	32.0
	S			91.2	55.9
MWC	P	90.0	33.0	64.8	29.5
	S	115.4	58.4	90.4	55.1
DLT	P			66.6	31.3
	S			92.5	57.2
PAS	P	90.7	33.7	66.8	31.5
	S			96.8	61.5
RVR	P	92.4	35.4	68.5	33.2
	S	122.1	65.1	97.6	62.3
SBC	P	100.4	43.4	73.7	38.4
	S	128.4	71.4	104.7	69.4
PVR	P			72.5	37.2
PLM	P	103.7	46.7	78.8	43.5
HAY	P			81.6	46.3
LJC	P	116.0	59.0		

TABLE 23

ARRIVAL AND TRAVEL TIMES FOR SHOCKS NEAR 35 25 N, 117 34 W

DATE	3 JUL 44	11 MAY 45	29 OCT 46	21 SEP 63
LAT	35 21.0	35 26.0	35 25.0	35 25.2
LONG	117 52.0	117 40.0	117 41.0	117 46.9
TIME	5 38 23.0	0 9 54.0	11 34 58.0	5 5 59.9
MAG	4.7	3.8	3.6	3.3

STA		ARRT	TRVT	ARRT	TRVT	ARRT	TRVT	ARRT	TRVT
TSA	P							71.1	11.2
HAI	P	38.5	15.5	69.0	15.0	73.3	15.3	73.5	13.6
	S	48.1	25.1	78.6	24.6	83.2	25.2	82.8	22.9
GSC	P							75.9	16.0
	S							84.1	24.2
FTC	P							78.9	19.0
	S							93.1	33.2
MWC	P	44.8	21.8	77.0	23.0	81.6	23.6	81.8	21.9
	S	59.8	36.8	93.4	39.4	99.1	41.1	98.6	38.7
PAS	P	45.9	22.9	78.6	24.6	83.5	25.5	83.5	23.6
	S	63.2	40.2	92.8	38.8	99.6	41.6	99.2	39.3
RVR	P	49.1	26.1	80.8	26.8	85.1	27.1	85.3	25.4
	S	68.1	45.1	99.7	45.7	104.5	46.5	104.4	44.5
KRC	P							82.5	22.6
TIN	P	53.7	30.7	84.4	30.4	90.7	32.7	88.6	28.7
	S	77.5	54.5	107.5	53.5	112.5	54.5		
SBC	P	54.6	31.6	90.0	36.0	94.0	36.0		
	S	80.4	57.4	114.2	60.2	120.3	62.3		
PLM	P	64.0	41.0	91.2	37.2	95.9	37.9	95.9	36.0
HAY	P							105.8	45.9
LJC	P	70.5	47.5	100.5	46.5	106.7	48.7		
	S	102.1	79.1	133.6	79.6				
BAR	P							105.5	45.6

FIGURE CAPTIONS

Figure 1. Key map showing location of Walker Pass region.

Figure 2. Epicenters in the Walker Pass region and surrounding area.

Figure 3. Aftershocks of the earthquake of March 15, 1946, in Walker Pass.

Figure 4. Locations of the earthquakes near Brown.

Figure 5. Locations of earthquakes near Haiwee during January, 1959.

Figure 6. Locations of earthquakes near Walker Pass during October and November of 1959.

Figure 7. Locations of earthquakes near Walker Pass during January and February, 1961.

Figure 8. Structures and velocities used in the location of earthquakes for the study of the Walker Pass region.

Figure 9. Region covered by the structure and velocity matrix and depths of the Mohorovicic Discontinuity used for the study of earthquakes in the Walker Pass region.

Figure 10. Method of formation of layers in the non-parallel plane layer travel time routine.

Figure 1

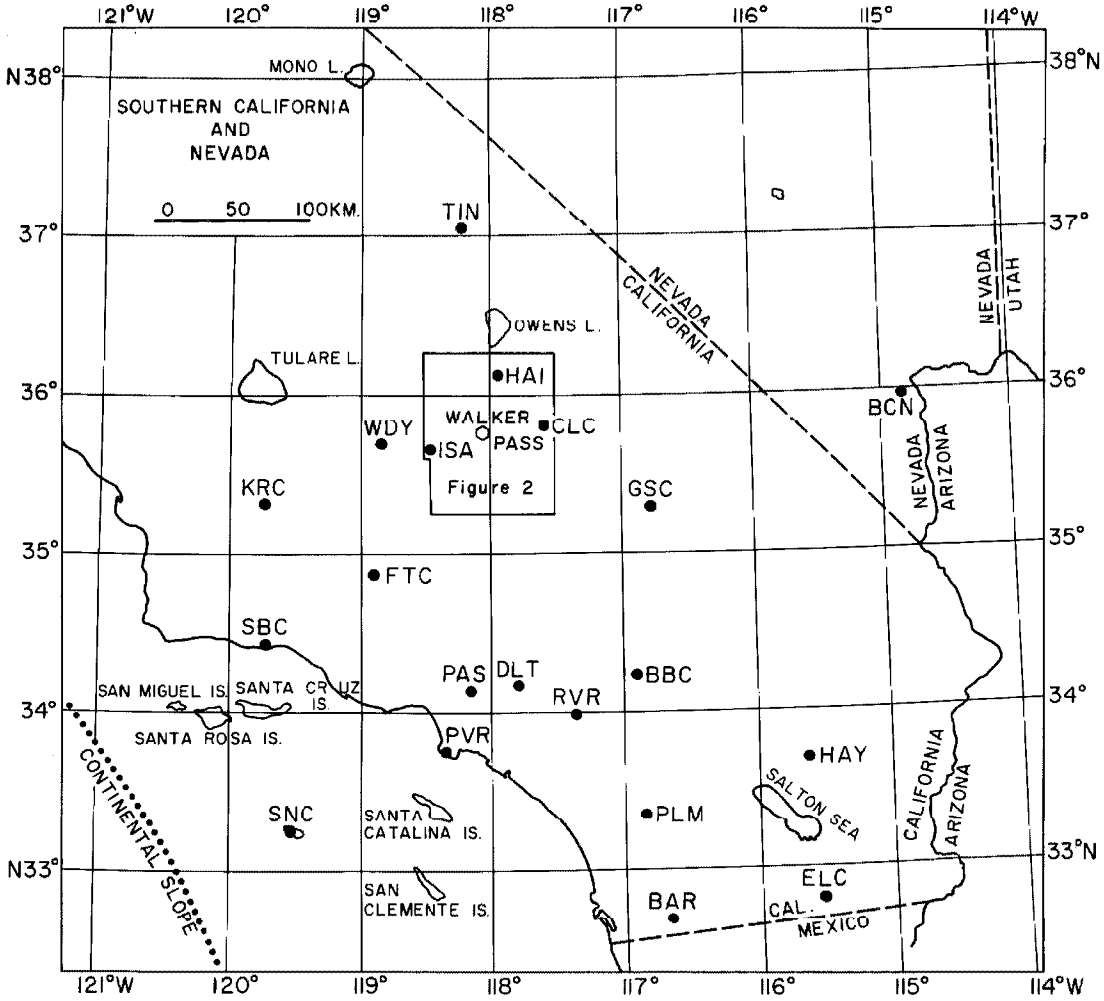
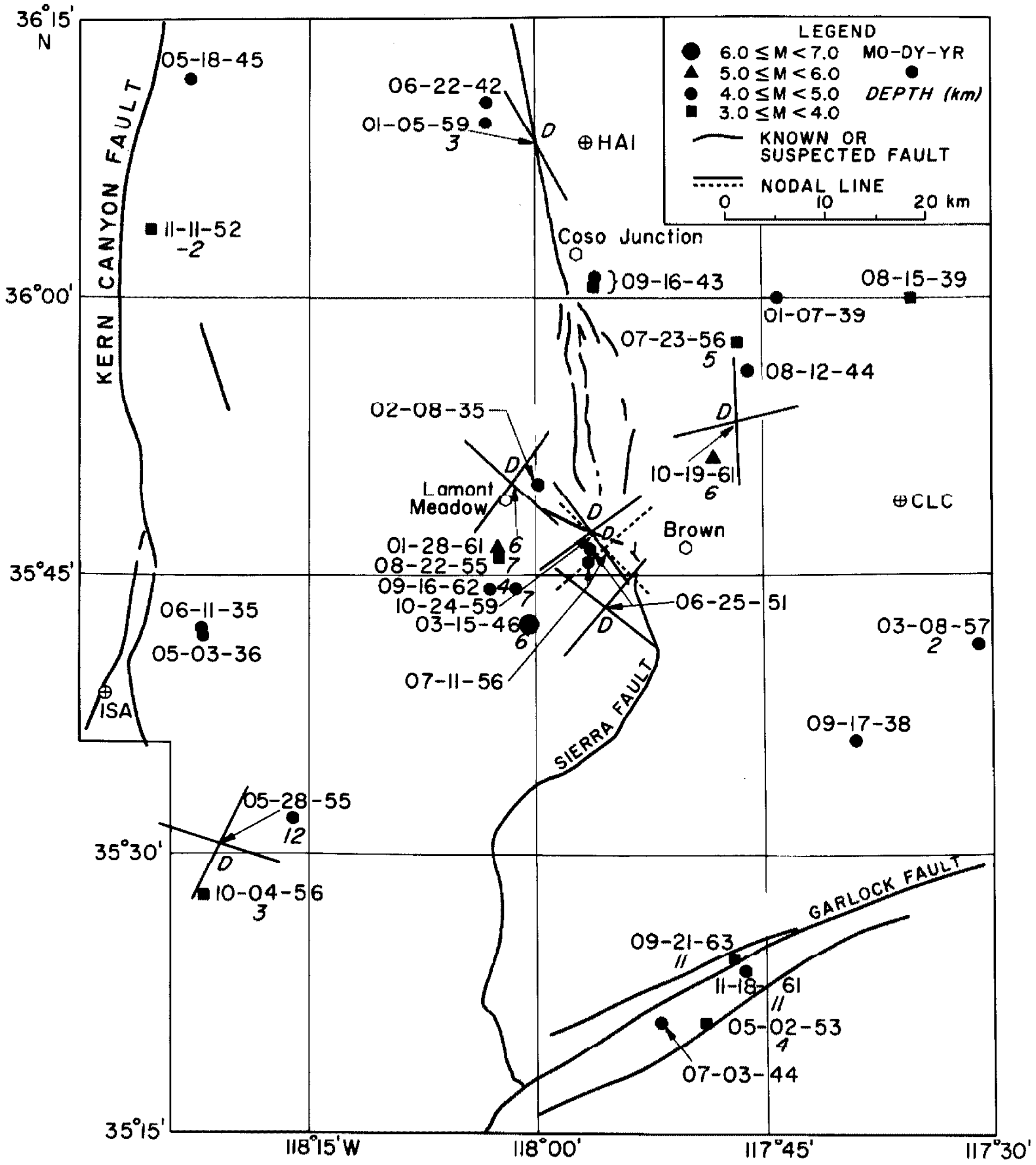

121°W
120°
119°
118°
117°
116°
115°
114°W
N38°
38°N
37°
36°
35°
34°
N33°
33°N
MONO L.
SOUTHERN CALIFORNIA
AND
NEVADA
0 50 100KM.
TIN
NEVADA
CALIFORNIA
NEVADA
UTAH
OWENS L.
TULARE L.
HAI
WALKER PASS
CLC
WDY
ISA
Figure 2
BCN
NEVADA
ARIZONA
KRC
GSC
FTC
SBC
PAS
DLT
RVR
BBC
SAN MIGUEL IS.
SANTA CRUZ IS.
SANTA ROSA IS.
PVR
HAY
SALTON SEA
CALIFORNIA
ARIZONA
CONTINENTAL SLOPE
SNC
SANTA CATALINA IS.
PLM
SAN CLEMENTE IS.
BAR
ELC
CAL.
MEXICO

Figure 2


LEGEND
● 6.0 ≤ M < 7.0
▲ 5.0 ≤ M < 6.0
● 4.0 ≤ M < 5.0
■ 3.0 ≤ M < 4.0
MO-DY-YR
DEPTH (km)
KNOWN OR SUSPECTED FAULT
NODAL LINE
0 10 20 km
36°15' N
36°00'
35°45'
35°30'
35°15'
118°15'W
118°00'
117°45'
117°30'
KERN CANYON FAULT
SIERRA FAULT
GARLOCK FAULT
HAI
CLC
ISA
Coso Junction
Lamont Meadow
Brown
05-18-45
06-22-42
01-05-59
3
11-11-52
-2
09-16-43
08-15-39
01-07-39
07-23-56
5
08-12-44
02-08-35
10-19-61
6
01-28-61
6
08-22-55
7
09-16-62
4
10-24-59
7
03-15-46
6
07-11-56
06-25-51
06-11-35
05-03-36
03-08-57
2
09-17-38
05-28-55
12
10-04-56
3
09-21-63
11
11-18-61
11
05-02-53
4
07-03-44
D

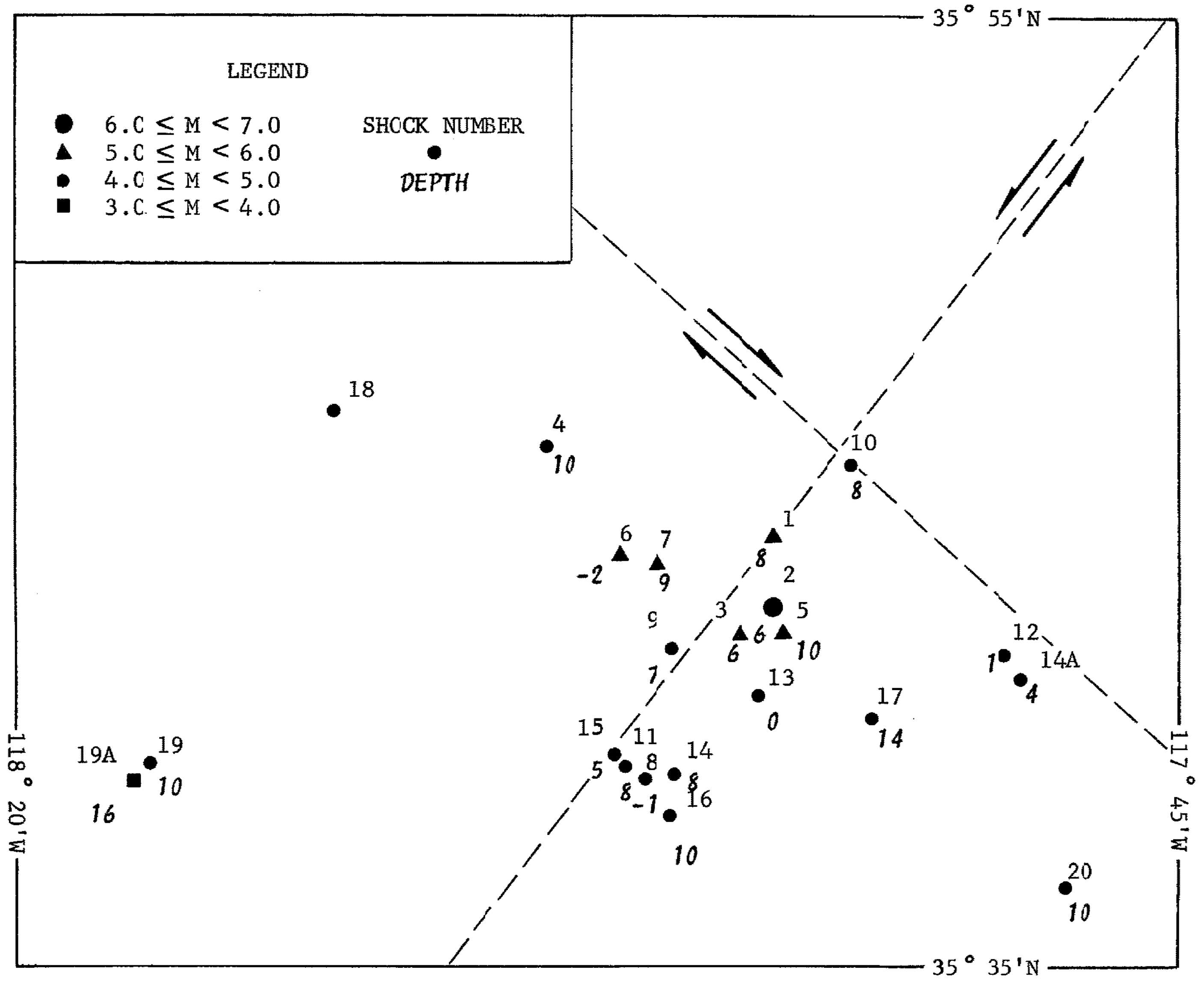

LEGEND
● 6.0 ≤ M < 7.0
▲ 5.0 ≤ M < 6.0
● 4.0 ≤ M < 5.0
■ 3.0 ≤ M < 4.0
SHOCK NUMBER
DEPTH
35° 55'N
35° 35'N
118° 20'W
117° 45'W
18
4
10
10
8
1
8
6
-2
7
9
2
5
10
3
6
6
9
7
13
0
12
1
14A
4
17
14
15
5
11
8
8
-1
14
8
16
10
19A
19
10
16
20
10

FIGURE 3

FIGURE 4

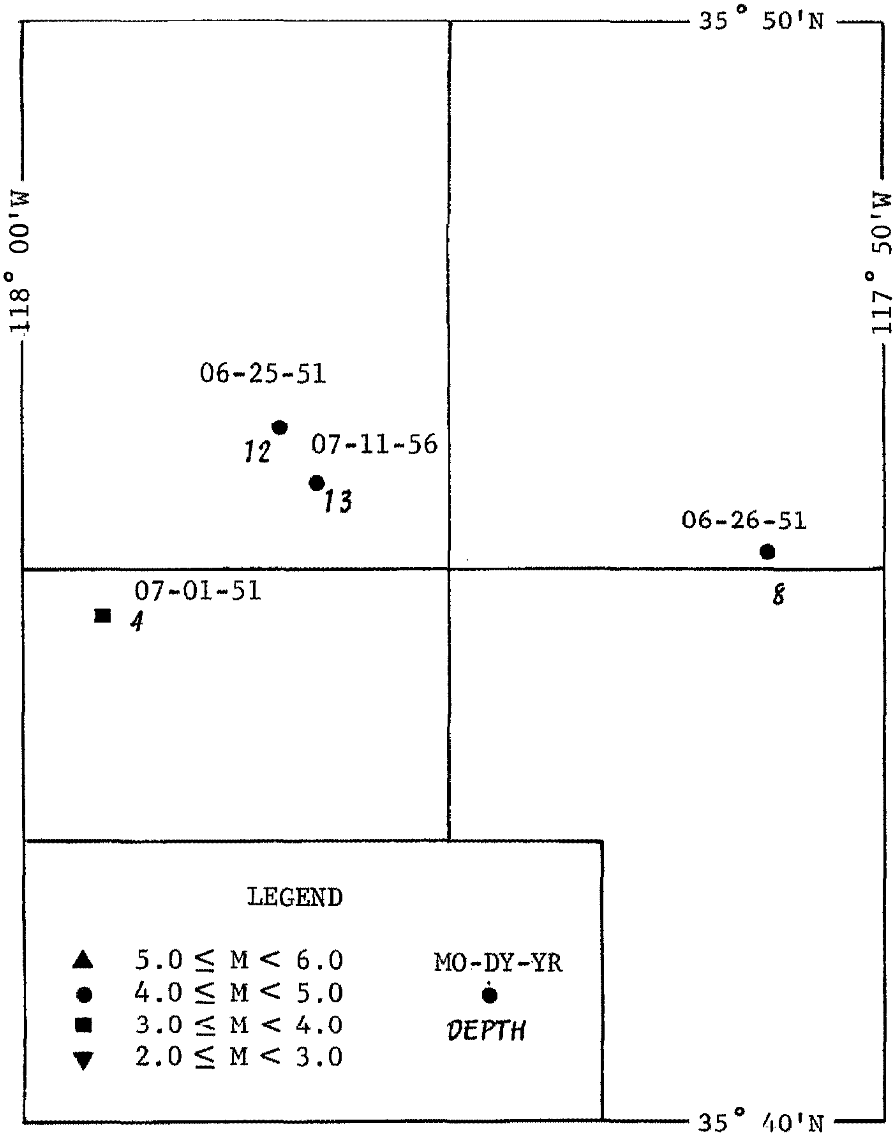

35° 50'N
118° 00'W
117° 50'W
06-25-51
12
07-11-56
13
06-26-51
8
07-01-51
4
LEGEND
▲ 5.0 ≤ M < 6.0
● 4.0 ≤ M < 5.0
■ 3.0 ≤ M < 4.0
▼ 2.0 ≤ M < 3.0
MO-DY-YR
DEPTH
35° 40'N

FIGURE 5

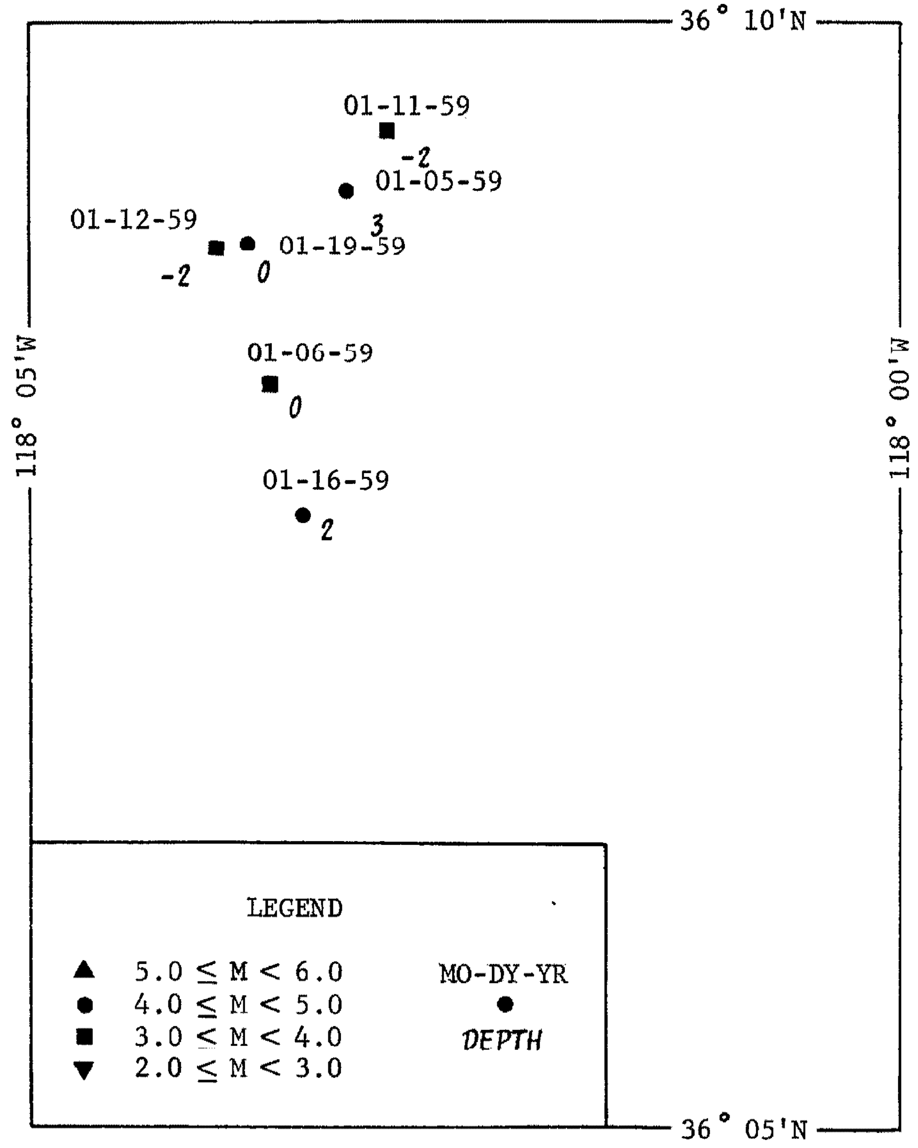

36° 10'N
01-11-59
-2
01-05-59
3
01-12-59
01-19-59
-2
0
01-06-59
0
01-16-59
2
118° 05'W
118° 00'W
LEGEND
▲ 5.0 ≤ M < 6.0
● 4.0 ≤ M < 5.0
■ 3.0 ≤ M < 4.0
▼ 2.0 ≤ M < 3.0
MO-DY-YR
●
DEPTH
36° 05'N

FIGURE 6

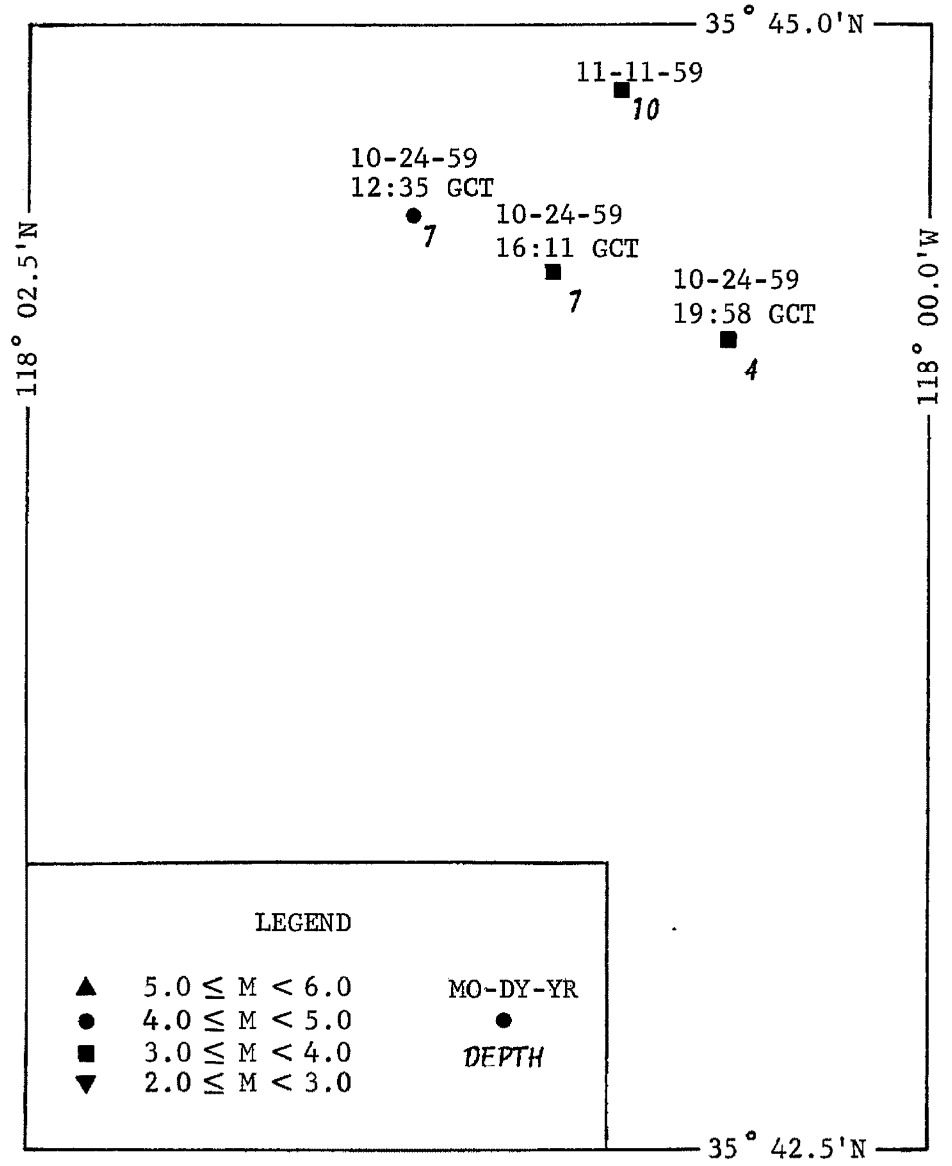

35° 45.0'N
35° 42.5'N
118° 02.5'N
118° 00.0'W
11-11-59
10
10-24-59
12:35 GCT
7
10-24-59
16:11 GCT
7
10-24-59
19:58 GCT
4
LEGEND
▲ 5.0 ≤ M < 6.0
● 4.0 ≤ M < 5.0
■ 3.0 ≤ M < 4.0
▼ 2.0 ≤ M < 3.0
MO-DY-YR
●
DEPTH

FIGURE 7

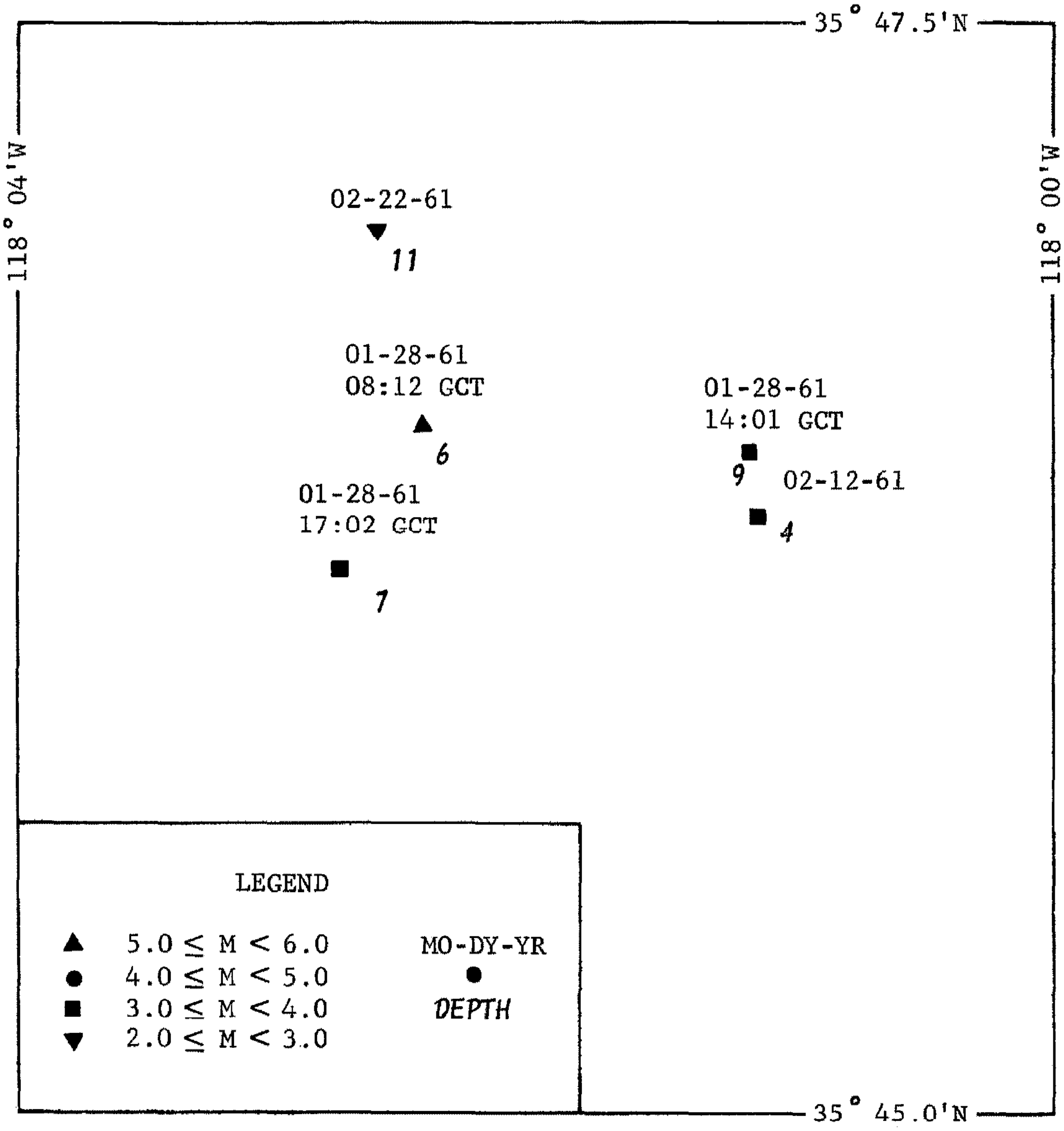

35° 47.5'N
118° 04'W
118° 00'W
02-22-61
11
01-28-61
08:12 GCT
6
01-28-61
14:01 GCT
9
02-12-61
4
01-28-61
17:02 GCT
7
LEGEND
▲ 5.0 ≤ M < 6.0
● 4.0 ≤ M < 5.0
■ 3.0 ≤ M < 4.0
▼ 2.0 ≤ M < 3.0
MO-DY-YR
●
DEPTH
35° 45.0'N

FIGURE 8A

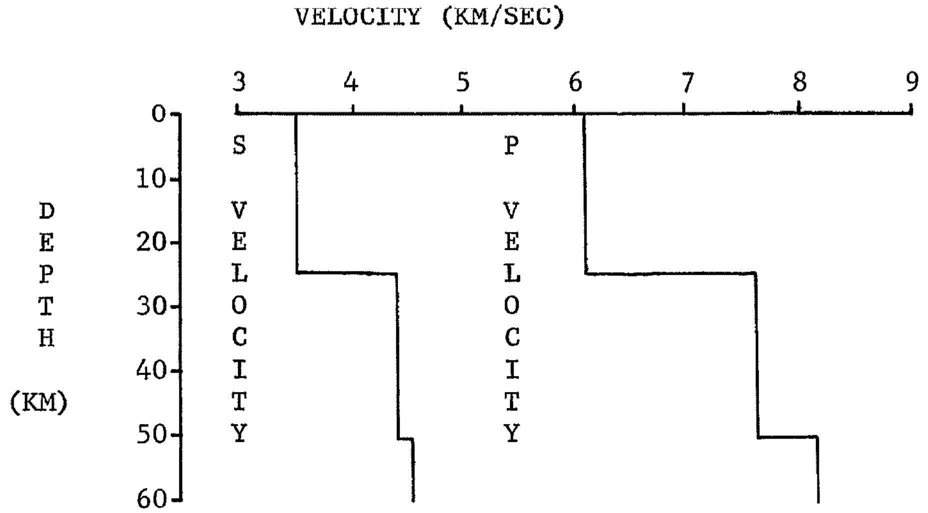
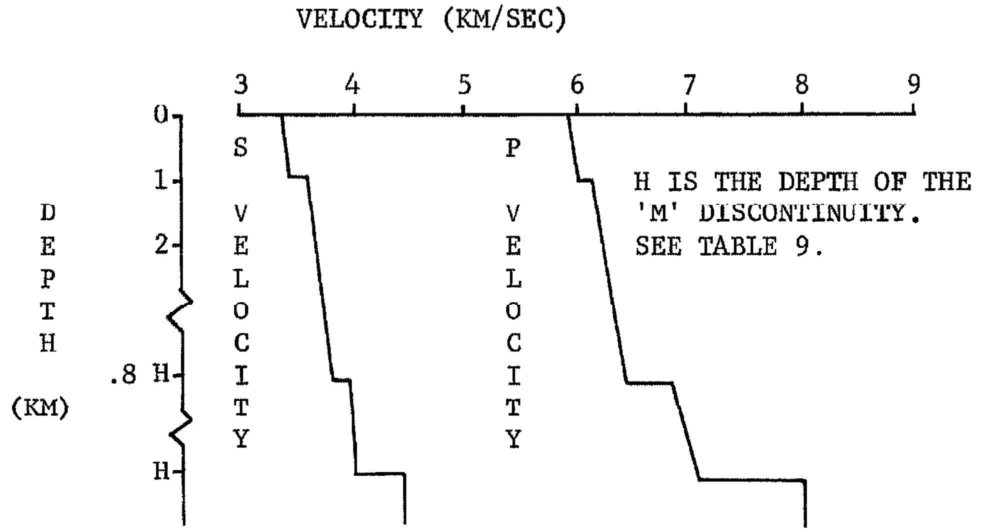


FIGURE 8A



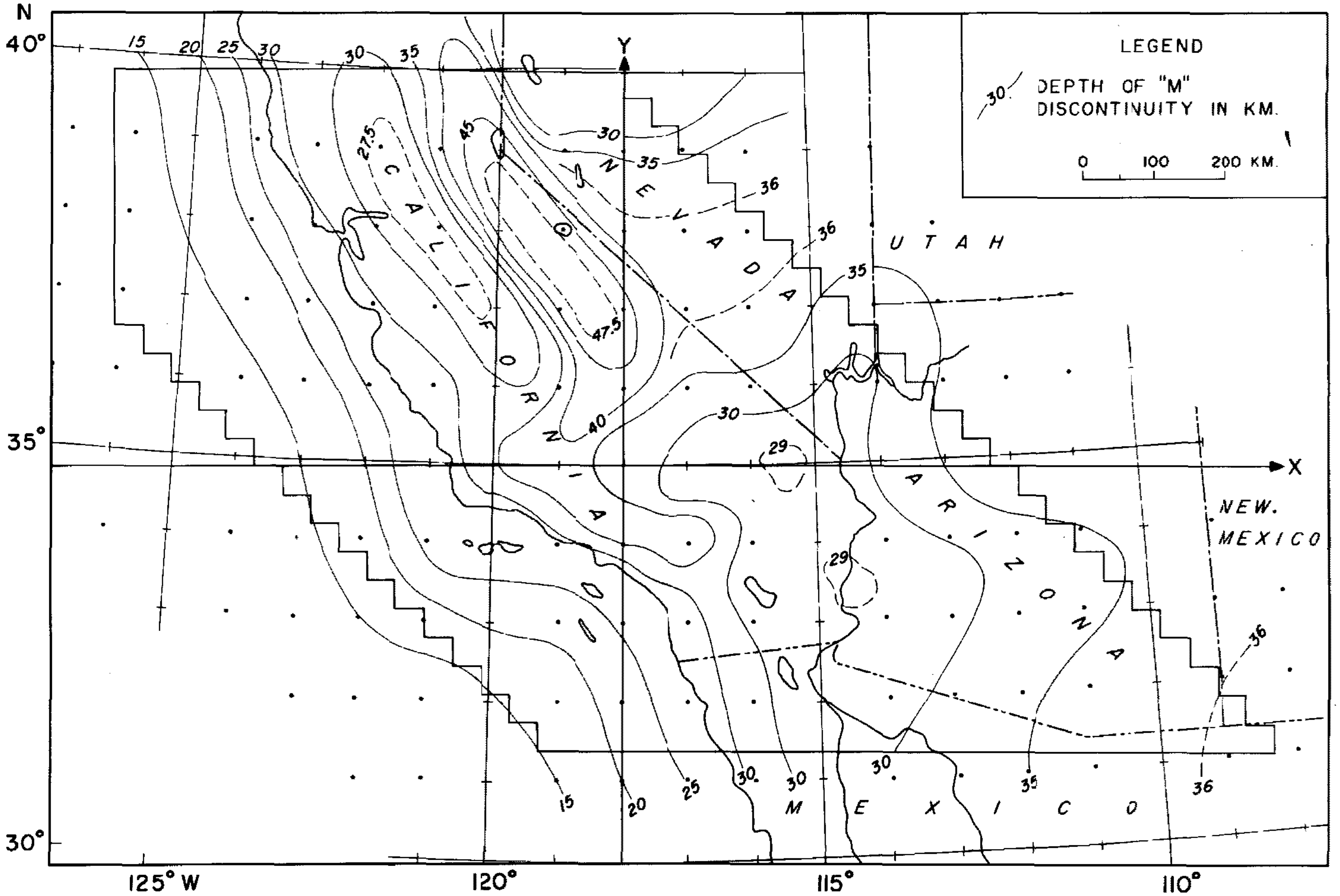
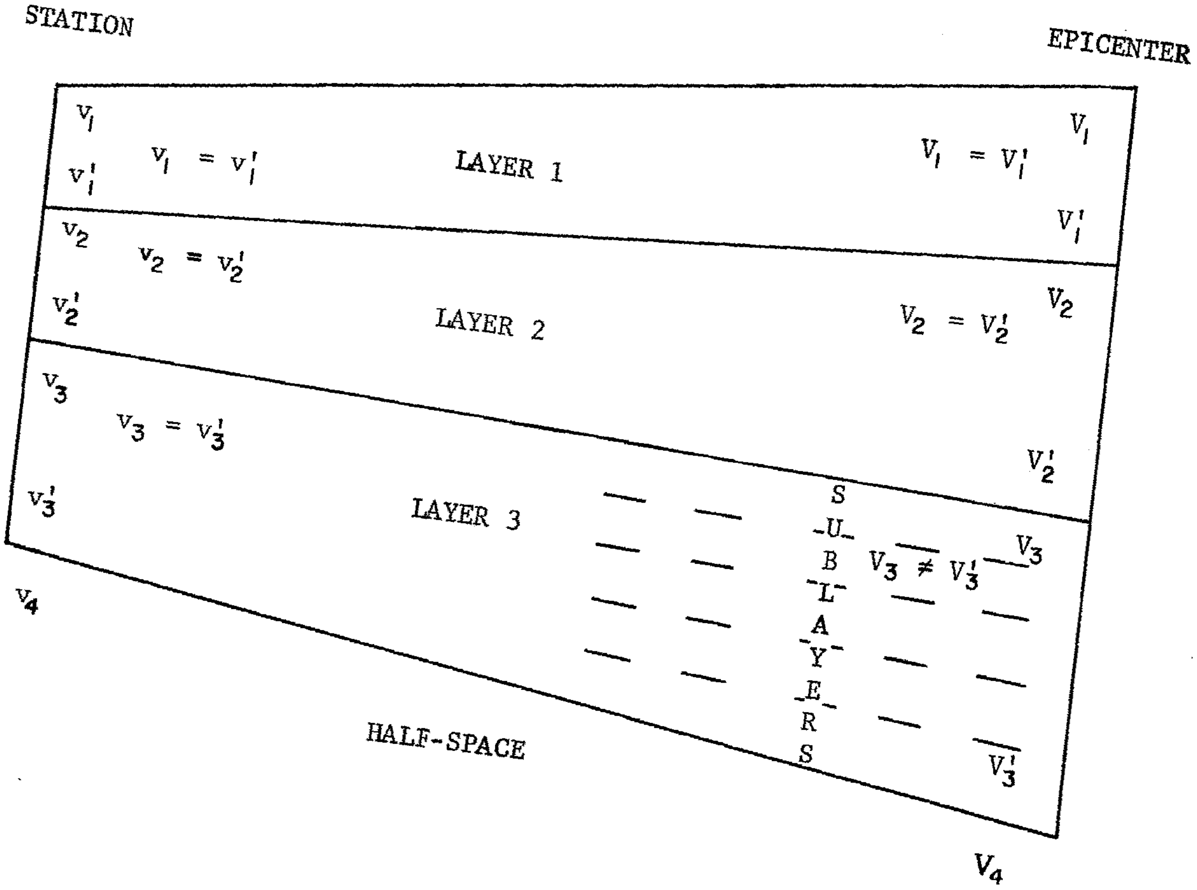

LEGEND
30
DEPTH OF "M" DISCONTINUITY IN KM.
0
100
200 KM.
N
40°
35°
30°
125° W
120°
115°
110°
Y
X
C A L I F O R N I A
N E V A D A
U T A H
A R I Z O N A
NEW. MEXICO
M E X I C O
15
20
25
30
35
36
40
45
47.5
27.5
29

Figure 9

FIGURE 10


STATION
EPICENTER
V_1
V'_1
$V_1 = V'_1$
LAYER 1
$V_1 = V'_1$
V_1
V'_1
V_2
$V_2 = V'_2$
V'_2
LAYER 2
$V_2 = V'_2$
V_2
V_3
$V_3 = V'_3$
V'_3
LAYER 3
V'_2
SUBLAYERS
$V_3 \neq V'_3$
V_3
V_4
HALF-SPACE
V'_3
V_4