

UNIVERSITY OF CALIFORNIA, SAN DIEGO
3 1822 00231 9556

C.A. WERNER

SCRIPPS INSTITUTION OF OCEANOGRAPHY LIBRARY
UNIVERSITY OF CALIFORNIA, SAN DIEGO
LA JOLLA, CALIFORNIA

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES

REPORT ON
PHYSICAL EFFECTS OF
ARVIN EARTHQUAKE
OF JULY 21, 1952

August, 1952

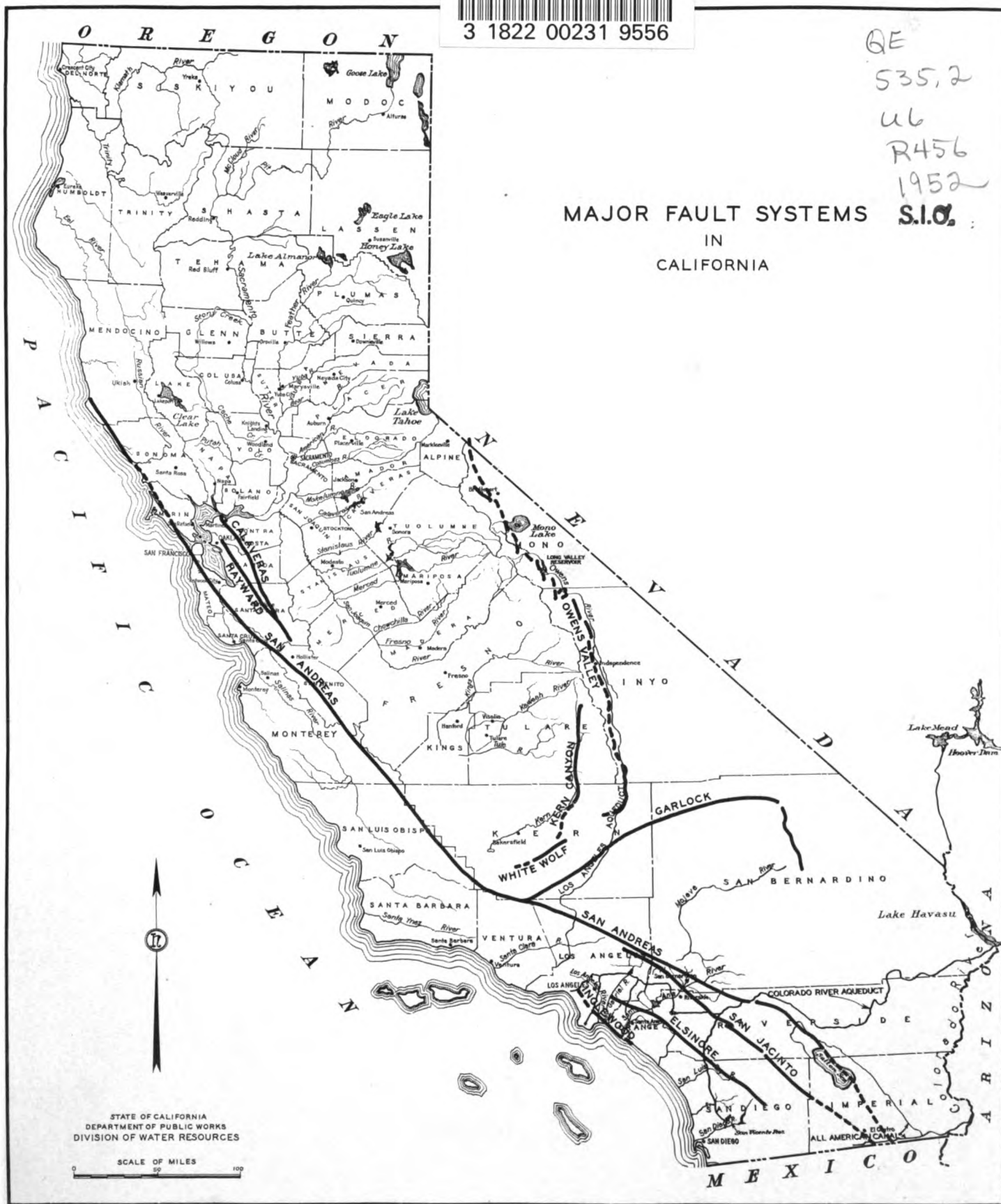
QE
535.2
U2
R456
1952

S.I.O.

UNIVERSITY OF CALIFORNIA, SAN DIEGO
3 1822 00231 9556

QE
535.2
UL
R456
1952
S.I.O.

MAJOR FAULT SYSTEMS
IN
CALIFORNIA



**STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES**

**REPORT ON
PHYSICAL EFFECTS OF
ARVIN EARTHQUAKE
OF JULY 21, 1952**

August, 1952

TABLE OF CONTENTS

	<i>Page</i>		<i>Page</i>
ACKNOWLEDGMENT	3	Man-made Features	8
ORGANIZATION	4	Irrigation Reservoirs and Canals	8
INTRODUCTION	5	Pumps and Standpipes	9
PURPOSE OF REPORT	5	Power Transformers and Haystacks	9
PROCEDURE	5	Buildings	9
GENERAL GEOLOGY OF THE MEGASEISMIC AREA	5	Highways and Roads	9
Faults	5	Subsurface Effects	10
MAIN SHOCK	6	Man-made Features	10
AFTERSHOCKS	6	Water Wells	10
PHYSICAL EFFECTS	6	Pipe Lines—Concrete Irrigation	10
Surface Effects	7	Pipe Lines—Oil	10
Natural Features	7	Oil Wells	10
Terrain	7	Railroad Tunnels	11
Springs and Streams	8	CONCLUSIONS	12
		RECOMMENDATIONS	12

APPENDIXES

	<i>Page</i>
A Modified Mercalli Intensity Scale of 1931	15
B Rossi-Forel Scale of Earthquake Intensity	16
C Richter Magnitude Scale	16

PLATES

Major Fault Systems in State of California	<i>Frontispiece</i>
	<i>Following Page</i>
A Fault Systems in Southern California	16
B Location Map of Faults and Photo Coverage	16
C Iseismal Map for Arvin Earthquake of July 21, 1952	16
D Hydrograph of Observation Well Showing Arvin Earthquake and Aftershocks	16
E Hydrograph of Kern River Showing Arvin Earthquake	16

PHOTOGRAPHS

Photographs of Earthquake Effects	<i>Following Plates</i>
---	-------------------------

ACKNOWLEDGMENT

Particular thanks are due to the following persons and agencies who cooperated and assisted greatly in this investigation: Dr. John P. Buwalda, Department of Geological Sciences, California Institute of Technology; Drs. Beno Gutenberg, Hugo Benioff, Charles F. Richter, and H. O. Wood of the California Institute of Technology Seismological Laboratory; Mr. Charles Herrick of the University of California Seismological Station; Mr. William Cloud, United States Coast and Geodetic Survey; Mr. E. E. Mayo, Chief Engineer, Mr. C. J. Astrue, and Mr. Franz Misch of Southern Pacific Company; Mr. George Henderson, Chief Engineer, and Mr. William Osborn, Mr. Glenn Stockbridge and Mr. Ralph Brodek of the Kern County Land Company; Mr. William Gealey of the Tectonic Division of Standard Oil Company.

The assistance of the California Highway Patrol, several graduate students of both the University of California and the California Institute of Technology, and various oil companies is gratefully acknowledged.

The voluntary and valuable cooperation received from these and other organizations and individuals is acknowledged with thanks.

ORGANIZATION

STATE DEPARTMENT OF PUBLIC WORKS DIVISION OF WATER RESOURCES

FRANK B. DURKEE.....Director of Public Works
A. D. EDMONSTON.....State Engineer
GERALD H. JONES.....Assistant State Engineer

This report was prepared under the direction of
E. C. MARLIAVE
Supervising Engineering Geologist

by

R. T. BEAN.....Associate Engineering Geologist
W. D. FUQUA.....Assistant Engineering Geologist
A. L. O'NEILL.....Junior Engineering Geologist
DAVID M. HILL.....Junior Engineering Geologist
PHILIP J. LORENS.....Junior Engineering Geologist
KEITH S. JONES.....Junior Engineering Geologist
C. T. JEFFREYS.....Senior Delineator

HENRY HOLSINGER.....Principal Attorney
T. R. MERRYWEATHER.....Administrative Officer

INTRODUCTION

At 4:52 on the morning of July 21, 1952, an earthquake of notable severity occurred in south central California. First reports available indicated great damage in the town of Tehachapi, accompanied by some loss of life, partial collapse of several Southern Pacific Railroad tunnels near the town of Caliente, and loss of communications to the aforementioned areas. Landslides and rock falls were also reported blocking the roads to Tehachapi. Nearby Arvin and Bakersfield were reported severely shaken with some damage to man-made structures. The shock was felt as far north as Red Bluff, south to the Mexican border, easterly to Bunkerville, Nevada (about 70 miles northeast of Las Vegas), and westerly to the shores of the Pacific Ocean where Santa Barbara and San Luis Obispo were moderately shaken. A series of aftershocks, some of moderately high intensity, continued to occur up to the time of writing and have caused additional damage.

PURPOSE OF THE REPORT

The purpose of this report is to describe physical effects of the shocks with particular regard to existing hydraulic engineering works, and to determine from study of the effects how more properly to locate and design similar works in the future to minimize potential earthquake damage.

PROCEDURE

The State Engineer sent field investigators to the area immediately after the main shock to observe, map, and plot physical effects, to gather available scientific data and to photograph certain features for a permanent record.

GENERAL GEOLOGY OF THE MEGASEISMIC AREA

The megaseismic area is located in portions of three of the eleven geomorphic provinces of California. It comprises the southeast corner of the Great Valley province, the north central portion of the adjacent Transverse Range province to the south, and the southerly end of the Sierra Nevada province to the east and northeast.

The Great Valley province is an elongated basin with a northwest-southeast trend filled with sediments of Tertiary and Quaternary age. The surficial deposits are gravels, sands, silts and clays of fluvial origin and are relatively unconsolidated. The Transverse Range province south of the San Joaquin Valley is

composed of a thick section of Cenozoic sediments, and more easterly is made up of acid intrusives and schists of earlier age. A pronounced east-west structural trend is apparent in this province. The Sierra Nevada province is a great tilted fault block having a core of granitics. This fault block is uplifted on the east side, and on the southerly end it is terminated by the Garlock fault which forms the north boundary of the Mojave Desert.

FAULTS

Several active faults are known to exist in the vicinity of the megaseismic area. (See Plate B). The San Andreas fault zone trending N. 60° W. is located to the south of the area shown on Plate B in the Transverse Ranges and joins the Garlock fault in the vicinity of Lebec. In the past, the San Andreas fault, particularly in its northerly and southerly extremities, has been responsible for considerable seismic activity. The Owens Valley fault zone lies along the east side of the tilted Sierran block and has been mapped as extending southerly almost to the megaseismic area and possibly projecting into it. The Kern Canyon fault, which roughly follows the Kern River to the north, extends in a southwesterly direction through Walker Basin and may possibly be connected with the White Wolf fault, although evidence from the July 21st quake indicates that the faults are offset as shown on Plate B. The Kern Gorge fault is a northwest-trending fault crossing the Kern River about 10 miles northeast of Bakersfield. The Tejon fault, located southeast of Arvin, projects from the White Wolf fault to the southeast.

The shock of July 21st originated along the White Wolf fault. The White Wolf fault trends about N. 45° E. along the northwest flank of Bear Mountain and its surface trace had been previously mapped from the vicinity of the mouth of Comanche Creek to a point about one mile southeast of the town of Caliente. This fault had been considered inactive. It may extend to the southwest into the Wheeler Ridge structure or branch in some other direction under the alluvial fill of the valley. The White Wolf fault is inferred by oil geologists to be a high angle to vertical fault at depth becoming a lower angle fault dipping approximately 45° SE. near the surface.

A break in ground water elevations in the area south and southwest of Arvin was found by the United States Bureau of Reclamation after a series of well measurements made in the spring of 1952. The break trends in the same direction as the White Wolf fault and is believed to be caused by a hydrologic barrier along either the main White Wolf or a subsidiary fault. The zone where cracking of the surface of the ground was most intense, as described in the following pages, was

actually a few miles to the north of the extension of the White Wolf fault as shown in Plate B.

The previously mentioned Garlock fault extends along the northern edge of the Mojave Desert and is considered to be seismically inactive. Numerous other small faults or fault zones are known to exist within a short distance of the megaseismic area, and while some have been suspected of producing minor shocks in the past, they have not been of as much importance as the San Andreas, Owens Valley or Kern Canyon faults.

MAIN SHOCK

Instrumental records indicate that the epicenter of the main shock was a few miles north of the easterly end of Wheeler Ridge and westerly from the vicinity of the intersection of Highway 99 and Highway 166. Preliminary calculations from instrumental records also indicate that this earthquake was of shallow origin, the focus being at a depth of about ten miles. From ground observation of fallen objects, which north and east of the epicentral area generally fell to the south, it might be inferred that the first motion in this area was in a north or northeasterly direction. The movement has been described as rolling rather than a sharp shock.

The magnitude was reported by the California Institute of Technology Seismological Laboratory to be 7.5 on the Richter Magnitude Scale as compared to 8.25 for the San Francisco shock of 1906 and 6.25 for the Long Beach shock of 1933. The strongest shock ever recorded occurred in Tibet about two years ago and its magnitude was 8.6. In the general area of greatest effect, the Arvin shock had an intensity of VIII+ on the frequently used Rossi-Forel Scale, and about VII+ on the Modified Mercalli Scale. Three intensity and magnitude scales for comparative purposes are included at the end of this report (Appendixes A, B, C).

A preliminary isoseismal map, Plate C, is included in this report. It has been constructed from data available at the United States Coast and Geodetic Survey office in San Francisco on August 15th, field checking of which was in progress at that date. The map is based on the modified Mercalli Scale of 1931. It will be noted that the megaseismic area is assigned an intensity of VII. Certain locations within this area had intensities as high as X, but a value of VII is generally appropriate as the individual areas of higher intensity would be difficult to show on a map of this scale.

The calculation of data from instrumental records for this earthquake has not been completed.

AFTERSHOCKS

Numerous aftershocks continued to occur to the time of writing of this report. An earthquake of this magnitude frequently produces aftershocks from 200 to 300

days after the main shock, although diminution of intensity increases with time. Between July 21st and August 1st, six aftershocks of magnitude six or greater and sixteen of magnitude five or greater, measured on the Richter Magnitude Scale, occurred. Eight of these aftershocks occurred on July 21st following the main shocks. A particularly damaging aftershock having an intensity of 6.1 on the Richter Magnitude Scale occurred at 3.41 p.m. on August 22d.

The stronger aftershocks produced effects similar to the main quake, though generally less violent. Damage was considerably increased by the aftershocks, particularly in Arvin and Bakersfield, and in Monolith a tall concrete smokestack at the Monolith Cement plant was toppled by one of the July aftershocks. The August 22d shock was responsible for a few deaths in downtown Bakersfield, where its intensity appeared greatest. Brick buildings in particular suffered heavy damage there, entire walls collapsing in some cases, though most of the damage was due to failure of parapet walls and decorative superstructure. (See photos 33 through 36.)

Generally speaking, the epicenters of the aftershocks migrated from southwest to northeast, or from the main shock area, located a short distance southwest of the junction of Highways 166 and 99, toward the communities of Arvin and Caliente. The epicenter of one of the later July aftershocks was recorded east of Bakersfield in the vicinity of the Kern Gorge fault. Preliminary location placed the epicenter of the August 22d aftershock about five miles southeast of Bakersfield. These epicenter locations indicate that movement during some of the aftershocks probably was centered on faults other than the White Wolf, and the differing isoseismal patterns of the shocks substantiate this observation.

PHYSICAL EFFECTS

Physical effects of the Arvin earthquake are described in the following pages in two sections, the first dealing with surface effects, and the second with subsurface effects. The most severe surface and subsurface effects in the alluviated San Joaquin Valley, aside from damage to buildings, occurred in a zone about 10 miles wide extending southwesterly from just south of Arvin across Highway 99 to Highway 166 (Maricopa Road). (See Plate B.) The central two-mile width of this zone, crossing Highway 99 about 17 miles south of Bakersfield and meeting Highway 166 near a General Petroleum substation about seven miles west of Highway 99, includes the area of greatest damage.

In the Tehachapi Mountains, the most severe effects aside from damage to buildings occurred along and near the White Wolf fault, whose location is shown on Plate B. Severe damage to buildings, and the only loss of life in the main quake, occurred in the town of Tehachapi.

SURFACE EFFECTS

Natural Features

Terrain. No single well-defined fault line such as occurs along the San Andreas and certain other faults could be found where the White Wolf fault crosses the San Joaquin Valley. Instead, somewhat irregular lines of cracking or fracturing appeared after the quake, many trending approximately in the same direction as the fault, and some approximately at right angles to it. Amount and direction of offsets were variable in these cracks. On sloping surfaces, the cracks commonly indicated slumping or lurching as a result of the quake. The cracks in general appear as though they were formed as a result of shaking of the thick San Joaquin Valley fill during the earthquake, rather than directly along the trace of a fault. However, it is assumed that the zone of strongest surface effects is related directly to movement along the fault at depth.

Where the White Wolf fault occurs in the mountains, some of the surface breaks or cracks appeared to be the result of slumping. Others were interpreted as more directly reflecting fault movement, and where these trended in a northeasterly direction, they most commonly showed a thrusting of the southeast block up and over the northwest block, and/or a lateral movement of the southeast block to the northeast.

The most southerly point observed in which relatively large-scale cracking or slumping of the ground occurred was about 12 miles airline southeast of Maricopa on Santiago Creek. Considerable slumping and cracking occurred in the low foothills immediately east of the mouth of Santiago Creek. Also prominent were a series of cracks trending east-west along a ridge northwest of Santiago Creek where it emerges from the foothills. An east-west striking fault has been previously mapped in this vicinity.

Cracking was observed across the tree-lined road leading into the San Emigdio Ranch. A relatively large number of surface slump cracks for the area were noted in the vicinity of the ranch. Slump type cracking is prominent in the vicinity of San Emigdio Creek which winds through the ranch area. Barbed wire fences trending east-west were offset slightly, the east side moving north. This effect near the creek may be locally due to slumping. Slacking of barbed wire between fence posts was also noted.

Fissures in the alluvium were very noticeable in the area between Highway 166 and Arvin. Those trending N. 65° E. with variations in strike up to 20 degrees were quite common. These cracks varied in size from hairline traces to openings five inches in width. Occasionally definite lateral offsets could be recognized. (See photo 1.) However, such movement was not found to be sufficiently consistent in this area to indicate more than local effect.

Many fissures striking approximately normal to the main northeast trend were noted, possible explanations of which are as follows: the cracks may be merely sympathetic expression of movement to the main northeast-southwest trend; such lines may be associated with drainage patterns previously existing on the reclaimed land; movement of the northwest-trending faults mapped in the area may have occurred in a large-scale block adjustment; tension cracking might be involved; or random cracking may be tangent to the wave fronts as they move out concentrically from the epicenter.

Offset cotton rows were observed at numerous points within the general northeast-trending zone. At one such point, located in T. 32 S., R. 28 E., M. D. B. & M., about 17 miles south of Bakersfield and about one-half mile east of Highway 99, cotton rows were offset on the order of three feet. (See photo 6.) Approximately three miles airline southwest of Arvin both north-south and east-west cotton rows were offset. Rows trending north and south showed movement to the west on the south side of the offset. East-west trending rows showed movement to the south on the west side of the offset. An east-west road in the vicinity of this location was offset in a northeast direction at least five feet.

Along the base of the foothills forming Comanche Point, at the mouth of Comanche Creek about 10 miles airline south of Arvin, and northeasterly to Sycamore Canyon, cracking was noted striking approximately N. 40 degrees E. In most cases, the southeast side of the fissures had moved upward in respect to the northwest side. Approximately normal to this strike, a northwesterly trending surface expression of cracking was observed about five miles southwest of Arvin in T. 32 S., R. 29 E., M. D. B. & M.

Northeast of the mouth of Comanche Creek and approximately six miles east of Arvin along the road to Highway 466, a narrow, scarp-like feature was extremely prominent. (See photo 13.) This feature could be easily traced along portions of the northwest flank of Bear Mountain. Vertical displacement on the gently sloping surface approached a maximum of three feet, the southeast side of the surface break being consistently upthrown. Thrusting of the southeast side over the northwest side was observed at some points with up to 40 inches of foreshortening. This break was fairly consistent but was occasionally lost for short sections. In the area immediately southwest of Highway 466, rifting trended approximately N. 50° E. Slump cracks were quite prominent from Sycamore Canyon to Highway 466. Large-scale sliding was observed in the steep-walled Sycamore Canyon and to a lesser degree in smaller canyons nearby. (See photo 12.)

The general zone of surface cracking crossed Highway 466 near the Bealville turnoff. The zone extended to the vicinity of the Southern Pacific tunnels on a bearing of about N. 50° E. and continued in the same

direction about $2\frac{1}{2}$ miles beyond the tunnels, where cracking became indistinct. (See Plate B, insert.)

Near the Bealville turnoff the zone of cracking was about three-tenths of a mile wide. Vertical offsets up to one foot were present in this area but most of these could be attributed to slump. (See photo 15.) The general pattern of cracking indicated that the main movement in this area was the southeast side moving up and to the northeast, each component of movement being only a few inches.

A prominent rift continued from the immediate area of the highway to above the gap between Southern Pacific tunnels 3 and 4. Along this rift, the ground was so broken that measurements were difficult, but for at least 200 feet along the hillside the southeast or downhill side of the zone had been raised from 1 to 12 inches vertically.

The general zone of cracking became indistinct in the ravine northeast of tunnels 3 and 4, although several large random cracks were present.

Several cracks of noteworthy size were present above tunnel 5. Settling of the ground on the hilltop above the tunnel probably took place, causing some slump cracks. Several large holes up to 10 feet deep were opened above this tunnel as the result of the earthquake. One prominent crack trending S. 70° E. began over tunnel 5 and could be traced for about 3,000 feet to the southeast. (See photos 19 and 20.) At all points along this crack the southwest side was uplifted, the maximum being 18 inches, and the northeast side moved to the northwest, the maximum being two inches. The slip plane dipped about 45 degrees to the northeast, as shown where it crossed ravines. With only the preliminary data available, it was assumed that this southeast-trending crack represents either a branch of the main northeast-trending White Wolf fault or a fault crossing the White Wolf at nearly right angles along which sympathetic movement has occurred.

About 500 feet upgrade from tunnel 6, the main northeast-trending rift continued down into Tehachapi Creek. From Tehachapi Creek, the zone trending about N. 50° E. continued up a ridge for approximately two miles. On the ridge, where the continuation of the zone became indistinct, the main cracks tended to curve sharply to the north and disappear. (See photos 27 and 28.) One such crack, according to University of California seismologists, was at least five feet deep and about five feet across.

Many evidences of earth movement were present in the canyon of Caliente Creek east of Caliente. Tremendous slides and rockfalls originally blocked the road up the canyon. Cracks in the road occurred in several places. One crack, located in the canyon about four miles airline east of Caliente, trended about N. 60° E. and showed evidence of thrusting of the

southeast block to the northwest. Additional compression was shown by a broad low arch in the road about 500 feet east of the crack just noted. The crest of this arch was about $1\frac{1}{2}$ feet above the general road level. Several bedrock slip planes having differing attitudes on which movement appears to have occurred during the Arvin earthquake were exposed in the walls of Caliente Canyon between about five and eight miles airline northeast of Caliente. Preliminary work for this report did not establish the connection of any of these features in Caliente Canyon with the cracking mentioned in the previous paragraph.

A brief reconnaissance by airplane over the areas farther to the northeast and in the vicinity of the Kern Canyon fault failed to reveal any further cracking of importance in those areas.

About 11 miles east of Bakersfield, however, an air reconnaissance showed cracking in the hills north of Highway 466, extending for about $1\frac{1}{2}$ miles in a southeasterly direction. Surface mapping of this feature was not possible in the limited time of this investigation. Minor movement may have occurred along the Kern Gorge fault, previously mapped near this location.

Springs and Streams. Many reports of changes in volume of flow of springs and surface streams were reported after the Arvin earthquake, both increases and decreases being reported. Since in most cases measurements of flow before the quake were either nonexistent or not easily available, and time did not permit gathering of old records or making new measurements, no quantitative measurements are presented herein. The following reports are considered to have come from reliable sources: Springs feeding tributaries of Caliente Creek increased in flow sufficiently to cause flow in that creek after July 21st although it had been dry previous to that date. Clear Creek ravine, crossed by the Southern Pacific tracks between tunnels 4 and 5, also increased in flow after the earthquake.

Stream gages located along the Kern River registered the Arvin earthquake by a sharp vertical line on the record, indicating an abrupt change in water level. A slight increase in stream flow was also recorded for a short time after the main shock. (See Plate E.)

Man-made Features

Irrigation Reservoirs and Canals. The walls of earthen reservoirs showed marked slumping in the zone of strong surface effects, particularly in the vicinity of Highway 99 and southwesterly to the Maricopa Highway (166). Slumping and rupture of the reservoirs resulted in water flowing into surrounding fields. The released water tended to bring about additional damage to roads, pumps, and other features. In many cases, existing cracks in the surface opened

by earth movement were enlarged by escaped water, thus making measurements of movement unreliable. (See photo 2.)

A portion of East Levee bounding part of Buena Vista Lake slumped vertically approximately two feet during the earthquake. It appears that solution cavities existing in soluble gypsiferous beds beneath may have allowed excessive settlement in this area. (See photos 37 and 38.) Severe damage to the Paloma oil field, farms, and residences in the area would have resulted had the lake levee been breached during the quake. Minor slumping was also noted along the railroad tracks which cross the southern portion of the levee. Slumping and fissuring were prominent along certain parts of the Kern Island Canal.

Pumps and Standpipes. Pumps resting on concrete bases which in turn rested on alluvium were occasionally reported to have shifted due to the earthquake. One pump, located about 17 miles south of Bakersfield and one-half mile east of Highway 99 was reported to have moved eight feet in a southwest direction. A pipe trending north-south at the same location showed lateral movement of 14 inches, the north side being shifted westerly. (See photo 7.)

Concrete standpipes were severely damaged. In general, ruptures occurred at the base of the standpipes. Metal standpipes anchored in concrete were occasionally toppled. Guy wires and bolts that supported large tanks and towers were stretched.

Power Transformers and Haystacks. A large number of power transformers were thrown from the power poles in the zone of strong surface effects. Observation indicated that this phase of activity was most severe in the southwest-trending belt between Arvin and Highway 166. Investigation disclosed that the transformers are not secured to the platforms upon which they rest, and thus were more easily thrown off during the quake. (See photo 4.) The loss of power resulting from the downed transformers had some effect on water well pumping within the stricken area, although prompt action by the electric utility company minimized the effect of the temporary power loss.

Many stacks of baled hay averaging 20 to 25 feet in height were badly shaken and toppled along the southwest-trending zone. Observations indicated that haystacks elongated in an east-west line were more severely affected than those stacked in a north-south direction. In either case, it was generally noted that most haystacks had fallen south and west.

Buildings. The following general observations on buildings located in the area are worthy of note. As is frequently the case, most severe damage occurred in buildings constructed of brick or adobe. Brick parapet walls and ornamental work suffered the most. Brick

buildings which were apparently poorly constructed were severely damaged. Poor mortar and/or bond, lack of or inadequate reinforcing steel, lack of bond beams, and thin walls appear to be responsible for most of the damage. Well built frame buildings and reinforced concrete buildings fared much better. Modern buildings, particularly schools that were designed and built after passage of the Field Act, suffered only slight damage. (Contrast photos 29 with 32 and 30 with 31.)

In general, buildings resting on relatively unconsolidated alluvial deposits suffered more heavily in the megaseismic area than those constructed on firmer terrain. Although most frame buildings incurred only slight damage, some were shaken from their foundations in the zone of strong surface effects. (See photos 8 and 9.)

Highways and Roads. Slumping and cracking of roadways occurred in areas of strong surface effects. Some rock sliding temporarily obstructed portions of lanes on Highway 99 about 30 miles south of Bakersfield. In the same area, slump of fill material caused separations up to two inches between concrete paved road sections and minor separations along the concrete center barrier.

The northbound lane of Highway 99 suffered minor slumping about 10 miles south of Bakersfield. (See photo 5.) Differential settling caused large cracks on the shoulder up to about three inches in width and about a five-inch vertical drop between the concrete road surface and the asphalt shoulder. (See photo 5.) Cracks and settling also were noted in the field to the east of this road slump. This area was marshy prior to construction of the highway. The highway fill was imported as select material. Increased consolidation at depth of the boggy material and/or fill probably resulted in the slumping brought about by the earth movement.

Dirt roads south of Bakersfield in the area of strong surface effects were badly cracked. Severe damage, however, was noted only where water from cotton fields adjacent to the roadway or from cracked farm reservoirs migrated along the fissures.

The paved highway from Arvin northeast to Highway 466 suffered damage due chiefly to slumping, along the outer edge of the fills. (See photo 14.) Numerous small earth slides from the poorly consolidated bank material also obstructed the road. Large rocks, loosened by the earth movement, rolled down from hillsides onto the roadway and caused minor damage to the pavement.

Highway 466 was badly cracked in the vicinity of the Bealville turnoff. Settlement of a fill on this same roadway about 12 miles east of Bakersfield during an aftershock occurring July 28th caused a large break in the pavement.

SUBSURFACE EFFECTS

Man-made Features

Water Wells. The effect of the earthshocks on water levels in wells was shown by the following available hydrographs, both operated by the Kern County Land Company and attached to water wells located between Highway 99, south of Bakersfield, and Buena Vista Lake. The hydrograph station 6E34-3, located $9\frac{1}{2}$ miles west of Highway 99 and one-half mile north of Highway 399, recorded sudden changes in the water level at the time of the earthquake amounting to a rise of 2.26 feet and a fall of 1.67 feet. (See Plate D.) The largest of the series of aftershocks also produced recorded water level changes. The surge of water in the well located three miles west of Highway 99 and $3\frac{1}{2}$ miles north of Highway 166 (station 6F26-2) caused the hydrograph to spin one or more complete turns and then stick. The water level measured independently of the hydrograph at the end of the recording period four days after the earthquake was still 20.6 feet above the level recorded prior to the quake. A water well about 100 feet deep, $1\frac{1}{2}$ miles north of the above station 6F26-2, started to flow after the earthquake and continued to flow for two days with a maximum estimated flow of 20 gallons per minute. This peculiar artesian flow was recorded for several other wells in the area which also had not flowed for several years prior to the quake.

In the Arvin area, the water level in wells rose as much as 60 feet during the week following the earthquake. However, this was to be expected inasmuch as the power to all of the wells had been cut off during the period, and the water table recovered from the lower levels of the cones of depression developed during pumping.

The near-surface bending of the casings in a few water wells was attributed to the shifting and settling of the upper 30 feet or so of the alluvium, especially near Wheeler Ridge. Holes were sunk adjacent to the crooked casings and the casings were straightened; or in some instances the casings were cut, pulled, and replaced with larger casings. At the time of this investigation, pumps were still stuck in the casings of at least two wells: the Coberly West well, about four miles east of photo locations 6 and 7 on Plate B, and the Frank Bury well, seven miles west of Highway 99 and one mile south of Highway 166. A sharp bend was visible in each well at depths of 30 feet and 20 feet respectively. The extent of damage below these bends could not be determined until the pumps were removed from the damaged wells.

Pipelines—Concrete Irrigation. Extensive rupturing of concrete irrigation pipes resulted from the Arvin earthquake. The pipes lie at shallow depths, and

were damaged by shifting, compaction, and settlement in the alluvium. Some crop damage was suffered because of damage to irrigation systems. Cotton, the chief crop in the area, suffered the most, as it begins to wilt within a few days, and vineyards and alfalfa were also affected. Emergency attempts to place water on the affected areas included use of iron pipelines placed on the surface, and portable sprinkler irrigation. Replacement of concrete pipelines by some other irrigation system is recommended by many local pump men.

Pipelines—Oil. Steel pipelines used in conveying petroleum were severed by landslides caused by the earthquake in the vicinity of Grapevine near Highway 99. Lateral displacement of alluvium in the area north of Highway 166 caused breaks in other oil lines. Several breaks occurred near the location of photos 1, 2, and 3 on Plate B. Rupture of lines appeared to take place at points of weakness, as all breaks do not necessarily appear to have occurred in areas of particularly sharp movement. A cumulative compression or stretching effect caused ruptures especially where the lines curved. These steel lines averaged five-sixteenths inch thick and ranged in diameter from 6 to 10 inches. The line to one General Petroleum pumping station, located about seven miles west of Highway 99 on Highway 166, bends gently to the north approximately $1\frac{1}{2}$ miles north of the station. The pipe at the bend was separated 18 inches. One-half mile to the north, a four-foot section of an oil line curving gently to the west was first buckled sharply to the west then straightened out before breaking six feet further north. In the same vicinity, two pipes on opposite sides of a road striking north-south suffered the opposite kind of action. The line on the east side telescoped approximately 36 inches, while that on the west side pulled apart approximately 55 inches. These lines were about 30 feet apart at points of rupture. (See photo 3.)

Oil Wells. The casing of an oil well in the Tejon field, located about 27 miles south of Bakersfield on Highway 99 in T. 11 N., R. 19 W., S. B. B. & M., was deformed at 2,500 feet. The exact type of damage could not be determined. The concrete bases of two oil wells at the Race Track Hill area of the Edison oil field, about seven miles southeast of Bakersfield, were cracked during an aftershock. Damage was also reported to wells in the Kern River and Kern Front oil fields, located from five to eight miles north of Bakersfield, but the nature of this damage could not be ascertained at the time of the investigation.

After the earthquake of July 21st, ephemeral increase in pressure was noted in the Paloma oil field, located just east of Buena Vista Lake, but this was attributed to the breaking loose of cement plugs which seal water horizons, allowing increased mixture of

water with oil. Notable increase in gas pressure, accompanied by decreased crude oil production, was observed in the Fruitvale field located about two miles west of Bakersfield. Here, too, production and pressure soon returned to normal. Very heavy crude oil began flowing at the rate of about 10 barrels per day from the open casings of some old oil wells near Maricopa which had been idle for years. These reports of increased crude oil production and of increased formation pressure were minimized by petroleum production engineers.

Heavy damage was suffered by a Paloma repressuring plant, located about four miles east of Buena Vista Lake, where a ruptured gas line caused a serious fire.

Railroad Tunnels. The most striking subsurface effects of the Arvin earthquake occurred in Southern Pacific railroad tunnels crossed by the White Wolf fault zone. The greatest effect was observed in tunnels 3, 4, 5, and 6, located from about three-tenths to one and three-tenths miles southeast of Bealville. (See Plate B.) All of these tunnels were in granitic rock which had been sheared and deeply weathered along the fault zone. All tunnels had been lined with about 18 inches of reinforced concrete over the original timbers.

In tunnel 3, trending nearly straight north-south about three-tenths of a mile southeast of Bealville, the effect of the disturbance showed mainly compression. Damage extended from a point about 550 feet from the north portal to and beyond the south portal. In this zone, the walls of the tunnel had been cracked, broken, and forced inward, constricting the tunnel as though the rock had moved inward into the only space available. The distance between the two walls in one place was reduced to 9.3 feet at floor level. The normal width of the tunnel is 15 feet. Generally, the west wall of the tunnel was disturbed more than the east wall. At a distance of 550 feet from the north portal, the rail bed was disturbed by vertical movement, the south side apparently moving up about two feet. The railroad track from this point to and beyond the south portal was compressed into an "S" curve, the force of compression thrusting one curve of the "S" under the base of the concrete lining which apparently had been raised to allow the rail to go underneath with little crushing of the concrete. (See photos 17 and 18.)

The effects of compression indicated by tight bending of the tracks continued to the southeast beyond the tunnel. The horizontal distance between the south portal of tunnel 3 and the northwest portal of tunnel 4 was reduced about eight feet in about 300 feet according to preliminary surveys made by Southern Pacific engineers. The compressive effects in the south of the tunnel can be explained in two ways: by thrusting of the southeast block to the northwest, and by essentially horizontal movement to the northeast of the southeast

block. It is doubtful if simple horizontal movement could explain all the compressional features observed.

The sharpest break noted was in tunnel 4, which was a curving tunnel trending approximately southeast at its west portal and nearly due east at its east portal. About 90 feet from the latter portal, the tunnel was crossed by a fault striking approximately N. 80° E. which broke the lining as it dropped the southeast side about 3½ feet and moved it northward about two feet. Rails east of the break were thus left unsupported for some distance.

Damage to tunnel 4 was of such a nature that officials of the Southern Pacific decided to daylight the tunnel. When daylighting was accomplished, a brecciated zone about 10 feet wide having a gouge matrix was exposed in the fresh cut. This zone has an approximate strike of N. 40° E. and dips about 45 degrees to the southeast. (See photo 16.) The movement which damaged the tunnel probably took place along this zone.

Tunnel 5, about 1,200 feet long, suffered the most severe damage. The tunnel was caved at two points, one about 590 feet from the south portal and the other about 200 feet from the north portal. (See photo 22.) The extent of damage to the area between these points was unknown until August 2d when a drift was driven from the north end into the doubtful area. The walls were forced inward for most of the distance, the east wall being forced more strongly westward. (See photos 23 and 24.)

A fresh cut at the south portal of tunnel 5 exposed a fault plane having a dark clayey gouge zone from 6 to 14 inches thick on its north side. This fault strikes N. 70° W. and the dip of the plane increases from 22 degrees to the north at the ground surface to 70 degrees to the north 30 feet lower in the cut. There was no indication of any recent movement along this fault. (See photo 21.)

Between the south portal and the collapse in tunnel 5, the walls were broken and moved inward in several places. During the repairing operation, the rock was exposed at a point 489 feet from the south portal. Another distinct fault was present at this point dipping 47 degrees to the north. A yellowish clayey gouge zone from 12 to 14 inches in width was present on the south side of the shear. The rock above the fault was a hard, fairly fresh granodiorite, while under the gouge the granodiorite was badly decomposed. The concrete walls in the vicinity of this zone were badly broken, although damage was localized near the plane of the fault in this portion of the tunnel.

Movement occurred where the main northeasterly-trending fault crosses the railroad approximately 500 feet up grade from tunnel 6. Fresh cuts on the northern side slope exposed a brecciated zone which includes some gouge. (See photo 26.) This zone had several cracks which could be traced on the surface and on the

cut to a depth of about 15 feet below the surface where they narrowed to fine lines. One such crack was directly along a shear which offset a bed $2\frac{1}{2}$ feet vertically. Most of the other cracks were at random in a zone about 80 feet wide near the ground surface.

Repair and replacement of the damaged tunnels has been accomplished as follows: The northern, undamaged portion of tunnel 3 has been retained, but the southern part has been daylighted. Tunnels 4 and 6 have been daylighted entirely. At the time of writing, a temporary track (shoofly) had been built around the nose through which tunnel 5 extended, but the tunnel itself was being repaired and, according to plans, was to be put back into service.

The process of daylighting and repairing tunnels (see photo 25) exposed many random clayey gouge zones, from a fraction of an inch to 14 inches in thickness, occurring in the sheared granodiorite bedrock throughout the area. Damage to the tunnels indicated that fault movement took place in a zone of considerable width, at least in that vicinity.

As shown in Plate B, the main White Wolf fault trends about N. 50° E. Other prominent fractures include three short, northward-trending splits, the curving fault extending through tunnel 4, and the southeast-trending fault crossing tunnel 5.

CONCLUSIONS

1. Structures built across the main trace of the fault were damaged during the Arvin earthquake, regardless

of how well the structures were built. Design cannot prevent such damage as the forces involved are too great.

2. Elsewhere in the megaseismic area, structures that were well built, particularly those designed against earthquake forces, received only slight damage if damaged at all.

3. The principal source of damage to hydraulic engineering works was caused by the slumping of artificial fills and the shaking and cracking of deep alluvial fills. The former resulted in damage to lake and reservoir levees and at least one dam, and the latter resulted in damaged pipelines and well casings.

RECOMMENDATIONS

1. Design of engineering structures in seismically active areas should be made with proper regard to earthquake forces.

2. Structures should be located on firm and consolidated foundations wherever possible.

3. Crossing of known fault zones with engineering structures should be avoided wherever possible, whether the zones are considered active or not. Where crossing of fault zones is necessary the crossing should be effected on the ground surface so that if necessary, repairs can be made expeditiously.

4. Means and ease of repair to canals, dams, tunnels, etc., constructed in seismically active areas or unavoidably crossing fault zones, should be considered in design and construction.

APPENDIXES

	Page
A Modified Mercalli Intensity Scale of 1931.....	15
B Rossi-Forel Scale of Earthquake Intensity.....	16
C Richter Magnitude Scale.....	16

A MODIFIED MERCALLI INTENSITY SCALE OF 1931

(Abridged)

- I. Not felt except by a very few under especially favorable circumstances. (I Rossi-Forel Scale.)
- II. Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing. (I to II Rossi-Forel Scale.)
- III. Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration like passing truck. Duration estimated. (III Rossi-Forel Scale.)
- IV. During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls made creaking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably. (IV to V Rossi-Forel Scale.)
- V. Felt by nearly everyone; many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop. (V to VI Rossi-Forel Scale.)
- VI. Felt by all; many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight. (VI to VII Rossi-Forel Scale.)
- VII. Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motor cars. (VIII Rossi-Forel Scale.)
- VIII. Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Disturbed persons driving motor cars. (VIII+ to IX Rossi-Forel Scale.)
- IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken. (IX+ Rossi-Forel Scale.)
- X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks. (X Rossi-Forel Scale.)
- XI. Few, if any, (masonry) structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipe lines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.
- XII. Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upward into the air.

NOTE—This scale used in drawing the preliminary isoseismal map included in this report.

B ROSSI-FOREL SCALE OF EARTHQUAKE INTENSITY

- I. Recorded by a single seismograph, or by some seismographs of the same pattern, but not by several seismographs of different kinds; the shock felt by an experienced observer.
- II. Recorded by seismographs of different kinds; felt by a small number of persons at rest.
- III. Felt by several persons at rest; strong enough for the duration or direction to be appreciable.
- IV. Felt by several persons in motion; disturbance of movable objects, doors, windows; creaking of floors.
- V. Felt generally by everyone; disturbance of furniture and beds; ringing of some bells.
- VI. General awakening of those asleep; general ringing of bells; oscillation of chandeliers, stopping of clocks; visible disturbance of trees and shrubs; some startled persons leave their dwellings.
- VII. Overthrow of movable objects, fall of plaster, ringing of church bells, general panic, without damage to buildings.
- VIII. Fall of chimneys, cracks in the walls of buildings.
- IX. Partial or total destruction of some buildings.
- X. Great disaster, ruins, disturbance of strata, fissures in the earth's crust, rock-falls from mountains.

C RICHTER MAGNITUDE SCALE

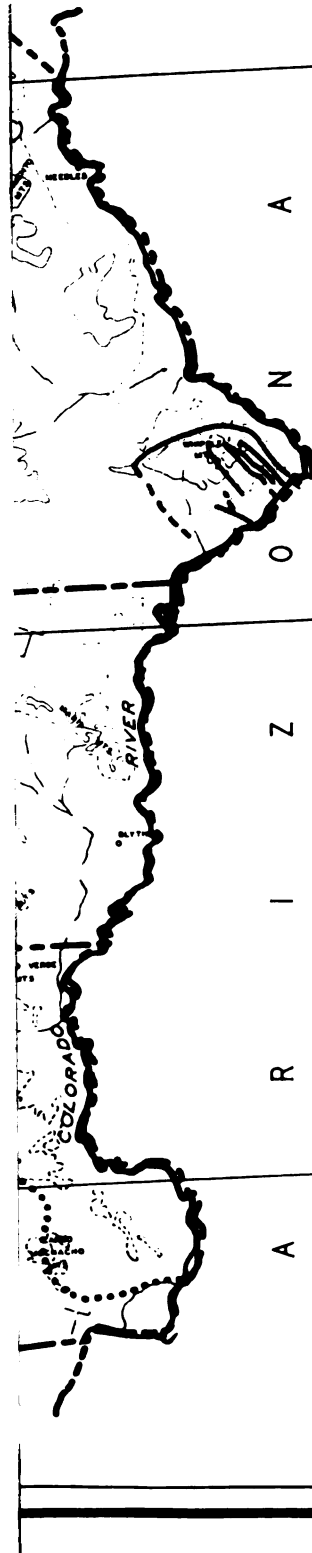
A magnitude scale based on instrumental records has been proposed by Dr. C. F. Richter of the California Institute of Technology Seismological Laboratory. His term magnitude refers to a quantity related to energy characteristic of the shock as a whole as contrasted to intensity which describes the effects of a shock at any particular location.

This magnitude is defined as the common logarithm to base 10 of the maximum registered horizontal trace

amplitude measured on a seismogram, expressed in units of one micron, or .001 mm., as recorded on a standard short-period torsion seismometer with $T_0 = 0.8$ sec., $V_s = 2,800$, $h = 0.8$, at a distance of 100 kilometers.

Modified from Leet, L. D.

Practical Seismology and Seismic Prospecting, D. Appleton-Century Co., Inc., 1938.



TAKEN FROM
GEOLOGIC MAP OF CALIFORNIA
DIVISION OF MINES
1938

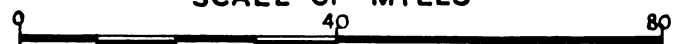
LEGEND

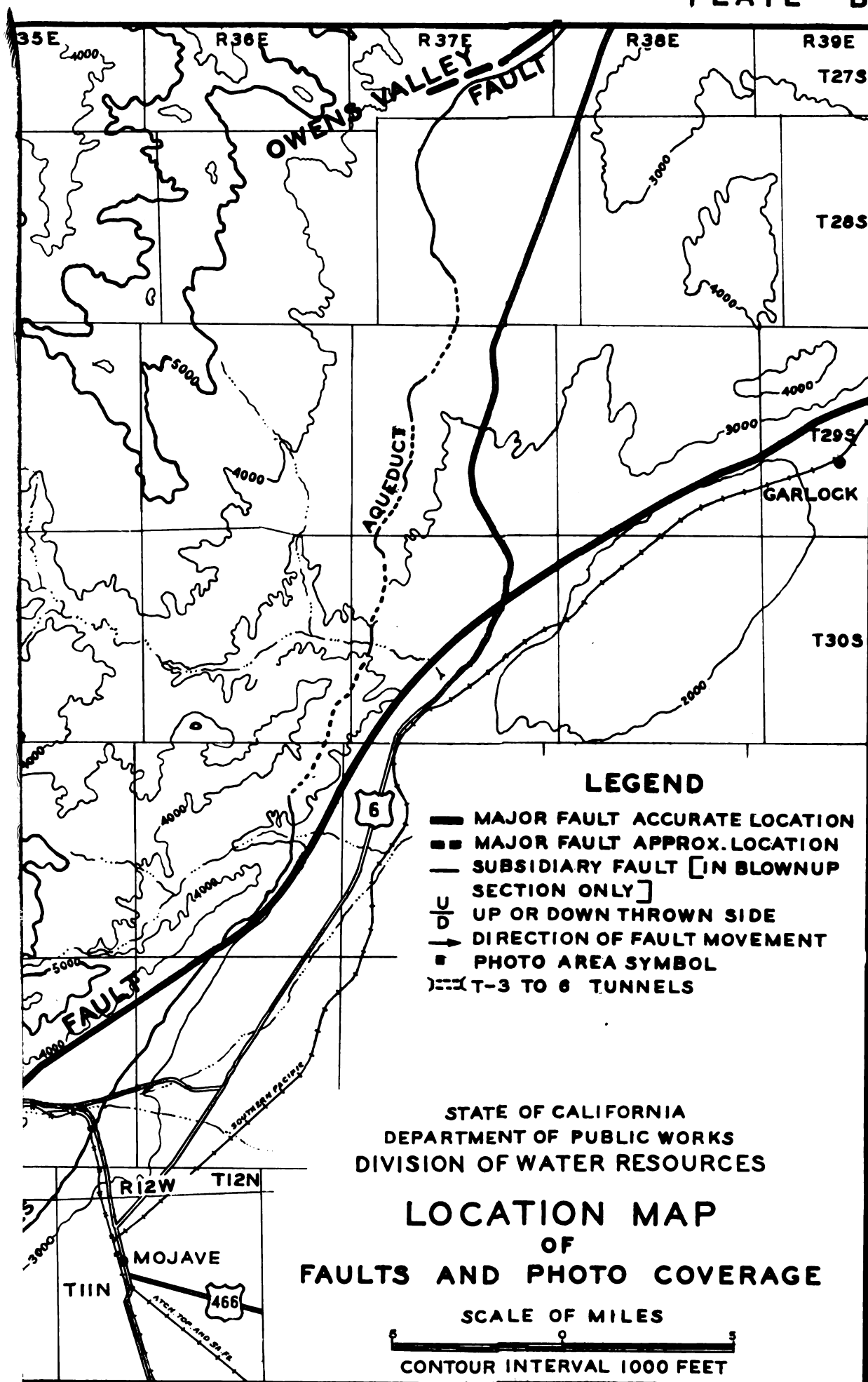
- MAJOR FAULT ACCURATE LOCATION
- MAJOR FAULT APPROX. LOCATION

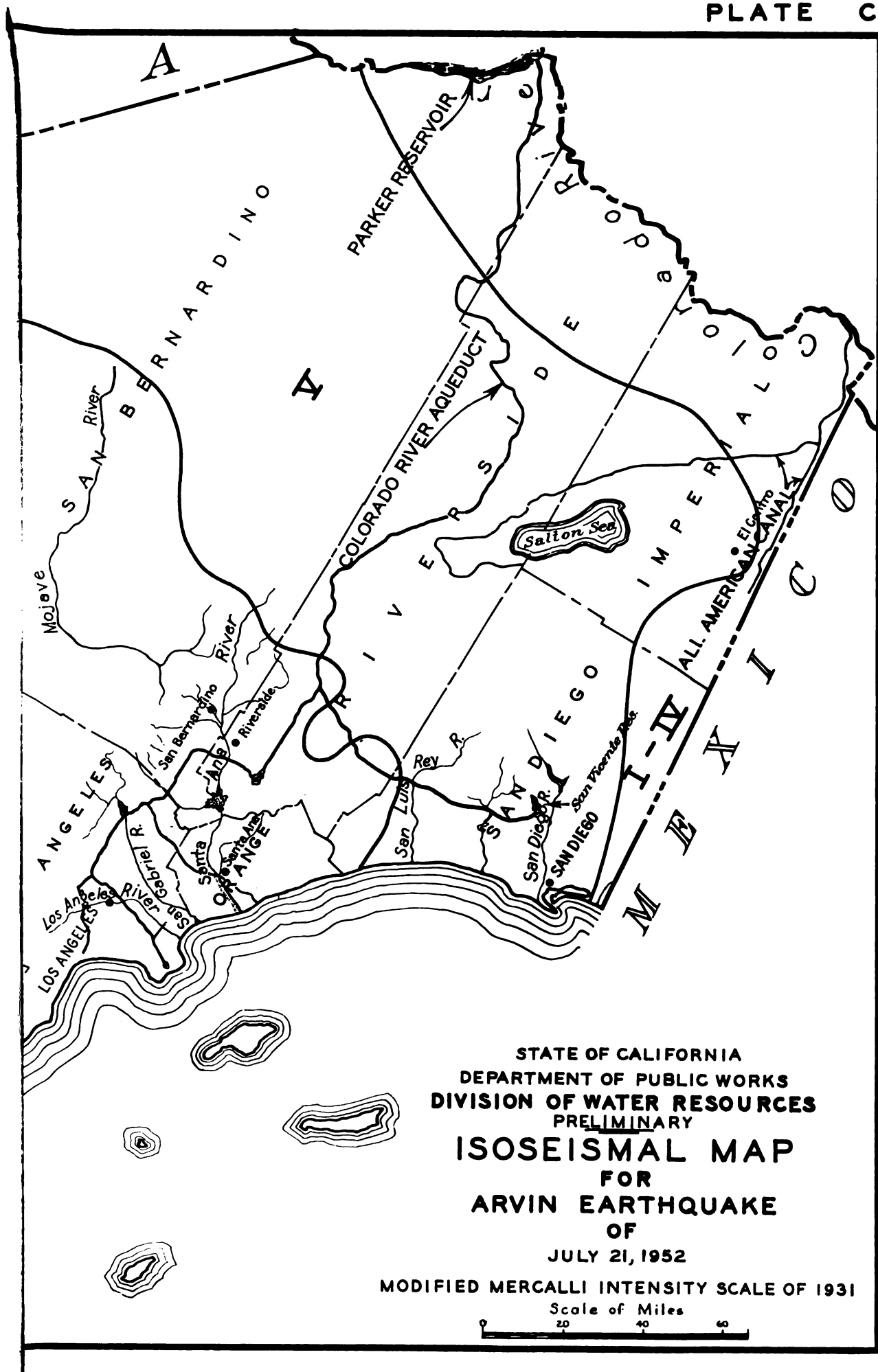
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES

FAULT SYSTEMS IN SOUTHERN CALIFORNIA

SCALE OF MILES







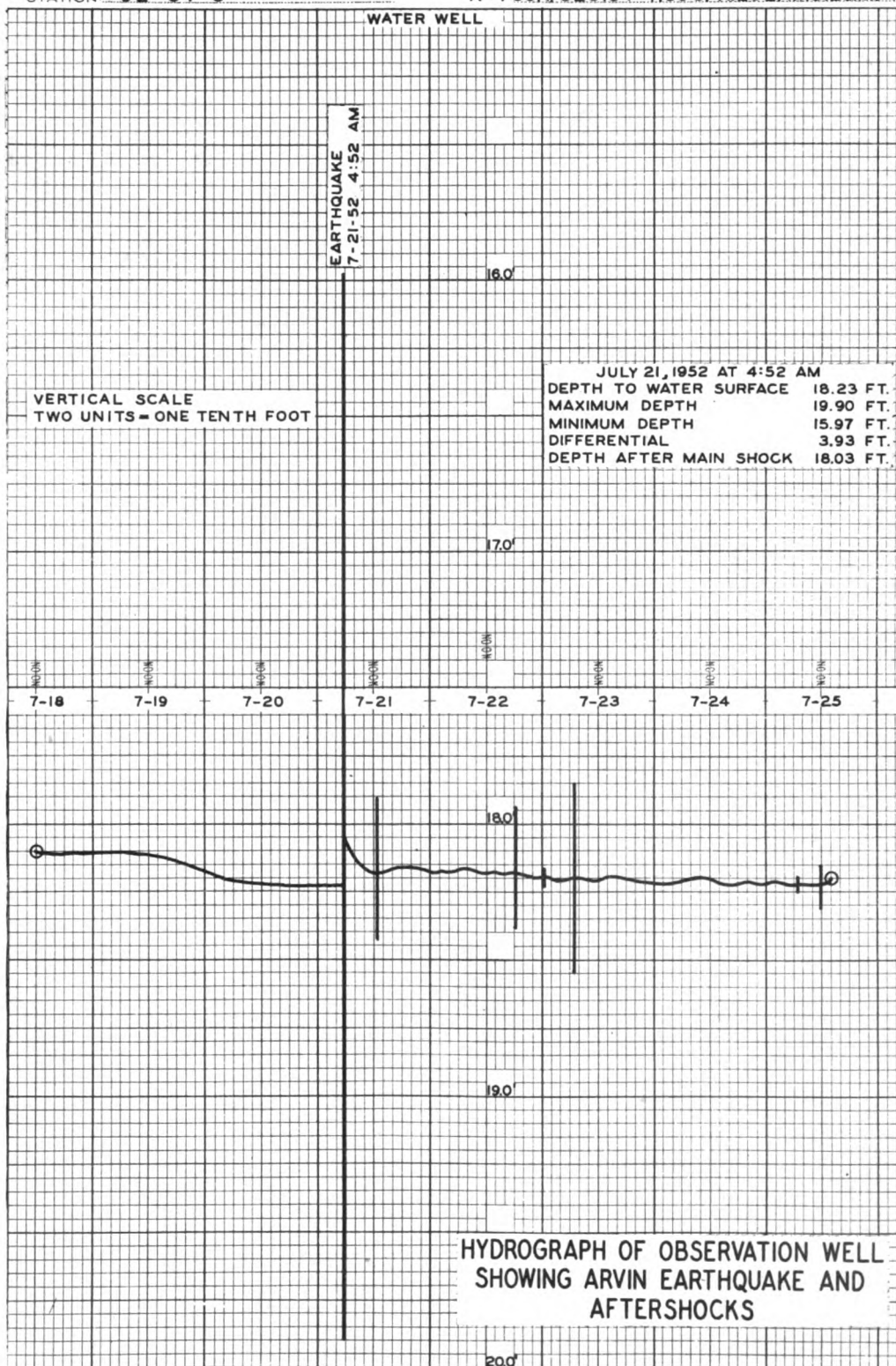
STATE PRINTING OFFICE
SHEET 4 52 1M. 3 PFO

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES

RECORD SHEET FOR WATER STAGE REGISTER

STATION: **6E 34-3**

N 1/4 COR. SEC. 34 T. 30 S. R. 26 E. M. D. B. & M.



Sheet placed by.....
 Time: **11:30 AM.** Day of Week..... Date **7/18/1952**
 Staff gage height **18.1**

Sheet removed by **C.Y.R.**
 Time: **4:45 P.M.** Day of Week..... Date **7/25/1952**
 Staff gage height **18.2**

45956 7-51 1M ① SPD

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES

RECORD SHEET FOR WATER STAGE REGISTER

STATION: SECOND POINT, KERN RIVER.

ONE MILE UP STREAM FROM ENOS

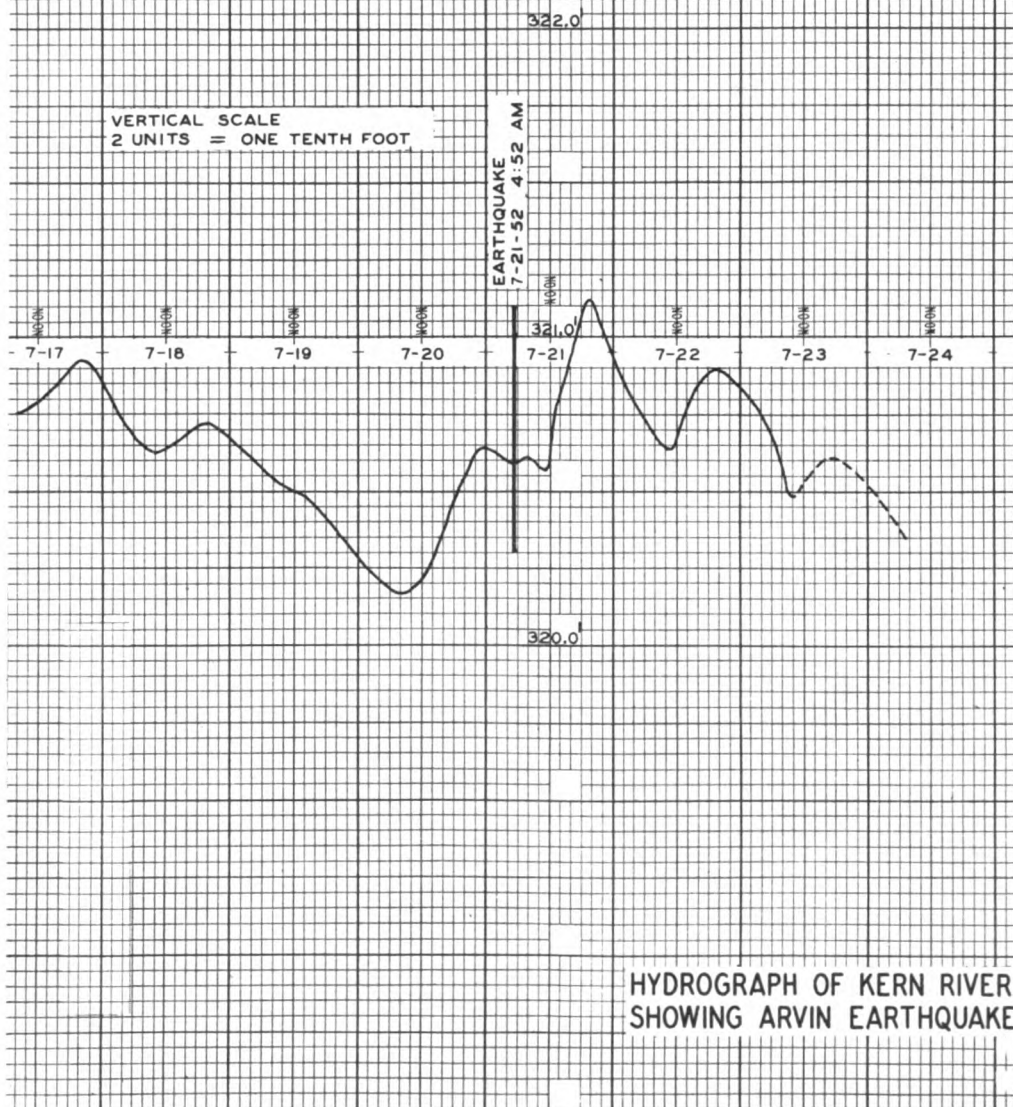
LANE
SE COR. SEC. 13 T30S R25E
M.D.B. & M.JULY 21, 1952 AT 4:52 AM
ELEVATION OF WATER SURFACE 320.6 FT.
MAXIMUM ELEVATION 321.1 FT.
MINIMUM ELEVATION 320.3 FT.
DIFFERENTIAL 0.8 FT.
ELEVATION AFTER MAIN SHOCK 320.6 FT.VERTICAL SCALE
2 UNITS = ONE TENTH FOOTEARTHQUAKE
7-21-52 4:52 AMSheet placed by.....
Time 7:20 AM., Day of Week..... Date 7/17/1952
Staff gage height 320.70Sheet removed by..... JACK HOGUE
Time 7:30 AM., Day of Week..... Date 7/24/1952
Staff gage height 320.34



Photo No. 1—A northeast trending crack in a dirt road about 15 miles south of Bakersfield. Movement is as noted. View is looking northeast.



Photo No. 2—Northwest trending cracks near a reservoir about 15 miles south of Bakersfield. Cracks have been widened by water pouring from the reservoir.



Photo No. 3—Replaced oil line pipes about 15 miles south of Bakersfield which have been bent, twisted, telescoped up to 36 inches and separated up to 55 inches. Pipes are constructed of five-sixteenth inch steel and range from six to 12 inches in diameter. Lines are generally placed from two to three feet below the ground surface.



Photo No. 4—Haystacks and transformers toppled about 15 miles south of Bakersfield along U. S. Highway 99.



Photo No. 5—U. S. Highway 99 about 10 miles south of Bakersfield. The concrete paved roadway sagged but did not fracture. Photo by Division of Highways.



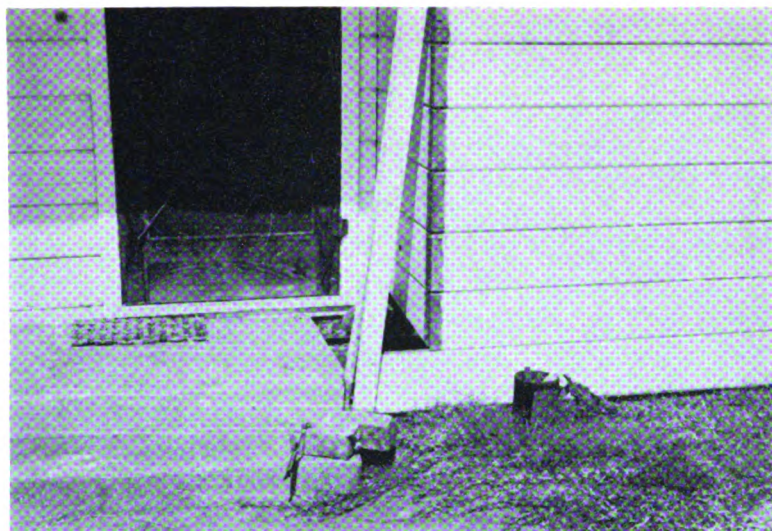
Photo No. 6—Offset cotton rows about 17 miles south of Bakersfield and one-half mile east of U. S. Highway 99.



Photo No. 7—Facing north, steel water line pipe separated about 17 miles south of Bakersfield, and one-half mile east of U. S. Highway 99.



Photo No. 8—Cracking of ground about three miles southwest of Arvin. Cracks turn and go under house, and though chimney fell and house was slightly damaged it still stands.
Photo by Division of Architecture.



**Photo No. 9—Same house as in Photo No. 8. House shifted one foot on its foundation.
Photo by Division of Architecture**



Photo No. 10—Cracking pattern in a plowed field about three miles southwest of Arvin. Swirl effect probably due to differential settlement of the sediments.



Photo No. 11—This school located about five miles west of Arvin was in the megaseismic area. Two stone ornaments insecurely fastened on either side of archway rocked loose and pulled out a few bricks. Balance of school undamaged.



Photo No. 12—Huge old slide in Sycamore canyon in foreground and recent minor slides on spurs. Note incipient slide near hilltop in the foreground.



Photo No. 13—Zone of fracturing in vicinity of the White Wolf fault about six miles east of Arvin. Breakage indicates that the southeast side had been uplifted and thrust to the northwest.



Photo No. 14—Road cracking and slumping on the Arvin-Tehachapi road. Photo by Division of Highways.



Photo No. 15—Offset of ground surface north of U. S. Highway 466 near the Bealville turnoff. Offset is one foot with the northwest side up. Much of this movement is probably due to slump.



Photo No. 16—View looking southwest toward former location of Southern Pacific Tunnel 4 on left and Tunnel 3 on right located south of Caliente. Note dark zone dipping 43 degrees to east in cut above Tunnel 4. This zone is a fault breccia with gouge matrix. Some movement probably took place along this zone for Tunnel 4 was damaged severely where this zone intersected the bore.



Photo No. 17—Rails and walls buckled by compression in Southern Pacific Tunnel 3 about one mile south of Caliente. Photo by Southern Pacific Company.



Photo No. 18—Rails twisted by compression between Southern Pacific Tunnels 3 and 4 about one mile south of Caliente. Photo by Southern Pacific Company.



Photo No. 19—Cracking on hillside over Southern Pacific Tunnel 5 south of Caliente. Prominent northwest trending crack, probably representing cross faulting at right angles to the main trend of the White Wolf fault, extends for approximately 3,000 feet. Construction work in picture shows beginning of cut for a temporary shoofly around Tunnel 5.



Photo No. 20—A northwest trending rift which began over Southern Pacific Tunnel 5 south of Caliente. This rift could be traced for about 3,000 feet and possibly represents a cross fault to the main northeast trending White Wolf fault. Nature of the cracking indicates that the northeast side of the rift has been dropped and that the plane of slippage dips approximately 45 degrees to the northeast.

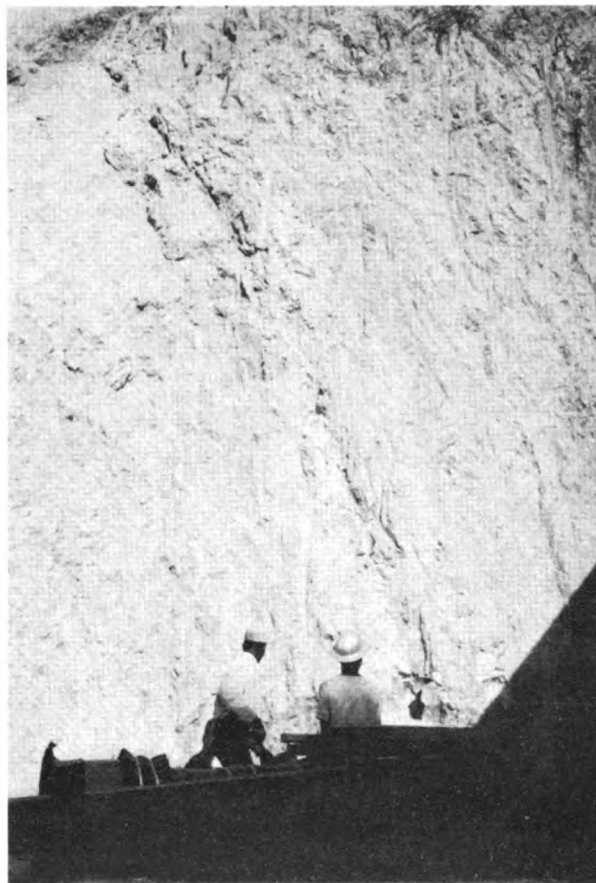


Photo No. 21—A fault exposed 21 feet north of the north portal of Southern Pacific Tunnel 5 south of Caliente. The dark zone to the right of the break is a dense gray gouge up to 14 inches thick. The fault strikes N. 70° W. and dips 22° N. at the surface steepening to 70 degrees at the base of the cut. No recent movement was apparent along this fault.

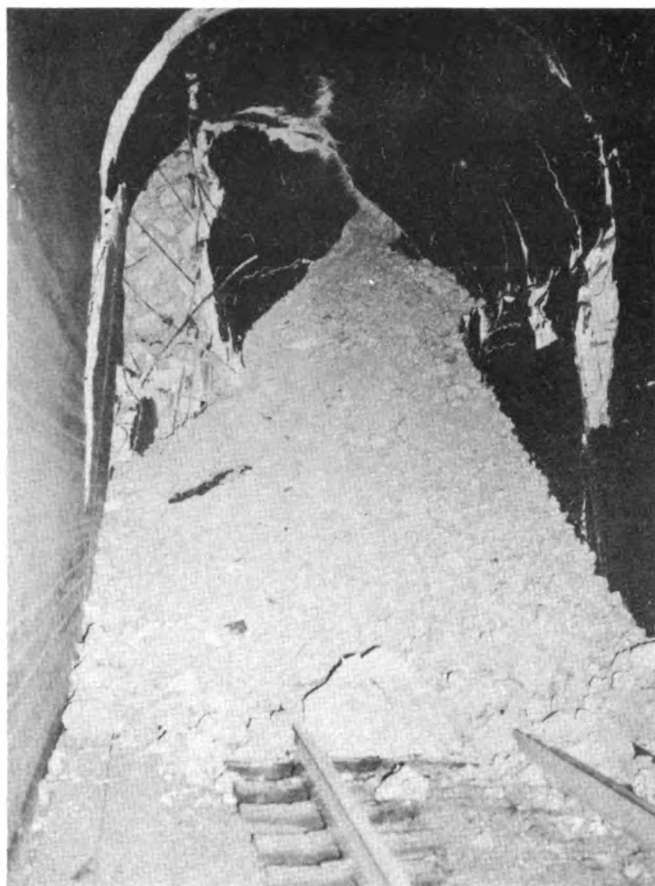


Photo No. 22—Cave-in in Southern Pacific Tunnel 5 about one mile south of Caliente. Photo by Southern Pacific Company.



Photo No. 23—Facing south in Southern Pacific Tunnel 5. Compression of east wall toward west. Photo by Southern Pacific Company.

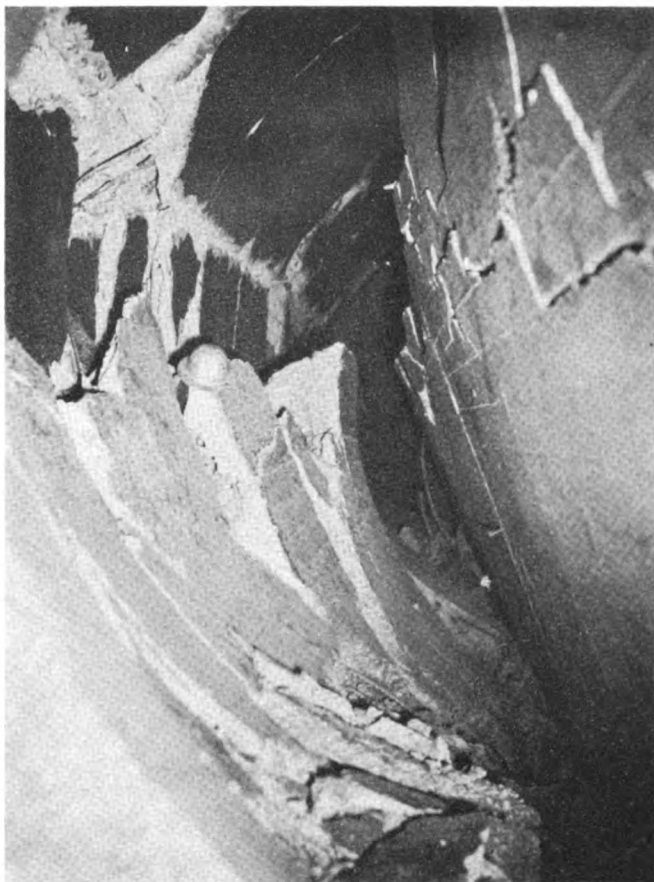


Photo No. 24—Facing north in Southern Pacific Tunnel 5. Extreme movement by east wall toward west. Photo by Southern Pacific Company.

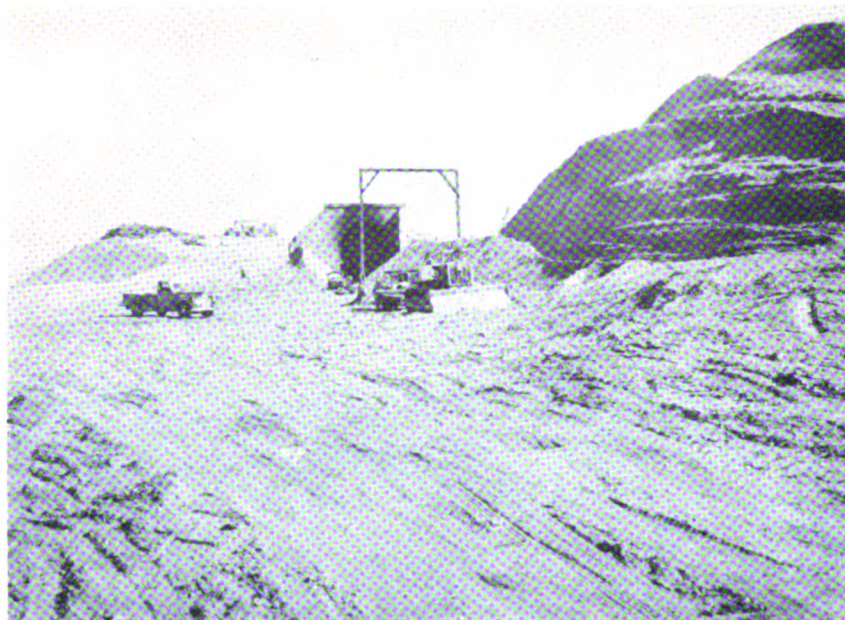


Photo No. 25—Southern Pacific Tunnel 6 about one mile south of Caliente. Tunnel has been daylighted and since has been entirely removed.



Photo No. 26—Fault zone about 500 feet upgrade from Southern Pacific Tunnel 6 south of Caliente. Some of the cracks that can be seen in the cut can be traced on the surface.

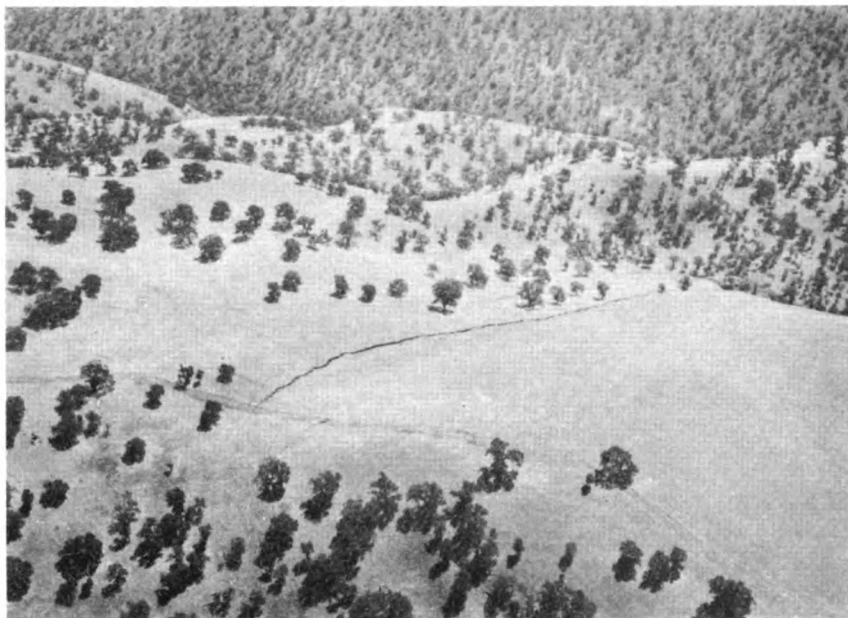


Photo No. 27—Large surface crack extending over ridge top northeast of Bealville. This crack is near the northeast extent of surface breaks along the trace of the fault.



Photo No. 28—Close-up of large surface crack on Photo No. 27. Largest surface expression noted in the area. Photo by Southern Pacific Company.

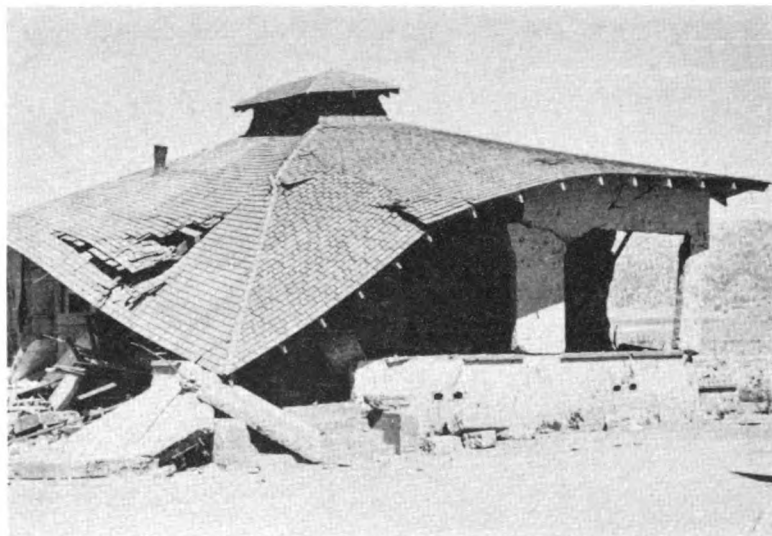


Photo No. 29—Cummings Valley School located nine miles southwest of Tehachapi in alluvial filled valley. This building, constructed prior to 1933 is allegedly built of reinforced concrete though reinforcing bars do not extend from columns into beams or foundation. Photo by Division of Architecture.

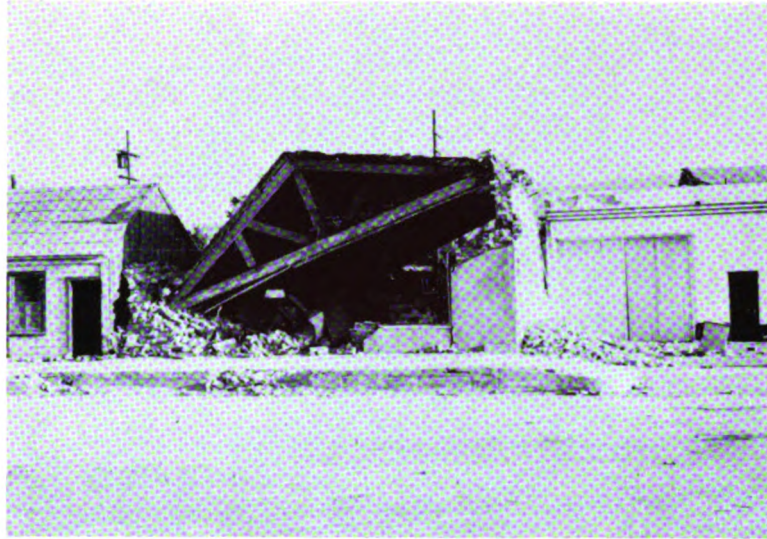


Photo No. 30—Main street of Tehachapi. Collapse of roof due to failure of brick and plaster walls. Poor bond and/or mortar may be responsible. *Photo by Division of Architecture.*



Photo No. 31—Brick building across street from previous photo showing good brick construction with bond beams. A few bricks fell as a result of racking of wooden truss roof. *Photo by Division of Architecture.*



Photo No. 32—Tehachapi school constructed more recently than Cummings Valley school. Though in a center of destruction, the only damage was reopening of a crack above an arch. The original crack was opened by a previous minor earth shock. Photo by Division of Architecture.



Photo No. 33—Kern County Courthouse roof showing failure of northeast corner of nonreinforced parapet. Brick construction with plaster coat. Steel column extends only to the roof. Photo by *The Bakersfield Californian*.



Photo No. 34—Eye Street apartment in Bakersfield. Complete collapse of brick rear wall. Photo by *The Bakersfield Californian*.



Photo No. 35—Salvation Army storeroom in Bakersfield on Sumner and Kings Streets. Brick construction; windows and doorways add to instability of a nonreinforced wall. Photo by The Bakersfield Californian.

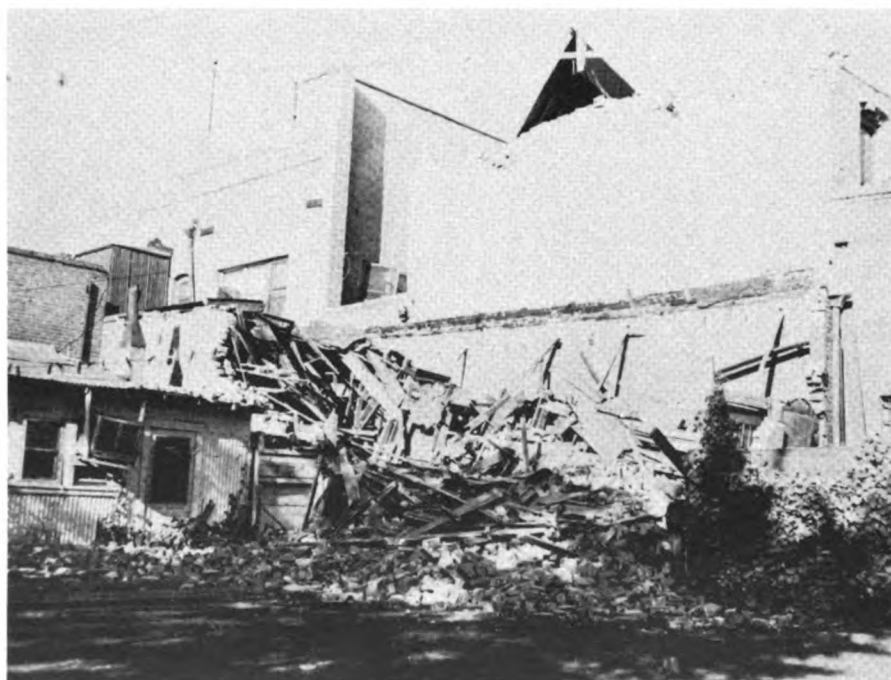


Photo No. 36—Rear of building next door to Metropole Hotel on Sumner Street. Parapets damaged on hotel roof. Roof failure as nonreinforced brick wall moved outward during earthquake. Photo by The Bakersfield Californian.



Photo No. 37—Buena Vista Dam No. 732. East levee, looking south. Subsidence and cracking of fill caused by earthquake of July 21, 1952. Maximum settlement of two feet.



Photo No. 38—Buena Vista Dam No. 732. East levee, looking north. Subsided section of fill. Dozer starting low levee construction using imported stockpiled materials.

