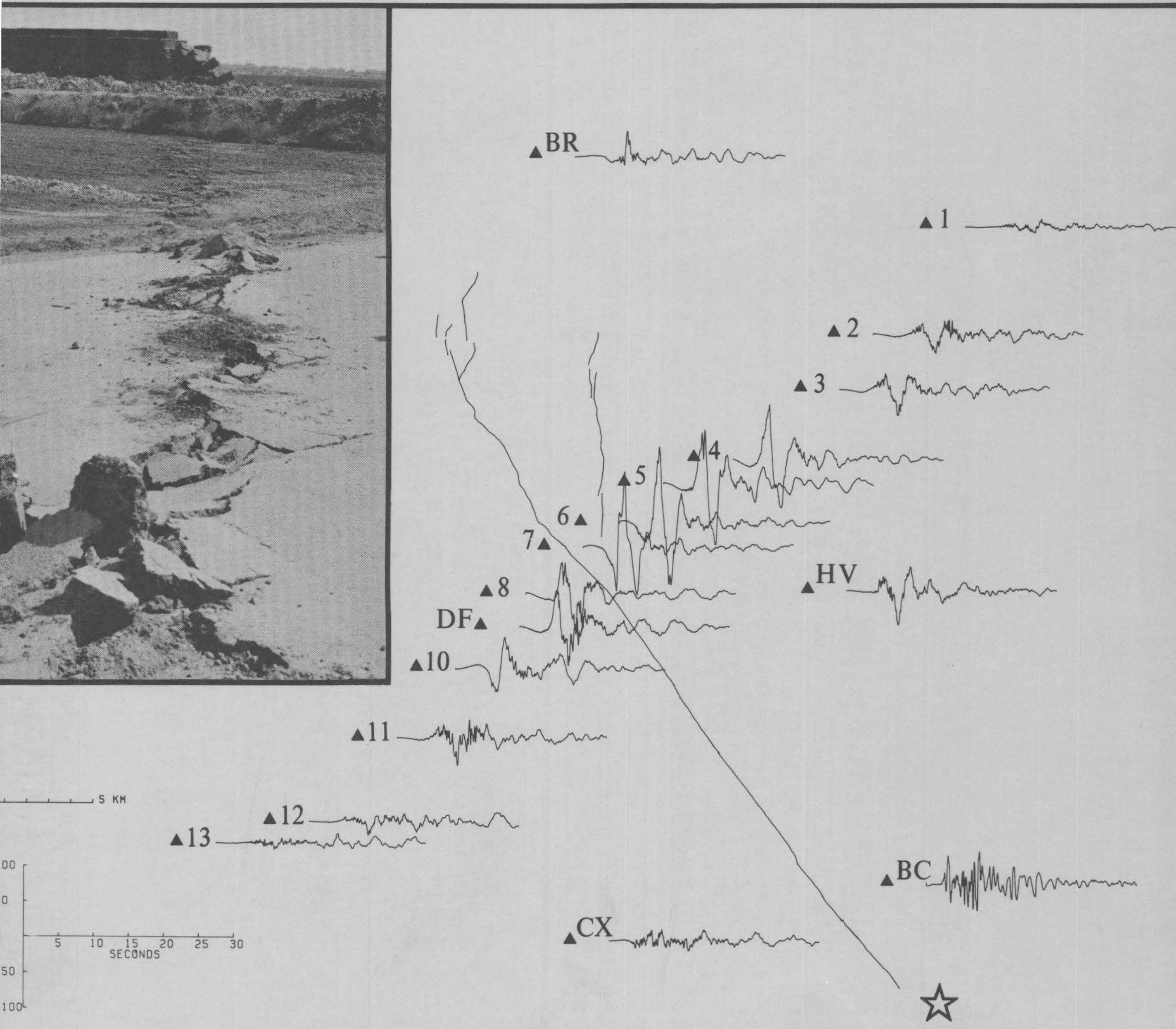
RC 818-C

Seismic Engineering Program Report September - December 1979

Prepared on behalf of the National Science Foundation Grant CA-114



GEOLOGICAL SURVEY CIRCULAR 818-C

Cover: Velocity traces of 230° components from close-in USGS accelerograph stations, Imperial Valley earthquake of October 15, 1979; for locations of indicated accelerograph stations see figure 4, this report. Photo shows October 15 Imperial fault rupture across Anderholt Road, 0.9 km north of Heber Road; view is toward the southeast (figure provided by R. J. Archuleta; photo by R. L. Porcella, October 16, 1979).

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United States Department of the Interior
CECIL D. ANDRUS, *Secretary*

Geological Survey
H. William Menard, *Director*

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604 South Pickett Street, Alexandria, VA 22304

PREFACE

This Seismic Engineering Program Report is an informal periodical primarily intended to keep the ever-growing international community of strong-motion data users apprised of the nature and availability of data recovered by the Seismic Engineering Branch of the U.S. Geological Survey (USGS). This Strong-Motion Program is administered by the USGS and supported by the National Science Foundation (Grant CA-114) in cooperation with numerous Federal, State, and local agencies and organizations. Major objectives of the program include recording both strong ground motion and the response of various types of engineered structures during potentially damaging earthquakes and disseminating this strong-motion information and data to the earthquake engineering research and design community.

This issue contains a summary of the accelerograms recovered from the USGS National Strong-Motion Network during the period September 1 through December 31, 1979. Reproductions of some of the more significant accelerograms are included. A report on strong-motion data recorded in the United States during the October 15, 1979 Imperial Valley earthquake is presented along with summaries of recent strong-motion reports, notes on the availability of digitized data, and additional general information pertinent to the USGS and other strong-motion programs. The data summary included in this issue contains information on those accelerograms recovered (although not necessarily recorded) during the period September - December 1979; this procedure has been adopted so that the dissemination of strong-motion information may be as expeditious and current as practicable.

Ronald L. Porcella, Editor
U.S. Geological Survey, Mail Stop 78
Menlo Park, California 94025

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Seismic Engineering Program Report
September - December 1979

RECENT STRONG-MOTION RECORDS

by R. L. Porcella

The USGS National Strong-Motion Network produced approximately 325 records during the reporting period September 1 - December 31, 1979; all but 20 of these are related to the October 15 Imperial Valley earthquake and aftershocks (see tables 1 and 2, end of report). Table 1 also includes main-shock data from this event that were recorded at several stations operated by the California Division of Mines and Geology, Office of Strong-Motion Studies (OSMS). The additional strong-motion records recovered during this reporting period are related to earthquakes in central and southern California, in south-central Alaska, and near the southern coast of Hawaii (see table 1). A magnitude 5.5 earthquake on September 22 triggered accelerographs at six USGS stations on the island of Hawaii. A maximum horizontal ground acceleration of 0.44 _g_ with a strong duration (acceleration greater than 0.1 _g_) of about 4.5 s was recorded at the U.S. Fish and Wildlife station in Hilo, Hawaii. The dominant frequencies apparent in this and numerous other records recovered from the Hawaii Network (fig. 1) suggest that the subsurface conditions vary considerably among the 18 accelerograph sites in this network (Porcella, 1979).

A total of 511 records were recovered from the USGS network during 1979, compared with a yearly average of 174 records for the period 1972 to 1978, inclusive; however, 70 percent of the 1979 records were related to either the August 6 Gilroy (Coyote Lake) or October 15 Imperial Valley earthquakes, both of which fortuitously occurred in areas that contained fairly extensive arrays of accelerographs jointly contrived by several groups but operated under the USGS Strong-Motion Program that is funded by the National Science Foundation. Organizations involved in the planning of these ground-motion arrays (Gilroy, Bear Valley, and Imperial Valley) include the USGS, the California Institute of Technology, the California Division of Mines and Geology, and the Federal Highways Administration. Although the number of accelerograms recorded at these three arrays is impressive, of much greater significance is the comprehensive azimuthal distribution and number (23) of close-in accelerograms (fault-station distance less than 20 km) recorded during these two earthquakes (Porcella and others, 1979; Porcella and Matthiesen, 1979). "Indeed, short of deploying perhaps ten times as many strong-motion accelerographs than presently exist, there is no reason to suspect that we will ever do any better for a magnitude [approximately] 7 earthquake than what is presently available for this [Imperial Valley] earthquake" (Hanks and Brady, 1980, page 3). Similar data sets are available for several Imperial Valley aftershocks that occurred during the first 24 hours (R. B. Matthiesen and R. L. Porcella, unpub. data, 1980; also, see table 2). A more complete summary of the USGS data recorded during the October 15 Imperial Valley earthquake and aftershocks is presented in the following summary report. For more detailed information and data obtained at strong-motion stations operated by OSMS, see California Division of Mines and Geology (1979) and Porter (1980). Brune and others (1980) discuss strong-motion data obtained in Mexico for the October 15 earthquake, which was recorded at stations operated jointly by the National University at Mexico City and the University of California at San Diego.

References:

Brune, J., Prince, J., Vernon III, F., Mena, E., and Simons, R., 1980, Strong-motion data recorded in Mexico during the main shock of the October 15, 1979 Imperial Valley earthquake: Institute of Geophysics and Planetary Physics, University of Californa, San Diego, La Jolla, California 92093, unpublished report.

California Division of Mines and Geology, 1979, Partial records and file data, Imperial Valley earthquake of October 15, 1979: Sacramento, Office of Strong-Motion Studies, 95816.

Hanks, T. C., and Brady, A. G., 1980, Studies of ground motion of two California earthquakes: U.S. Geological Survey, Menlo Park, California 94025, proposal submitted to the National Science Foundation, 32 p., bibliography.

Porcella, R. L., 1979, Recent strong-motion records, _in_ Seismic Engineering Program Report: U.S. Geological Survey Circular 818-B, 24 p.

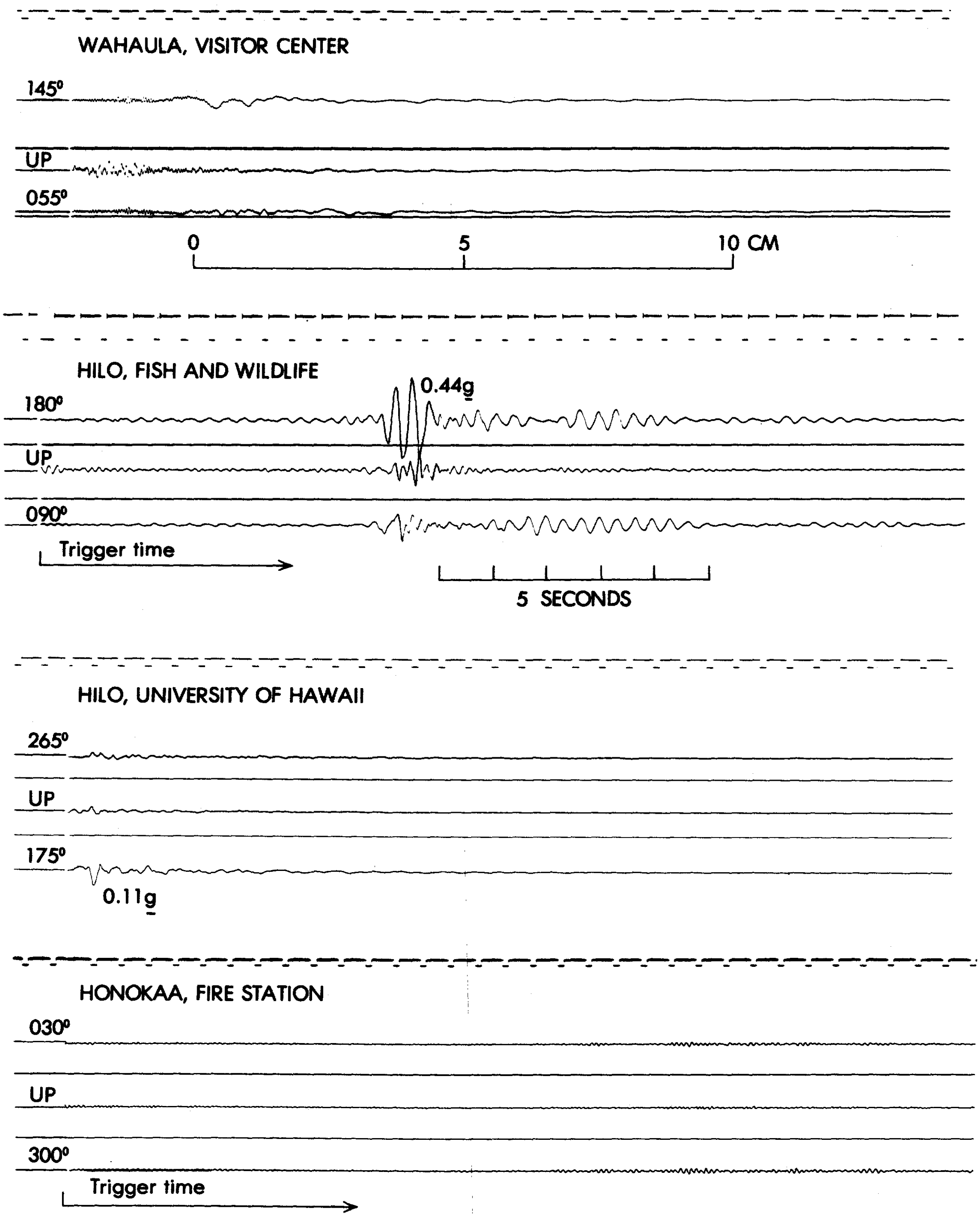


Figure 1 - Selected accelerograms from the USGS Hawaii network, earthquake of September 22, 1979.

Porcella, R. L., and Matthiesen, R. B., 1979, Preliminary summary of the U.S. Geological Survey strong-motion records from the October 15, 1979 Imperial Valley earthquake: U.S. Geological Survey Open-File Report 79-1654, 41 p.

Porcella, R. L, Matthiesen, R. B., McJunkin R. D., and Ragsdale, J. T., 1979, Compilation of strong-motion records from the August 6, 1979 Coyote Lake earthquake: U.S. Geological Survey Open-File Report 79-385 and California Division of Mines and Geology Preliminary Report 25, 71 p.

Porter, L. D., 1980, Data processing procedures for the main-shock motions recorded by the California Division of Mines and Geology Strong-Motion Network, Imperial Valley earthquake of October 15, 1979: Office of Strong-Motion Studies, Sacramento, California 95816, unpublished report.

STRONG-MOTION DATA SUMMARY IMPERIAL VALLEY EARTHQUAKE OF OCTOBER 15, 1979 AND AFTERSHOCKS

by R. B. Matthiesen and R. L. Porcella

INTRODUCTION

The October 15, 1979 Imperial Valley earthquake, which was centered at lat 32.64° N and long 115.33° W, triggered all of the USGS accelerographs within about 100 km of the epicenter and one as far away as 196 km (Porcella and Matthiesen, 1979a). With this initial information, all of the stations within about 200 km of the epicenter were inspected to ascertain which instruments had been triggered. The complete set of data including that from Baja California is, in several respects, the most significant set of ground motion data collected from a single event and provides a rewarding result from several years of planning and execution of a cooperative effort by the U.S. Geological Survey (USGS), the California Division of Mines and Geology (CDMG), and the Earthquake Engineering Research Laboratory of the California Institute of Technology (CIT) and a similar effort in Baja California by the National University at Mexico City (UNAM) and the University of California at San Diego (UCSD). The locations of the instruments known to be operational in the greater Imperial Valley region at the time of the earthquake are shown in figure 2.

A standard U.S. Coast and Geodetic Survey accelerograph was first installed at the site of the Imperial Irrigation District Substation on Commercial Avenue in El Centro (presently designated as El Centro array station 9) in July 1932 as a part of a program designed simply to gather strong-motion records from active regions in the western United States. Prior to the October 15, 1979 earthquake, more than 250 accelerograms had been recovered from the Imperial Valley region; nearly 200 of these records had been recovered since January 1975 and contain accelerations as high as 0.5 g from moderate-size (magnitude 4-5) earthquakes. All of the records recovered prior to 1966 were obtained at the Commercial Avenue station, the only station in the Imperial Valley during that time. The increase in numbers of records and peak-acceleration levels reported since 1966 is due to the increase in the number of stations in that area and a consequent decrease in the epicentral distances. Because of the short durations of many of these accelerograms, the data are of minimal engineering significance; however, many of the records contain useful seismological information relevant to epicenter determinations and wave-propagation and source-mechanism studies of the Imperial Valley region (Porcella and Matthiesen, 1979b).

On May 18, 1940, a magnitude 7.1 (M_S) earthquake triggered the strong-motion instrument in El Centro and those in San Diego, San Bernardino, and Los Angeles (Neumann, 1942). For many years, the 1940 El Centro accelerograph record was used worldwide in earthquake engineering studies as a representative ground motion from a strong local earthquake. Although the three acceleration traces of the 1940 accelerograph record went off scale (six-inch photographic paper was used at the time), it is of some interest to compare the 1940 record with the record obtained in 1979 from a similar instrument (recording on 12-inch photographic paper) at the same site. The two records are presented to the same scale in figure 3. In this figure, the component traces of the 1940 record were plotted from a digitized version that includes the parts extrapolated beyond the limits of the original record, whereas the 1979 record was traced in order to separate the three traces. Although the reported values of peak acceleration for the 1979 record are higher than those reported for the 1940 record, this difference may be an artifact because the peak accelerations of the 1940 record cannot be accurately ascertained. On the other hand, the high accelerations in the 1940 record lasted longer, and this difference can be attributed to the fact that the 1940 event has been interpreted to be a multiple event with five or more smaller events occurring within seconds of one another (Trifunac and Brune, 1970).

A preliminary interpretation of all of the 1979 records suggests that this earthquake was also a multiple event in which most of the accelerographs triggered on the motion from the event at the reported epicenter, but most of the energy came from a later (2- to 3-s) event associated with the surface faulting (T. Hanks, oral commun., 1979); this interpretation and speculation regarding the influence of the direction of rupture propagation on the values

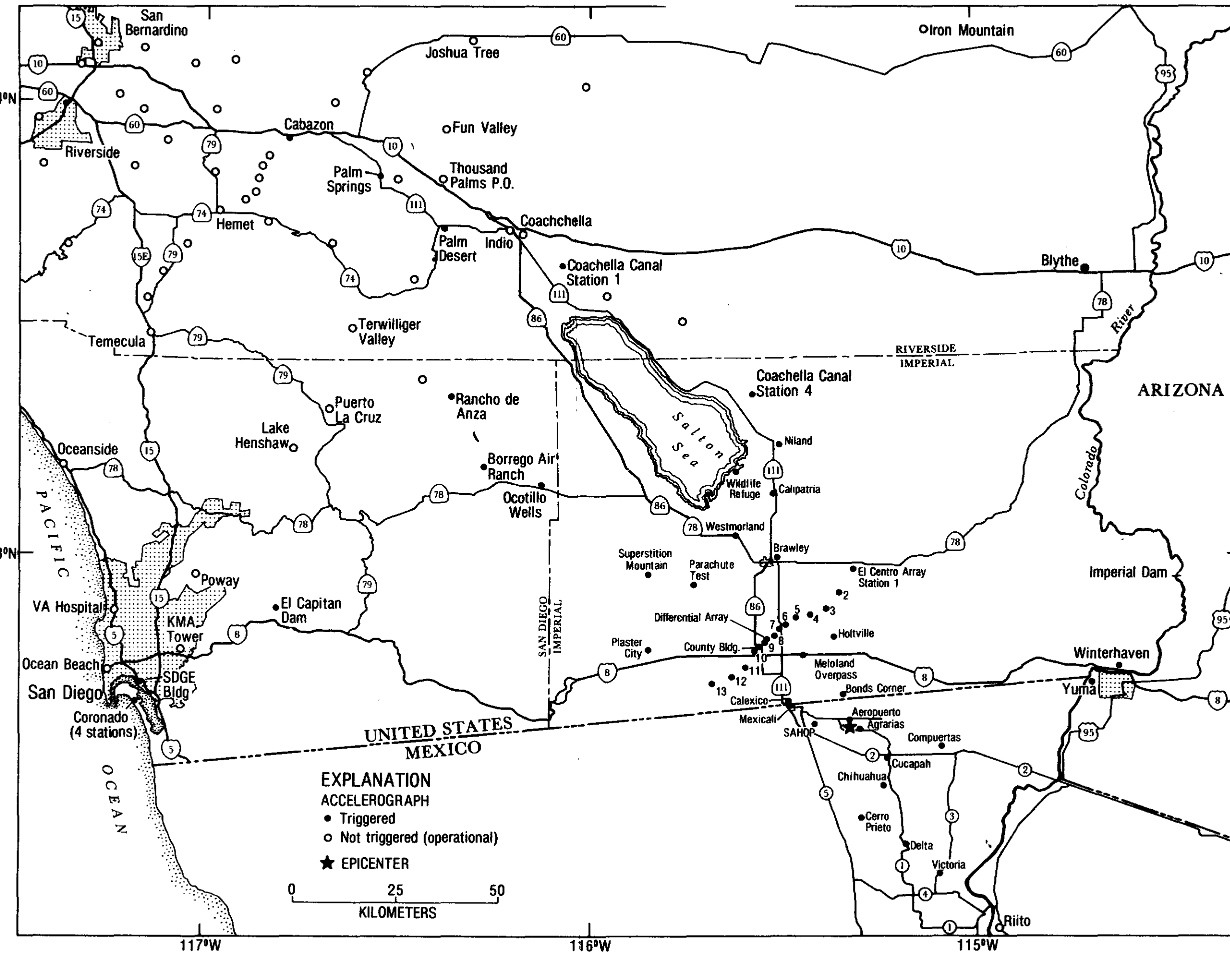


Figure 2 - Strong-motion stations in the greater Imperial Valley region that are known to have been operational at the time of the October 15, 1979 earthquake (R. B. Matthiesen and R. L. Porcella, unpub. data, 1980).

of acceleration are tentative and require further substantiation as these records and the other seismological data are studied in detail in the next few years.

DEVELOPMENT OF THE IMPERIAL VALLEY NETWORK

In the early 1970's, the number of accelerograph stations in the Imperial Valley increased as a part of the programs of several organizations. The program operated by the USGS was in the process of a nationwide reorganization; the CIT program developed a network of accelerographs along the San Jacinto fault system (which includes the Imperial fault); the CDMG program (CSMIP) had begun to place accelerographs throughout the active regions of the State of California; and the network in Baja California had been started. In 1975, the three groups operating networks in California combined their efforts throughout the State and exchanged instrument sites and maintenance responsibility for greater operational efficiency. The USGS became responsible for most of the stations established by CIT in southern California and most of the ground stations in the Imperial Valley, and the CDMG became responsible for most of the stations throughout the remainder of the State. The CDMG retained responsibility for the instruments on structures in the Imperial Valley, although the planning of this instrumentation was conducted in cooperation with personnel of the USGS and other organizations (Rojahn and Ragsdale, 1978). The USGS also began a concerted effort to develop several specialized ground-motion arrays within the Imperial Valley to fulfill specific research needs required for studies of source mechanism, attenuation of ground motion, and differential ground motions. The locations of these arrays and their proximity to the Imperial and Brawley faults are shown infigure 4.

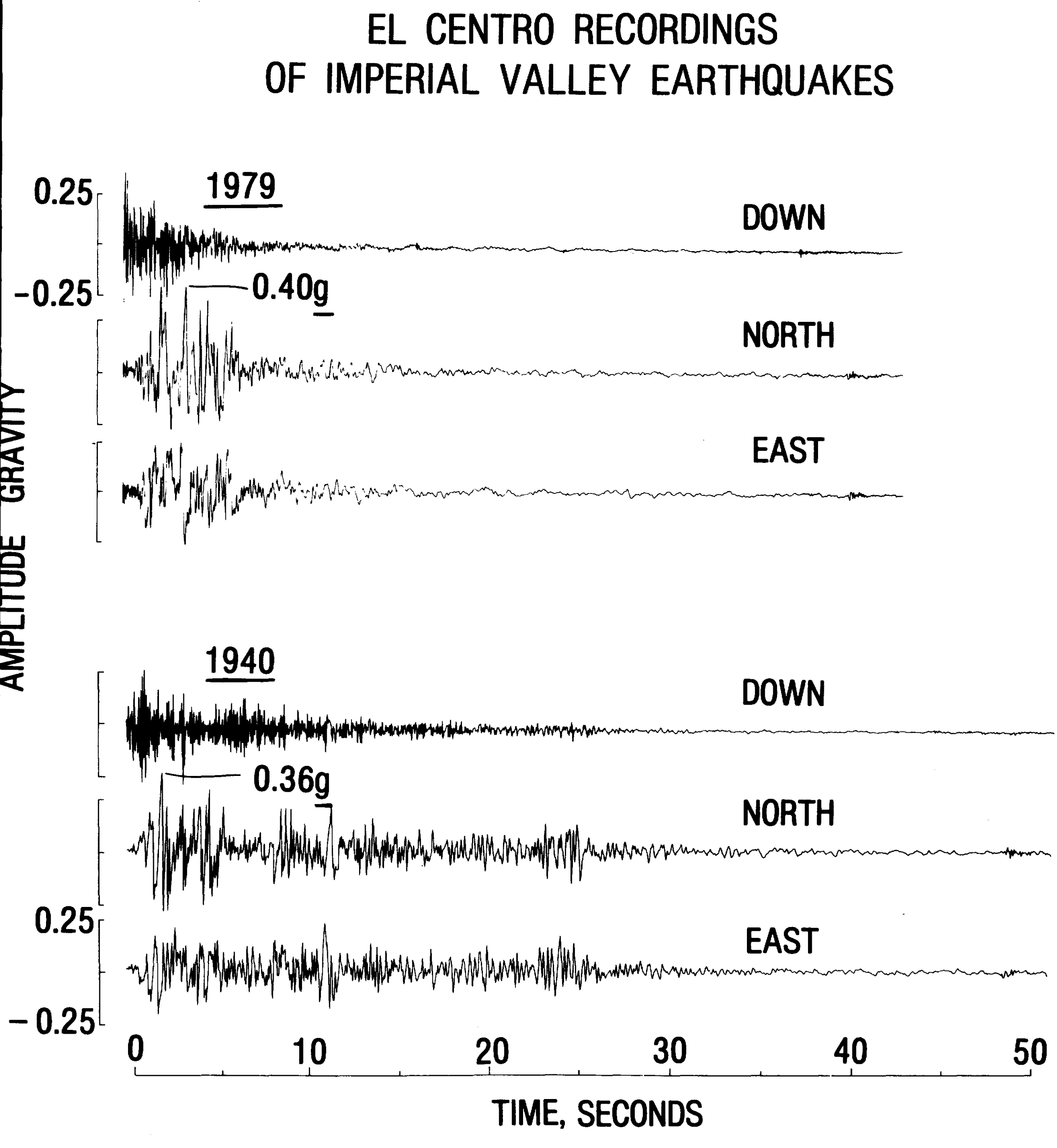


Figure 3 - Accelerograms from El Centro array station 9 (Commercial Avenue), Imperial Valley earthquakes of October 15, 1979 and May 18, 1940 (R. B. Matthiesen and R. L. Porcella, unpub. data, 1980).

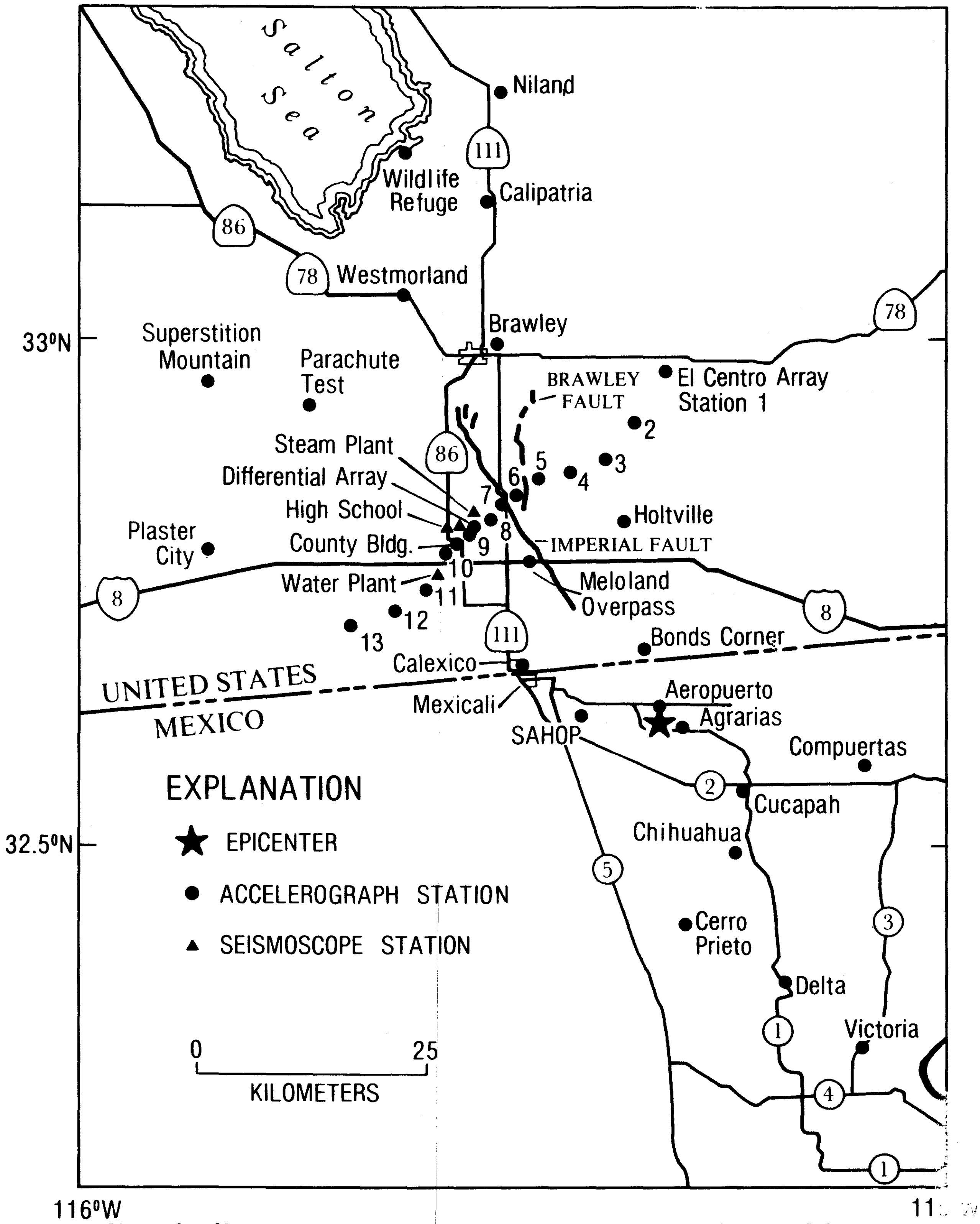


Figure 4 - Close-in strong-motion stations that operated during the October 15, 1979 Imperial Valley earthquake (R. B. Matthiesen and R. L. Porcella, unpub. data, 1980).

The El Centro array, comprising 13 stations at 3- to 5-km spacings, was established to obtain information on the attenuation of motion with distance from the causative fault and to provide information on the near-field motion for interpretation of source motions. Many of the instruments in this array, which extends a total length of 45 km transverse to the 1940 fault trace, are located in small fiberglass housings so as to approximate a "free-field" condition. Most of the instruments (Kinemetrics model SMA-1T)* are equipped with a vertical starter to allow early triggering (usually within 0.2 s of the P-wave arrival) and a WWVB radio receiver to record real time on the accelerograph record.

In cooperation with the Federal Highways Administration, the USGS installed a linear array of six accelerometers to record the differential motions of the ground surface. The array extends in a north-south direction for a total distance of 305 m, over which accelerometers are located at 0, 18, 55, 128, 214, and 305 m. The six interconnected digital recorders (Terra Technology model 300) and a film-recording accelerograph (Kinemetrics model SMA-1T) are located in a small concrete-block structure 8 m south of the array. The accelerometer spacings are such that the distances between pairs of stations are similar to the typical distances between bridge piers as well as to the half-wavelengths of relevant surface waves (G. N. Bycroft, oral commun., 1979). The primary objective of the array is to obtain data on differential ground displacement (doubly integrated acceleration) for use as input motion in studies of dams, pipelines, and bridge structures.

The CDMG, working in cooperation with the California Department of Transportation, has instrumented the Meloland Overpass across Interstate 8 near El Centro. The instrumentation scheme consists of 26 channels of data centrally recorded on two interconnected film recorders (Kinemetrics model CRA-1) and includes triaxial accelerometers that measure the motion in the "free-field," at both approach embankments, and at the base of the central pier, as well as 14 uniaxial accelerometers measuring the motion of the deck. The objective is to record the input motion as well as the modal response so as to deduce the response characteristics of a typical freeway-overpass structure (Christopher Rojahn, oral commun., 1979).

The six-story Imperial County Services Building in El Centro also was instrumented under the CSMIP program. A 13-channel recording accelerograph system (Kinemetrics model CRA-1) was installed, and accelerometers were located at the ground level, the second and fourth floors, and the roof. The building is a reinforced-concrete structure designed to resist lateral forces in the transverse direction (north-south) by shear walls and in the longitudinal direction (east-west) by frame action (Rojahn and Ragsdale, 1978). In addition, a "free-field" instrument was installed about 100 m to the east of the building in a parking lot. Ambient-vibration measurements of the building motions were made in May 1979, and forced-vibration tests were conducted in the summer of 1979 (Gerard Pardoen, oral commun., 1979). The major objective of the CDMG Building Instrumention Program is to record the response of representative buildings during potentially damaging earthquakes in order to provide information that will lead to improved earthquake-resistant design (Wootton and others, 1976).

DATA FROM THE MAIN SHOCK

The strong-motion accelerograph network in the Imperial Valley operated by the USGS consists of 24 stations; 21 of these stations are instrumented with triaxial film-recording accelerographs (Kinemetrics model SMA-1T) equipped with vertical starters (capable of bringing the instrument into full operation within 0.2 s of the first vertical motion greater than 0.01 *g*) and WWVB radio receivers that record absolute time codes on the accelerograms. Consequently, during the October 15 earthquake and aftershocks, each accelerograph typically triggered on the first-arriving P wave; the resultant accelerogram commonly displays a time interval between the first S-wave arrival and the trigger time (S - t) that can be used with the WWVB time code in epicenter determinations.

In addition to the Imperial Valley network, the main shock was recorded on numerous instruments elsewhere in southern California. The ground motion data obtained from the main shock are summarized in table 1, and the instruments that were operational but did not trigger are indicated in figure 2; this information is listed in alphabetical order of stations for convenience in correlating the information with the station locations (see figs. 2 and 4 and table 1). Some of the more distant stations were triggered by S-wave arrivals; in table 1 under the S - t column, a dash denotes that either the instrument was triggered by the S wave or the S-wave arrival could not be identified.

The data from stations beyond 10 km are consistent with peak acceleration values recorded during previous events of this magnitude; but these data provide significant new information on the motions within 10 km of the fault trace (D. M. Boore and R. L. Porcella, unpub. data, 1980). Of particular interest relative to the close-in stations is the observation that many of the vertical

*Use of product trade names or trademarks is for descriptive purposes only and does not imply endorsement by the U.S. Geological Survey.

accelerations are higher than the corresponding horizontal accelerations, in contrast to observations from data obtained at more distant stations in previous events (Maley and Cloud, 1973; Newmark Consulting Engineering Services, 1973).

Copies of the main-shock accelerograph records from the USGS stations within 30 km of the fault rupture are shown in figure 5. Of particular significance is the long-period pulse that is evident in all of the records from stations within 10 km of the fault. This acceleration pulse can be integrated to yield significant velocity and displacement changes. In that regard, the close-in records from the main shock have been digitized and processed to obtain velocity and displacement time-histories and spectra (Brady and others, 1980).

Five seismoscopes located in the Imperial Valley region at the time of the October 15, 1979 earthquake provide additional data on ground motions. The locations of the four close-in stations are shown in figure 4, and the results of all five records are summarized in table 3. One of the seismoscopes is located at the site of the original El Centro accelerograph station (El Centro array station 9), and another is located within 1 km of the El Centro differential array. Copies of the seismoscope plates are shown in figure 6.

DATA FROM AFTERSHOCKS

The close-in Imperial Valley accelerograph network recorded at least 82 identifiable aftershocks at 21 stations during the first week after the October 15 main shock; 14 of these aftershocks were recorded at three or more stations. This data set contains more than 150 records that can be used in epicenter and magnitude determinations, as well as for studies of source mechanisms and ground motion attenuation. In all, 22 stations within 30 km of the main-shock surface rupture produced at least 165 aftershock records; 49 of these records contain peak accelerations greater than 0.1 *g* (table 2).

A line in the trigger-time column in table 2 indicates that either the accelerograph does not contain a WWVB radio receiver or that the WWVB time code was not adequately recorded for positive correlation with an event. Approximately 15 percent of the trigger times are listed in parentheses; these times are questionable because they were determined by correlating the record with one from a nearby station. Only two of the 22 stations that recorded aftershocks do not have WWVB time capability; however, only 44 percent of the 247 records recovered at stations with WWVB receivers contain good-quality time-code traces. Consequently, several of the stations, including El Centro array stations 6 and 7, differential array, Holtville, and Parachute Test Site, produced a significant number of records that cannot be positively correlated with an event.

The reported numbers of aftershocks recorded at several stations require some clarification. The Brawley Airport station recorded 40 aftershocks (although the instrument was actually triggered only 26 times), but the instrument ran out of film within four hours after the main shock. The airport manager noted that the accelerograph counter (which is tripped once each time the trigger is actuated) indicated 19 triggerings approximately two hours after the main shock and 77 triggerings approximately 18 hours after the main shock (Ken Bemis, oral commun., 1979); the counter indicated 89 triggerings at 1545 on October 17 (UTC) when the record was recovered from the station. El Centro array station 6, located between the Brawley and Imperial fault traces (fig. 4), recorded 38 aftershocks (16 triggerings) before the accelerograph ran out of film. Because of the intermittent operation of the WWVB time-code generator, the time at which the film supply became exhausted cannot be determined; a new supply of film was installed approximately 24 hours after the main shock, at which time the counter indicated 39 triggerings. Other stations at which the film supply ran out and at which some triggerings were not recorded include: El Centro array station 8, four unrecorded triggerings; El Centro array station 12, two unrecorded triggerings; and Calipatria Fire Station, eight unrecorded triggerings (table 2).

SUMMARY

Forty-three U.S. strong-motion stations within an epicentral distance of 150 km were in operation during the main shock of the October 15, 1979 Imperial Valley earthquake; more than 265 aftershock records were obtained at 20 stations within 25 km of the main-shock surface rupture. Maximum horizontal ground accelerations of greater than 0.5 *g* were measured at seven stations within 10 km of the Imperial fault rupture; a maximum vertical acceleration of 1.74 *g* recorded at El Centro array station 6 exhibits a duration (peak accelerations greater than 0.1 *g*) of more than 6 s. These accelerograms contain the most comprehensive collection of close-in strong-motion data ever recorded. Because absolute times were recorded on many of the records, detailed studies of the source mechanism and ground-motion characteristics are possible.

References:

Brady, A. G., Perez, Virgilio, and Mork, P. N., 1980, The Imperial Valley earthquake, October 15, 1979--digitization and processing of accelerograph records: U.S. Geological Survey Open-File Report 80-703, 309 p.

Hudson, D. E., and Cloud, W. K., 1967, An analysis of seismoscope data from the Parkfield earthquake of June 27, 1966: Seismological Society of America Bulletin, v. 57, no. 6, p. 1143-1159.

Maley, R. P., and Cloud, W. K., 1973, Strong-motion accelerograph records, in Murphy, L. M., ed., San Fernando, California earthquake of February 9, 1971: Washington, D.C., Department of Commerce, v. 3, p. 325-348.

Neumann, Frank, 1942, United States earthquakes - 1940: Washington, D.C., Government Printing Office, Department of Commerce, Serial No. 647, 74 p.

Newmark Consulting Engineering Services, 1973, A study of vertical and horizontal earthquake spectra: Washington, D.C., Government Printing Office, Directorate of Licensing, U.S. Atomic Energy Commission, WASH-1255, UC-11.

Porcella, R. L., and Matthiesen, R. B., 1979a, Preliminary summary of the U.S. Geological Survey strong-motion records from the October 15, 1979 Imperial Valley earthquake: U.S. Geological Survey Open-File Report 79-1654, 41 p.

_____, 1979b, Strong-motion instrumentation in the Imperial Valley, California: Simposium los Asentamientos Humanos en la Falla de San Andreas, Instituto Tecnologico Regional de Tijuana, B.C., September 5-8, 1979, Proceedings, 609 p.

Rojahn, Christopher, and Ragsdale, J. D., 1978, Building instrumentation phase of the California strong-motion instrumentation program: Structural Engineers Association of California, 48th annual convention, Lake Tahoe, Calif., October 1978, Proceedings.

Trifunac, M. D., and Brune, J. N., 1970, Complexity of energy release during the Imperial Valley, California earthquake of 1940: Seismological Society of America Bulletin, v. 60, no. 1, p. 137-160.

Wootton, T. M., Wells, W. M., and Power, J. H., 1976, Second report on the strong-motion instrumentation program: California Division of Mines and Geology Special Publication 48, 39 p.

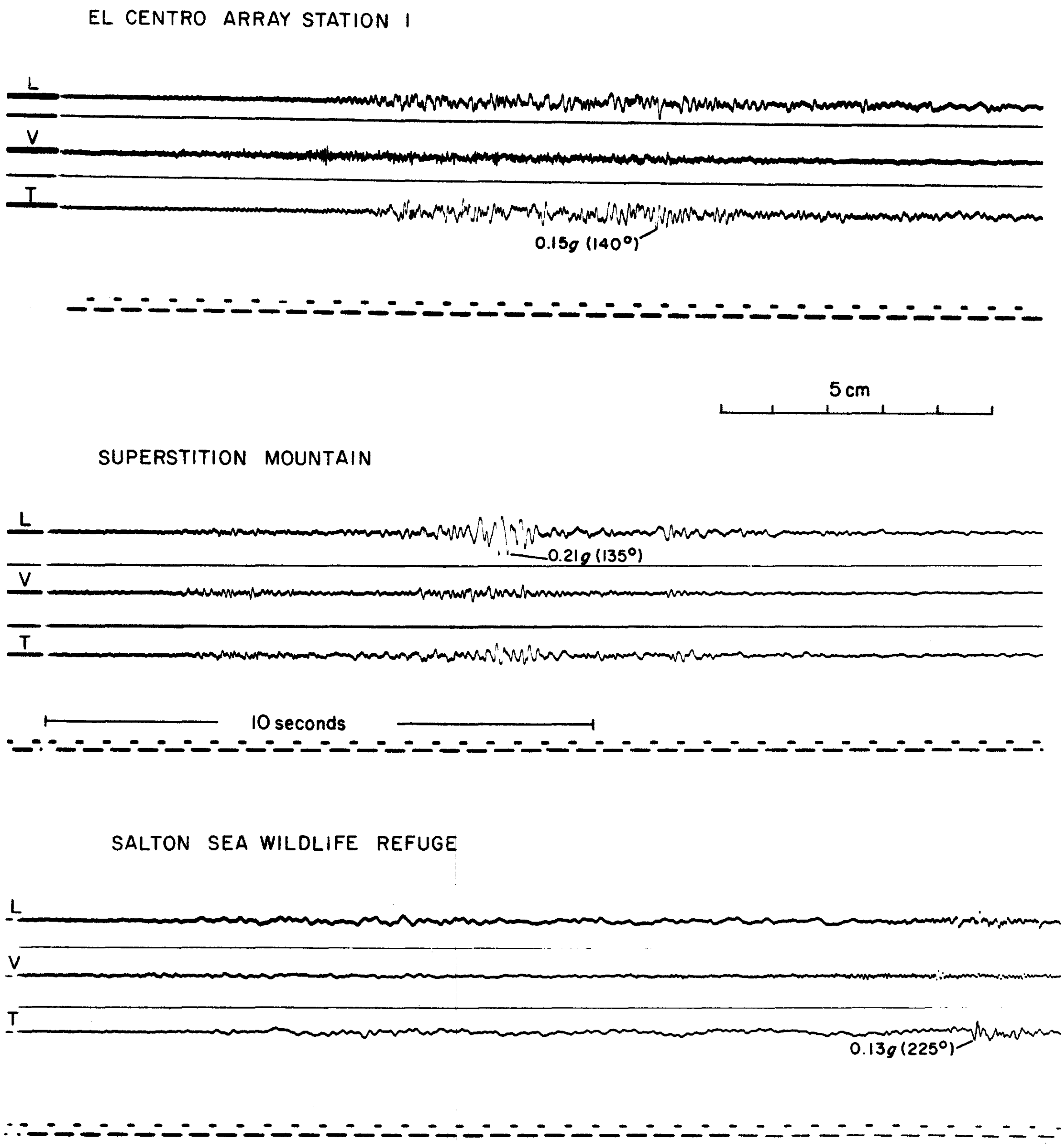
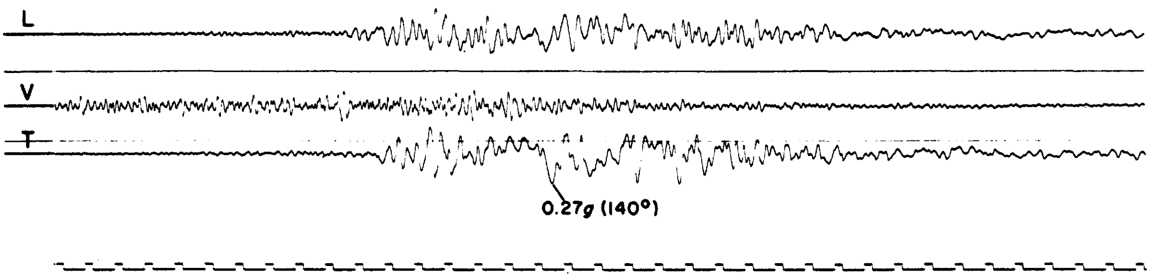
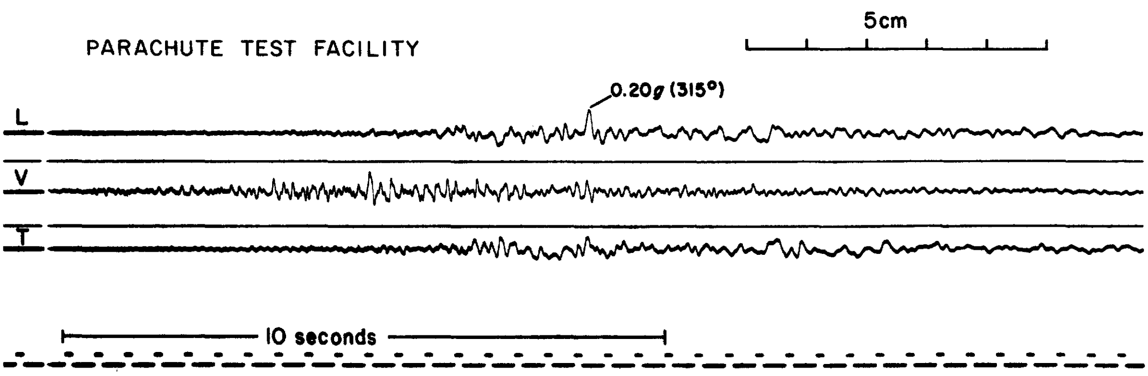


Figure 5 - USGS accelerograms from stations within 30 km of the October 15, 1979 Imperial fault rupture (array station 9 accelerogram is shown in figure 3).

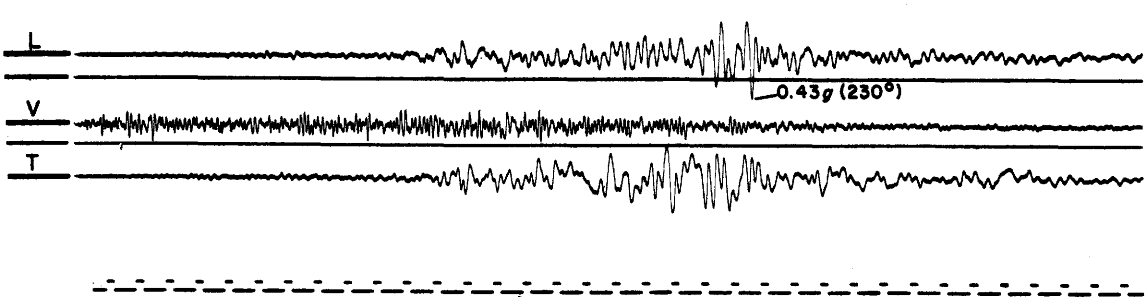
EL CENTRO ARRAY STATION 3

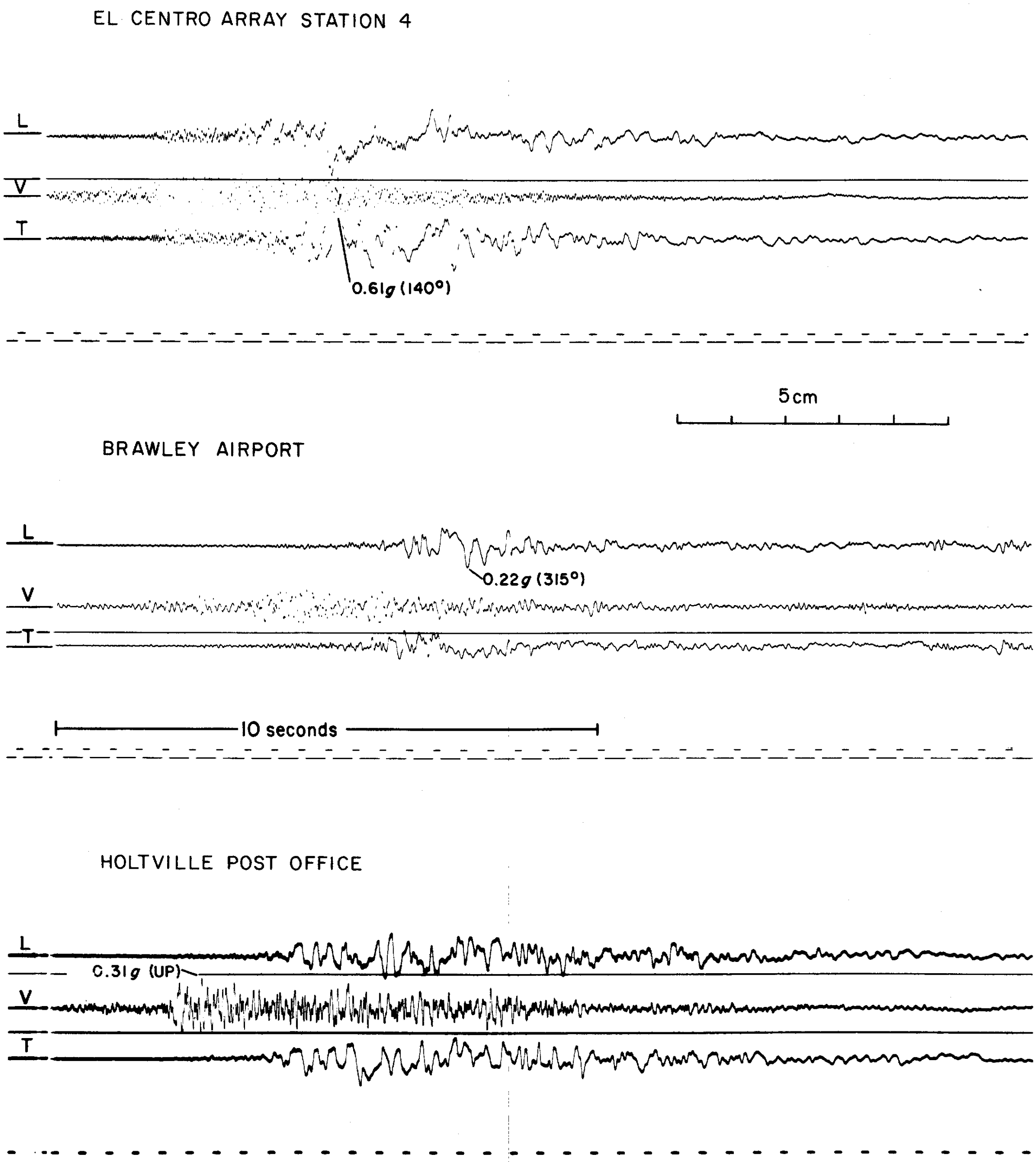


PARACHUTE TEST FACILITY



EL CENTRO ARRAY STATION 2

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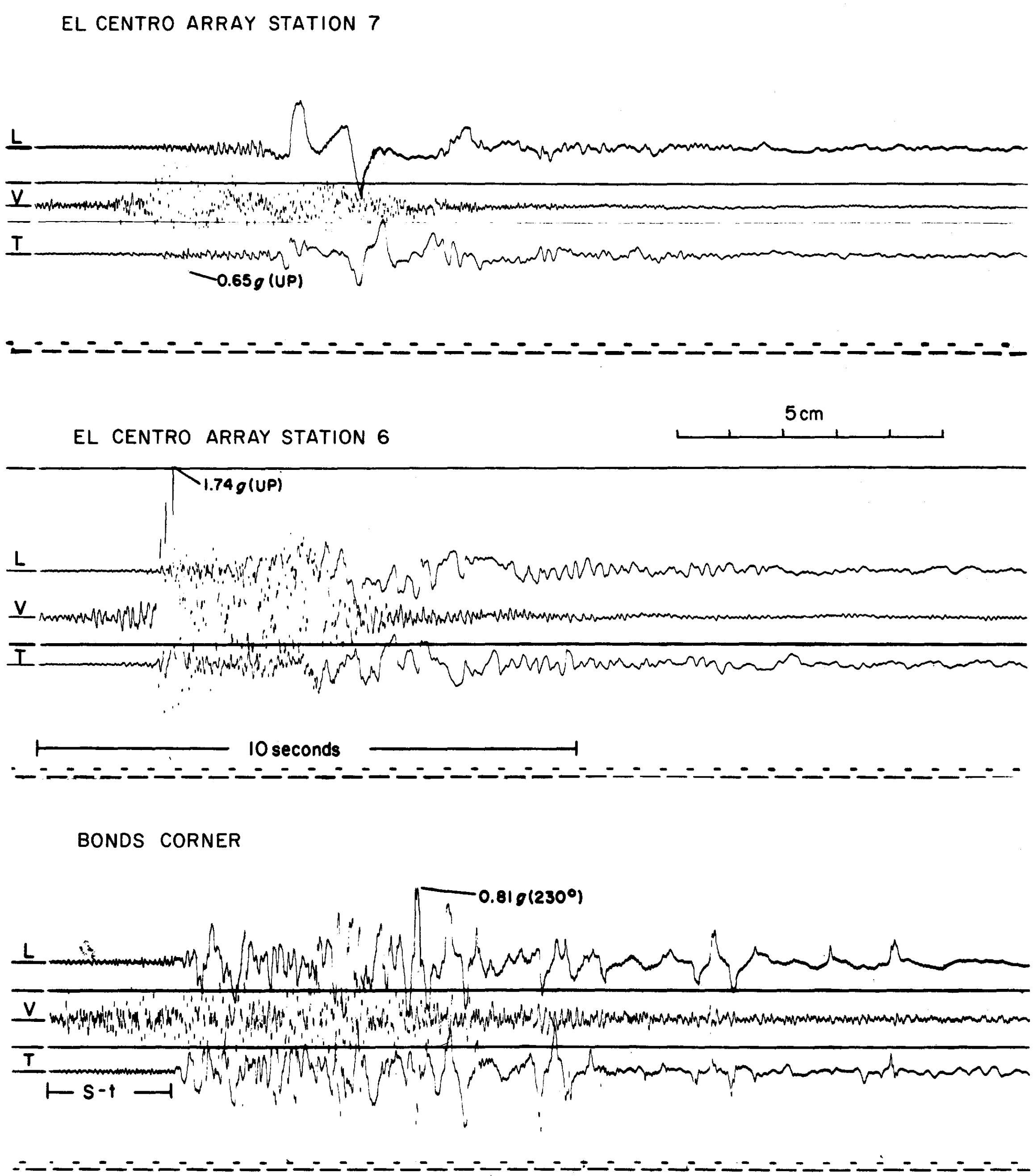
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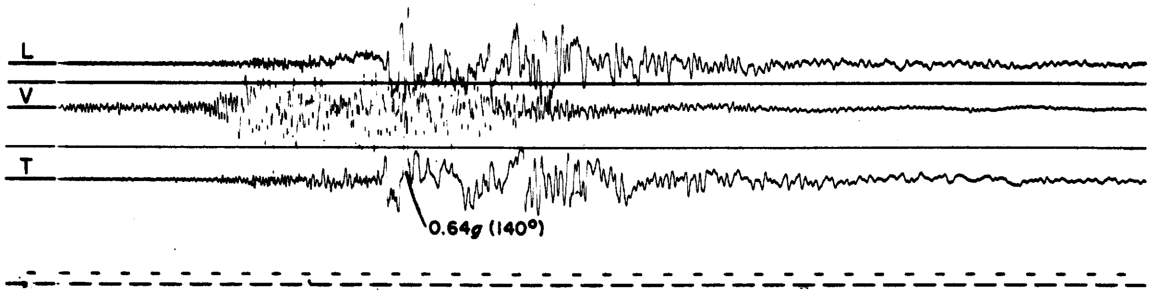

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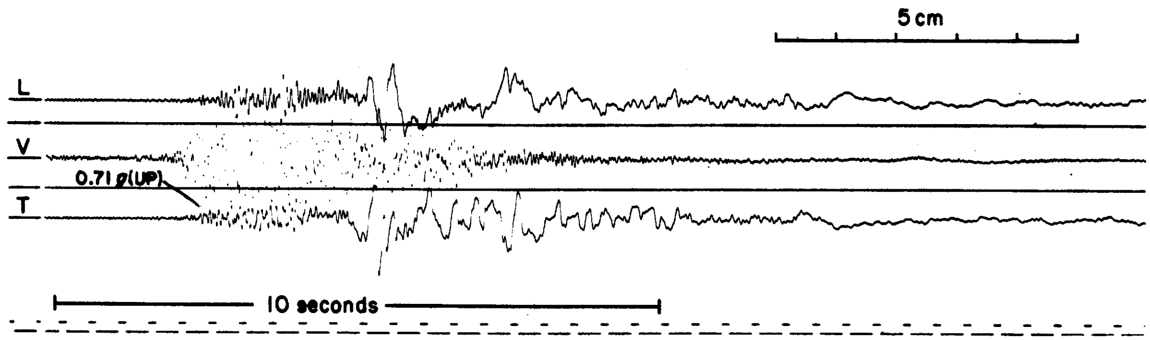
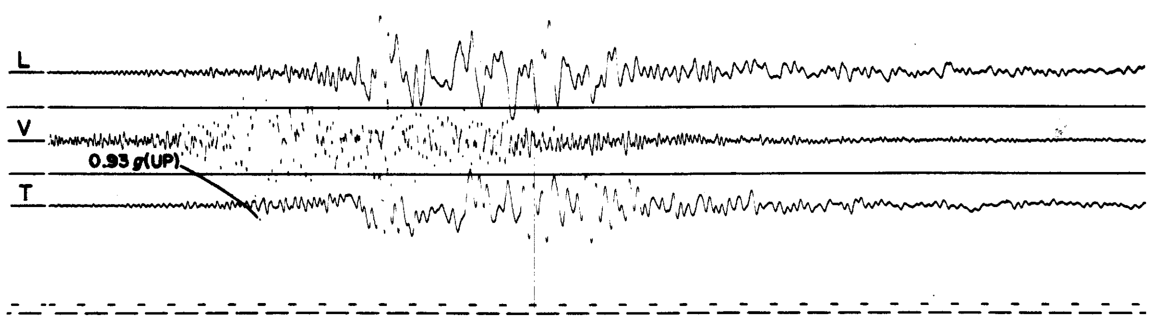
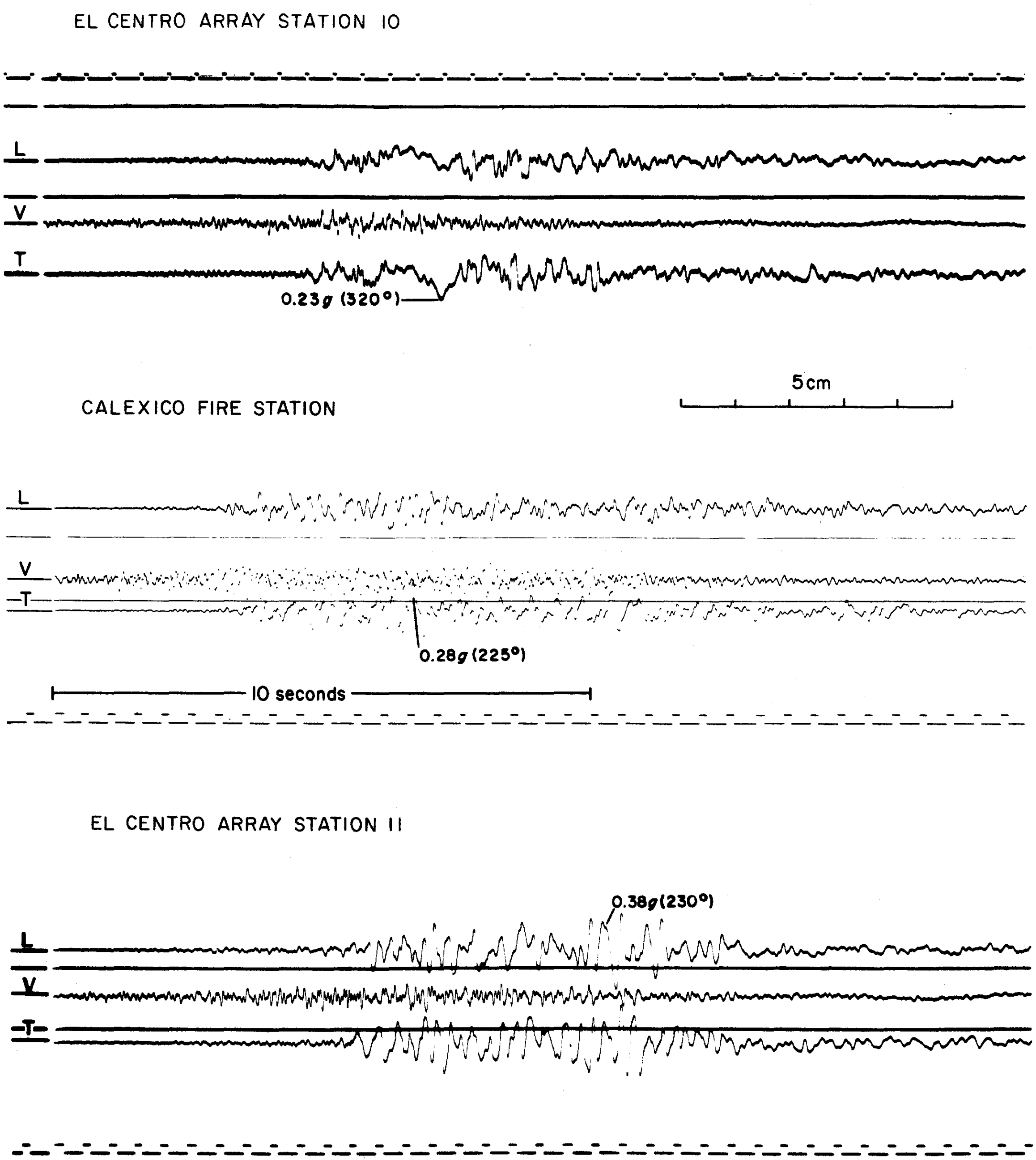


EL CENTRO DIFFERENTIAL ARRAY

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0.38g (230°)
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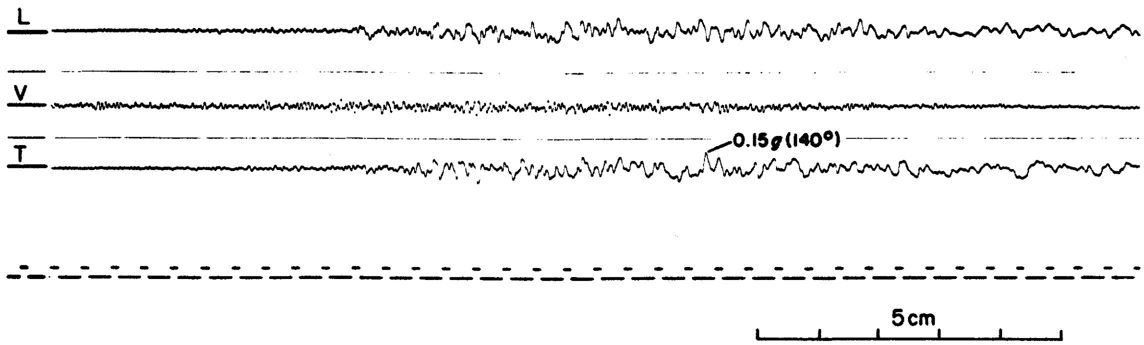
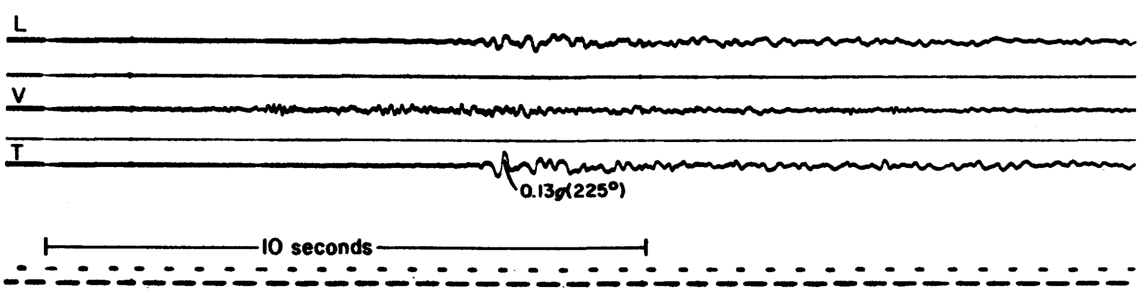
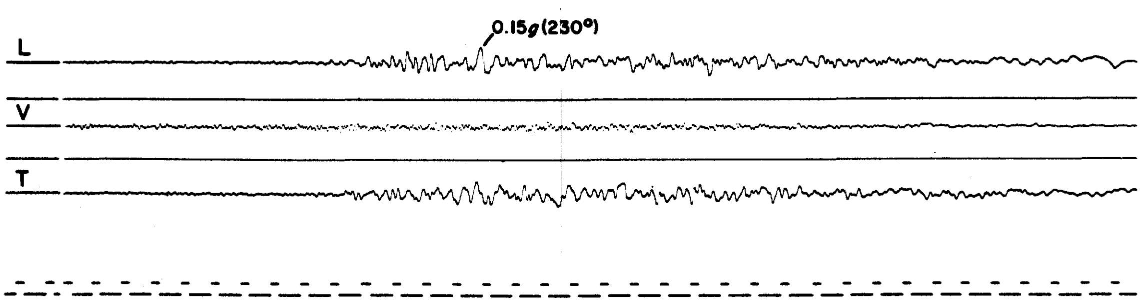
EL CENTRO ARRAY STATION 12



CALIPATRIA FIRE STATION



EL CENTRO ARRAY STATION 13



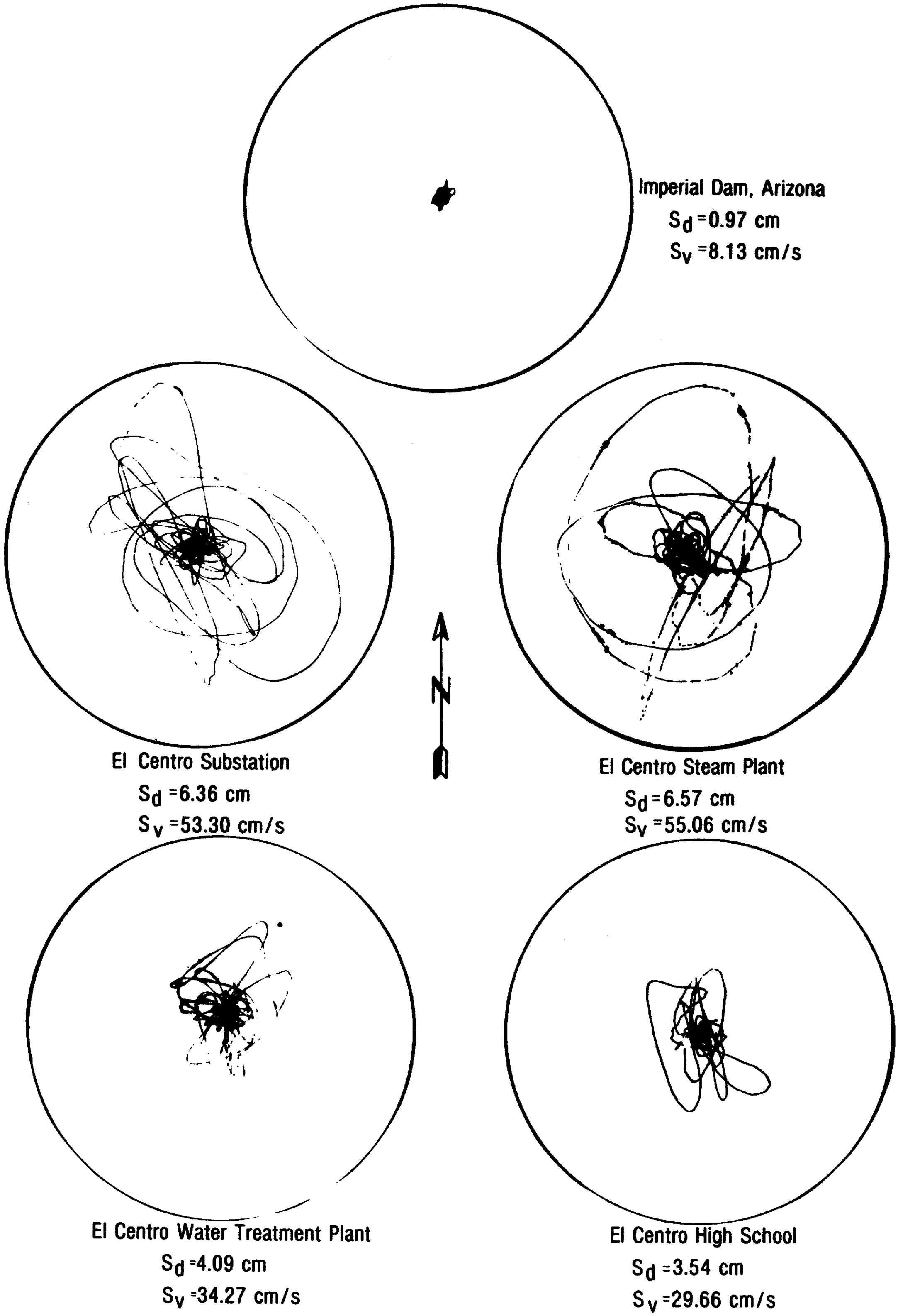


Figure 6 - USGS seismoscope records from the October 15, 1979 Imperial Valley earthquake (R. B. Matthiesen and R. L. Porcella, unpub. data, 1980).

SUMMARIES OF RECENT STRONG-MOTION REPORTS

RECONNAISSANCE REPORT IMPERIAL COUNTY, CALIFORNIA EARTHQUAKE OCTOBER 15, 1979

Gregg E. Brandow, Coordinator
David J. Leeds, Editor

This is a special report published and distributed by the Earthquake Engineering Research Institute (EERI) as part of the "Learning from Earthquakes Project." It presents observations of EERI reconnaissance team members who investigated the October 15, 1979 Imperial Valley, California earthquake. Members of the reconnaissance team did not visit the affected area as a group but as individuals investigating their own special fields of interest. The report is a collection of observations of these persons whose participation in the reconnaissance was made possible by their respective firms and agencies. The report covers the most interesting engineering aspects of this seismic event; it does not examine the socioeconomic ramifications of the earthquake, including impact on the public - a task that we hope will be undertaken by other investigators. Because most of the investigators are engineers, structural behavior is emphasized. Some other aspects, including geology, seismology, and soils of the affected area, are also described.

The strong-motion instrumentation program summarized here provides data that can be combined with other engineering data to perform in-depth studies of the severely damaged Imperial County Services Building (designed in 1968, completed 1971). The earthquake was a near replay of the May 18, 1940 event that provided the historic strong-motion accelerogram that has served as the classic for nearly 40 years. The equally high quality accelerograms written by the October 15, 1979 shock in an instrumental array crossing the fault may well become new classic models of strong ground motion for as long a time.

For the most part, the exact words, photographs, and diagrams submitted by the various authors are presented intact. Where the contributions duplicated one another, the editor has combined some of the material for brevity. Views expressed are those of the individual authors and not necessarily those of EERI, the report coordinator, or the editor.

Reference: 194 pages, published by and available from EERI (See Data Sources, this report).

THE RELATION OF SUSTAINED MAXIMUM GROUND ACCELERATION AND VELOCITY TO EARTHQUAKE INTENSITY AND MAGNITUDE

by Otto W. Nuttli

Sustained maximum ground acceleration and velocity are measures of the strongest prolonged, rather than peak, acceleration and velocity. This report contains the sustained maximum ground acceleration, velocity, and duration for the accelerograms contained in the California Institute of Technology collection, Parts A-Y. Correlations are presented between sustained maximum acceleration, velocity, and the product of acceleration and duration versus MM intensity. In order to compare earthquakes in the Western United States with earthquakes occurring in other parts of the world, relations are developed between the local and Richter magnitude scales and the more universal body-wave and surface-wave magnitude scales. The point at which ground acceleration and velocity decrease as a function of distance from the fault rupture and body-wave magnitude is determined for western United States, coastal California, and central United States earthquakes. The logarithm of the sustained maximum acceleration is shown to scale as 0.5 times the body-wave magnitude, and the logarithm of the sustained maximum velocity is shown to scale as the body-wave magnitude. The vertical components of ground acceleration and velocity are found to have very nearly one-half the amplitude of the larger of the two horizontal components of strong ground motion for western United States earthquakes. On the average, the peak ground acceleration is found to be 1.4 times the sustained maximum (3 cycles) ground acceleration, and the peak ground velocity 1.75 times the sustained maximum (3 cycles) ground velocity. The semi-empirical equations developed in this report can be used to estimate ground acceleration, velocity, and duration at a site if the earthquake magnitude and distance from the fault rupture are known, or if the site MM intensity is known.

Reference: Report 16, November 1979, request copies from Ellis Krinitzsky, Geotechnical Laboratory, U.S. Army Engineer Waterways Experiment Station, P.O. Box 631, Vicksburg, Miss. 39180.

* Inclusion of strong-motion information sources is intended as a service to our readers and does not imply endorsement of these reports by the U.S Geological Survey.

READING AND INTERPRETING STRONG-MOTION ACCELROGRAMS

by D. E. Hudson

In 1978 there were about 5,000 strong-motion accelerographs distributed very unevenly throughout the seismic regions of the world. In a typical year, these instruments will generate several dozen records of strong earthquake ground motion to be added to the several hundred important records already in existence. Nearly all of these accelerographs produce a record as an analog trace of acceleration versus time, in the form of either a photographic trace on film or paper, or a scratch on waxed paper.

This report explains to the nonspecialist in instrumentation and data processing the way in which the information contained in these analog traces can be as accurately and completely recovered as is feasible. The emphasis is on the mechanical-optical, photographic-recording accelerograph, which has been standard in the U.S. network for some 45 years. Most of the basic ideas and theory apply with only minor modifications to other types of recording, such as the waxed-paper system used in some standard Japanese accelerographs.

Currently under development are new generations of strong-motion instrumentation based on direct digital magnetic tape recording. As yet, few instruments of this type have been deployed in the field, and such digital magnetic tape recordings probably will not be widely available for several years. The method of reading information from digital magnetic tapes differs from the techniques used for analog traces and will require specialized data processing devices. Many of the problems of data correction, however, will be very similar to those discussed in the present report.

The analog photographic-trace, acceleration-time record of the current standard accelerograph is of special significance in that, by inspection and by simple scaling, it yields a great deal of information of immediate practical importance without the need for more elaborate data processing. Any engineer with a modest amount of special knowledge and experience will be able to learn much from such records. Part I of this report is devoted to this simplified type of data analysis using only dividers and scales without trace digitization or calculations. Part II shows how additional information of importance can be derived from the record by special data processing techniques. Because deploying and maintaining suitable instrumentation networks result in a direct cost of about $10,000 for each important strong-motion accelerogram, it is clear that a major data processing effort is justified in the interest of learning as much as possible from each record.

Reference: This volume is one of a series titled: Engineering Monographs on Earthquake Criteria, Structural Design, and Strong-Motion Records; it is published by and available from EERI (see Data Sources, this report).

AND FAULTING AND SEISMIC ENGINEERING

(January 1977 - September 1979)

by Kaye M. Walz

This bibliography provides a compilation of references for studies undertaken in the U.S. Geological Survey by the Branch of Ground Motion and Faulting and the Branch of Seismic Engineering during the period January 1977 to September 1979. A subject index, constructed primarily from title key words, and a junior-author index are included.

Studies conducted in the Branch of Ground Motion and Faulting are organized into three principal categories: fault studies, ground-motion studies, and regional seismic-network studies. Studies to be conducted during fiscal year 1980 are also summarized. In general, the fault studies are directed at developing an improved basis for interpreting surface-fault characteristics (including recurrence intervals) and their relation to local tectonics for an improved definition of the earthquake hazard associated with surface faulting. The ground-motion studies are divided into two principal groups: seismic zonation studies directed toward improved delineations of geographic variations in ground-shaking characteristics induced by earthquakes, and prediction methodology development for prediction of strong earthquake induced ground-shaking characteristics at specific sites of interest for earthquake resistant design. The regional seismic-network studies are concerned primarily with improved definitions of seismicity in Alaska and southern Nevada for purposes of earthquake hazard reduction and site selection for nuclear waste repositories, respectively.

The Branch of Seismic Engineering was established to conduct a national strong-motion program funded by the National Science Foundation. Principal goals of the program include the design, installation, and maintenance of a national network of instruments to record strong earthquake motions and the collection, processing, archival, and dissemination of the recorded data. The National Strong-Motion Data Center operated by the program provides data processing, archival, and dissemination facilities for several participating agencies including the U.S Army Corps of Engineers, Bureau of Reclamation, Federal Highway Administration, Veterans Administration, General Services Administration, Department of Energy, and the Metropolitan Water District of Southern California, California Department of Water Resources, California Department of Transportation, and Washington State Department of Highways.

Reference: Copies available from USGS (see Data Sources, this report).

GEOLOGIC DESCRIPTION OF SELECTED STRONG-MOTION ACCELEROGRAPH SITES

by B. L. Silverstein

One of the major tasks of the U.S. Geological Survey (USGS) with regard to seismic engineering is the collection and dissemination of strong-motion accelerograph records. In analyzing these records, certain information describing the instrument site is important: local geology, instrument housing (buildings, dams, bridges, instrument shelters); local topography; and proximity of an accelerograph to man-made structures that might influence the record. A series of reports that summarize the site information in the USGS files is being prepared. These reports describe local geologic conditions of selected sites and will cover strong-motion accelerograph sites in the western hemisphere. Station locations described in Parts III and IV include 20 in northern California, 5 in southern California, and 3 in Managua, Nicaragua.

Reference: U.S. Geological Survey Open-File Reports 79-1619 (Part III), 1979, 35 p. and 80-473 (Part IV), 1980, 26 p.

THE IMPERIAL VALLEY EARTHQUAKE, OCTOBER 15, 1979 DIGITIZATION AND PROCESSING OF ACCELEROGRAPH RECORDS

by A. G. Brady, V. Perez, and P. N. Mork

This data report documents digital magnetic tapes containing the results of processing the USGS strong-motion data from the Imperial Valley earthquake of October 15, 1979, reproduces the more important graphical results, and documents a tape containing digital recordings from the Northern Baja California strong-motion array.

This report is a follow-up of the preliminary summary by Porcella and Matthiesen (USGS Open-File Report 79-1654). Of the 30 mainshock accelerogram recordings from the network in the Imperial Valley, 22 of the 70-mm film records have been chosen for digitization, omitting the low-amplitude records with epicentral distances greater than 60 km. The 66 components have been processed for (a) uncorrected acceleration; (b) corrected acceleration, velocity, and displacement; and (c) response spectra. These results are available on two magnetic tapes (designated IV), available from Environmental Data and Information Service (see Data Sources, this report). Computer plots of the data contained on the tapes are provided, and the log-log plots of the Fourier amplitude spectra, calculated by the FFT algorithm, are also included.

Documentation of a tape containing the seven digital recordings from the Northern Baja California strong-motion array is included in an appendix. A description of the tape contents and format and reproductions of the computer plots of the records are taken directly from an unpublished manuscript provided by J. Brune and others at the University of California, San Diego. Copies of the tape are available from EDIS (see Data Sources, this report). The data on this tape will be processed using the techniques that produced the plots in this report, and a tape containing these processed data will be available from EDIS.

Reference: U.S. Geological Survey Open-file Report 80-703, 1980, 309 p.

STRONG-MOTION INFORMATION, DATA REPORTS, AND AVAILABILITY OF DIGITIZED DATA

U.S. STRONG-MOTION NETWORK DATA

A strong-motion information retrieval system (SMIRS) has been developed to provide up-to-date information about strong-motion records and the circumstances in which they were recorded. The system is accessible through a data terminal (30 cps, half duplex). The system is operational, but the information within it is incomplete and needs to be verified. A user's manual is available (Converse, 1978). To retrieve information, dial (415) 329-8600 and place the telephone handset into the terminal. When the carrier light comes on, press the "line-feed" key and wait for the computer to respond (two lines will be printed); type the following:

enter yourname SMIRS

Type the "enter" and "SMIRS" exactly as shown above, but replace yourname with your own name. The word "enter" is five lowercase characters followed by one space; your name is typed as one continuous character string and followed by one space; and "SMIRS" is five uppercase characters. Type the carriage-return key and then the line-feed key; then you will be given instructions.

The strong-motion records from the February 9, 1971 San Fernando, California, earthquake and most of the significant records prior to that event have been digitized by the California Institute of Technology (CIT) (Hudson, 1976). Processing and analysis of the data have been presented in a series of reports containing (1) uncorrected digital data, (2) corrected accelerations, velocities, and displacements, (3) response spectra, and (4) Fourier amplitude spectra. All of these data reports are available through the National Technical Information Service (NTIS, see Data Sources, this report).

The digitization and analysis of the records collected by the State of California Strong-Motion Instrumentation Program are being handled by the Office of Strong-Motion Studies (OSMS), California Division of Mines and Geology. When completed, reports on these analyses will be available from OSMS (see Data Sources, this report).

The digitized data from the CIT digitization program are available from the Environmental Data and Information Service (EDIS) and the National Information Service for Earthquake Engineering at the University of California, Berkeley (NISEE) (see Data Sources, this report). The magnetic tape digital data from subsequent years will be available from EDIS and NISEE at approximately the same time as the data reports are published.

References:

Converse, April, 1978, Strong-motion information retrieval system user's manual: U.S. Geological Survey Open-File Report, 79-289, 51 p.

Hudson, D. E., 1976, Strong-motion earthquake accelerograms - index volume: California Institute of Technology, EERI report 76-02, 72 p.

CALIFORNIA DIVISION OF MINES AND GEOLOGY STRONG-MOTION DATA

Processed strong-motion data from selected earthquakes are available from the California Division of Mines and Geology. The data have been prepared by the interim CDMG strong-motion data processing system. This system is composed of a series of programs that have been developed by the California Institute of Technology, the U.S. Geological Survey, and the California Division of Mines and Geology, with special emphasis on the handling of long-duration film records from multiple-channel central recording instruments.

The data are grouped by phase:

Phase I	Uncorrected accelerations
Phase II	Corrected accelerations, velocities, and displacements
Phase III	Response spectra

Each phase contains three-channel subgroups arranged by station. At the present time, data from the following earthquakes have been processed:

Santa Barbara earthquake of August 13, 1978

Station	Channels
UCSB Goleta	3
UCSB North Hall	9
Feitas Building	9

Imperial Valley earthquake of October 15, 1979

El Centro free-field	3
Imperial County Services Bldg.	13

The data are available on standard nine-track tapes, along with a microfiche copy of the tape contents. Interested parties should contact the CDMG Office of Strong-Motion Studies (see Data Sources, this report).

It is the policy of the CDMG to make all strong-motion record data promptly available to the public in a manner consistent with good data management. Requests for copies of records, personal access to record or data files, and copies of data files should be made to the Chief, Office of Strong-Motion Studies (OSMS), and should specify identity and medium of materials to be provided or reviewed. Desired access or delivery dates should be specific. When a request for copies of materials or personal access to files is received, OSMS staff will provide the requested material or will set an appointment time for personal review of files; the requestor will be notified immediately of any significant delay or other problems that prevent meeting the request. Charges for copying or other processing of materials will be based on the actual cost of producing and delivering the items, and OSMS will retain control of originals and master copies of all items.

FOREIGN STRONG-MOTION DATA

Because of the long history of close cooperation between the U.S. and the Central and South American strong-motion programs, much of the data from those programs are available from the same sources as the U.S. data (see below). Information about strong-motion data from the Western Hemisphere will be included in the Strong-Motion Information Retrieval System operated by the USGS.

The USGS does not attempt to obtain first-class copies of records from those foreign organizations that prepare data reports comparable to those prepared by the USGS. Abstracts of the data reports from such organizations are presented in this Seismic Engineering Program Report series, and through informal arrangements, copies of the data and records are made available.

EDIS/NOAA WORLDWIDE STRONG-MOTION DATA

A worldwide collection of strong-motion seismograms for dissemination to the scientific and engineering community is available from World Data Center A for Solid Earth Geophysics and the National Geophysical and Solar-Terrestrial Data Center (NGSDC). Countries contributing to the strong-motion data base include Australia, Italy, Japan, New Zealand, Rumania, U.S.S.R., and Yugoslavia. The U.S. Geological Survey has furnished records from its network of cooperative strong-motion stations, including those in Central and South America.

Copies of strong-motion records are available on 35-mm film, on 70-mm film chips, as paper copies, and as digitized data on punched cards or magnetic tape. A listing of most records can be obtained from the World Data Center A publication "Catalog of Seismograms and Strong-Motion Records, Report SE-6." This catalog can be ordered from NGSDC (EDIS/NOAA) for $2.00 (see Data Sources, this report).

The most significant strong-motion records recorded in the United States and Latin America between 1931 and 1971 have been copied on eight reels of 35-mm film (12x reduction) and 70-mm film chips (approximately 8x reduction). The film chips are available for $.50 per chip; longer records are continued on additional chips. The 35-mm film copies can be purchased for $20 per reel, the complete set of reels for $130.

Full-size paper copies (12 x 36 inches) are available for many of the events in the United States and Latin America at a cost of $1.50 per record. Other records are available as paper copies, but at a reduced scale.

Japan and Australia have supplied magnetic tapes of digitized data from stations located in the western Pacific Ocean (the Japanese Islands, New Guinea, and New Britain). A series of 400 U.S. strong-motion records (1933-1971) were digitized by the California Institute of Technology and are now available on six magnetic tapes. The U.S. Geological Survey is digitizing post-1971 records from its network; they have generated five tapes of strong-motion records recorded from 1967 to 1975 in the United States and Latin America (Chile, Nicaragua, San Salvador, and Mexico).

Other digitized data include punched cards containing strong-motion records from the March 4, 1977 earthquake in Rumania (recorded in Bucharest); the Gazli earthquake of May 17, 1976, in Uzbek, USSR; and three earthquakes in the New Madrid seismic zone (located in midcontinental United States) in 1975 and 1976.

Recent acquisitions include a magnetic tape of strong-motion records triggered by a swarm of earthquakes that occurred in northern Italy near the town of Friuli in 1976; these were compiled by the National Commission for Nuclear Energy and have been given to the Center for distribution.

A table listing all digitized strong-motion records available on magnetic tape may be obtained free of charge from EDIS/NOAA. Digitized strong-motion records may be purchased either in punched card format at $20 per record (including all three instrument components) or in tape format at $60 per tape.

Checks or money orders should be made payable to "Commerce/NOAA/NGSDC"; inquiries should be addressed to EDIS/NOAA (see Data Sources, this report). Phone: (303) 499-1000, ext. 6744; FTS phone 323-6477.

DATA SOURCES

For reports or information regarding strong-motion records and data, address inquiries to the appropriate agency listed below:

1. Branch of Distribution
   U.S. Geological Survey
   1200 South Eads Street
   Arlington, VA 22202

2. Earthquake Engineering Research Institute
   2620 Telegraph Avenue
   Berkeley, CA 94704

3. EDIS/NOAA
   National Geophysical and Solar-Terrestrial Data Center (D62)
   Boulder, CO 80302

4. National Technical Information Service
   U.S. Dept. of Commerce
   Springfield, VA 22151

5. NISEE/Computer Applications
   Davis Hall, UC Berkeley
   Berkeley, CA 94720.

6. Office of Strong-Motion Studies
   California Division of Mines and Geology
   2811 "O" Street
   Sacramento, CA 95816

7. Open-file Services Section
   Branch of Distribution
   U.S. Geological Survey
   Box 25425, Federal Center
   Denver, CO 80225

8. Seismic Engineering Branch
   U.S. Geological Survey
   345 Middlefield Road, MS 78
   Menlo Park, CA 94025.

ERRATA

Reference	Error	Correction
CIT; EERL S-M earthquake accelerograms, digitized & plotted data; vol II, III, IV; Part B; Record #037 (1966 Parkfield earthquake)	Temblor, Calif. No. 2 USGS Station No. 1097 35 45'07" N 120 15'52" W	Temblor, Calif. USGS Station No. 1438 35 42'36" N 120 10'12" W
same as above: vol I, II; Part C Record #041 (1971 San Fernando earthquake; Component direction- Pacoima Dam accelerogram)	L - S74W V - Down T - S16E	L - N76W V - Down T - S14W
USGS S-M Station No. 1250 Gilroy, Gavilan College (Component direction - all S-M records since Oct. 1972)	L - S67W V - Down T - S13E	L - S67W V - Down T - S23E
USGS S-M Station 2420 New Madrid, Missouri (Component direction- events of 6-13-75 and 3-24-76)	L - S19W V - Down T - S71E	L - West V - Down T - South
USGS S-M Station no. 181; Los Angeles, 640 Marengo, 1st floor (Component direction prior to 7-15-70)	L - N36W V - Down T - S54W	L - S54W V - Down T - S36E
NOTE: Since 7-15-70, the 1st floor (also 4th floor and roof) component directions are:		L - N36W V - Down T - S54W
USGS S-M Station No. 122; Glendale, California (Component direction - events of 4/8/68 and 2/9/71)	L - S70E V - Down T - S20W	L - S72E V - Down T - N18E
USGS S-M Station No. 125(828); Lake Hughes Array Station 1 (1A) Component direction:		
event 9/12/70	L - N21E V - Down T - N69W	L - S21W V - Down T - S69E
event 2/9/71	L - N21E V - Down T - S69E	L - S21W V - Down T - S69E

Table 1. - - *Summary of accelerograms recovered during September - December 1979*

Event	Station name (owner)[1]	Station coord.	S-t[2] (s)	Direction[3]	Max accl[4] (g)	Duration[5] (s)
12 May 1979 0203 UTC So. California 34.22N, 117.53W Magnitude 3.4	Sycamore Forest Sta Angeles Forest (USGS)	34.19° N 117.42° W	1.2		**	
27 June 1979- 12 September 1979 Central California Epicenter and magnitude unknown	New Hogan Dam (ACOE)	38.15° N 120.81° W	-			
	Crest station				**	
	Gallery station				**	
	Downstream station				**	
	Note: These records may be related to the Gilroy (Coyote Lake) earthquake of August 6, epicentral distance approx. 130 km.					
22 August 1979 0201 UTC So. California 33.72N, 116.83W Magnitude 4.1	Cranston Forest Station (USGS)	33.74° N 116.84° W	2.2		**	
3 September 1979 1144 UTC So. California 33.38N, 116.33W Magnitude 3.8	Rancho De Anza Anza-Borrego Park (USGS)	33.35° N 116.40° W	-	135° Up 045°	0.08 .02 .04	- - -
22 September 1979 0759 UTC So. Hawaii 19.35N, 155.07W Magnitude 5.5	Hilo, Hawaii Fish & Wildlife (USGS)†	19.731° N 155.096° W	6.2	180° Up 090°	.44 .18 .17	4.4 0.6 2.7
	Hilo, Hawaii Univ of Hawaii (USGS)†	19.707° N 155.083° W	-	265° Up 175°	.02 .03 .11	- - 1-peak
	Hilo Hawaii Sewage Plant (USGS)†	19.734° N 155.050° W	-		**	
	Honokaa, Hawaii Fire Station (USGS)†	20.081° N 155.465° W	-		**	
	Pahala, Hawaii Kau Hospital (USGS)†	19.20° N 155.47° W	-		**	

See footnotes at end of table.

Table 1. - - *Summary of accelerograms recovered during September - December 1979* - continued

Event	Station name (owner)[1]	Station coord.	S-t[2] (s)	Direction[3]	Max accl[4] (g)	Duration[5] (s)
22 September 1979 0759 UTC -continued-	Wahaula, Hawaii Visitor Center (USGS)†	19.33° N 155.03° W	-	145° Up 055°	0.04 .11 .04	- 1-peak -
	Note: Two additional records recovered at Wahaula and one additional record recovered at Hilo Fish and Wildlife; maximum acceleration less than 0.05 g					
15 October 1979 2316 UTC Imperial Valley, Ca 32.63N, 115.33W Magnitude 6.6	Blythe CDF Fire Station (CDMG)†	33.67° N 114.71° W	-		**	
	Bonds Corner Highways 98 & 115 (USGS)	32.693° N 115.338° W	2.4	230° Up 140°	.81 .47 .66	13.2 12.0 13.3
	Borrego Air Ranch Borrego Springs (USGS)	33.19° N 116.28° W	8.2		**	
	Brawley Airport Brawley (USGS)	32.988° N 115.509° W	6.3	315° Up 225°	.22 .18 .17	2.2 5.2 1.8
	Cabazon Post Office Cabazon (USGS)	33.92° N 116.78° W	-		**	
	Calexico Fire Sta Fifth & Mary (USGS)	32.669° N 115.492° W	3.2	315° Up 225°	.22 .21 .28	9.5 8.8 10.8
	Calipatria Fire Sta Calipatria (USGS)	33.13° N 115.52° W	7.4	315° Up 225°	.09 .07 .13	- - 1-peak
	Coachella Canal Station 1 (USGS)	33.64° N 116.08° W	-		**	
	Coachella Canal Station 4 (USGS)	33.36° N 115.59° W	8.5	135° Up 045°	.14 .04 .11	0.5 - 0.3
	Note: Anomalously high accelerations recorded at Coachella Canal Station 4 may be a result of structure response.					
	Coronado 1770 Ava del Mundo (CCO)	32.68° N 117.17° W	-		**	

See footnotes at end of table.

Table 1.--*Summary of accelerograms recovered during September - December 1979* - continued

Event	Station name (owner)[1]	Station coord.	S-t[2] (s)	Direction[3]	Max accl[4] (g)	Duration[5] (s)
15 October 1979 2316 UTC -continued-	Coronado 1780 Ava del Mundo (CCO)	32.68° N 117.17° W	-		**	
	El Capitan Dam Left Abutment (CDMG)	32.88° N 116.82° W	-		**	
	El Centro, Imperial County Services Bldg (CDMG)	32.793° N 115.564° W	5.0	360°	0.29	6
				Up	.19	
				090°	.32	
	El Centro, Imperial County Center (CDMG)	32.79° N 115.56° W	5.0	092°	.24	5
				Up	.27	
				002°	.24	
	El Centro array sta 1 Borchard Ranches (USGS)	32.960° N 115.319° W	6	230°	.15	3.1
				Up	.10	1-peak
				140°	.15	4.8
	El Centro array sta 2 Keystone Road (USGS)	32.916° N 115.366° W	6	230°	.43	5.7
				Up	.17	9.3
				140°	.33	9.2
	El Centro array sta 3 Pine Union School (USGS)	32.894° N 115.380° W	5.4	230°	.22	6.2
				Up	.15	5.6
				140°	.27	6.0
	El Centro array sta 4 2905 Anderson Road (USGS)	32.864° N 115.432° W	4.8*	230°	.38	6.5
				Up	.32	6.7
				140°	.61	6.8
	El Centro array sta 5 2801 James Road (USGS)	32.855° N 115.466° W	5.1	230°	.40	7.6
				Up	.71	5.6
				140°	.56	7.4
	El Centro array sta 6 551 Huston Road (USGS)	32.839° N 115.487° W	5*	230°	.45	7.9
				Up	1.74	6.2
				140°	.72	11.8
	El Centro array sta 7 Imperial Val College (USGS)	32.829° N 115.504° W	4.6	230°	.52	4.9
				Up	.65	5.5
				140°	.36	3.7
	El Centro array sta 8 95 E Cruickshank Road (USGS)	32.811° N 115.532° W	5*	230°	.50	6.9
				Up	.55	5.8
				140°	.64	6.9

See footnotes at end of table.

Table 1.--*Summary of accelerograms recovered during September - December 1979* - continued

Event	Station name (owner)[1]	Station coord.	S-t[2] (s)	Direction[3]	Max accl[4] (g)	Duration[5] (s)
15 October 1979	El Centro array sta 9	32.794° N	-	Down	0.38	4.7
2316 UTC	302 Commercial Avenue	115.549° W		360°	.40	7.4
-continued-	(USGS)			090°	.27	7.0
	El Centro array sta 10	32.780° N	4.9	050°	.20	5.2
	Community Hospital	115.567° W		Up	.15	2.2
	(USGS)			320°	.23	5.1
	El Centro array sta 11	32.752° N	5.6	230°	.38	6.5
	McCabe School	115.594° W		Up	.16	7.7
	(USGS)			140°	.38	7.0
	El Centro array sta 12	32.718° N	5.2	230°	.11	4.9
	907 Brockman Road	115.637° W		Up	.08	-
	(USGS)			140°	.15	3.8
	El Centro array sta 13	32.709° N	5.1	230°	.15	5.0
	Strobel Residence	115.683° W		Up	.06	-
	(USGS)			140°	.12	2.4
	El Centro diff array	32.796° N	5	360°	.51	10.2
	Dogwood Road	115.535° W		Up	.93	7.0
	(USGS)			270°	.37	7.0
	El Centro, Route I-8	32.773° N	-	360°	.32	7
	Meloland Overpass	115.448° W		Up	.23	
	(CDMG)			270°	.25	
	Holtville	32.812° N	4.1	315°	.22	7.5
	Post Office	115.377° W		Up	.31	7.0
	(USGS)			225°	.26	6.2
	Niland Fire Station	33.24° N	5.7	090°	.10	1-peak
	8071 Luxor Avenue	115.51° W		Up	.03	-
	(CDMG)			360°	.07	-
	Ocotillo Wells	33.14° N	7.5*	315°	.05	-
	Burro Bend Cafe	116.13° W		Up	.03	-
	(USGS)			225°	.04	-
	Palm Desert	33.76° N	-		**	
	Kiewit Building	116.41° W				
	(CDMG)					
	Palm Springs	33.84° N	-		**	
	Desert Hospital	116.51° W				
	(CDMG)					
	Parachute Test Site	32.93° N	7.0	315°	.20	1.5
	Imler Road	115.70° W		Up	.18	5.2
	(USGS)			225°	.11	1.4

e footnotes at end of table.

Table 1.--*Summary of accelerograms recovered during September - December 1979* - continued

Event	Station name (owner)[1]	Station coord.	S-t[2] (s)	Direction[3]	Max accl[4] (g)	Duration[5] (s)
15 October 1979	Plaster City	32.79° N	5*	135°	0.07	-
2316 UTC	Storehouse	115.86° W		Up	.03	-
-continued-	(USGS)			045°	.05	-
	Rancho de Anza	33.35° N	-		**	
	Anza Borrego Park	116.40° W				
	(USGS)					
	Riverside, County	33.98° N	-		**	
	Administrative Bldg	117.37° W				
	(CDMG)					
	Salton Sea	33.18° N	3.5*	315°	.06	-
	Wildlife Refuge	115.62° W		Up	.03	-
	(USGS)			225°	.06	-
	San Diego	32.72° N	-		**	
	SDGE Office Bldg	117.16° W				
	(CDMG)					
	Superstition Mountain	32.955° N	7.2*	135°	.21	1.1
	USAF Camera Site	115.823° W		Up	.09	-
	(USGS)			045°	.12	0.6
	Westmorland	33.04° N	5.4	175°	.11	1-peak
	Fire Station	115.62° W		Up	.08	-
	(CDMG)			085°	.08	-
	Winterhaven	32.74° N	-	180°	.05	-
	Sheriff Substation	114.64° W		Up	.02	-
	(CDMG)			090°	.07	-
	Yuma, Arizona	32.73° N	-		**	
	Strand Avenue	114.70° W				
	(USGS)					
	Note: See table 2 for aftershock data from 22 USGS Imperial Valley accelerograph stations within 30 km of the main-shock surface rupture.					
19 October 1979	Lytle Creek	34.26° N	0.9	315°	.07	-
1222 UTC	Mann Residence	117.50° W		Up	.04	-
So. California	(USGS)			225°	.16	0.4
34.14N, 117.57W						
Magnitude 4.1	Big Pines Station	34.38° N	1.4	300°	.05	-
	Angeles Forest	117.69° W		Up	.03	-
	(USGS)			210°	.07	-

See footnotes at end of table.

Table 1. - - *Summary of accelerograms recovered during September - December 1979* - continued

Event	Station name (owner)[1]	Station coord.	S-t[2] (s)	Direction[3]	Max accl[4] (g)	Duration[5] (s)
19 October 1979 1222 UTC -continued-	Lone Pine Canyon Clyde Ranch (USGS)	34.32° N 117.57° W	1.7		**	
20 October 1979 2052 UTC Imperial Valley, Ca Epicenter and magnitude unknown	Salton Sea Wildlife Refuge (USGS)	33.18° N 115.62° W	0.9		**	
21 October 1979 0459 UTC Imperial Valley, Ca Epicenter and magnitude unknown	Salton Sea Wildlife Refuge (USGS)	33.18° N 115.62° W	1		**	
29 October 1979 0542 UTC Imperial Valley, Ca Epicenter and magnitude unknown	Salton Sea Wildlife Refuge (USGS)	33.18° N 115.62° W	1.1		**	
14 November 1979 2300 UTC Cent. Alaska 61.35N, 150.13W Magnitude 5.1	Anchorage, Alaska Westward Hotel (USGS) Basement level Roof (22nd) level	61.22° N 149.89° W	5.3		 ** **	
	Note: One additional event recorded at this station between 10 September 1979 and 17 May 1980; maximum acceleration less than 0.05 g at basement level.					
20 November 1979 0655 UTC So. California 34.15N, 116.98W Magnitude 4.2	Sunnymead Merchant Farms (USGS)	33.95° N 117.50° W	3.9		**	
21 December 1979 2040 UTC Imperial Valley, Ca 32.45N, 115.20W Magnitude 4.8	El Centro array sta 3 Pine Union School (USGS)	32.894° N 115.380° W	6.8		**	
	El Centro array sta 11 McCabe School (USGS)	32.752° N 115.594° W	-	230° Up 140°	0.04 .02 .07	- - -
	Bonds Corner Highways 98 and 115 (USGS)	32.693° N 115.338° W	4.1	230° Up 140°	.12 .05 .10	0.2 - 1-peak

See footnotes at end of table.

Table 1. - - *Summary of accelerograms recovered during September - December 1979* - continued

Event	Station name (owner)[1]	Station coord.	S-t[2] (s)	Direction[3]	Max accl[4] (g)	Duration[5] (s)
21 December 1979 2040 UTC -continued-	Calexico Fire Station Fifth and Mary (USGS)	32.669° N 115.492° W	5		**	
	Holtville Post Office (USGS)†	32.812° N 115.377° W	6.0	315° Up 225°	.05 .02 .05	- - -
	Parachute Test Site Imler Road (USGS)†	32.93° N 115.70° W	2.3		**	
	El Centro diff array Dogwood Road (USGS)†	32.796° N 115.535° W	-	360° Up 270°	.06 .03 .08	- - -
	El Centro array sta 9 302 Commercial Avenue (USGS)†	32.794° N 115.549° W	-	Down 360° 090°	.02 .07 .07	- - -

Note: One additional record recovered at array station 9; maximum acceleration less than 0.05 g.

1 Station owner code:
ACOE - U.S. Army Corps of Engineers
CCO - City of Coronado
CDMG - California Division of Mines and Geology
USGS - U.S. Geological Survey
† - WWVB time code not legible or instrument not equipped with a radio receiver; correlation of accelerogram with event may be questionable.

2 S-wave arrival minus trigger time (S - t) interval.
* S - t interval is questionable.

3 Direction of case acceleration for upward trace deflection on accelerogram. Horizontal components are listed as azimuth in degrees clockwise from north; compass direction indicates orientations are based on a reference north. Vertical components are listed as "up" or "down."

4 Peak acceleration recorded at ground level on one vertical and two orthogonal horizontal components.
** Denotes maximum acceleration is less than 0.05 g at ground level or less than 0.10 g at upper floors of buildings.

5 Duration between first and last peaks of acceleration greater than 0.10 g.

Table 2 - *Summary of USGS accelerograph aftershock data from the October 15, 1979 Imperial Valley earthquake*

[From R. B. Matthiesen and R. L. Porcella, unpub. data, 1980]

Trigger time [1] Day/hr/min/sec (UTC)	S - t interval[2] (s)	Acceleration		
		Direction[3]	Maximum[4] (g)	Duration[5] (s)
		Bonds Corner, Hiway 98 & 115		
288/23:18:49	-	230°	0.029	-
		up	.012	-
		140°	.129	-
288/23:19:33	3.1*	230°	.129	1-peak
		up	.052	-
		140°	.074	-
289/05:49:26	-	230°	.023	-
		up	.012	-
		140°	.023	-
289/06:20:03	-	230°	.029	-
		up	.012	-
		140°	.046	-
		Brawley Airport		
288/23:17:28	2.8*	315°	0.017	-
		up	.016	-
		225°	.011	-
288/23:17:38	2.8*	315°	.006	-
		up	.016	-
		225°	.006	-
288/23:17:47	2.3*	315°	.006	-
		up	.011	-
		225°	.006	-
288/23:18:05	2.4*	315°	.011	-
		up	.016	-
		225°	.011	-
288/23:19:35	4.3	315°	.057	-
		up	.043	-
		225°	.045	-

See footnotes at end of table

Table 2 - *Summary of USGS accelerograph aftershock data* - continued

Trigger time[1] Day/hr/min/sec (UTC)	S - t interval[2] (s)	Acceleration		
		Direction[3]	Maximum[4] (g)	Duration[5] (s)
		Brawley Airport - continued		
288/23:20:30	2.1*	315°	0.023	-
		up	.011	-
		225°	.023	-
288/23:20:36	2.3*	315°	.017	-
		up	.016	-
		225°	.017	-
288/23:25:58	0.8	315°	.023	-
		up	.011	-
		255°	.017	-
288/23:28:20	2.2	315°	.017	-
		up	.011	-
		225°	.011	-
288/23:32:31	2.2	315°	.023	-
		up	.016	-
		225°	.023	-
288/23:53:07	1.9	315°	.080	-
		up	.027	-
		225°	.056	-
288/23:55:07	2.5	315°	.074	-
		up	.027	-
		225°	.062	-
289/00:02:44	1.7	315°	.040	-
		up	016	-
		225°	.056	-
289/00:22:16	2.1	315°	.170	0.1
		up	.096	1-peak
		225°	.169	0.1
289/00:22:34	2.3*	315°	.023	-
		up	.005	-
		225°	.011	-

See footnotes at end of table

Table 2 - *Summary of USGS accelerograph aftershock data* - continued

Trigger time[1] Day/hr/min/sec (UTC)	S - t interval[2] (s)	Acceleration		
		Direction[3]	Maximum[4] (g)	Duration[5] (s)
		Brawley Airport - continued		
289/00:27:55	2.1	315°	0.028	-
		up	.032	-
		255°	.034	-
289/00:28:04	2.2*	315°	.011	-
		up	.016	-
		225°	.011	-
289/00:30:03	2.1	315°	.028	-
		up	.016	-
		225°	.023	-
289/00:51:02	-	315°	.017	-
		up	.011	-
		225°	.034	-
________	2.6	315°	.085	-
		up	.032	-
		225°	.090	-
289/01:07:14	2.2	315°	.028	-
		up	.027	-
		225°	.028	-
289/01:14:24	2.4	315°	.102	1-peak
		up	.053	-
		225°	.079	-
289/01:39:06	2.6	315°	.080	-
		up	.027	-
		225°	.028	-
289/01:41:36	2.2	315°	.023	-
		up	.005	-
		225°	.017	-
289/01:42:09	2.2*	315°	.051	-
		up	.027	-
		225°	.028	-

See footnotes at end of table

Table 2 - *Summary of USGS accelerograph aftershock data* - continued

Trigger time [1] Day/hr/min/sec (UTC)	S - t interval [2] (s)	Acceleration		
		Direction [3]	Maximum [4] (g)	Duration [5] (s)
		Brawley Airport - continued		
289/01:42:41	2.0*	315°	0.011	-
		up	.005	-
		225°	.011	-
289/02:00:08	2.0	315°	.034	-
		up	.011	-
		225°	.023	-
289/02:00:23	2.4*	315°	.011	-
		up	.005	-
		225°	.006	-
289/02:36:37	2.4	315°	.045	-
		up	.016	-
		225°	.034	-
289/03:10:49	2.1	315°	.176	0.3
		up	.101	1-peak
		225°	.164	0.3
Note: Film supply ran out during this event; new film supply installed approximately 290/15:30 (63 unrecorded triggerings).				
290/16:17:38	2.1	315°	0.017	-
		up	.011	-
		225°	.011	-
290/19:03:05	1.3	315°	.168	-
		up	.037	-
		225°	.090	-
290/19:14:41	2.6	315°	.034	-
		up	.016	-
		225°	.040	-
290/22:45:35	1.7	315°	.273	0.9
		up	.160	1.5
		225°	.266	1.2
290/22:45:56	1.8*	315°	.097	1-peak
		up	.101	1-peak
		225°	.198	0.2

See footnotes at end of table

Table 2 - *Summary of USGS accelerograph aftershock data* - continued

Trigger time[1] Day/hr/min/sec (UTC)	S - t interval[2] (s)	Acceleration Direction[3]	Maximum[4] (g)	Duration[5] (s)
		Brawley Airport - continued		
290/22:47:08	1.9*	315°	0.057	-
		up	.043	-
		225°	.073	-
290/22:47:13	1.9*	315°	.057	-
		up	.027	-
		225°	.051	-
291/02:19:14	1.5	315°	.034	0.1
		up	.021	-
		225°	.068	0.1
291/12:42:24	1.4	315°	.176	-
		up	.037	-
		225°	.119	-
291/14:56:21	1.8	315°	.028	-
		up	.027	-
		225°	.028	-
		Calexico Fire Station		
288/23:18:03	1.9*	315°	0.011	-
		up	.006	-
		225°	.010	-
288/23:19:33	2.9	315°	.011	-
		up	.034	-
		225°	.097	1-peak
288/23:21:52	3.7	315°	.005	-
		up	.006	-
		225°	.005	-
289/05:49:18	3.7	315°	.016	-
		up	.011	-
		225°	.015	-

See footnotes at end of table

Table 2 - *Summary of USGS accelerograph aftershock data* - continued

Trigger time[1] Day/hr/min/sec (UTC)	S - t interval[2] (s)	Acceleration		
		Direction[3]	Maximum[4] (g)	Duration[5] (s)
		Calexico Fire Station - continued		
289/06:58:51	5.5	315°	0.033	-
		up	.022	-
		225°	.026	-
289/11:47:02	-	315°	.005	-
		up	.011	-
		225°	.010	-
		Calipatria Fire Station		
289/00:22:19	-	315°	0.005	-
		up	.027	-
		225°	.011	-
289/00:27:58	-	315°	.005	-
		up	.022	-
		225°	.006	-
289/01:14:27	4.1	315°	.022	-
		up	.022	-
		225°	.017	
289/03:10:52	4.2	315°	.016	-
		up	.022	-
		225°	.011	-
289/03:39:39	4.1	315°	.022	-
		up	.043	-
		225°	.028	-
289/04:32:58	-	315°	.005	-
		up	.011	-
		225°	.006	-
289/05:49:15	-	315°	.022	-
		up	.038	-
		255°	.028	-

See footnotes at end of table

Table 2 - *Summary of USGS accelerograph aftershock data* - continued

Trigger time[1] Day/hr/min/sec (UTC)	S - t interval[2] (s)	Acceleration		
		Direction[3]	Maximum[4] (g)	Duration[5] (s)
		Calipatria Fire Station - continued		
289/06:19:53	4.4	315°	0.032	-
		up	.081	-
		225°	.039	-
289/06:55:28	3.5	315°	.016	-
		up	.016	-
		225°	.034	-
289/06:58:47	3.6	315°	.124	0.6
		up	.177	2.5
		225°	.168	-
________	-	315°	.016	-
		up	.005	-
		225°	.010	-

Note: Film supply ran out during this event; new film supply installed approximately 291/23:30 (8 unrecorded triggerings).

		El Centro array station 1, Borchard Ranch		
288/23:19:35	4.0	230°	0.060	-
		up	.033	-
		140°	.033	-
(289/05:49:20)	-	230°	.027	-
		up	.017	-
		140°	.027	-
289/06:19:53	3.3	230°	.043	-
		up	.055	-
		140°	.049	-
289/06:58:48	3.8	230°	.114	1-peak
		up	.066	-
		140°	.093	-
289/23:16:38	0.9	230°	.054	-
		up	.022	-
		140°	.038	-

See footnotes at end of table

Table 2 - *Summary of USGS accelerograph aftershock data* - continued

Trigger time[1] Day/hr/min/sec (UTC)	S - t interval[2] (s)	Acceleration		
		Direction[3]	Maximum[4] (g)	Duration[5] (s)
		El Centro array station 1 - continued		
290/08:38:56	-	230°	0.082	-
		up	.033	-
		140°	.066	-
290/22:45:40	1.4	230°	.054	-
		up	.017	-
		149°	.038	-
		El Centro array station 2, Keystone Road		
288/23:19:34	3.6	230°	0.089	-
		up	.054	-
		150°	.154	1-peak
(289/00:22:18)	3.3	230°	.018	-
		up	.016	-
		140°	.017	-
289/05:49:15	2.5	230°	.089	-
		up	.048	-
		140°	.086	-
289/06:19:53	3.5	230°	.083	-
		up	.065	-
		140°	.080	-
289/06:58:48	4.0	230°	.113	1-peak
		up	.151	0.1
		140°	.091	-
289/11:47:00	3.8	230°	.024	-
		up	.027	-
		140°	.017	-
289/12:01:53	-	230°	.101	1-peak
		up	.016	-
		140°	.046	-

See footnotes at end of table

Table 2 - *Summary of USGS accelerograph aftershock data* - continued

Trigger time[1] Day/hr/min/sec (UTC)	S - t interval[2] (s)	Acceleration Direction[3]	Maximum[4] (g)	Duration[5] (s)
		El Centro array station 2 - continued		
289/23:16:36	3.2	230°	0.137	0.2
		up	.027	-
		140°	.069	-
290/22:45:40	1.7	230°	.089	-
		up	.022	-
		140°	.057	-
		El Centro array station 3, Pine Union School		
288/23:19:33	3.5	230°	0.103	1-peak
		up	.039	-
		140°	.147	0.4
________	2.8	230°	.054	-
		up	.022	-
		140°	.071	-
________	3.4	230°	.043	-
		up	.022	-
		140°	.033	-
________	4.0	230°	.120	1-peak
		up	.067	-
		140°	.130	1-peak
________	3.6	230°	.022	-
		up	.006	-
		140°	.011	-
________	3.3	230°	.043	-
		up	.017	-
		140°	.038	-
________	3.2	230°	.054	-
		up	.017	-
		140°	.049	-

See footnotes at end of table

Table 2 - *Summary of USGS accelerograph aftershock data* - continued

Trigger time[1] Day/hr/min/sec (UTC)	S - t interval[2] (s)	Acceleration		
		Direction[3]	Maximum[4] (g)	Duration[5] (s)
		El Centro array station 3 - continued		
———	2.8	230°	0.190	1-peak
		up	.034	-
		140°	.054	-
		El Centro array station 4, Anderson Road		
288/23:19:33	3.1	230°	0.168	0.7
		up	.079	-
		140°	.237	0.5
289/05:49:15	2.7	230°	.053	-
		up	.045	-
		140°	.047	-
289/06:19:59	-	230°	.032	-
		up	.022	-
		140°	.026	-
289/06:58:50	1.4	230°	.063	-
		up	.039	-
		140°	.032	-
289/11:47:03	-	230°	.021	-
		up	.017	-
		140°	.021	-
		El Centro array station 5, James Road		
288/23:17:37	2.4*	230°	0.054	-
		up	.058	-
		140°	.059	-
288/23:17:42	2.5*	230°	.042	-
		up	.035	-
		140°	.041	-

See footnote at end of table

Table 2 - *Summary of USGS accelerograph aftershock data* - continued

Trigger time[1] Day/hr/min/sec (UTC)	S - t interval[2] (s)	Acceleration Direction[3]	Maximum[4] (g)	Duration[5] (s)
		El Centro array station 5 - continued		
288/23:18:21	2.7*	230°	0.048	-
		up	.023	-
		140°	.047	-
288/23:19:33	3.2	230°	.286	0.2
		up	.117	1-peak
		140°	.235	0.3
288/23:55:07	2.9	230°	.060	-
		up	.041	-
		140°	.059	-
289/01:00:16	2.9	230°	.101	1-peak
		up	.041	-
		140°	.147	0.3
289/01:00:31	2.9*	230°	.030	-
		up	.018	-
		140°	.029	-
289/01:14:25	2.7	230°	.083	-
		up	.035	-
		140°	.059	-
289/04:25:32	-	230°	.196	0.3
		up	.029	-
		140°	.200	0.2
289/05:49:13	3.3	230°	.143	1.8
		up	.058	-
		140°	.171	1.0
289/06:04:42	2.7	230°	.048	-
		up	.018	-
		140°	.041	-
289/06:13:53	2.6	230°	.077	-
		up	.023	-
		140°	.053	-

See footnotes at end of table

Table 2 - *Summary of USGS accelerograph aftershock data* - continued

Trigger time[1] Day/hr/min/sec (UTC)	S - t interval[2] (s)	Acceleration		
		Direction[3]	Maximum[4] (g)	Duration[5] (s)
		El Centro array station 5 - continued		
289/06:19:53	2.1	230°	0.095	1-peak
		up	.029	-
		140°	.094	-
289/06:58:48	3.6	230°	.161	1.4
		up	.053	-
		140°	.118	1.2
289/07:23:27	2.7	230°	.048	-
		up	.053	-
		140°	.073	-
289/09:33:55	2.7	230°	.042	-
		up	.018	-
		140°	.047	-
289/09:36:48	-	230°	.077	-
		up	.018	-
		140°	.047	-
289/09:37:09	2.7*	230°	.030	-
		up	.018	-
		140°	.035	-
289/12:01:47	2.3	230°	.137	0.1
		up	.041	-
		140°	.153	0.4
289/17:22:58	2.5	230°	.119	1-peak
		up	.047	-
		140°	.076	-
		El Centro array station 6, Huston Road		
288/23:17:37	2.3*	230°	0.043	-
		up	.046	-
		140°	.051	-

See footnotes at end of table

Table 2 - *Summary of USGS accelerograph aftershock data* - continued

Trigger time[1] Day/hr/min/sec (UTC)	S - t interval[2] (s)	Acceleration		
		Direction[3]	Maximum[4] (g)	Duration[5] (s)
		El Centro array station 6 - continued		
288/23:17:41	2.6*	230°	0.097	1-peak
		up	.143	0.1
		140°	.085	-
288/23:18:21	2.6*	230°	.102	1-peak
		up	.051	-
		140°	.079	-
288/23:18:42	2.6*	230°	.167	0.2
		up	.069	-
		140°	.113	1-peak
288/23:18:57	2.4*	230°	.022	-
		up	.029	-
		140°	.034	-
288/23:19:01	2.8*	230°	.016	-
		up	.011	-
		140°	.006	-
288/23:19:20	2.8*	230°	.011	-
		up	.011	-
		140°	.006	-
288/23:19:32	2.9*	230°	.263	1.3
		up	.080	-
		140°	.175	0.3
________	2.4	230°	.048	-
		up	.017	-
		140°	.023	-
________	3.0*	230°	.022	-
		up	.011	-
		140°	.011	-
________	2.4*	230°	.022	-
		up	.011	-
		140°	.028	-

See footnotes at end of table

Table 2 - *Summary of USGS accelerograph aftershock data* - continued

Trigger time[1] Day/hr/min/sec (UTC)	S - t interval[2] (s)	Acceleration		
		Direction[3]	Maximum[4] (g)	Duration[5] (s)
		El Centro array station 6 - continued		
________	2.5	230°	0.022	-
		up	.029	-
		140°	.023	-
________	2.5*	230°	.070	-
		up	.023	-
		140°	.040	-
________	3.0*	230°	.032	-
		up	.006	-
		140°	.023	-
________	2.9	230°	.043	-
		up	.023	-
		140°	.034	-
________	2.2	230°	.059	-
		up	.034	-
		140°	.034	-
________	2.0*	230°	.016	-
		up	.006	-
		140°	.011	-
________	3.0*	230°	.016	-
		up	.017	-
		140°	.028	-
________	2.6	230°	.011	-
		up	.023	-
		140°	.011	-
________	3.2*	230°	.054	-
		up	.017	-
		140°	.040	-
(288/23:55:07)	2.7	230°	.124	0.5
		up	.040	-
		140°	.079	-

See footnotes at end of table

Table 2 - *Summary of USGS accelerograph aftershock data* - continued

Trigger time[1] Day/hr/min/sec (UTC)	S - t interval[2] (s)	Acceleration		
		Direction[3]	Maximum[4] (g)	Duration[5] (s)
		El Centro array station 6 - continued		
(288/23:56:32)	2.2	230°	0.054	-
		up	.017	-
		140°	.028	-
(288/23:56:54)	2.0*	230°	.016	-
		up	.011	-
		140°	.023	-
(288/23:57:05)	2.8*	230°	.005	-
		up	.011	-
		140°	.006	-
________	2.9	230°	.075	-
		up	.034	-
		140°	.040	-
________	2.9*	230°	.027	-
		up	.011	-
		140°	.017	-
________	2.7	230°	.048	-
		up	.034	-
		140°	.023	-
________	2.9*	230°	.102	1-peak
		up	.040	-
		140°	.068	-
________	3.0*	230°	.183	0.6
		up	.057	-
		140°	.169	1-peak
________	3.0*	230°	.054	-
		up	.023	-
		140°	.034	-
________	2.9	230°	.043	-
		up	.029	-
		140°	.028	-

ee footnote at end of table

Table 2 - *Summary of USGS accelerograph aftershock data* - continued

Trigger time[1] Day/hr/min/sec (UTC)	S - t interval[2] (s)	Acceleration		
		Direction[3]	Maximum[4] (g)	Duration[5] (s)
		El Centro array station 6 - continued		
________	3.0	230°	0.188	0.7
		up	.069	-
		140°	.175	0.4
________	3.3*	230°	.032	-
		up	.011	-
		140°	.028	-
________	2.8	230°	.081	-
		up	.017	-
		140°	.045	-
________	3.1	230°	.038	-
		up	.011	-
		140°	.034	-
________	1.0	230°	.070	-
		up	.029	-
		140°	.068	-
________	2.9	230°	.032	-
		up	.023	-
		140°	.040	-
________	2.9	230°	.027	-
		up	.017	-
		140°	.028	-
Note: Film supply ran out during this event; new film supply installed approximately 290/06:00 (23 unrecorded triggerings).				
290/11:57:56	1.9	230°	0.043	-
		up	.017	-
		140°	.119	1-peak
291/13:20:29	2.7	230°	.022	-
		up	.017	-
		140°	.023	-

See footnotes at end of table

Table 2 - *Summary of USGS accelerograph aftershock data* - continued

Trigger time[1] Day/hr/min/sec (UTC)	S - t interval[2] (s)	Acceleration Direction[3] (g)	Maximum[4] (s)	Duration[5]
		El Centro array station 6 - continued		
291/16:24:40	2.7	230°	0.027	-
		up	.011	-
		140°	.011	-
293/14:52:57	2.6	230°	.086	-
		up	.023	-
		140°	.085	-
294/18:18:00	3.0	230°	.016	-
		up	.023	-
		140°	.028	-
		El Centro array station 7, Imperial Valley College		
(288/23:17:40)	2.1*	230°	0.043	-
		up	.038	-
		140°	.042	-
(288/23:18:19	2.1*	230°	.033	-
		up	.016	-
		140°	.047	-
(288/23:18:40)	2.1*	230°	.027	-
		up	.011	-
		140°	.021	-
(288/23:19:35)	2.6	230°	.230	0.4
		up	.086	-
		140°	.147	0.3
________	2.1	230°	.118	1-peak
		up	.032	-
		140°	.079	-
________	1.8	230°	.080	-
		up	.038	-
		140°	.084	-

See footnotes at end of table

Table 2 - *Summary of USGS accelerograph aftershock data* - continued

Trigger time[1] Day/hr/min/sec (UTC)	S - t interval[2] (s)	Acceleration		
		Direction[3]	Maximum[4] (g)	Duration[5] (s)
		El Centro array station 7 - continued		
________	2.7	230°	0.059	-
		up	.022	-
		140°	.058	-
________	2.2	230°	.048	-
		up	.027	-
		140°	.053	-
________	-	230°	.037	-
		up	.016	-
		140°	.026	-
________	2.5	230°	.193	0.8
		up	.038	-
		140°	.111	0.4
________	2.7*	230°	.080	-
		up	.022	-
		140°	.063	-
________	1.9	239°	.080	-
		up	.027	-
		140°	.068	-
		El Centro array station 8, Cruickshank Road		
288/23:17:38	2.2*	230°	0.021	-
		up	.026	-
		140°	.044	-
288/23:17:42	2.3*	230°	.026	-
		up	.015	-
		140°	.078	-
288/23:18:21	2.3*	230°	.026	-
		up	.010	-
		140°	.028	-

See footnotes at end of table

Table 2 - *Summary of USGS accelerograph aftershock data* - continued

Trigger time[1] Day/hr/min/sec (UTC)	S - t interval[2] (s)	Acceleration		
		Direction[3]	Maximum[4] (g)	Duration[5] (s)
	El Centro array station 8 - continued			
288/23:18:43	2.0	230° up 140°	0.042 .015 .039	- - -
288/23:19:33	2.7*	230° up 140°	.157 .056 .128	0.2 - 0.8
288/23:25:56	2.8	230° up 140°	.026 .026 .022	- - -
________	2.2	230° up 140°	.131 .072 .117	0.7 - 1-peak
________	2.7*	230° up 140°	.126 .021 .017	- - -
________	2.9	230° up 140°	.047 .036 .028	- - -
289/05:17:12	2.5	230° up 140°	.010 .015 .022	- - -
289/05:49:14	2.7	230° up 140°	.141 .046 .100	1.2 - 1-peak
289/05:50:25	3.0*	230° up 140°	.010 .010 .006	- - -
289/06:04:42	2.7	230° up 140°	.047 .026 .033	- - -

See footnotes at end of table

Table 2 - *Summary of USGS accelerograph aftershock data* - continued

Trigger time [1] Day/hr/min/sec (UTC)	S - t interval[2] (s)	Acceleration		
		Direction[3]	Maximum[4] (g)	Duration[5] (s)
		El Centro array station 8 - continued		
289/06:05:17	3.0*	230°	0.010	-
		up	.010	-
		140°	.011	-
289/06:19:53	3.0	230°	.068	-
		up	.031	-
		140°	.050	-
(289/06:58:49)	3.0	230°	.052	-
		up	.031	-
		140°	.067	-

Note: Film supply ran out during this event; new film supply installed approximately 289/23:00 (4 unrecorded triggerings).

		El Centro array station 9, Commercial Avenue		
(288/23:17:41)	3.0	down	0.023	-
		360°	.019	-
		090°	.020	-
(288/23:18:20)	2.8	down	.016	-
		360°	.007	-
		090°	.012	-
(288/23:18:41)	2.9	down	.008	-
		380°	.030	-
		090°	.035	-
(288/23:19:30)	3.6*	down	.078	-
		390°	.086	-
		090°	133	0.6
(288/23:19:57)	3.6*	down	.004	-
		390°	.007	-
		090°	.004	-
________	-	down	.002	-
		390°	.006	-
		090°	.014	-

See footnotes at end of table

Table 2 - *Summary of USGS accelerograph aftershock data* - continued

Trigger time[1] Day/hr/min/sec (UTC)	S - t interval[2] (s)	Acceleration		
		Direction[3]	Maximum[4] (g)	Duration[5] (s)
		El Centro array station 9 - continued		
________	-	down	0.010	-
		390°	.022	-
		090°	.031	-
________	-	down	.002	-
		390°	.010	-
		090°	.012	-
________	-	down	.010	-
		390°	.013	-
		090°	.023	-
________	-	down	.002	-
		390°	.007	-
		090°	.010	-
		El Centro array station 10, Community Hospital		
(288/23:19:35)	2.7	050°	0.055	-
		up	.026	-
		320°	.051	-
________	1.3	050°	.016	-
		up	.016	-
		320°	.027	-
________	1.6	050°	.011	-
		up	.011	-
		320°	.011	-
________	2.7*	050°	.011	-
		up	.005	-
		320°	.010	-
________	2.3	050°	.038	-
		up	.047	-
		320°	.036	-

See footnotes at end of table

Table 2 - *Summary of USGS accelerograph aftershock data* - continued

Trigger time[1] Day/hr/min/sec (UTC)	S - t interval[2] (s)	Acceleration		
		Direction[3]	Maximum[4] (g)	Duration[5] (s)
		El Centro array station 10 - continued		
________	1.5	050°	0.033	-
		up	.021	-
		320°	.036	-
________	-	050°	.033	-
		up	.021	-
		320°	.046	-
________	0.9	050°	.027	-
		up	.021	-
		320°	.041	-
		El Centro array station 11, McCabe School		
288/23:19:33	3.4	230°	0.192	0.5
		up	.063	-
		140°	.098	1-peak
289/05:49:18	1.6	230°	.026	-
		up	.016	-
		140°	.027	-
289/06:19:57	1.6	230°	.047	-
		up	.016	-
		140°	.043	-
289/06:58:50	4.4	230°	.036	-
		up	.026	-
		140°	.033	-
		Ed Centro array station 12, Brockman Road		

Note: Film supply ran out during main event; new film supply installed approximately 289/22:00 (2 unrecorded triggerings).

See footnotes at end of table

Table 2 - *Summary of USGS accelerograph aftershock data* - continued

Trigger time[1] Day/hr/min/sec (UTC)	S - t interval[2] (s)	Acceleration Direction[3]	Maximum[4] (g)	Duration[5] (s)
El Centro array station 13 - Strobel Residence				
(289/06:58:59)	-	230°	0.022	-
		up	.022	-
		140°	.022	-
El Centro differential array - Dogwood Road				
(288/23:17:41)	2.5*	360°	0.047	-
		up	.016	-
		270°	.045	-
(288/23:18:20)	2.4*	360°	.021	-
		up	.016	-
		270°	.028	-
(288/23:18:42)	2.1	360°	.047	-
		up	.022	-
		270°	.051	-
(288/23:19:35)	2.8*	360°	.146	0.9
		up	.103	1-peak
		270°	.147	0.5
________	2.2	360°	.021	-
		up	.016	-
		270°	.011	-
________	1.8*	360°	.036	-
		up	.022	-
		270°	.028	-
________	2.9	360°	.010	-
		up	.022	-
		270°	.028	-
________	2.8	360°	.047	-
		up	.049	-
		270°	.045	-

See footnotes at end of table

Table 2 - *Summary of USGS accelerograph aftershock data* - continued

Trigger time[1] Day/hr/min/sec (UTC)	S - t interval[2] (s)	Acceleration		
		Direction[3]	Maximum[4] (g)	Duration[5] (s)
		El Centro differential array - continued		
________	2.6	360°	0.010	-
		up	.011	-
		270°	.011	-
________	2.8*	360°	.016	-
		up	.022	-
		270°	.011	-
________	3.1*	360°	.010	-
		up	.022	-
		270°	.011	-
________	2.2	360°	.068	-
		up	.043	-
		270°	.107	1-peak
________	3.0	360°	.068	-
		up	.027	-
		270°	.073	-
________	3.7	360°	.089	-
		up	.049	-
		270°	.102	1-peak
________	3.0	360°	.083	-
		up	.027	-
		270°	.079	-
________	3.0	360°	.120	0.1
		up	.119	0.3
		270°	.107	1-peak
________	3.1*	360°	.036	-
		up	.022	-
		270°	.023	-
________	2.7	360°	.010	-
		up	.022	-
		270°	.011	-

See footnotes at end of table

Table 2 - *Summary of USGS accelerograph aftershock data* - continued

Trigger time[1] Day/hr/min/sec (UTC)	S - t interval[2] (s)	Acceleration		
		Direction[3]	Maximum[4] (g)	Duration[5] (s)
		El Centro differential array - continued		
______	2.8	360°	0.005	-
		up	.005	-
		270°	.006	-
______	2.7	360°	.021	-
		up	.016	-
		270°	.017	-
______	3.0	360°	.026	-
		up	.038	-
		270°	.062	-
______	2.8	360°	.016	-
		up	.038	-
		270°	.017	-
______	2.6	360°	.010	-
		up	.005	-
		270°	.011	-
		Holtville Post Office		
(288/23:18:43)	2.5	315°	0.026	-
		up	.011	-
		225°	.037	-
(288/23:19:33)	2.7*	315°	.264	0.3
		up	.042	-
		225°	.116	0.4
______	3.6	315°	.016	-
		up	.011	-
		225°	.016	-
______	4.1	315°	.016	-
		up	.011	-
		225°	.016	-

See footnotes at end of table

Table 2 - *Summary of USGS accelerograph aftershock data* - continued

Trigger time[1] Day/hr/min/sec (UTC)	S - t interval[2] (s)	Acceleration		
		Direction[3]	Maximum[4] (g)	Duration[5] (s)
		Holtville Post Office - continued		
________	3.0	315°	0.026	-
		up	.026	-
		225°	.037	-
________	4.0	315°	.047	-
		up	.042	-
		225°	.048	-
________	4.4	315°	.047	-
		up	.032	-
		225°	.058	-
________	-	315°	.026	-
		up	.021	-
		225°	.021	-
		Parachute Test Site		
________	4.5	315°	0.042	-
		up	.025	-
		225°	.048	-
________	-	315°	.005	-
		up	.010	-
		225°	.005	-
________	1.1	315°	.016	-
		up	.025	-
		225°	.021	-
________	2.9	315°	.011	-
		up	.010	-
		225°	.011	-
________	3.0	315°	.016	-
		up	.015	-
		225°	.021	-

See footnotes at end of table

Table 2 - *Summary of USGS accelerograph aftershock data* - continued

Trigger time[1] Day/hr/min/sec (UTC)	S - t interval[2] (s)	Acceleration Direction[3]	Maximum[4] (g)	Duration[5] (s)
		Parachute Test Site - continued		
________	2.7	315°	0.068	-
		up	.051	-
		225°	.063	-
________	-	315°	.021	-
		up	.015	-
		225°	.021	-
________	2.1	315°	.026	-
		up	.040	-
		225°	.021	-
________	2.9	315°	.047	-
		up	.051	-
		225°	.063	-
________	1.1	315°	.042	-
		up	.015	-
		225°	.026	-
________	2.7	315°	.147	2.5
		up	.076	-
		225°	.116	2.5
________	2.6*	315°	.011	-
		up	.020	-
		225°	.016	-
________	-	315°	.016	-
		up	.010	-
		225°	.021	-
________	-	315°	.005	-
		up	.015	-
		225°	.005	-
________	-	315°	.011	-
		up	.010	-
		225°	.005	-

See footnotes at end of table

Table 2 - *Summary of USGS accelerograph aftershock data* - continued

Trigger time[1] Day/hr/min/sec (UTC)	S - t interval[2] (s)	Acceleration		
		Direction[3]	Maximum[4] (g)	Duration[5] (s)
		Parachute Test Site - continued		
________	2.2	315°	0.032	-
		up	.020	-
		225°	.026	-
________	-	315°	.021	-
		up	.015	-
		225°	.021	-
________	3.4	315°	.074	-
		up	.035	-
		225°	.112	1-peak
		Salton Sea Wildlife Refuge		
288/23:17:26	0.7*	315°	0.103	1-peak
		up	.060	-
		225°	.115	1-peak
289/06:19:02	1.4	315°	.103	1-peak
		up	.076	-
		225°	.098	1-peak
289/06:19:55	3.9*	315°	.022	-
		up	.011	-
		225°	.016	-
289/06:58:48	3.1	315°	.082	-
		up	.038	-
		225°	.071	-
289/23:16:41	-	315°	.016	-
		up	.011	-
		225°	.016	-
290/09:17:24	1.4	315°	.027	-
		up	.043	-
		225°	.049	-
290/22:45:40	0.7	315°	.027	-
		up	.011	-
		225°	.022	-

See footnotes at end of table

Table 2 - *Summary of USGS accelerograph aftershock data* - continued

Trigger time[1] Day/hr/min/sec (UTC)	S - t interval[2] (s)	Acceleration		
		Direction[3]	Maximum[4] (g)	Duration[5] (s)
		Salton Sea Wildlife Refuge - continued		
291/00:29:49	1.3	315°	0.016	-
		up	.011	-
		225°	.027	-
291/02:14:50	1.6	315°	.016	-
		up	.011	-
		225°	.022	-
		Superstition Mountain, USAF Camera Site		
289/03:39:44	-	315°	0.021	-
		up	.011	-
		225°	.020	-
289/06:58:49	2.4	135°	.031	-
		up	.021	-
		045°	.025	-

[1] Trigger time listed in parentheses is questionable, whereas line indicates trigger time could not be determined. Event origin time is equal to the trigger time minus the trigger-delay and triggering-wave travel times.

[2] S-wave arrival minus trigger time (S - t) interval. Dash indicates S - t or S - P time was not determined, often because instrument triggered late.
* S-wave arrival minus P-wave arrival time (S - P) interval.

[3] Direction of case acceleration for upward trace deflection on accelerogram. Horizontal components are listed as azimuth in degrees clockwise from north; vertical components are listed as "up" or "down."

[4] Peak acceleration recorded at ground level on one vertical and two orthogonal horizontal components.

[5] Duration between first and last peaks of acceleration greater than 0.10 g.

Table 3 - *Seismoscope data, Imperial Valley earthquake of October 15, 1979*

[From R. B. Matthiesen and R. L. Porcella, unpub. data, 1980]

Station identification: Name (Data source)	Station identification: Coord.	Epicentral distance[2] (km)	S_v[3] (cm/s)	S_d[4] (cm)
El Centro High School (USGS)	32.79° N 115.56° W	27 [8]	29.7	3.5
El Centro Steam Plant (USGS)	32.80° N 115.54° W	26 [5]	55.1	6.6
El Centro Substation[1] (USGS)	32.794° N 115.549° W	27 [6]	53.3	6.4
El Centro Water Plant (USGS)	32.77° N 115.56° W	26 [10]	34.3	4.1
Imperial Dam (USGS)	32.88° N 114.47° W	85 [89]	8.1	1.0

[1] Same site as accelerograph station 117, El Centro array station 9.

[2] Station distance from epicenter at 32.64° N and 115.33° W. Bracketed number is distance from the nearest point on the 1979 Imperial fault trace, which is assumed to extend from 32.94° N, 115.54° W to 32.72° N, 115.40° W.

[3] Relative velocity response spectrum ordinate (Hudson and Cloud, 1967).

[4] Relative displacement response spectrum ordinate (Hudson and Cloud, 1967).

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