U.S. STRONG MOTION PROGRAMS

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SUMMARY

Safeguarding life and property from the destructive effects of earthquakes is a major national as well as world-wide problem. Since the most widespread destructive effects of earthquakes are due to strong shaking, either directly through shaking-induced structural damage, or indirectly through shaking-induced ground failures, effective programs to measure strong ground motions generated by earthquakes are vital to national as well as international efforts to reduce earthquake hazards. Strong-motion programs in the United States are supported by a number of federal and state agencies with coordination provided by a national program operated by the United States Geological Survey and supported by the National Science Foundation. The cooperative national program is designed to collect, analyze, and disseminate structural response and ground motion data. Agencies developing centers to process strong-motion data include U.S. Geological Survey, the California Division of Mines and Geology, the University of Southern California, and Stanford University. Automatic digitization procedures and interactive software being developed at the centers permit rapid processing and dissemination of the data to interested researchers. The extreme importance of obtaining strong-motion data at distances less than 40 kilometers from large (M>7) earthquakes provides an urgent need for international cooperative efforts to acquire and disseminate near-field strong-motion data.

INTRODUCTION

Earthquake strong motion data provide the basis for design of critical structures as well as the basis for research on fundamental problems related to engineering design, earthquake processes, and internal structure of the earth. Consequently, effective programs to record strong motions generated by large earthquakes are vital to national as well as international efforts designed to reduce earthquake hazards.

Presently, few strong-motion data exist for large (M>7) earthquakes at distances less than forty kilometers even though several such damaging earthquakes occur each year in different parts of the world. This lack of crucial data is due to inadequate instrumentation and defines an urgent need for expanding both national and international programs to collect and disseminate near-fault strong-motion data. Detailed recommendations for program expansion in the United States have been developed by Matthiesen (1978). Recommendations for increased international efforts have been developed by the International Workshop on Strong-Motion Earthquake Instrument Arrays (Iwan, 1978). Acquisition and dissemination of the necessary data will depend in part upon successful implementation of recommendations similar to those suggested in these reports. This paper briefly summarizes existing strong-motion programs in the United States and data centers involved with the processing and dissemination of strong-motion data.

STRONG-MOTION PROGRAMS

Strong-motion instrumentation programs in the United States are supported by a number of federal, state, and local agencies with varying degrees of coordination provided by a national program operated by the United States Geological Survey with funding provided under the Earthquake Hazard Reduction Act of 1977. The national program began with the installation of 51 standard accelerographs following the disastrous 1933 Long Beach earthquake in southern California. Since that time the number of strong-motion instrument locations in the United States (Fig. 1) has increased substantially with a number of federal and state agencies initiating programs as a result of the 1964 Alaska and 1971 San Fernando, California earthquakes.

Instrumentation programs currently being conducted at the federal level on a reimbursable basis by the U.S. Geological Survey include: Corps of Engineers (250 instruments installed on 70 dams, 55 of which are maintained by USGS and 15 by COE, with plans for 150 additional instruments to be installed), Bureau of Reclamation (34 instruments installed on 16 dams maintained by USGS with plans for 4 dams with downhole systems to be installed), Federal Highway Administration (four multi-channel systems installed on bridges), Veterans Administration (66 instruments installed at hospital sites and five multi-channel systems installed in buildings), and small programs for the General Services Administration and the Department of Energy.

Instrumentation owned and operated by the U.S. Geological Survey with support from the National Science Foundation include 273 instruments, 255 of which are installed to measure strong ground motion and 17 installed to measure building response. These instruments are located in southern California (90 instruments), northern California (52 instruments), the Pacific Northwest (16 instruments), the Mississippi Valley (17 instruments), Alaska (33 instruments), Hawaii (15 instruments), and Puerto Rico (6 instruments). An additional 250 seismoscopes are also maintained (170 in California and 80 in Alaska). A network of 80 strong-motion accelerographs are being installed with NSF support in the Los Angeles, California area by the University of Southern California and a network of 20 accelerographs is operated by California Institute of Technology in the area of Pasadena, California.

The principal instrumentation program being conducted at the state level with state funding is the California Strong Motion Instrumentation Program. This program is one of the largest in the U.S. with over 400 instruments (43 structures) currently installed and plans to install over 1000 instruments. This program is independent of other U.S. strong-motion programs but network planning and data processing are closely coordinated with the national program.

Other state and local instrumentation programs operated on a reimbursable basis by the U.S. Geological Survey include: Metropolitan Water District of Southern California (25 instruments), California Department of Water Resources (60 instruments maintained cooperatively), California Department of Transportation (4 multi-channel analog systems installed on bridges), and the Washington Department of Highways (3 multi-channel digital systems installed on bridges).

Local instrumentation programs operated and funded by the host agency include: Los Angeles Department of Water and Power, United Water Conservation District, Los Angeles County Flood Control District, and a number of other small programs initiated primarily by public utility commissions and local building regulations. (More than 225 buildings of six stories or more are instrumented in the U.S. with most of these being a result of the Los Angeles Building Code passed in 1965, Rojahn and Matthiesen, 1977.)

Instrumentation objectives of the various programs vary from regulatory monitoring to basic research, with instrumentation guidelines prepared for buildings (Rojahn and Matthiesen, 1977), bridges (Raggett and Rojahn, 1978) and dams (Bolt and Hudson, 1975). More extensive guidelines for dams are presently being compiled (Rojahn, pers. comm., 1980). Details on established networks are available in published reports for central and eastern United States (Porcella, 1978), Imperial Valley, California (Porcella, 1978), central California (Porcella, 1979), Alaska (Porcella, 1979), and Hawaii (Porcella, 1977).

The most common type of strong-motion instrument utilized by the programs for measurement of ground motion and in some cases building response is a self-triggering tri-axial analog accelerograph designed to record signals up to 1 g on 70 mm photographic film. The system has a dynamic range of about 55 db at a sensitivity of 1.8 cm/g, a useable frequency bandwidth of about 0.06-35 Hz, and a natural frequency of 20-25 Hz with critical damping 60-70 percent. Many of the recently installed systems are also equipped to record an external time standard.

Other instruments utilized include both analog and digital multichannel systems for measurement of ground motion in drill holes, and measurement of the responses of buildings, dams, and bridges. A summary of specifications for typical systems is provided by Iwan (1978) and Hudson (1979). With the improvements in field reliability, digital event recorders are becoming more useful.

Centers in the U.S. established to process strong-motion data are located at the U.S. Geological Survey in Menlo Park, California, the California Division of Mines and Geology in Sacramento, California, the University of Southern California, Los Angeles, California and Stanford University, Stanford, California. These centers utilize laser-scan automatic digitization procedures to process the analog film records. These procedures together with interactive computer software permit rapid processing and dissemination of the data to interested researchers.

Current information about strong-motion data available in the western hemisphere can be easily accessed via the Strong Motion Information Retrieval Systems developed at the National Strong Motion Data Center in Menlo Park, California (Converse, 1978). The system provides users with information on data characteristics, recording environment, and archive location via computer terminal and telephone (415-329-8600). Digital and analog copies of the more significant strong-motion records collected in the United States are available from the National Geophysical and Solar Terrestrial Data Center (D62) in Boulder, Colorado, 80302 and the National Information Service for Earthquake Engineering, California Institute of Technology, Pasadena, California. (Analog copies are available on 35 or 70 mm film chips, and on paper; digital copies are available on punched cards and magnetic tape.) Two recent data sets of considerable significance to earthquake engineering are those collected from the Coyote Lake, California earthquake of August 6, 1979 (Porcella et al., 1979) and the Imperial Valley, California earthquake of October 15, 1979 (Porcella and Matthiesen, 1979). Each of the earthquakes yielded significant sets of near-field strong ground motion data from linear accelerograph arrays (Figs. 2 and 3) as well as data on the response and failure process of modern engineered structures (Figs. 2 and 3).

The Coyote Lake earthquake (M5.7) initiated at a depth of 9 km on the Calaveras fault, showed very small strike-slip displacements (less than 5 mm) along the ground surface for a distance of about 5-6 km, yielded more than 54 free-field accelerograph records at distances from 0.1 km to 114 km, and produced more than 22 recordings of building response mostly at distances greater than 40 km. The damage from this event in nearby communities was relatively minor, but the strong-motion data should prove especially useful for inferring the characteristics of the earthquake rupture process, the nature of near-field earthquake motions, and the influence of geology on strong ground motion.

The Imperial Valley earthquake (M6.4) occurred on a portion of the Imperial and Brawley faults that ruptured during the 1940 Imperial Valley Earthquake (M7.0). The Imperial Valley earthquake initiated at a depth of about 15 km on the Imperial fault, resulted in both strike-slip and dip-slip surface displacements (max. 55 and 20 cm, respectively), produced 33 free-field records in the U.S. and several others in northern Mexico (11 of these records were within 9 km of the fault), and yielded detailed recordings documenting the failure process of a six-story building (Rojahn and Ragsdale, 1980), the response of a highway overpass, and differential short-period ground motions. Comparison of the famous 1940 El Centro accelerogram with that obtained on a similar instrument at the same location (Fig. 4) shows that the 1979 event generated ground motions with similar peak amplitudes but substantially shorter durations. Peak horizontal accelerations recorded within 1 km of the surface rupture for the 1979 event range from 0.65 g to 0.72 g; the maximum peak vertical acceleration recorded was 1.74 g. Data from this earthquake should prove especially useful for studies of the response of engineered structures, the nature of near-field ground motions and comparative studies with the 1940 Imperial Valley earthquake.

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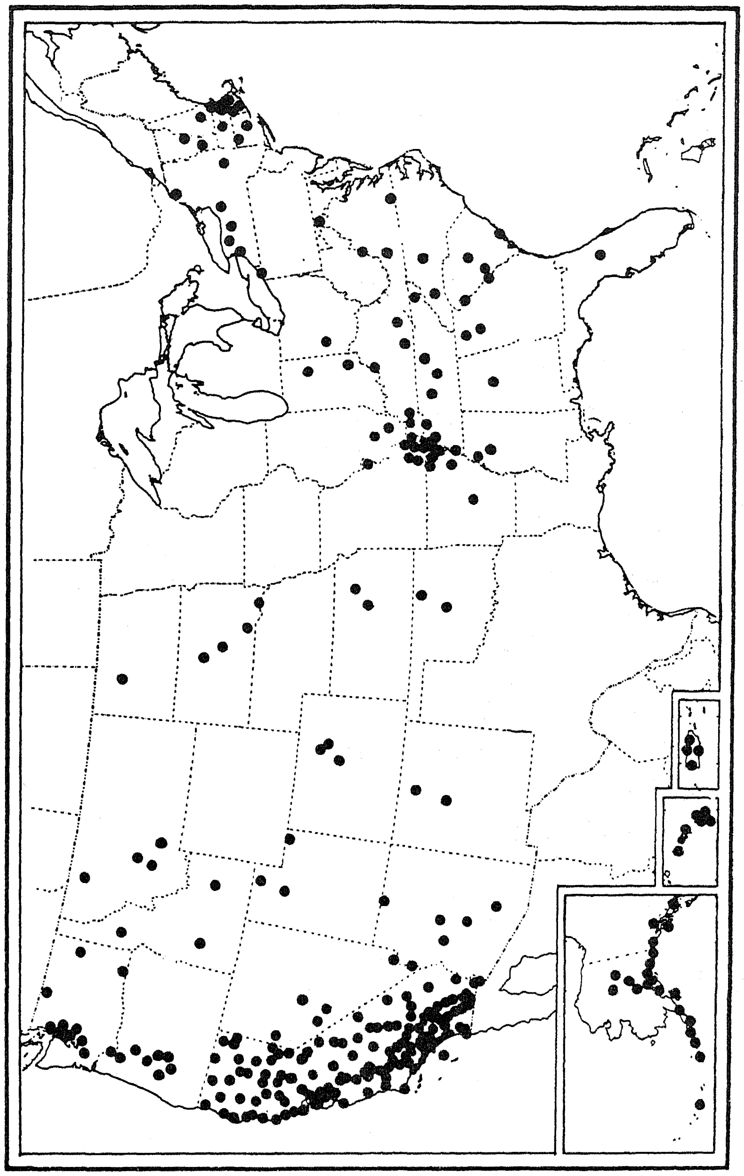

Figure 1. Location of strong-motion accelerographs in the United States (Matthiesen, 1978).

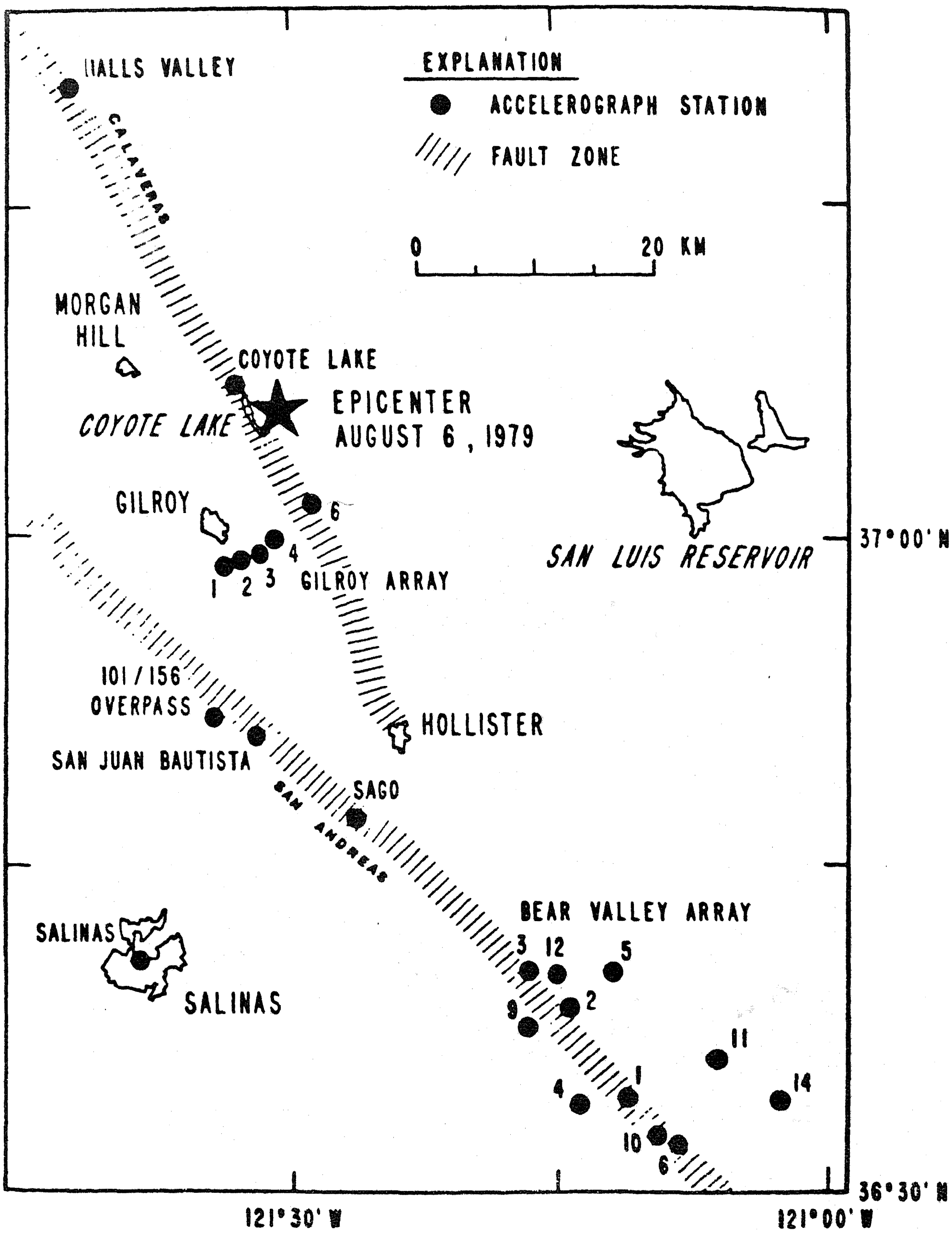

Figure 2. Location map of instrumentation arrays and stations close to epicenter of the Coyote Lake earthquake (Porcella <u>et al</u>., 1979).