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GUERRERO, MEXICO STRONG MOTION ARRAY

John G. Anderson[1] and Roberto Quaas[2]

[1] Seismological Laboratory, Makay School of Mines, University of Nevada-Reno, Reno, Nevada 89557-0047, USA.

[2] Instituto de Ingeniería, Universidad Nacional Autónoma de México, Apartado 70-472, Coyoacán 04510, México D.F.

SUMMARY

A strong motion array, consisting of 29 digital accelerographs, installed on hard rock sites in Guerrero and neighboring states, México, is presented in this paper. The purpose of the network is to record near-field ground motions from great earthquakes. The array was brought into operation in 1985, shortly before the September earthquakes, and has produced more than 300 accelerograms from at least 130 different earthquakes with magnitudes ranging between 2.2 and 8.1.

INTRODUCTION

Planning for the Guerrero array began after the International Workshops on Strong-Motion Earthquake Instrumentation Arrays held in Honolulu, Hawaii, in 1978. The main objective of this network is to record near field ground motions from great earthquakes along the Mexican subduction zone. In particular the Michoacan and Guerrero seismic gaps were the original targets of the array. The instrumentation, site selection, installation and operation of the Guerrero strong motion accelerograph array has been a joint project of the Institute of Geophysics and Planetary Physics, University of California, San Diego and the Instituto de Ingeniería of the Universidad Nacional Autónoma de México, UNAM, with support by the National Science Foundation. Since March 1988, the operation is a joint effort between the Seismology Laboratory, Makay School of Mines of the University of Nevada-Reno and the Instituto de Ingeniería, UNAM.

ARRAY CHARACTERISTICS

The network, shown on the map of Fig. 1, consists of 29 digital accelerograph stations. Most of the stations are located along the coast, covering all the state of Guerrero and part of Michoacan. Some sites are installed inland, with a group of instruments located on a line between Acapulco and Mexico City. The array layout was designed to obtain accelerograms from the anticipated rupture of the Guerrero seismic gap (Ref. 1). The last time this gap had large earthquakes was around the turn of the century (1899, 1908, 1909, 1911). Thus it represents a very likely location for a next large earthquake in Mexico. Given the high overall seismicity of Mexico (over 40 events with M) 7 since 1900), we believe that the Guerrero gap is one of the most likely places in the world to record accelerations from a major earthquake. A list of all the stations of the array, geographic coordinates, instrument type and geology at each site, is given in Table 1.

There are other locations along the Mexican subduction zone that also have the possibility of producing a large earthquake. At the time the array was designed, there had not been any large earthquakes in the Michoacan gap (Ref. 1), and we placed a small number of stations within this gap. East of the Guerrero gap, a similar situation exists. The eastern limit of the Guerrero gap is defined by the rupture zone of the 1957 Acapulco earthquake. Considering that 31 years have passed since that event, a recurrence of an earthquake there is a possibility.

Most of the stations were installed on solid rock. Each station is formed of a metal box with two compartments, built into a concrete pier and firmly anchored to the underlying rock by means of four steel bars. One of the compartments holds the batteries and regulators, and the other the accelerograph and clock. A 9 m high guyed tower close to the pier, supports the solar panels above the surrounding vegetation.

The three types of instruments installed are DSA-1, PDR-1 and DCA-333. These are digital strong motion accelerographs, operated with batteries and record on magnetic tape. The sampling rate is 200 sps, 100 for the DCA-333, and word length of 12 bits. The trigger of the DSA-1 and PDR-1 is vertical and omnidirectional for the DCA-333. The sensors are triaxial 2 g, forced-ballance accelerometer with a natural frequency of 50 Hz, 30 Hz for the DCA-333 and damping of .7 of critical. As an external time reference the OMEGA navigation system is used. Time marks are recorded simultaneously with the three acceleration components. The timing signal is received by one unit (OMEGAREC) and decoded by another unit (OMEGAFACE) inside the steel box. A timing precision of ± 10 msec is attainable.

The first 8 stations were installed in February 1985 and 12 more in August. 20 instruments were operating when the September 1985 earthquakes occurred. These stations produced an important set of high quality accelerograms (Ref. 2). The rest of the stations were finished by the end of 1985 and beginning of 1986.

The routine operation and maintenance of the array is done through periodic visits to the stations each two months. In general the whole array has performed very well with few failures, mostly related to the environment. Data playback from the digital cassettes is accomplished through an IBM-PC based data reduction system (Ref. 3). Features of the system are off-line processing, time efficiency, availability and low cost. Output of the system includes high quality plots, floppy disks with binary or ASCII files for distribution of data, and serial communication with a main-frame computer for more advanced processing.

DATA SUMMARY

The vast amount of high quality data so far obtained by the array, is the result of a high seismicity in general in the vicinity of the array and a efficient operation, which has prevented data loss related to instrument malfunction. During 1985 we recorded 75 accelerograms from at least 39 different earthquakes. In 1986, which was the first year of complete operation, 83 records from at least 48 earthquakes were obtained. 1987 produced 116 accelerograms from at least 44 events. In January to March 1988, 25 accelerograms have been recorded. Event magnitudes range from 2.2 to 8.1. The most important data recorded to date come from the earthquakes of Sept. 19, 1985 (M=8.1, 16 records, amax=166 cm/sec^2 above the fault) and Sept. 21, 1985 (M=7.6, 13 records, amax=243 cm/sec^2 close to the fault. Additional interesting records have been obtained from the following earthquakes:

April 30, 1986 (M=7.0, 4 records, amax=100 cm/sec^2 at 40 km)
May 29. 1986 (M=5.2, 5 records, amax=68 cm/sec^2 at 60 km)
June 16, 1986 (M=4.5, 6 records, amax=165 cm/sec^2 at 35 km)

March 26,1987 (M=4.8, 8 records, amax=33 cm/sec^2 at 21 km)
June 7, 1987 (M=4.8, 13 records, amax=78 cm/sec^2 at 44 km)
June 9, 1987 (M=4.2, 10 records, amax=63 cm/sec^2 at 42 km)
October 25, 1987 (M=4.6, 4 records, amax=161 cm/sec^2 at 25 km)
February 8, 1988 (M=5.8, 13 records, amax=435 cm/sec^2 at 29 km), (Ref. 4)

Fig. 2 shows a map with all the epicenters of the events recorded during 1985 and 1986. Most of the earthquakes have been located at the southeast end of the array, and in a cluster near Papanoa. The largest events have mostly been located at the northwest section of the network. Fig. 3 shows the magnitudes and distances of all 1985 and 1986 events. Reports which describe this data in detail are now available (Refs. 5,6,7,8).

It is evident from Fig. 3 that these data provide an opportunity to examine how the ground motions change with increasing magnitude. Fig. 4 shows the horizontal (north-south) component of ground motion for six earthquakes, all plotted on the same scale. The events were chosen to have magnitudes as near as possible to integer values from 3 to 8 and s-p time of as close to 3 seconds. Based on the rule of thumb, that the epicentral distance is (8 km/sec)*(s-p time), this implies that the epicenters of each of the events are about 25 km from the station. Fig. 4 shows the progression of the nature of ground motion as the size of the earthquakes increases. As this increases, the dimension of the source also increases. Consequently the duration of shaking, which is related to the source size, increases progressively as the magnitude goes up. A larger source also allows significant excitation and increase of low frequency waves.

The response spectra which correspond to these records are shown on Fig. 5. It shows that at high frequencies, there is less than a factor of 10 difference between the response to the magnitude 3.1 and 8.1 events. However, as the period lengthens, the difference rapidly grows, in a relatively systematic manner. Finally Fig. 6 shows the Fourier spectra of the same set of accelerograms. Again, the smallest and largest event are not separated by very much at the high frequency end. At low frequencies, this figure has not truncated the spectra where they dip into the noise level of the instrument, at about 10**-1 cm/sec.

CONCLUSIONS

The Guerrero strong motion array has been operating very efficiently. Far more than expected, it has produced a vast catalog of over 300 high quality accelerograms from near source earthquakes, being the most important ones, those from the September 1985, Michoacan earthquakes. This data allows extensive research, now in progress, on different aspects of seismology and earthquake engineering. The rapid rate of high quality data collection, demonstrates the value of using digital technology in strong motion. Even though the network covers most of the area where major earthquakes are expected, expansion of the array is needed, to provide more dense coverage of the important city of Acapulco, half way between two seismic gaps, and thus currently subjected to a very high probability of strong ground shaking.

REFERENCES

1. Sing, S. K., L. Astiz, J. Havskov. Seismic gaps and recurrence periods of large earthquakes along the Mexican subduction zone: a re-examination, Bull. Seism. Soc. Am. 71, 827-843, (1981).
2. Anderson, J. G., P. Bodin, J. N. Brune, J. Prince, S. K. Singh, R. Quaas and M. Oñate. Strong ground motion from the Michoacan, Mexico, earthquake, Science 233, 1043-1049, (1986).

3. Quaas, R. Sistema Universal de Reducción de Datos Acelerográficos Digitales, proceedings VII Congreso National de Ingeniería Sísmica, Nov. 1987, Querétaro, Mexico, (1987).
4. Quaas, R., J. G. Anderson, D. Almora, S. K. Singh and others. Accelerograms from the Guerrero Array for the Earthquake of February 8, 1988 (Ms=5.8): A Preliminary Report, Report GAA-4, Instituto de Ingeniería, UNAM, Mexico, (1988).
5. Anderson, J. G., R. Quaas, D. Almora, J. M. Velasco and others. Guerrero, Mexico Accelerograph Array: Summary of data collected in 1985, Report GAA-2, Institute of Geophysics & Planetary Physics, UC San Diego, La Jolla, California, (1987).
6. Anderson, J. G., R. Quaas, D. Almora, J. M. Velasco and others. Guerrero, Mexico Accelerograph Array: Summary of data collected in 1986, Report GAA-3, Institute of Geophysics & Planetary Physics, UC San Diego, La Jolla, California, (1987).
7. Anderson, J. G., R. Quaas, D. Almora, J. M. Velasco and others. Guerrero, Mexico Accelerograph Array: Summary of data collected in January to June 1987, Report GAA-5, Seismological Laboratory, Makay School of Mines, University of Nevada-Reno, Reno, Nevada, (1988).
8. Anderson, J. G., R. Quaas, D. Almora, J. M. Velasco and others. Guerrero, Mexico Accelerograph Array: Summary of data collected in July to December 1987, Report GAA-6, Seismological Laboratory, Makay School of Mines, University of Nevada-Reno, Reno, Nevada, in preparation, (1988).

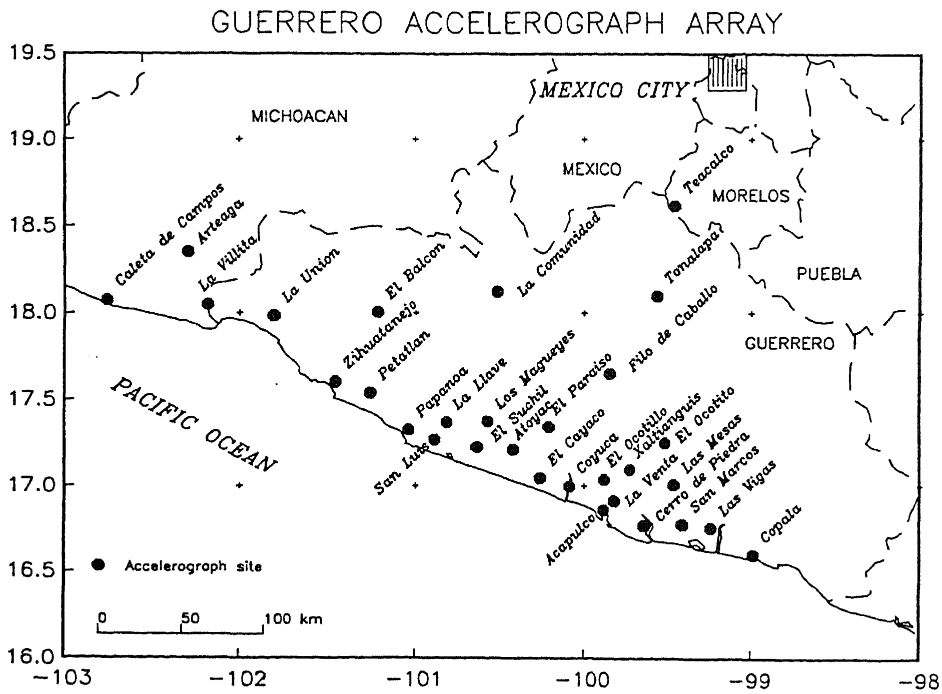

Fig. 1 Locations of strong motion stations in the Guerrero Accelerograph Array.

STATION	CODE	LOCATION Lat. N	Long. W	INSTRUMENT TYPE	GEOLOGY
ACAPULCO	ACAR	16.8600	99.8790	-----	--------
ARTEAGA	ARTG	18.3500	102.2950	DSA-1	TONALITE
ATOYAC	ATYC	17.2113	100.4309	DSA-1	GRANODIORITE
CALETA DE CAMPOS	CALE	18.0727	102.7552	DSA-1	META-ANDESITE BRECCIA
CAYACO	CAYA	17.0452	100.2664	DSA-1	ALLUVIUM (SAND)
CERRO DE PIEDRA	CPDR	16.7692	99.6326	DCA-333	WEATHERED GNEISS
COPALA	COPL	16.6000	98.9870	DSA-1	WEATHERED GRANITE-GNEISS
COYUCA	COYC	16.9967	100.0900	DCA-333	GRANITE GNEISS
EL BALCON	BALC	18.0050	101.2220	DSA-1	ANDESITE
FILO DE CABALLO	FIC2	17.6520	99.8420	PDR-1	PORPHYRITIC ANDESITE
LA COMUNIDAD	COMD	18.1220	100.5220	DSA-1	ANDESITE
LA LLAVE	LLAV	17.3720	100.8120	DSA-1	GRANITIC
LA UNION	UNIO	17.9824	101.8054	DSA-1	META-ANDESITE BRECCIA
LA VENTA	VNTA	16.9129	99.8159	DSA-1	GRANITIC-GNEISS
LAS MESAS	MSAS	17.0070	99.4565	DSA-1	GRANITIC-GNEISS
LAS VIGAS	VIGA	16.7560	99.2359	DCA-333	QUARTZ MONZONITE
LOS MAGUEYES	MAGY	17.3770	100.5770	DSA-1	ANDESITE
OCOTILLO	OCLL	17.0378	99.8749	DCA-333	SAWEATHERED PLUTONIC/METAMORFIC
OCOTITO	OCTT	17.2500	99.5106	DCA-333	WEATHERED QUARTZ MONZONITE
PAPANOA	PAPN	17.3278	101.0399	DCA-333	LEVCOCRATIC DYLCES INTRUDING ALTERED GRANODIORITE
PARAISO	PARS	17.3444	100.2145	DSA-1	DIORITE
PETATLAN	PETA	17.5400	101.2630	DSA-1	QUARTZ DIORITE
SAN LUIS	SLUI	17.2700	100.8880	-----	--------
SAN MARCOS	SMR2	16.7760	99.4077	DSA-1	GRANDIORITE
SUCHIL	SUCH	17.2258	100.6418	DCA-333	GRANODIORITE
TEACALCO	TEAC	18.6174	99.4528	PDR-1	RHYODACITE TUFF
TONALAPA	TNLP	18.0975	99.5594	PDR-1	SHALE INTERBEDDED WITH SANDSTONE
VILLITA	VILE	18.0475	102.1840	DSA-1	TONALITE
XALTIANGUIS	XALT	17.0950	99.7201	PDR-1	TONALITE
ZIHUATENEJO	AZIH	17.6030	101.4550	DCA-333	TONALITE

Table 1 Guerrero Array stations (1987)

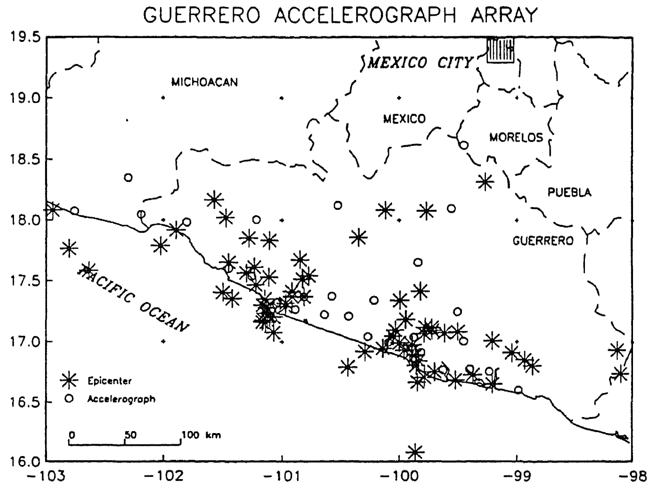

Fig. 2
Epicenters of events recorded during 1985 and 1986.

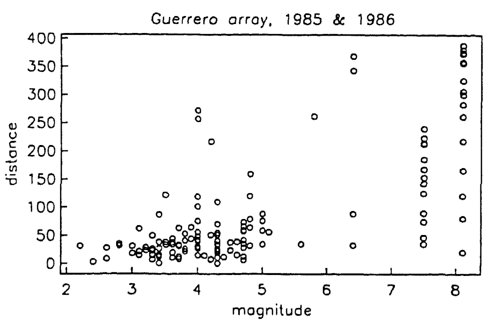

Fig. 3
Magnitude and distances of all 1985 and 1986 earthquakes.

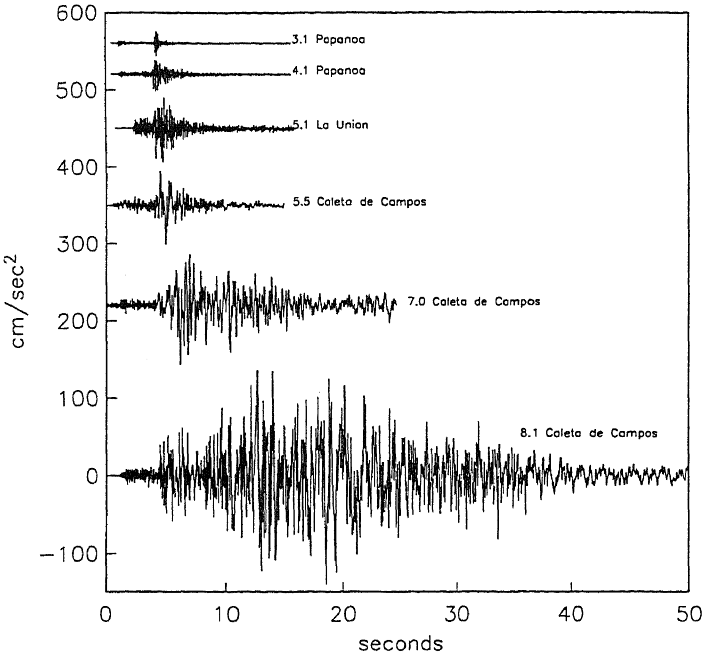

Fig. 4 N-S components of six earthquakes recorded on the Guerrero array all having epicenters about 25 km from the station.

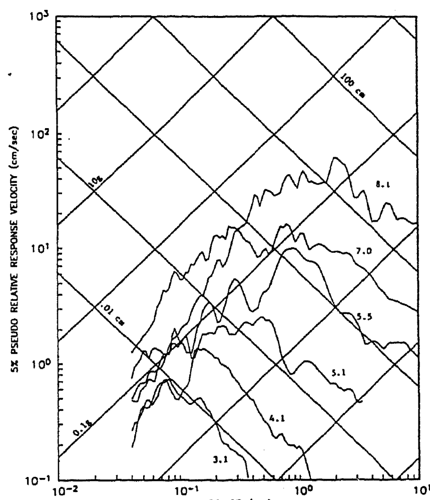

Fig. 5
Response spectra corresponding to accelerograms of Fig 4.

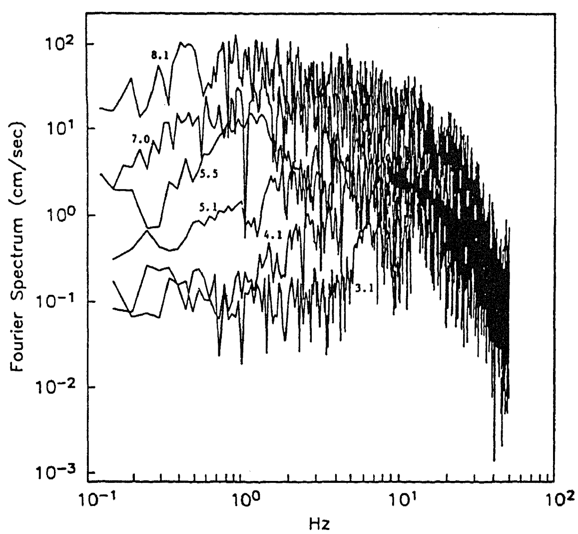

Fig. 6
Fourier amplitude spectra corresponding to accelerograms of Fig. 4