U.S. Dept. of the Interior

Geological Survey

Anomalous Free Field Recordings at Certain Seismograph Locations

by

G. N. Bycroft

Open File Report

No. 82-318

This report is preliminary and has not been edited or reviewed for conformity with Geological Survey standards and nomenclature.

Menlo Park, California

1981

Anomalous Free Field Recordings at Certain Accelerograph Locations

Introduction.

Accelerographs are used to measure both the "free-field" motion of the ground during an earthquake and the motion of points on a structure.

In general free-field accelerograms exhibit a somewhat random signal and to the eye show no particular character or dominant frequency. This is better shown by a spectral analysis. However, occasionally a record is obtained which does not fit this general pattern. It is then generally difficult to decide if the record is true or spurious. The record may indeed be true being the result of a highly unusual local terrain, that is there may be a large underground rock lying in a low velocity medium nearby or an underground cavity, trench, or tunnel of such dimensions as to impose an atypical character on the record. A low velocity layer overlying rock may produce a dominant surface wave. On the other hand, the record may be anomalous because of instrument malfunction, improper or loose mounting, or local noise. The recording may appear to be normal but actually has been compromised by soil-structure interaction. The effect of soil-structure interaction is discussed by Bycroft[1] for the case of typical free-field instrument locations consisting of a concrete pad and a housing to protect the instrument. He showed that for low-velocity terrain and typical housings of the heavier type the higher frequencies can be substantially magnified. For convenience, instruments are often located in the basement of buildings. In this case the motion of the structure modifies the free-field motion. Many studies have been made which show that soil-structure interaction in certain cases has a substantial effect on the motion of the foundation and hence on any recordings made there.

A typical study on this effect is that by Hadrilek and others[2]. By taking spectral ratios of a basement recording and a nearby free-field instrument recording of a common event it is shown that the natural frequencies of the structure appear in the basement recording. Crouse and Jennings[3] discuss similar soil-structure interactions at the Hollywood Storage Building. Some examples are now given of some further records that are suspect or show evidence of soil-structure interaction.

Coachella Engine House No. 4.

This case is more fully discussed in two other reports which describe a theoretical and an experimental investigation. Fig. 1 shows the recording obtained in the Coachella Engine House No. 4 of the October 15, 1979 Imperial Valley earthquake. A dominant 2 Hz frequency is seen in the three components. This is better shown in Figures 2, 3, 4 which show velocity response and Fourier amplitude spectra. As the engine house is a massive bunker-like structure located on a terrain of low shear wave velocity, soil-structure interaction appeared as a likely explanation. However, the experimental and theoretical study failed to show a 2 Hz frequency although the experiments agree well with the theory. This agreement is a good test for soil-structure interaction theory but does not explain these unusual records. It is possible that the close proximity of the canal is the cause or perhaps resonance in soil layers.

Meloland Overcrossing:

Rojahn and others[4] describe the instrumentation of the Meloland Overcrossing of Interstate Route 8 in the Imperial Valley and the records obtained in the October 15, 1979 Imperial Valley earthquake.

As well as instrumentation on the overcrossing there is a free-field instrument. Figures 5 and 6 show the records at various stations. By comparing the free-field records with the records obtained on the embarkments clear evidence of soil-structure interaction is seen. Table 1 compares the peak accelerations at the three locations. The embankments are massive rigid structures and move differently from the free-field motion.

Hawaii Earthquake of November 29, 1975 Record at Honokaa

Fig. 7 shows the location of various instruments on the Island of Hawaii. A recording of the November 29, 1975 earthquake obtained at Honokaa is shown in Fig. 8 and consists primarily of a 7 Hz oscillation. This is a most unlikely accelerogram. The record obtained at Hilo showed none of this character. An investigation was made to find an explanation for this unusual record. The instrument is located on the concrete floor of the county service building in Honokaa. The building has a steel frame with corrugated iron roof and walls and is much too light for soil-structure interaction to be significant. The 6" thick concrete floor lies on 30" of crushed rock over 3 to 4 ft of top soil and then competent rock. The structure lies close to the edge of a small cliff at the bottom of which there is a road. Measurements of the noise level on the floor and at various points on the structure were made using a Kinemetric VM-1.

Trucks passing on the road below produced significant readings. Fig. 9 shows part of a record taken on the floor close to the seismograph location during the passage of a truck on the road below. A strong 7 Hz signal dominates the record. Thus it appear that this location is an unusual one in that an excitation produces an oscillation of 7 Hz. It is known that this region is permeated with large lava tubes up to 30 ft. in diameter and of considerable length. It is possible that these tubes form a structure having a 7 Hz natural frequency and that an excitation from any source will excite this frequency.

Imperial Valley County Services Building

The Imperial Valley County Services Building is instrumented and there is an adjacent free-field instrument. Fig. 10 shows the records obtained from the ground floor and the free-field site during the October 15, 1979 Imperial Valley earthquake. These records differ substantially and provide another example of soil-structure interaction. Caution must be exercised in assuming that the motion of the base of the structure is the free-field motion.

Pleasant Valley Pumping Plant:

This pumping plant is of a fairly massive structure and has instruments on the roof, on the ground floor, in the basement and a free-field instrument in the switchyard. Fig. 11 shows that the motion of the ground floor and the basement are very similar but quite different from the free-field motion in the switchyard showing again the effect of interaction.

Bonds Corner

Fig. 12 shows the accelerogram obtained at Bonds Corner from the Imperial Valley Earthquake of October 15, 1979. In both the horizontal traces there is seen a series of spikes especially in the latter part of the record. These spikes are atypical and would not be generated by normal earthquake processes, but rather by some sort of impacting mechanisms. During the earthquake a heavy steel beam fell on to the steel cover protecting the instrument. Such an incident would satisfactorily explain a single spike, but not a series of spikes. Possibly after the beam fell on to the cover it continued to rattle around in some fashion. Impacting can also arise from a loose mounting but an inspection showed this not to be the case.

El Centro Differential Array

An array of six accelerographs was installed in El Centro in order to measure differential displacements. The recorders for these instruments are located in a small building constructed of concrete blocks. As well as the six instruments an SMA-1 is located inside the recording building and this instrument showed significantly higher maximum accelerations than No. 1 instrument of the array located about 50 ft. away for the Imperial Valley earthquake of October 15, 1979. The terrain has a very low shear wave velocity, the building is relatively heavy and the maximum accelerations are associated with the higher frequencies. Bycroft[1] discusses how in these circumstances soil-structure interaction can amplify the higher frequencies.

Conclusions

Care should be taken in locating free-field accelerographs. Instruments housed in the basements of buildings may have their readings compromised by soil structure interaction. Certain free-field sites may have a pathological character such as the site at Honokaa, Hawaii. Although the recordings from such sites may indeed be true they are so atypical as to be of little use for design purposes and the instruments could be better used elsewhere.

REFERENCES

1. Bycroft, G. N. "The Effect of Soil Structure Interaction on Seismometer Readings", Bull. Seis. Soc. Am. Vol. 68, June 1978, pp 823-863.

2. Hadrilek, P. J., A. R. Carrivean, G. R. Sarogoni and C. M. Duke, "Evidence of Soil Structure Interaction in Earthquakes", Fifth World Conference on Earthquake Engineering, Rome, 1973.

3. Crouse, C. B. and P. C. Jennings, "Soil Structure Interaction During the San Fernando Earthquake", Bull. Seis. Soc. Am. Vol. 65, No. 1, February 1975

4. Rojahn, C., J. T. Ragsdale, J. D. Raggett, J. H. Gates, "October 15, 1979 Main-Shock Strong-Motion Records from the Meloland Road Interstate 8 Overcrossing, Imperial County, California", U.S. Geological Survey Open-File Report 80-1054.

TABLE 1
Peak Accelerations

	Up	North	West
Free-Field	0.23g	0.32g	0.30g
N Embankment	0.26g	0.36g	0.39g
S Embankment	0.28g	0.28g	0.43g

Fig 1

UNCORRECTED ACCELEROGRAM
COACHELLA CANAL NO. 4 .CALIFORNIA..10/15/79.2317UTC
THE 3 PEAK VALUES(G) ARE .1281 .0378 .1157

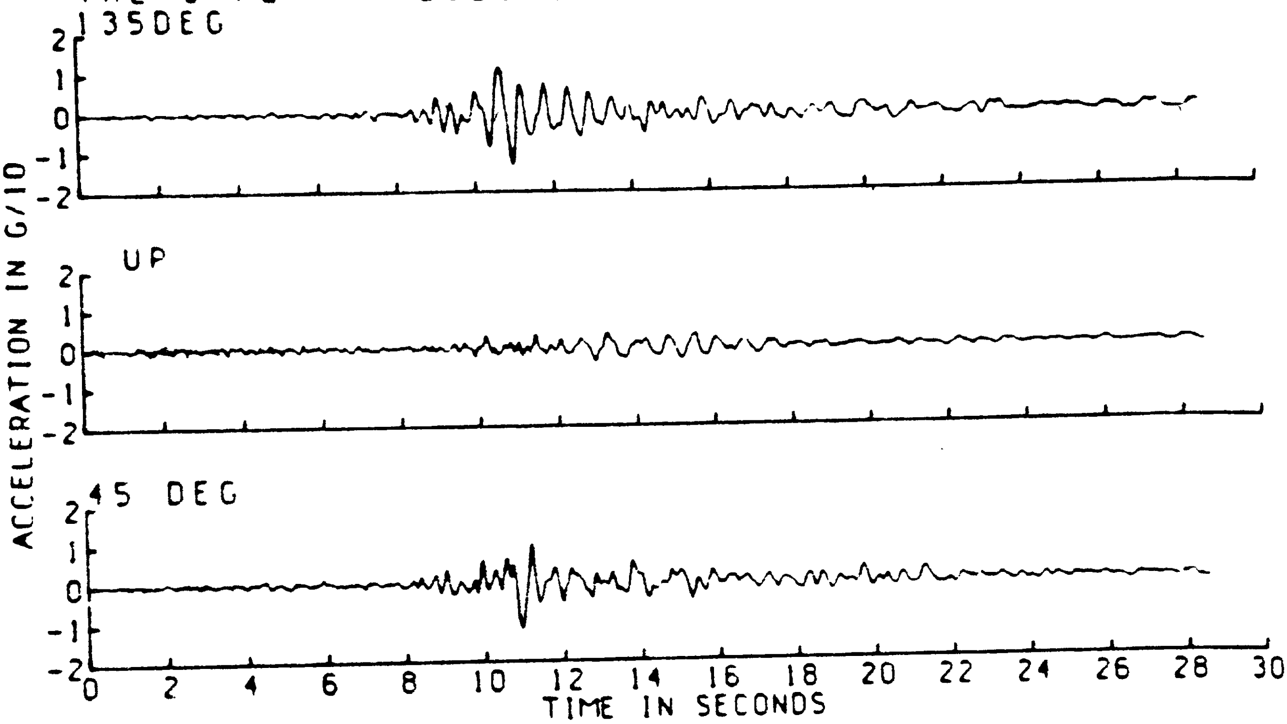
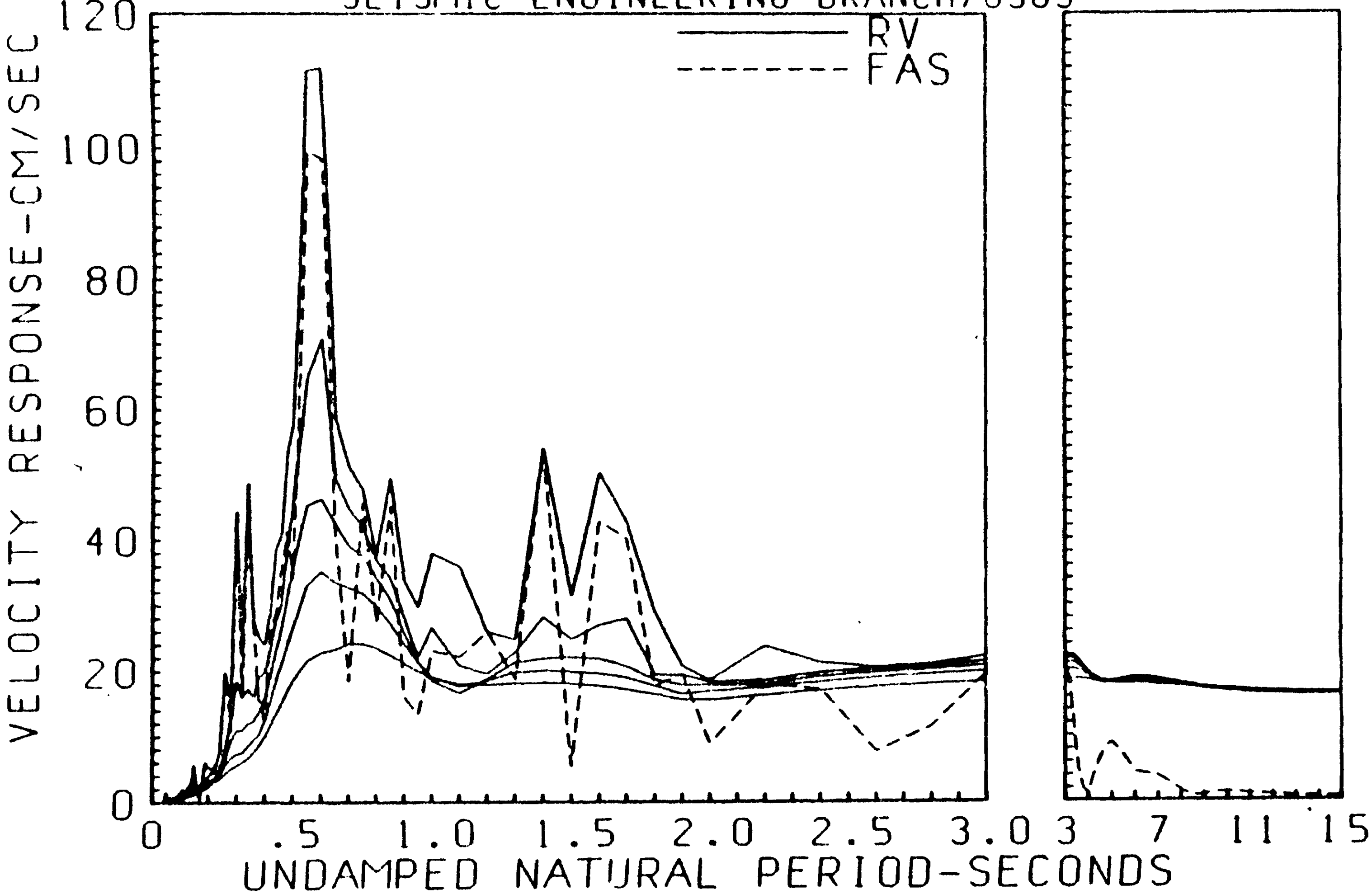


Fig 2

RELATIVE VELOCITY RESPONSE SPECTRUM
COACHELLA CANAL 4,10/15/79,2317,135 DEG
0,2,5,10,20 PERCENT CRITICAL DAMPING
BAND PASSED FROM .030- .170 TO 23.00-25.00 HZ
SEISMIC ENGINEERING BRANCH/USGS



FOURIER AMPLITUDE SPECTRUM OF ACCELERATION
IMPERIAL VALLEY EARTHQUAKE OF OCTOBER 15, 1979 - 2317UTC
COACHELLA CANAL NUMBER 4, CALIFORNIA, COMP UP
BAND PASSED FROM .030- .170 TO 23.00-25.00 HZ
SEISMIC ENGINEERING BRANCH/USGS

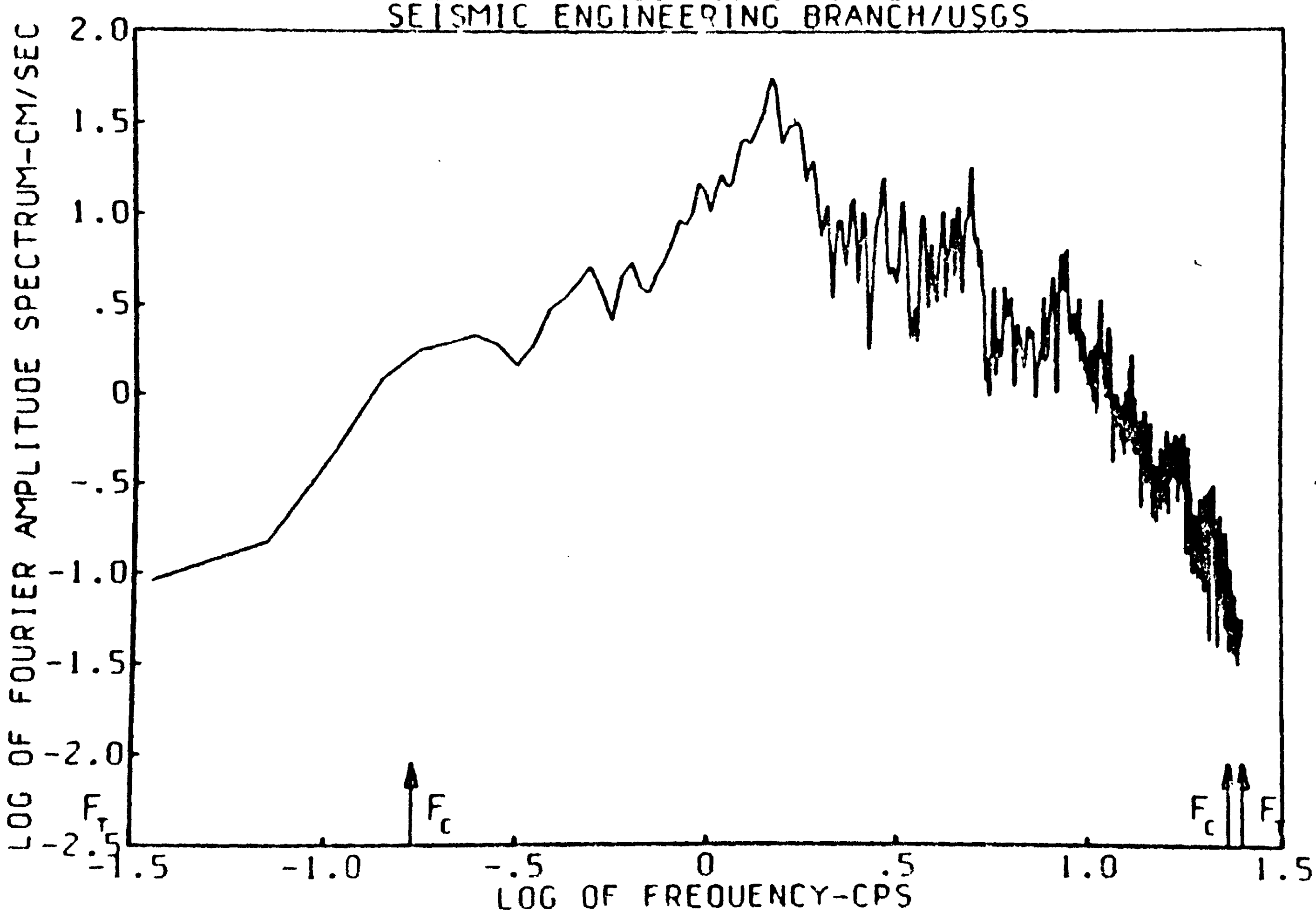
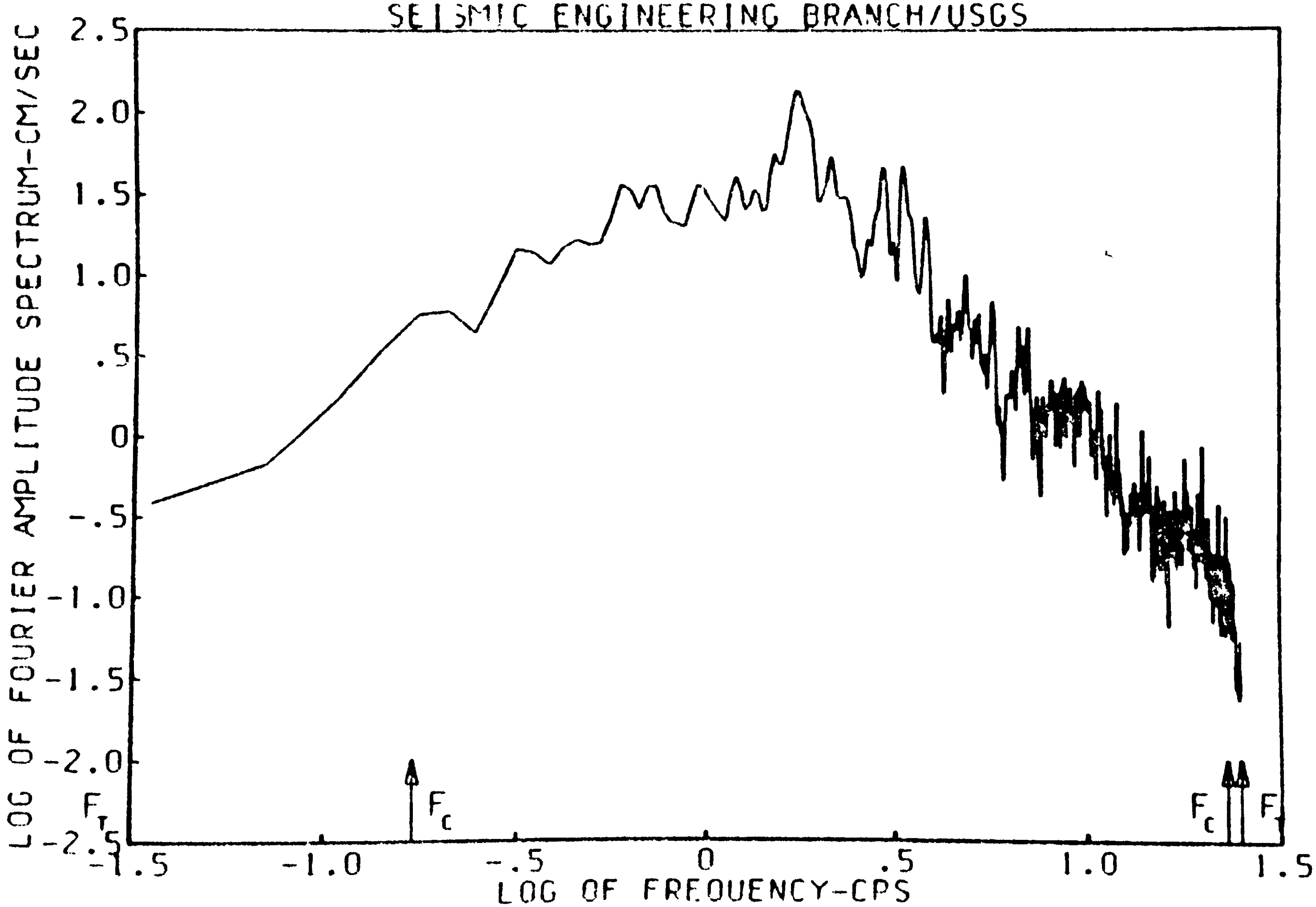


Fig 6

FOURIER AMPLITUDE SPECTRUM OF ACCELERATION
IMPERIAL VALLEY EARTHQUAKE OF OCTOBER 15,1979 - 2317UTC
COACHELLA CANAL NUMBER 4,CALIFORNIA,COMP 135 DEGREES
BAND PASSED FROM .030- .170 TO 23.00-25.00 HZ
SEISMIC ENGINEERING BRANCH/USGS



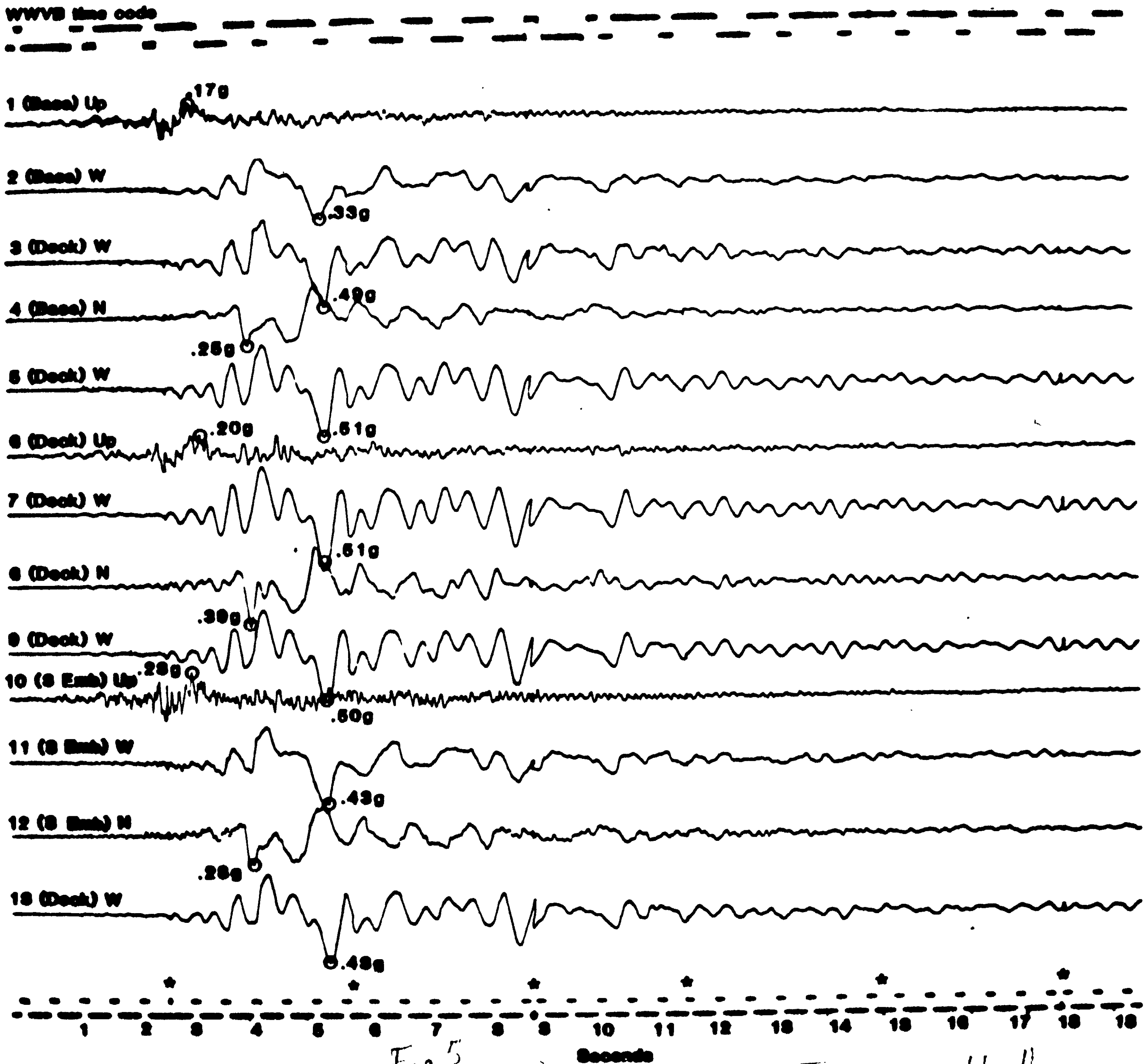


Fig 5

Meloland Overcrossing ... Imperial Valley

12

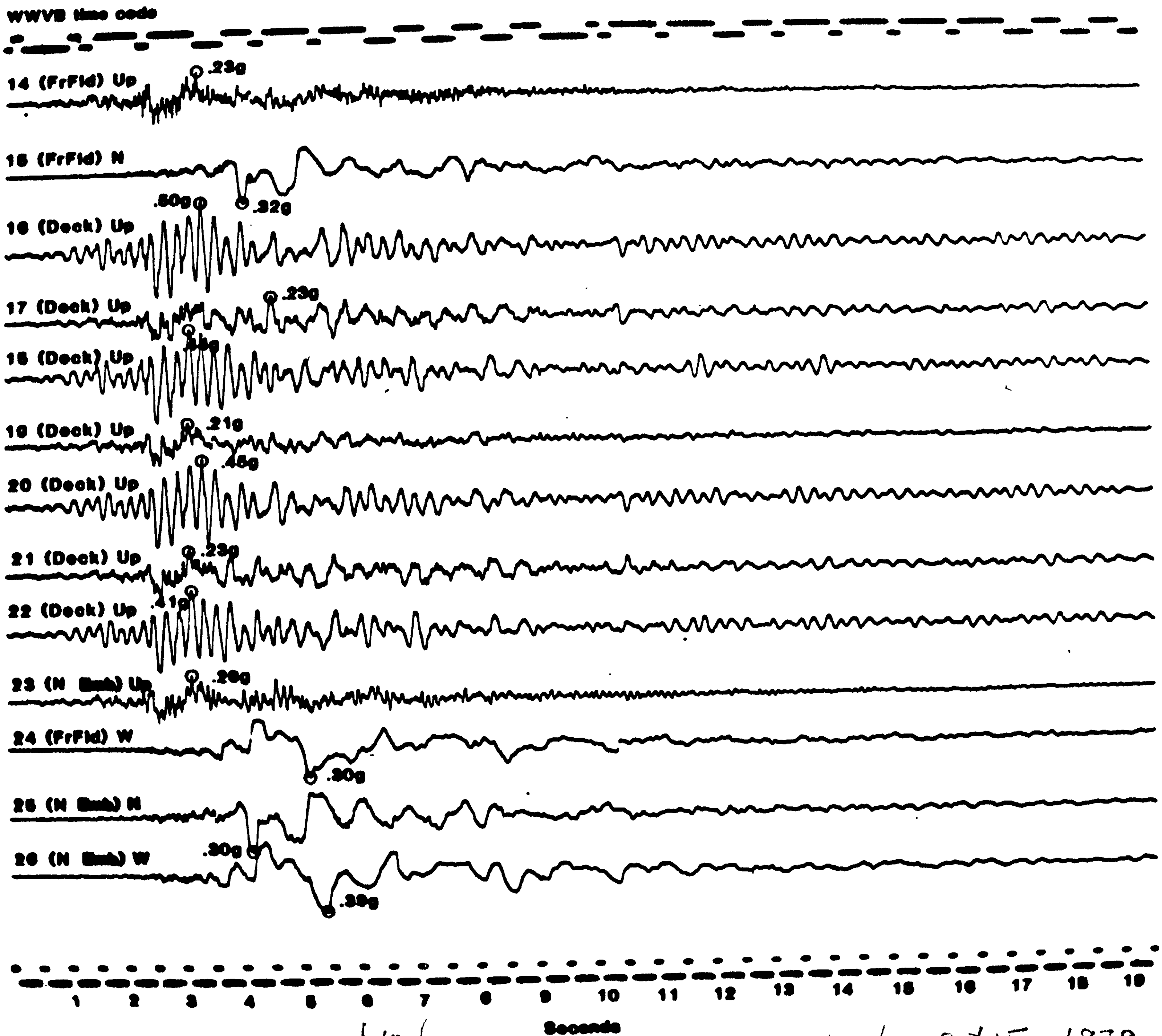


Fig 6 … Oct 15 1979

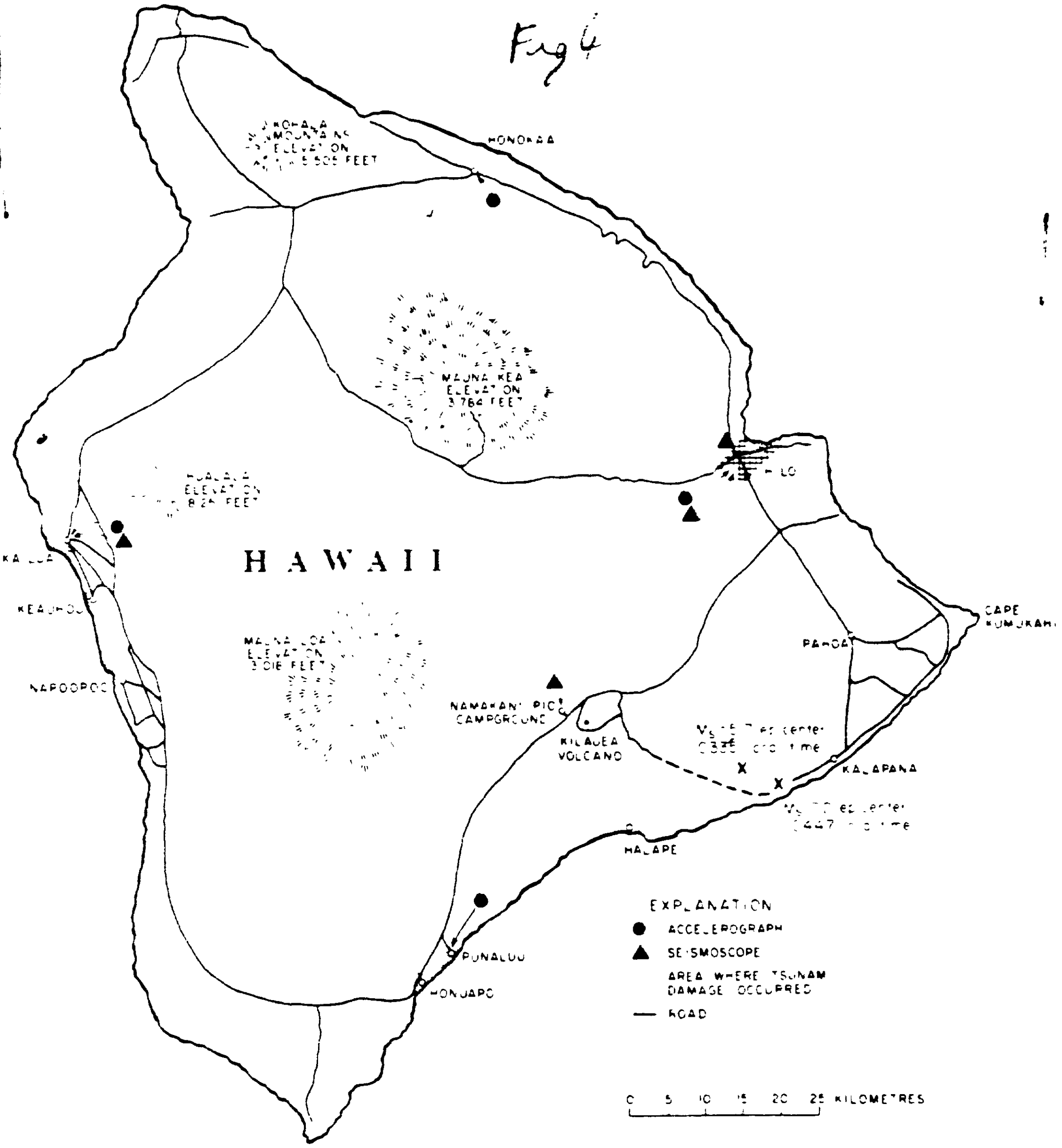


Fig. ~~4~~7 Location of Instruments
Island of Hawaii

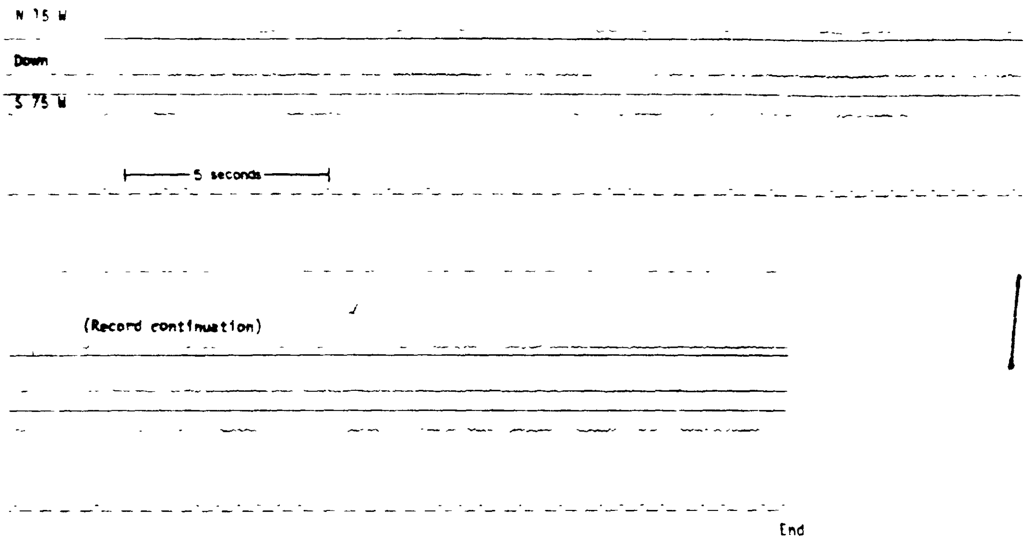


FIG 8 Honokaa accelerograph record of the 0447 (local time) November 29, 1975 island of Hawaii earthquake (M_S = 7.2).

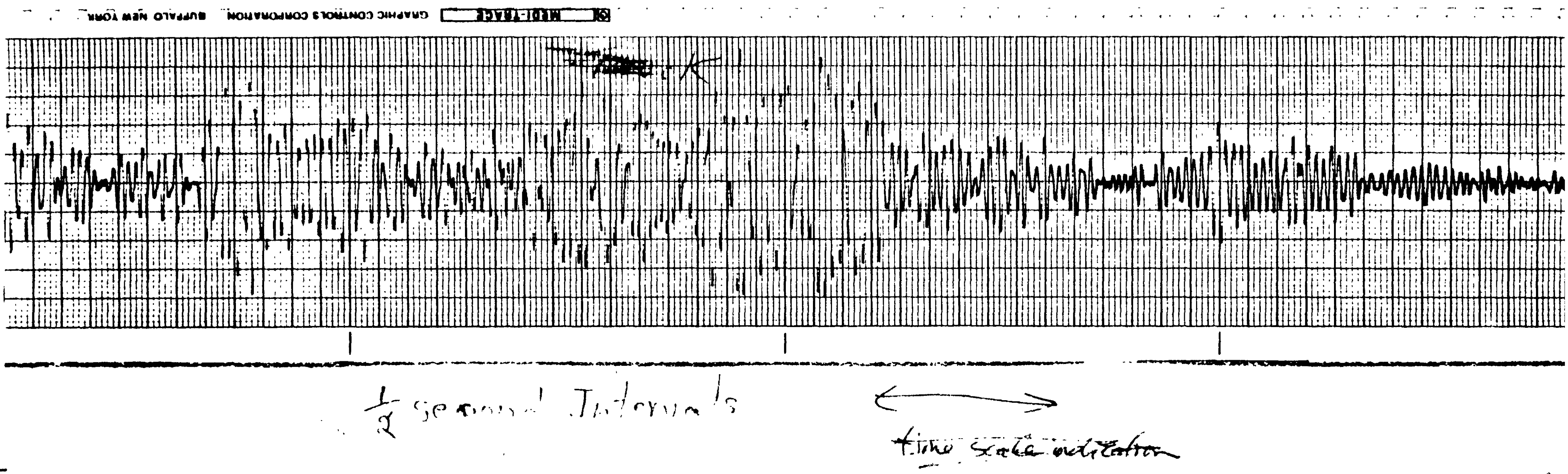


Fig. 7 Motion on Floor During Passage of a Truck.

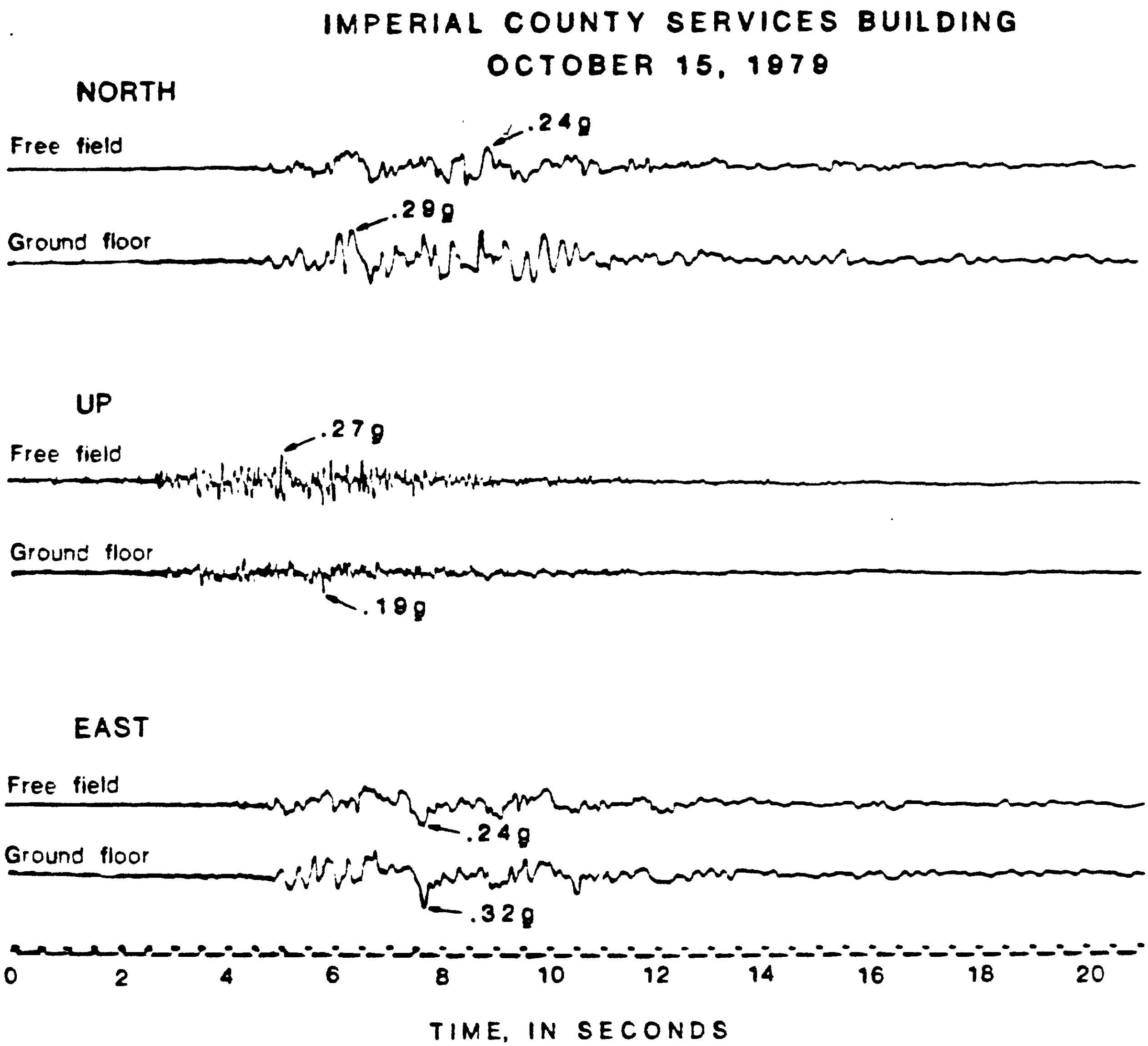
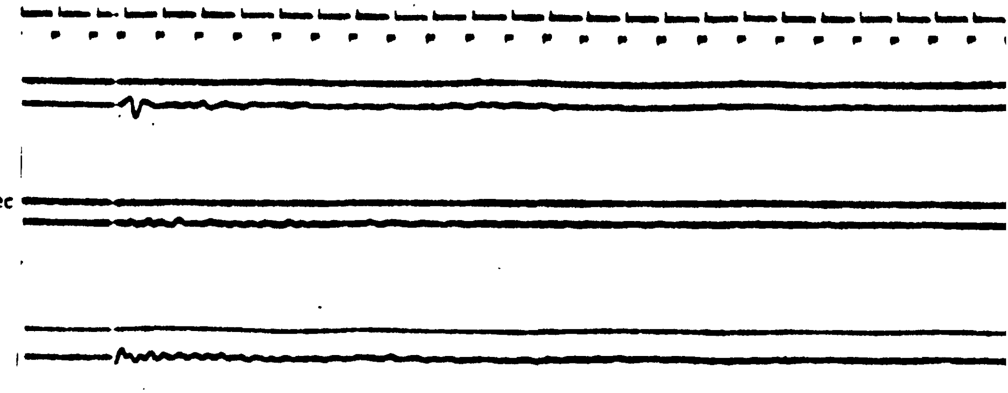


Figure 10 --October 15 acceleration-time histories recorded at Imperial County Services Building and adjacent free-field site.

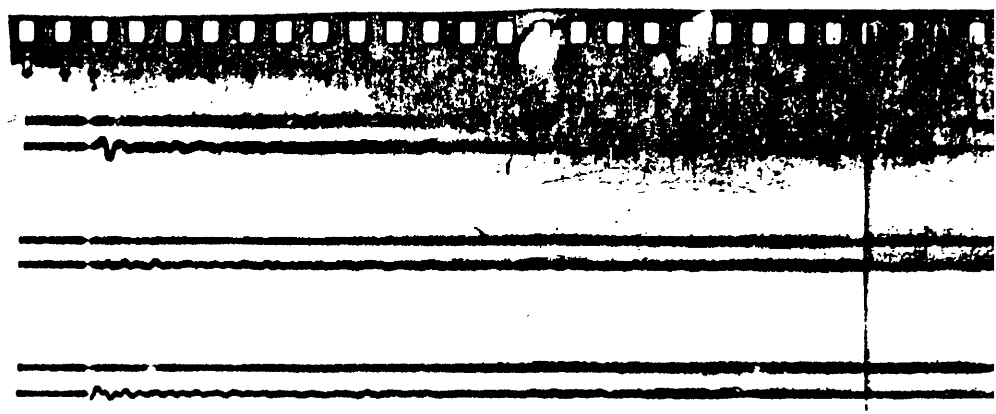
U. S. STRONG-MOTION NETWORK
STATION NO. 1162, 36.31N, 120.25W
PLEASANT VALLEY PUMPING PLANT, CA.
RFT-250, NO. 262 GROUND FLOOR
EARTHQUAKE OF 2 AUGUST 1975, 2235 PST
3 AUGUST 1975, 0635 GMT

N44W	Sens.	= 1.90 cm/g	FILM SPEED
	Per.	= .042 sec	2 time marks/sec
	Damp.	= 0.55 crit	
Down	Sens.	= 1.90 cm/g	5 cm
	Per.	= .041 sec	
	Damp.	= 0.59 crit	
S46W	Sens.	= 1.90 cm/g	
	Per.	= .041 sec	
	Damp.	= 0.59 crit	



U. S. STRONG-MOTION NETWORK
STATION NO. 1162 36.31N, 120.25W
PLEASANT VALLEY PUMPING PLANT, CA.
RFT-250, NO. 261 BASEMENT
EARTHQUAKE OF 2 AUGUST 1975, 2235 PST
3 AUGUST 1975, 0635 GMT

N44W	Sens.	= 1.90 cm/g	FILM SPEED
	Per.	= .043 sec	2 time marks/sec
	Damp.	= 0.57 crit	
Down	Sens.	= 1.90 cm/g	5 cm
	Per.	= .048 sec	
	Damp.	= 0.56 crit	
S46W	Sens.	= 1.90 cm/g	
	Per.	= .046 sec	
	Damp.	= 0.57 crit	



U. S. STRONG-MOTION NETWORK
STATION NO. 1162, 36.31N, 120.25W
PLEASANT VALLEY PUMPING PLANT
RFT-250, NO. 264 SWITCHYARD
EARTHQUAKE OF 2 AUGUST 1975, 2235 PST
3 AUGUST 1975, 0635 GMT

N45E	Sens.	= 1.90 cm/g	FILM SPEED
	Per.	= 0.44 sec	2 time marks/sec
	Damp.	= 0.56 crit	
Down	Sens.	= 1.90 cm/g	5 cm
	Per.	= .043 sec	
	Damp.	= 0.56 crit	
N45W	Sens.	= 1.90 cm/g	
	Per.	= .043 sec	
	Damp.	= 0.56 crit	

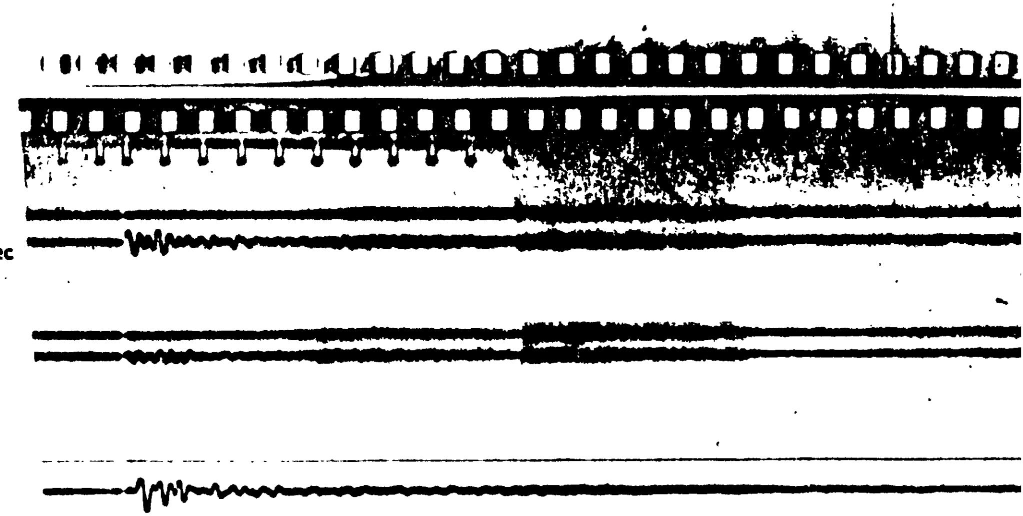
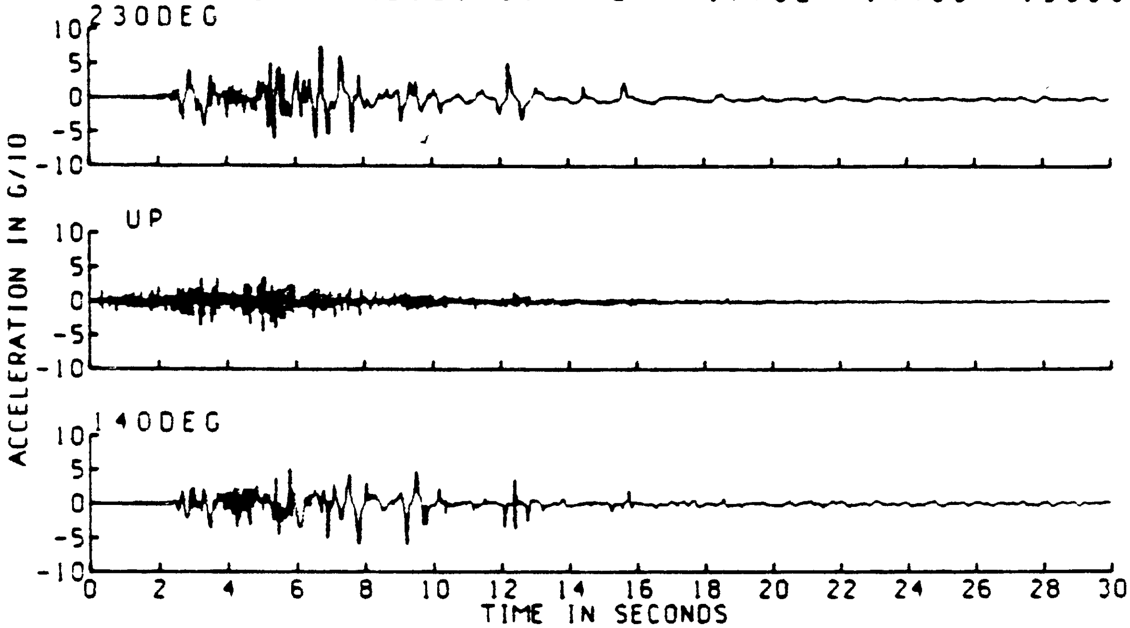


Fig 11

Fig 12

UNCORRECTED ACCELEROGRAM
EL CENTRO, BONDS CORNER, 10/15/79, 2317UTC
THE 3 PEAK VALUES(G) ARE .7782 .4435 .5959



EL CENTRO, BONDS CORNER, 10/15/79, 2317UTC