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SOME RECENT NEAR-SOURCE STRONG MOTION ACCELEROGRAMS

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SUMMARY

Uniformly processed accelerograms recorded in the epicentral regions of ten earthquakes occurring since 1976 are reproduced with common time and amplitude scales, along with a compilation of significant peak values, duration, spectral amplitudes, and energy input. Information on such earthquake source parameters as magnitudes, depth, and fault parameters is also tabulated. The diversity of earthquake ground motion is emphasized, along with the need to retain for our investigations the full information contained in the acceleration-time curves. Attention is drawn to the need for additional basic parameters to describe the mechanics of earthquake energy release and propagation.

NEAR-SOURCE ACCELEROGRAMS

In 1977 when a compilation of near-source records was attempted (Ref. 1), only a few such accelerograms were available, and most of them were from relatively small earthquakes. Since that time a greatly expanded world-wide network of strong-motion accelerographs has produced many more such records, some of them from events as large as M 8.1.

By a near-source record is meant an accelerogram whose peak values are associated with distances from energy release which are smaller than the overall dimensions of the causative faulting. Since the details of faulting for a particular event are rarely known with a precision sufficient to accurately associate particular peaks with distances to corresponding regions of energy release, significant differences in distance for near-source records can seldom be established. Distance is thus not a parameter reported in the present compilations.

EARTHQUAKE SOURCE PARAMETERS

Table I collects the major information on earthquake source parameters available for a selected list of recent earthquakes for which near-source accelerograms have been obtained. The size of the events is measured by the various magnitude scales and by the seismic moment. The magnitude scales describe the earthquake in different frequency regimes: M_L involves periods around 1 second; M_S around 20 seconds; m_b at intermediate periods. The seismic moment M_0 is usually calculated from very long period (256 second) waves. The moment magnitude M_W is derived empirically from the seismic moment using standard empirical relationships. Magnitudes are usually averages for a number of stations, and are generally agreed on within a range of 0.1.

TABLE I. EARTHQUAKE SOURCE PARAMETERS

Earthquake	Date	Magnitude M_L	m_b	M_S	Focal Depth km	Seismic Moment dyne/cm	Fault Parameters L,km	W,km	D,cm
Gazli[1]	5/17/76	6.4	6.2	7.0	15	$1.6\text{–}2.4 \cdot 10^{26}$	54	8–15	330
Tabas[2]	9/16/78	7.0	6.5	7.4	<20	$1.3\text{–}1.6 \cdot 10^{27}$	65	37	300
Montenegro[3]	4/15/79	6.7		7.0	25–40	$1.0\text{–}4.6 \cdot 10^{26}$	50		
Imperial[4]	10/15/79	6.6	5.7	6.9	12	$2.5\text{–}8.7 \cdot 10^{25}$	35	15	55
Coalinga[4]	5/2/83	6.7	6.2	6.5	10	$2.3\text{–}6.0 \cdot 10^{25}$	25	15	20
Chile	3/3/85		6.9	7.8	10–40	$1.1 \cdot 10^{28}$	125	90	
Mexico	9/19/85			8.1	16	$0.9\text{–}1.5 \cdot 10^{28}$	170	50	284
Nahanni[5]	12/23/85		6.4	6.9	6	$1.5 \cdot 10^{26}$	25	15	130
Palm Springs[4]	7/8/86	5.9	5.8	6.0	11	$2 \cdot 10^{25}$			.7
San Salvador	10/10/86		5.1	5.4	8				

[1]USSR [2]Iran [3]Yugoslavia [4]USA [5]Canada

ACCELEROGRAM CHARACTERISTICS

In Fig. 1, sample component accelerograms are displayed to the same time and amplitude scale to permit an overall visual comparison of the events. The eye and the brain are pattern recognition instruments of unequalled power, which should be applied to the acceleration-time record itself, since it represents the most complete information available on the earthquake ground motion.

Table II summarizes some of the main characteristics of the accelerograms. The original records have been analyzed by persons with a broad experience in the interpretation of such accelerograms, and it is believed that the digitizations are a fair representation of the earthquake ground motion over the frequency range of engineering interest. From the digitization on, all processing has been done on a uniform basis so that comparisons can be as meaningful as possible (Ref. 2). In comparing the values given in Table I with those in other sources, it should be remembered that processed peak acceleration values can be somewhat lower than those scaled off analog records, and that the values of calculated peak velocities and displacements can depend upon filter characteristics. The duration given in Table II is calculated from the $\int a^2 dt$ curve as the time from the 5% to the 95% level of the cumulative energy integral. The value for the maximum RMS acceleration, $\bar{a}_{max}$, is the square root of the maximum slope of the smoothed energy input curves.

EARTHQUAKE EVENTS

Gazli The SSRZ accelerograph is a 3-component direct optical device recording on 35mm film. Frequency range specified as 0-20 Hz, film speed 15mm/sec, trigger delay < 0.2 sec. The instrument was within 10 km of major energy release, located on 1420 meters of clay and sandstone underlain by metamorphic schist. No surface faulting was observed. Rupture started at depth of 15 km and propagated unilaterally upwards towards the accelerograph station with a

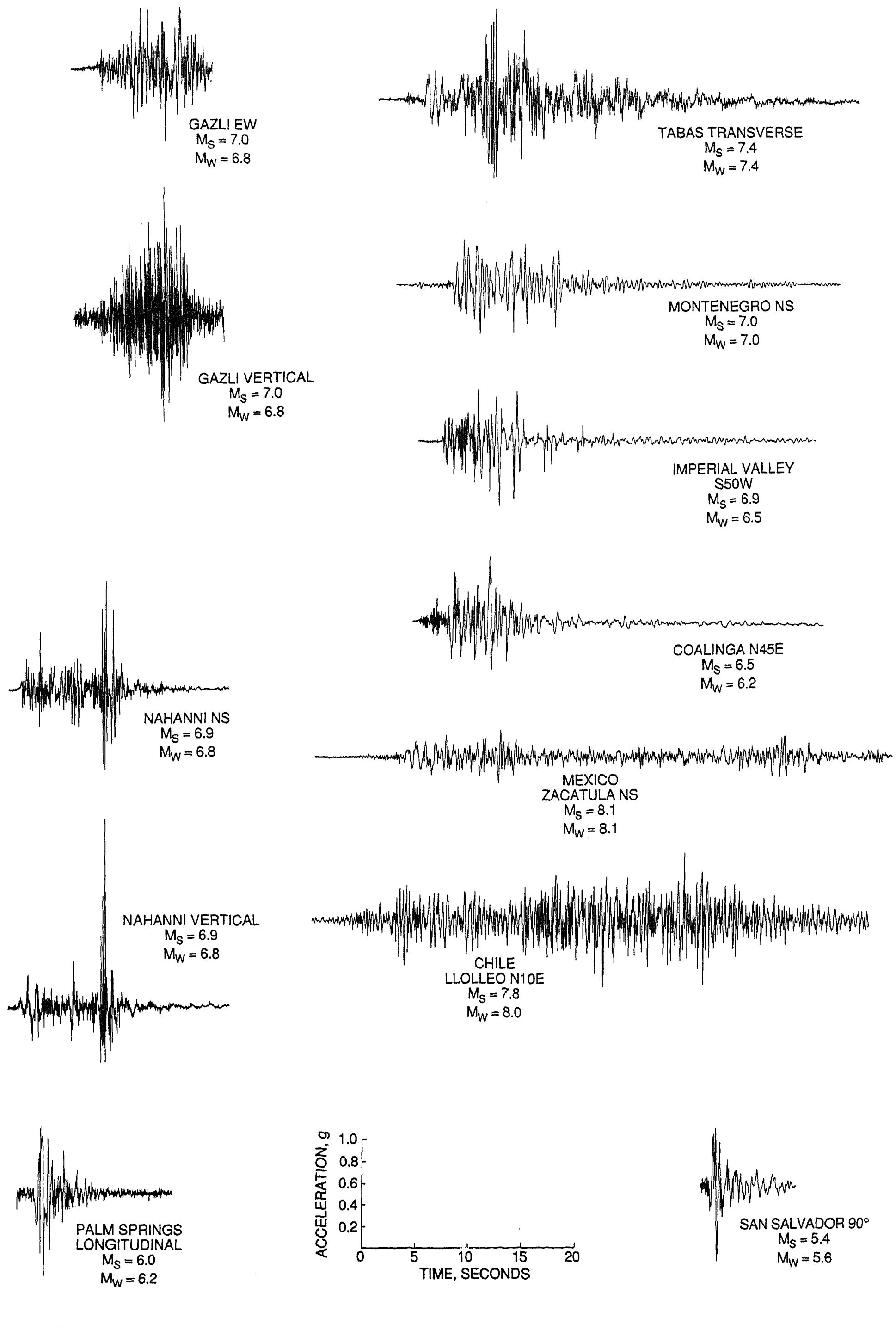

FIG. 1 NEAR-SOURCE ACCELEROGRAMS

TABLE II. RECENT NEAR-SOURCE ACCELEROGRAMS

Earthquake	Station	Comp	Peak Values A g	Peak Values V *cm/sec*	Peak Values D *cm*	$\int a^2 dt$ $cm^2/sec^3 \cdot 10^{-4}$	Dur. *sec*	$\bar{a}_{max}$ g	PSV, 5% *cm/sec* 1 Hz	PSV, 5% *cm/sec* 10 Hz	Filter Pass-band *Hz*	Inst. Type
Gazli	Karakyr Pt.	EW	0.68	68.0	19.6	29.0	7.0	0.22	63.5	24.1	.20-25	SSRZ
		V	1.20	62.0	16.6	76.0	6.6	0.41	66.0	50.8	.20-25	
		NS	0.54	56.3	18.9	27.5	7.2	0.21	114.3	20.3	.20-25	
Iran	Tabas	L	0.82	99.3	38.6	67.5	16.9	0.34	114.3	25.4	.10-25	SMA-1
		V	0.60	38.7	11.3	34.5	17.0	0.20	76.7	17.8	.14-25	
		T	0.87	121.0	94.6	69.0	18.0	0.32	101.6	25.4	.07-25	
Montenegro	Petrovac	EW	0.31	25.8	3.0	29.5	13.0	0.13	23.1	5.3	.225-25	SMA-1
		V	0.21	17.9	8.9	35.5	14.0	0.06	23.8	7.1	.07-25	
		NS	0.45	39.4	13.7	12.8	12.0	0.18	88.9	8.1	.07-25	
Imperial	Bonds Cor.	S40E	0.60	46.7	18.5	24.5	11.0	0.19	96.5	15.0	.07-25	SMA-1
		V	0.33	11.8	2.9	6.6	10.0	0.12	25.4	11.9	.125-25	
		S50W	0.78	44.2	16.9	37.5	11.0	0.30	81.3	19.1	.07-25	
Coalinga	Pleasant Val.	S45E	0.53	39.2	5.0	24.0	9.3	0.23	71.1	9.7	.50-25	SMA-1
		V	0.37	16.1	9.6	9.5	11.0	0.12	33.0	21.1	.07-22.5	
		N45E	0.60	59.8	28.2	25.7	7.6	0.22	121.9	14.7	.07-25	
Chile	Llolleo	S80E	0.35	23.6	3.7	42.0	41.0	0.12	53.3	10.4	.20-25	SMA-1
		V	0.75	38.2	36.6	58.0	30.0	0.17	43.2	16.0	.07-25	
		N10E	0.62	42.8	17.2	92.0	35.0	0.19	88.9	16.0	.10-25	
Mexico	Zacatula	EW	0.17	13.3	2.5	8.8	41.0	0.05	43.2	6.6	.28-25	DCA 333
		V	0.13	7.7	1.2	4.5	41.0	0.03	16.5	6.4	.35-25	
		NS	0.25	29.3	8.2	14.1	49.0	0.06	55.9	8.4	.20-25	
Nahanni	Site 1	EW	0.79	42.3	16.5	23.3	8.0	0.37	86.4	25.4	.07-25	SMA-1
		V	1.73	37.9	17.5	25.0	7.5	0.47	66.0	61.0	.07-25	
		NS	0.99	43.8	8.7	27.0	8.0	0.35	61.0	23.1	.07-25	
Palm Springs	Substation	L	0.76	84.1	20.6	21.0	3.4	0.40	152.4	25.4	.07-25	SMA-2
		V	0.48	21.9	2.5	6.0	5.4	0.12	22.9	10.2	.225-25	
		T	0.65	31.7	4.0	7.8	4.8	0.27	45.7	12.2	.25-25	
San Salvador	G.I.C.	90	0.69	80.0	11.9	15.5	4.4	0.46	101.6	14.2	.16-23	SMA-1
		V	0.39	10.9	2.3	5.9	3.2	0.18	33.0	17.3	.16-23	
		180	0.42	61.8	14.8	10.8	3.3	0.27	66.0	9.1	.16-23	

strong directivity effect. A notable example of a near-source record for which the peak vertical acceleration was much higher than the larger horizontal component (Ref. 3).

Tabas The accelerograph was within 3 km of nearest fault outcrop, on thick quaternary gravel fan deposits. This intraplate thrust earthquake consisted of four approximately equal energy sub-events propagating towards Tabas (Ref. 4).

Montenegro Instrument was located on soil 28 m to bedrock, distant approximately 24 km from nearest point on rupture zone. Complex source thrust fault. Apparently no direct surface faulting, but numerous cracks, slumps, rock-falls, and landslides (Ref. 5).

Imperial Valley Ground rupture followed same trace as the 1940 event for about 30 km. Accelerograph 3 km from surface fault rupture. Located on thick alluvium, upper 30 m silt and clay. Another accelerograph located 1 km from fault showed vertical 1.7 g and maximum horizontal 0.7 g. Unilateral faulting with non-uniform rupture velocity and strong directivity effects (Ref. 6).

Coalinga No surface faulting. Accelerograph located at switchyard ground site on a 4 x 4 ft concrete pad with a small metal shelter, about 9 km from epicenter. Station on thick quaternary sediments (Ref. 7).

Chile Accelerograph located in basement of one-story building on sandstone and volcanic rock. Thrust faulting directed from epicenter towards station which was about 30 km from supposed plane of faulting. The main shock was preceded 10 sec by a m_b 5.2 sub-event about 50 km from the main shock (Ref. 8).

Mexico Two main sub-events about 27 sec and 95 km apart. Zacatula accelerograph founded on river deposit sediments directly above fault rupture some 20 km below. Nearby free-field station mounted on small pier on hard crystalline basement rock showed smaller peak accelerations of EW 0.14 g, V 0.1 g, NS 0.16 g. Note that the epicentral accelerations were much lower than those of the smaller 1985 Chile event, which had many similar characteristics (Refs. 9, 10, 11).

Nahanni Instrument was bolted down to bedrock. Subsurface geology, down to 1-1/2 km, shale, mudstone and siltstone. Accelerograph was directly above hypocenter some 8-10 km below. Although peak vertical trace was offscale, several experienced experts examining the original record agreed that peak vertical acceleration was at least 2 g, making this record the largest ground acceleration so far recorded. No surface faulting (Refs. 12, 13).

Palm Springs Accelerograph about 4 km from epicenter in region of surface trace fractures which follow a known fault for some 6 km. Instrument located on poorly consolidated alluvial materials (Ref. 14).

San Salvador Instrument about 4 km from epicenter in first floor of a two-story reinforced concrete building. Site geology - 30 m of poorly consolidated tuff materials. No surface faulting observed (Ref. 15).

CONCLUSIONS

Earthquake ground motions occur with an even greater variation in shape and size than had been generally realized. There are evidently important parameters involving details of energy release and propagation which have not yet been adequately defined and studied. Continued expansion and improvement of the world-wide strong-motion accelerograph network, and an increased effort at a more detailed understanding of past records will be essential for the development of more effective techniques for the assessment and mitigation of seismic hazards.

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REFERENCES

1. Hudson, D. E., "Strong Motion Earthquake Measurements in Epicentral Regions," Proc. 6WCEE, New Delhi, (1977).
2. Lee, V. W. and Trifunac, M. D., "Current Developments in Data Processing of Strong Motion Accelerograms," Report No. CE 84-01, University of Southern California, Los Angeles, (1984).
3. Hartzell, S., "Faulting Process of the May 17, 1976 Gazli, U.S.S.R. Earthquake," Bull. Seism. Soc. Amer., vol. 70, no. 5, (1980).
4. Shoji-Taheri, J. and Anderson, J. G., "The 1978 Tabas, Iran, Earthquake: An Interpretation of the Strong Motion Records," Bull. Seism. Soc. Amer., vol. 78, no. 1, (1988).
5. Petrovski, J. and Paskalov, T. (eds.), The Montenegro, Yugoslavia, Earthquake of April 15, 1979, Pub. No. 65, Inst. of E. Q. Eng. and Eng. Seis., University "Kirol and Metodij," Skopje, (1981).
6. Brady, A. G., Perez, V., and Mork, P. N., The Imperial Valley Earthquake, October 15, 1979. Digitization and Processing of Accelerograph Records, Open-File Report 80-703, U.S.G.S., Menlo Park, California, (1980).
7. Scholl, R. E. and Stratta, J. L. (eds.), Coalinga, California, Earthquake of May 2, 1983, Reconnaissance Report, EERI, Berkeley, (1984).
8. Scholl, R. E. and Thiel, C. C. (eds.), "The Chile Earthquake of March 3, 1985," Earthquake Spectra, vol. 2, no. 2, (1986).
9. Quaas, R. and Mena, E., "Strong Motion Arrays and Characteristics," Proc. Int. Conf. on the Mexican Earthquakes - 1985, A.S.C.E., New York, (1987).
10. Anderson, J. G., Brune, J. R., Prince, J., Mena, E., Bodin, P., Onote, M., Quaas, R., and Singh, S. K., "Aspects of Strong Motion," Proc. Int. Conf. on the Mexico Earthquakes - 1985, A.S.C.E., New York, (1987).
11. Eder, S. J. and Swan, S. W., "Summary of the Effects of the 1985 Mexico Earthquake to Power and Industrial Facilities," Proc. Int. Conf. on the Mexico Earthquakes - 1985, A.S.C.E., New York, (1987).
12. Weichert, D. H., Wetmiller, R. J., and Munro, P., "Vertical Earthquake Acceleration Exceeding 2 g?," Bull. Seism. Soc. Amer., vol. 76, no. 5, (1986)
13. Wetmiller, R. J., Horner, R. B., Hasegawa, H. S., North, R. G., Lamontagne, M., Weichert, D. H., and Evans, S. G., "An Analysis of the 1985 Nahanni Earthquake," Bull. Seism. Soc. Amer., vol. 78, no. 2, (1988).
14. Report on the North Palm Springs, California, Earthquake - July 8, 1986, LFE Project Report, EERI, El Cerrito, California, (1986).
15. Shakal, A. F., Huang, M. J., and Linares, R., "The San Salvador Earthquake of October 10, 1986 - Processed Strong Motion Data," Earthquake Spectra, vol. 3, no. 3, (1987).