DEPARTMENT OF THE INTERIOR

U. S. GEOLOGICAL SURVEY

Near-Source High-Frequency Seismic Waveform Data Available from the U. S. Geological Survey

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Open-File Report 88–596

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1988

INTRODUCTION

As part of the National Earthquake Hazards Reduction Program, the United States Geological Survey (USGS) collects near-source, high-frequency seismic waveform data from several sources. These diverse datasets have formed the basis of recent research in the areas of seismotectonics, ground-motion estimation and attenuation, seismic source mechanics, seismic wave propagation and site amplification, and structural response by investigators both inside and outside the Geological Survey. The purpose of this report is to make all members of the seismology and earthquake-engineering communities aware of the datasets collected and archived by the USGS at Menlo Park, California.

INSTRUMENTATION

Waveform data come primarily from two sources: permanently installed analog strong-motion accelerographs and portable digital seismographs.

Analog strong-motion data are recorded by a national network of strong-motion accelerographs maintained by the USGS, which has grown from its antecedents in California in the 1930s to approximately 1000 strong-motion accelerographs today (~40% of the U. S. total). A typical modern analog strong-motion accelerograph is mechanically triggered by strong shaking and records several seconds to several minutes of three-component ground motion on 75 *mm* photographic film. These instruments are designed to record the strongest motions (typical trigger threshold = 0.02 *g*, typical maximum on-scale amplitude = 1 *g*), and are expected, with proper maintenance, to operate dependably after decades of dormancy.

Digital data are recorded by several dozen portable seismographs: principally Sprengnether DR100 recorders from 1979 to 1983, and USGS-developed GEOS recorders from 1983 to the present. Most digital data have come from aftershock deployments following most of the significant crustal earthquakes in the 48 conterminous United States since 1979. More recently, portable digital recorders have been successfully used in refraction and short-baseline-array experiments and structural-engineering studies. We currently rely on the microprocessor-controlled GEOS seismograph (Borcherdt *et al*, 1985) for most applications. The range of recorded ground-motion amplitudes can be tailored to the purpose of each experiment: from microearthquake recordings with geophones recorded at high gain to strong-motion recordings with force-balance accelerometers recorded at low gain. In a typical aftershock deployment, a GEOS simultaneously records three-component ground velocity and three-component ground acceleration at two hundred samples-per-second-per-component. It is triggered by an algorithm that compares ground-motion amplitudes in adjustable short- and long-duration windows with an adjustable threshold, and records several seconds to several minutes of digitized ground motion, including a pre-trigger interval, on magnetic tape.

In conjunction with scientists at the Institute of Geophysics and Planetary Physics at the University of California, San Diego, we have also collected and archived (continuously since October 1982) an extensive waveform dataset from a permanent network of digital seismographs at Anza, California (Berger *et al*, 1985; Fletcher *et al*, 1987).

A historical distinction exists between data from permanently installed analog strong-motion accelerographs and data from portable digital seismographs, due primarily to data-processing differences. It is convenient to maintain that distinction here (to be precise, we will refer to "strong-motion" data and "portable-digital-seismograph" data in this report), but we wish to point out its limited usefulness, especially from a research point of view. For example, analog strong-motion accelerographs have been deployed in aftershock zones, and significant strong-motion accelerograms have been recorded by portable digital seismographs equipped with force-balance accelerometers, rendering simple distinctions such as "permanent *vs.* portable", and "strong-motion *vs.* aftershock" somewhat arbitrary. These distinctions will erode even further in the future as digital instrumentation becomes more widely used in strong-motion work. The portable-digital-seismograph dataset is now much larger than the strong-motion dataset. The strong-motion dataset, however, includes the greatest-amplitude records and is more geographically and temporally uniform through the United States; it remains the primary research tool of strong-motion seismologists and earthquake engineers.

PROCESSING AND ARCHIVING

We currently accomplish waveform processing and analysis in an interactive computing environment based on Digital Equipment Corporation (DEC) PDP/RSX and VAX/VMS systems. The basic data unit is the single-component evenly sampled seismic waveform, stored one-component-per-file in a block-binary format. A typical file consists of one integer header block, followed by one real header block, followed by one-or-more real (most strong-motion data) or integer (most portable-digital-seismograph data) data blocks. Following processing, strong-motion waveforms are stored on 9-track archive tape using DEC's

BACKUP utility (VMS operating system) and/or converted to ASCII card-image format and sent to the National Geophysical Data Center (NGDC) in Boulder, Colorado. Full datasets and subsets of portable-digital-seismograph waveforms are archived on 9-track tape using DEC's BRU (RSX operating system) and BACKUP (VMS operating system) utilities. Waveforms can be exported to the seismology and engineering research communities from the USGS in Menlo Park or from NGDC in Boulder.

We are also currently implementing two new computer databases to facilitate the organization and retrieval of waveforms and related data. The strong-motion database, ESM (Converse, 1987), is related to the old SMIRS hierarchical database that might be familiar to previous users of USGS strong-motion data. The portable-digital-seismograph database (Mueller, 1988) is a new design. Both are based on event, instrument, and record concepts, and are implemented on the VAX/VMS system using INGRES relational database software.

WAVEFORM DATA

Strong-motion Waveforms

The available strong-motion waveform dataset is summarized in Table 1. For historical reasons, this dataset divides naturally into two groups:

- Waveforms from analog accelerograms recorded before the USGS took over digitizing and processing activities. This dataset, which includes North American strong-motion records up to and including those recorded during the 1971 San Fernando earthquake, was processed at the Earthquake Engineering Research Laboratory of the California Institute of Technology during the years 1968 to 1975. These waveforms are available from NGDC.
- Waveforms from analog accelerograms collected since the San Fernando earthquake. These records have been digitized and processed by the USGS and are also available from NGDC. Recent improvements in data preparation include high-resolution trace-following laser digitization and enhanced processing methods. The current processing package, AGRAM (Converse, 1984), is running on the VAX/VMS system and is available to users who wish to do their own processing; FORTRAN sources and documentation are available from A. Converse.

Portable-Digital-Seismograph Waveforms

The available portable-digital-seismograph waveform dataset is summarized in Table 2.

Tape cartridges from portable digital recorders are played back and data files are organized on the PDP/RSX system. Waveforms are archived and analyzed on both the PDP/RSX and VAX/VMS systems. Table 2 lists datasets collected through early 1988 that we feel might be of particular interest to the seismology and earthquake-engineering research communities.

DATA EXPORT

A typical data request might include the following steps. First, a researcher provides data-selection criteria (for example: all acceleration waveforms recorded within 20 km of Coalinga aftershocks with magnitude greater than 3). Based on these criteria, we might refer all or part of the request to NGDC, an agency whose primary responsibility is data archiving and distribution. A list of filenames is constructed (possibly from a database) and block-binary waveform files are retrieved from archive tape. Finally, waveform files are translated to ASCII card-image format, and written to an export tape (for example, unlabelled, 1600 cpi, recordsize=80, blocksize=2000). We request that users supply their own blank magnetic tapes.

Data requests to USGS in Menlo Park should be made in writing to:

ES&G Data Project
US Geological Survey MS 977
345 Middlefield Rd.
Menlo Park, CA 94025.

Data requests to NGDC should be made in writing to:

National Geophysical Data Center
NOAA, Code E/GC11
325 Broadway
Boulder, CO 80303.

The bibliography at the end of this report includes a sample of data reports and research papers that might be particularly useful to potential users of the waveform datasets. Users needing comprehensive reference lists should consult the bibliographies (e.g. Gessner, 1986) that are available from the USGS in Menlo Park at the above address.

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TABLE 1 - Strong-Motion Data

Year	Name	Date	Time	Lat	Lon	Mag	Records
1933	Long Beach	10-mar-33	1754 pst	33.58	-117.98	6.3	3
	Southern Cal	02-oct-33	0110 pst	33.78	-118.13	5.4	2
1934	Eureka	06-jul-34	1449 pst	41.70	-124.60		1
	Lower Cal	30-dec-34	0552 pst	32.20	-115.50	6.5	1
1935	Helena MT	31-oct-35	1137 mst	46.62	-111.97	6.0	1
	Helena as	31-oct-35	1218 mst	-	-	-	1
	Helena as	21-nov-35	2058 mst	-	-	-	1
	Helena as	28-nov-35	0742 mst	-	-	-	1
1937	Humboldt Bay	06-feb-37	2042 pst	40.50	-125.25	5.8	1
1938	Imperial Valley	12-apr-38	0825 pst	32.89	-115.58	4.5	1
	Imperial Valley	05-jun-38	1842 pst	32.90	-115.22	5.0	1
	Imperial Valley	06-jun-38	0435 pst	32.25	-115.17	4.0	1
	Northwest Cal #1	11-sep-38	2210 pst	40.30	-124.80	5.5	1
1940	El Centro	18-may-40	2037 pst	32.72	-115.50	6.7	1
	El Centro as (+45.5)	18-may-40	2037 pst	-	-	-	1
	El Centro as (+84.0)	18-may-40	2037 pst	-	-	-	1
	El Centro as (+101.5)	18-may-40	2037 pst	-	-	-	1
	El Centro as (+125.0)	18-may-40	2037 pst	-	-	-	1
	El Centro as (+154.0)	18-may-40	2037 pst	-	-	-	1
	El Centro as (+203.0)	18-may-40	2037 pst	-	-	-	1
	El Centro as (+242.0)	18-may-40	2037 pst	-	-	-	1
	El Centro as (+282.0)	18-may-40	2037 pst	-	-	-	1
	El Centro as (+313.0)	18-may-40	2037 pst	-	-	-	1
1941	Northwest Cal #2	09-feb-41	0144 pst	40.70	-125.40	6.0	1
	Santa Barbara	30-jun-41	2351 pst	34.37	-119.58	5.9	1
	Northern Cal	03-oct-41	0813 pst	40.40	-124.80	6.4	1
	Torrance-Gardena	14-nov-41	0042 pst	33.78	-118.25	5.4	2
1942	Borrego Valley	21-oct-42	0922 pst	32.97	-116.00	6.5	1
1949	Northern Cal	09-mar-49	0428 pst	37.02	-121.48	5.2	1
	Western Washington	13-apr-49	1155 pst	47.10	-122.70	7.1	2
1951	Imperial Valley	23-jan-51	2317 pst	33.12	-115.57	5.6	1
	Northwest Cal	07-oct-71	2011 pst	40.28	-124.80	5.8	1
1952	Kern County	21-jul-52	0437 pst	35.00	-119.00	7.7	6
	Kern County as	-	-	-	-	-	1
	Kern County as	-	-	-	-	-	1
	Kern County as	-	-	-	-	-	1
	Northern Cal	22-sep-52	0441 pst	40.20	-124.42	5.5	1
	Southern Cal	21-nov-52	2346 pst	35.83	-121.17	6.0	1
1953	Imperial Valley	13-jun-53	2017 pst	32.83	-115.67	5.5	1
1954	Wheeler Ridge	12-jan-54	1534 pst	35.00	-119.02	5.9	1
	Central Cal	25-apr-54	1234 pst	36.93	-121.68	5.3	1
	Lower Cal	12-nov-54	0427 pst	31.50	-116.00	6.3	1
	Eureka	21-dec-54	1156 pst	40.82	-124.08	6.5	2

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Table 1. Strong-motion data.

TABLE 1 (continued)

Year	Name	Date	Time	Lat	Lon	Mag	Records
1955	San Jose or W Cent Cal	04-sep-55	1801 pst	37.37	-121.78	5.8	2
	Imperial County fs	16-dec-55	2117 pst	-	-	4.3	1
	Imperial County fs	16-dec-55	2142 pst	-	-	3.9	1
	Imperial County	16-dec-55	2207 pst	33.00	-115.50	3.9	1
1956	El Alamo Baja	09-feb-56	0633 pst	31.75	-115.91	6.8	1
	El Alamo Baja as	09-feb-56	0725 pst	31.70	-115.90	4.5	1
1957	Southern Cal	18-mar-57	1056 pst	34.10	-119.17	4.7	1
	SF or Daly City fs	22-mar-57	1048 pst	37.67	-122.47	3.8	1
	SF or Daly City	22-mar-57	1144 pst	37.67	-122.48	5.3	6
	SF or Daly City as	22-mar-57	1515 pst	37.65	-122.45	4.4	6
	SF or Daly City as	22-mar-57	1627 pst	37.65	-122.48	4.0	1
1960	Central Cal	19-jan-60	1926 pst	36.78	-121.43	5.0	1
	Northern Cal	05-jun-60	1718 pst	40.82	-124.88	5.7	1
1961	Hollister or Cent Cal	08-apr-61	2323 pst	36.68	-121.30	5.6	1
	Hollister or Cent Cal as	08-apr-61	2325 pst	36.70	-121.30	5.5	1
1962	Northern Cal	04-sep-62	0917 pst	40.97	-124.20	5.0	1
1965	Puget Sound WA	29-apr-65	0729 pst	47.40	-122.30	6.5	2
	Southern Cal	15-jul-65	2346 pst	34.49	-118.52	4.0	1
1966	Parkfield CA	27-jun-66	2026 pst	35.92	-120.53	5.3	7
	Gulf of California	07-aug-66	0936 pst	31.80	-114.50	6.3	1
	Northern Cal	12-sep-66	0841 pst	39.42	-120.15	6.0	1
1967	Northern Cal	18-dec-67	0925 pst	37.00	-121.78	5.3	2
1967	Ferndale or NW Cal #2	10-dec-57	0407 pst	40.50	124.70	5.6	2
1968	Borrego Mountain	08-apr-68	1830 pst	33.20	-116.11	6.5	15
1970	Lytle Creek	12-sep-70	0631 pst	34.27	-117.54	5.4	36
1971	Aleutian Is AK	02-may-71	0608 gmt	51.42	-177.21	6.0	1
	Isabella	08-mar-71	2308 gmt	35.55	118.39	4.7	1
	Northern Cal	12-sep-71	1932 gmt	41.49	-123.79	4.9	1
	San Fernando	09-feb-71	0601 pst	34.41	-118.40	6.4	233
	San Fernando as (+52.6)	09-feb-71	1401 gmt	-	-	-	1
	San Fernando as (+69.6)	09-feb-71	1401 gmt	-	-	-	1
	San Fernando as (+104.6)	09-feb-71	1401 gmt	-	-	-	1
	San Fernando as (+162.0)	09-feb-71	1401 gmt	-	-	-	1
	San Fernando as (+230.1)	02-feb-71	1401 gmt	-	-	-	1
	San Fernando as (+309.1)	09-feb-71	1401 gmt	-	-	-	1
1973	Point Mugu	21-feb-73	1445 gmt	34.07	-119.04	5.7	1
	Hawaii	26-apr-73	2026 gmt	20.05	-155.16	6.2	1
	Central Cal	22-jun-73	0129 gmt	36.40	-121.40	4.5	1
1974	Central Cal	28-nov-74	2301 gmt	36.78	-121.60	5.0	1
1975	Southern Alaska	01-jan-75	0355 gmt	61.90	-149.70	5.9	4
	Cape Mendocino	12-jan-75	0137 gmt	40.29	-124.62	4.7	1
	Cape Mendocino	07-may-75	0235 gmt	40.38	-124.62	4.5	1
	Cape Mendocino	07-jun-75	0846 gmt	40.59	-124.18	5.4	1
	New Madrid MO	13-jun-75	2240 gmt	36.55	-89.72	4.2	1
	Palm Springs	02-aug-75	0014 gmt	33.52	-116.55	4.6	1

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Table 1 (continued).

TABLE 1 (continued)

Year	Name	Date	Time	Lat	Lon	Mag	Records
1975	Oroville	01-aug-75	2020 gmt	39.44	-121.53	5.7	2
	Oroville as	02-aug-75	2059 gmt	39.41	-121.71	5.1	3
	Oroville as	02-aug-75	2022 gmt	39.45	-121.46	5.1	2
	Oroville as	03-aug-75	0103 gmt	39.45	-121.52	4.6	8
	Oroville as	03-aug-75	0247 gmt	39.48	-121.50	4.1	8
	Oroville as	06-aug-75	0350 gmt	39.48	-121.52	4.7	10
	Oroville as	08-aug-75	0700 gmt	39.50	-121.51	4.9	9
	Oroville as	11-aug-75	0611 gmt	39.45	-121.48	4.3	9
	Oroville as	16-aug-75	0548 gmt	39.47	-121.52	4.0	11
	Oroville as	26-sep-75	0231 gmt	39.49	121.57	4.0	10
	Oroville as	27-sep-75	2234 gmt	39.51	121.54	4.6	10
	Hawaii	29-nov-75	1335 gmt	19.48	-155.17	5.7	1
	Hawaii as	29-nov-75	1447 gmt	19.46	-155.14	6.0	1
1976	Whittier	01-jan-76	1720 gmt	33.57	-117.99	4.6	1
	Arkansas	25-mar-76	0041 gmt	35.65	-90.34	4.9	1
	Arkansas as	25-mar-76	0100 gmt	35.57	-90.36	4.5	1
1978	Coyote Dam	26-mar-78	0027 gmt	39.09	-123.34	4.5	3
	Santa Barbara	13-aug-78	2254 gmt	34.37	-119.72	5.7	1
	Monticello Dam SC	27-aug-78	1023 gmt	34.31	-81.33	2.7	1
1979	Coyote Lake	06-aug-79	1705 gmt	37.11	-121.53	5.7	6
	Imperial Valley	15-oct-79	2317 gmt	32.63	-115.33	6.6	22
	Imperial Valley as	15-oct-79	2317 gmt	-	-	-	6
	Imperial Valley as	15-oct-79	2318 gmt	-	-	-	7
	Imperial Valley as	15-oct-79	2318 gmt	-	-	-	6
1981	Solomon Islands	13-dec-81	0139 gmt	-6.39	154.93	6.0	3
	Solomon Islands as	13-dec-81	1324 gmt	-6.34	154.92	5.7	1
1983	Monasavu Dam Fiji	13-feb-83	0953 gmt	-17.74	178.07	3.2	1
	Monasavu Dam as	14-feb-83	1218 gmt	-17.76	178.06	2.7	1
	Monasavu Dam as	23-feb-83	1517 gmt	-17.76	178.02	2.9	1
	Solomon Islands	18-mar-83	0905 gmt	-4.83	153.57	7.9	3
	Coalinga	02-may-83	2342 gmt	36.23	-120.30	6.5	2
	Coalinga as	09-may-83	0249 gmt	36.23	-120.31	5.2	11
	Coalinga as	09-jul-83	0740 gmt	36.25	-120.40	5.3	7
	Coalinga as	22-jul-83	0239 gmt	36.24	-120.41	6.0	12
1984	Morgan Hill	24-apr-84	2105 gmt	37.32	-121.68	6.1	11
1985	Nahanni NWT Canada	09-nov-86	0446 gmt	-	-	-	1
	Nahanni NWT Canada	23-dec-85	0516 gmt	-	-	-	3
	Nahanni NWT Canada	23-dec-85	0548 gmt	-	-	-	1
	Nahanni NWT Canada	25-dec-85	1543 gmt	-	-	-	1
1986	Hollister	26-jan-86	1920 gmt	36.81	-121.28	5.5	5
	North Palm Springs	08-jul-86	0920 gmt	34.00	-116.61	6.0	17
1987	Whittier Narrows	01-oct-87	1442 gmt	34.05	-118.08	5.9	70
	Whittier Narrows as	04-oct-87	1059 gmt	34.07	-118.10	5.3	15
	Superstition Hills	24-nov-87	0154 gmt	33.08	-115.78	6.5	5
	Superstition Hills	24-nov-87	1315 gmt	33.01	-115.85	6.7	28

Table 1 (continued).

TABLE 2 - Portable-Digital-Seismograph Data

Dataset	Type	Scientist	Date	Records
Monticello, SC	E	Fletcher	79/130-161	
Coyote Lake, CA	E	Fletcher/Spudich	79/220-261	
*Imperial Valley, CA	E	Fletcher	79/290-321	2400
Diablo, CA	E	Fletcher	80/024-038	
Eureka, CA	E	Mueller	80/314-323	<100
*Mammoth Lakes, CA	E	Mueller	80/147-165	8000
*Miramichi, Canada	E	Cranswick	82/015-022	600
Enola, AR	E	Haar	82/175-186	2300
*Coalinga, CA	E	Mueller	83/123-145	31000
Goodnow, NY	E	Cranswick	83/284-290	
Borah Peak, ID	E	Boatwright	83/302-312	3500
*Morgan Hill, CA	E	Archuleta	84/116-174	13000
*Chile I	E	Algermissen/Celebi	85/082-098	6600
*Chile II	E,ES	Celebi/Algermissen	85/208-228	7200
Parkfield, CA	E,EB	Borcherdt	85/231-active	
*Pace, AZ	CS	Borcherdt	85/308-317	
Mexico	E,ES	Celebi	86/009-018	
*Painesville, OH	E	Borcherdt	86/032-042	<100
*Lovelock, NV	CS	Borcherdt/Dietel	86/198-214	
Whittier, CA	E,ES	Mueller	87/275-313	16000
Superstition, CA	E	MAndrews	87/329-342	15000

* data report available

'Type' code : E = earthquake, surface recording

EB = earthquake, borehole recording

ES = earthquake, recordings in structures

CS = crustal structure deployment

Table 2. Portable-digital-seismograph data.