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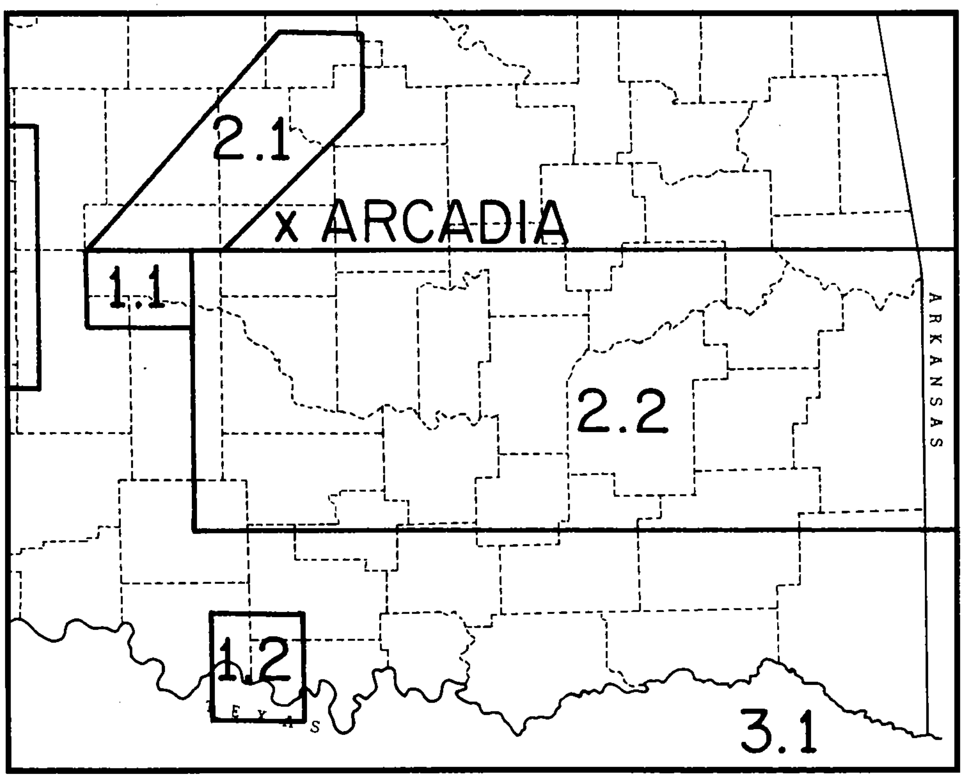
James E. Lawson, Jr.



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EXPECTED EARTHQUAKE GROUND-MOTION PARAMETERS AT THE ARCADIA, OKLAHOMA, DAM SITE

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ADVANCE SUMMARY

A study of earthquake distribution and intensity values in Oklahoma was used to divide Oklahoma and parts of the adjacent states into six seismic-source zones. These zones, in order of decreasing seismic activity, embrace certain areas herein referred to as central Oklahoma (also referred to as zone 1.1), south-central Oklahoma (zone 1.2), north-central Oklahoma (zone 2.1), southeast Oklahoma (zone 2.2), west-central Oklahoma (zone 2.3), and residual (an area that encompasses all remaining parts of the State, (zone 3.1). The proposed Arcadia dam site, 30 km northeast of Oklahoma City, is within zone 3.1, the least active zone, and is nearly 35 km from the nearest part of zone 1.1 and is less than 15 km from the nearest part of zones 2.1 and 2.2 (see fig. 2).

For zone 1.1, the largest earthquake magnitude (M) expected in a given number of years (y) was computed from the following expression:

$$M = 2.72 - 0.880 \log(1/y).$$

This equation was used to determine expected earthquake magnitudes for various time intervals. For the corresponding time periods of 100, 200, 500, 1000, and 2000 years, the computed magnitudes are 4.5, 4.8, 5.1, 5.4, and 5.6, respectively.

A probabilistic estimate indicates that an earthquake in zone 1.1, 46 km away from Arcadia, would cause the largest ground motion at the dam site. The earthquake-magnitude values calculated for the selected time intervals were used to compute expected horizontal ground accelerations and horizontal ground velocities at the dam site. The values are listed below.

Period (years)	Magnitude (M)	Site acceleration (% of g)	Site velocity (cm/sec)
100	4.5	3.0	0.8
200	4.8	4.2	1.5
500	5.1	6.4	3.3
1000	5.4	8.7	6.0
2000	5.6	12.0	11.2

INTRODUCTION

The U.S. Army Corps of Engineers is currently investigating a location near Arcadia in central Oklahoma as a potential dam site (fig. 1). The proposed Arcadia site, on the Deep Fork of the North Canadian River, is about 12 km northeast of Oklahoma City.

The present report summarizes a study to determine the largest earthquake-generated ground motion that would probably occur at the Arcadia dam site over various periods of time. The ground motion is described in terms of the maximum horizontal ground velocity and the maximum horizontal ground acceleration. These two parameters are evaluated for periods of 100, 200, 500, 1000, and 2000 years, and equivalent Modified Mercalli intensity at the proposed dam site is calculated for each period. Also, the magnitude of the earthquake expected to cause the largest ground motion, and the distance of that earthquake from the site, are tabulated for each of these time periods.

This study takes into account all known historical earthquakes capable of causing significant ground motion at the Arcadia site. For Oklahoma and nearby areas, felt historical earthquakes and smaller instrumentally located earthquakes are grouped into six source zones shown in figure 2. Magnitude-frequency relations were determined for each zone, and these were used to evaluate the expected Arcadia-site ground motion.

DATA BASE

A new earthquake data base was assembled in order to evaluate earthquake risk at the Arcadia dam site. The new data base also includes all earthquakes that could possibly have an effect on any site within the State of Oklahoma. The data base was conveniently subdivided into four main parts. These four parts and the sources of information for each part are listed as follows:

PART I - Includes all earthquakes known to have occurred in Oklahoma through the end of 1979.

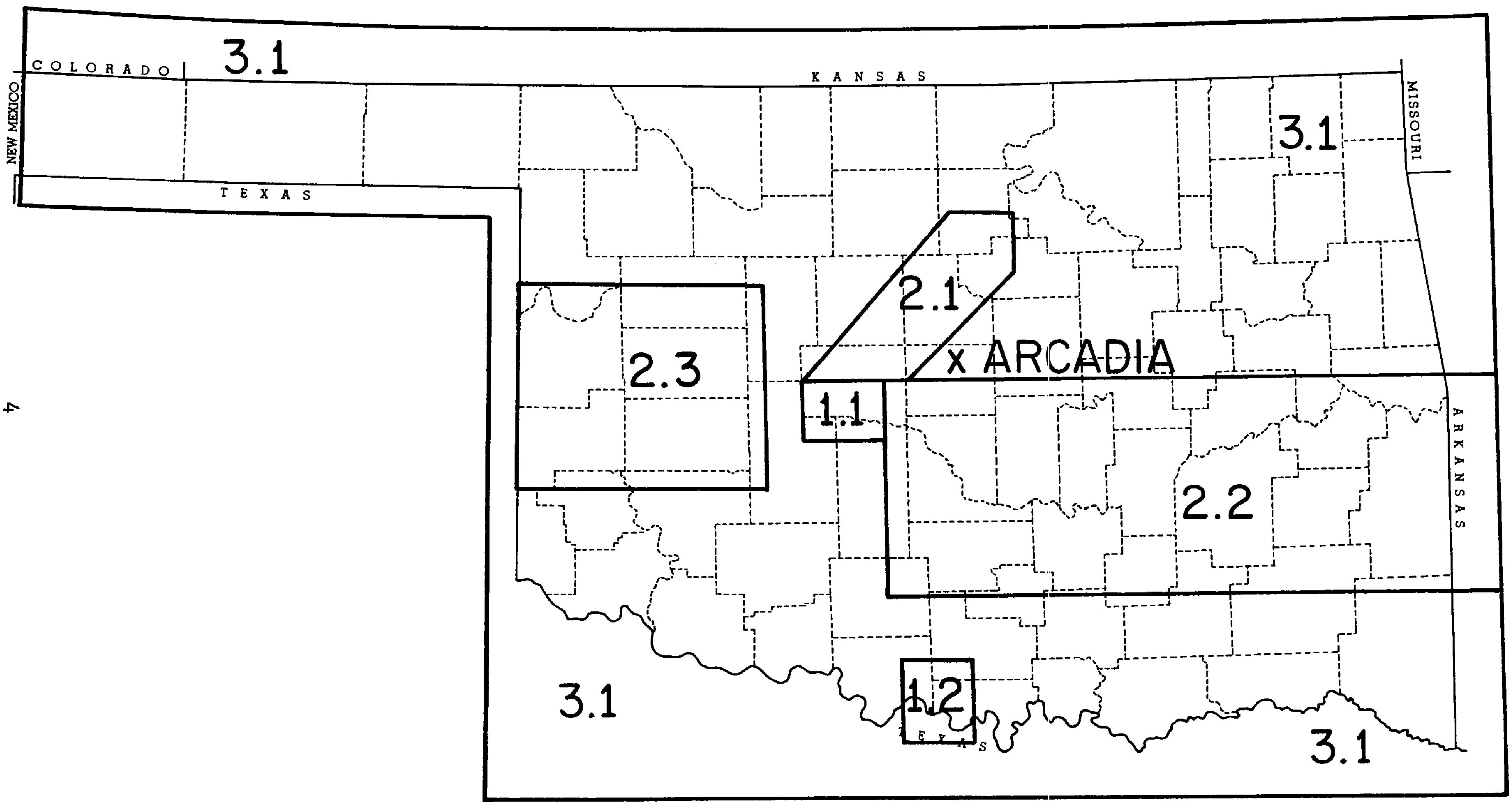

Fig. 1. Index map showing seismic-source zones and the Arcadia dam-site project.

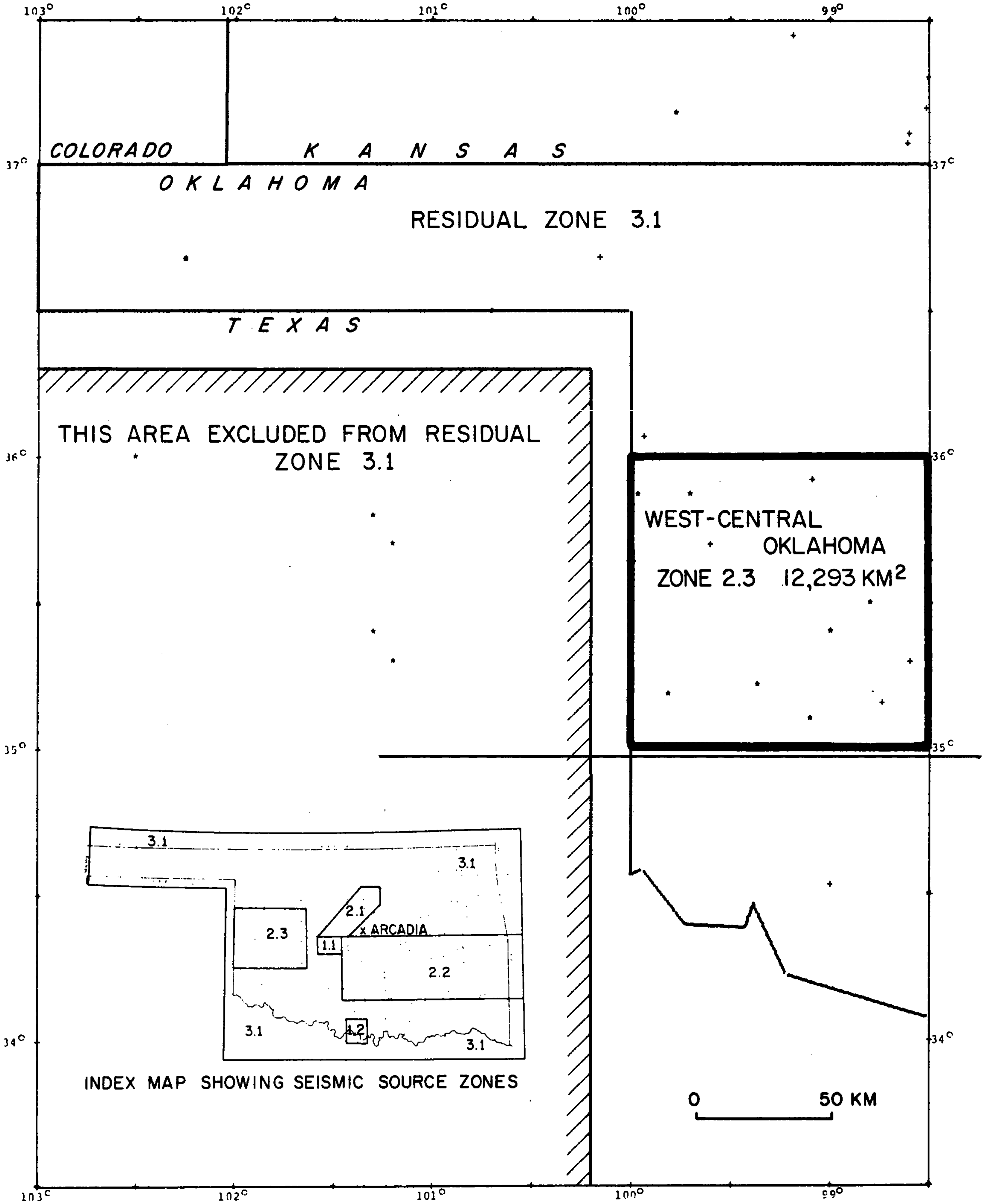

Fig. 2a. Seismic-source zones for western Oklahoma and adjacent states.

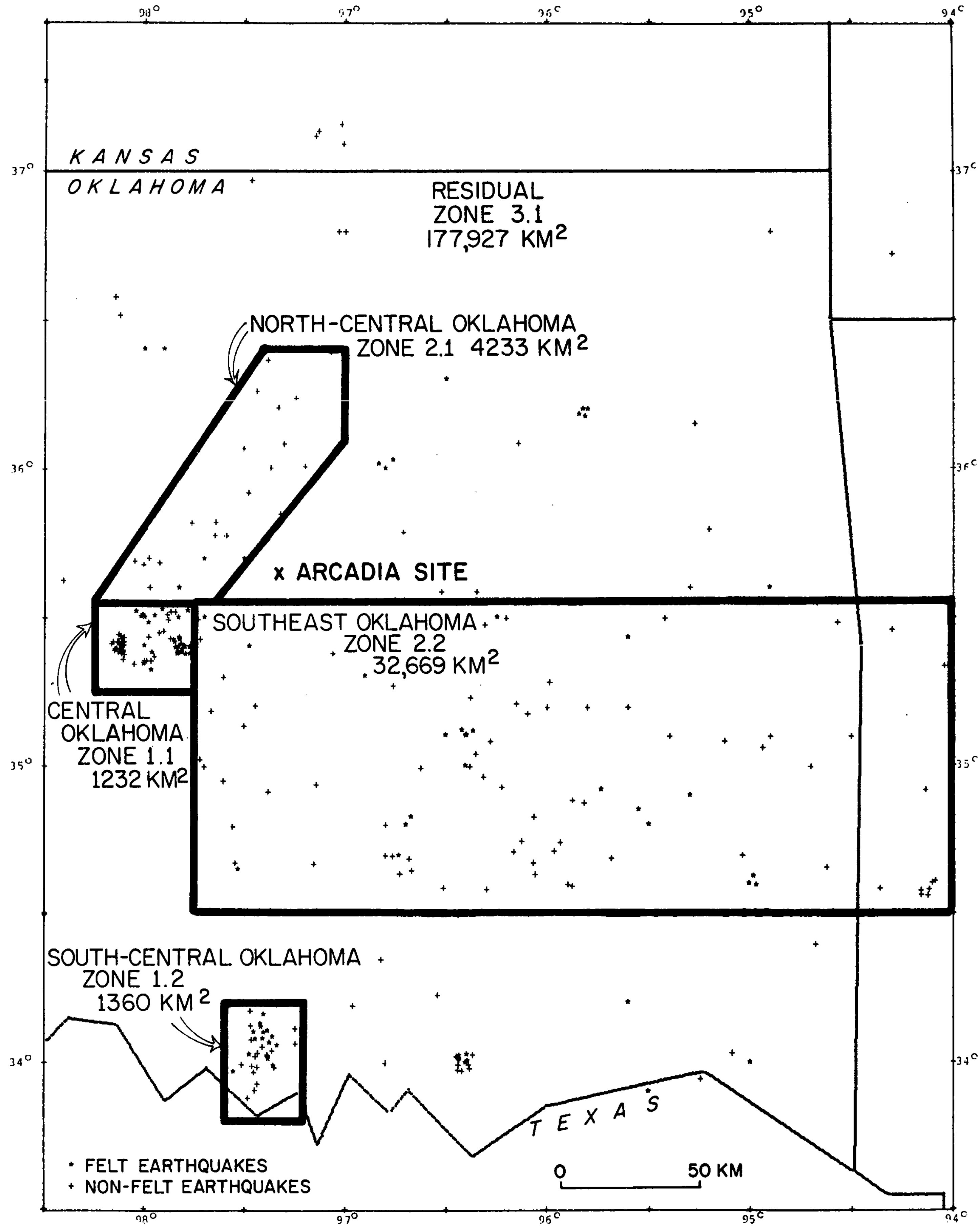

Fig. 2b. Seismic-source zones for eastern Oklahoma and adjacent states.

Sources: Ia - Lawson, J.E., Jr., Dubois, R.L., Foster, P.H., and Luza, K.V., 1979, Earthquake map of Oklahoma (with accompanying text and catalog): Oklahoma Geological Survey Map GM-19, 15 pages, map scale 1:750,000. (Contains all known Oklahoma earthquakes through the end of 1978.)

Ib - Lawson, J.E., Jr., and Luza, K.V., 1980, Oklahoma earthquakes, 1979: Oklahoma Geology Notes, v. 40, p. 95-105.

PART II - Includes all earthquakes not listed in Part I with an intensity (Modified Mercalli) of V or greater that have occurred between 32° and 44° north latitude and 92° and 104° west longitude.

Sources (for earthquakes not already included in Part I): IIa - Coffman, J.L., and von Hake, C.A. (editors), 1973, Earthquake history of the United States, revised edition (through 1970): NOAA publication 41-1, 208 p.

IIb - Coffman, J.L., 1979, Earthquake history of the United States (1971-76 supplement): NOAA and USGS joint publication 41-1, 41 p.

IIc - DuBois, S.M., and Wilson, F.W., 1978, A revised and augmented list of earthquake intensities for Kansas 1867-1977: U.S. Nuclear Regulatory Commission NUREG/CR-0294, 56 p. (Used only for earthquakes not found in sources IIa and IIb.)

IId - Burchett, R.R., 1979, Earthquakes in Nebraska: University of Nebraska Conservation and Survey Division Education Circular 4, 20 p. (Used only for earthquakes not found in sources IIa and IIb.)

PART III - Includes small (MM Intensity V) earthquakes located by the Kansas, Nebraska, and Oklahoma networks in the States of Kansas, Nebraska, Missouri, Texas, and Arkansas for the inclusive period 1977-79.

Sources: IIIa - Luza, K.V., DuBois, R.L., Lawson, J.E., Jr., Foster, Paul, and Koff, Leonid, 1978, Seismicity and tectonic relationships of the Nemaha Uplift in Oklahoma: U.S. Nuclear Regulatory Commission NUREG/CR-0050, 67 p.

IIIb - Luza, K.V., and Lawson, J.E., Jr., 1979, Seismicity and tectonic relationships of the Nemaha Uplift in Oklahoma, Part II: U.S. Nuclear Regulatory Commission NUREG/CR-0875, 81 p.

IIIc - Luza, K.V., and Lawson, J.E., Jr., 1980, Seismicity and tectonic relationships of the Nemaha Uplift in Oklahoma, Part III: U.S. Nuclear Regulatory Commission NUREG/CR-1500, 70 p.

Note: Sources in Parts IIa, IIIb, and IIIc include Kansas, Nebraska, and some Missouri earthquakes located by Don Steeples of the Kansas Geological Survey, and this information has also been published in U.S. Nuclear Regulatory Comission NUREG documents and other reports by the Kansas Geological Survey. Some Kansas and Nebraska earthquakes in sources IIIa, IIIb, and IIIc give both Oklahoma Geophysical Observatory and Kansas Geological Survey locations. When this has been the case, only the Oklahoma Geophysical Observatory location was entered in the Arcadia study data base. The two locations were never far enough apart to indicate any effect on seismic risk.

PART IV - Includes the three largest earthquakes of the 1811 and 1812 Mississippi Valley sequence.

Sources: IVa, Nuttli, O.W., 1973, The Mississippi Valley earthquake of 1811 and 1812: intensities, ground motion and magnitudes: Bulletin of the Seismological Society of America, v. 63, p. 227-248.

The resulting data base consists of 428 earthquakes, which are listed chronologically in table 1 (Appendix). Table 1 also lists the distance of each epicenter from the Arcadia site in kilometers and the expected acceleration and velocity at the Arcadia site for each earthquake. The acceleration is computed from the following formulae of Nuttli and Herrmann (1978):

$$\log(aH) = -0.36 + 0.52\ mb \qquad R < 15\ \text{km}$$

$$\log(aH) = -0.84 + 0.52\ mb - 1.02 \log(R) \qquad R \geq 15\ \text{km}, \tag{1}$$

where aH = maximum horizontal acceleration of ground at site in cm/sec^2, and R = great-circle distance from earthquake to site in km. The formulae have two forms, the first being applied for distances less than 15 km, and the second for distances of 15 km or greater. In the same publication, Nuttli and Herrmann gave a single formula for maximum horizontal ground velocity:

$$\log(vH) = -2.92 + 1.0\ mb - 1.0 \log(R).$$

Because this equation would allow vH to approach infinity as distance approached zero, the equation was converted to the following pair of formulae analogous to (1):

$$\log(vH) = -4.10 + 1.0\ mb \qquad R < 15\ km$$

$$\log(vH) = -2.92 + 1.0\ mb - 1.0 \log(R) \qquad R \geq 15\ km, \tag{2}$$

where vH = maximum horizontal ground velocity at site in cm/sec. All accelerations calculated from formula (1) were reduced to a percentage of g by dividing them by measured gravity at the Oklahoma Geophysical Observatory "rock gravity station" (U.S. Department of Defense catalog number 5279-1), and multiplying the quotient by 100. The "rock gravity station" has a measured gravitational acceleration of 979.720 cm/sec/sec.

Table 2 lists all of the earthquakes from table 1 which would have produced a horizontal acceleration of 0.1% g or greater at the Arcadia site. The listing is in order of acceleration. Only 10 earthquakes would have produced an acceleration of 1.0% g or more. They are the three large Mississippi Valley earthquakes of 1811-12, the 1952 El Reno earthquake and four of its aftershocks, the 1956 Edmond earthquake, and a 1939 Hughes County earthquake. The greatest site ground velocities listed were caused by the 1811-12 Mississippi Valley earthquakes.

OKLAHOMA SEISMIC-SOURCE ZONES

On the basis of the patterns of historical earthquakes and network earthquakes ("network earthquakes" refer to earthquakes located by arrival times at three or more network seismograph stations), Oklahoma and nearby areas were divided into six seismic-source zones. The zones were based on consistent patterns of earthquake occurrence. The zones do not appear to coincide with major geologic features, except that zone 2.2, southeast Oklahoma, contains most of the Ouachita front.

Table 2. Earthquakes from table 1 which would have produced a maximum horizontal ground acceleration of 0.1% g or more at the Arcadia site, listed in acceleration order. See table 1 for caption information.

YEAR	DATE	UTC	LAT DN	LON DW	ST	MM	MAG	DELTAkm	Ah %g	Vh cm/sec
1812	FEB 7	0945	36.600	89.600	MO	12	7.40	701.787	6.219690	43.032327
1952	APR 9	1629	35.400	97.800	OK	7	5.04	50.778	5.369235	2.596139
1811	DEC16	0815	36.600	89.600	MO	12	7.20	701.787	4.895181	27.151563
1956	FEB16	2330	35.700	97.500	OK	6	3.97	16.320	4.745926	0.687507
1812	JAN23	1500	36.600	89.600	MO	12	7.10	701.787	4.342789	21.567253
1929	DEC28	0030	35.500	98.000	OK	6	4.04	62.806	1.305377	0.209893
1952	APR16	0605	35.400	97.800	OK	5	3.85	50.778	1.291554	0.167621
1952	APR11	2030	35.400	97.800	OK	4	3.85	50.778	1.291554	0.167621
1952	APR16	0558	35.400	97.800	OK	F	3.85	50.778	1.291554	0.167621
1939	JUN 1	0730	35.000	96.400	OK	4	4.37	111.021	1.083889	0.253860
1953	MAR17	1425	35.400	98.000	OK	6	3.82	66.656	0.944015	0.119168
1937	JUN 8	1426	35.300	96.900	OK	4	3.61	55.015	0.892907	0.089026
1969	MAY 2	1133	35.500	96.200	OK	F	4.08	103.480	0.822898	0.139683
1975	OCT12	0258	35.500	97.700	OK		3.20	37.364	0.810952	0.050997
1959	JUN15	1245	34.800	96.700	OK	5	3.97	110.414	0.675168	0.101619
1918	SEP11	0630	35.500	98.000	OK	6	3.44	62.806	0.636409	0.052723
1918	SEP10	1630	35.500	98.000	OK	5	3.44	62.806	0.636409	0.052723
1882	OCT22	2215	35.000	94.000	AR	7	4.80	310.419	0.635493	0.244372
1925	JUL30	1217	35.400	101.300	TX	5	4.92	360.102	0.630585	0.277699
1976	OCT22	1715	35.380	97.060	OK		3.00	38.685	0.616041	0.031079
1867	APR24	2022	39.500	96.700	KS	7	5.05	431.391	0.612815	0.312701
1959	JUN17	1027	34.500	98.500	OK	6	4.22	166.284	0.599833	0.119991
1956	OCT30	1036	36.200	95.800	OK	7	4.12	150.629	0.588616	0.105218
1942	JUN12	0550	36.400	97.900	OK	3	3.70	97.824	0.552899	0.061597
1933	AUG19	1930	35.500	98.000	OK	5	3.31	62.806	0.544673	0.039084
1926	JUN20	1420	35.600	94.900	OK	5	4.28	219.554	0.485428	0.104342
1956	JAN 6	1158	37.300	98.500	KS	6	4.20	211.057	0.459209	0.090282
1915	NOV 8	0000	36.200	95.800	OK	F	3.86	150.629	0.431153	0.057822
1975	NOV29	1429	34.650	97.530	OK	5	3.60	112.595	0.424961	0.042509
1976	NOV11	1612	35.850	97.320	OK		2.20	22.242	0.415699	0.008567
1961	APR27	0730	34.900	95.300	OK	5	4.08	202.134	0.415667	0.071509
1974	DEC16	0230	35.400	97.470	OK	3	2.42	30.529	0.391645	0.010358
1978	JUN16	1146	32.961	100.794	TX	F	4.66	436.323	0.379746	0.125948
1919	JUL26	1400	37.680	97.330	KS	5	4.09	225.572	0.376139	0.065572
1919	MAY27	0400	37.680	97.330	KS	4	4.07	225.572	0.367238	0.062620
1936	JUN20	0324	35.800	101.300	TX	5	4.45	358.520	0.360823	0.094512
1877	NOV15	1830	41.000	97.000	NE	7	4.81	595.182	0.331097	0.130422
1979	NOV27	0910	35.630	98.408	OK		3.25	97.375	0.324102	0.021956
1961	JAN11	0140	34.800	95.500	OK	5	3.81	191.088	0.318595	0.040622
1978	MAY18	0019	35.502	97.949	OK	3	2.74	58.311	0.296915	0.011330
1948	MAR12	0429	36.000	102.500	TX	6	4.51	467.418	0.295800	0.083233
1974	FEB15	1334	36.500	100.700	TX	5	4.17	317.060	0.292505	0.056036
1979	JUL31	1911	36.086	97.305	OK		2.52	48.500	0.275321	0.008208
1979	JUL24	0224	36.070	97.506	OK		2.50	49.288	0.264425	0.007714
1935	MAR 1	1100	40.300	96.200	NE	6	4.51	526.098	0.262186	0.073949

Table 2. (continued)

YEAR	DATE	UTC	LAT DN	LON DW	ST	MM	MAG	DELTA km	Ah %g	Vh cm/sec
1939	JUN19	2143	34.100	93.100	AR	5	4.32	422.332	0.261295	0.059477
1956	APR 2	1603	34.200	95.600	OK	5	3.76	225.395	0.253568	0.030694
1966	JUL20	0905	35.700	101.200	TX	5	4.13	349.374	0.252546	0.046420
1979	MAR18	2044	35.379	98.124	OK	3	2.85	77.873	0.252164	0.010930
1961	APR26	0705	34.600	95.000	OK	3	3.81	241.775	0.250621	0.032106
1929	SEP23	1100	39.000	96.600	KS	5	4.19	377.796	0.250551	0.049288
1918	OCT 4	0921	34.700	92.300	AR	5	4.37	468.903	0.249341	0.060106
1934	APR11	1740	33.900	95.500	OK	5	3.85	256.345	0.247683	0.033203
1975	OCT30	0037	35.270	96.760	OK		2.70	66.667	0.246893	0.009038
1969	JAN 1	2336	34.800	92.600	AR	6	4.30	439.619	0.244884	0.054566
1975	SEP13	0125	34.100	97.400	OK	5	3.40	172.353	0.216647	0.017522
1951	JUN20	1937	35.500	103.000	TX	6	4.32	512.721	0.214397	0.048991
1927	JAN 7	0930	38.350	97.680	KS	5	3.86	301.625	0.212345	0.028876
1968	OCT14	1442	34.000	96.400	OK	6	3.50	202.021	0.207680	0.018819
1979	MAR14	0437	35.519	97.781	OK	5	2.17	43.278	0.203380	0.004109
1906	JAN 8	0015	39.300	96.600	KS	7	4.08	410.662	0.201718	0.035198
1978	JAN 8	1019	35.824	97.642	OK		1.96	34.143	0.201432	0.003211
1979	MAY 8	1123	35.923	97.480	OK		1.92	33.212	0.197503	0.003011
1929	OCT21	2130	39.200	96.500	KS	5	4.03	401.215	0.194560	0.032109
1911	MAR31	1657	33.800	92.200	AR	5	4.23	511.629	0.192914	0.039907
1941	OCT18	0748	35.400	99.000	OK	5	3.20	153.561	0.191819	0.012408
1961	DEC25	1258	39.100	94.600	KS	5	4.11	452.858	0.189242	0.034201
1979	SEP13	0049	35.217	99.362	OK	4	3.37	190.162	0.189057	0.014821
1964	MAR28	1009	42.900	101.600	NE	7	4.68	885.394	0.188981	0.064993
1978	FEB14	0109	35.777	97.585	OK		1.69	26.990	0.185298	0.002182
1979	AUG19	0158	35.203	97.445	OK		2.22	50.750	0.183550	0.003932
1979	JUL 4	0345	35.705	97.978	OK		2.34	58.809	0.182333	0.004473
1979	SEP16	1557	35.343	97.997	OK	4	2.48	69.317	0.182322	0.005238
1978	MAY18	0032	35.601	97.828	OK	2	2.11	45.309	0.180631	0.003418
1979	JAN29	1920	34.916	97.383	OK		2.61	81.703	0.180142	0.005995
1957	MAR19	0016	32.000	95.000	TX	5	4.08	459.086	0.180039	0.031485
1978	MAY17	2311	35.525	97.910	OK	1	2.26	54.221	0.179989	0.004035
1875	NOV 8	1040	39.300	95.500	KS	5	4.03	436.512	0.178526	0.029512
1979	SEP17	2041	35.320	97.968	OK	4	2.45	68.389	0.178326	0.004955
1979	MAR18	2142	35.394	98.108	OK		2.53	75.894	0.176476	0.005368
1976	APR19	0442	35.870	99.970	OK	5	3.50	239.301	0.174733	0.015888
1977	OCT 6	0036	35.820	97.767	OK		2.05	43.709	0.174386	0.003086
1904	OCT27	2359	37.700	100.000	KS	5	3.77	329.412	0.174262	0.021491
1978	SEP26	2117	35.519	97.866	OK		2.15	50.578	0.169380	0.003358
1974	FEB15	2249	34.000	93.000	AR	5	3.98	435.453	0.168569	0.026367
1979	MAR18	2005	35.416	98.110	OK		2.48	75.173	0.167848	0.004830
1978	SEP27	0156	35.519	97.843	OK		2.10	48.591	0.166194	0.003115
1979	MAR19	0342	35.400	98.110	OK		2.46	75.813	0.162466	0.004574
1936	MAR14	1720	34.000	95.000	OK	5	3.57	280.692	0.161474	0.015914
1966	AUG14	1526	32.000	102.600	TX	6	4.26	633.373	0.160844	0.034541

Table 2. (continued)

YEAR	DATE	UTC	LAT DN	LON DW	ST	MM	MAG	DELTAkm	Ah %g	Vh cm/sec
1902	JUL28	1800	42.500	97.500	NE	5	4.41	761.306	0.159554	0.040592
1979	NOV 7	0554	35.510	97.888	OK		2.12	52.773	0.156471	0.003003
1974	NOV10	0619	34.800	96.800	OK		2.71	105.998	0.155702	0.005817
1976	APR16	1859	35.870	99.970	OK	4	3.40	239.301	0.155016	0.012620
1917	MAR27	1956	35.300	101.200	TX	6	3.71	352.356	0.151418	0.017499
1976	FEB16	0559	35.590	96.520	OK		2.34	73.469	0.145302	0.003580
1950	FEB 8	0010	37.400	92.400	MO	5	3.94	481.260	0.145101	0.021758
1979	MAR18	2024	35.420	98.110	OK		2.34	75.019	0.142241	0.003506
1979	MAR18	1913	35.418	98.155	OK		2.38	78.930	0.141681	0.003654
1977	APR28	0230	36.009	97.201	OK		1.83	41.550	0.141109	0.001956
1933	FEB20	1700	39.800	99.800	KS	5	3.96	509.687	0.140168	0.021513
1978	MAY19	0627	36.002	97.367	OK		1.76	39.256	0.137505	0.001762
1979	SEP 5	0404	35.427	97.717	OK		1.83	42.878	0.136653	0.001896
1979	MAY12	2156	35.301	97.601	OK		1.86	45.884	0.132192	0.001898
1979	SEP16	1042	35.455	97.905	OK		2.03	56.318	0.131474	0.002287
1979	MAR18	1830	35.418	98.108	OK		2.26	74.926	0.129412	0.002920
1977	DEC 8	1947	35.449	97.927	OK		2.03	58.412	0.126667	0.002205
1979	MAR14	0310	35.498	97.826	OK	4	1.86	47.905	0.126506	0.001818
1932	JAN29	0015	39.000	99.600	KS	6	3.71	422.851	0.125715	0.014582
1976	DEC19	0826	34.920	95.730	OK	1	2.90	166.259	0.123508	0.005744
1978	MAY19	0039	35.135	97.503	OK		2.02	59.333	0.123178	0.002122
1975	JUN16	0159	34.230	96.540	OK		2.91	173.424	0.119731	0.005635
1967	NOV23	0624	43.700	99.400	SD	5	4.32	911.859	0.119171	0.027547
1970	JAN12	1121	36.100	103.200	NM	6	3.85	530.892	0.117867	0.016032
1977	JUN 2	2329	34.587	94.118	AR		3.39	314.933	0.115748	0.009371
1979	MAR18	1930	35.418	98.101	OK		2.16	74.332	0.115745	0.002338
1979	FEB 4	1655	34.672	97.157	OK		2.49	109.805	0.115415	0.003384
1934	JUL30	0720	42.700	103.000	NE	6	4.30	923.177	0.114897	0.025985
1975	MAR31	0952	35.606	95.296	OK		2.91	183.775	0.112857	0.005318
1971	MAR13	1922	35.200	95.800	OK		2.72	147.286	0.112661	0.004284
1979	SEP 5	0238	35.429	97.871	OK		1.87	54.735	0.111755	0.001628
1979	MAR14	0402	35.781	97.650	OK		1.42	32.333	0.111549	0.000978
1929	DEC 7	0802	39.200	96.500	KS	5	3.56	401.215	0.110829	0.010880
1979	AUG 3	1029	35.683	98.005	OK		1.93	61.046	0.107430	0.001676
1979	DEC14	1320	35.187	97.664	OK		1.90	59.680	0.106060	0.001600
1979	MAR23	1726	35.411	98.163	OK		2.14	79.872	0.105016	0.002078
1976	NOV19	0552	35.230	96.380	OK		2.30	97.851	0.103400	0.002452
1979	SEP15	0342	35.493	97.882	OK		1.77	52.854	0.102745	0.001339
1979	DEC20	1458	36.367	97.379	OK		2.12	79.794	0.102633	0.001986
1979	SEP 4	0740	34.799	97.557	OK		2.28	96.781	0.102092	0.002367
1977	MAR12	2104	34.994	96.625	OK		2.28	96.949	0.101912	0.002363
1979	MAR18	2340	35.433	98.102	OK		2.04	73.849	0.100922	0.001785

Zones are assigned descriptive names and, for convenience in computer use, were also assigned numbers. Zones with the most concentrated activity were numbered "1.X," where .X is a decimal fraction identifying the specific zone. Zones with less activity were numbered "2.X," and the remaining area was named "RESIDUAL," with a number of 3.1. Table 3 gives the source zone names, numbers, boundaries, and areas.

Figures 2a and 2b show a map of the zone boundaries, along with all earthquakes known to have occurred through the end of 1979. The earthquake symbols are divided into two classes. An asterisk (*) is used to denote earthquakes known to have been felt, whereas a plus (+) is used to denote earthquakes not known to have been felt (instrumentally located earthquakes). Most earthquakes prior to 1977 are known to have been felt. Because of poor seismograph-station coverage in this region, nearly all earthquakes prior to 1972 are only known because they were felt. The zones listed in table 3 occupy the entire area of the map except for the large rectangle excluded in the Texas Panhandle.

Because of uncertainty in locating epicenters, the older historical felt earthquakes tended to have identical coordinates listed for several different earthquakes, causing several earthquakes to be plotted as one symbol. To show more clearly the number of earthquakes, where two or more earthquakes are listed with exactly the same coordinates, they were spread slightly by having their symbols displaced by the following amount:

$$\text{LATITUDE DISPLACEMENT} = 0.09x \text{ degrees}$$
$$\text{and} \qquad (3)$$
$$\text{LONGITUDE DISPLACEMENT} = 0.06x \text{ degrees,}$$

where x = a random number $-0.5 \leq x \leq +0.5$. The constants 0.09 and 0.06 in formula 3 were selected to spread the points just enought to be seen without moving them beyond their probable error of location. The difference in 0.09 and

Table 3. Seismic source zones of Oklahoma and surrounding areas.

Zone name	Zone number	Area (km^2)	Boundaries (Given as latitude and longitude of each straight-line intersection starting at the most northeasterly and proceeding clockwise)
Central Oklahoma	1.1	1,232.4	35.55N 97.75W
			35.25N 97.75W
			35.25N 98.25W
			35.55N 98.25W
			35.55N 97.75W
South-central Oklahoma	1.2	1,359.8	34.2 N 97.2 W
			33.8 N 97.2 W
			33.8 N 97.6 W
			34.2 N 97.6 W
			34.2 N 97.2 W
North-central Oklahoma	2.1	4,232.8	36.4 N 97.0 W
			36.1 N 97.0 W
			35.55N 97.65W
			35.55N 98.25W
			36.4 N 97.4 W
			36.4 N 97.0 W
Southeast Oklahoma	2.2	32,668.9	35.55N 94.0 W
			34.5 N 94.0 W
			34.5 N 97.75W
			35.55N 97.75W
			35.55N 94.0 W
West-central Oklahoma	2.3	12,292.7	36.0 N 98.5 W
			35.0 N 98.5 W
			35.0 N 100.0 W
			36.0 N 100.0 W
			36.0 N 98.5 W
Residual	3.1	177,927.4	37.5 N 94.0 W
			33.5 N 94.0 W
			33.5 N 100.2 W
			36.3 N 100.2 W
			36.3 N 103.0 W
			37.5 N 103.0 W
			37.5 N 94.0 W
			Excluding area inside zone 1.1, 1.2, 2.1, 2.2, 2.3.

0.06 reflects the difference in the length of 1 degree of latitude and 1 degree of longitude. At the equator, both are the same, but at 36°N latitude, 1 degree of latitude is 1.53 times greater ($1/\cos^2(36°)$) than 1 degree of longitude. It should be noted that the inclusion of a random number will cause maps printed at different times to vary in fine detail.

MAGNITUDE-FREQUENCY RELATIONS IN OKLAHOMA SEISMIC-SOURCE ZONES

Magnitude was plotted against the cumulative frequency per year (the number of earthquakes of that magnitude or greater). Three different magnitudes, which were assumed to be nearly equivalent, were used. Where more than one magnitude was available for an earthquake, they were used in this order of preference:

1. mbLg of Nuttli (1973).
2. m3Hz of Nuttli (see Zollweg, 1974).
3. MDUR of Lawson (see Luza and Lawson, 1979).

For some of the earlier earthquakes for which the felt areas were known, mbLg was calculated using the formula developed by Nuttli and Zollweg (1974). Their formula was calibrated against six Oklahoma earthquakes and one Nebraska earthquake that occurred during 1974-78 (Luza and Lawson, 1980). Luza and Lawson (1980) included a table of 26 Oklahoma earthquakes (table 4, p. 59) for which magnitude was calculated from area. Of particular interest is the resulting 5.04 magnitude for the 1952 El Reno earthquake. This earthquake has been rated at magnitude 5.5 on the basis of one P-wave amplitude recorded at Pasadena, California. Also of importance to the Arcadia study is the 3.97 magnitude of the 1956 Edmond earthquake, calculated from its felt area of 12,950 km^2.

Figure 3 shows the log cumulative frequency vs. magnitude plot for zone 1.1, central Oklahoma. Network-located earthquakes of magnitude 2.0 to 3.0 were assumed to be complete for 3 years (1977-79 inclusive). Historical earthquakes with magnitudes between 3.0 to 4.0 were assumed complete from 1900 to 1976

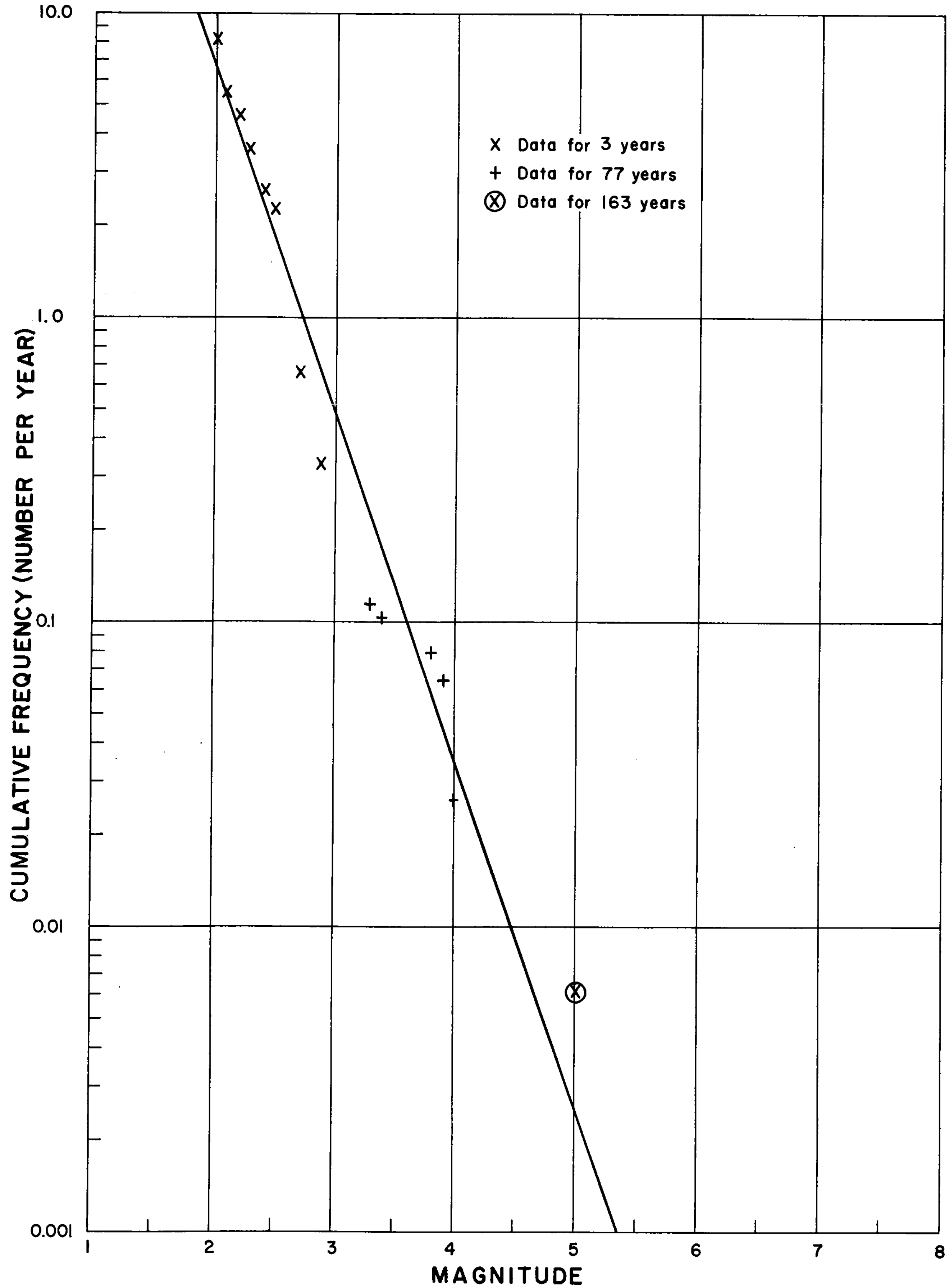

Fig. 3. Magnitude vs. earthquake frequency for Zone 1.1, central Oklahoma.

inclusive, a period of 77 years. Dr. Bob Fay (Oklahoma Geological Survey, personal communication) is fairly certain that no earthquake as large as the 1952 El Reno earthquake could have occurred in the past 163 years without having been documented; thus that earthquake is plotted with a frequency of 1/163.

The network and the historical earthquakes in figure 3 fit a straight line fairly well. Using all the points with equal weight, with methods given by Lapin (1975), a least-squares line was calculated (see table 4). Student's T 95% confidence limits on the constants were calculated by the method of Hyans and Philpot (1971).

Similar graphs and calculations were made for the other seismic zones (table 4). South-central Oklahoma (zone 1.2) is omitted from the table because preliminary calculations gave an apparently anomalous least-squares line. This zone should not be important to the Arcadia study. The Texas Panhandle area was excluded from the residual areas (see fig. 2a) because it appears anomalous whether combined with the residual area, combined with the west-central Oklahoma area, or taken by itself.

Except for central Oklahoma (zone 1.1) and south-central Oklahoma (zone 1.2), the frequencies in the other zones were divided by their areas in 1,000-km^2 units and the lines recalculated. This procedure was suggested by Professors Otto Nuttli and Robert Herrmann (1978) to equalize frequencies in large source zones.

Most magnitude vs. log-frequency calculations give log frequency as a function of magnitude:

$$\log(N) = a + bm. \qquad (4)$$

This study gives magnitude as a function of frequency:

$$m = A + B \log(N). \qquad (5)$$

The lines given by (4) and (5) cannot be converted from one form to the other by simple algebraic manipulation. The least-squares fitting procedure calculates a

Table 4. Equations estimating largest magnitude (M) that will occur with frequency of <u>f per year per 1,000 km²</u> of source zone. (For zone 1.1, frequency is f per year for entire zone, which is 1,232 km^2 in area. Numbers following ± indicate 95% confidence limits.)

Zone 1.1 Central Oklahoma

$$M = 2.7241 \pm 0.049893 -(0.87951 \pm 0.048971) \log(f)$$

Zone 2.1 North-central Oklahoma

$$M = 1.8241 \pm 0.019184 -(0.86024 \pm 0.018579) \log(f)$$

Zone 2.2 Southeast Oklahoma

$$M = 1.1716 \pm 0.052239 -(0.99229 \pm 0.026765) \log(f)$$

Zone 2.3 West-central Oklahoma

$$M = 1.5062 \pm 0.21077 -(0.72025 \pm 0.090866) \log(f)$$

Zone 3.1 Residual

$$M = -0.27607 \pm 0.13897 -(1.2692 \pm 0.057652) \log(f)$$

slightly different line for (4) and (5). The relationship in formula (5) is preferred in this study because it gives the magnitude of the largest earthquake to be expected in any source zone for any given time interval. Table 4 gives the equations in formula (5) for all zones except 1.2, south-central Oklahoma. In table 4, the equation for the largest magnitude expected in the entire zone with an earthquake frequency of f per year may be obtained by adding the following number to the right-hand side of the equation:

$$\log(\text{zone area in km}^2/1{,}000).$$

This does not apply to zone 1.1 because the equation represents the entire zone.

The largest magnitude earthquake expected in each 1,000 km^2 of a zone in a period of P years is determined by substituting 1/P for f in the appropriate equation and calculating M. This procedure was used to produce table 5, giving the largest earthquake expected for the entire zone and for each 1,000 km^2 of the zone for various periods.

ASSESSMENT OF MAXIMUM HORIZONTAL GROUND VELOCITY AND HORIZONTAL GROUND ACCELERATION EXPECTED AT ARCADIA DAM SITE FROM EARTHQUAKES

For each seismic-source zone, a maximum expected earthquake magnitude for a given period was taken from table 5. This earthquake was assumed to occur at about 900 to 1,000 points of a square grid evenly and completely filling the source zone. The distance to the Arcadia dam site for each grid point was calculated, after which formulae (1) and (2) were used to calculate the aH and vH caused by the hypothetical earthquake. Approximately 900 to 1,000 values of aH and vH were stored in arrays. For aH, the largest one-tenth of the values were sorted and their arithmetic mean taken. The same sorting and averaging procedures were then done for vH. The resulting average aH and vH values were listed as the aH and vH expected at the site during the given time period from earthquakes within the

Table 5. Largest-magnitude earthquake expected in entire seismic zone (part a), and in each 1,000 km^2 of each zone (part b), for various periods.

(a) Entire zones

Zone	Period in years 100	200	500	1000	2000
1.1	4.48	4.75	5.10	5.36	5.63
2.1	4.08	4.34	4.68	4.94	5.20
2.2	4.66	4.96	5.35	5.65	5.94
2.3	3.65	3.86	4.15	4.37	4.58
3.1	5.01	5.38	5.85	6.22	6.58

(b) Each 1,000 km^2 of zone, except entire zone 1.1

Zone	Period in years 100	200	500	1000	2000
1.1	4.48	4.75	5.10	5.36	5.63
2.1	3.54	3.80	4.15	4.40	4.66
2.2	3.16	3.45	3.85	4.15	4.45
2.3	2.95	3.16	3.45	3.67	3.88
3.1	2.26	2.64	3.15	3.53	3.91

source zone being studied. The values of the expected aH and vH,together with the expected maximum magnitude from table 5, were used with formulae (1) and (2) to calculate the "equivalent distance" at which the maximum-magnitude earthquake would have to occur to produce the given motion. Using this equivalent distance and the maximum magnitude (from table 5), the following equations of Nuttli and Herrmann (1978) were used to calculate an equivalent Modified Mercalli intensity at the site:

$$I = -3.5 + 2\ mb \qquad R < 20\ km$$

$$I = -0.4 + 2\ mb - 2.46\ \log(R) \qquad R \geq 20\ km, \tag{6}$$

where I = equivalent Modified Mercalli intensity at the site, and R = great-circle distance from earthquake site to km. In common with formulae (1) and (2), this has two forms. The near-field form, or distances less than 20 km, simply gives a constant value dependent only on magnitude. The second form, for distances of 20 km or more, attenuates the intensity with distance. As with formulae (1) and (2), when R approaches zero, I will approach infinity; therefore, two separate forms, near field and far field, were used to avoid this situation.

The Modified Mercalli intensity scale was defined in 12 discrete steps. However, because it is common to assign in-between values--i.e., MM III-IV--the decimal fractions produced by formula (6) are not inconsistent with the MM intensity scale. A more serious problem occurs when formula (6) produces a number greater than 12 (mb 7.75 in the near field). Because the MM scale defines 12 as "damage total," any number greater than 12 could be simply considered 12. Any intensity number less than 1.0 could be simply considered not felt. The lower cutoff is not strictly accurate, because a 1.6-magnitude earthquake was felt in Love County, Oklahoma (Lawson and DuBois, 1976), and an earthquake as small as 0.8 magnitude was felt in Glenalmond, Scotland (Crampin and others, 1972).

Earthquakes of less than 2.25 magnitude would be below MM intensity 1.0 in the near field.

Values for aH and vH were calculated separately. Because aH attenuates as -1.02 log(R) and vH attenuates as -1.00 log(R), for some site source-zone geometries the equivalent distances could be different. However, this difference was found to be in no case greater than 0.4%, so it was ignored and the equivalent distance for aH was listed.

The calculations were done separately for each seismic source zone, and only the zone giving the largest values of aH and vH was used in the final assessment. As an example, consider the calculation of site aH and vH expected in 2000 years from earthquakes in seismic source zone 1.1. From table 5 (which came in turn from the least-squares line in fig. 3), the maximum expected earthquake in 2000 years would have a magnitude of 5.63. It is assumed to occur at each point of a square grid that uniformly fills the entire zone with 930 points. The grid spacing is 1.17 km (0.0105 degrees of latitude and 0.0159 degrees of longitude). When site accelerations from magnitude-5.63 earthquakes are calculated for each point, the resulting accelerations vary from 14.0% g to 0.583% g. The average of all 930 points is only 7.78% g, but the average of the 93 largest values of aH is 12.0% g, which is the figure used. From formula (1), a 12.0% acceleration would be produced by a magnitude-5.63 earthquake if it were 46.0 km away from the site. The figure 46.0 km is the equivalent distance. From formula (6), a magnitude-5.63 earthquake at a distance of 46.0 km produces an equivalent site intensity of 6.77. The calculations for vH gave 11.2 cm/sec.

Because zone 1.1 gave higher aH and vH than any other zone, we would assess the 2000-year strongest ground motion as:

aH = 12.0%
vH = 11.2 cm/sec
(which is equivalent to a magnitude-5.63
earthquake at a distance of 46.0 km, and
which is also equivalent to an MM intensity
of 6.32 at the site).

Table 6 lists the parameters of the largest expected ground motion at Arcadia dam site for six different time periods. For reference, table 7 lists the acceleration expected from each zone for different periods. For reasons mentioned previously, zone 1.2 is omitted. However, calculations show that for any given period, an earthquake in zone 1.2 would necessarily exceed magnitude 6.7 to produce a greater acceleration than earthquakes in zone 1.1. An earthquake exceeding magnitude 6.1 in zone 1.2 would be necessary to produce a greater site velocity than that produced by earthquakes in zone 1.1. Although a stable least-squares line relating log frequency to magnitude in zone 1.2 has not yet been determined, there is nothing to suggest that earthquakes of magnitude 6.1, and particularly 6.7, could be expected to occur there in periods of 2000 years or less.

COMPARISON WITH HISTORICAL GROUND MOTION

Table 2 indicates an aH of 6.2% g and a vH of 43.0 cm/sec for the Arcadia dam site from the Feb. 7, 1812, Mississippi Valley earthquake. Nuttli and Herrmann (1978) considered this the maximum-magnitude earthquake that could occur in the Mississippi Valley. The 1952 El Reno earthquake produced an aH of 5.4% g and a vH of 2.6 cm/sec and probably had a Modified Mercalli intensity of 4.5 to 5.5 at the site (unpublished study of newspaper reports). Except for vH, these parameters are consistent with ground motion projected for 500 years or less in table 6.

DISCUSSION OF ASSUMPTIONS USED IN ARCADIA STUDY

The overall assumption in the study is that future seismicity, for as long as 2000 years, will follow the spatial and temporal patterns of the last 70 years. This assumption should be rated fair to poor. The July 27, 1980, earthquake

Table 6. Largest expected earthquake magnitude, equivalent distance, site intensity, and site aH and vH at Arcadia site for various periods.

Period (years)	Largest magnitude	Equivalent distance (km)	Equivalent site intensity (MM)	Site aH (% of g)	Site vH (cm/sec)
100	4.48	46.0	4.47	3.04	0.790
200	4.75	46.0	5.01	4.20	1.47
500	5.10	46.0	5.71	6.38	3.29
1000	5.36	46.0	6.23	8.71	5.99
2000	5.63	46.0	6.77	12.0	11.2

Table 7. Acceleration values, aH, in percent g, expected at Arcadia site for each seismic-source zone (except for 1.2) for various periods.

Period (years)	Zone 1.1	2.1	2.2	2.3	3.1
100	3.04	2.36	0.796	0.192	0.131
200	4.20	3.22	1.13	0.246	0.207
500	6.38	4.89	1.82	0.349	0.381
1000	8.71	6.60	2.60	0.454	0.600
2000	12.0	9.01	3.73	0.583	0.946

northeast of Lexington, Kentucky, having a magnitude of 5.3 (Oklahoma Geophysical Observatory, mbLg), occurred in an area essentially free of historical seismicity. The method used in this study would have assigned extremely low risk to this area. However, the 1952 earthquake at El Reno, Oklahoma, having a magnitude of 5.0, was preceded by earthquakes (as early as 1908) and followed by earthquakes (as late as 1980). In more active seismic areas of the world, particularly at lithospheric plate boundaries, causative geological structures might be identifiable but even in such cases past seismicity is relied upon to define which of these structures may be active.

A discussion of detailed assumptions follows:

1. Seismicity in Oklahoma is confined to fairly well-defined source zones and is reasonably homogeneous within those zones. The assumption is fair to good in describing seismicity to date, especially in the light of the close agreement between historical felt earthquakes and network-located earthquakes. As noted above, the assumption is fair to poor when extended to long periods in the future.
2. Seismicity follows the formulae in table 4. This assumption is good. Note that if the 1952 El Reno earthquake were removed from figure 3, the least-squares line would be almost unchanged. In effect, if the El Reno earthquake had not occurred until after this study, it would have been accounted for by the least-squares line. This assumption is only fair when projected far into the future.
3. Attenuation relations (1), (2), and (6) are correct. This assumption is good. Nuttli and Herrmann based the formulae on much Mississippi Valley and other data. Oklahoma appears to have the same attenuation characteristics.

4. The three magnitudes used are equivalent. This assumption is very good.
5. When estimated from felt areas using Nuttli and Zollweg's (1974) relation, mbLg is equivalent to mbLg calculated from seismograph-measured LgZ waves. This assumption is very good. The relations have been checked against all Oklahoma earthquakes with both accurately measured LgZ waves and well-defined felt areas.
6. Assessed risk is not a strong function of grid spacing within the source zones. This is a good assumption. The 2000-year aH value for Arcadia was 12.0% g with 1.17-km grid spacing in zone 1.1, 12.2% g with 2.34-km spacing, and 12.5% g with 4.67-km spacing.
7. It is reasonable to average ground motion produced by earthquakes at grid points accounting for only the largest 10% of the aH values. This assumption is an arbitrary deterministic element. If earthquakes are, as assumed, equally likely to occur anywhere within a source zone, this assumption could be accounted for by stating that the aH (or vH or I) for a given period had about a 95% probability of not being exceeded.

DISCUSSION OF RESULTS

Table 6 gives a list of maximum horizontal ground acceleration, maximum horizontal ground velocity, and equivalent Modified Mercalli intensity to be expected at the Arcadia dam site for various time periods. The aH, vH, and intensity between the tabulated values may be obtained by log log interpolation. For graphical interpolation, plot aH (or vH or intensity) on the horizontal axis of log log paper, and the frequency in number per year (1/period in years) on the vertical axis. It probably would not be useful to extrapolate the values outside the table values. The maximum magnitude of earthquakes expected for periods between the tabulated values may be obtained by log linear interpolation (as in fig. 3) or from the first equation in table 4, keeping in mind that for each given period the maximum ground-motion parameters were due to earthquakes in seismic-source zone 1.1, central Oklahoma.

The different values for the ground-motion parameters are intended to be a guide for the construction engineer, who can select the appropriate interval to satisfy one or more of the following conditions: (1) structure to remain completely undamaged, (2) structure to be damaged only slightly, and (3) structure to sustain severe damage but catastrophic failure to be avoided. Having selected one or more time intervals, table 6 (with interpolation if necessary) may be used to determine the relevant ground-motion parameters. Except as noted below, very little arbitrary conservatism has been built into the results in table 6. The design may be made more conservative by extending the period used in determining the ground-motion parameters beyond the expected life of the structure, but only the design engineer should decide whether or not to make any extension, and how large the extension should be. It is also possible that for non-critical substructures, tradeoffs in cost and other factors may make it desirable to decrease the period used in determining ground motion to something less than the life of the structure.

The method used in this study is both probabilistic and deterministic. It is probabilistic in defining source zones and determining the largest earthquake expected in the source zones in any given period. It is deterministic in that it averages the ground motion from only the 10% of grid points within the zone that would produce the largest ground motion at the site. This averaging the largest 10% is an almost arbitrary conservatism. In the case of the Arcadia 2000-year risk, had all the grid points in zone 1.1 been averaged, the value of aH would have been 7.87% instead of the 12% given in table 6.

The earthquakes that occurred at or very near the Arcadia dam site were not ignored. In zone 3.1, some grid points were at and very near the site. Nuttli and Herrmann's (1978) equations limit the near-field (nearer than 15 km) ground motion. The limit is very realistic. If the equations contained a term in minus log(R) for all distances, aH and vH would approach infinity as the distance to the site approached zero.

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APPENDIX

Earthquake List

Table 1. List of 428 earthquakes, January 1, 1800, to December 31, 1979, used in the Arcadia study.

YEAR	DATE	UTC	LAT DN	LON DW	ST	MM	MAG	DELTAkm	Ah %g	Vh cm/sec
1811	DEC16	0815	36.600	89.600	MO	12	7.20	701.787	4.895181	27.151563
1812	JAN23	1500	36.600	89.600	MO	12	7.10	701.787	4.342789	21.567253
1812	FEB 7	0945	36.600	89.600	MO	12	7.40	701.787	6.219690	43.032327
1867	APR24	2022	39.500	96.700	KS	7	5.05	431.391	0.612815	0.312701
1872	OCT 9	1600	42.700	97.000	NE	5	3.80	783.905	0.074602	0.009677
1875	NOV 8	1040	39.300	95.500	KS	5	4.03	436.512	0.178526	0.029512
1877	NOV15	1745	41.000	97.000	NE	F		595.182	0.000000	0.000000
1877	NOV15	1830	41.000	97.000	NE	7	4.81	595.182	0.331097	0.130422
1882	OCT22	2215	35.000	94.000	AR	7	4.80	310.419	0.635493	0.244372
1895	OCT11	2355	43.900	103.300	SD	5	3.65	1048.973	0.046315	0.005120
1895	OCT12	0125	43.900	103.300	SD	5	3.65	1048.973	0.046315	0.005120
1900	DEC 0	0000	36.000	96.800	OK	4		61.585	0.000000	0.000000
1901	APR 1	0000	36.000	96.800	OK	F		61.585	0.000000	0.000000
1901	APR 8	1330	36.000	96.800	OK	F		61.585	0.000000	0.000000
1902	JUL28	1800	42.500	97.500	NE	5	4.41	761.306	0.159554	0.040592
1904	OCT27	2359	37.700	100.000	KS	5	3.77	329.412	0.174262	0.021491
1906	JAN 8	0015	39.300	96.600	KS	7	4.08	410.662	0.201718	0.035198
1906	MAY10	0027	43.000	101.300	NE	6	4.03	885.151	0.086804	0.014554
1908	JUL19	0000	35.700	97.700	OK	3		33.857	0.000000	0.000000
1909	JAN26	2015	42.350	97.767	NE	5	3.56	745.453	0.058915	0.005856
1910	0	0000	35.500	98.000	OK	F		62.806	0.000000	0.000000
1910	FEB26	0800	41.433	97.383	NE	5		642.618	0.000000	0.000000
1911	MAR31	1657	33.800	92.200	AR	5	4.23	511.629	0.192914	0.039907
1915	OCT23	0605	43.800	101.500	SD	5		973.220	0.000000	0.000000
1915	NOV 8	0000	36.200	95.800	OK	F	3.86	150.629	0.431153	0.057822
1917	MAR27	1956	35.300	101.200	TX	6	3.71	352.356	0.151418	0.017499
1918	0	0000	35.500	97.700	OK	4		37.364	0.000000	0.000000
1918	SEP10	1630	35.500	98.000	OK	5	3.44	62.806	0.636409	0.052723
1918	SEP11	0630	35.500	98.000	OK	6	3.44	62.806	0.636409	0.052723
1918	SEP11	0900	35.500	98.000	OK	6		62.806	0.000000	0.000000
1918	OCT 4	0921	34.700	92.300	AR	5	4.37	468.903	0.249341	0.060106
1919	MAY27	0400	37.680	97.330	KS	4	4.07	225.572	0.367238	0.062620
1919	JUL26	1400	37.680	97.330	KS	5	4.09	225.572	0.376139	0.065572
1924	JUN 3	0000	36.300	96.500	OK	3		103.864	0.000000	0.000000
1925	JUL30	1217	35.400	101.300	TX	5	4.92	360.102	0.630585	0.277699
1926	0	0000	38.850	101.750	KS	F		528.471	0.000000	0.000000
1926	JUN20	1420	35.600	94.900	OK	5	4.28	219.554	0.485428	0.104342
1927	JAN 7	0930	38.350	97.680	KS	5	3.86	301.625	0.212345	0.028876
1927	MAR18	1725	40.000	95.300	KS	5	3.33	515.161	0.065210	0.004989
1928	NOV16	1345	44.000	103.700	SD	5	3.71	1075.366	0.048519	0.005734
1929	SEP23	1000	39.000	96.600	KS	F		377.796	0.000000	0.000000
1929	SEP23	1100	39.000	96.600	KS	5	4.19	377.796	0.250551	0.049288
1929	OCT21	2130	39.200	96.500	KS	5	4.03	401.215	0.194560	0.032109
1929	NOV26	1620	37.180	99.770	KS	4		276.605	0.000000	0.000000
1929	DEC 7	0802	39.200	96.500	KS	5	3.56	401.215	0.110829	0.010880

Table 1. (continued)

YEAR	DATE	UTC	LAT DN	LON DW	ST	MM	MAG	DELTAkm	Ah %g	Vh cm/sec
1929	DEC28	0030	35.500	98.000	OK	6	4.04	62.806	1.305377	0.209893
1931	AUG 9	1818	39.100	94.700	KS	6	3.33	448.219	0.075158	0.005735
1932	JAN29	0015	39.000	99.600	KS	6	3.71	422.851	0.125715	0.014582
1933	FEB20	1700	39.800	99.800	KS	5	3.96	509.687	0.140168	0.021513
1933	AUG 8	0000	41.867	103.667	NE	5		882.469	0.000000	0.000000
1933	AUG19	1930	35.500	98.000	OK	5	3.31	62.806	0.544673	0.039084
1934	APR11	1740	33.900	95.500	OK	5	3.85	256.345	0.247683	0.033203
1934	JUL30	0720	42.700	103.000	NE	6	4.30	923.177	0.114897	0.025985
1935	MAR 1	1100	40.300	96.200	NE	6	4.51	526.098	0.262186	0.073949
1935	NOV29	0000	36.200	97.000	OK	F		67.947	0.000000	0.000000
1936	MAR14	1720	34.000	95.000	OK	5	3.57	280.692	0.161474	0.015914
1936	JUN20	0324	35.800	101.300	TX	5	4.45	358.520	0.360823	0.094512
1936	JUL12	0023	36.900	103.000	OK	F	3.31	526.583	0.062259	0.004662
1937	JUN 8	1426	35.300	96.900	OK	4	3.61	55.015	0.892907	0.089026
1938	OCT11	0937	43.550	96.720	SD	5	3.80	879.392	0.066349	0.008626
1939	JUN 1	0730	35.000	96.400	OK	4	4.37	111.021	1.083889	0.253860
1939	JUN19	2143	34.100	93.100	AR	5	4.32	422.332	0.261295	0.059477
1941	OCT18	0748	35.400	99.000	OK	5	3.20	153.561	0.191819	0.012408
1942	JUN12	0550	36.400	97.900	OK	3	3.70	97.824	0.552899	0.061597
1942	SEP10	1000	38.850	99.330	KS	5		397.155	0.000000	0.000000
1948	MAR12	0429	36.000	102.500	TX	6	4.51	467.418	0.295800	0.083233
1948	APR 2	1530	37.700	97.330	KS	4		227.794	0.000000	0.000000
1950	FEB 8	0010	37.400	92.400	MO	5	3.94	481.260	0.145101	0.021758
1951	JUN20	1937	35.500	103.000	TX	6	4.32	512.721	0.214397	0.048991
1952	APR 9	1629	35.400	97.800	OK	7	5.04	50.778	5.369235	2.596139
1952	APR 9	1830	35.400	97.800	OK	F		50.778	0.000000	0.000000
1952	APR11	2030	35.400	97.800	OK	4	3.85	50.778	1.291554	0.167621
1952	APR16	0558	35.400	97.800	OK	F	3.85	50.778	1.291554	0.167621
1952	APR16	0605	35.400	97.800	OK	5	3.85	50.778	1.291554	0.167621
1952	MAY 1	1140	35.400	97.800	OK	F		50.778	0.000000	0.000000
1952	MAY 2	0155	35.400	97.800	OK	F		50.778	0.000000	0.000000
1952	JUN16	0000	35.400	97.800	OK	F		50.778	0.000000	0.000000
1952	JUN16	0000	35.400	97.800	OK	F		50.778	0.000000	0.000000
1952	JUN16	0000	35.400	97.800	OK	F		50.778	0.000000	0.000000
1952	JUN16	0000	35.400	97.800	OK	F		50.778	0.000000	0.000000
1952	JUN16	0000	35.400	97.800	OK	F		50.778	0.000000	0.000000
1952	JUN16	0000	35.400	97.800	OK	F		50.778	0.000000	0.000000
1952	JUN16	0030	35.400	97.800	OK	4		50.778	0.000000	0.000000
1952	JUL17	0200	35.400	97.800	OK	F		50.778	0.000000	0.000000
1952	AUG14	2140	35.400	97.800	OK	4		50.778	0.000000	0.000000
1952	OCT 8	0415	35.100	96.500	OK	4		96.904	0.000000	0.000000
1953	MAR16	1250	35.400	97.800	OK	3		50.778	0.000000	0.000000
1953	MAR17	1312	35.400	98.000	OK	5		66.656	0.000000	0.000000
1953	MAR17	1425	35.400	98.000	OK	6	3.82	66.656	0.944015	0.119168
1953	JUN 6	1740	34.800	96.700	OK	4		110.414	0.000000	0.000000

Table 1. (continued)

YEAR	DATE	UTC	LAT DN	LON DW	ST	MM	MAG	DELTAkm	Ah %g	Vh cm/sec
1954	APR 0	0000	35.100	96.400	OK	4		104.092	0.000000	0.000000
1954	APR11	0000	35.100	96.400	OK	4		104.092	0.000000	0.000000
1954	APR12	2305	35.100	96.400	OK	4		104.092	0.000000	0.000000
1954	APR13	1848	35.100	96.400	OK	4		104.092	0.000000	0.000000
1956	JAN 6	1158	37.300	98.500	KS	6	4.20	211.057	0.459209	0.090282
1956	FEB16	2330	35.700	97.500	OK	6	3.97	16.320	4.745926	0.687507
1956	APR 2	1603	34.200	95.600	OK	5	3.76	225.395	0.253568	0.030694
1956	OCT30	1036	36.200	95.800	OK	7	4.12	150.629	0.588616	0.105218
1957	MAR19	0016	32.000	95.000	TX	5	4.08	459.086	0.180039	0.031485
1959	JUN15	1245	34.800	96.700	OK	5	3.97	110.414	0.675168	0.101619
1959	JUN17	1027	34.500	98.500	OK	6	4.22	166.284	0.599833	0.119991
1960	MAR18	2130	36.200	95.800	OK	F		150.629	0.000000	0.000000
1960	MAR18	2330	36.200	95.800	OK	F		150.629	0.000000	0.000000
1961	JAN11	0140	34.800	95.500	OK	5	3.81	191.088	0.318595	0.040622
1961	APR13	2115	39.900	100.000	KS	5	3.63	527.276	0.091205	0.009727
1961	APR26	0705	34.600	95.000	OK	3	3.81	241.775	0.250621	0.032106
1961	APR27	0300	34.600	95.000	OK	F		241.775	0.000000	0.000000
1961	APR27	0500	34.600	95.000	OK	F		241.775	0.000000	0.000000
1961	APR27	0730	34.900	95.300	OK	5	4.08	202.134	0.415667	0.071509
1961	DEC25	1220	39.100	94.600	KS	4		452.858	0.000000	0.000000
1961	DEC25	1258	39.100	94.600	KS	5	4.11	452.858	0.189242	0.034201
1962	APR28	0609	35.300	98.600	OK			121.327	0.000000	0.000000
1962	MAY18	0240	35.100	95.400	OK			185.238	0.000000	0.000000
1962	AUG 4	0018	35.200	95.600	OK			164.435	0.000000	0.000000
1962	SEP 1	0209	35.200	96.000	OK			130.397	0.000000	0.000000
1963	JAN15	0533	34.600	95.900	OK			174.653	0.000000	0.000000
1963	MAR13	0933	34.600	95.900	OK			174.653	0.000000	0.000000
1963	JUN12	1208	34.700	96.800	OK			116.021	0.000000	0.000000
1963	JUN12	1638	34.700	96.800	OK			116.021	0.000000	0.000000
1963	JUL14	0808	35.000	97.700	OK			79.637	0.000000	0.000000
1963	JUL14	0810	35.000	97.700	OK			79.637	0.000000	0.000000
1964	FEB 2	0822	35.100	99.100	OK	5		171.620	0.000000	0.000000
1964	MAR24	0612	43.500	103.500	SD	5	3.65	1019.876	0.047663	0.005266
1964	MAR28	1009	42.900	101.600	NE	7	4.68	885.394	0.188981	0.064993
1966	MAR26	0517	35.700	99.600	OK		2.30	204.980	0.048635	0.001170
1966	JUL20	0905	35.700	101.200	TX	5	4.13	349.374	0.252546	0.046420
1966	AUG14	1526	32.000	102.600	TX	6	4.26	633.373	0.160844	0.034541
1967	NOV23	0624	43.700	99.400	SD	5	4.32	911.859	0.119171	0.027547
1968	JAN 4	2230	34.850	95.550	OK	4		184.371	0.000000	0.000000
1968	OCT11	0222	34.000	96.400	OK	F	2.30	202.021	0.049362	0.001187
1968	OCT11	0240	34.000	96.400	OK	F	1.93	202.021	0.031695	0.000507
1968	OCT11	0855	34.000	96.400	OK	F	2.80	202.021	0.089824	0.003755
1968	OCT11	0933	34.000	96.400	OK	F	2.40	202.021	0.055641	0.001495
1968	OCT11	2144	34.000	96.400	OK		2.00	202.021	0.034466	0.000595
1968	OCT12	0350	34.000	96.400	OK		1.80	202.021	0.027127	0.000375

Table 1. (continued)

YEAR	DATE	UTC	LAT DN	LON DW	ST	MM	MAG	DELTAkm	Ah %g	Vh cm/sec
1968	OCT12	1119	34.000	96.400	OK		1.80	202.021	0.027127	0.000375
1968	OCT12	2146	34.000	96.400	OK		2.60	202.021	0.070696	0.002369
1968	OCT14	0345	34.000	96.400	OK		2.00	202.021	0.034466	0.000595
1968	OCT14	1427	34.000	96.400	OK			202.021	0.000000	0.000000
1968	OCT14	1442	34.000	96.400	OK	6	3.50	202.021	0.207680	0.018819
1968	OCT17	0719	34.000	96.400	OK		1.70	202.021	0.024065	0.000298
1968	OCT17	2154	34.000	96.400	OK		2.00	202.021	0.034466	0.000595
1968	OCT18	2114	34.000	96.400	OK		2.80	202.021	0.089824	0.003755
1968	NOV15	1041	34.000	96.800	OK		2.60	189.613	0.075418	0.002524
1969	JAN 1	2336	34.800	92.600	AR	6	4.30	439.619	0.244884	0.054566
1969	MAY 2	1133	35.500	96.200	OK	F	4.08	103.480	0.822898	0.139683
1969	MAY 2	1154	35.500	96.200	OK			103.480	0.000000	0.000000
1970	JAN12	1121	36.100	103.200	NM	6	3.85	530.892	0.117867	0.016032
1971	MAR 1	1927	35.100	94.900	OK			228.493	0.000000	0.000000
1971	MAR13	1922	35.200	95.800	OK		2.72	147.286	0.112661	0.004284
1972	OCT16	0548	42.300	99.600	NE	5		764.518	0.000000	0.000000
1973	JAN10	1638	36.400	98.000	OK	1	2.28	102.815	0.095984	0.002228
1973	SEP28	2203	36.800	94.900	OK		2.00	252.542	0.027448	0.000476
1973	OCT27	1008	35.800	95.200	OK		1.92	192.868	0.032835	0.000518
1973	NOV13	2343	36.800	97.000	OK		1.94	131.166	0.049833	0.000798
1973	NOV18	1003	35.000	94.700	OK		2.48	249.136	0.049446	0.001457
1973	DEC25	0411	35.100	94.500	OK		2.80	263.593	0.068477	0.002878
1974	JAN 3	2212	36.800	97.030	OK		2.18	130.586	0.066724	0.001393
1974	FEB15	1334	36.500	100.700	TX	5	4.17	317.060	0.292505	0.056086
1974	FEB15	2249	34.000	93.000	AR	5	3.98	435.453	0.168569	0.026367
1974	MAY10	0115	34.200	97.300	OK		2.60	161.146	0.089030	0.002970
1974	NOV10	0619	34.800	96.800	OK		2.71	105.998	0.155702	0.005817
1974	DEC16	0230	35.400	97.470	OK	3	2.42	30.529	0.391645	0.010358
1975	MAR31	0952	35.606	95.296	OK		2.91	183.775	0.112857	0.005318
1975	MAY13	0754	42.100	98.400	NE	6		722.670	0.000000	0.000000
1975	MAY25	1658	35.000	96.380	OK		2.00	112.404	0.062676	0.001070
1975	JUN16	0159	34.230	96.540	OK		2.91	173.424	0.119731	0.005635
1975	SEP13	0125	34.100	97.400	OK	5	3.40	172.353	0.216647	0.017522
1975	OCT12	0258	35.500	97.700	OK		3.20	37.364	0.810952	0.050997
1975	OCT30	0037	35.270	96.760	OK		2.70	66.667	0.246893	0.009038
1975	NOV29	1429	34.650	97.530	OK	5	3.60	112.595	0.424961	0.042509
1975	DEC19	0529	34.100	97.400	OK	2	2.50	172.353	0.073748	0.002206
1976	JAN16	1943	35.900	92.100	AR	5		472.318	0.000000	0.000000
1976	JAN20	0005	35.540	95.420	OK		2.06	173.013	0.043377	0.000798
1976	FEB16	0559	35.590	96.520	OK		2.34	73.469	0.145302	0.003580
1976	MAR16	0739	35.430	95.600	OK	4	2.68	158.323	0.099762	0.003635
1976	MAR30	0653	36.680	102.250	OK	5	2.10	455.965	0.016935	0.000332
1976	MAR30	0927	36.680	102.250	OK	5	2.70	455.965	0.034737	0.001322
1976	APR16	1859	35.870	99.970	OK	4	3.40	239.301	0.155016	0.012620
1976	APR17	0248	34.100	97.400	OK	2	2.40	172.353	0.065426	0.001752

Table 1. (continued)

YEAR	DATE	UTC	LAT DN	LON DW	ST	MM	MAG	DELTAkm	Ah %g	Vh cm/sec
1976	APR19	0442	35.870	99.970	OK	5	3.50	239.301	0.174733	0.015888
1976	JUN 7	0130	34.660	94.620	OK		1.90	269.664	0.022775	0.000354
1976	JUN23	0821	34.100	97.400	OK	3	2.70	172.353	0.093703	0.003496
1976	JUN24	0802	34.100	97.400	OK	2	1.40	172.353	0.019758	0.000175
1976	JUN24	1528	35.600	103.300	NM	5		539.255	0.000000	0.000000
1976	SEP20	0940	34.160	97.400	OK	3	2.10	165.690	0.047557	0.000913
1976	OCT 3	1631	34.930	96.220	OK		2.30	128.595	0.078251	0.001865
1976	OCT19	1351	35.560	95.680	OK		1.60	149.405	0.029043	0.000320
1976	OCT20	0405	34.750	96.120	OK		2.50	148.568	0.085809	0.002559
1976	OCT22	1715	35.380	97.060	OK		3.00	38.685	0.616041	0.031079
1976	NOV11	1612	35.850	97.320	OK		2.20	22.242	0.415699	0.008567
1976	NOV19	0552	35.230	96.380	OK		2.30	97.851	0.103400	0.002452
1976	DEC17	0000	34.100	97.400	OK	F		172.353	0.000000	0.000000
1976	DEC19	0826	34.920	95.730	OK	1	2.90	166.259	0.123508	0.005744
1977	FEB 4	2052	34.065	97.370	OK	2	1.90	176.161	0.035162	0.000542
1977	FEB10	0128	34.065	97.370	OK	2	1.95	176.161	0.037331	0.000608
1977	MAR 3	1408	36.263	97.437	OK		1.62	68.793	0.065615	0.000729
1977	MAR 9	1621	34.588	96.511	OK		2.10	139.525	0.056670	0.001085
1977	MAR12	2104	34.994	96.625	OK		2.28	96.949	0.101912	0.002363
1977	MAR26	2137	34.065	97.370	OK	3	2.35	176.161	0.060266	0.001528
1977	APR28	0230	36.009	97.201	OK		1.83	41.550	0.141109	0.001956
1977	MAY22	1215	36.240	97.246	OK		1.42	65.994	0.053877	0.000479
1977	JUN 2	2329	34.587	94.118	AR		3.39	314.933	0.115748	0.009371
1977	JUN 2	2335	34.601	93.898	AR		2.63	332.981	0.044018	0.001540
1977	JUN 2	2340	34.587	94.358	AR		1.05	294.825	0.007515	0.000046
1977	JUN 3	0006	34.612	94.087	AR		1.50	316.482	0.011982	0.000120
1977	JUN 3	0014	34.921	94.135	AR		1.19	300.910	0.008703	0.000062
1977	JUN 3	0135	34.587	94.118	AR		1.04	314.933	0.006942	0.000042
1977	JUN 3	0147	34.587	94.118	AR		0.66	314.933	0.004405	0.000017
1977	JUN 3	0229	34.587	94.118	AR		0.78	314.933	0.005085	0.000023
1977	JUN 3	0758	34.587	94.118	AR		0.66	314.933	0.004405	0.000017
1977	JUN 3	0816	34.650	93.931	AR		2.08	328.203	0.023122	0.000440
1977	JUN 7	2301	32.858	100.774	TX		3.45	443.066	0.087801	0.007648
1977	JUN 8	0051	32.858	100.774	TX		2.26	443.066	0.021120	0.000494
1977	JUN16	0202	34.041	97.358	OK		1.97	178.809	0.037658	0.000627
1977	JUN16	2224	33.909	97.444	OK		1.80	193.738	0.028310	0.000392
1977	JUN17	0337	32.346	100.401	TX		2.48	463.497	0.026250	0.000783
1977	JUN30	2303	34.193	96.958	OK		2.46	165.410	0.073310	0.002096
1977	JUL 9	2023	35.337	94.040	AR		2.02	299.675	0.023611	0.000420
1977	JUL10	0839	35.476	96.304	OK		1.64	94.737	0.048490	0.000554
1977	AUG10	0011	34.677	97.546	OK		1.86	109.885	0.054243	0.000793
1977	AUG18	1034	41.139	98.581	NE		2.70	619.586	0.025407	0.000973
1977	SEP12	0236	33.947	95.243	OK		2.49	268.467	0.046369	0.001384
1977	SEP26	0155	33.987	97.346	OK		1.65	184.797	0.024824	0.000291
1977	SEP29	0719	36.394	97.072	OK		2.11	85.863	0.094106	0.001804

Table 1. (continued)

YEAR	DATE	UTC	LAT DN	LON DW	ST	MM	MAG	DELTAkm	Ah %g	Vh cm/sec
1977	OCT 6	0036	35.820	97.767	OK		2.05	43.709	0.174386	0.003086
1977	NOV 3	1100	33.384	94.130	TX		2.29	386.317	0.025178	0.000607
1977	NOV25	1726	37.958	95.864	KS		2.19	287.725	0.030168	0.000647
1977	NOV26	0418	34.427	92.884	AR	4	2.84	426.718	0.043950	0.001949
1977	NOV27	2048	32.862	100.676	TX		2.34	436.364	0.023608	0.000603
1977	NOV28	0140	33.022	100.842	TX		2.79	434.878	0.040603	0.001705
1977	DEC 1	1304	40.408	100.303	NE		2.36	589.274	0.017798	0.000467
1977	DEC 1	1322	40.732	99.846	NE		2.71	605.951	0.026303	0.001018
1977	DEC 8	1947	35.449	97.927	OK		2.03	58.412	0.126667	0.002205
1977	DEC16	0612	37.160	97.017	KS		1.81	170.109	0.032716	0.000456
1977	DEC20	0756	37.095	97.007	KS		1.80	163.147	0.033734	0.000465
1978	JAN 8	0416	36.971	97.463	OK		1.53	147.271	0.027103	0.000277
1978	JAN 8	1019	35.824	97.642	OK		1.96	34.143	0.201432	0.003211
1978	JAN11	2132	38.876	96.235	KS			371.319	0.000000	0.000000
1978	JAN12	2015	40.356	95.450	MO			548.223	0.000000	0.000000
1978	JAN27	1125	39.890	95.995	KS			485.518	0.000000	0.000000
1978	FEB 3	0025	40.078	100.321	NE		2.72	557.624	0.028975	0.001132
1978	FEB10	0642	34.712	96.157	OK		1.54	149.041	0.027097	0.000280
1978	FEB11	1759	36.725	94.300	MO		2.04	296.835	0.024419	0.000444
1978	FEB14	0109	35.777	97.585	OK		1.69	26.990	0.185298	0.002182
1978	FEB21	1112	34.535	99.003	OK		2.19	196.184	0.044584	0.000949
1978	MAR 3	0224	35.086	96.278	OK		2.13	114.080	0.072134	0.001422
1978	MAR 5	1446	34.699	95.033	OK		2.88	233.870	0.085142	0.003900
1978	MAR 9	0630	34.010	97.378	OK	2	2.55	182.288	0.073948	0.002340
1978	APR 2	2132	34.635	96.057	OK		2.31	161.556	0.062749	0.001519
1978	APR11	0149	35.558	93.759	AR		1.90	322.789	0.018958	0.000296
1978	APR11	0743	35.542	92.869	AR		1.97	403.254	0.016429	0.000278
1978	APR11	0851	34.693	95.681	OK		1.74	183.693	0.027818	0.000360
1978	APR13	0235	35.539	92.625	AR		1.75	425.309	0.011957	0.000159
1978	APR13	0343	34.351	96.820	OK		1.95	151.625	0.043502	0.000707
1978	APR14	2327	39.838	96.385	KS			472.716	0.000000	0.000000
1978	APR19	1420	36.088	96.136	OK		1.47	118.018	0.031616	0.000301
1978	APR20	0813	34.586	96.293	OK		1.68	151.203	0.031575	0.000381
1978	APR22	1014	34.572	93.977	AR		1.87	327.481	0.018022	0.000272
1978	MAY 1	2259	34.400	94.673	OK		2.20	278.833	0.031524	0.000683
1978	MAY 4	0435	35.588	96.345	OK		1.33	89.241	0.035557	0.000288
1978	MAY 7	1606	42.310	101.716	NE	5	3.87	831.393	0.076400	0.010720
1978	MAY17	2311	35.525	97.910	OK	1	2.26	54.221	0.179989	0.004035
1978	MAY18	0019	35.502	97.949	OK	3	2.74	58.311	0.296915	0.011330
1978	MAY18	0032	35.601	97.828	OK	2	2.11	45.309	0.180631	0.003418
1978	MAY19	0039	35.135	97.503	OK		2.02	59.333	0.123178	0.002122
1978	MAY19	0627	36.002	97.367	OK		1.76	39.256	0.137505	0.001762
1978	MAY20	0153	40.110	100.320	NE		2.80	560.697	0.031710	0.001353
1978	MAY22	0428	39.138	96.295	KS		1.93	398.208	0.015863	0.000257
1978	MAY28	0919	35.213	96.144	OK		0.94	117.850	0.016786	0.000089

Table 1. (continued)

YEAR	DATE	UTC	LAT DN	LON DW	ST	MM	MAG	DELTAkm	Ah %g	Vh cm/sec
1978	JUN16	1146	32.961	100.794	TX	F	4.66	436.323	0.379746	0.125948
1978	JUN16	1153	33.067	101.193	TX		3.44	456.015	0.084244	0.007261
1978	JUN22	0510	35.923	99.089	OK		2.00	161.432	0.043326	0.000745
1978	AUG 3	0035	36.689	100.162	OK		2.11	279.045	0.028282	0.000555
1978	AUG 6	0428	36.073	99.935	OK		2.16	239.255	0.035128	0.000726
1978	AUG 8	1207	34.127	97.463	OK		2.16	169.668	0.049878	0.001024
1978	AUG26	1457	34.178	97.463	OK		1.40	164.015	0.020783	0.000184
1978	SEP 8	0516	36.155	95.275	OK		1.40	193.292	0.017578	0.000156
1978	SEP14	0806	40.426	100.326	NE		2.90	591.944	0.033820	0.001613
1978	SEP26	2117	35.519	97.866	OK		2.15	50.578	0.169380	0.003358
1978	SEP27	0156	35.519	97.843	OK		2.10	48.591	0.166194	0.003115
1978	SEP27	2056	33.883	97.477	OK		2.43	196.805	0.059235	0.001644
1978	OCT31	1205	35.458	94.297	AR		1.83	275.021	0.020528	0.000296
1978	NOV 1	0845	39.883	97.352	KS			470.371	0.000000	0.000000
1978	DEC 4	2306	37.449	99.179	KS		2.63	259.237	0.056823	0.001978
1978	DEC 4	2306	38.492	100.440	KS			419.237	0.000000	0.000000
1978	DEC 8	1118	34.676	96.063	OK		1.76	157.990	0.033227	0.000438
1978	DEC10	1341	39.351	93.525	MO		2.42	530.701	0.021279	0.000596
1978	DEC19	0200	35.086	95.125	OK		1.70	209.398	0.023201	0.000288
1978	DEC27	2200	33.996	97.512	OK		1.96	184.539	0.036032	0.000594
1978	DEC28	0530	34.080	97.462	OK		1.92	174.871	0.036285	0.000572
1978	DEC28	1354	33.991	97.456	OK		2.08	184.704	0.041562	0.000783
1979	JAN 3	0003	35.557	93.468	AR		2.01	349.073	0.019967	0.000352
1979	JAN 7	0445	34.912	93.215	AR		2.12	382.172	0.020768	0.000415
1979	JAN 8	1135	36.579	98.146	OK		2.12	126.577	0.064105	0.001252
1979	JAN24	0342	39.634	96.094	KS			455.861	0.000000	0.000000
1979	JAN24	0515	33.985	97.434	OK		1.43	185.256	0.019027	0.000175
1979	JAN24	0525	34.022	97.381	OK		2.07	180.962	0.041933	0.000781
1979	JAN28	1024	35.483	94.568	OK		1.40	250.342	0.013502	0.000121
1979	JAN29	1920	34.916	97.383	OK		2.61	81.703	0.180142	0.005995
1979	FEB 1	1231	34.830	96.062	OK		1.72	146.783	0.034142	0.000430
1979	FEB 4	1655	34.672	97.157	OK		2.49	109.805	0.115415	0.003384
1979	FEB 5	1423	35.177	96.092	OK		1.81	123.823	0.045231	0.000627
1979	FEB10	1956	39.257	95.891	KS			420.427	0.000000	0.000000
1979	FEB25	1929	39.134	92.671	MO		1.90	564.809	0.010714	0.000169
1979	MAR 1	0342	33.969	97.446	OK		2.00	187.091	0.037274	0.000643
1979	MAR 9	1147	37.137	97.135	KS		1.60	166.152	0.026060	0.000288
1979	MAR 9	1243	37.121	97.148	KS		1.87	164.265	0.036429	0.000543
1979	MAR13	2329	35.421	97.851	OK	2	1.68	53.544	0.091036	0.001075
1979	MAR14	0310	35.498	97.826	OK	4	1.86	47.905	0.126506	0.001818
1979	MAR14	0402	35.781	97.650	OK		1.42	32.333	0.111549	0.000978
1979	MAR14	0437	35.519	97.781	OK	5	2.17	43.278	0.203380	0.004109
1979	MAR15	1038	35.689	97.923	OK		1.62	53.707	0.084464	0.000933
1979	MAR16	1238	36.517	98.123	OK		1.88	119.803	0.050870	0.000761
1979	MAR18	1725	35.377	98.100	OK		1.62	75.965	0.059302	0.000660

Table 1. (continued)

YEAR	DATE	UTC	LAT DN	LON DW	ST	MM	MAG	DELTAkm	Ah %g	Vh cm/sec
1979	MAR18	1733	35.410	98.115	OK		0.84	75.832	0.023348	0.000110
1979	MAR18	1735	35.410	98.115	OK		1.01	75.832	0.028619	0.000162
1979	MAR18	1739	35.410	98.115	OK		1.52	75.832	0.052705	0.000525
1979	MAR18	1744	35.410	98.115	OK		1.61	75.832	0.058702	0.000646
1979	MAR18	1752	35.344	98.053	OK		1.79	73.718	0.074950	0.001006
1979	MAR18	1755	35.384	98.110	OK		1.57	76.489	0.055466	0.000584
1979	MAR18	1807	35.439	98.118	OK		1.98	75.005	0.092450	0.001531
1979	MAR18	1814	35.410	98.116	OK		1.72	75.916	0.066889	0.000831
1979	MAR18	1830	35.418	98.108	OK		2.26	74.926	0.129412	0.002920
1979	MAR18	1846	35.443	98.126	OK		2.04	75.554	0.098600	0.001745
1979	MAR18	1857	35.416	98.130	OK		2.02	76.872	0.094583	0.001638
1979	MAR18	1913	35.418	98.155	OK		2.38	78.930	0.141681	0.003654
1979	MAR18	1930	35.413	98.101	OK		2.16	74.332	0.115745	0.002338
1979	MAR18	1941	35.406	98.110	OK		2.01	75.568	0.095102	0.001628
1979	MAR18	2005	35.416	98.110	OK		2.48	75.173	0.167848	0.004830
1979	MAR18	2024	35.420	98.110	OK		2.34	75.019	0.142241	0.003506
1979	MAR18	2044	35.379	98.124	OK	3	2.85	77.873	0.252164	0.010930
1979	MAR18	2107	35.429	98.114	OK		1.82	75.022	0.076315	0.001059
1979	MAR18	2116	35.379	98.118	OK		1.76	77.373	0.068324	0.000894
1979	MAR18	2142	35.394	98.108	OK		2.53	75.894	0.176476	0.005368
1979	MAR18	2208	35.396	98.126	OK		1.90	77.324	0.081437	0.001235
1979	MAR18	2242	35.416	98.126	OK		1.85	76.532	0.077514	0.001112
1979	MAR18	2319	34.100	97.448	OK	3	2.34	172.570	0.060813	0.001524
1979	MAR18	2340	35.433	98.102	OK		2.04	73.849	0.100922	0.001785
1979	MAR19	0054	35.408	98.102	OK		2.01	74.813	0.096082	0.001644
1979	MAR19	0342	35.400	98.110	OK		2.46	75.813	0.162466	0.004574
1979	MAR21	0455	35.043	96.349	OK		1.19	111.603	0.023937	0.000167
1979	MAR23	0131	34.034	97.430	OK		1.29	179.800	0.016589	0.000130
1979	MAR23	0601	34.022	97.440	OK		1.84	181.180	0.031800	0.000459
1979	MAR23	0757	35.361	98.108	OK		1.76	77.357	0.068838	0.000894
1979	MAR23	0841	35.387	98.108	OK		1.93	76.192	0.085694	0.001343
1979	MAR23	1043	35.605	97.974	OK		1.53	58.381	0.069647	0.000698
1979	MAR23	1726	35.411	98.163	OK		2.14	79.872	0.105016	0.002078
1979	APR 1	1229	35.420	98.132	OK		1.73	76.892	0.066819	0.000840
1979	APR 8	2246	40.969	98.564	NE		2.40	600.720	0.018308	0.000503
1979	APR22	0922	35.789	96.711	OK		1.58	57.940	0.074517	0.000789
1979	MAY 8	1123	35.923	97.480	OK		1.92	33.212	0.197503	0.003011
1979	MAY12	2156	35.301	97.601	OK		1.86	45.884	0.132192	0.001898
1979	MAY22	0349	34.027	97.470	OK	3	1.89	180.798	0.033835	0.000516
1979	MAY23	1730	34.055	97.405	OK		2.17	177.367	0.048245	0.001003
1979	JUN 1	1100	36.207	97.330	OK		1.44	61.893	0.058914	0.000535
1979	JUN 3	0506	39.444	97.788	KS		2.20	423.515	0.020582	0.000450
1979	JUN 6	1616	40.144	100.348	NE	3	2.50	565.107	0.021965	0.000673
1979	JUN 7	0739	35.187	99.812	OK	3	2.94	230.572	0.092819	0.004541
1979	JUN12	1113	40.406	96.054	NE		1.80	540.095	0.009949	0.000140

Table 1. (continued)

YEAR	DATE	UTC	LAT DN	LON DW	ST	MM	MAG	DELTAkm	Ah %g	Vh cm/sec
1979	JUN15	0508	39.840	97.220	KS		1.90	465.689	0.013045	0.000205
1979	JUN19	0449	34.715	95.965	OK		1.44	161.749	0.022115	0.000205
1979	JUN19	0453	34.746	95.932	OK		1.76	161.879	0.032413	0.000427
1979	JUN25	0730	38.016	97.005	KS		1.60	264.511	0.016218	0.000181
1979	JUN26	1304	39.296	96.016	KS		2.00	421.400	0.016282	0.000285
1979	JUN30	2046	39.937	97.274	KS	4	3.10	476.359	0.053630	0.003177
1979	JUN30	2110	39.908	97.292	KS		1.40	473.179	0.007053	0.000064
1979	JUL 1	0700	34.028	97.383	OK		1.83	180.300	0.031578	0.000451
1979	JUL 1	1959	39.952	97.286	KS		2.00	478.027	0.014317	0.000252
1979	JUL 4	0345	35.705	97.978	OK		2.34	58.809	0.182333	0.004473
1979	JUL 7	0115	34.879	95.814	OK		1.61	162.044	0.027057	0.000302
1979	JUL13	0748	34.033	95.087	OK		1.34	272.267	0.011535	0.000097
1979	JUL14	1832	39.526	99.256	KS		2.10	462.856	0.016678	0.000327
1979	JUL16	0003	40.168	100.287	NE	3	2.70	565.000	0.027913	0.001066
1979	JUL16	0134	40.193	100.345	NE	3	2.50	569.829	0.021779	0.000667
1979	JUL16	0527	40.191	100.333	NE		1.30	569.108	0.005183	0.000042
1979	JUL16	0608	40.189	100.346	NE		1.50	569.431	0.006582	0.000067
1979	JUL16	0705	40.200	100.332	NE		1.10	569.966	0.004073	0.000027
1979	JUL24	0224	36.070	97.506	OK		2.50	49.288	0.264425	0.007714
1979	JUL24	0416	40.208	100.433	NE		2.20	574.864	0.015071	0.000331
1979	JUL24	0804	40.466	99.623	NE		1.90	571.488	0.010586	0.000167
1979	JUL25	0315	33.967	97.549	OK	5	2.74	188.078	0.089924	0.003513
1979	JUL31	1911	36.086	97.305	OK		2.52	48.500	0.275321	0.008208
1979	AUG 2	0416	40.172	100.357	NE		2.50	568.281	0.021840	0.000669
1979	AUG 2	1046	38.930	96.563	KS		2.20	370.696	0.023578	0.000514
1979	AUG 3	0529	32.851	100.737	TX		2.57	441.203	0.030744	0.001012
1979	AUG 3	1029	35.683	98.005	OK		1.93	61.046	0.107430	0.001676
1979	AUG 9	0004	33.930	97.432	OK		2.35	191.351	0.055390	0.001407
1979	AUG13	1109	40.113	100.502	NE		1.70	568.654	0.008374	0.000106
1979	AUG14	2359	40.173	100.343	NE		1.50	567.796	0.006601	0.000067
1979	AUG15	0645	40.145	100.339	NE		1.50	564.855	0.006636	0.000067
1979	AUG15	1607	40.142	100.441	NE		1.30	568.779	0.005186	0.000042
1979	AUG16	0727	34.953	97.602	OK		1.85	81.283	0.072895	0.001047
1979	AUG19	0158	35.203	97.445	OK		2.22	50.750	0.183550	0.003932
1979	AUG31	0800	40.139	100.337	NE	4	2.20	564.169	0.015362	0.000338
1979	SEP 4	0740	34.799	97.557	OK		2.28	96.781	0.102092	0.002367
1979	SEP 5	0238	35.429	97.871	OK		1.87	54.735	0.111755	0.001628
1979	SEP 5	0404	35.427	97.717	OK		1.83	42.878	0.136653	0.001896
1979	SEP 9	0000	39.391	95.892	KS		1.50	434.586	0.008671	0.000087
1979	SEP13	0049	35.217	99.362	OK	4	3.37	190.162	0.189057	0.014821
1979	SEP13	0219	35.380	99.360	OK		1.88	186.042	0.032471	0.000490
1979	SEP15	0342	35.493	97.882	OK		1.77	52.854	0.102745	0.001339
1979	SEP15	1401	35.369	97.952	OK		1.90	64.346	0.098222	0.001484
1979	SEP16	0604	35.355	97.997	OK		1.70	68.667	0.072346	0.000878
1979	SEP16	0627	35.435	97.981	OK		1.69	63.524	0.077393	0.000927

Table 1. (continued)

YEAR	DATE	UTC	LAT DN	LON DW	ST	MM	MAG	DELTAkm	Ah %g	Vh cm/sec
1979	SEP16	1042	35.455	97.905	OK		2.03	56.318	0.131474	0.002287
1979	SEP16	1107	35.355	97.989	OK		1.83	68.032	0.085336	0.001195
1979	SEP16	1557	35.343	97.997	OK	4	2.48	69.317	0.182322	0.005238
1979	SEP16	2216	35.355	97.966	OK		1.87	66.216	0.092027	0.001346
1979	SEP17	1438	35.063	94.937	OK		1.81	226.463	0.024434	0.000343
1979	SEP17	2041	35.320	97.968	OK	4	2.45	68.389	0.178326	0.004955
1979	OCT 6	1108	34.887	95.873	OK		1.49	157.038	0.024198	0.000237
1979	OCT19	1617	37.077	98.605	KS		2.18	195.345	0.044247	0.000932
1979	OCT19	2112	37.113	98.599	KS		1.85	198.283	0.029354	0.000429
1979	OCT21	0729	34.502	96.432	OK		2.15	151.465	0.055332	0.001121
1979	NOV 7	0554	35.510	97.888	OK		2.12	52.773	0.156471	0.003003
1979	NOV11	1026	35.695	98.050	OK		1.92	65.186	0.099280	0.001534
1979	NOV16	0550	35.285	95.987	OK		1.31	128.130	0.024004	0.000192
1979	NOV19	0458	40.248	100.046	NE		1.50	563.603	0.006651	0.000067
1979	NOV27	0910	35.630	98.408	OK		3.25	97.375	0.324102	0.021956
1979	NOV29	2202	40.163	100.361	NE		1.90	567.568	0.010661	0.000168
1979	DEC 7	1417	39.694	97.619	KS		2.10	450.103	0.017160	0.000336
1979	DEC 9	2312	33.988	97.353	OK	3	2.51	184.692	0.069554	0.002106
1979	DEC10	0825	34.965	96.307	OK		1.46	119.997	0.030715	0.000289
1979	DEC14	1320	35.187	97.664	OK		1.90	59.680	0.106060	0.001600
1979	DEC15	0730	37.199	98.513	KS		1.87	202.026	0.029497	0.000441
1979	DEC16	1237	35.158	98.741	OK		2.45	138.999	0.086502	0.002438
1979	DEC20	1458	36.367	97.379	OK		2.12	79.794	0.102633	0.001986

Note: Delta is the distance from the Arcadia site and Ah and Vh are the expected maximum horizontal ground velocity and acceleration at the site. Both Ah and Vh are printed as zero when the magnitude is not known. F in the intensity column indicated that the earthquake was felt but the intensity was not known. Dates and times are in Coordinated Universal Time (subtract six hours to obtain Central Standard Time; subtract one day from the date if the resulting CST is between 1800 and 2359 inclusive).