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REPORT ON MICROEARTHQUAKE MONITORING IN THE VICINITY OF AUBURN DAM, CALIFORNIA: NOVEMBER 1976 - MARCH 1977.

by

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Introduction - The Network and Its Equipment

The Auburn Dam Seismic Network is operated by the U. S. Geological Survey in cooperation with the Bureau of Reclamation to provide information on seismicity in the Sierra Nevada foothills, particularly near Auburn Dam, and to provide a record of earthquakes near the Dam before, during, and after construction and filling of the reservoir. The Auburn Network is operated as part of a broader Sierra Foothills Seismic Network that stretches from Don Pedro Dam in the south to Chico in the north. The southern part of the network surrounds the New Melones Dam and is supported by the Corps of Engineers. The northern part of the network surrounds the Oroville Dam and was established by the U.S.G.S. to study aftershocks of the 1975 earthquake near Oroville Dam. Names, coordinates, elevations, and installation dates of stations of the Sierra Foothills Network are listed in Table 1 and the stations are plotted on Figure 2.

In Table 1 the first group of stations (BFS to STN) constitute the Melones Network; the second group (AARS to AVRS), the Auburn Network; and the third group (OBLO to OWYN), the Oroville Network. JAS is operated by the U. C. Berkeley near the Melones Dam and KPK, MGL, ORV, and PAM are operated by the California Division of Water Resources around the Oroville Dam. The Melones Network was installed in 1972 to study the question of reservoir-induced earthquakes in conjunction with raising the level of the Melones Reservoir. It was rearranged, in part, during 1976 to provide broader earthquake coverage in the Melones region.

The CDWR stations at Oroville were installed prior to the 1975 Oroville earthquake to monitor seismic activity in the vicinity of the Oroville Dam. The U.S.G.S. Oroville Network was installed after the 1975 Oroville earthquake for a detailed study of its aftershocks. It was modified in late 1976 to provide broader coverage of adjacent portions of the Sierra foothill fault zone.

The first four stations of the present Auburn network were installed in January and February, 1976. The network has increased by seven stations in July 1976 and by an additional seven stations during the last three months of the year. During February 1977, two stations were added to the northern edge of the Auburn net and one station (ABAB) was removed. Currently, the network consists of nineteen stations.

Signals from all stations of the network are telemetered to Menlo Park, where they are recorded on 16 mm film strip recorders (Develocorders) and on magnetic tape. APHR, ORV and JAS are also recorded on standard format (24 hours of record on one 30 cm by 90 cm sheet at 1 mm/sec) direct-write seismic recorders (Helicorders) to facilitate the identification of small events that occur in the Auburn, Oroville, and Melones regions. All stations are equipped with short period (1 hz) vertical seismometers with velocity transducers and employ frequency modulated audio frequency carriers for transmittal of data over voice-grade phone lines, with signals from as many as eight stations multiplexed on a single line. For the U.S.G.S. stations, the overall system response is limited at high frequencies by the Develocorder galvanometers (10 hz) or by the 30 hz high-cut filters in the seismic amplifiers and the discriminators, in the case of signals played back from magnetic tape.

The systems are operated at sufficiently high magnification at each site to permit the prevailing seismic background noise to be recorded clearly. This practice insures that small seismic events will not be "lost" solely because their records are too small to see. However, the background noise at most stations of the network is strongly influenced, in some cases dominated, by cultural noise - primarily vehicular traffic. The situation is particularly severe for the critical stations that lie along the westernmost edge of the network on sediments of the Great Valley. Response curves for the standard U.S.G.S. seismic system recorded on a Develocorder are shown in Figure 1.

Procedure - Data Analysis

This report is concerned primarily with seismic events in the region of the Auburn Dam that were recorded by the Auburn Network from the time it reached full strength (November 1976) until the end of March, 1977. Events were selected for analysis on the basis of a careful study of the Helicorder record from station APHR, which is located about 13 km west of the dam site. The most common events visible at this station are: 1) explosions from sources in the Auburn area - primarily from dam construction, but also from a number of commercial quarries; 2) explosions from sources in the Melones region - presumably from commercial quarries or mining operations; 3) occasional aftershocks of the 1975 Oroville earthquake; 4) earthquakes from the central coast ranges and from the eastern Sierra Nevada. Repeated explosions from the larger quarries produce monotonously similar records; so a representative selection, not all, of them were selected for analysis. Several earthquakes from the Oroville aftershock region, one from northwest of the Sutter Buttes, one from the Sierra Nevada east of Oroville, and one from near Donner Lake were also selected for analysis in order to evaluate crustal velocity models employed for hypocenter determinations in the Sierra Nevada foothill region. In addition to the "known" events listed above, all small seismic events with S-P intervals less than five seconds (origins within about 40 km of APHR) and all sharp seismic events of larger size for which more distant origins could not be established from other data were examined on the Develocorder films. P-arrival times and first motion directions, and S-arrival times (if readable) were determined for all stations of the Sierra Foothills Network that recorded the event, and event duration times were measured at several stations. On subsequent analysis, this last set of events was found to consist of small to moderate explosions from sites scattered through the Auburn region and a group of small natural earthquakes from depths of 10 to 15 km near Auburn. All but one of these quakes emanated from a small region 12 to 15 km beneath the town of Rocklin; the lone earthquake originated about half-way between Auburn and Georgetown at a depth of 10 km.

Hypocenter Determinations

Hypocenters were determined by the computer program HYPO71 (Lee & Lahr, 1975), which is used for the uniform processing of central California microearthquake data. This program compares the observed arrival times of P waves (and S waves, if they can be read) with those computed for a trial hypocenter and origin time in an earth model consisting of flat-lying constant velocity layers. The trial hypocenter and origin time are then adjusted systematically to minimize the differences between the observed and computed times according to the criterion of least squares. In the least squares calculations individual arrivals are weighted according to clarity of the arrivals and distance of the station from the epicenter. Judicious use of the distance weighting factor can help to minimize the dependence of the calculated hypocenter on the details of the crustal velocity model of the lower crust.

The crustal velocity model used to locate events in the Melones and Oroville regions (Table 2) was adapted from a seismic refraction profile between Shasta Lake and Mono Lake, (Eaton, 1966). The crustal model used to locate events in the Auburn region (Table 2) was modified from the above model to accomodate additional information on near-surface velocities from observations of quarry blasts near Auburn, (Cramer, written communication). These models should be regarded as hypotheses, and a further effort should be made to determine them more precisely. For this purpose, detonation times of future explosions at a number of quarries scattered through the foothill belt should be timed accurately to permit a better determination of shallow crustal structure from records of these blasts at network stations. Such studies would also establish, or set limits on, possible delays at individual stations resulting from local variations in the thickness and/or velocity of low velocity near-surface materials beneath the stations.

In HYPO71 only the P-velocity model is specified. S-wave travel times are based on a stipulated constant V_p/V_s velocity ratio throughout the crust and on the calculated P-wave travel times. A ratio V_p/V_s of 1.78 was used in the present analysis.

Hypocenters for the events selected for analysis were computed from P-wave arrival times along (Table 3) and from both P-wave and S-wave (when timeable) arrival times (Table 4). For well recorded events that occurred within the network the differences between the solutions are not great. For events that were recorded on only a few stations or that occurred outside of the network, the differences were substantial in some cases. We have adopted solutions based on both P and S data as the more reliable, and these were used for the epicenter plots that follow.

Seismicity

Figure 2 shows the Sierra Foothills network and all of the seismic events that were located for this study. Focal depth and magnitude are indicated by the plotted symbol and its height, respectively.

The shallow events in the Melones and Auburn regions (depths of 0 to 4 km) can be identified as explosions by the general character of their records and the fact that all of the clear P-onsets they produced were compressional.

Their origin times (10:00 am to 5:00 pm local time) are also compatible with such an origin. The Melones blasts, with magnitudes from 1.4 to 2.2 occurred about 110 km from APHR. Because they were selected for study on the basis of their records at APHR, it appears that magnitude 1.5 is the detection threshold at about 100 km for the method we employed to identify events for study. Calculated focal depths for the blasts are generally less than 1 km. This fact is significant when we argue that deeper events in the same reigon located with the same crustal velocity models are indeed natural earthquakes, not blasts mislocated with an inappropriate crustal velocity model. The Melones and Auburn seismic events are plotted in Figures 3 and 4, respectively.

In the Auburn region the larger blasts are concentrated at or near the dam construction site and near Clarksville (quarry?). Smaller blasts, including one with a calculated depth of 3.3 km at the town of Rocklin, are scattered through the densest part of the network where such small events (magnitudes from 0 to 1) can be detected on the minimum number of stations required for hypocenter determination. The most interesting events recorded were small natural earthquakes originating at depths of 10 to 15 km in the Auburn region. From November 1976 through March 1977, nine such events were identified: eight of them occurred beneath the town of Rocklin about 19 km southwest of the dam site and one occurred between Auburn and Georgetown about 9 km east of the dam site. The largest of these events had a magnitude of 1.6; the smallest, 0.2. On Figure 4 the cluster of earthquakes beneath Rocklin appears to be elongated in a northwest-southeast direction, but the elongation is small and could be an artifact of the hypocenter determination procedure. This problem will be pursured further.

Focal Mechanisms

A focal plane solution for the M=1.6 Rocklin earthquake of 21 February 1977 is shown in Figure 5. All stations show dilatational first motions except AFID, which lies west of the epicenter. One plane has a strike azimuth of 0° and dips 26° toward the west; the other has a strike azimuth of 350° and dips 64° toward the east. The data are consistent with a shallower dip on the first plane, coùpled with steeper dip on the second; but both planes must strike nearly to the north.

A composite fault plane solution for the next two most clearly recorded events is similar to that for the 21 February quake (Figure 6). The M = 1.0 quake on 28 November 1976, beneath Rocklin, constrains one plane, and the M = 1.1 quake 19 November 1976, east of the dam site, constrains the other. Both planes must have northerly strikes, but their strike azimuths are not well determined.

For the 21 February 1977 Rocklin earthquake we would tentatively identify the plane (#2) dipping steeply toward the east as the fault plane and the plane (#1) dipping gently toward the west as the auxilliary plane. In such an interpretation, the Sierrian (eastern) block was downdropped relative to the Valley (western) block on a northerly striking normal fault that dips 64° toward the east.

We also constructed a fault plane solution for the M = 3.6 Oroville earthquake of 9 January 1977 (Figure 7). This event is an aftershock of the 1975 Oroville quake and has a fault plane solution similar to earlier aftershocks from the same region. Both planes strike in a northerly direction. One dips 44° towards the west; the other 50° toward the east. On geologic evidence and on geodetic evidence for the 1975 earthquake, the west dipping plane is considered to be the fault plane. Thus, the Valley block is down-dropped relative to the Sierra block on a northerly striking normal fault that dips about 45° toward the west.

The Oroville and Rocklin earthquakes have rather similar fault plane solutions and we have inferred normal faults in both cases. However in the Oroville region the downthrown block is on the west, and in the Auburn region the downthrown block is on the east.

Prior to the period covered by this report, when the U.S.G.S. Auburn Network was still being installed, portable microearthquake networks were operated in the Roseville-Rocklin-Auburn region, first by Woodward-Clyde and Associates and then by the California Division of Mines and Geology. Data from stations of the incomplete U.S.G.S. network were read by these investigators and used to augment the portable network data.

The nest of earthquakes beneath Rocklin was discovered by the Woodward-Clyde group and confirmed by the somewhat later studies of CDMG. This work was summarized by Dr. C. Cramer of CDMG at the spring meeting of the Seismological Society of America. He has kindly furnished copies of the summary list of earthquakes and maps presented in his paper. These documents are transmitted herewith (Appendix 1) for completeness.

Magnitudes of the events reported by Cramer are uniformly smaller than that for the Rocklin quakes listed in this report. Unfortunately, there is no overlap between events on the two lists; so a simple comparison cannot be made. The U.S.G.S. stations will be reread for the earlier events and the magnitudes of those events will be determined by the standard U.S.G.S. procedures, so that a direct comparison of the magnitudes can be made. The CDMG map also shows events from a source north of Rocklin that is not represented by earthquakes recorded after November 1.

References

Eaton, J. P., 1966, Crustal Structure in northern and central California from seismic evidence: California Division of Mine and Geology Bulletin 190, p. 419-426.

Lee, W. H. K., and J. C. Lahr, 1975, HYPO71: A computer program for determining hypocenter, magnitude, and first motion pattern of local earthquake: USGS Open-File Report 75-311, 114 p.

Table 1

Stations of the Sierra Foothills Network

Name Lat Long Elev.	Instal. Date	Atten.
BFS3740.71N12021.80W 309	761027	18 - BFS
CNS3756.33N12031.76W 373	720120	18
COP3758.36N12037.02W 336	720324	
CRH3801.12N12030.57W 475	720120	12
MWV3803.83N12010.89W1411	761027	
NHR3808.75N12048.82W 219	761027	18
OBF3754.00N12034.04W 176	720415	12
RFR3814.72N12031.24W 799	7607 2	18
STN3754.27N12024.29W 366	720120	12
AARS3916.57N12101.53W 930	760720	24 - AARS
ABAB3852.76N12104.05W 422	761038	24
ABJS3909.09N12111.47W 457	760727	18
ABRS3908.11N12129.21W 24	770209	30
ADWD3826.35N12050.89W 251	760721	18
AFHD3856.69N12058.10W 524	760129	6
AFHS3902.51N12047.48W1064	760721	24
AFID3847.54N12120.91W 31	761202	24
AGRI3850.68N12058.88W 305	760130	12
AHDR3902.90N12104.59W 483	760129	18
AHFR3851.26N12104.23W 354	760201	18
ALIN3855.78N12117.27W 54	761202	24
AOHO3922.52N12115.36W 457	770210	12
AOTD3836.89N12043.71W 520	761019	12
APHR3852.62N12113.03W 133	760716	12
ARPW3858.38N12109.73W 320	760129	12
ARRA3845.92N12110.31W 127	761202	12
ARWJ3841.19N12057.38W 460	761123	18
ASHR3829.86N12112.29W 52	760721	30
AVRS3901.49N12116.08W 911	760716	6
OBLO3939.10N12127.70W 916	750906	18 - OBLO
OCOR3952.55N12145.92W 530	761218	12
OGOO3939.22N12136.72W 158	761229	12
OHON3920.18N12129.05W 76	750805	18
ORAT3928.13N12124.80W 585	750805	12
OSTI3922.12N12135.80W 29	750805	18
OSUT3916.23N12151.10W	760316	12
OTAB3932.75N12133.65W 223	750906	18
OWYN3927.19N12129.20W 177	750805	18
JAS3756.80N12026.30W 457		
KPK3935.01N12118.32W 897		
MGL3948.71N12133.42W1010		
ORV3933.33N12130.00W 362		
PAM3926.94N12131.19W 131		

Table 2

Crustal Velocity Structure Models Used to Locate Sierra Foothill Earthquakes

A. Oroville and Melones Regions

Veloc (Km/sec)	Depth to Layer (Km)
5.0	0.0
6.0	1.0
6.4	5.0
6.8	25.0
8.0	35.0

B. Auburn Region

Veloc (Km/sec)	Depth to Layer (Km)
5.5	0.0
6.3	1.0
6.8	20.0
8.0	35.0

DATE	ORIGIN	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	QM
	JAMESTOWN BLASTS			S DATA NOT USED								
770105	2355 59.76	37-57.88	120-33.10	0.07	2.20	9	88	3.5	0.05	0.3	0.5	A1
770129	049 16.56	37-58.01	120-33.04	0.70	2.08	7	116	3.6	0.06	0.5	0.7	B1
770208	036 29.68	37-57.30	120-33.25	0.76	1.42	8	99	2.8	0.08	0.5	0.8	B1
770211	2356 1.55	37-57.43	120-32.63	0.60	1.85	7	166	2.4	0.03	0.3	0.3	B1
770215	0 2 17.68	38- 6.59	120-24.52	1.24	1.91	8	137	13.4	0.08	0.6	36.3	C1
770218	013 51.39	37-57.46	120-33.22	0.55	1.97	9	122	3.0	0.06	0.4	0.6	B1
770218	2348 59.19	37-57.51	120-32.89	0.94	2.19	8	117	2.7	0.06	0.5	85.7	C1
770315	2356 59.42	37-57.74	120-32.83	0.95	1.86	8	170	3.0	0.06	0.5	78.2	C1
770325	025 18.42	37-57.37	120-32.85	0.61	2.19	9	116	2.5	0.06	0.4	0.5	B1
770405	2012 31.59	37-56.02	120-32.77	0.27	1.50	8	109	1.6	0.07	0.6	0.6	B1
770408	2341 34.32	37-57.54	120-32.70	0.77	1.55	8	115	2.6	0.08	0.6	0.7	B1
	OROVILLE QUAKES			S DATA NOT USED								
770109	2324 40.20	39-29.06	121-29.18	6.72	3.56	23	84	4.9	0.21	0.8	1.3	B1
770112	330 13.65	39-24.55	121-28.95	3.14	2.35	23	89	8.1	0.19	0.7	1.2	B1
770116	455 17.12	39-32.91	121- 8.11	15.96	1.38	15	208	25.5	0.11	1.1	2.4	C1
770207	1449 2.22	39-20.31	121-21.49	0.83	1.33	17	133	10.9	0.19	0.8	11.3	C1
	DEEP AUBURN QUAKES			S DATA NOT USED								
761119	511 11.72	38-53.87	120-53.95	16.26	1.07	6	279	8.0	0.06	6.1	7.3	D1
761128	7 2 28.35	38-44.61	121-17.20	16.89	1.06	7	296	16.0	0.09	7.3	4.4	D1
761128	1235 37.54	38-45.79	121-16.02	15.24	1.01	7	290	13.4	0.07	5.2	3.2	D1
761216	1227 17.47	38-48.34	121-12.21	8.12	0.31	6	199	5.3	0.05	1.7	2.8	C1
761231	943 4.43	38-47.71	121-16.19	18.20	0.39	6	249	9.1	0.02	0.9	1.2	C1
770103	623 28.35	38-48.12	121-14.55	1.08	0.13	5	231	7.4	0.15	6.1	324.0	D1
770121	1750 22.13	38-45.30	121-15.08	16.09	0.55	8	277	7.0	0.07	3.2	3.5	D1
770122	13 0 31.36	38-46.24	121-14.10	14.31	0.54	8	258	5.5	0.05	1.8	2.2	C1
770221	2137 25.04	38-46.88	121-13.36	14.35	1.63	15	99	4.8	0.06	0.4	0.7	B1
	AUBURN BLASTS ?			S DATA NOT USED								
DATE	ORIGIN	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	QM
761108	2335 5.56	38-51.00	121- 3.48	5.00	0.12	3	187	1.2	0.17			C1
770105	2336 50.05	38-53.69	121- 2.30	1.34	1.41	11	91	5.3	0.18	0.8	13.7	C1
770113	2348 35.75	38-52.92	121- 3.57	0.09	1.73	12	76	3.2	0.16	0.8	2.4	B1
770117	2026 27.02	38-53.81	121- 0.95	1.00	1.19	13	102	6.5	0.12	0.6	144.9	C1
770121	1925 56.21	38-39.26	121- 0.09	0.23	1.40	15	103	5.3	0.14	0.8	2.0	B1
770121	2219 55.82	38-53.07	121- 3.21	0.01	0.16	9	79	1.3	0.05	0.3	0.6	A1
770126	2338 38.32	38-45.27	121-10.15	1.47	0.10	5	285	1.2	0.06	21.3	6.2	D1
770131	2310 19.07	38-39.29	121- 0.46	1.00	1.22	14	75	5.7	0.09	0.5	100.6	C1
770207	2351 39.65	38-52.96	121- 3.92	1.26	1.59	15	67	3.2	0.15	0.6	6.5	B1
770209	2338 25.44	38-53.30	121- 3.92	0.38	0.90	9	70	3.8	0.11	0.6	1.5	A1
770212	2337 1.77	38-53.14	121- 3.50	0.69	1.57	14	71	3.6	0.17	0.7	1.7	B1
770215	2336 49.14	38-53.17	121- 3.73	0.07	1.26	9	72	3.6	0.07	0.4	1.2	A1
770218	2357 27.82	38-39.18	120-59.94	0.56	2.02	14	75	5.3	0.14	0.8	1.8	B1
770226	2222 15.33	38-53.06	121- 3.55	1.01	0.46	9	74	3.5	0.08	0.5	101.6	B1
770303	20 8 30.23	38-47.93	121-13.77	1.02	0.62	7	139	6.2	0.09	0.8	137.7	C1
770303	2339 55.93	38-52.68	121- 3.71	1.02	1.31	11	70	2.7	0.10	0.5	120.1	B1
770305	1814 27.08	38-52.71	121- 3.76	0.17	0.76	8	76	2.8	0.09	0.6	1.4	A1
770318	18 0 17.12	38-46.54	121-15.89	1.09	-0.03	4	282	8.2	0.02			C1
770325	23 9 29.10	38-40.77	120-59.49	1.53	1.43	14	115	3.2	0.19	1.1	5.5	C1
770406	019 3.71	38-53.92	121- 0.76	1.05	0.60	11	105	6.4	0.08	0.4	101.3	C1
770408	2332 22.09	38-52.68	121- 3.20	0.01	0.79	9	76	3.0	0.07	0.4	0.9	A1
DATE	ORIGIN	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	QM

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Table 3 Locations of Sierra foothills seismic events for 1 November 1976 to 8 April 1977 based on P-arrivals only.

DATE	ORIGIN	LAT N	LONG W	DEPTH		MAG	NO	GAP	DMIN	RMS	ERH	ERZ	QM
	JAMESTOWN BLASTS			AVAILABLE S DATA USED									
770105	2355 59.76	37-57.88	120-33.10	0.07	P	2.20	9	88	3.5	0.05	0.3	0.5	A1
770129	049 16.56	37-58.01	120-33.04	0.70	P	2.08	7	116	3.6	0.06	0.5	0.7	B1
770208	036 29.68	37-57.30	120-33.25	0.76	P	1.42	8	99	2.8	0.08	0.5	0.8	B1
770211	2356 1.55	37-57.43	120-32.63	0.60	P	1.85	7	166	2.4	0.03	0.3	0.3	B1
770215	0 2 17.67	38- 6.40	120-24.55	0.97		1.91	14	136	13.1	0.12	0.5	0.9	B1
770218	013 51.39	37-57.46	120-33.22	0.55	P	1.97	9	122	3.0	0.06	0.4	0.6	B1
770218	2348 59.19	37-57.51	120-32.89	0.94		2.19	8	117	2.7	0.06	0.5	85.7	C1
770315	2356 59.42	37-57.74	120-32.83	0.95	P	1.86	8	170	3.0	0.06	0.5	78.2	C1
770325	025 18.42	37-57.37	120-32.85	0.61		2.19	9	116	2.5	0.06	0.4	0.5	B1
770405	2012 31.61	37-56.00	120-32.68	0.39		1.50	9	107	1.5	0.10	0.7	0.7	B1
770408	2341 34.32	37-57.54	120-32.70	0.77	P	1.55	8	115	2.6	0.08	0.6	0.7	B1
	OROVILLE QUAKES			AVAILABLE S DATA USED									
770109	2324 40.20	39-29.06	121-29.18	6.72	P	3.56	23	84	4.9	0.21	0.8	1.3	B1
770112	330 13.65	39-24.55	121-28.95	3.14	P	2.35	23	89	8.1	0.19	0.7	1.2	B1
770116	455 17.22	39-32.11	121- 8.70	17.03		1.37	27	205	24.2	0.14	0.7	1.1	C1
770207	1449 2.10	39-19.83	121-22.80	4.31		1.33	30	125	9.0	0.25	0.8	1.2	B1
	DEEP AUBURN QUAKES			AVAILABLE S DATA USED									
761119	511 12.80	38-54.60	120-57.14	10.04		1.06	10	219	4.1	0.10	0.9	1.2	C1
761128	7 2 29.62	38-48.38	121-13.74	13.39		0.99	14	273	7.9	0.16	1.2	1.0	C1
761128	1235 38.22	38-48.19	121-14.09	14.02		0.96	14	275	8.3	0.11	0.8	0.7	C1
761216	1227 16.76	38-47.66	121-14.12	12.73		0.46	13	233	6.4	0.10	0.6	0.6	C1
761231	943 5.05	38-48.72	121-15.13	14.03		0.33	13	230	7.8	0.12	0.7	0.8	C1
770103	623 27.96	38-47.81	121-14.03	9.44		0.16	10	230	6.4	0.22	1.8	1.8	C1
770121	1750 22.88	38-47.13	121-13.61	12.28		0.41	16	237	5.3	0.08	0.4	0.5	C1
770122	13 0 31.66	38-46.94	121-13.24	12.79		0.48	17	236	4.6	0.10	0.5	0.5	C1
770221	2137 25.28	38-47.45	121-13.26	12.55		1.63	18	93	5.1	0.08	0.4	0.6	B1
	AUBURN BLASTS ?			AVAILABLE S DATA USED									
761108	2335 5.81	38-50.39	121- 4.32	2.24		0.12	5	202	1.6	0.11	2.1	1.5	C1
770105	2336 50.04	38-53.96	121- 2.41	0.90		1.41	14	89	5.6	0.19	0.8	2.6	B1
770113	2348 35.75	38-53.04	121- 3.67	0.21		1.73	14	72	3.4	0.16	0.8	2.0	B1
770117	2026 27.05	38-53.83	121- 0.98	1.04		1.19	16	102	6.6	0.13	0.5	151.2	C1
770121	1925 56.20	38-39.17	120-59.57	3.78		1.42	16	112	4.9	0.13	0.7	1.9	B1
770121	2219 55.80	38-53.05	121- 3.08	0.21		0.17	13	81	1.5	0.08	0.3	0.5	A1
770126	2338 37.88	38-43.67	121-10.43	0.26		0.14	7	294	4.2	0.07	1.1	0.8	C1
770131	2310 19.06	38-39.21	121- 0.34	1.04		1.22	18	75	5.6	0.13	0.6	148.2	C1
770207	2351 39.59	38-53.06	121- 4.03	0.24		1.59	21	67	3.4	0.13	0.4	1.0	A1
770209	2338 25.47	38-53.25	121- 4.07	0.71		0.90	13	69	3.7	0.12	0.4	0.9	A1
770212	2337 1.76	38-53.17	121- 3.43	0.66		1.57	17	72	3.7	0.17	0.6	1.3	B1
770215	2336 49.17	38-53.23	121- 3.86	0.15		1.26	14	71	3.7	0.09	0.3	0.7	A1
770218	2357 27.87	38-39.33	120-59.83	2.67		2.02	17	74	5.0	0.14	0.6	2.8	B1
770226	2222 15.34	38-52.94	121- 3.64	1.06		0.46	13	72	3.2	0.08	0.2	4.7	B1
770303	20 8 30.17	38-47.82	121-13.73	3.31		0.62	10	142	6.1	0.09	0.5	1.4	B1
770303	2339 55.88	38-52.68	121- 3.70	0.47		1.31	14	70	2.7	0.09	0.3	0.7	A1
770305	1814 27.10	38-52.52	121- 3.62	0.09		0.77	11	84	2.5	0.18	0.9	2.2	B1
770318	18 0 17.18	38-46.60	121-15.54	1.04		-0.04	6	279	7.7	0.03	0.7	54.2	D1
770325	23 9 29.03	38-40.47	120-59.77	0.40		1.43	21	117	3.7	0.18	0.7	1.3	B1
770406	019 3.67	38-53.96	121- 0.62	2.97		0.61	14	106	6.2	0.08	0.4	1.5	B1
770408	2332 22.14	38-52.56	121- 3.29	0.92		0.79	12	74	2.8	0.10	0.4	0.6	A1
	DONNER LAKE												
770111	850 8.56	39-21.85	120-19.90	18.66		3.12	34	222	53.5	0.19	1.8	1.3	C1
	BUTTE CITY												
770328	0349 45.27	39-22.59	121-57.94	26.19		2.29	44	128	15.3	0.45	1.2	1.8	C1

DATE ORIGIN LAT N LONG W DEPTH MAG NO GAP DMIN RMS ERH ERZ QM

Table 4 Locations of Sierra foothills seismic events for 1 November 1976 to 8 April 1977 based on P-arrivals and S-arrivals.

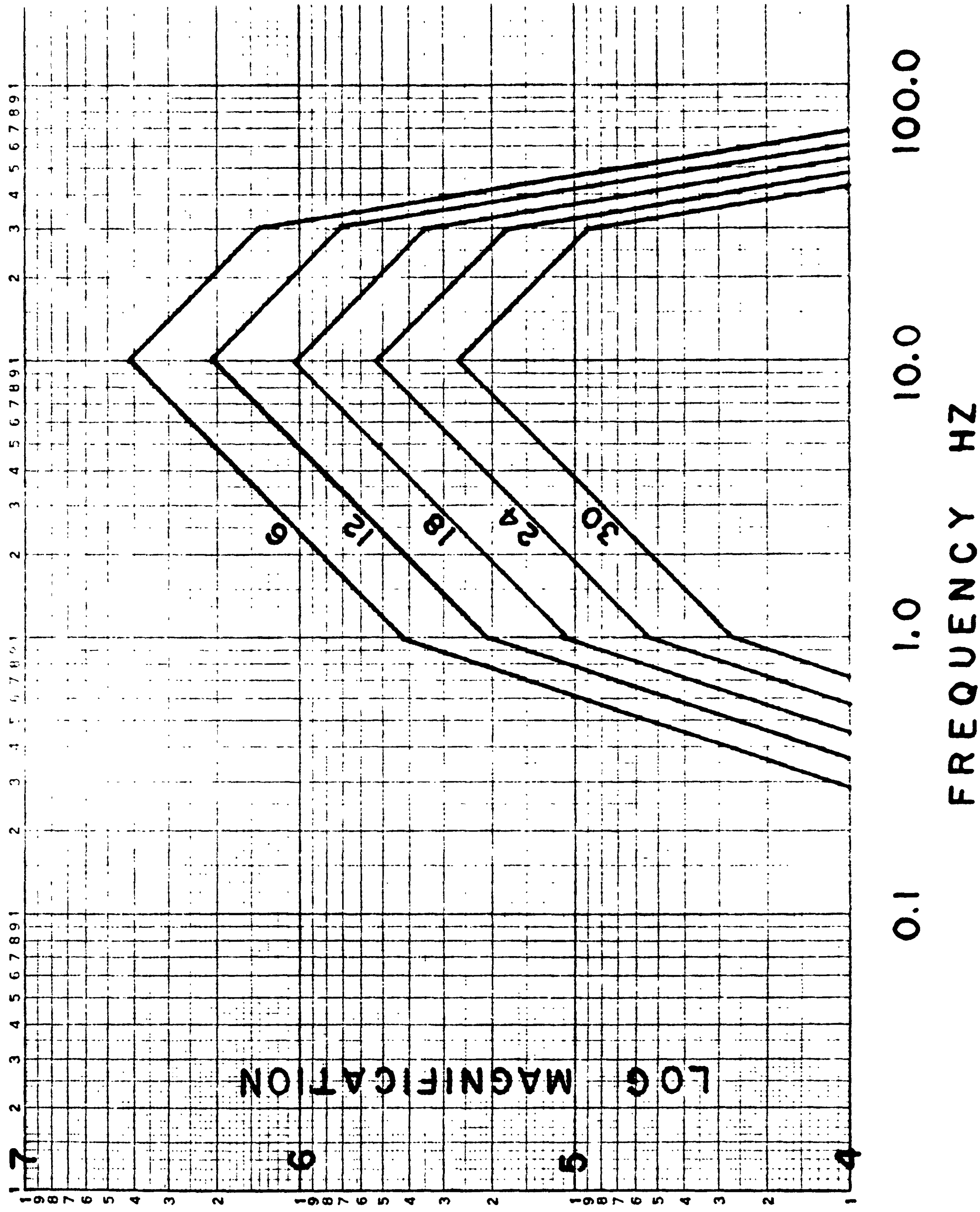


Figure 1 Response curves of the standard U.S.G.S. seismic system when recorded on a Develocorder and viewed on a Geotech Film Viewer with X20 magnidication. The attenuation setting of the seismic amplifier is the variable parameter on the curves. Attenuator settings at the Sierra foothills stations range from -6 db to -30 db, but most are either -12 db or -18 db.

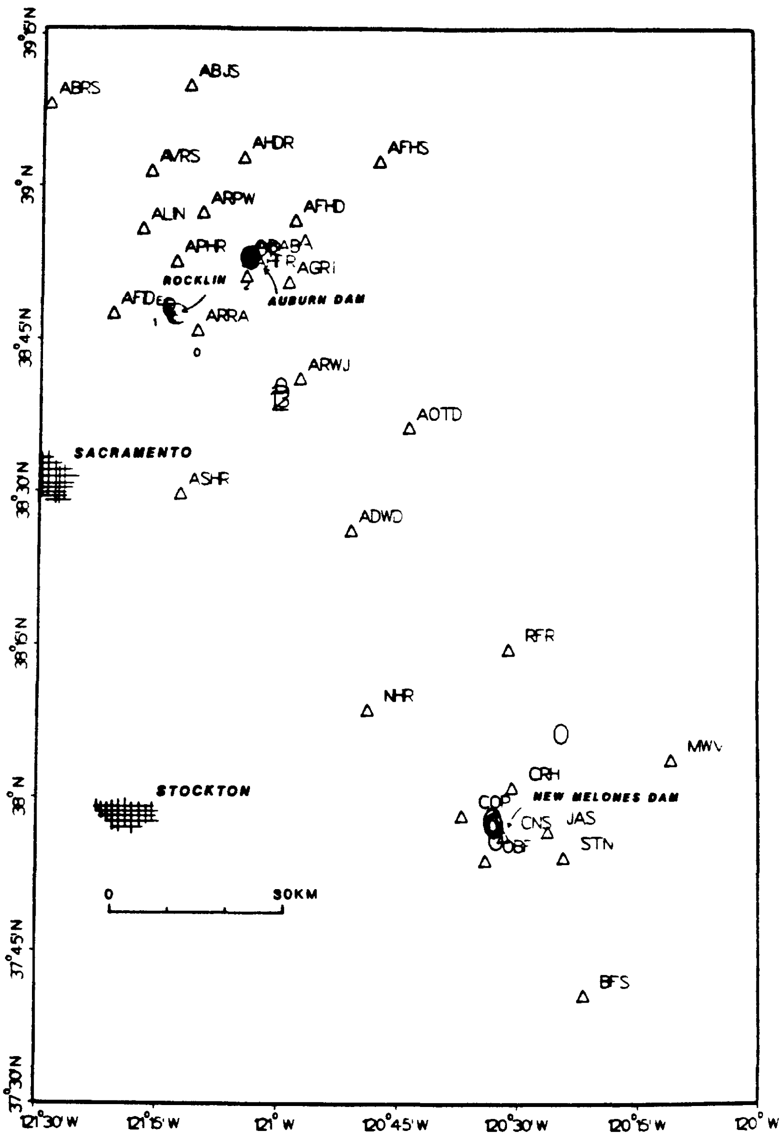


Figure 2 Map of Sierra Foothills Seismic Network showing the locations of seismic stations and of seismic events, from P- and S-data, for 1 November 1976 to 8 April 1977.

Depths and magnitudes of seismic events are represented by the plotted symbol and its height, respectively. Stations are represented by triangles:

Depth (Km)	Symbol	Magnitude	Symbol Ht. (inches)
0 to 1	0	<0.5	0.1
1 to 2	1	0.5 to 1.0	0.2
2 to 3	2	1.0 to 1.5	0.3
3 to 4	3	1.5 to 2.0	0.4
:		2.0 to 2.5	0.5
>25	Ø	etc.	etc.

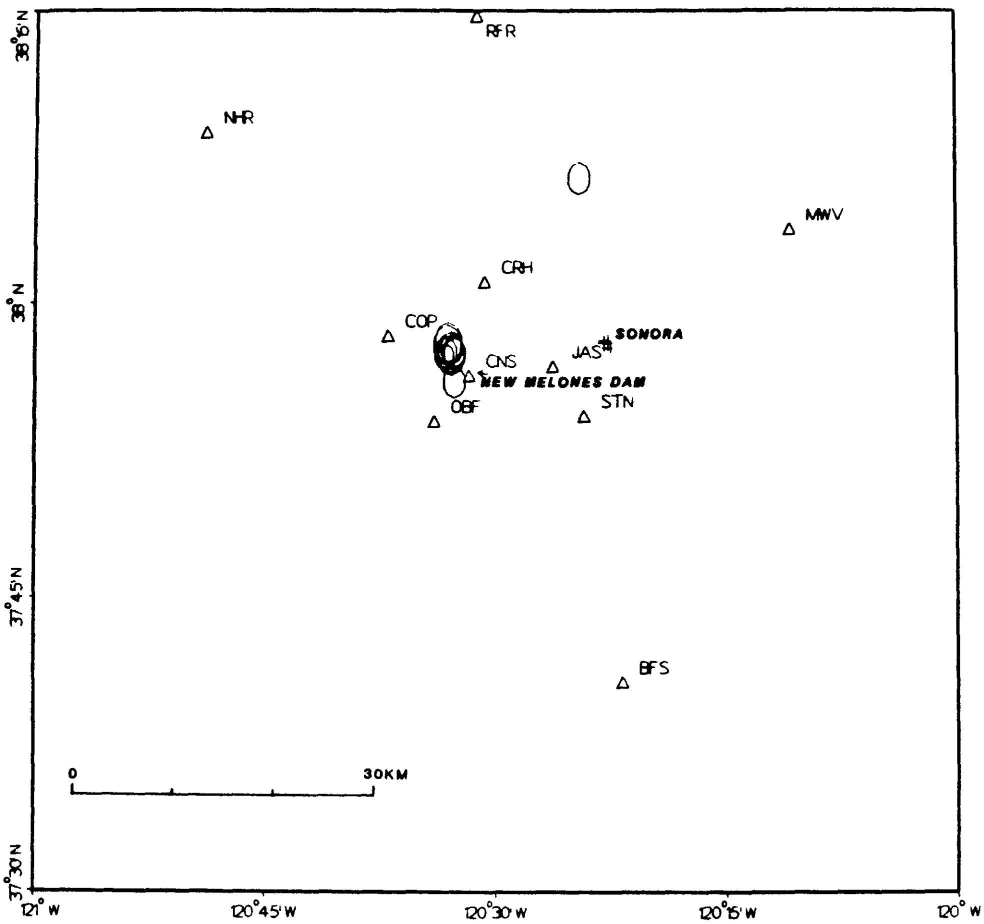


Figure 3 Map of the Melones region showing the location of stations and of selected quarry blasts between 1 November 1976 and 8 April 1977. Blast locations were determined primarily from P-arrivals, but S-arrivals were used also when available. Computed magnitudes and depths are indicated by the plotted symbol and its height, respectively. Stations are represented by triangles:

Depth (Km)	Symbol	Magnitude	Symbol Ht. (inches)
0 to 1	0	<0.5	.10
1 to 2	1	0.5 to 1.0	.20
2 to 3	2	1.0 to 1.5	.30
3 to 4	3	1.5 to 2.5	.40
:		2.0 to 2.5	.50
>25	Ø	etc.	etc.

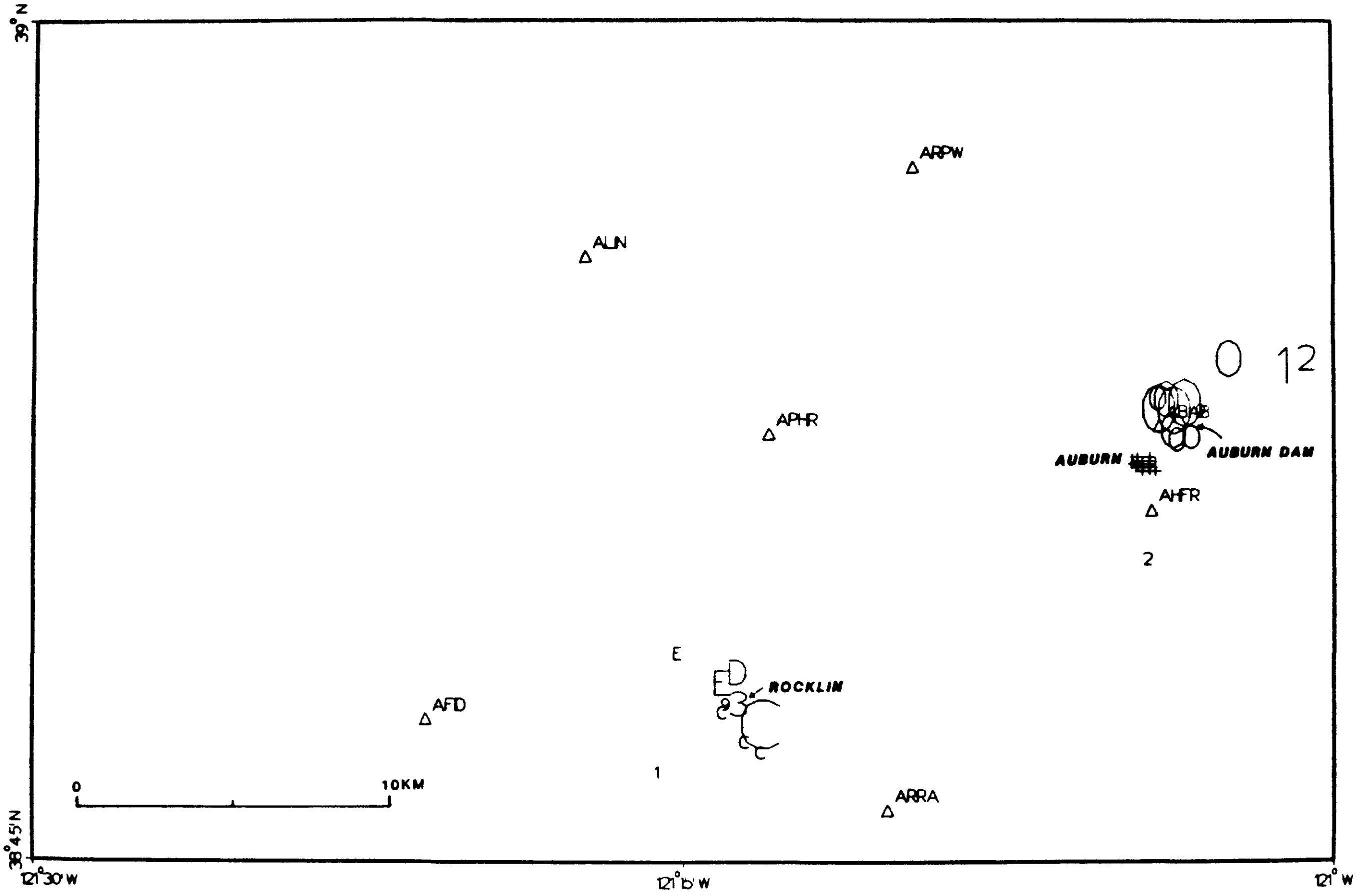


Figure 4 Map of the Auburn region showing the location of stations, earthquakes, and selected blasts between 1 November 1976 and 8 April 1977. Locations were determined from both P- and S-arrivals. Computed magnitudes and depths are indicated by the plotted symbol and its height, respectively. Stations are represented by triangles:

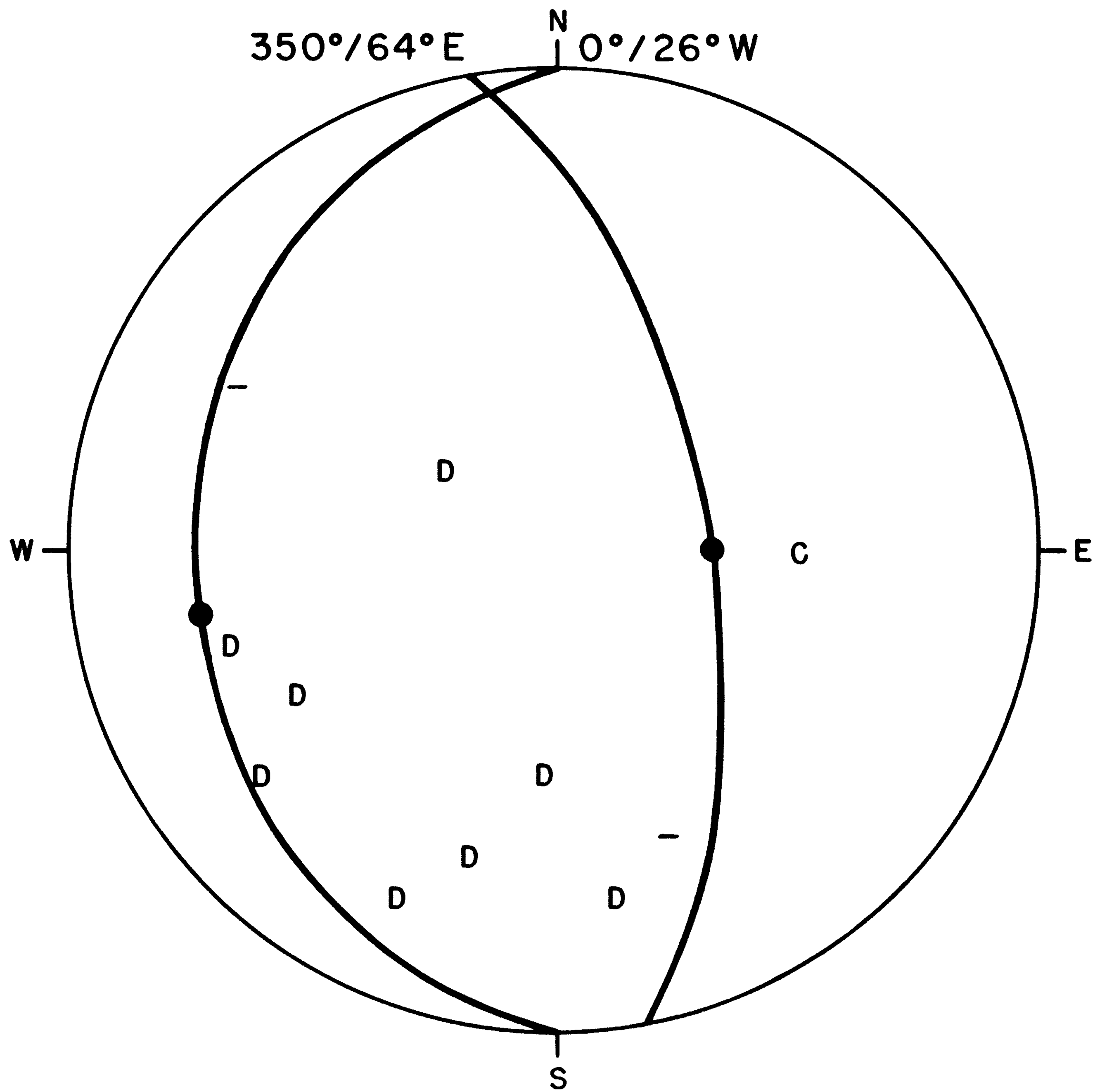
Depth (Km)	Symbol	Magnitude	Symbol Ht. (inches)
0 to 1	0	<0.5	0.15
1 to 2	1	0.5 to 1.0	0.30
2 to 3	2	1.0 to 1.5	0.45
3 to 4	3	1.5 to 2.0	0.60
:		2.0 to 2.5	0.75
>25	Ø	etc.	etc.

77 02 21 21:37:25 Z

$38^{o}47.45'N$ $121^{o}13.26'W$

Depth 12.6 km Mag. 1.6

Figure 5



COMPOSITE

76 11 28 12:35:38 Z

38°48.19'N 121°14.09'W

Depth 14.0 km Mag. 1.0

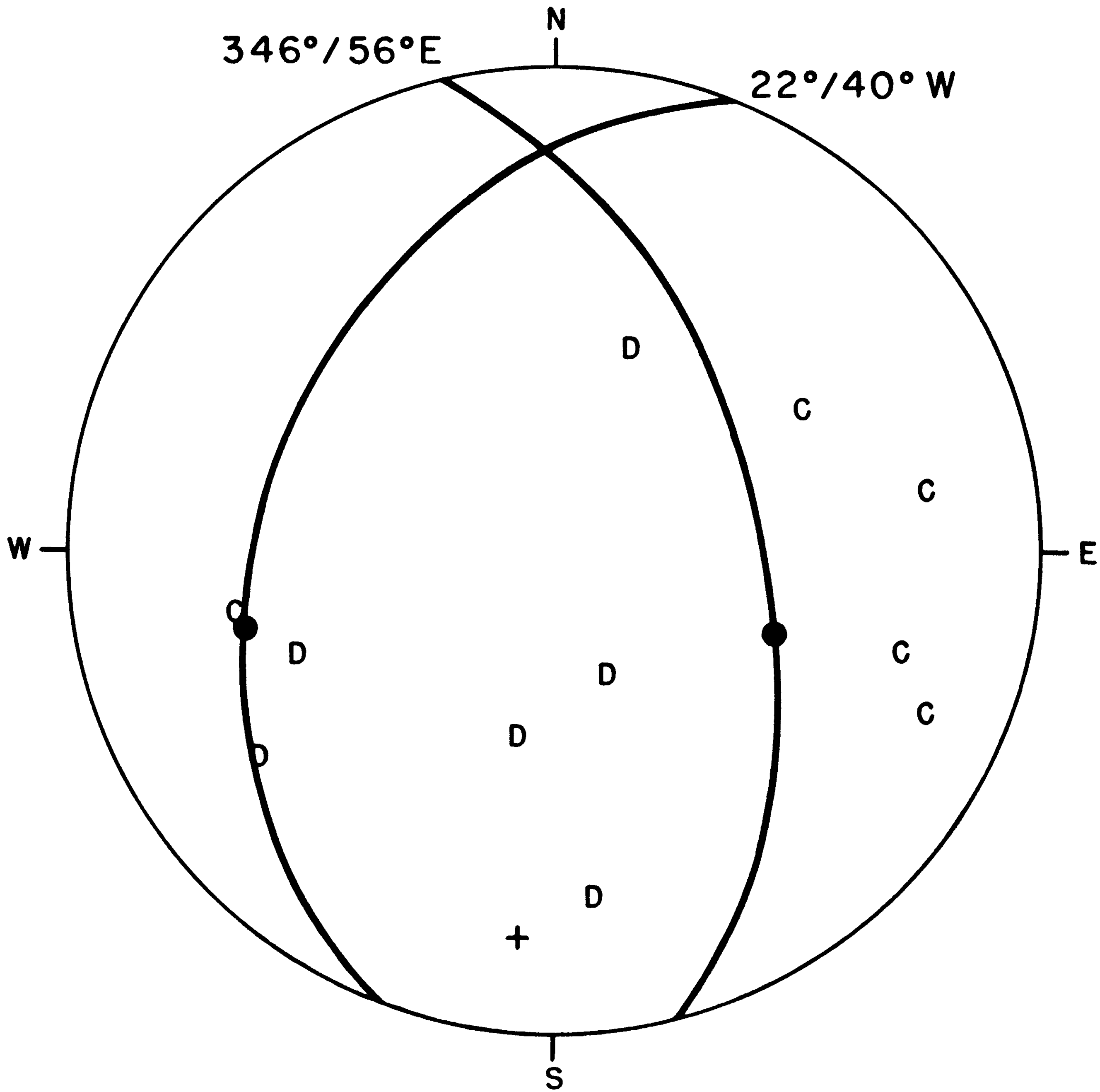
and

76 11 19 05:11:13 Z

38°54.60'N 120°57.14'W

Depth 10.0 km Mag. 1.1

Figure 6

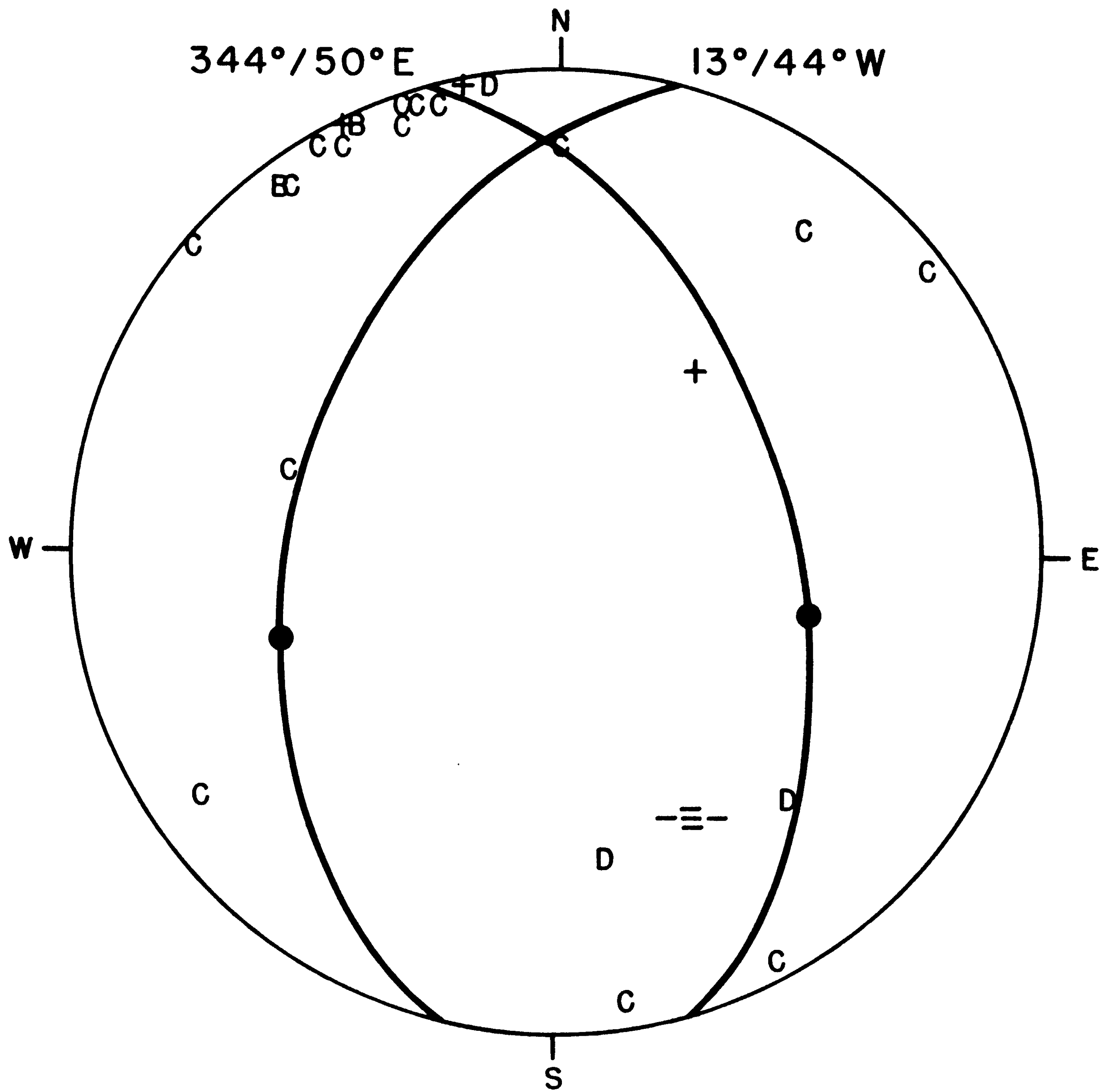


77 01 09 23:24:40 Z

$39^{o}29.06'N$ $121^{o}29.18'W$

Depth 6.7 km Mag. 3.6

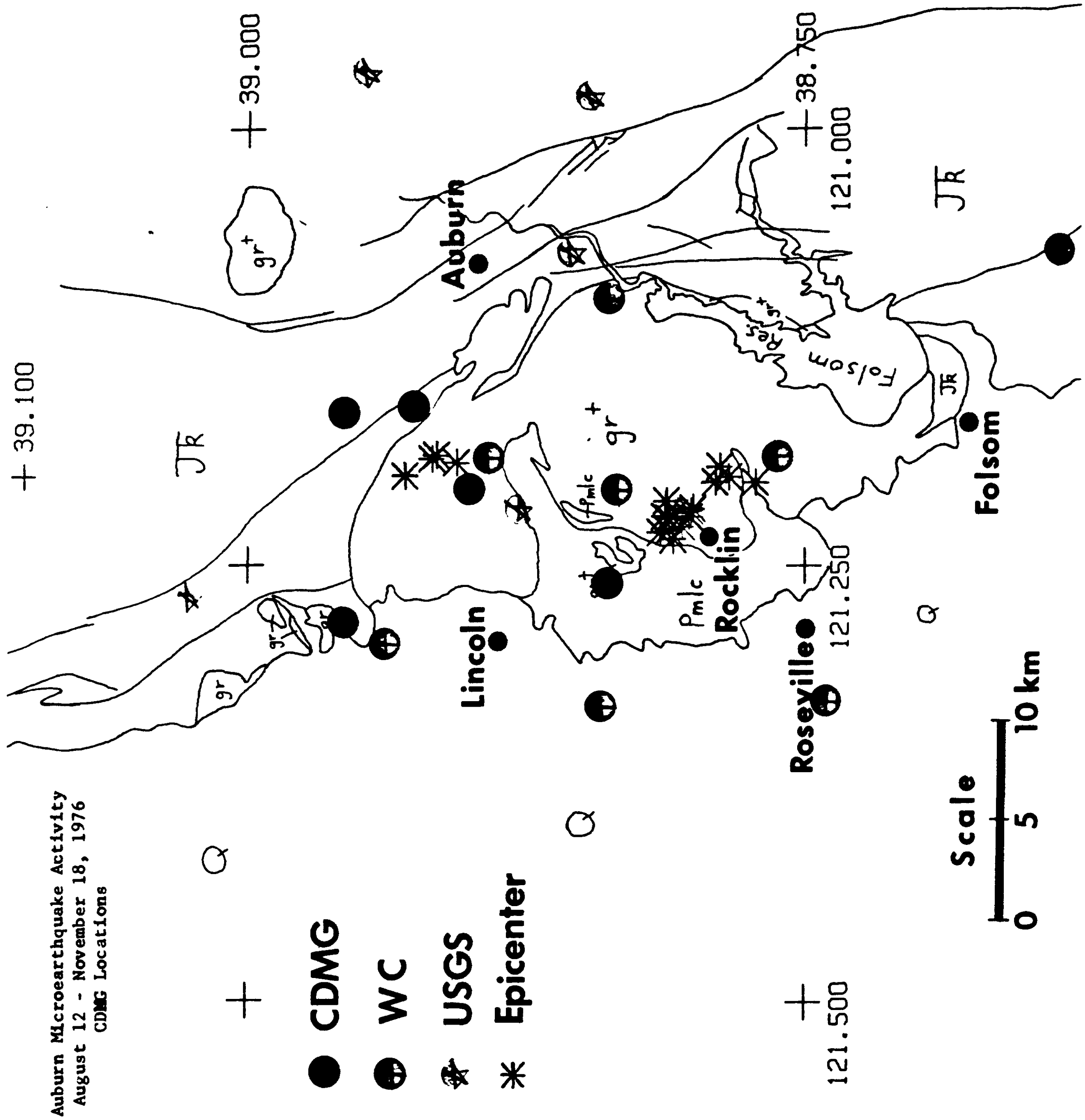
Figure 7



CDMG AUBURN-LINCOLN-ROSEVILLE EVENTS AUG 12 - NOV 18, 1976 APPENDIX 1

DATE	ORIGIN	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	QS
760819	13 1 32.48	38N48.48	121W13.20	13.00	-.3	14	290	7.7	0.05	0.9	0.7	C
760820	245 34.81	38N54.93	121W11.21	4.82	-.9	11	156	5.0	0.03	0.3	0.4	B
760824	13 7 39.31	38N55.01	121W11.37	4.59	-.5	17	148	5.0	0.04	0.2	0.3	B
760826	2230 53.26	38N48.00	121W13.03	12.45	0.3	18	170	8.5	0.07	0.7	0.7	B
760827	037 32.06	38N48.08	121W13.31	12.29	0.3	23	88	5.4	0.05	0.3	0.4	A
760827	1230 4.14	38N48.07	121W13.12	12.49	-.2	15	170	5.4	0.03	0.6	0.4	B
760907	2114 7.26	38N48.66	121W13.79	12.76	0.2	18	156	7.4	0.05	0.6	0.6	B
760909	1142 3.11	38N48.64	121W13.37	13.29	-.2	19	140	6.3	0.03	0.5	0.3	B
760910	656 19.88	38N54.39	121W11.44	4.94	-.6	8	147	6.0	0.01	0.2	0.3	B
760910	7 9 18.45	38N48.88	121W13.85	13.45	0.3	20	101	7.0	0.04	0.4	0.4	B
760911	157 20.01	38N48.79	121W13.31	13.42	-.2	11	156	6.5	0.03	0.8	0.6	B
760912	948 1.49	38N48.73	121W12.77	13.32	-.2	10	289	9.7	0.02	0.6	0.3	C
760929	737 13.92	38N55.73	121W11.94	6.95	-.5	18	114	4.4	0.07	0.4	0.6	B
761013	150 54.29	38N47.31	121W11.56	13.99	-.2	7	318	15.5	0.06	2.4	2.1	D
761029	2339 18.92	38N48.57	121W14.12	13.26	-.3	10	298	10.3	0.02	2.1	0.7	C
761031	558 16.35	38N47.06	121W11.94	10.64	-.4	13	247	12.8	0.05	0.9	1.2	C
761107	1051 42.50	38N48.28	121W13.69	12.99	-.0	9	298	10.7	0.02	2.0	0.9	C
761107	1453 4.70	38N46.34	121W12.14	9.90	-.0	8	328	20.7	0.02	0.8	1.3	C
761108	2 2 53.94	38N48.00	121W13.06	12.57	-.1	12	298	11.1	0.03	0.4	0.5	C
761108	711 28.39	38N48.13	121W13.33	12.12	-.0	12	298	10.9	0.02	0.4	0.3	C
761108	711 41.90	38N48.08	121W13.14	12.49	-.6	7	297	14.7	0.01	0.6	0.6	C
761115	845 12.80	38N47.40	121W12.14	11.49	0.1	14	258	12.2	0.02	0.3	0.4	C

APPENDIX 2


Auburn Microearthquake Activity
August 12 - November 18, 1976
CDMG Locations
CDMG
WC
USGS
Epicenter
39.100
39.000
38.750
121.000
121.250
121.500
Auburn
Lincoln
Rocklin
Roseville
Folsom
Folsom Res.
Scale
0
5
10 km
gr
JR
Q
Pmlc