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**A DETAILED MICROEARTHQUAKE SURVEY OF LONG VALLEY, CALIFORNIA,
KNOWN GEOTHERMAL RESOURCE AREA, JULY-SEPTEMBER, 1981**

By
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July 1983
Date Submitted

MASTER

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Sacramento, California

and

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Covering the period, 30 September 1980 to 31 June 1983

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KNOWN GEOTHERMAL RESOURCE AREA, JULY - SEPT., 1981.

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SUMMARY

This report presents the results of a detailed microearthquake survey of the geothermal area at Long Valley, California. High quality digital data from a dense 3-component array covering a three-month period during the summer of 1981 have been processed for locations, velocity structure, magnitudes, focal mechanisms, and source parameters. Hypocenter locations determined from this array have estimated errors of 0.5 km in epicenter and 1.0 km in depth relative to one another. Detailed hypocentral locations show two complex zones of seismicity beneath the south moat of the caldera which seems associated with the major hot spring activity within the caldera and could be part of the conduit system feeding hydrothermal waters to these hot springs. Seismic activity at Long Valley appears to be influenced by both regional tectonic stresses and local volcanotectonic activity. Inversion of P and S-wave arrival times provides the first detailed determination of P and S-wave velocity structure within Long Valley caldera. The resulting Poisson's ratio analysis suggests high ratios (~ 0.3) in the upper 5 km of the crust and low ratios (~ 0.2) below 5 km within the caldera. When this information is combined with other geophysical, geologic, and hydrologic data, it suggests that the hydrothermal reservoir at Long Valley lies between 2 and 5 km with the possibility of hot dry or undersaturated rock below 5 km. Spectral analysis results suggest that microearthquakes have nearly constant source dimensions (.1-.3 km) and steep high-frequency roll-offs (-3 to -5). This is probably due to high attenuation rather than an actual source effect, and may be characteristic of geothermal/volcanic areas. Geothermal events were difficult to discriminate from volcanotectonic activity at Long Valley. Despite some limitations, we conclude that a detailed microearthquake survey is definitely of value as a tool in geothermal exploration, particularly when

microseismic activity is high as at Long Valley. Although we found conducting this detailed a microearthquake survey at Long Valley to be a fairly expensive and time-consuming effort, recent developments in mobile seismic data acquisition and processing systems should make this technique more cost-effective, and the results more timely in the future. However, the technique will always be more cost-effective in obtaining more detailed structural information on a prospective geothermal area than in use as a general reconnaissance tool.

INTRODUCTION

Microearthquake surveys of geothermal areas have been developing as a geothermal exploration technique over the last decade. In California, such studies have been conducted by Combs and Rotstein (1975) and Walter and Weaver (1980) for the Coso Geothermal Area, by Steeples and Pitt (1976) for the Long Valley and surrounding area, and by Majer and McEvilly (1979), and Peppin and Bufe (1980) for the Geysers geothermal area. Of course, this is not an exhaustive worldwide list of microearthquake studies in geothermal areas. Besides the spacial distribution of earthquake activity in and around a geothermal area, P and S velocity structure, Poisson's ratio, focal mechanism variations, body-wave attenuation, and microearthquake source properties (spectra) have been examined as potential tools for delineating geothermal reservoirs. With the recent advent of portable digital event recorders and advances in seismic data recording and processing, it is possible to conduct very detailed microearthquake studies (200 sample/sec digital recording by 3-component arrays of seismographs with interstation spacings of 4 km or less). Such high-quality data can be processed directly with a computer and interpreted for variations in both source and media seismic parameters which might indicate the presence at a geothermal reservoir.

In 1981, under a co-operative agreement with the Department of Energy (DOE), the California Division of Mines and Geology (CDMG), and the University of California, Riverside (UCR) undertook a state-of-the-art microearthquake survey of Long Valley KGRA for the purpose of obtaining high-quality digital data required to evaluate microearthquake analysis as a tool in geothermal exploration. Earthquake data recorded on a dense array (spacing ≤ 4 km) of digital, event-recording, seismograph systems during three months of monitoring were computer processed for locations, velocity structure, focal mechanisms, source parameters, and magnitudes. In addition, calibration shots were recorded on an augmented refraction array of seismographs in order to delineate shallow subsurface structure as well as station corrections needed for precise hypocenter determinations. The results of the detailed microearthquake survey and data processing have been examined for variations in subsurface properties associated with the geothermal system and for the relationship of earthquake activity to the geothermal area.

PREVIOUS WORK

Long Valley, California, was chosen as the best target for a detailed microearthquake study of a geothermal area because 1) geologic and geophysical background data have already been obtained from previous geophysical surveys, 2) seismic activity has been high in and around the geothermal area since June, 1979, 3) the geothermal system is the more common hot water dominated system unlike the rarer vapor dominated system at The Geysers, California, 4) the ground water hydrology is fairly well understood in its relationship to the geothermal area, and 5) the geothermal system is still in its natural state (unexploited) although some exploratory drilling has been conducted.

Long Valley's potential as a geothermal resource area was investigated extensively by the U.S. Geological Survey in the early 1970's. The results of that investigation, which supported the existence of a high temperature geothermal resource near Casa Diablo, were published as a series of papers in 1976 (for example, see Muffler and Williams, 1976; Bailey et al., 1976; Hill, 1976; Lachenbruch et al., 1976a, 1976b; Hoover et al., 1976; Stanley et al., 1976; Steeples and Pitt, 1976; and Steeples and Iyer, 1976). These studies also provide an existing data base for use in evaluating the results from a detailed microearthquake investigation of the Casa Diablo area.

The geologic history of Long Valley has been reviewed by Bailey et al. (1976). The ground water hydrology of Long Valley and the geothermal system is discussed in Sorey et al. (1978).

The historical seismicity in the Long Valley-Bishop area has been reviewed by Cramer and Topozada (1980). Long Valley and Bishop are just north of the portion of the eastern Sierra Nevada frontal fault zone that ruptured during the great earthquake of 1872. Since this 1872 Owens Valley earthquake, seismicity along the eastern front of the Sierra Nevada has been highest between Long Valley and Bishop (figure 1). This clustering of seismic activity may have resulted from the concentration of stress near the northern end of the 1872 rupture.

The first microearthquake studies of the Long Valley region were conducted by the USGS in the early 1970's. These were reported on by Pitt and Steeples (1975) and Steeples and Pitt (1976). Their results from a three-week and a five-week monitoring effort in 1970 and 1973 show microearthquake activity concentrated between Long Valley and Bishop with few events inside Long Valley Caldera. Microearthquake activity within Long Valley was limited to a cluster (a small swarm of $M_{\leq 3}$ events) near Whitmore Hot Springs and a couple of events near Casa Diablo. There was a strong cluster (small swarm again) beneath Sherwin Canyon just south of the Caldera and SSW of Casa Diablo.

Figure 1

Earthquake activity within Long Valley increased in 1979 after the October 4, 1978 M5.7 earthquake south of Lake Crowley. The pattern of regional seismicity for the eastern front of the Sierra Nevada including Long Valley is presented by Van Worman and Ryall (1980). This increased activity in Long Valley resulted in a series of four M6 earthquakes along the southern margin of Long Valley and beneath the Sierra Nevada Mountains to the south. This initial sequence of activity has been described by Cramer and Toppozada (1980) and Ryall and Ryall (1980). Since this 1980 sequence, seismic activity has remained high beneath the south moat of Long Valley Caldera and to the south of the Caldera. Recent papers by Savage and Clark (1982), Ryall and Ryall (1983), and others have suggested a volcanic relationship to this increased activity.

INSTRUMENTATION

A goal of this study was to conduct a state-of-the-art, detailed microearthquake study of a geothermal area. This was accomplished by deploying ten 3-component digital event recorders in a dense (≤ 4 km) array on a small geothermal target (Hot Creek-Whitmore Hot Springs portion of Long Valley). This small target geothermal area (figure 2) was selected on the basis of hot spring distribution, geology, electrical-conductivity anomalies, and seismic refraction data (Bailey et al., 1976; Hill, 1976; Lachenbruch et al., 1976a, 1976b; Sorey and Lewis, 1976; Mariner and Willey, 1976; Hoover et al., 1976; and Stanley et al., 1976).

The field monitoring by CDMG/UCR was conducted between 30 June and 24 September, 1981. Ten 3-component stations (figure 3) were augmented by up to six single component, radio telemetry stations distributed around the margins of Long Valley Caldera. This was done to improve earthquake location and first-motion control of the dense 3-component array because significant

Figure 2

LONG VALLEY GEOTHERMAL AREA

5 0 5 km

Figure 3

LONG VALLEY
CDMG SEISMOGRAPH ARRAY
DOE PROJECT

July - Sept 1981

earthquake activity was expected to occur along the south margin of the caldera as well as in the geothermal target area. In addition, a single-component, analog recorder was operated at one 3-component site (CCEX) in order to maintain a continuous recording of activity and document the performance of the digital event recorders.

The 3-component instrumentation was mainly composed of Sprengnether DR-100 digital event recorders with Sprengnether S6000 2Hz seismometer packages. The DR-100's are three-channel, 12-bit, digital event recorders with DR-100-1A signal conditioning lids and have an overall dynamic range of 66dB. Sample rates on the 3-component sites were set at 200 samples per second per channel, and the 5-pole Butterworth anti-alias filters were set for 100 Hz. Two of the ten sites (CL04 CL06) had DR100 recorders without signal conditioning lids and with Mark Products L4C 1 Hz seismometers. Signal conditioning at the latter two stations was accomplished with only the on-amplifier filters (the 2-pole high-cut filter set at 30 Hz).

The ancillary single-component stations were Mark Products L4C 1 Hz vertical seismometers with a Sprengnether PTS-3 (AS-110 amplifier and TC-10 VCO) connected to FM-radio telemetry links. Signal conditioning was accomplished by the on-amplifier, 2-pole, high-cut filter being set to 10 Hz. Two DR100's were used to record the data from the six telemetered sites. The FM-telemetry signals were discriminated at the recorder locations by Sprengnether TC-20 Discriminators. Sample rates on the telemetry DR100 recorders were set at 100 samples per second per channel.

The analog recorder at CCEX was a Sprengnether MEQ-800 smoked-paper system connected to a Mark Products L4C 1 Hz vertical seismometer. As at the telemetry stations, the AS-110 amplifier high-cut filter was set at 1 Hz.

Table 1 and Appendix I documents station histories and coordinates. Individual recorders all had internal clocks for accurate timing, and these clocks were calibrated to WWV daily. Timing accuracy of the internal clocks

TABLE 1

CDMG SEISMOGRAPH STATIONS - DOE LONG VALLEY, CA. ARRAY

STN CODE	LAT N	LONG W	ELEV (M)	TYPE*	OPERATIONAL DATES (UT)
CL01	37 37.25	118 52.30	2182	3-COMP DIG	810610 - 810924
CL03	37 39.23	118 51.78	2292	3-COMP DIG	810610 - 810924
CL04	37 39.33	118 54.30	2402	3-COMP DIG	810805 - 810924
CL05	37 39.73	118 50.40	2195	3-COMP DIG	810805 - 810924
CL06	37 40.93	118 51.50	2243	3-COMP DIG	810806 - 810924
CL08	37 38.80	118 49.53	2195	3-COMP DIG	810701 - 810924
CL09	37 39.40	118 46.89	2121	3-COMP DIG	810701 - 810924
CL11	37 37.80	118 47.13	2103	3-COMP DIG	810805 - 810924
CCEX	37 36.84	118 49.83	2158	3-COMP DIG	810630 - 810924
CCBR	37 40.76	118 49.11	2121	3-COMP DIG	810701 - 810924
CLRL	37 36.40	118 55.13	2585	1-COMP TDG	810704 - 810922
CMIL	37 37.28	118 59.23	2536	1-COMP TDG	810704 - 810922
CLKM	37 43.60	118 56.83	2487	1-COMP TDG	810704 - 810922
COHC	37 44.86	118 44.05	2316	1-COMP TDG	810806 - 810925
CWTC	37 38.28	118 49.05	2256	1-COMP TDG	810806 - 810925
CMGC	37 32.72	118 48.80	2536	1-COMP TDG	810806 - 810925

*DIG - DIGITAL; TDG - TELEMETRY, DIGITAL

with respect to WWV could be determined to within 10 ms. Amplitude calibrations of each recording system were also made daily. Appendix II documents each digital station's time and amplitude calibrations.

At the end of the field monitoring, five calibration shots were fired to help calibrate the monitoring array and to provide information about the shallow velocity structure in the target area. Four 1,000-lb. shots and one 400-lb. shot were set off in the early morning hours of 23 and 24 September, 1981. To better define the velocity structure 13 extra smoke-drum (MEQ-800's with L4C vertical seismometers) and three extra digital recorders (DR-100's with S6000 3-component seismometers) were deployed first along a 10 km north-south refraction line (23 September) and then along a 10 km east-west refraction line (24 September) (figure 4). For added regional velocity control, 9 CDMG and 7 California Institute of Technology (CIT) 1980 aftershock monitoring stations (vertical component, analog recording) were reoccupied to supplement the 4 University of Nevada, Reno (UNR) regional telemetry (vertical only) stations in the vicinity of Long Valley.

DATA REDUCTION

The digital data were spot checked in the field as a means of maintaining data quality, and then sent to Sacramento along with the analog, smoke-drum records. At Sacramento, the smoke-drum records were scanned for all events with durations longer than 10 sec. to form a complete list of activity in the Long Valley area. The digital data cassettes were played back onto 9-track computer tape via a SYM-1 microprocessor connected to a DP-100 playback unit and a Pertec formatter/Cyper 9-track tape drive. The 9-track tape copies of the digital data were then entered into a Data General Eclipse S-250 for further processing and archiving.

Figure 4

LONG VALLEY

CDMG CALIBRATION SHOTS

DOE PROJECT

SEPT. 23-24, 1981

Once in the Eclipse computer system, the digital data were processed for event P and S phase arrivals, amplitudes, and locations, and a copy of selected digital wave forms sent to UCR for spectral analysis. The process of preparing the records for analysis involved identifying individual records by DR100 headers and trailers, demultiplexing the data, and processing the time and amplitude calibrations for clock corrections and system magnification values at each station. The digital data were then grouped into events and interactively processed for P and S arrivals, maximum trace amplitude, and event locations with magnitude estimates. Processing the data turned out to be a fairly time-consuming task. With changing tapes once a day on 12 recorders, the data reduction task took about twice the elapse time as the data recording phase.

Most of the extra data recorded during the two days of calibration shots were on analog records. The five shot and eight selected earthquake records for each analog station were manually timed for P and S arrivals and added to the digitally processed event recorder records. Analog phase arrival picking errors were typically within .03 sec. while digitally picked arrivals had timing errors within .01 sec.

ANALYSES

The results of our analyses of the digital data will be presented in five sections: 1) Location, 2) Magnitude, 3) Velocity, 4) Focal Mechanism, 5) Spectra. Although the results in one section may be related or dependent on those of another, the details of each analysis will be confined to their appropriate section. The first section will focus on event locations, accuracies, spacial distributions, and the limitations of using event recorders. The second section will focus on the techniques used to determine event magnitude and discuss b-value relationships. The third section will

focus on the results of P and S velocity determinations using refraction and inversion of arrival time data, and then will discuss velocity structure and the spacial distribution of Poisson's ratio (via V_p/V_s ratio). The fourth section will present focal mechanism determinations and their implications. And the fifth section will present an analysis of short-period body-wave spectra, including moment, stress drop, and magnitude-moment relationships.

Location analysis:

Final hypocenters have been determined by using the inversion velocity model and station corrections presented in the velocity analysis section and the location program HYPOELLIPSE (Lahr, 1983). The velocity inversion used the calibration shots in order to determine the best station corrections for locating events within the geothermal area and under the south moat of the caldera. A comparison is also made between the VELEST inversion locations (Fig. 5 and Plate I) and the final HYPOELLIPSE locations for the same subset of events (Plate II).

Appendix III presents 309 final hypocenter solutions of all qualities. Of these 309 earthquakes, 20 are A-quality solutions, 55 are B-quality, 22 are C-quality, and 212 are D-quality (USGS standards, Lee and Lahr, 1972). Final magnitudes have been determined from amplitude via the method of Eaton et al. (1970) and cover the range $1 < M < 4$ (see magnitude and analysis section).

Figure 5 shows the VELEST inversion epicenters for the 87 earthquakes and 10 shots used in the velocity inversion. Plate I shows those inversion epicenters within Long Valley Caldera at an expanded scale. Epicenters within the caldera suggest two linear trends of activity: a WNW trend of seismicity between Casa Diablo and the Hilton Creek fault, and a few events along a NNW trend through Hot Creek Ranch.

In order to have more good quality locations defining these trends, all the processed events from July and August, 1981, were relocated using the

Figure 5

EPICENTERS FROM SIMULTANEOUS
VELOCITY AND HYPOCENTER
DETERMINATION

inversion velocity model and station corrections and a recent version of HYPOELLIPSE which allows a layered structure with independent P and S velocity structures. Unfortunately, when the S-wave arrival times were included and the locations of the earthquakes used in the P-wave inversion were redetermined, the results did not match the inversion results very well although the general pattern was similar. This indicates that the variability of the S-wave arrivals (not picking error) and the errors in the S-velocity model used may be too large for highly accurate relocation within the caldera. Restricting the HYPOELLIPSE relocations to P-wave data only improved the agreement with the inversion results as shown by comparing Plate II with Plate I.

Figure 6 and Plate III present the P-wave only HYPOELLIPSE relocations for the 1 July - 14 August, 1981, earthquakes located by our array. Only A-C quality events are shown, most of the locations within the caldera being quality A and B. Relative location errors of events beneath the south moat area and near Hot Creek are believed to be less than 0.5 km in epicenter and 1.0 km in depth. The two linear trends of seismic activity mentioned above are filled in with more activity. Perpendicular cross-sections to each trend, shown in figures 7a and 8a, suggest vertical zones of earthquake activity extending from 3 to 11 km. The WNW zone in particular seems to be comprised of several faults and not just a single fault. Figures 7b and 8b are sections parallel to these linear seismic zones and show the distribution of seismic activity along each zone.

Digital event recorders with limited data storage, such as the the Sprengnether DR100's used in this study, obviously impose limitations on the number of events that can be recorded particularly in an area as active as the Mammoth Lakes-Long Valley area was at the time of this study. There are problems recording and locating all the events that occur in an earthquake

Figure 6

EPICENTERS FROM FINAL
HYPOELLIPSE SOLUTIONS
(P-waves only; A-C quality)

Large Symbol - $M \geq 3.0$

Small Symbol - $M < 3.0$

Figure 7

1 JULY - 31 AUG 1981, NE, A4B, WNW ZONE

A) Perpendicular Section

1 JULY - 31 AUG 1981, SE, A4B, WNW ZONE

B) Parallel Section

Figure 8

1 JULY - 31 AUG 1981, NE, A4B, NNW ZONE

A) Perpendicular Section

1 JULY - 31 AUG 1981, SE, A4B, NNW ZONE

B) Parallel Section

swarm. Table 2 shows some statistics on how well the digital array performed in terms of the number of events located verses the number of events registered on a single smoke-drum recorder. These results are presented in terms of a magnitude threshold and indicate that down to magnitude 2.0 the digital array captured about two-thirds of the activity near Long Valley. Considering the high level of swarm activity at times, these results are encouraging and indicate that in an area with a lower level of activity better results might be obtained. Our experience in Long Valley suggests that the biggest problem in recording swarms with event recorders is their limited data storage (tape runs out) and not a decrease in their reliability to trigger on swarm events.

Table 2

Event Recorder Array operation statistics

1 July - 14 August, 1981

Magnitude Range	Number of Earthquakes Recorded		Percentage Located
	Smoke Paper	Digital Array	
$M_{\geq}1.0$	858	308	36
$M_{\geq}2.0$	247	195*	80
$M_{\geq}3.0$	23	16	70

* Number located probably is slightly high due to slightly different magnitudes estimated by two different techniques (smoke-drum magnitudes estimated from duration; digital array done from trace amplitude). The $M_{\geq}3.0$ counts have been corrected for this discrepancy (duration magnitude estimates have been used in both cases to determine if a given event is truly magnitude 3.0 or greater).

Magnitude analysis:

The determination of earthquake magnitude was first developed by Richter (1935) based on the peak amplitude recorded on a Wood-Anderson seismograph, corrected to a standard distance (100 km) from the earthquake. The estimation of magnitude has since been extended to other seismograph systems and other parameters of a seismogram. Eaton et al. (1970) suggested a means of estimating local (Richter) magnitude (M_L) from peak amplitude on microearthquake seismograph systems. Eaton's approach is based on knowing the system response of the seismograph as a function of signal frequency, and from the measured peak amplitude and its frequency determining the equivalent Wood-Anderson seismograph amplitude and, hence, M_L . This approach is based on the assumption that a peak amplitude on a Wood-Anderson seismograph would have the same frequency as that recorded on the microearthquake seismograph system. Local magnitude estimates made in this manner can be checked by comparison with actual Richter magnitude determinations. Another approach has been to use signal duration to estimate M_L such as was first developed for use in California by Lee et al. (1972) and extended to total duration by Real and Teng (1973). In this approach, earthquake signal durations are calibrated directly to independently determined M_L . Most recently, techniques of Fourier transforming digital seismograms to equivalent Wood-Anderson seismograms and determining M_L in the standard manner have been developed (i.e. Bakun and Lindh, 1977).

In our geothermal study at Long Valley, we chose to maintain one analog recorder to provide a continuous record of microearthquake activity in the area. This was to compensate for the limited recording capacity of the digital event recorders. Thus magnitude estimates used in the occurrence

statistics are based on signal durations measured from the smoke-drum records at station CCEX. Magnitudes were also estimated from amplitudes via Eaton et al.'s (1970) method for those events located by the digital processing system. The final magnitudes listed in Appendix III were estimated using the HYPOELLIPSE (Lahr, 1983) program's implementation of Eaton's method. More sophisticated approaches were not used because of time and computer programming constraints, nor would it have been desirable to use such techniques considering the limited recording capabilities of the digital event recorders used.

To obtain earthquake occurrence statistics and estimates of M_L , the smoke-drum records were scanned for all events with durations of about 10 sec. or greater ($M_L \geq 1$). Each event's duration was tabulated (Appendix IV) along with the event's date, arrival time (nearest preceding second), and estimate of S-P time (nearest second). The measure of duration chosen was the time from P-wave onset to the point where the earthquake coda dropped below 1 mm peak-to-peak in amplitude on the smoked-paper record. No correction for varying gains was necessary because the MEQ-800 recorder was always operated at a constant gain of 60dB with the high-cut and low-cut filters set at 10 Hz and out respectively. CIT and University of California, Berkeley preliminary location listings were then scanned and their respective M_L magnitudes added to the tabulation. (No UNR preliminary magnitudes were available at the time - fall of 1981.)

The measured durations have been calibrated to CIT M_L magnitudes using linear regression. CIT magnitudes were available for earthquakes down to M_L 2.0. UCB's reporting magnitudes for events with $M_L \geq 3.0$ provided too little data for calibrating duration to Berkeley magnitude, so it has not been done. Figure 9 shows a CIT magnitude vs. $\log_{10}$ duration plot for 115 events

Figure 9

CIT Magnitude verses log Duration for the Long Valley Area

available from our tabulation. M_L is usually estimated from duration by a equation of the form.

$$M = A + B \log_{10} \tau + C \Delta, \quad (1)$$

where M = magnitude, τ = duration (in seconds), and Δ = epicentral distance of the station from the earthquake (in kilometers). The coefficient C is generally so small in California that the distance correction is not significant at distances less than 50 km (Lee, et al., 1972). Hence, for our local seismograph, M_L for local events can be estimated by using

$$M = A + B \log_{10} \tau. \quad (2)$$

For the data in figure 9, the least squares regression results in

$$M = 1.17 + 2.30 \log_{10} \tau \pm 0.23 \quad (3)$$

Equation (3) has been used to estimate M_L in Appendix IV.

Figure 10 shows the cumulative frequency vs. magnitude of occurrence plot for all the data in Appendix IV. The least squares regression of these data yields a cumulative magnitude-frequency relationship of

$$\log_{10} N = 4.46 - 0.97M \pm 0.03 \quad (4)$$

over the magnitude range $1.5 \leq M \leq 3.5$ and where N is the number of earthquakes of magnitude M and greater. The b-value estimate of 0.97 compares favorably with the b-value of 0.89 (Cramer and Topozada 1980) and 0.93 (Uhrhammer and Ferguson, 1980) for the May 1980 Mammoth Lakes sequence.

Figure 10

Magnitude verses Cumulative Frequency
for all data in Appendix IV

B-values in the 0.9 to 1.0 range are typical for tectonic earthquakes in California. On the other hand, at Mount St. Helens, b-values for earthquakes other than low-frequency events also typically have b-values below 1.0 (Endo et al., 1981). Majer and McEvilly (1979) found that b-values in The Geysers, California were about 1.1 which may be slightly higher than regional b-values.

Because we cannot locate many of the events tabulated in Appendix IV and, hence, cannot easily differentiate which are inside the geothermal target at Long Valley, we cannot easily test whether microearthquakes inside a geothermal area have different b-values from those outside. Most of the activity located by the digital processing occurred outside the geothermal area. However, an attempt was made to select only those events with preliminary locations within a box $37^{\circ} 37.5'$ to $37^{\circ} 42.0'$ in latitude and $118^{\circ} 48.0'$ to $118^{\circ} 52.0'$ in longitude. Figure 11 shows the recurrence plot for the 43 events selected. The b-value of 0.6 appears low but is probably influenced by the systematic loss of smaller events because of non-triggering of the event recorders as discussed in the previous section.

Velocity Analysis:

Seismic velocities are important in accurately locating earthquakes relative to known geologic structures. A knowledge of both P and S velocity structure also allows the inference of certain physical properties of the material transmitting seismic waves. In particular, seismic velocity ratios are sensitive to the degree of water saturation which could be important in defining a hydrothermal system.

In our analysis of the data collected at Long Valley, we have investigated the shallow velocity structure by using refraction techniques and local P and S arrival time inversion. The short (~10 km) refraction profiles, gathered by using the calibration shots as sources, provide a crustal model for the top

Figure 11

Cumulative Frequency Magnitude Plot for events between
37° 37.5'N and 37° 42.0'N and between 118° 48.0W
and 118° 52.0'W

2 km; the 1D inversion using local earthquake sources plus the surface shot data defined both P and S velocities down to 13 km. In addition, Poisson's ratio was also estimated from P and S arrival times. The Poisson's ratio analysis will be presented first, followed by the calibration shot refraction results and the velocity inversion results.

A preliminary Poisson's ratio analysis was conducted by Charles Real, who is a member of CDMG's seismology staff. His approach was to use P and S arrival times from 15 well located earthquakes plus the origin times for those earthquakes to obtain P and S travel times. Poisson's ratio was then estimated from the P and S travel times.

In detail, Charles Real's approach is based on the well known relation between Poisson's ratio (σ) and V_p/V_s ratio (Majer and McEvelly, 1979)

$$\sigma = \frac{1/2 (V_p/V_s)^2 - 1}{(V_p/V_s)^2 - 1}$$

for isotropic media. Also well known is that the travel time of P and S (T_p and T_s) is related to V_p/V_s by

$$T_s/T_p = V_p/V_s, \quad (6)$$

and, hence

$$\sigma = \frac{1/2 (T_s/T_p)^2 - 1}{(T_s/T_p)^2 - 1} \quad (7)$$

Given the P and S arrival times (t_p and t_s) and a good estimate of the origin time (t_0) of an earthquake, the average Poisson's ratio (σ) along a path from a hypocenter to a specific station can be estimated by substituting $T_s = t_s - t_0$ and $T_p = t_p - t_0$ in equation (7) and getting

$$\sigma = \frac{1/2 (t_s - t_0 / t_p - t_0)^2 - 1}{(t_s - t_0 / t_p - t_0)^2 - 1} \quad (8)$$

Figure 12 shows the sensitivity of σ to errors in t_0 , t_p , and t_s . Given errors in t_p and t_s of less than 0.05 sec. and errors in estimating t_0 at 0.1 sec., figure 12 suggests that Poisson's ratio can be estimated to within a value of 0.1.

Table 3 taken from Appendix V summarizes the Poisson's ratio determinations. Mean Poisson's ratios for each station tabulated tend to be in the range .26-.32 with the exception of CLO4 (.21) and CLKM (.22) which have ray paths passing beneath Casa Diablo for the events chosen. An investigation of the arrivals for these events at CLO4 and CLKM revealed that most of the S-arrivals at these two stations used in this analysis were questionable or should have been picked later. Hence, average Poisson's ratios to these two stations should have been higher which would have made them similar in value to those observed at the other stations.

Five calibration shots were set off at the end of the field monitoring program. Besides calibrating the microearthquake network, 11 km long reversed seismic refraction profiles were also obtained. Figure 4 shows the location of the two refraction profiles, and the calibration shots. Also shown are the reoccupied 1980 aftershock study stations which were used to better define the regional velocity structure.

Figure 12

Sensitivity of Poisson's Ratio to errors in origin time t_0 ,
and P and S arrival times t_p & t_s .

TABLE 3

Mammoth Lakes Poisson's Ratio- σ

EVENT	CL01	CL03	CL04	CL05	CL06	CL08	CL09	CL11	CCEX	CCBR	CLRL	CMIL	CLKM
1*	.30	.28	.22	.31	.30	.21	--	.25	.23	--	--	--	--
2	.32	.27	.15	.27	.24	.26	.30	.30	.27	.32	--	--	--
3	.31	.23	.15	.30	.30	.26	.31	.31	.28	--	.31	.23	--
4	.32	.29	.23	--	.27	.25	.29	.30	.27	--	--	.28	--
5	--	.15	.26	--	.29	.27	--	.31	.30	--	.30	.26	--
6*	.21	.28	.24	.29	.30	.08	--	--	--	.17	--	--	--
7	.31	.25	.17	.25	.25	.25	--	.29	.28	.31	.33	.35	--
8	--	--	--	.27	--	--	--	--	--	--	.23	.36	--
9	--	.33	.27	--	.28	.29	--	.30	.30	--	.25	.29	.20
10	--	--	--	--	--	--	--	--	--	--	.34	.25	.26
11	--	--	--	--	--	--	--	--	--	--	.26	.26	--
12	.32	--	--	--	--	.24	.30	--	.27	.30	.34	.27	.18
13	.32	--	--	--	--	--	--	--	--	.31	.30	.29	.26
14	--	.31	--	.29	.29	.29	.30	--	--	.30	--	.27	--
15	.31	.29	--	.27	.27	--	.29	--	--	.28	--	.24	.18
Mean	.316	.265	.205	.275	.274	.264	.298	.302	.281	.303	.296	.279	.216
σ	.005	.056	.055	.018	.021	.018	.008	.008	.013	.014	.040	.040	.041
S.E.	.002	.020	.022	.007	.007	.007	.003	.003	.005	.006	.013	.012	.018
RES**	.076	.025	.035	.035	.034	.024	.058	.062	.041	.063	.056	.039	-.024

* NOT INCLUDED IN MEANS - DIFFERENT LOCATION

** σ_{OB} - σ_{MOD} $\sigma_{MOD} = .24$

Plate IV presents the P-velocity data for the two refraction profiles. These data were interpreted using Dobrin (1961, p. 81-83) two-layer equations for dipping interfaces. Figure 13 presents a summary of the shallow refraction results in the form of layer velocities and depth to the second layer below each shot. The N-S profile is composed of three shots 5.5 km apart, the middle shot being near the Hot Creek hot springs area. As shown in Figure 13 low-velocity ash and sediments (1.2-2.5 k/s) overlies intermediate velocity (3.3 k/s) volcanic deposits. Sediment thickness averages about 1.5 km along the N-S profile with a subsurface ridge or dome approximately lying under the middle shot. The W-E profile composed of two shots 11 km apart indicate a low-velocity layer of 2.1-2.7 k/s over a 3. + k/s layer. The depth to the second layer at the west end is comparable to the depth at the south end of the N-S profile, while the depth increases to close to 1 km at the east end of the profile near Lake Crowley.

These shallow refraction results are consistent with the geology under the profiles. The 1.2-1.6 k/s surface sediment velocities correspond to ash and pumaceous tuff deposits while velocities closer to 2.5 k/s correspond to interlayered fluvial and ash deposits and volcanic flows. The 2.1 k/s surface velocity near Lake Crowley may represent a mixture of ash and fluvial deposits. The dome-like, 3.3 k/s feature on the N-S profile correlates with a portion of the resurgent dome crossed by that profile (figure 4). The slight thickening to the west of the first layer corresponds to the W-E profile extending into the middle of the south moat of the caldera. The extensive thickening to the east of the first layer corresponds to the thick sediment deposits of the Owens River Valley.

To improve our understanding of the velocity structure at Long Valley, arrival times from 87 selected local earthquakes, from the five 1981

Figure 13

PRELIMINARY INTERPRETATION SHALLOW REFRACTION DATA (P-wave Velocity)

calibration shots, and from five 1982 USGS shots (recorded at CDMG/UCR stations only) were simultaneously inverted for hypocenters and velocity structure.

Figure 14 and Table 4 show the resulting P and S velocity models with two standard deviation error bars indicated in the figure. Although the layer boundaries are specified prior to inversion, the layer boundaries in the model shown were determined by first specifying a series of thinner layers in an initial inversion and then combining layers with similar velocities into one layer in the final inversion. The only layer boundary that is somewhat arbitrarily set is the one at 9 km. The results of the inversion show that there is no significant change in velocity across this boundary.

The results for the P-velocity determination are quite good indicating that the P-velocity is fairly uniform laterally beneath the array except for the near-surface variations incorporated into the station corrections. The stability of the P-wave data provide the best estimates of earthquake location.

The inversion for a one-dimensional velocity model, hypocenters, and station correction was done in the manner described by Taylor and Scheimer (1982). Their program, VELEST, which is based on Roecher (1981) and Crosson (1976), was employed to obtain an average P and S velocity model for the geothermal area of Long Valley Caldera. First, P-wave data was inverted for a velocity model and station corrections, then the resulting hypocenters were damped heavily and the S-wave inversion done separately using the same layer boundaries as the P-velocity model.

Plate V shows a map and contouring of the P-wave station corrections. These corrections have been fixed relative to station CMIL. Generally, these station corrections reflect surface geology with stations outside the caldera having significantly negative station corrections (early arrivals) and stations in the eastern part of the south moat and in the eastern part of the

Figure 14

P and S velocity-depth function from data inversion.

Error bars show two standard deviations

TABLE 4+

Tabulated Results of Velocity Inversion with Errors in Velocity Estimates
and
With Estimates of V_p/V_s Ratio and Poisson's Ratio.

Depth to top (km)	V_p (k/s)	V_s (k/s)	V_p/V_s ratio	Poisson's ratio
0	3.07 ± 0.04	1.70 ± 0.13	1.81	0.28
1.5	5.89 ± 0.03	3.21 ± 0.08	1.83	0.29
5	6.19 ± 0.03	3.71 ± 0.03	1.67	0.22
9	6.24 ± 0.06	3.59 ± 0.32	1.74(?)	0.25(?)
13	6.41 ± 0.02	3.90 ± 0.13	1.64	0.20
27	6.87 ± 0.02	4.0*	--	--
50	7.9*	4.5*	--	--

* Not determined by 1D inversion.

+ Errors given are Standard Deviations.

caldera having strong positive station corrections (late arrivals). The late arrivals generally correspond with thick sedimentary deposits having lower velocities. Interestingly, there are also late arrivals associated with the stations near Lookout Mountain in the NW portion of the caldera. Lookout Mountain is part of the resurgent dome and does not appear to have thick near-surface sedimentary deposits like those near the Owens River.

The S-wave model in figure 14 represents the first determination of S-wave structure beneath Long Valley. Generally, the error in the velocity determination is fairly small, indicating a good velocity determination. The exception is the velocity determination for the layer between 9 and 13 km. Although the average velocity between 9 and 13 km is almost the same as between 5 and 9 km, the large error in the estimate of the velocity suggests either a significant lateral variation within that layer or a problem in the S-data.

Table 4 also presents average layer Poisson's ratios derived via equation (5) from the average layer V_p/V_s ratios. A Poisson's ratio of 0.28-0.29 for the upper 5 km is consistent with the previous determination of average σ . Poisson's ratio drops to the 0.20 - 0.22 range below 5 km. One interpretation of this change in Poisson's ratio is that above 5 km the rocks are water-saturated and represent the hydrothermal/ground-water circulation zones of Sorey et al. (1978). Below 5 km, the rocks may be undersaturated or dry possibly due to the geothermal heat source under Long Valley.

Focal Mechanism Analysis:

Standard P-wave first-motion analysis was used to determine focal mechanisms for the 71 July-August, 1981, events used in the velocity inversion. Readings from seven regional stations recorded by California Department of Water Resources (CDWR) in Sacramento were used to augment the local array's first-motion data. The final earthquake locations and the inversion P-velocity model were used by the program HYPOELLIPSE (Lahr, 1983) to obtain ray take-off angles and azimuths for the first-motion plots. Only 25 reasonably well constrained focal mechanisms were obtained as a result of this analysis. Most focal mechanisms were from individual events, but two were composites of tight clusters of events in space and time.

Appendix VI presents each mechanism determined and the data on which the focal mechanism solution is based. The results are summarized on Plate VI with the mechanisms within the caldera shown in figure 15. Earthquake epicenters are also shown on Plate VI and figure 15.

Outside the caldera to the south, only two earthquakes were sufficiently well constrained by the regional station coverage to provide meaningful focal mechanisms (Plate VI). One is a normal focal mechanism with a NE-SW tensions axis, and the other is a strike-slip mechanism with an E-W tension axis.

Figure 15
 FOCAL MECHANISMS - SOUTH MOAT AREA
 Lower Hemisphere Projection
 Shaded Quadrant is Compressional
 Numbers Correspond to Order in
 Appendix VI

Inside the caldera along the WNW trend of hypocenters, there is a combination of right-lateral strike-slip and normal oblique mechanisms with WNW fault planes. Dips on the W- to NW-trending fault planes are near vertical for the strike-slip mechanisms and 51° - 75° to the north for the normal oblique mechanisms with one mechanism at the east end of the zone showing a south dip. Five of the mechanisms shown could be either strike-slip or normal oblique as indicated by the arrows. Four mechanisms are dominantly normal dip-slip on NW trending planes, and two mechanisms are thrust mechanisms on NE trending planes. These exceptions seem distributed along the WNW zone of activity. Depths for these events range from 4 to 9 km with no preference in depth for any one type of focal mechanism. Tension axis are oriented ENE to NNE. This mixing of focal mechanism type suggests a complex zone of deformation accommodating both right-lateral strike-slip and extensional movements.

Along the NNW trend of hypocenters beneath Hot Creek Ranch, there is a slightly different sense of motion. Three of the four focal mechanisms are from events 8 to 9 km deep and indicate right-lateral strike-slip on NW-trending planes with a small component of reverse (compressional) motion. The fourth focal mechanism is a composite of three shallower events (3 to 4 km) clustered in time and that mechanism is reverse oblique with a left-lateral component on the NNW-trending fault plane. P and T axis are interchanged on the fourth mechanism when compared to the other three mechanisms along this trend and the rest of the mechanisms within the caldera. These differences in focal mechanisms and fault plane trends indicate that the NNW trend is also a zone of deformation composed of two or more faults instead of a single fault plane.

Spectral Analysis:

This section presents the spectral analysis results of our University of Riverside colleagues. It is taken from Don Stierman's report to CDMG on the spectral analysis.

Data Transfer

Data files received from the California Division of Mines and Geology (CDMG) on 811 BPI tapes were read into the NOVA 3 computer in the UCR Geography Laboratory. Spectral analysis requires interactive computing procedures, so a Tektronix 4152 desk-top computer was programmed to perform this function. This decision was based on the relatively unstable configuration of the centralized computing facilities at UCR and on the availability of rapid calculation of the Fast Fourier Transform (FFT) by the R08 Signal Processing ROM Pack No. 2 installed in the 4152.

Preparation of a single earthquake for analysis required 4 conversions of the data. First, the tape was searched for a specific range of files (corresponding to the seismograms of a selected earthquake), and those files were dumped to the NOVA disk. Second, a program (written by Frank Kuykendall) converted the characters of the files into characters compatible with the 4152. Third, the converted files were read from the NOVA disk and copied to cassette tapes on the 4152 as DATA ASCII files. Fourth, the DATA files were interpreted and converted to digital format appropriate for analysis. At this stage, the operator could view the seismogram on the 4152 CRT and correct spikes associated with bad data points. Under the best circumstances, this data transfer required about 4 hours per 4152 tape (18 to 21 seismograms, or,

6 to 7 3-component stations for 1 earthquake). Bad data points were automatically removed by interpolation when flagged, but many records containing unflagged spikes or two or more bad points in sequence had to be cleaned up by manually inserting acceptable digits into the time series.

Spectral Parameters

Digital values (1 to 4195) were first converted to their corresponding voltages, and then the voltage converted to ground motion (velocity) using the values provided in the header blocks. Amplitudes computed using the gain settings and generator constants provided by Sprengnether were consistent with amplitudes calculated from calibration pulses, so amplitudes were calculated from gain settings. Because the velocity transducers used have a flat response above 2 Hz, and because the amplifiers likewise have no frequency-dependent response in the frequency range of interest, no instrument response adjustment was made in the frequency domain.

P-wave spectra were measured only on vertical-component records. A time window between 1 and 2.5 seconds long (usually about 1.2 to 1.5s long) was operator-selected from the CRT display. Zeros were then added to this time series to increase the total number of points to 512 (for 111 samples/second records) or to 1124 (for 211 samples/second seismograms). A 1.1 cosine (Hanning) window was used to taper the time series, to lessen truncation effects. The discrete Fourier transform of the time series was then calculated. The real and imaginary coefficients were separated into separate arrays and used to calculate the amplitude spectrum. Each element of the amplitude (velocity) spectrum was divided by the frequency, converting the spectral information from velocity to a displacement spectrum. The logarithm

(base 10) of the amplitude values were calculated, along with an array containing the corresponding logarithms of the frequency values (in hz). Log amplitude was plotted as a function of log frequency on the CRT. The operator estimated the location of the corner frequency as input, and the average low-frequency spectral level was computed as the average of the low-amplitude-spectrum values of all lower-frequency points. A line corresponding to this average value was plotted. Then, the operator selected two frequency values between which the least-squares fit of the high-frequency decay was to be calculated. If the calculated line did not appear consistent with a good "eye-ball" fit to the data, this step could be repeated until the operator was satisfied with the fit. The corner frequency is calculated as the intersection of the low-frequency spectral level with the high-frequency decay line. Then, upon command, a copy of the spectra, with the best-fit lines and relevant information, was plotted on paper to provide a permanent record. Under good conditions, the operator can process one seismogram in just under 3 minutes.

Shear-wave spectra were calculated in a similar manner. However, prior to taking the spectra, the horizontal N-S and E-W components were rotated into the transverse elements. In some cases where one of the horizontal channels was down, or when azimuthal information was not provided on the header block, the shear-wave spectra for a single component was computed. Tests of rotated vs. individual shear-wave records showed that, in most cases, rotation of the seismogram produced only a trivial increase in the spectral amplitude over the amplitude of the stronger individual component. Shear-wave windows ranged from 1.5 to 4 seconds in length, the shorter windows corresponding to records where there was the possibility of strong surface-wave contamination. Longer windows were used when the shear-wave arrival was obscure. Most shear-waves were quite distinct, and most windows were about 2 to 2.5 seconds in length.

Source Parameters

The seismic moment was computed from the spectral parameters using the relationship published by Brune (1970)

$$M_0 = \frac{4\pi\rho\beta^3R\Omega_0}{2(rf)}$$

where ρ is the density, β is the shear-wave velocity at the source, R is the hypocentral distance between source and receiver, rf is the radiation pattern coefficient, and Ω_0 is the average low-frequency spectral level. The values used for density, radiation pattern, and velocity were the same as used by Archuleta and others (1982) to convert spectral data into source parameters for the Mammoth Lakes region. The moment of a single event was likewise calculated using the average of the logarithms of the individual station moments, rather than the raw average of the moments, following the example of Archuleta and others. The results are summarized in Table 5.

The source radius is computed from Brune's (1970) equation

$$r = \frac{2.34\beta}{2\pi f_c}$$

where f_c is the shear-wave corner frequency at each station. The mean source dimension is the algebraic average of the individually calculated source radii. Individual station shear-wave spectral parameters and source parameters are listed in Table II of Appendix VII. The stress drop for each earthquake is calculated using the average moment and mean radius (Brune, 1970)

$$\Delta\sigma = \frac{7\bar{M}_0}{16r^3}$$

P-wave spectral information is tabulated in Table III of Appendix VII.

TABLE 5

SUMMARY, SOURCE PARAMETERS MAMMOTH LAKES MICROEARTHQUAKES

DAY	HR:MN	LATITUDE* (N)	LONGITUDE* (W)	FOCAL DEPTH* (km)	MAG*	MOMENT (dyne-cm)	SOURCE RADIUS (km)	STRESS DROP (bars)	N
183	13:48	37-38.91	118-50.65	8.51	2.9	5.94E+19	0.21	2.87	5
183	14:07	37-38.16	118-50.77	8.16	2.7	2.61E+19	0.18	1.87	6
186	2:36	37-38.72	118-54.99	6.59	2.3	1.67E+19	0.29	0.31	5
186	2:42	37-38.50	118-55.17	7.28	3.0	5.44E+19	0.23	1.96	6
186	3:53	37-38.52	118-54.93	8.17	2.1	1.75E+19	0.18	1.30	6
187	17:28	37-38.42	118-55.21	9.61	2.2	6.13E+18	0.18	1.00	4
189	14:23	37-38.95	118-56.72	3.11	2.1	8.79E+18	0.21	0.40	5
190	5:41	37-37.33	118-52.25	10.52	2.7	1.43E+19	0.17	1.31	6
190	12:46	37-37.75	118-52.49	8.67	2.0	3.60E+18	0.13	0.73	5
190	12:46	37-38.70	118-55.92	6.91	2.7	3.19E+19	0.18	2.32	6
190	13:38	37-38.98	118-54.74	2.43	1.8	3.90E+18	0.15	0.48	3
191	21:12	37-35.92	118-47.65	5.49	2.0	7.06E+18	0.16	0.74	5
204	21:57	37-39.62	118-51.88	5.13	1.9	3.47E+18	0.15	0.42	3
218	4:52	37-38.10	118-52.88	6.14	2.4	1.74E+19	0.21	0.84	10
218	4:54	37-38.02	118-52.74	6.19	2.1	3.38E+19	0.15	4.65	6
233	9:17	37-39.57	118-50.86	2.90	1.2	7.95E+17	0.19	0.052	4
234	14:11	37-38.81	118-51.75	0.71	1.8	7.09E+18	0.20	0.38	5

* Final Values from HYPOELLIPSE solutions.

Moment vs. Magnitude

Those epicenters located between $118^{\circ}48'$ and $118^{\circ}53'W$, and between $37^{\circ}37'$ and $37^{\circ}40'N$ are considered (for the purpose of this study) associated with the "geothermal" area of the Long Valley Caldera. The remaining events are considered, for the sake of discussion, "tectonic".

Figure 16 shows the moment-magnitude plot for the 17 earthquakes studied. There is a hint of a slightly lower moment for those earthquakes occurring near the hot springs, but, without data regarding the standard errors in magnitude determination, its significance cannot be assessed. The errors in moment alone make it unlikely that a real difference exists between the magnitude-moment of the "geothermal" vs. "tectonic" earthquakes. However, since the "tectonic" events themselves may be triggered by hot fluids circulating at depth, we may not have in the Long Valley Caldera a set of true nongeothermal earthquakes against which to compare the geothermal-related events.

Figure 16 also shows a least squares regression of local magnitude against log moment of the form

$$\text{Log } M_0 = AM_L + B \pm \sigma, \quad (9)$$

where σ is the standard deviation of the regression.

The line in figure 16 is the result for the 17 events in Table 5 which gives

$$\log M_0 = 0.94 M_L + 16.96 \pm 0.23. \quad (10)$$

Magnitudes (M_L) were taken from the final location and magnitude determinations listed in Appendix III. Equation (10) is similar to the results of

Figure 16

Local Magnitude versus Moment, Long Valley, Ca.

Archuleta, et al. (1982) although coefficient B is about a unit smaller (16.96 vs. 17.76). Considering the variations in Archuleta, et al.'s results and the uncertainty in moment determinations, equation (10) does not significantly vary from their results for the 1980 Mammoth Lakes aftershocks.

Figure 17 shows that the moment-source dimension relationship does not appear to discriminate between the tectonic and the geothermal micro-earthquakes. However, an examination of figure 17 and Table 5 suggests that the source dimension of these events are essentially constant at 0.20 ± 0.1 km (corner frequency is always 5-10 Hz). This apparent constant source dimension could be an artifact of high attenuation. Another alternative is that it is a real source property of microearthquakes near Long Valley.

In most cases, the high-frequency roll-off of the shear-wave spectra was between -3 and -5, far greater than the -2 roll-off commonly expected. Archuleta and others (1982) also observed this steep decrease in amplitudes at high frequencies. In a few cases, some hint of a "normal" -2 roll-off could be detected (see figures G-36, G-37 in Appendix VII for a case of this feature in a P-wave spectrum). However, this was the rare exception and was usually associated with an irregular spectrum (one with numerous lumps and troughs). This again suggests high attenuation somewhere along the path.

No direct determination of attenuation has been made in this study. The short propagation paths from source to receiver limit our ability to accurately determine crustal Q. Lack of time due to problems in data processing prevented an examination of relative attenuation effects via the method of spectral ratios. Archuleta et al. argue that their spectra for Mammoth Lakes/Long Valley events are little affected by whole-path attenuation and estimate Q to be above 250. However, Archuleta et al.'s arguments do not eliminate the possibility of high attenuation along a portion of the travel path.

MAMMOTH LAKES SOURCE PARAMETERS

Figure 17

INTERPRETATION

This section begins with a presentation of other geophysical and geologic information available in Long Valley Caldera. Then the results and interpretations from this detailed microearthquake study will be presented. Several plates (VII-XIV) have been included in the back of this report reproducing gravity, magnetics, and electrical data for Long Valley published by others.

Other geophysical and geological results:

Kane, et al. (1976) published detailed gravity and magnetics maps of Long Valley Caldera along with an interpretation of these data. Plates VII-IX reproduce these maps at a common scale of 1:62,500. Plate VII shows a complete Bouguer gravity map of the caldera. Kane, et al. (1976) interpreted the gravity data on Plate VII as showing Long Valley caldera is a steep-sided depression filled with porous clastic and volcanic materials to depths as deep as 3 km. Depths of low-density fill beneath our monitoring array range from 1 to 2 km from Kane, et al.'s gravity modeling (see Kane, et al.'s figure 3). Kane, et al. indicate that the two prominent gravity lows in the caldera correspond to two thick (~3 km) basins under the eastern and western portions of the caldera, the western basin being shallower than the eastern basin. The gravity high between these two basins is interpreted by them as corresponding to the northward extensions of the Hilton Creek fault which divides the caldera in two and along which the eastern portion of the caldera basement is down-dropped relative to the western portion. Kane, et al. also suggest that gentle gravity gradients outside the caldera and sloping towards it is

indicative of a deeper seated low-density body beneath the caldera, possibly a magma chamber that would serve as a heat source for the hydrothermal system.

Plate VIII and IX show the aeromagnetic data over the caldera flown at high (13,500 feet above sea level) and low (9,000 feet above sea level) levels. From Plate VIII, Kane, et al. interpret the extension of the sharp low-magnetic anomalies over the metasedimentary rocks in the Sierra Nevada into the caldera near Casa Diablo as suggesting those rocks comprise the basement material beneath that portion of Long Valley Caldera (see the deep-drill logs below for confirmation). From Plate IX, they also interpret the small (shallow) low-magnetic anomalies between Casa Diablo and Hot Creek as evidence of hydrothermal alteration affecting ferrimagnetic minerals near the hot spring activity. Finally, they interpret the broad positive magnetic anomaly near the center of the caldera and running southeastward as being due to a thick section of magnetic volcanic-flow rocks underlying the eastern portion of Long Valley Caldera.

Plates X - XIV present the resistivity results of Stanley, et al. (1976) and Hoover et al. (1976). Plate X is Stanley et al.'s composite total field resistivity map of Long Valley. Plates XI-XIV present details of audio-magnetic-telluric (AMT) results by Hoover et al. Plate XI presents an apparent resistivity map of 8 Hz band AMT data. Plates XII and XIII are similar maps for an E-W electric line and a N-S electric line taken at 26 Hz. Plate XIV is an apparent resistivity map for 7,000 Hz data. All the resistivity data show shallow low-resistivity zones at Casa Diablo and between Cashbaugh Ranch and Whitmore Hot Springs (see Plate X). These low resistivities are interpreted by both groups of authors as being associated with the presence of shallow hot water and alteration zones from the geothermal system. These authors also conclude that the flow of geothermal waters and, hence, resistivity anomalies are controlled by fracture systems

and faults zones within Long Valley Caldera. The presence of a deeper (1-2 km) resistivity low near Whitmore Hot Springs is shown by the sections in Hoover et al.'s figures 9 and 10 and Stanley et al.'s figure 9. This resistivity low may be indicative of geothermal waters circulating up along the extension of the Hilton Creek fault zone within Long Valley Caldera.

Turning to the pertinent geological information, Bailey et al. (1976) provides the best geologic summary of the history of Long Valley. Summarizing from Bailey et al., Long Valley Caldera formed 0.7 myr. ago by the eruption of the Bishop Tuff. The formation of the resurgent dome and the emplacement of the early rhyolite domes occurred 0.6-0.7 myr. ago. Volcanic activity at Long Valley continued with the emplacement of the moat rhyolite domes at 0.5, 0.3, and 0.1 myr. ago and the emplacement of the (western) rim rhyolites about 0.1 myr. ago. Outflows of intracaldera basalts and andesites occurred in the western half of the caldera between 0.2 and 0.05 myr. ago. Finally the emplacement of the Inyo-Mono rhyolites took place between .20 and 0.007 myr. ago with phreatic and dome eruptions occurring as recently as 400 years ago (Miller et al., 1982 and Kilbourne et al., 1980). Coincidentally, the maximum intensity of hydrothermal activity within the caldera seemed to peak about 0.3 myr. ago, possibly soon after the emplacement of the 0.3 myr. moat rhyolite dome just north of Whitmore Hot Springs.

Three deep wells (~2 km) have been drilled in Long Valley. Figure 18 shows the location of these wells. The first hole was drilled in 1976 by Republic Geothermal NE of Whitmore Hot Springs and east of the northward extension of the Hilton Creek fault zone (Republic Geothermal No. 66-29). The second and third holes were drilled in 1979 by Union Oil at the clay pit in the middle of the caldera (Clay pit no. 1) and at Casa Diablo (Mammoth No. 1). Figure 19, taken from Toppozada and Cramer (1981), shows the temperature and generalized lithologic logs from these three holes. These

Figure 18
MAMMOTH LAKES EARTHQUAKES
25 May - 31 May 1980
Magnitude ≥ 5.0

Figure 19. Temperature and lithologic logs of the three deep wells in Long Valley caldera. Temperature log of the Casa Diablo well (Mammoth no. 1) is dashed.

holes show some shallow circulation of only warm waters and constant temperatures down to 1,500 m, at which point the temperature gradient may start increasing. The Casa Diablo hole (Mammoth No. 1) intersects two zones of hotter water circulation at fairly shallow depths. The lithology in these holes confirms some of the geological and geophysical results. The Bishop Tuff is a thicker and deeper sequence east of the Hilton Creek fault as suggested by the gravity interpretation by Kane, et al. (1976), and the geologic interpretation of Bailey, et al. (1976). In the western part of the caldera, depth to basement rocks is about 1300-1400m which corresponds well with Kane et al.'s (1976) estimates from gravity of caldera fill thickness at those drill-hole sites. The Casa Diablo hole also confirms Kane et al.'s interpretation of the magnetic data as showing metasedimentary basement rocks extending under the caldera at Casa Diablo.

The hydrology, hot springs activity, and heat flow of Long Valley Caldera and its geothermal system have been described by several authors [Sorey, et al. (1978), Lachenbruch, et al. (1976a, 1976b), Sorey and Lewis (1976), and Mariner and Willey (1976)]. Sorey, et al. (1978) best summarized the hydrological system in Long Valley. Meteoric ground water circulation is from the Sierra Nevadas into the caldera on the west and from the Glass Mountain area into the caldera on the east and northeast. Meteoric water circulating deep within the western portion of the caldera is heated by the residual magma beneath Long Valley. The cold meteoric waters from the east of the caldera are not heated. They mix with the heated waters from the west near the northward extension of the Hilton Creek fault. The areas of hot spring activity at Casa Diablo and around the Hot Creek area are locations of upwelling of geothermal waters from depth along fracture zones as indicated by geochemical measurements (Mariner and Willey, 1976). Near-surface (0.5 km) heated waters mix with cold ground water and spread eastward from Casa Diablo

and particularly the Hot Creek area, forming lower temperature springs in the eastern part of the caldera as these waters flow into Lake Crowley. Sorey, et al. (1978) developed a ground water/geothermal water circulation model extending down 4 to 6 km with lateral spreading of cold and hot waters at several layers. Clearly, the deep drill holes suggest that the hotter geothermal waters result from meteoric water circulation below 2 km and, hence, below the Bishop Tuff fill in the caldera.

The heat balance calculations of Sorey, et al. (1978) and others suggest that the high rate of heat flowing out of Long Valley Caldera could not be maintained over the last 0.7 myrs. since the caldera formed without heat being replenished to the magma chamber below the caldera. Recently, Bailey (1983) presented chemical and petrologic evidence that the magma chamber may have been reheated about 0.3 myr. ago. This suggestion is based on the reduction in phenocrysts in the most rhyolites erupted 0.3 myr. ago as compared with earlier rhyolite eruptions. There were also changes in chemical composition of the 0.3 myr.-old rhyolites supporting this suggestion. Possibly coincidentally surface geothermal activity in Long Valley also reached its peak in about 0.3 myr. ago, although as mentioned above, this may have been associated with the emplacement of the 0.3 myr.-old rhyolites themselves.

Evidence for a shallow crustal magma body beneath Long Valley has been accumulating over the last 10 years. Steeples and Iyer (1976) used tele-seismic P-waves to detect the presence of a low-velocity (magma or partial melt) body beneath the western half of the caldera. Steeples and Iyer estimate that the top of the low-velocity body lies below 7 km and that the body might extend as deep as 25 km. Hill (1976) also noted P-wave reflections off a low-velocity horizon beneath the NW part of the caldera. Hill's estimate of the depth to the top of the low-velocity horizon (possible top of a magma chamber) is between 7 and 8 km. More recently, Ryall and Ryall (1981)

noted attenuated S-wave arrivals at regional stations for ray paths passing through Long Valley Caldera from events along the southern boundary of the caldera. Most recently, Sanders and Ryall (1983) have carefully examined these ray paths with anomalous S-wave arrivals and located an attenuating body (magma) beneath the central part of the caldera. This body may be as shallow as 4.5-5.0 km in depth, a few kilometers wide in horizontal extent, and is centered near the S.E. boundary of the resurgent dome.

Results of 1981 detailed microearthquake study:

The pattern of seismicity recorded and located during the summer of 1981 appears to be associated with zones of deformation and faulting along the southern boundary of Long Valley Caldera and the extension of the Hilton Creek Fault into the caldera. There is no distinct volume of seismicity associated with the geothermal system such as at The Geysers, California. Rather, micro-earthquake activity at Long Valley is confined to major zones of faulting beneath the south moat of the caldera (Plate III). These zones, as well as other faults mapped after the May 1980 series of M6 earthquakes (Taylor and Bryant, 1980), probably serve as conduits for deep circulation of hydrothermal fluids. Interestingly, the two linear zones of microearthquake activity outlined by our 1981 survey each pass near one of the two major areas of hydrothermal hot spring activity. The most prominent zone with the WNW trend passes near Casa Diablo; the second zone trending NNW beneath Hot Creek Ranch parallels the surface trace of a splay-fault of the Hilton Creek fault that passes through the Hot Bubbling Pool (Casa Diablo Hot Pool) and lies upstream (SW) of the hot springs in Hot Creek gorge. Because both these zones have microearthquakes to depths of 8 to 10 km, they could allow the upward circulation of hydrothermal waters from those depths.

Microearthquake activity at Long Valley currently seems related to the regional tectonics and recent uplift of the resurgent dome (inflation of the magma chamber beneath the caldera) and not concentrated beneath the hydrothermal hot springs. Earthquake activity near Long Valley, in general, has been high since the fall of 1979. A series of M6 earthquakes in May 1980 has been followed by continued activity and three series of M5 earthquakes, one in September-October 1981, in January 1983, and in July 1983. Activity has continued throughout this period on the WNW trending zone beneath the south moat of the caldera. Figures 20 and 21 show maps and perpendicular cross-sections of south moat earthquake activity prior to the May 1980 sequence and for the first two weeks of the 1980 sequence, respectively (data from Cramer and Topozada, 1980; Cramer, unpublished data). These show trends and depth distributions similar to our 1981 results (figures 6 and 7) and to the distribution of earthquakes reported by Pitt and Cockerham (1983) for the 7 January 1983, M5 sequence.

For comparison, Figure 22 shows the historical seismicity for the east front of the Sierra Nevada Mountains (Cramer and Topozada, 1980) and Figure 23 shows the results of two previous microearthquake monitoring periods in 1970 (3 weeks) and 1973 (5 weeks) (Steeple and Pitt, 1976). Both figures 22 and 23 show the region between Long Valley and Bishop to the SE as being historically active. The microearthquake surveys of Pitt and Steeples (1975) and Steeples and Pitt (1976) (figure 23) show a little activity within the caldera and a swarm of microearthquakes both at Whitmore Hot Springs (inside the caldera) and just outside the caldera S.W. of Casa Diablo. Although the results of Steeples and Pitt have been cited as evidence for no micro-earthquake activity within Long Valley Caldera, figure 23 clearly shows that some low-level activity and probably microearthquake swarms have been occurring in and beneath Long Valley as far back as the early 1970's.

Figure 20a
M4 EARTHQUAKES
1 JUNE 1979 - 24 MAY 1980

Figure 20b

M 4 EARTHQUAKES

1 JUNE 1979 - 24 MAY 1980

Figure 21a
MAMMOTH LAKES EARTHQUAKES

25 MAY - 8 JUNE 1980

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Figure 21b

Figure 22

Figure 23

STEEPLES AND PITT: LONG VALLEY SYMPOSIUM

Fig. 3. All microearthquakes from both studies (1970 and 1973). Triangles show 1973 station locations; 1970 stations are not plotted but are shown in the work by Pitt and Steeples (1975). Note the low level of activity in the Long Valley caldera. Focal depths of microearthquakes in kilometers are indicated by numbers and letters (A = 10 km, B = 11 km, etc.). Note the north-south trend from Chalet Valley to Owens Valley and the northwest-southeast trend from Long Valley caldera to Owens Valley.

Figure 1 of Steeples and Pitt (1976) clearly shows a microearthquake swarm in 1973 occurring beneath or very close to the surface-trace of one of the splay-faults of the Hilton Creek fault within Long Valley, suggesting the same sort of activity on these faults in 1973 as we observed in 1981.

Our b-value (magnitude vs. frequency of occurrence analysis) results also suggest that most of the activity recorded in 1981 is related to regional tectonic (volcanic?) processes. A b-value of .97 was obtained for activity in and near Long Valley over a three-month period. This value is typical for earthquakes in California and for previous b-value estimates for the May 1980 earthquake sequence. An attempt to determine a b-value for events within the geothermal area provided unsatisfactory results because of incomplete sampling of small magnitude events and difficulty in determining which events are associated with the geothermal area.

Another aspect of the seismicity at Long Valley that is common with many other geothermal areas is the apparent shallowing of the maximum depth of earthquake activity as the caldera is approached from the south. South of the caldera, earthquakes occur to depths of 15 to 20 km while beneath the south moat, earthquakes extend down to 10 to 12 km. Earthquake activity decreases rapidly north of the south moat to a much lower or a nonexistent level (Cramer and Topozada, 1980; Ryall and Ryall, 1980, 1981). Also, the large earthquakes tend to occur at or south of the southern boundary and at depths of 8 to 20 km. These trends may reflect the presence of hotter rock beneath the caldera.

Focal mechanisms from our 1981 study also suggest that the zones of activity beneath the south moat are complex zones of faulting rather than simple vertical faults. The focal mechanisms also are compatible with the regional focal mechanisms reinforcing the idea that activity within the caldera is more in response to regional tectonic and volcanic stresses.

Vetter and Ryall (1982) and Vetter (1983) show that earthquakes in Nevada and along the eastern front of the Sierra Nevada Mountains have dominantly strike-slip mechanisms above 9 km and normal mechanisms below 9 km. For Long Valley, this reinforces an earlier and similar conclusion by Pitt and Steeples (1975) as far as activity above and below 10 km. Regional tension axes along the eastern front of the Sierra Nevada Mountains are E-W and NE-SW. Our 1981 results for the south moat of the caldera show dominantly normal, right-lateral oblique mechanisms mixed with some pure strike-slip and normal mechanisms and an occasional compressional mechanism over a depth range of 3 to 10 km. Tension axes are dominantly NE-SW. Dips on nodal planes within the apparently vertical zones of activity beneath the south moat vary from 60° SW through vertical to 60° NE, suggesting complex fault interactions within these zones.

Shifting to those observations more indicative of physical properties of rocks under Long Valley Caldera, Poisson's ratio indicates a fair degree of water saturation in the shallow crust. Poisson's ratios from both the analysis of P and S arrival times and the inversion of P- and S-wave data indicate Poisson's ratios near 0.3 within and beneath Long Valley Caldera. The inversion results also suggest a drop in Poisson's ratio to near 0.2 below a depth of 5 km beneath Long Valley. The high Poisson's ratio (higher degree of water saturation) in the top 5 km of the crust matches well Sorey et al.'s (1978) hydrological-geothermal model for Long Valley and suggests water circulation and saturation down to 5 km. The drop in Poisson's ratio below 5 km suggests drier and possibly hotter rocks below that depth and indicates that the main portion of the hydrothermal reservoir lies in the top 5 km of the crust at Long Valley.

Our shallow refraction profiles over the geothermal area indicate 0.5 to 1.0 km of ash and fluvial deposits (V_p of 1.2 to 2.6 km/s) over more competent

volcanic rocks with V_p around 3.3 km/s. The portion of one profile in the south moat suggests a higher second layer P-velocity of ~4.4 km/s. The earlier refraction results of Hill (1976) and more recent refraction work by Mooney, Luetgert, and Hill (oral communication, 1983) indicate that second layer P-velocities of 4.0 to 4.5 km/s are common under most of the caldera and to the north of the caldera. A couple of 3.4 km/s exceptions in Hill's (1976) data occur on the north flank of the resurgent dome and beneath a portion of the NW moat area of the caldera. Our inversion results are dominated by our shallow refraction results and, hence, an average P-velocity of 3.1 km/s for the first 1.5 km of the inversion model best describes the velocity beneath most of geothermal monitoring array (the effect of low-velocity surface sediments have been incorporated into individual station corrections). Because our monitoring array and refraction profiles overlie the geothermal area, the lower P-velocities there as compared to elsewhere in the caldera may reflect the effects of hydrothermal alteration which would be in keeping with surface geology (see Bailey et al.'s, 1976, figure 5 for the surface extent of hydrothermal attenuation in the study area).

Below 1.5 km, the velocities are fairly high (~6.0 km/s for P-waves, and ~3.5 km/s for S-waves) indicating basement rocks. The sharp velocity boundary at about 1.5 km ($\pm$ 0.5 km) corresponds in the two western deep drill holes (figure 18, no. 2 3) to the boundary between the Bishop Tuff and basement rocks (1.3-1.4 km in these two drill holes). This also corresponds well with Kane et al.'s (1976) estimates from gravity data of thickness (1-2 km) of Bishop Tuff in the western portion of the caldera.

Thus, the velocity information obtained from the inversion strongly reflects the geology under the detailed array, and the Poisson's ratio analysis suggests the hot water reservoir would be in the upper 5 km of the crust. Combining this information with the deep temperature profiles and the

hydrological model of Sorey, et al. (1978) suggests that the hotter water of the hydrothermal system should lie between 2 to 5 km below Long Valley Caldera and its fill of Bishop Tuff. Further, if the Poisson's ratio analysis based on the velocity inversion is valid, undersaturated or dry conditions exist below 5 km. This suggests the possibility of either hot, dry, or undersaturated rock (more likely), or steam (less likely) below 5 km. Finally, below 7-9 km there is some evidence for partial melt or magma in the geophysical data.

Our spectral results also provide some useful insight into crustal properties. Figure 24 shows our results plotted on figure 11 of Archuleta et al. (1982). The addition of CDMG/UCR's results lends support to Archuleta et al.'s suggestion that at Mammoth Lakes/Long Valley earthquakes above a moment of $\sim 10^{21}$ dyne-cm follow a constant stress drop curve while earthquakes with moments below $\sim 10^{21}$ dyne-cm, appear to have a constant source dimension. A constant source dimension behavior for microearthquakes also appears to be the case in The Geysers, California. The published data of Majer and McEvilly (1979) for The Geysers (represented by rectangular box in figure 24) shows similar behavior but at a smaller (.04-.07) source dimension. Conversely, Mueller and Cranswick (1982) presented data from the New Brunswick earthquakes of 1982 (nongeothermal area) suggesting micro-earthquakes there still show constant stress-drop behavior. Possibly this difference is related to the presence of a geothermal/volcanic region which effects spectral characteristics via high attenuation or the altering of fault rupture processes.

If attenuation is the main cause of the altered spectra, part of the high attenuation zone must be near the earthquake source area because Archuleta et al.'s bedrock stations to the southeast also are effected. Surficial ash deposits may also contribute to waveform attenuation at stations within the

Figure 24

Seismic Moment versus Source Radius - Combined Results

caldera. On the other hand, if the spectra are reflecting true source behavior, fault properties may be effected by low effective stress (high pore pressure) or increased crustal temperatures. Further work is required to determine the cause of this spectral behavior and whether it can serve as a discriminant between "geothermal" and "nongeothermal" earthquakes.

Value of Detailed Microearthquake Survey

The results of our detailed microearthquake survey at Long Valley, California on a known Geothermal Resource Area (KGRA) indicate the positive value of such surveys in geothermal exploration. At Long Valley, our results help delineate active fault zones (from locations) and their mode of deformation (from focal mechanism). The two active fault zones identified in our 1981 survey seem spacially associated with hot springs at Casa Diablo, at Hot Bubbling Pool (Casa Diablo Hot Pool), and in Hot Creek gorge. Fault movements along these zones (and others not delineated due to the short monitoring period) probably maintain pathways and conduits for the upward circulation of hydrothermal waters to surface hot springs. Although the identified zones of faulting are complex zones of deformation, their location and oblique normal and right-lateral strike-slip mode of deformation fit into the pattern of regional tectonics. This suggests that earthquake activity is influenced by both regional stress patterns and more localized volcano-tectonic activity.

A second important result from our Long Valley microearthquake survey is the better definition of the local velocity structure which aids in the accurate location of microearthquakes as well as improving our knowledge of the geologic structure within the caldera. The application of velocity inversion techniques to accurately timed P- and S-wave arrivals provided a

more detailed definition of P- and S-wave velocity structure beneath the geothermal area in Long Valley Caldera. Station corrections obtained as part of the inversion process reflect the distribution of surface sediments and variations in surface geology. The shallow velocity structure also correlates well with geologic data from deep drill holes and estimates of Bishop Tuff thickness from other geophysical techniques.

A third result of this study is the constraints on location of the geothermal reservoir suggested by the Poisson's ratio results. Poisson's ratios are near 0.3 above 5 km and near 0.2 below 5 km at Long Valley. This suggests a higher degree of water saturation above 5 km and dry or undersaturated conditions below 5 km, and thus, implies the geothermal reservoir must be dominantly above 5 km. Combining this information with the deep temperature profiles and hydrological modelling done by others, further constrains the geothermal reservoir to probably lie between a depth of 2 to 5 km (below the Bishop Tuff fill of Long Valley Caldera). Hot, dry rock may underlie the geothermal reservoir (a steam reservoir seems less likely).

An interesting aspect of the spectral results from Long Valley is that microearthquakes appear to have nearly constant source dimensions (.1-.3 km) and steeper high-frequency roll-offs (slopes of -3 to -5). This suggests high attenuation or a smoother rupture process that could be characteristic of geothermal/volcanic areas. A similar result has been reported for The Geysers, California (Majer and McEvilly, 1979) but was not observed in New Brunswick for an aftershock sequence unrelated to a geothermal area (Mueller and Cranswick, 1982).

Of course, the 1981 detailed microearthquake survey at Long Valley, California will also serve as background data for comparison to future microearthquake surveys after development of the geothermal resource there. This is of value because to the date of our survey only exploration drilling

has been conducted at Long Valley and no major geothermal production has occurred.

Foulger (1982) has also reviewed the value of passive seismic surveys in geothermal exploration and reservoir monitoring. Foulger discusses regional and teleseismic earthquake techniques as well as local earthquake studies. He finds positive value in the use of local earthquake surveys in geothermal exploration and recommends further developments and the building up of several good case histories. CDMG/UCR's work at Long Valley, California provides another example of the value detailed microearthquake surveys can make to geothermal exploration.

We have also found some of the limitations to the microearthquake survey technique. The most obvious is that earthquake activity must exist in and around a geothermal prospect in order to obtain any results. A second limitation is that velocity inversion results depend on recording a good distribution of ray paths through the study area from earthquakes and shots. This implies both good station distribution and a favorable distribution of earthquakes and shots. Good S-wave data also depends on the availability of three-component data for the reliable picking of S-wave arrivals, particularly in a laterally complex and varying area such as Long Valley, California. We found that S to P converted phases frequently arrive prior to S on vertical components at Long Valley which complicates the picking of S-waves and potentially bias S-wave results and Poisson's ratio determinations unless horizontal components are also available.

A fourth limitation is the manner in which the digital data is recorded and processed. We used individual event recorders at each station (Sprengnether DR-100's). They have a limited recording capacity, and data can be lost even under moderate rates of seismicity (more than 10 events of interest per day). Also a means of computer processing the event recorder

data for the desired results must already be operational if timely results are going to be available for evaluation of the geothermal resource let alone to influence the course of the monitoring effort itself. Having to load event-recorder tapes into a computer system for further processing can be almost as time-consuming as recording the original data. A microprocessor based portable system such as ASP (McEvelly and Majer, 1982) certainly provides timely results but for a higher equipment cost than event recorders. The ASP system also has drawbacks because waveforms are not saved: 1) repicking of weak arrivals, especially S-arrivals, cannot be done, and 2) spectral ratio techniques cannot be applied (not only are waveforms not kept, neither are complete spectra, only 3 spectral parameters). A newly developed microcomputer based recording system (LLNL's Newt system) shows a great deal of promise in combining the best features of individual-event recorders and the ASP system. The Newt system is less expensive equipment wise than the current ASP system and probably approaches event recorder costs when a dozen 3-component stations are contemplated. The Newt system provides real-time data processing as well as waveform recording, unlike event recorders, and it, or a system like it, may become the recording system of the future in geothermal exploration.

Finally, detailed microearthquake studies certainly are an important component of geothermal exploration but of themselves are not a panacea. They are an element of an integrated study approach incorporating geologic, gravity, magnetic, electric, and seismologic techniques.

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APPENDICES I - VII

- I - Station Histories
- II - DMG Calibration History, DOE Long Valley Array
- III - List of Microearthquake Locations
- IV - Tabulation of Events and Magnitudes from Smoke Drum Records
- V - Poisson Ratio Summaries
- VI - Focal Mechanism Summaries
- VII - Spectral Tabulations and Selected Plots

NOTE:

Appendices I, II, and IV are on microfiche,

CMAPNDI - Appendix I

CMAPNDII - Appendix II

CMAPNDIV - Appendix IV

Appendices III, and V-VII follow this page.

The above microfiche is available from
the author at the address below.

California Department of Conservation
Division of Mines and Geology
1416 Ninth Street
Sacramento, CA 95814

Appendix III

Summary list of microearthquake locations for the Long Valley area for the period 1 July through 14 August 1981. Information provided for each event is described below.

- (1) EVENT identification number for each event.
- (2) Origin time in Greenwich Civil Time (GCT):
YEAR, MON (month), DY (day), HR (hour), MN (minute), and SEC (second).
- (3) Epicenter in degrees and minutes of north latitude (LAT N) and west longitude (LONG W).
- (4) DEPTH, depth of focus in kilometers.
- (5) MAG, estimated magnitude (M_L) of the earthquake.
- (6) NO, number of phase arrivals used in locating earthquake.
- (7) GAP, largest azimuthal separation in degrees between stations.
- (8) DMIN, epicentral distance in kilometers to the nearest station.
- (9) RMS, root-mean-square error of the time residuals: $RMS = (\sum (R_i^2 / NO))^{1/2}$
 R_i is the observed seismic-wave arrival time minus the computed time at the i th station.
- (10) ERH, standard error of the epicenter in kilometers: $ERH = (SDX^2 + SDY^2)^{1/2}$
SDX and SDY are the standard errors in latitude and longitude, respectively of the epicenter.
- (11) ERZ, standard error of the focal depth in kilometers.

- (12) Q, solution quality of the hypocenter. This measure is intended to indicate the general stability of each solution.

<u>Q</u>	<u>Epicenter</u>	<u>Focal Depth</u>
A	excellent	good
B	good	fair
C	fair	poor
D	poor	poor

Q is based on both the nature of the station distribution with respect to the earthquake and the statistical measure of the solution. These two factors are each rated independently according to the following schemes.

Station Distribution

	<u>NO</u>	<u>GAP</u>	<u>DMIN</u>
A	> 6	< 90	< DEPTH or 5 km
B	> 6	< 135	< 2 x DEPTH or 10 km
C	> 6	< 180	< 50 km
D	Others		

Statistical Measures

	<u>RMS (sec)</u>	<u>ERH (km)</u>	<u>ERZ (km)</u>
A	< 0.15	< 1.0	< 2.0
B	< 0.30	< 2.5	< 5.0
C	< 0.50	< 5.0	
D	Others		

Q is taken as the average of the ratings from the two schemes, i.e., an A and a C yield a B, and two B's yield a B. When the two ratings are only one level apart the lower one is used, i.e., an A and a B yield a B.

- (13) T, method of magnitude determination. X - amplitude method after Eaton. D - Duration method after Lee et al.

APPENDIX III

COMG FINAL HYPOCENTER SOLUTIONS - DOE LONG VALLEY, CA. ARRAY

PAGE C 1

A	DATE	ORIGIN	LAT	LONG	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	FRZ	Q	T
1	DATE	ORIGIN	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	Q	S
2	310701	1746	16.25	37N35.23	118W52.90	0.50	2.15	6 269	2.1	0.30	30.7	16.2	D	X
3	310701	1119	34.43	37N37.49	118W52.28	0.81	2.27	7 155	0.5	0.25	4.6	2.1	D	X
4	310701	1133	21.52	37N33.54	118W51.54	5.00*	1.83	3 263	1.3	0.00	99.0	99.0	D	X
5	310701	12 6	37.35	37N37.73	118W51.96	7.37	2.44	4 165	1.3	0.00	34.7	76.7	D	X
6	310701	1230	19.34	37N36.23	118W53.39	1.07	3.02	7 269	6.3	0.17	9.9	5.5	D	X
7	310701	2133	6.13	37N37.55	118W51.74	7.32	2.20	5 131	3.9	0.00	28.9	62.7	D	X
8	310701	2213	6.95	37N37.39	118W52.21	6.05	1.79	4 255	4.3	0.00	38.8	50.6	D	X
9	310702	1242	9.77	37N38.55	118W57.72	6.90	3.12	11 79	8.8	0.10	1.0	2.1	B	X
10	310702	1337	57.42	37N38.13	118W50.62	5.00*	1.46	3 184	2.0	0.00	99.0	99.0	D	X
11	310702	1343	57.64	37N38.33	118W50.78	8.37	2.86	12 100	2.0	0.03	0.9	0.6	B	X
12	310702	14 7	27.45	37N33.16	118W50.77	8.16	2.73	13 80	2.2	0.07	0.7	0.5	A	X
13	310702	1420	43.82	37N34.39	118W51.07	7.63	2.80	12 74	1.9	0.07	0.6	0.6	A	X
14	310702	1656	12.87	37N40.54	118W46.53	1.50*	2.07	7 137	2.2	2.41	44.5	99.0	D	X
15	310702	1818	3.43	37N37.73	118W50.12	7.02	2.51	11 101	1.8	0.12	1.5	1.3	B	X
16	310702	1956	22.16	37N34.18	118W50.82	7.94	2.52	11 101	2.2	0.09	1.1	0.8	B	X
17	310703	721	43.52	37N38.56	118W50.57	7.31	2.37	8 97	1.6	0.11	1.8	1.5	B	X
18	310703	734	4.14	37N42.55	119W 9.74	20.03*	3.22	6 265	30.5	8.39	97.4	29.4	D	X
19	310704	7 9	5.37	37N38.01	118W51.55	5.00*	1.87	3 238	2.3	0.00	99.0	99.0	D	X
20	310705	217	23.62	37N33.29	118W55.51	8.53	2.04	4 113	3.5	0.00	9.3	16.6	D	X
21	310705	230	55.86	37N33.76	118W55.71	5.00*	1.65	3 179	4.4	0.00	99.0	99.0	D	X
22	310705	236	9.27	37N39.03	118W54.28	4.30	1.49	4 137	5.0	0.00	6.5	13.4	D	X
23	310705	236	40.74	37N38.71	118W55.11	6.70	2.35	11 31	4.3	0.09	1.2	1.2	B	X
24	310705	237	18.35	37N38.22	118W55.06	9.59	2.19	5 113	3.4	0.03	11.8	31.6	D	X
25	310705	238	16.81	37N39.13	118W55.55	1.26	1.59	4 109	5.1	0.03	5.1	99.0	D	X
26	310705	242	1.53	37N33.50	118W55.17	7.23	3.04	15 72	3.9	0.06	0.5	0.5	A	X
27	310705	243	43.24	37N38.50	118W55.09	9.44	2.14	5 110	3.5	0.03	8.9	30.1	D	X
28	310705	253	29.52	37N38.52	118W54.93	8.17	2.11	8 93	3.9	0.03	0.9	2.5	B	X
29	310705	315	1.91	37N38.52	118W57.44	5.00*	2.22	3 139	3.6	0.00	99.0	99.0	D	X
30	310705	321	58.72	37N23.24	120W56.61	20.29	4.05	5 304	174.9	0.65	99.0	99.0	D	X
31	310705	352	0.83	37N33.33	118W54.95	6.95	2.64	15 73	3.6	0.12	1.1	1.1	B	X
32	310705	442	18.73	37N38.59	118W54.44	6.75	2.22	10 78	4.0	0.07	0.9	1.2	B	X
33	310705	443	31.70	37N38.45	118W54.40	7.26	1.94	5 144	3.9	0.00	6.2	19.4	D	X
34	310705	523	28.43	37N41.22	118W52.85	0.63*	1.85	9 113	4.0	1.93	23.5	25.1	C	X

#	DATE	ORIGIN	LAT	LONG	DEPTH	MAG	NO	GAP	DMIN	RMS	SRH	FRZ	Q T
35	310705	746	5.10	37N33.78	118W55.69	5.00A	1.78	3 130	4.5	0.00	99.0	99.0	0 X
36	310705	812	44.04	37N33.74	118W55.72	5.00*	1.90	3 179	4.4	0.00	99.0	99.0	0 X
37	310705	11 5	48.11	37N33.36	118W55.10	7.42	2.57	14 74	4.6	0.03	0.9	1.0	A X
38	310705	11 8	0.32	37N33.06	118W55.10	9.9J		5 114	3.1	0.03	11.1	32.4	0
39	310705	1119	2.15	37N38.23	118W54.87	9.39	2.32	4 125	3.4	0.00	14.8	52.6	0 X
40	310705	13 2	50.12	37N33.53	118W50.02	11.76	2.52	5 294	5.9	0.02	40.2	39.5	0 X
41	310705	1421	1.39	37N38.27	118W55.10	10.50	2.46	7 92	3.5	0.02	1.0	3.6	B X
42	310705	1513	50.74	37N38.58	118W54.16	7.40*	1.66	4 138	4.3	0.10	11.7	43.2	0 X
43	310705	1513	25.08	37N37.43	118W55.21	14.30	2.54	4 121	1.9	0.00	27.8	89.5	0 X
44	310705	1541	57.42	37N38.74	118W55.09	7.40	2.93	10 73	4.3	0.04	0.5	0.5	A X
45	310705	1756	18.02	37N34.78	118W54.26	4.05	1.24	4 141	4.0	0.00	9.0	14.6	0 X
46	310705	1940	29.85	37N37.32	118W52.31	11.09	2.49	7 76	0.1	0.02	1.8	3.9	B X
47	310705	2323	14.24	37N37.71	118W51.33	5.64	2.23	5 142	1.1	0.01	15.4	29.6	0 X
48	310706	754	23.22	37N38.65	118W57.79	5.00*	2.01	3 149	3.3	0.03	99.0	99.0	0 X
49	310706	1723	32.14	37N33.42	118W55.21	9.61	2.21	8 96	3.7	0.02	0.9	2.8	B X
50	310707	725	1.66	37N33.12	118W43.60	5.45	1.91	5 304	7.1	0.02	50.1	20.5	0 X
51	310707	1642	16.60	37N32.51	118W49.54	4.44	2.51	9 256	7.8	0.03	1.2	0.7	C X
52	310707	2049	57.76	37N34.20	118W52.95	4.07	1.93	7 252	5.2	0.02	1.3	0.3	C X
53	310707	2112	33.67	37N33.20	118W54.92	6.54	2.22	5 118	3.3	0.04	5.6	12.4	0 X
54	310707	2338	22.93	37N37.52	118W49.62	11.91	2.26	4 137	1.3	0.00	31.6	99.0	0 X
55	310708	2 3	53.35	37N27.79	118W47.55	6.32	2.90	12 174	17.1	0.07	1.4	3.1	C X
56	310708	854	44.23	37N17.95	118W33.53	19.87	3.40	6 296	45.2	0.03	29.8	32.3	0 X
57	310708	1029	25.16	37N37.25	118W51.57	5.76	1.67	5 147	1.1	0.01	9.0	12.7	0 X
58	310708	1421	43.32	37N38.55	118W56.77	5.00*	1.77	3 150	4.4	0.00	99.0	99.0	0 X
59	310708	1423	0.03	37N38.95	118W56.72	3.11*	2.09	4 129	4.8	0.01	99.0	99.0	0 X
60	310709	517	33.67	37N33.55	118W52.14	8.05	2.55	9 92	1.2	0.13	2.5	2.7	C X
61	310709	541	3.02	37N37.33	118W52.25	10.52	2.63	10 100	0.2	0.02	0.3	0.4	B X
62	310709	555	43.19	37N37.36	118W52.43	10.14	2.11	6 108	0.3	0.02	1.5	3.6	B X
63	310709	9 5	53.11	37N31.61	118W54.01	2.91	2.24	5 276	9.0	0.03	24.6	19.7	0 X
64	310709	1236	53.93	37N33.99	118W55.86	2.65	1.29	4 113	4.9	0.02	68.2	99.0	0 X
65	310709	1246	0.17	37N37.75	118W52.49	8.67	2.01	8 75	1.0	0.02	0.7	1.5	A X
66	310709	1246	53.11	37N33.70	118W55.92	6.91	2.79	11 110	4.4	0.04	0.6	1.1	B X
67	310709	1249	35.05	37N39.09	118W55.91	2.69	1.66	4 115	5.1	0.02	99.0	99.0	0 X
68	310709	1329	52.33	37N38.76	118W55.74	6.42	2.45	8 108	4.5	0.02	0.4	1.5	B X
69	310709	1330	44.73	37N38.73	118W55.39	6.99	2.73	10 110	4.5	0.04	0.7	1.2	B X
70	310709	1331	16.09	37N33.70	118W55.95	6.53	3.13	9 111	4.4	0.03	0.5	1.1	B X
71	310709	1334	6.32	37N33.38	118W56.08	6.44	2.81	9 115	4.8	0.03	0.5	1.7	B X

#	DATE	ORIGIN	LAT	LONG	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	Q	T
72	310709	1335	5.67	37N33.30	118W55.90	6.05	2.03	7 111	4.6	0.03	0.8	3.1	B	X
73	310709	1338	52.17	37N38.98	118W54.74	2.43	1.83	6 96	4.4	0.09	2.0	21.2	C	X
74	310709	1343	24.36	37N39.02	118W55.91	3.43	1.62	4 114	5.0	0.01	99.0	99.0	D	X
75	310709	1350	52.74	37N33.66	118W55.52	6.40	2.27	8 105	4.2	0.03	0.5	1.9	B	X
76	310709	14 0	35.74	37N33.39	118W56.34	5.00*	1.63	3 164	4.9	0.00	99.0	99.0	D	X
77	310709	1452	29.43	37N34.75	118W55.35	6.57	2.28	7 110	4.5	0.02	0.5	1.2	B	X
78	310709	1452	55.55	37N34.69	118W55.91	7.00	3.03	14 67	4.4	0.06	0.6	0.7	A	X
79	310709	1455	55.72	37N38.75	118W55.90	5.00*	2.10	3 174	4.5	0.00	99.0	99.0	D	X
80	310709	1553	52.24	37N38.71	118W55.43	7.04	2.82	12 70	4.3	0.09	1.1	1.1	A	X
81	310709	1625	23.77	37N33.42	118W56.20	5.23	2.61	11 70	4.1	0.04	0.5	1.1	A	X
82	310709	1626	42.34	37N33.70	118W56.08	3.64	2.72	8 113	4.5	0.05	0.8	1.5	B	X
83	310709	1630	2.23	37N36.91	119W 5.02	0.20	3.24	4 311	8.6	0.66	99.0	99.0	D	X
84	310709	1638	57.57	37N37.80	118W58.17	12.15	2.44	4 132	1.8	0.00	15.4	13.7	D	X
85	310709	1639	11.05	37N38.61	118W56.84	1.65*	2.56	4 125	4.3	0.10	6.2	21.5	D	X
86	310709	1952	16.36	37N38.52	118W56.73	4.36*	2.51	5 117	4.2	0.15	9.5	37.8	D	X
87	310709	1956	19.43	37N38.30	118W56.15	5.00*	1.64	3 163	3.8	0.00	99.0	99.0	D	X
88	310709	20 7	29.32	37N34.56	118W56.63	5.00*	1.55	3 153	4.5	0.00	99.0	99.0	D	X
89	310709	20 8	29.02	37N38.49	118W56.57	5.00*	1.67	3 153	4.4	0.00	99.0	99.0	D	X
90	310709	2028	22.89	37N38.32	118W56.35	5.00*	1.45	3 157	4.0	0.00	99.0	99.0	D	X
91	310709	2042	3.72	37N38.31	118W56.51	5.00*	1.83	3 153	4.1	0.00	99.0	99.0	D	X
92	310709	2043	57.28	37N33.86	119W 2.12	55.19	3.25	4 318	7.6	0.04	99.0	99.0	D	X
93	310709	22 9	6.30	37N38.26	118W54.61	8.02	2.58	7 110	3.5	0.03	0.9	2.0	B	X
94	310709	23 6	56.91	37N33.57	118W56.11	5.00*	1.74	3 166	4.3	0.00	99.0	99.0	D	X
95	310709	2321	54.97	37N33.93	118W57.48	5.00*	1.96	3 146	4.0	0.00	99.0	99.0	D	X
96	310710	0 5	7.26	37N34.09	118W56.35	6.84	2.49	5 106	3.6	0.01	24.2	75.9	D	X
97	310710	049	52.13	37N33.80	118W56.76	5.00*	2.38	3 152	4.6	0.00	99.0	99.0	D	X
98	310710	130	22.11	37N33.32	118W56.37	5.00*	2.26	3 144	4.0	0.00	99.0	99.0	D	X
99	310710	139	7.27	37N37.31	118W53.41	8.42	2.50	9 100	3.6	1.44	19.2	22.2	C	X
100	310710	146	53.73	37N40.46	118W56.45	5.00*	2.29	3 171	5.8	0.00	99.0	99.0	D	X
101	310710	2 5	17.78	37N37.40	118W57.81	10.60	2.43	4 148	2.1	0.00	68.0	99.0	D	X
102	310710	234	59.97	37N37.98	118W55.46	6.36	2.38	10 93	3.0	0.16	2.0	2.1	B	X
103	310710	331	17.45	37N33.16	118W55.96	6.07	2.59	11 38	3.5	0.03	0.7	0.9	A	X
104	310710	655	59.39	37N38.35	118W56.66	9.10	3.3	7 97	66.1	0.14	2.1	6.0	D	D
105	310710	1126	29.04	37N33.34	118W56.61	6.90	3.3	7 97	66.1	0.13	2.7	7.8	D	D
106	310710	1635	51.22	37N33.90	118W56.67	7.29	3.3	7 97	66.1	0.16	2.5	7.1	D	D
107	310710	2027	48.76	37N38.23	118W56.33	6.38	3.30	14 62	3.8	0.09	0.7	0.9	A	X
108	310710	2047	1.16	37N44.34	118W54.82	4.04	2.90	4 270	3.2	0.00	99.0	99.0	D	X

#	DATE	ORIGIN	LAT	LONG	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	FRZ	Q T
109	810710	2043	10.60	37N37.57	118W56.11	2.67	2.53	13 69	2.6	0.07	0.5	1.2	A X
110	810710	2053	41.53	37N35.00	118W55.96	5.00*	1.93	3 165	3.2	0.00	99.0	99.0	D X
111	810710	2054	22.62	37N38.11	118W55.94	5.00*	2.23	3 166	3.4	0.00	99.0	99.0	D X
112	810710	2054	36.91	37N38.56	118W57.20	5.00*	2.17	3 139	3.8	0.00	99.0	99.0	D X
113	810710	21 7	17.86	37N38.41	118W56.21	6.51	2.63	13 71	4.1	0.07	0.6	0.8	A X
114	810710	2112	0.71	37N35.92	118W47.65	5.49	2.04	7 265	3.6	0.02	1.7	1.0	C X
115	810710	22 9	36.95	37N38.13	118W56.06	5.00*	2.23	3 163	3.5	0.00	99.0	99.0	D X
116	810710	2257	21.22	37N38.20	118W56.27	5.69	2.64	5 107	3.7	0.00	9.1	27.5	D X
117	810711	1 2	21.86	37N38.52	118W55.77	7.20	2.99	13 67	4.2	0.08	0.7	0.7	A X
118	810711	122	13.45	37N38.38	118W55.62	9.06	1.53	4 119	3.7	0.00	33.1	99.0	D X
119	810711	643	13.61	37N38.63	118W55.50	7.01	2.60	6 103	4.2	0.02	1.0	3.6	B X
120	810711	7 9	44.84	37N32.05	118W47.56	4.95	3.08	14 106	11.9	0.11	1.1	1.6	C X
121	810711	8 2	7.19	37N30.98	118W56.21	37.00	3.46	4 316	10.1	0.01	99.0	99.0	D X
122	810711	843	40.63	37N30.75	118W53.24	5.00*	2.57	3 336	10.8	0.04	99.0	99.0	D X
123	810711	855	59.96	37N38.15	118W56.26	5.00*	2.14	3 158	3.6	0.00	99.0	99.0	D X
124	810711	20 7	19.23	37N38.31	118W55.99	7.42	2.75	6 113	4.6	0.02	0.7	2.4	B X
125	810711	2010	53.84	37N38.02	118W56.48	14.53	2.76	4 106	3.6	0.00	99.0	99.0	D X
126	810711	2047	21.72	37N39.01	118W56.11	5.00*	2.32	3 170	5.0	0.00	99.0	99.0	D X
127	810711	2242	35.82	37N38.05	118W57.11	7.16	2.34	4 117	3.4	0.00	50.0	99.0	D X
128	810711	2244	52.83	37N38.46	118W56.69	5.87	2.89	13 59	4.3	0.06	0.5	0.8	A X
129	810712	1933	49.48	37N38.18	118W56.15	6.26	2.85	14 63	3.6	0.06	0.5	0.7	A X
130	810712	2355	45.06	37N38.04	118W56.00	7.66	2.93	5 100	3.3	0.02	26.8	96.3	D X
131	810712	2356	59.43	37N38.49	118W56.37	5.00*	2.11	3 159	4.3	0.00	99.0	99.0	D X
132	810712	2358	59.91	37N38.51	118W56.23	5.00*	2.16	3 163	4.2	0.00	99.0	99.0	D X
133	810713	0 4	6.34	37N33.74	118W57.03	5.00*	2.42	3 145	4.2	0.00	99.0	99.0	D X
134	810713	015	50.36	37N15.49	119W 3.79	131.59	4.41	4 347	40.7	0.08	99.0	99.0	D X
135	810713	112	50.93	37N36.07	118W49.29	6.36	2.45	8 225	1.6	0.04	2.1	1.6	D X
136	810713	113	47.44	37N36.79	118W50.55	3.89	2.34	12 84	1.2	0.05	0.6	0.6	A X
137	810713	159	15.84	37N36.65	118W56.57	16.32	2.76	4 134	2.2	0.00	99.0	99.0	D X
138	810713	3 1	42.54	37N33.58	118W56.83	5.00*		3 148	4.3	0.00	99.0	99.0	D
139	810713	624	23.96	37N33.45	118W45.01	12.83	2.85	5 323	9.5	0.00	99.0	99.0	D X
140	810713	1430	1.25	37N33.73	118W55.44	5.00*	2.15	3 314	4.9	0.00	99.0	99.0	D X
141	810713	1637	9.02	38N 2.35	118W44.61	1.44	3.41	9 119	39.0	0.15	2.5	82.1	C X
142	810713	1845	13.86	37N38.36	118W56.37	5.00*	2.18	3 157	4.1	0.00	99.0	99.0	D X
143	810713	2323	0.23	37N32.14	118W52.78	5.19	2.85	5 331	9.5	0.01	99.0	26.5	D X
144	810714	422	52.00	37N35.79	118W53.47	5.00*	2.29	3 335	3.2	0.00	99.0	99.0	D X
145	810715	214	36.69	37N36.33	118W51.08	25.64	2.80	4 250	2.1	0.01	99.0	99.0	D X

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#	DATE	ORIGIN	LAT	LONG	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	Q	T
145	310715	229	39.01	37N37.14	118W51.50	16.23	2.60	4	178	1.0	0.00	99.0	99.0	0 X
147	310715	1949	52.83	37N34.52	118W52.60	5.00*	2.04	3	320	4.9	0.00	99.0	99.0	0 X
148	310715	2113	28.64	37N38.64	118W56.19	4.83	1.79	4	120	4.4	0.00	16.5	93.9	0 X
149	310715	2115	8.57	37N39.02	118W55.23	3.90	2.22	7	103	4.8	0.02	0.3	0.8	8 X
150	310716	042	48.60	37N39.15	118W55.36	5.00*	1.93	3	320	5.3	0.00	99.0	99.0	0 X
151	310716	1021	28.39	37N37.87	118W54.54	3.63	2.05	4	309	3.5	0.00	99.0	99.0	0 X
152	310716	1033	16.63	37N38.13	118W55.09	5.00*	1.98	3	316	4.4	0.00	99.0	99.0	0 X
153	310716	1213	23.95	37N38.35	118W53.06	2.69	2.38	4	258	2.3	0.01	99.0	99.0	0 X
154	310716	1224	45.13	37N38.25	118W52.73	1.41	1.99	4	237	2.0	0.00	9.6	99.0	0 X
155	310718	035	12.67	37N28.20	119W 2.78	55.32	2.97	4	334	18.9	0.01	99.0	99.0	0 X
156	310718	412	38.77	37N35.22	118W49.85	9.98	2.10	4	271	1.1	0.00	36.5	49.7	0 X
157	310718	438	24.37	37N36.37	118W49.46	9.88	2.45	8	179	1.0	0.04	1.3	0.9	C X
158	310718	549	18.31	37N38.59	118W56.03	5.00*	2.07	3	191	4.3	0.00	99.0	99.0	0 X
159	310718	1628	37.71	37N37.96	118W50.57	2.50*	1.53	5	107	2.2	0.14	4.0	17.1	0 X
160	310718	2030	59.43	37N36.19	118W51.51	5.00*	1.74	3	210	2.3	0.00	99.0	99.0	0 X
161	310720	2219	2.84	37N35.53	118W49.39	14.53	2.86	4	306	2.5	0.00	59.8	99.0	0 X
162	310721	1940	52.52	37N33.54	118W54.75	5.00*	1.73	3	154	4.0	0.00	99.0	99.0	0 X
163	310722	1612	10.24	37N35.74	118W48.42	6.10	1.99	5	302	2.9	0.02	46.9	43.0	0 X
164	310722	1859	30.56	37N37.33	118W56.74	6.25	2.03	6	221	3.6	0.01	1.1	2.0	C X
165	310723	529	18.09	37N33.08	118W52.83	7.83	1.81	5	103	1.7	0.00	6.4	15.7	0 X
166	310723	529	44.88	37N50.54	121W 3.90	5.00*	3.68	3	356	137.0	2.12	99.0	99.0	0 X
167	310723	634	16.07	37N38.55	118W53.54	5.00*	1.37	3	170	3.0	0.00	99.0	99.0	0 X
168	310723	822	48.27	37N36.57	118W52.32	5.00*	1.33	3	254	1.2	0.00	99.0	99.0	0 X
169	310723	1244	12.53	37N38.25	118W44.35	5.00*	1.54	3	319	11.8	0.11	99.0	99.0	0 X
170	310723	1815	3.55	37N37.87	118W53.76	5.00*	1.33	3	141	2.4	0.00	99.0	99.0	0 X
171	310723	2040	45.91	37N33.99	118W51.40	5.00*	1.75	3	272	0.7	0.00	99.0	99.0	0 X
172	310723	2157	41.92	37N39.62	118W51.32	5.13	1.85	5	107	0.7	0.02	4.9	3.7	0 X
173	310724	1928	3.04	36N42.55	118W27.60	46.66	3.73	4	356	105.7	0.06	99.0	99.0	0 X
174	310724	2142	54.63	37N46.73	118W13.79	5.00*	3.40	3	346	52.3	0.20	99.0	99.0	0 X
175	310725	143	53.95	37N34.07	118W52.90	5.36	2.02	4	231	5.4	0.00	22.8	13.5	0 X
176	310725	3	20.90	37N37.32	118W52.96	5.00*	1.29	3	144	1.0	0.00	99.0	99.0	0 X
177	310725	437	59.33	37N37.82	118W53.72	8.45	2.49	8	111	2.3	0.04	0.9	1.3	8 X
178	310725	439	18.22	37N37.57	118W56.08	5.00*	1.81	3	207	2.6	0.00	99.0	99.0	0 X
179	310725	2320	14.53	37N34.43	118W52.02	9.22	2.84	12	121	5.2	0.05	0.8	0.7	8 X
180	310726	1	35.00	37N34.28	118W53.87	2.33	1.94	4	291	3.0	0.00	99.0	99.0	0 X
181	310726	956	46.33	37N37.42	118W35.26	0.00*	2.84	4	143	21.1	9.09	7.0	99.0	0 X
182	310726	2144	19.47	37N32.98	118W45.24	5.00*	2.10	3	334	9.8	0.01	99.0	99.0	0 X

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A	DATE	ORIGIN	LAT	LONG	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	Q	T
183	810726	2214	3.24	37N33.77	118W52.14	5.00*	1.62	3 174	5.8	0.00	99.0	99.0	D	X
184	810727	150	25.43	37N39.23	118W54.42	5.00*	1.89	3 239	4.8	0.00	99.0	99.0	D	X
185	810727	723	14.33	37N34.29	118W54.01	5.53	1.93	4 132	3.2	0.00	22.6	56.1	D	X
186	810727	918	46.02	37N38.38	118W54.07	5.00*	1.25	3 151	3.3	0.00	99.0	99.0	D	X
187	810727	1249	1.43	37N37.33	118W53.69	7.76	2.65	14 69	2.3	0.05	0.5	0.5	A	X
188	810727	1346	15.48	37N36.76	118W51.77	2.73	1.15	5 175	1.2	0.01	3.9	8.2	D	X
189	810728	14 7	59.86	37N26.65	118W52.57	5.00*	2.67	3 336	18.4	0.05	99.0	99.0	D	X
190	810728	1722	49.02	37N27.02	118W52.75	5.00*	2.49	3 335	17.7	0.05	99.0	99.0	D	X
191	810728	1913	50.53	37N37.99	118W55.71	3.54	2.29	6 137	3.1	0.06	3.1	9.0	D	X
192	810728	2018	17.76	37N37.83	118W53.87	5.00*	1.79	3 165	3.2	0.00	99.0	99.0	D	X
193	810728	2144	11.23	37N34.48	118W53.11	5.00*	2.21	3 272	4.6	0.00	99.0	99.0	D	X
194	810730	515	20.73	37N38.84	118W55.66	5.00*	1.70	3 131	4.6	0.00	99.0	99.0	D	X
195	810730	716	14.67	37N37.29	118W50.43	12.95*	2.17	4 295	2.7	0.10	99.0	99.0	D	X
196	810730	10 8	55.05	37N36.92	118W51.66	5.61	1.81	6 166	1.1	0.03	1.2	1.3	C	X
197	810730	1025	23.66	37N38.07	118W52.74	6.72	1.77	4 137	1.7	0.01	92.0	99.0	D	X
198	810730	2327	6.95	37N33.03	118W55.82	7.71	2.33	10 97	3.2	0.04	0.6	0.9	B	X
199	810731	227	55.70	37N37.56	118W54.00	5.00*	1.82	3 238	2.7	0.00	99.0	99.0	D	X
200	810731	5 5	40.21	37N36.65	118W51.64	10.06	2.02	5 239	1.5	0.02	18.6	26.4	D	X
201	810731	959	12.00	37N35.90	118W43.50	4.33	2.44	15 124	2.6	0.06	0.7	0.8	B	X
202	810731	10 3	47.82	37N33.62	118W54.30	5.00*	1.29	3 218	4.3	0.00	99.0	99.0	D	X
203	810731	10 4	27.22	37N39.52	118W59.66	9.75	2.87	10 81	11.6	1.27	16.4	22.9	C	X
204	810731	10 5	47.33	37N38.31	118W56.44	5.00*	2.13	3 155	4.0	0.00	99.0	99.0	D	X
205	810731	1016	24.85	37N38.19	118W55.33	7.01	2.74	12 69	3.3	0.07	0.7	0.7	A	X
206	810731	1943	11.16	37N35.39	118W51.46	4.51	2.28	4 314	3.6	0.00	46.4	30.2	D	X
207	810801	4 0	4.54	37N33.59	118W55.08	7.86	2.09	5 105	4.1	0.03	6.2	21.5	D	X
208	810801	1026	54.38	37N33.97	118W56.67	5.00*	2.23	3 156	4.9	0.00	99.0	99.0	D	X
209	810802	2151	46.89	37N43.02	118W55.98	20.66	3.21	14 86	1.6	1.35	20.9	13.3	C	X
210	810802	2230	19.80	37N33.28	118W54.76	7.24	2.23	12 84	3.5	0.14	1.4	1.6	B	X
211	810802	2231	1.47	37N38.30	118W54.78	7.04	2.30	4 155	3.6	0.00	5.7	13.1	D	X
212	810802	2255	2.26	37N38.77	118W56.35	7.31	2.98	14 63	4.7	0.06	0.5	0.6	A	X
213	810802	2256	7.06	37N39.16	118W56.33	3.42*	2.10	4 124	5.4	0.01	31.3	99.0	D	X
214	810802	23 6	45.38	37N39.08	118W56.50	5.00*	1.81	3 151	5.2	0.00	99.0	99.0	D	X
215	810802	2327	27.06	37N39.02	118W56.29	5.00*	2.02	3 166	5.1	0.00	99.0	99.0	D	X
216	810802	2231	1.50	37N37.65	118W55.72	5.00*	2.17	3 252	6.5	0.00	99.0	99.0	D	X
217	810802	2255	2.23	37N33.31	118W56.26	7.68	2.97	6 118	4.8	0.01	0.5	1.3	B	X
218	810803	130	58.30	37N36.33	118W50.53	10.01	2.67	13 102	1.4	0.10	1.3	1.0	B	X
219	810803	554	27.32	37N34.95	118W48.74	4.35	2.44	6 267	3.8	0.03	2.2	2.3	C	X

N	DATE	ORIGIN	LAT	LONG	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	Q	T
220	810803	1212	29.50	37N33.49	118W54.27	5.00*	1.89	3 220	4.1	0.00	99.0	99.0	D	X
221	810803	2024	12.74	37N37.53	118W51.95	4.48	1.92	9 144	0.5	0.04	0.6	0.7	B	X
222	810804	415	51.16	37N37.53	118W54.08	5.00*	1.89	3 234	2.8	0.00	99.0	99.0	D	X
223	810804	1435	25.21	37N38.56	118W56.29	5.00*	1.99	3 163	4.5	0.00	99.0	99.0	D	X
224	810805	711	51.79	37N39.63	118W51.77	3.47	2.04	6 173	0.7	0.02	0.7	0.9	B	X
225	810805	925	59.15	37N38.13	118W52.26	4.97	1.95	5 138	1.6	0.01	8.1	9.1	D	X
226	810805	1114	25.15	37N34.55	118W48.95	5.00*	1.83	3 290	9.7	0.00	99.0	99.0	D	X
227	810806	145	58.81	37N36.91	118W54.48	5.49	2.34	4 314	5.8	0.00	99.0	93.5	D	X
228	810806	426	8.11	37N37.83	118W53.32	6.71	2.19	8 195	3.4	0.03	1.2	0.9	C	X
229	810806	437	37.16	37N37.12	118W52.73	6.83	1.82	4 333	4.1	0.00	56.1	34.8	D	X
230	810806	439	38.12	37N36.54	118W52.95	7.16	1.88	4 334	5.1	0.00	99.0	72.7	D	X
231	810806	452	22.33	37N33.10	118W52.88	6.16	2.42	17 57	1.8	0.06	0.5	0.7	A	X
232	810806	454	56.55	37N38.02	118W52.74	6.19	2.08	11 74	1.6	0.03	0.4	0.5	A	X
233	810806	455	50.76	37N36.26	118W52.33	4.36	1.57	4 195	1.9	0.00	14.6	20.8	D	X
234	810806	514	19.16	37N28.24	118W44.94	5.05	2.46	5 306	22.7	0.02	4.4	24.1	D	X
235	810806	514	45.84	37N38.31	118W52.44	5.00*	1.80	3 216	2.0	0.00	99.0	99.0	D	X
236	810806	640	59.83	37N38.09	118W52.81	6.17	2.05	11 73	1.7	0.03	0.4	0.6	A	X
237	810806	10 1	33.33	37N37.23	118W52.67	6.60	2.11	4 332	3.9	0.00	60.0	38.8	D	X
238	810806	1638	38.96	37N39.66	118W51.30	5.00*	1.59	3 269	1.3	0.00	99.0	99.0	D	X
239	810806	1644	37.27	37N38.03	118W52.19	4.86	1.34	4 185	1.5	0.00	12.0	23.5	D	X
240	810806	17 2	31.86	37N38.01	118W52.11	5.00*	1.19	3 181	1.4	0.00	99.0	99.0	D	X
241	810806	1953	38.86	38N28.68	118W34.35	5.00*	2.96	3 350	91.8	0.01	99.0	99.0	D	X
242	810806	2033	2.60	37N31.34	118W52.54	3.10	2.42	16 104	10.9	0.05	1.3	2.6	C	X
243	810806	2222	58.92	37N33.20	118W52.25	4.48	1.69	4 190	1.8	0.00	11.1	18.3	D	X
244	810806	2231	8.66	37N31.41	118W49.33	10.96	3.36	18 105	10.1	0.10	1.4	1.4	B	X
245	810806	2344	8.05	37N38.09	118W52.38	5.00*	1.17	3 208	1.6	0.00	99.0	99.0	D	X
246	810806	2222	58.92	37N38.22	118W52.36	4.44	1.69	4 197	1.8	0.00	14.9	24.7	D	X
247	810807	219	31.83	37N38.44	118W52.93	5.00*	1.76	3 327	2.2	0.00	99.0	99.0	D	X
248	810807	328	9.39	37N23.58	118W54.91	19.56	2.48	4 332	25.6	0.00	99.0	99.0	D	X
249	810807	328	45.77	37N37.54	118W51.75	5.49	2.11	13 121	1.0	0.03	0.4	0.5	B	X
250	810807	513	17.01	37N36.99	118W50.15	5.58	1.67	9 158	0.6	0.03	0.7	0.9	B	X
251	810807	943	22.07	37N37.52	118W52.88	6.08	2.07	12 145	0.9	0.04	0.6	0.8	B	X
252	810807	10 0	31.64	37N34.19	118W52.50	5.00*	1.30	3 206	1.8	0.00	99.0	99.0	D	X
253	810807	10 8	57.57	37N38.10	118W51.90	5.00*	1.48	3 194	1.7	0.00	99.0	99.0	D	X
254	810808	018	15.66	37N38.57	119W 2.82	23.87	3.11	5 350	12.7	0.02	99.0	99.0	D	X
255	810808	116	52.34	37N39.02	118W54.79	5.00*	1.72	3 333	0.9	0.00	99.0	99.0	D	X
256	810808	2 6	52.42	37N39.32	118W52.56	4.29	1.38	4 214	1.2	0.00	9.9	15.4	D	X

A	DATE	ORIGIN	LAT	LONG	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	Q	T
257	310808	5 3 0.15	37N33.38	118W51.17	3.51	1.73	8	97	1.1	0.03	0.5	1.1	B	X
258	310808	510 53.74	37N33.94	118W51.15	3.28	1.67	5	112	1.1	0.02	4.3	10.4	D	X
259	310809	4 5 53.00	37N40.16	118W53.40	5.00*	1.58	3	203	2.0	0.00	99.0	99.0	D	X
260	310809	942 41.42	37N37.75	118W50.33	3.01	1.10	5	110	1.8	0.30	7.6	14.7	D	X
261	310809	1050 47.83	37N39.36	118W51.54	4.04	1.67	7	92	0.4	0.02	0.5	1.4	B	X
262	310809	1059 43.00	38N13.22	120W11.82	5.00*	3.89	3	357	132.0	0.21	99.0	99.0	D	X
263	310809	1411 10.07	37N38.74	118W51.30	3.10	1.87	9	76	1.1	0.05	0.6	1.4	A	X
264	310809	1422 57.16	37N31.03	118W46.04	0.30*	2.46	19	108	12.1	1.44	16.3	99.0	D	X
265	310809	1543 56.73	37N38.17	118W55.25	7.34	2.32	16	93	2.6	0.03	0.9	1.1	B	X
266	310809	1552 2.69	37N33.45	118W54.96	7.80	3.8	22	54	1.9	0.07	0.5	0.5	A	D
267	310809	1559 31.45	37N33.40	118W55.51	7.77	3.25	22	58	2.5	0.18	1.2	1.3	B	X
268	310809	16 0 40.65	37N33.68	118W57.94	34.52	2.74	4	299	6.5	0.00	99.0	99.0	D	X
269	310809	16 1 10.45	37N33.25	118W55.00	8.29	3.26	20	55	2.3	0.06	0.4	0.5	A	X
270	310809	16 5 35.84	37N33.13	118W55.34	8.23	2.25	8	183	4.8	0.01	0.4	0.3	C	X
271	310809	16 7 32.41	37N37.54	118W55.24	11.76	2.07	4	134	2.1	0.00	99.0	99.0	D	X
272	310809	16 9 37.92	37N44.74	119W 8.66	7.97	2.64	5	323	17.6	0.43	99.0	99.0	D	X
273	310809	1613 16.72	37N37.33	118W55.50	7.59	2.60	16	66	2.7	0.10	0.8	1.0	A	X
274	310809	1620 57.90	37N33.21	118W55.57	7.92	2.09	10	97	2.8	0.02	0.3	0.5	B	X
275	310809	1627 22.25	37N37.24	118W55.82	13.84		4	124	1.9	0.00	99.0	99.0	D	
276	310809	17 6 56.71	37N33.95	118W53.98	5.00*	1.70	3	226	4.8	0.00	99.0	99.0	D	X
277	310809	1719 56.41	37N33.31	118W55.32	5.00*	1.86	3	198	3.5	0.00	99.0	99.0	D	X
278	310809	1811 23.73	37N33.32	118W54.44	7.99	2.59	15	76	3.7	0.03	0.6	0.7	A	X
279	310809	1816 27.23	37N33.75	118W54.56	5.80	1.64	5	91	4.3	0.03	10.2	39.4	D	X
280	310809	1936 39.05	37N39.02	118W52.47	5.00*	1.95	3	322	4.4	0.00	99.0	99.0	D	X
281	310809	23 1 50.34	37N33.32	118W54.57	6.35	1.97	5	186	4.4	0.01	17.5	53.7	D	X
282	310809	2344 13.25	37N33.31	118W55.95	5.00*	2.12	3	139	5.3	0.00	99.0	99.0	D	X
283	310810	016 25.97	37N29.27	119W 4.12	27.44	2.83	4	355	25.9	0.00	99.0	99.0	D	X
284	310810	632 44.07	37N33.75	118W54.17	7.32	2.21	10	109	3.6	0.03	0.6	0.3	B	X
285	310810	1421 50.75	37N36.38	118W54.69	5.00*	1.80	3	305	4.3	0.00	99.0	99.0	D	X
286	310810	1524 50.27	37N36.13	118W52.43	27.07*	2.83	4	258	7.3	0.03	99.0	99.0	D	X
287	310810	2331 17.91	37N38.21	118W52.49	4.22	1.61	4	205	1.8	0.00	11.2	18.1	D	X
288	310811	2 3 53.23	37N33.25	118W52.86	5.00*	1.43	3	245	2.0	0.00	99.0	99.0	D	X
289	310811	414 44.52	37N33.36	118W54.86	7.32	2.26	10	91	4.3	0.02	0.3	0.5	B	X
290	310811	512 37.50	37N33.08	118W54.88	6.80	2.09	9	145	4.1	0.03	0.5	1.1	B	X
291	310811	1853 41.54	38N35.23	119W30.73	5.00*	4.17	3	358	115.7	0.17	99.0	99.0	D	X
292	310811	1853 59.73	37N33.29	118W53.13	7.81	2.20	5	252	2.3	0.01	38.1	99.0	D	X
293	310811	1923 4.82	37N33.35	118W54.53	5.07	1.82	4	132	3.9	0.01	99.0	99.0	D	X

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#	DATE	ORIGIN	LAT	LONG	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	Q	T
294	310811	1958	30.03	37N37.25	118W50.44	0.81	1.41	4 140	1.2	0.00	2.2	2.1	0	X
295	310811	23 0	49.51	37N39.08	118W56.47	6.91	2.71	16 30	6.9	0.04	0.5	0.7	A	X
296	310811	23 3	51.54	37N39.10	118W55.16	5.00*	1.66	3 331	5.0	0.00	99.0	99.0	0	X
297	310812	5 5	5.67	37N39.21	118W54.97	5.00*	1.42	3 329	4.7	0.00	99.0	99.0	0	X
298	310812	751	20.73	37N39.02	118W56.05	3.02	1.93	4 154	5.7	0.00	15.9	99.0	0	X
299	310812	1020	28.66	37N25.34	119W 0.31	12.31	3.13	11 102	21.8	0.25	2.9	4.8	C	X
300	310812	2330	57.97	37N29.73	118W44.93	3.15	3.04	14 109	15.0	0.12	1.2	2.4	C	X
301	310813	039	13.12	37N25.52	118W41.43	4.74	2.47	8 327	24.2	0.02	10.7	22.6	0	X
302	310813	659	5.37	37N37.12	118W51.07	7.85	2.00	4 254	1.8	0.00	53.3	97.3	0	X
303	310813	9 5	48.01	37N37.56	118W53.79	4.72	1.86	10 161	2.3	0.03	0.5	0.6	B	X
304	310813	1017	27.52	37N34.28	118W52.48	4.34	1.71	7 277	5.5	0.02	2.0	1.5	C	X
305	310813	1527	41.72	37N32.35	118W49.45	4.16	2.58	14 166	8.3	0.03	1.1	1.3	B	X
306	310813	2031	21.97	37N31.78	118W52.80	5.24	3.37	18 103	10.1	0.10	1.1	2.4	B	X
307	310813	2356	30.27	37N31.59	118W52.79	3.83	2.44	11 134	10.3	0.05	1.7	2.6	C	X
308	310814	644	19.01	37N33.79	118W50.68	3.60	1.90	6 250	5.8	0.01	1.2	1.2	C	X
309	310814	719	8.97	37N29.17	118W48.74	13.63	2.85	14 107	15.8	0.05	1.2	1.7	B	X
310	310814	1146	1.73	37N37.93	118W54.73	7.82	2.21	5 197	6.7	0.00	6.4	10.1	0	X

APPENDIX V

Poisson's ratio determinations by Charles Real, CDMG seismologist. Event summary information is taken from well determined preliminary hypocentral solutions. Summary information listed for each event is date, origin time, latitude (N), longitude (W), depth (km), and HYP071 overall quality, in that order.

1 EVENT: 810809 1411 10.11 37. 38.65 118 51.59 3.14 A

	TP	S-P	σ	Δ	AZ	PRES	SRES
CLO3	.79	0.64	0.28	1.1	345	.01	.07
CLO1	1.12	0.96	0.30	2.8	202	.17	.41
CLO4	1.19	.80	0.22	4.2	288	.02	.06
CLO5	.88	.81	0.36	2.7	41	-.07	.03
CLO6	1.12	0.99	0.30	4.2	1	-.08	-.02
CLO8	0.94	0.61	0.21	3.0	85	-.05	-.19
CL11	1.66	1.20	0.25	6.7	103	.07	.07
CCEX	1.14	0.78	0.23	4.3	142	-.06	-.18
CCBR							

2 EVENT: 810809 1552 2.75 37 37.66 118 55.32 7.43 A

	TP	S-P	σ	Δ	AZ	PRES	SRES
CLO1	1.72	1.63	0.32	4.5	100	.05	.42
CLO3	1.78	1.40	0.27	6.0	61	-.06	-.03
CLO4	1.57	0.88	0.15	3.4	26	-.01	-.31
CLO5	2.02	1.57	0.27	8.2	62	-.09	-.09
CLO6	2.03	1.75	0.24	8.3	42	-.11	-.25
CLO8	2.09	1.59	0.26	8.8	76	-.09	-.13
CCEX	2.10	1.64	0.27	8.2	101	-.02	.04
CLO9	2.84	2.47	0.30	12.8	75	.06	.45
CL11	2.76	2.37	0.30	12.0	88	.12	.50
CCBR	2.41	2.28	0.32	10.8	57	-.07	.36
CLRL							
CHIL							
CLRM							
CUTC							
CHGX							
CHXC							

3 EVENT: 810809 1559 31.67 37 37.67 118 55.15 $\Sigma = 6.13$

	TP	S-P	σ	Δ	AZ	PRES	RES
CL01	1.63	1.46	0.31	4.3	100	.14	.48
CL04	1.39	0.78	0.15	3.3	23	-.00	-.26
CL05	1.86	1.59	0.30	8.0	61	-.11	.00
CL06	1.86	1.61	0.30	8.1	42	-.12	.00
CL03	1.73	1.20	0.23	5.8	130	.06	.01
CL08	1.93	1.46	0.26	8.5	76	-.12	-.20
CL09	2.68	2.38	0.31	12.6	75	.02	.40
CL11	2.63	2.37	0.31	11.9	89	.08	.54
CL1X	1.94	1.57	0.28	8.0	141	-.03	.06
CLRL	1.29	1.17	0.31	2.4	177	-.03	.15
CMIL	1.70	1.18	0.23	6.0	263	-.06	.46
CLKM	-	-	-	-	-	-	-
- CWTG	4.70	1.89	-0.04?	-	-	.89	-.23
CM6C	2.34	1.77	0.29	-	-	-.21	-.15
- CWTG	4.65	2.14	0.06?	-	-	.69	-.30

4 EVENT: 810809.1601 10.69 37. 37.86 118 54.89 $\bar{z} = 6.64$

STN	TP	S-P	σ	Δ	Az	PRES	SRES
CLO1	1.61	1.49	0.32	5.0	106	-0.09	.44
CLO3	1.62	1.36	0.29	5.2	61	-0.03	.09
CLO4	1.42	0.98	0.23	2.8	17	-0.0	-0.09
CLO6	1.90	1.47	0.27	7.5	41	-0.05	-0.05
CLO8	1.97	1.43	0.25	8.0	77	-0.04	-0.12
CCEX	1.98	1.54	0.27	7.7	104	.02	.09
CLO9	2.72	2.27	0.29	12.1	76	.11	.42
CL11	2.66	2.28	0.30	11.4	113	.16	.55
CLRL	—						
CMIL	1.70	1.36	0.28	6.5	261	-0.11	-0.11
CLKM	—						
CWTC	3.88	2.94	0.26			-0.07	-0.10
CMGC	—						
COHC	3.88	2.81	0.25			-0.09	-0.26

5 EVENT: 810809 1618 17.04 37 37.76 118 55.33 $\bar{z} = 6.16$

STN	TP	S-P	σ	Δ	Az	PRES	SRES
CLO3	1.65	0.93	0.15	5.9	62	-0.03	-0.36
CLO4	1.41	1.08	0.26	3.3	27	.02	.05
CLO6	1.89	1.56	0.29	8.2	43	-0.10	-0.04
CLO8	1.99	1.58	0.27	8.7	77	-0.08	-0.06
CL11	2.68	2.44	0.31	12.1	89	.10	.60
CCEX	1.97	1.70	0.30	8.3	102	-0.03	.17
CLRL	1.31	1.14	0.30	2.5	173	-0.02	.12
CMIL	1.64	1.22	0.26	3.3	27	-0.03	-0.07
CLKM	—						
CLJ9	—						

#6	810809	1050	47.77	37	39.26	118	51.86	3.97	13
	STN	T_p	$T_s - T_p$	σ	A	AZ	PRES	SRES	
	CL01	1.24	.80	.21	3.8	190	.06	-.03	
	CL03	0.81	0.66	.28	.2	125	-.06	-.05	
	CL04	1.14	0.81	.24	3.6	272	-.01	-.06	
	CL05	0.95	0.80	.29	2.3	68	-.04	.02	
	CL06	1.08	0.94	.30	3.1	9	-.01	.11	
	CL08	1.08	0.52	.08	?	104	-.06	-.40	
	CCEX								
	CCBR	1.34	0.79	.17	4.8	55	.01	-.20	

#7	810809	1543	36.84	37	38.09	118	55.58	6.76	B
	STN	T_p	$T_s - T_p$	σ	A	AZ	PRES	SRES	
	CL01	1.76	1.57	.31	5.0	108	.12	.46	
	CL03	1.75	1.30	.25	6.0	69	0.00	-.01	
	CL04	1.57	.93	.17	3.0	39	.12	-.04	
	CL05	2.02	1.50	.25	8.2	68	-.02	-.05	
	CL06	2.05	1.51	.25	8.0	48	.04	.04	
	CL08	2.08	1.54	.25	9.0	81	-.07	-.14	
	CL11	2.77	2.36	.29	12.4	92	.10	.46	
	CCEX	2.08	1.69	.28	8.8	105	-.04	.06	
	CCBR	2.43	2.18	.31	10.7	62	.03	.41	
	CLRL	1.51	1.49	.33	3.3	164	.04	.43	
	CMIL	1.50	1.63	.35	5.6	255	-.21	.14	

#8	810809	1600	44.83	37.37.57	118	55.50	6.7	B
STN	Tp	Ts-Tp	5	A	Az	PRES	SRES	
CLO5	2.05	1.60	0.27	8.5	61	-0.03	.01	
CLO4				3.7	28	-	-0.09	
CLRL	1.47	1.02	0.23	2.3	166	.08	.06	
CMIL	1.61	1.82	0.36	5.5	265	-0.08	.47	
CLKM				11.3	351	.04		

#9	810809	1620	38.09	37.37.84	118	55.55	6.76	B
STN	Tp	Ts-Tp	5	A	Az	PRES	SRES	
CLO4	1.47	1.15	.27	3.3	33	-0.01	.03	
CLO6	1.97	1.57	.28	8.3	46	-0.08	-0.05	
CLO8	2.07	1.73	.29	9.0	78	-0.09	.02	
CL11	2.77	2.39	.30	12.4	90	.11	.50	
CCEX	2.07	1.82	.30	8.6	102	-0.03	.21	
* CLO3	1.72	1.67	.33	6.1	65	-0.95	2.29	
CLRL	1.41	1.02	.25	2.8	167	-0.02	-0.08	
CMIL	1.69	1.41	.29	5.5	259	-0.01	.12	
CLKM	2.56	1.63	.20	10.8	350	.14	-0.05	

#10	810809	1706	57.10	37.38.32	118	55.09	2.51	B
STN	Tp	Ts-Tp	5	A	Az	PRES	SRES	
CCEX								
CLRL	0.96	1.01	.34	3.6	182	-0.10	.12	
CMIL	1.58	1.14	.25	6.4	253	.05	.05	
CLKM	2.11	1.61	.26	10.1	346	-0.03	-0.02	

#11 810809 1719 56.28 37 36.96 118 55.19 - 6.74 B
 STN T_p $T_s - T_p$ σ Δ AZ PRES SRES
 CCEX 7.8 7106
 CLRL 1.32 1.01 .26 1.1 176 -.02 -.01
 CMIL 1.76 1.34 .26 6.0 276 .01 .04
 CLKM 12.5 349 -101

#12 810809 1811 23.79 37 37.48 118 54.46 - 8.12 B
 STN T_p $T_s - T_p$ σ Δ AZ PRES SRES
 CL01 1.35 1.65 .32 3.1 98 .09 .50
 CL08 2.04 1.44 .24 7.5 71 -.06 -.19
 CL09 2.75 2.38 .30 11.6 72 .11 .51
 CCEX 2.05 1.59 .27 6.8 100 .04 .12
 CCBR 2.34 2.00 .30 9.8 52 -.05 .16
 CLRL 1.51 1.57 .34 2.3 209 -.11 .25
 CMIL 2.13 1.64 .27 7.1 267 .08 .18
 CLKM 2.70 1.61 .18 11.9 343 .02 -.38

#13 810809 1816 27.28 37 37.73 118 54.19 - 6.65 B
 STN T_p $T_s - T_p$ σ Δ AZ PRES SRES
 CL01 1.59 1.50 .32 2.9 108 .16 .59
 CL08 7.1 74 . . . -.06
 CCBR 2.21 2.01 .31 9.3 53 .02 .39
 CLRL 1.35 1.18 .30 2.8 210 -.07 .04
 CMIL 1.93 1.63 .29 7.5 264 -.00 .18
 CLKM 2.51 1.90 .26 11.5 341 -.01 .00

#14	810810	0639	44.09	37	38.38	118	54.27	7.8	B
	STN	Tp	Ts-Tp	σ	Δ	AZ	PRES	SRES	
	CLO3	1.57	1.42	0.31	4.0	66	-1.11	.05	
	CLO5	1.87	1.56	0.29	6.2	66	-1.03	.10	
	CLO6	1.83	1.51	0.29	6.3	40	-1.08	-.01	
	CLO8	1.92	1.62	0.29	7.0	83	-1.08	.04	
	CLO9	2.64	2.30	0.30	11.0	80	.11	.51	
	CCBR	2.24	1.93	0.30	8.8	59	.02	.28	
	CLRL				5.9	199	.05		
	CMIL	2.07	1.60	0.27	7.6	255	-.00	.04	
	CLKM				10.4	339	.16		
	CCEX				7.1	113		.20	

#14	810811	0414	44.50	37	37.66	118	54.68	8.08	B
	STN	Tp	Ts-Tp	σ	Δ	AZ	PRES	SRES	
	CLO1	1.78	1.61	0.31	3.6	102	.09	.43	
	CLO3	1.74	1.48	0.29	5.2	55	-.09	.02	
	CLO5	2.02	1.56	0.27	7.3	58	-1.05	-.04	
	CLO6	1.78	1.55	0.27	7.7	37	-.13	-.16	
	CLO8				7.8	74		-.09	
	CLO9	2.81	2.40	0.29					
	CCEX				7.3	58		-.05	
	CCBR	2.48	2.00	0.28	10.0	55	.07	.26	
	CMIL	1.77	1.40	0.24	6.8	264	-.03	-.13	
	CLKM	2.72	1.62	0.18	11.4	344	.10	-.25	
	CL11				11.1	88		.71	
	CLRL				2.5	196		.21	

#16	810811	0512	37.30	37	37.61	118	54.25	9.78	B
	STN	Tp	Ts-Tp	σ	Δ	Az	PRES	SRES	
	CLO1	1.91	1.67	0.30	3.0	103	.00	.24	
	CLO3	1.88	1.51	0.28	4.7	50	-.15	-.16	
	CLO5	2.16	1.58	0.25	6.9	55	-.07	-.16	
	CLO6	2.14	1.57	0.25	7.3	33	-.14	-.28	
	CCGX	2.19	1.82	0.29	6.7	102	-.01	.16	
	CCBR	2.66	1.85	0.23	9.5	52	.13	.08	
	CMIL	2.07	1.92	0.32	7.3	265	-.26	.00	
	CLRM				11.7	342	.11		
	CLRL	2.5	1.84	.0002	?	2.6	210	.61	.22
									BAD P

#17	810811	1928	04.76	37	37.59	118	53.74	7.02	B
	STN	Tp	Ts-Tp	σ	Δ	Az	PRES	SRES	
	CLO1	1.53	1.60	0.34	2.5	104	.08	.59	
	CLO6	1.84	1.53	0.29	7.2	30	-.09	-.01	
	CLO3				4.4	46		-.07	
	CLO5				6.5	52		-.04	
	CLRL				?	2.8	219	1.35	.24
									BAD P
	CMIL	1.93	1.44	0.26	7.8	266	-.09	-.17	
	CLRM	2.73	2.62	0.32	11.9	340	.12	.78	

Mammoth Lakes Volcanic Hazards
Velocity - σ
Poisson's Ration

EVENT	CL01	CL03	CL04	CL05	CL06	CL08	CL09	CL11	CCEX	CCBR	CLRL	CMIL	CLKH
1*	.30	.28	.22	.31	.30	.21	--	.25	.23	--	--	--	--
2	.32	.27	.15	.27	.24	.26	.30	.30	.27	.32	--	--	--
3	.31	.23	.15	.30	.30	.26	.31	.31	.28	--	.31	.23	--
4	.32	.29	.23	--	.27	.25	.29	.30	.27	--	--	.28	--
5	--	.15	.26	--	.29	.27	--	.31	.30	--	.30	.26	--
6*	.21	.28	.24	.29	.30	.08	--	--	--	.17	--	--	--
7	.31	.25	.17	.25	.25	.25	--	.29	.28	.31	.33	.35	--
8	--	--	--	.27	--	--	--	--	--	--	.23	.36	--
9	--	.33	.27	--	.28	.29	--	.30	.30	--	.25	.29	.20
10	--	--	--	--	--	--	--	--	--	--	.34	.25	.26
11	--	--	--	--	--	--	--	--	--	--	.26	.26	--
12	.32	--	--	--	--	.24	.30	--	.27	.30	.34	.27	.18
13	.32	--	--	--	--	--	--	--	--	.31	.30	.29	.26
14	--	.31	--	.29	.29	.29	.30	--	--	.30	--	.27	--
15	.31	.29	--	.27	.27	--	.29	--	--	.28	--	.24	.18
Mean	.316	.265	.205	.275	.274	.264	.298	.302	.281	.303	.296	.279	.216
σ	.005	.056	.055	.018	.021	.018	.008	.008	.013	.014	.040	.040	.041
S.E.	.002	.020	.022	.007	.007	.007	.003	.003	.005	.006	.013	.012	.018
RES**	.076	.025	.035	.035	.034	.024	.058	.062	.041	.063	.056	.039	-.024

* NOT INCLUDED IN MEANS - DIFFERENT LOCATION

** σ_{OB} - σ_{MOD} $\sigma_{MOD} = .24$

APPENDIX VI

CDMG FOCAL MECHANISM SUMMARY - DOE LONG VALLEY, CA. ARRAY

PAGE F 1

TABLE OF EVENTS CONTRIBUTING TO EACH FOCAL MECHANISM

DATE	ORIGIN	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	QS
MECHANISM 1:												
810808	503	0.16	37N38.88	118W51.17	3.51	1.78	8	97	1.1	0.03	0.5	1.1 B
810809	1050	47.88	37N39.36	118W51.54	4.04	1.67	7	92	0.4	0.02	0.5	1.4 B
810809	1411	10.07	37N38.74	118W51.30	3.10	1.87	9	76	1.1	0.05	0.6	1.4 A
MECHANISM 2:												
810702	1420	43.82	37N38.39	118W51.07	7.63	2.80	12	74	1.9	0.07	0.6	0.6 A
MECHANISM 3:												
810702	1348	57.64	37N38.33	118W50.78	8.37	2.86	12	100	2.0	0.08	0.9	0.6 B
MECHANISM 4:												
810702	1407	27.45	37N38.16	118W50.77	8.16	2.73	13	80	2.2	0.07	0.7	0.5 A
MECHANISM 5:												
810718	438	24.39	37N36.37	118W49.46	9.88	2.46	8	179	1.0	0.04	1.3	0.9 C
MECHANISM 6:												
810731	959	12.00	37N35.90	118W48.50	4.33	2.44	15	124	2.6	0.06	0.7	0.8 B
MECHANISM 7:												
810803	130	58.30	37N36.33	118W50.53	10.01	2.67	13	102	1.4	0.10	1.3	1.0 B
MECHANISM 8:												
810807	513	17.01	37N36.99	118W50.15	5.58	1.67	9	158	0.6	0.03	0.7	0.9 B
MECHANISM 9:												
810709	541	3.02	37N37.33	118W52.25	10.52	2.68	10	100	0.2	0.02	0.3	0.4 B
MECHANISM 10:												
810807	943	22.07	37N37.32	118W52.88	6.08	2.07	12	145	0.9	0.04	0.6	0.8 B

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CDMG FOCAL MECHANISM SUMMARY - DOE LONG VALLEY, CA. ARRAY

PAGE F 2

DATE	ORIGIN	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	QS
MECHANISM 11:												
810806	452	22.33	37N38.10	118W52.88	6.16	2.42	17	57	1.8	0.06	0.5	0.7 A
810806	454	56.55	37N38.02	118W52.74	6.19	2.08	11	74	1.6	0.03	0.4	0.5 A
810806	640	59.88	37N38.09	118W52.81	6.17	2.05	11	73	1.7	0.03	0.4	0.6 A
MECHANISM 12:												
810727	1249	1.43	37N37.83	118W53.69	7.76	2.65	14	69	2.3	0.05	0.5	0.5 A
MECHANISM 13:												
810725	437	59.33	37N37.82	118W53.72	8.45	2.49	8	111	2.3	0.04	0.9	1.3 B
MECHANISM 14:												
810809	1601	10.45	37N38.25	118W55.00	8.29	3.26	20	55	2.3	0.06	0.4	0.5 A
MECHANISM 14:												
810809	1601	10.45	37N38.25	118W55.00	8.29	3.26	20	55	2.3	0.06	0.4	0.5 A
MECHANISM 15:												
810809	1618	16.79	37N37.83	118W55.50	7.59	2.60	16	66	2.7	0.10	0.8	1.0 A
MECHANISM 16:												
810730	2329	6.95	37N38.03	118W55.82	7.71	2.38	10	97	3.2	0.04	0.6	0.9 B
MECHANISM 17:												
810712	1933	49.48	37N38.18	118W56.15	6.26	2.85	14	63	3.6	0.06	0.5	0.7 A
MECHANISM 18:												
810710	2027	48.76	37N38.23	118W56.33	6.38	3.30	14	62	3.8	0.09	0.7	0.9 A
MECHANISM 19:												
810709	1625	23.79	37N38.42	118W56.20	5.23	2.61	11	70	4.1	0.04	0.5	1.1 A
MECHANISM 20:												
810709	1452	35.55	37N38.69	118W55.91	7.00	3.08	14	67	4.4	0.06	0.6	0.7 A
MECHANISM 20:												
810709	1452	35.55	37N38.69	118W55.91	7.00	3.08	14	67	4.4	0.06	0.6	0.7 A
MECHANISM 21:												
810809	1559	31.45	37N38.40	118W55.51	7.77	3.25	22	58	2.5	0.18	1.2	1.3 B

CDMG FOCAL MECHANISM SUMMARY - DOE LONG VALLEY, CA. ARRAY

PAGE F 3

DATE	ORIGIN	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	QS
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MECHANISM 21:

810809	1559	31.45	37N38.40	118W55.51	7.77	3.25	22	58	2.5	0.18	1.2	1.3 B
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MECHANISM 22:

810705	242	1.53	37N38.50	118W55.17	7.28	3.04	15	72	3.9	0.06	0.5	0.5 A
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MECHANISM 22:

810705	242	1.53	37N38.50	118W55.17	7.28	3.04	15	72	3.9	0.06	0.5	0.5 A
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MECHANISM 22:

810705	242	1.53	37N38.50	118W55.17	7.28	3.04	15	72	3.9	0.06	0.5	0.5 A
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MECHANISM 23:

810809	1552	2.69	37N38.45	118W54.96	7.80		22	54	1.9	0.07	0.5	0.5 A
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MECHANISM 23:

810809	1552	2.69	37N38.45	118W54.96	7.80		22	54	1.9	0.07	0.5	0.5 A
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MECHANISM 23:

810809	1552	2.69	37N38.45	118W54.96	7.80		22	54	1.9	0.07	0.5	0.5 A
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MECHANISM 24:

810813	2031	21.97	37N31.78	118W52.80	5.24	3.37	18	103	10.1	0.10	1.1	2.4 B
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MECHANISM 25:

810806	2231	8.66	37N31.41	118W49.33	10.96	3.36	18	105	10.1	0.10	1.4	1.4 B
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103

1: NS2E, 60NW & N26W, 70NE

2: N34E, 60SE & N56W, 90

3: N41E, 64SE & N63W, 65NE

4: N33E. 70SE & N61W. 75NE

S: N20E, 55SE & N46W, 60SW

6: N10E, 90 & N80W, 70N

7: N32E, 70SE & N81E, 30N

8: N24E, 90 & N67W, 85NE

9: N62W, 60SW & N62W, 30NE

10: N14E, 90 & N76W, 90

11: N37W, 65SW & N 8W, 28E

12: N21E, 44NW & N61W, 90NE

13: N70W, 90 & N20E, 45NW

14: N20E, 90 & N70W, 90

14: N 7E, 60W & N67W, 64NE

15: N56W, 40SW & N42W, 51NE

16: N41E, 38SE & N84W, 66N

17: N13W, 80W & N80E, 70N

18: N38W, 40SW & N90E, 60N

19: N61W, 42SW & N84W, 50N

20: N67W, 90 & N23E, 60NW

20: N18W, 47W & N83W, 65N

21: N44E, 90 & N47W, 80NE

21: N19E, 65W & N56W, 60NE

22: N64W, 90 & N26E, 65NW

22: N10W, 60W & N80W, 60N

22: N58E, 78SE & N58E, 12NW

23: N32E, 50SE & N57W, 90

23: N 2W, 70W & N80W, 60N

23: N16W, 70W & N16W, 20E

24: N50W, 40SW & N50W, 50NE

25: N65E, 85SE & N24W, 84SW

Appendix VII

Spectral tabulations and selected plots from UC Riverside report by Don Stierman. Table I of this appendix differs from Table 5 of the text in that preliminary hypocentral parameters and magnitudes are listed in Table I (and in this appendix) while final values are listed in Table 5.

TABLE I

SUMMARY, SOURCE PARAMETERS MAMMOTH LAKES MICROEARTHQUAKES

DAY	HR:MN	LATITUDE (N)	LONGITUDE (W)	FOCAL DEPTH (km)	MAG	MOMENT (dyne-cm)	SOURCE RADIUS (km)	STRESS DROP (bars)	N
183	13:48	37-38.79	118-50.68	7.13	2.4	5.94E+19	0.21	2.87	5
183	14:07	37-38.30	118-49.81	8.29	2.4	2.61E+19	0.18	1.87	6
186	2:36	37-37.97	118-55.29	7.23	2.1	1.67E+19	0.29	0.31	5
186	2:42	37-37.96	118-55.24	6.72	2.6	5.44E+19	0.23	1.96	6
186	3:52	37-38.10	118-55.22	5.92	2.2	1.75E+19	0.18	1.30	6
187	17:28	37-33.77	118-57.33	2.58	2.0	6.13E+18	0.14	1.00	4
189	14:22	37-38.27	118-57.09	7.98	2.1	8.79E+18	0.21	0.40	5
190	5:41	37-37.31	118-52.71	7.77	2.4	1.43E+19	0.17	1.31	6
190	12:46	37-37.41	118-52.93	7.84	2.0	3.60E+18	0.13	0.73	5
190	12:46	37-38.49	118-55.98	5.96	2.4	3.19E+19	0.18	2.32	6
190	13:38	37-38.48	118-54.79	1.99	1.7	3.90E+18	0.15	0.48	3
191	21:12	37-34.23	118-47.22	4.12	1.7	7.06E+18	0.16	0.74	5
204	21:57	37-38.82	118-51.97	5.58	1.8	3.47E+18	0.15	0.42	3
218	4:52	37-37.84	118-52.97	5.24	2.2	1.74E+19	0.21	0.84	10
218	4:54	37-37.81	118-53.09	5.01	2.3	3.38E+19	0.15	4.65	6
233	9:17	37-39.53	118-50.87	2.66	1.5	7.95E+17	0.19	0.052	4
234	14:11	37-38.71	118-51.98	0.61	2.2	7.09E+18	0.20	0.38	5

Table II

EQ1

183

13:48

MOMENT = 5.93836535E+19 DYNE-CM

FOCAL DEPTH = 7.1 KM

STRESS DROP = 2.87289298 BARS

SOURCE RADIUS = 20834.1206 CM

CL01: 5.6E-05 7.88 HZ -4.02 MOMENT = 5.83777597E+19 16541.6254 3.7
 L03: 4.79E-05 7.4 HZ -2.86 MOMENT = 4.56825943E+19 17614.5957 1.8
 CL08: 4.275E-05 5.04 HZ -2.54 MOMENT = 4.05117951E+19 25862.7001 1.6
 CL09: 4.28E-05 6.47 HZ -4.47 MOMENT = 5.03931088E+19 20146.5237 5.6
 CCB: 1.255E-04 5.43 HZ -3.86 MOMENT = 1.35638731E+20 24005.1581 4.3

EQ2

183

14:07

MOMENT = 2.61251777E+19 DYNE-CM

FOCAL DEPTH = 8.3 KM

STRESS DROP = 1.87244356 BARS

SOURCE RADIUS = 18275.7914 CM

L03: 4.065E-05 9.13 HZ -2.56 MOMENT = 4.72756979E+19 14276.8903 3.3
 CL01: 5.45E-06 10.49 HZ -3.44 MOMENT = 6.56927278E+18 12425.9303 4.1
 L08: 6.6E-05 5.13 HZ -2.18 MOMENT = 7.18425664E+19 25408.9685 1
 L09: 4.675E-05 6.84 HZ -4.48 MOMENT = 5.80610605E+19 19056.7264 4.7
 CCB: 1.475E-04 5.6 HZ -3.78 MOMENT = 1.82248626E+20 23276.4301 4.6
 CEX: 1.185E-06 8.57 HZ -3.45 MOMENT = 1.34669491E+18 15209.8026 2.7

EQ3

186

2:36

MOMENT = 1.67258368E+19 DYNE-CM

FOCAL DEPTH = 7.2 KM

STRESS DROP = .314816629 BARS

SOURCE RADIUS = 28538.8246 CM

CB: 2.055E-05 3.34 HZ -3.05 MOMENT = 3.38455987E+19 39026.3498 10.4
 L08: 1.02E-05 3.22 HZ -2.53 MOMENT = 1.47944542E+19 40480.748 8.5
 CL03: 1.23E-05 5.86 HZ -3.2 MOMENT = 1.46082152E+19 22243.6875 5.6
 CEX: 8.75E-06 5.67 HZ -3.76 MOMENT = 1.25183196E+19 22989.0667 8.3
 CL01: 1.285E-05 7.26 HZ -3.86 MOMENT = 1.42953549E+19 17954.2711 4.6

Table II (cont.)

EQ4

186

2:41

MOMENT = 5.43580663E+19 DYNE-CM

FOCAL DEPTH = 6.7 KM

STRESS DROP = 1.95674678 BARS

SOURCE RADIUS = 22991.5972 CM

CCBR: 4.215E-05 4.44 HZ -3.08 MOMENT = 6.74353587E+19 29357.6596 10.3
 CCEX: 4.63E-05 6.09 HZ -3.62 MOMENT = 6.38369729E+19 21403.6139 8.2
 CL09: 2.505E-05 5.64 HZ -4.13 MOMENT = 4.62580515E+19 23111.349 12.5
 CL08: 2.975E-05 4.45 HZ -2.61 MOMENT = 4.19246999E+19 29291.6873 8.5
 CL03: 3.86E-05 7.56 HZ -3.13 MOMENT = 4.38871735E+19 17241.8001 5.6
 CL01: 6.7E-05 7.43 HZ -4.25 MOMENT = 7.04091436E+19 17543.4735 4.5

EQ5

186

3:52

MOMENT = 1.75331109E+19 DYNE-CM

FOCAL DEPTH = 5.9 KM

STRESS DROP = 1.29521486 BARS

SOURCE RADIUS = 18092.4927 CM

CCBR: 8.05E-06 8.38 HZ -4.39 MOMENT = 1.23509171E+19 15554.6549 10.2
 CCEX: 2.235E-05 5.4 HZ -3.46 MOMENT = 2.93977718E+19 24138.5201 8.2
 CL09: 1.35E-05 5.18 HZ -3.59 MOMENT = 2.41379538E+19 25163.7082 12.4
 CL08: 6.25E-06 7.77 HZ -3.52 MOMENT = 8.35350795E+18 16775.8055 8.4
 CL03: 1.745E-05 11.18 HZ -5.37 MOMENT = 1.81724712E+19 11659.0347 5.4
 CL01: 2.26E-05 8.54 HZ -4.13 MOMENT = 2.18351875E+19 15263.2328 4.5

EQ6

187

17:28

MOMENT = 6.12984674E+18 DYNE-CM

FOCAL DEPTH = 2.6 KM

STRESS DROP = .998614025 BARS

SOURCE RADIUS = 13899.8465 CM

CL03: 3.275E-06 12.04 HZ -3.94 MOMENT = 5.65329579E+18 10826.2465 13
 CL08: 1.445E-06 9.61 HZ -3.22 MOMENT = 2.80869479E+18 13563.7886 14.7
 CCEX: 8.1E-06 8.05 HZ -4.16 MOMENT = 1.32590574E+19 16192.2992 12.3
 CCBR: 2.895E-06 8.68 HZ -4.29 MOMENT = 6.70624675E+18 15017.0517 17.6

Table II (cont.)

EQ7

89

14:23

MOMENT = 8.78574828E+18 DYNE-CM

FOCAL DEPTH = 8 KM

STRESS DROP = .404999362 BARS

SOURCE RADIUS = 21172.2733 CM

CL03: 4.895E-06 9.51 HZ -3.9 MOMENT = 7.2108766E+18 13706.4152 8
 CCEX: 1.085E-05 5.14 HZ -2.99 MOMENT = 1.91011755E+19 25359.5347 10.9
 CL01: 3.87E-06 10.29 HZ -4.4 MOMENT = 5.45722476E+18 12667.4449 7.3
 CL08: 3.645E-06 4.62 HZ -2.72 MOMENT = 6.49370323E+18 28213.8546 11.1
 CCBR: 5.55E-06 5.03 HZ -3.84 MOMENT = 1.07246055E+19 25914.117 12.5

EQ8

190

5:41

MOMENT = 1.42821582E+19 DYNE-CM

FOCAL DEPTH = 7.8 KM

STRESS DROP = 1.31036295 BARS

SOURCE RADIUS = 16831.6528 CM

CL01: 1.14E-05 11.07 HZ -4.75 MOMENT = 1.16547181E+19 11774.8878 .9
 CL03: 8.55E-06 10.73 HZ -4.53 MOMENT = 9.70836524E+18 12147.9971 3.9
 CL08: 1.695E-05 6.61 HZ -3.58 MOMENT = 2.11916877E+19 19719.8197 5.6
 CCEX: 6.25E-06 9.2 HZ -3.98 MOMENT = 7.3691488E+18 14168.2618 4.6
 CCBR: 2.31E-05 7.44 HZ -4.12 MOMENT = 3.44778396E+19 17519.8936 8.4
 CL09: 8.65E-06 5.08 HZ -3.61 MOMENT = 1.3931318E+19 25659.0568 9.6

EQ9

190

12:46

MOMENT = 3.1869283E+19 DYNE-CM

FOCAL DEPTH = 6 KM

STRESS DROP = 2.32096006 BARS

SOURCE RADIUS = 18178.6193 CM

CL01: 1.975E-05 10.82 HZ -4.57 MOMENT = 2.16393783E+19 12046.9509 5.9
 CL03: 4.39E-05 8.17 HZ -3.46 MOMENT = 4.97295072E+19 15954.4686 6.3
 CL08: 1.925E-05 6.53 HZ -3.56 MOMENT = 2.79512653E+19 19961.4102 9.4
 CL09: 1.66E-05 5.29 HZ -3.78 MOMENT = 3.17338349E+19 24640.4553 13.4
 CCEX: 2.105E-05 6.94 HZ -3.74 MOMENT = 3.07962741E+19 18782.1338 9.5
 CCBR: 2.2E-05 7.37 HZ -4.47 MOMENT = 3.56412206E+19 17686.2969 10.9

Table II (cont.)

G06

EQ10A

190 12:46
MOMENT = 3.60430848E+18 DYNE-CM
FOCAL DEPTH = 7.8 KM
STRESS DROP = .732251095 BARS
SOURCE RADIUS = 12913.5801 CM

CL01: 4.18E-06 11.65 HZ -4.6 MOMENT = 4.27339665E+18 11188.6703 .9
CL03: 1.77E-06 11.37 HZ -3.44 MOMENT = 1.98961575E+18 11464.2048 3.7
CL08: 1.295E-06 8.41 HZ -2.7 MOMENT = 1.61906995E+18 15499.1687 5.6
CCEX: 5.1E-06 9.63 HZ -4.24 MOMENT = 6.01322542E+18 13535.6187 4.6
CCBR: 4.955E-06 10.12 HZ -5.03 MOMENT = 7.34842473E+18 12880.238 8.3

EQ10B

190 12:46
MOMENT = 4.78048785E+18 DYNE-CM
FOCAL DEPTH = 7.8 KM
STRESS DROP = .717391419 BARS
SOURCE RADIUS = 14285.5851 CM

CCBR: 3.935E-06 7.98 HZ -3.49 MOMENT = 5.83573186E+18 16334.3369 8.3
CCEX: 2.76E-06 6.69 HZ -3.52 MOMENT = 3.25421611E+18 19484.0072 4.6
CL08: 1.165E-05 9.4 HZ -2.7 MOMENT = 1.45653783E+19 13866.8094 5.6
CL03: 1.765E-06 12.5 HZ -3.96 MOMENT = 1.98399536E+18 10427.8407 3.7
CL01: 4.45E-06 11.52 HZ -4.4 MOMENT = 4.54942944E+18 11314.9313 .9

Table II (cont.)

G07

EQ11

190 13:38
 MOMENT = 3.89992425E+18 DYNE-CM
 FOCAL DEPTH = 2 KM
 STRESS DROP = .477364605 BARS
 SOURCE RADIUS = 15289.5489 CM

CCBR: 4.05E-06 6.83 HZ -4.06 MOMENT = 5.01632539E+18 19084.6279 9.3
 CL08: 4.305E-06 8.15 HZ -3.58 MOMENT = 4.45934513E+18 15993.6207 7.7
 CL03: 4.06E-06 12.08 HZ -4.81 MOMENT = 2.65162274E+18 10790.3981 4.6

EQ12

191 21:12
 MOMENT = 7.05751568E+18 DYNE-CM
 FOCAL DEPTH = 4.1 KM
 STRESS DROP = .741205179 BARS
 SOURCE RADIUS = 16090.2881 CM

CL01: 5.75E-06 10.74 HZ -4.75 MOMENT = 7.6093645E+18 12136.6861 9.3
 CL08: 6.75E-06 14.74 HZ -4.95 MOMENT = 8.77217778E+18 8843.14847 9.1
 CL09: 8.9E-07 9.42 HZ -2.94 MOMENT = 1.19904093E+18 13837.3682 9.5
 CCEX: 9.5E-06 9.47 HZ -3.5 MOMENT = 9.09141071E+18 13764.3092 6.1
 CCBR: 1.415E-05 4.09 HZ -3.11 MOMENT = 2.4062356E+19 31869.9287 12.4

EQ13

199 16:28
 MOMENT = 3.51067365E+18 DYNE-CM
 FOCAL DEPTH = 8.4 KM
 STRESS DROP = .711854307 BARS
 SOURCE RADIUS = 12921.8829 CM

CCEX: 5.75E-06 11.53 HZ -4.73 MOMENT = 6.58330764E+18 11305.1178 2.6
 CL08: 2.495E-06 7.77 HZ -2.39 MOMENT = 2.94391593E+18 16775.8055 3.4
 CL03: 1.33E-06 14.09 HZ -3.81 MOMENT = 1.55055782E+18 9251.10068 3.1
 CL01: 4.54E-06 9.08 HZ -3.49 MOMENT = 5.05480407E+18 14355.5075 1.6

Table II (cont.)

G08

EQ14
 204 21:57
 MOMENT = 3.46560192E+18 DYNE-CM
 FOCAL DEPTH = 5.6 KM
 STRESS DROP = .417373495 BARS
 SOURCE RADIUS = 15372.4807 CM

CL03: 3.97E-06 11.28 HZ -3.82 MOMENT = 2.92412463E+18 11555.6745 .8
 CL08: 6.8E-06 6.64 HZ -3.09 MOMENT = 5.84698984E+18 19630.7242 3.5
 CCEX: 2.535E-06 8.73 HZ -3.58 MOMENT = 2.43448889E+18 14931.0434 4.8

EQ15
 218 4:52
 MOMENT = 1.73965176E+19 DYNE-CM
 FOCAL DEPTH = 5.24 KM
 STRESS DROP = .842935137 BARS
 SOURCE RADIUS = 20823.2609 CM

CL01: 2.85E-05 7.2 HZ -3.93 MOMENT = 2.02259545E+19 18103.8901 1.5
 CL03: 7.84E-06 13.3 HZ -4.89 MOMENT = 6.21503644E+18 9800.60214 3.1
 CL05: 7.05E-05 4.54 HZ -2.98 MOMENT = 6.71219932E+19 28711.0151 5.1
 CL06: 3.78E-05 6.66 HZ -3.73 MOMENT = 3.95790672E+19 19571.773 6.1
 CL08: 1.58E-05 4.76 HZ -2.98 MOMENT = 1.53327523E+19 27384.0354 5.3
 CL09: 8.68E-06 4.42 HZ -3.27 MOMENT = 1.20643159E+19 29490.4996 9.3
 CL11: 1.16E-05 5.8 HZ -3.44 MOMENT = 1.50817766E+19 22473.7946 8.5
 CCEX: 1.4E-05 7 HZ -3.74 MOMENT = 1.30775195E+19 18621.1441 4.9
 CCBR: 1.18E-05 6.72 HZ -4.28 MOMENT = 1.44373285E+19 19397.0251 7.8
 CL04: 1.79E-05 8.88 HZ -3.49 MOMENT = 1.44328636E+19 14678.8298 3.3

Table II (cont.)

EQ16

218

4:54

MOMENT = 3.37603734E+19 DYNE-CM

FOCAL DEPTH = 5.01 KM

STRESS DROP = 4.65084948 BARS

SOURCE RADIUS = 14698.8832 CM

CL03: 3.225E-05 12.2 HZ -4.53 MOMENT = 2.49628397E+19 10684.263 3.2

CL11: 2.88E-05 7.56 HZ -4.08 MOMENT = 3.76471243E+19 17241.8001 8.7

CL05: 2.32E-04 7.61 HZ -3.27 MOMENT = 2.20309777E+20 17128.5162 5.3

CL01: 9E-05 8.09 HZ -3.82 MOMENT = 6.16310781E+19 16112.2384 1.6

CL02: 3.16E-05 9.07 HZ -4.24 MOMENT = 2.94151339E+19 14371.335 5.1

CL04: 5.05E-06 10.3 HZ -4.13 MOMENT = 3.94469371E+18 12655.1464 3.3

EQ17

223

9:17

MOMENT = 7.9539239E+17 DYNE-CM

FOCAL DEPTH = 2.7 KM

STRESS DROP = .0524472591 BARS

SOURCE RADIUS = 18790.8127 CM

CL03: 1.165E-06 11.26 HZ -3.81 MOMENT = 4.61346441E+17 11576.1997 1.4

CL05: 1.01E-05 6.51 HZ -2.79 MOMENT = 3.66810328E+18 20022.7356 .7

CL06: 1.395E-06 8.89 HZ -4.13 MOMENT = 6.93558905E+17 14662.3182 2.7

CL08: 7.25E-07 4.51 HZ -1.86 MOMENT = 3.41015128E+17 28901.9974 2.4

EQ18

234

14:11

MOMENT = 7.09513228E+18 DYNE-CM

FOCAL DEPTH = .61 KM

STRESS DROP = .37643291 BARS

SOURCE RADIUS = 20203.0524 CM

CL03: 4.19E-06 10.78 HZ -3.78 MOMENT = 6.39053603E+17 12091.652 1

CL05: 8.61E-05 6.51 HZ -3.87 MOMENT = 3.43203724E+19 20022.7356 3

CL06: 3.435E-05 7.3 HZ -4.42 MOMENT = 1.85393817E+19 17855.8916 4.1

CL08: 1.495E-05 4.99 HZ -3.06 MOMENT = 7.10756527E+18 26121.8454 3.6

CL09: 6.35E-06 5.23 HZ -3.05 MOMENT = 6.22152849E+18 24923.1374 7.5

Table III

G10

EQ1

183

13:48

MOMENT = 5.93836535E+19 DYNE-CM

FOCAL DEPTH = 7.1 KM

STRESS DROP = 2.87289298 BARS

SOURCE RADIUS = 20834.1206 CM

CL01:	4.215E-06	20.5	-4.27	5.6E-05	7.88	-4.02	3.7
CL03:	1.14E-05	8.66	-2.75	4.79E-05	7.4	-2.86	1.8
CL08:	1.315E-05	7.25	-3.81	4.275E-05	5.04	-2.54	1.6
CL09:	9.45E-06	6.82	-3.6	4.28E-05	6.47	-4.47	5.6
CCBR:	1.615E-05	9.7	-5.13	1.255E-04	5.43	-3.86	4.3

EQ2

183

14:07

MOMENT = 2.61251777E+19 DYNE-CM

FOCAL DEPTH = 8.3 KM

STRESS DROP = 1.87244356 BARS

SOURCE RADIUS = 18275.7914 CM

CL03:	7.5E-06	13.5	-3.47	4.065E-05	9.13	-2.56	3.3
CL01:	6.55E-06	22.87	-5.59	5.45E-06	10.49	-3.44	4.1
CL08:	1.19E-05	9.05	-2.03	6.6E-05	5.13	-2.18	1
CL09:	9.65E-06	7.95	-3.83	4.675E-05	6.84	-4.48	4.7
CCBR:	1.955E-05	10.1	-3.56	1.475E-04	5.6	-3.78	4.6
CCEX:	2.605E-07	20.87	-3.17	1.185E-06	8.57	-3.45	2.7

EQ3

186

2:36

MOMENT = 1.67258368E+19 DYNE-CM

FOCAL DEPTH = 7.2 KM

STRESS DROP = .314816629 BARS

SOURCE RADIUS = 28538.8246 CM

CCBR:	4.745E-11	3.25	-2.42	2.055E-05	3.34	-3.05	10.4
CL08:	2.44E-06	4.32	-3.13	1.02E-05	3.22	-2.53	8.5
CL03:	5.2E-06	3.6	-2.18	1.23E-05	5.86	-3.2	5.6
CCEX:	0 0 0	8.75E-06	5.67	-3.76	8.3		
CL01:	0 0 0	1.285E-05	7.26	-3.86	4.6		

Table III (cont.)

EQ4

186

2:41

MOMENT = 5.43580663E+19 DYNE-CM

FOCAL DEPTH = 6.7 KM

STRESS DROP = 1.95674678 BARS

SOURCE RADIUS = 22991.5972 CM

CCBR:	1.165E-05	7.04	-3.05	4.215E-05	4.44	-3.08	10.3
CCEX:	1.55E-06	19.67	-6.03	4.63E-05	6.09	-3.62	8.2
CL09:	3.94E-06	8	-4.16	2.505E-05	5.64	-4.13	12.5
CL08:	8.45E-06	5.87	-2.67	2.975E-05	4.45	-2.61	8.5
CL03:	7.85E-06	9.98	-3.18	3.86E-05	7.56	-3.13	5.6
CL01:	3.015E-06	21.15	-6.46	6.7E-05	7.43	-4.25	4.5

EQ5

186

3:52

MOMENT = 1.75331109E+19 DYNE-CM

FOCAL DEPTH = 5.9 KM

STRESS DROP = 1.29521486 BARS

SOURCE RADIUS = 18092.4927 CM

CCBR:	7.7E-06	8.01	-4.15	8.05E-06	8.38	-4.39	10.2
CCEX:	8.9E-07	17.51	-5.63	2.235E-05	5.4	-3.46	8.2
CL09:	1.455E-06	8.91	-4.39	1.35E-05	5.18	-3.59	12.4
CL08:	3.855E-06	8.75	-4.59	6.25E-06	7.77	-3.52	8.4
CL03:	8.55E-06	5.77	-2.39	1.745E-05	11.18	-5.37	5.4
CL01:	1.06E-06	16.04	-3.17	2.26E-05	8.54	-4.13	4.5

EQ6

187

17:28

MOMENT = 6.12984674E+18 DYNE-CM

FOCAL DEPTH = 2.6 KM

STRESS DROP = .998614025 BARS

SOURCE RADIUS = 13899.8465 CM

CL03:	1.785E-06	9.49	-2.71	3.275E-06	12.04	-3.94	13
CL08:	8.9E-07	8.97	-2.52	1.445E-06	9.61	-3.22	14.7
CCEX:	3.26E-07	19.68	-6.1	8.1E-06	9.05	-4.16	12.3
CCBR:	9.55E-07	10.09	-3.26	2.895E-06	8.68	-4.29	17.6

Table III (cont.)

EQ7

189

14:23

MOMENT = 8.78574828E+18 DYNE-CM

FOCAL DEPTH = 8 KM

STRESS DROP = .404999362 BARS

SOURCE RADIUS = 21172.2733 CM

CLO3: 2.185E-06 6.41 -2.32 4.895E-06 9.51 -3.9 8

CCEX: 0 0 0 1.085E-05 5.14 -2.99 10.9

CLO1: 0 0 0 3.87E-06 10.29 -4.4 7.3

CLO8: 0 0 0 3.645E-06 4.62 -2.72 11.1

CCBR: 0 0 0 5.55E-06 5.03 -3.84 12.5

EQ8

190

5:41

MOMENT = 1.42821582E+19 DYNE-CM

FOCAL DEPTH = 7.8 KM

STRESS DROP = 1.31036295 BARS

SOURCE RADIUS = 16831.6528 CM

CLO1: 1.55E-06 20.59 -5.94 1.14E-05 11.07 -4.75 .9

CLO3: 1.495E-05 9.04 -2.25 8.55E-06 10.73 -4.53 3.9

CLO8: 3.5E-06 5.6 -2.79 1.695E-05 6.61 -3.58 5.6

CCEX: 2.11E-05 16.12 -5.1 6.25E-06 9.2 -3.98 4.6

CCBR: 3.4E-06 11.13 -4.6 2.31E-05 7.44 -4.12 8.4

CLO9: 0 0 0 8.65E-06 5.08 -3.61 9.6

EQ9

190

12:46

MOMENT = 3.1869283E+19 DYNE-CM

FOCAL DEPTH = 6 KM

STRESS DROP = 2.32096006 BARS

SOURCE RADIUS = 18178.6193 CM

CLO1: 4.4E-06 10.84 -3.49 1.975E-05 10.82 -4.57 5.9

CLO3: 1.215E-05 6.35 -2.07 4.39E-05 8.17 -3.46 6.3

CLO8: 5.7E-06 7.43 -3.11 1.925E-05 6.53 -3.56 9.4

CLO9: 2.175E-06 8.81 -4.15 1.66E-05 5.29 -3.78 13.4

CCEX: 2.485E-06 7.44 -2.24 2.105E-05 6.94 -3.74 9.5

CCBR: 6E-06 9.98 -3.77 2.2E-05 7.37 -4.47 10.9

Table III (cont.)

EQ10A

190

12:46

MOMENT = 3.60430848E+18 DYNE-CM

FOCAL DEPTH = 7.8 KM

STRESS DROP = .732251095 BARS

SOURCE RADIUS = 12913.5801 CM

CL01:	5.05E-07	17.27	-3.61	4.18E-06	11.65	-4.6	.9
CL03:	6.75E-07	18.39	-4.95	1.77E-06	11.37	-3.44	3.7
CL08:	8.4E-07	13.36	-3.12	1.295E-06	8.41	-2.7	5.6
CCEX:	7.15E-07	19.06	-4.17	5.1E-06	9.63	-4.24	4.6
CCBR:	9.6E-07	10.6	-3.93	4.955E-06	10.12	-5.03	8.3

EQ10B

190

12:46

MOMENT = 4.78048785E+18 DYNE-CM

FOCAL DEPTH = 7.8 KM

STRESS DROP = .717391419 BARS

SOURCE RADIUS = 14285.5851 CM

CCBR:	9.05E-07	10.98	-3.87	3.935E-06	7.98	-3.49	8.3
CCEX:	7.3E-07	18.94	-4.27	2.76E-06	6.69	-3.52	4.6
CL08:	8.4E-07	9.06	-2.18	1.165E-05	9.4	-2.7	5.6
CL03:	7.2E-07	9.96	-2.26	1.765E-06	12.5	-3.96	3.7
CL01:	3.74E-07	21.34	-4.67	4.45E-06	11.52	-4.4	.9

Table III (cont.)

EQ11

190

13:38

MOMENT = 3.89992425E+18 DYNE-CM

FOCAL DEPTH = 2 KM

STRESS DROP = .477364605 BARS

SOURCE RADIUS = 15289.5489 CM

CCBR: 6.65E-07 12.8 -3.87 4.05E-06 6.83 -4.06 9.3
 CL08: 0 0 0 4.305E-06 8.15 -3.58 7.7
 CL03: 1.805E-06 9.41 -3.38 4.06E-06 12.08 -4.81 4.6

EQ12

191

21:12

MOMENT = 7.05751568E+18 DYNE-CM

FOCAL DEPTH = 4.1 KM

STRESS DROP = .741205179 BARS

SOURCE RADIUS = 16090.2881 CM

CL01: 9.45E-07 21.63 -6.5 5.75E-06 10.74 -4.75 9.3
 CL08: 9.15E-07 23.18 -3.9 6.75E-06 14.74 -4.95 9.1
 CL09: 1.035E-06 12.17 -3.83 8.9E-07 9.42 -2.94 9.5
 CCEX: 1.29E-06 18.13 -4.24 9.5E-06 9.47 -3.5 6.1
 CCBR: 0 0 0 1.415E-05 4.09 -3.11 12.4

EQ13

199

16:28

MOMENT = 3.51067365E+18 DYNE-CM

FOCAL DEPTH = 8.4 KM

STRESS DROP = .711854307 BARS

SOURCE RADIUS = 12921.8829 CM

CCEX: 7E-07 20.3 -4.93 5.75E-06 11.53 -4.73 2.6
 CL08: 1.235E-06 11.22 -3.13 2.495E-06 7.77 -2.39 3.4
 CL03: 4.85E-07 19.5 -5.57 1.33E-06 14.09 -3.81 3.1
 CL01: 6E-07 23.47 -5 4.54E-06 9.08 -3.49 1.6

EQ14

204

21:57

MOMENT = 3.46560192E+18 DYNE-CM

FOCAL DEPTH = 5.6 KM

STRESS DROP = .417373495 BARS

SOURCE RADIUS = 15372.4807 CM

CL03: 1.32E-06 13.55 -4.14 3.97E-06 11.28 -3.82 .8

CL08: 9.35E-07 16 -3.84 6.8E-06 6.64 -3.09 3.5

CCEX: 0 0 0 2.535E-06 8.73 -3.58 4.8

EQ15

218

4:52

MOMENT = 1.73965176E+19 DYNE-CM

FOCAL DEPTH = 5.24 KM

STRESS DROP = .842935137 BARS

SOURCE RADIUS = 20823.2609 CM

CL01: 2.29E-06 21.16 -4.84 2.85E-05 7.2 -3.93 1.5

CL03: 4.12E-06 20.26 -5.68 7.84E-06 13.3 -4.89 3.1

CL05: 1.05E-05 10.13 -3.81 7.05E-05 4.54 -2.98 5.1

CL06: 0 0 0 3.78E-05 6.66 -3.73 6.1

CL08: 3.68E-06 8.48 -3.16 1.58E-05 4.76 -2.98 5.3

CL09: 0 0 0 8.68E-06 4.42 -3.27 9.3

CL11: 3.6E-06 7.53 -3.78 1.16E-05 5.8 -3.44 8.5

CCEX: 7.33E-07 16.8 -4.39 1.4E-05 7 -3.74 4.9

CCBR: 2.66E-06 10.8 -4.15 1.18E-05 6.72 -4.28 7.8

CL04: 0 0 0 1.79E-05 8.88 -3.49 3.3

Table III (cont.)

EQ16

218

4:54

MOMENT = $3.37603734E+19$ DYNE-CM

FOCAL DEPTH = 5.01 KM

STRESS DROP = 4.65084948 BARS

SOURCE RADIUS = 14698.8832 CM

CL03: 1.745E-05 11.3 -3.85 3.225E-05 12.2 -4.53 3.2

CL11: 1.44E-05 6.85 -3.19 2.88E-05 7.56 -4.08 8.7

CL05: 1.83E-04 9.72 -3.68 2.32E-04 7.61 -3.27 5.3

CL01: 7E-06 20 -4.86 9E-05 8.09 -3.82 1.6

CCEX: 4.925E-06 19.2 -6.31 3.16E-05 9.07 -4.24 5.1

CL04: 0 0 0 5.05E-06 10.3 -4.13 3.3

EQ17

223

9:17

MOMENT = $7.9539239E+17$ DYNE-CM

FOCAL DEPTH = 2.7 KM

STRESS DROP = .0524472591 BARS

SOURCE RADIUS = 18790.8127 CM

CL03: 1.135E-07 17.9 -3.86 1.165E-06 11.26 -3.81 1.4

CL05: 1.3E-06 12 -3.07 1.01E-05 6.51 -2.79 .7

CL06: 0 0 0 1.395E-06 8.89 -4.13 2.7

CL08: 2.885E-07 14.2 -3.47 7.25E-07 4.51 -1.86 2.4

EQ18

234

14:11

MOMENT = $7.09513228E+18$ DYNE-CM

FOCAL DEPTH = .61 KM

STRESS DROP = .37643291 BARS

SOURCE RADIUS = 20203.0524 CM

CL03: 8.05E-07 13.34 -3.54 4.19E-06 10.78 -3.78 1

CL05: 4.44E-06 10.96 -3.92 8.61E-05 6.51 -3.87 3

CL06: 4.17E-06 8.41 -3.06 3.435E-05 7.3 -4.42 4.1

CL08: 3.105E-06 7.5 -2.25 1.495E-05 4.99 -3.06 3.6

CL09: 6.65E-07 7.13 -3.26 6.35E-06 5.23 -3.05 7.5

log amplitude (cm/sec)
126

CL03
DAY 218 - 4:52
LEVEL = 4.12316634E-6 CORNER = 20.2556459427
SPECTRAL DECAY = -5.68498482059
DELTA = 3.100001KM: Z = 5.24KM
AZIMUTH OF RAY: 34
COMPONENT = VR - 0

619

CL05
DAY 218 - 4:52
LEVEL = $7.045388899 \times 10^{-5}$ CORNER = 4.54096437213
SPECTRAL DECAY = -2.98419061264
DELTA = 5.100001KM: Z=5.24KM
AZIMUTH OF RAY: 47
COMPONENT = HR TRANSVERSE ELEMENTS

131

622

CL06
DAY 218 - 4:52
LEVEL = $3.775199402 \times 10^{-5}$ CORNER = 6.65641474694
SPECTRAL DECAY = -3.73415127403
DELTA = 6.100001KM: Z=5.24KM
AZIMUTH OF RAY: 20
COMPONENT = HR TRANSVERSE ELEMENTS

G23

CL08
DAY 218 - 4:52
LEVEL =3.673955474E-6 CORNER =8.48456783824
SPECTRAL DECAY =-3.16082664736
DELTA =5.300001KM: Z=5.24KM
AZIMUTH OF RAY:70
COMPONENT = VR - 0

G24

CL09
DAY 218 - 4:52
LEVEL = $8.682279984E-6$ CORNER = 4.41777064756
SPECTRAL DECAY = -3.27060132292
DELTA = $9.300001KM$: Z = $5.24KM$
AZIMUTH OF RAY: 72
COMPONENT = HR TRANSVERSE ELEMENTS

G26

135

CL11
DAY 218 - 4:52
LEVEL = $3.595573353E-6$ CORNER = 7.53394622319
SPECTRAL DECAY = -3.77706227942
DELTA = 8.5KM: Z = 5.24KM
AZIMUTH OF RAY: 90
COMPONENT = VR - 0

G27

137

-3

-4

-5

-6

-7

-8

-9

CL11
DAY 218 - 4:52
LEVEL = $1.157000925E-5$ CORNER = 5.79524612086
SPECTRAL DECAY = -3.43695798291
DELTA = 8.5KM: Z = 5.24KM
AZIMUTH OF RAY: 90
COMPONENT = HR TRANSVERSE ELEMENTS

G28

140

CCBR
DAY 218 - 4:52
LEVEL = 2.659699349E-6 CORNER = 10.8004578413
SPECTRAL DECAY = -4.1489260421
DELTA = 7.800001KM: Z = 5.24KM
AZIMUTH OF RAY: 46
COMPONENT = VR - 0

G31

CCBR
DAY 218 - 4:52
LEVEL = $1.179037138E-5$ CORNER = 6.71604128144
SPECTRAL DECAY = -4.28069891347
DELTA = 7.800001KM : $Z=5.24\text{KM}$
AZIMUTH OF RAY: 46
COMPONENT = HR TRANSVERSE ELEMENTS

632

141

CL04
DAY 218 - 4:52
LEVEL = $1.794465568 \times 10^{-5}$ CORNER = 8.8762200693
SPECTRAL DECAY = -3.48770731702
DELTA = 3.300001KM: Z=5.24KM
AZIMUTH OF RAY: 325
COMPONENT = HR TRANSVERSE ELEMENTS

G33

143

CLKM
DAY 218 - 4:52
LEVEL =5.250602237E-6 CORNER =7.94514031136
SPECTRAL DECAY =-4.27678991153
DELTA =12KM: Z=5.24KM
AZIMUTH OF RAY:332
COMPONENT = VR - 0

G34

CLRL
DAY 218 - 4:52
LEVEL =5.280800513E-6 CORNER =4.19389118289
SPECTRAL DECAY =-2.6168540084
DELTA =4.2KM: Z=5.24KM
AZIMUTH OF RAY:230
COMPONENT = VR - 0

635

CMIL
DAY 218 - 4:52
LEVEL = 2.225107191E-6 CORNER = 6.81924251677
SPECTRAL DECAY = -4.02209644903
DELTA = 9.2KM: Z = 5.24KM
AZIMUTH OF RAY: 264
COMPONENT = VR - 0

G36

145

INVERSION EPICENTERS

PLATE I

DOE DATA: MAMMOTH, CA INVERSION LOCATIONS

PLANE PROJECTION BASED ON RICHTER'S SHORT DISTANCE FORMULAS
SCALE = 1/82500

MAGNITUDE

① 0.0 TO 3.9

— Faults from Taylor and Bryant (1980)

● Shot Locations

(DATA SOURCES ARE: FOR 1900-1931, CONG SPECIAL REPORT 136; FOR 1932-1974, CALTECH AND U.C. BERKELEY FOR SOUTHERN AND NORTHERN CALIFORNIA RESPECTIVELY; AND SINCE 1968, THE USGS FOR CENTRAL CALIFORNIA. A COMPREHENSIVE CATALOG OF CALIFORNIA EARTHQUAKES IS AVAILABLE ON MAGNETIC TAPE AND MICROFICHE FROM CONG.)

P-WAVE ONLY EPICENTERS FOR EVENTS USED IN INVERSION

PLATE II

DOE DATA: MAMMOTH, CA
P-WAVE ONLY LOCATIONS

PLANE PROJECTION BASED ON RICHTER'S SHORT DISTANCE FORMULAS
SCALE = 1/82500

MAGNITUDE

Faults from Taylor and Bryant (1980)

DATA SOURCES ARE: FOR 1900-1931, COMD SPECIAL REPORT 135; FOR 1932-1974, CALTECH AND U.C. BERKELEY FOR SOUTHERN AND NORTHERN CALIFORNIA RESPECTIVELY; AND SINCE 1969, THE USGS FOR CENTRAL CALIFORNIA. A COMPREHENSIVE CATALOG OF CALIFORNIA EARTHQUAKES IS AVAILABLE ON MAGNETIC TAPE AND MICROFILME FROM COMD.

1 JULY - 14 AUG 1981

QUAL. A-C

PLATE III

DOE DATA: MAMMOTH, CA
1 JULY - 14 AUG, 1981 QUAL. A-C
PLANE PROJECTION BASED ON RICHTER'S SHORT DISTANCE FORMULAS
SCALE = 1/62500

MAGNITUDE

Faults from Taylor and Bryant (1980)

(DATA SOURCES ARE: FOR 1900-1931, COMG SPECIAL REPORT 135; FOR 1932-1974, CALTECH AND U.C. BERKELEY FOR SOUTHERN AND NORTHERN CALIFORNIA RESPECTIVELY; AND SINCE 1980, THE USGS FOR CENTRAL CALIFORNIA. A COMPREHENSIVE CATALOG OF CALIFORNIA EARTHQUAKES IS AVAILABLE ON MAGNETIC TAPE AND MICROFICHE FROM COMG.)

PLATE IV

P-WAVE STN. CORRECTION

PLATE V

PLATE VI

DCE DATA: MAMMOTH, CA FOCAL MECHANISMS

PLANE PROJECTION BASED ON RICHTER'S SHORT DISTANCE FORMULAS
SCALE = 1/62500

MAGNITUDE

0	 1.0 TO 1.9
1	 2.0 TO 2.9
2	 3.0 TO 3.9

(DATA SOURCES ARE: FOR 1900-1931, COWG SPECIAL REPORT 138; FOR 1941-1974, CALTECH AND U.C. BERKELEY FOR SOUTHERN AND NORTHERN CALIFORNIA RESPECTIVELY; AND SINCE 1969, THE USGS FOR CENTRAL CALIFORNIA. A COMPREHENSIVE CATALOG OF CALIFORNIA EARTHQUAKES IS AVAILABLE ON MAGNETIC TAPE AND MICROFILM FROM COWG.)

SCALE : 1:62500

Complete Bouguer gravity map (Long Valley Caldera)
 Modified from: Oster + Robbins (1977)
 Contour Interval: 5 mgals (KANE 1., 1976)

PLATE VII

137° 30'

SCALE = 1:62,500

High-level residual magnetic intensity map (LVC)
 (KANE et al., 1976) Datum 51,895 gammas - IGRF removed.
 Contour interval: 10 gammas

PLATE VIII

SCALE 1:62500
 Low-level total magnetic intensity map (LVC)
 Mag. contours from Pakiser et al. (1964) (KANE et al, 1976)
 Contour interval: 50 gammas (arbitrary datum)

PLATE IX

SCALE 1:62500

Composite total field resistivity map (LVC)
Contours in ohm-meters (Stanley et. al, 1976)

PLATE X

119°00'

118°55'

118°50'

118°45'
7 37°45'

The 8-Hz apparent resistivity map, Long Valley, California. Values are in ohm meters; contours are dashed where they are approximate. (HOOVER et al., 1976)

PLATE XI

SCALE: 1:62500

+ 37°35'

119° 00'

118° 55'

118° 50'

118° 45'
7 37° 45'

SCALE : 1 : 62500

The 26-Hz apparent resistivity map, Long Valley, California (electric line East-West).
Values are in ohm-meters; contours are dashed where they are approximate.
(HOOVER et al., 1976)

PLATE VII

119°00'

118°55'

118°50'

118°45'
37°45'

26 HZ APPARANT RESISTIVITY MAP, LONG VALLEY, CALIFORNIA (ELECTRIC LINE NORTH - SOUTH).

VALUES ARE IN OHM-METERS, CONTOURS DASHED WHERE APPROXIMATE (HOOVER et al., 1976)

SCALE: 1:62500

PLATE XIII

119°00'

118°55'

118°50'

118°45'
37°45'

7000 Hz APPARANT RESISTIVITY MAP, LONG VALLEY, CALIFORNIA. VALUES IN OHM-METERS, CONTOURS DASHED WHERE APPROXIMATE. (HOOVER et al., 1976)

SCALE: 1:62500

PLATE XIV

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160

+ 37°35'