Section II: Analysis Procedures

Upgrade of the Data Analysis and Research Computer Systems

We continued the development of new data analysis procedures appropriate for the broadband data on SUN computer system during 1992. A program for manipulation of the waveform data was developed by Andrew Yu, an undergraduate student working for the Seismographic Station and the Center for Computational Seismology at the Lawrence Berkeley Laboratory. 'Seistool' is a simple program for basic seismological operations such as phase picking, waveform rotation, and spectral analysis. This program is used for the daily analysis of local, regional, and teleseismic earthquake data.

Local Magnitude

The UC Berkeley determination of local magnitude (M_L) is traditionally based on the measurements from analog records of Wood-Anderson instruments located at four sites in northern and central California (BKS, MHC, ARC, and MIN) using station corrections designed to bring the mean UCB M_L in agreement with the mean Caltech M_L (Bolt and Miller, 1975) (Table 7). Careful calibration of these instruments has been conducted (Uhrhammer and Collins, 1990) to enable synthesizing the Wood-Anderson response using modern broadband instruments. An extensive comparison of maximum amplitudes from real and synthethic Wood-Andersons recorded at ARC, MHC, and BKS found that magnitudes from synthetic records correlate consistently with magnitudes generated from analog records; a preliminary comparison of waveforms is also satisfactory. As a result of this study (Anderson et al., 1993), the Wood-Anderson instruments were turned off at these three stations on January 15, 1993 (see Table 2). A similar study was conducted for the the Wood-Anderson instrument recorded at MIN and this site was terminated on January 16, 1994 (Uhrhammer et al., 1995).

Table 7: WOOD-ANDERSON M_L CORRECTIONS

Station	Traditional Correction	Synthetic Correction
ARC	+0.2	+0.11
BKS	0.0	0.00
CMB	*	+0.20
HOPS	*	**
JRSC	*	**
MHC	+0.1	+0.03
MIN	-0.1	-0.05
ORV	*	+0.46
PKD1	*	-0.29
SAO	*	+0.21
STAN	*	-0.29
WDC	*	+0.47
YBH	*	+0.37

* indicates that the correction did not exist
** indicates that the correction is not determined

In 1993, the Seismographic Station replaced the 'traditional' Wood-Anderson readings for the determination of local magnitude with those determined from synthesized records using the stations corrections presented in Table 7. Two magnitudes are computed for each event - one based on BKS, MIN, ARC, and MIN and one based on the average of all BDSN stations. The first magnitude is a continuation of the traditional Berkeley M_L using modern methods, while the second is a more robust estimate based on the entire network. The 'network average' is the magnitude reported to the public.

The M_L values reported in this Bulletin were obtained from the traditional measurement procedures from photographic records. The 1993 bulletin will mark the transition to the synthetic Wood-Anderson magnitudes.

Moment-Magnitude and Moment Tensor Solutions

The 1990-1991 Bulletin marked the introduction of moment-magnitude and moment-tensor solutions as part of the routine analysis procedures at the Seismographic Station. The ability to determine these parameters is a result of the enhanced capability of the digital broadband network. Moment-magnitude is a valuable parameter as it provides a more robust estimate of earthquake size than the traditional local magnitude. The determination of moment tensor solutions by waveform inversion, as opposed to P-wave first motions, provides more reliable estimates of faulting parameters, especially when an event is located offshore or near the edge of a network.

Three different methods of determining moment magnitude and moment-tensor solutions are in use at the Seismographic Station. The first approach utilizes the ramps and steps of a near field recording to invert for source parameters; the second employs full waveform modeling from a single or multiple stations; and the third uses surface waves recorded at regional distances. These methods are described in Romanowicz et al. (1993).

Earthquake Location and Origin Time

In the current Bulletin, the epicenters are located individually using the best possible distribution of stations (in both azimuth and distance), an appropriate velocity model, and a set of station adjustments from the tables below. Where possible both P- and S-wave onset times are used. However, the readings of P arrivals greatly outnumber those of S arrivals. Output from the analysis of BDSN waveforms is combined with phase picks from the USGS Northern California Seismic Network and incorporated in the location program developed by Dr. Robert Uhrhammer, 'st-relp', for the determination of event origin time and hypocenter.

Group Location Method

Northern and central California are provisionally divided up into five regions (Figure 7) for grouping the earthquakes. Special areas where there have been numerous earthquakes (Halls Valley, Coalinga, Bishop, Santa Cruz Mountains) have their own regions, velocity models and station adjustments (Table 8). For a group of selected earthquakes within each region, the group location procedure simultaneously locates the hypocenters, estimates the station adjustments, and determines the velocity model. A brief description of the program, called GHYP2, is given in Appendix A of Volume 47, No. 1. Once the station adjustments and velocity parameters are known, the hypocenter locations are individually determined using the program st-relp. The station adjustments, velocity models, and groups are occasionally revised as required.

Table 8: SOLUTION GROUPS

Region	Region Name	Number of Earthquakes 1992
a	Northern Coast	304
b	Northern California	4
c	Ukiah-Willits	23
d	Central Coast	90
e	Sierra Nevada	101
h	Halls Valley	4
k	Coalinga	11
m	Mammoth	0
s	Bishop	6
z	Santa Cruz Mtns	23
o	Outside	1

Station Adjustments

The station adjustments for the nine regions used in this Bulletin are given in Table 9. The station adjustments are in the form of P/S in units of tenths of seconds. These station adjustments are to be added to the calculated travel times.

Table 9: STATION ADJUSTMENTS

STATION	Region a	b	c	d	e	h	k	m	s	z
ARC	-2/-9									
BKS	1/15		0/5	-1/1					11/	-1/3
BRK	1/0		2/5	-1/1		1/			-2/	-2/1
CMB										
EKR										
FHC	-1/-7	3/10	11/		1/-1					
FOX										
FRI				0/-6			-2	-5/32	0/-4	2/-6
GCC			-2/	-4/-5		2/			1/0	1/-5
KVN										
LLA				-2/0		-6/	-2/	-9/	6/	-2/-1
MHC			-1/	2/1		0/	3/	-21/	5/	6/1
MIN	-2/15	-2/0	3/3					-7/18	2/	
ORV	-1/13	-4/-3	-5/-7	-6/					5/	-5/
PCC	0/		-1/6	-4/-4		-3/			0/	-2/-4
PKD1										
PRI				3/3		-1/			1/26	6/3
PRS				-2/-4		-2/	2/		4/	-2/-4
SAO				-2/		2/	5/		5/	-5/
STAN										
WDC	0/7	-5/0	-4/4							
ZSP	-2/		0/6	1/6					13/	1/6

Velocity Models

Initially, three primary velocity models were developed, the first for region a, the second for regions b and e (the Sierra model described in Appendix B of Volume 48), and the third for regions c and d (the coastal model described in Volume 47). The velocity models are defined by a layer with a linear velocity gradient ($v_o = a + bz$) over a halfspace ($v_1 = c$) where a is the velocity at the top of the layer, b is the velocity gradient, and c is the velocity in the halfspace. In this Bulletin, four velocity models are used for locating the hypocenters in the nine regions. The parameters for the velocity models are given in Table 10. Figure 7 illustrates the regionalization employed by the Seismographic Station.

Table 10: VELOCITY MODELS

Region	P-wave a (km/sec)	P-wave b (1/sec)	P-wave c (km/sec)	S-Wave a (km/sec)	S-Wave b (1/sec)	S-Wave c (km/sec)	Layer Thickness (km)
a	5.24	.068	7.98	3.03	.039	4.61	25.
b,e,m,s	6.00	.024	7.85	3.46	.014	4.53	45.
c,d,h,z	5.28	.075	7.70	2.98	.043	4.36	25.
k	5.20	.120	7.50	2.20	.042	4.50	18.

Velocity Models For Northern California

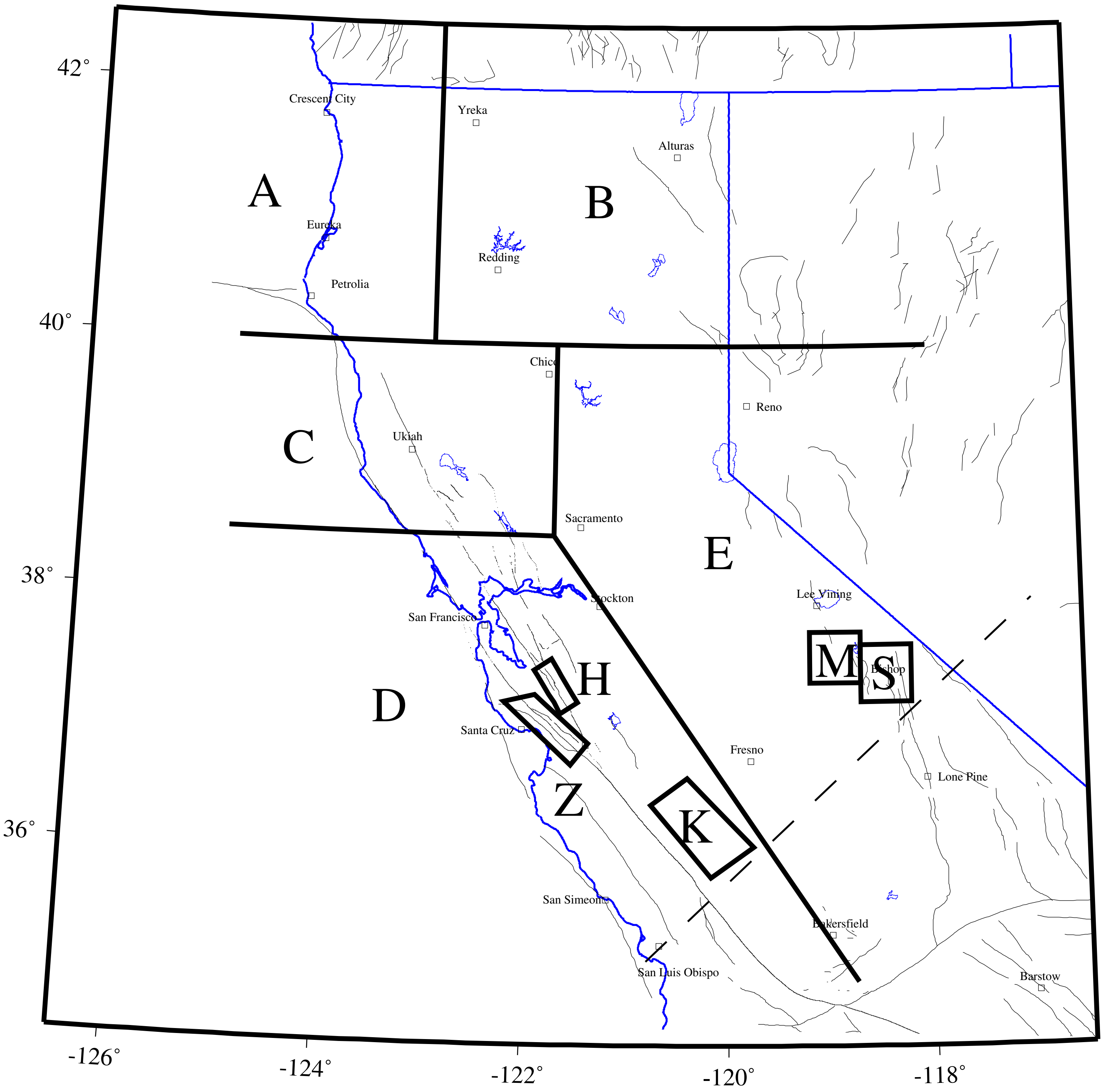

Figure 7: Velocity model regionalization for earthquake location