Earthquake Catalog for the Utah Region

January 1, 1986 to December 31, 1988

Susan J. Nava
James C. Pechmann
Walter J. Arabasz
Ethan D. Brown
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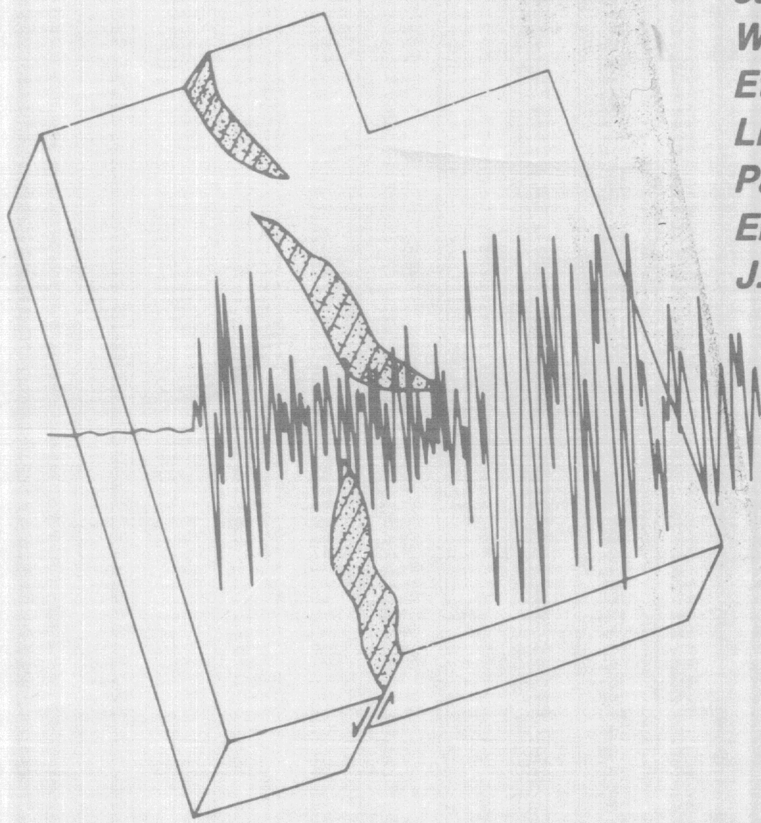

UUSS

UNIVERSITY OF UTAH SEISMOGRAPH STATIONS
DEPARTMENT OF GEOLOGY AND GEOPHYSICS
UNIVERSITY OF UTAH

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July 1990

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PREVIOUS CATALOGS OF EARTHQUAKES IN THE UTAH REGION

Earthquake data for the specified time periods may be found in the following publications of the University of Utah Seismograph Stations:

1850 - 1978: Arabasz, W.J., R.B. Smith, and W.D. Richins, Editors (1979). *Earthquake Studies in Utah, 1850 - 1978*, University of Utah Seismograph Stations, Salt Lake City, Utah, 552 pp.

1978 - 1980: Richins, W.D., W.J. Arabasz, G.M. Hathaway, P.J. Oehmich, L.L. Sells, and G. Zandt (1981). *Earthquake Data for the Utah Region: July 1, 1978 to December 31, 1980*, University of Utah Seismograph Stations, Salt Lake City, Utah, 127 pp.

1981 - 1983: Richins, W.D., W.J. Arabasz, G.M. Hathaway, E. McPherson, P.J. Oehmich, and L.L. Sells (1984). *Earthquake Data for the Utah Region: January 1, 1981 to December 31, 1983*, University of Utah Seismograph Stations, Salt Lake City, Utah, 111 pp.

1984 - 1985: Brown, E.D., W.J. Arabasz, J.C. Pechmann, E. McPherson, L.L. Hall, P.J. Oehmich, and G.M. Hathaway (1986). *Earthquake Data for the Utah Region: January 1, 1984 to December 31, 1985*, University of Utah Seismograph Stations, Salt Lake City, Utah, 83 pp.

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PREFACE

This report continues a modern series of special publications begun by the University of Utah Seismograph Stations in 1979 (Arabasz *et al.*, 1979) when a revised compilation was presented of all available earthquake data for the Utah region from 1850, the date of publication of the first newspaper in Utah, through June 1978. This report extends the published record of earthquake activity in the Utah region through the years 1986, 1987, and 1988 (for 1978 - 1985, see page *iv*).

Although seismographic recording at the University of Utah's Salt Lake City campus began as early as 1907, instrumental surveillance of local earthquakes effectively dates from 1962 when the first three stations of a Utah network began continuous operation. The term "University of Utah Seismograph Stations" (UUSS) originally implied the small group of earthquake-recording installations of the 1960's, but now refers to an organizational entity. In effect, the UUSS is a research, educational, and public-service group that forms an integral part of a larger seismological research and teaching program within the Department of Geology and Geophysics of the University of Utah.

The earthquake information in this report was made possible by financial support from a number of organizations and agencies. During the 1986-1988 period, the most significant support for the operation of the University of Utah seismic network—and for associated earthquake research—was provided by the National Earthquake Hazards Reduction Program of the U.S. Geological Survey, by the State of Utah, and by the U.S. Bureau of Reclamation. This includes: U.S. Geological Survey Cooperative Agreement Nos. 14-08-0001-A0265, 14-08-0001-A0621, 14-08-0001-G1163, and 14-08-0001-G1349; and U.S. Bureau of Reclamation Cooperative Agreement Nos. 6-PG-40-05650 and 7-FC-40-04770. Partial support for operation of the University of Utah's Worldwide Standardized Seismograph Station at Dugway, Utah, was provided by the U.S. Geological Survey, Branch of Global Seismology and Geomagnetism.

A key factor contributing to successful earthquake surveillance in the Utah region is the cooperation received from various seismological groups in the recording and location of local and regional earthquakes. UUSS directly records continuous seismic data from seismographic stations operated by: 1) the U.S. Geological Survey, Branch of Global Seismology and Geomagnetism, Golden, Colorado; 2) the U.S. Geological Survey, Branch of Geologic Risk Assessment, Golden, Colorado; 3) the Idaho National Engineering Laboratory, Idaho Falls, Idaho; 4) Ricks College, Rexburg, Idaho; and 5) Snow College, Ephraim, Utah. Also, seismic arrival-time data were kindly provided upon request for stations operated during the report period in southeastern Utah by Woodward-Clyde Consultants of San Francisco, California, in the Utah-Colorado border region by the U.S. Bureau of Reclamation and the U.S. Geological Survey, in the Teton Range of western Wyoming and eastern Idaho by the U.S. Bureau of Reclamation, and in northern Arizona by Northern Arizona University, Flagstaff, Arizona.

We sincerely thank all the individuals and organizations whose efforts, encouragement, cooperation, and financial assistance make possible the ongoing earthquake research and seismic network operations reflected in this report. We thank all the members of the seismology research group at the University of Utah for their contributing efforts and R.B. Smith for his supportive involvement. We also thank R. Clothier for operating station PTI on a volunteer basis. Parts of this report are adapted from earlier UUSS publications, to which W.D. Richins made substantial contributions.

Salt Lake City, Utah
July 1990

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INTRODUCTION

The purpose of this report is to summarize data compiled by the University of Utah Seismograph Stations (UUSS) for local earthquakes in the Utah region during the period January 1, 1986 through December 31, 1988. The term "Utah Region," as used in this report, signifies the rectangular area extending from latitude 36°45′N to 42°30′N, and from longitude 108°45′W to 114°15′W. This report is basically a continuation of previous catalogs of earthquake hypocentral and magnitude data (see page *iv*).

Since 1974, the UUSS has operated a telemetered network of high-gain short-period seismic stations in the Intermountain region. During 1974-1980, data from this network were centrally recorded at the University of Utah in Salt Lake City, primarily on 16-mm analog film recorders (Develocorders). On January 1, 1981, a computer system (described elsewhere in this report) provided by the U.S. Geological Survey for on-line digital recording of the network data became fully operational and the analog film recording was discontinued. In December 1988, the UUSS network consisted of 77 stations, 26 of which were funded and maintained by other agencies. Local earthquake coverage extends throughout most of Utah—with a focus on the densely-populated Wasatch Front area—southeastern Idaho, and western Wyoming (Figure 1). Earthquake data (1986-1988) for the region of Yellowstone National Park are reported separately (see Smith *et al.*, 1987; Nagy *et al.*, 1989a; Nagy *et al.*, 1989b).

The heart of this report is a catalog of instrumentally located earthquakes for the Utah region from 1986 through 1988. Background information relevant to technical details of the catalog is provided in the preliminary sections (see Arabasz *et al.* [1979]) for additional background).

The Appendices represent updated summaries that were begun in the 1979 volume of this series. They include abstracts from a selection of pertinent University of Utah graduate theses and a bibliography of selected seismological publications resulting from research at the University of Utah during the period of this report.

STATION DATA AND INSTRUMENTATION

The seismic network recorded by the UUSS in December 1988 (see Figure 1) consists of 77 short-period stations, 26 of which are operated and maintained by other agencies. Essential information for each station is summarized in Tables 1 and 2. All of the stations are equipped with vertical-component seismometers, and four stations (DUG, GMU, HVU, and JLU) are also equipped with two horizontal-component seismometers. The vertical-component seismometers at HVU and JLU are recorded at two different gain levels. Station DUG operates as part of the Worldwide Standardized Seismograph Network (WWSSN), and it has six short-period components (three components with low and high gain) telemetered to the University of Utah. All stations are centrally recorded at the University of Utah. The network has an approximate station spacing of 15 to 35 km in north-central Utah and 30 to 100 km in central and southwestern Utah. Six of the stations operated during the time period of this report were portable telemetry stations that were moved around to supplement stations in areas of special interest or high seismic activity (Tables 1 and 2). Table 3 lists other supplemental recording stations where portable seismographs (MEQ's) were deployed for short time periods immediately following four moderate earthquakes that occurred during the report period.

The instrumentation in the UUSS network is illustrated in the block diagram in Figure 2. Data from each seismometer are telemetered via telephone, microwave, and/or radio data transmission links to a central recording facility located on the University of Utah campus in Salt Lake City. The standard instrumentation at each field site consists of a vertical seismometer with a natural frequency of 1.0 Hz, an amplifier/voltage controlled oscillator (VCO) package, a 100-milliwatt radio transmitter, a 9 db gain directional Yagi antenna, and interfacing electronics powered by air-cell batteries or solar electric panels. The central recording facility incorporates a bank of discriminators, a time code receiver, 12 drum recorders, and a PDP 11/34 computer.

At each field site, the seismometer acts as a transducer to convert ground motion to an electrical signal, which is amplified and converted into a frequency-modulated (FM) audio tone within the amplifier/VCO unit. Eight FM center frequencies ranging from 680 to 3060 Hz are in use with a 340 Hz separation between center frequencies and an individual fixed bandwidth of 250 Hz. Typically, data from several field sites are transmitted via VHF radio link in the 160-174 MHz range to a receiver site where up to eight data channels are multiplexed and transmitted to the University of Utah campus via additional VHF radio links, microwave links, and/or voice-grade telephone lines. At the recording site, each FM seismic signal is demodulated by a discriminator and the resulting amplified seismometer signal is routed to a multiplexed analog-to-digital (A/D) converter in the PDP 11/34 computer. A program in the PDP 11/34 continuously monitors all the seismic signals. When the occurrence of an earthquake is detected, the digitized signals are recorded on magnetic tape for the duration of the earthquake. In addition, 20 seismic signals are recorded on the drum recorders to provide a continuous visual record.

Figure 3 illustrates the response characteristics of the entire telemetered system from seismometer (Mark Products L4C or Geotech S13) to the input of the A/D converter. The complete system gain ranges from 1.0×10^6 to 8.0×10^6 counts/cm/sec. The gain for a particular station is determined according to the level of ground noise at the site.

Station siting is constrained by several factors including accessibility (especially difficult during winter months), requirements for unobstructed line-of-sight radio transmission, exposure of bedrock if available, difficulty in obtaining land permits, and the need for broad geographic coverage of Utah. Economic factors also govern the variable station spacing within the network.

Polarities of Seismograph Stations

A vertical component seismograph is normally polarized if upward ground motion produces upward motion of the trace on the record; otherwise, it is reversely polarized. It has proven difficult to keep all of the stations in the UUSS network operating with normal polarity, because there are many different places in the instrumentation where the polarity of the signal can become reversed. Consequently, the station polarities are routinely checked using seismograms of explosions and teleseisms (earthquakes more than 1000 km away) with clear first arrivals (see Bjarnason, 1987).

Appendix A of Bjarnason (1987) gives polarities of the stations recorded by the UUSS during the time period January 1, 1981, to June 30, 1986. Tables 4 and 5 list the polarities by years for the vertical components of stations recorded during the time period covered by this report, 1986 through 1988. For years in which a change in polarity occurred, the probable date of the change, when known, is given in parentheses. An asterisk next to the date indicates that the polarity was changed intentionally by UUSS personnel.

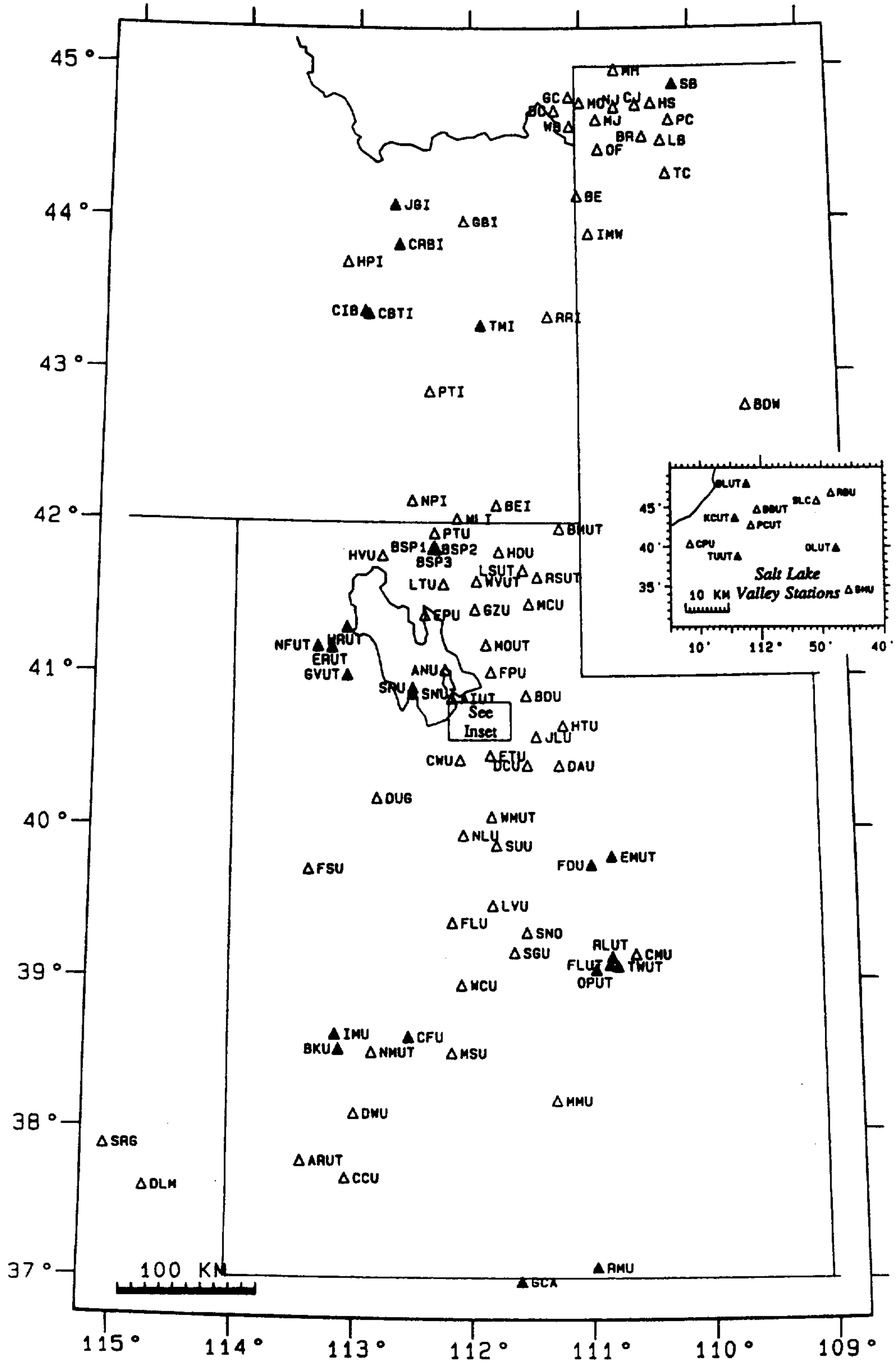

Figure 1. Map of University of Utah seismic network. Open triangles represent seismograph stations that operated during the entire report period of January 1, 1986 through December 31, 1988. Solid triangles represent stations that operated for a portion of the report period. Refer to Tables 1 and 2 for more complete information.

TABLE 1

UNIVERSITY OF UTAH REGIONAL SEISMIC NETWORK
Operating Seismograph Stations: December 31, 1988

	Code	Station Name	Lat(N)	Long(W)	Elev (m)	Opened
	AIUT	S. Antelope Island, UT	40° 51.35′	112° 10.53′	1334	04-83
	ANU	Antelope Island, UT	41° 02.38′	112° 13.90′	1353	11-75
	ARUT	Antelope Range, UT	37° 47.28′	113° 26.42′	1646	12-80
P	BBUT	Bumble Bee, UT	40° 44.73′	112° 00.67′	1291	07-85
	BDU	Big Ditch, UT	40° 52.45′	111° 32.04′	2198	09-74
*	BDW	Boulder, WY	42° 46.57′	109° 34.10′	2190	06-77
	BEI	Bear River Range, ID	42° 07.00′	111° 46.94′	1859	10-74
	BMUT	Black Mtn., UT	41° 57.49′	111° 14.05′	2243	10-79
**	CBTI	Cedar Butte, ID	43° 23.01′	112° 54.49′	1690	07-86
	CCU	Cedar City, UT	37° 40.52′	113° 04.11′	1775	12-68
	CMU	Cedar Mtn., UT	39° 10.28′	110° 37.16′	2332	06-78
	CPU	Coon Peak, UT	40° 40.34′	112° 11.78′	2377	11-74
**	CRBI	Circular Butte, ID	43° 49.82′	112° 38.07′	1543	11-87
	CWU	Camp Williams, UT	40° 26.75′	112° 06.13′	1945	10-74
	DAU	Daniels Canyon, UT	40° 24.75′	111° 15.35′	2771	11-74
	DCU	Deer Creek Res., UT	40° 24.82′	111° 31.61′	1829	11-74
*	DLM	Delmar Mtns., NV	37° 36.35′	114° 44.33′	1730	03-80
†††	DUG	Dugway, UT	40° 11.70′	112° 48.80′	1477	05-62
	DWU	Dry Willow, UT	38° 06.32′	112° 59.85′	2270	09-82
	EMUT	Emma Park, UT	39° 48.84′	110° 48.92′	2268	10-86
	EPU	E. Promontory, UT	41° 23.49′	112° 24.53′	1436	09-75
	FLU	Fools Peak, UT	39° 22.69′	112° 10.23′	1950	09-81
	FPU	Francis Peak, UT	41° 01.58′	111° 50.21′	2816	09-74
	FSU	Fish Springs, UT	39° 43.35′	113° 23.48′	1487	06-79
**	GBI	Big Grassy Butte, ID	43° 59.25′	112° 03.80′	1561	12-81
†	GMU	Granite Mtn., UT	40° 34.53′	111° 45.79′	1829	08-70
	GZU	Grizzly Peak, UT	41° 25.53′	111° 58.50′	2646	11-81
	HDU	Hyde Park, UT	41° 48.27′	111° 45.89′	1853	03-75
**	HPI	Howe Peak, ID	43° 42.68′	113° 05.90′	2597	03-81
	HTU	Hoyt Peak, UT	40° 40.52′	111° 13.21′	2576	11-74
††	HVU	Hansel Valley, UT	41° 46.78′	112° 46.50′	1609	11-76
	IMU	Iron Mtn., UT	38° 37.99′	113° 09.50′	1833	09-88
***	IMW	Indian Meadow, WY	43° 53.82′	110° 56.35′	2646	08-80
††	JLU	Jordanelle, UT	40° 36.11′	111° 26.95′	2304	09-81
	LSUT	Lucky Star, UT	41° 41.09′	111° 33.45′	2225	11-79
	LTU	Little Mtn., UT	41° 35.51′	112° 14.83′	1585	09-74
	LVU	Levan Peak, UT	39° 29.50′	111° 49.60′	2530	01-78
	MCU	Monte Cristo Peak, UT	41° 27.70′	111° 30.45′	2664	12-74
	MLI	Malad Range, ID	42° 01.61′	112° 07.53′	1896	10-74
	MMU	Miners Mtn., UT	38° 11.91′	111° 17.66′	2387	10-80
	MOUT	Mount Ogden, UT	41° 11.94′	111° 52.73′	2743	09-80

	Code	Station Name	Lat(N)	Long(W)	Elev (m)	Opened
	MSU	Marysvale, UT	38° 30.80′	112° 10.45′	2141	11-75
	NLU	North Lilly, UT	39° 57.29′	112° 04.50′	2036	08-81
	NMUT	North Mineral, UT	38° 30.99′	112° 51.00′	1853	10-87
	NPI	N. Pocatello Valley, ID	42° 08.84′	112° 31.10′	1640	04-75
P	PCUT	Pearl Courtright, UT	40° 42.72′	112° 01.68′	1295	08-85
	PTI	Pocatello, ID	42° 52.22′	112° 22.21′	1670	10-84
	PTU	Portage, UT	41° 55.76′	112° 19.48′	2192	12-76
	RBU	Red Butte Canyon, UT	40° 46.85′	111° 48.50′	1676	06-74
	RMU	Rainbow Bridge, UT	37° 04.56′	110° 58.20′	1536	11-81
***	RRI	Red Ridge, ID	43° 21.84′	111° 19.14′	2566	10-85
	RSUT	Red Spur, UT	41° 38.31′	111° 25.90′	2682	10-79
	SGU	Sterling, UT	39° 10.97′	111° 38.60′	2365	10-78
	SLC	Salt Lake City, UT	40° 45.83′	111° 50.87′	1423	04-62
****	SNO	Snow College, UT	39° 18.86′	111° 32.28′	2446	10-81
	SNUT	Stansbury North, UT	40° 53.14′	112° 30.54′	1652	09-86
*	SRG	Seaman Range, UT	37° 52.93′	115° 04.08′	1645	03-80
	SUU	Santaquin Canyon, UT	39° 53.32′	111° 47.50′	1987	08-74
	WCU	Willow Creek, UT	38° 57.88′	112° 05.40′	2714	01-78
	WMUT	West Mountain, UT	40° 04.60′	111° 50.00′	1981	08-81
	WVUT	Wellsville, UT	41° 36.61′	111° 57.55′	1828	08-79
*	YPBE	Bechler	44° 08.97′	111° 02.34′	1966	09-85
*	YPBR	Bridge Bay	44° 32.20′	110° 26.37′	2383	12-83
*	YPCJ	Canyon Village	44° 44.63′	110° 29.85′	2426	12-83
*	YPDC	Denny Creek	44° 42.57′	111° 14.38′	2025	12-83
*	YPGC	Grayling Creek	44° 47.77′	111° 06.39′	2075	12-83
*	YPHS	Hot Springs Basin	44° 45.33′	110° 21.24′	2621	12-83
*	YPLB	Lake Butte	44° 30.68′	110° 16.32′	2565	12-83
*	YPMC	Maple Creek	44° 45.56′	111° 00.37′	2073	12-83
*	YPMH	Mammoth Hot Springs	44° 58.62′	110° 41.12′	1781	12-83
*	YPMJ	Madison Junction	44° 38.90′	110° 51.52′	2111	12-83
*	YPNJ	Norris Junction	44° 43.82′	110° 41.58′	2290	12-83
*	YPOF	Old Faithful	44° 27.15′	110° 50.48′	2260	12-83
*	YPPC	Pelican Cone	44° 38.84′	110° 11.58′	2939	12-83
*	YPSB	Soda Butte	44° 53.04′	110° 09.06′	2072	12-83
*	YPTC	Trail Creek	44° 17.79′	110° 13.92′	2360	12-83
*	YPWB	West Yellowstone	44° 36.35′	111° 06.05′	2310	12-83

KEY

*	Station operated by U.S. Geological Survey and recorded by UUSS
**	Station operated by Idaho National Engineering Laboratory and recorded by UUSS
***	Station operated by Ricks College, Rexburg, Idaho and recorded by UUSS
****	Station operated by Snow College, Ephraim, Utah and recorded by UUSS
†	3-component station (one vertical, two horizontals)
††	4-component station (high- and low-gain verticals plus two horizontals)
†††	6-component station (three high-gain, three low-gain)
P	Portable Telemetry Station

TABLE 2

UNIVERSITY OF UTAH REGIONAL SEISMIC NETWORK
Discontinued Seismograph Stations: January 1, 1986 - December 31, 1988

	Code	Station Name	Lat(N)	Long(W)	Elev(m)	Opened	Closed
†	BLUT	Bailey Lake, UT	40° 48.02′	112° 02.40′	1286	10-85	08-88
	BKU	Beaver Lake Mts., UT	38° 32.11′	113° 07.61′	1859	12-80	09-88
†	BSP1	Blue Springs Hills, UT	41° 50.40′	112° 19.52′	1598	04-87	10-87
†	BSP2	Blue Springs Hills, UT	41° 49.54′	112° 20.60′	1634	04-87	10-87
†	BSP3	Blue Springs Hills, UT	41° 49.40′	112° 18.56′	1658	04-87	10-87
*	CIB	Cedar Butte, ID	43° 24.07′	112° 56.51′	1611	03-81	09-86
	CFU	Cove Fort, UT	38° 37.13′	112° 32.32′	2012	03-77	08-87
†	ERUT	Eagle Range, UT	41° 10.89′	113° 12.51′	1309	10-87	08-88
	FDU	Ford Ridge, UT	39° 45.41′	110° 59.40	2975	03-78	10-86
†	FLUT	Fuller Bottom, UT	39° 06.00′	110° 50.33′	1682	08-88	12-88
	GCA	Glen Canyon, AZ	36° 58.42	111° 35.58′	1339	12-76	12-88
†	GVUT	German Valley, UT	41° 00.23′	113° 04.48′	1530	10-87	08-88
†	HRUT	Hogup Ridge, UT	41° 13.63′	113° 04.85′	1408	10-87	08-88
*	JGI	Juniper Gulch, ID	44° 05.56′	112° 40.61′	1657	02-80	01-88
†	KCUT	Kersey Creek, UT	40° 43.66′	112° 04.37′	1288	08-85	08-87
†	NFUT	Newfoundland Mts., UT	41° 11.26′	113° 19.93′	1378	10-87	08-88
†	OLUT	Mt. Olympus, UT	40° 39.83′	111° 47.76′	1646	01-86	12-88
†	OPUT	Oscar's Pond, UT	39° 04.07′	110° 57.21′	1768	08-88	12-88
†	RLUT	Red Ledges, UT	39° 09.13′	110° 49.12′	1779	08-88	12-88
	SNU	Stansbury North, UT	40° 55.43′	112° 30.60′	1378	05-78	09-86
*	TMI	Taylor Mtn, ID	43° 18.33′	111° 55.09′	2179	12-76	09-86
†	TUUT	Thad Utley, UT	40° 38.77′	112° 03.92	1573	11-85	08-87
†	TWUT	The Wedge, UT	39° 05.42′	110° 46.30′	1878	08-88	12-88

* - Station operated by Idaho National Engineering Laboratory and recorded by UUSS

† - Portable telemetry station

Note: "Opened" and "Closed" in this table indicate the period for which seismic data are on file at the University of Utah.

TABLE 3

UNIVERSITY OF UTAH SUPPLEMENTAL MICROEARTHQUAKE RECORDING STATIONS
January 1, 1986 - December 31, 1988

Code	Station Name	Lat (N)	Long (W)	Elev (m)	Opened	Closed
BHW	Big Hollow, UT	39° 16.41′	112° 04.08′	1789	03-29-86	03-31-86
FAV	Favorite Hills, UT	39° 08.21′	110° 52.53′	1646	08-16-88	08-31-88
FBD	Fuller Bottom Draw, UT	39° 07.84′	110° 50.39′	1625	08-27-88	08-31-88
FHI	Fish Haven, ID	42° 02.97′	111° 27.46′	2097	11-20-88	11-23-88
FUL	Fuller Bottom, UT	39° 06.26′	110° 51.32′	1640	08-16-88	08-31-88
GCU	Garden City, UT	41° 57.51′	111° 24.68′	1966	11-20-88	11-23-88
GRMU	German Valley, UT	40° 59.63′	113° 02.69′	1493	09-27-87	10-07-87
HAY	Haye Canyon, UT	39° 13.16′	111° 55.72′	1789	03-27-86	03-31-86
HOGS	Hogup Ridge South, UT	41° 13.76′	113° 04.83′	1414	09-25-87	10-07-87
JPV	Japanese Valley, UT	39° 09.43′	112° 00.30′	1951	03-27-86	03-31-86
LAK	Laketown, UT	41° 59.09′	111° 25.64′	1890	11-20-86	11-23-88
LRY	Lowry, UT	39° 11.47′	111° 59.83′	1847	03-27-86	03-31-86
MEL	Mellor Canyon, UT	39° 15.09′	111° 49.59′	1679	03-27-86	03-31-86
NNFU	N. Newfoundland Mts., UT	41° 16.42′	113° 19.04′	1289	09-25-87	10-07-87
NJV	N. Japanese Valley, UT	39° 14.56′	111° 59.03′	1934	03-28-86	03-31-86
OIL	Oil Can, UT	39° 12.26′	110° 56.20′	1768	08-16-88	08-31-88
PRC	Painted Rock Canyon, UT	39° 18.41′	111° 58.77′	1843	03-27-86	03-31-86
RED	Red Ledges, UT	39° 04.55′	110° 56.26′	1699	08-17-88	08-24-88
SCI	St. Charles, ID	42° 05.81′	111° 30.99′	2073	11-20-88	11-23-88
SJRU	S. Newfoundland Mts., UT	41° 01.84′	113° 20.84′	1292	09-26-87	10-07-87
SKI	Beaver Mtn. Ski Resort, UT	41° 58.22′	111° 32.51′	2219	11-20-88	11-23-88
STP	Steep Canyon, UT	39° 10.50′	111° 55.60′	1664	03-27-86	03-31-86
WEG	Wedge, UT	39° 05.33′	110° 45.32′	1902	08-18-88	08-31-88

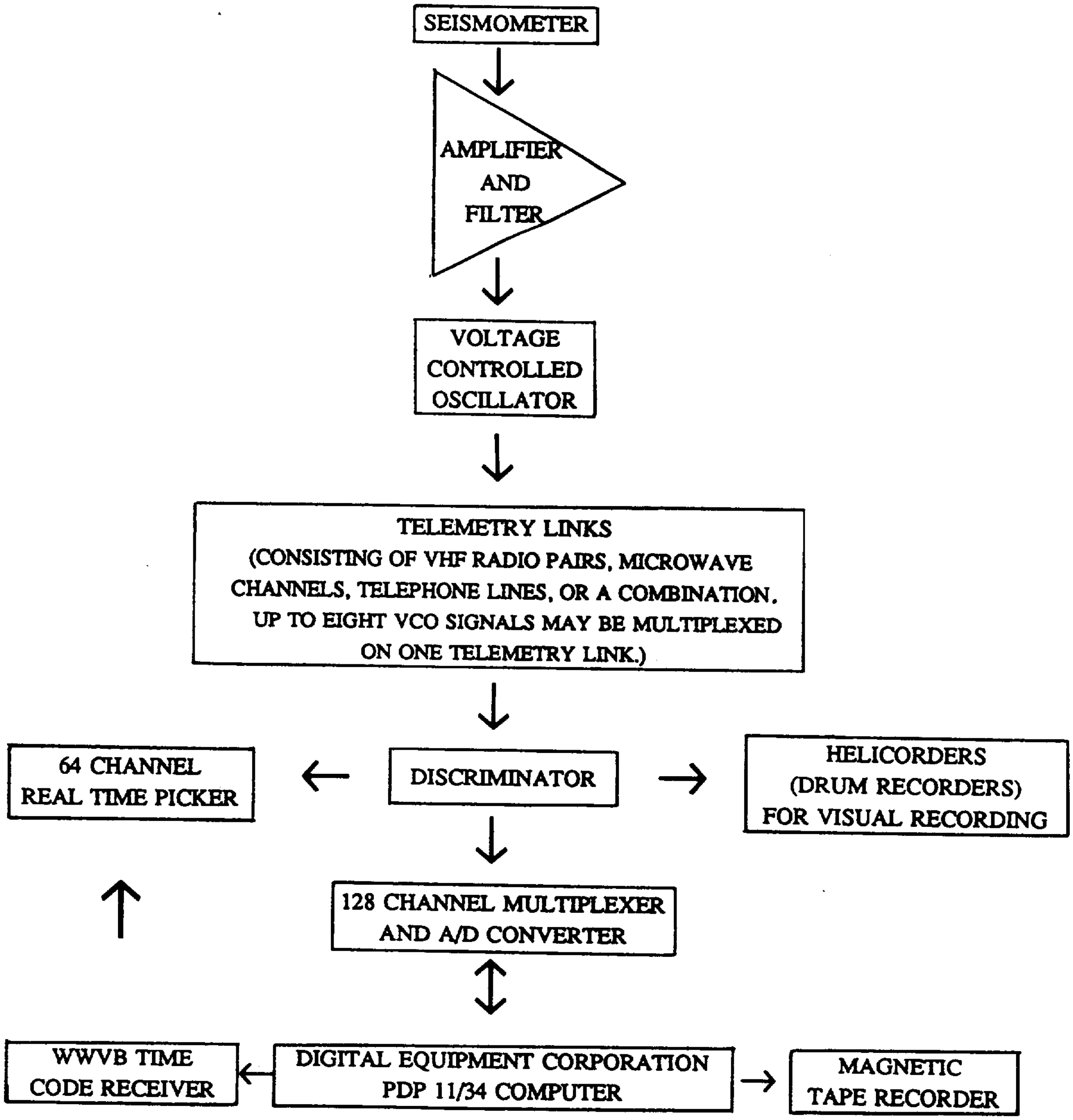

Figure 2. Schematic diagram of University of Utah telemetered seismic network.

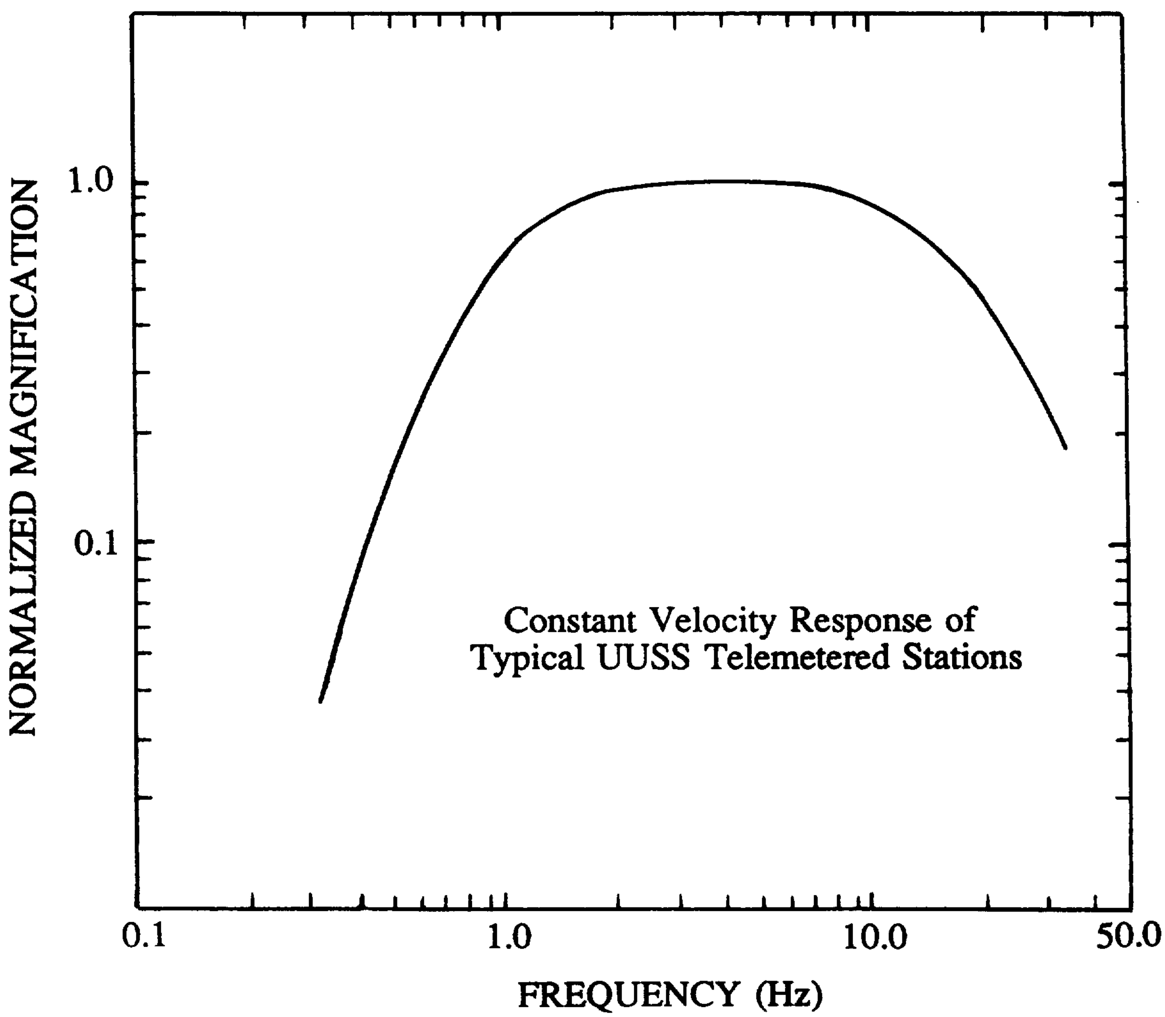

Figure 3. Constant velocity response of typical University of Utah seismic network telemetered stations.

TABLE 4

UNIVERSITY OF UTAH REGIONAL SEISMIC NETWORK
Polarities of Operating Stations: January 1, 1986 - December 31, 1988

Station Name	1986	1987	1988
AIUT	N	/	/
ANU	R⇒N (*Mar 6)	N	N
ARUT	N	N	N
BBUT	/	/	/
BDU	R	R	?
BDW	N	N	N
BEI	N	N	N
BMUT	N	N	N
CBTI	R⇒N (Oct 30 or Nov 3)	N	n
CCU	R⇒N (Date Unknown)	N	?
CMU	R	R	R
CPU	R	R	r
CRBI		/	R⇒? (Oct)
CWU	N	N	N
DAU	N	N	N
DCU	N	N⇒R (Aug 10)	R
DLM	R	R	R
DUG	N	N	N
DWU	N	N	N
EMUT	N	N	N
EPU	N	N	N
FLU	R	R	R⇒N (*Jan 27)
FPU	R	R	R
FSU	R	R	R
GBI	R (Dec 15)	N	N
GMU	N	N	N
GZU	N	N	N
HDU	N	N	N⇒R (Jan 15)
HPI	R	R	R
HTU	N	N	n
HVU	N	N	N
IMU			N
IMW	N	N	N
JLU	N	N	N
LSUT	N	N	N
LTU	N	N	N
LVU	n	N	N
MCU	?	R	R
MLI	N	N	N
MMU	R	R	R⇒N (*Apr 30)
MOUT	N	N	N

Station Name	1986	1987	1988
MSU	R	R	R
NLU	R⇒N (Jul 16)	N⇒R (Jul 15-Nov 17)	R
NMUT		R	R
NPI	R	R	R
PCUT	N	/	/
PTI	r	R	?
PTU	N⇒?	R⇒N (Jul 19)	N⇒R (*Jun 22)
RBU	N	N	N
RMU	N	N	N
RRI	n	N	N
RSUT	R	R⇒N (Sep 30)	N
SGU	R	R	R
SNO	N	N	N
SNUT	?	N	N
SRG	R	R	R
SUU	N	N	N
WCU	R	R	R
WMUT	N	N	?
WVUT	N	N	n
YPBE	N	N	N
YPBR	?	/	n
YPCJ	N	n	?
YPDC	N	N	N
YPGC	N	N	N
YPHS	N	N	N
YPLB	/	N	N
YPMC	N	N	N
YPMH	N	N	N
YPMJ	N	N	N
YPNJ	?	?	/
YPOF	N	N	N
YPPC	N	N	N
YPSB	N	n	N
YPTC	N	/	?
YPWB	N	N	N

Symbol Key

(Jul 16)	Probable date of polarity change.
*	Polarity intentionally changed by UUSS personnel.
N	Good to strong evidence for normal polarity.
n	Insufficient or contradictory data, but probably normal.
R	Good or strong evidence for reversed polarity.
r	Insufficient or contradictory data, but probably reversed.
/	Station officially operated for all or part of the year, but no data were found to determine its polarity.
?	Polarity checks were done for the station, but without conclusive results.
	A blank indicates that the station was not recorded by the UUSS in that year.

TABLE 5
UNIVERSITY OF UTAH REGIONAL SEISMIC NETWORK
Polarities of Discontinued Stations: January 1, 1986 to December 31, 1988

Station Name	1986	1987	1988
BLUT	/⇒N (*May 11)	/	/
BKU	R	R	R
BSP1		N	
BSP2		R	
BSP3		N	
CIB	R		
CFU	R	R	
ERUT		/	/
FDU	R		
FLUT			N
GCA	R⇒N (*Mar 20)	N	/
GVUT		R	R
HRUT		N	N
JGI	N⇒R (Jul 31?)	R⇒N(Feb 23 or Oct 24)	/
KCUT	N	/	
NFUT		N	N
OLUT	N	N	N⇒R (Before Nov 3)
OPUT			N
RLUT			N
SNU	n		
TMI	R		
TUUT	n	/	
TWUT			R

Symbol Key

(Jul 16)	Probable date of polarity change.
*	Polarity intentionally changed by UUSS personnel.
N	Good to strong evidence for normal polarity.
n	Insufficient or contradictory data, but probably normal.
R	Good or strong evidence for reversed polarity.
r	Insufficient or contradictory data, but probably reversed.
/	Station officially operated for all or part of the year, but no data were found to determine its polarity.
?	Polarity checks were done for the station, but without conclusive results.
	A blank indicates that the station was not recorded by the UUSS in that year.

DATA PROCESSING AND ANALYSIS

General Procedure

During the period of this report, seismic network data were chiefly recorded on digital tape using the PDP-11/34 computer system operating in an event detection mode. The on-line recording system is closely modeled after the CEDAR system designed by C. Johnson (1979). The current code was written at the University of Washington by A. Bittenbinder. The system is currently capable of recording 128 channels of digital data, including time code, in a multiplexed format on tape.

Tapes written by the on-line PDP-11/34 system are read onto a PDP-11/70 computer for analysis and eventual archival of the seismic data. Software developed primarily by S. Malone, A. Bittenbinder and D. Leaver at the University of Washington was adapted to the UUSS PDP-11/70 system for routine earthquake analysis. The following steps summarize the analysis process:

1) *Demultiplexing and scanning*. Data tapes from the PDP-11/34 system are demultiplexed (a software process that separates the multiplexed 128 channel data into individual data files) and scanned to identify seismic events of interest. Scanning is accomplished by visually examining trace data from individual stations displayed on either a Versatec printer/plotter or a Tektronix graphics terminal.

2) *Timing*. Events provisionally identified as local earthquakes within the UUSS network are timed as accurately as possible (with reading errors less than about ± 0.01 sec for the best data) using the computer program "PING". This routine uses the Tektronix interactive graphics terminals to display seismic trace data from individual stations. Each channel may be scaled in either time or amplitude, band-pass filtered to reduce site or transmission noise, and saved or deleted from the archive file at the option of the analyst. Arrival times and total signal duration can be read using the terminal cursor controls. These data are automatically stored on disk. A time code trace is used to establish absolute timing.

3) *Location procedure*. The computer program HYPOINVERSE (Klein, 1978) is used for earthquake location as described in the next section. The hypocentral solution for each event is analyzed by a geophysicist and checked for errors. Arrival times having large residuals are re-timed. Additional data are sought from other networks for events recorded by a poor spatial distribution of stations. Poor hypocentral solutions are reprocessed and checked for remaining errors. Small earthquakes (magnitude < 1.5) that cannot be reliably located are deleted.

4) *Data archival*. Seismic trace data as well as arrival times, signal durations, first motion directions, location, origin time, and magnitude information are archived on digital tape for each local earthquake processed.

5) *Magnitude check.* Wood-Anderson seismograms from stations DUG and SLC are examined and read for all earthquakes with local magnitude greater than 2.5.

6) *Elimination of blasts and check for completeness.* Located seismic events identifiable as blasts are deleted. To ensure that all data are accounted for, final data files are correlated with preliminary scanning lists, felt earthquake lists, press releases, and the U.S. Geological Survey serial publication *Preliminary Determination of Epicenters.*

7) *Final processing.* A final batch run on the computer is made of all data to create a catalog summary of hypocentral information.

Computation of Earthquake Locations

The computer program HYPOINVERSE (Klein, 1978) was used to locate earthquakes in the Utah region for the January 1986 through December 1988 time period. This program determines hypocenters by minimizing differences between observed and computed travel-times using a generalized inverse (singular value decomposition) technique. Computed travel-times are calculated by assuming a trial hypocenter and then finding the appropriate ray path through a horizontally layered velocity model back to each station.

Two velocity models were used in order to approximate the transition in crustal structure across Utah from the Basin and Range province on the west to the Middle Rocky Mountains-Colorado Plateau on the east. A third velocity model was used to model crustal structure for stations in the southeast/central Idaho-western Wyoming area.

The first model, informally designated the "Wasatch Front model," was applied to all stations west of 111°W longitude and south of 42.5°N latitude, with the exception of GCA and MMU. The model was determined by seismic refraction profiling (Keller *et al.*, 1975) south of Salt Lake City along the Basin and Range-Colorado Plateau transition zone using local quarry blasts. A 7.9 km/sec halfspace at 42 km depth has been added in order to fit observed travel time data from earthquakes at distances greater than about 250 km (Pechmann *et al.*, 1984). The model is specified by:

Layer	*Depth (km)*	*P-Velocity (km/sec)*
1	0 to 1.4	3.4
2	1.4 to 15.5	5.9
3	15.5 to 25.4	6.4
4	25.4 to 42.0	7.5
5	42.0+	7.9

The second model, informally designated the "Colorado Plateau model," was applied to all stations east of 111°W longitude and south of 40°N latitude plus GCA and MMU. This model is modified from Roller (1965) and is specified by:

Layer	*Depth (km)*	*P-Velocity (km/sec)*
1	0 to 1.5	3.4
2	1.5 to 27.5	6.2
3	27.5 to 40.0	6.8
4	40.0 to 80.0	7.8
5	80.0+	7.9

The third model, informally designated the "southeast Idaho model," was applied to all stations north of 42.5°N latitude. This model was determined for analysis of the 1983 Borah Peak, Idaho sequence using data from several seismic refraction profiles near Mackay, Idaho (Richins *et al.*, 1987).

Layer	*Depth (km)*	*P-Velocity (km/sec)*
1	0 to 1.1	4.8
2	1.1 to 6.5	5.6
3	6.5 to 18.0	6.2
4	18.0 to 40.0	6.8
5	40.0+	8.0

Reliable S-wave arrival times for stations less than 75 km from the epicenter were used in addition to P-wave arrival times whenever possible. The S-wave velocity models were calculated from the P-wave velocity models using an empirically determined V_p / V_s ratio of 1.74, corresponding to a Poisson's ratio of 0.25. S-wave arrivals prove particularly helpful in controlling locations near or slightly outside the boundaries of the network. Corrections for elevation were made to a datum level of 1500 m (above mean sea level) using the angle of incidence and the near-surface velocity of 3.4 km/sec for P-waves and 1.95 km/sec for S-waves. Some corrections are as large as 0.3 sec for P-waves. Empirical station delays were not applied to the data set due to the large geographical area involved.

Magnitude Estimation

Magnitude estimates for earthquakes in the Utah region are based directly or indirectly on the Richter local magnitude (M_L) scale. We refer the reader to Griscom and Arabasz (1979) for a critical evaluation of local magnitude in the Utah region, and for the technical basis of the following discussion.

For the larger earthquakes in this catalog, local magnitude was determined directly from measurements of peak amplitude on standard Wood-Anderson-type seismographs operating at Dugway and Salt Lake City, Utah, using Richter's original definition:

$$M_L = \log A - \log A_o$$

Here, A is the maximum trace amplitude recorded for a given earthquake at a given distance, and log A_o is a distance correction taken from Richter (1958). At the University of Utah, the procedure for determining the maximum trace amplitude is to measure the maximum peak-to-peak amplitude and divide by two. The Wood-Anderson instrument operating at Dugway is a true Wood-Anderson torsional seismograph built to the original specifications. The instrument at Salt Lake City is an electronically simulated Wood-Anderson. When available, magnitude estimates from both horizontal components at each of the two stations were averaged to obtain the M_L value for the earthquake. If measurements from only one of the two Wood-Anderson stations were available, the M_L value was averaged with a coda magnitude (M_C) calculated from the total signal duration measured on paper records from the Benioff short-period vertical seismograph at Dugway. The relation used was

$$M_C = -4.26 + 2.79 \log \tau + 0.0026 \Delta$$

where τ is the total signal duration in seconds measured from the P-wave onset and Δ is the epicentral distance in kilometers. Using this equation, the standard error of magnitude estimation compared to M_L values determined directly from Wood-Anderson amplitude measurements is $\pm$ 0.28. Magnitudes from Wood-Anderson records and duration measurements on the Dugway Benioff are indicated by a "W" in the earthquake listings. For earthquakes where magnitudes can be calculated from only one Wood-Anderson station (either DUG or SLC) and no duration measurements from the Dugway Benioff record can be made, the reported magnitude M_C is calculated from the signal duration measurement of the digital recordings of the telemetry stations, as outlined below.

Wood-Anderson magnitudes cannot be determined for most earthquakes in Utah because Wood-Anderson instruments are operated at relatively low gains. Magnitudes for the majority of the earthquakes in this catalog were estimated from signal durations measured from digital recordings of the telemetry stations. These magnitudes were calculated using the equation

$$M_C = -3.13 + 2.74 \overline{\log \tau} + 0.0012 \overline{\Delta}$$

where $\overline{\log \tau}$ is the average logarithm of total signal duration in seconds (measured from the P-wave onset) and $\overline{\Delta}$ is the average epicentral distance in kilometers. This equation was originally determined by calibration of duration measurements from 16 mm Develocorder film records against Wood-Anderson local magnitudes. Preliminary evaluations indicate that this equation yields reasonable magnitude estimates when applied to signal durations from the digital data. Some signal durations were determined with the aid of an automatic duration measurement routine which fits the amplitude decay for the latter part of the seismogram with a function of the form

$$f(t) = A_o \, (t - t_p)^{-\alpha}$$

where t is time, t_p is the p-wave arrival time, and A_o and α are free parameters.

It is important to note compelling evidence that coda-magnitude scales cannot justifiably be extrapolated below about M_L = 1.5 without special calibration (Bakun and Lindh, 1977; Suteau and Whitcomb, 1979). Thus, magnitudes below 1.5 listed in this catalog should be interpreted only as indicating relatively small size.

Quality and Completeness of Data

The quality of hypocenter locations is governed by many factors and should be considered when assessing earthquake hazards, comparing relative seismicity of various parts of Utah, associating earthquakes with mapped faults, and in other applications of these data. The accuracy (difference between actual and calculated locations) is limited by systematic errors such as inadequate velocity models, possible consistent misidentification of phases, and systematic station delays (dependent on the local geology beneath the site). Accuracy can be evaluated using data from explosions where the origin time and location is known. Precision (a measure of the ability to recalculate the same location, which determines the reliability of seismicity patterns) is affected by random timing errors and the use of a variety of station subsets. Precision can be estimated for each earthquake using standard statistical methods in the location routine, HYPOINVERSE (Klein, 1978).

For each earthquake located, four parameters that relate to the quality of the solution are listed (NO, GAP, DMN, and RMS; see Data Explanation, Page 32). The RMS residual listed for each solution is a weighted root-mean-square of the differences between the observed and calculated arrival times. The RMS residual reflects both random timing errors and systematic errors due to such factors as inaccurate velocity models, misinterpretation of phases, and consistent but uncorrected station delays. Generally, if the hypocenter is well-surrounded by stations (as determined by a small value for GAP), the number of arrival times used (NO) is greater than 5, and the velocity model is well known, then RMS is a measure of the correctness of the velocity model and of phase identification and timing. HYPOINVERSE (Klein, 1978) also calculates lengths, in kilometers, and orientations of the three mutually perpendicular principal axes of a confidence ellipsoid. The earthquake hypocenter has a statistical probability of 32% of lying within the region described by the confidence ellipsoid, and a statistical probability of 95% of lying within a region 2.4 times larger than the confidence ellipsoid. Hence, the smaller the ellipsoid, the better the estimate of the location. The ellipsoid is a function of a user-specified estimate of random reading error, the RMS residual, the array geometry used to locate the earthquake, and the velocity model. The calculation assumes that the only source of error is random errors in the arrival times, thus it is a measure of the precision of each earthquake hypocenter.

Surface explosions from many quarries, particularly in north-central Utah along the Wasatch Front, are routinely recorded. Known locations of several blasts from the Keigley quarry, the Bingham Canyon Copper mine, and the Devil's Slide quarry (see Table 6) have been compared with our instrumental locations. The comparisons suggest a map-location accuracy of approximately ± 1 km for well-recorded earthquakes. Using well-recorded earthquakes, Kastrinsky (1977) estimated epicentral errors for earthquakes located on the Wasatch Front during 1975-1976 (using 30 stations) at ± 2.0 km. Depth determinations are judged to be reliable to within ± 2.0 km if DMN (the distance to the closest recording station) is approximately equal to or less than the depth. An asterisk next to the depth is used in the earthquake catalog to indicate events with poor depth control, i.e., earthquakes that do not have a recording station within 10 km of the epicenter or within a distance to the epicenter of twice the depth.

The catalog is estimated to be systematically complete above magnitude (M_L) 1.5 in north-central Utah, above magnitude 2.5 in central and southwestern Utah, and above magnitude 3.0 in southeastern Utah and the eastern Uinta Basin. Magnitudes are judged to be accurate to within ± 0.3 magnitude units.

Blasting in the Utah Region

Blasting for mining, road and dam construction, seismic exploration, and military ammunition disposal is common in the Utah region. Most of these blasts are too small for an epicenter calculation and are automatically excluded from the catalog. Nevertheless, locatable blasts are recorded regularly in the region. Known sites of active blasting operations during the report period are listed in Table 6 and shown in Figure 4. Events identified as blasts by contacting individual blasting operations and/or correlation with known blasting areas and the time of day of frequent blasting have been removed from the earthquake catalog. Blasting data are kept, however, for analysis in special studies. Note that some blasts may still be included in the catalog.

TABLE 6

KNOWN BLASTING SITES IN THE UTAH REGION
1986 - 1988

Site Name	Lat (N)	Long (W)
Bingham	40° 31′	112° 08′
Black Mesa	36° 30′	110° 20′
Carr Fork	40° 33′	112° 12′
Devils Slide	41° 03′	111° 33′
Diamond Mountain	40° 37.5′	109° 30′
Dolomite	40° 42′	112° 35′
Dugway	40° 7.5′	112° 52.5′
Elkol Mine	41° 44′	110° 37′
Georgia Pacific	38° 55′	111° 53′
Ireco	40° 14′	112° 18′
Keigley	40° 01′	111° 49′
Lakeside Mountain	40° 54′	112° 50′
Lakeside	41° 13′	112° 52′
Mercur	40° 18.54′	112° 12.32′
Monroc	40° 49.62′	111° 53.35′
Pelican Point	40° 15.55′	111° 52.31′
Promontory Point	41° 14′	112° 25′
Providence Canyon	41° 41′	111° 44′
Skull Point	41° 40′	110° 32′
Staker	40° 49.62′	111° 53.3′
Thiokol	41° 35′	112° 25′
Tooele	40° 30′	112° 28′
Topaz	39° 42′	113° 13′
US Air Force Disposal	41° 05′	113° 01′
US Gypsum	38° 53′	111° 55′
Western States	39° 31.49′	113° 00.23′
Wolfe Bros.	40° 49.6′	111° 53.35′

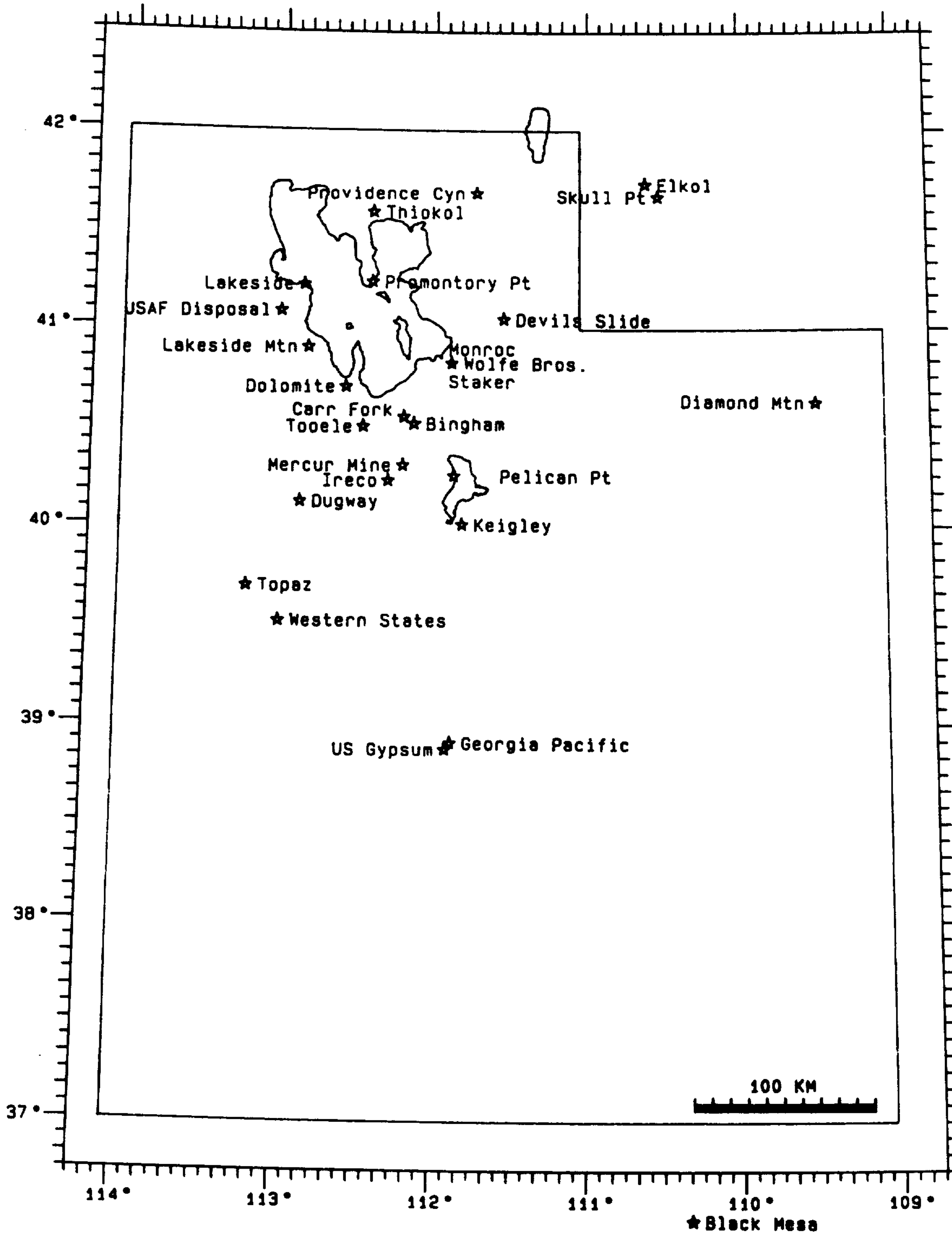

Figure 4. Map of known blasting sites operating in the Utah region during the report period, January 1, 1986 to December 31, 1988. Refer to Table 4 for more complete information.

OVERVIEW OF SEISMICITY

Recent publications by the UUSS have examined detailed characteristics of seismicity in Utah. Earthquake data for the time period 1850 through 1985 are presented in previously published earthquake catalogs (listed on page *iv*). The Appendices of these volumes contain bibliographies of UUSS publications for the appropriate time periods. Publications from 1986 through 1988 are listed in Appendices A and B of this volume.

Annual maps of seismicity in the Utah region for 1986, 1987, and 1988 are shown in Figures 5, 6, and 7, respectively. The generalized fault map used as the base map for these figures is modified from Arabasz *et al.* (1979) and Arabasz *et al.* (1987a,b) and is shown separately as Figure 8. A total of 1838 earthquakes were located during the report period in the Utah region including 52 felt shocks (see page 79) and 67 earthquakes of magnitude 3.0 or greater (see Table 7). The total number of earthquakes located in the Utah region is 19% more than the number located during the preceding three year period. This increase is chiefly due to the number of aftershocks following three moderate-sized earthquakes of M_L 4.8 to 5.3 that occurred during the 1986 - 1988 period. Before this period, no earthquakes larger than M_L 4.6 had occurred in the Utah region since the 1975 M_L 6.0 Pocatello Valley earthquake.

The largest shock of the reporting period was one of M_L 5.3, which occurred on August 14, 1988, on the northwest edge of the San Rafael swell in central Emery County, Utah, 20 km southeast of Castle Dale and 55 km south of Price. The San Rafael swell earthquake was felt strongly throughout central Utah (modified Mercalli intensity V to VI), where it caused some minor damage, and was reported felt as far away as Golden, Colorado, and Albuquerque, New Mexico (U.S. Geological Survey, *Preliminary Determination of Epicenters*). Six foreshocks, magnitude 1.8 to 3.8, occurred during the 65 minutes prior to the main shock. By the end of 1988, 200 locatable earthquakes associated with the San Rafael swell earthquake sequence had occurred. The largest aftershock in the sequence, of magnitude 4.4, occurred on August 18 and was felt in nearby small towns. For more detailed information on the San Rafael swell earthquake sequence, the reader is referred to Nava *et al.* (1988a).

On November 19, 1988, an M_L 4.8 earthquake occurred on the Utah-Idaho border, 5 km west of Bear Lake, in northern Rich County, Utah. This earthquake was preceded by a foreshock of M_L 2.6 that occurred 5 minutes before the main shock. The Bear Lake earthquake was felt widely in northern Utah and southern Idaho (modified Mercalli intensity IV to V (U.S. Geological Survey, *Preliminary Determination of Epicenters*)), and as far south as the Salt Lake Valley. Minor damage was reported in Logan and Ogden. As of December 31, 1988, 50 locatable earthquakes associated with the Bear Lake earthquake sequence had occurred. The largest aftershock of the sequence, of magnitude 4.3, occurred 18 minutes after the main shock, on November 19, 1988. For additional information on the Bear Lake earthquake sequence, see Nava *et al.* (1988b).

From September 1987 through March 1988, an earthquake sequence which included eight events of magnitude 3.8 to 4.8 occurred beneath a desert basin west of Utah's Great Salt Lake.

Errata Sheet

The following corrigenda should be appended to p. 23 of "The Earthquake Catalog for the Utah Region January 1, 1986 to December 31, 1988."

Additional areas of seismic activity in the Utah region shown in Figures 5 through 7 are summarized below: Figure 10A

(1) North of the Great Salt Lake, along the Utah-Idaho border, several clusters of earthquakes have occurred in the vicinity of the magnitude 6.0 Pocatello Valley earthquake of March 1975 (see Arabasz *et al.* 1981). The recent activity includes 323 earthquakes, 14 of magnitude 3.0 and larger, occurring primarily in three clusters (Figure 10). One cluster of 101 events occurred from September 1986 through April 1987, 10 kilometers northeast of Howell in the Blue Springs Hills, and included seven earthquakes of magnitude 3.0 to 3.7. A small cluster of 19 earthquakes occurred about 25 kilometers to the south of Howell in October and November 1987 and included 2 events of magnitude greater than 3.0. Most of the remaining activity of the region occurred about 10 kilometers to the south and southeast of Snowville, episodically throughout the report period (Figure 11). Figure 10B

Figure 11A

(2) Clusters of earthquakes in the vicinity of Price (see Figure 12) are predominantly related to the extensive coal mining in the region. A dominant cluster (187 events) is located 15 kilometers to the west of Huntington. The rate of seismicity near Price within the area of

Figure 11B Figure 12 (exclusive of the 1988 San Rafael swell earthquake sequence—shaded box,

Figure 11A Figure 12) rose from a rate of 4 events per month, from January 1986 to September 1987, to 11 events per month, from October 1987 to October 1988, to a rate of 36 events per month in November and December 1988 (Figure 13). The largest earthquake to Figure 11B

occur during the report period in the subcluster west of Huntington was a shock of magnitude 3.3 on December 16, 1987. Earthquake activity in the areas north and northeast of the towns of Price and Helper (Figure 12) is a continuation of coal-mining-related

Figure 11

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seismicity observed in past years. For detailed studies on coal-mining-related seismicity in Utah, the reader is referred to Smith *et al.* (1974), McKee and Arabasz (1982), McKee (1982), Williams (1987), and Williams and Arabasz (1989).

(3) Ongoing seismic activity is observed in a north-south zone located between 5 to 35 kilometers east of a line from Logan to Salt Lake City. The largest events to occur in this zone were both of magnitude 3.6, one on June 5, 1986, located 25 kilometers east of Ogden, and the other on July 10, 1988, located 30 kilometers east of Ogden.

(4) A persistent cluster of earthquakes appears 40 to 60 kilometers southwest of Richfield, near Cove Fort, adjacent to the Roosevelt Hot Springs geothermal region. During the report period, 104 earthquakes occurred in this locale, including three greater than magnitude 3.0. Two temporal clusters were observed during the report period. From September to October 1986, a cluster of 37 events occurred, including shocks of magnitude 3.0 and 3.4. In August and September 1987, 26 earthquakes occurred, including a magnitude 3.4 shock on September 2, 1987.

The two largest shocks of the sequence, magnitude 4.8 and 4.7, occurred on September 25, 1988 and October 26, 1988, respectively. The two largest earthquakes were felt throughout northern Utah and into southern Idaho and eastern Nevada with modified Mercalli intensities of IV to V for the M_L 4.8 event and III for the M_L 4.7 event (U.S. Geological Survey, *Preliminary Determination of Epicenters*). As of December 31, 1988, a total of 238 locatable earthquakes associated with the Lakeside sequence had occurred. See Brown *et al.* (1988) for further information on the Lakeside earthquakes.

On March 24, 1986, a magnitude 4.4 earthquake occurred in central Utah, 8 km east of Scipio, in the vicinity of Japanese Valley. This earthquake was reported felt (maximum Modified Mercalli Intensity V) in the towns within a 60 km radius from the epicenter. A total of 50 earthquakes associated with the Japanese Valley sequence were located from March through April 1986, including 7 foreshocks of magnitude 1.0 to 3.3 during the two weeks preceding the main shock. The largest aftershock of the sequence was a magnitude 3.9 shock occurring a little over four hours after the main shock on March 25, 1986. For more information on the 1986 Japanese Valley earthquake sequence the reader is referred to Brown *et al.* (1986). Seismic activity in the Japanese Valley area continued episodically throughout the report period (Figure 9). A small swarm of 14 earthquakes occurred in October and November 1986. From May through December 1988, the rate of earthquake activity rose to 2.7 events per month, as compared with a rate of 0.9 events per month in the preceding 18 months.

Additional areas of seismic activity in the Utah region shown in Figures 5 through 7 are summarized below:

(1) North of the Great Salt Lake, along the Utah-Idaho border, several clusters of earthquakes have occurred in the vicinity of the magnitude 6.0 Pocatello Valley earthquake of March 1975 (see Arabasz *et al.* 1981). The recent activity includes 323 earthquakes, 14 of magnitude 3.0 and larger, occurring primarily in three clusters (Figure 10). One cluster of 101 events occurred from September 1986 through April 1987, 10 kilometers northeast of Howell in the Blue Springs Hills, and included seven earthquakes of magnitude 3.0 to 3.7. A small cluster of 19 earthquakes occurred about 25 kilometers to the south of Howell in October and November 1987 and included 2 events of magnitude greater than 3.0. Most of the remaining activity of the region occurred about 10 kilometers to the south and southeast of Snowville, episodically throughout the report period (Figure 11).

(2) Clusters of earthquakes in the vicinity of Price (see Figure 12) are predominantly related to the extensive coal mining in the region. A dominant cluster (187 events) is located 15 kilometers to the west of Huntington. The rate of seismicity near Price within the area of Figure 12 (exclusive of the 1988 San Rafael swell earthquake sequence—shaded box, Figure 12) rose from a rate of 4 events per month, from January 1986 to September 1987, to 11 events per month, from October 1987 to October 1988, to a rate of 36 events per month in November and December 1988 (Figure 13). The largest earthquake to occur during the report period in the subcluster west of Huntington was a shock of magnitude 3.3 on December 16, 1987. Earthquake activity in the areas north and northeast of the towns of Price and Helper (Figure 12) is a continuation of coal-mining-related

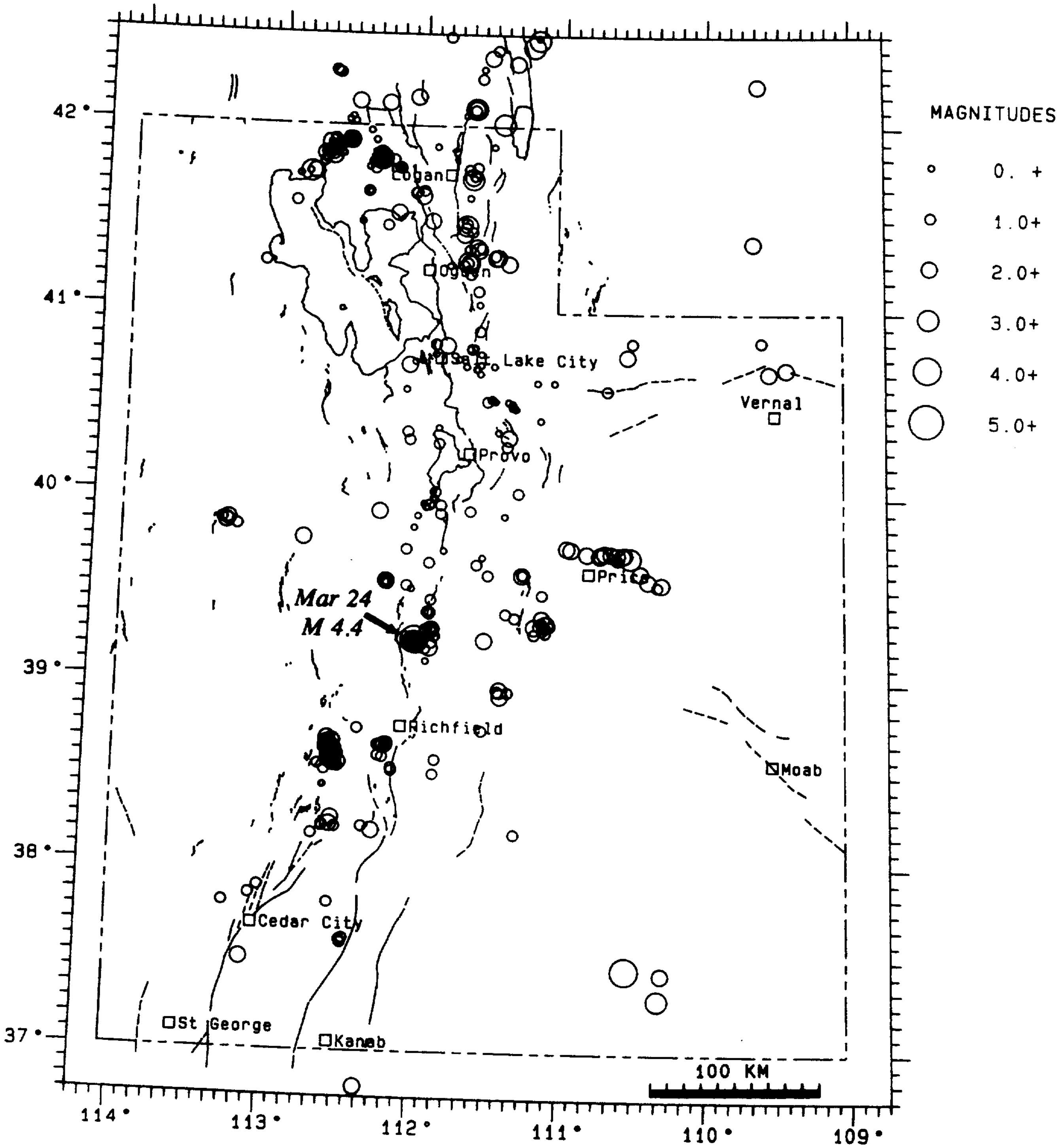


Figure 5. Epicenter map of earthquakes located in the Utah region from January 1 through December 31, 1986.

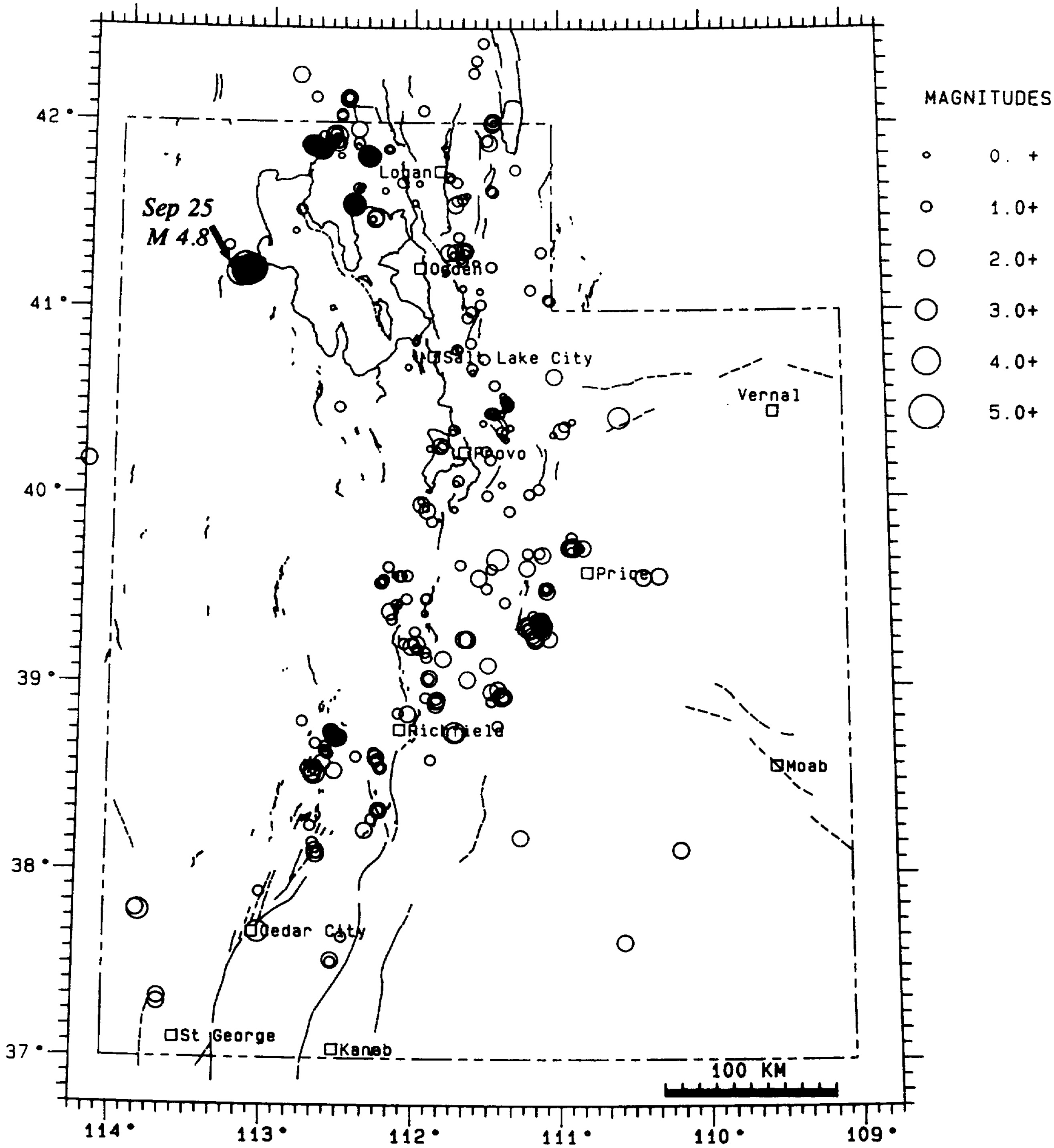


Figure 6. Epicenter map of earthquakes located in the Utah region from January 1 through December 31, 1987.

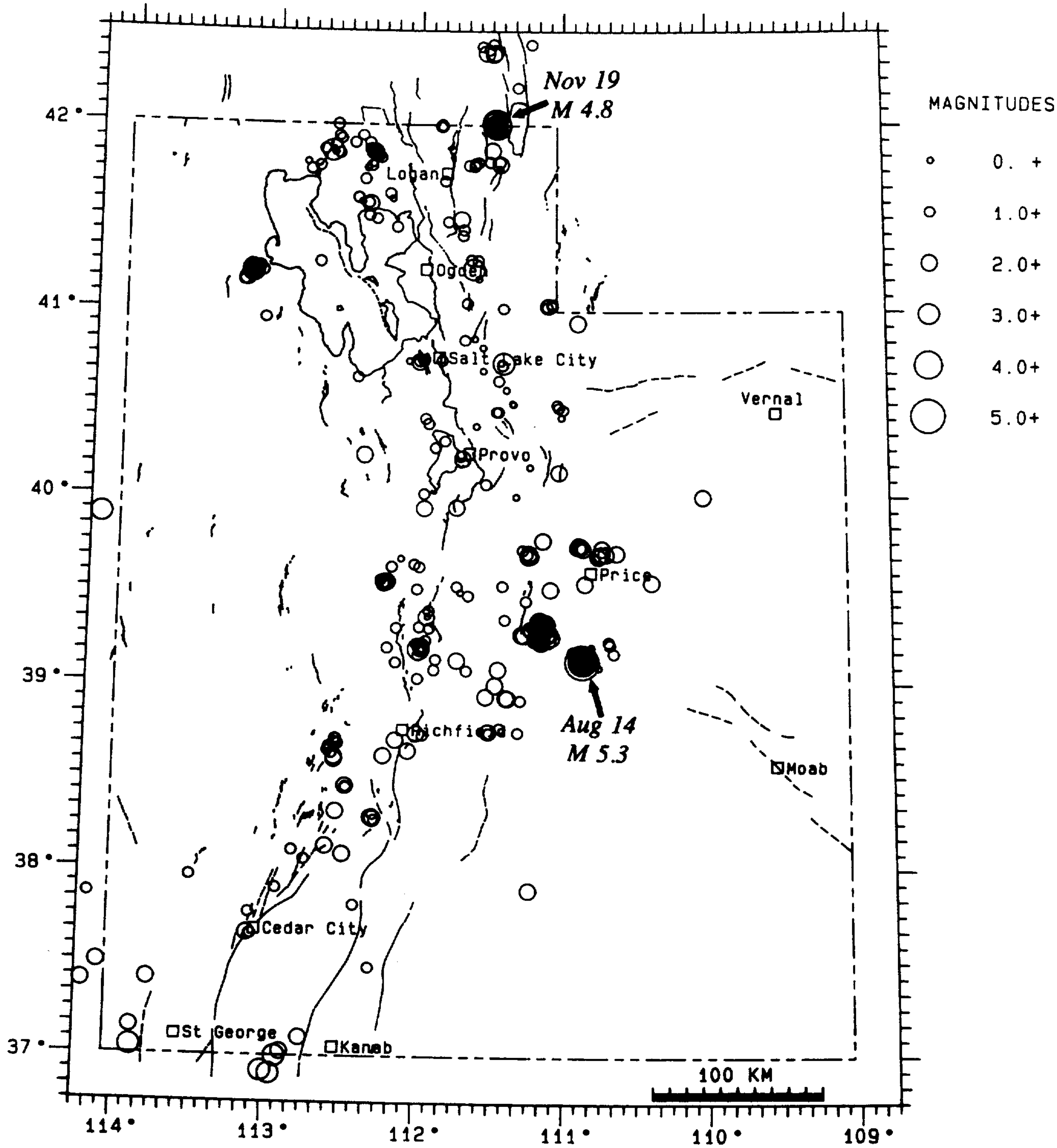


Figure 7. Epicenter map of earthquakes located in the Utah region from January 1 through December 31, 1988.

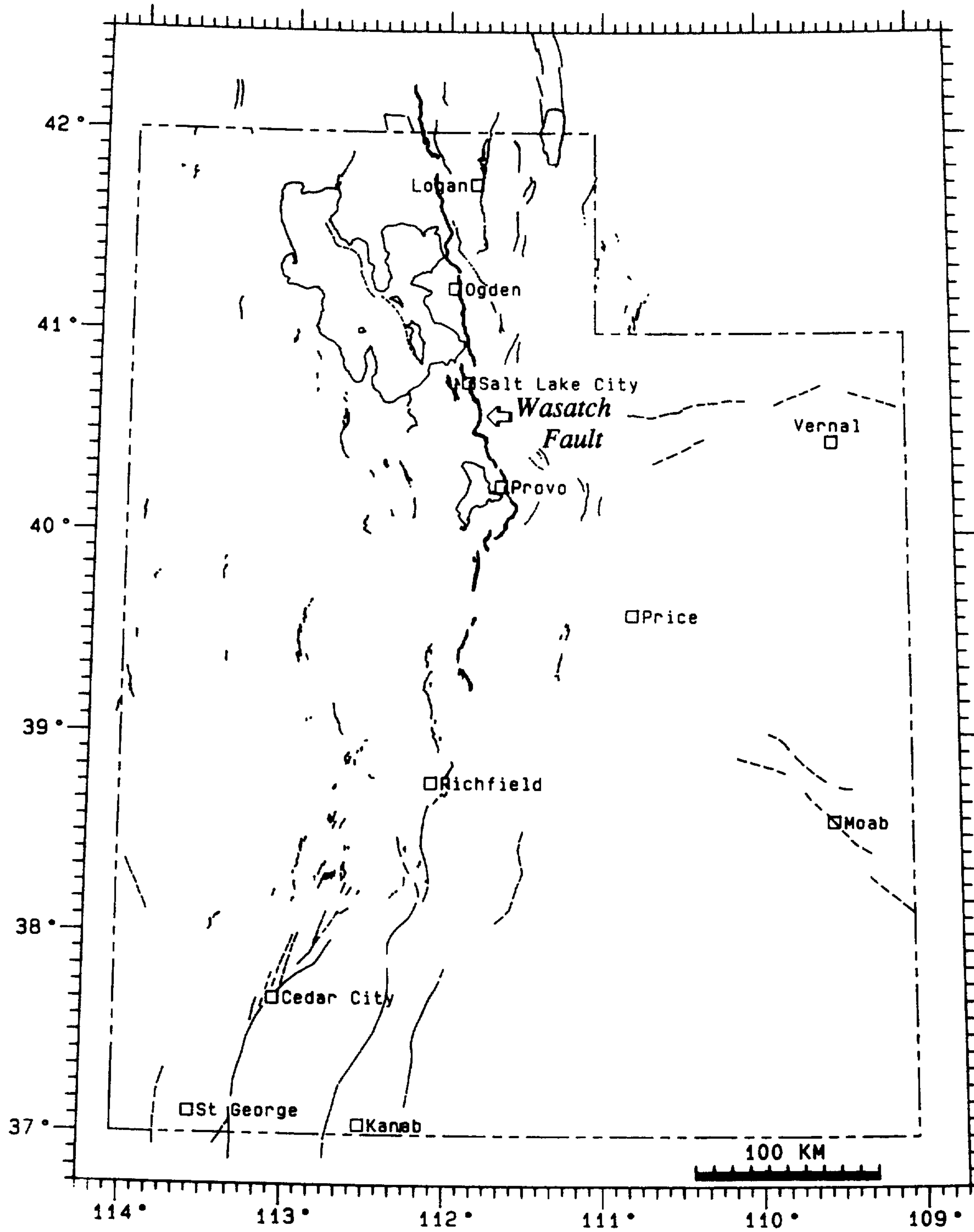
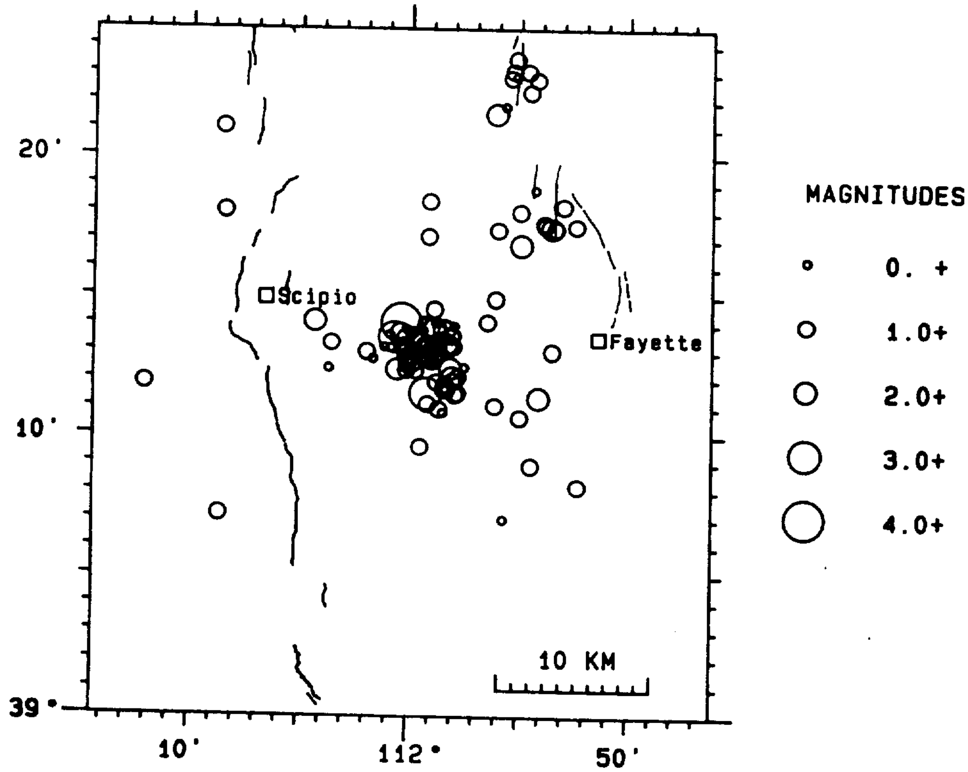


Figure 8. Generalized fault map of the Utah region modified from Arabasz *et al.* (1979) and Arabasz *et al.* (1987a,b).

(A)



(B)

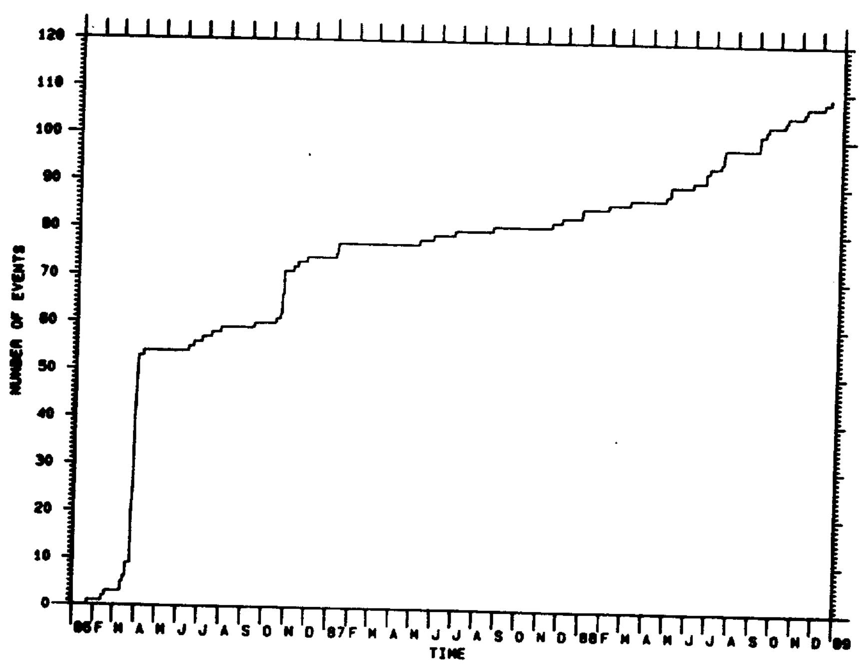
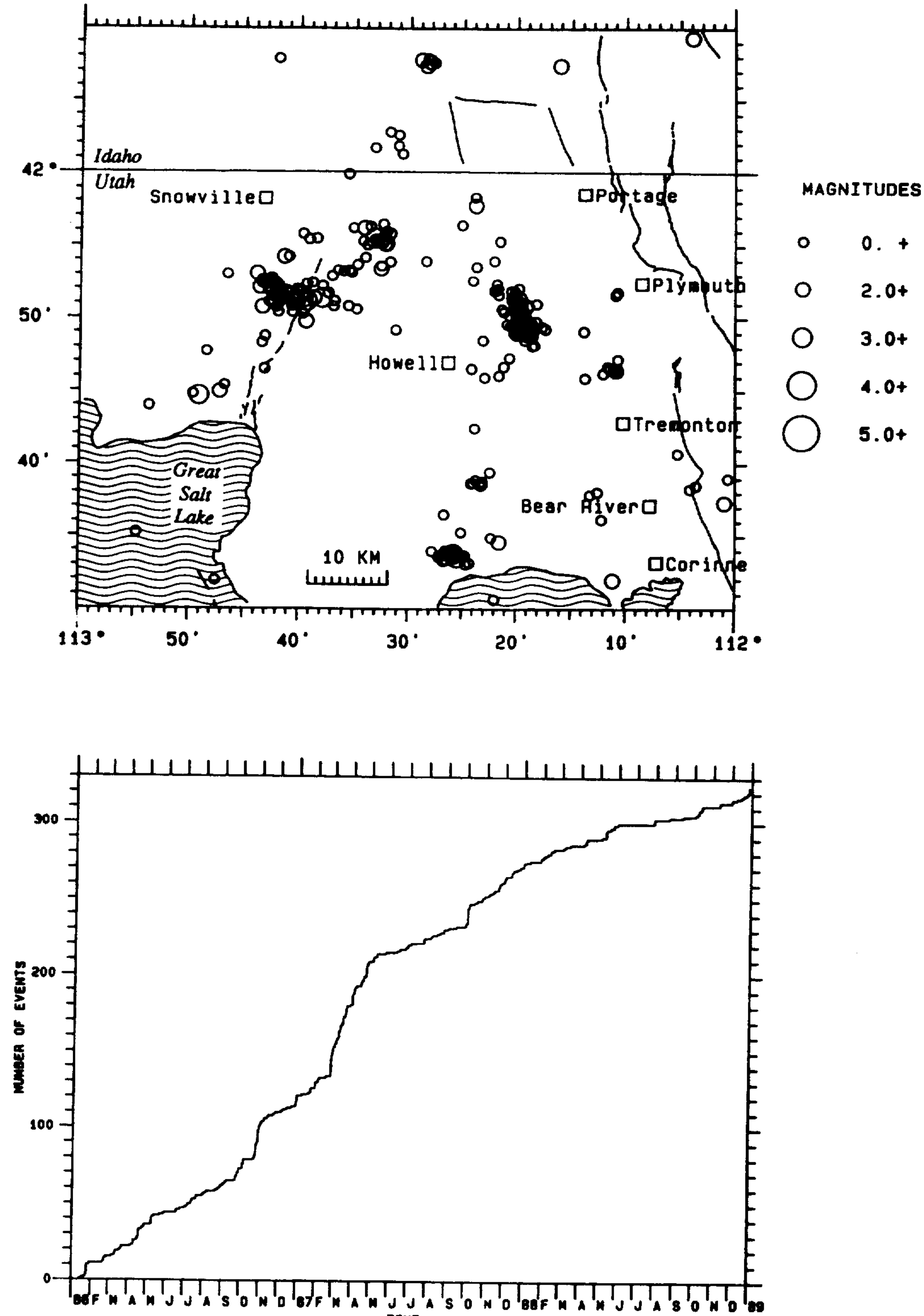


Figure 9. Earthquake activity in the Japanese Valley, Utah, area from January 1, 1986 through December 31, 1988. (A) Earthquake epicenter map, (B) Plot of the cumulative number of earthquakes vs time.

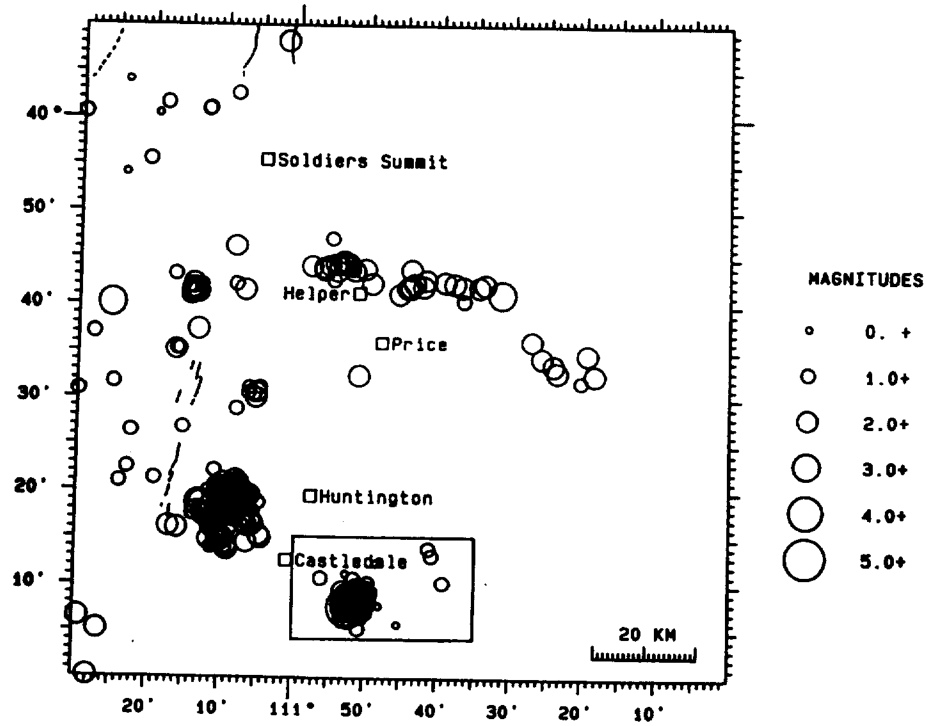
(A)



(B)

Figure 10. Earthquake activity in the Utah-Idaho border area from January 1, 1986 through December 31, 1988. (A) Earthquake epicenter map, (B) Plot of the cumulative number of earthquakes vs time.

(A)



(B)

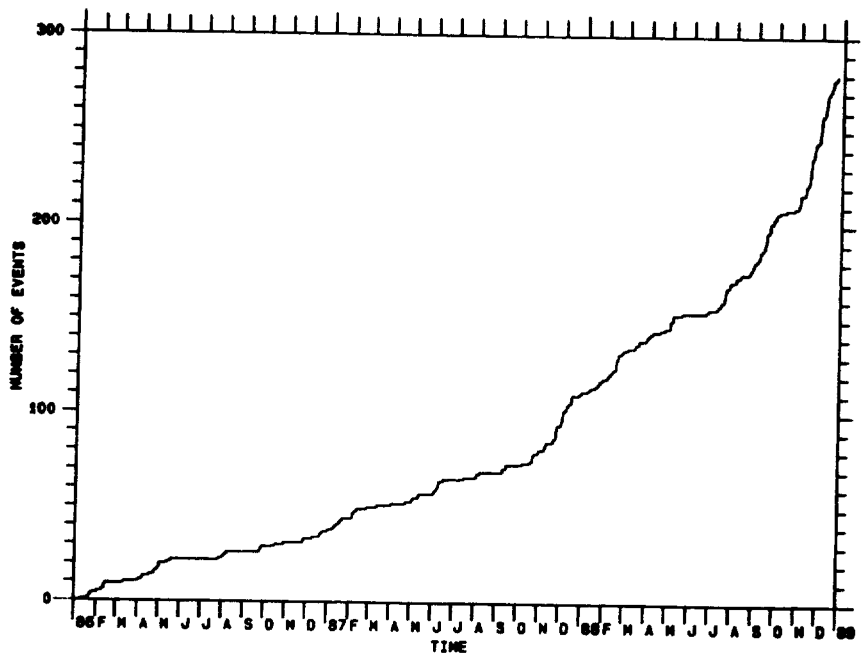


Figure 11. Earthquake activity in the Price, Utah, area from January 1, 1986 through December 31, 1988. (A) Earthquake epicenter map, box indicates those earthquakes associated with the 1988 San Rafael swell earthquake sequence, (B) Plot of the cumulative number of earthquakes vs time, does not include those earthquakes within the box of (a).

EARTHQUAKE DATA FOR THE UTAH REGION

Explanation

The following data are listed for each event:

1. Year (YR), date and origin time in Universal Coordinated Time (UTC). Subtract seven hours to convert to Mountain Standard Time (MST) and six hours to convert to Mountain Daylight Time (MDT).
2. Earthquake location coordinates in degrees and minutes of north latitude (LAT-N) and west longitude (LONG-W), and depth in kilometers. "*" indicates poor depth resolution: no recording stations within 10 km or twice the depth.
3. MAG, the computed local magnitude (M_L) for each earthquake. "W" indicates peak amplitude measurements from Wood-Anderson records were used. Otherwise, the estimate is calculated from signal durations and is more correctly identified as coda magnitude M_C . "--" indicates that no magnitude calulation was possible.
4. NO, the number of P and S readings used in the solution.
5. GAP, the largest azimuthal separation in degrees between recording stations used in the solution.
6. DMN, the epicentral distance in kilometers to the closest station.
7. RMS, the root-mean-square of the travel-time residuals in seconds:

$$RMS = \left\{ \frac{\sum_i \left[W_i R_i\right]^2}{\sum_i \left[W_i\right]^2} \right\}^{\frac{1}{2}}$$

where:

R_i is the observed minus the computed arrival time for the i-th P or S reading,

W_i is the relative weight given to the i-th P or S arrival time (0.0 for no weight through 1.0 for full weight).

TABLE 7

MAGNITUDE 3.0 AND LARGER EARTHQUAKES IN THE UTAH REGION: 1986 - 1988

yr	*date*	*origin time*	*latitude*	*longitude*	*depth*	*mag*	*no*	*gap*	*dmin*	*rms*
86	113	1232 4.63	41° 42.91′	111° 39.88′	7.5	3.3W	20	64	13	0.24
86	214	56 21.31	39° 41.18′	110° 31.50′	0.2*	3.2	14	239	41	0.38
86	221	2320 12.51	41° 44.69′	112° 49.11′	7.4	3.6W	19	225	5	0.23
86	324	2233 41.23	39° 13.34′	111° 59.90′	0.1*	3.3W	16	105	23	0.25
86	324	2240 23.41	39° 14.04′	112° 0.37′	0.9*	4.4W	17	87	21	0.27
86	325	253 1.34	39° 13.53′	112° 0.68′	1.5*	3.9W	17	90	22	0.28
86	514	1502 55.72	37° 17.66′	110° 19.16′	7.9*	3.1	15	255	63	0.46
86	605	805 41.73	41° 15.99′	111° 41.03′	9.6	3.6W	17	153	18	0.25
86	730	819 7.85	42° 26.23′	111° 14.51′	7.0*	3.7W	13	208	53	0.95
86	822	1326 33.66	37° 27.15′	110° 32.38′	3.0*	4.0W	6	146	50	0.11
86	829	826 24.33	42° 5.73′	111° 38.97′	3.8*	3.2W	15	123	34	0.14
86	919	1041 28.20	41° 27.99′	111° 42.11′	7.5*	3.4W	27	70	16	0.27
86	925	2231 14.96	38° 36.14′	112° 33.29′	0.0*	3.1	16	103	50	0.46
86	1005	1547 33.43	38° 37.87′	112° 33.48′	0.3*	3.3W	15	101	51	0.38
86	1018	2121 29.02	42° 0.86′	111° 26.89′	7.2*	3.5	19	147	19	0.22
86	1026	1431 56.67	41° 49.47′	112° 18.97′	4.1*	3.0W	27	73	12	0.26
86	1029	2213 14.48	41° 49.27′	112° 19.09′	4.7*	3.6W	19	75	12	0.15
86	1031	1158 28.16	41° 49.38′	112° 18.97′	3.6*	3.5W	22	73	12	0.15
86	1107	131 53.66	37° 25.82′	110° 17.83′	1.3*	3.0	7	187	71	0.23
86	1126	13 9.86	42° 28.55′	111° 12.26′	5.7*	3.5	13	188	58	0.22
86	1231	1121 56.48	41° 49.31′	112° 18.98′	4.7*	3.3W	18	73	12	0.16
87	214	1954 0.50	37° 47.05′	113° 49.28′	4.5*	3.2W	7	157	34	0.15
87	225	1230 33.50	41° 49.10′	112° 19.09′	3.1*	3.7W	21	74	12	0.18
87	305	302 50.21	40° 25.45′	110° 35.47′	5.2*	3.7W	22	214	56	0.33
87	322	241 55.10	41° 52.27′	112° 42.40′	6.7	3.4W	19	163	12	0.15
87	401	1640 41.08	41° 49.23′	112° 19.60′	5.6*	3.6W	18	75	12	0.17
87	401	2144 46.00	41° 49.34′	112° 19.67′	4.4*	3.3W	18	74	12	0.17
87	404	624 34.83	37° 40.66′	113° 1.47′	10.9*	3.1	6	140	119	0.09
87	424	1932 28.80	41° 51.20′	112° 39.33′	5.4*	3.3W	21	140	13	0.15
87	626	1236 27.09	38° 44.97′	111° 42.90′	1.4*	3.2W	13	88	40	0.34
87	902	500 20.87	38° 31.85′	112° 39.57′	2.4*	3.4W	8	164	42	0.50
87	917	831 26.85	41° 12.52′	113° 6.94′	10.2*	3.8W	27	217	62	0.15
87	925	409 54.54	41° 12.41′	113° 8.14′	10.8*	4.1W	20	197	64	0.32
87	925	427 58.36	41° 12.81′	113° 7.91′	10.7*	4.8W	23	219	64	0.25
87	925	518 13.58	41° 11.74′	113° 12.82′	6.2*	4.3W	24	239	68	0.26
87	926	28 2.11	41° 12.54′	113° 9.00′	10.1	4.0W	31	221	6	0.27
87	926	1447 49.38	41° 12.01′	113° 10.70′	10.0	3.1W	21	88	14	0.18
87	928	606 52.25	41° 13.60′	113° 10.85′	9.2	4.0W	23	93	8	0.23
87	1001	916 31.25	41° 12.70′	113° 10.83′	7.8	3.6W	25	86	9	0.21
87	1002	1435 48.79	41° 33.80′	112° 25.77′	7.7*	3.4W	25	124	16	0.18
87	1004	1738 26.44	41° 33.52′	112° 25.49′	11.9	3.3W	20	125	15	0.21
87	1005	1031 3.09	41° 12.13′	113° 10.52′	8.0	3.3W	26	86	9	0.20
87	1019	717 9.92	39° 40.11′	111° 25.52′	1.0*	3.6W	19	72	40	0.18
87	1023	1944 50.45	41° 11.78′	113° 10.16′	9.5	4.2W	22	120	8	0.17
87	1026	416 0.94	41° 12.05′	113° 10.66′	9.4	4.7W	23	123	9	0.22

MAGNITUDE 3.0 AND LARGER EARTHQUAKES IN THE UTAH REGION: 1986 - 1988

yr	*date*	*origin time*		*latitude*	*longitude*	*depth*	*mag*	*no*	*gap*	*dmin*	*rms*
87	1216	1743	7.50	39° 18.70′	111° 12.92′	0.5*	3.3W	26	78	28	0.44
87	1221	115	36.62	41° 55.55′	112° 33.21′	3.0*	3.2W	25	137	19	0.21
88	102	2310	48.93	36° 59.82′	112° 54.36′	2.8*	3.5	12	206	77	0.32
88	130	537	13.27	41° 12.31′	113° 10.46′	9.1	3.1W	22	125	4	0.17
88	504	545	4.68	39° 20.18′	111° 10.27′	9.0*	3.0	16	82	32	0.16
88	511	1031	30.09	41° 51.40′	112° 38.00′	7.9*	3.3W	21	206	27	0.12
88	522	1910	47.95	39° 53.38′	114° 10.82′	4.6*	3.6W	30	187	70	0.31
88	522	1922	45.87	36° 55.06′	112° 59.91′	1.6*	3.8	11	135	85	0.47
88	710	2045	59.41	41° 13.49′	111° 37.73′	7.0*	3.6W	8	154	51	0.23
88	711	1146	55.99	39° 11.51′	111° 59.25′	1.7*	3.1W	17	63	26	0.26
88	809	2307	52.90	42° 22.63′	111° 29.95′	8.6*	3.0	19	147	37	0.23
88	814	1907	58.88	39° 7.86′	110° 52.22′	9.2*	3.8W	13	122	22	0.16
88	814	2003	3.94	39° 7.67′	110° 52.15′	9.9*	5.3W	11	123	22	0.17
88	815	1450	23.56	39° 7.58′	110° 52.45′	6.9*	3.0W	7	162	23	0.13
88	818	1244	53.49	39° 7.93′	110° 52.04′	11.9	4.4W	13	122	1	0.16
88	821	2321	51.15	37° 2.52′	113° 52.14′	1.0*	3.5W	7	164	99	0.19
88	921	1758	25.89	39° 18.48′	111° 9.88′	9.1*	3.1	20	80	32	0.18
88	1106	1530	58.83	40° 43.30′	111° 25.07′	11.0	3.3W	23	131	14	0.31
88	1119	1942	37.35	41° 59.75′	111° 28.33′	6.0*	4.8W	17	139	20	0.17
88	1119	2000	53.11	42° 0.44′	111° 28.62′	4.9*	4.3W	19	142	21	0.15
88	1128	1046	46.80	41° 59.80′	111° 28.67′	5.5*	3.2W	20	139	21	0.18
88	1229	1818	57.59	36° 54.15′	112° 56.58′	1.5*	3.3	13	214	87	0.34

number of earthquakes = 67

* indicates poor depth control
W indicates Wood-Anderson data used for magnitude calculation

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Earthquakes in the Utah Region: 1986 - 1988

yr	*date*	*origin time*	*latitude*	*longitude*	*depth*	*mag*	*no*	*gap*	*dmin*	*rms*
86	104	356 57.83	39° 26.93′	111° 54.09′	10.1	1.7	14	62	8	0.40
86	104	1637 27.02	40° 31.97′	111° 30.09′	6.6	0.3	8	106	9	0.20
86	104	1641 4.85	40° 31.64′	111° 30.55′	9.6	--	8	107	10	0.24
86	104	1642 25.52	40° 31.22′	111° 28.76′	2.2	--	6	176	9	0.09
86	104	1649 1.14	40° 31.59′	111° 29.73′	4.8	0.8	8	100	9	0.16
86	108	120 3.13	41° 15.70′	111° 23.86′	0.1*	2.1W	26	158	24	0.30
86	108	914 24.80	41° 2.34′	111° 36.07′	10.5	0.6	13	193	19	0.20
86	110	1612 35.43	39° 41.93′	110° 34.65′	0.3*	2.4	10	274	36	0.20
86	110	1840 56.93	37° 52.91′	113° 1.59′	4.4*	1.5	5	144	23	0.28
86	110	2203 14.64	39° 33.07′	112° 12.46′	1.8*	1.5	10	103	20	0.43
86	112	2116 19.12	41° 12.14′	111° 40.06′	3.3*	1.2	11	141	18	0.30
86	112	2358 52.68	41° 53.92′	112° 31.75′	1.8*	0.8	11	124	17	0.15
86	113	836 39.71	41° 43.50′	111° 39.98′	10.4	2.1W	22	66	10	0.24
86	113	1232 4.63	41° 42.91′	111° 39.88′	7.5	3.3W	20	64	13	0.24
86	117	609 18.54	41° 46.12′	112° 21.64′	5.0*	1.2	14	87	18	0.27
86	120	2240 55.49	39° 18.83′	111° 7.68′	5.1*	1.7	12	192	35	0.32
86	121	2214 17.16	39° 32.90′	112° 12.30′	1.2*	1.6	15	103	19	0.48
86	122	525 7.18	39° 41.96′	110° 36.93′	0.2*	2.3	12	271	33	0.31
86	122	748 50.93	38° 12.92′	112° 20.27′	2.4*	1.6	9	168	36	0.20
86	122	1102 26.52	40° 30.99′	111° 23.26′	7.0	0.2	6	164	11	0.13
86	122	1138 20.31	39° 12.33′	111° 59.73′	0.5*	1.2	9	99	24	0.14
86	123	524 17.51	39° 55.63′	111° 38.28′	2.3*	1.3	13	77	14	0.26
86	123	812 40.29	41° 58.33′	112° 23.88′	5.7	0.8	12	99	8	0.23
86	123	1612 15.30	39° 34.99′	111° 30.58′	5.2*	1.3	6	220	30	0.11
86	123	1929 1.13	41° 21.04′	111° 37.56′	9.3	2.7W	26	117	16	0.24
86	123	1941 7.79	41° 20.57′	111° 35.51′	10.9	1.3	13	143	15	0.35
86	124	456 28.11	41° 55.16′	112° 32.13′	5.9*	2.5W	15	131	17	0.18
86	124	1154 48.41	39° 42.28′	110° 43.63′	0.1*	2.2W	12	263	23	0.46
86	124	2337 58.65	41° 55.21′	112° 32.13′	2.2*	2.2	16	131	17	0.18
86	125	34 50.66	41° 55.44′	112° 33.18′	11.4	1.5	14	137	19	0.30
86	125	55 32.20	41° 55.84′	112° 32.27′	2.5*	0.9	12	133	18	0.15
86	125	122 51.27	41° 55.37′	112° 32.43′	3.4*	1.5	14	133	18	0.20
86	125	135 48.79	41° 55.86′	112° 31.70′	6.9*	0.8	12	130	17	0.30
86	125	1248 38.58	41° 55.68′	112° 32.22′	5.6*	1.0	14	132	18	0.18
86	127	1416 21.73	37° 36.44′	112° 26.60′	1.2*	1.3	10	156	74	0.35
86	128	2230 26.83	39° 32.85′	112° 12.52′	1.4*	1.2	16	110	19	0.35
86	129	913 27.38	41° 56.00′	112° 32.10′	8.0*	1.3	14	133	17	0.25
86	130	950 52.79	42° 20.69′	111° 21.57′	1.5*	2.5W	15	239	43	0.16
86	201	2319 50.79	40° 1.61′	111° 18.36′	5.1*	1.0	12	245	43	0.25
86	204	55 52.06	38° 40.59′	112° 10.60′	2.0*	1.4	11	85	18	0.20
86	205	852 17.61	41° 24.97′	111° 43.09′	8.4*	2.0	26	117	21	0.30
86	206	1219 28.68	37° 35.84′	112° 27.67′	2.3*	1.8	8	224	54	0.31
86	207	359 14.06	41° 43.25′	111° 39.34′	17.2	0.7	10	129	13	0.31
86	207	542 34.85	41° 44.05′	111° 39.07′	10.0	1.4	18	134	10	0.30
86	208	1303 35.55	38° 39.64′	112° 11.56′	1.9*	2.3	11	100	16	0.19

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yr	*date*	*origin time*	*latitude*	*longitude*	*depth*	*mag*	*no*	*gap*	*dmin*	*rms*
86	208	1306 19.31	38° 39.01′	112° 11.44′	2.5*	1.3	9	90	15	0.43
86	208	1309 18.98	38° 39.36′	112° 11.23′	1.8*	1.4	9	89	16	0.38
86	208	1350 48.52	38° 39.41′	112° 11.40′	2.5*	1.4	9	134	16	0.36
86	208	1411 6.96	38° 39.53′	112° 11.07′	5.2*	1.4	9	89	16	0.27
86	208	2112 12.03	39° 17.36′	111° 7.78′	0.4*	1.9	15	215	35	0.41
86	210	242 7.68	38° 31.35′	112° 35.98′	7.0*	1.9	8	134	37	0.90
86	210	605 15.61	40° 41.55′	111° 36.30′	2.5*	0.2	9	187	16	0.15
86	210	605 29.39	40° 41.47′	111° 36.95′	7.9	0.8	17	76	16	0.20
86	210	2241 39.32	40° 49.38′	111° 54.05′	6.4	1.5	18	97	9	0.34
86	211	817 47.04	40° 53.69′	111° 35.64′	12.5	1.2	16	141	6	0.34
86	211	2030 17.26	40° 21.18′	111° 27.20′	10.0	0.6	7	246	9	0.19
86	211	2208 53.56	39° 18.49′	111° 11.22′	0.9*	2.1	18	89	30	0.43
86	211	2309 13.10	39° 42.20′	110° 33.88′	0.2*	2.7	14	265	37	0.31
86	212	2122 54.66	39° 22.85′	111° 55.43′	14.8	1.7	13	72	15	0.29
86	214	56 21.31	39° 41.18′	110° 31.50′	0.2*	3.2	14	239	41	0.38
86	216	550 25.38	37° 47.55′	113° 15.78′	3.2*	1.3	6	134	16	0.08
86	216	1923 52.45	40° 50.46′	110° 31.26′	0.9*	1.7W	11	266	78	0.33
86	217	756 3.54	39° 7.01′	111° 55.68′	12.5	0.9	5	196	22	0.17
86	221	103 33.31	41° 44.98′	112° 47.19′	7.1	2.1W	12	219	3	0.21
86	221	2320 12.51	41° 44.69′	112° 49.11′	7.4	3.6W	19	225	5	0.23
86	222	8 28.73	41° 44.81′	112° 49.65′	7.9	0.9	6	271	6	0.06
86	222	2318 1.28	40° 51.04′	109° 37.13′	10.8*	1.8	9	239	147	0.39
86	223	1105 31.54	39° 55.29′	112° 15.93′	2.3*	2.1	17	86	17	0.37
86	224	819 45.34	41° 46.57′	112° 24.18′	2.3*	0.9	9	109	18	0.11
86	224	2316 19.82	39° 32.72′	112° 12.41′	1.7*	1.7	12	103	19	0.36
86	304	2002 34.94	40° 46.08′	110° 33.43′	0.2*	2.7W	19	250	71	0.31
86	305	10 54.37	37° 47.86′	112° 33.14′	2.5*	1.9	9	151	52	0.37
86	306	1738 3.92	41° 39.01′	112° 0.61′	4.2	1.5	15	101	6	0.20
86	309	2048 6.34	40° 40.90′	109° 34.03′	3.5*	2.5	18	253	139	0.48
86	311	2044 3.82	39° 18.24′	111° 53.01′	0.1*	1.6	12	83	21	0.29
86	312	5 12.73	41° 55.46′	112° 39.12′	3.2*	1.0	11	170	19	0.19
86	312	6 4.33	41° 55.83′	112° 39.67′	1.6*	0.9	11	176	19	0.16
86	312	47 25.14	39° 11.08′	111° 56.10′	1.6*	1.5	10	108	25	0.13
86	312	132 9.82	40° 42.82′	111° 35.04′	2.3*	0.5	10	165	17	0.16
86	312	617 24.67	39° 19.54′	111° 5.96′	0.3*	2.6W	19	177	38	0.40
86	313	249 6.89	41° 55.36′	112° 32.54′	5.5*	2.4W	15	133	18	0.13
86	313	1147 5.10	39° 31.50′	112° 4.20′	2.6*	1.2	10	135	21	0.30
86	315	309 51.99	39° 17.41′	111° 53.36′	0.8*	1.7	13	116	23	0.26
86	316	1011 40.40	40° 16.58′	111° 23.47′	9.8	1.2	13	182	19	0.15
86	317	2213 13.61	39° 56.81′	111° 56.85′	13.9	0.8	5	160	11	0.02
86	317	2213 23.33	40° 1.78′	111° 53.00′	2.3	1.1	5	154	7	0.26
86	318	306 6.36	39° 17.62′	111° 53.88′	7.3*	1.3	10	144	23	0.12
86	318	450 3.89	39° 17.52′	111° 53.85′	2.6*	1.0	9	144	23	0.07
86	318	2023 40.13	39° 17.51′	111° 52.43′	2.9*	1.0	10	139	23	0.18
86	319	2053 36.02	41° 55.18′	112° 32.28′	1.5*	2.3	14	198	18	0.17

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86	319	2259 58.50	39° 32.75′	112° 12.46′	0.0*	1.8	11	154	19	0.38
86	320	149 52.04	39° 57.63′	111° 55.60′	2.2*	1.0	7	144	13	0.45
86	320	1154 14.74	38° 32.22′	112° 8.84′	6.9*	1.4	5	127	48	0.10
86	321	1018 22.46	39° 57.99′	111° 57.65′	6.7	0.7	13	101	10	0.27
86	321	2159 50.93	39° 30.43′	112° 2.21′	2.6*	1.0	10	101	18	0.30
86	321	2320 32.76	41° 36.92′	111° 40.93′	3.2*	0.8	8	147	21	0.11
86	322	1331 38.11	41° 51.22′	112° 41.66′	8.1	1.9	14	164	11	0.11
86	323	437 1.28	41° 51.55′	112° 42.48′	8.0	0.7	11	173	10	0.30
86	324	1550 37.05	41° 20.01′	111° 40.70′	4.0*	1.5	15	129	23	0.22
86	324	2233 41.23	39° 13.34′	111° 59.90′	0.1*	3.3W	16	105	23	0.25
86	324	2240 23.41	39° 14.04′	112° 0.37′	0.9*	4.4W	17	87	21	0.27
86	324	2334 9.90	39° 12.59′	111° 59.86′	2.8*	1.4	11	125	24	0.23
86	324	2352 54.32	39° 12.80′	112° 0.15′	2.3*	2.0	9	126	23	0.20
86	325	249 6.53	39° 13.67′	112° 0.37′	1.3*	2.8W	10	95	22	0.45
86	325	253 1.34	39° 13.53′	112° 0.68′	1.5*	3.9W	17	90	22	0.28
86	325	300 7.56	39° 12.54′	112° 0.09′	2.6*	1.4	9	127	24	0.07
86	325	302 15.44	39° 12.85′	112° 0.29′	15.5	0.9	6	128	23	0.10
86	325	350 12.84	39° 12.75′	111° 59.73′	2.6*	2.0	14	124	24	0.25
86	325	352 37.05	39° 12.34′	112° 0.15′	3.6*	1.3	9	128	24	0.15
86	325	432 23.24	39° 13.23′	111° 59.30′	3.0*	1.3	9	121	24	0.40
86	325	1855 21.95	39° 12.67′	112° 0.12′	0.2*	1.5	9	127	24	0.30
86	325	1916 34.73	39° 12.98′	112° 0.19′	5.0*	1.2	7	127	23	0.26
86	326	1350 21.41	39° 12.78′	111° 59.25′	0.1*	1.3	8	122	24	0.14
86	326	1932 21.73	39° 17.43′	111° 53.53′	2.1*	2.4	19	76	23	0.33
86	327	615 16.86	39° 13.30′	111° 59.42′	1.7	--	6	238	3	0.49
86	327	1239 43.93	39° 17.36′	111° 55.99′	9.0	1.0	11	89	12	0.23
86	327	1306 55.52	39° 10.82′	111° 58.47′	1.3	--	5	126	2	0.17
86	327	2018 52.98	39° 13.16′	112° 1.15′	1.7	--	10	155	4	0.13
86	327	2023 39.11	39° 13.14′	112° 0.85′	1.7	--	8	169	3	0.11
86	327	2027 34.94	39° 12.74′	112° 1.66′	1.1	--	6	165	4	0.03
86	327	2157 16.41	39° 13.99′	111° 58.29′	5.9	--	7	126	4	0.16
86	327	2221 2.07	39° 12.98′	112° 1.95′	2.8	1.9	16	136	4	0.24
86	327	2301 53.51	39° 18.81′	111° 54.31′	3.6	--	8	194	10	0.04
86	328	340 52.66	39° 13.57′	111° 58.52′	9.0	--	16	109	2	0.37
86	328	424 21.41	39° 13.29′	111° 58.79′	5.7	--	10	112	2	0.06
86	328	506 36.92	39° 13.45′	111° 59.07′	4.9	--	11	120	2	0.12
86	328	656 7.72	39° 13.77′	112° 0.04′	0.2	--	12	136	2	0.18
86	328	848 47.24	39° 12.92′	111° 59.87′	0.9	--	12	135	3	0.08
86	328	1221 11.85	39° 14.13′	111° 59.39′	6.8	--	10	127	1	0.08
86	328	1334 57.62	39° 13.44′	111° 59.14′	6.3	--	10	122	2	0.06
86	328	1532 27.79	39° 13.77′	111° 59.36′	5.0	--	8	127	2	0.08
86	328	1934 35.13	39° 13.94′	111° 57.95′	5.0	--	8	121	2	0.06
86	329	732 59.22	38° 34.96′	111° 50.98′	4.1*	1.1	9	117	29	0.16
86	329	1329 59.17	39° 14.07′	111° 58.80′	5.9	--	7	117	5	0.16
86	329	1347 21.04	39° 13.02′	111° 53.50′	19.9	1.0	19	60	3	0.19