PNE-WW-33

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Las Vegas, Nevada

SEISMIC INVESTIGATIONS IN WYOMING AS PART OF THE WAGON WHEEL DEFINITION STUDIES

USGS Open File 74-30
1974

This report is preliminary and has not been edited or reviewed for conformity with Geological Survey standards and nomenclatures

Prepared Under
EPNG Letter of Agreement (Nov. 10, 1972)
for
El Paso Natural Gas Company
El Paso, Texas 79978

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by
Kenneth C. Bayer and Geraldine M. Wuollet

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Illustrations

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Abstract

As part of the Wagon Wheel definition studies, seismic investigations were conducted in Wyoming by personnel of the United States Geological Survey, Las Vegas, Nevada. From March 22, 1973 to February 22, 1974, a seismograph station recorded seismic activity at five different areas in the vicinity of the proposed Project Wagon Wheel location in the Green River basin of Wyoming. The short period vertical component station, located near and around ground zero (GZ) operated for approximately two months at each of five locations at distances from 3 to 21 km from GZ.

One hundred and twenty nine (129) natural and man-made events identifiable as located within a radius of 100 km from the station were recorded during the eleven-month study. Calculated magnitudes ranged from M_L - 0.6 to M_L 2.6.

Introduction

The principal objective of the study was to monitor the seismic activity in the vicinity of the proposed Wagon Wheel drill-site in the Green River Basin of Wyoming. PIN, the first of five locations occupied by a short period vertical seismograph, started telemetering data to Las Vegas on March 22, 1973. The five station locations are shown in figure 1 and the corresponding station descriptions are listed in table 1.

The station configuration consists of an S-13 short period vertical seismometer operating through a 6202 VCO amplifier system. The seismic signal is transmitted via radio frequency to Rock Springs, thence via telephone line to Boulder, Colorado and on to Las Vegas, Nevada. In Las Vegas the signal is recorded on 16 mm film with a Geotech Develocorder and on heat sensitive paper with a Geotech Helicorder. The magnification response curve of the total system is shown in figure 2. The magnification was 125K at 1 Hz, 975K at 5 Hz, and 1,950K at 10 Hz. Due to a high background noise, the operating gain was reduced by 6 db (factor of 2) at PI-4.

Observations and Discussions

The seismic activity was monitored at 5 locations (see figure 1), for a total time period of 11 months. Thus, an approximate time of two months was planned for each of the 5 sites (table 1).

A total of 130 events are tabulated in table 2. For general interest, the arrival time of the Plowshare event Rio Blanco is included on table 2. These data represent the number of detectable and identifiable earthquakes and chemical explosions recorded at that individual station, occurring at a radius of 100 km or less. The S-P time used as the cutoff was 12 seconds. Occasionally if an S or L phase was not in evidence a PG-PN time interval was used as a time-distance parameter. With the exception of the last recording site (PI-4), the number of identifiable disturbances originating within 100 km and recorded at the stations was approximately one every 2.3 days. The system magnification at PI-4 was lowered by a factor of 2, and at that station the number of events recorded was approximately one every 6.6 days.

With only one station being moved approximately every two months, evaluation of recorded events was naturally limited. For example, with one seismometer the ground motion at the station can be determined, the distance of the event from the station estimated, and the magnitude computed. Numerous additional seismic events notincluded in table 2 were recorded at each of the stations; however, with only the initial P phase discernible, the distance and magnitude values could not be computed.

Data provided by companies conducting blasting operations, such as coal mines, iron mines, seismic prospecting, road construction, etc., plus previous experience on the Nevada Test Site, indicate that the majority of the events recorded during normal working hours are probably man-made explosions. A graph, figure 3, shows the 129 local events from table 2, distributed according to the hour of the day they occurred. The time is shown as Greenwich-Mean-Time (GMT), which is customarily used to record earthquakes. GMT - 7 hours = Mountain Standard Time (MST); and GMT - 6 hours = Mountain Daylight Time (MDT). From the graph it was determined approximately 64 percent of the events are non-tectonic in origin. It may be observed that the incidence of events was much greater after 1600 GMT, which is 9:00 a.m. MST or 10:00 a.m. MDT. During the eleven months of recording a total of 31 events occurred between the hours of 0 GMT and 16 GMT, (figure 3), or less than 2 events for each hour. There were 98 events observed during the eight hours between 16 GMT and 24 GMT, or more than 12 events for each hour. If the activity had occurred during the 16 to 24 GMT time period (8 hours), as frequently as during the other 16 hours there would have been only a total of about 47 events during the eleven months of recording (31 events + 2 events/ hour x 8 hours = 47 events).

There are numerous mines in the area, and blasting operations may have been conducted at any hour of the day; in which case, more than 64 percent of the events could have been non-tectonic in origin.

An analysis was made by plotting the distance-radius of the 129 events as concentric circles around each individual seismic station monitored. Many of the circles intersected near areas where blasts have been known to occur, such as mines near Kemmerer and Lander.

Circles were plotted on a map representing events which occurred between 0 hours GMT and 16 hours GMT only. Many of these circles intersected near areas where earthquakes have been known to occur near the western boundary of Wyoming, in the Wind River Range, and near Rock Springs (figure 1). Many circles intersected in the vicinity of the Wyoming Range; however, there are numerous mines in the area.

Equivalent local magnitudes (M_L) were determined by the method developed by C. F. Richter (1958) for determining magnitude based on his work in California using the Wood-Anderson seismometer. The magnitudes were computed by reducing the recorded trace amplitudes of the S-13 system to the amplitude equivalent to that of a standard Wood-Anderson seismograph at a magnification of 2800, and then using Richter's formula:

$$M_L = \log A - A_o$$

In the formula, M_L is the Richter magnitude where A is the calculated equivalent Wood-Anderson amplitude and A_o is a distance attenuation factor. Frequency corrections were applied to the calculations when the responses of both systems required it. The magnitudes calculated ranged from M_L -0.6 to M_L 2.6.

The stations occupied for the study are situated in seismic Zone 1 as defined by Algermissen (1969) as follows: "Minor damage; distant earthquakes may cause damage to structures with fundamental periods greater than 1.0 second; corresponds to intensities V and VI of the Modified Mercalli Intensity Scale of 1931". A part of the area of study is classified as Zone 2, as shown in figure 4. The Modified Mercalli Intensity Scale of 1931 is explained in the Appendix.

An attempt was made to evaluate the seismic background and eliminate sporadic noise such as high winds, telephone line dropout, radio frequency interference, and occasional air and surface vehicle noise. Background noise had been evaluated at various sites in Wyoming by Navarro (1973) prior to selection of the stations. The evaluation was made monitoring with high gain seismic equipment.

Extremely noisy prospective sites were eliminated for future monitoring for this study. The system gains at the selected sites were easily set as a result of the background noise study. Table 3 lists ambient background noise values measured at each of the five stations monitored during the study by Navarro. The stations are tabulated in ascending order of noise. After visually scanning the records, the authors also found the stations to have background noise in the same order, i.e. with PI-3 having the least noise and PI-4 the most. In fact, it was necessary to reduce the gain by a factor of 2 at PI-4 due to high background noise.

Conclusions and Recommendations

Documentation of seismic events in the vicinity of the Wagon Wheel proposed location ($\sim$ 100 km radius) substantiates Algermissen's classification of the site as seismic Zone 1. During the eleven months of earthquake monitoring, events identifiable as microearthquakes ($1.0 \leq M \leq 3.0$) and ultra microearthquakes ($M < 1.0$) were detected within 100 km of the proposed Wagon Wheel site. All the events were smaller than M_L 3.0.

It is recommended that a minimum of 3 station (optimum 5 station) seismic array be installed six months prior to detonation time. The stations should be equidistantly spaced from the Wagon Wheel site at bearings of 0°, 135°, and 225°. A distance of approximately 30 km from GZ is proposed. It is strongly recommended that each station consist of a 3-component high gain system with the seismometers placed vertically and transversely, and radially to GZ. The importance of the data and its analysis may warrant recording two levels of gain (factor of 4 separation) with a Geotech Develocorder on 16 mm film.

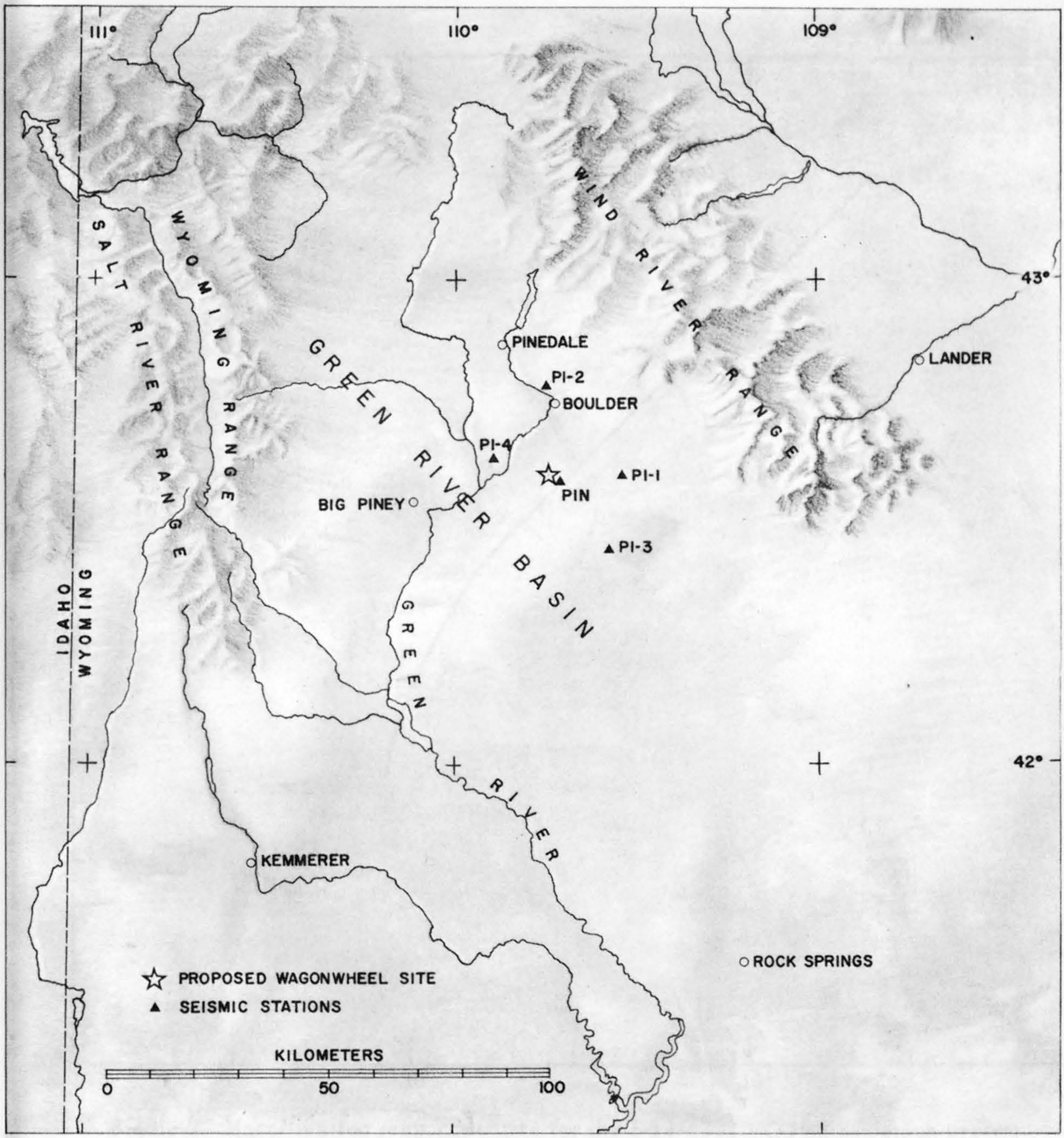

Figure 1. Seismic Station locations.

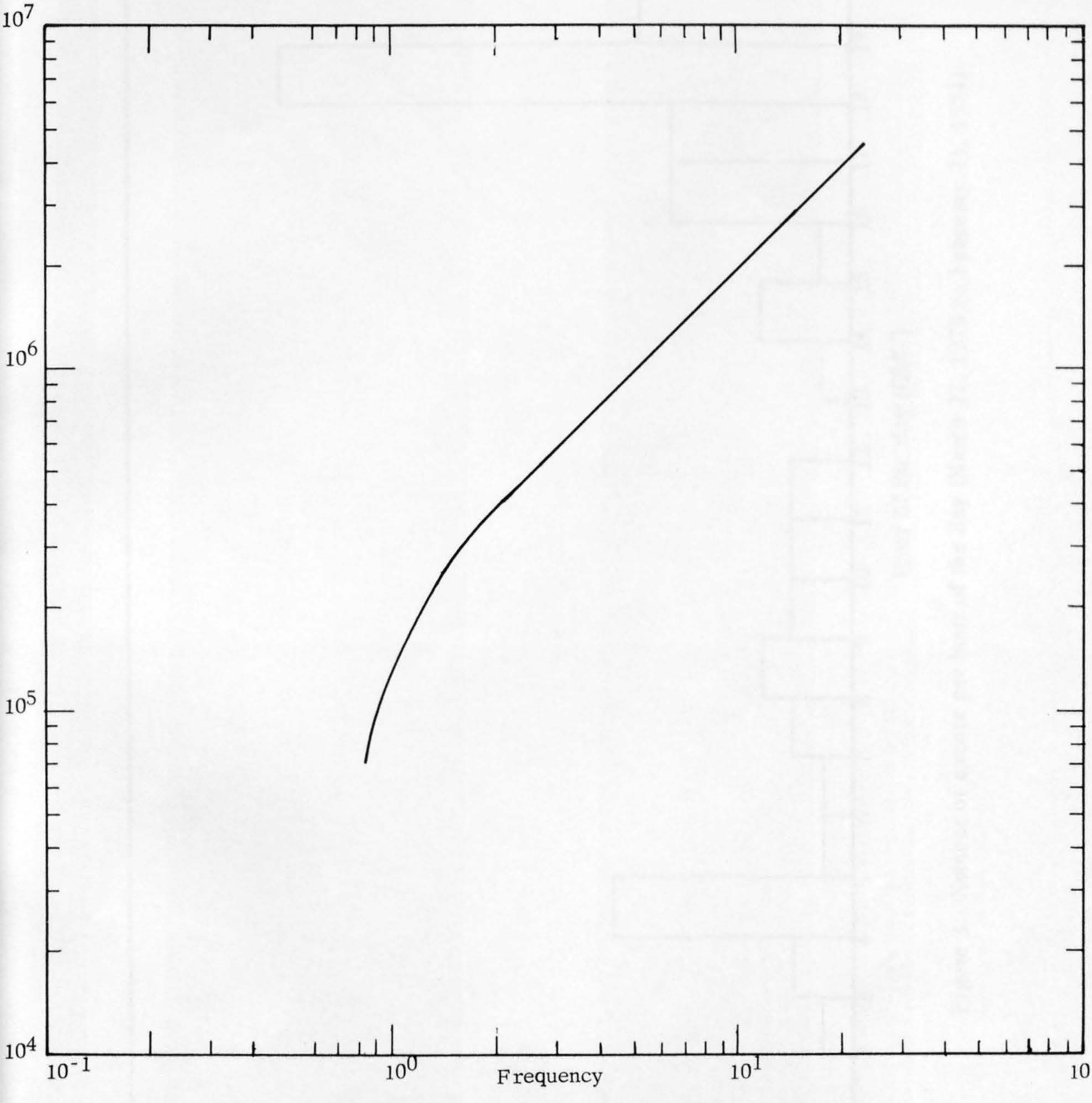

Figure 2. Magnification response curve for the S-13/6202 VCO seismograph system.

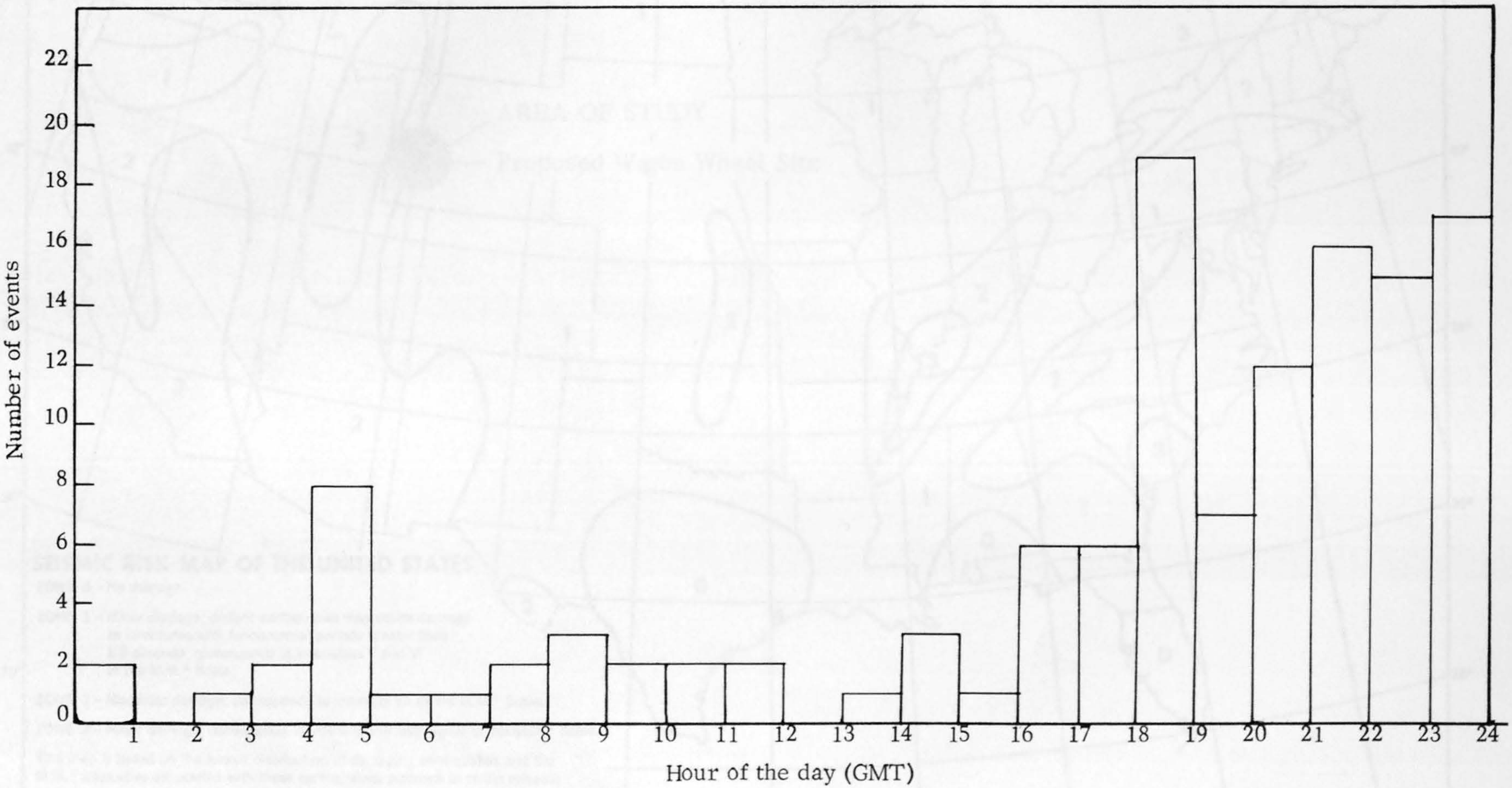

Figure 3. Number of events per hour of the day (March 22, 1973 to February 23, 1974)

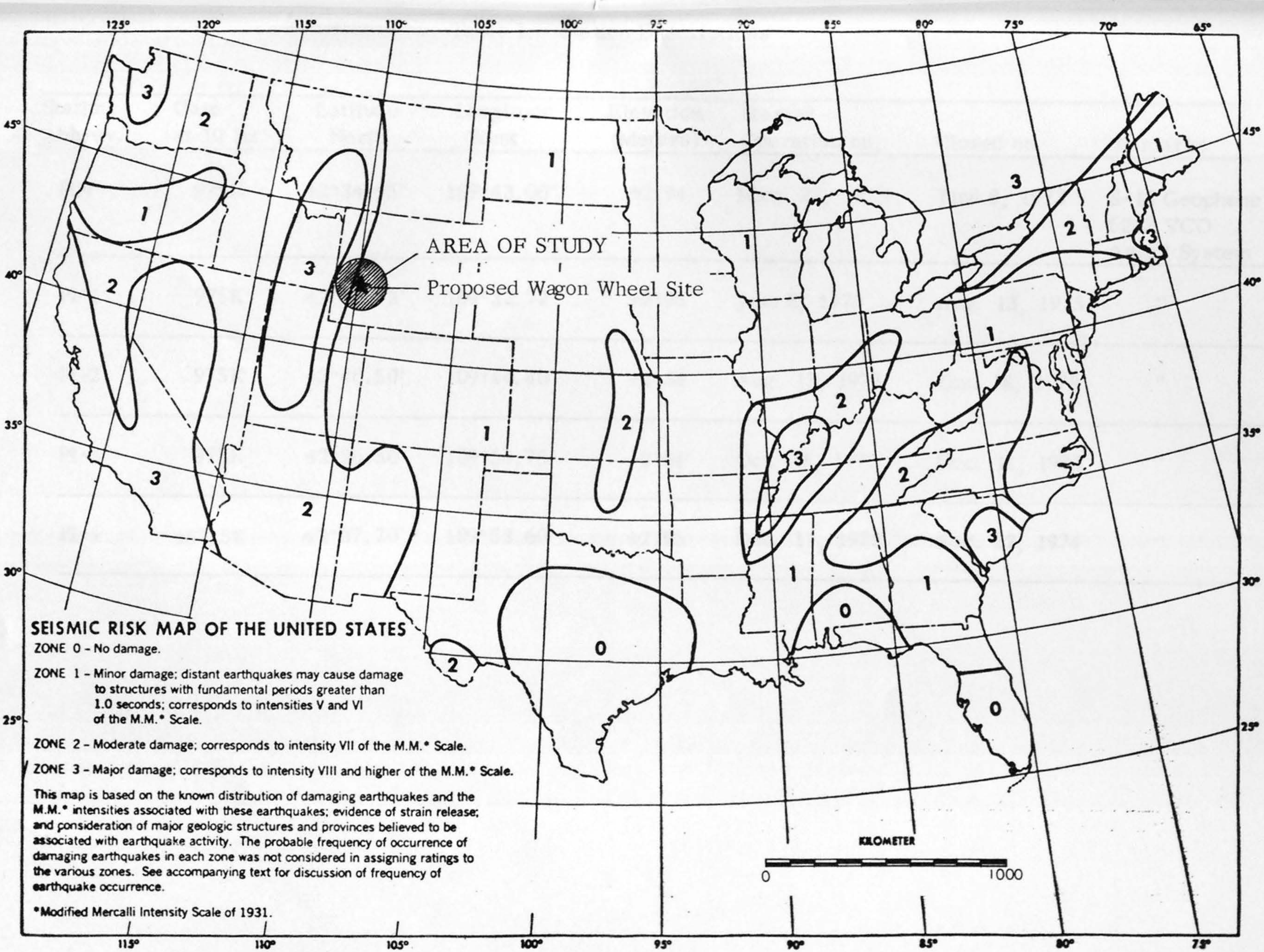

Figure 4. Seismic risk map of the United States (after Algermissen).

Table 1. Station Descriptions

Station Abbrev.	Gain at 10 Hz	Latitude North	Longitude West	Elevation (Meters)	Started Operation on,	Closed on.	Remarks
PIN	975K	42°34.95'	109°43.00'	+2194	Mar. 22, 1973	June 8, 1973	S-13 Geophone 6202 VCO Amp'l System
PI-1	975K	42°35.72'	109°32.72'	+2195	June 8, 1973	Aug. 13, 1973	"
PI-2	975K	42°46.50'	109°44.40'	+2134	Aug. 13, 1973	Oct. 18, 1973	"
PI-3	975K	42°26.50'	109°34.75'	+2164	Oct. 18, 1973	Dec. 11, 1973	"
PI-4	487.5K	42°37.70'	109°53.60'	+2195	Dec. 11, 1973	Feb. 22, 1974	"

Table 2

Wyoming Seismic Events

Event No.	Date d m y	Phase	Arrival time (GMT)	T, period (secs)	Amp'l Max p-p (mm)	Remarks
1.	22 03 73	I(P)G	233911.2	-	**	~ 90 km from PIN
		IPN	233911.8			Probable earthquake
						$2.3 \leq M_L < 3$
2.	27 03 73	IPC	043059.5	0.3	61.0	~ 40 km from PIN
		E(S)	043109.5			$M_L = 1.8$
3.	27 03 73	I(P)	215611.2	0.3	36.0	~ 80 km from PIN
		I(S)	215622.3			$M_L = 2.1$
4.	28 03 73	I(P)	225534.3	0.2	25.0	~ 100 km from PIN
		E(S)	225546.2			$M_L = 1.9$
5.	02 04 73	IPC	205004.2	0.2	57.0	~ 9 km from PIN
		IS	205005.3			Local EQ $M_L = 1.6$
6.	04 04 73	IPD	182555.6	0.2	20.0	~ 75 km from PIN
		ES	182604.2			Local EQ $M_L = 1.6$
7.	04 04 73	I(P)	231345.1	0.2	17.0	~ 100 km from PIN
		ES	231357.1			Local EQ $M_L = 1.7$
8.	09 04 73	IPC	182329.1	0.2	62.0	~ 70 km from PIN
		I(S)	182337.5			$M_L = 2.1$
9.	11 04 73	EPgC	231435.8	0.2	26.0	~ 85 km from PIN
		IP*	231436.4			$M_L = 1.8$
10.	12 04 73	IP	034647.9	0.2	36.0	~ 75 km from PIN
		I(S)	034656.6			$M_L = 1.9$
11.	13 04 73	I(P)	225928.2	0.1	27.0	~ 95 km from PIN
		E(S)	225940.0			$M_L = 1.6$
12.	16 04 73	IPC	234757.5	-	**	~ 85 km from PIN
		E(S)	234808.1			$2.2 \leq M < 3$

Table 2

Wyoming Seismic Events

Event No.	Date d m y	Phase	Arrival time (GMT)	T, period (secs)	Amp'l Max p-p (mm)	Remarks
13.	17 04 73	IPD	215832.6	0.2	55.4	~ 15 km from PIN
		I(S)	215834.4			$M_L = 0.8$
14.	19 04 73	I(P)	170156.9	0.2	32.0	~ 95 km from PIN
		ES	170208.5			$M_L = 1.9$
15.	19 04 73	IP	202535.3	-	**	~ 10 km from PIN
		I(S)	202536.8			$M_L > 0.8$
16.	21 04 73	EP	105816.4	0.25	3.5	~ 80 km from PIN
		ES	105825.7			$M_L = 0.9$
17.	21 04 73	IPC	114821.4	0.1	24.0	~ 80 km from PIN
		I(S)	114830.4			$M_L = 1.4$
18.	25 04 73	I(P)	175721.0	-	**	~ 80 km from PIN
		ES	175730.0			$2.2 \leq M_L < 3$
19.	25 04 73	IP	230219.0	-	**	~ 80 km from PIN
		I(S)	230230.3			$2.2 \leq M_L < 3$
20.	30 04 73	IPD	194031.9	-	**	~ 10 km from PIN
		I(S)	194033.5			$M_L > 0.8$
21.	02 05 73	IP	202423.8	0.1	28.0	~ 45 km from PIN
		E(S)	202429.8			$M_L = 1.1$
22.	11 05 73	IPD	233002.6	0.1	3.8	~ 20 km from PIN
		IS	233005.1			$M_L = -0.6$
23.	15 05 73	EPGD	165811.4	0.1	53.0	~ 80 km from PIN
		IP*	165812.1			$M_L = 1.8$
24.	15 05 73	EP	200510.0	0.1	40.0	~ 55 km from PIN
		E(S)	200517.0			$M_L = 1.5$

Table 2

Wyoming Seismic Stations

Event No.	Date d m y	Phase	Arrival time (GMT)	T, period (secs)	Amp'l Max p-p (mm)	Remarks
25.	17 05 73	IPC	160050.8	-	-	Rio Blanco, Colorado M_L = 5.45 from NV network
26.	17 05 73	IPC IS	163253.6 163300.8	0.2	100?	~ 60 km from PIN $M_L \simeq$ 2.5
27.	23 05 73	E(P) ES	174836.4 174840.6	0.1	15.0	~ 35 km from PIN M_L = 1.6
28.	01 06 73	I(P) I(S)	045344.2 045352.1	0.15	49.0	~ 65 km from PIN M_L = 1.6
29.	01 06 73	IPC ES	143300.1 143309.4	0.15	24.0	~ 80 km from PIN M_L = 1.4
30.	01 06 73	I(P) ES	215904.0 215916.2	0.1	27.0	~ 100 km from PIN M_L = 1.6
31.	04 06 73	EPD I(S)	182136.8 182139.3	0.1	29.5	~ 10 km from PIN M_L = 0.1
32.	08 06 73	IPC IS	215733.8 215742.5	0.1	80?	~ 75 km from PI-1 $M_L \simeq$ 1.9
33.	13 06 73	IPC I(S)	215503.1 215512.3	0.15	37.0	~ 80 km from PI-1 M_L = 1.6
34.	14 06 73	IP E(S)	215854.4 215902.8	0.2	13.0	70 km from PI-1 M_L = 1.4
35.	15 06 73	EP E(S)	113027.9 113034.8	0.8	10.0	~ 55 km from PI-1 Distance questionable
36.	19 06 73	IPC I(S)	215441.8 215450.0	0.1	100.0	~ 70 km from PI-1 M_L = 2.0

Table 2

Wyoming Seismic Events

Event No.	Date d m y	Phase	Arrival time (GMT)	T, period (secs)	Amp'l Max p-p (mm)	Remarks
37.	22 06 73	IP	203100.9	0.15	17.0	$\sim$90 km from PI-1
		IS	203112.0			M_L = 1.5
38.	22 06 73	IPC	222138.0	0.15	9.0	$\sim$70 km from PI-1
		IS	222146.4			M_L = 1.0
39.	10 07 73	IPC	185818.4	0.2	29.0	$\sim$12 km from PI-1
		IS	185819.8			M_L = 0.5
40.	10 07 73	IPD	213354.5	0.15	60.0	$\sim$12 km from PI-1
		I(S)	213355.9			M_L = 0.7
41.	11 07 73	IPC	213235.1	0.35	11.0	$\sim$95 km from PI-1
		ES	213246.8			M_L = 1.7
42.	11 07 73	E(P)	221116.7	0.35	17.0	$\sim$95 km from PI-1
		IS	221128.3			M_L = 1.9
43.	11 07 73	IP	043842.5	0.3	32.0	$\sim$15 km from PI-1
		I(S)	043844.5			M_L = 0.8
4.	12 07 73	IPD	071037.4	0.3	100.0	$\sim$85 km from PI-1
		IS	071047.6			M_L = 2.6
5.	12 07 73	IPC	183217.2	0.3	72.0	$\sim$25 km from PI-1
		IS	183220.1			M_L = 1.1
6.	13 07 73	IPC	190651.8	0.2	80.0	$\sim$10 km from PI-1
		IS	190653.0			M_L = 0.6
7.	16 07 73	IPC	054849.8	0.25	10.0	$\sim$70 km from PI-1
		ES	054858.0			M_L = 1.7
8.	17 07 73	IPC	183432.6	0.3	6.0	$\sim$65 km from PI-1
		ES	183440.5			M_L = 1.0

Table 2

Wyoming Seismic Events

Event No.	Date d m y	Phase	Arrival time (GMT)	T, period (secs)	Amp'l Max p-p (mm)	Remarks
49.	18 07 73	IPC ES	003623.8 003631.6	0.3	22.0	$\sim$65 km from PI-1 $M_L = 1.5$
50.	18 07 73	IPC ES	074134.9 074143.0	0.3	25.0	$\sim$70 km from PI-1 $M_L = 1.6$
51.	18 07 73	EP ES	082635.3 082643.8	0.3	17.0	$\sim$70 km from PI-1 $M_L = 1.4$
52.	18 07 73	EP ES	183156.2 183208.0	0.3	7.0	$\sim$100 km from PI-1 $M_L = 1.2$
53.	18 07 73	EP E(S)	212838.9 212850.6	0.3	7.0	$\sim$100 km from PI-1 $M_L = 1.2$
54.	20 07 73	IPC I(S)	225923.9 225925.6	-	clipped	$\sim$13 km from PI-1 $M_L > 0.9$
55.	21 07 73	EP ES	094910.8 094913.3	0.2	5.4	$\sim$20 km from PI-1 $M_L = -0.4$
56.	24 07 73	IP ES	183106.7 183118.7	0.2	6.0	$\sim$100 km from PI-1 $M_L = 0.9$
57.	24 07 73	IP I(S)	190412.9 190413.4	-	clipped	$\sim$5 km from PI-1 $M_L > 0.7$
58.	26 07 73	I(P) IS	045250.0 045251.4	0.15	26.0	$\sim$10 km from PI-1 $M_L = -0.0$
59.	08 08 73	IP I(S)	181154.8 181156.2	0.1	68.0	$\sim$12 km from PI-1 $M_L = 0.2$
60.	09 08 73	IP ES	064806.2 064817.9	0.1	30.0	$\sim$95 km from PI-1 $M_L = 1.3$

Table 2

Wyoming Seismic Events

Event No.	Date d m y	Phase	Arrival time (GMT)	T, period (secs)	Amp'l Max p-p (mm)	Remarks
61.	16 08 73	IPD I(S)	174042.6 174043.0	0.1	70.0	$\sim$3 km from PI-2 M_L = 0.1
62.	16 08 73	IP I(S)	183114.9 183115.6	0.1	80.0	$\sim$7 km from PI-2 M_L = 0.2
63.	16 08 73	EP IS	231624.8 231626.2	0.1	15.5	$\sim$12 km from PI-2 M_L = -0.4
64.	17 08 73	IP I(S)	230337.3 230346.0	0.1	15.4	$\sim$75 km from PI-2 M_L = 0.9
65.	21 08 73	IPD I(S)	184306.1 184307.6	0.1	84.0	$\sim$13 km from PI-2 M_L = 0.3
66.	22 08 73	IPC I(S)	105201.3 105206.5	0.2	11.0	$\sim$35 km from PI-2 M_L = 0.5
67.	23 08 73	IPD I(S)	175949.2 180001.3	0.1	35.0	$\sim$100 km from PI-2 M_L = 1.4
68.	24 08 73	EP I(S)	040857.3 040900.0	0.1	74.0	$\sim$23.0 km from PI-2 M_L = 0.8
69.	24 08 73	IP I(S)	042653.5 042655.9	0.1	110.0	$\sim$20 km from PI-2 M_L = 0.9
70.	24 08 73	IP E(S)	183145.3 183152.9	0.1	100.0	$\sim$54 km from PI-2 M_L = 1.8
71.	27 08 73	IPD I(S)	085810.5 085818.0	0.1	100.0	$\sim$55 km from PI-2 M_L = 1.9
72.	29 08 73	IP IS	040315.2 040316.9	0.1	56.0	$\sim$14 km from PI-2 M_L = 0.5

Table 2

Wyoming Seismic Events

Event No.	Date d m y	Phase	Arrival time (GMT)	T, period (secs)	Amp'l Max p-p (mm)	Remarks
73.	31 08 73	IP	181120.6	0.2	30.0	~72 km from PI-2
		E(S)	181130.3			M_L = 1.8
74.	31 08 73	EP	202356.2	0.1	24.0	~73 km from PI-2
		E(S)	202406.0			M_L = 1.4
75.	05 09 73	EP	031913.4	0.1	23.0	~100 km from PI-2
		I(S)	031926.2			M_L = 1.5
76.	06 09 73	E(P)	195438.4	0.1	140.0	~45 km from PI-2
		I(S)	195443.7			M_L = 1.8
77.	11 09 73	IPD	184625.4	0.1	68.0	~22 km from PI-2
		I(S)	184628.0			M_L = 0.8
78.	13 09 73	IPD	172015.2	0.1	80.0	~95 km from PI-2
		I(S)	172026.8			M_L = 2.1
79.	27 09 73	EP	082126.2	0.1	8.5	~50 km from PI-2
		ES	082132.7			M_L = 0.7
80.	27 09 73	IP	165318.1	0.1	140.0	~35 km from PI-2
		I(S)	165322.3			M_L = 1.6
81.	28 09 73	EP	204034.1	0.2	12.5	~95 km from PI-2
		ES	204046.1			M_L = 1.6
82.	02 10 73	IPD	043009.2	0.2	64.0	~75 km from PI-2
		I(S)	043019.0			M_L = 1.1
83.	05 10 73	EP	182708.4	0.2	35.0	~55 km from PI-2
		E(S)	182716.2			M_L = 1.7
84.	05 10 73	IPC	215848.6	0.2	40.0	~95 km from PI-2
		E(S)	215900.6			M_L = 2.1

Table 2

Wyoming Seismic Events

Event No.	Date d m y	Phase	Arrival time (GMT)	T, period (secs)	Amp'l Max p-p (mm)	Remarks
85.	06 10 73	IP	133657.7	0.1	34.0	~57 km from PI-2
		IS	133705.8			$M_L = 1.4$
86.	08 10 73	EP	181102.6	0.1	23.0	~70 km from PI-2
		ES	181112.5			$M_L = 1.3$
87.	09 10 73	IPC	215620.1	0.1	25.0	~80 km from PI-2
		ES	215631.1			$M_L = 1.5$
88.	11 10 73	EP	185001.5	0.1	33.0	~70 km from PI-2
		E(S)	185011.5			$M_L = 1.5$
89.	20 10 73	IPD	232802.3	0.2	20.0	~40 km from PI-3
		IS	232807.0			$M_L = 1.3$
90.	20 10 73	IPD	233207.8	0.2	16.0	~40 km from PI-3
		IS	233212.5			$M_L = 1.1$
91.	20 10 73	IPC	234031.2	0.25	24.0	~44 km from PI-3
		I(S)	234036.4			$M_L = 1.4$
92.	25 10 73	EP	215330.6	0.2	18.0	~41 km from PI-3
		ES	215335.4			$M_L = 1.1$
93.	26 10 73	E(P)	155324.0	0.1	50.0	~30 km from PI-3
		ES	155327.5			$M_L = 1.0$
94.	26 10 73	E(P)	161344.6	0.1	30.0	~42 km from PI-3
		ES	161349.5			$M_L = 1.1$
95.	28 10 73	EP	223705.2	0.2	19.0	~41 km from PI-3
		ES	223710.0			$M_L = 1.2$
96.	28 10 73	EP	224334.9	0.2	22.0	~41 km from PI-3
		ES	224339.7			$M_L = 1.2$

Table 2

Wyoming Seismic Events

Event No.	Date d m y	Phase	Arrival time (GMT)	T, period (secs)	Amp'l Max p-p (mm)	Remarks
97.	31 10 73	EP IS	230100.7 230111.0	0.2	o-p amp'l = 53.0	$\sim$78 km from PI-3 M_L = 2.4
98.	03 11 73	IPC I(S)	224946.2 224949.7	0.2	o-p amp'l = 29.0	$\sim$30 km from PI-3 M_L = 1.0 Probable blast
99.	03 11 73	EPC E(S)	215401.6 215406.7	0.1	9.0	$\sim$43 km from PI-3 M_L = 0.6 Probable blast
100.	03 11 73	EP ES	230926.0 230930.7	0.2	12.0	$\sim$40 km from PI-3 M_L = 0.9 Probable blast
101.	03 11 73	EP ES	231722.7 231727.4	0.2	10.0	$\sim$40 km from PI-3 M_L = 0.9 Probable blast
102.	03 11 73	EP ES	232750.2 232754.9	0.2	7.0	$\sim$40 km from PI-3 M_L = 0.7 Probable blast
103.	04 11 73	IPC I(S)	223002.7 223003.0	0.1	43.0	$\sim$3 km from PI-3 M_L = 0.2
104.	05 11 73	EP I(S)	225834.9 225846.7	0.15	66.0	$\sim$90 km from PI-3 M_L = 2.2 Probable blast
105.	08 11 73	EP I(S)	191027.6 191039.7	0.2	o-p amp'l = 64.0	$\sim$95 km from PI-3 M_L = 2.6 Probable blast

Table 2

Wyoming Seismic Events

Event No.	Date d m y	Phase	Arrival time (GMT)	T, period (secs)	Amp'l Max p-p (mm)	Remarks
106.	09 11 73	EP I(S)	230141.4 230151.9	0.2	o-p amp'l = 52.0	~ 80 km from PI-3 M_L = 2.4 Probable blast
107.	15 11 73	IPD ES	181725.7 181734.5	0.1	12.0	~ 65 km from PI-3 M_L = 1.4
108.	19 11 73	I(P) E(S)	202651.7 202654.2	0.1	15.0	~ 21 km from PI-3 M_L = 0.1 Unusual signature
109.	19 11 73	IPD I(S)	213504.1 213505.2	0.2	10.0	~ 9 km from PI-3 M_L = -0.1
110.	21 11 73	E(P) I(S)	225915.6 225925.8	0.1	48.0	~ 75 km from PI-3 M_L = 1.7 Possible blast
11.	26 11 73	IPC I(S)	192917.4 192927.8	0.1	o-p amp'l = 65.0	~ 78 km from PI-3 M_L = 2.2 Possible blast
12.	26 11 73	EPD I(S)	230157.8 230208.9	0.1	o-p amp'l = 37.0	~ 82 km from PI-3 M_L = 1.9 Possible blast
13.	30 11 73	IPC I(S)	201116.5 201125.4	0.1	o-p amp'l = 58.0	~ 65 km from PI-3 M_L = 2.0 Possible blast
14.	05 12 73	EP IS	225957.3 230008.0	0.1	o-p amp'l = 31.0	~ 80 km from PI-3 M_L = 1.8 Possible blast

Table 2

Wyoming Seismic Events

Event No.	Date d m y	Phase	Arrival time (GMT)	T, period (secs)	Amp'l Max p-p (mm)	Remarks
15.	06 12 73	EPC ES	224420.9 224425.8	0.2	15.0	~42 km from PI-3 M_L = 1.4 Possible blast
16.	06 12 73	EPC ES	225304.1 225308.9	0.2	12.0	~41 km from PI-3 M_L = 1.3 Possible blast
17.	07 12 73	EPC E(S)	092604.7 092611.0	0.1	9.0	~45 km from PI-3 M_L = 0.9
18.	07 12 73	EPC ES	225848.3 225859.2	0.1	41.0	~80 km from PI-3 M_L = 2.0 Possible blast
19.	14 12 73	IPC ES	000307.6 000320.1	0.1	19.0	~100 km from PI-4 M_L = 1.7 Possible blast
20.	17 12 73	I(P)D I(S)	205609.3 205617.7	0.15	o-p amp'l = 43.0	~61 km from PI-4 M_L = 2.1
21.	20 12 73	E(P) I(S)	023345.0 023349.1	0.1	o-p amp'l = 38.0	~35 km from PI-4 M_L = 1.3 Possible earthquake
22.	20 12 73	IPC I(S)	193853.5 193855.7	0.1	o-p amp'l = 71.0	~19 km from PI-4 M_L = 1.0 Possible blast
23.	21 12 73	EP I(S)	184611.9 184620.6	0.2	o-p amp'l = 60.0	~64 km from PI-4 M_L = 2.3 complex event

Table 2

Wyoming Seismic Events

Event No.	Date d m y	Phase	Arrival time (GMT)	T, period (secs)	Amp'l Max p-p (mm)	Remarks
124.	11 01 74	EP	143714.0	0.12	14.0	~21 km from PI-4
		ES	143716.5			M_L = 0.1
125.	11 01 74	EP	145514.8	0.15	7.0	~12 km from PI-4
		ES	145516.2			M_L = 0.3
126.	11 01 74	EP	162152.1	0.13	10.0	~24 km from PI-4
		I(S)	162154.9			M_L = 0.1
127.	21 01 74	EP	160821.0	0.15	10.0	~27 km from PI-4
		E(S)	160824.2			M_L = 0.6
						Possible earthquake
128.	05 02 74	EP	211340.0	0.18	19.0	~87 km from PI-4
		I(S)	211351.2			M_L = 1.9
						Possible blast
129.	05 02 74	EP	214336.8	0.13	12.0	~80 km from PI-4
		E(S)	214347.3			M_L = 1.5
						Possible blast
130.	22 02 74	EP	201341.7	0.12	4.0	~44 km from PI-4
		E(S)	201346.9			M_L = 0.6

Phase Nomenclatures

Body Waves

- P = primary longitudinal (pressure) phase or wave.
- P_g = primary phase which travels through the earth directly from source to station
- P* = primary phase which has been refracted from the Conrad discontinuity.
- P_n = primary phase which has been refracted from the Mohorovicic discontinuity.

- S = secondary transverse (shear) phase.

Nature of Motion

- I = impulsive phase
- E = emergent phase
- C = compressional
- D = dilatational
- ( ) = questionable phase

** Trace turning points obscure

Table 3. Seismic Background Noise Levels

Station (abbrev)	Approx. Background Noise (cm/sec P-P)
PI-3	$3.5x10^{-6}$
PI-1	$5.5x10^{-6}$
PI-2	$5.5x10^{-6}$
PIN	$1.0 x10^{-5}$
PI-4	$2.0x10^{-5}$

Selected References

Algermissen, S. T. (1969), Seismic Risk Studies in the United States, U. S. Department of Commerce/ESSA.

Eppley, R. A., Earthquake History of the United States, U. S. Department of Commerce, 1965.

Navarro, R. (1973), Seismic Background Noise Investigations Around the Wagon Wheel Site (NOAA Tech Memo ERL ESL-22).

Richter, C. F., (1958), Elementary Seismology, San Francisco, W. H. Freeman & Co., P-340-346.

United States Earthquakes, U. S. Department of Commerce, Annual Publications, 1928-1970.

APPENDIX

MODIFIED MERCALLI INTENSITY SCALE OF 1931
(abridged)

I. Not felt except by a very few under especially favorable circumstances. (I Rossi-Forel Scale).

II. Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing. (I to II Rossi-Forel Scale).

III. Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motorcars may rock slightly. Vibration like passing truck. Duration estimated. (III Rossi-Forel Scale).

IV. During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, and doors disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing motorcars rocked noticeably. (IV to V Rossi-Forel Scale).

V. Felt by nearly everyone; many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop. (V to VI Rossi-Forel Scale).

VI. Felt by all; many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight. (VI to VII Rossi-Forel Scale).

VII. Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well built ordinary structures; considerable in poorly built or badly designed structures. Some chimneys broken. Noticed by persons driving motorcars. (VIII Rossi-Forel Scale).

VIII. Damage slight in specially designed structures; considerable in ordinary substantial buildings, with partical collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving motorcars disturbed. (VIII+ to IX Rossi-Forel Scale).

IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken. (IX+ Rossi-Forel Scale).

X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundation; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks. (X Rossi-Forel Scale).

XI. Few, if any (masonry), structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.

XII. Damage total. Waves seen on ground surface. Lines of sight and level distorted. Objects thrown upward into the air.

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