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GEOLOGICAL SURVEY

SEISMIC REFRACTION STUDIES IN THE SAN JUAN BASIN, NORTHWEST NEW MEXICO

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ABSTRACT

The U.S. Geological Survey is studying some of the features of the earth's crust in the San Juan Basin region, northwest New Mexico. As a part of this study seismic refraction-reflection measurements were made in and around the basin using explosions and earthquakes as energy sources. Record sections and traveltime tables were derived from the measurements.

INTRODUCTION

A network of eight permanent seismograph stations located in the northwest quadrant of New Mexico is maintained by the Albuquerque Seismic Laboratory for the purpose of studying the seismicity and crustal structure of the San Juan Basin region. In order to obtain additional crustal structure data for the region, a temporary 16 station seismic refraction line was established between the San Juan/Navajo mines and the Jackpile mine (Figure 1). Explosions from these mines were timed by USGS personnel and recorded along the refraction line. Additional data were obtained from explosions at White Sands, New Mexico, the Nevada Test Site, and from well recorded regional earthquakes (Figure 2).

This report briefly discusses the explosions and earthquakes used as energy sources and the instrumentation used to record the seismic waves. The traveltime tables, record sections, and other pertinent information for this experiment are also presented.

ACQUISITION OF DATA

1) EXPLOSIONS -

Information on the explosions and earthquakes used as energy sources in this study are given in Table 1. Data from the Navajo and San Juan mines was obtained with the cooperation of Utah International, Inc. and the data

from the Jackpile mine was obtained with the cooperation of the Anaconda Company. The Department of Defense provided parameters for the DISTANT RUNNER explosions. The Department of Energy provided data on the NTS shot.

In the Navajo, San Juan, and Jackpile mines instrumentation was set-up within 100 m of the explosion to monitor the seismic waves and to precisely determine the time of the detonation. Timing is thought to be accurate to 50 milliseconds. The origin times for subsequent explosions at Navajo, San Juan, and Jackpile were estimated from:

$$\Delta t = \frac{\Delta X}{V} \qquad (1)$$

where: Δt(s) = difference in traveltime (between a timed shot and a subsequent shot) to a reference station.
ΔX(km) = difference in shot location relative to the reference station.
V(km/s) = the refractor velocity between the shot and the reference station.

2) EARTHQUAKES -

Earthquake data (except for event E-8) was derived from the Earthquake Data Report (EDR) and the Preliminary Determination of Epicenters (PDE) as published by the National Earthquake Information Service (NEIS), Golden, Colorado. Data for event E-8, an unpublished earthquake, was provided through personal communication with Mr. John Minsch at NEIS.

INSTRUMENTATION

The instrument array is depicted in Figure 1. The instrumentation used in the temporary array consisted of the ASC-1 analog, FM tape systems described by Hoffman and Harding (1977). Self-contained pen and ink drum

recorders utilizing a precision timing system were used in addition to the ASC-1 units for the timed shots. The vertical sensors used on the temporary array have a natural frequency of 1.0 hertz. The permanent array used the same sensor with the necessary electronics to telemeter the seismic data to the Albuquerque laboratory. At the laboratory the data were recorded on 16 mm film. Table 2 is a list of the seismograph stations occupied by this equipment during this study.

TRAVELTIME TABLES

Traveltime tables were derived from the first arrivals after calculating station distances. The station distances were determined using the computer program HYPO-71 (Lee and Lahr, 1972). This program uses Richter's method for computing small distances (Richter, 1958). The distances calculated in this manner are correct to about 0.1 km. Elevation corrections can be made by calculating the delay times (Nettleton, 1940) due to different thicknesses of surface rock beneath each station. All of the shots and arrival times can be adjusted to the elevation of the Navajo explosion by using:

$$\text{Correction} = \frac{\text{Navajo elevation - station or shot elevation}}{V_0} (\text{COS}i_c)$$

where: i_c = ARCSIN $\frac{4.0}{6.0}$ for Pg arrivals and $\frac{4.0}{8.0}$ for Pn

V_0 = 4.0 km/sec

Tables 3 thru 7 list the data collected from the timed explosions (San Juan, Navajo, Jackpile, DRI, DRII) and Table 8 lists distances and traveltimes from regional seismic events to the permanent stations in the network. The data in Table 8 were calculated by DISTAZ, an unpublished computer program of the Office of Earthquake Studies, Menlo Park, California.

RECORD SECTIONS

Figures 3 and 4 are record sections which were constructed by digitizing the analog data acquired by the ASC-1 tape units. Fifty samples per second were digitized from a play-back system without the use of filtering. The resulting information was plotted at 20 mm of data per second. The amplitude of each plot was roughly normalized to the amplitude of the Pg phase.

SUMMARY

A seismic refraction study in the San Juan Basin region of northwest New Mexico has been conducted. The data is considered to be of high quality and suitable for further interpretation. Record sections with related charts and tables have been compiled. Interpretation of the data and conclusions are presented in a companion paper.

REFERENCES CITED

Hoffman, J.P. and Harding, S.T., 1977, Strong Ground Motion in the Tularosa Basin, New Mexico: United States Geological Survey Open-File Report 77-143, 46 p.

Lee, W.H.K., and Lahr, J.C., 1972, HYPO-71 (Revised), A Computer Program for Determining Hypocenter, Magnitude, and First Motion Pattern of Local Earthquakes: USGS Open-File Report 75-311, 113 p.

Richter, C.F., 1958, Elementary Seismology: San Francisco, W.H. Freeman and Co., 768 p.

Nettleton, L.L., 1940, Geophysical Prospecting for Oil: New York, McGraw-Hill Book Co., 444 p.

FIGURE CAPTIONS

Figure 1. Plan view of the seismic refraction line in northwest New Mexico, including permanent and temporary station locations.

Figure 2. Plan view showing: 1) seismic event locations used in the time-term solution, and 2) the relative location of the study area.

Figure 3. Record section for Navajo/San Juan to Jackpile data.

Figure 4. Record section for DISTANT RUNNER to Red Mountain data.

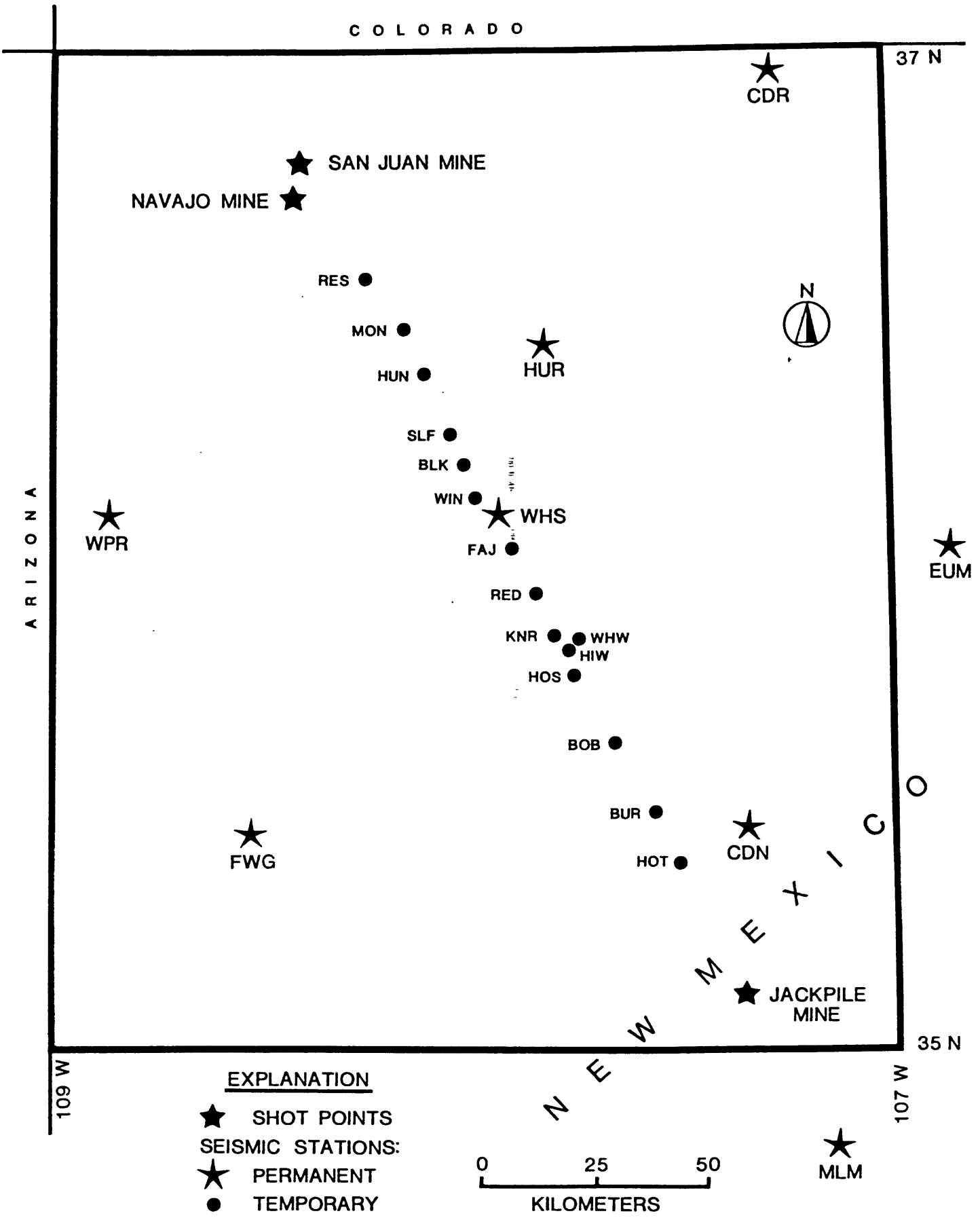
COLORADO
37 N
CDR
SAN JUAN MINE
NAVAJO MINE
RES
MON
HUN
HUR
N
SLF
BLK
WIN
WHS
WPR
FAJ
EUM
RED
KNR
WHW
HIW
HOS
BOB
BUR
CDN
FWG
HOT
NEW MEXICO
JACKPILE MINE
35 N
ARIZONA
109 W
107 W
EXPLANATION
SHOT POINTS
SEISMIC STATIONS:
PERMANENT
TEMPORARY
0
25
50
KILOMETERS
MLM

FIGURE 1

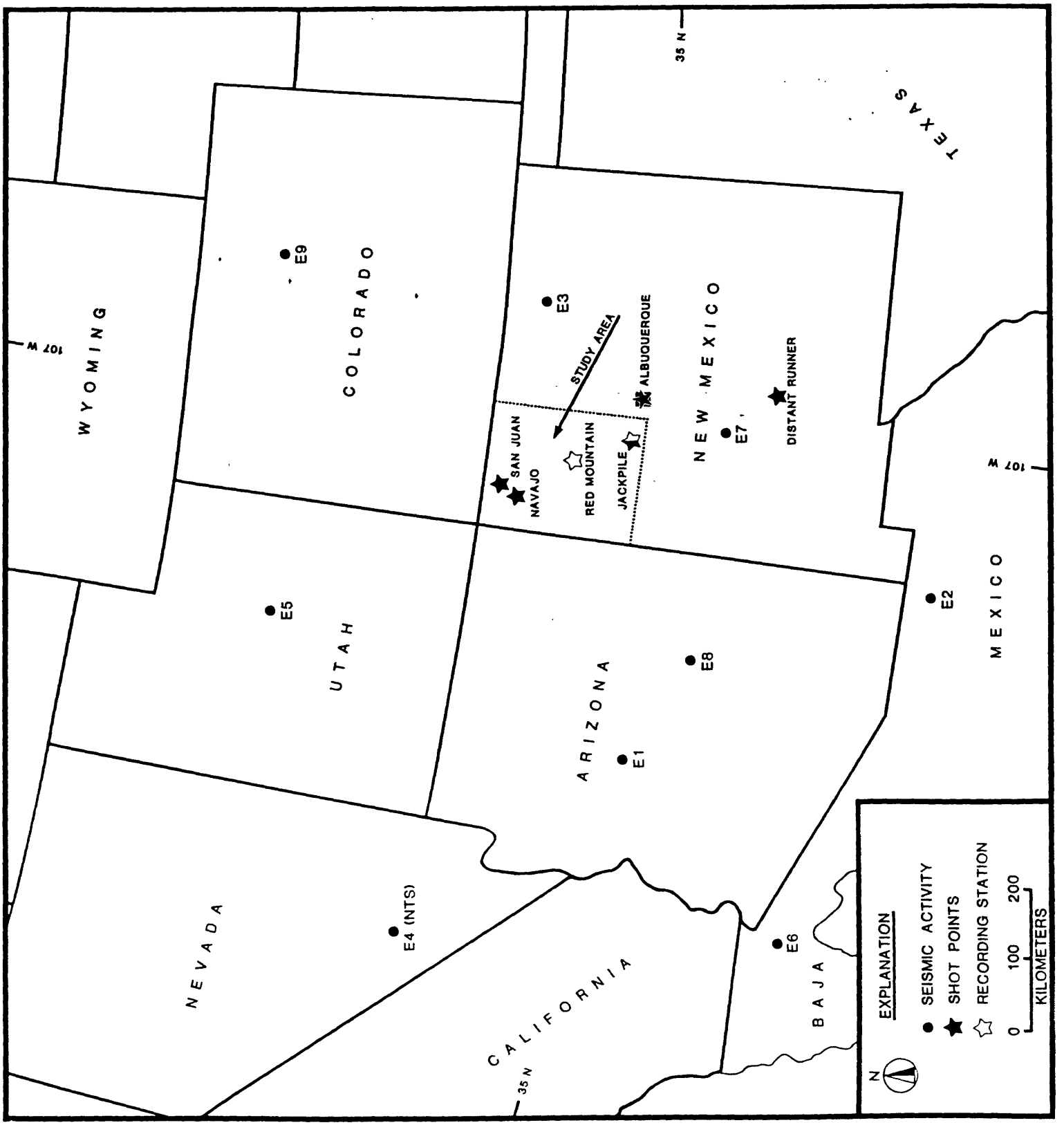
WYOMING
COLORADO
NEW MEXICO
TEXAS
UTAH
ARIZONA
NEVADA
CALIFORNIA
BAJA MEXICO
E9
E3
E5
E8
E2
E1
E4 (NTS)
E6
E7
STUDY AREA
ALBUQUERQUE
SAN JUAN
NAVAJO
RED MOUNTAIN
JACKPILE
DISTANT RUNNER
107 W
35 N
EXPLANATION
SEISMIC ACTIVITY
SHOT POINTS
RECORDING STATION
0 100 200
KILOMETERS
N

FIGURE 2

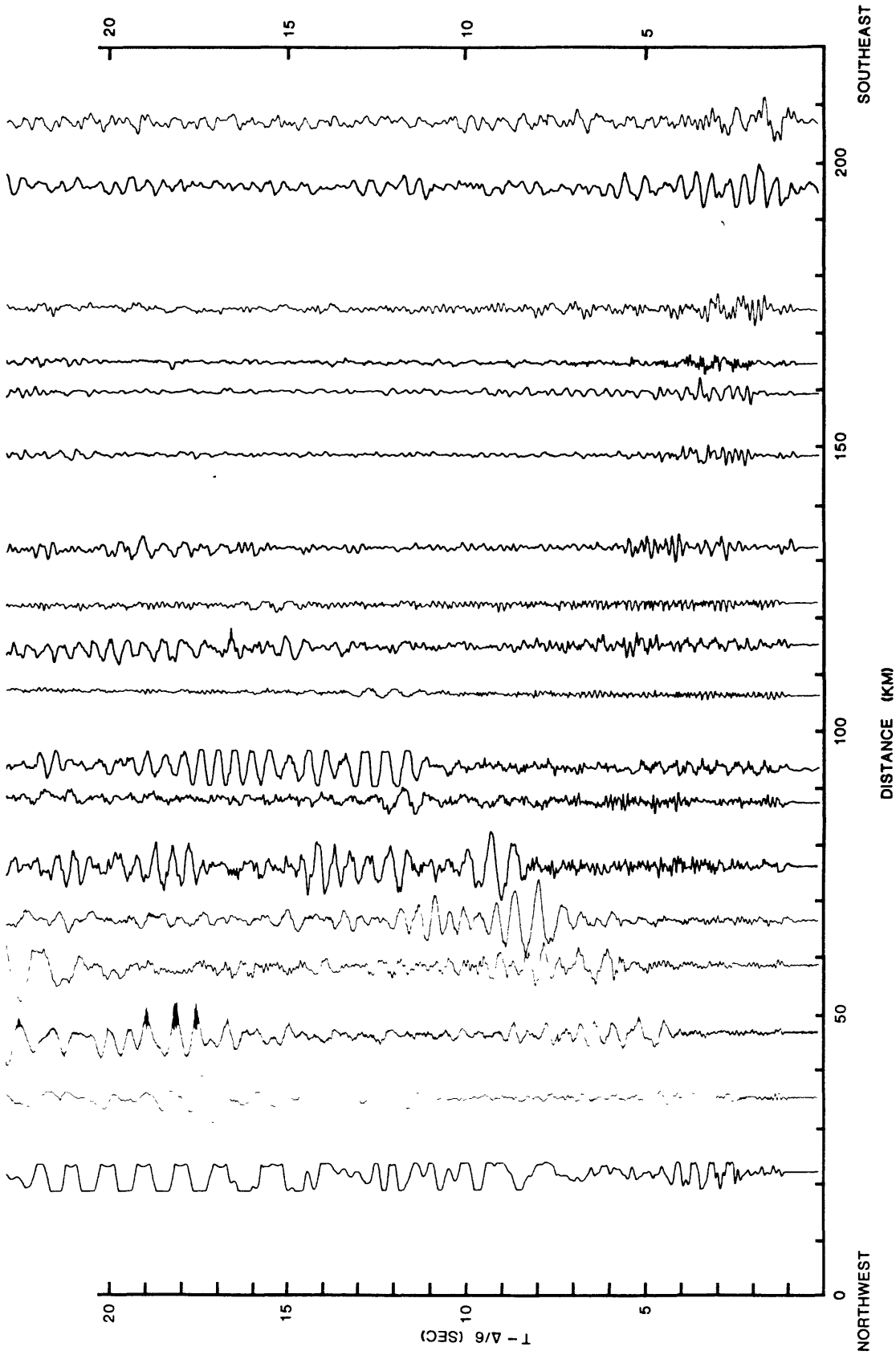
20
15
10
5
SOUTHEAST
200
150
100
50
0
NORTHWEST
DISTANCE (KM)
T - Δ/6 (SEC)
NAVAJO / SAN JUAN - JACKPILE

FIGURE 3

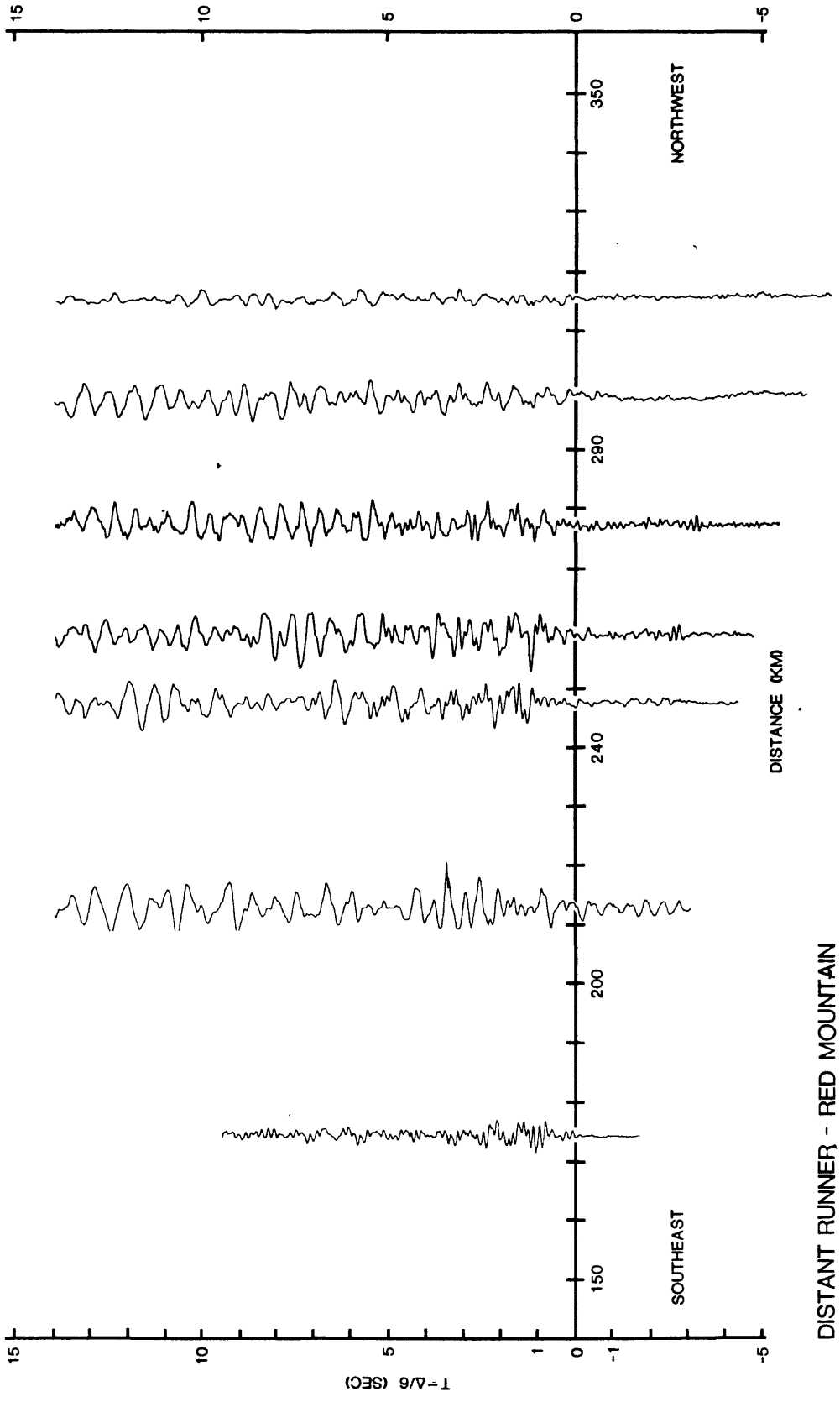
15
10
5
0
-5
NORTHWEST
350
290
240
200
150
SOUTHEAST
DISTANCE (KM)
T=Δ/6 (SEC)
15
10
5
1
0
-1
-5
DISTANT RUNNER - RED MOUNTAIN

FIGURE 4

	Station (I.D. & Name)	Latitude (N)	Longitude (W)	Elevation (Meters)
BLK	Black Lake	36° 11.61'	108° 01.39'	1884
BOB	Bobcat Hill	35° 37.68'	107° 40.72'	2091
BUR	Burns Benchmark	35° 28.69'	107° 35.40'	2073
CDN	Cerro del Durazno	35° 27.28'	107° 20.91'	2591
CDR	Cedar Rock	36° 57.33'	107° 15.18'	2490
EUM	Eureka Mesa	36° 00.78'	106° 50.63'	2750
FAJ	Fajada Butte	36° 00.83'	107° 55.20'	1884
FWG	Fort Wingate	35° 26.52'	108° 31.85'	2626
HIW	Highway 9	35° 48.41'	107° 47.30'	2067
HOS	Hospah	35° 45.47'	107° 45.49'	2170
HOT	Hoot Owl Tank	35° 23.46'	107° 32.09'	2512
HUN	Hunter Wash	36° 21.79'	108° 08.35'	1936
HUR	Huerfano Mesa	36° 24.93'	107° 50.64'	2466
JAK	Jackpile Mine	35° 06.71'	107° 22.85'	2200
KNR	Kin Nahzin Ruin	35° 49.99'	107° 49.24'	2012
MLM	Mesa Lucero	34° 48.86'	107° 08.70'	2088
MON	Monsescu Mesa	36° 26.91'	108° 11.18'	1896
RED	Red Mountain	35° 56.21'	107° 52.41'	1957
RES	Reservation Boundry	36° 32.80'	108° 16.12'	1885
SLF	Split Lip Flat	36° 15.30'	108° 04.25'	1851
WHS	Chaco Canyon	36° 04.68'	107° 57.27'	1926
WHW	Whitehorse Well	35° 49.66'	107° 44.46'	2054
WIN	Windmill	36° 07.33'	107° 58.96'	1910
WPR	Washington Pass	36° 04.58'	108° 51.92'	3100

Table 1 - Seismograph Stations

Event	Region	Location	h(km)	Origin Date/Time(UTC)
E1	Western Arizona	34.655 N 112.500 W	12	02/04/76 00:04:58.10
E2	Southeast Arizona	31.024 N 109.227 W	5	06/08/77 13:09:07.40
E3	Northern New Mexico	36.459 N 105.187 W	5	09/11/80 17:34:37.50
E4	Nevada Test Site	37.087 N 116.045 W	0	01/15/81 20:25:00.09
E5	Northeast Utah	39.481 N 111.060 W	1	05/14/81 05:11:04.10
E6	California - Mexico Border Area	32.220 N 114.985 W	5	06/09/80 03:28:18.90
E7	South New Mexico	33.994 N 107.030 W	5	05/09/81 12:35:50.80
E8	Eastern Arizona	34.000 N 110.750 W	5	01/18/81 23:48:41.60
E9	Northeast Colorado	39.910 N 104.964 W	8	04/02/81 16:10:06.46
DISTANT RUNNER I	Southern New Mexico	33.383 N 106.364 W	0	09/02/81 17:00:00.16
DISTANT RUNNER II	Southern New Mexico	33.381 N 106.367 W	0	10/07/81 16:59:59.87
NAVAJO	Northwest New Mexico	36.712 N 108.418 W	0	06/26/80 20:45:12.90
SAN JUAN	Northwest New Mexico	36.798 N 108.419 W	0	07/18/80 21:09:05.43
JACKPILE	Central New Mexico	35.123 N 107.372 W	0	07/02/80 22:03:43.75

Table 2 - Locations, depths, and origin times of events used as sources of p-waves for this study.

Station	Distance (Δ km)	Traveltime (sec)
RES	22.67	4.93
MON	35.82	7.21
HUN	46.05	8.89
SLF	59.46	11.10
HUR	61.44	11.30
BLK	67.51	12.40
WHS	81.69	14.68
CDN	169.50	29.20
WHW	115.42	20.41

Table 3 - Navajo Shot

Station	Distance (Δ km)	Traveltime (sec)
MLM	- 40.03	7.45
HOT	33.31	6.68
CDN	36.86	7.33
BOB	62.66	11.49
HOS	78.67	14.30
WHW	85.04	15.25
KNR	88.67	15.84
FAJ	110.61	19.60
WHS	118.45	20.92
BLK	132.59	23.70
SLF	140.62	25.01

Table 4 - Jackpile Shot

Station	Distance (Δ km)	Traveltime (sec)
WIN	84.52	15.33
WHS	90.06	16.22
FAJ	97.81	17.65
RED	107.31	19.05
KNR	119.75	21.20
HIW	123.67	21.85
HOS	129.74	22.72
BOB	145.86	25.21
BUR	164.33	28.37

Table 5 - San Juan Shot

Station	Distance (Δ km)	Traveltime (sec)
MLM	174.35	28.99
SVM	192.41	31.14
CDN	247.00	40.99
HOT	247.38	38.84
BUR	258.29	40.28
BOB	276.78	42.84
EUM	295.07	47.92

Table 6 - DISTANT RUNNER I Shot

Station	Distance (Δ km)	Traveltime (sec)
MLM	174.49	29.18
JAK	213.57	35.01
CDN	247.10	40.58
HOT	247.51	39.13
EUM	295.28	48.08
HIW	299.09	46.97
RED	315.40	48.13

Table 7 - DISTANT RUNNER II Shot

Source	Station	Distance (Δ km)	Traveltime (sec)
E1	CDN	478.22	67.82
E1	MLM	490.71	68.90
E1	EUM	535.78	74.36
E2	CDN	521.64	73.87
E2	MLM	463.27	65.77
E3	CDN	224.59	35.80
E3	HUR	238.29	38.30
E3	WHS	252.25	39.95
E4	WPR	652.14	89.19
E4	FWG	699.29	95.82
E4	WHS	732.48	99.63
E4	HUR	735.94	100.75
E4	CDR	782.27	105.22
E4	CDN	801.86	108.01
E4	MLM	841.27	112.70
E5	WPR	424.47	52.76
E5	CDR	435.56	53.25
E5	HUR	442.33	53.85
E5	WHS	446.36	56.70
E5	FWG	501.00	61.70
E5	EUM	534.97	64.75
E5	CDN	554.49	67.34
E5	MLM	623.81	75.35
E6	FWG	695.96	94.21
E6	WPR	707.93	97.15
E6	CDN	792.38	108.76
E6	CDR	882.20	119.54
E7	EUM	224.63	35.82
E7	WHS	246.11	39.38
E8	FWG	258.66	38.50
E8	WPR	287.46	42.45
E8	MLM	343.53	49.82
E8	WHS	343.81	49.82
E8	EUM	420.70	59.85
E9	EUM	463.01	66.29
E9	WPR	546.32	77.72

Table 8 - Input Data to Time Term Program