United States
Department of the Interior
Geological Survey

COMPILATION OF THE DATA FROM THE 1978 HAWAII SEISMIC REFRACTION EXPERIMENT ON THE WEST FLANK OF MAUNA LOA

by

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

Introduction

In October 1978 (J.D. 286), the U.S. Geological Survey (USGS) established a seismic refraction line perpendicular to the Kona coast of Hawaii (Fig. 1). The purpose of the experiment was to define the crustal structure of the Kona coast and its relationship to the tectonics of Mauna Loa volcano. This open-file report describes the experiment and presents the data without interpretation. A similar experiment was performed earlier off the southeast coast of Hawaii. Those data are described in Zucca and others (1979) and the results presented in Zucca and Hill (1980).

The Mauna Loa experiment consisted of 30 evenly spaced shots oriented in a line roughly 100 km long (Fig. 1). The shots weighed 300 lbs except for the five shots closest to the coast, which all weighed 180 lbs. The charges, which consisted of the commercial explosive Tovex, were deployed from the fantail of the USGS research vessel "Samuel P. Lee". The shots were detonated by a fuse which burned about 80 seconds allowing the charge to sink to a depth of roughly 60 meters before firing.

Shot locations were obtained using minirangers. This is a system of accurately located land-based transponders that communicate on demand with a ship-based device. Slant ranges accurate to 1 part in 50,000 can be obtained in this fashion. For this experiment, four transponders were used (Fig. 1 and Table 1). Slant ranges to at least two, and many times three, transponders were taken at the point where the charge was dropped overboard and at the point where the water wave from the explosion arrived at the ship. The ship's location at charge-drop and water-wave arrival positions were obtained by minimizing residuals of the set of miniranger distances in a least-squares manner using the algorithm in HYPO71 (Lee and Lahr, 1975). The distance between the charge-drop and water-wave arrival positions averaged about 0.4 km. The most distant shot subtends an angle of 30 degrees with the transponder array on shore. The shots were located to an accuracy of $\pm$ 0.05 km along the length of the profile, but the locations are poorly constrained perpendicular to the profile and may be in error by several km.

The water wave from the explosion was used to estimate the detonation time of the shot. Its arrival at the ship was detected by a hydrophone mounted in the hull. The signal was recorded on board against an IRIG-C time code on a strip-chart recorder. Absolute time was obtained by referring the IRIG-C code to WWVH. By knowing the distance between the point where the shot was deployed and the point where the water wave arrived at the ship, the velocity of sound in water (standard average of 1.5 km/s), and the charge depth, the firing time was estimated by a correction to the water-wave arrival based on these parameters. Relative timing between shots to $\pm$ .05 second was obtained through this method. However, the absolute shot times may be systematically off by as much as .2 second due to errors in knowing the depth of detonation and location of the ship. Table 2 is a listing of the shot locations, sizes, and detonation times. Figure 2 shows the bathymetry beneath the shot profile.

The energy from the explosions was recorded on two different seismic systems (Fig. 1):

1) USGS Permanent Hawaii Seismic Station Network

2) USGS Portable 5-Day Recorders.

In addition, five sonobouys were deployed over the shot line in an attempt to better define the upper crustal structure along the profile. However, all five failed to operate properly and no data were obtained.

The data from each system are presented in record sections in fixed-receiver format. Thus, the seismogram written from each shot at a particular station is plotted in one record section where the horizontal axis represents distance from the shot to the station. The distance from shot to receiver was calculated using Richter's short-distance formula (1958). The vertical axis is time-reduced to 8 km/s where the relationship is: $T = t - \Delta/8.0$ where T = reduced time, t = total travel time, and Δ = distance. The horizontal axis is in kilometers and the vertical axis is in seconds. No corrections have been applied to the record sections for station elevation or water depth beneath the shot points. The amplitude of each trace is scaled individually. The record sections from the two seismic systems are presented and described separately.

USGS Permanent Stations

The USGS operates and maintains a network of some 40 seismographic stations on the island of Hawaii designed to study the seismicity of the island and its relation to volcanic processes (Koyanagi and others, 1978). Figure 1 and Table 3 give the locations of the stations that recorded signals from the shots that were clear enough to warrant the construction of a record section. The stations all have vertical seismometers with 1-second free period. The data are telemetered from the field site to the Hawaiian Volcano Observatory (HVO) on the rim of Kilauea caldera. Here it is recorded both on 1-inch analog magnetic tape and a Develocorder system. The magnetic tape containing the data was taken to Menlo Park where it was played back, passed through a high-cut aliasing filter, [and] a low-cut filter to remove long period noise, and digitized at 100 samples/second. Record sections (Fig. 3.1-3.15) were constructed from the digital data using a computer.

USGS Temporary Stations

In addition to the permanent stations, seven 5-day seismic recording units (Eaton and others, 1970) were deployed. Each recorded a vertical and two horizontal components with a 1-second free period. Only the vertical component is plotted in the record sections presented here. The stations were deployed in a line across the north flank of Mauna Loa, perpendicular to the Kona coast (Fig. 1). The field tapes were processed in the same manner as for the permanent stations in Menlo Park. Record sections (Fig. 4.1-4.7) were constructed from the digital data.

Other Plotting Options

In addition to the fixed-receiver record sections, the data from the permanent and temporary stations can be combined to form a ten-station linear profile which runs across the north flank of Mauna Loa (Fig. 1). Figures 5.1 and 5.2 are two representative record sections constructed from this profile of stations in a fixed-shot format. Record sections for the other shots may also be obtained on request from the authors.

The fixed-receiver records sections may also be plotted in a manner which preserves true amplitude across the section (Fig. 6). In constructing these record sections, it is assumed that shots of equal weight and fuse burn-time will release equal amounts of seismic energy. For the smaller shots, the amplitude of the seismogram can be corrected for weight using the empirical relation (John Orcutt, personal communication, 1979):

$$\text{Amplitude multiplier} = \left(\frac{\text{Charge weight}}{\text{Normalizing weight}} \right)^{0.65}$$

The amplitude of each seismogram is multiplied by the distance (x) from the station to the given shot. The amplitudes were then scaled by a constant for plotting.

Acknowledgements

We would like to thank the Conservation Division of the USGS for their efforts in obtaining the shooting permits. We are also indebted to Fred Klein and Bob Koyanagi of HVO for their help with the field operations and making available the tape containing the data from the permanent seismographs.

Ed Criley and John Coakley of Menlo Park did an excellent job of deploying the temporary seismographs. Finally, we would like to thank our shooter, Gene Taylor of Menlo Park, for his fine work in handling the explosives.

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List of Tables

Figure Captions

Figure 1: Location Map. Closed circles: shots. Open circles: transponders. Closed triangles: permanent seismographs. Open triangles: temporary seismographs. Contours in kilometers of elevation.

Figure 2: Bathymetric profile under shot line. Closed circle: shots.

Figures 3.1 to 3.15. Record sections for the seismographs in the permanent HVO network.

Figures 4.1 to 4.7. Record sections for the portable 5-day seismographs.

Figures 5.1 and 5.2. Two examples of fixed-shot record sections across the linear profile of stations.

Figure 6. An example of a fixed-receiver record section with true amplitude preserved.

RANGER NO.	LAT.		LONG.		ELEVATION(m)
001	19	30.58	155	55.23	478.7
002	19	25.38	155	53.08	271.3
003	19	18.70	155	52.67	399.7
004	19	44.51	155	57.37	982.1
005	19	10.61	155	45.53	3661.6

TABLE 1

SHOT NO.	LAT.		LONG.		FIRING TIME		
1	19	9.12	156	51.60	19	34	38.70
2	19	10.26	156	48.96	19	44	7.79
3	19	10.44	156	48.04	19	54	7.35
4	19	10.97	156	46.25	20	4	8.21
5	19	11.19	156	44.45	20	14	2.01
6	19	11.57	156	40.97	20	33	10.96
7	19	11.82	156	39.23	20	43	19.35
8	19	12.28	156	37.57	20	53	24.06
9	19	12.72	156	35.88	21	3	17.00
10	19	13.20	156	34.26	21	13	15.04
11	19	13.63	156	32.60	21	23	19.82
12	19	13.90	156	30.86	21	33	23.30
13	19	14.53	156	29.21	21	43	19.05
14	19	14.91	156	27.59	21	53	17.36
15	19	15.67	156	25.87	22	3	19.84
16	19	16.10	156	24.20	22	13	19.39
17	19	17.01	156	21.31	22	30	19.84
18	19	17.50	156	19.62	22	40	21.97
19	19	17.93	156	17.92	22	50	18.98
20	19	18.45	156	16.21	23	0	20.65
21	19	18.89	156	14.41	23	10	18.47
22	19	19.43	156	12.70	23	20	19.34
23	19	19.89	156	10.98	23	30	20.83
24	19	20.45	156	8.95	23	42	20.27
25	19	20.92	156	7.17	23	52	16.15
26	19	21.27	156	5.52	0	2	20.56
27	19	21.69	156	3.82	0	12	17.90
28	19	22.03	156	2.03	0	22	17.60
29	19	22.41	156	0.25	0	32	33.73
30	19	22.64	155	58.12	0	42	16.84

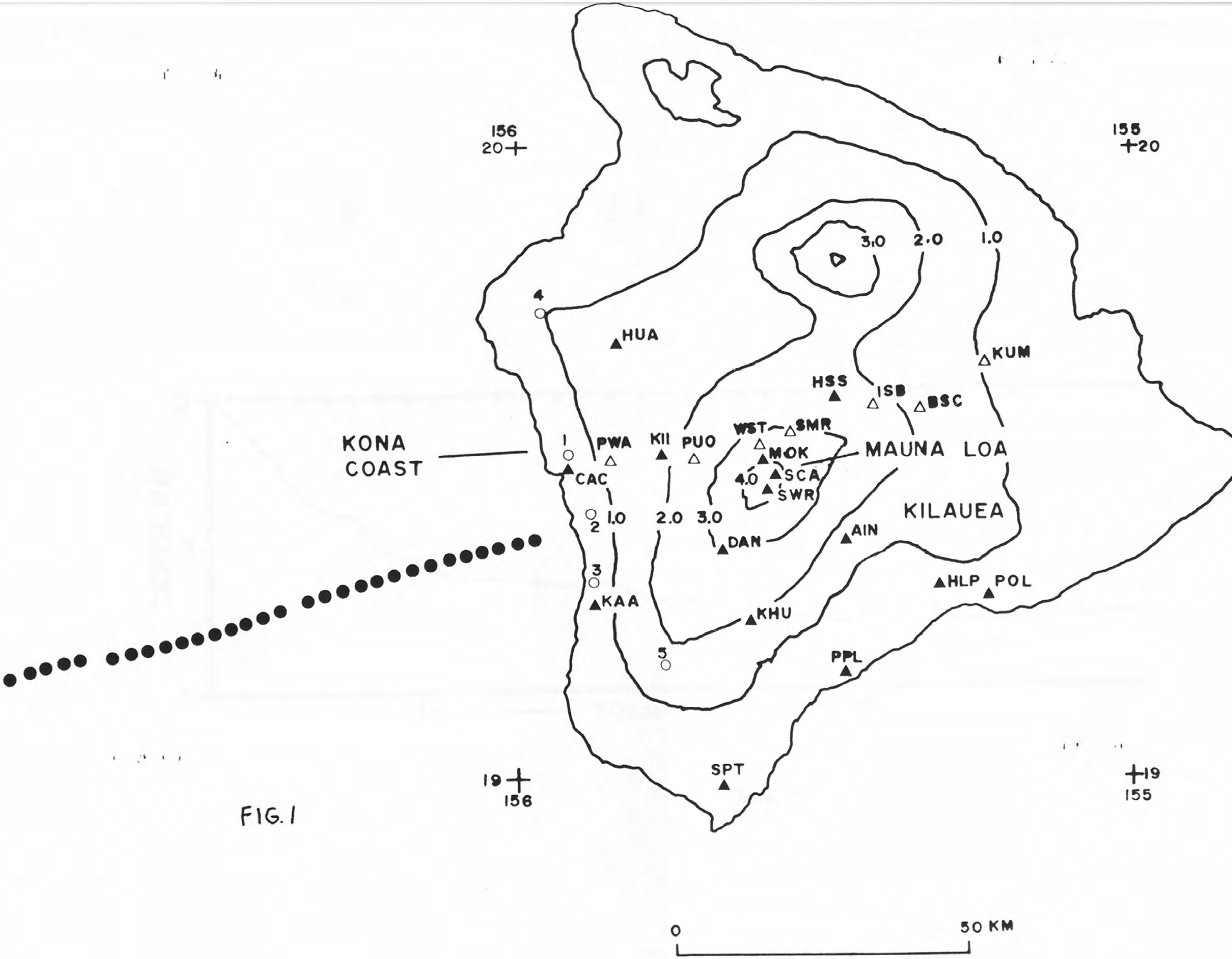
TABLE 2

STATION	LAT.	LONG.	ELEVATION (m)
AIN	19N 22.50	155E 27.60	1524
CAC	19N 29.29	155E 55.00	323
DAN	19N 21.42	155E 40.00	3003
HLP	19N 17.96	155E 18.60	707
HSS	19N 36.31	155E 29.10	2445
HUA	19N 41.25	155E 50.30	2189
KAA	19N 15.98	155E 52.20	524
KHU	19N 14.90	155E 37.10	1939
KII	19N 30.56	155E 45.90	1841
MOK	19N 29.28	155E 35.90	4000
POL	19N 17.02	155E 13.40	169
PPL	19N 9.50	155E 27.80	35
SCA	19N 28.20	155E 35.00	4048
SPT	18N 58.91	155E 39.90	244
SWR	19N 27.26	155E 36.30	4048

TABLE 3

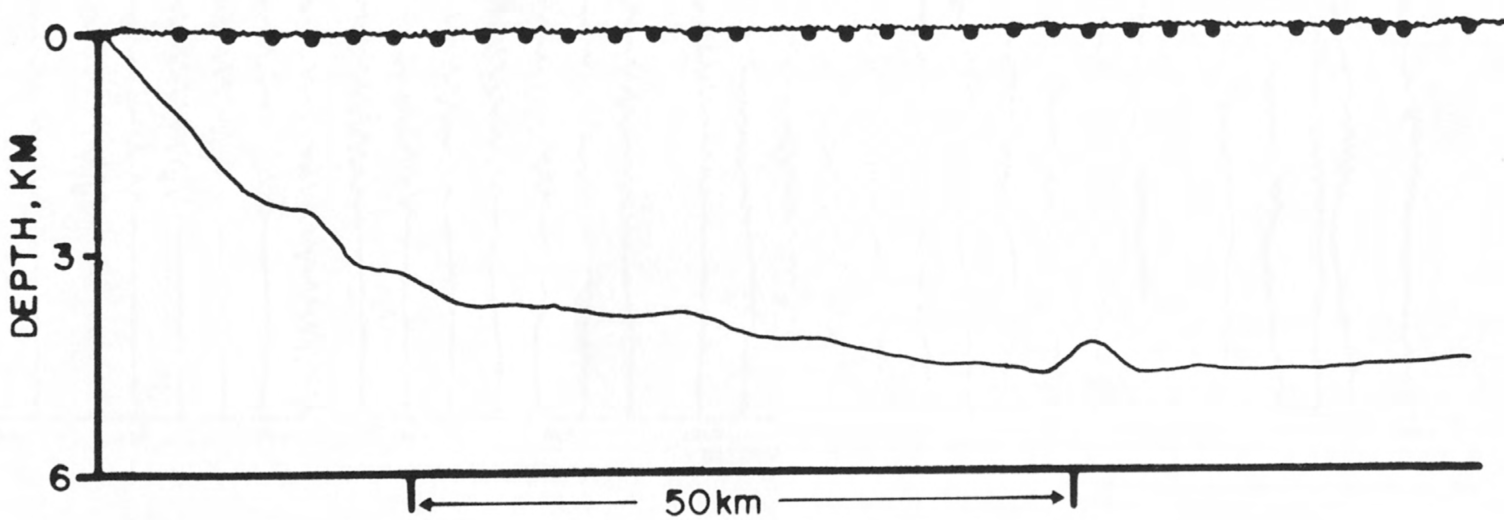
STATION	LAT.		LONG.		ELEVATION (m)
bsc	19	35.47	155	19.85	1696
isb	19	35.91	155	24.47	2119
kum	19	39.85	155	13.45	851
puo	19	30.45	155	42.36	2512
pwa	19	30.33	155	50.76	1183
smr	19	33.07	155	32.83	3186
wst	19	31.95	155	35.74	3494

TABLE 4



156
20
155
20
3.0
2.0
1.0
4
HUA
KUM
HSS
ISB
BSC
WST
SMR
KONA
COAST
1
PWA
KII
PUO
MOK
MAUNA LOA
CAC
4.0
SCA
SWR
KILAUEA
2
1.0
2.0
3.0
DAN
AIN
3
HLP
POL
KAA
KHU
5
PPL
SPT
19
156
19
155
0
50 KM

FIG. 1



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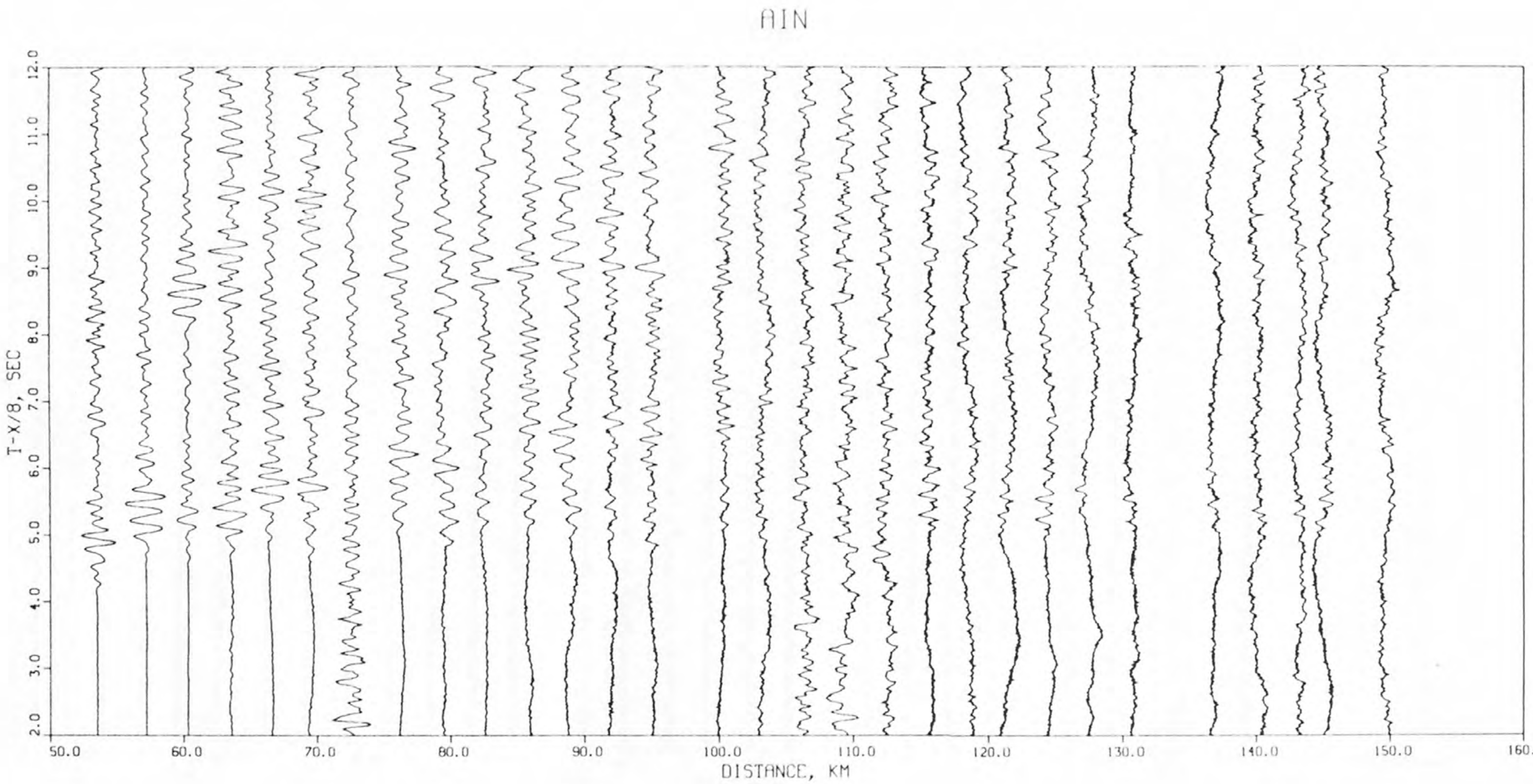
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12.0
50.0
60.0
70.0
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100.0
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130.0
140.0
150.0
160.0
DISTANCE, KM

FIG 3.1

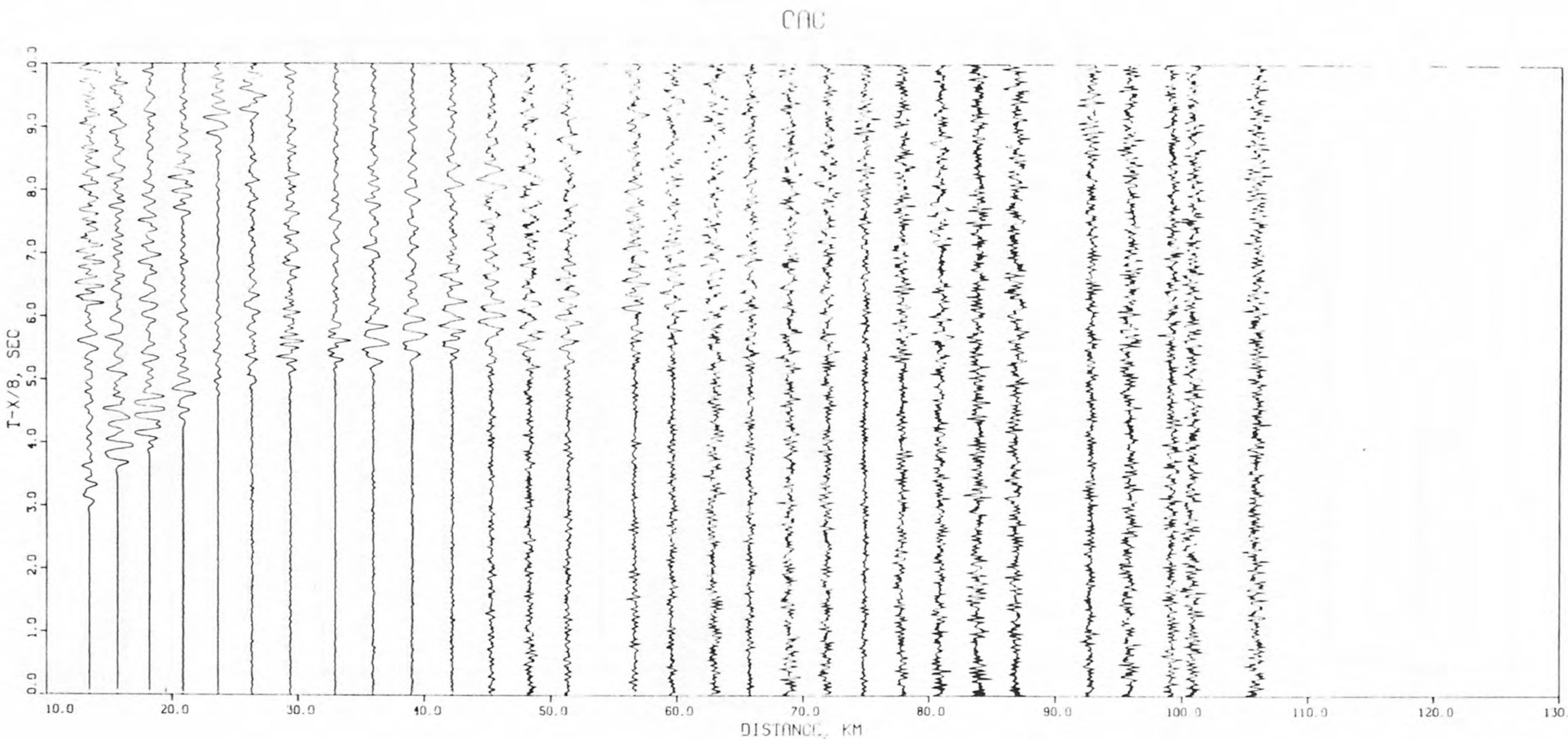
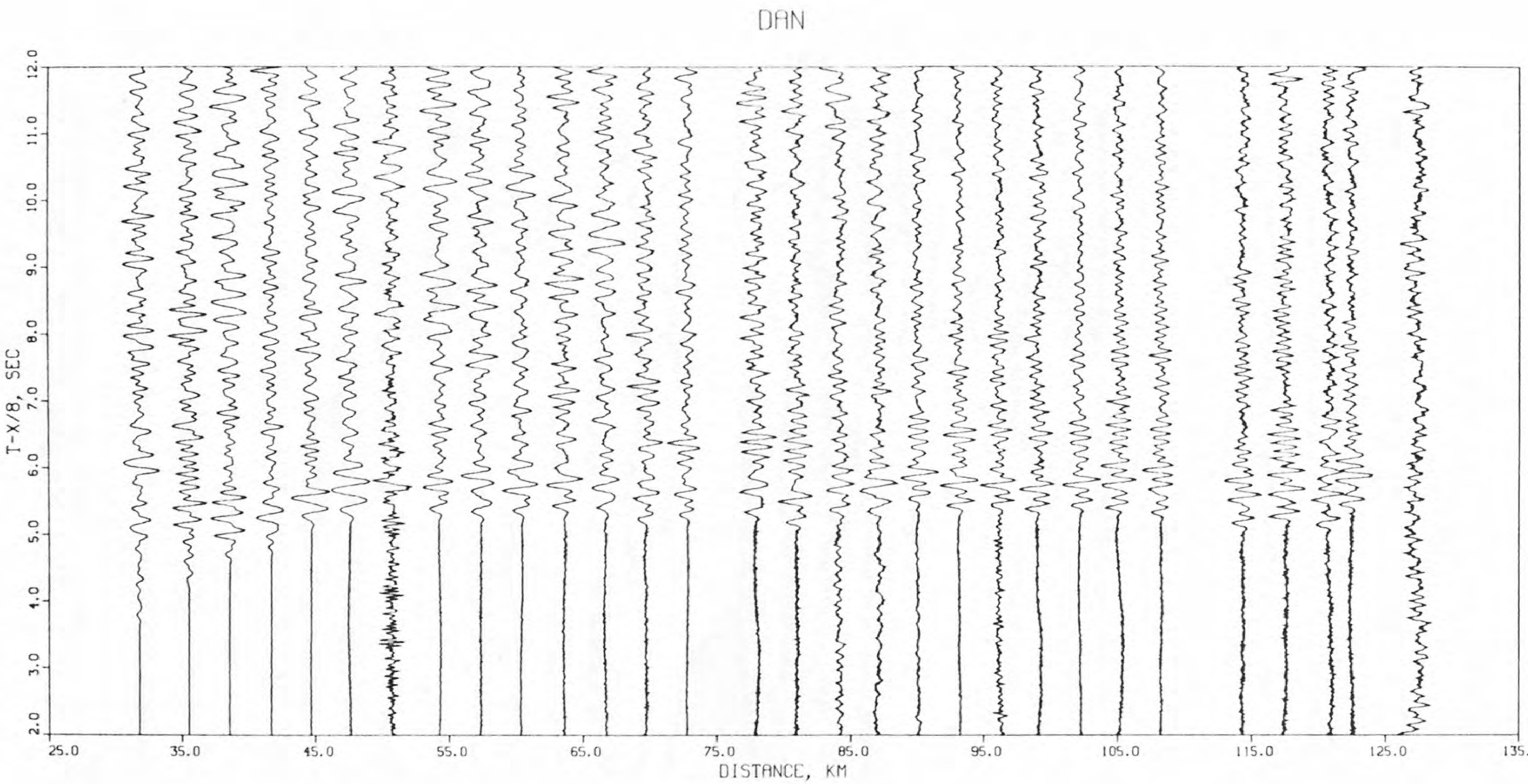


FIG 3.2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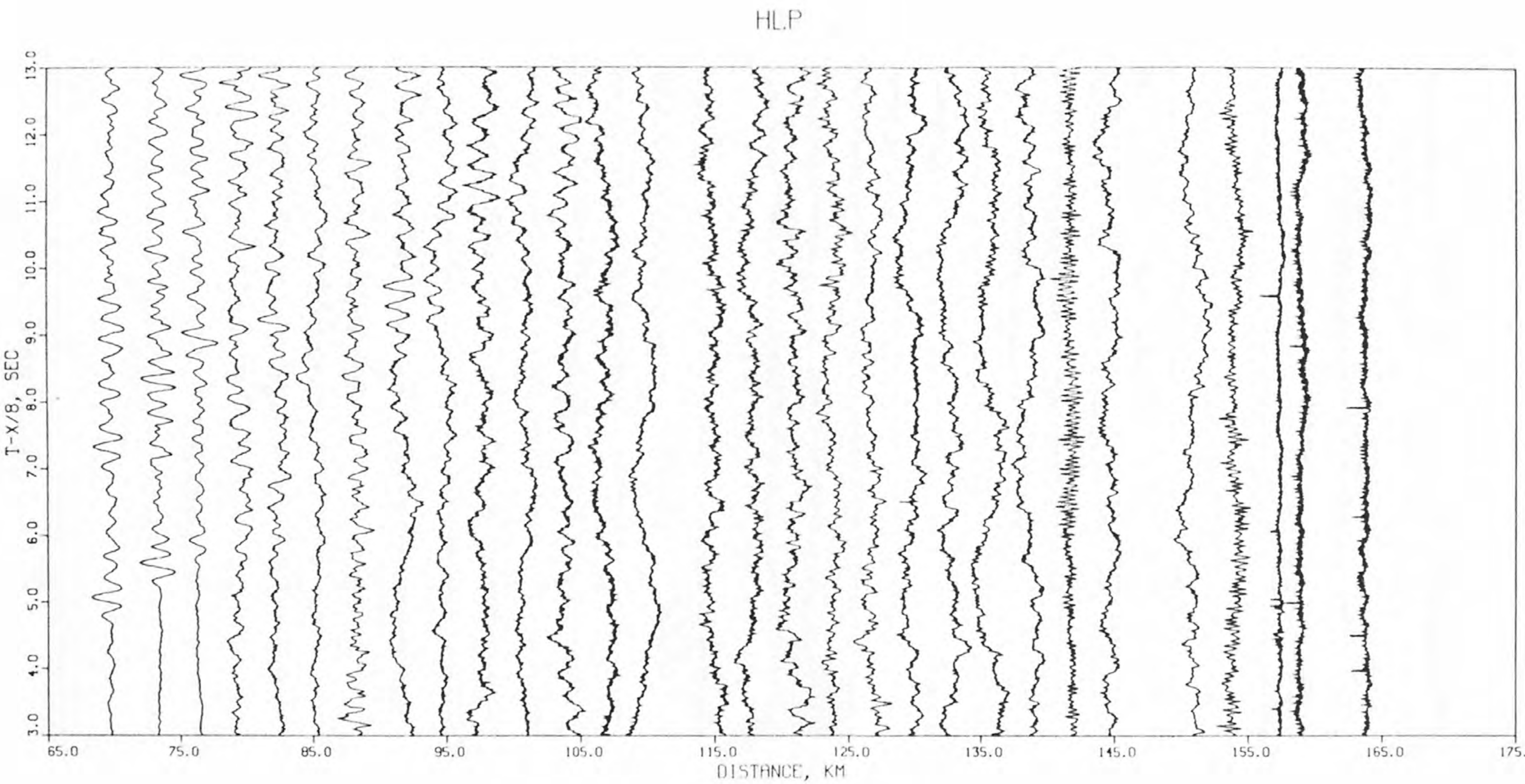
2.0
25.0
35.0
45.0
55.0
65.0
75.0
85.0
95.0
105.0
115.0
125.0
135.0
DISTANCE, KM

FIG 3.3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13.0
65.0
75.0
85.0
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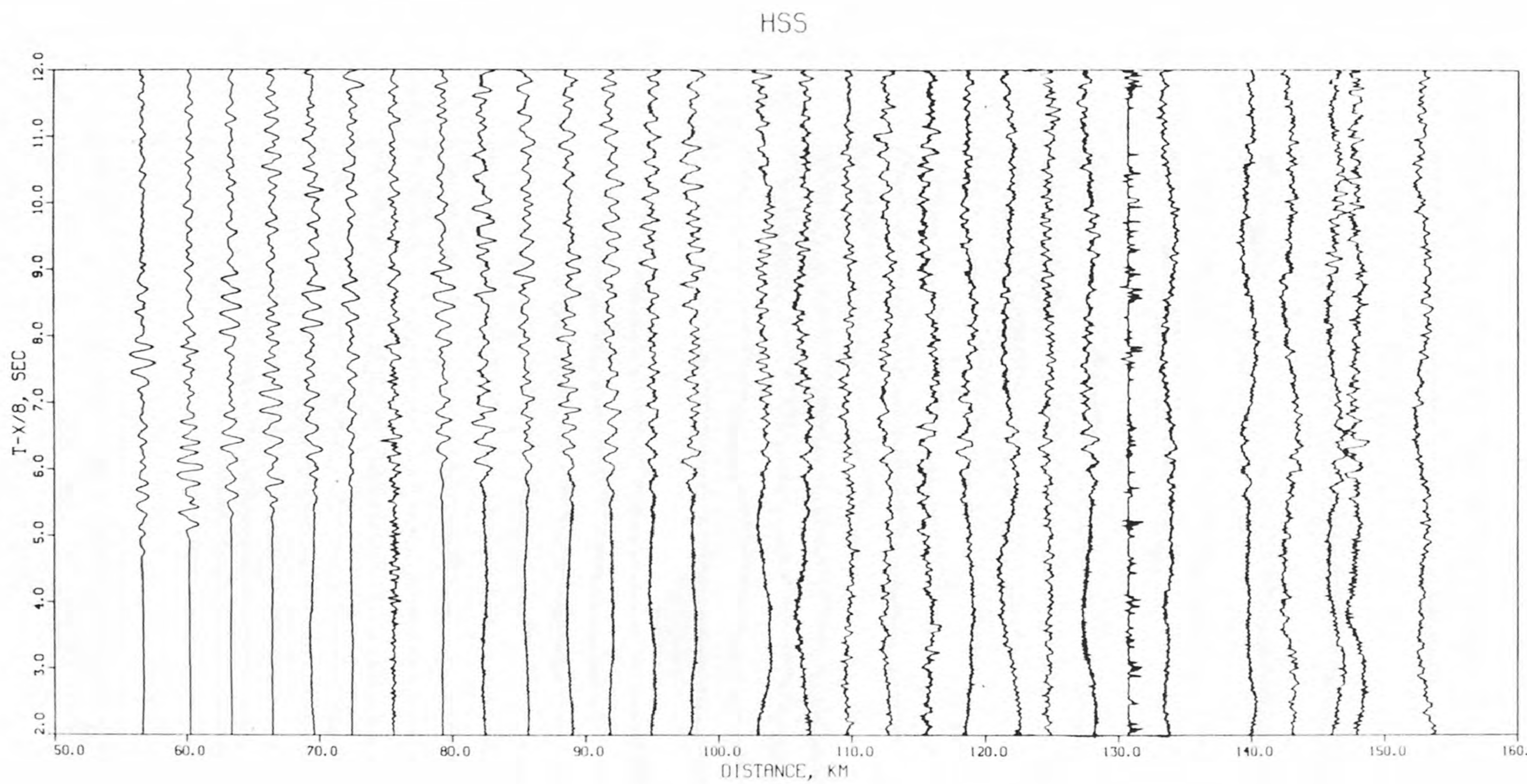
105.0
115.0
125.0
135.0
145.0
155.0
165.0
175.0
DISTANCE, KM

FIG 3.4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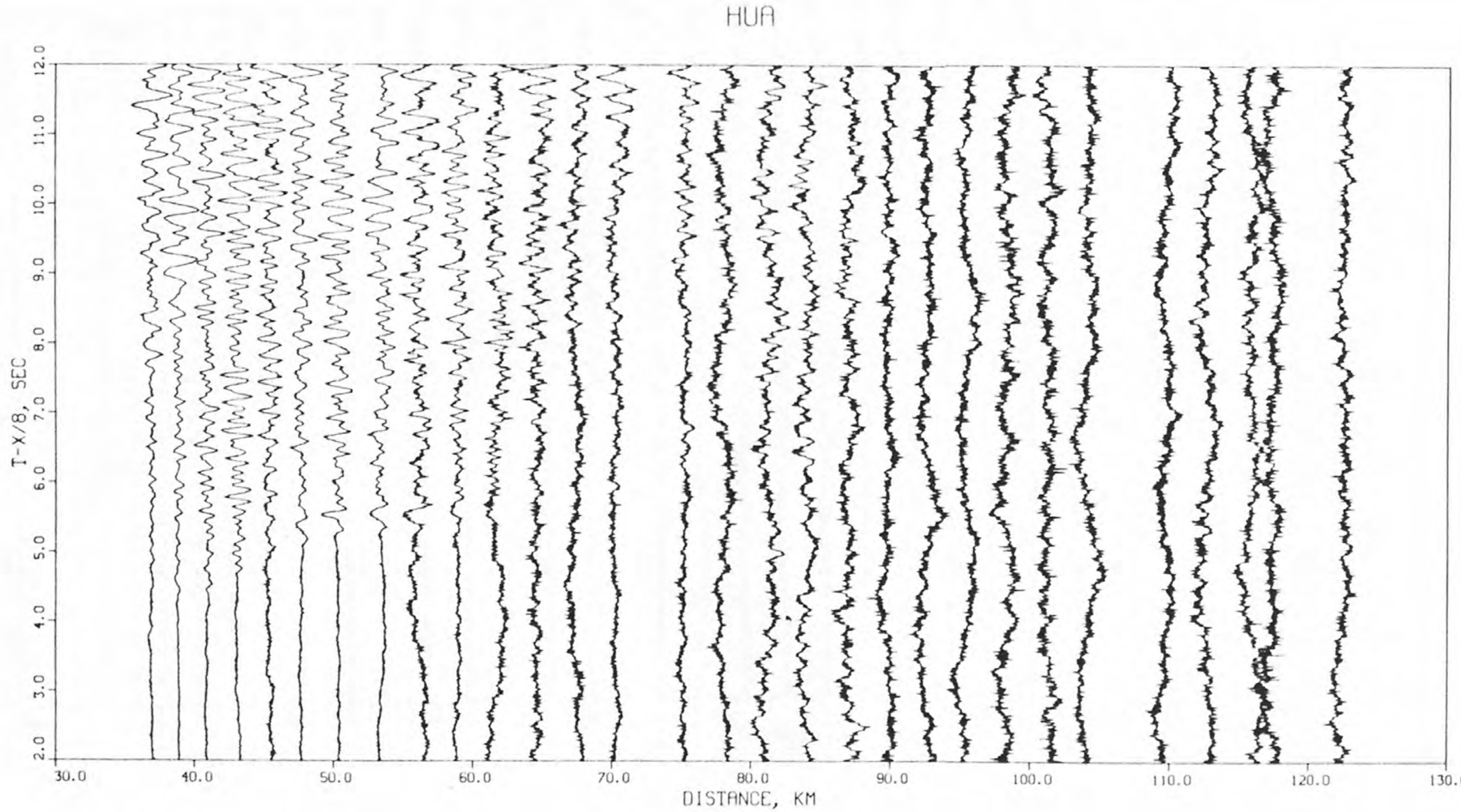
11.0
12.0
50.0
60.0
70.0
80.0
90.0
100.0
110.0
120.0
130.0
140.0
150.0
160.0
DISTANCE, KM

FIG 3.5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11.0
12.0
30.0
40.0
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70.0
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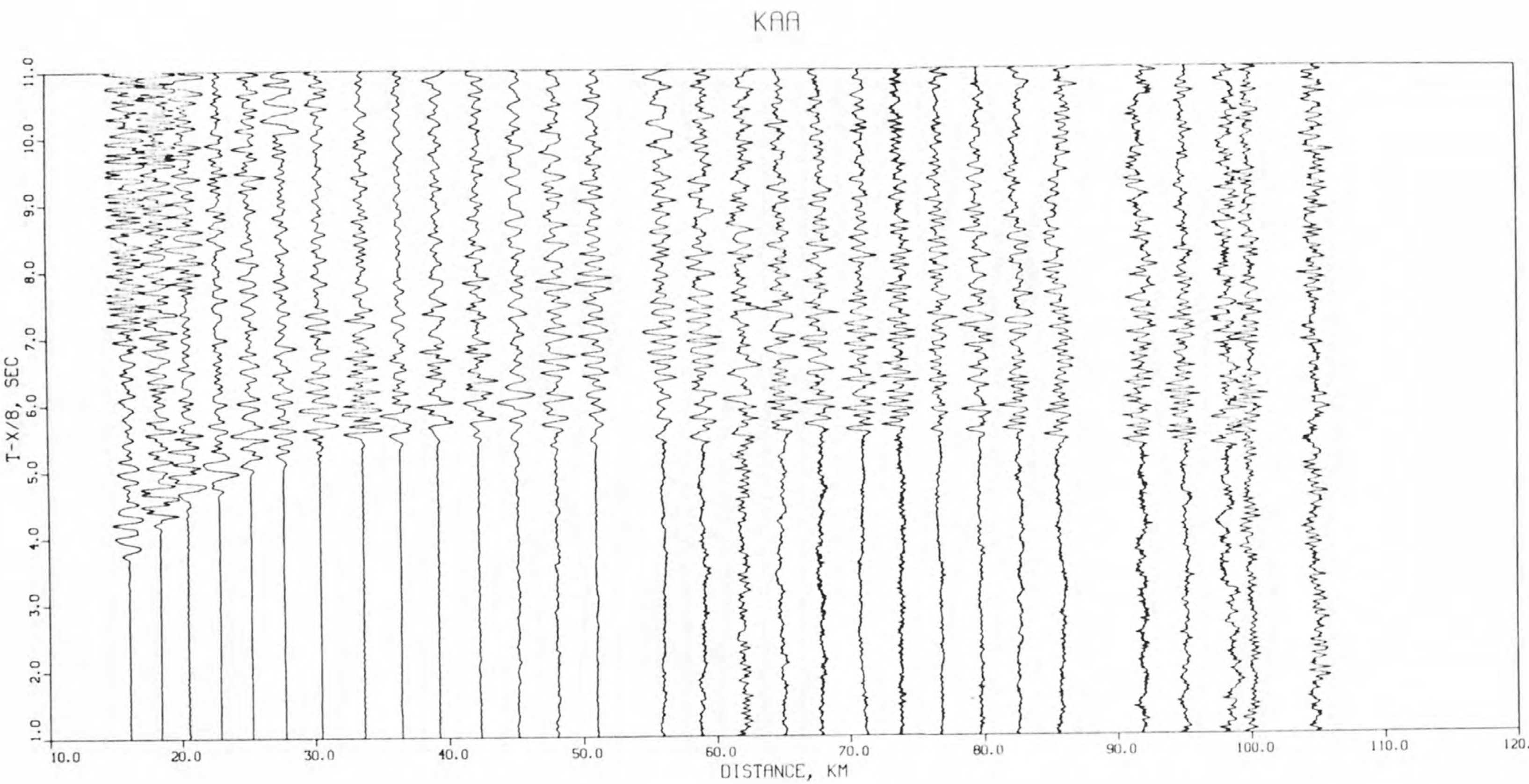
90.0
100.0
110.0
120.0
130.0
DISTANCE, KM

FIG 3.6


KAA
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3.0
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6.0
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11.0
10.0
20.0
30.0
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60.0
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80.0
90.0
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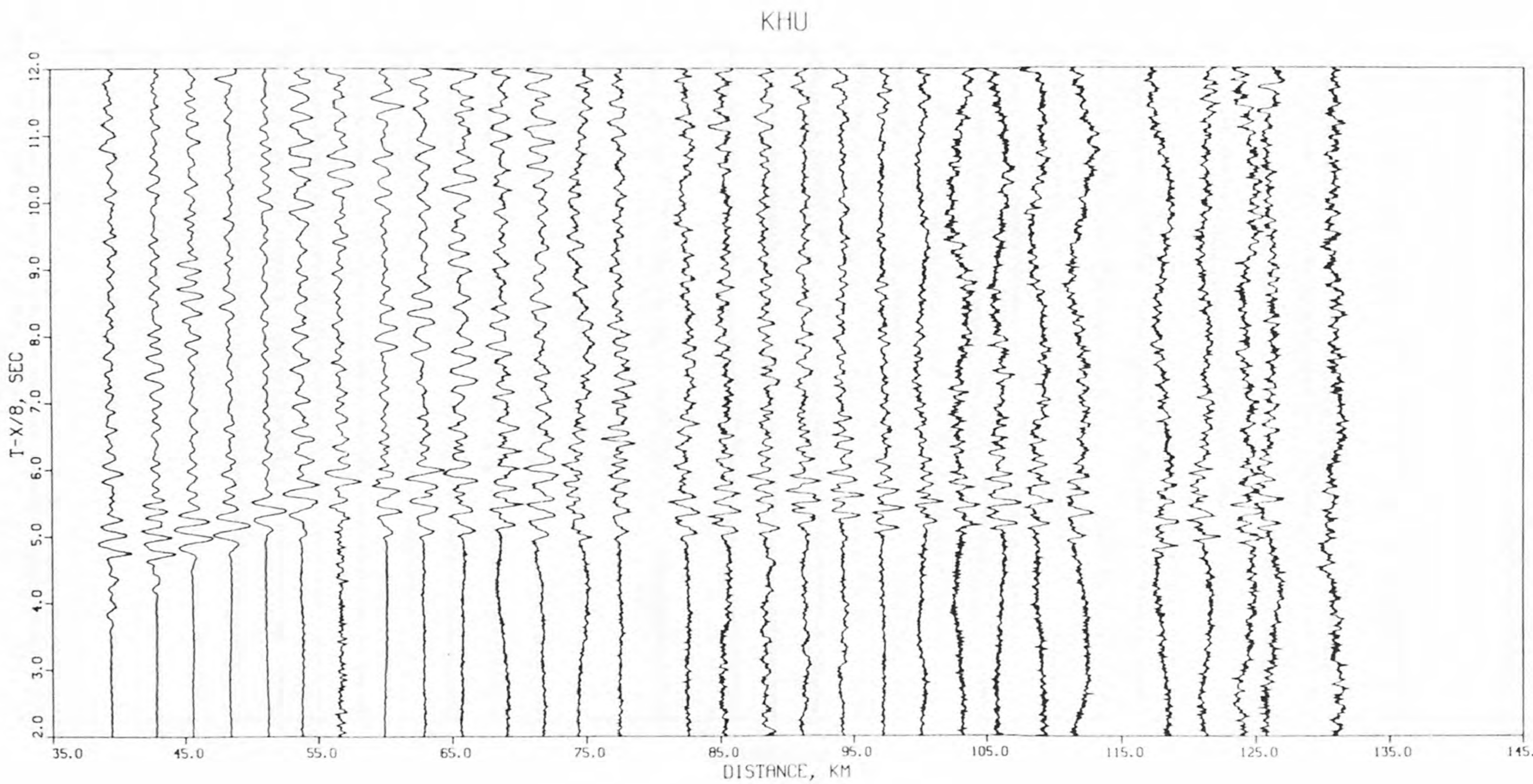
120.0
DISTANCE, KM

FIG 3.7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10.0
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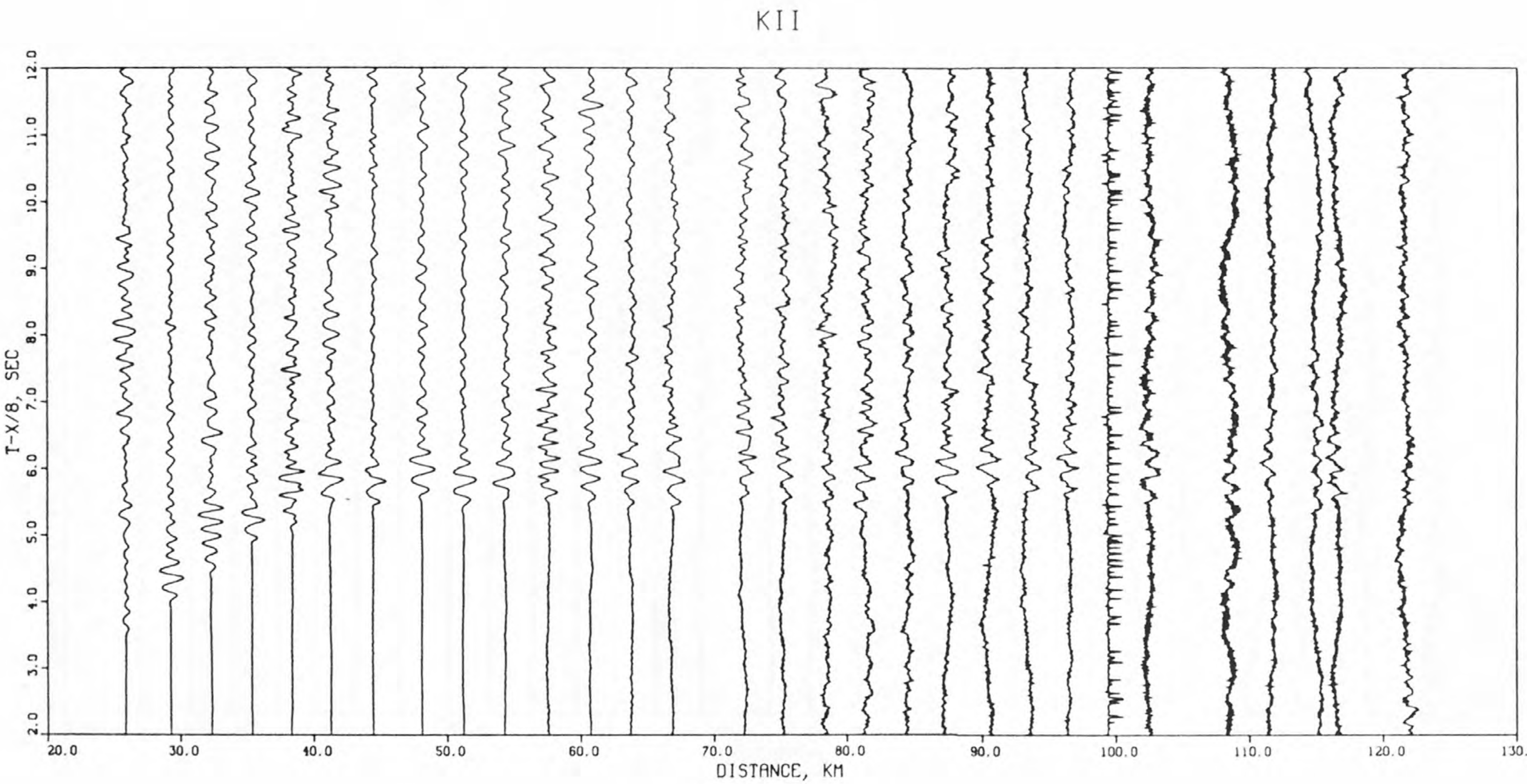
12.0
35.0
45.0
55.0
65.0
75.0
85.0
95.0
105.0
115.0
125.0
135.0
145.0
DISTANCE, KM

FIG 3.8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6.0
7.0
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9.0
10.0
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12.0
20.0
30.0
40.0
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110.0
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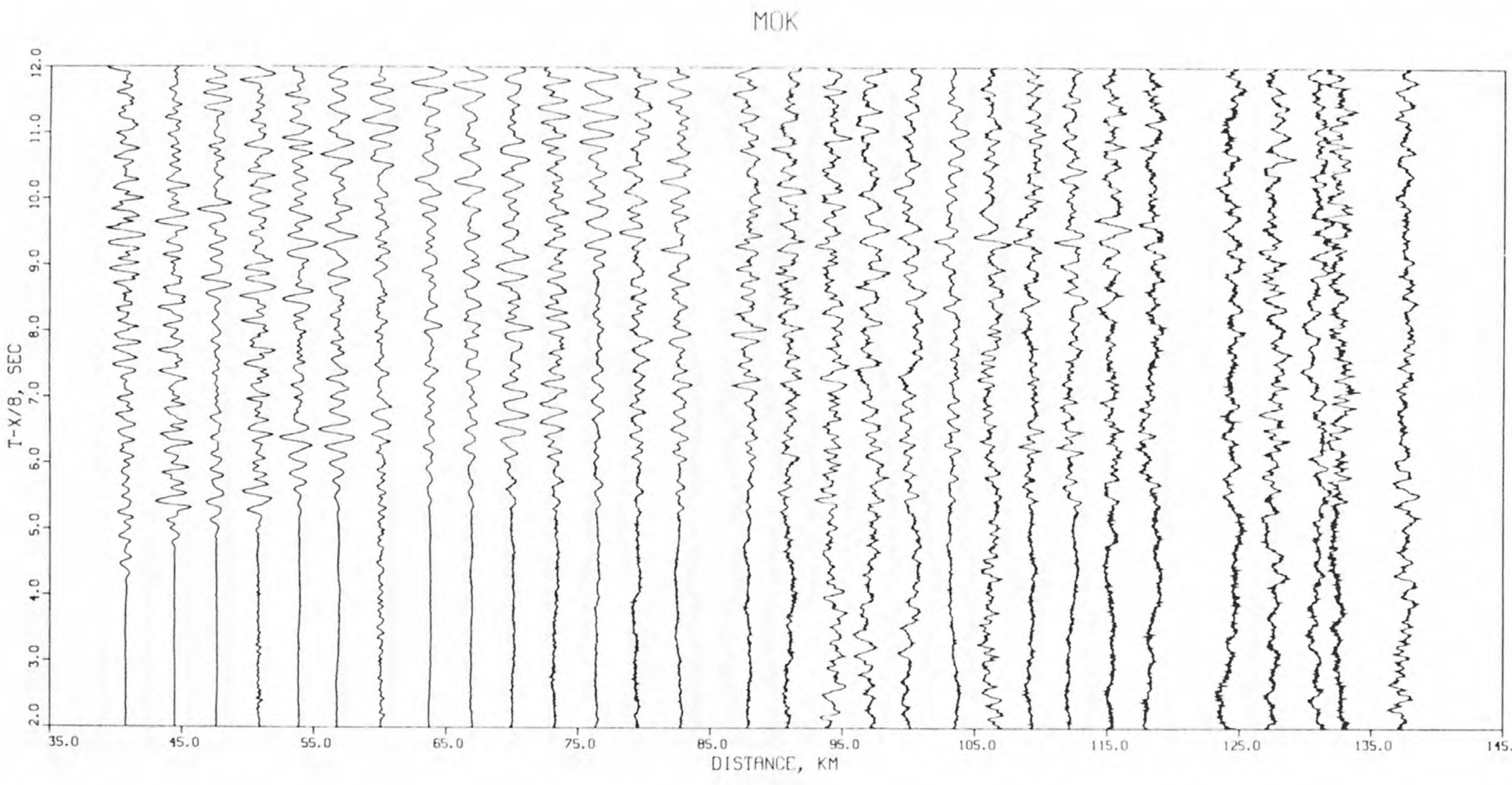
DISTANCE, KM

FIG 3.9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7.0
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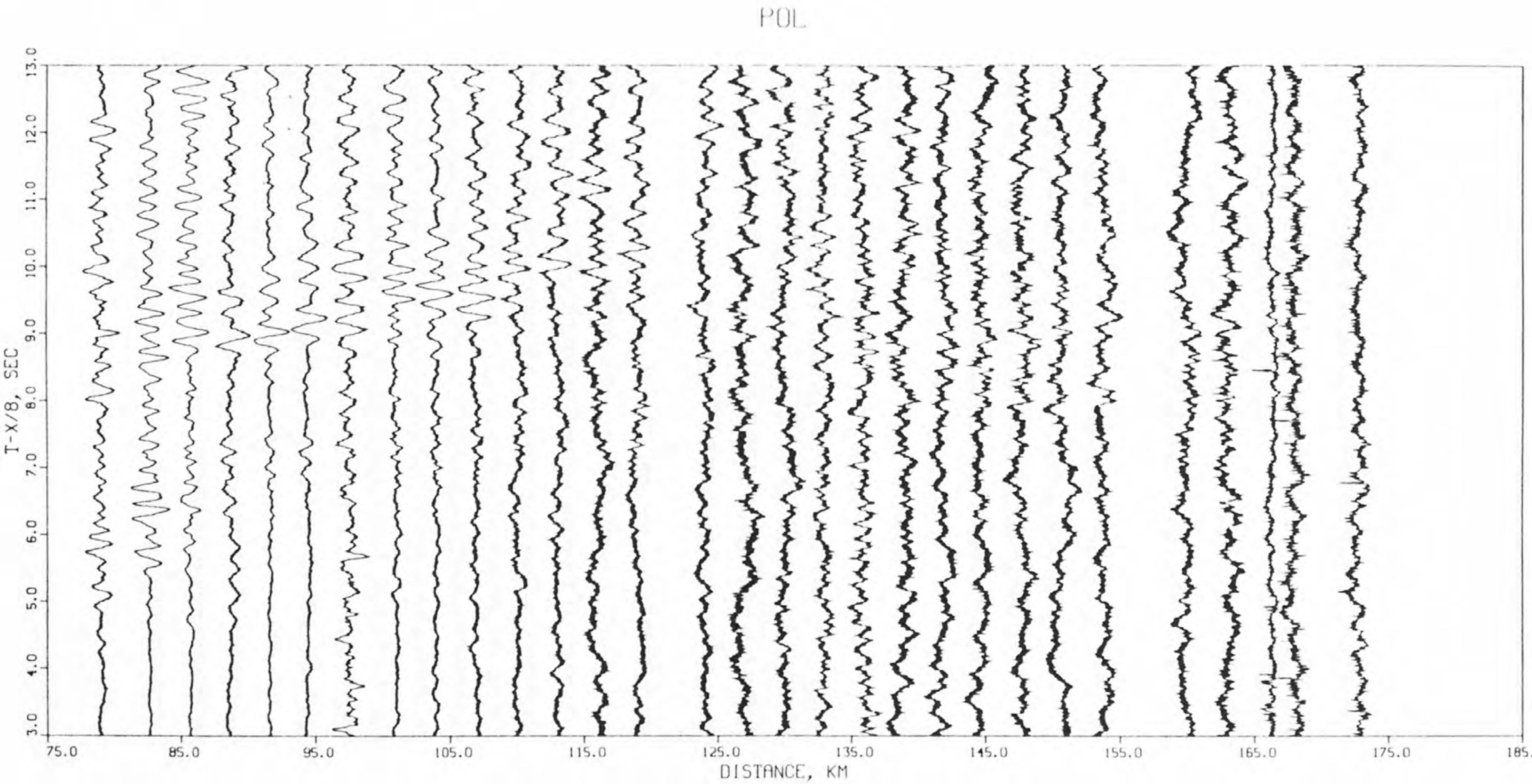
12.0
35.0
45.0
55.0
65.0
75.0
85.0
95.0
105.0
115.0
125.0
135.0
145.0
DISTANCE, KM

FIG 3.10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6.0
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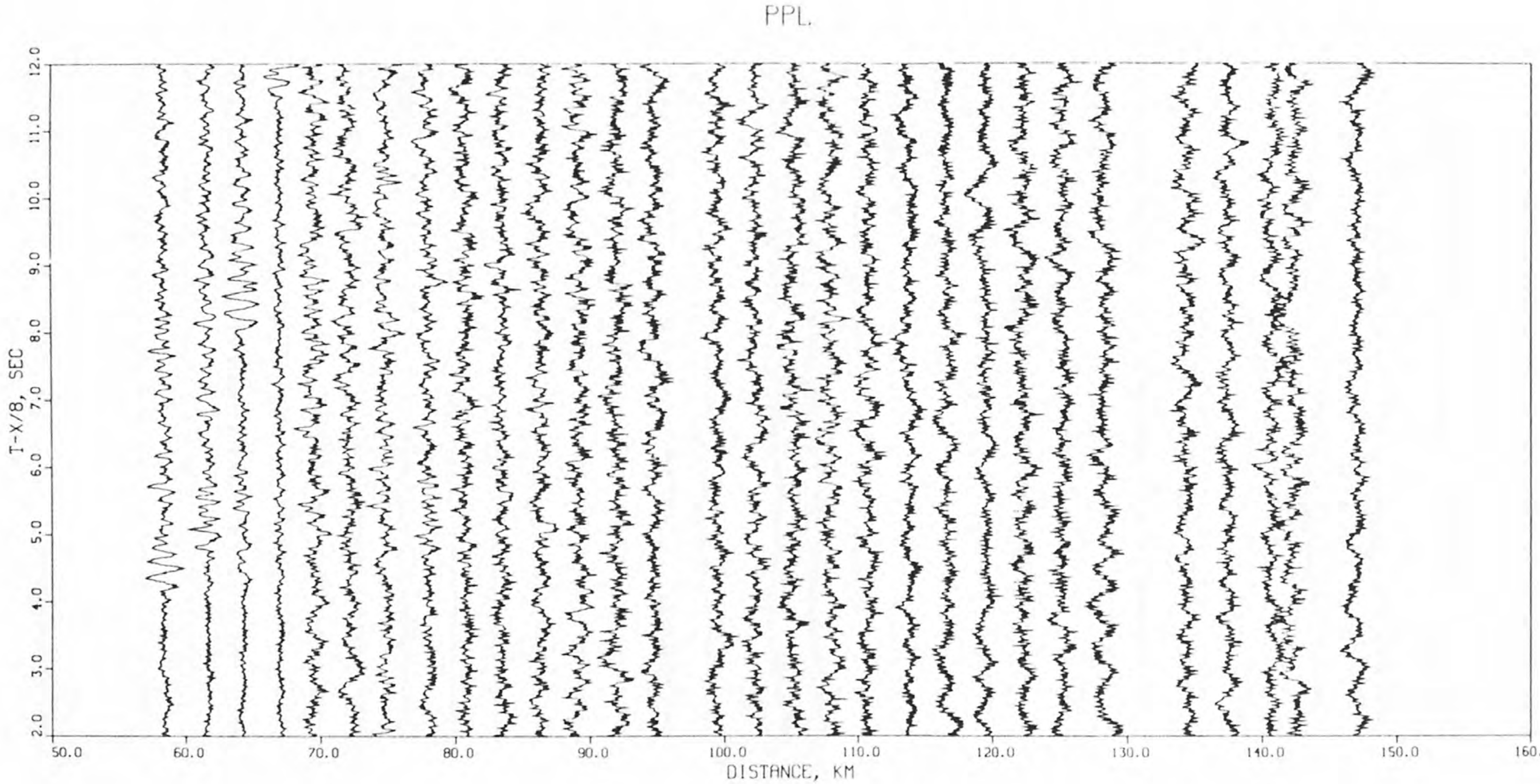
3.0
75.0
85.0
95.0
105.0
115.0
125.0
135.0
145.0
155.0
165.0
175.0
185.0
DISTANCE, KM

FIG 3.11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50.0
60.0
70.0
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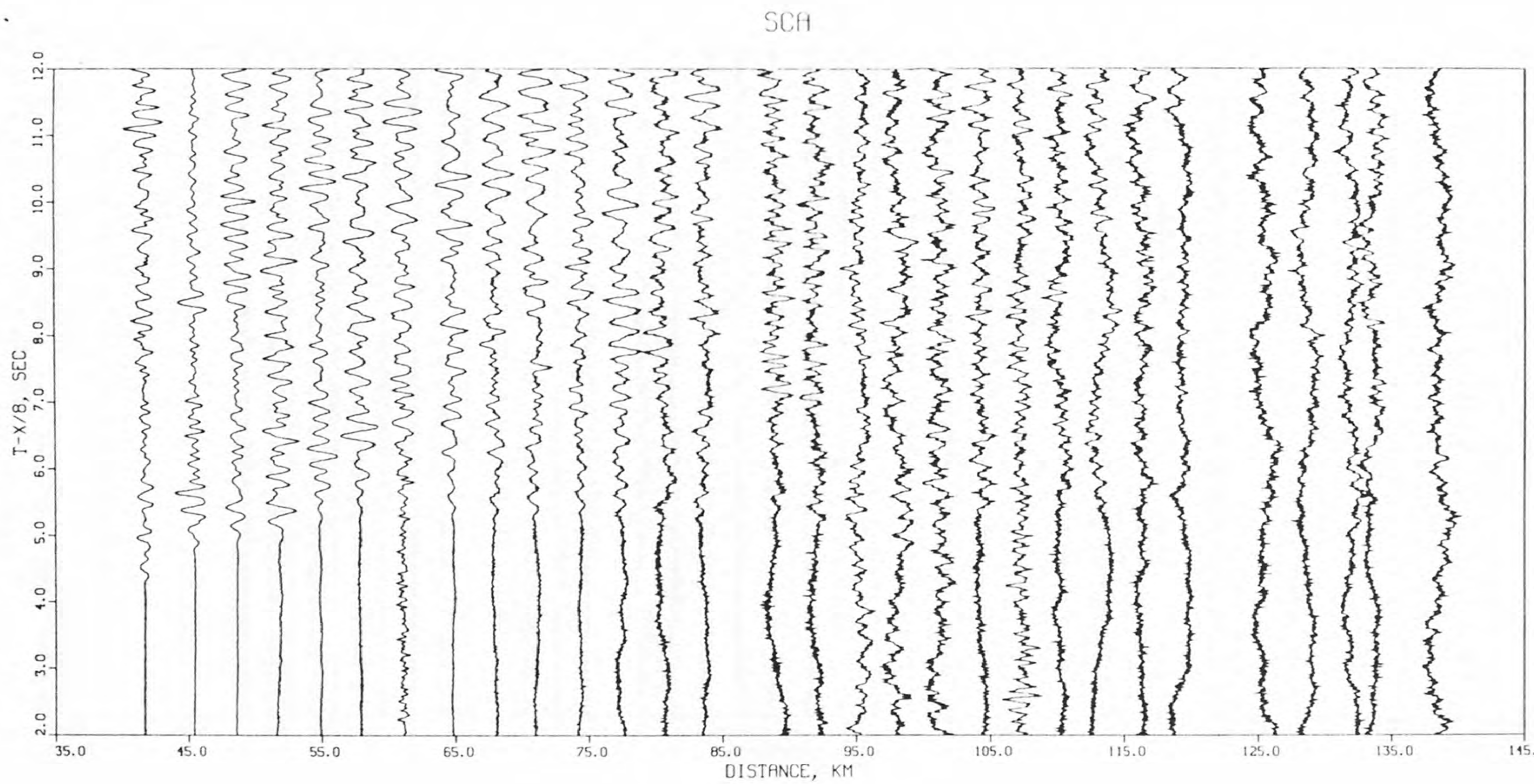
DISTANCE, KM

FIG 3.12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12.0
35.0
45.0
55.0
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105.0
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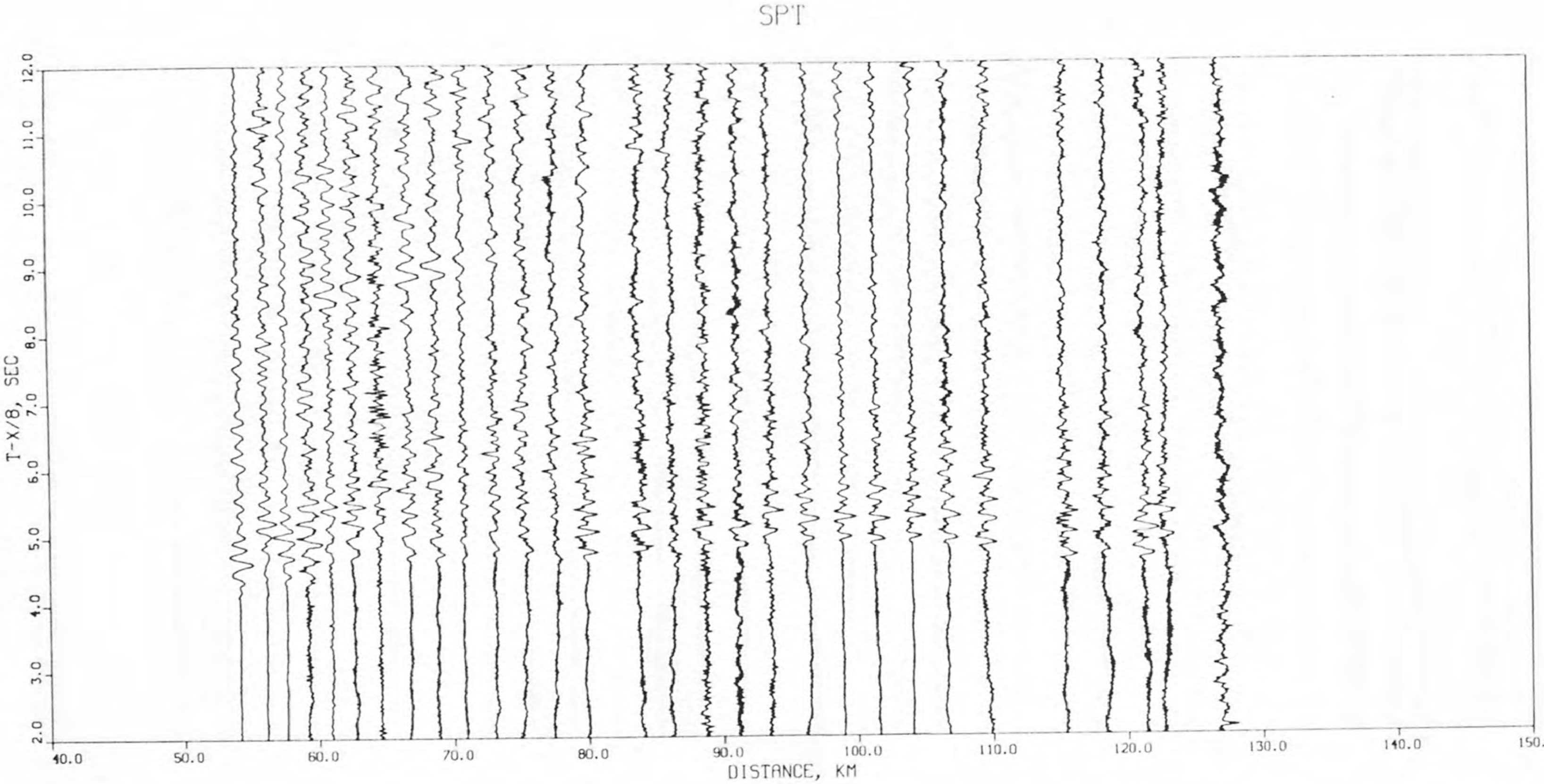
DISTANCE, KM

FIG 3.13



SPT
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12.0
40.0
50.0
60.0
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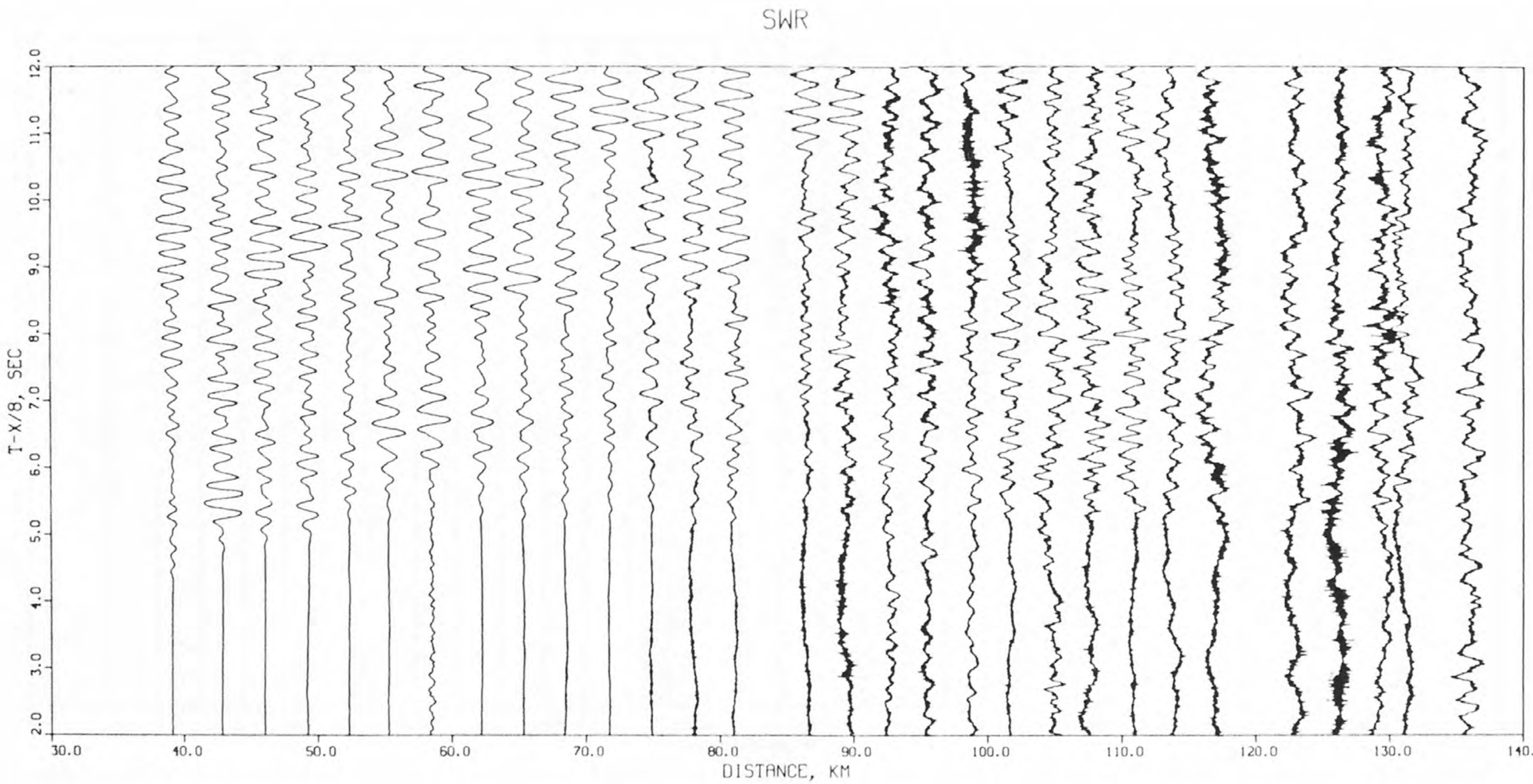
DISTANCE, KM

FIG 3.14



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12.0
30.0
40.0
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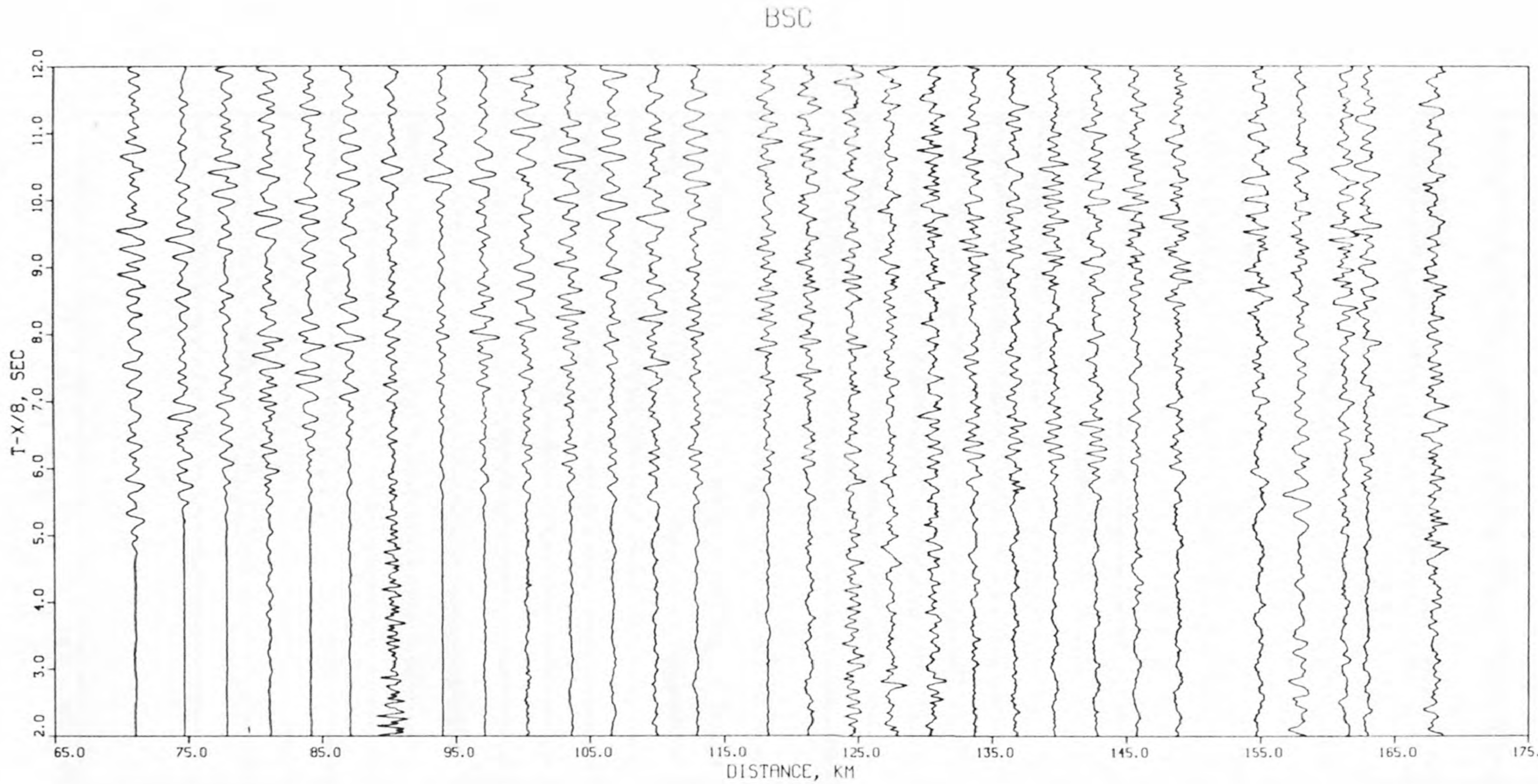
DISTANCE, KM

FIG 3.15



BSC
T-X/8, SEC
DISTANCE, KM
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3.0
4.0
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6.0
7.0
8.0
9.0
10.0
11.0
12.0
65.0
75.0
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125.0
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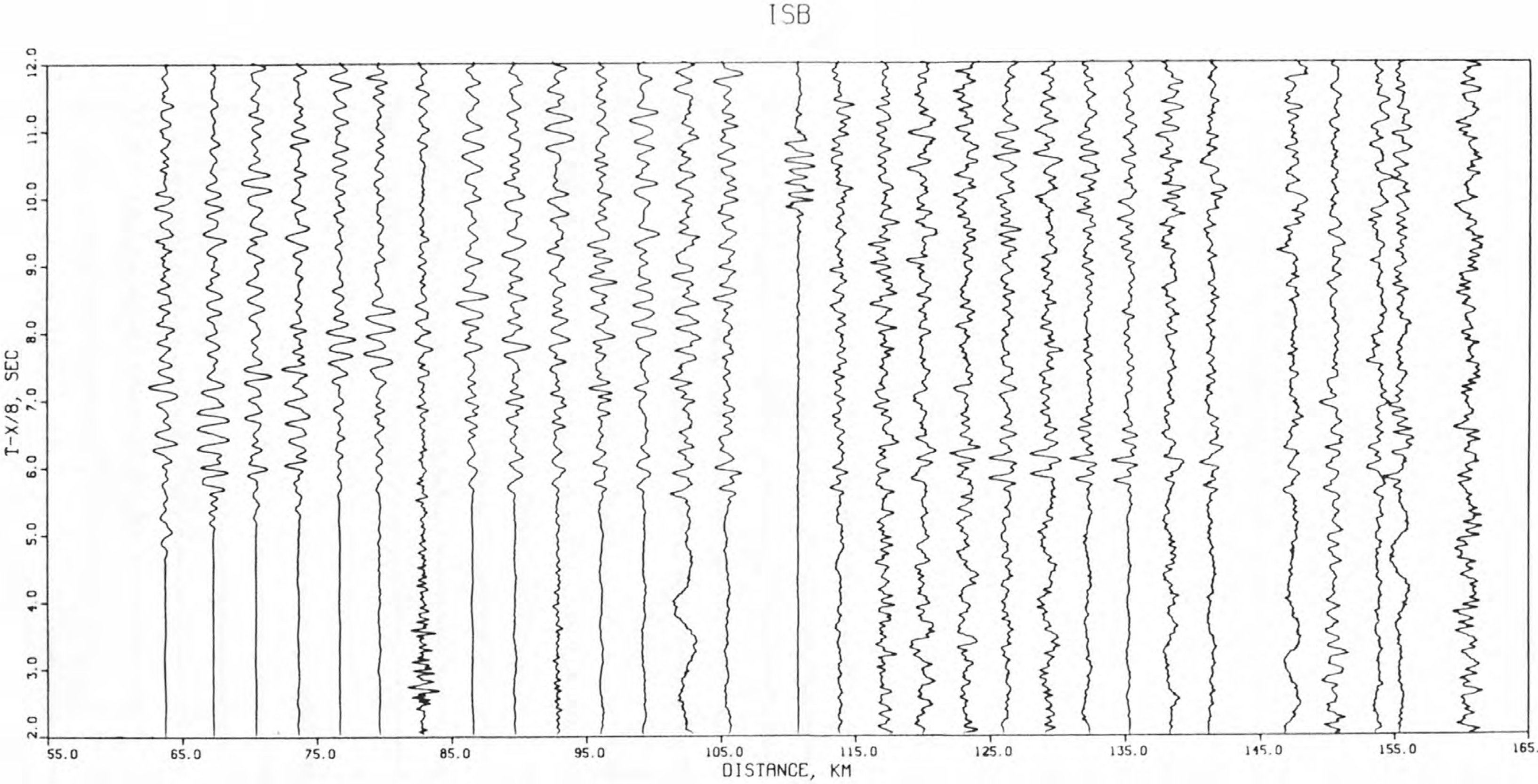
155.0
165.0
175.0

FIG 4.1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3.0
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T-X/8, SEC
55.0
65.0
75.0
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95.0
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115.0
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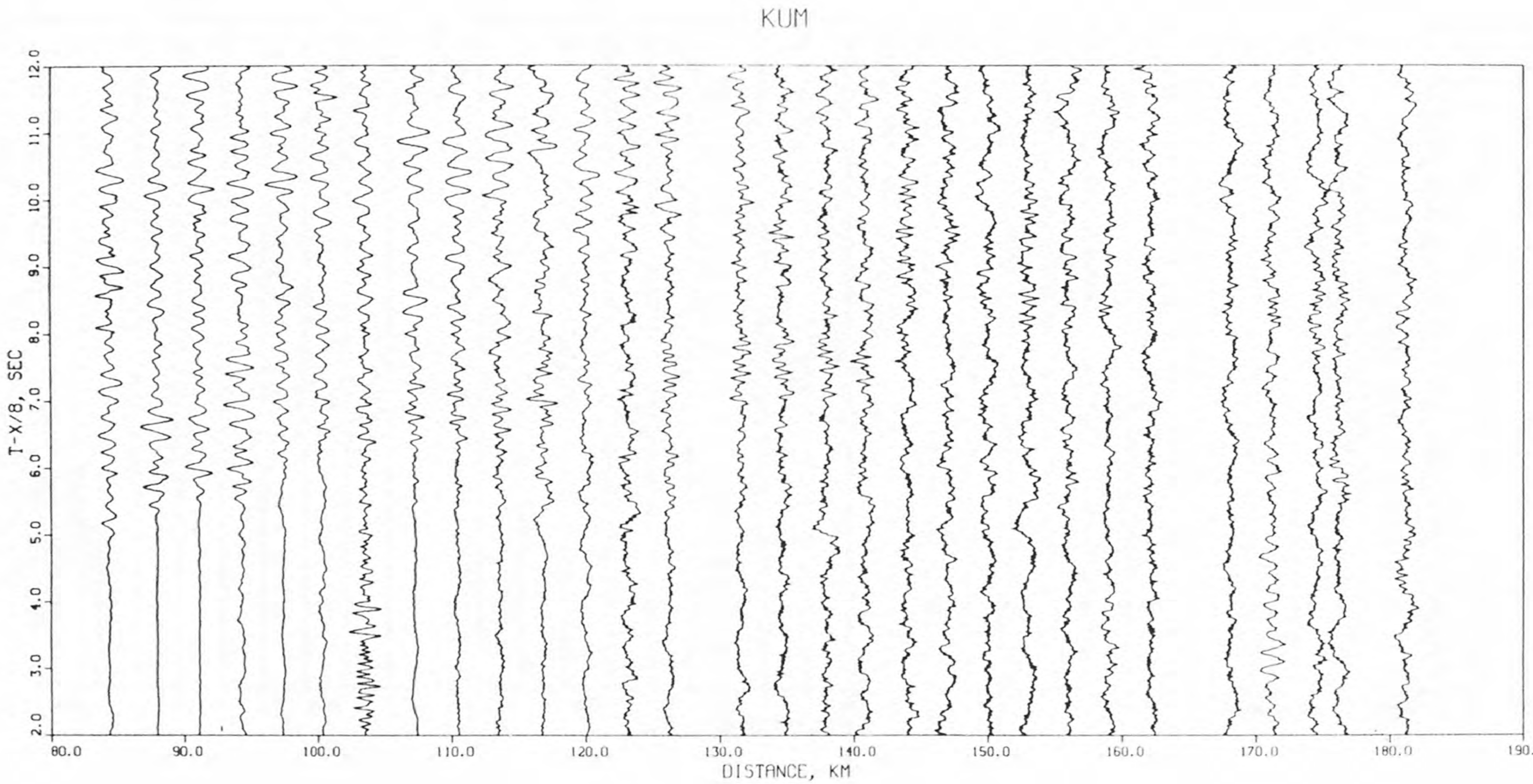
145.0
155.0
165.0
DISTANCE, KM

FIG 4.2


KUM
T-X/8, SEC
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11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
80.0
90.0
100.0
110.0
120.0
130.0
140.0
150.0
160.0
170.0
180.0
190.0
DISTANCE, KM

FIG 4.3

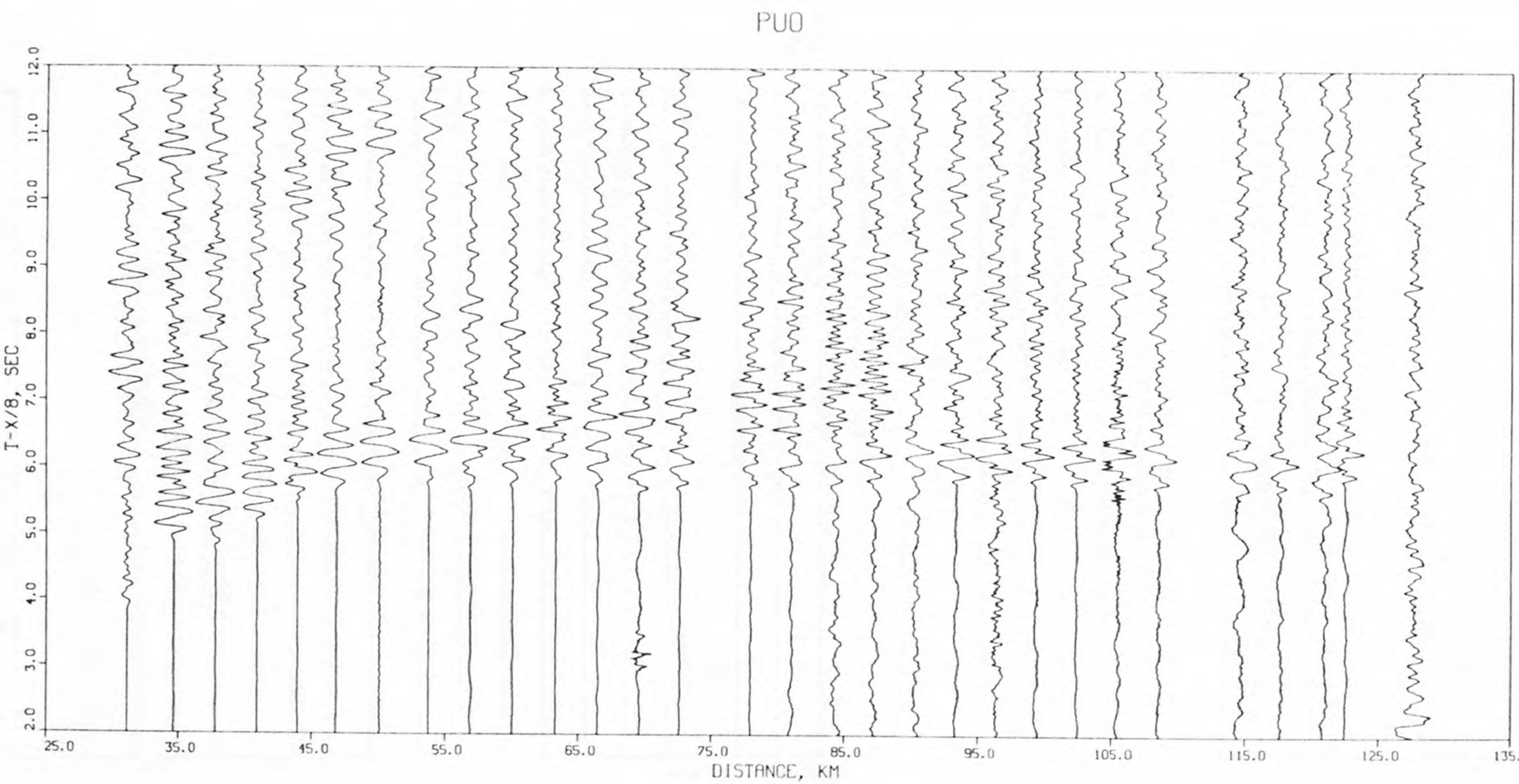
PUO
T-X/8, SEC
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
25.0
35.0
45.0
55.0
65.0
75.0
85.0
95.0
105.0
115.0
125.0
135.0
DISTANCE, KM

FIG 4.4

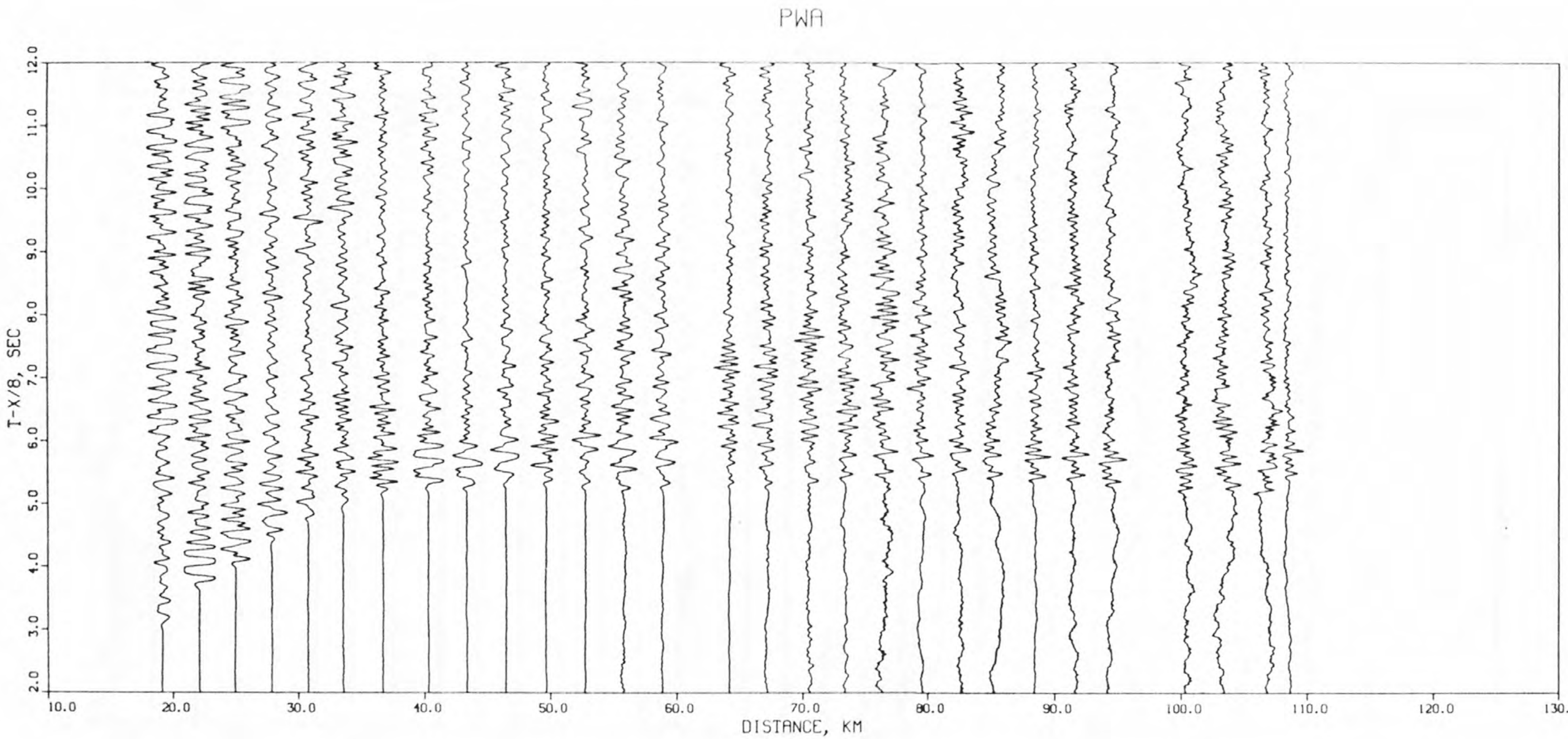
PWA
T-X/8, SEC
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
110.0
120.0
130.0
DISTANCE, KM

FIG 4.5

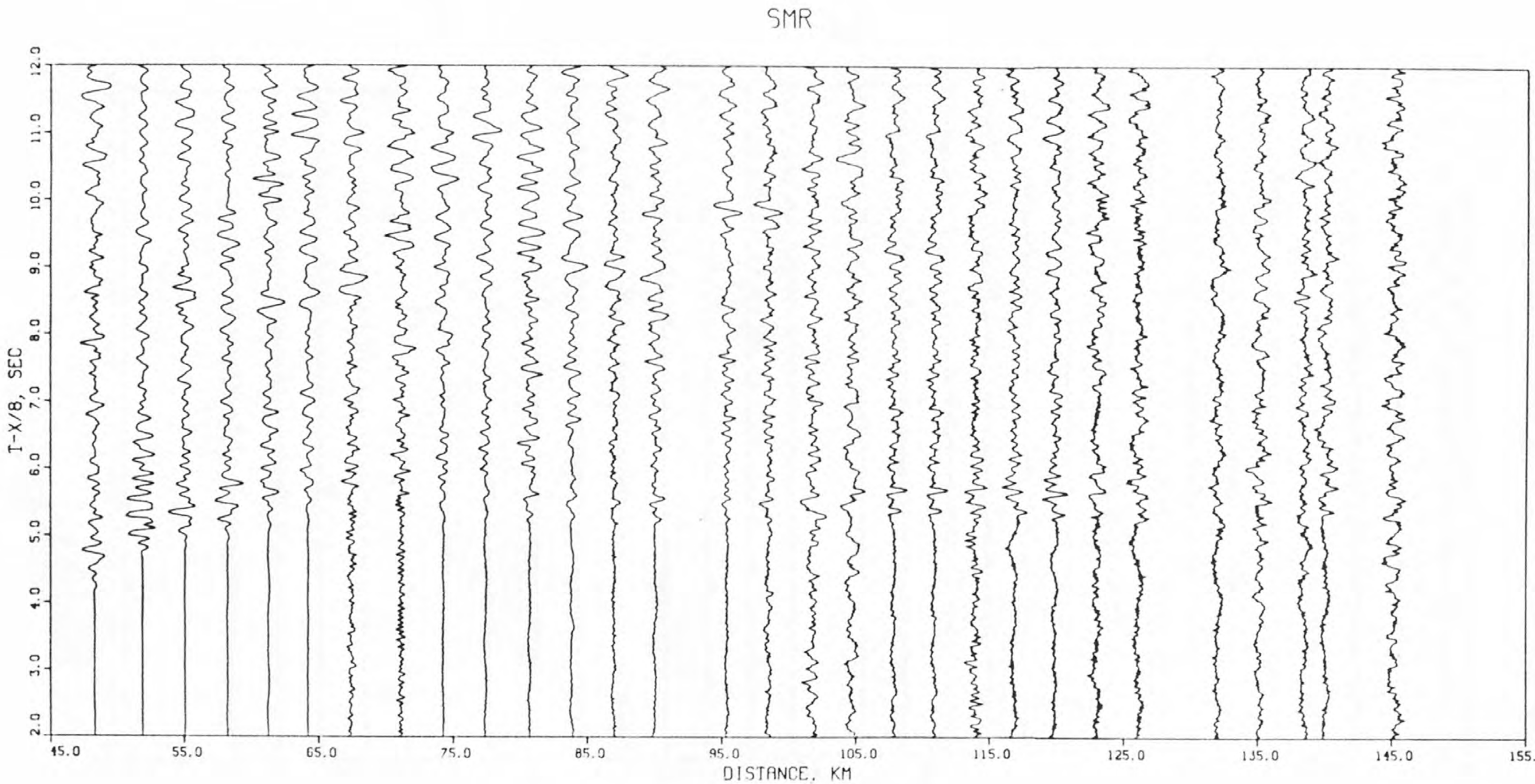
SMR
T-X/8, SEC
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
45.0
55.0
65.0
75.0
85.0
95.0
105.0
115.0
125.0
135.0
145.0
155.0
DISTANCE, KM

FIG 4.6

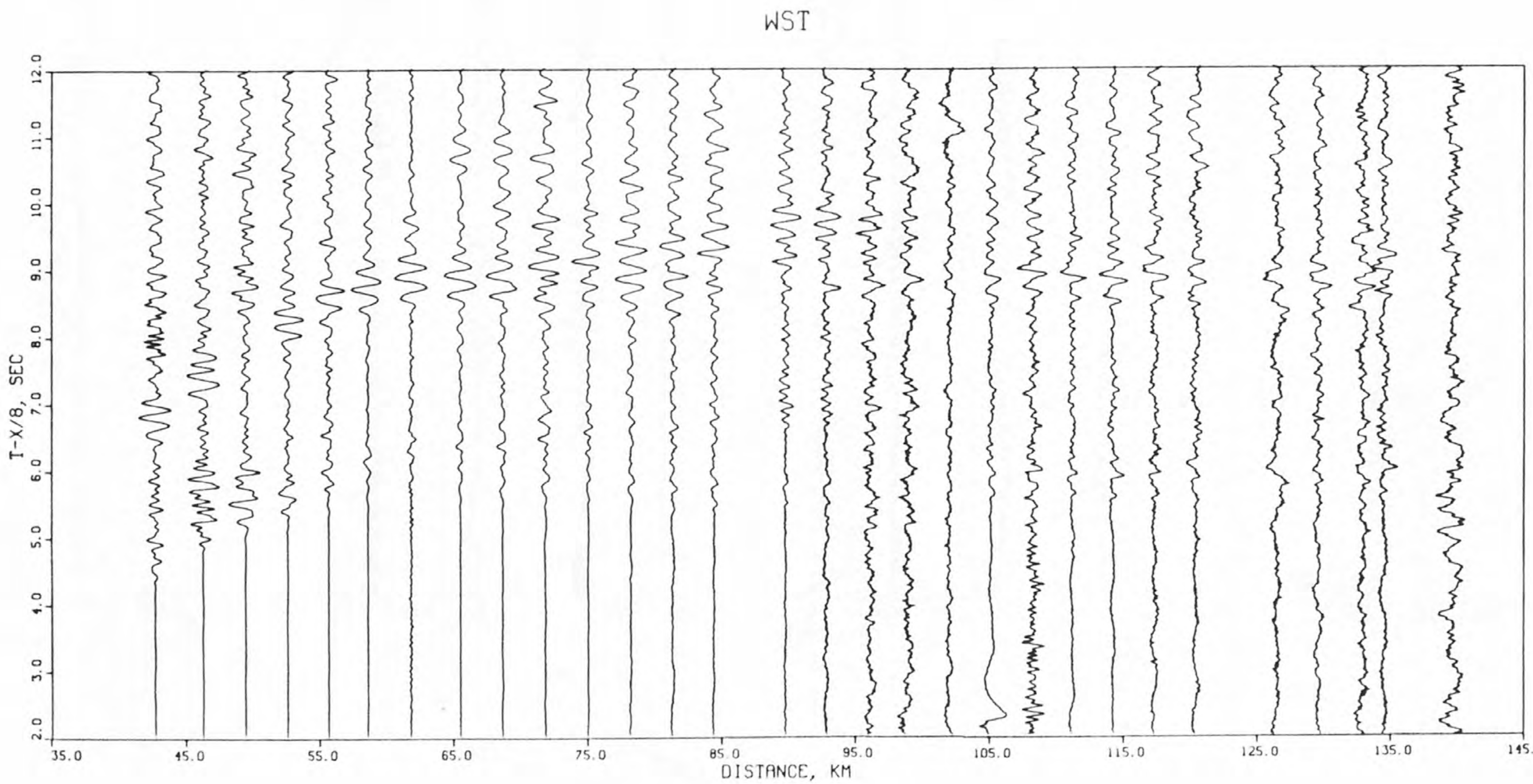
WST
T-X/8, SEC
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
35.0
45.0
55.0
65.0
75.0
85.0
95.0
105.0
115.0
125.0
135.0
145.0
DISTANCE, KM

FIG 4.7

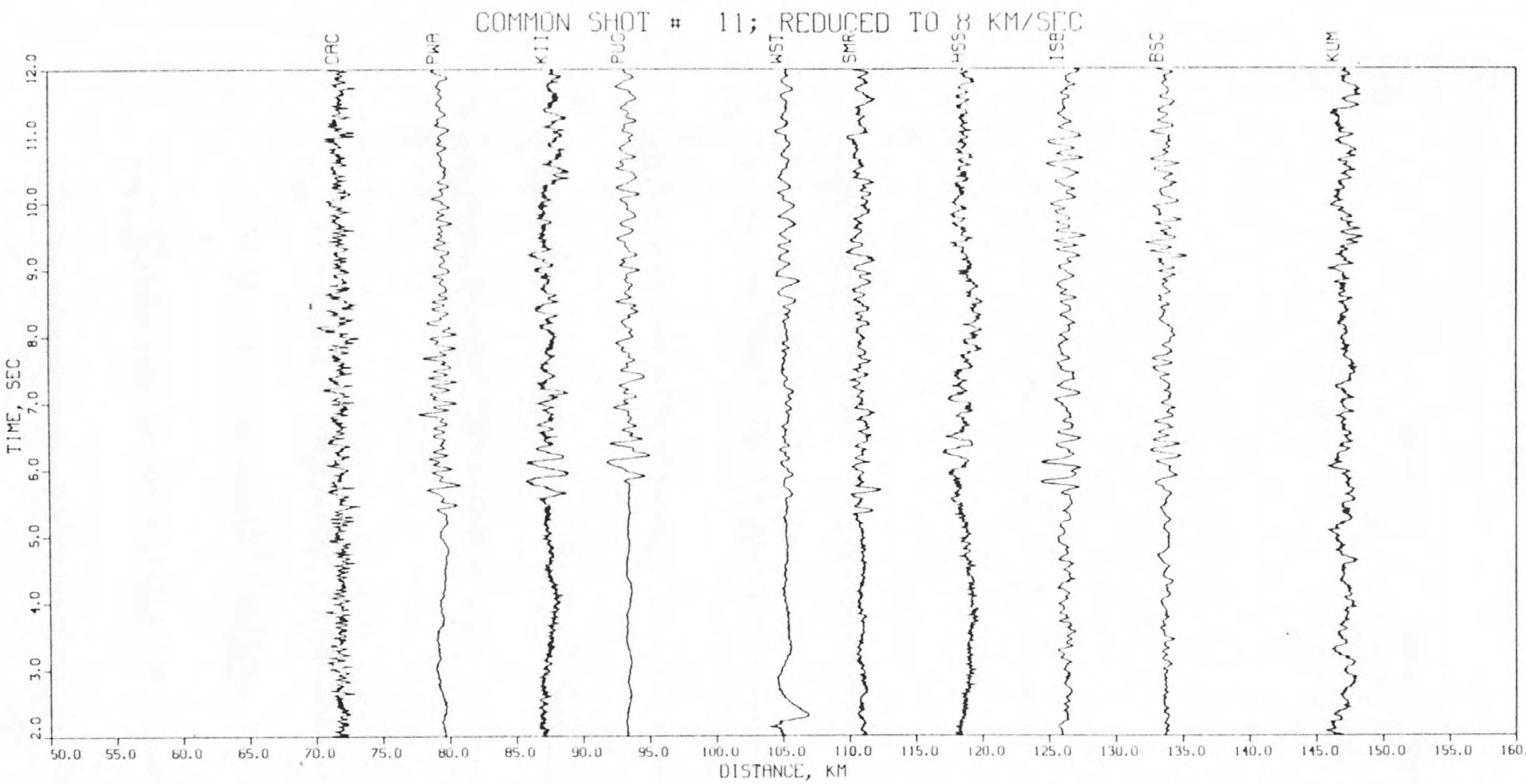
COMMON SHOT # 11; REDUCED TO 8 KM/SEC
CAC
PWA
KII
PUO
WST
SMR
HSS
ISB
BSC
KUM
TIME, SEC
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
50.0 55.0 60.0 65.0 70.0 75.0 80.0 85.0 90.0 95.0 100.0 105.0 110.0 115.0 120.0 125.0 130.0 135.0 140.0 145.0 150.0 155.0 160.0
DISTANCE, KM

FIG 5.1

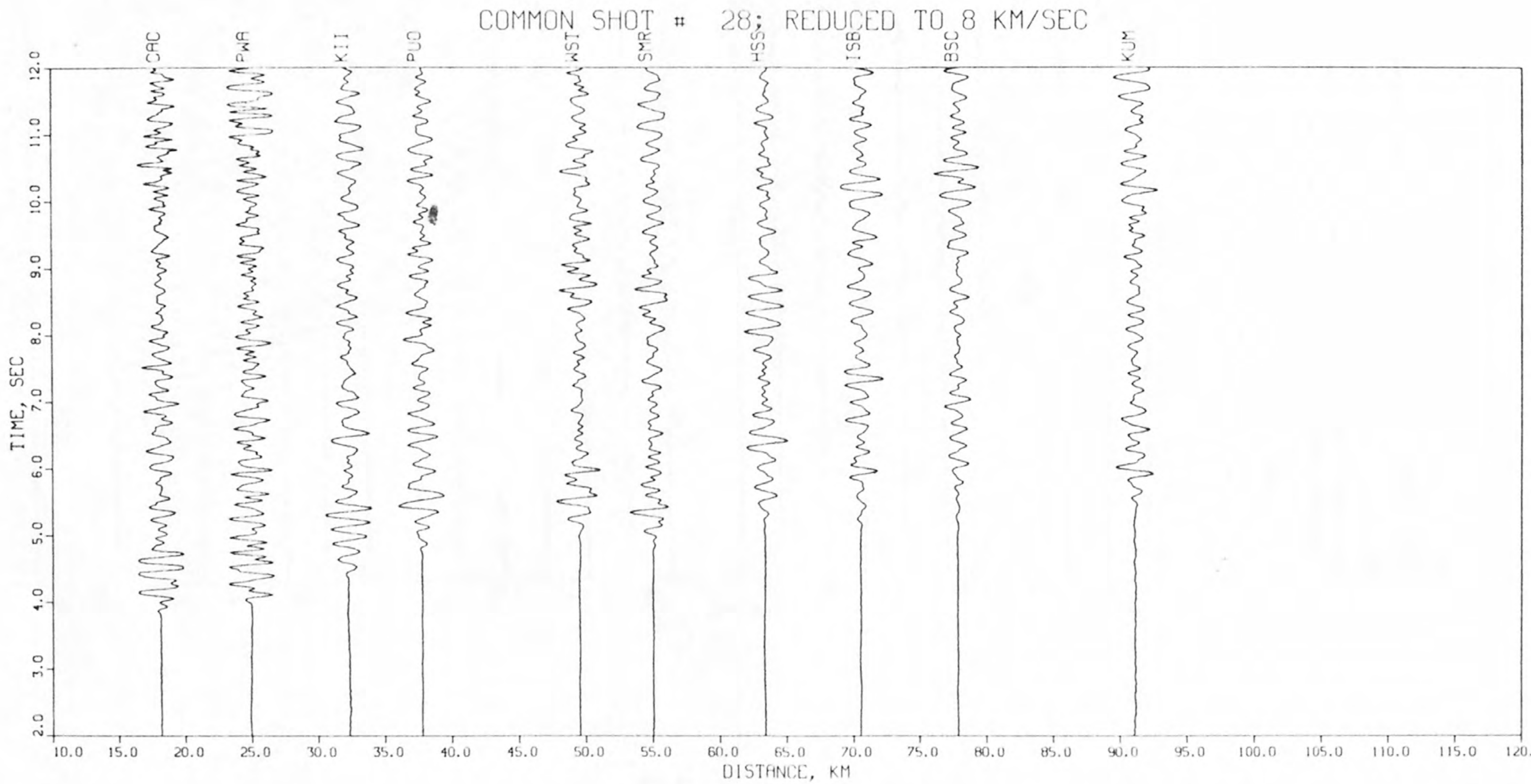
COMMON SHOT # 28; REDUCED TO 8 KM/SEC
CAC
PWA
KII
PUO
WST
SMR
HSS
ISB
BSC
KUM
TIME, SEC
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
55.0
60.0
65.0
70.0
75.0
80.0
85.0
90.0
95.0
100.0
105.0
110.0
115.0
120.0
DISTANCE, KM

FIG 5.2

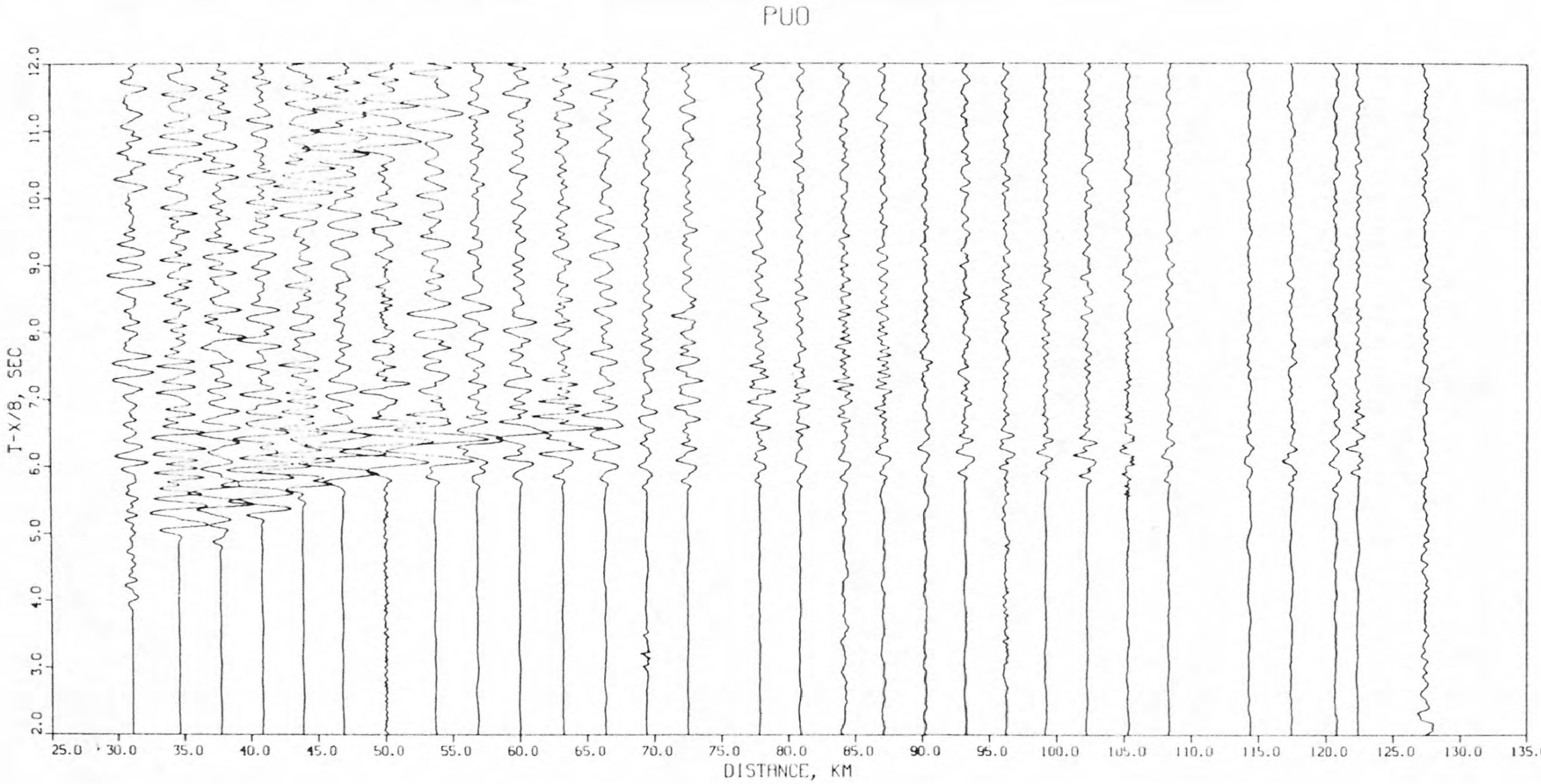
PUO
T-x/8, SEC
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
25.0
30.0
35.0
40.0
45.0
50.0
55.0
60.0
65.0
70.0
75.0
80.0
85.0
90.0
95.0
100.0
105.0
110.0
115.0
120.0
125.0
130.0
135.0
DISTANCE, KM

FIG 6