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(Department of the Interior)
Geological Survey.

A COMPILATION OF THE DATA FROM THE 1976 HAWAII SEISMIC REFRACTION EXPERIMENT

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 November 1976, the U.S. Geological Survey (USGS) in conjunction with the Hawaii Institute of Geophysics (HIG) of the University of Hawaii established a seismic refraction line perpendicular to the southeast coast of Hawaii (Fig. 1). The purpose of the experiment was to define the crustal structure of the southeast coast and its relationship to the tectonics of Kilauea volcano. This open-file report describes the experiment and presents the data without interpretation.

The experiment consisted of 43 shots oriented in a line roughly 100 km long (Fig. 1). The shots were of two sizes: twenty-three 300-lb shots fired at about 5 km intervals, and twenty 5 lb shots interspersed with the large shots. The charges, which consisted of the commercial explosive Tovex, were deployed from the fantail of the USGS research vessel "Sammuel P. Lee". The shots were detonated by a fuse which burned about 80 seconds allowing the charges 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). Slant ranges to at least 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 boat. The separation between these two points averaged about .4 km. The ship's location at charge-drop positions was 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 most distant shot subtends an angle of 30 degrees with the transponder array on shore. The shots are located within an error ellipse whose short axis is about .1 km long and oriented perpendicular to the southeast coast.

The water wave from the explosion was used to estimate the detonation time of the shot. The water-wave arrival at the ship was detected by a hydrophone mounted in the hull. The signal from the hydrophone was transmitted to the Hawaiian Volcano Observatory (HVO) on the rim of Kilauea volcano, where it was recorded on the same time-base as the telemetered seismic network (described below). 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, and the charge depth, the firing time can be estimated by adding a correction to the water-wave arrival time based on these parameters. Relative timing between shots to $\pm$ .05 was obtained through this method; however, the absolute shot times may be systematically off by as much as .2 s due to errors in knowing the depth of detonation and location of the ship. Table 1 is a listing of the shot locations, sizes, and detonation times.

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

1. USGS Permanent Hawaii Seismic Station Network
2. USGS Portable 5-Day Recorders
3. HIG Ocean Bottom Seismographs (OBS).

The data from each system will be presented and described separately. No corrections have been applied to the data for station elevation or water depth beneath the shot points.

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 2 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 shown all have vertical seismometers with 1 second free period. The data are telemetered from the field site to 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 recorded from the shots was taken to Menlo Park where it was played back and digitized at 100 samples/sec. Record sections (Figs. 4a-4dd) were then constructed from the digital data using a computer.

The record sections are plotted in a 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 8.0 km/sec 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. Only the data from the large 300-lb shots are plotted and individual seismograms are sometimes omitted if the data are particularly noisy.

USGS TEMPORARY STATIONS

In addition to the permanent stations, five portable 5-day seismic recording units (Eaton and others, 1970) were deployed. Stations OPK, NLU, and KMA (Fig. 1) recorded three components (only the vertical component is plotted in the record sections presented here). Station ANO (Fig. 1) consists of two recording units which recorded three vertical components each. The data from these recording units combine to form a short linear array of stations about 3.5 km long, spaced at roughly .6 km intervals intentionally oriented at about a 30 degree angle with the line of shots. These stations have been named, from north to south, AR6-AR1 (Fig. 3). Table 3 lists the location of these units.

The field tapes from the portable seismic units were played back and digitized at 100 samples/second in Menlo Park. Record sections (Figs. 5a-5i) were constructed in the same manner as described for the permanent stations. In addition, the data from AR1-AR6 are plotted in a fixed-shot format (Figs. 5j-5ff). This is the inverse format of the record sections previously discussed. Here the seismogram at each of the AR1-AR6 stations is plotted relative to a particular shot. The distance axis is now distance from the shot instead of from the station. The time axis is as in the previous record sections: $T = t - \Delta/8.0$.

Inspection of Figures 5j-5ff shows a time offset between stations AR3 and AR4 which varies in magnitude but can be as much as 0.5 sec on some record sections. This offset is suspect as a timing error because stations AR1-AR3 and AR4-AR6 were recorded on different units. Furthermore, preliminary inspection of geologic maps for the area show no surface feature between stations AR3 and AR4 that could cause such an effect. However, a check for timing errors in the data uncovered none; therefore either there is some aspect of the timing that is being overlooked, or the offset is a real effect associated with the structure along the array.

HIG OCEAN BOTTOM STATIONS

Off-shore, the energy from the shots was recorded on University of Hawaii HIG pop-up ocean-bottom seismographs (OBS). A description of the system can be found in Sutton, et al. (1977). Four OBS's were deployed; however, one did not pop up, and one did not record. The locations of the two that operated are shown in Figure 1. Figure 2 is a profile of the bathymetry under the shot line also showing the location of the OBS's. The exact location of the instrument on the ocean floor cannot be known since the OBS is deployed from the water surface and must fall several kilometers to the ocean floor. Each OBS was located by looking for the two shots with shortest water-wave traveltimes and then placing the OBS midway between those two shots. The depth of the instrument could then be read off the bathymetric profile. The slant range from shot to OBS was found through the traveltime of the direct water wave; and horizontal distance was then determined by solving for the unknown side of the triangle using the range and the depth for the known sides. In the two record sections (Figs. 6a-6b), the vertical geophone channel is plotted in a fixed receiver format as before, except the data are reduced by a velocity of 6.0 km/sec. Some traces have been omitted due to unresolvable timing errors. Refer to Figure 2 for recording geometry.

ACKNOWLEDGMENTS

We would like to thank the Conservation Division of the USGS for their efforts in obtaining the shooting permits. The personnel of the HVO, and especially Bob Koyanagi, were invaluable in setting up the field operations.

We are especially grateful to our colleagues with the Hawaii Institute of Geophysics at the University of Hawaii for their contributions to the success of this work. In particular, we thank Chuck Helsley for helping with logistics and arranging deployment of the HIG ocean-bottom seismographs and Luigi Pozzi for his expert help with the shooting and his unflagging enthusiasm.

REFERENCES

Eaton, J. P., O'Neill, M. E., and Murdock, J. N., 1970, Aftershocks of the 1966 Parkfield-Chalome, California, earthquake: a detailed study: Bulletin Seismological Society of America, v. 60, pp. 1151-1197.

Koyanagi, R. Y., Meagher, K., Klein, F. W., and Puniwai, G. S., 1978, Hawaiian Volcano Observatory Summary 76, January to December 1976: U.S. Geological Survey, Menlo Park, CA, 68 p.

Lee, W. H. K., and Lahr, J. C., 1975, HYPO71 (revised): A computer program for determining hypocenter, magnitude, and first motion pattern of local earthquakes: U.S. Geological Survey Open-File Report 75-311.

Richter, C. B., 1958, Elementary seismology: San Francisco, Freeman, 768 p.

Sutton, G. H., Kasahara, J., Ichinose, W. N., and Byrne, D. A., 1977, Ocean bottom seismograph development at Hawaii Institute of Geophysics: Marine Geophysical Research #3, p. 153-177.

FIGURE CAPTIONS

Fig. 1. Locations map.

Contour interval: 2000 feet, Small solid triangles: permanent stations of the USGS Hawaii Net, Small hollow triangles: temporary USGS 5-day recorders AMP, Large solid triangles: HIG ocean-bottom seismometers, Solid circles: 300 lb shots, Hollow circles: 5-lb shots, Hollow squares: transponder locations.

Fig. 2. Bathymetric profile under shot line.

Solid circles: shot points, Solid triangles: seismometer locations marked with depth below sea level. Note that the average slope of the volcano flank can be approximated by a slope of about 5.5 degrees.

Fig. 3. Blow-up of area around station ANO of Figure 1 showing location of temporary stations AR1-AR6.

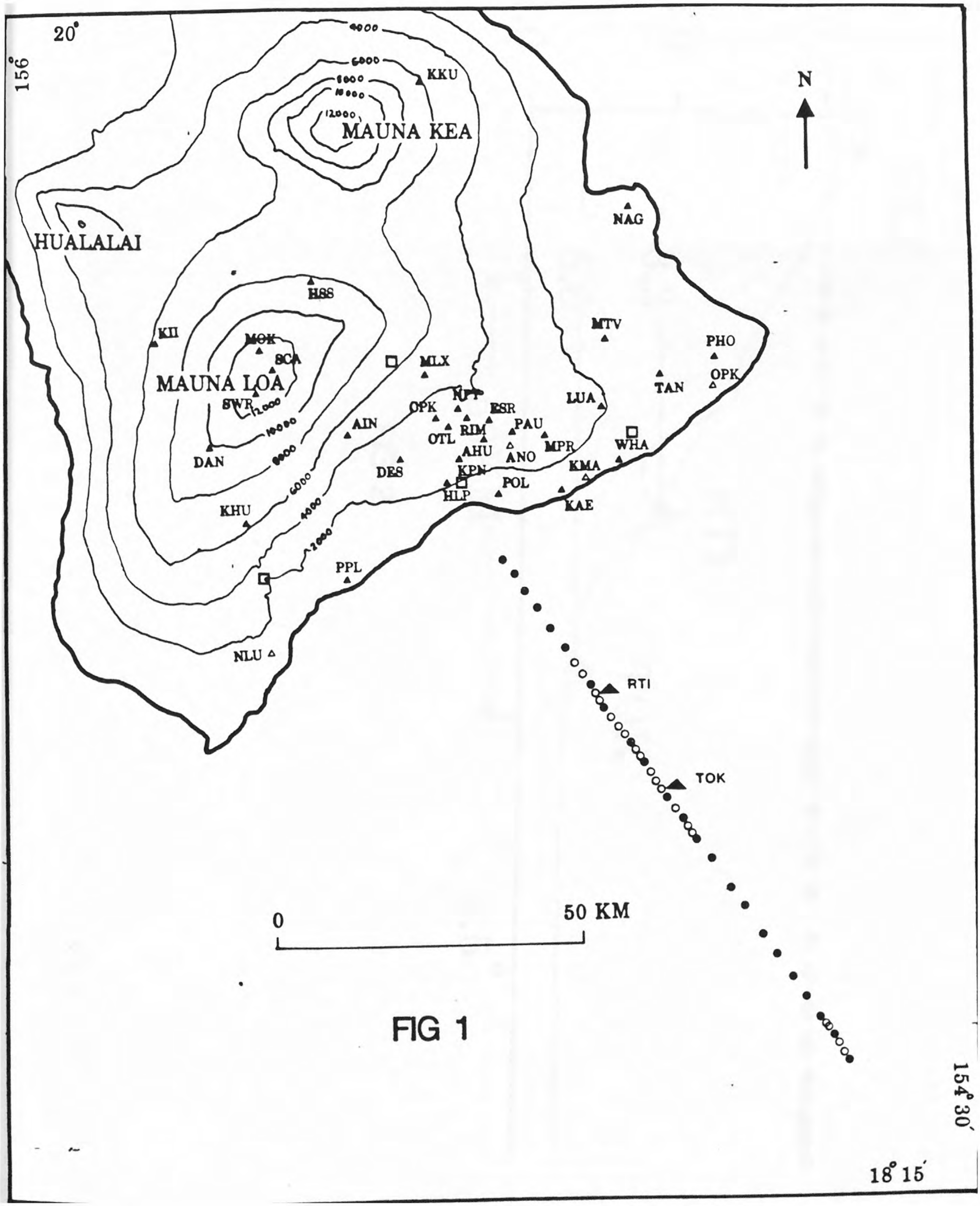
Fig. 4a-4dd. Record sections for stations in the permanent HVO seismograph network with the time axis reduced according to $T = t - \Delta/8.0$. See Figure 1 for station locations.

Fig. 5a-5i. Record sections for the temporary 5-day recorder seismograph stations with the time axis reduced to $T = t - \Delta/8.0$.

Fig. 5j-5ff. Record sections for AR1-AR6 plotted in fixed-shot format.

Fig. 6a-6b. Record sections for the University of Hawaii Ocean Bottom Seismograph units with the time axis reduced to $T = t - \Delta/6.0$.

LIST OF TABLES



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MAUNA LOA
SWR
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PHO
OPK
TAN
LUA
ESR
AIN
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KPN
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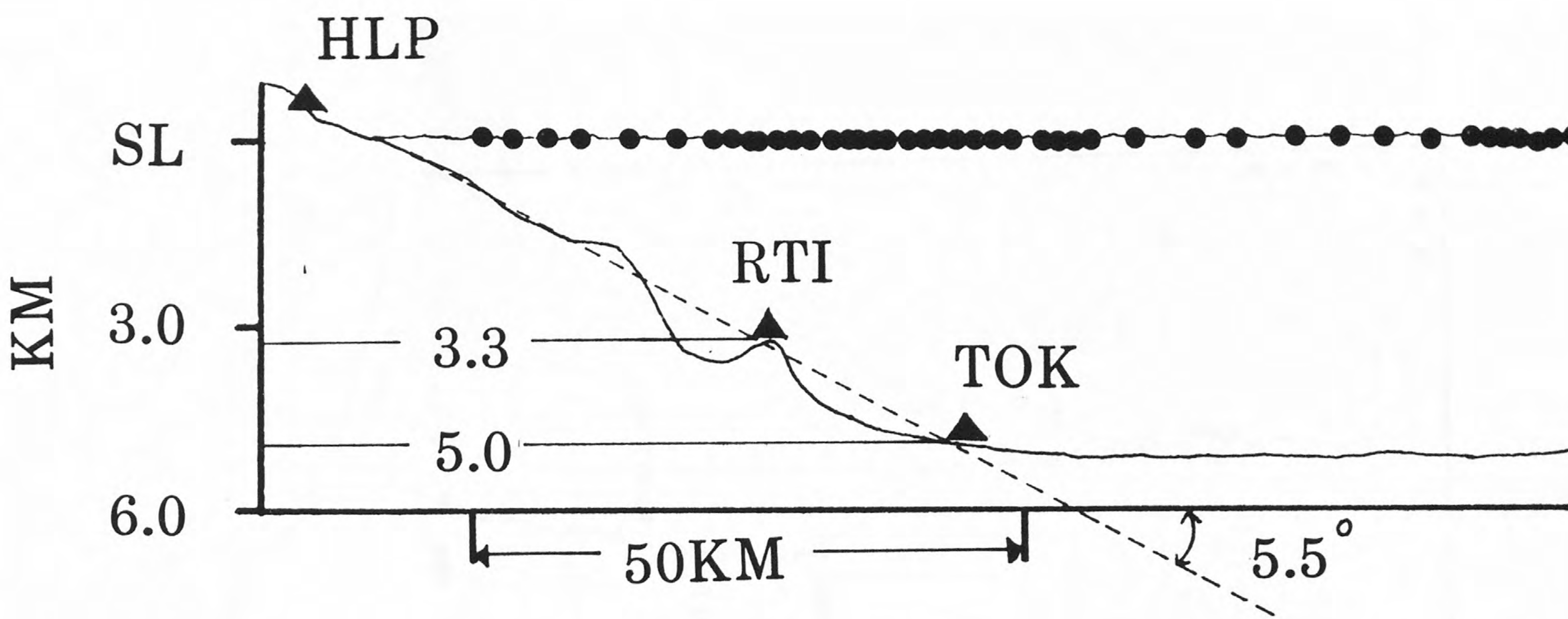
18° 15′

FIG 1



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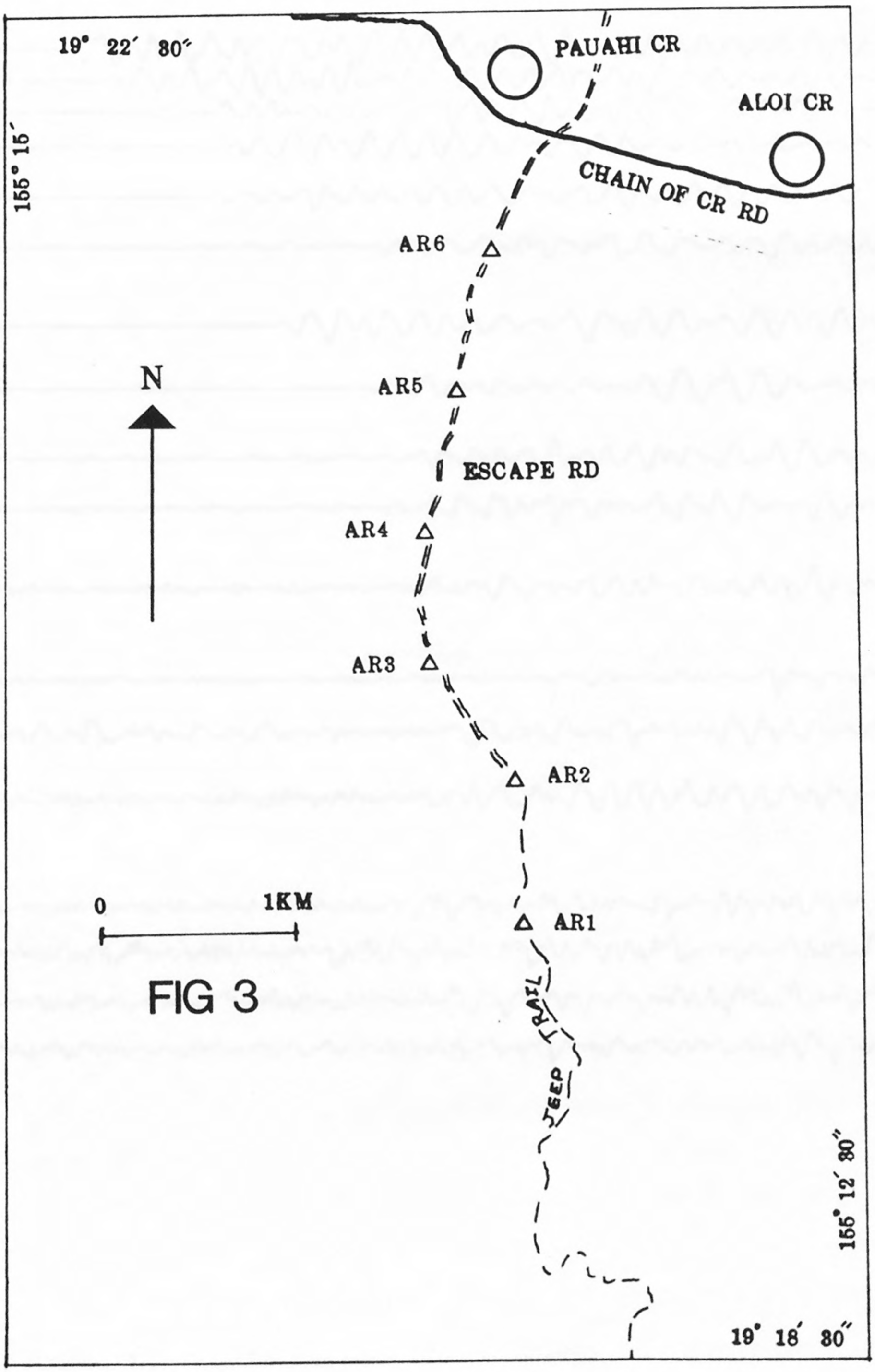
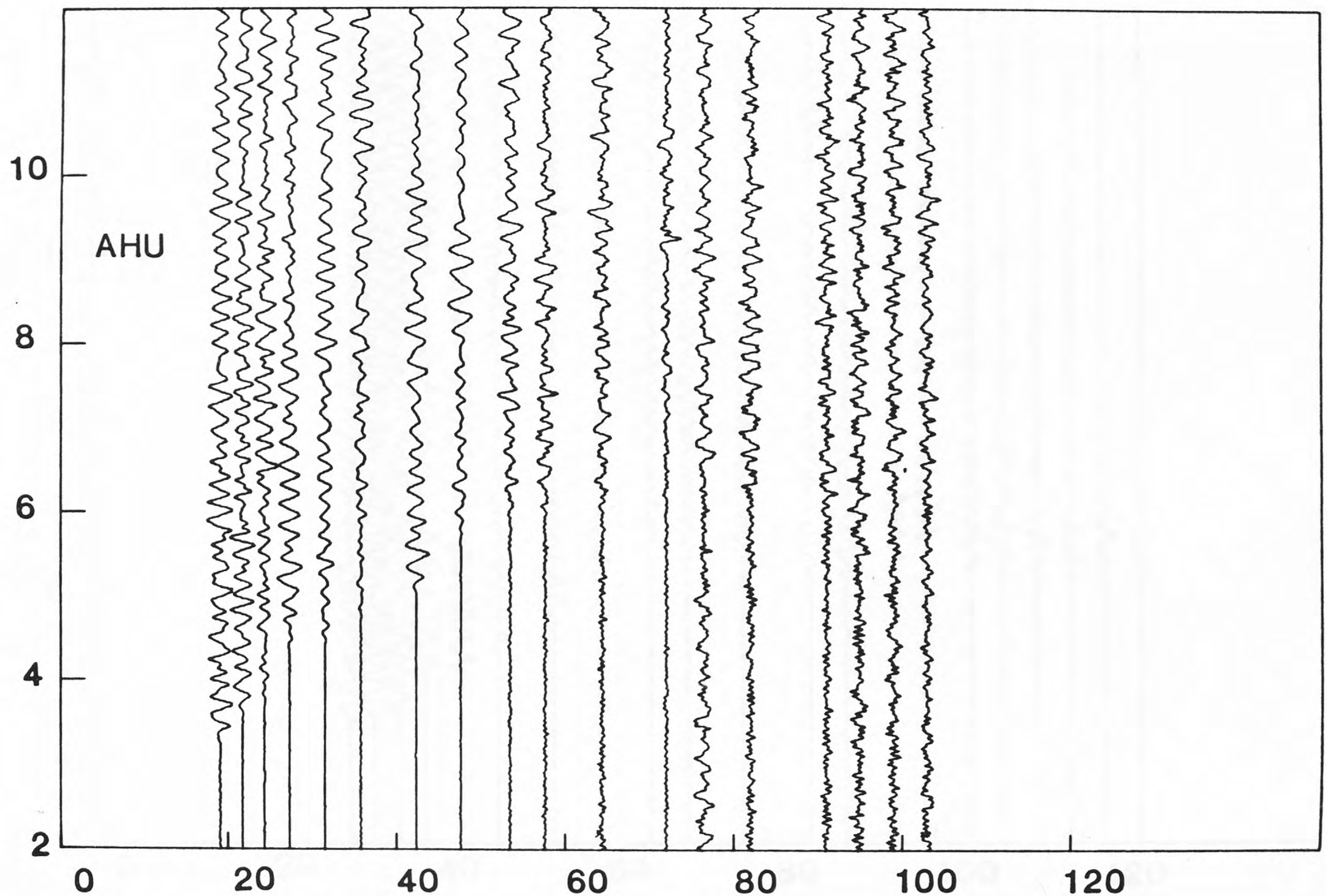

19° 22′ 30″
155° 15′
PAUAHI CR
ALOI CR
CHAIN OF CR RD
AR6
N
AR5
ESCAPE RD
AR4
AR3
AR2
0
1KM
AR1
JEEP TRAIL
155° 12′ 30″
19° 18′ 30″

FIG 3



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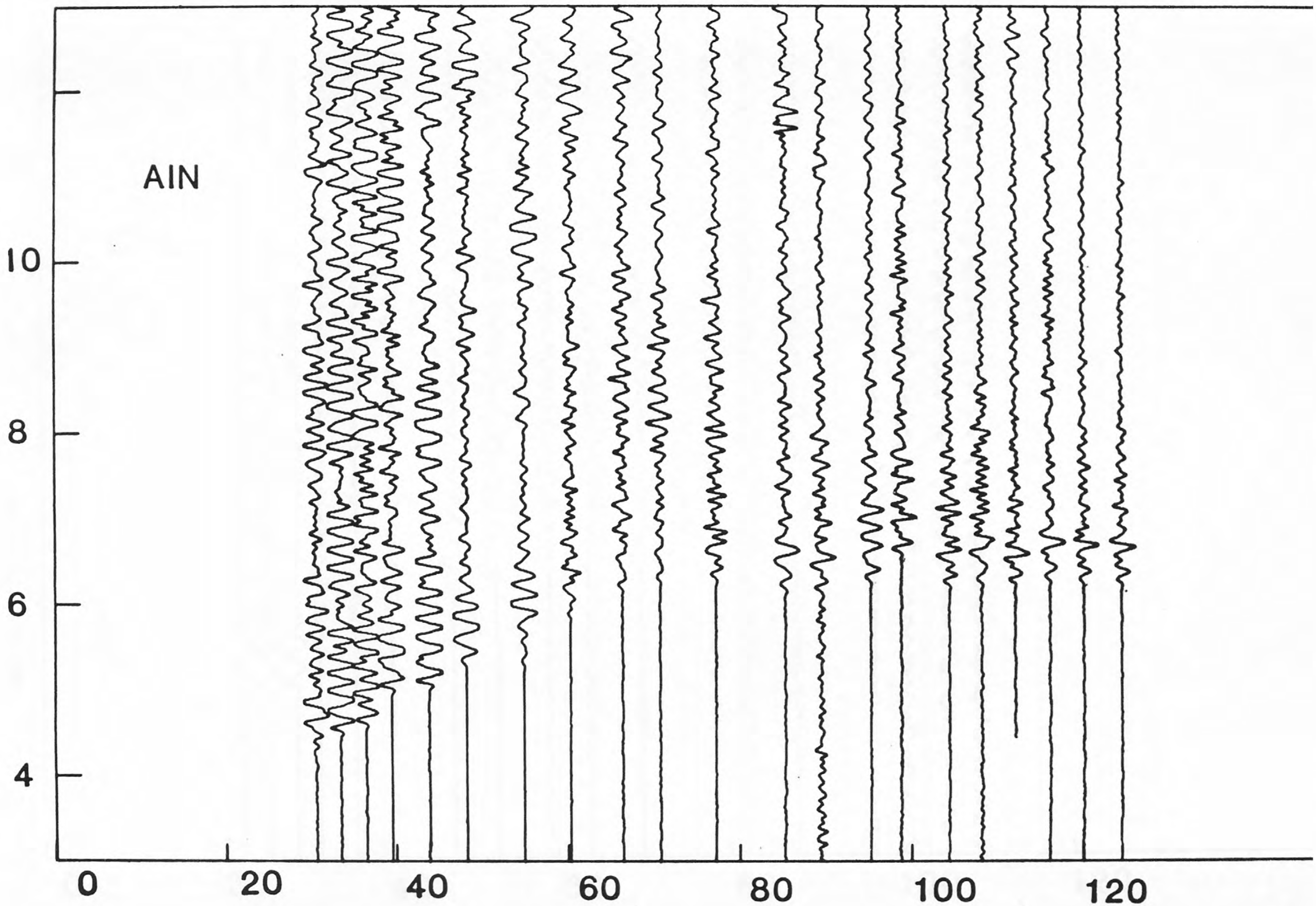

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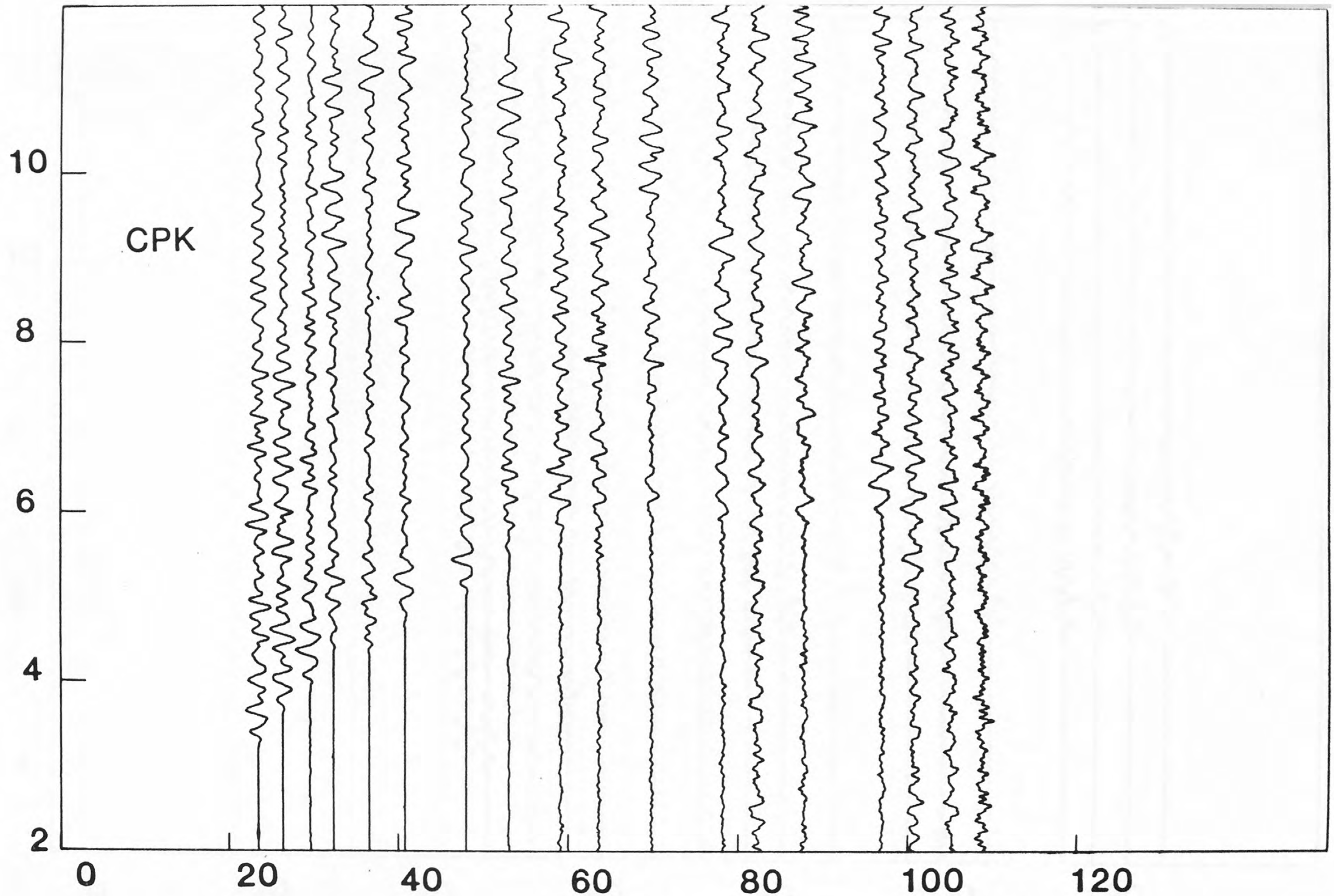

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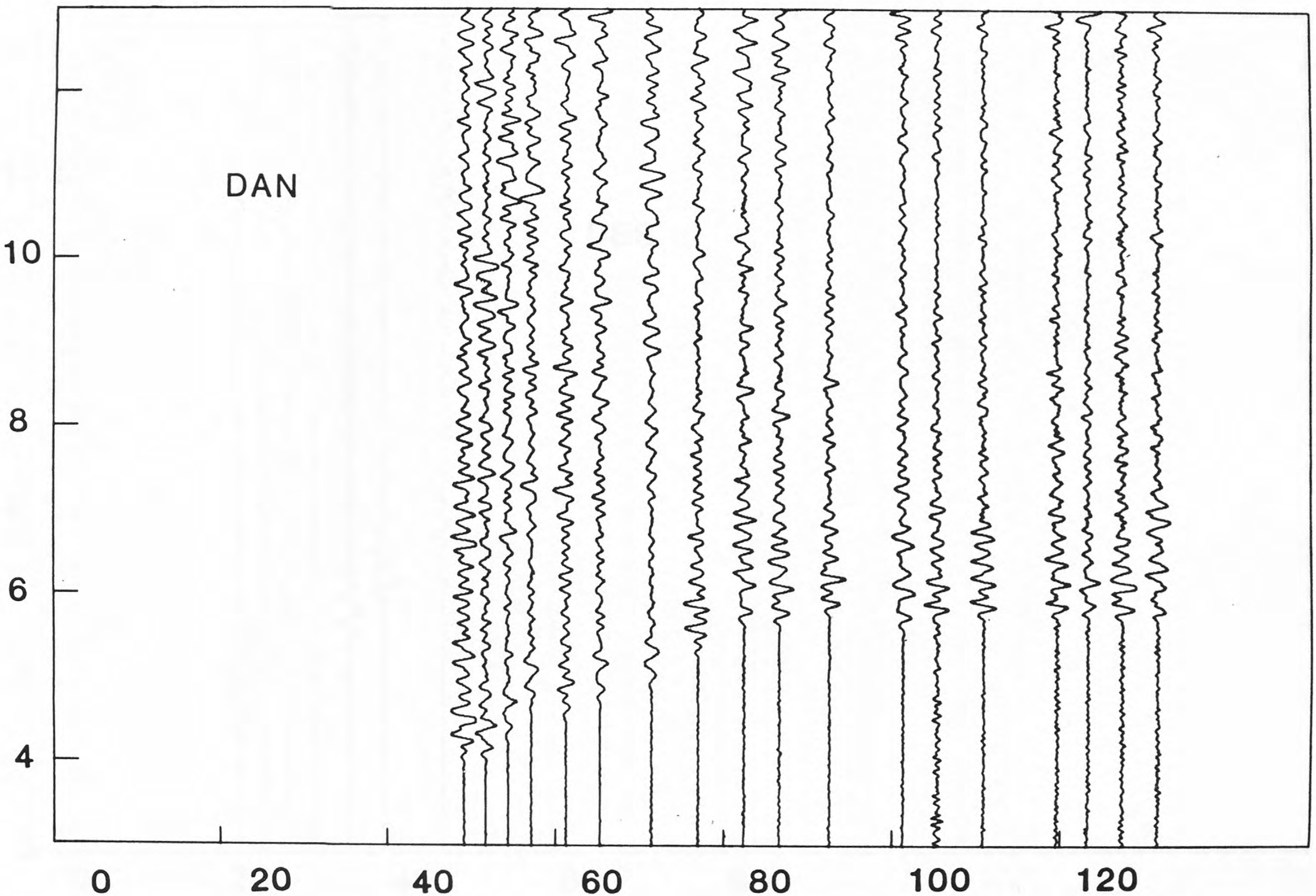

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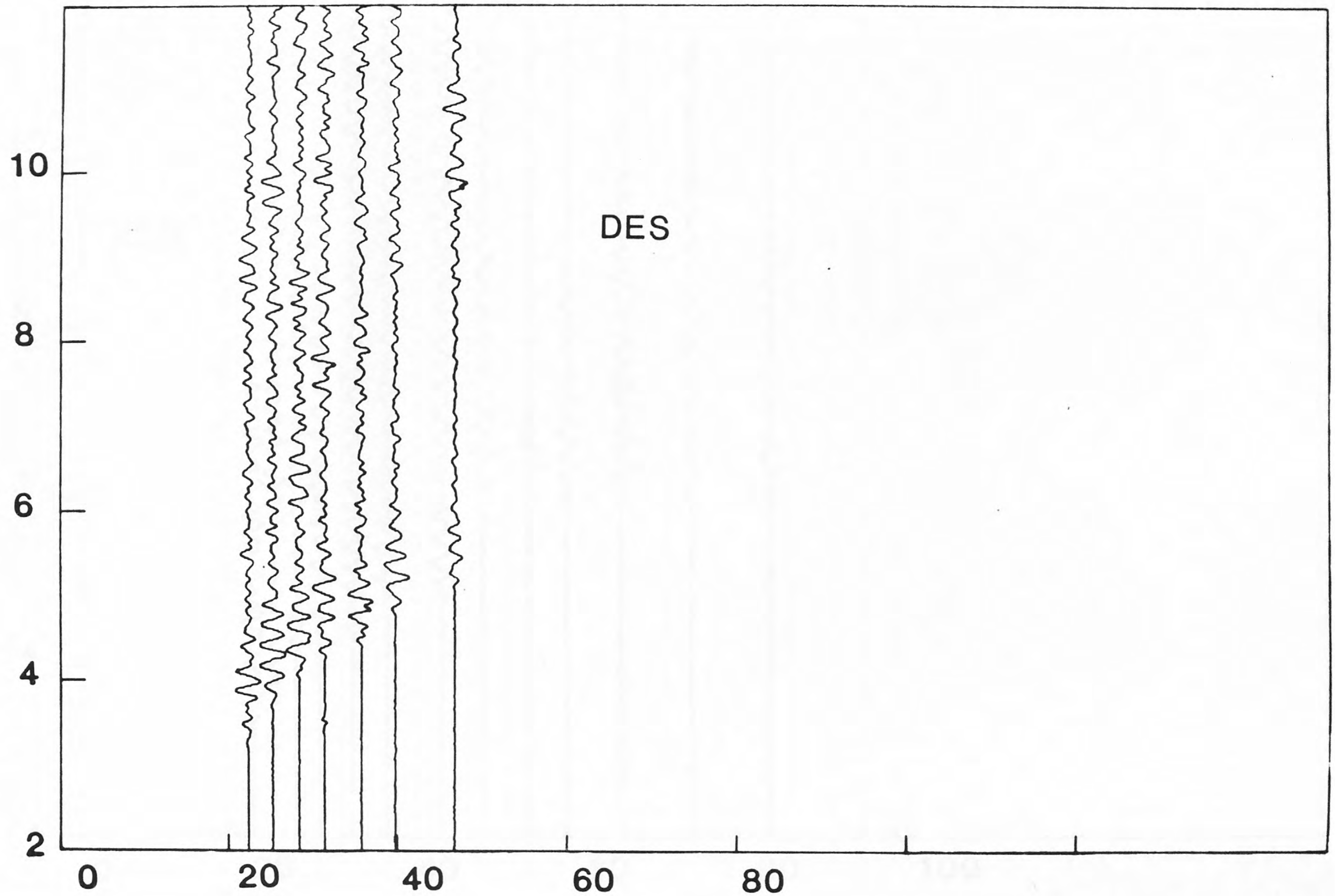

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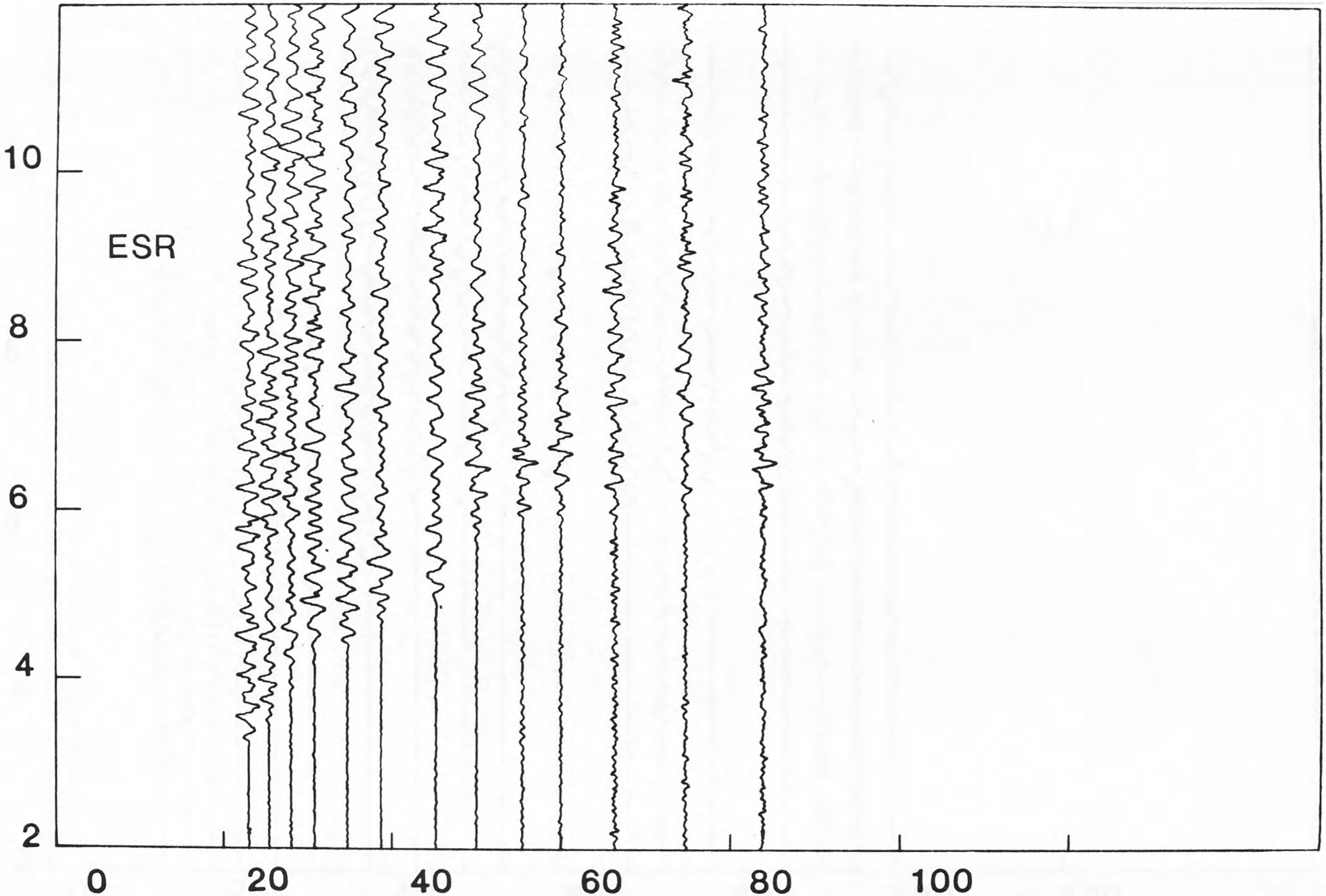

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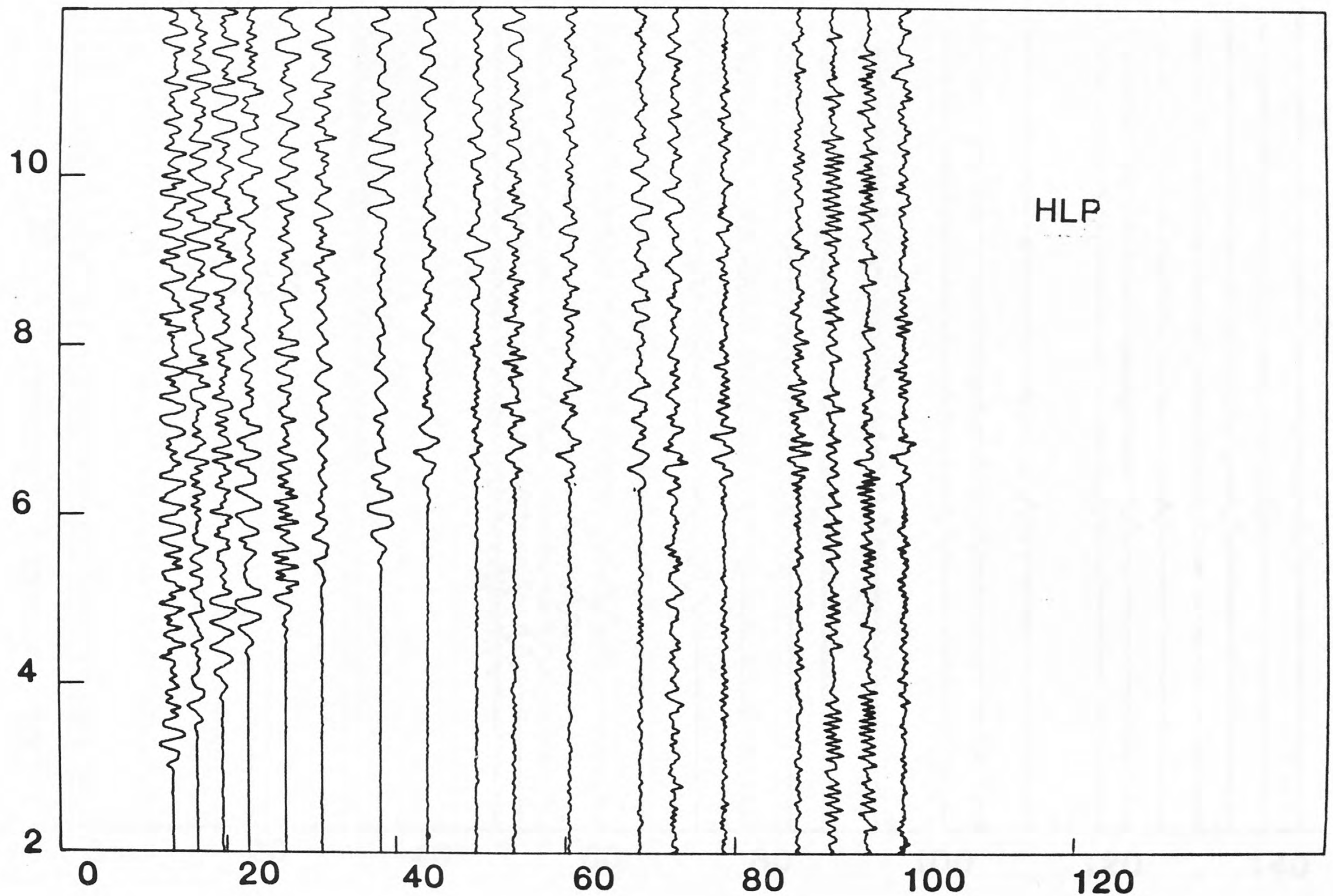

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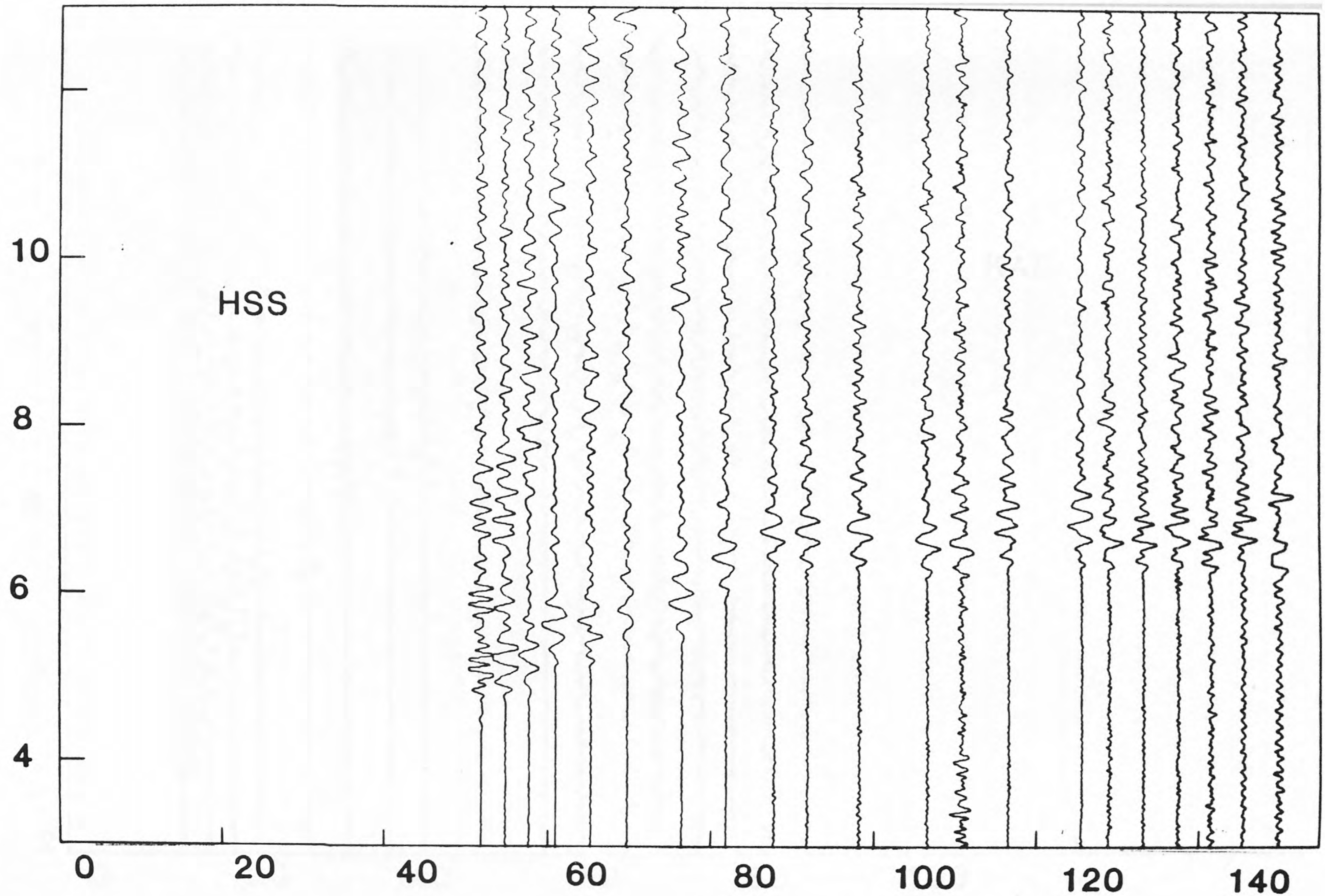

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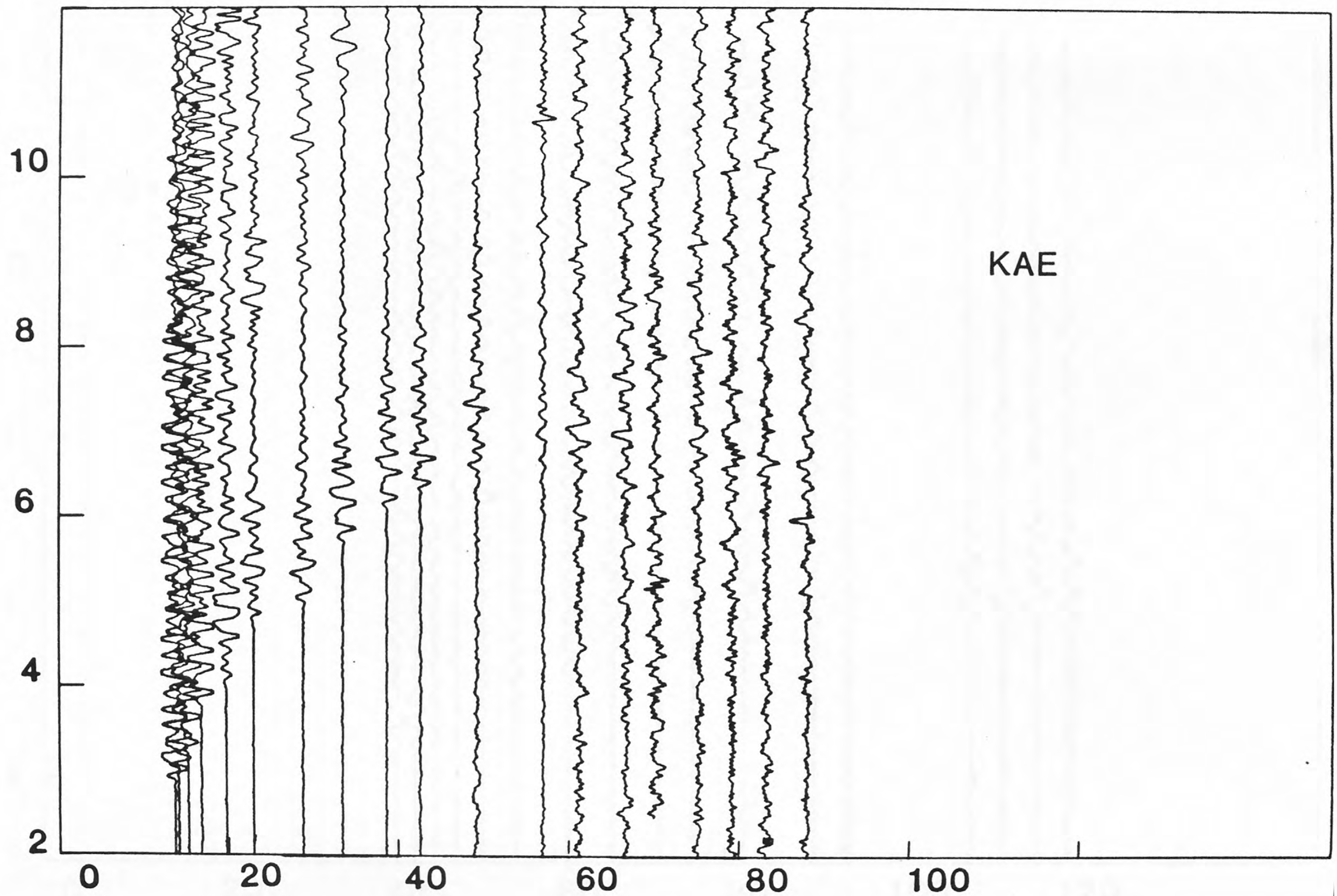

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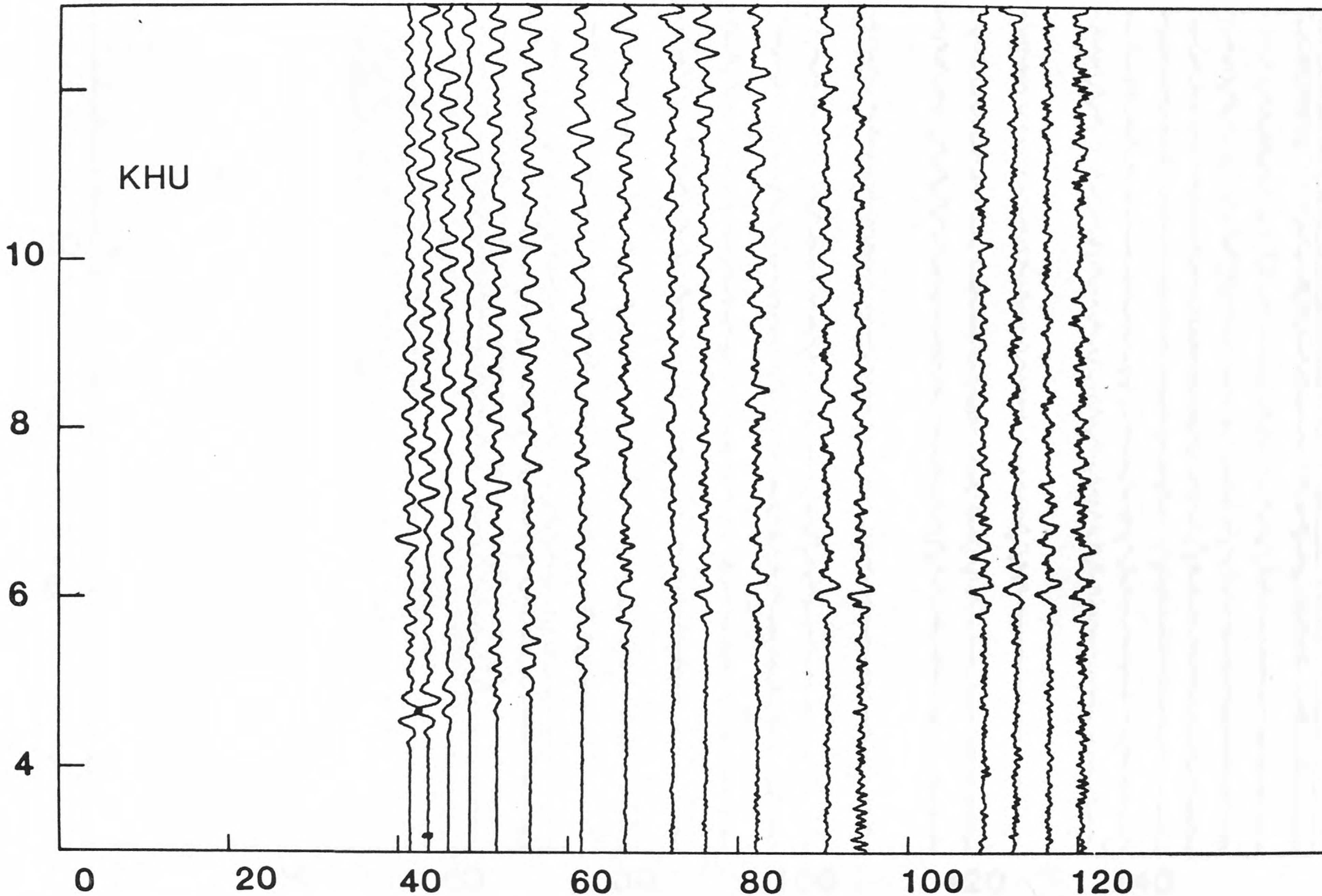

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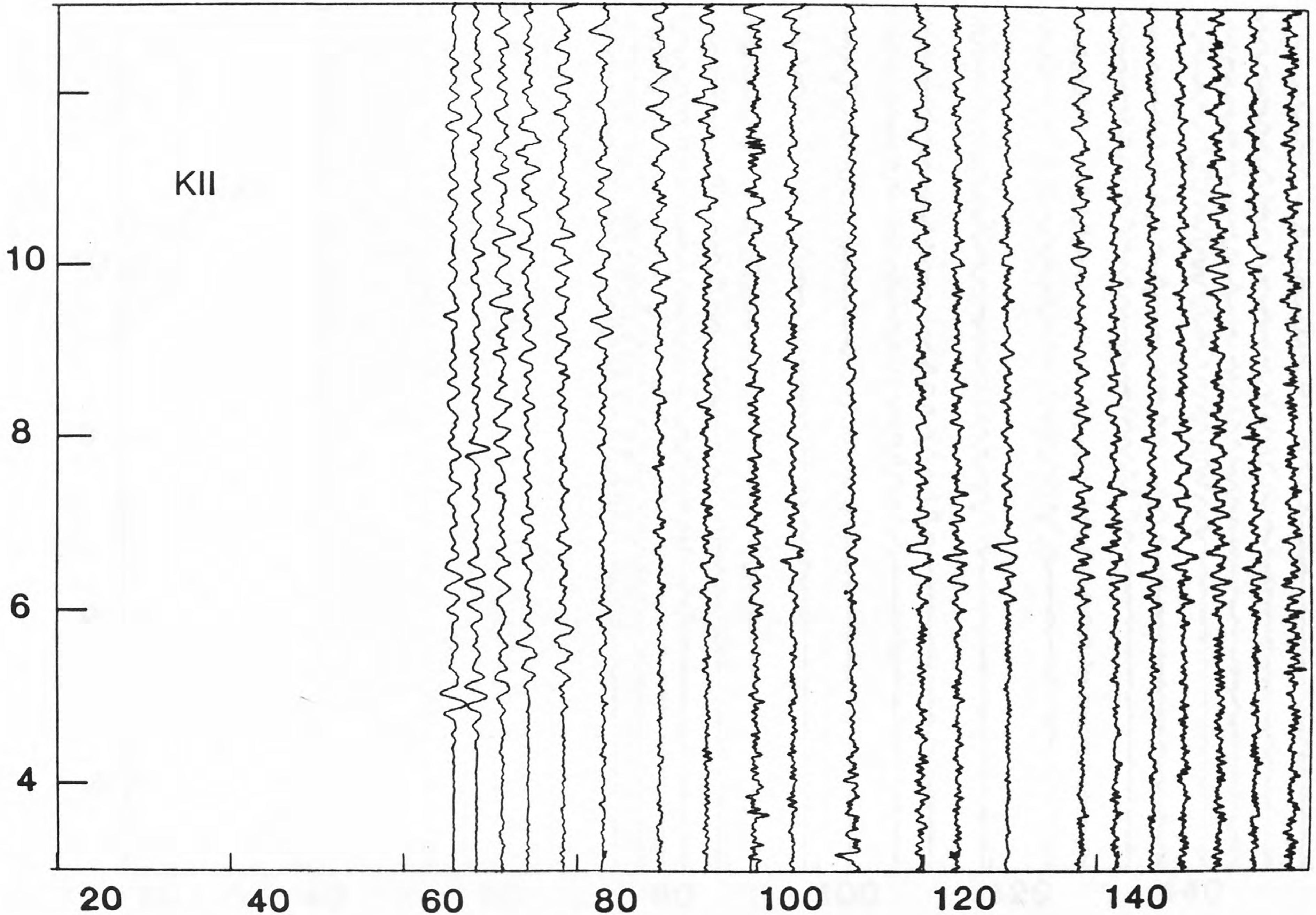

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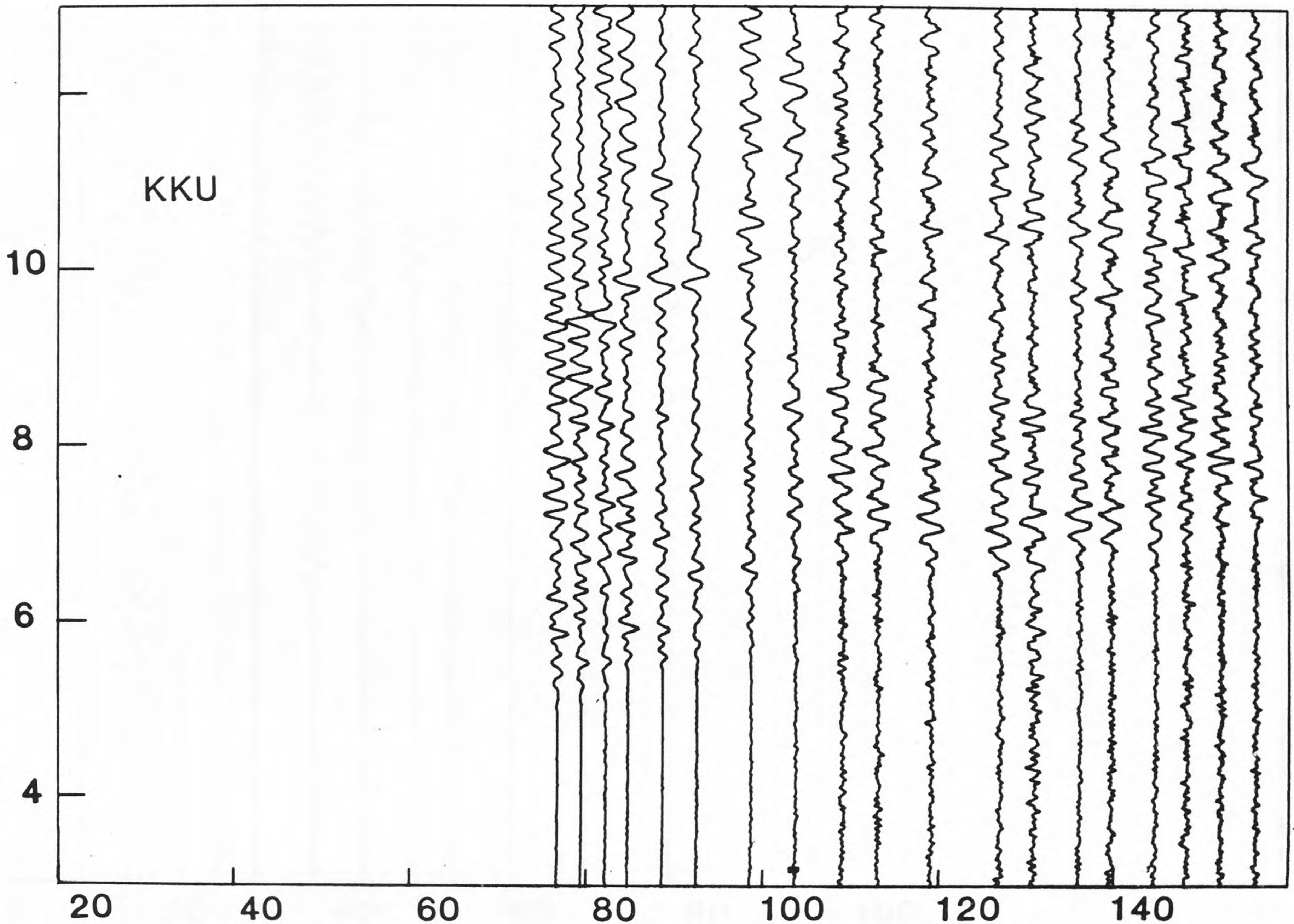

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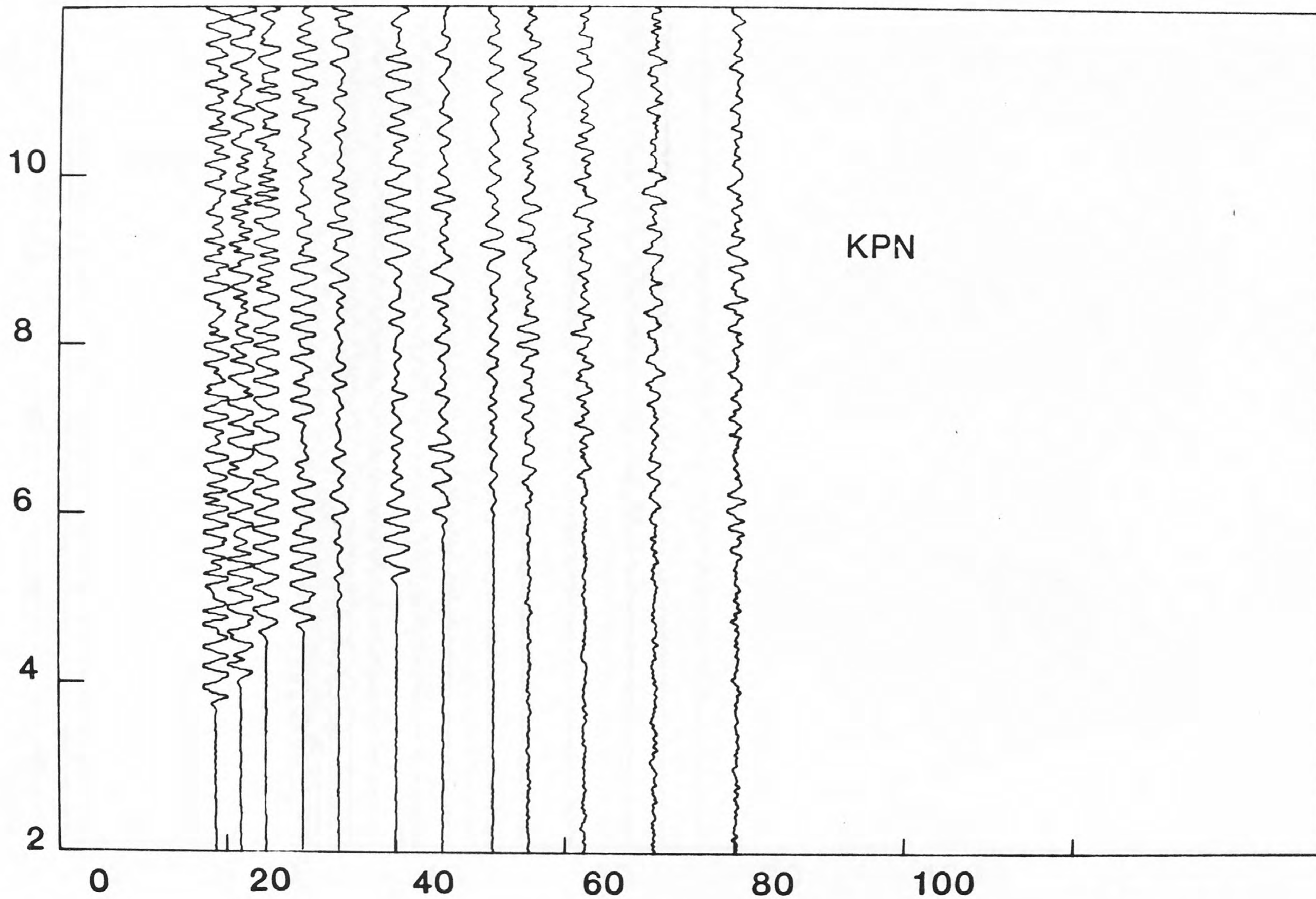

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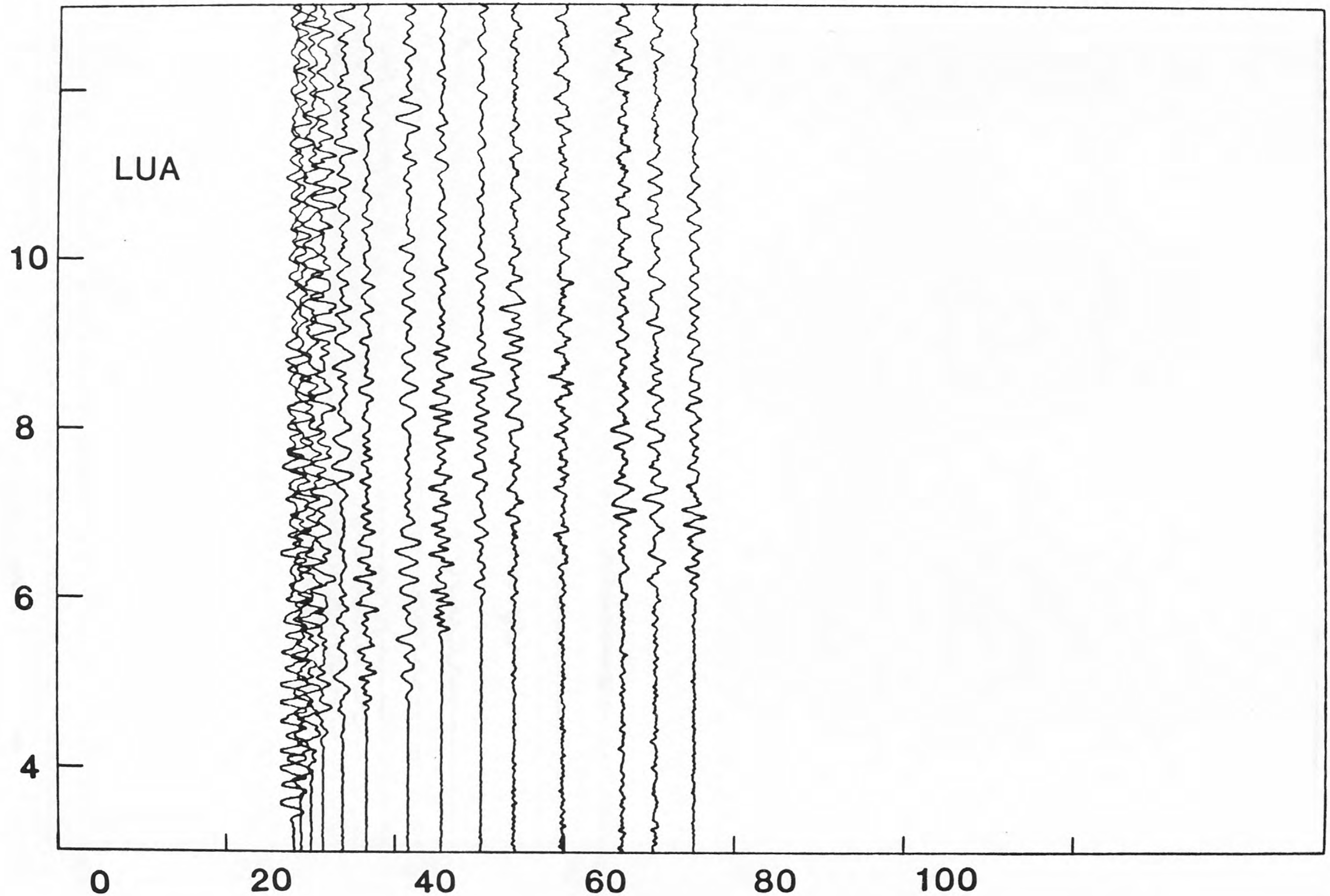

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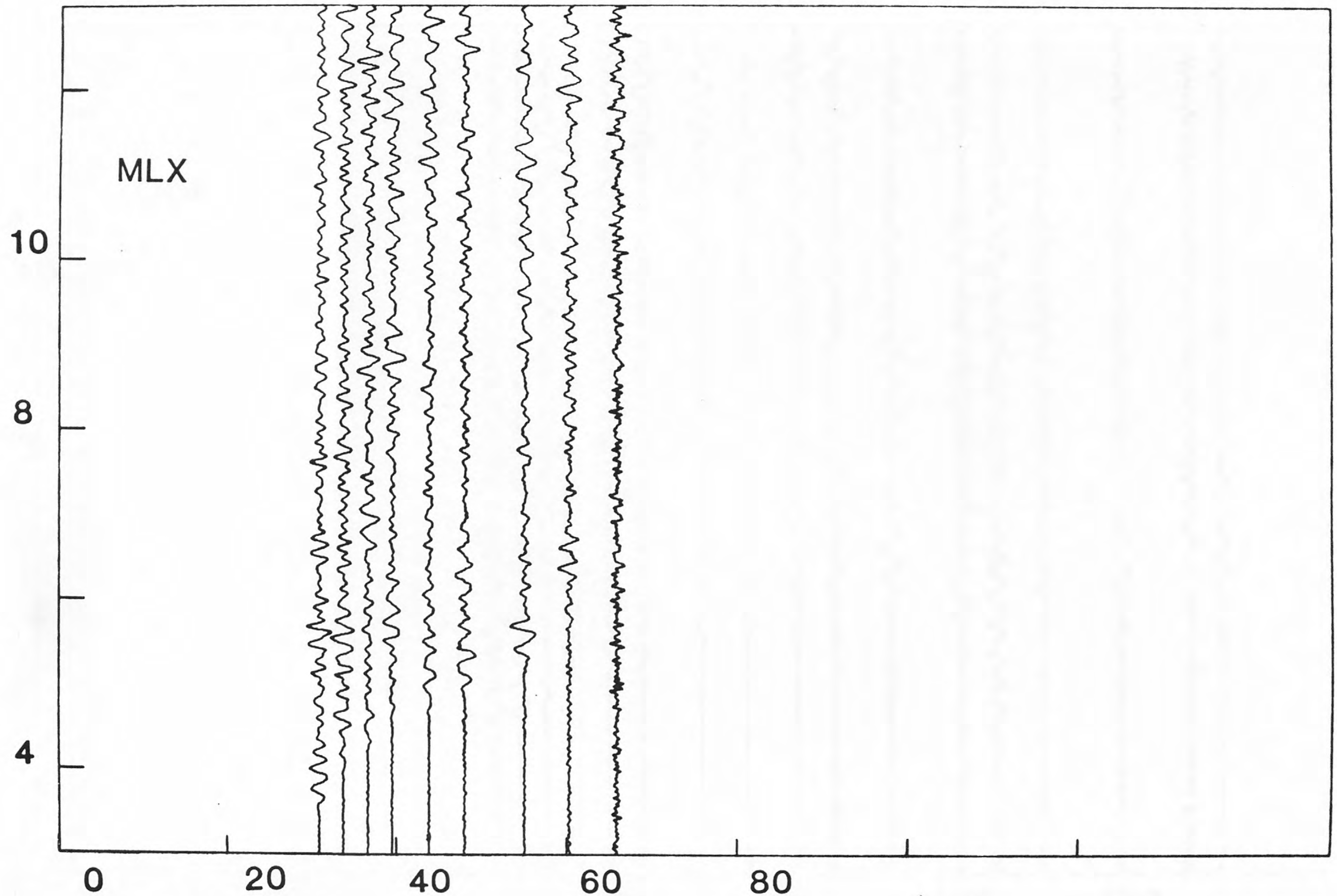

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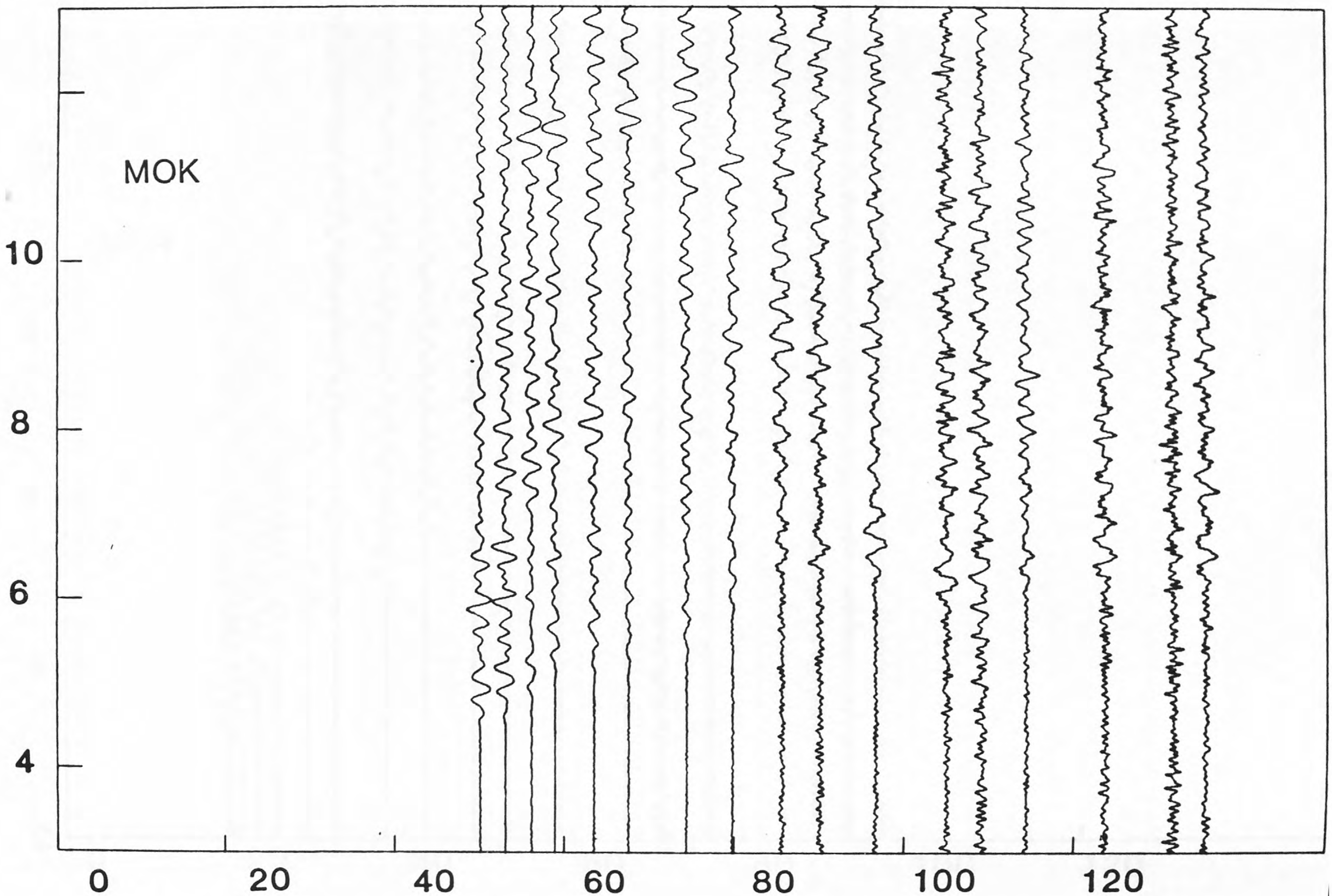

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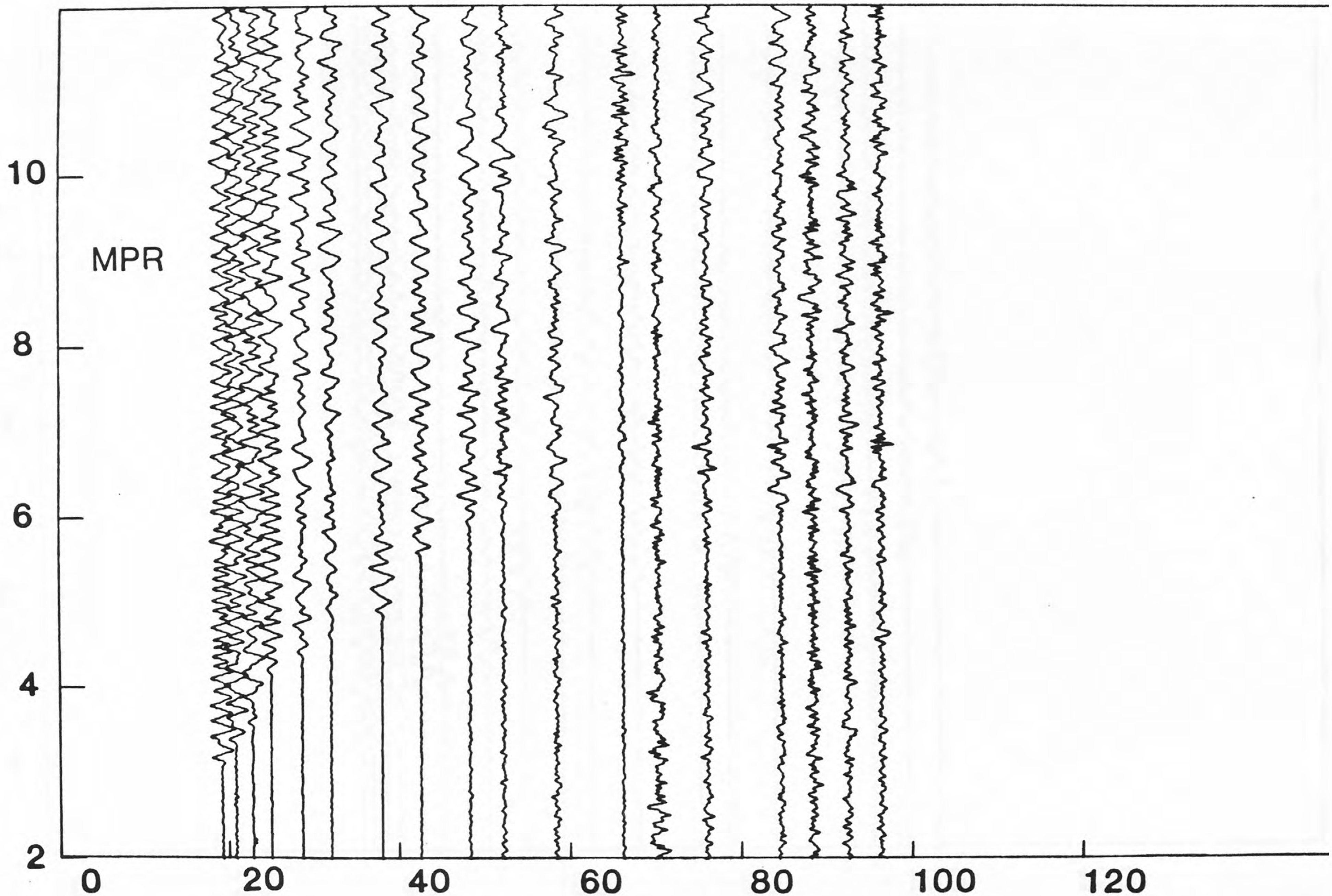

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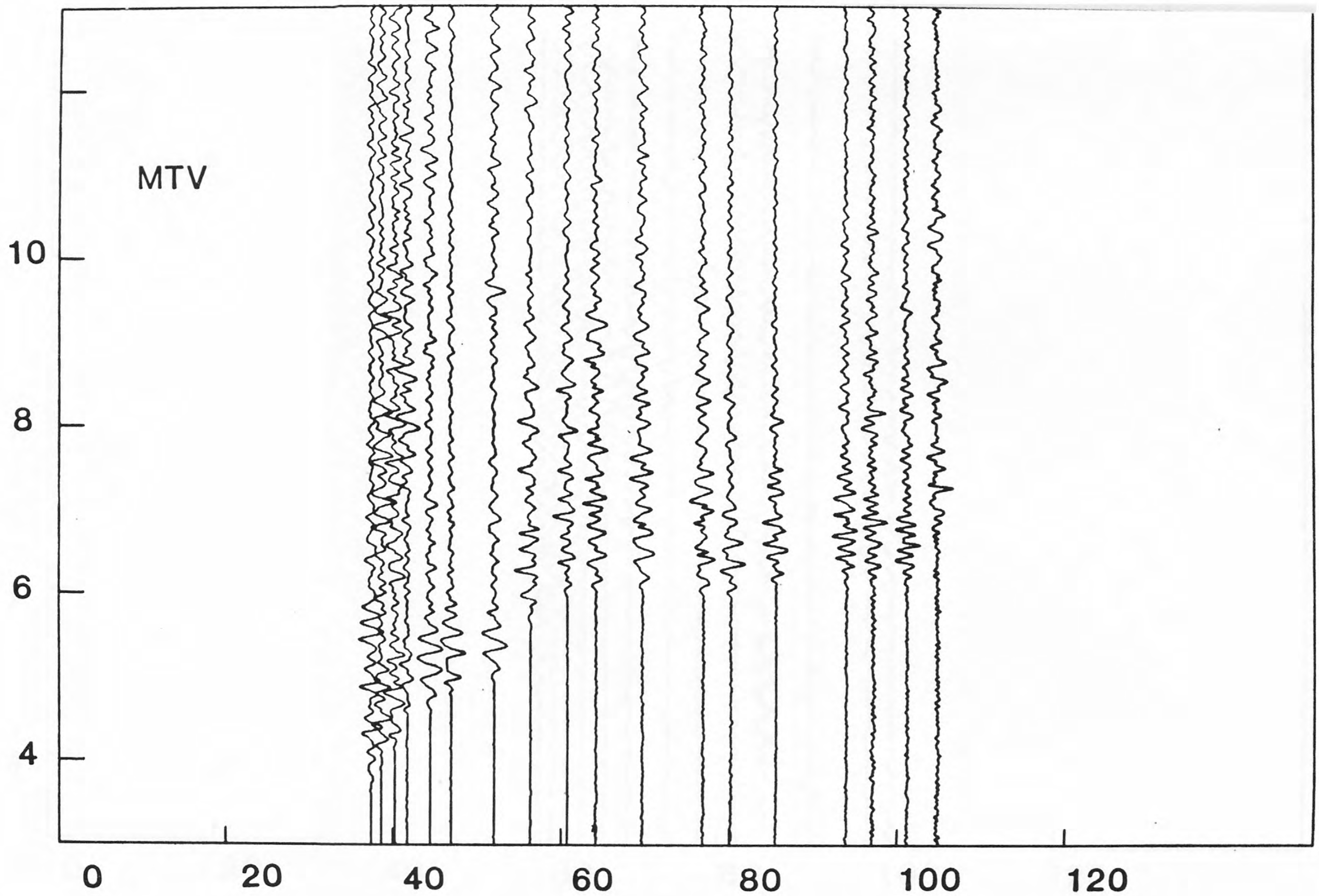

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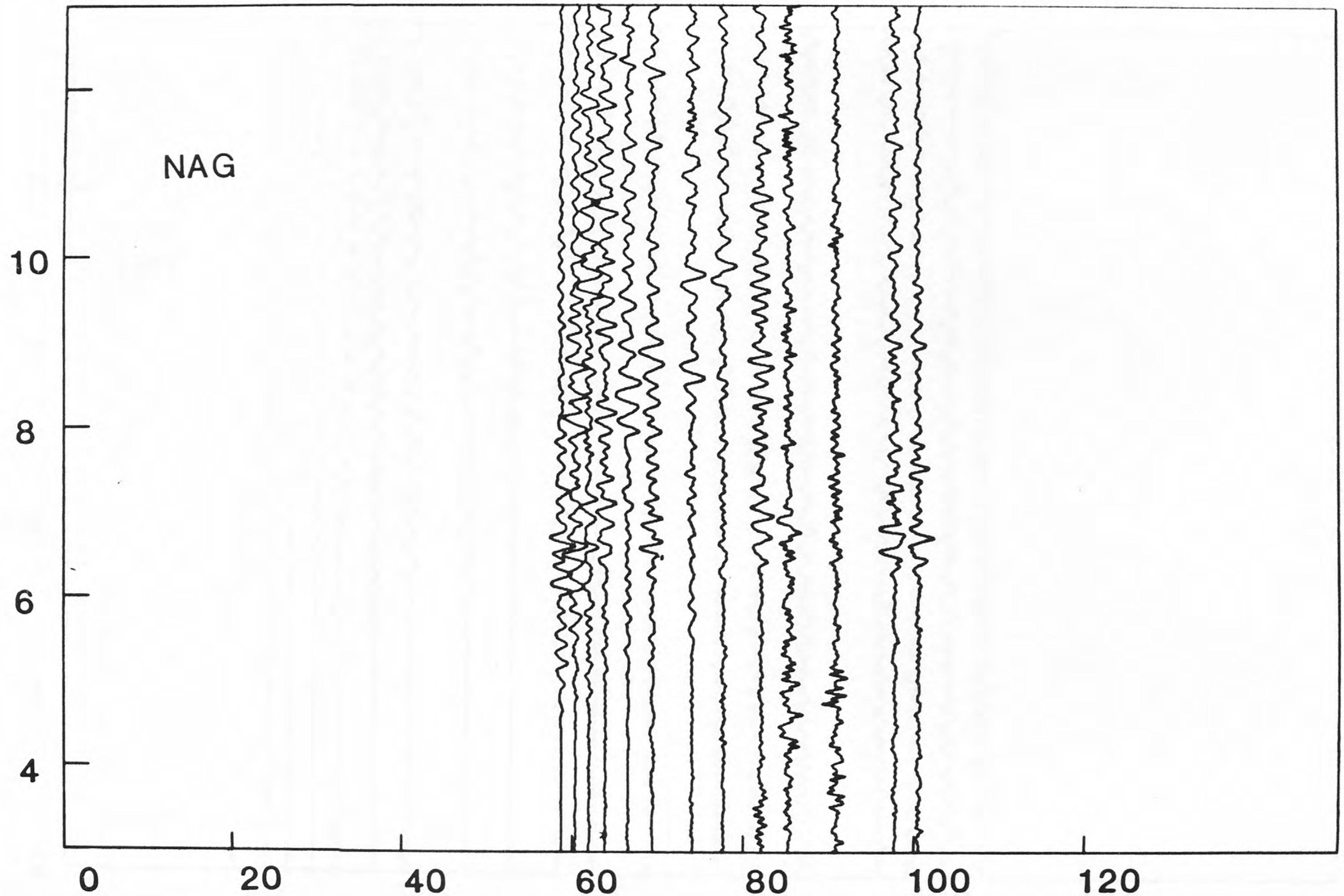

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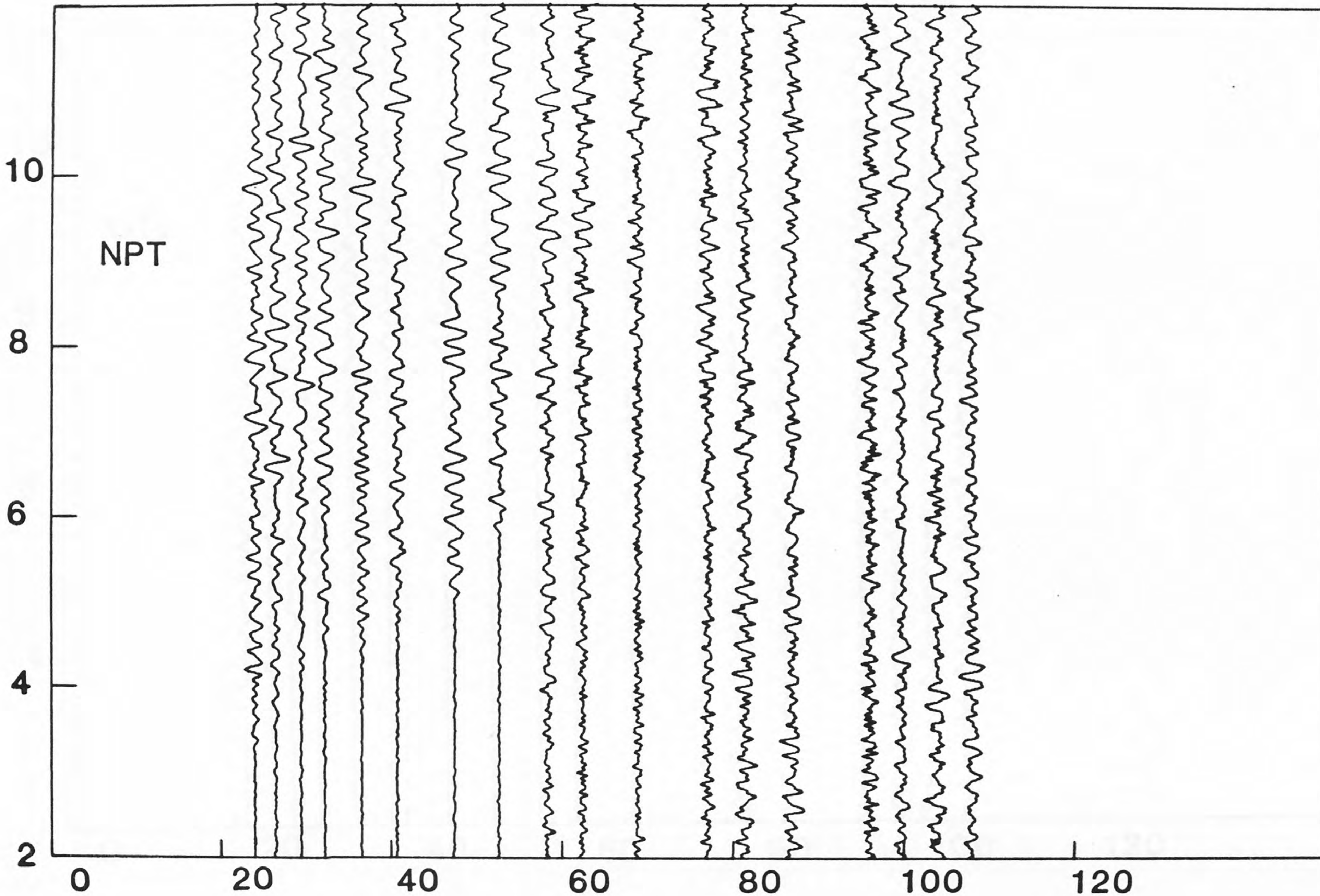

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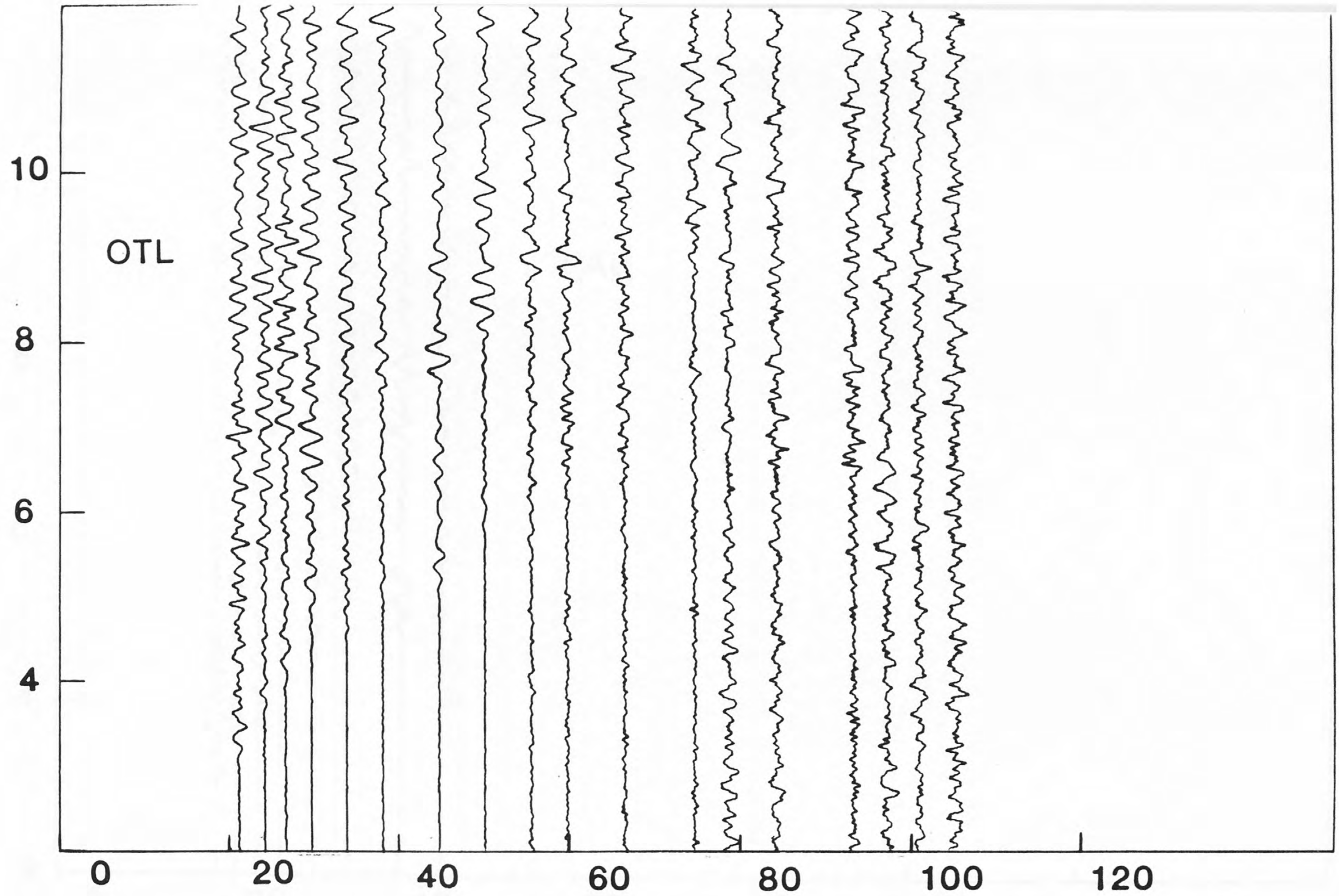

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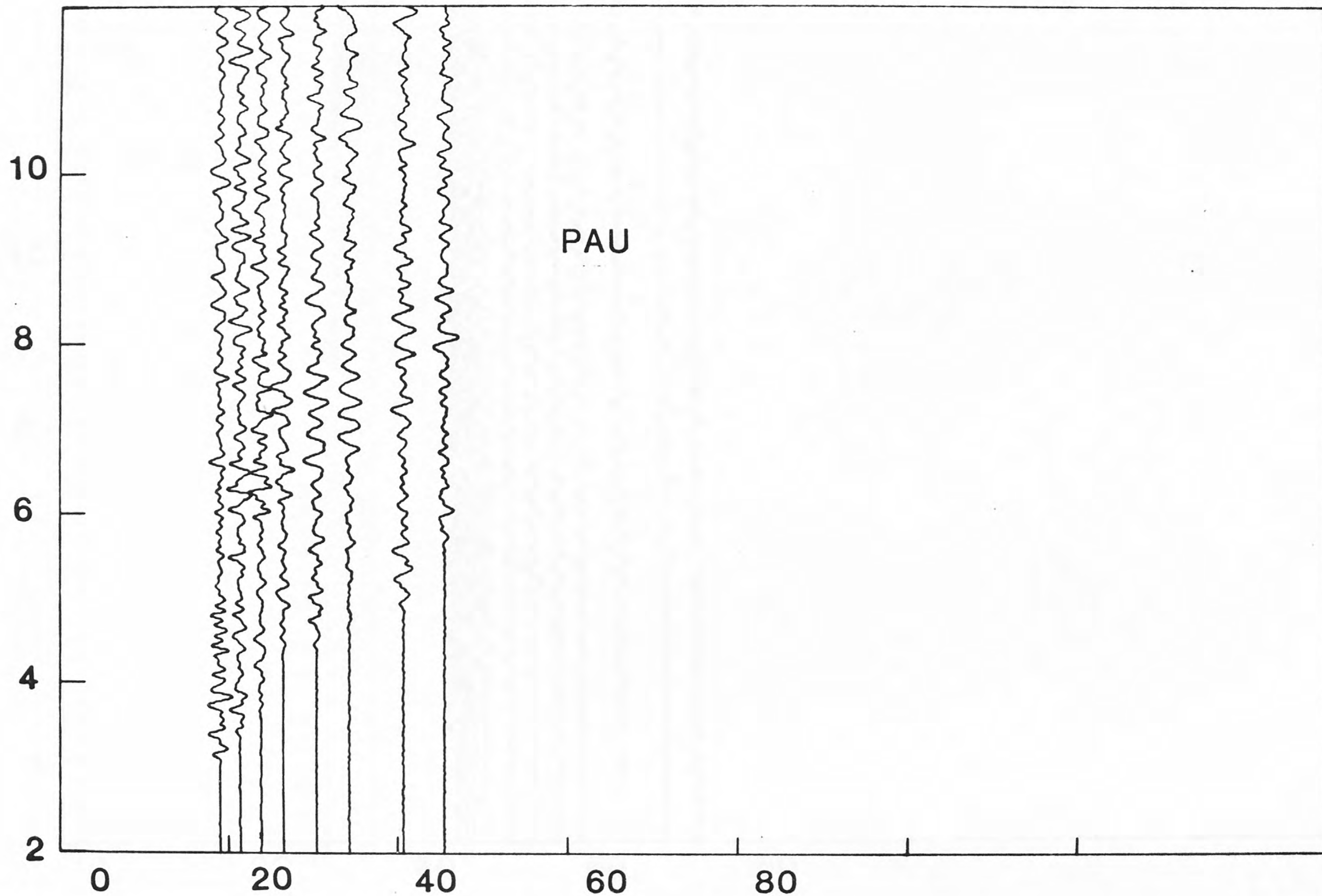

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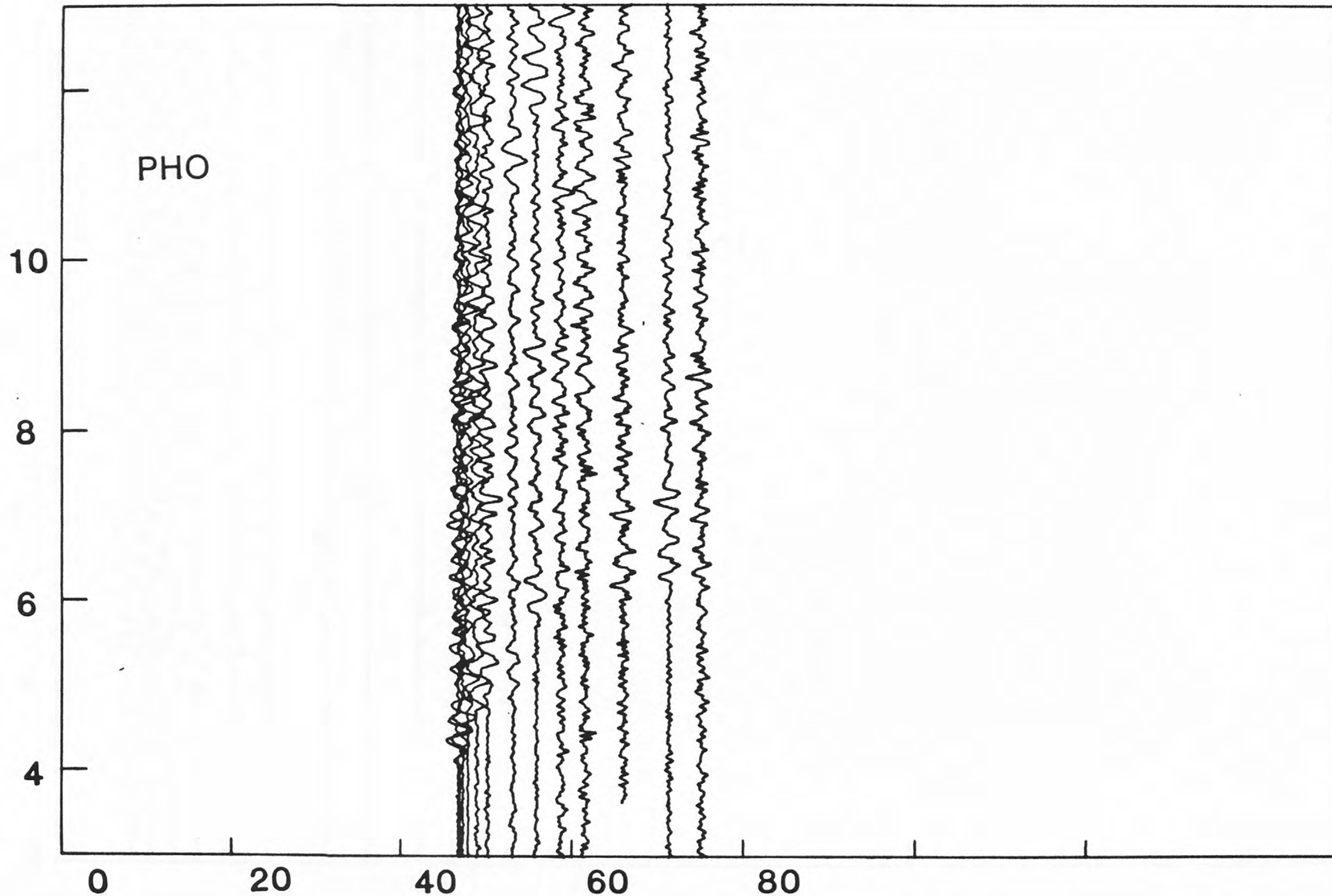

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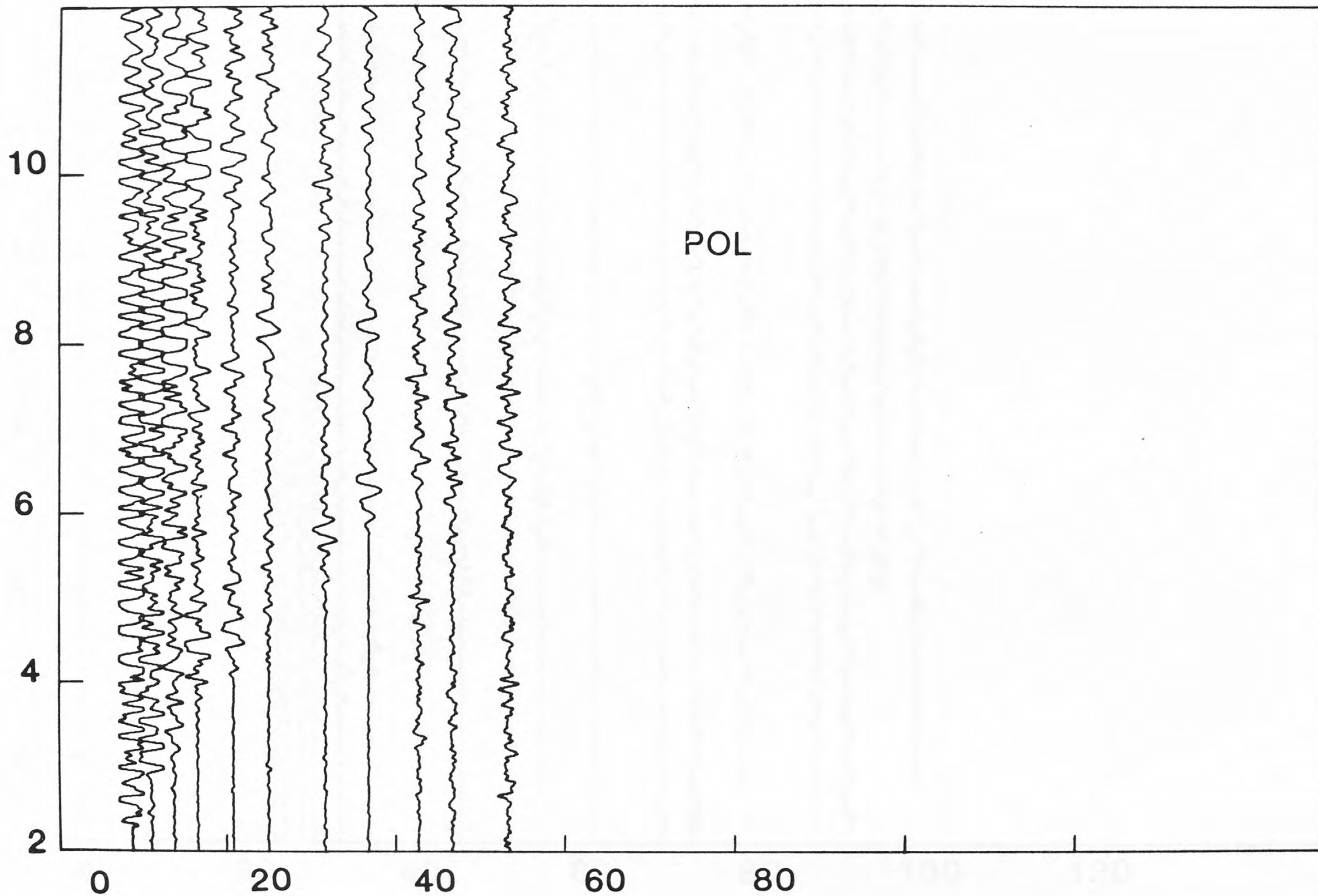

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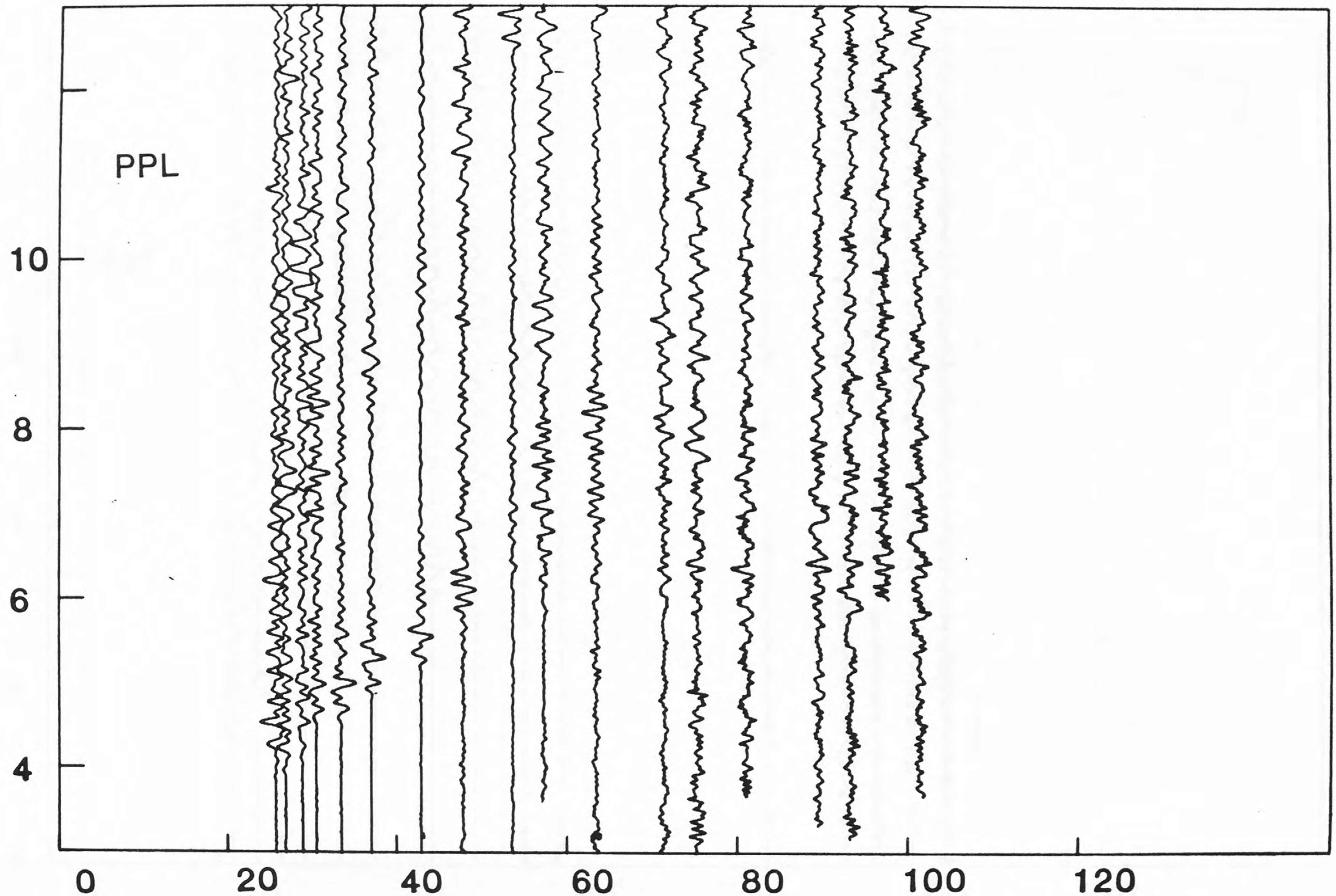

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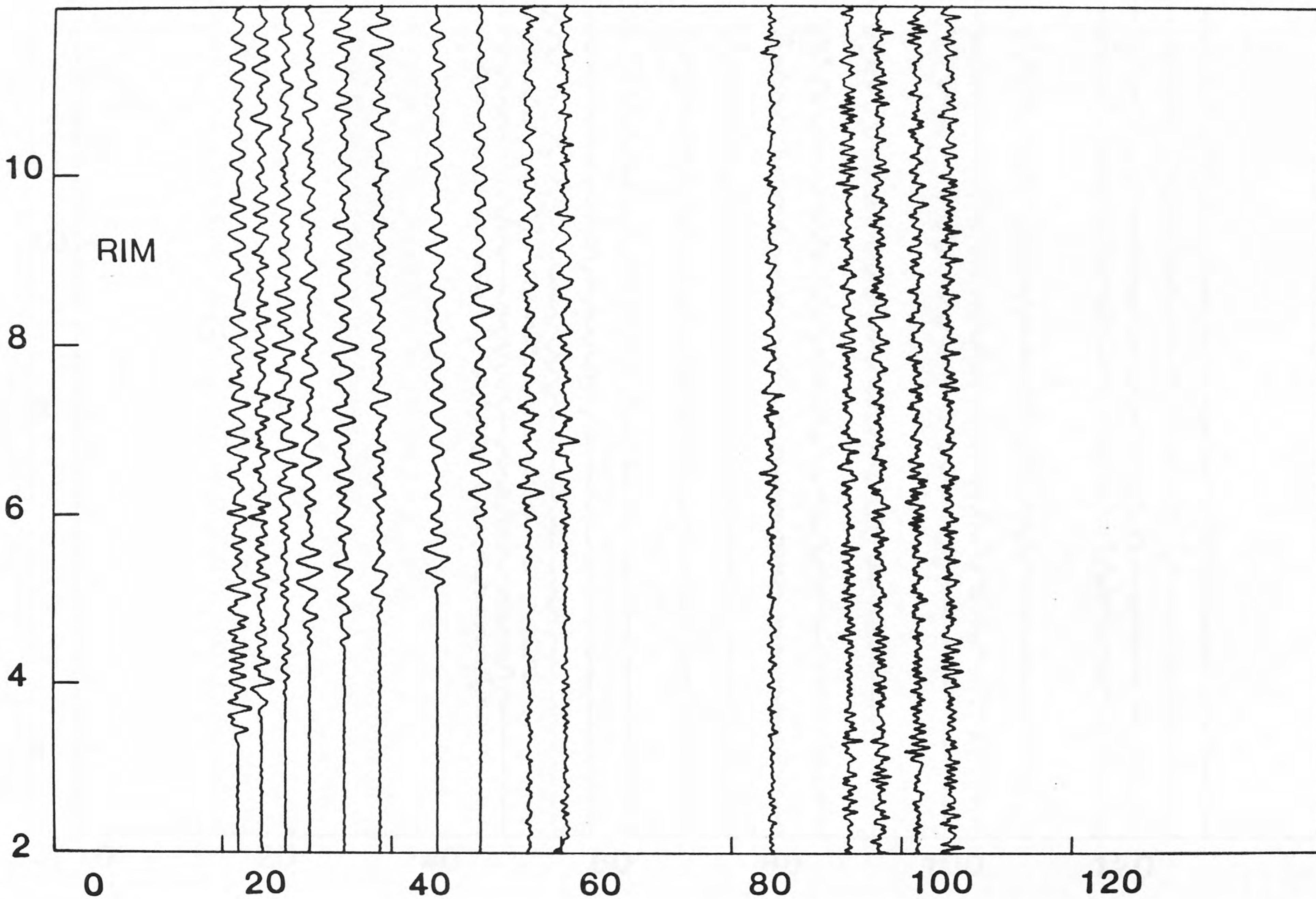

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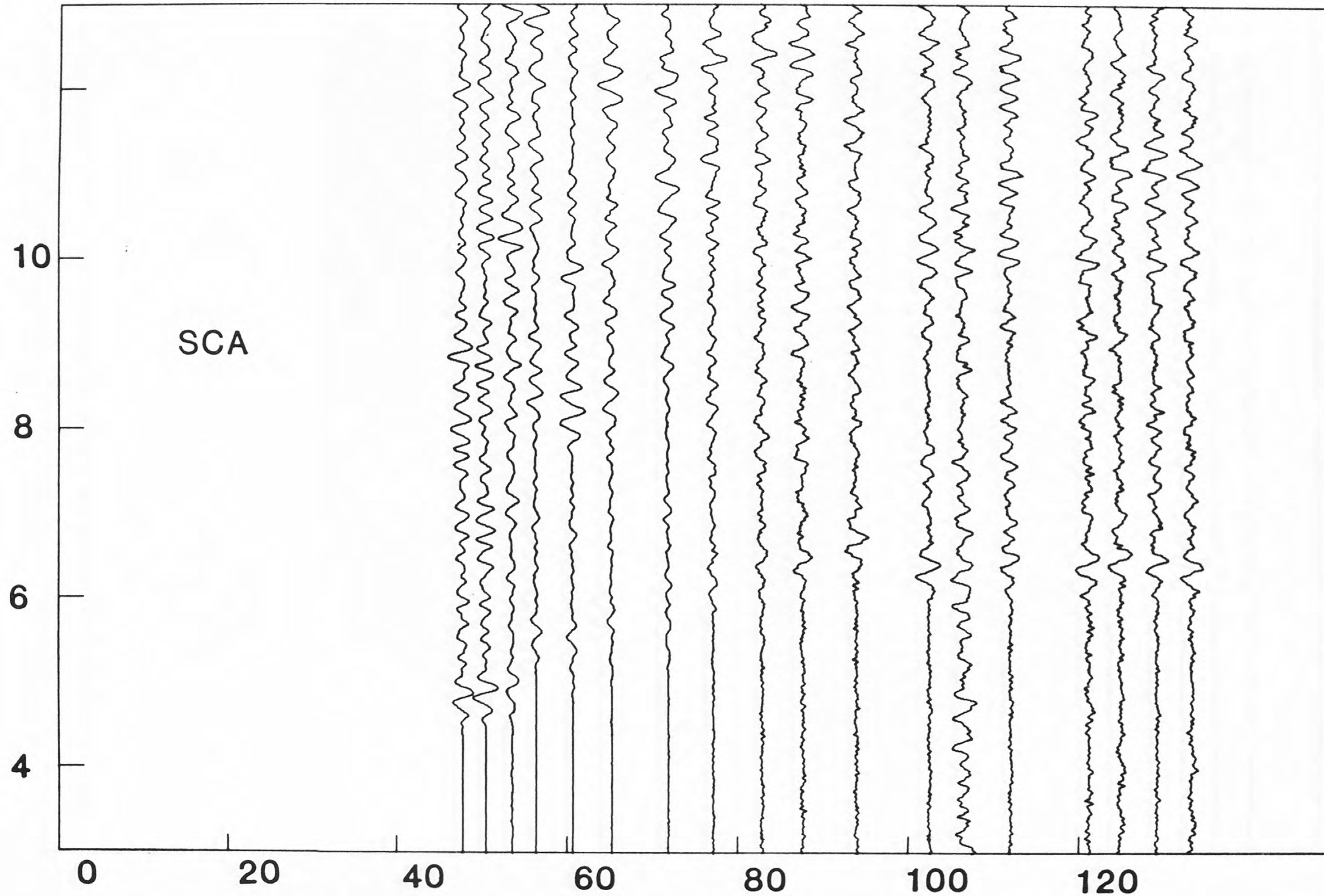

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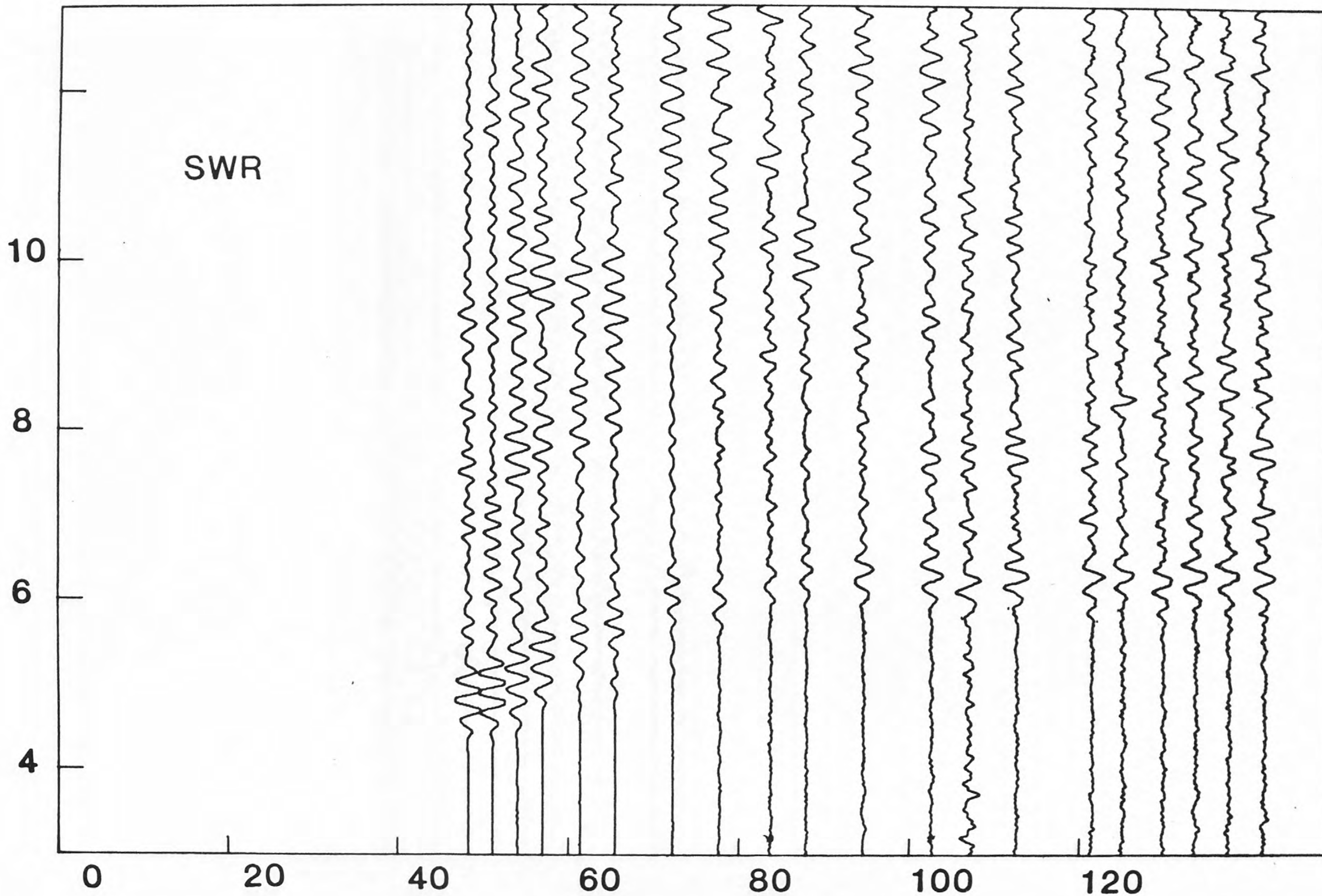

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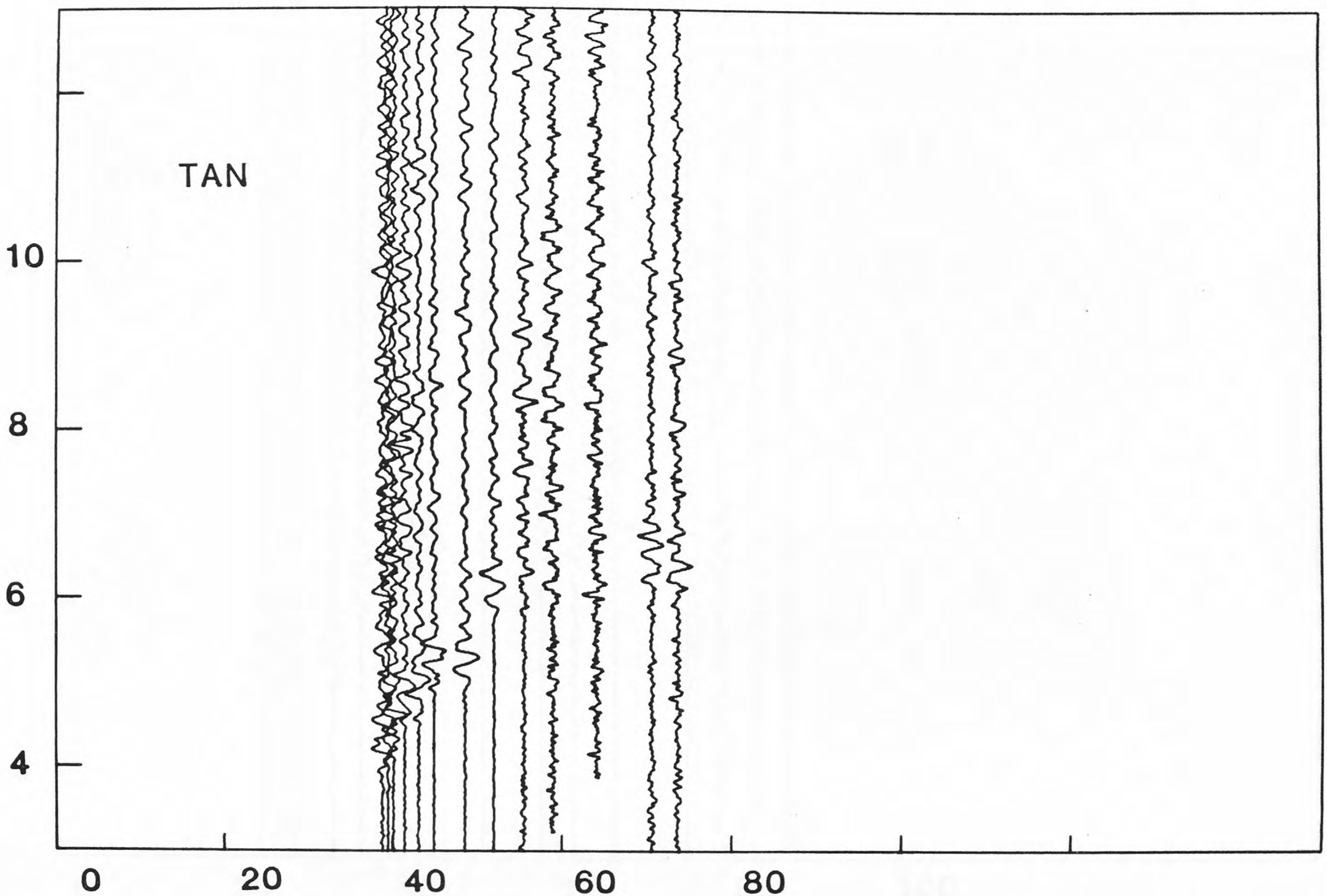

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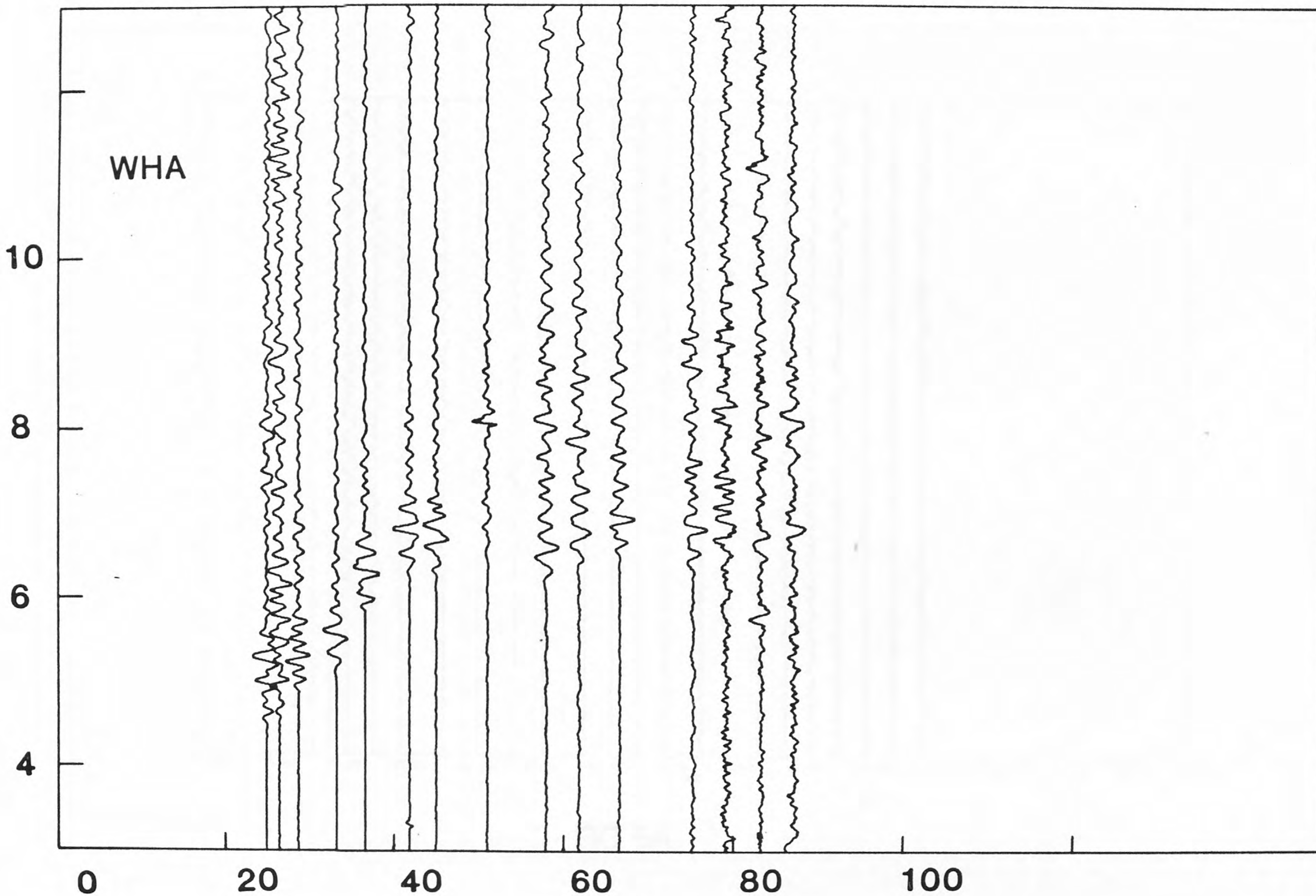

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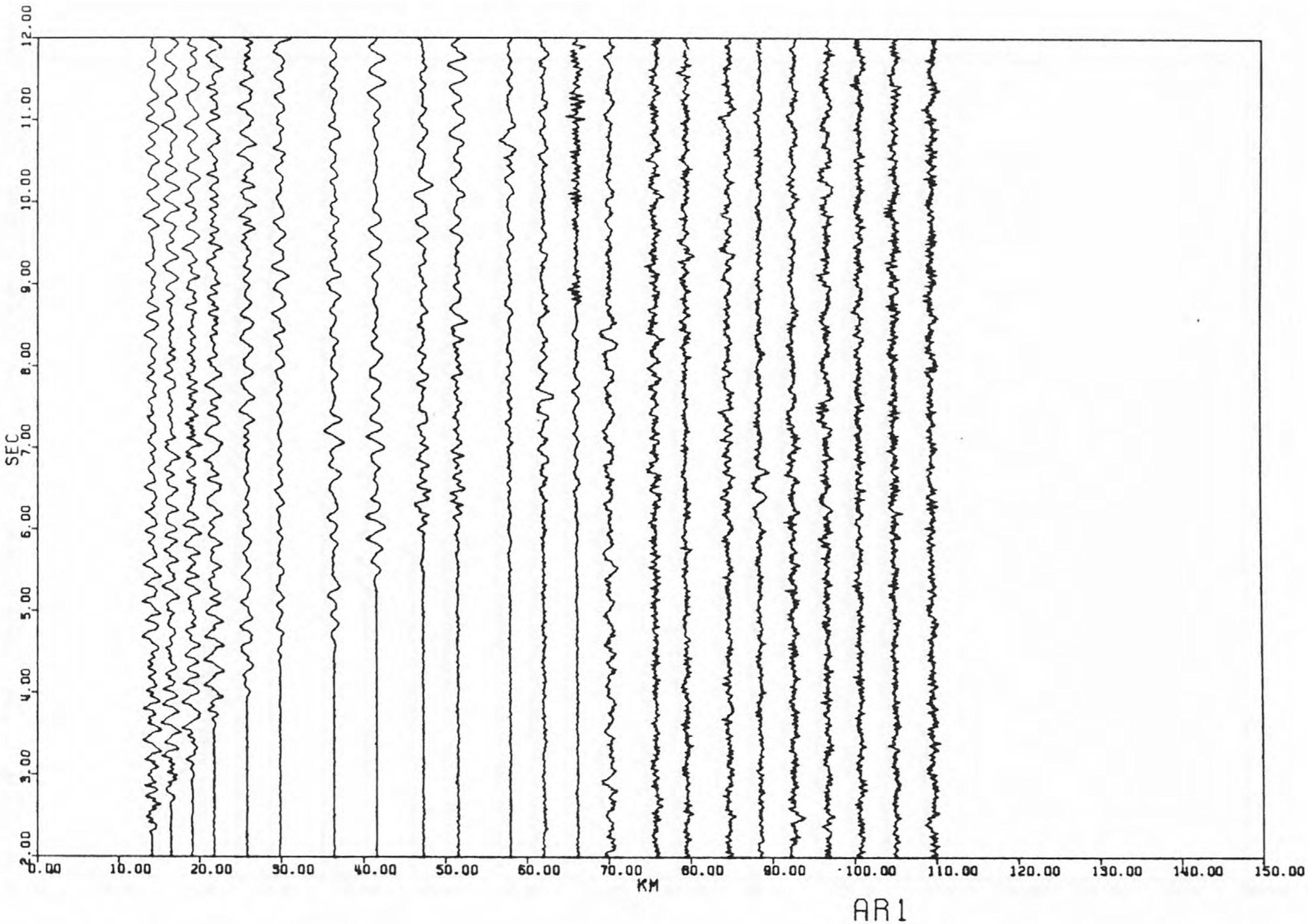

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FIG 5A

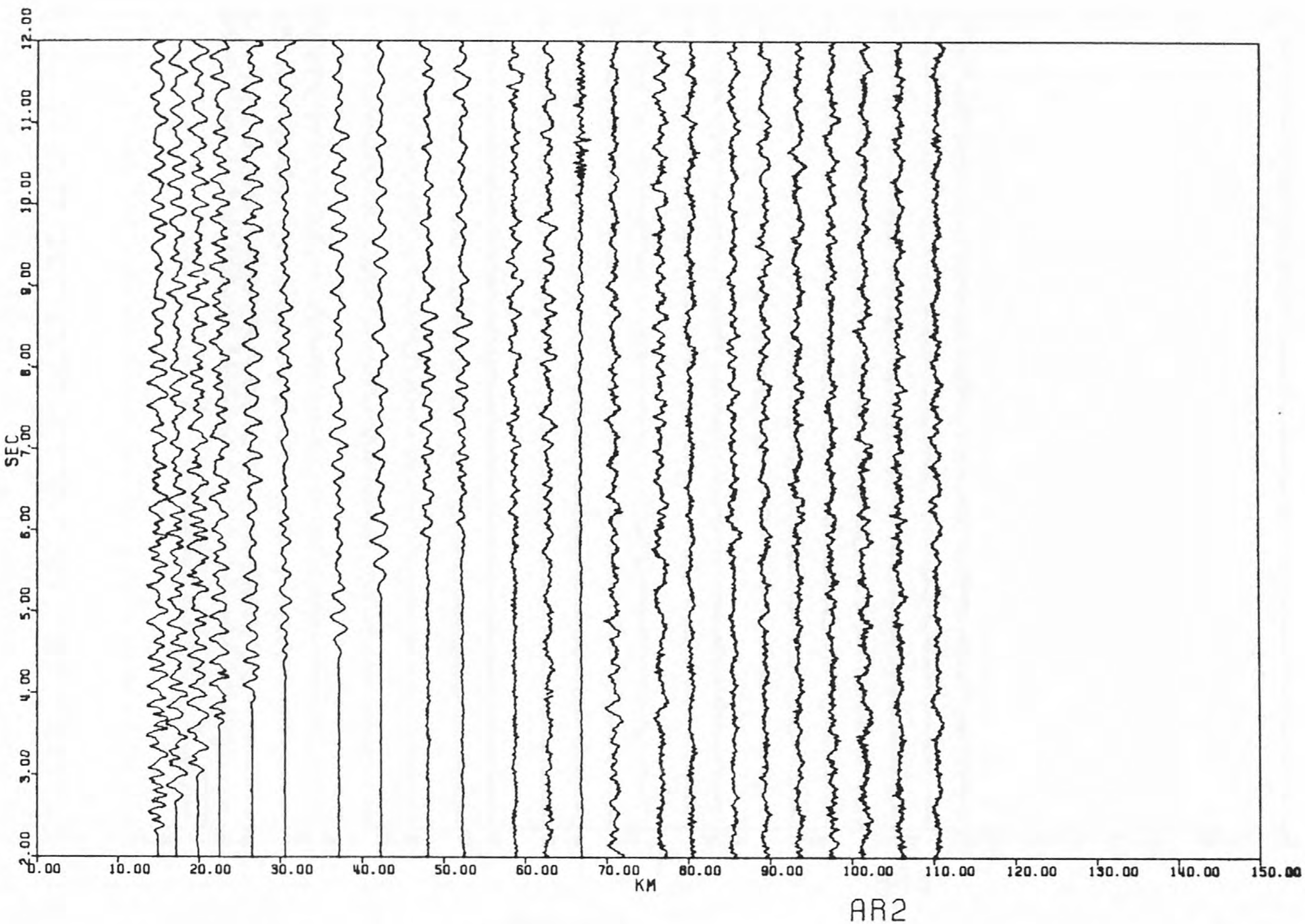

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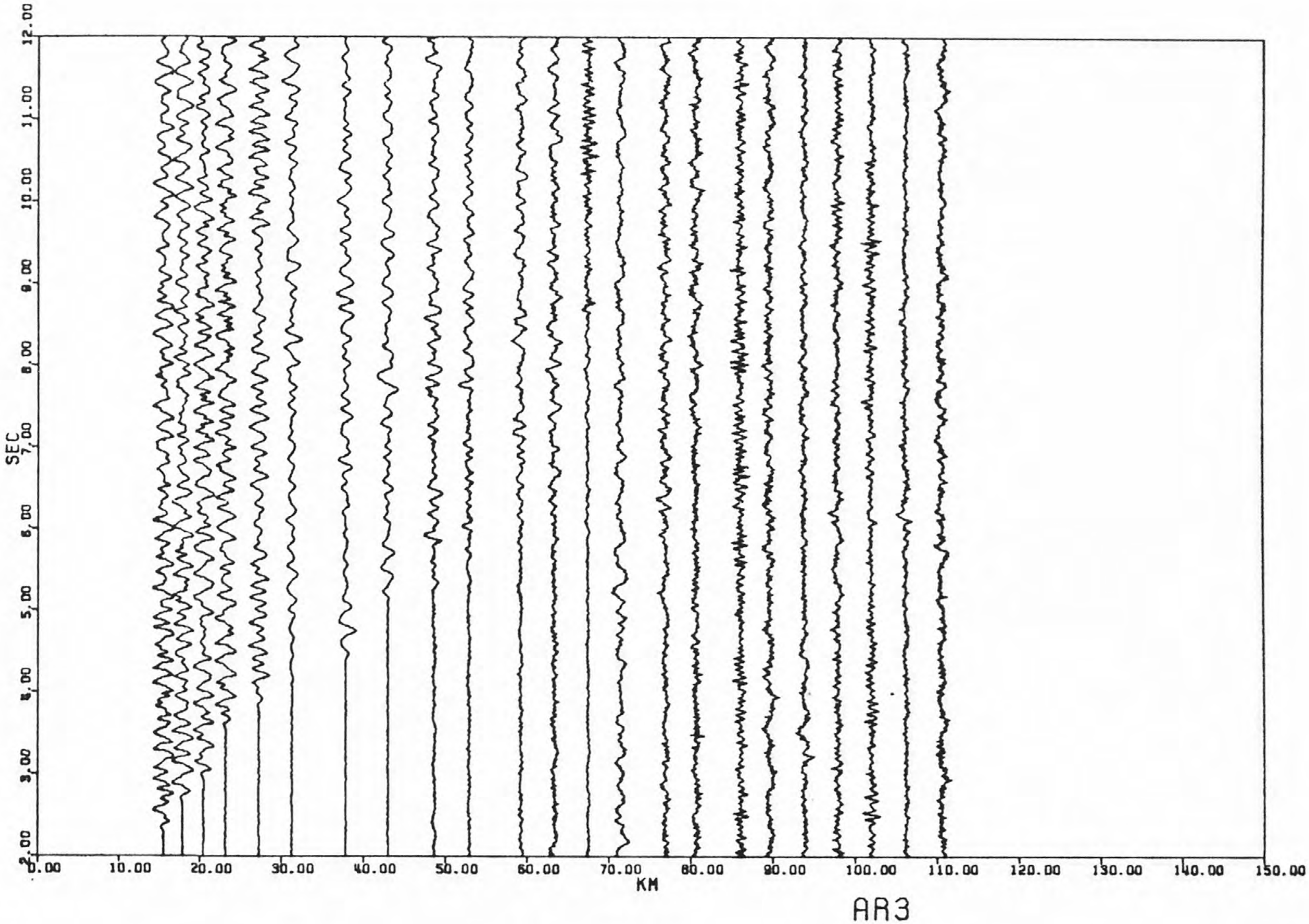
FIG 5B



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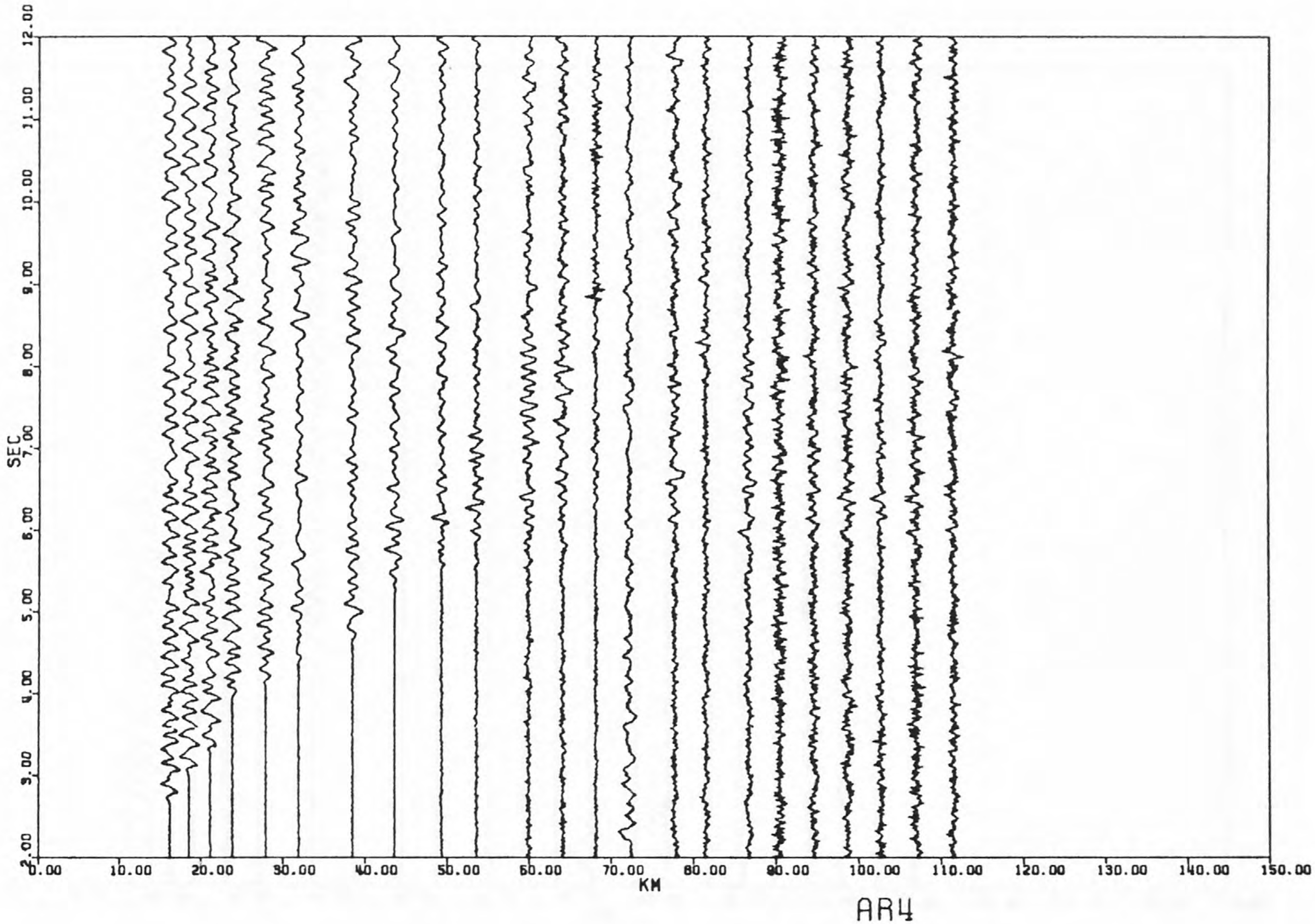

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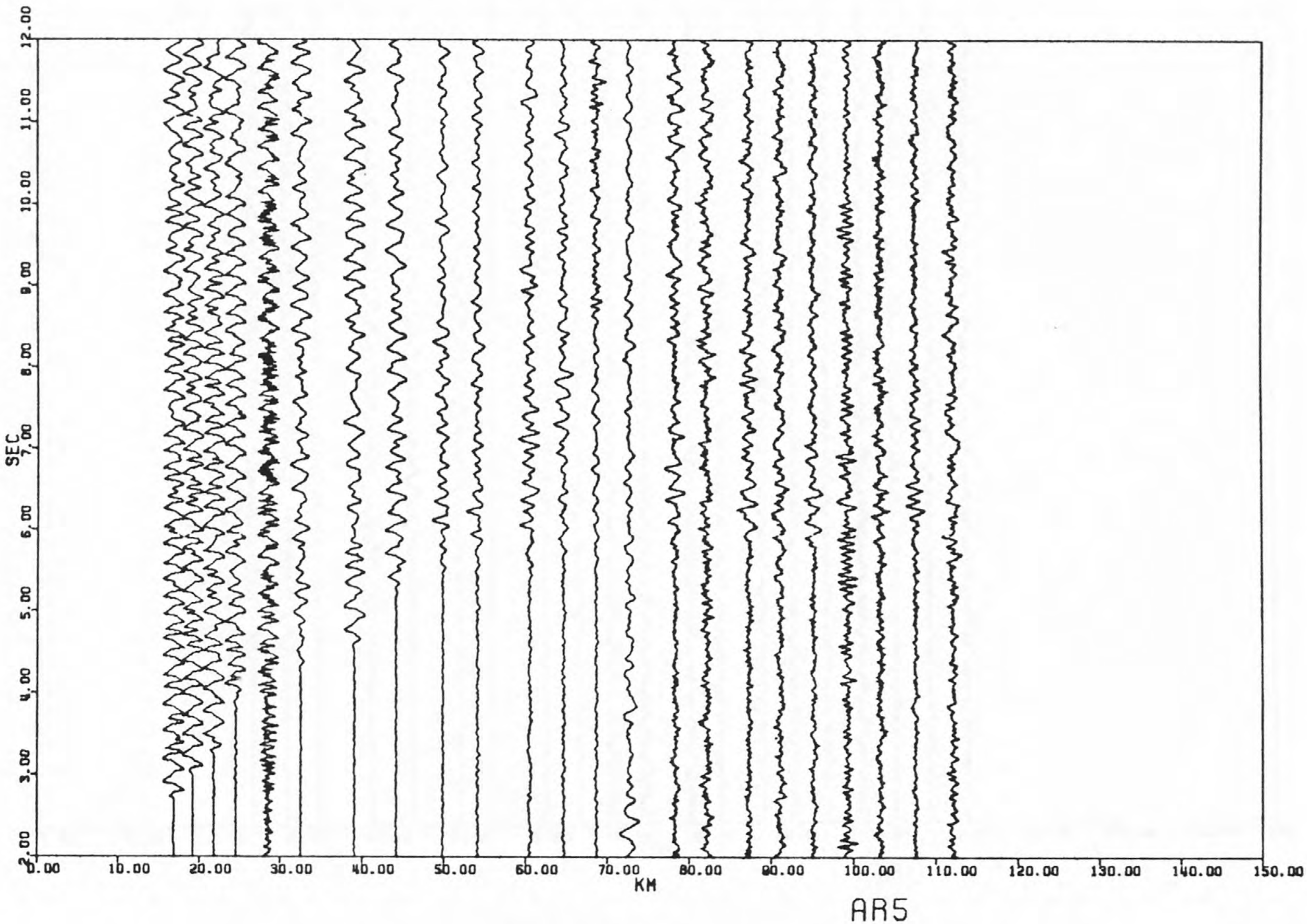
FIG 5D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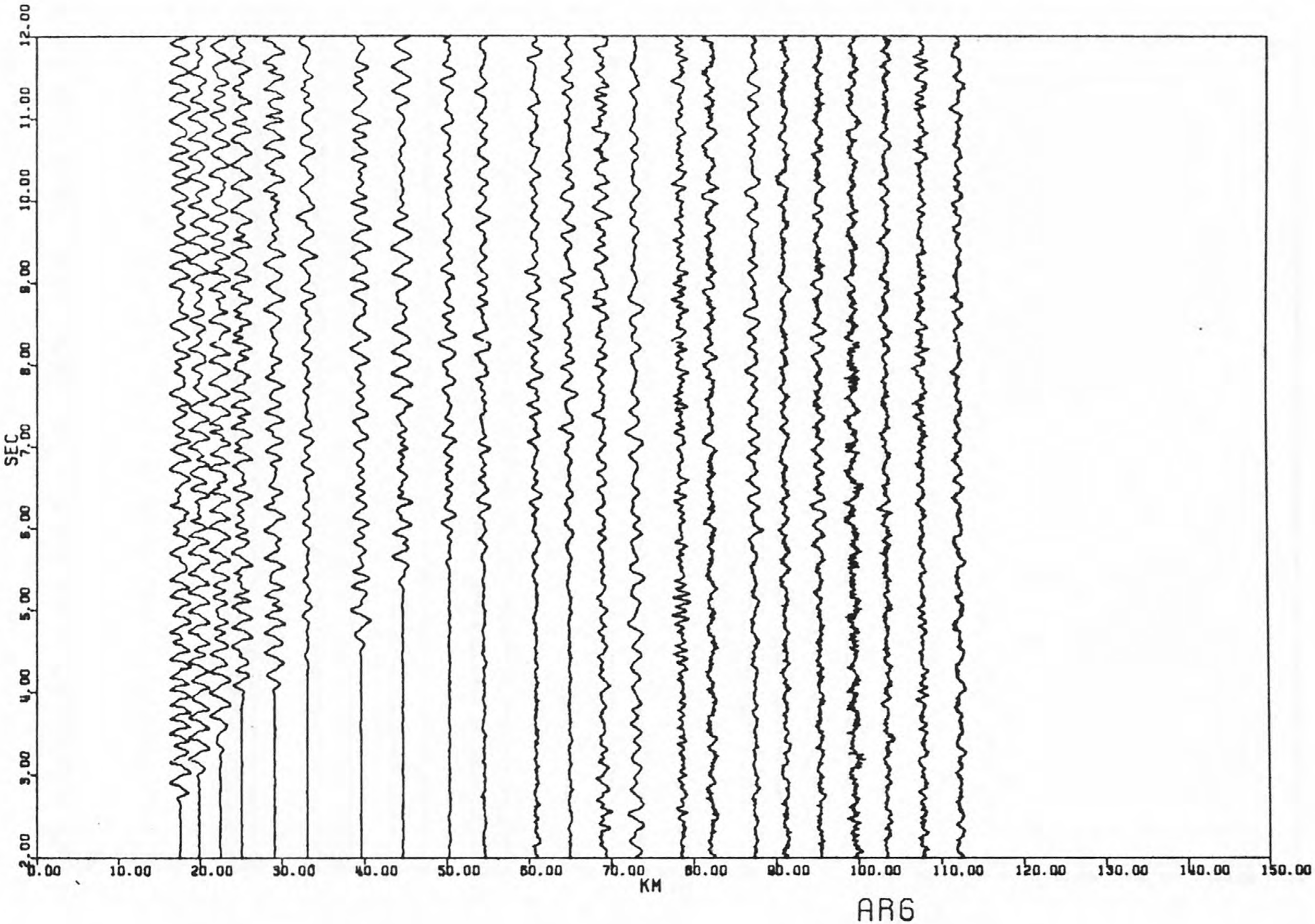
KM
AR5

FIG 5E



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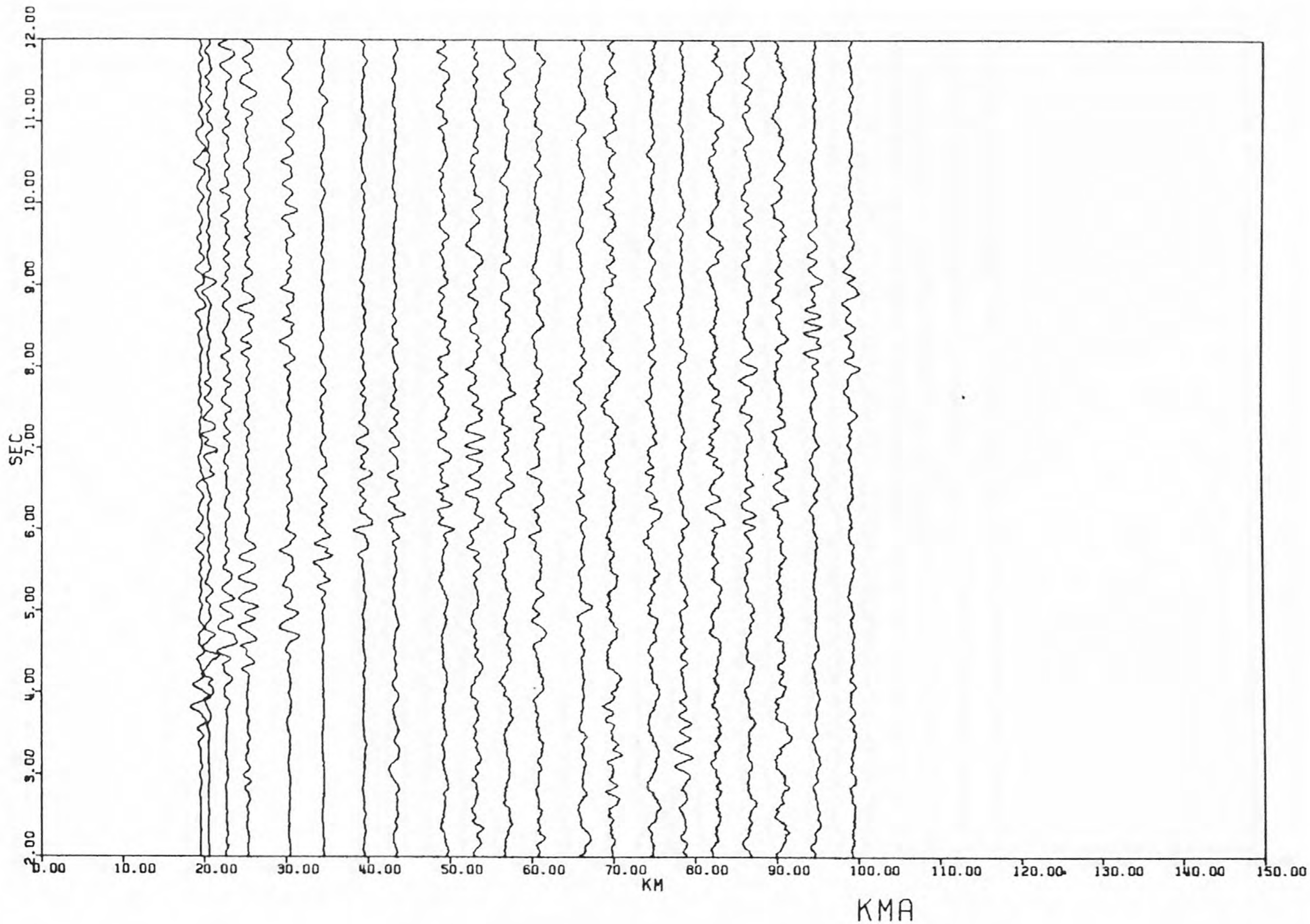

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30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
110.00
120.00
130.00
140.00
150.00
KM
KMA

FIG 5G

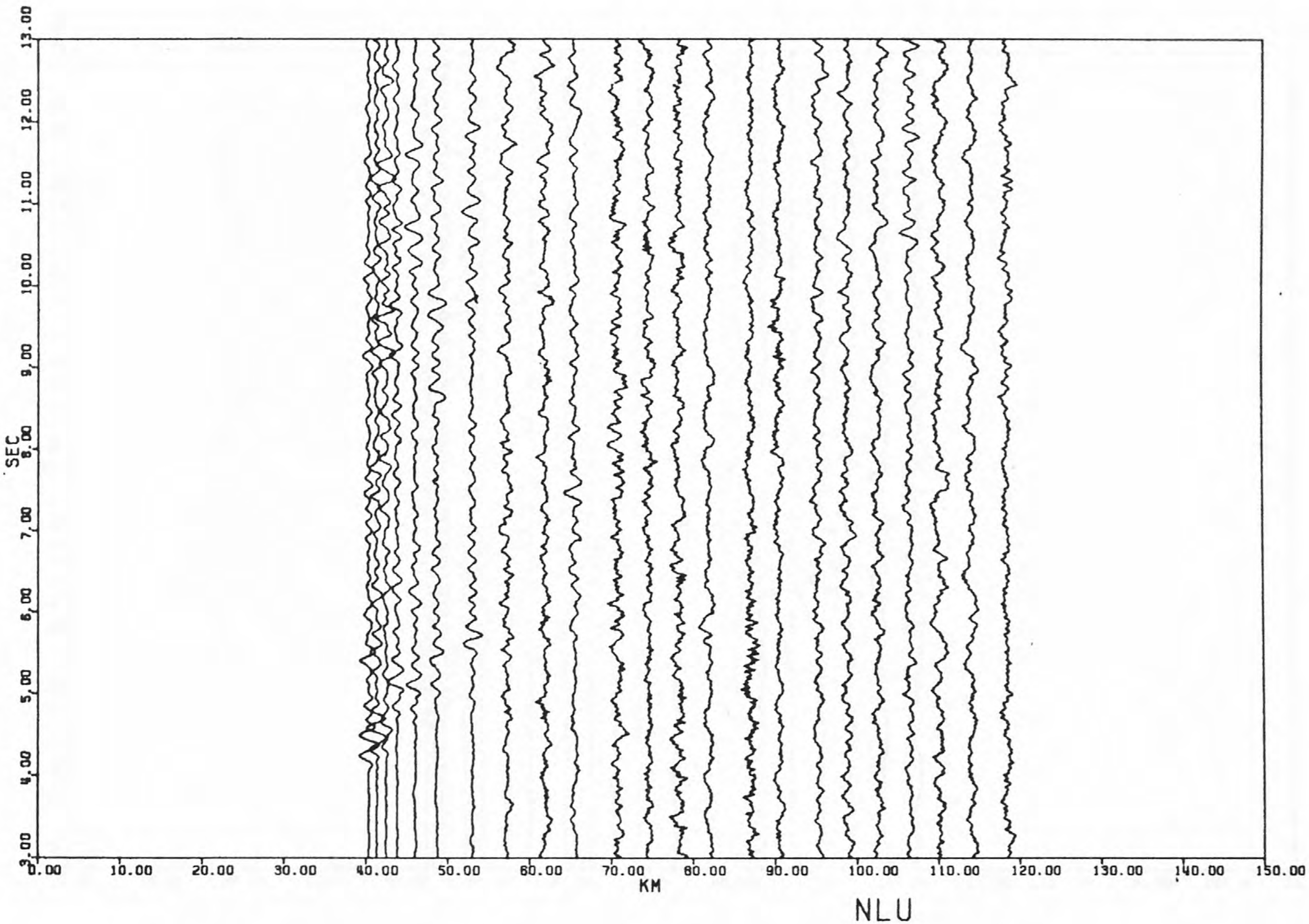

13.00
12.00
11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
SEC
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
110.00
120.00
130.00
140.00
150.00
KM
NLU

FIG 5H

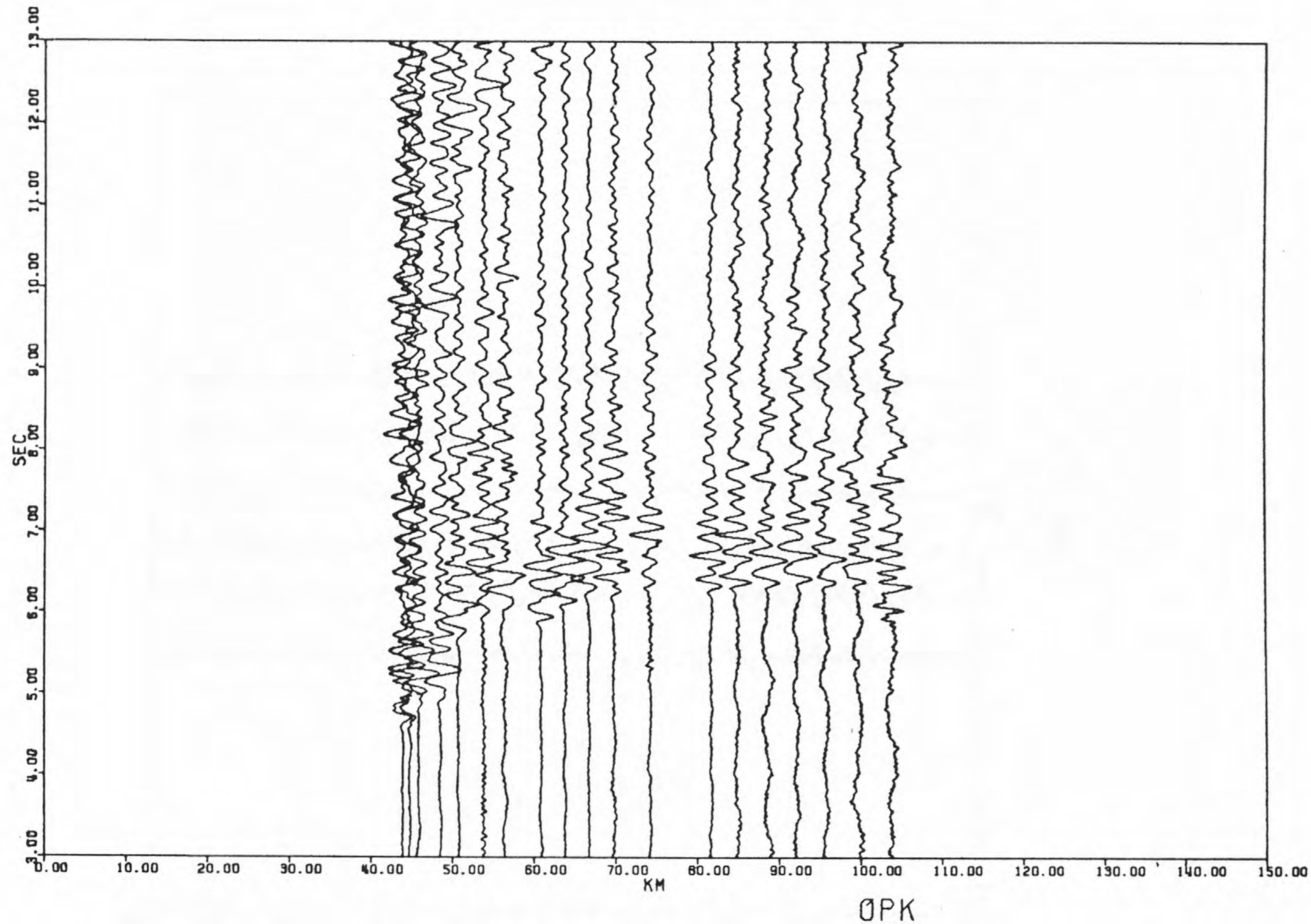
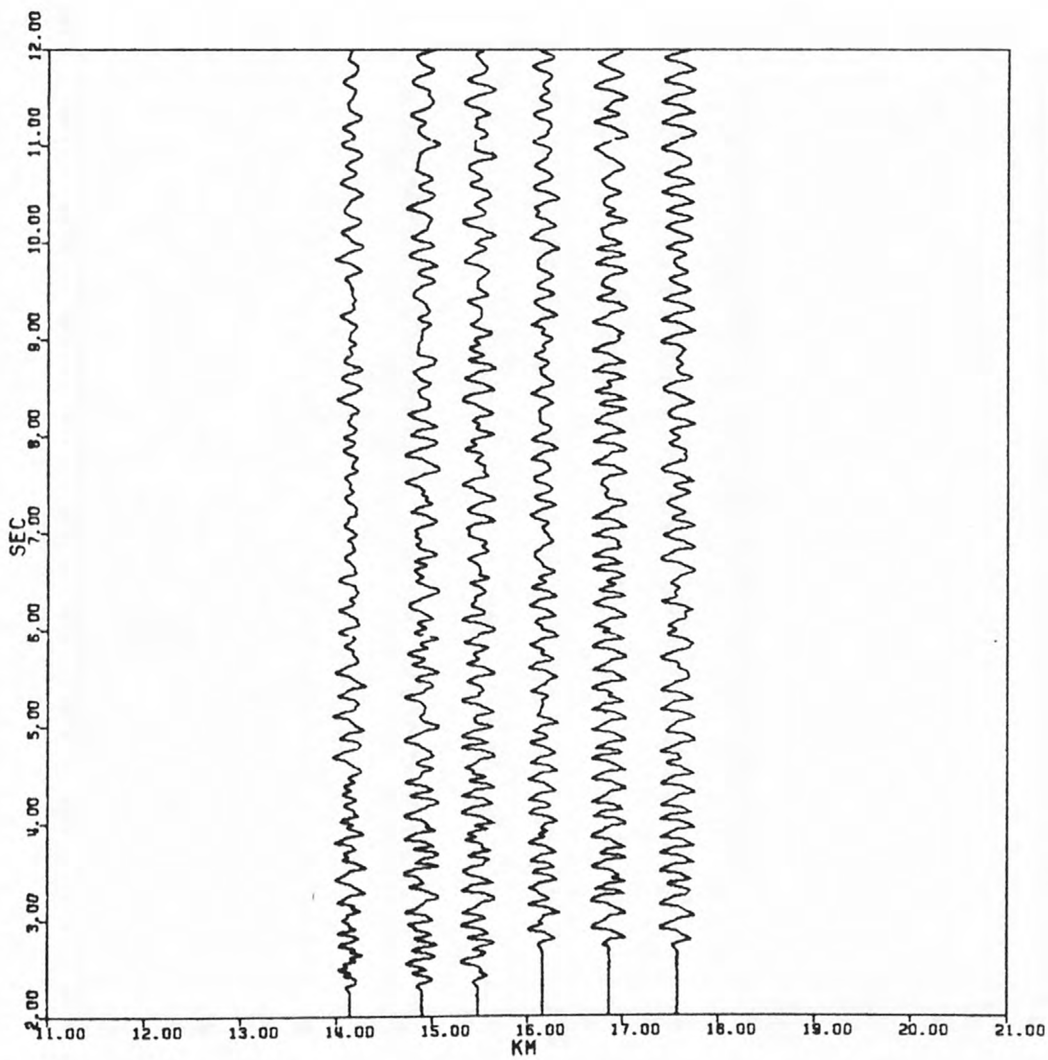


FIG 5I



SEC
12.00
11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
11.00
12.00
13.00
14.00
15.00
16.00
17.00
18.00
19.00
20.00
21.00
KM

FIG 5J

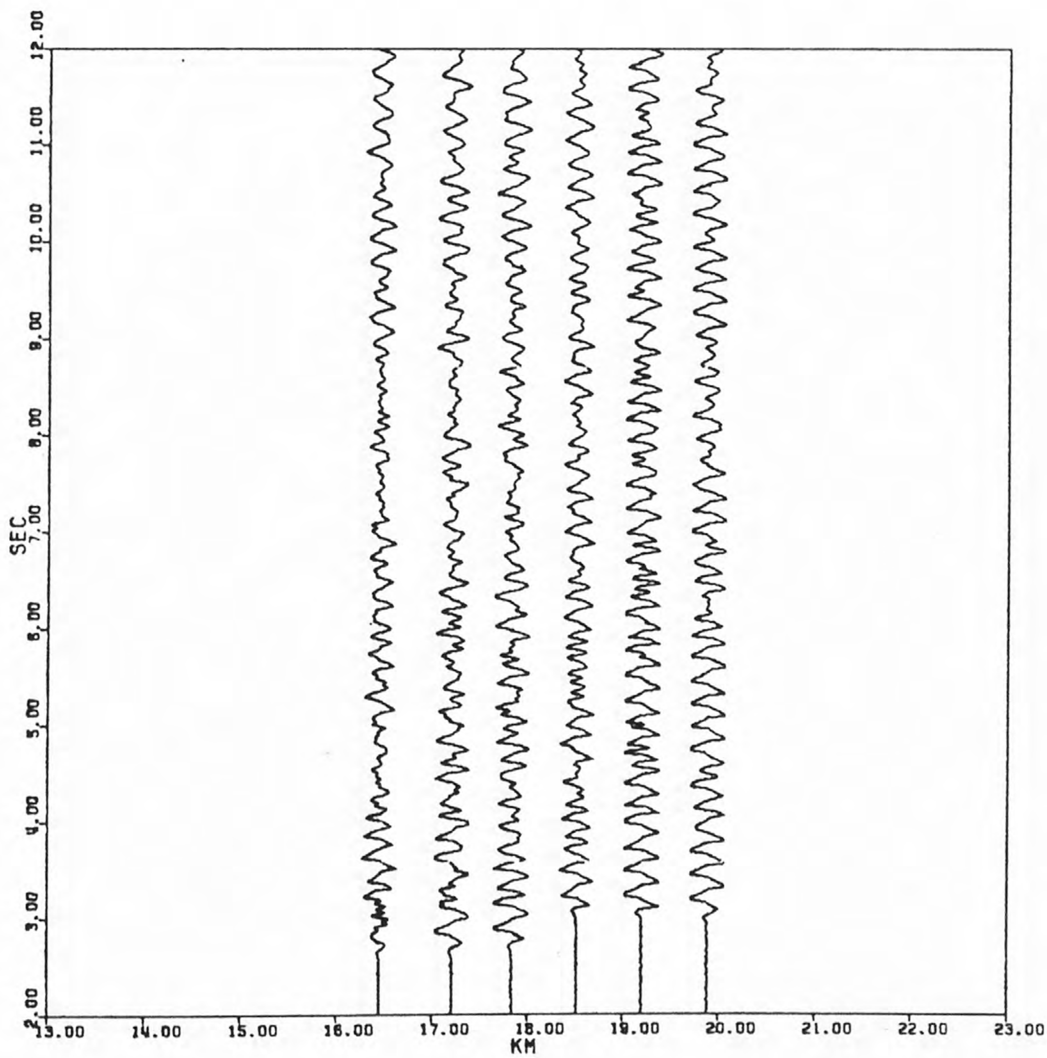

SEC
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
13.00
14.00
15.00
16.00
17.00
18.00
19.00
20.00
21.00
22.00
23.00
KM

FIG 5K

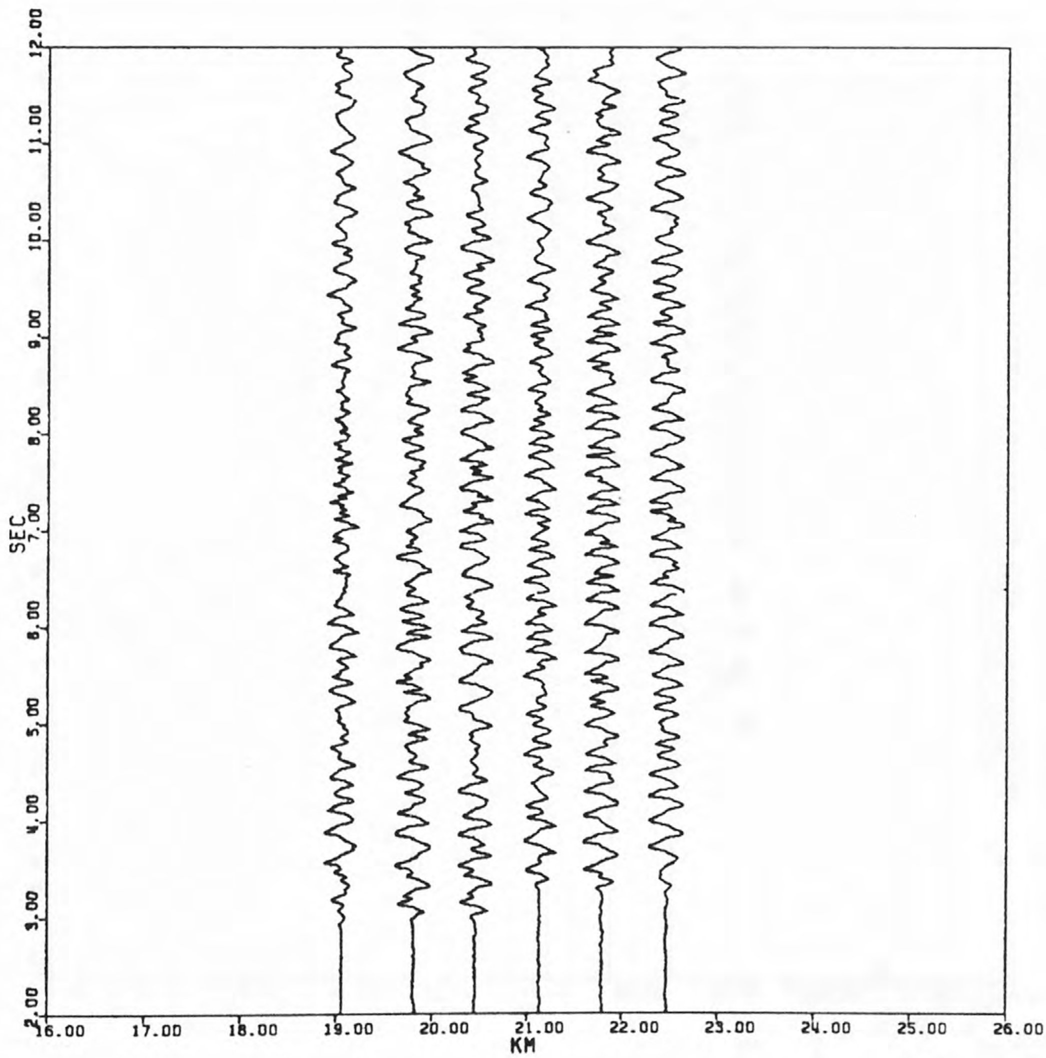
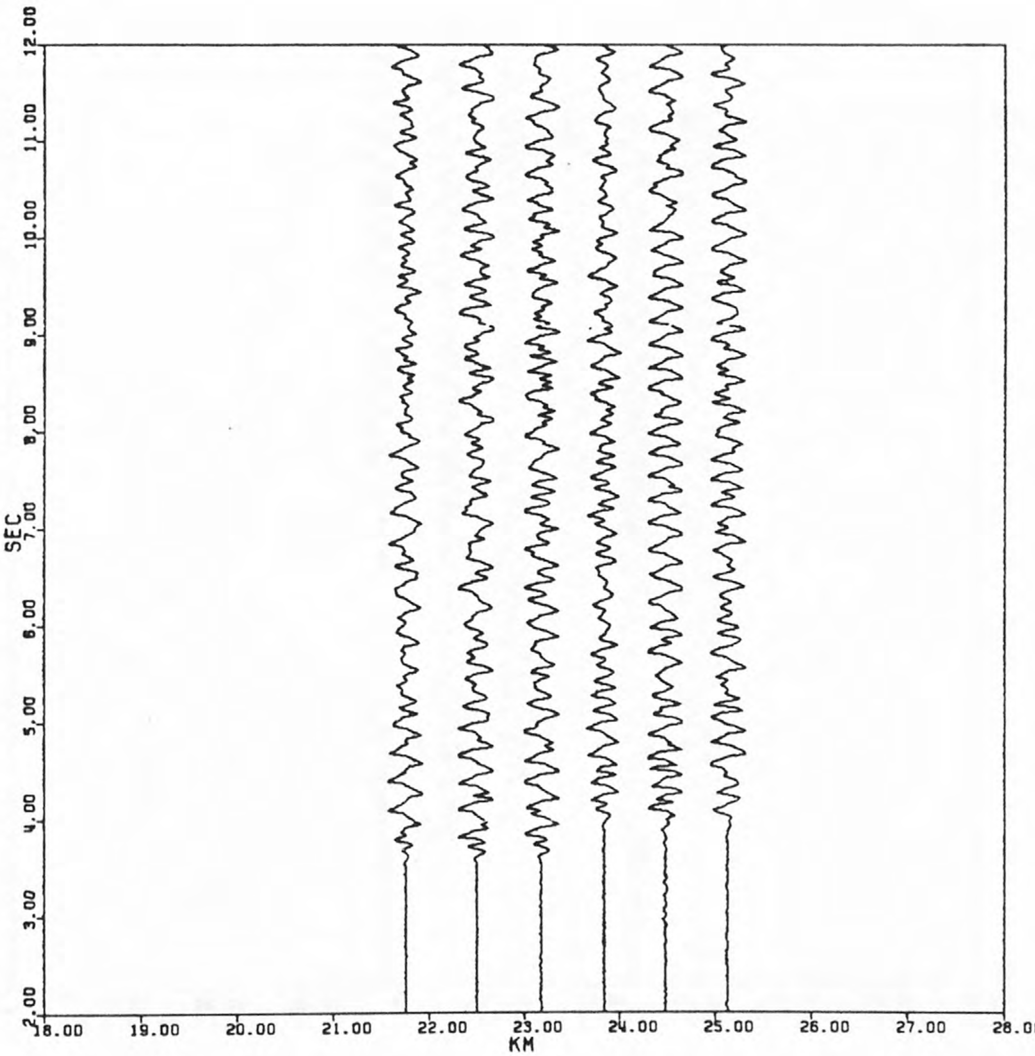
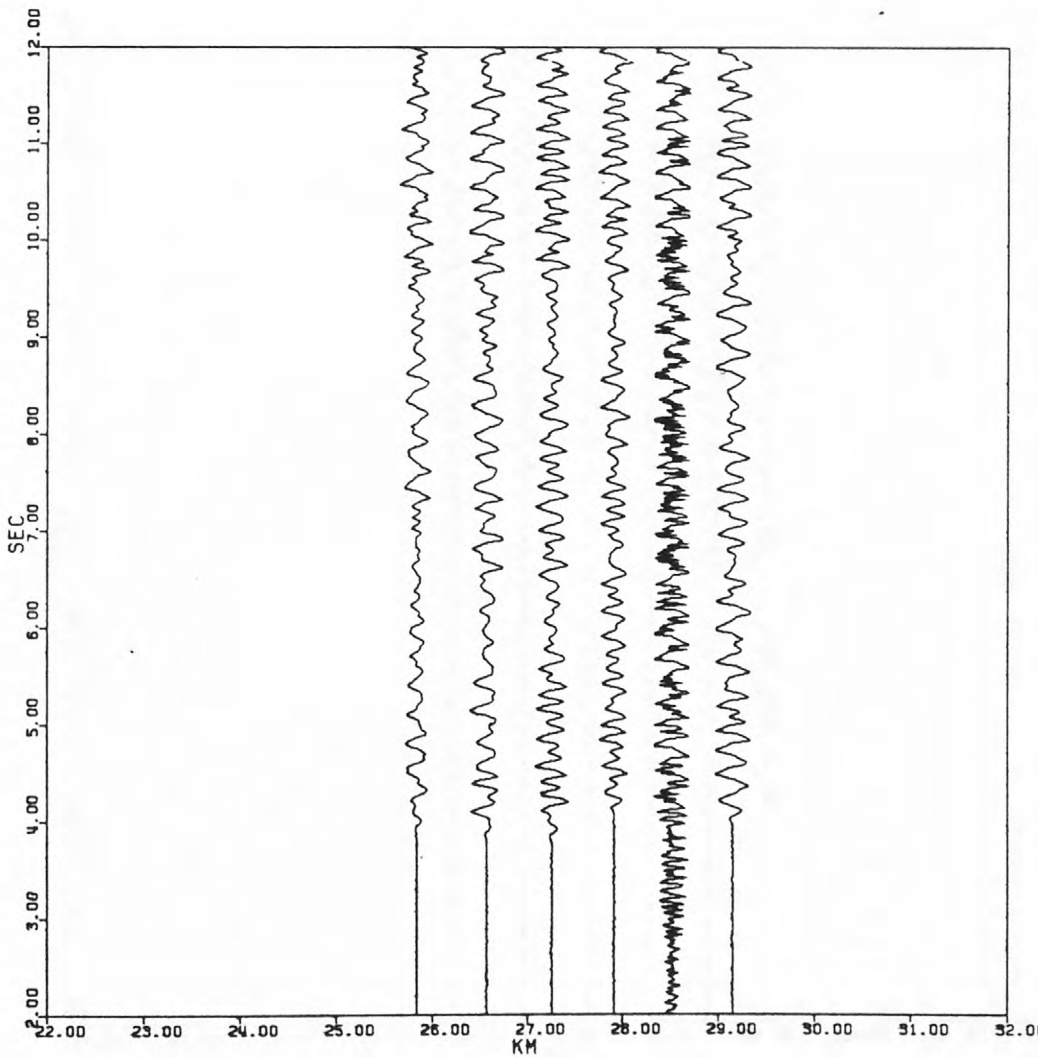

12.00
11.00
10.00
9.00
8.00
7.00
SEC
6.00
5.00
4.00
3.00
2.00
16.00
17.00
18.00
19.00
20.00
21.00
22.00
23.00
24.00
25.00
26.00
KM

FIG 5L



12.00
11.00
10.00
9.00
8.00
SEC
7.00
6.00
5.00
4.00
3.00
2.00
18.00
19.00
20.00
21.00
22.00
23.00
24.00
25.00
26.00
27.00
28.00
KM

FIG 5M



SEC
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
22.00
23.00
24.00
25.00
26.00
27.00
28.00
29.00
30.00
31.00
32.00
KM

FIG 5N

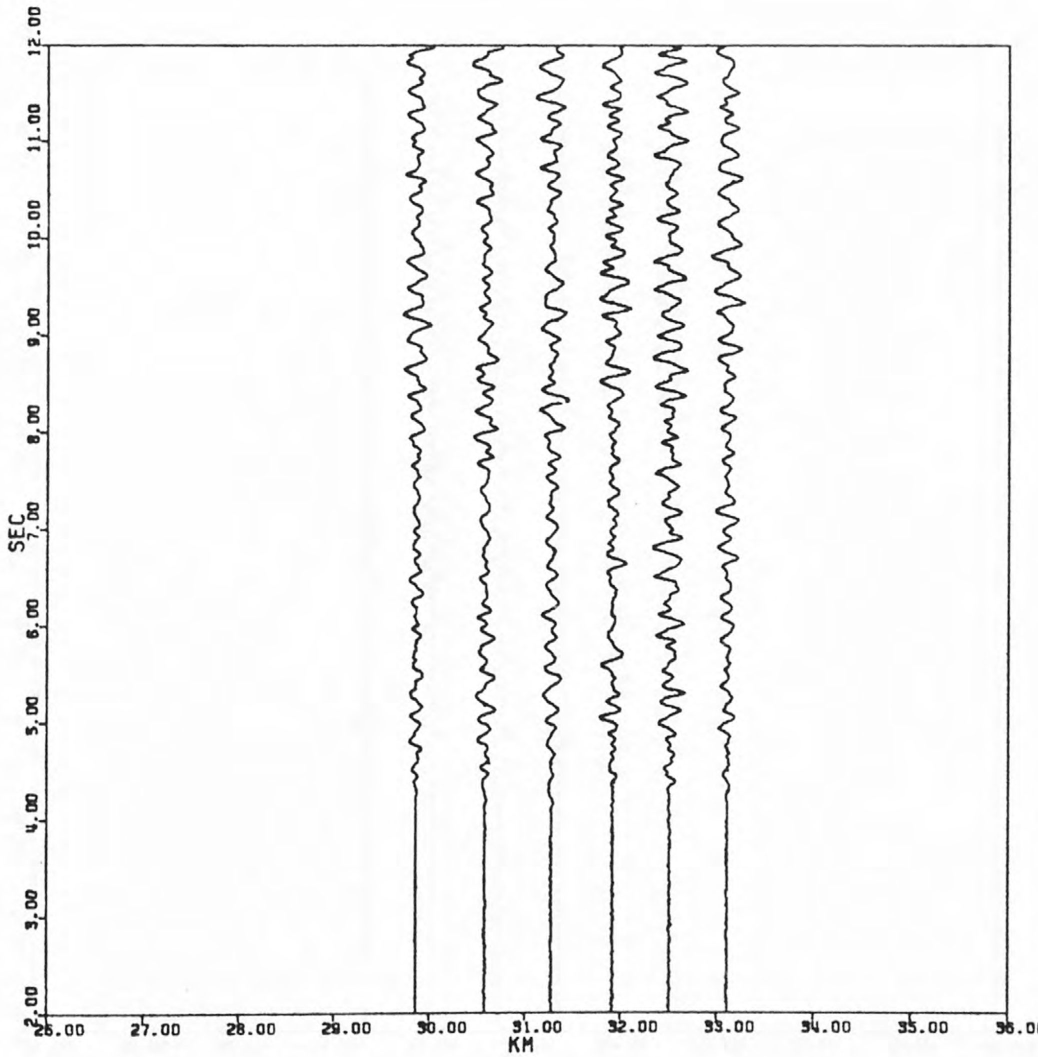
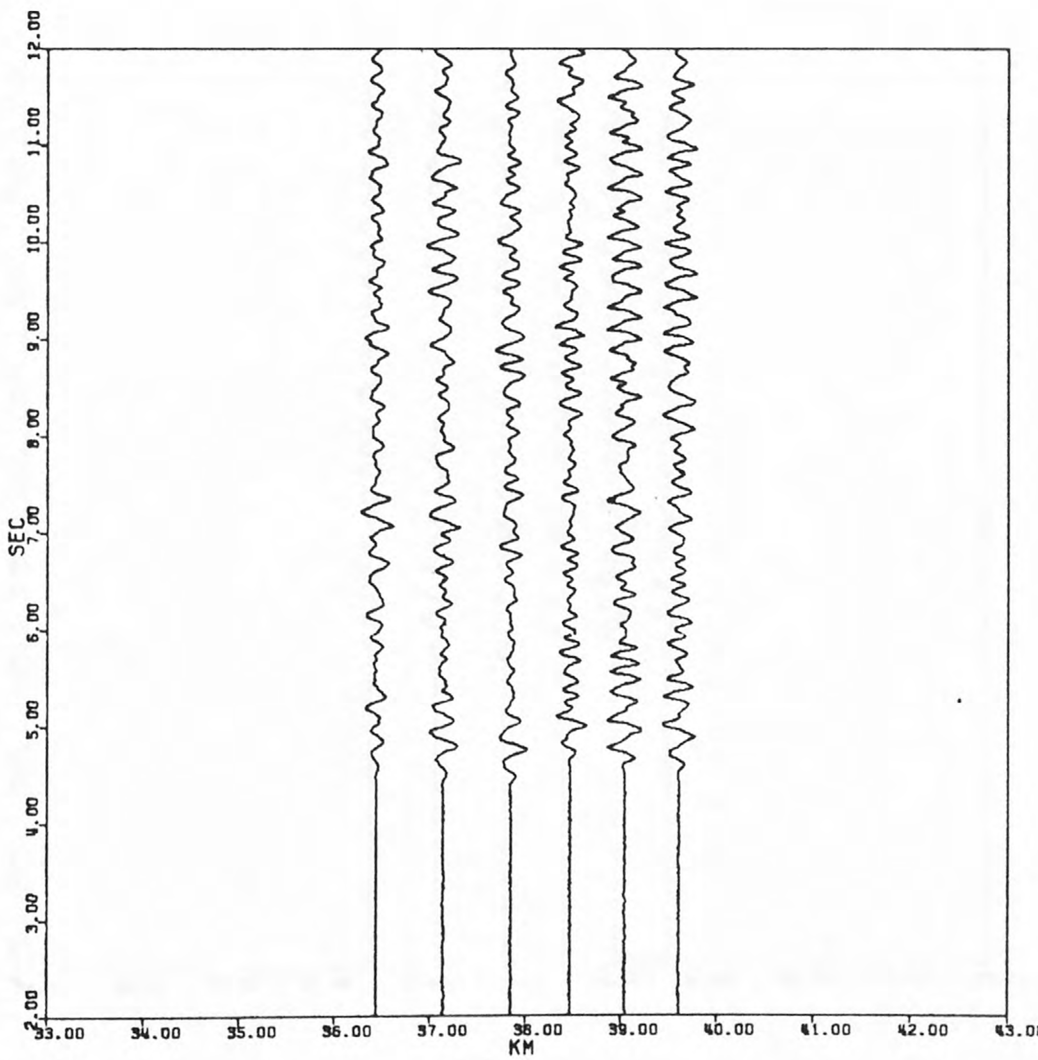
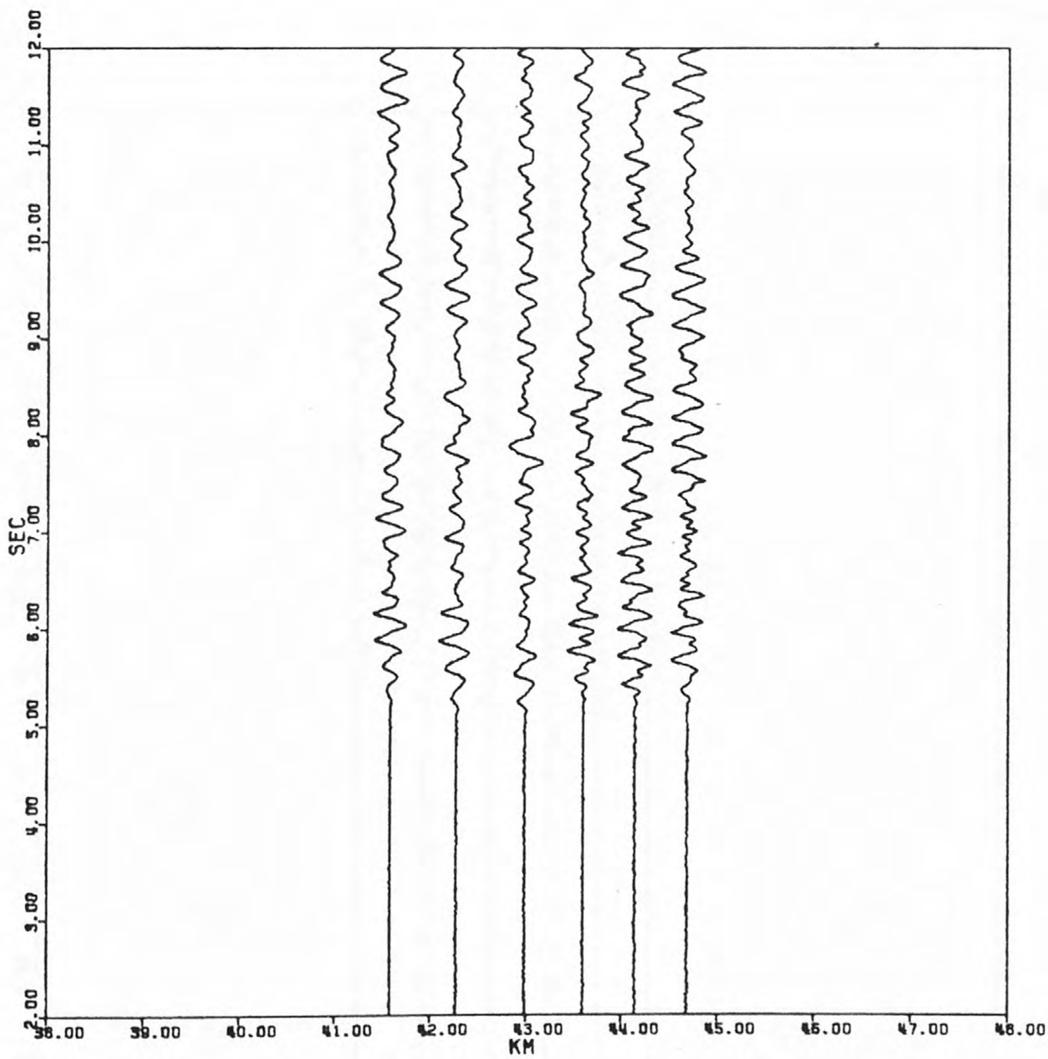

12.00
11.00
10.00
9.00
8.00
SEC
7.00
6.00
5.00
4.00
3.00
2.00
26.00
27.00
28.00
29.00
30.00
31.00
32.00
33.00
34.00
35.00
36.00
KM

FIG 5O



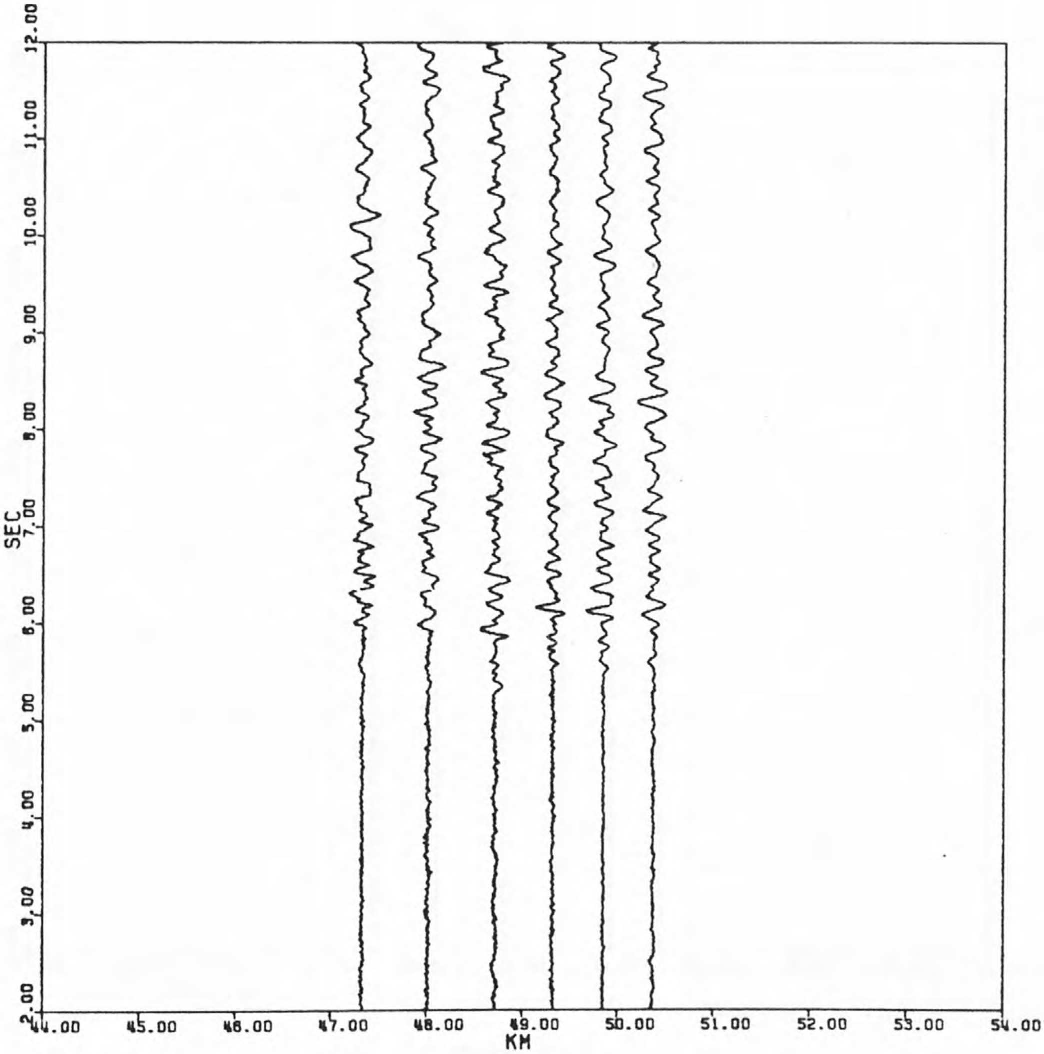
12.00
11.00
10.00
9.00
8.00
SEC
7.00
6.00
5.00
4.00
3.00
2.00
33.00
34.00
35.00
36.00
37.00
38.00
39.00
40.00
41.00
42.00
43.00
KM

FIG 5P



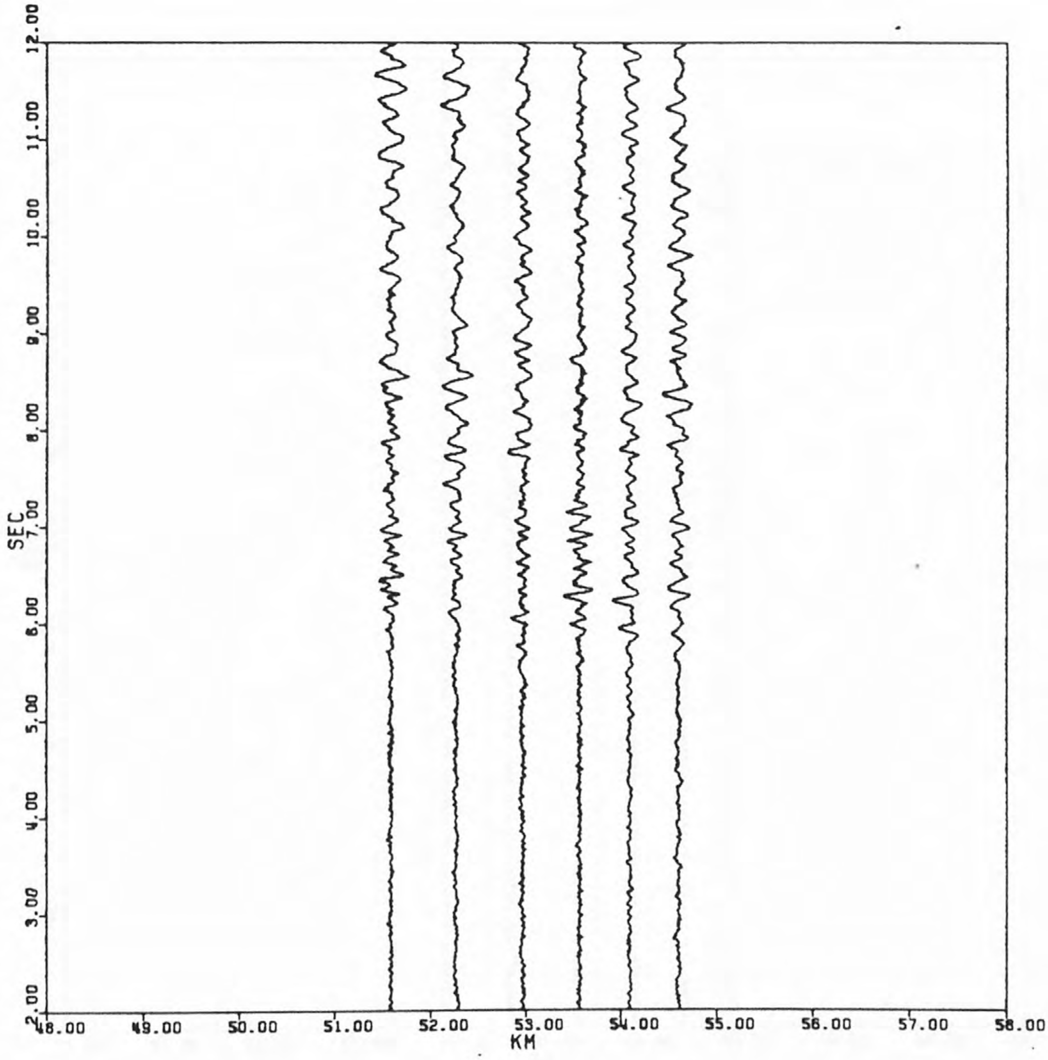
12.00
11.00
10.00
9.00
8.00
SEC
7.00
6.00
5.00
4.00
3.00
2.00
38.00
39.00
40.00
41.00
42.00
43.00
44.00
45.00
46.00
47.00
48.00
KM

FIG 5Q



12.00
11.00
10.00
9.00
8.00
7.00
SEC
6.00
5.00
4.00
3.00
2.00
44.00
45.00
46.00
47.00
48.00
49.00
50.00
51.00
52.00
53.00
54.00
KM

FIG 5R



SEC
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
48.00
49.00
50.00
51.00
52.00
53.00
54.00
55.00
56.00
57.00
58.00
KM

FIG 5S

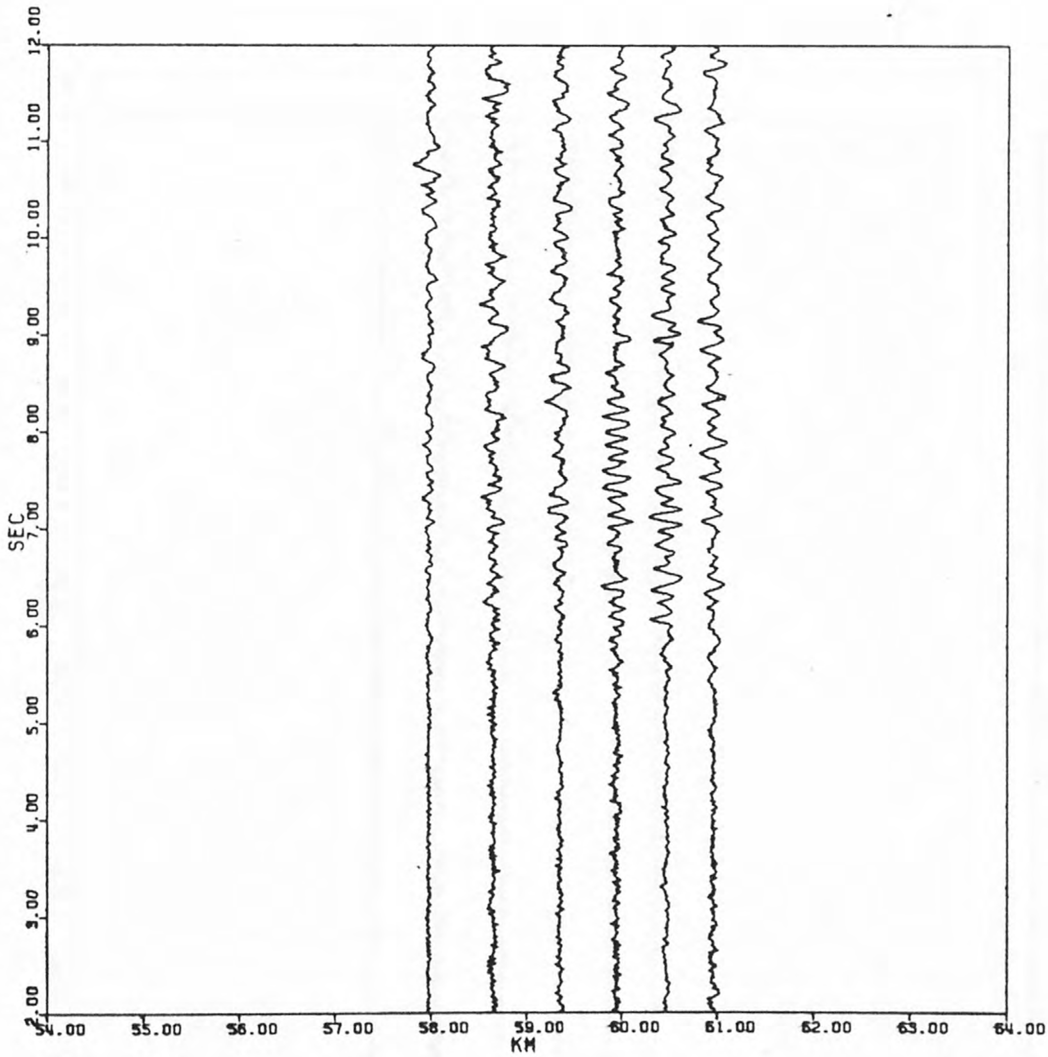
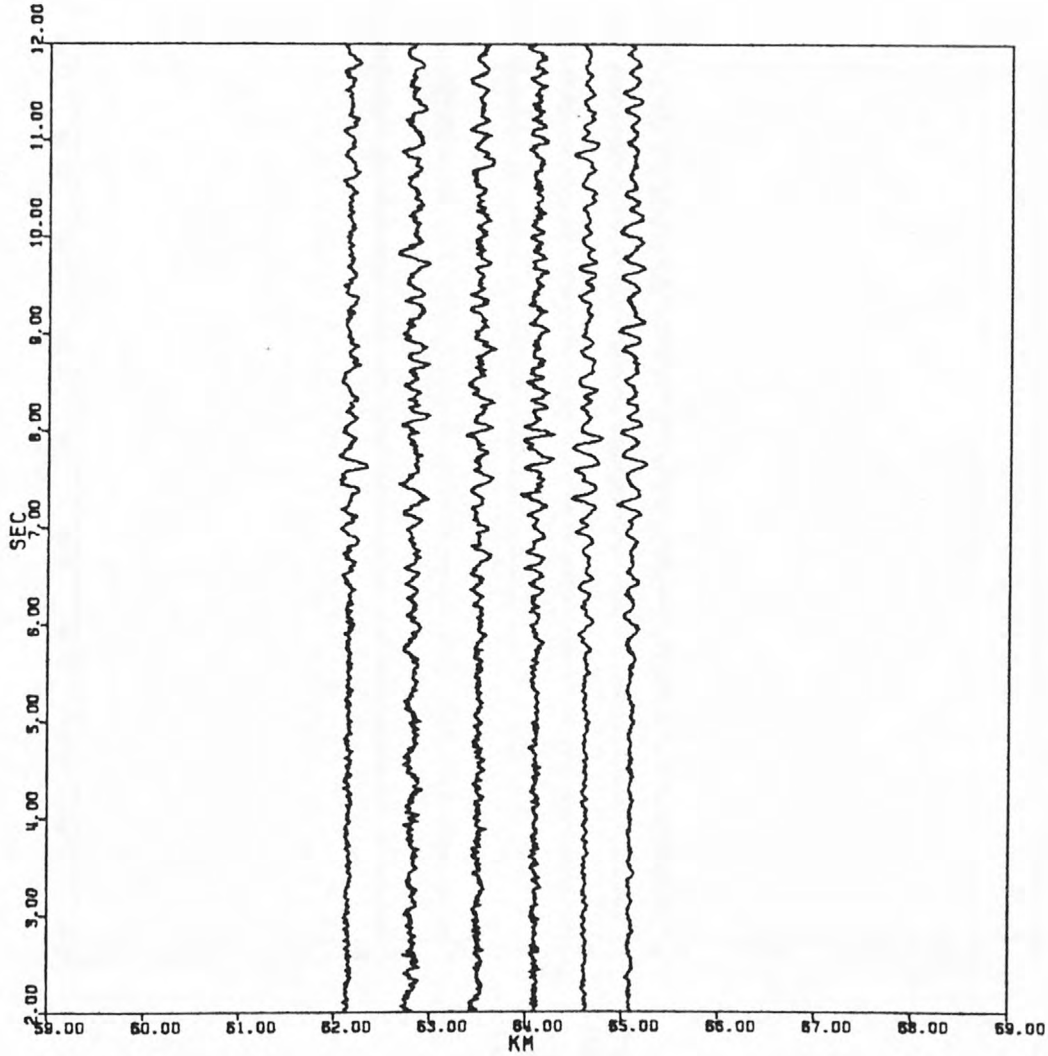
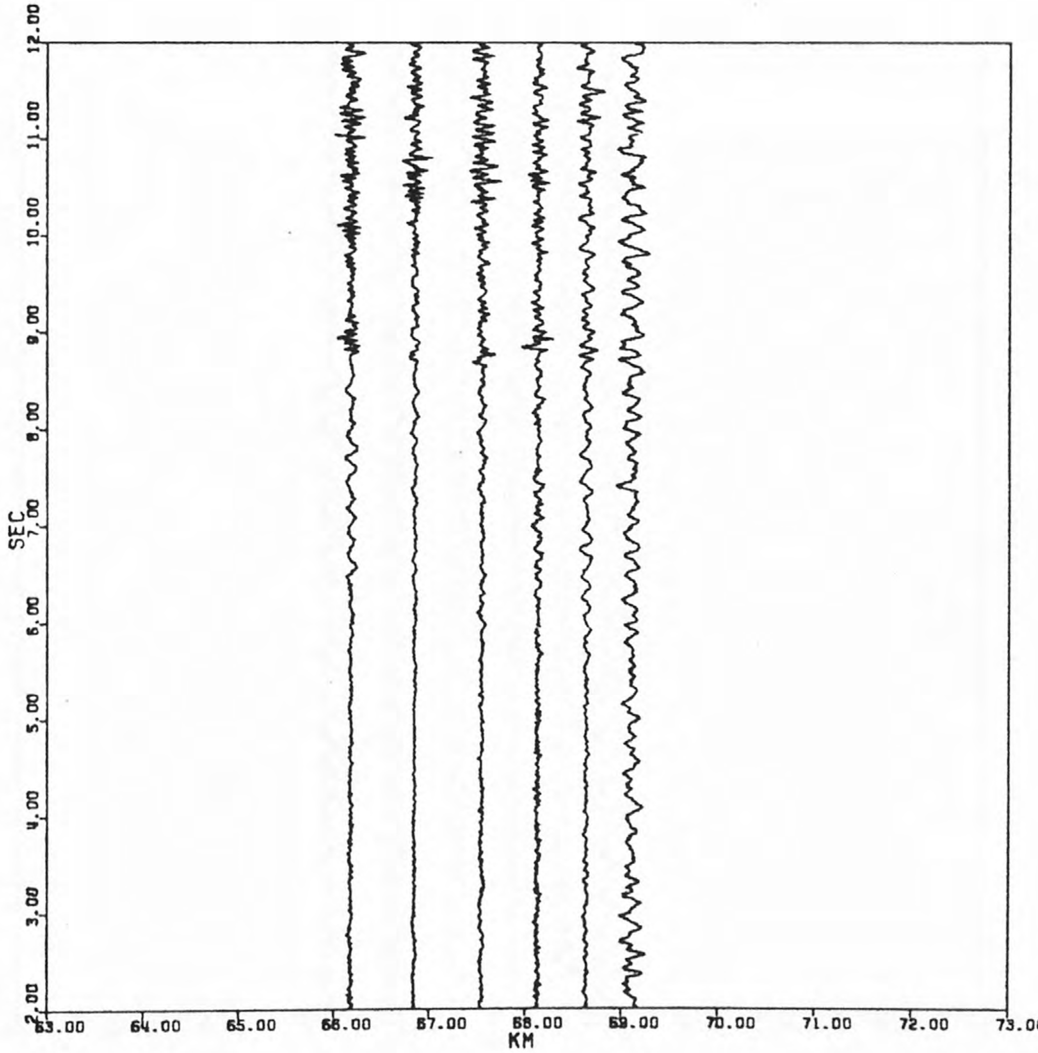

SEC
KM
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
54.00
55.00
56.00
57.00
58.00
59.00
60.00
61.00
62.00
63.00
64.00

FIG 5T



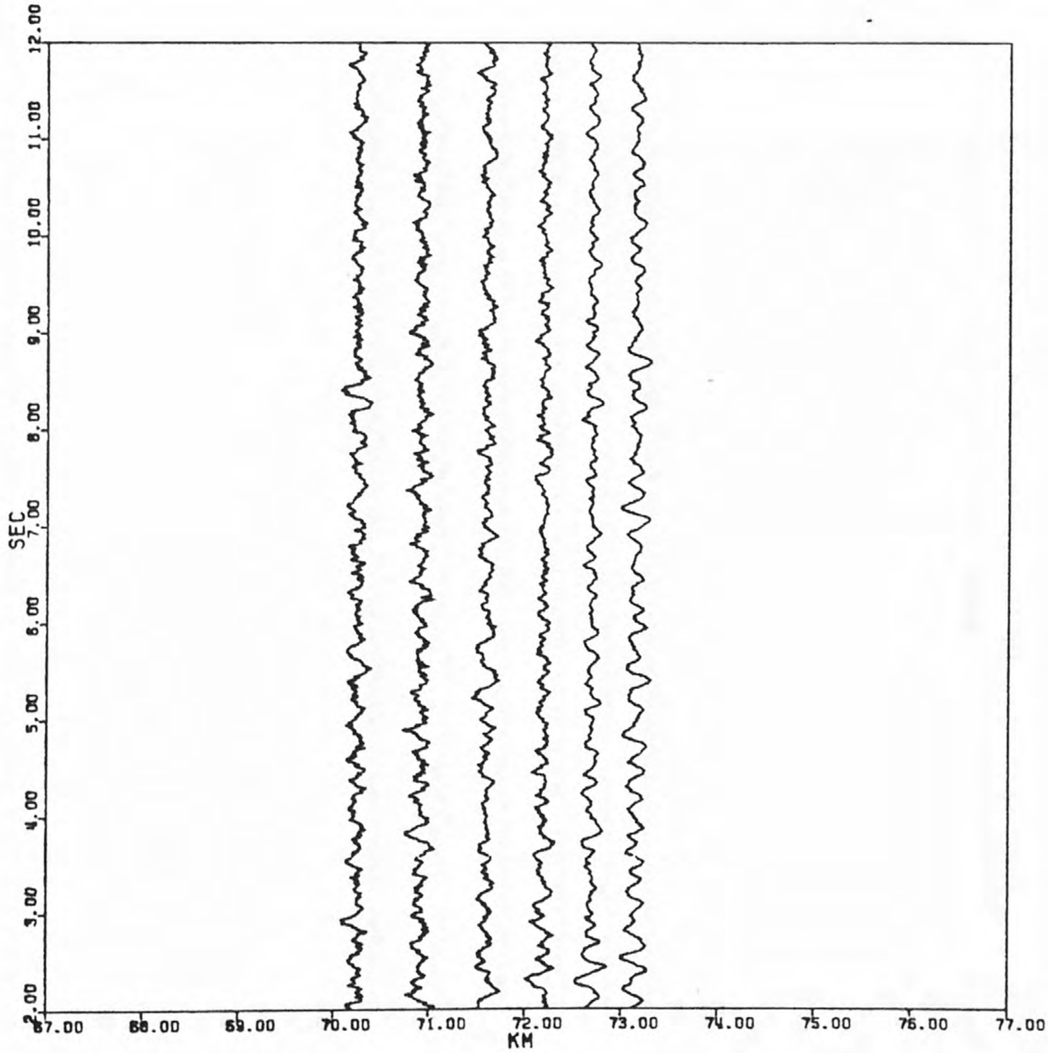
12.00
11.00
10.00
9.00
8.00
7.00
SEC
6.00
5.00
4.00
3.00
2.00
59.00
60.00
61.00
62.00
63.00
64.00
65.00
66.00
67.00
68.00
69.00
KM

FIG 5U



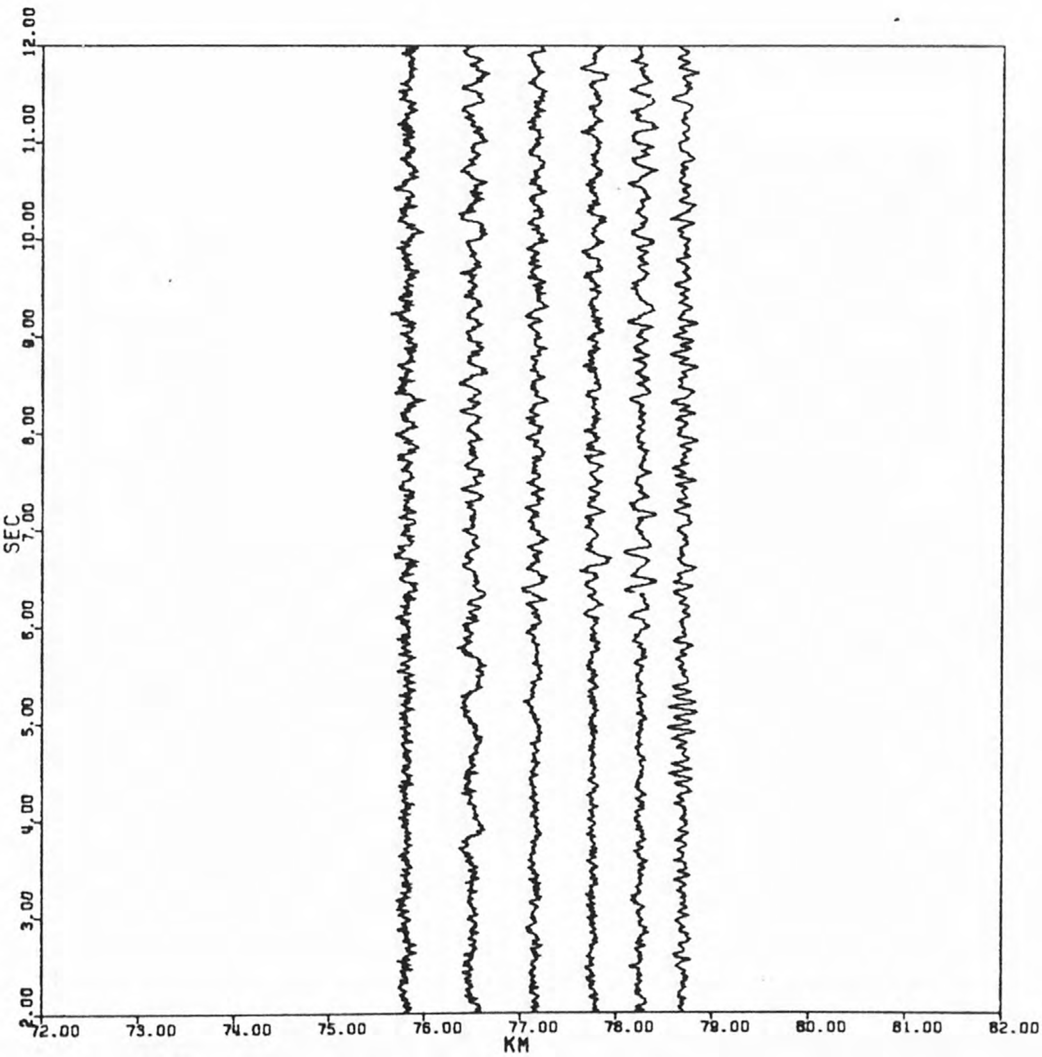
SEC
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
63.00
64.00
65.00
66.00
67.00
68.00
69.00
70.00
71.00
72.00
73.00
KM

FIG 5V



SEC
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
67.00
68.00
69.00
70.00
71.00
72.00
73.00
74.00
75.00
76.00
77.00
KM

FIG 5W



12.00
11.00
10.00
9.00
8.00
SEC
7.00
6.00
5.00
4.00
3.00
2.00
72.00
73.00
74.00
75.00
76.00
77.00
78.00
79.00
80.00
81.00
82.00
KM

FIG 5X

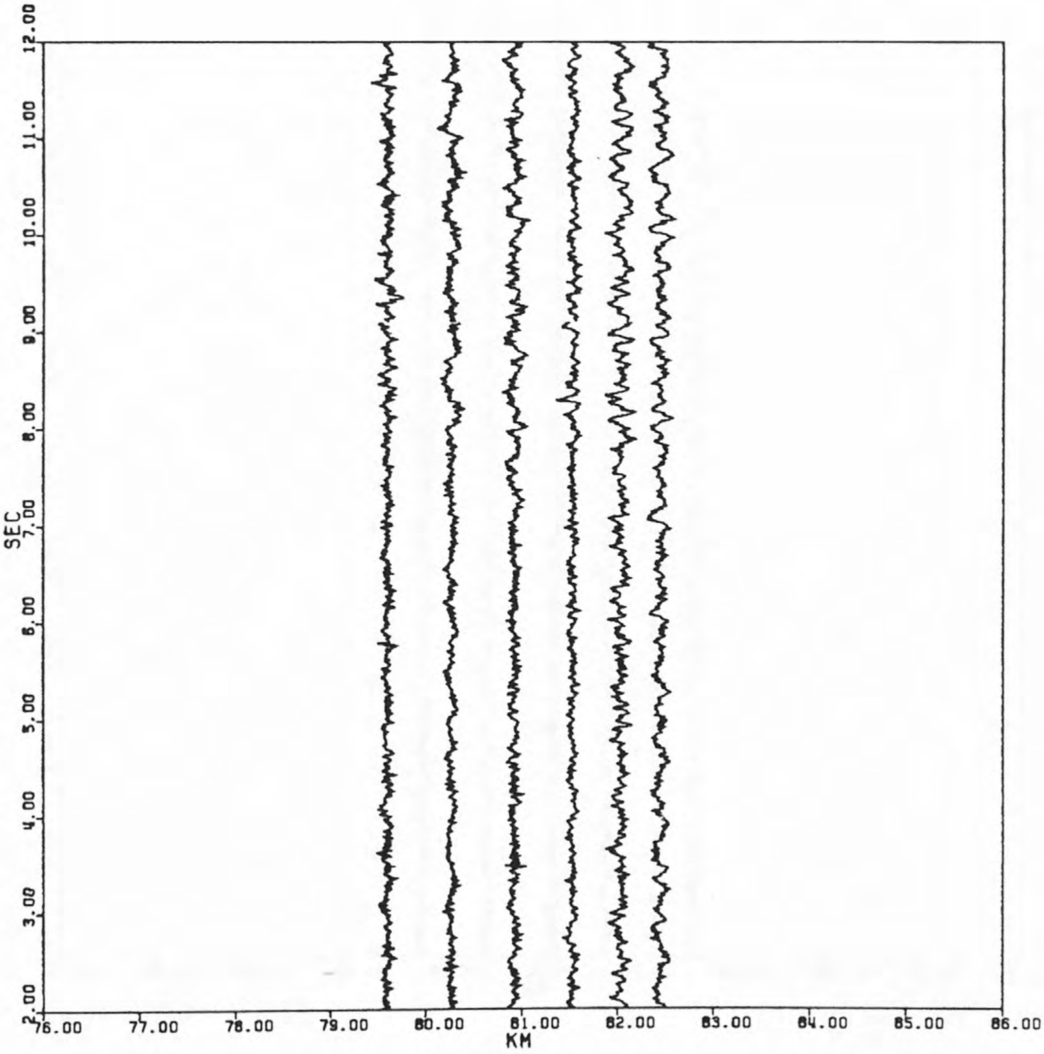
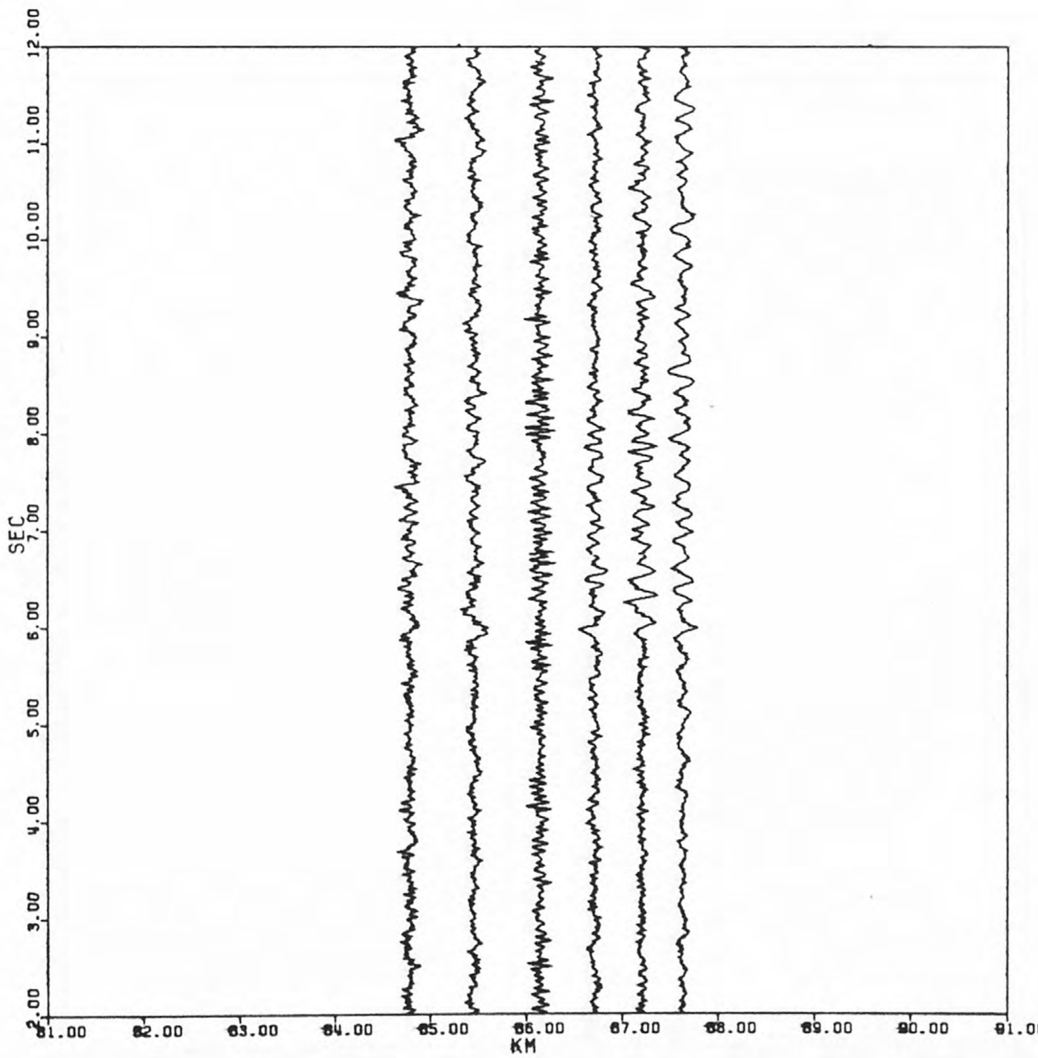

12.00
11.00
10.00
9.00
8.00
SEC
7.00
6.00
5.00
4.00
3.00
2.00
76.00
77.00
78.00
79.00
80.00
81.00
82.00
83.00
84.00
85.00
86.00
KM

FIG 5Y



12.00
11.00
10.00
9.00
8.00
SEC
7.00
6.00
5.00
4.00
3.00
2.00
81.00
82.00
83.00
84.00
85.00
86.00
87.00
88.00
89.00
90.00
91.00
KM

FIG 5Z

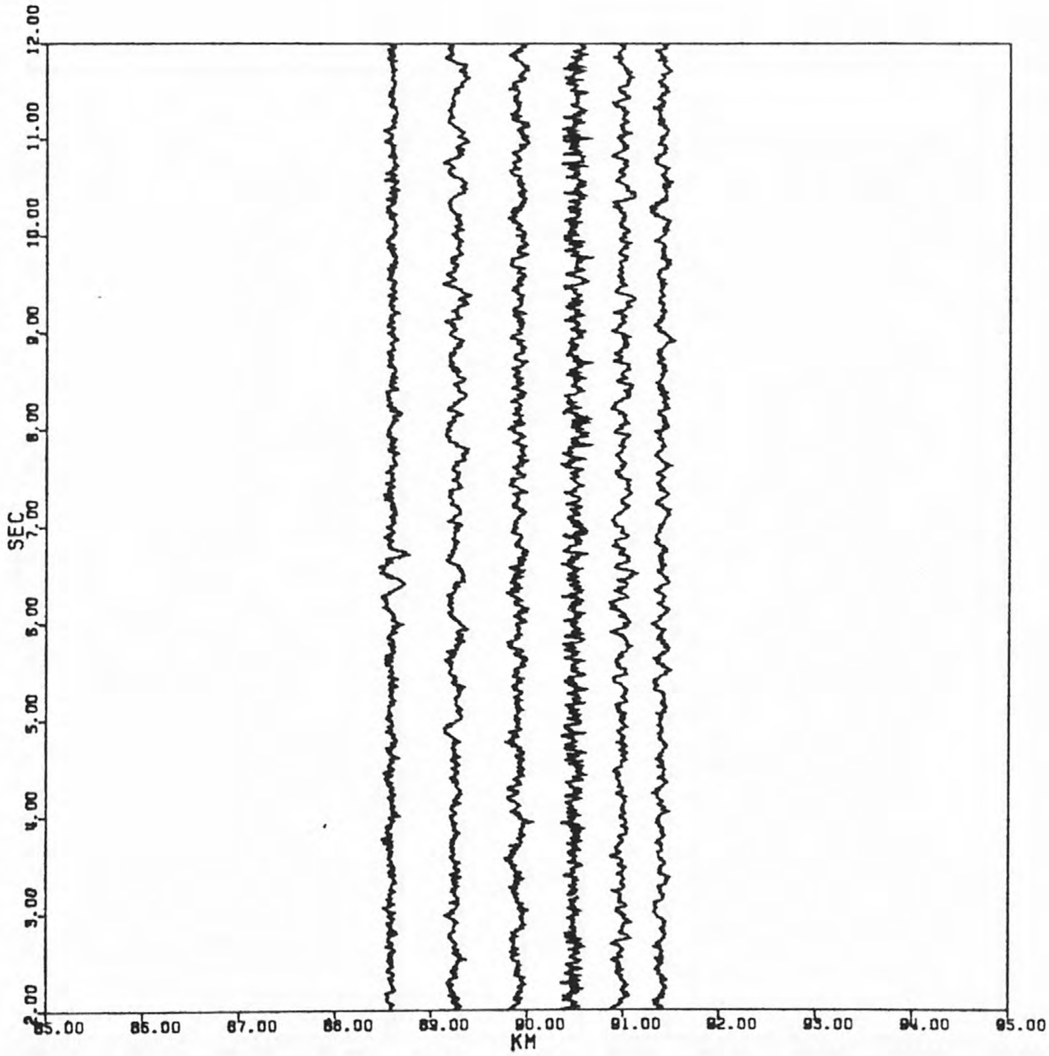

SEC
12.00
11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
KM
87.00
93.00
95.00

FIG 5AA

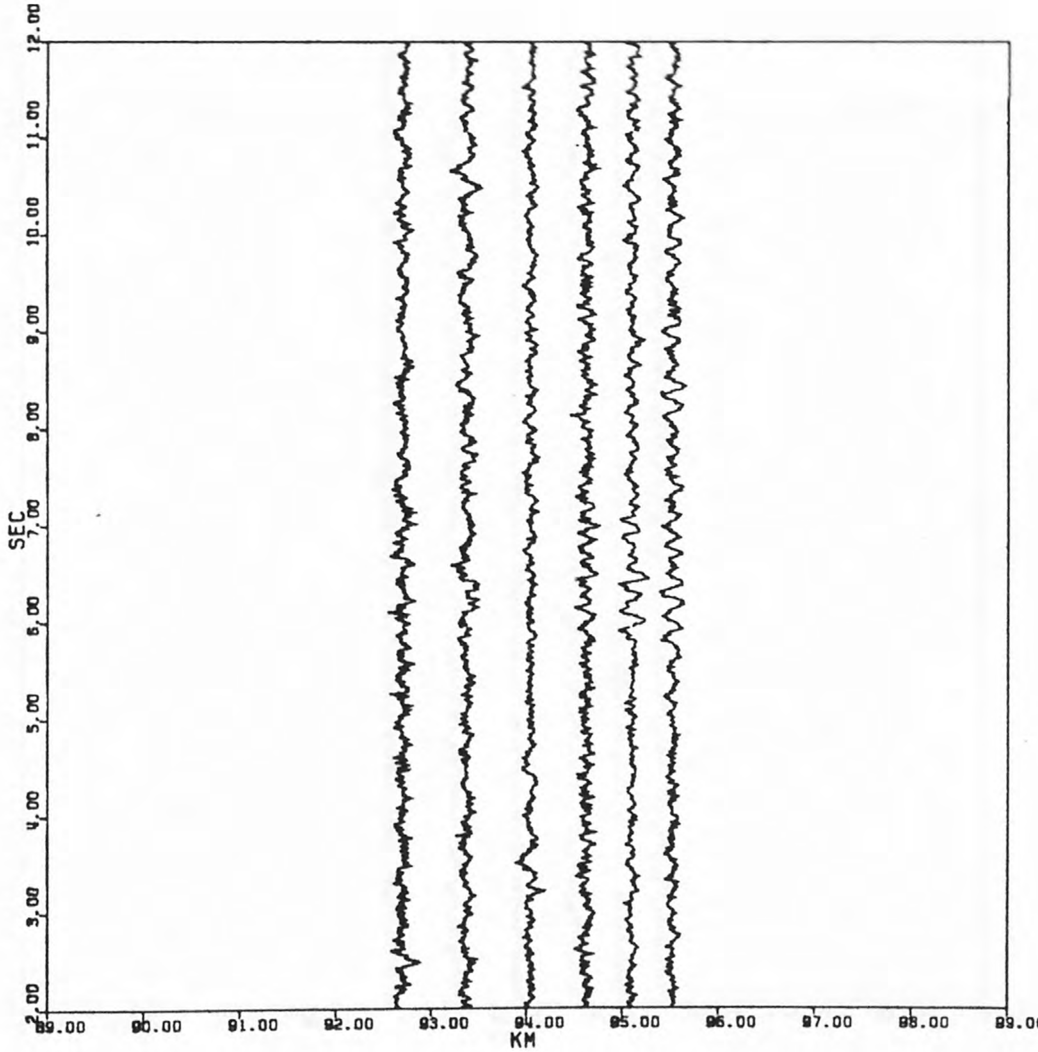

SEC
KM
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
89.00
90.00
91.00
92.00
93.00
94.00
95.00
96.00
97.00
98.00
99.00

FIG 5BB

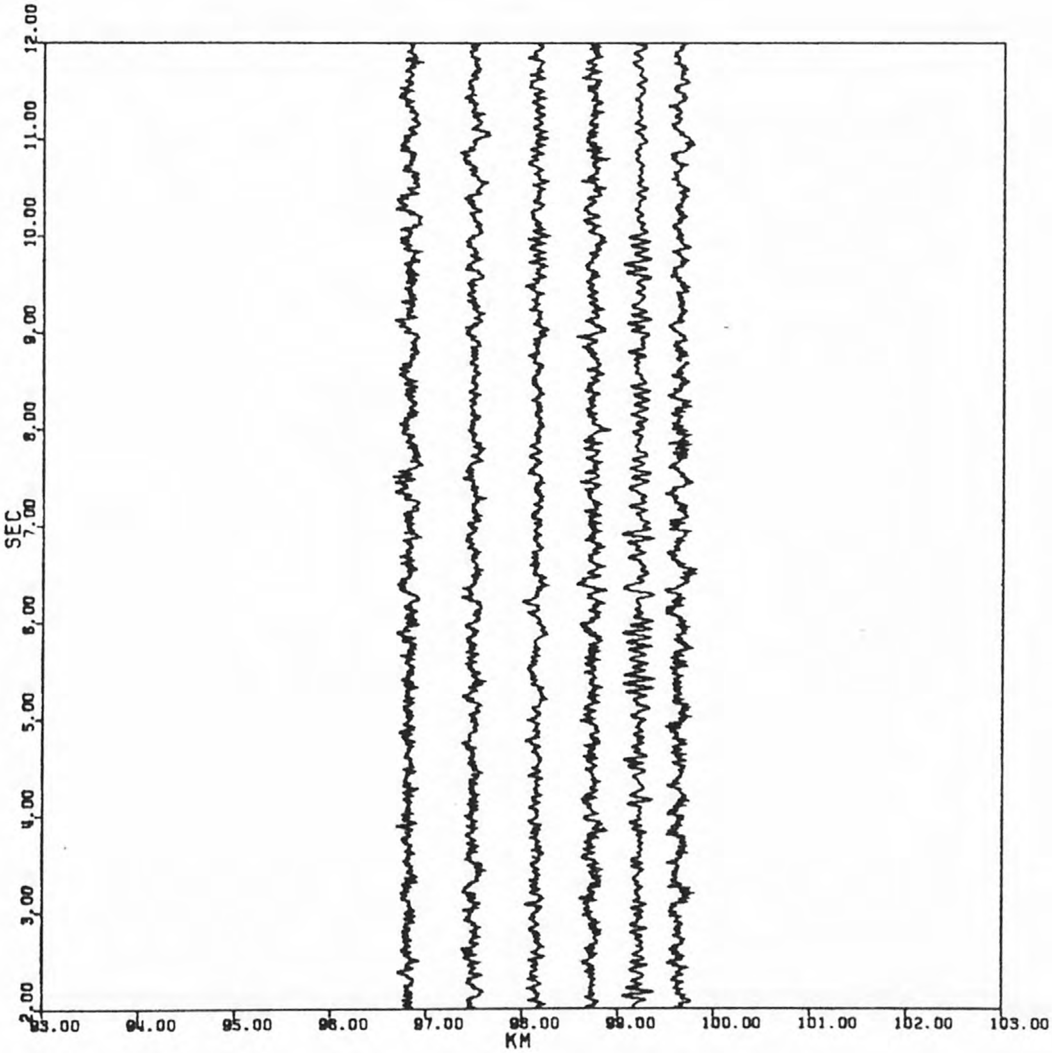
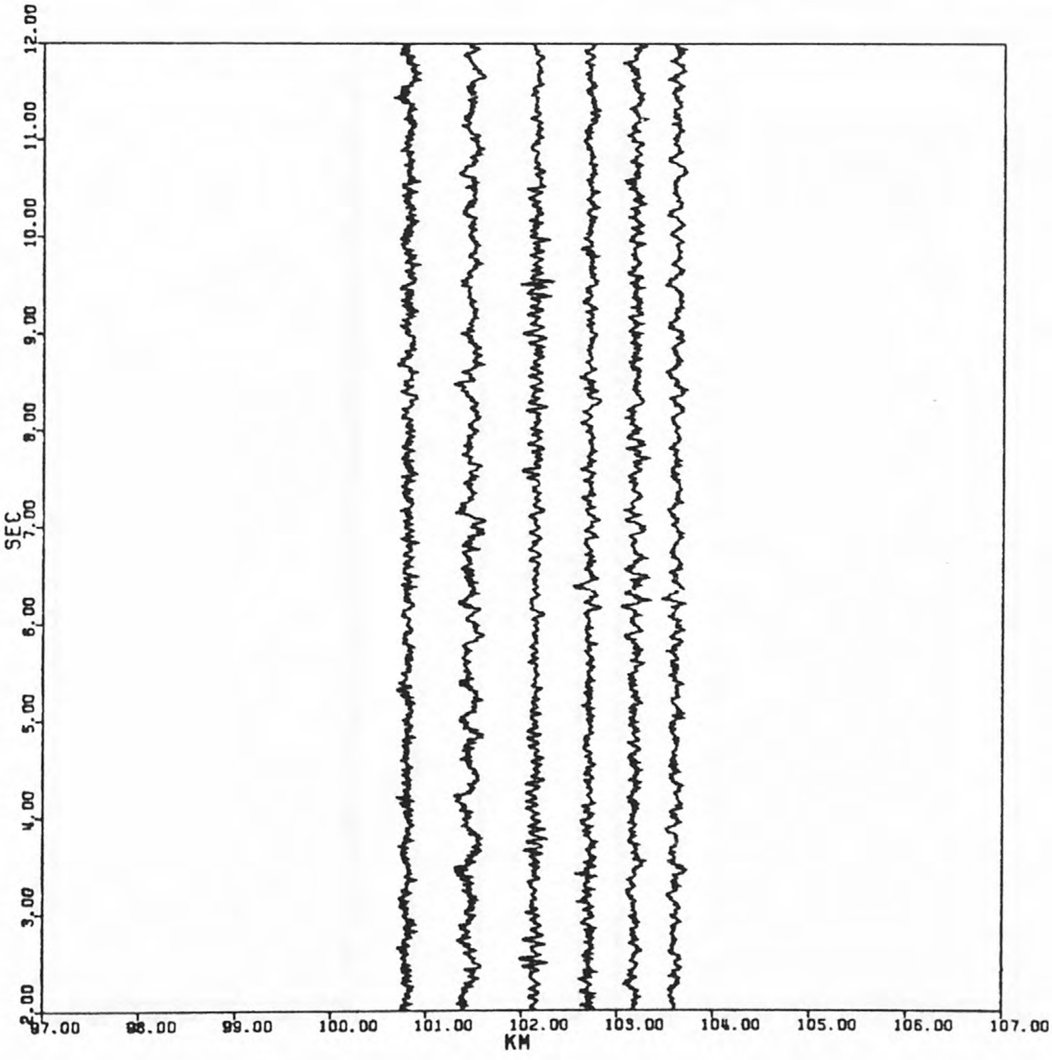
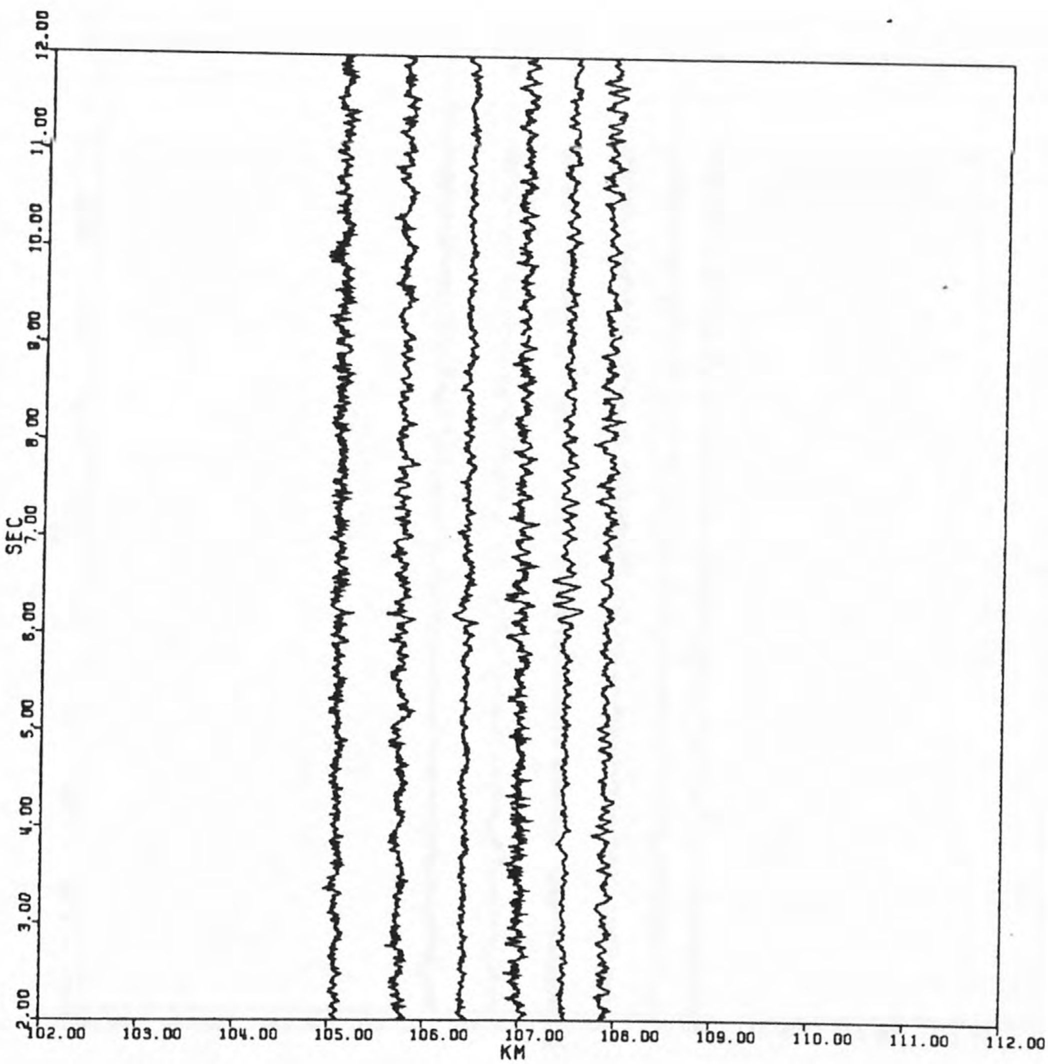

SEC
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
93.00
94.00
95.00
96.00
97.00
98.00
99.00
100.00
101.00
102.00
103.00
KM

FIG 5CC



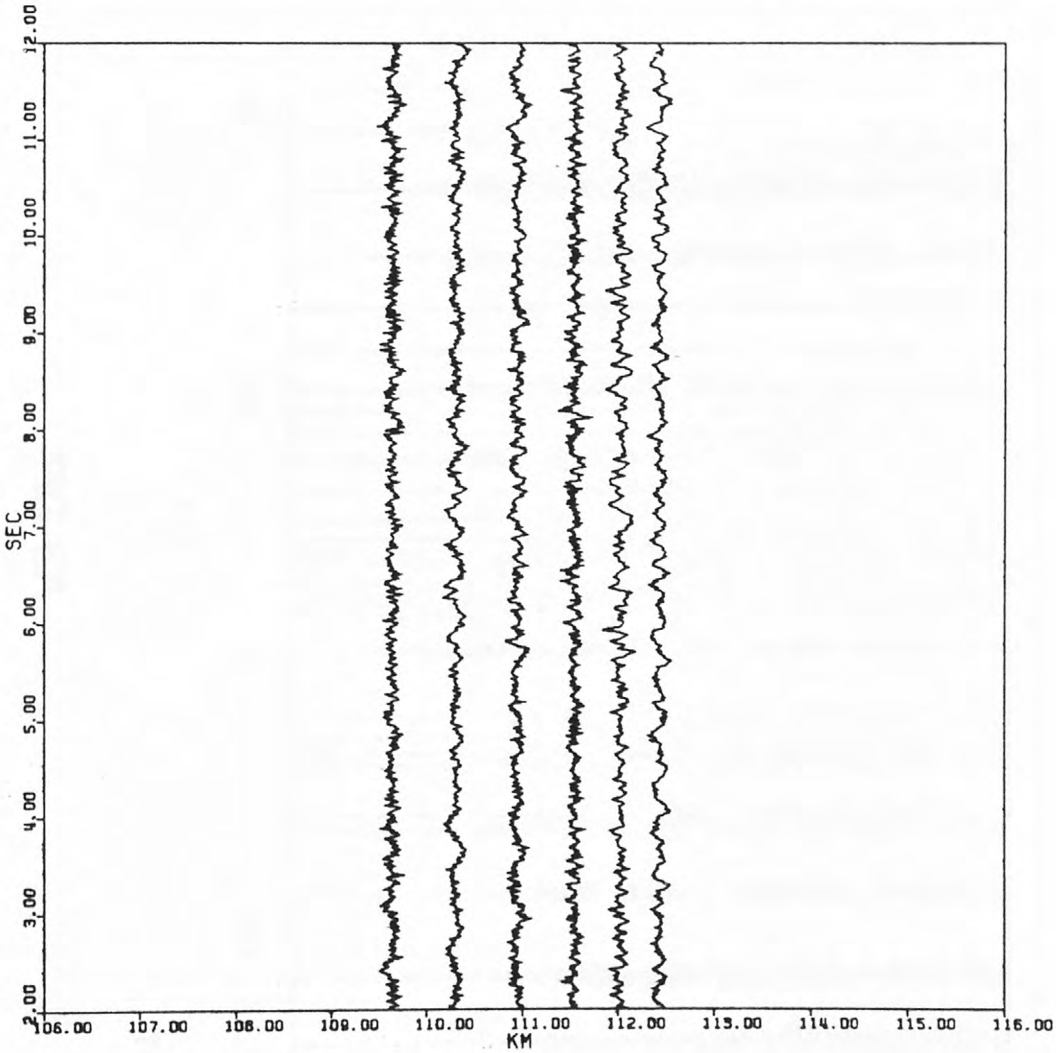
12.00
11.00
10.00
9.00
8.00
SEC
7.00
6.00
5.00
4.00
3.00
2.00
97.00
98.00
99.00
100.00
101.00
102.00
103.00
104.00
105.00
106.00
107.00
KM

FIG 5DD



12.00
11.00
10.00
9.00
8.00
7.00
SEC
6.00
5.00
4.00
3.00
2.00
102.00
103.00
104.00
105.00
106.00
107.00
108.00
109.00
110.00
111.00
112.00
KM

FIG 5EE



SEC
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
106.00
107.00
108.00
109.00
110.00
111.00
112.00
113.00
114.00
115.00
116.00
KM

FIG 5FF

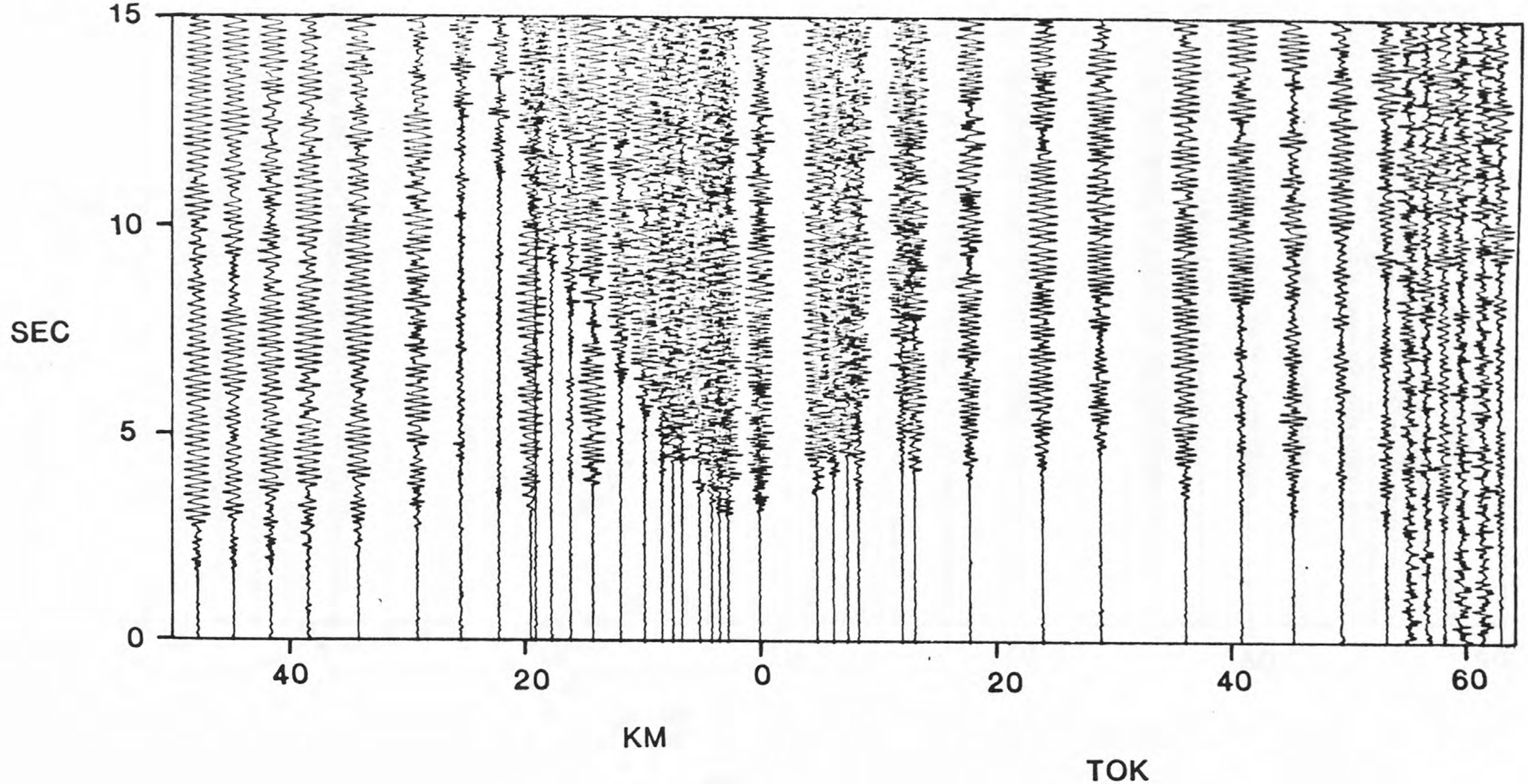


FIG 6A

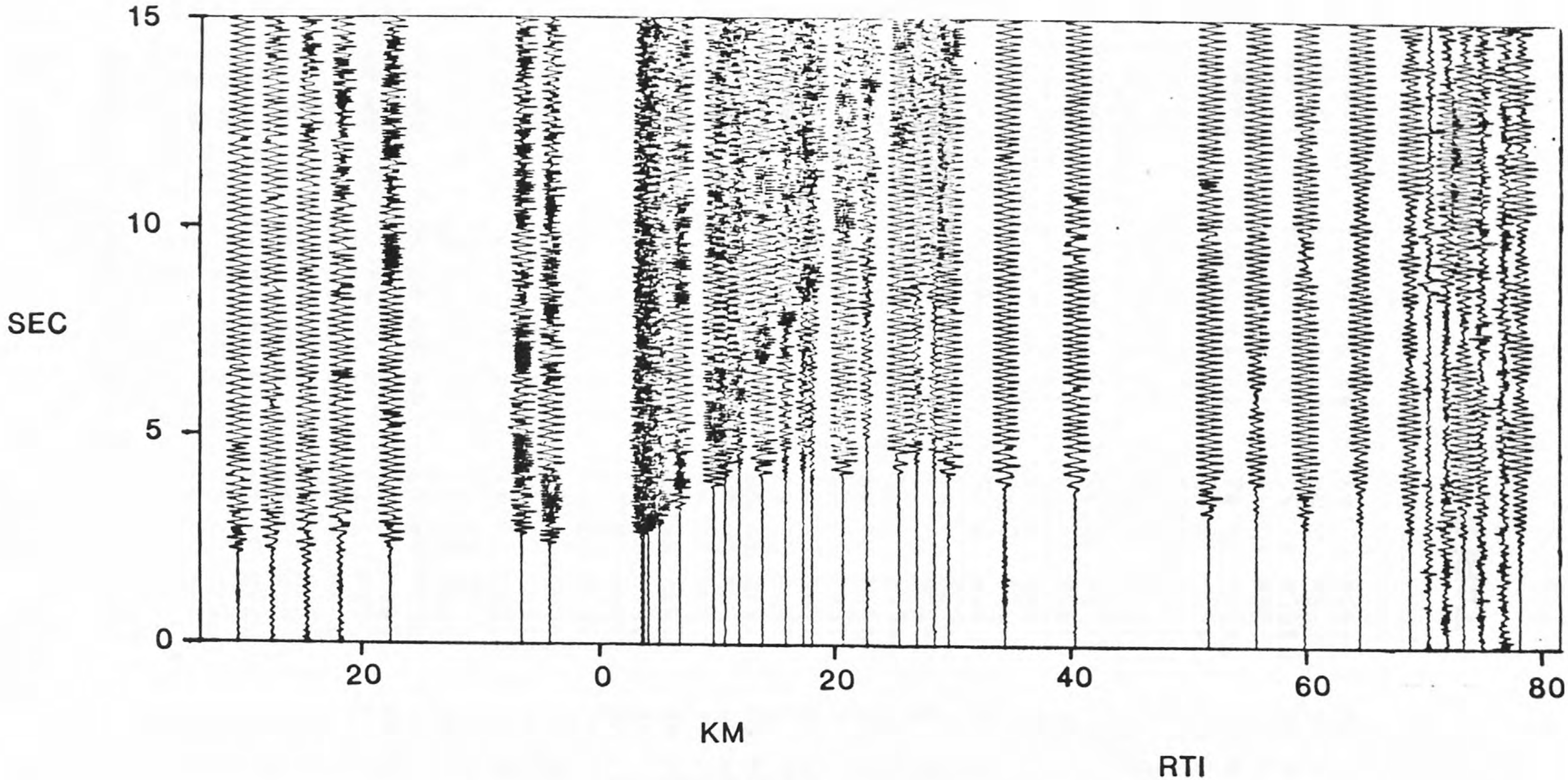


FIG 6B

LATITUDE		LONGITUDE		OTIME(HMS)			SIZE
18N	32.33	154W	36.09	9	11	29.27	large
18N	33.19	154W	36.23	9	15	40.88	small
18N	33.53	154W	37.36	9	20	39.90	small
18N	34.17	154W	37.84	9	26	26.30	large
18N	34.76	154W	38.33	9	30	44.36	small
18N	35.37	154W	38.81	9	35	42.35	small
18N	36.01	154W	39.33	9	41	30.74	large
18N	37.63	154W	40.83	9	56	28.70	large
18N	39.29	154W	42.42	10	11	24.86	large
18N	41.01	154W	43.93	10	26	28.20	large
18N	42.51	154W	45.43	10	41	27.50	large
18N	44.61	154W	47.43	11	1	26.81	large
18N	46.13	154W	48.91	11	16	24.24	large
18N	48.36	154W	51.11	11	36	23.97	large
18N	49.98	154W	52.73	11	51	25.20	large
18N	50.52	154W	53.31	11	55	38.52	small
18N	51.02	154W	53.84	12	0	41.38	small
18N	51.57	154W	54.38	12	6	28.04	large
18N	52.67	154W	55.52	12	15	38.74	small
18N	53.22	154W	56.08	12	21	30.18	large
18N	54.08	154W	56.65	12	25	41.80	small
18N	54.69	154W	57.26	12	30	41.76	small
18N	55.28	154W	57.87	12	35	36.89	small
18N	55.89	154W	58.48	12	41	25.43	large
18N	56.44	154W	59.04	12	45	42.07	small
18N	57.56	154W	59.69	12	50	40.51	small
18N	57.62	155W	0.18	12	56	28.80	large
18N	58.19	155W	0.81	13	0	42.27	small
18N	58.41	155W	1.31	13	5	40.29	small
18N	58.99	155W	1.85	13	10	39.84	small
18N	59.97	155W	2.49	13	16	30.86	large
19N	0.58	155W	3.05	13	20	39.19	small
19N	1.16	155W	3.60	13	25	40.84	small
19N	1.80	155W	4.18	13	30	41.69	small
19N	2.04	155W	4.71	13	36	23.19	large
19N	2.63	155W	5.28	13	40	40.00	small
19N	3.61	155W	5.94	13	45	41.37	small
19N	4.91	155W	7.17	13	56	26.44	large
19N	6.66	155W	8.82	14	11	31.71	large
19N	8.52	155W	10.41	14	26	28.53	large
19N	9.79	155W	11.51	14	36	29.03	large
19N	11.07	155W	12.60	14	46	29.23	large
19N	12.29	155W	13.69	14	56	24.71	large

TABLE 1

NAME	LATITUDE	LONGITUDE	ELEVATION(METERS)
AHU	19N 22.40	155W 15.90	1070
AIN	19N 22.50	155W 27.60	1524
CPK	19N 23.70	155W 19.70	1038
DAN	19N 21.42	155W 40.00	3003
DES	19N 20.20	155W 23.30	815
ESR	19N 24.68	155W 14.30	1177
HLP	19N 17.96	155W 18.60	707
HSS	19N 36.31	155W 29.10	2445
KAE	19N 17.35	155W 7.90	37
KHU	19N 14.90	155W 37.10	1939
KII	19N 30.56	155W 45.90	1841
KKU	19N 53.39	155W 20.50	1863
KPN	19N 20.10	155W 17.40	924
LUA	19N 24.55	155W 4.20	622
MLX	19N 27.60	155W 20.70	1475
MOK	19N 29.28	155W 35.90	4000
MPR	19N 22.07	155W 9.80	881
MTV	19N 30.25	155W 3.70	409
NAG	19N 42.12	155W 1.70	18
NPT	19N 24.90	155W 17.00	1115
OTL	19N 23.40	155W 16.80	1084
PAU	19N 22.62	155W 13.10	994
PHO	19N 28.90	154W 53.40	215
POL	19N 17.02	155W 13.40	169
PPL	19N 9.50	155W 27.80	35
RIM	19N 23.90	155W 16.60	1128
SCA	19N 28.20	155W 35.00	4048
SWR	19N 27.26	155W 36.30	4048
TAN	19N 27.79	154W 58.50	351
WHA	19N 19.90	155W 2.90	29

TABLE 2

NAME	LATITUDE	LONGITUDE	ELEVATION(METERS)
KMA	19N 18.50	155W 05.21	19
NLU	19N 03.81	155W 34.90	195
OPK	19N 26.14	154W 53.55	58
AR1	19N 19.95	155W 13.47	799
AR2	19N 20.36	155W 13.49	838
AR3	19N 20.68	155W 13.73	890
AR4	19N 21.05	155W 13.73	925
AR5	19N 21.43	155W 13.63	960
AR6	19N 21.82	155W 13.50	973

TABLE 3