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(re-issue)

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ATOMIC WEAPONS RESEARCH ESTABLISHMENT

AWRE REPORT No. O 16/84 (re-issue)

**Body Wave Magnitudes and Locations of Soviet Underground
Explosions at the Semipalatinsk Test Site**

(UK UNCLASSIFIED)

P D Marshall

T C Bache

R C Lilwall

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**AWRE,
MOD(PE),
Aldermaston, Berks.**

UK UNLIMITED

October 1985

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**P D Marshall
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Recommended for issue by

A Douglas, Superintendent

Approved by

F E Whiteway, Head of Division

**† Science Applications Inc
10210 Campus Point Drive
P O Box 2351
San Diego
CA 92121
USA**

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ISBN 0 85518159 1

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This report is a re-issue of AWRE Report O16/84, December 1984. It contains minor amendments to table A1, figure A1 and tables 1, 4 and 7.

SUMMARY

At their underground nuclear test site near Semipalatinsk in eastern Kazakhstan the Soviet Union detonates explosions in three distinct areas called Shagan River, Degelen Mountain and Konystan. A least squares joint estimate of origin time, epicentre and magnitude is presented for explosions in each of these areas. These are based on data taken from the bulletins of the International Seismological Centre. Further, explosions in the northeast and southwest portions of the Shagan River site write distinctly different waveforms, suggesting that this site can be sub-divided into two test areas characterised by different geophysical properties.

1. INTRODUCTION

Basic source information (location, origin time, depth, yield, etc) about underground nuclear explosions is important to seismologists interested in fundamental properties of the structure of the earth, as well as those interested in discrimination between earthquake and explosion generated seismic signals. Numerous scientists have appealed for the release of epicentral details of explosions to aid research programmes (Bullen, 1958, Griggs and Press, 1961, Teller, 1963) (1-3). In response, Springer and Kinnaman (1971, 1975) (4,5) published the basic epicentre details for all underground nuclear explosions, US and British, detonated in the USA from 1961 to 1973. Numerous yield estimates were also included. The origin times and precise epicentres of French underground nuclear explosions in the Sahara between 1961 and 1966 have been published by Duclaux and Michaud (1970) (6). However, no comparable data are available for underground explosions in the USSR.

Several international data centres collect seismic wave arrival times from all over the world and compute estimates of the origin time, epicentre, depth and size for seismic disturbances. Bulletins containing these data are published by the US National Earthquake Information Service (NEIS) in Colorado, USA, and the International Seismological Centre (ISC) in Newbury, UK. A similar service is provided by the Institute of Physics of the Earth in Moscow, but the Soviet bulletin does not report data on Soviet nuclear explosions.

To provide the seismological community with improved estimates for some of the basic source information about USSR presumed underground nuclear explosions, seismic wave arrival time and amplitude data collected by the ISC have been analysed using a joint epicentre technique (JED) to relocate the epicentres, and a least squares analysis (LSMF) of amplitude data to provide consistent estimates of the seismic magnitude. The results are for explosions provisionally located by the ISC at the principal Soviet test site in Kazakhstan. Within this test area three distinct groups of epicentres emerge and are associated with regions called Shagan River, Degelen Mountain and Konystan. In our analysis each region is treated as separate and distinct.

The seismic waveforms from the UK type arrays EKA (Eskdalemuir, Scotland), GBA (Gauribidanur, India) and WRA (Warramunga, Australia) are presented in appendix A for most Shagan River and Degelen Mountain events. A remarkable feature of the Shagan River waveforms is that they divide into two distinctly different classes which turn out to be almost perfectly correlated with location in the northeast and southwest portions of the site. Analysis of the spectra of events in the two regions indicates that northeast Shagan events have systematically lower corner frequency, which appears to be due almost entirely to source material property differences. Thus, the Shagan River site can be subdivided into two regions which seem to be characterised by different geophysical properties.

It is planned to extend this study at a later date to include other Soviet test sites, eg, Novaya Zemlya and North Caspian Sea. A similar report is also planned to provide estimates of the basic epicentral data for French underground nuclear explosions at Mururoa in the South Pacific.

2. JOINT EPICENTRE RELOCATIONS

The Joint Epicentre Determination (JED) method described by Douglas (1967) (7) was used to relocate the events. The P wave arrival time data were taken from International Seismological Centre (ISC) bulletin tapes which contain arrival times, distance, azimuth, etc, for each explosion at the Semipalatinsk test site. JED is most effective when all the events are from a limited spatial region, since deviations from the assumed travel time curve can then be corrected by a single term for each station. The explosions for the Shagan, Degelen and Konystan sites were therefore located as three separate groups. To obtain stable solutions, the epicentre and origin time of one explosion from each group was restrained to a predetermined value. For Shagan the cratering shot of 15 January 1965, was used since the absolute location of the crater is known from published satellite data (Shore, 1982) (8). Unfortunately, the number of stations recording this and other Shagan explosions is relatively small (70 out of a total of 599 used), and is even less for the Degelen and Konystan sites. Relocations for the latter sites were therefore tied to those for Shagan in the following way. First the Degelen explosions were located by including the best recorded Shagan explosion (22 April 1981), constrained to its relocated position. Similarly the explosions at Konystan were relocated with respect to the well recorded Degelen explosion of 26 March 1978. Relative locations within each group are thus optimised by keeping the groups spatially small. The absolute locations tied directly (Shagan) or indirectly to the only known location at the Semipalatinsk site. Clearly, this procedure cannot allow for lateral variations in seismic velocities across the three sites, and absolute locations for explosions at Degelen and Konystan will have larger errors.

A system of weighting arrival time reading was used to remove gross errors and allow for variations in the quality of arrival time measurements between stations. Gross errors were removed by the method of uniform reduction (Jeffreys 1961) (9). For all three sites the arrival time residuals were small (standard deviation ≈ 0.2 s), indicating that, in general, the P wave onsets were well identified and accurately timed.

With such high quality data, arrival times with residuals in excess of 0.6 s are effectively given zero weight. For the Shagan and Degelen data the large number of readings contributed by many of the stations enabled estimates of the standard deviation of the residuals for each station to be made, and the readings were also weighted to account for variations in this. For the Konystan data all station weights were set to unity.

Tables 1, 4 and 7 give the locations together with their 95% confidence limits. All depths were constrained to 0.0 km. The confidence limits indicate that with few exceptions locations are accurate to 3 km or better. For the Degelen and Konystan sites, however, the confidence limits for the absolute locations will be underestimated, as they do not include uncertainties in the location of the restrained event ($\approx \pm 1.5$ km) or uncertainties due to lateral variations in velocity structure when moving away from the Shagan site.

3. DETERMINATION OF MAGNITUDE

The size of a seismic source is measured by its magnitude. For short period (SP) seismic P wave data the Gutenberg and Richter definition is used:-

$$m_b = \log_{10} A/T + B(\Delta) + S, \quad (1)$$

where A is the amplitude of the P wave in nm, T its predominant period in seconds, $B(\Delta)$ a distance normalising term and S a station correction.

Consider n explosions recorded at some or all of q stations. Then if m is the magnitude of the i th explosion recorded at station j , we can write

$$m_{ij} = b_i + s_j + \epsilon_{ij}, \quad (2)$$

where b_i depends on the seismic size of the explosion, s_j is a station correction and ϵ_{ij} is an error term. Least squares can be used to estimate b_i and s_j if it is assumed that

$$\sum^i b_i = \sum^j s_j = 0.$$

By making the further assumption that the errors ϵ_{ij} are normally distributed, confidence limits can be determined for b_i and s_j . This is the procedure used to obtain the least squares estimate of the magnitude of explosions (Douglas, 1966) (10).

The basic input data are taken from the ISC bulletins, either as m_b or in the form of $\log_{10} A/T$ from which m_b is calculated. The stations used are located in the distance range 9 to 100° . The mean magnitude, which is a least squares estimate, is given for most explosions in tables 1, 4 and 7. Station corrections are given in tables 2, 5 and 8 and the statistical results of the least squares analysis in tables 3, 6 and 9, together with the 95% confidence limits and the number of observations. At present the least squares estimate of m_b is not available for all of the presumed explosions for which epicentres have been recalculated.

4. BISECTION OF THE SHAGAN RIVER TEST SITE

A remarkable feature of the Shagan River recordings from the UK seismological array stations (table 10) is that the character of the waveforms gives a consistent indication of whether the explosion is in the northeast or southwest half of the test site. Summed array recordings for most Shagan River and Degelen explosions are given in appendix A. Here we show a few examples to indicate the basis for the waveform classification. We also discuss the spectral characteristics of events in the two areas which suggest that the near source geology is different in the northeast and southwest portions of the Shagan River site.

The waveforms from explosions at Shagan River consistently fall into two classes. For example, at Eskdalemuir, Scotland (EKA) the waveforms for many explosions are quite simple, while others exhibit a consistent type of complexity. It is easy to recognise the two types and separate the explosions into Class 1, characterised by simple waveforms, and Class 2. Typical waveforms from each class are shown in figure A1. The Class 1 and Class 2 explosions also write distinctly different seismograms at Gauribidanur, India (GBA) and Warramunga, Australia (WRA) as shown in figure A2. At GBA the Class 1 explosions write very simple seismograms while the Class 2 explosions show a strong interference shortly after the second peak. At WRA Class 1 explosions write seismograms with little energy after the second peak, while Class 2 explosions are characterised by complex signals that continue for several cycles. At the Yellowknife, Canada (YKA) array data are too sparse to tell whether a similar separation occurs. However, the YKA single channel velocity broad-band data do not seem to separate into two classes. This may indicate that the waveform dichotomy does not occur at all azimuths, or (less likely) that array beaming to remove near receiver effects is necessary to bring out the differences.

For the three stations where the separation into two classes is clear, the waveform classification for 57 Shagan River explosions is summarised in table A1. Fifteen of these are observed at only one station, while 29 are observed at two and 13 at all three stations. Of the latter 42 explosions, the classification is ambiguous for only three. Thus, the waveform complexity for Class 2 explosions must be due to something about the source and/or its vicinity.

We note from the summary at the end of table A1 that while the Class 2 explosions have generally small m_b , there is too much overlap to attribute the waveform differences to source size. The examples in figures A1 and A2 also demonstrate this point. The explanation almost certainly must be in systematically different source coupling and/or near source geology.

In figure A3 the explosions of table A1 are plotted at the locations listed in table 1. The waveform differences correlate almost perfectly with location on either side of a N45°W line bisecting the test site. Note that there is only one exception (explosion 18) and that two of the three ambiguous explosions lie close to the dividing line. Clearly, there is some important difference between the northeast and southwest portions of the site.

The probable explanation for the waveform difference is that explosions in the northeast are in different source media than those in the southwest. The other possibility is that the waveform differences are due to systematic path differences, but the similar effects seen at three well separated azimuths argue against this. More important, there seems to be systematic differences in the source corner frequency between explosions in the two areas, and these can only be caused by differences in source coupling.

Bache et al (1984) computed spectra for most of the Shagan River and Degelen explosions for which waveforms appear in appendix A. For each array the explosion P wave spectra were computed by summing individual element energy density spectra (corrected by subtracting an estimate of the noise power spectrum) over all elements of the array. A station-source "path spectrum" was then computed by stacking spectra from groups of similar explosions. These spectra are plotted in figure A4. Except for YKA, where the Shagan River, southwest Shagan River and Degelen. All spectra have been multiplied by f^2 to correct for the source spectrum (Bache et al (1984)). (12).

The three populations of explosion spectra in Figure A4 are characterised by differences that are consistent from station-to-station and appear to be due to systematic corner frequency differences. The SALMON* spectrum is included to show the kind of spectrum we expect for a source with a corner frequency well above 1 Hz, which it must be for this small explosion. The P wave spectra for the Degelen explosions also show a clear indication that the corner frequency for most of these explosions must be over 1 Hz. In fact, it appears that the corner is greater than 2 Hz. Finally, the differences between the northeast and southwest Shagan spectra are just as we would expect if the corner frequency were lower for the latter population.

What is the cause of the corner frequency differences? We know that the corner frequency is controlled by the yield and the properties of the near source geology. These two effects can be separated to a large degree. When all else is equal, the corner frequency is inversely proportional to the cube-root of the yield, though in most cases the depth of burial increases with yield, which tends to make the corner frequency shift somewhat less than this (eg, Murphy, 1977) (13). The m_b gives a rough indication of relative yields, and the difference in mean m_b for the southwest Shagan and Degelen populations is 0.64 at GBA, 0.54 at WRA and 0.43 at EKA. In the simplest interpretation, assuming yield proportional to m_b and corner frequency to cube-root of yield, this translates to a corner frequency shift of 40 to 60%, which is enough less than the difference (a factor of two or more) needed to explain the spectra in figure A4 to conclude that there must be some source material property contribution to the corner frequency shift between Degelen and southwest Shagan. This conclusion is supported by the YKA data, since there is a perceptible difference even though the Degelen population for this station has a higher average m_b than the Shagan River population.

* A 5 kt explosion detonated in salt in Mississippi, Eastern USA.

When the yield and depth of burial are the same, the corner frequency should generally be higher for more competent or higher strength materials. For example, an explosion in granite would be expected to have a higher corner frequency than one in a porous sedimentary rock. Thus, the source material property contribution to the shift between Degelen and southwest Shagan is consistent with the expectation that the former events are in granite, while the latter are in a weaker or more porous material.

Nearly all the differences in corner frequency between the northeast and southwest Shagan populations must be attributed to differences in the source material since the mean m_b for the two populations is not very different. In fact, we show in figure A5 that the spectral differences persist almost unchanged when the populations are carefully selected to have the same mean m_b . Thus it seems likely that the northeast events are in a stronger material (more like Degelen) than the southwest events. This argument is further strengthened by observing (appendix A) that the northeast Shagan waveforms at GBA and EKA are more like the waveforms from explosions at Degelen than to those for southwest Shagan River. This picture is not perfect, since at WRA the Degelen explosions write waveforms that distinctly belong to a third class, but this exception could easily be caused by path effects, since Shagan and Degelen are more than 50 km apart.

In summary, the major conclusions drawn from an analysis of the spectra in figure A4 are as follows:-

- (a) The spectral differences at low frequencies are due to variations in the average corner frequency characterising Degelen, southwest Shagan and northeast Shagan explosions.
- (b) Rough estimates for the characteristic corner frequencies are <1 Hz for southwest Shagan, > 2 Hz for Degelen and intermediate between the two for northeast Shagan.
- (c) Some of the differences between Degelen and Shagan are due to the Degelen events having generally lower yield. This may be enough to explain all the difference between Degelen and northeast Shagan, but there must be some source material property contribution to the difference between Degelen and southwest Shagan.
- (d) The difference between northeast and southwest Shagan appears to be due almost entirely to source material differences.
- (e) From these data it appears that the Degelen explosions are in a higher strength source medium than those in southwest Shagan; for example, in granite compared to softer sedimentary rocks. The source material properties for northeast Shagan explosions appear to be more like those for Degelen than for the explosions in the southwest Shagan River area.

5. ACKNOWLEDGMENTS

The authors would like to express their appreciation to Mrs P Warburton and Mrs E Bradley for their help in the preparation of the data for subsequent analysis.

APPENDIX A

WAVEFORMS FOR SEMIPALATINSK EXPLOSIONS

In section 4 and table A1, the large Shagan River explosions are listed with an indication of the UK array stations for which good data are available. In this appendix are shown the waveforms corresponding to these tables; also included are some Degelen waveforms. These are beam sum seismograms resulting from delay-and-sum processing of the individual channels, using the slowness derived from the ISC locations and the Jeffreys-Bullen travel time tables. During the processing, channels which have a maximum amplitude larger than 90% of the clipping level are discarded. All data were examined and channels with obvious faults (spikes, dropouts and excessive system noise) were discarded.

The beam sum displayed here was computed from essentially the same channels used to compute the spectra discussed in section 4. Occasionally there are faults (small spikes) that only become apparent when the high frequency spectra are examined, but fewer than 5% of the data were discarded for this reason. However, the small spike problem is much more severe at WRA and 30 to 50% of the channels used to compute the WRA beam sum seismograms displayed here were discarded in computing the final spectra.

The seismograms are divided into three classes: southwest Shagan River, northeast Shagan River and Degelen. The reasons for the bisection of the Shagan River site are given in section 4.

TABLE A1
WAVEFORM CLASSIFICATION FOR SHAGAN RIVER EXPLOSIONS

No.	Date	m _b	Class*	EKA	GBA	WRA
1	15.01.65	5.85	'2'	2	X	X
2	19.06.68	5.35	'2'	2	X	X
3	30.11.69	6.00	'2'	2	X	X
4	30.06.71	5.29	2	2	2	X
5	10.02.72	5.37	2	2	X	2
7	10.12.72	6.00	2	2	X	2
9	14.12.73	5.82	2	2	X	2
11	31.05.74	5.83	'1'	1	X	X
12	16.10.74	5.47	2	2	2	X
13	27.12.74	5.50	2	2	2	X
14	27.04.75	5.56	2	2	2	X
15	30.06.75	4.63	2	2	2	X
16	29.10.75	5.74	?	1	2	X
17	25.12.75	5.70	2	2	2	X
18	21.04.76	5.28	'2'	2	X	X
19	09.06.76	5.12	2	2	2	X
20	04.07.76	5.81	'1'	1	X	X
21	28.08.76	5.82	2	2	2	X
22	23.11.76	5.87	2	2	2	X
23	07.12.76	5.90	'1'	1	X	X
24	29.05.77	5.77	'1'	1	X	X
25	29.06.77	5.22	2	2	2	2
26	05.09.77	5.74	2	2	2	2
28	30.11.77	5.92	'1'	1	X	X
29	11.06.78	5.86	1	1	X	1
30	05.07.78	5.83	'1'	1	X	X
31	29.08.78	5.95	2	2	2	2
32	25.09.78	5.99	1	1	X	1
33	04.11.78	5.56	2	2	2	2
34	29.11.78	6.07	'1'	1	X	X
35	01.02.79	5.38	2	2	X	X
36	23.06.79	6.22	1	1	X	1
37	07.07.79	5.73	'2'	2	X	1
38	04-08-79	6.16	1	1	X	1
39	18.08.79	6.12	2	2	X	2
40	28.10.79	5.96	2	2	X	2
41	02.12.79	6.01	1	1	X	1
42	23.12.79	6.18	1	1	X	1
43	25.04.80	5.50	'1'	X	1	X
44	12.06.80	5.59	2	X	2	2
45	29.06.80	5.74	1	1	X	1
46	14.09.80	6.21	1	X	1	1
47	12.10.80	5.90	2	2	2	2
48	14.12.80	5.95	?	2	1	1
49	27.12.80	5.88	2	2	2	2
50	29.03.81	5.61	2	2	2	X
51	22.04.81	6.05	1	1	1	1
52	27.05.81	5.46	'2'	X	2	X
53	13.09.81	6.18	1	1	1	1
54	18.10.81	6.11	1	1	1	1

*'1' and '2' indicate classification by only one waveform

CONTINUED/

Table A1 (cont'd)

<u>No.</u>	<u>Date</u>	<u>m_b</u>	<u>Class*</u>	<u>EKA</u>	<u>GBA</u>	<u>WRA</u>
55	29.11.81	5.73	1	1	1	X
56	27.12.81	6.31	1	X	1	1
57	25.04.82	6.1	1	X	1	1
58	04.07.82	6.1	'1'	X	1	X
59	31.08.82	5.4	?	1	2	X
60	05.12.82	6.1	1	1	X	1
61	26.12.82	5.7	2	2	2	2

SUMMARY

<u>m_b</u>	<u>Class 1</u>	<u>Class 2</u>
≤5.3	0	5
5.4-5.5	1	6
5.6-5.7	2	7
5.8-5.9	6	8
6.0-6.1	9	4
≥6.2	6	0
Total	24	30

* '1' and '2' indicate classification by only one waveform

TABLE A2
EXPLOSIONS INCLUDED IN STACKED SPECTRA IN FIGURE A5

SW SHAGAN		NE SHAGAN	
Date	m_b	Date	m_b
04-08-79	6.16	14-12-80	5.95
13-09-81	6.18	12-10-80	5.90
18-10-81	6.11	23-11-76	5.87
22-04-81	6.05	28-08-76	5.82
29-11-81	5.74	27-12-80	5.88
29-10-75	5.74	26-12-82	5.71
25-04-80	5.50	04-11-78	5.56
31-08-82	5.41	27-12-74	5.50
Mean	5.86		5.77
Standard Deviation	0.31		0.17

* From NEIS/PDE service

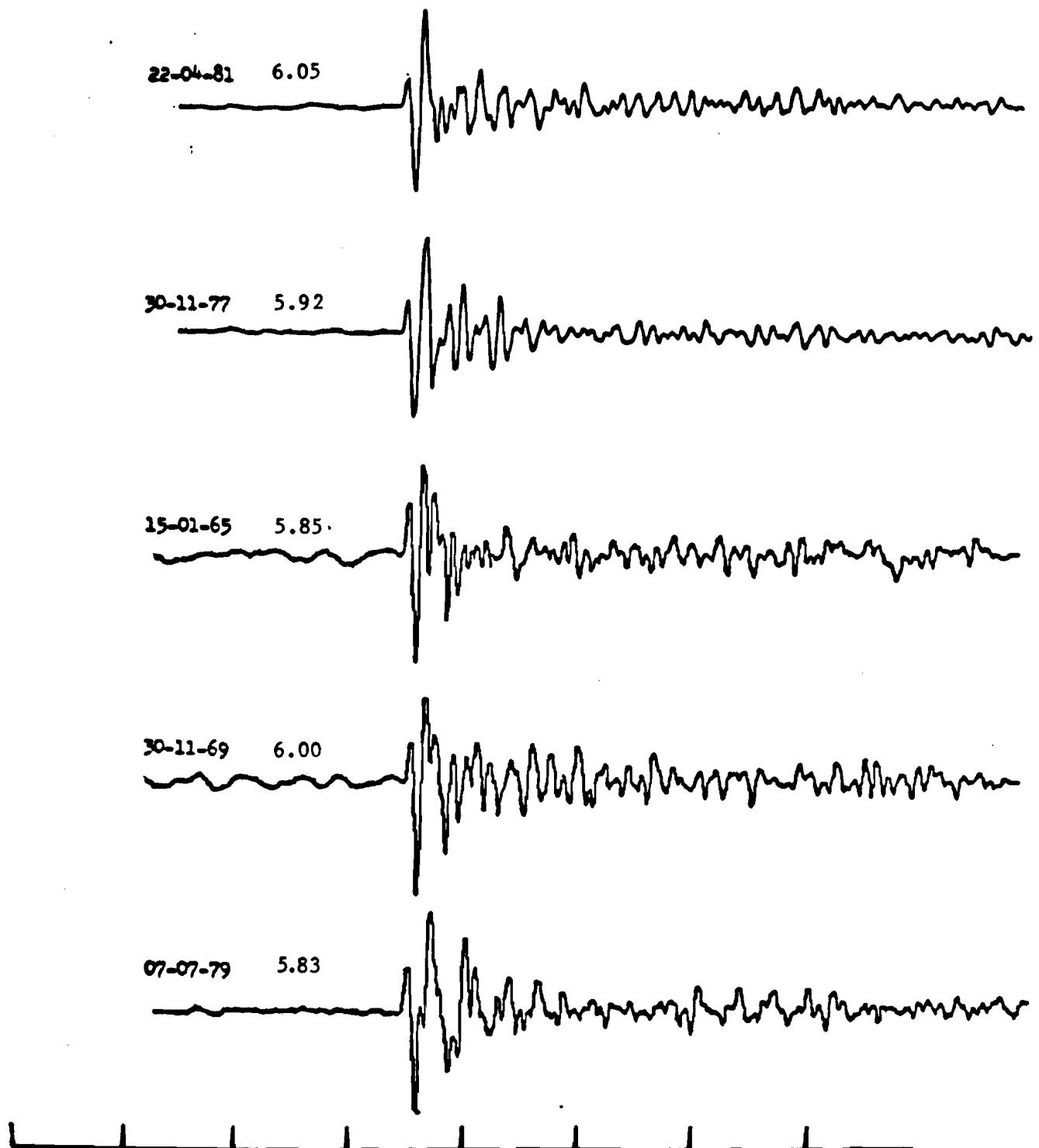


FIGURE A1 The YKA P-Wave seismograms (beamed array sum) are plotted for two Class 1 and three Class 2 Shagan River events. The m_b are indicated for each event.

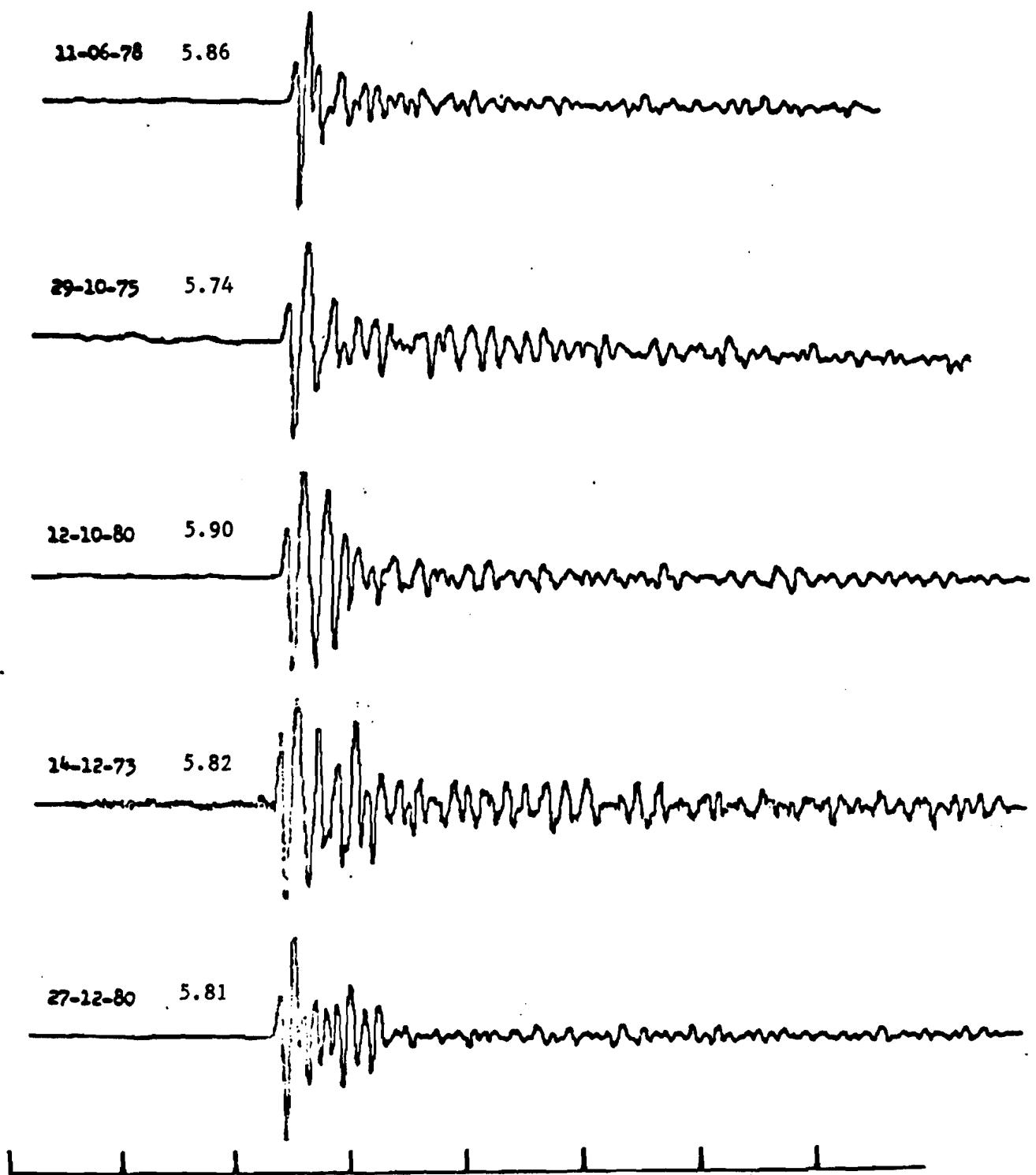


FIGURE A2

Two Class 1 and three Class 2 seismograms are plotted for WRA.

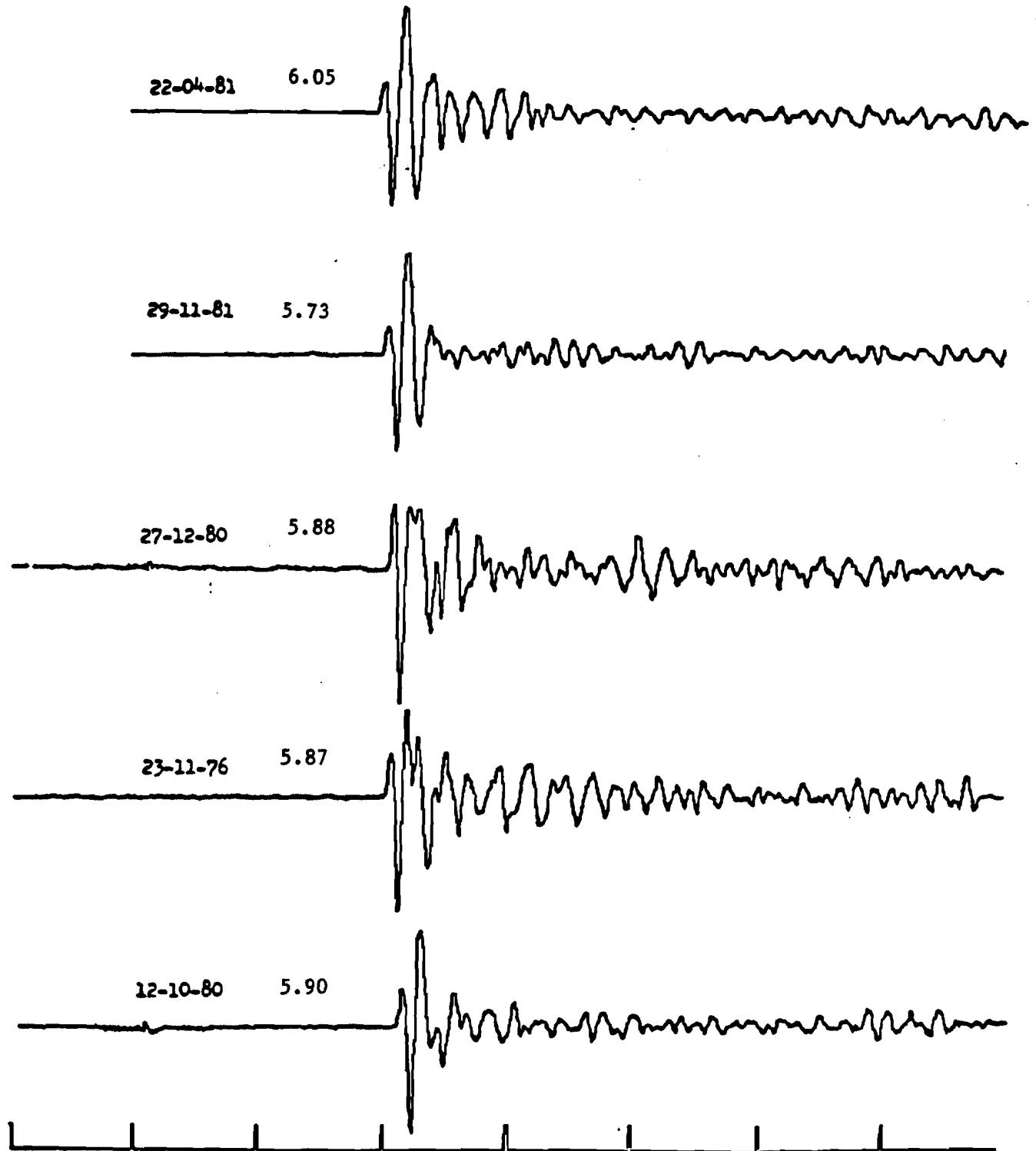


FIGURE A2 (cont'd) Two Class 1 and three Class 2 seismograms are plotted for GBA.

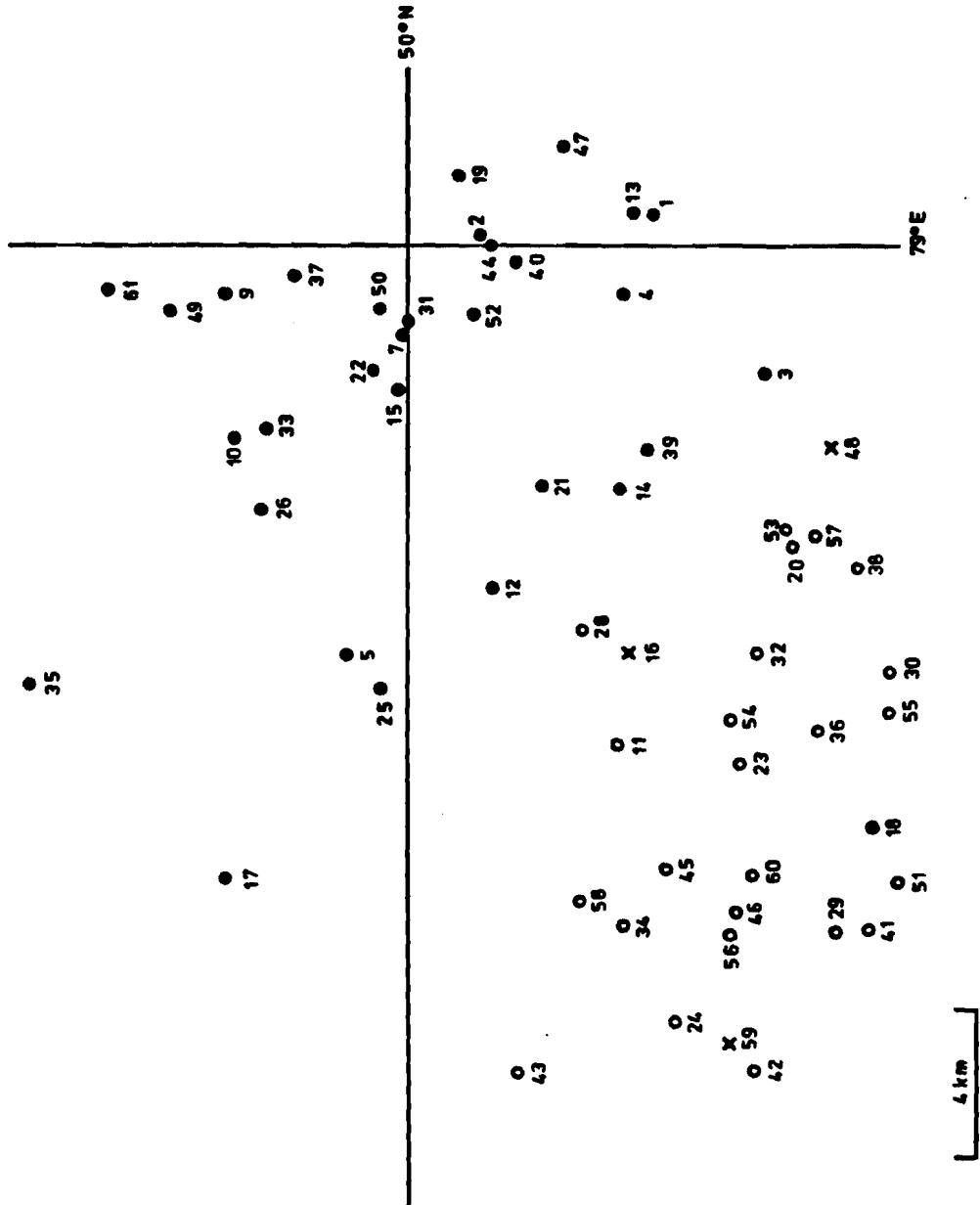


FIGURE A3 The Locations of Shagan River Explosions are Plotted with Symbols Representing Explosion Classification According to Waveform (Table A1). The Open and Solid Circles Represent Class 1 and Class 2 Events Respectively, while an X Represents an Explosion of Ambiguous Classification.

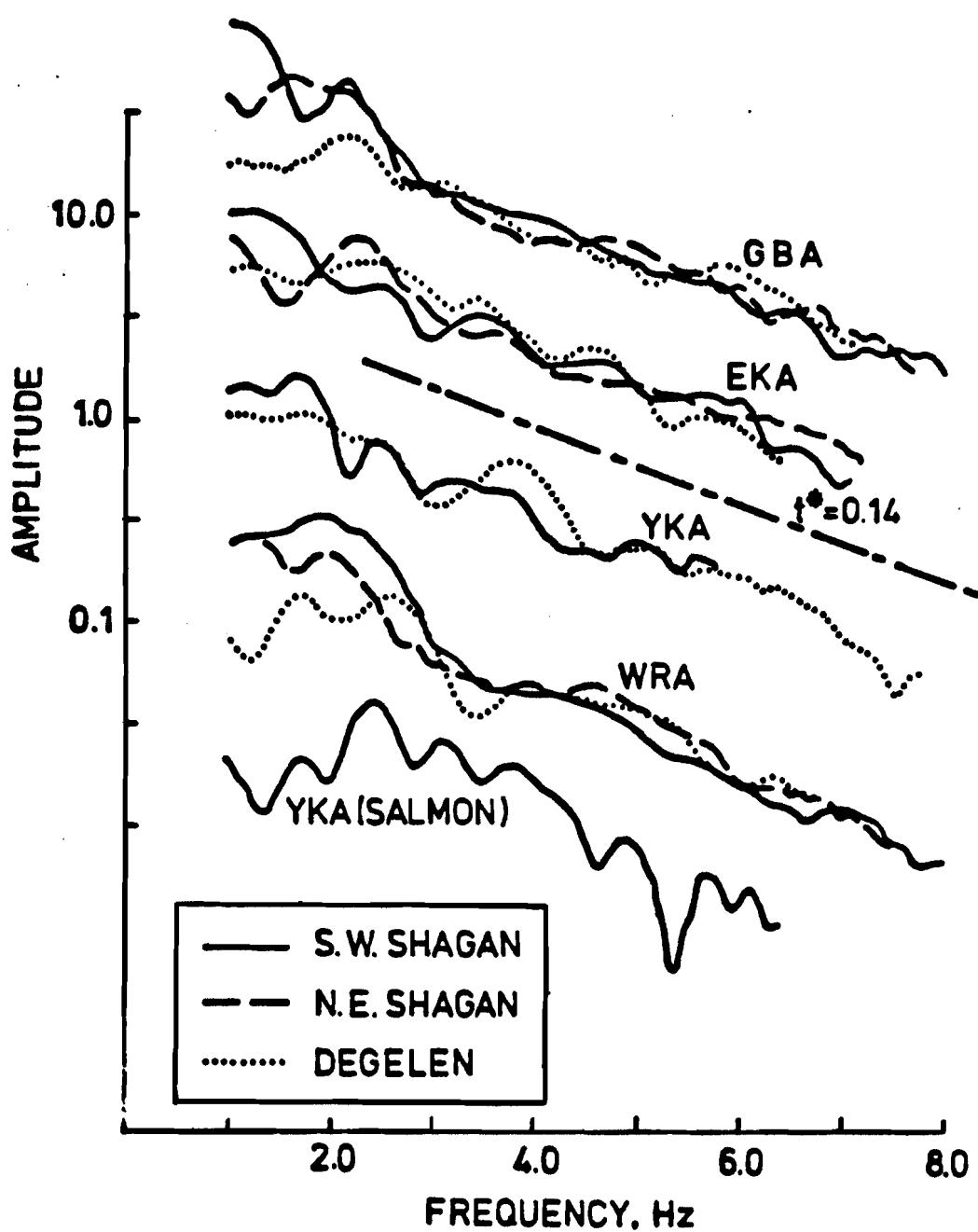


FIGURE A4 The stacked spectra are shown for E Kazakh explosions recorded at the UK arrays. The total number of spectra included are 36 at GBA, 38 at EKA, 16 at YKA and 28 at WRA. The events are divided into three populations, except at YKA where unclipped data were available for only five Shagan River events. At each station the stacked spectra are superimposed so that the least squares linear fit in the 2.5 to 8.0 Hz band passes through the same value at 5 Hz. Also shown is the spectrum for SALMON at YKA and a line with slope corresponding to $t^* = 0.14$.

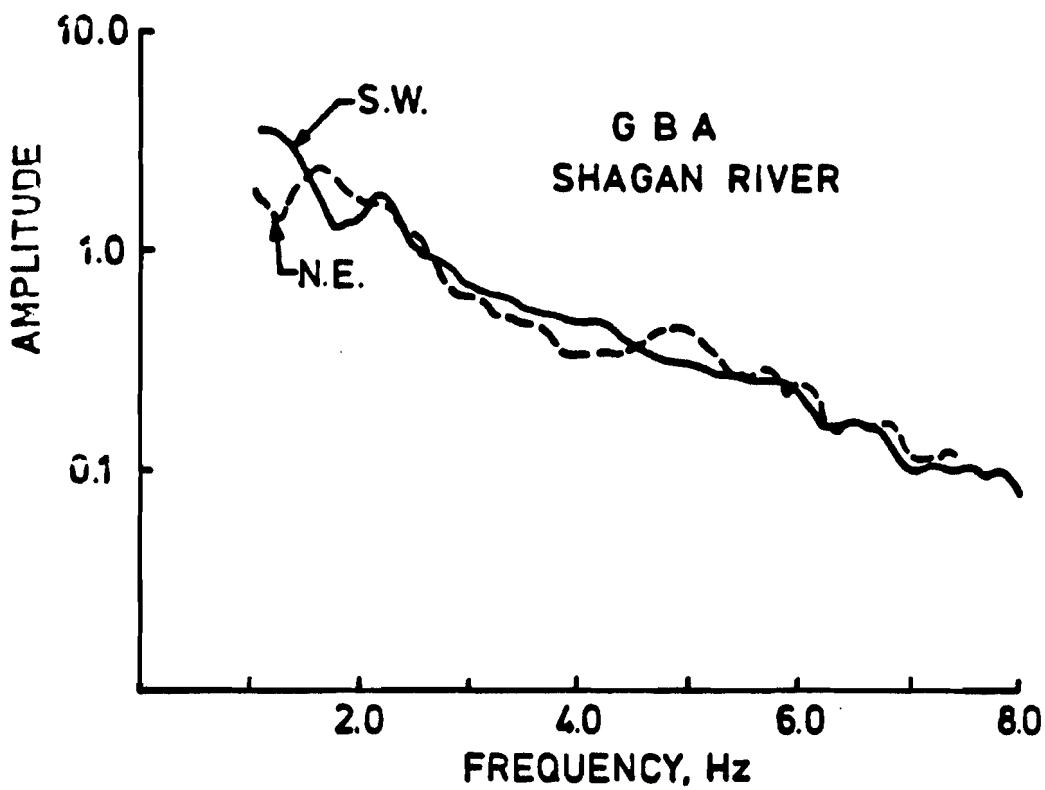
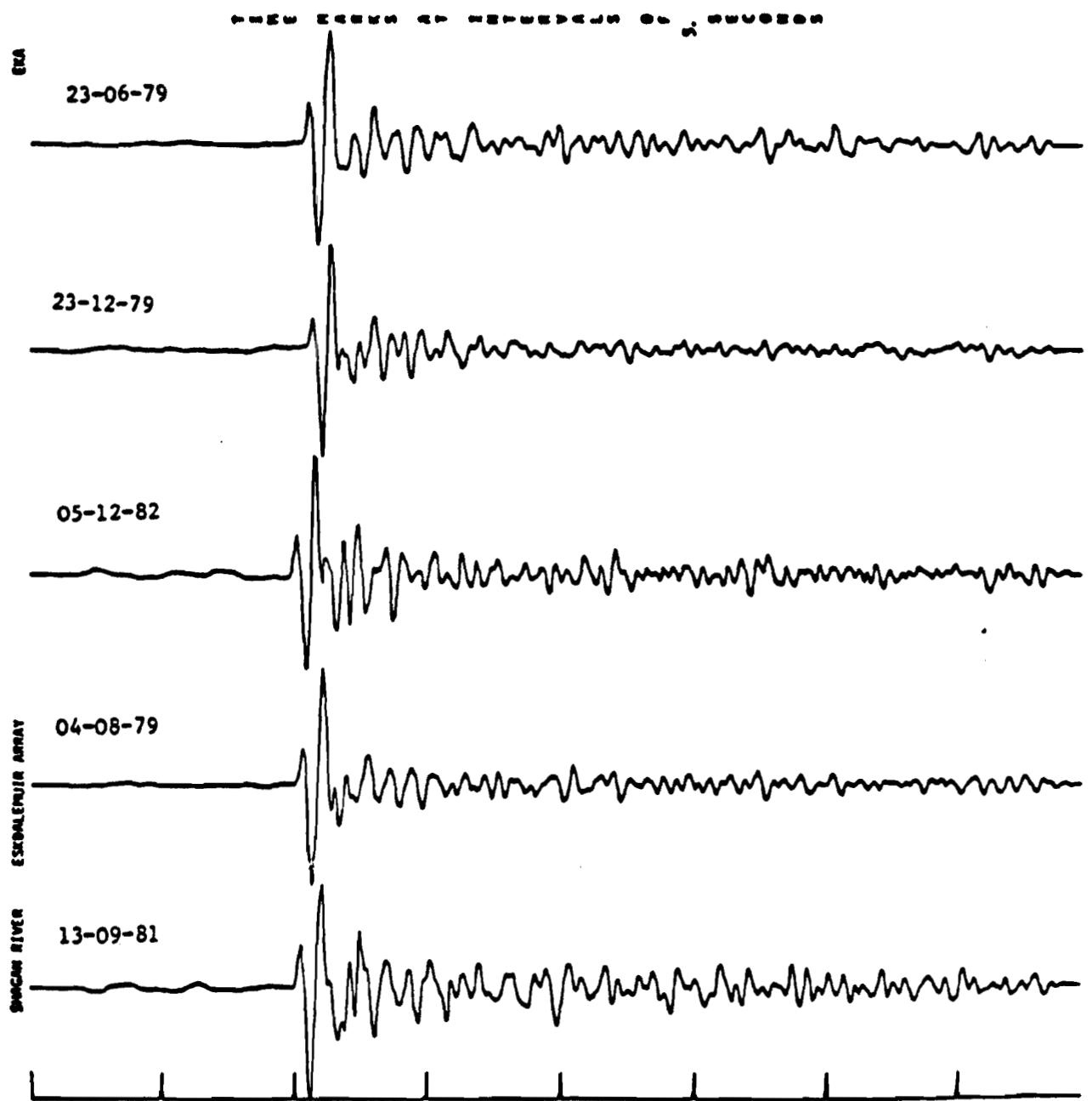
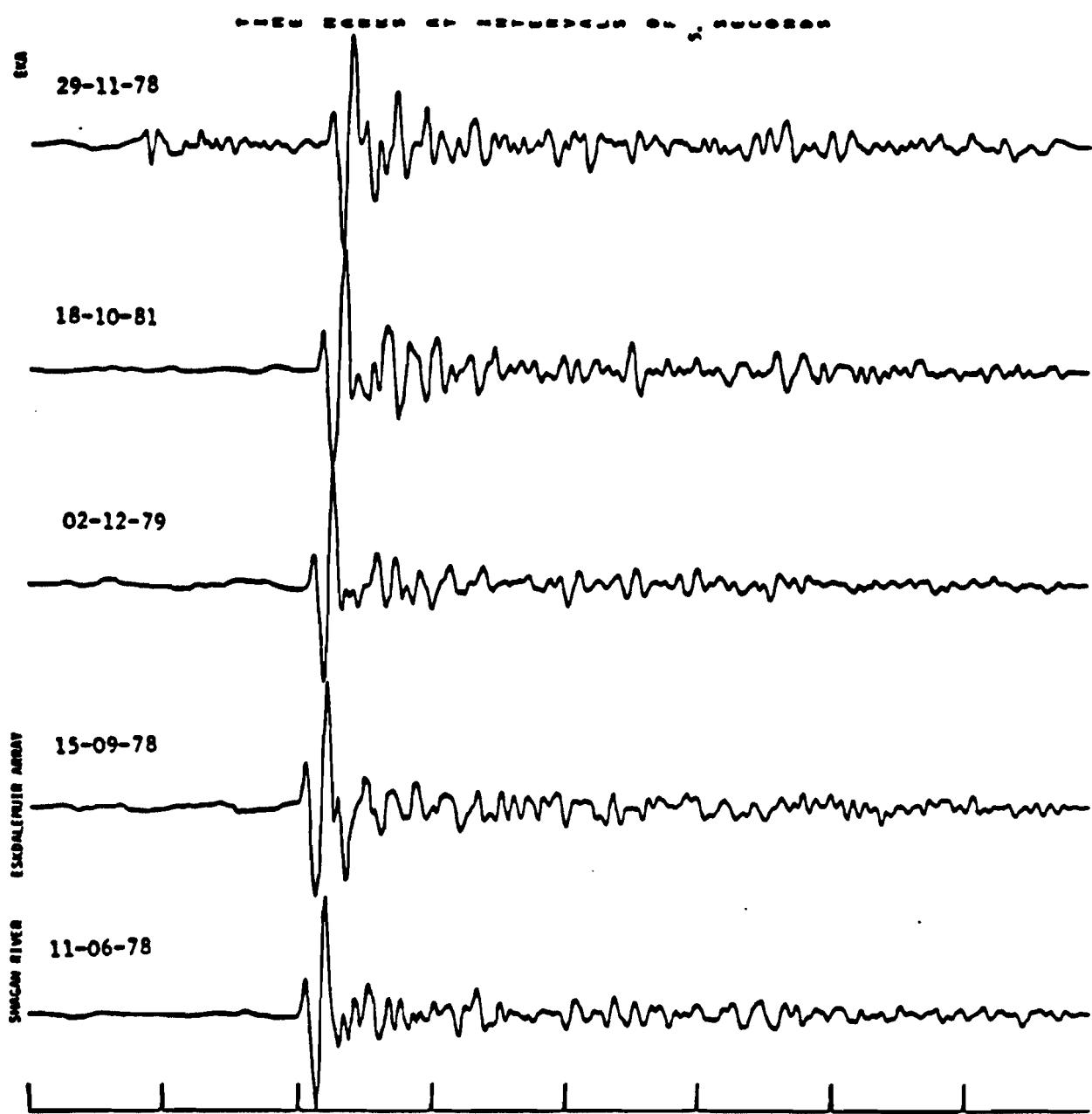


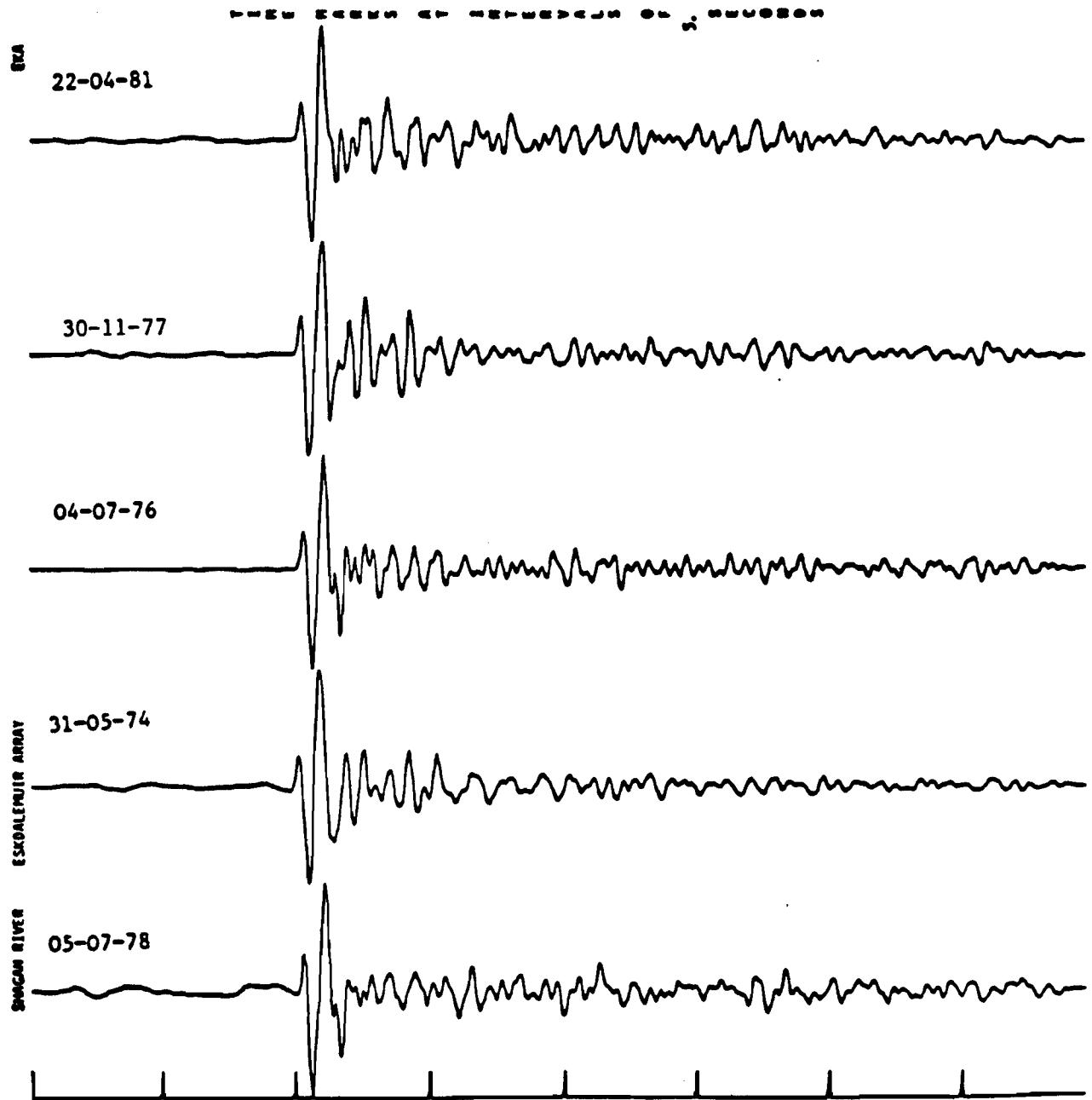
FIGURE A5 Stacked spectra are compared for eight event populations of NE and SW Shagan events chosen so the mean m_b is nearly the same. The explosions are listed in Table A2.



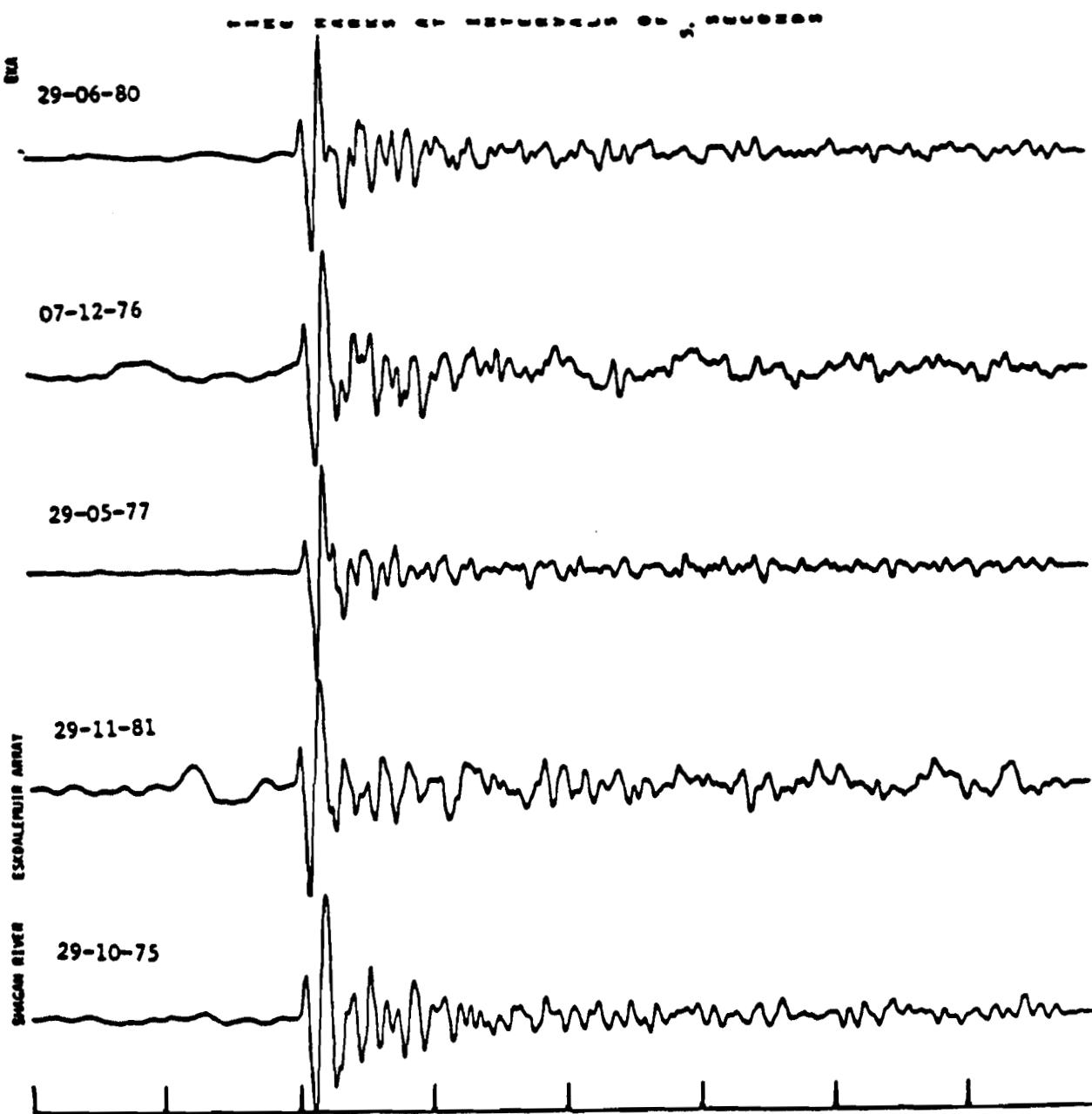
EKA Southwest Shagan River



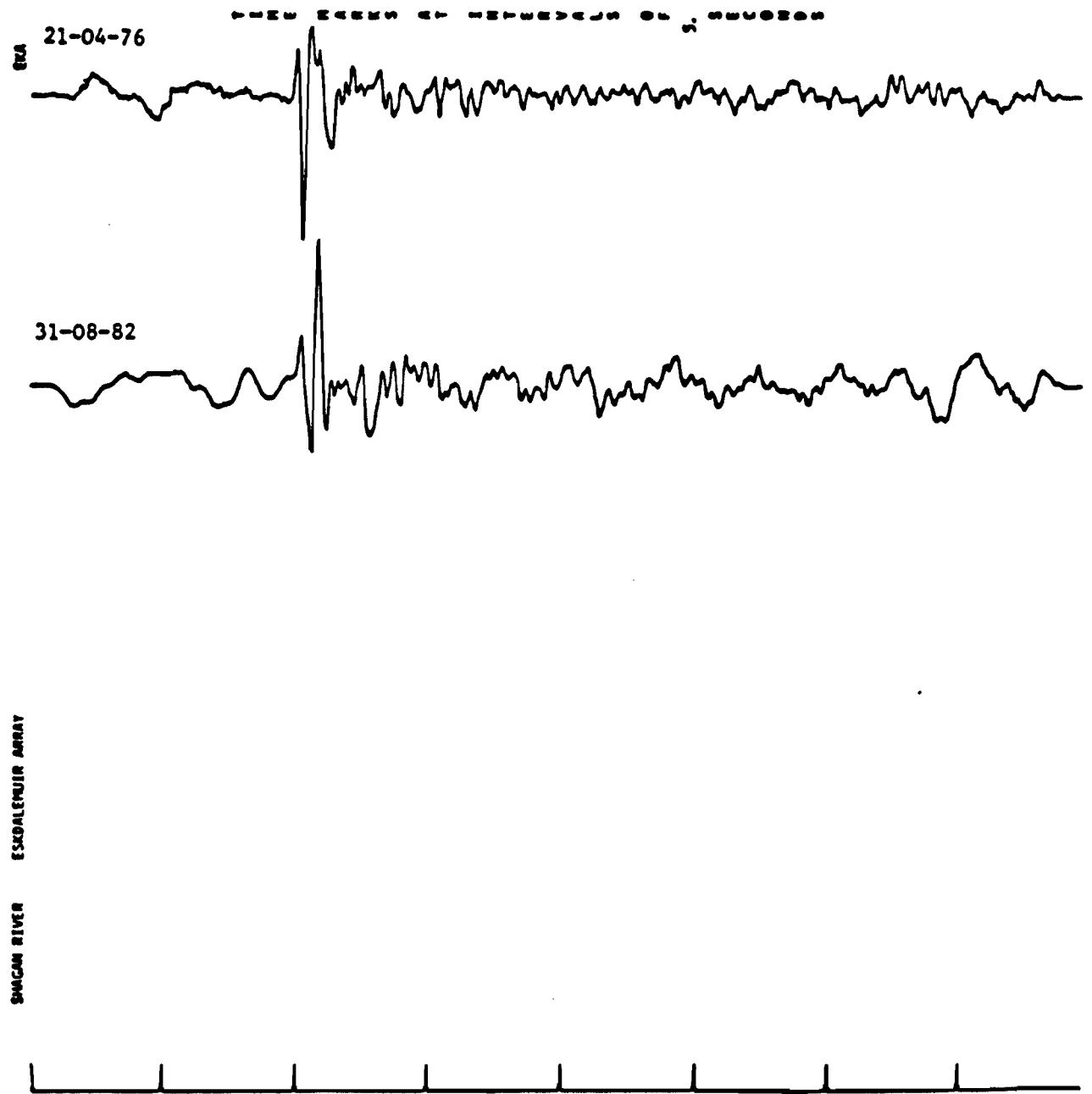
EKA Southwest Shagan River



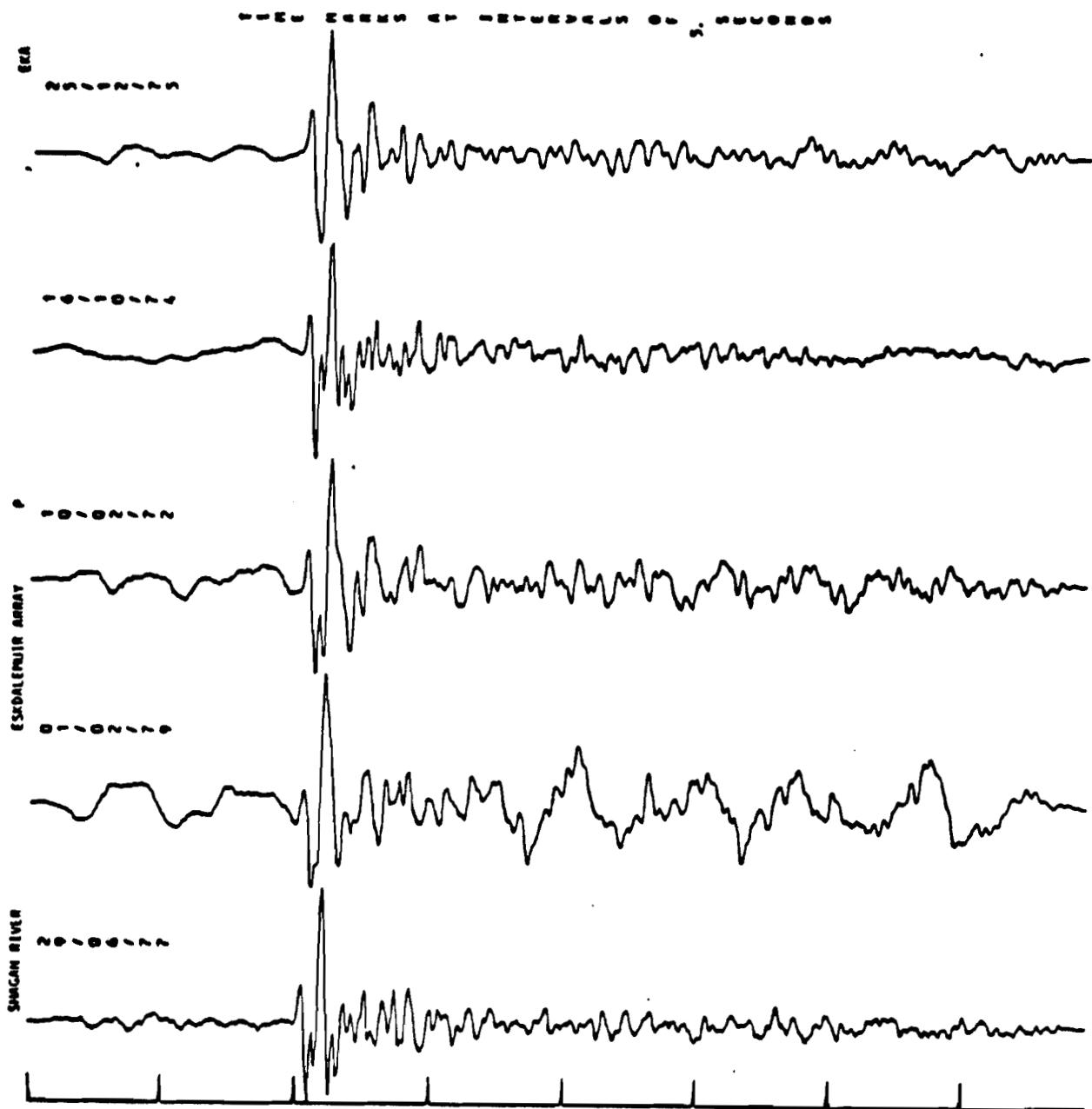
EKA Southwest Shagan River



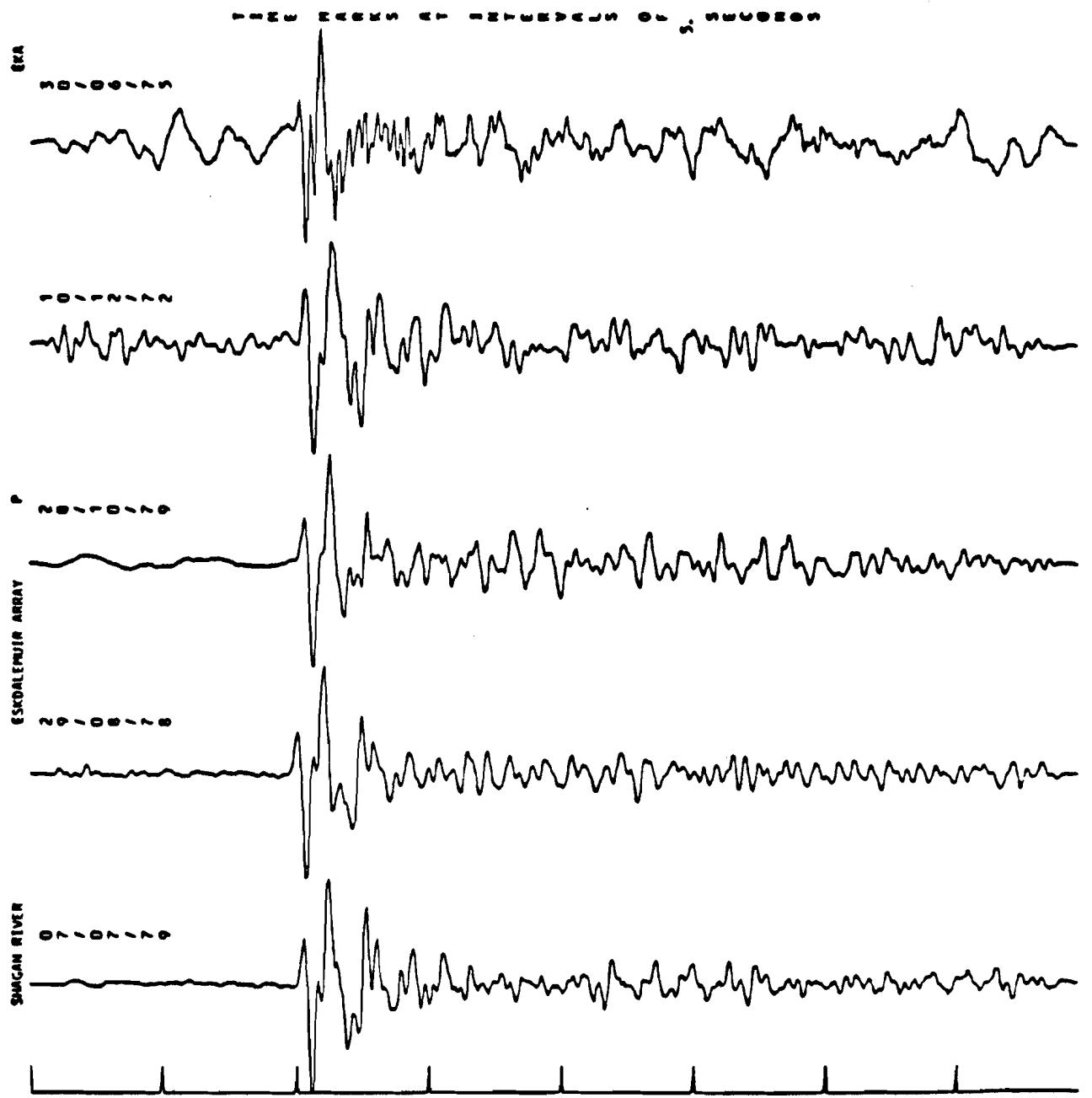
EXA Southwest Shagan River



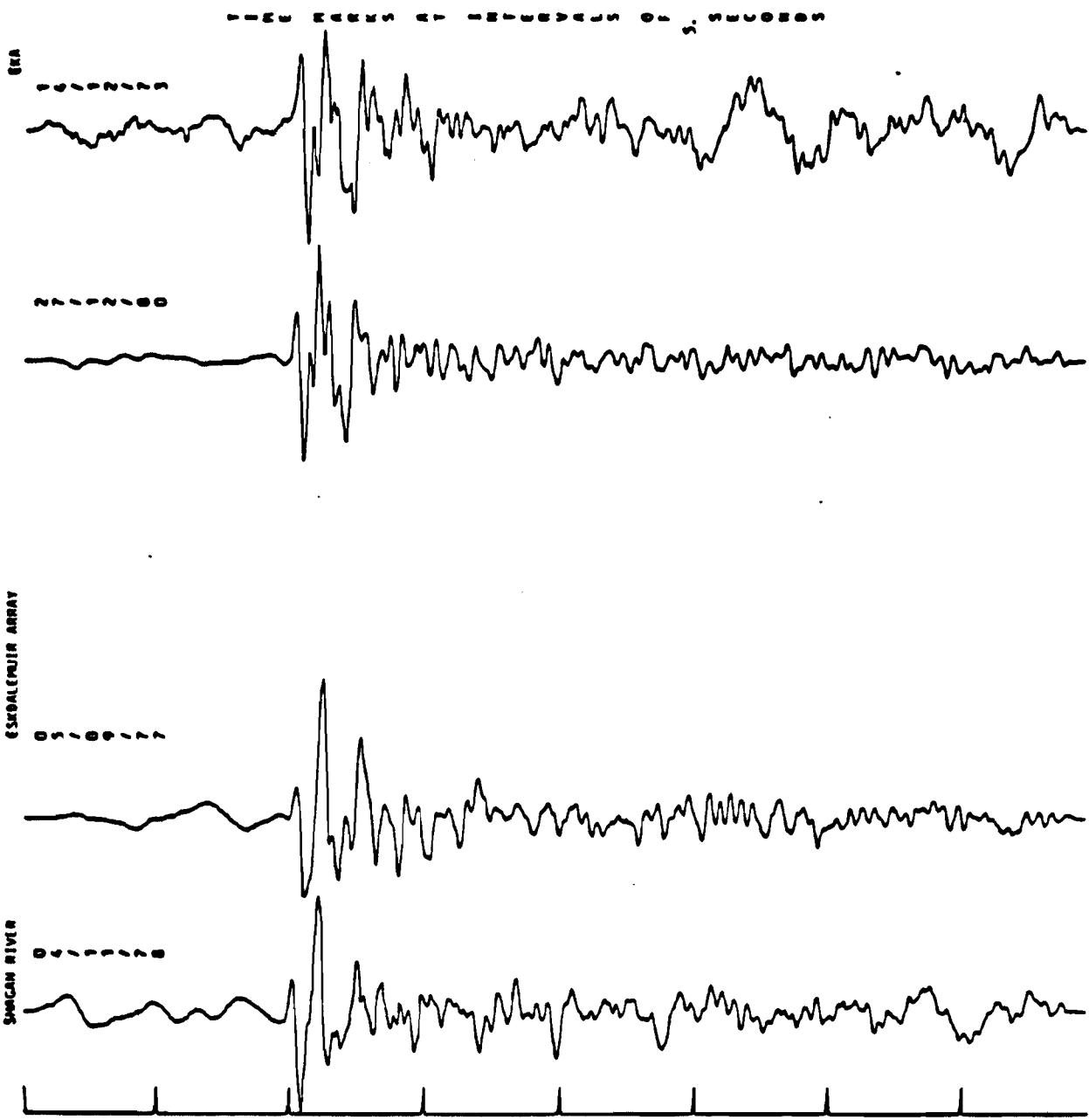
EKA Southwest Shagan River



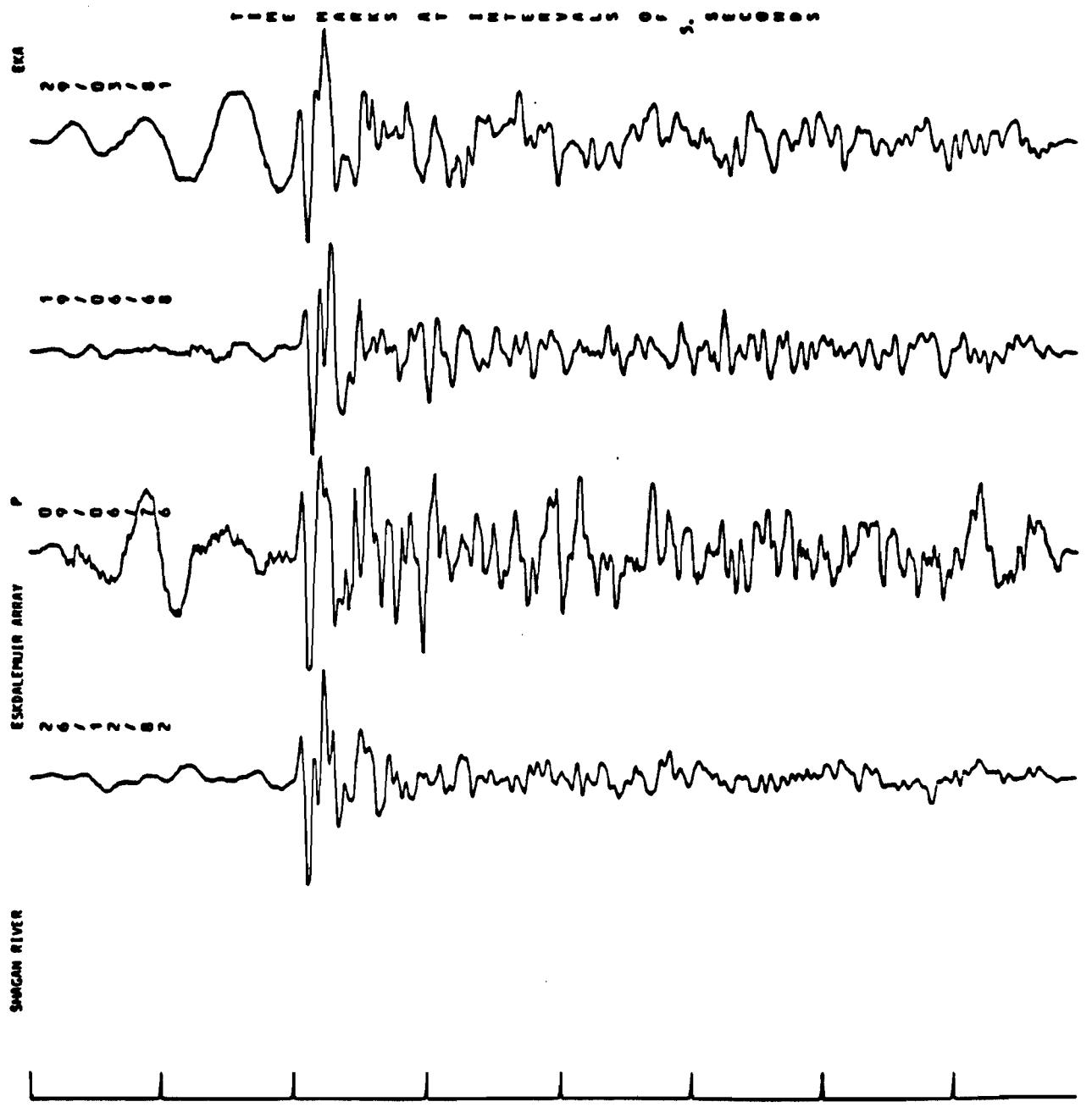
EKA Northeast Shagan River



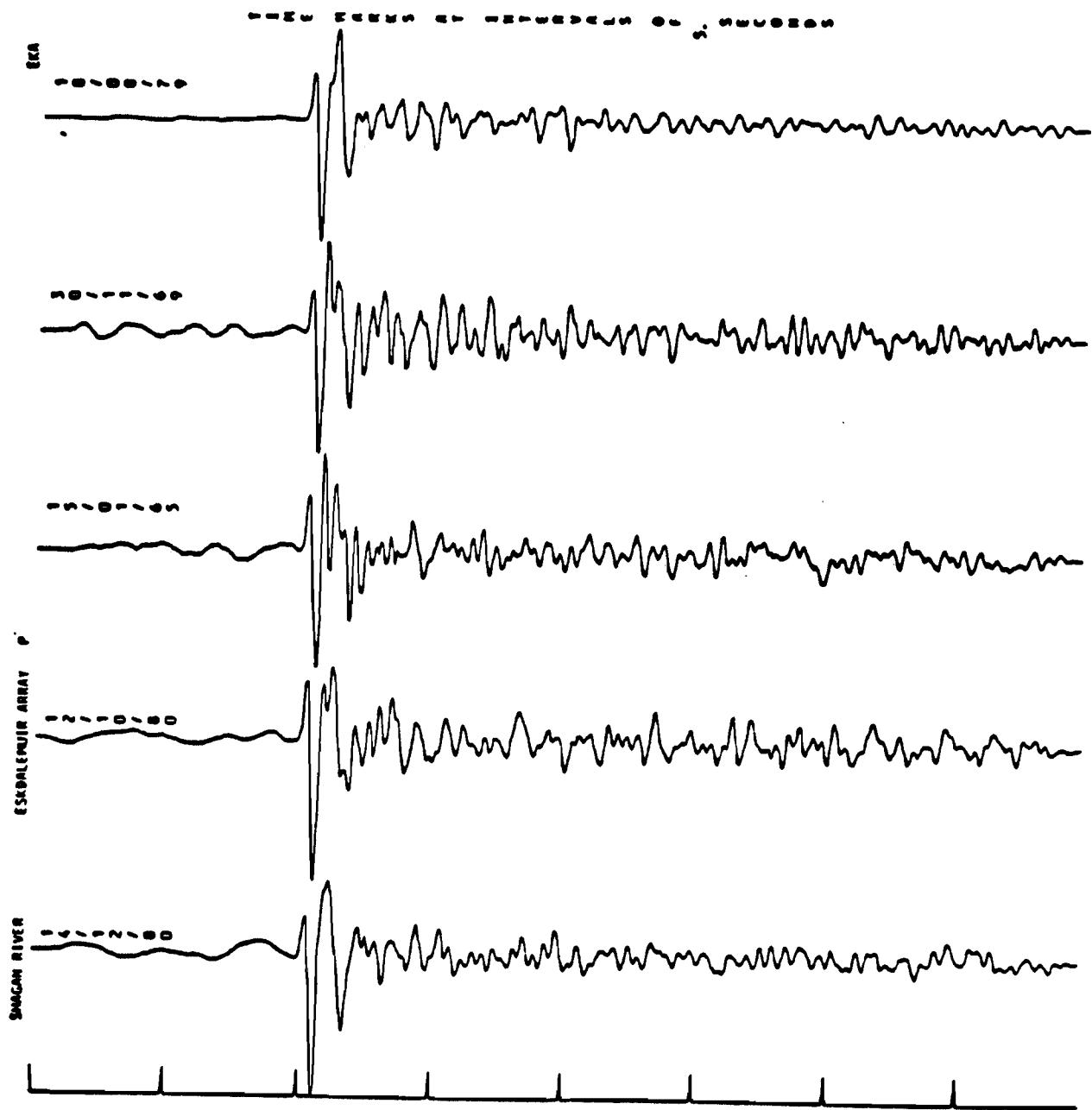
EKA Northeast Shagan River



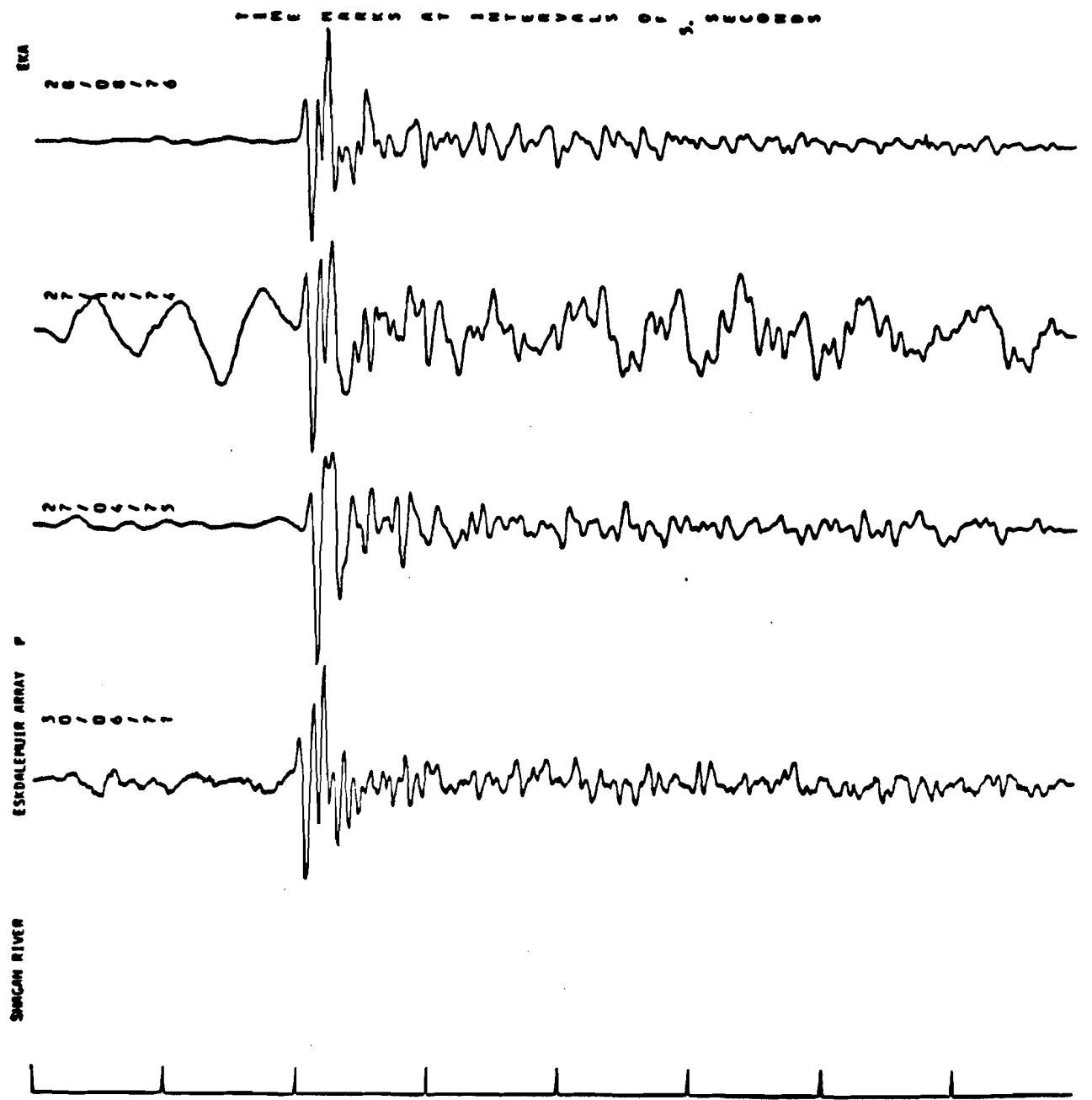
ESEA Northeast Shagan River



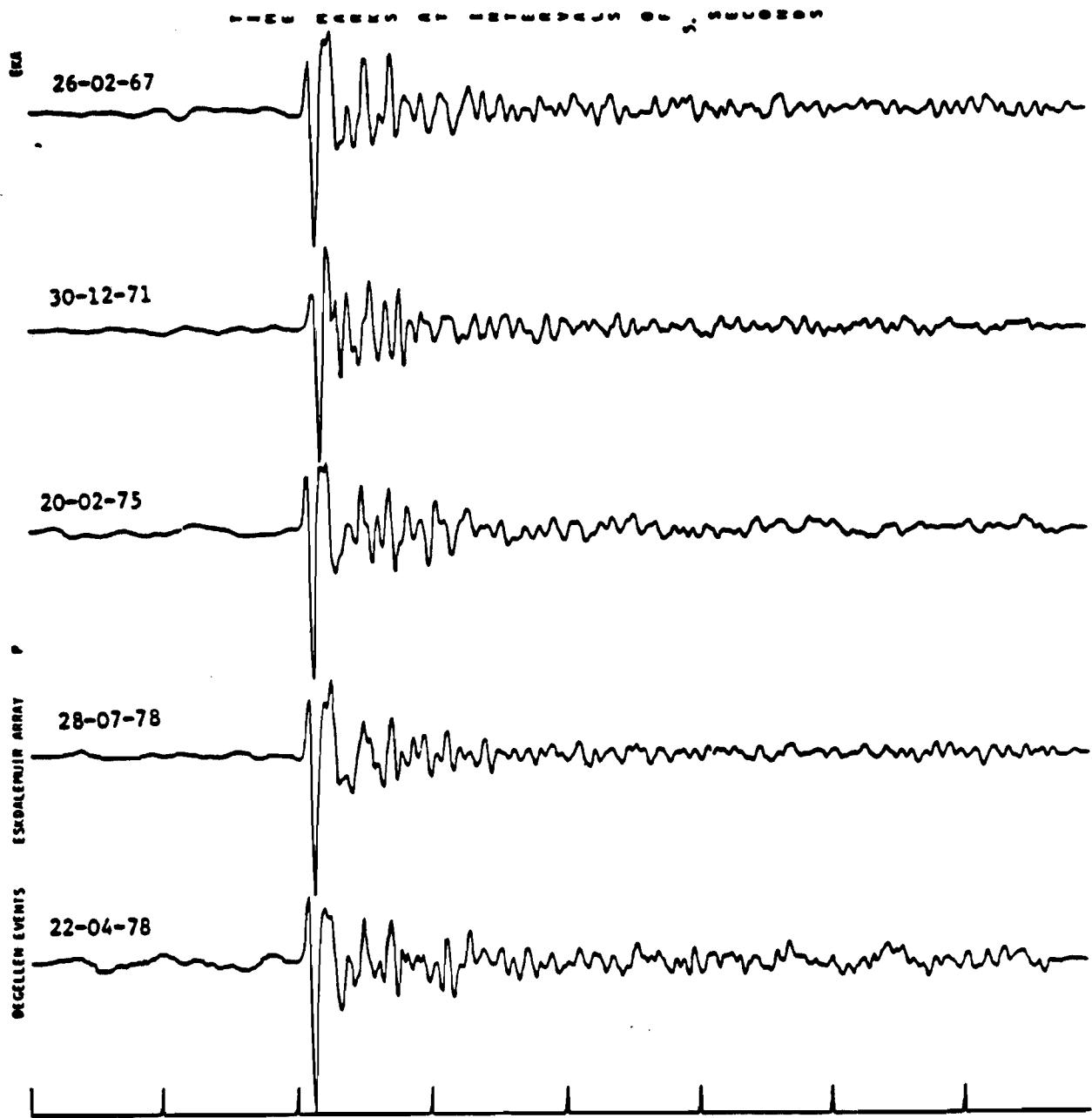
EKA Northeast Shagan River



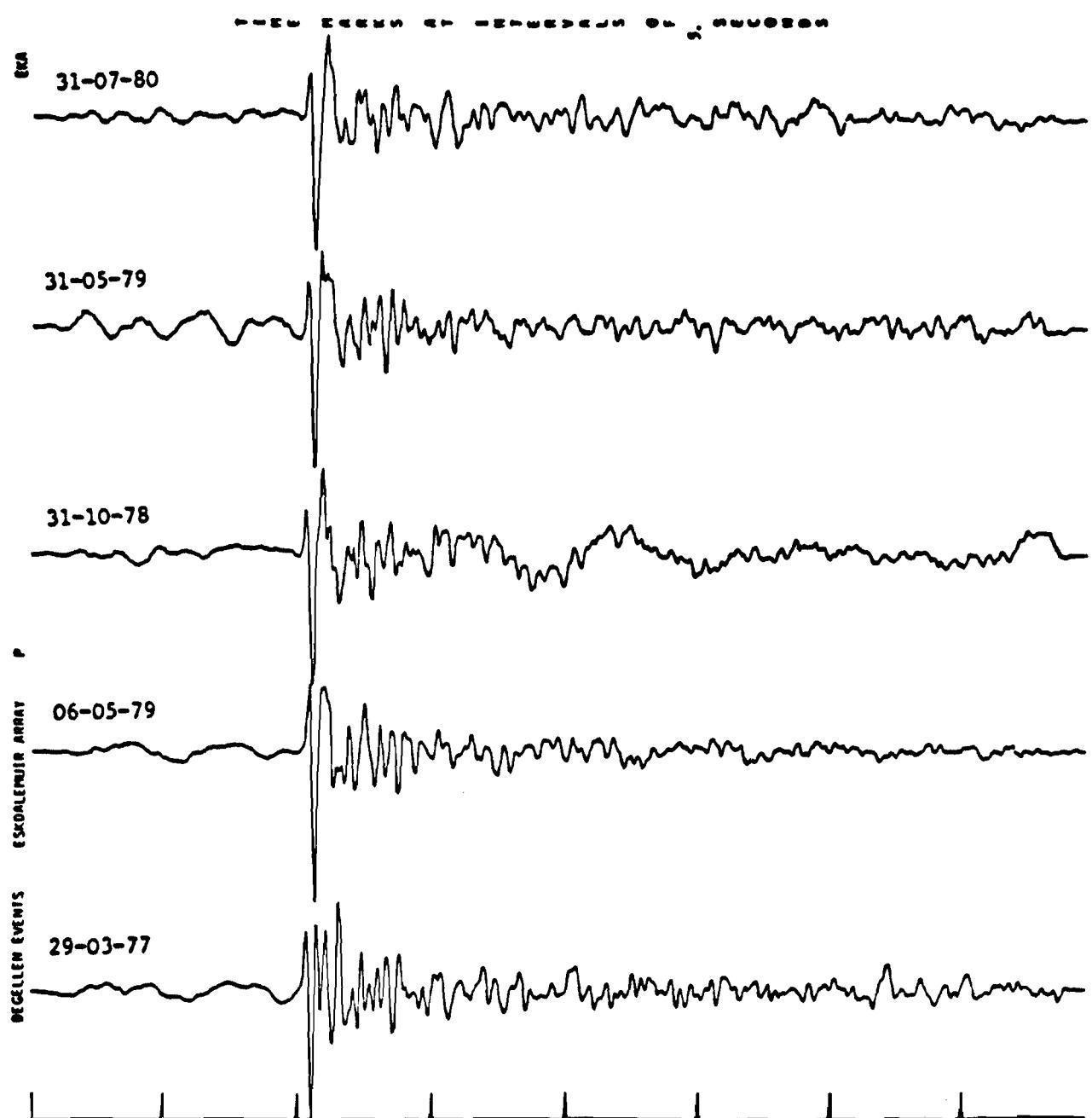
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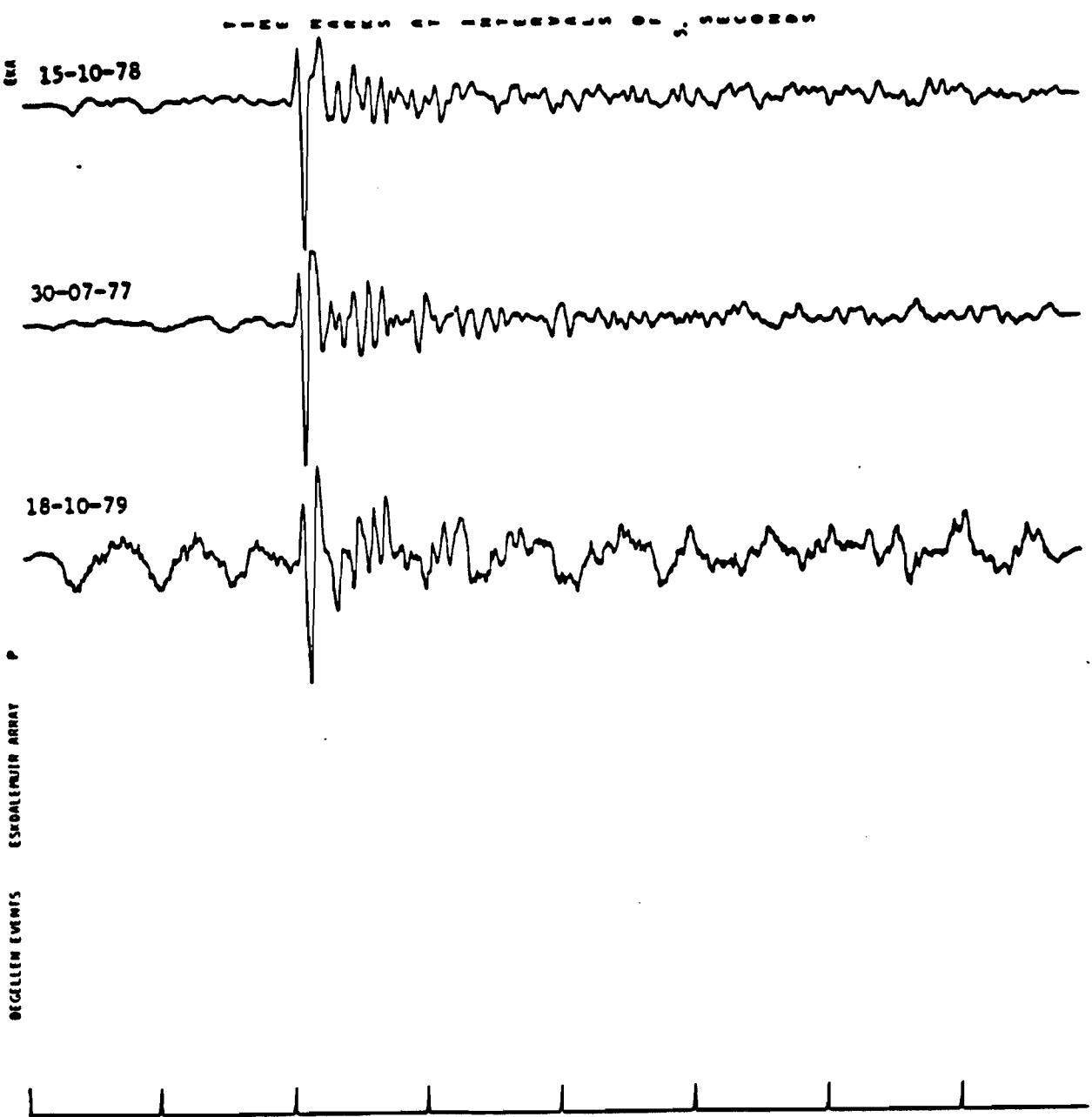
EKA Northeast Shagan River



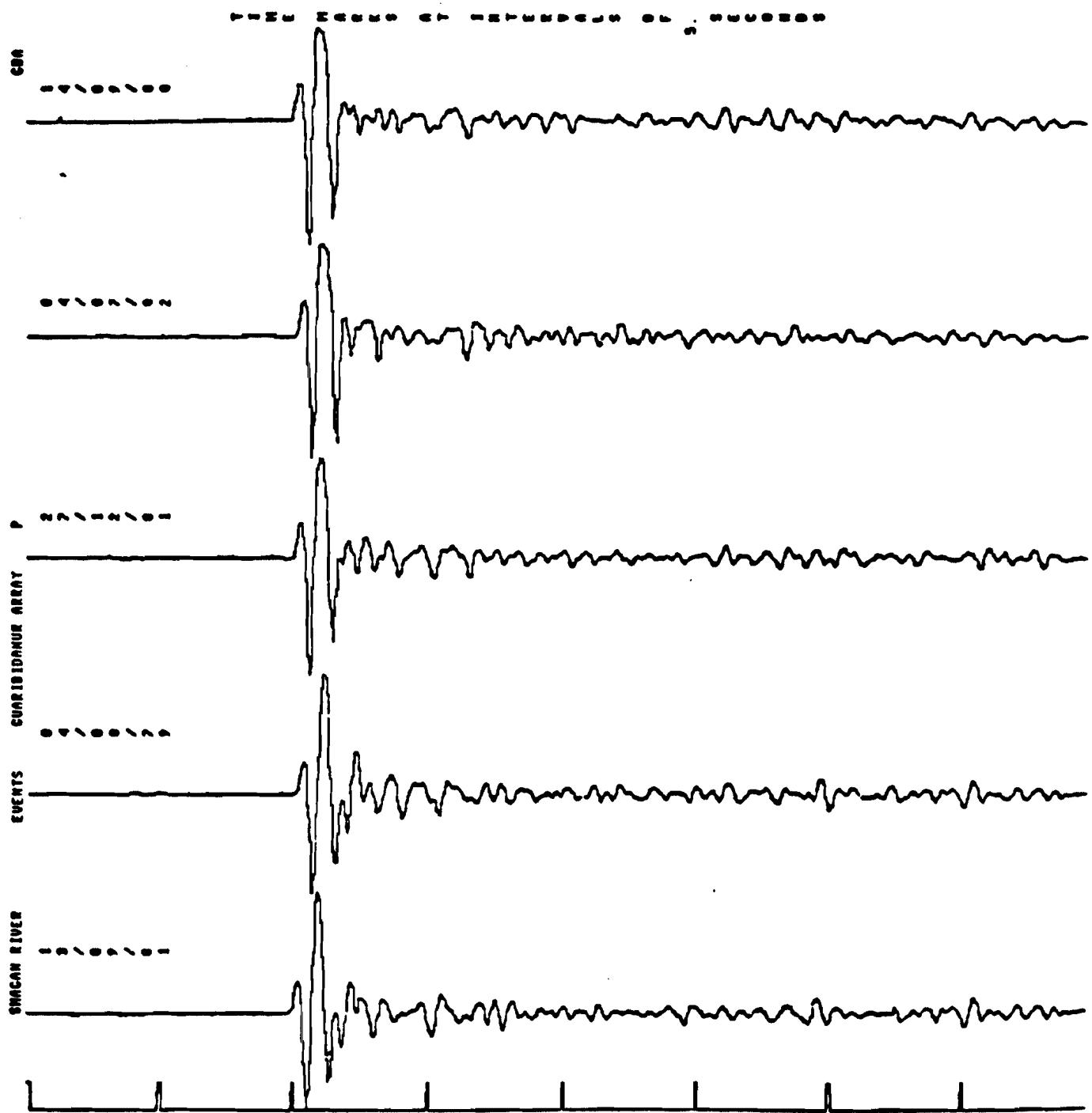
EKA Degelen



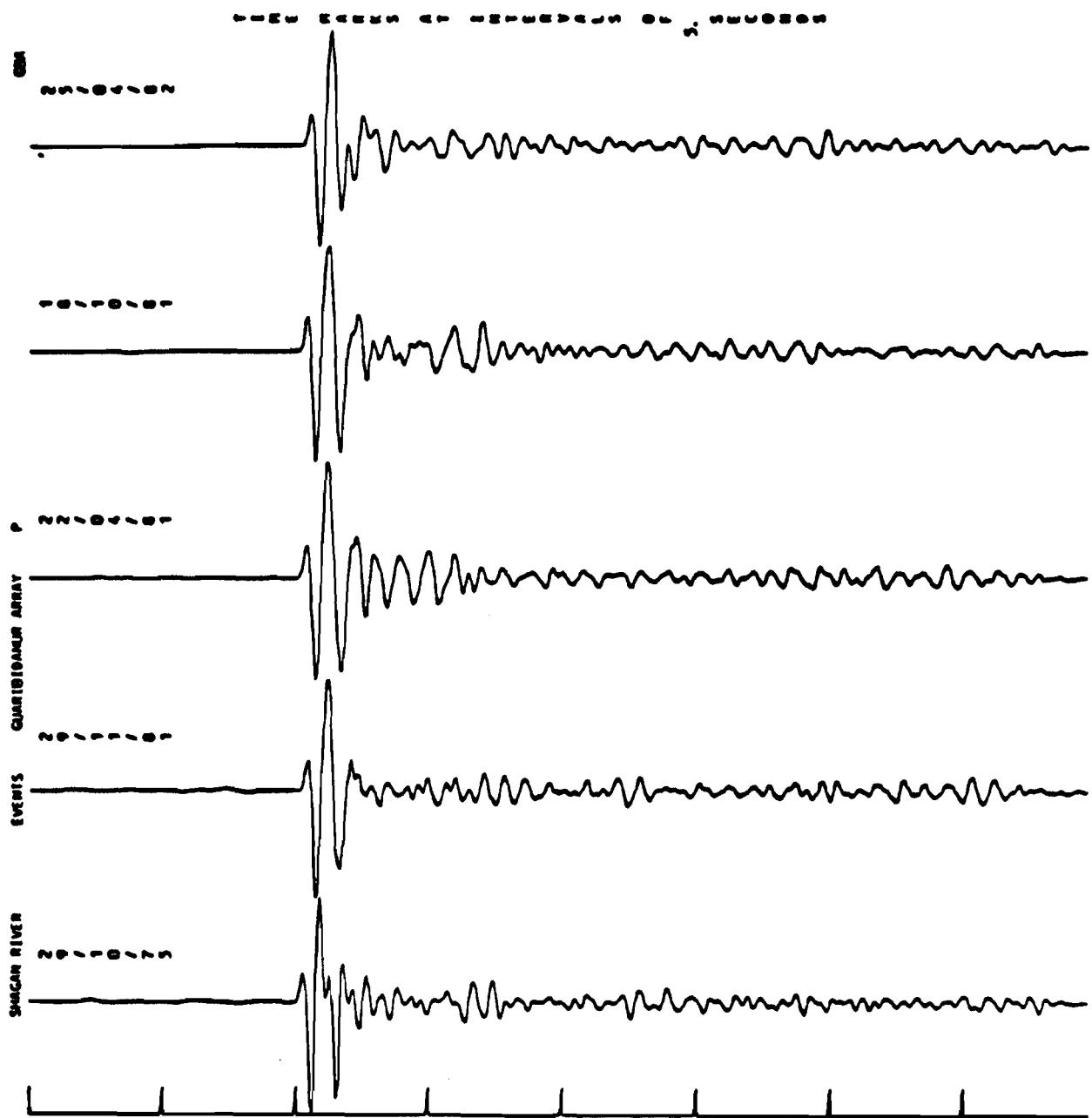
EEG Degelen



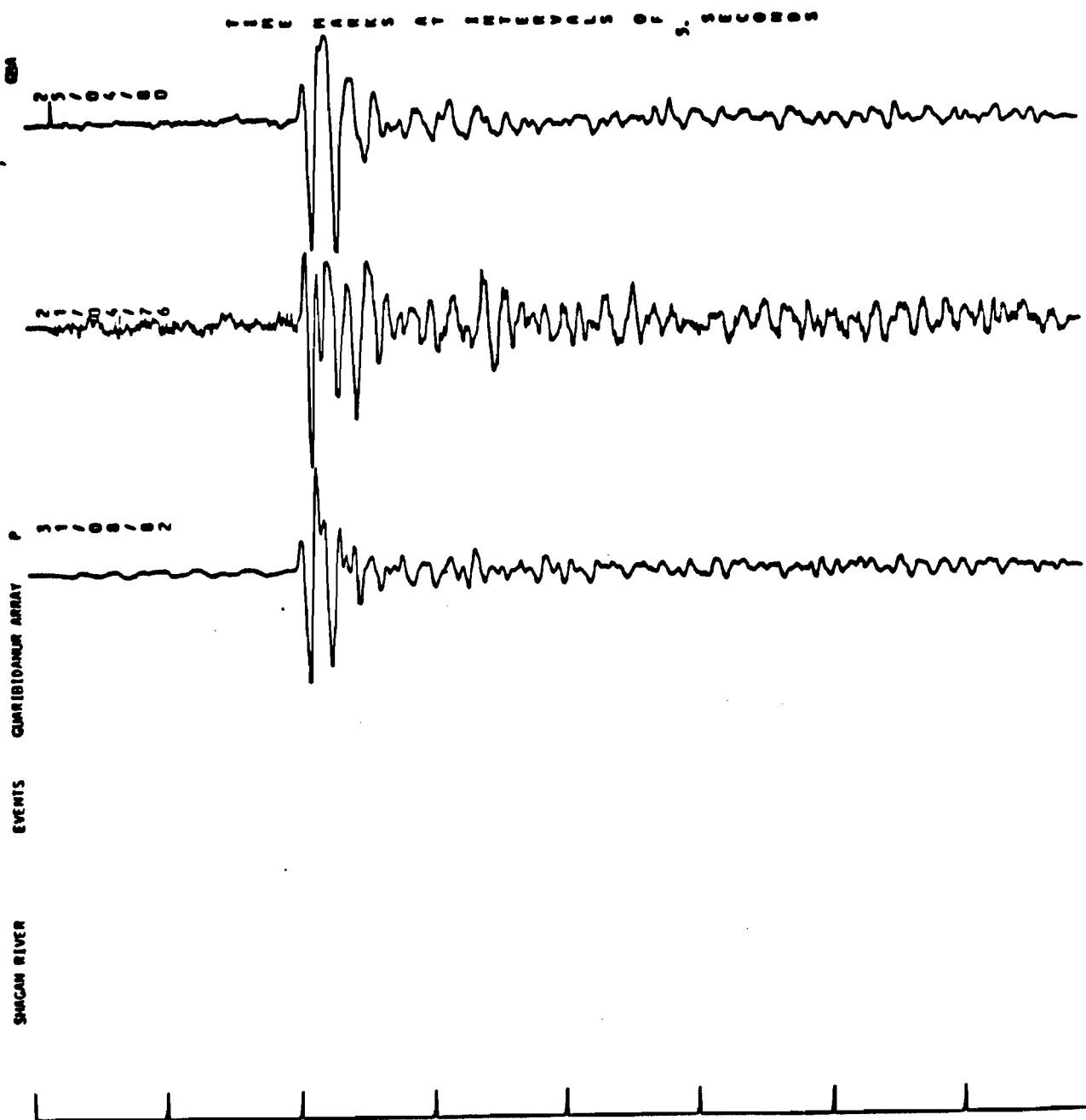
EKA Degelen



GBA Southwest Shagan River

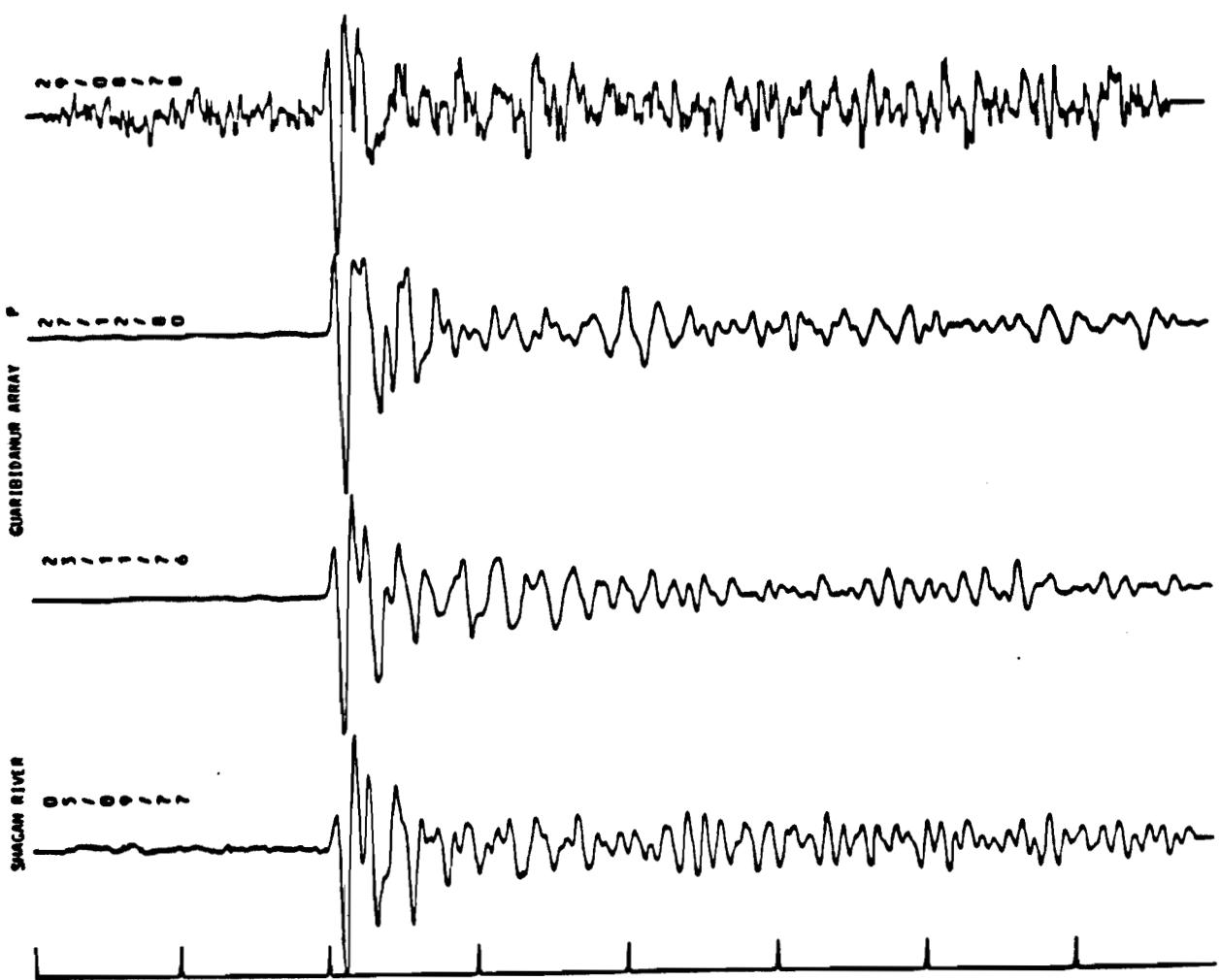


GBA Southwest Shagan River



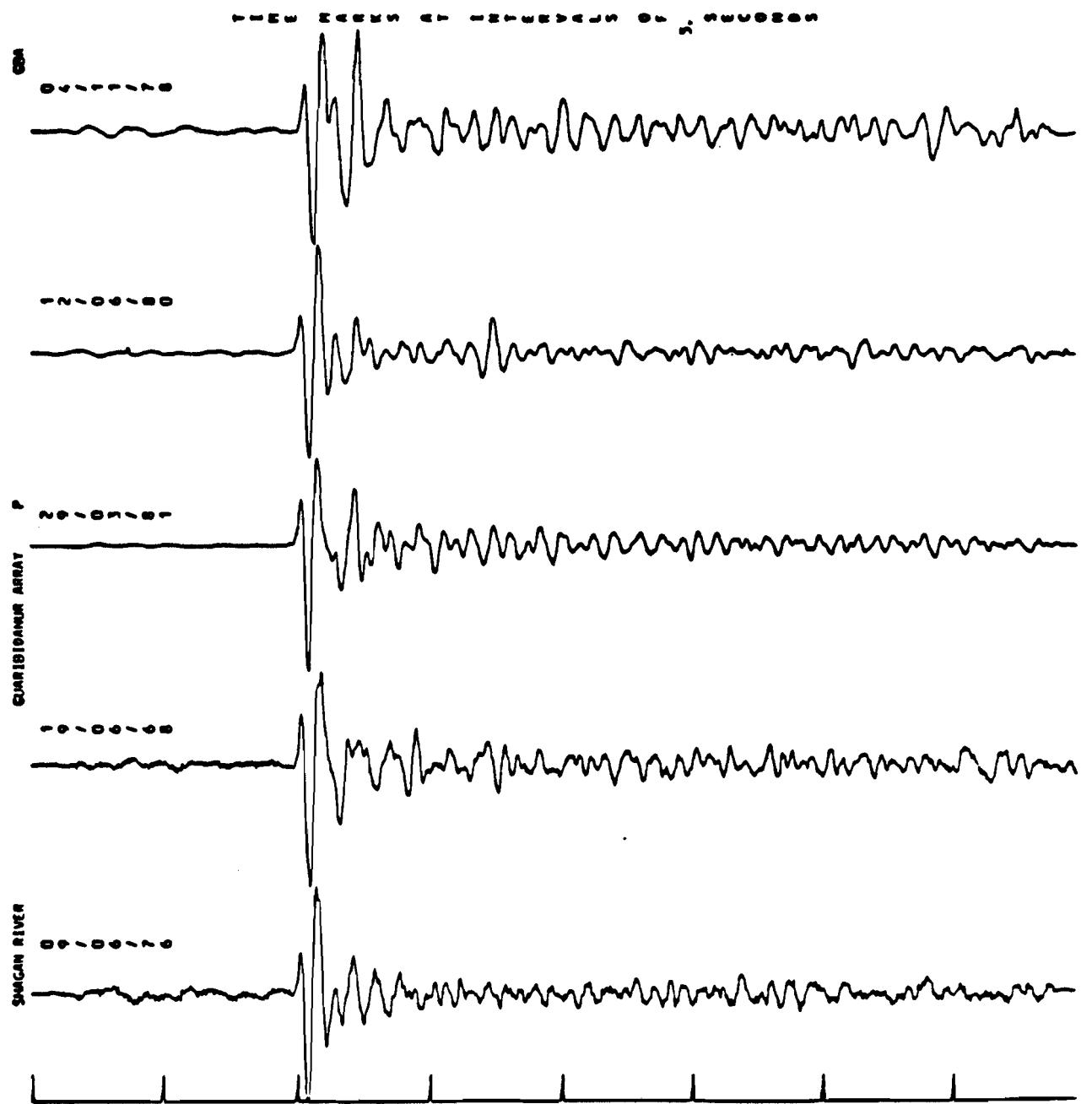
CBA Southwest Shagan River

...NEW RECORDS OF MEGADEMUM ON AQUATIC

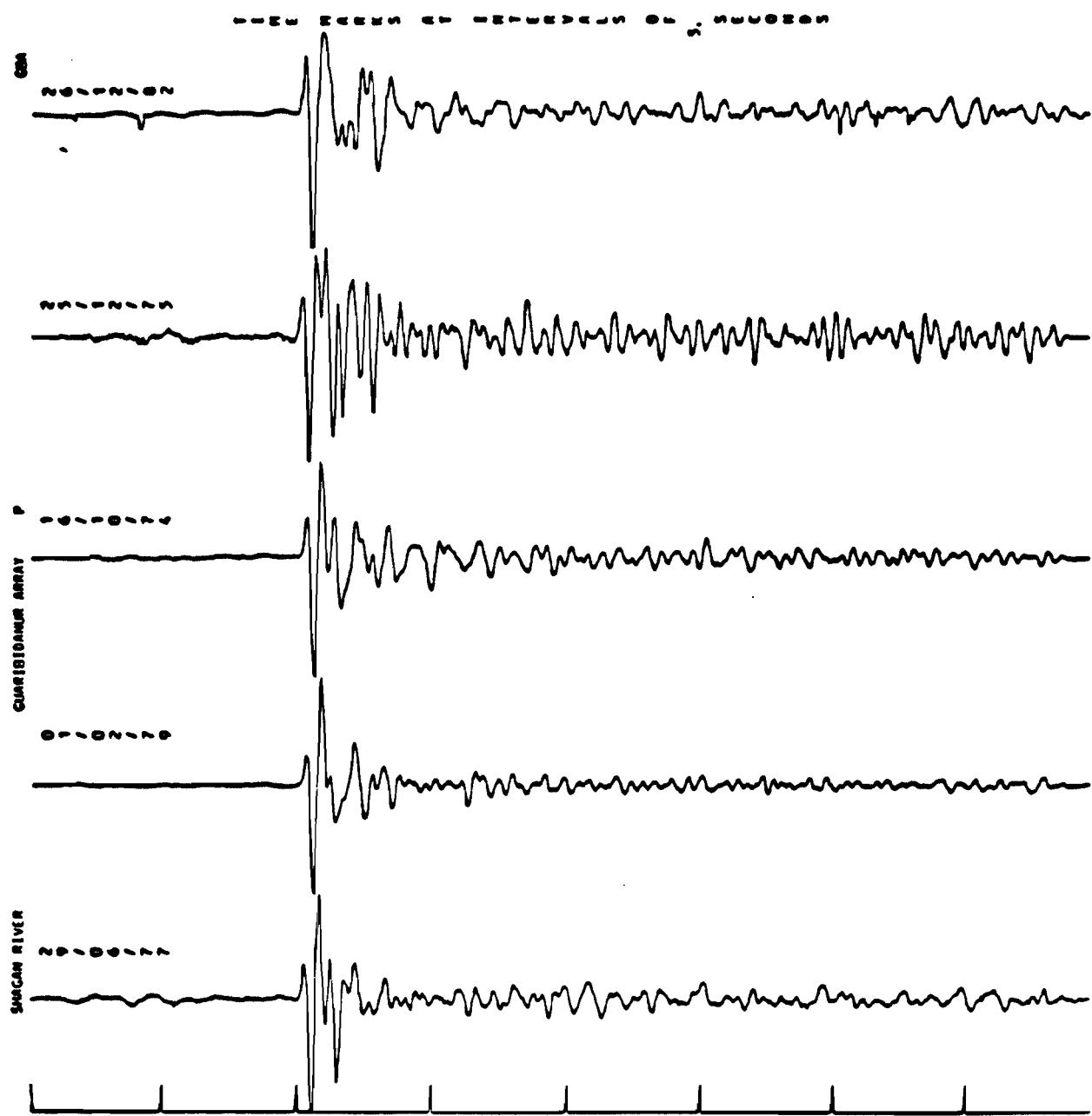


GRISEBAND ARRAY
SHAGAN RIVER

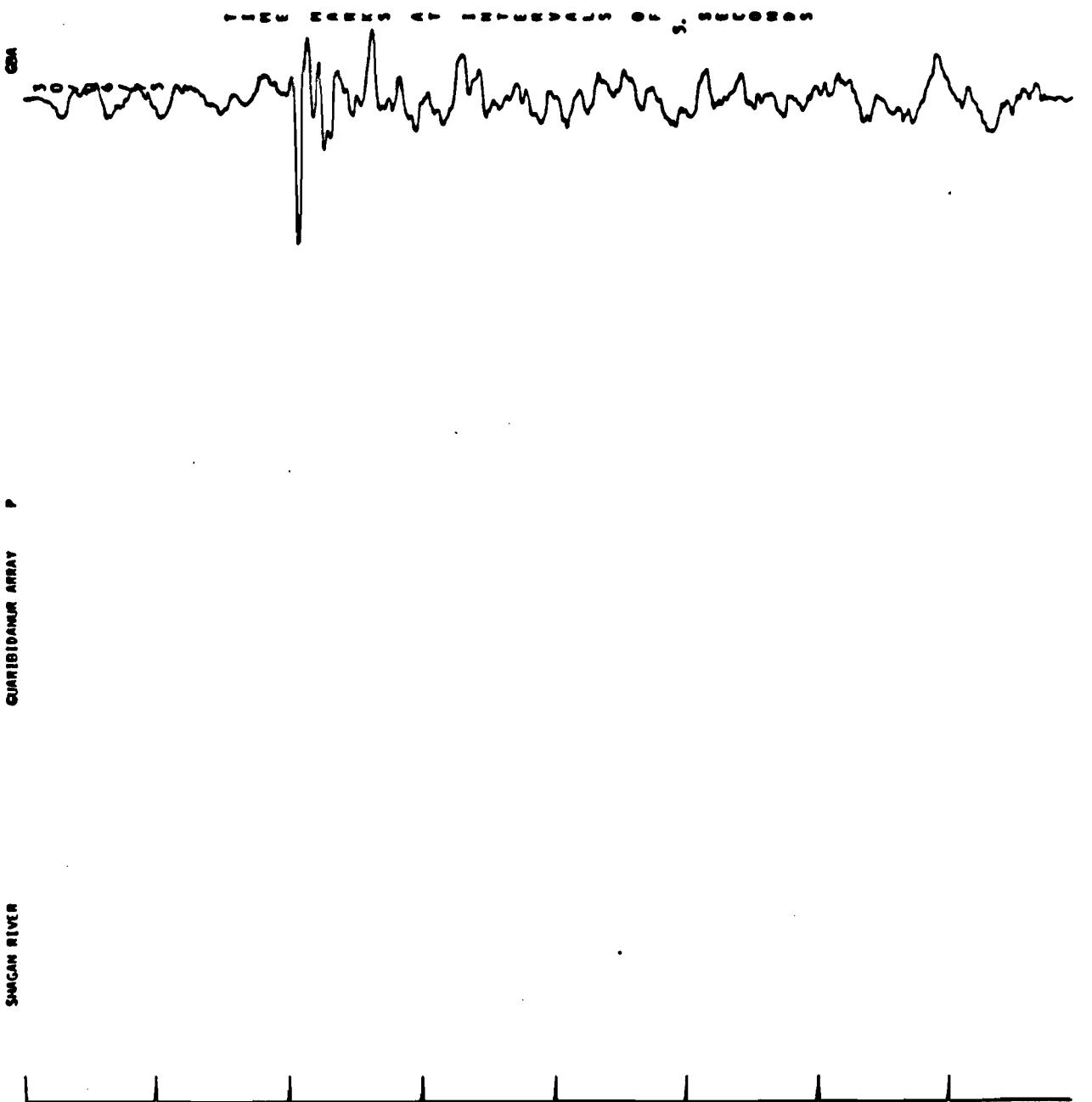
GRIA Northeast Shagan River



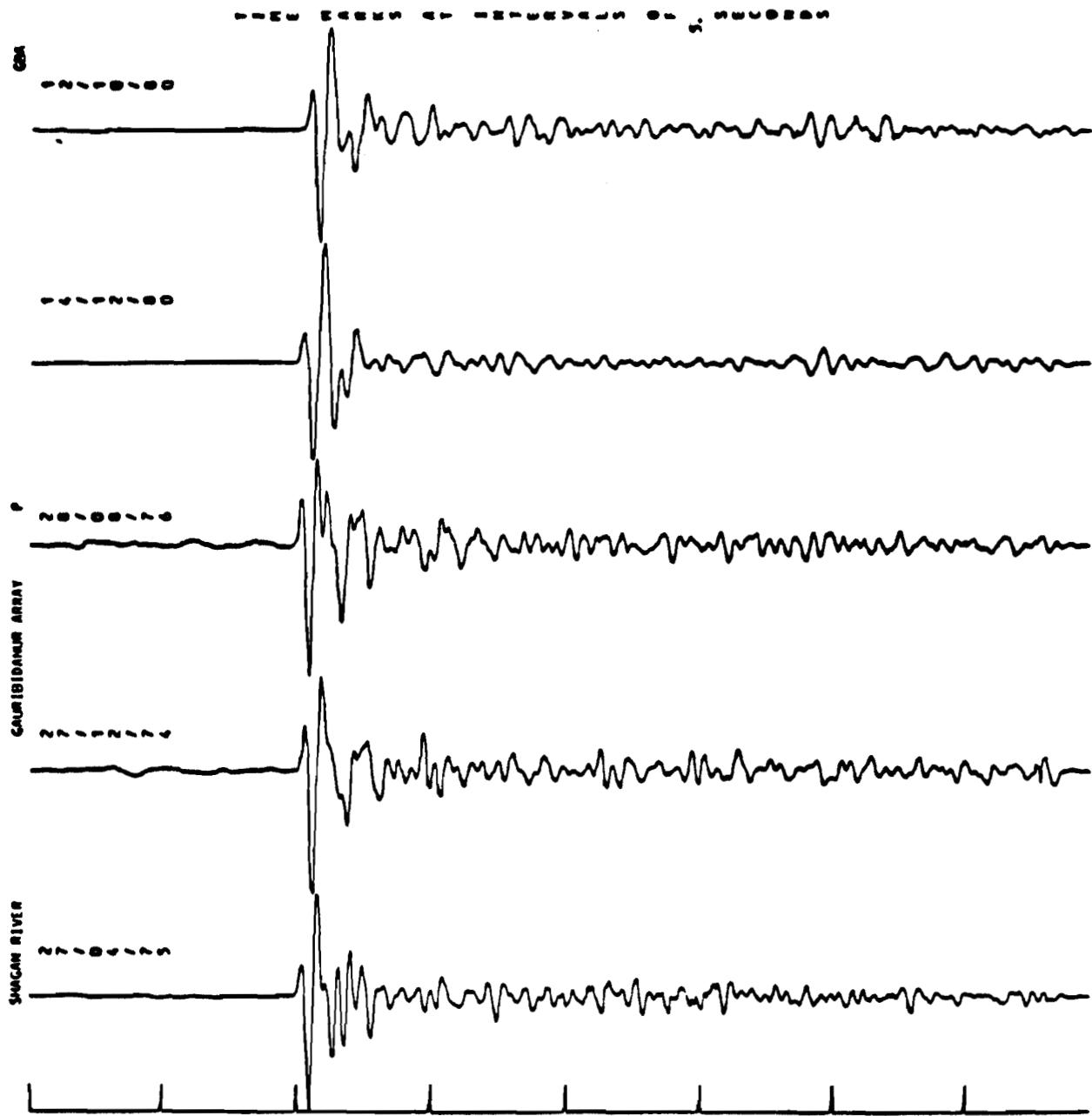
GBA Northeast Shagan River



CBA Northeast Shagan River



GBA Northeast Shagan River



GBA Northeast Shagan River

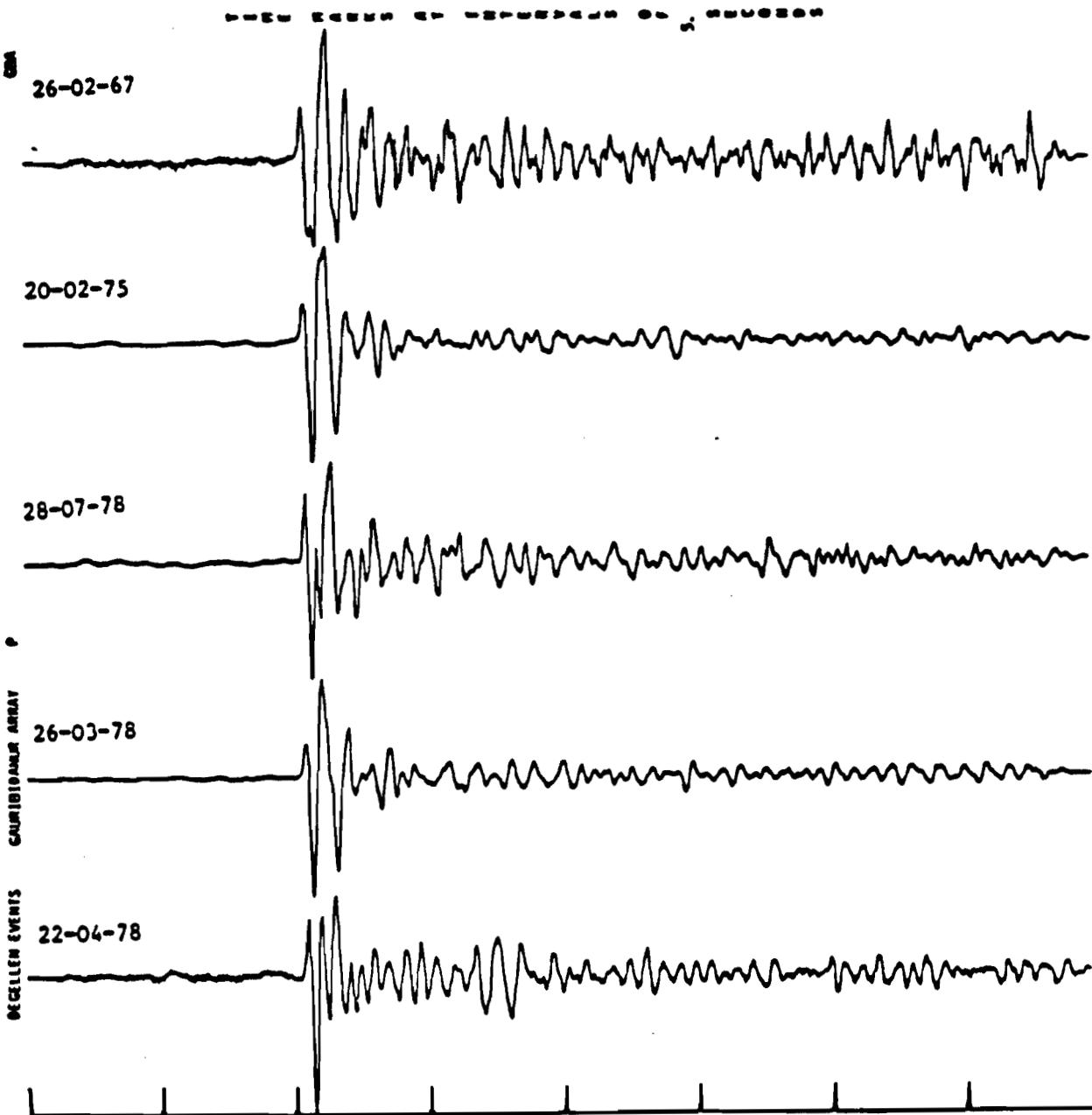
SHAGAN RIVER

CARLISLE DAM ARRAY

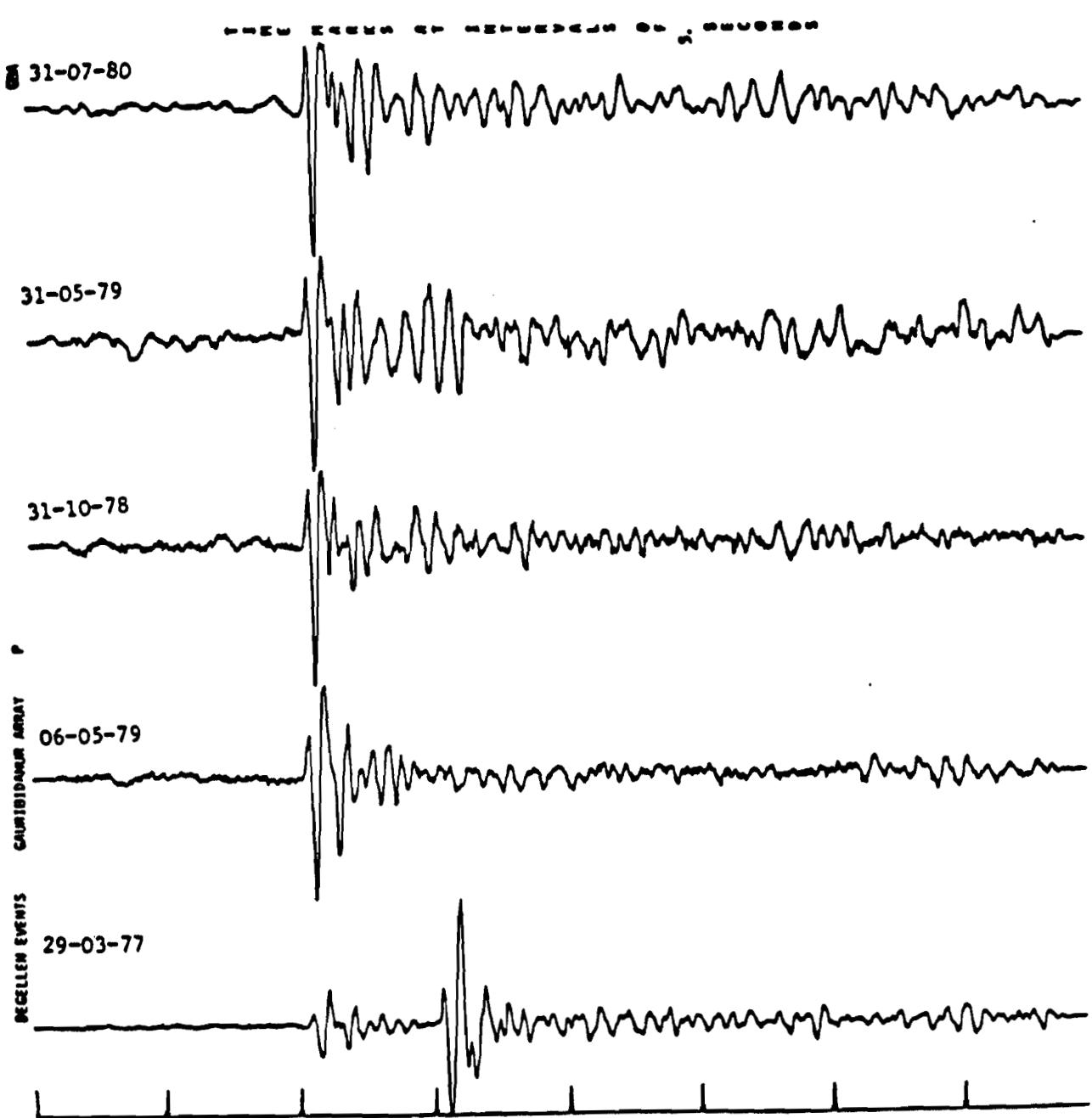
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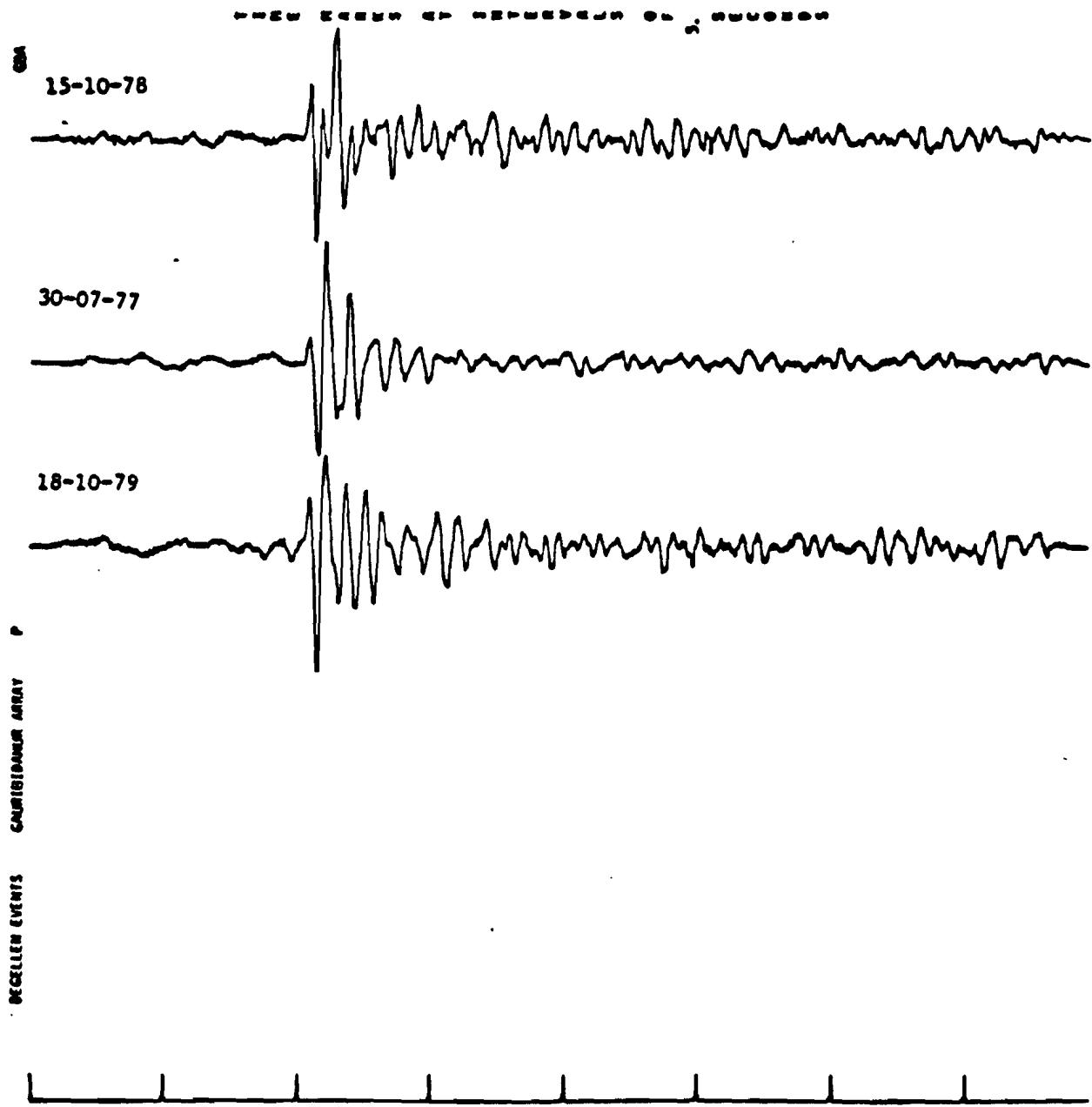


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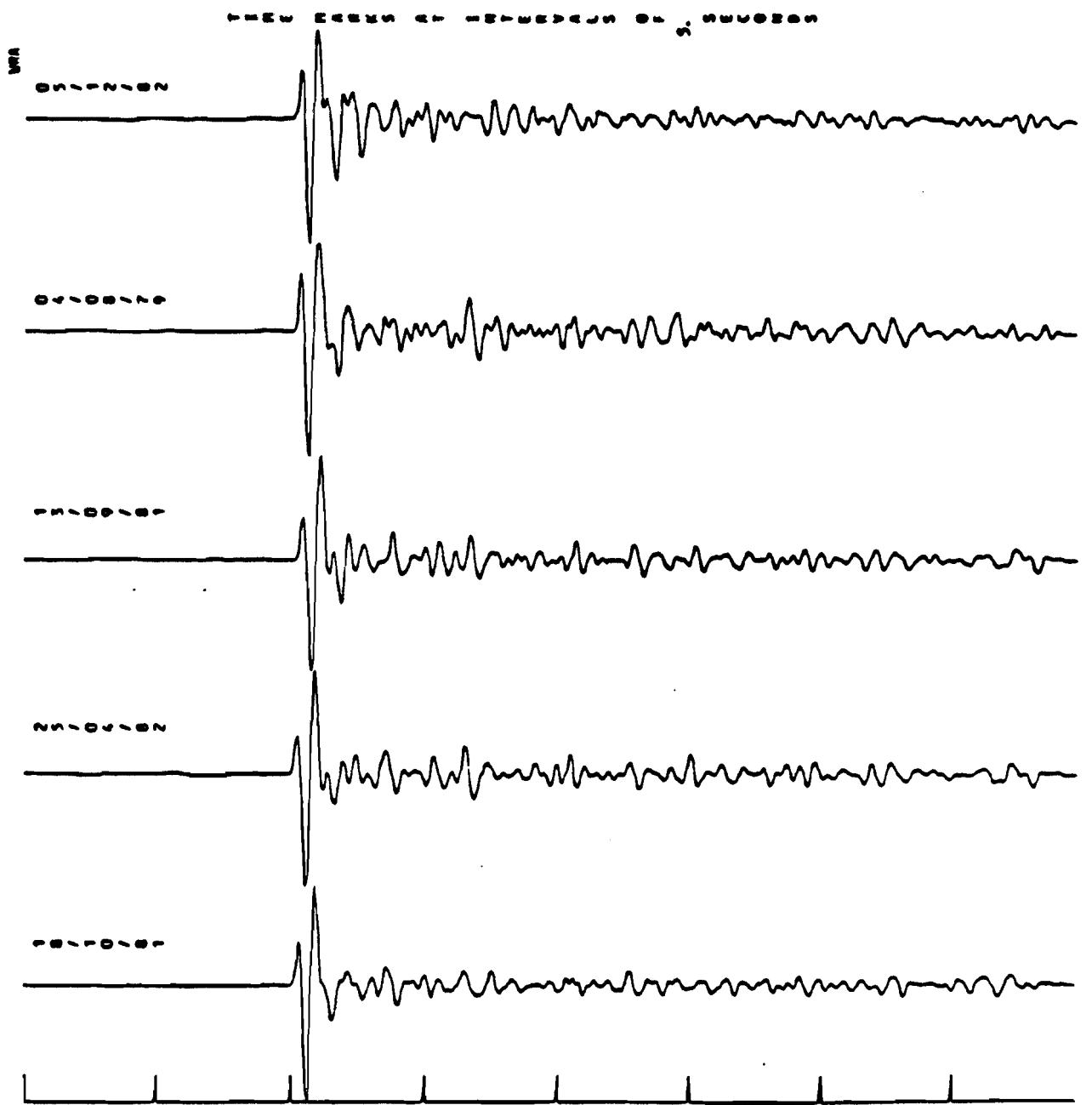


GBA Degelen

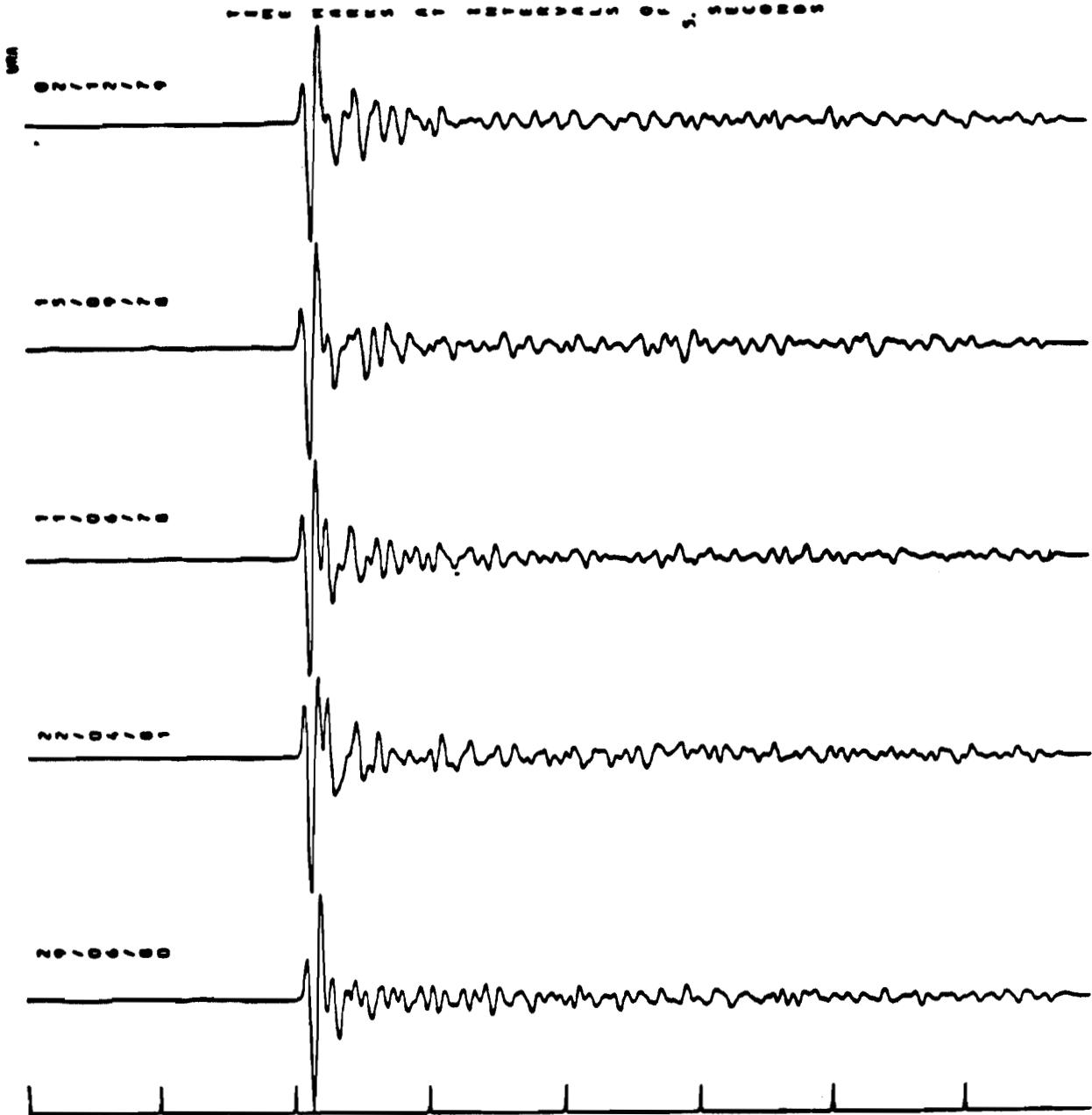




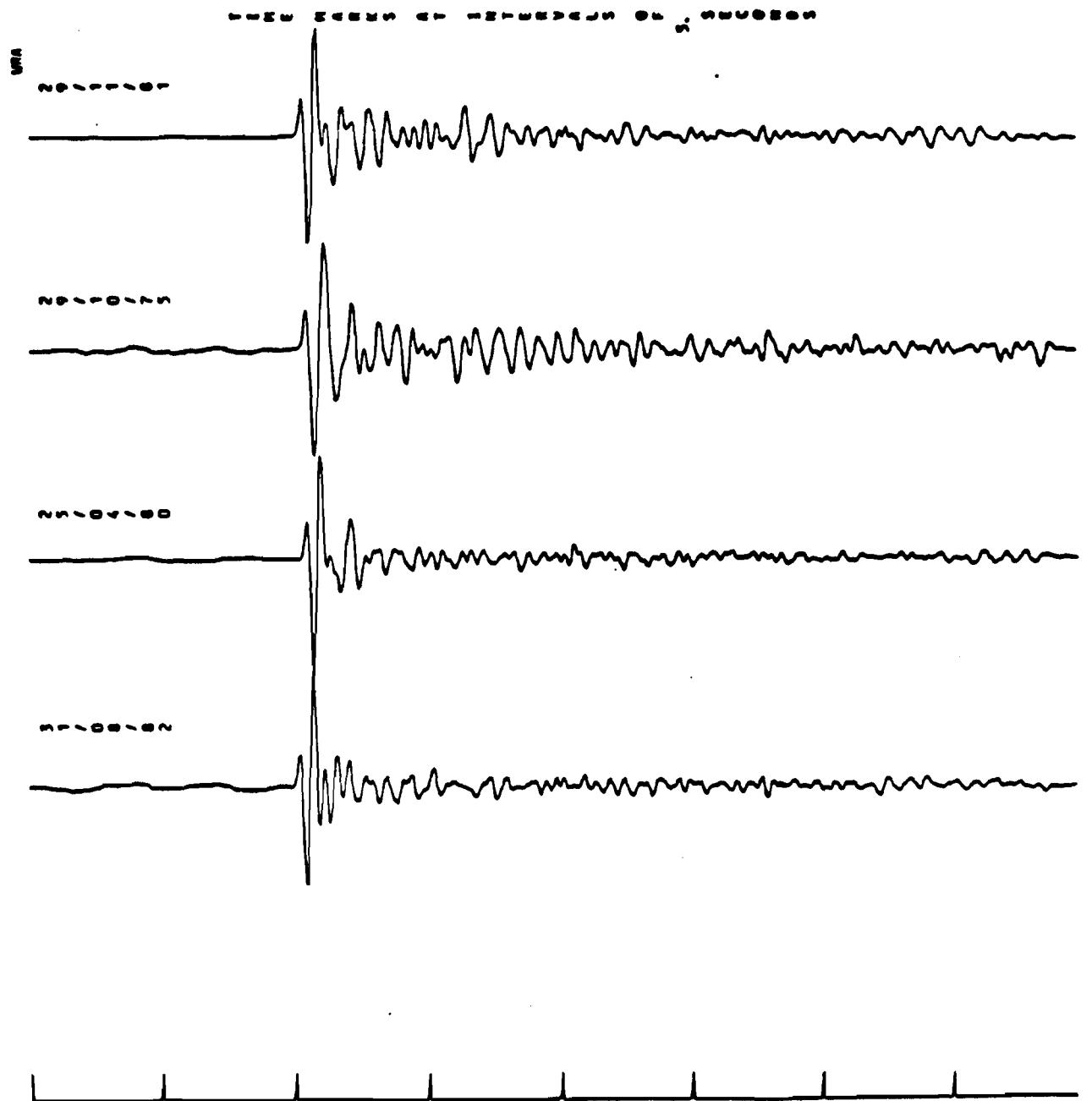
GBA Degelen



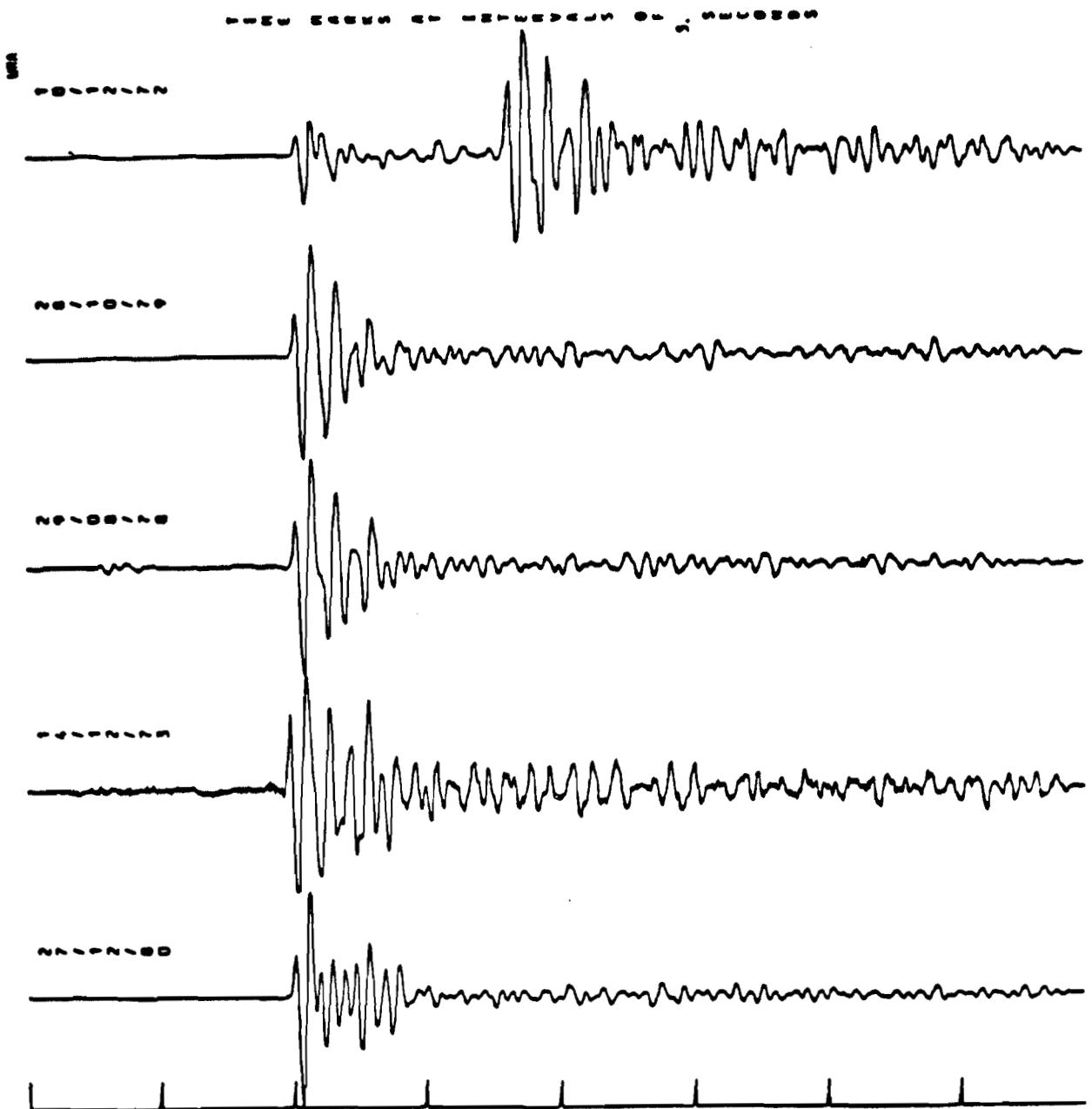
WRA Southwest Shagan River



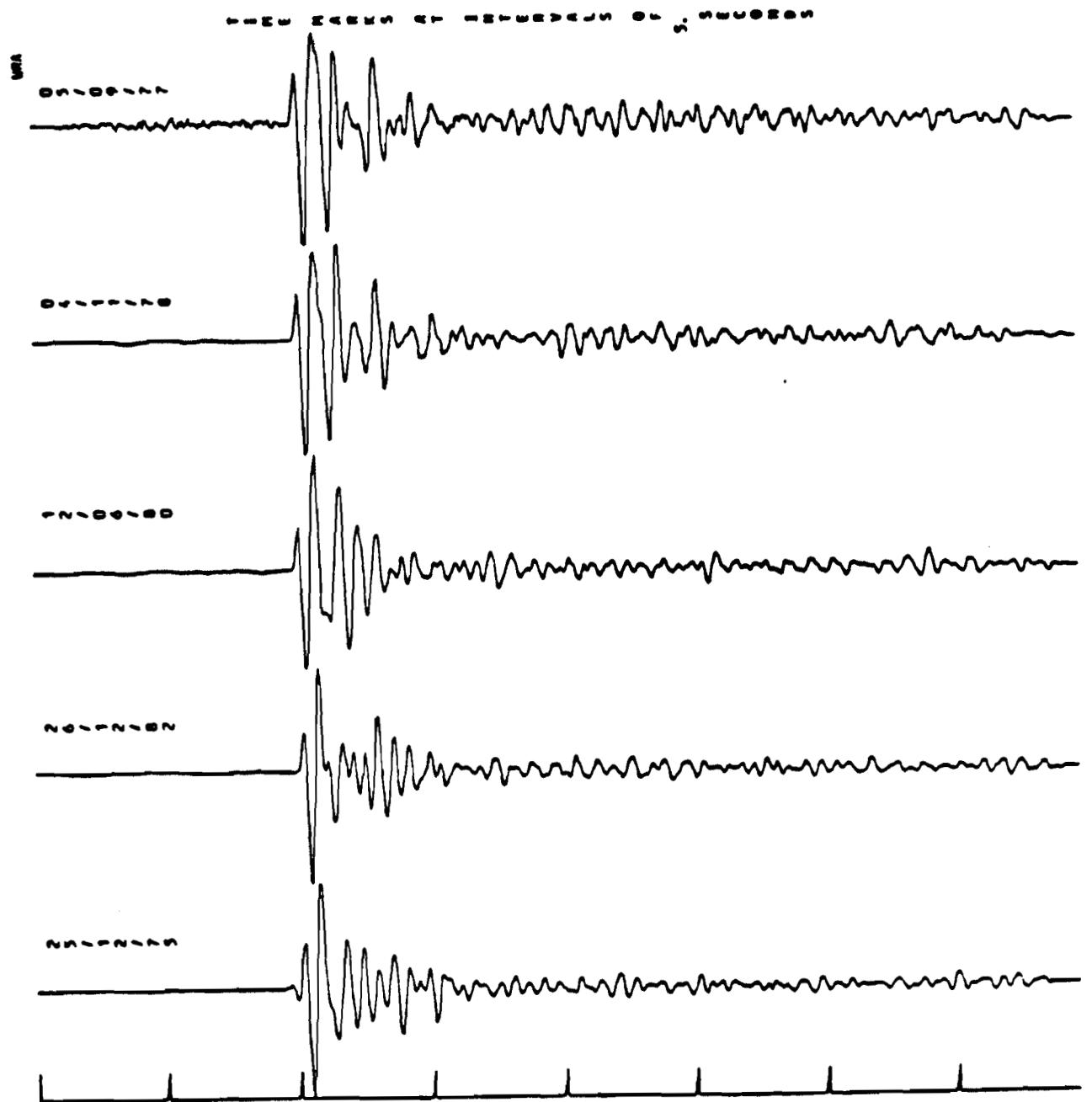
WRA Southwest Shagan River



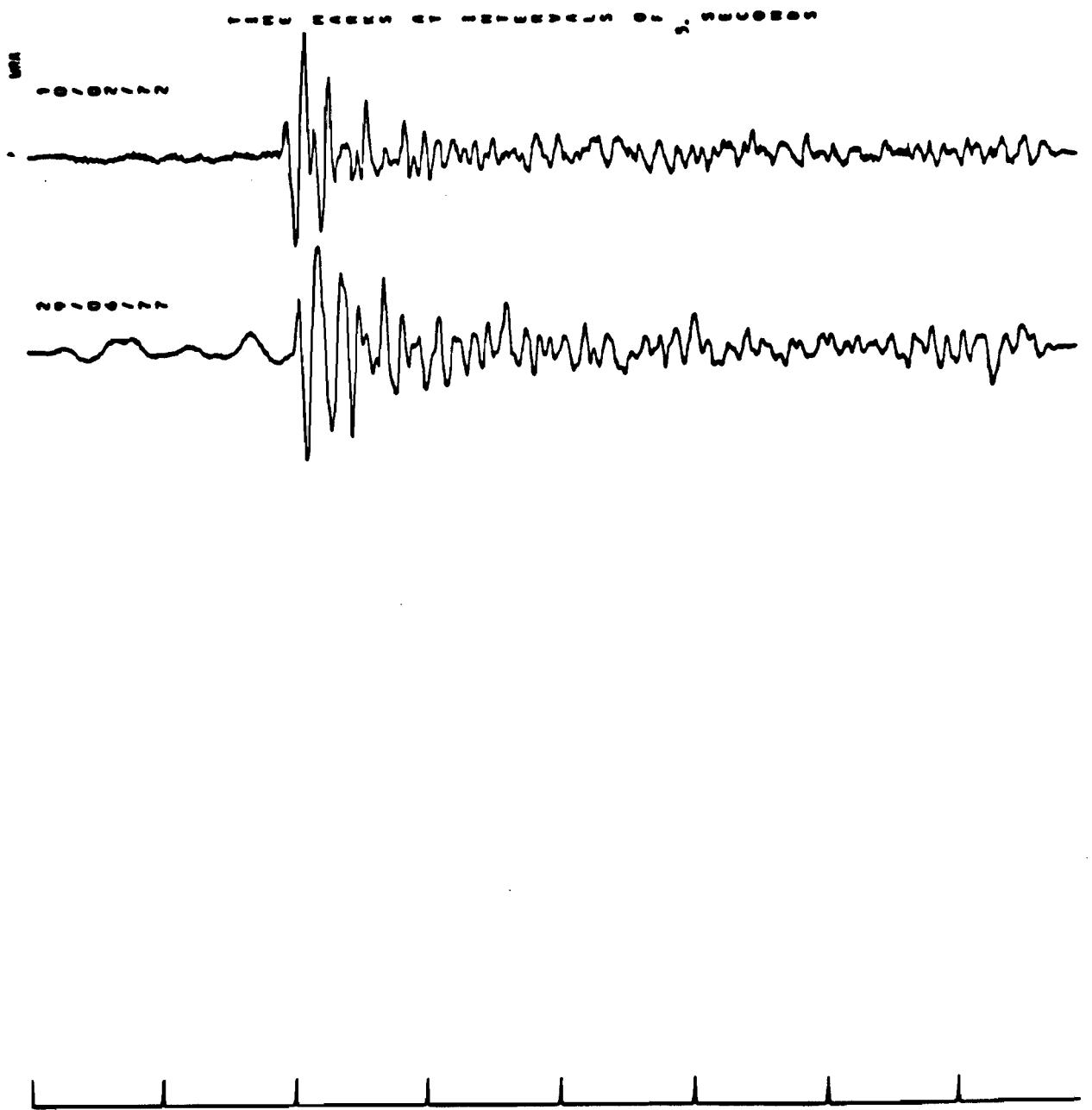
WRA Southwest Shagan River



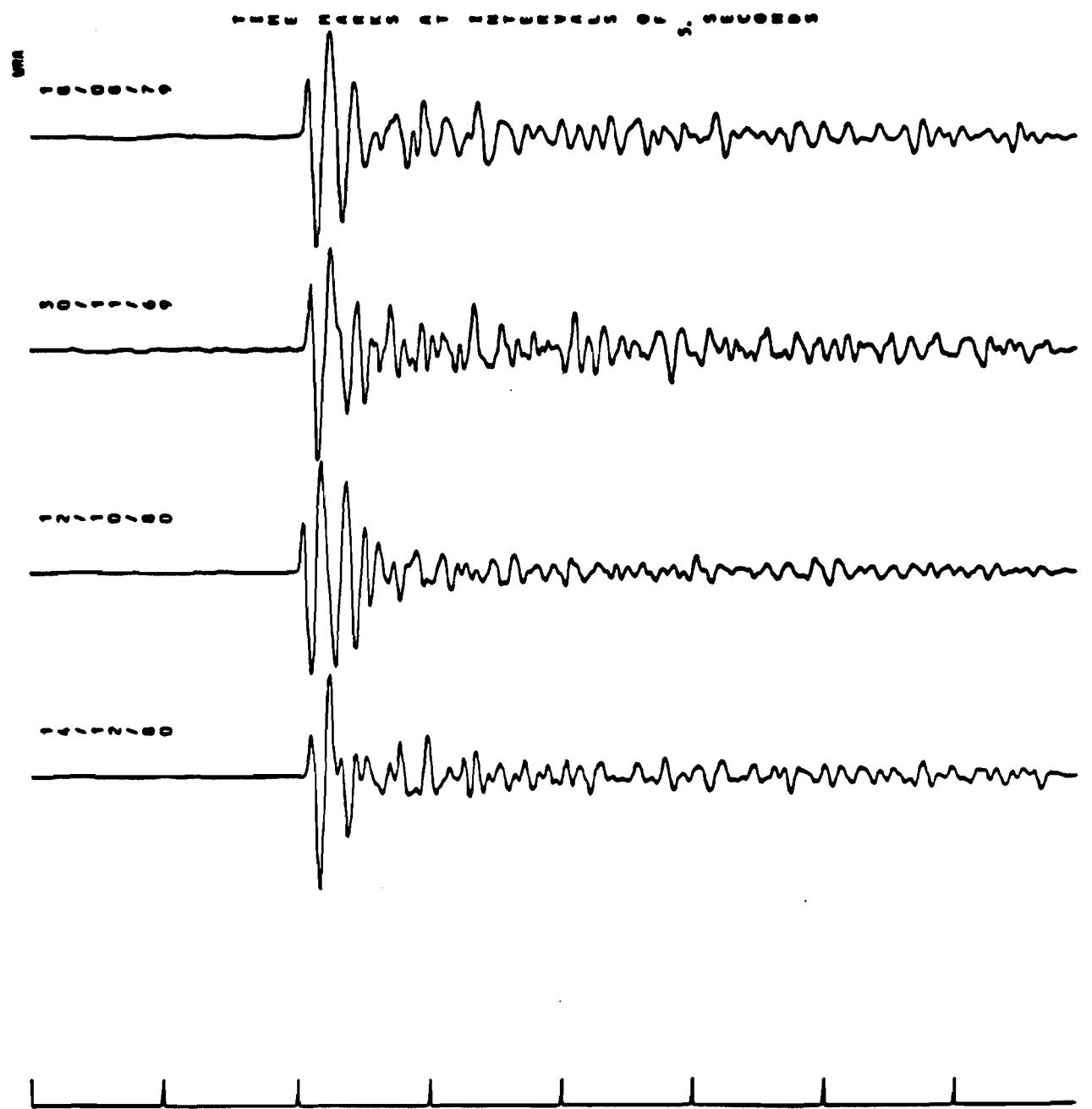
WRA Northeast Shagan River

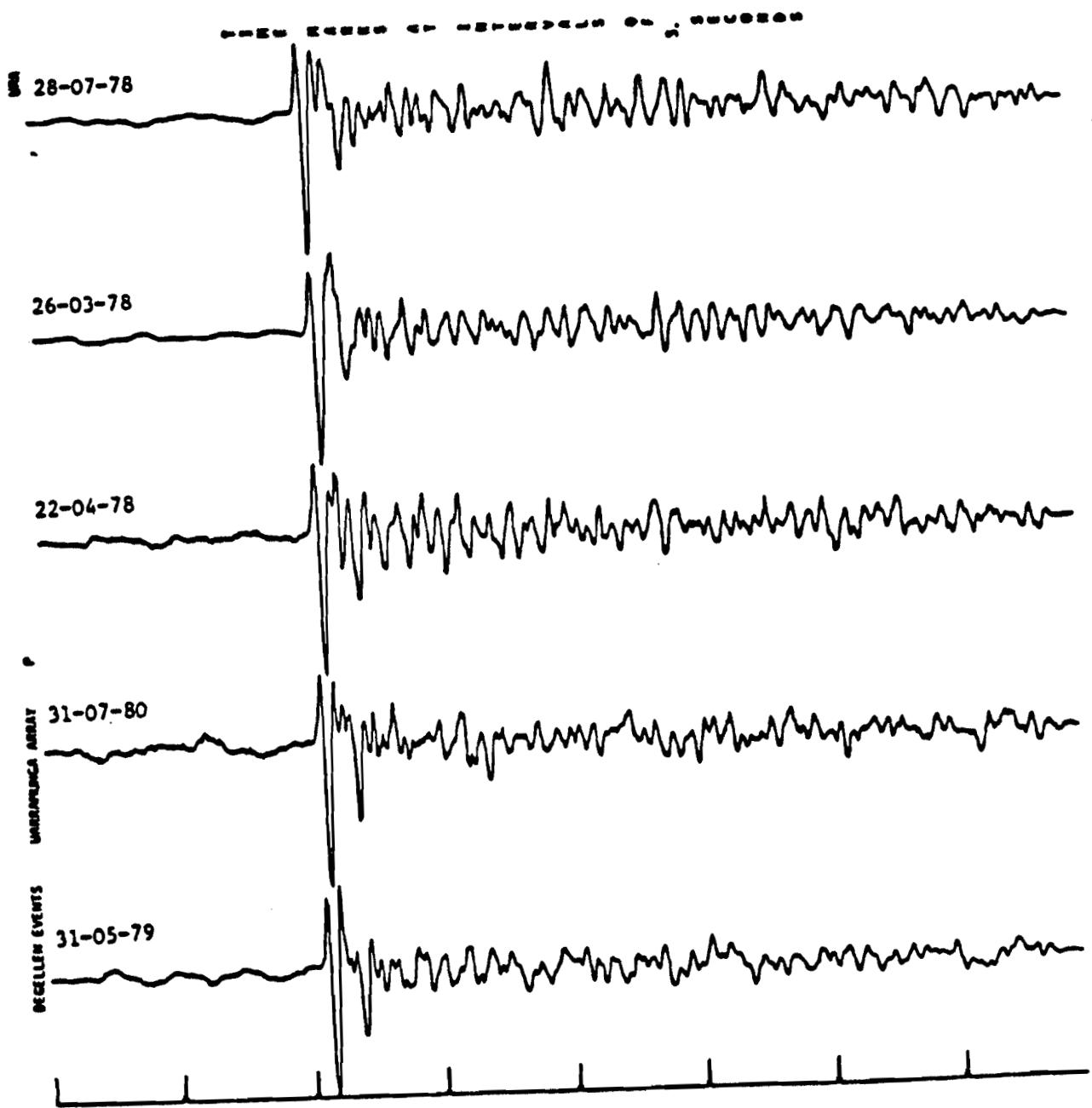


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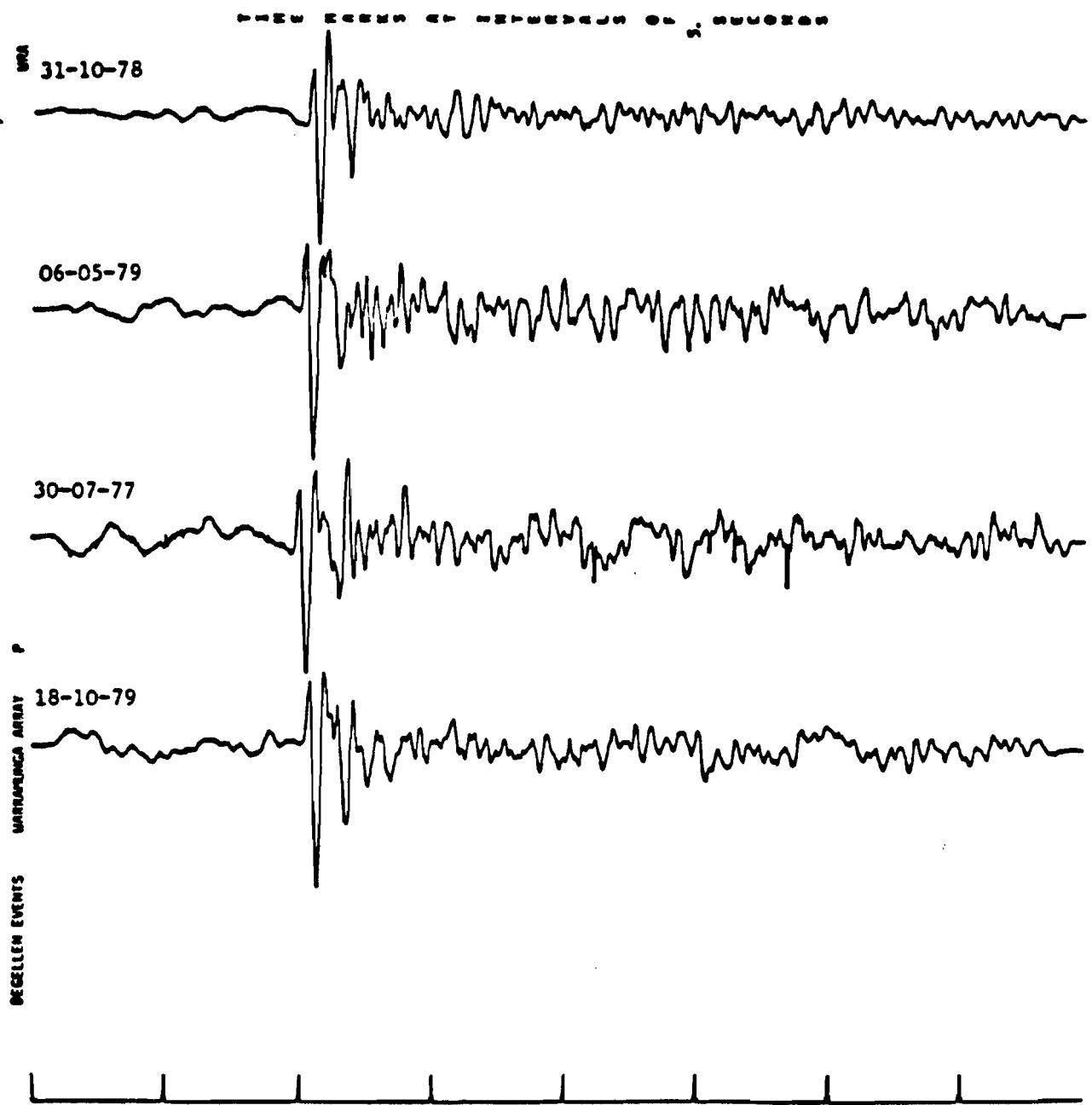


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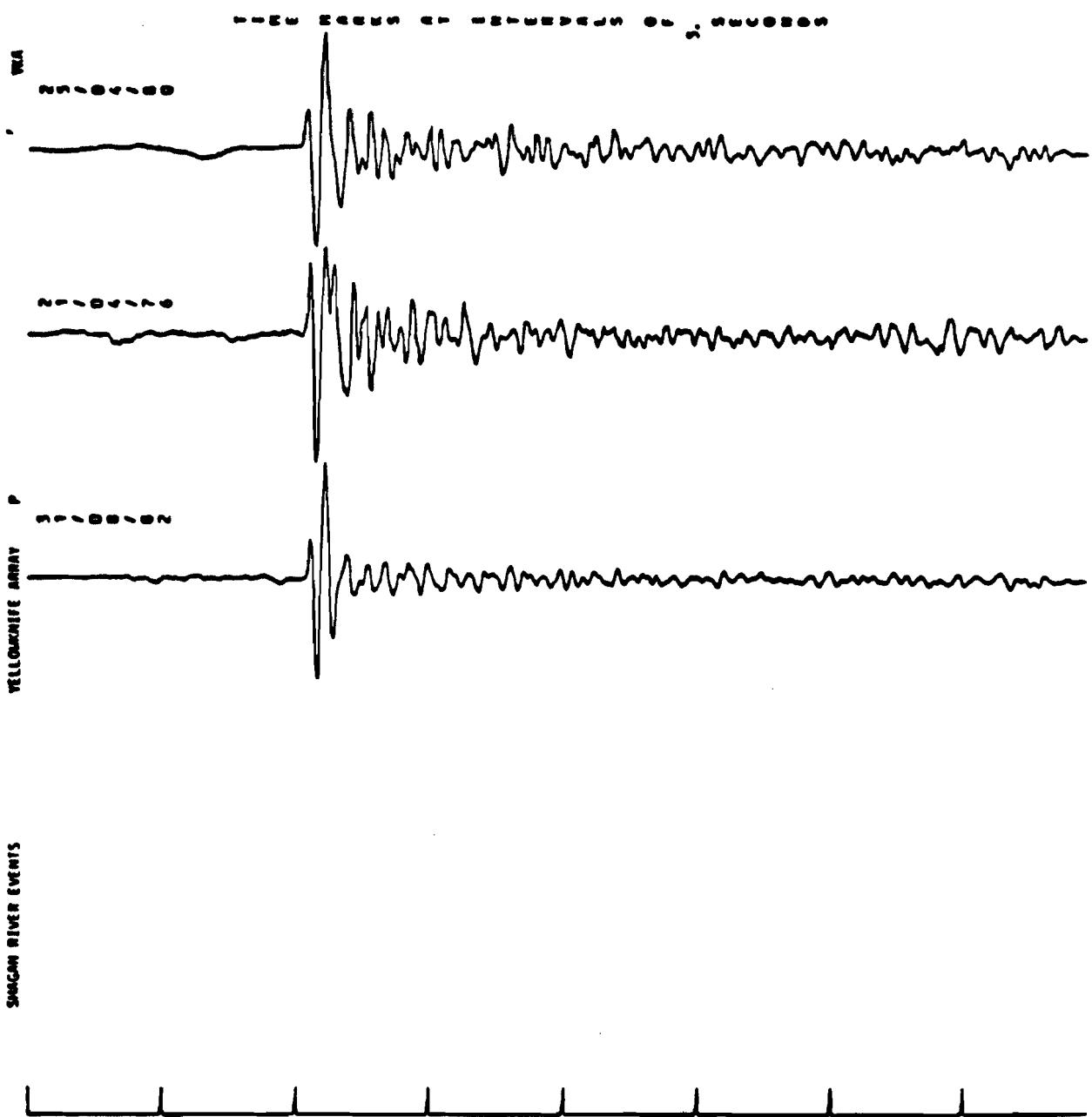




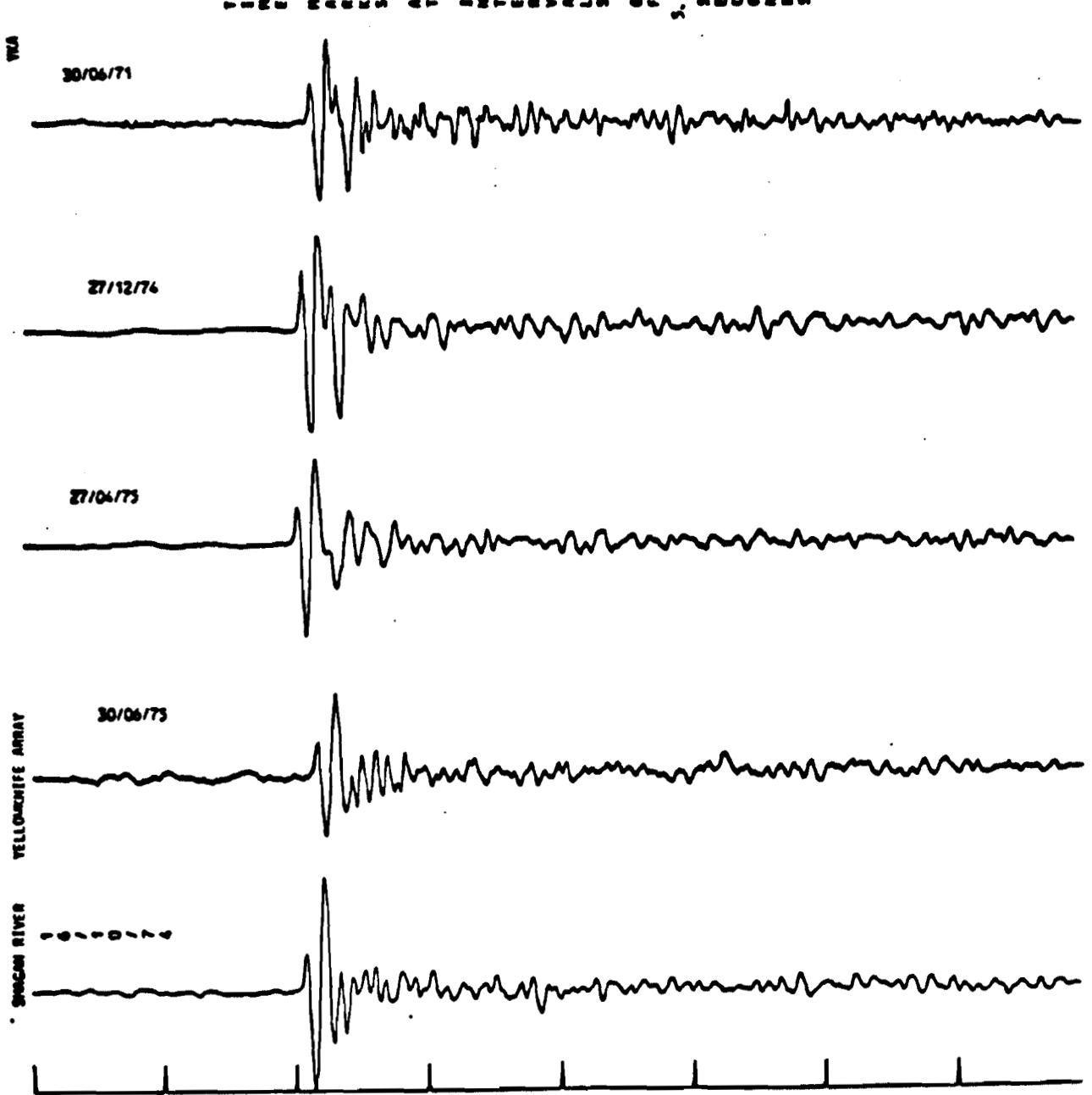
WRA Dugelan



WRA Degelen

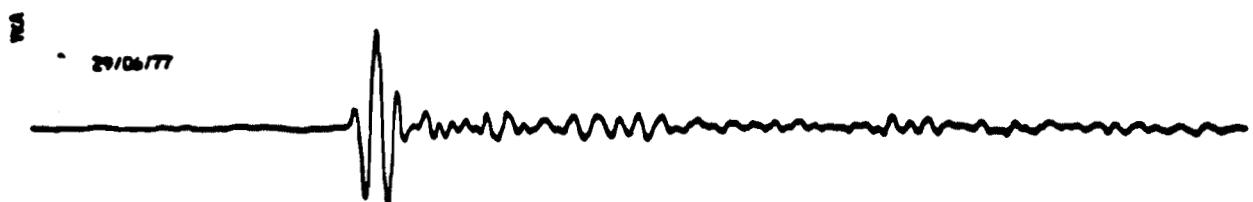


YKA Shagan River



YKA Shagan River

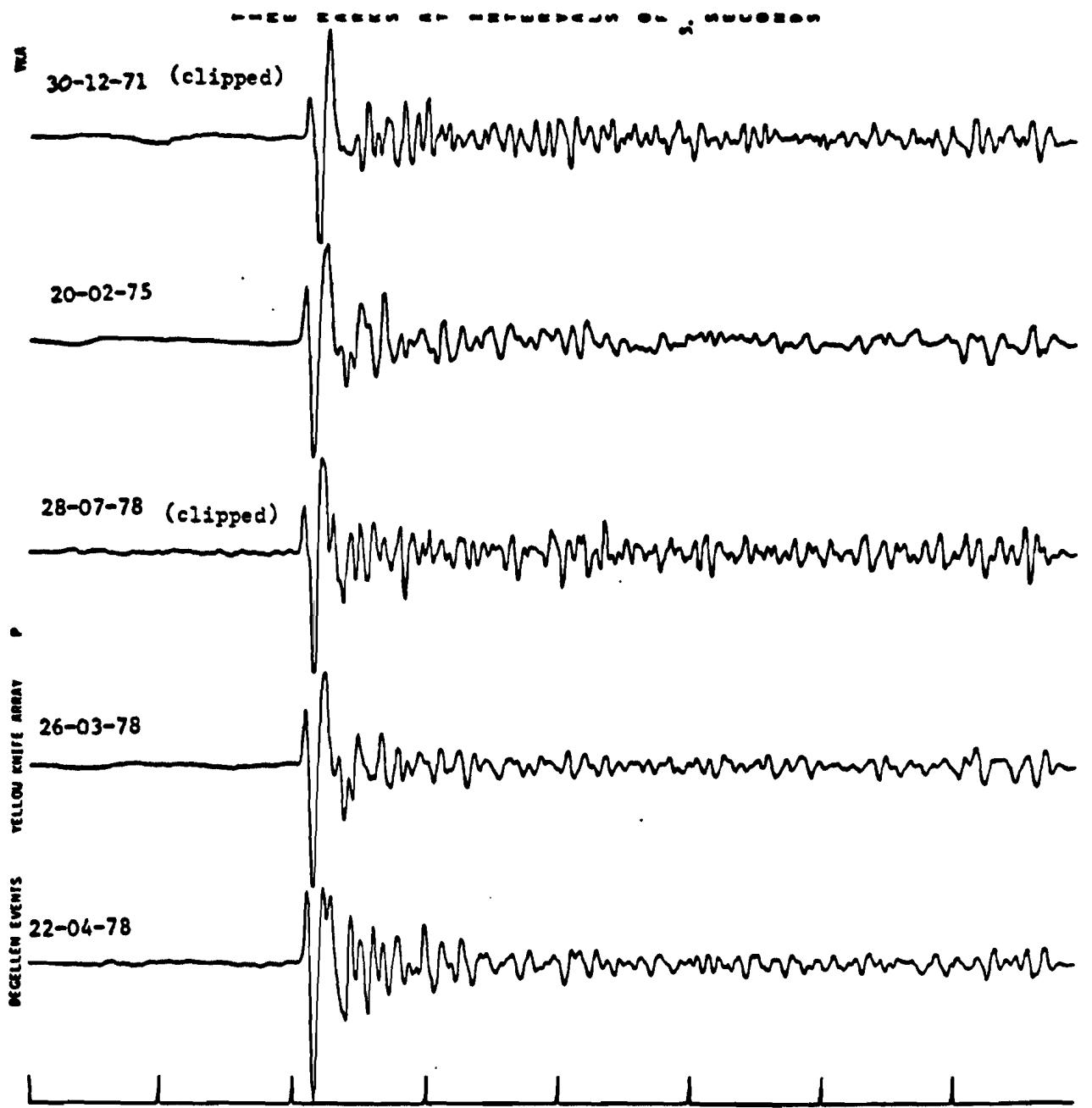
29/06/77



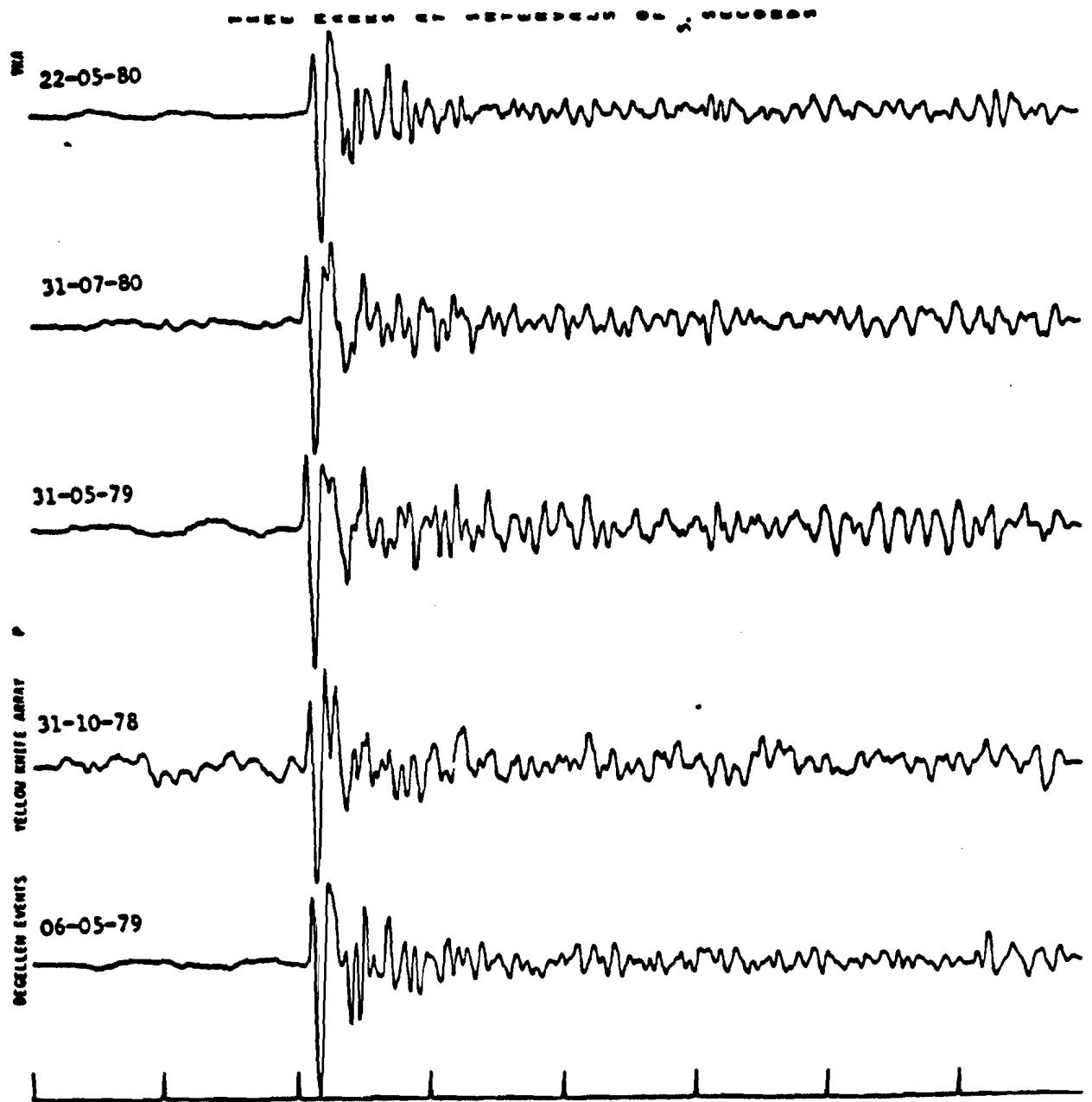
YELLOEONITE MOUNTAIN
SHAGAN RIVER



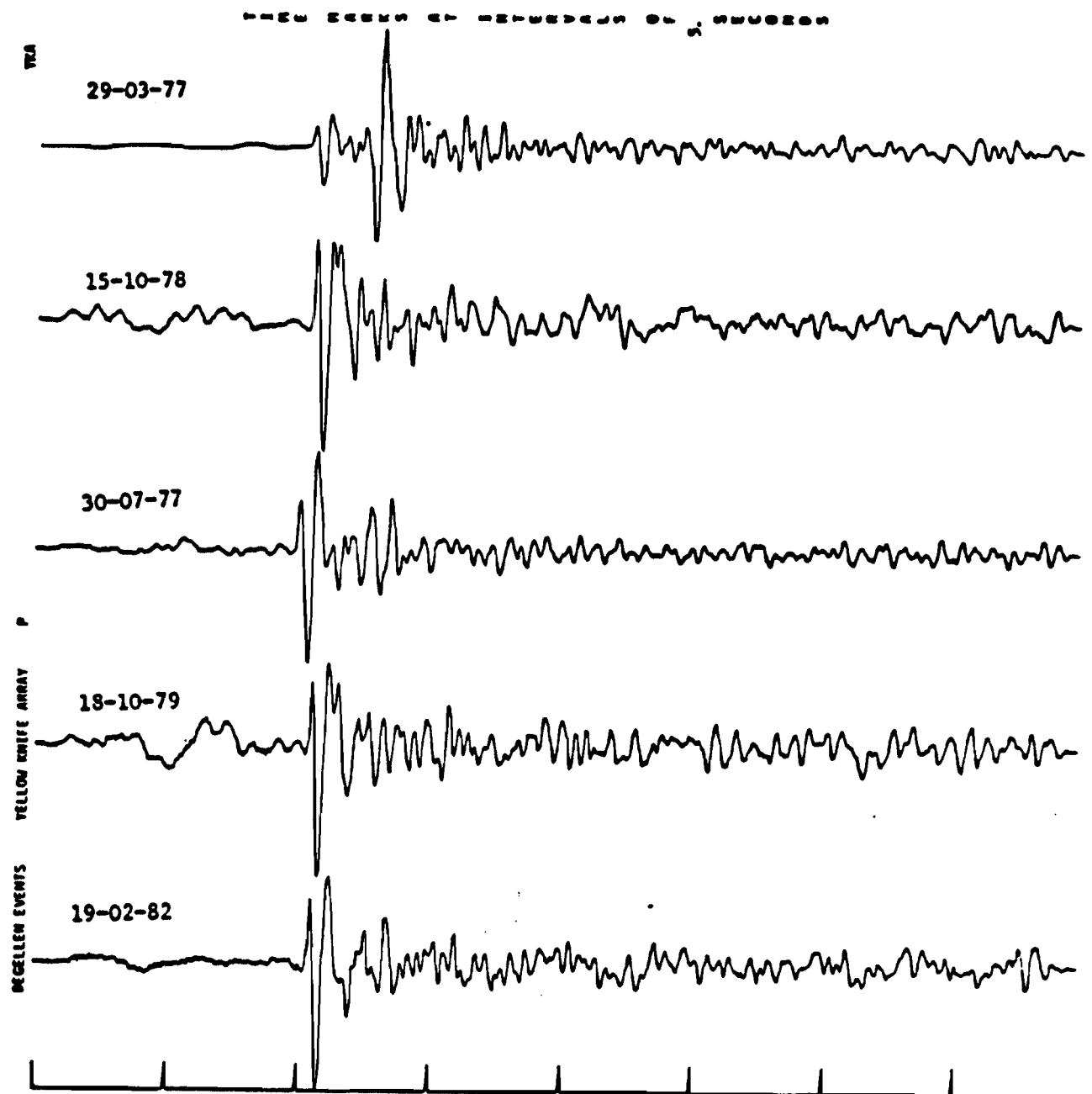
TKA Shagan River



YKA Degelen



YKA Degelen



YKA Degelen

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TABLE 1

JED Epicentre and Least Square Estimates of m_b for Explosions at Shagan RiverMean Epicentre: 49.988°N 78.892°E

Page 1

No.	Date	Origin Time	\pm sec	Latitude, $^{\circ}\text{N}$	\pm km	Longitude, $^{\circ}\text{E}$	\pm km	Area of Confidence Region, sq km	n	m_b	$\pm 95\%$ CL	n
1	15.01.65*	05 59 58.40	0.0	49.940	0.011	79.010	0.007	0.00	78	5.85	0.156	8
2	19.06.68	05 05 57.31	0.10	49.982	1.877	79.003	1.222	11.20	119	5.35	0.068	25
3	30.11.69	03 32 57.07	0.10	49.913	1.797	78.961	1.154	10.15	201	6.00	0.068	44
4	30.06.71	03 56 57.37	0.10	49.949	1.909	78.986	1.188	11.11	113	5.29	0.097	22
5	10.02.72	05 02 57.52	0.10	50.014	1.831	78.878	1.166	10.47	143	5.37	0.077	35
6	02.11.72	01 26 57.62	0.09	49.923	1.708	78.815	1.118	9.34	258	6.14	0.055	38
7	10.12.72	04 27 07.31	0.11	50.001	2.155	78.973	1.209	12.75	133	6.00	0.085	14
8	23.07.73	01 22 57.64	0.09	49.962	1.718	78.812	1.113	9.35	258	6.18	0.064	60
9	14.12.73	07 46 57.15	0.09	50.044	1.736	78.987	1.124	9.54	209	5.82	0.062	54
10	16.04.74	05 52 57.40	0.16	50.041	2.620	78.943	1.737	22.33	23	4.44	0.138	10
11	31.05.74	03 26 57.47	0.10	49.950	1.722	78.852	1.125	9.49	236	5.83	0.055	70
12	16.10.74	06 32 57.58	0.10	49.979	1.797	78.898	1.155	10.17	167	5.47	0.060	57
13	27.12.74	05 46 56.87	0.10	49.943	1.806	79.011	1.146	10.13	175	5.50	0.064	50
14	27.04.75	05 36 57.25	0.10	49.949	1.806	78.926	1.134	10.03	201	5.56	0.059	60
15	30.06.75	03 26 57.58	0.20	50.004	2.533	78.957	2.250	27.80	38	4.63	0.121	13
16	29.10.75	04 46 57.33	0.10	49.946	1.814	78.878	1.144	10.14	207	5.74	0.061	55
17	25.12.75	05 16 57.16	0.10	50.044	1.735	78.814	1.116	9.47	231	5.70	0.059	59
18	21.04.76	05 02 57.19	0.11	49.890	1.884	78.827	1.211	11.19	125	5.28	0.042	52
19	09.06.76	03 02 57.23	0.10	49.989	1.854	79.022	1.169	10.61	143	5.12	0.071	39

*Restrained hypocentre and origin time

1 Shagan River

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No.	Date	Origin Time	\pm sec	Latitude, °N	\pm km	Longitude, °E	\pm km	Area of Confidence sq km	n	m_b	$\pm 95\% CL$	n
20	04.07.76	02 56 57.46	0.10	49.909	1.730	78.911	1.139	9.64	231	5.81	0.057	66
21	28.08.76	02 56 57.48	0.10	49.969	1.753	78.930	1.123	9.64	223	5.82	0.054	73
22	23.11.76	05 02 57.28	0.10	50.008	1.722	78.963	1.119	9.43	263	5.87	0.053	76
23	07.12.76	04 56 57.38	0.09	49.922	1.721	78.846	1.121	9.43	236	5.90	0.059	60
24	29.05.77	02 56 57.58	0.10	49.937	1.715	78.770	1.113	9.35	288	5.77	0.053	77
25	29.06.77	03 06 57.76	0.11	50.006	1.930	78.869	1.157	10.95	171	5.22	0.059	59
26	05.09.77	03 02 57.34	0.10	50.035	1.737	78.921	1.112	9.46	293	5.74	0.051	84
27	29.10.77	03 07 02.47	0.11	50.069	2.093	78.975	1.232	12.65	147	5.54	0.061	40
28	30.11.77	04 06 57.36	0.10	49.958	1.731	78.885	1.114	9.45	284	5.92	0.043	49
29	11.06.78	02 56 57.57	0.09	49.898	1.725	78.797	1.110	9.34	279	5.86	0.053	76
30	05.07.78	02 46 57.47	0.09	49.887	1.681	78.871	1.108	9.10	279	5.83	0.052	81
31	29.08.78	02 37 06.25	0.09	50.000	1.752	78.978	1.117	9.54	246	5.95	0.052	42
32	15.09.78	02 36 57.42	0.09	49.916	1.710	78.879	1.109	9.26	276	5.99	0.053	80
33	04.11.78	05 05 57.32	0.09	50.034	1.723	78.943	1.106	9.31	261	5.56	0.048	95
34	29.11.78	04 33 02.49	0.10	49.949	1.774	78.798	1.151	9.98	213	6.07	0.054	39
35	01.02.79	04 12 57.64	0.10	50.090	1.754	78.870	1.150	9.85	177	5.38	0.052	79
36	23.06.79	02 56 57.52	0.09	49.903	1.687	78.855	1.094	9.02	334	6.22	0.047	103
37	07.07.79	03 46 57.33	0.09	50.026	1.716	78.991	1.103	9.24	289	5.83	0.049	90
38	04.08.79	03 56 57.09	0.09	49.894	1.678	78.904	1.095	8.98	736	6.16	0.046	110

No.	Date	Origin Time	\pm sec	Latitude, °N	\pm km	Longitude, °E	\pm km	Area of Confidence Region, sq km	n	m_b	$\pm 95\% CL$	n
39	18.08.79	02 51 57.13	0.09	49.943	1.668	78.938	1.091	8.89	338	6.12	0.045	115
40	28.10.79	03 16 56.94	0.09	49.973	1.691	78.997	1.094	9.04	305	5.96	0.047	103
41	02.12.79	04 36 57.45	0.09	49.891	1.720	78.796	1.105	9.27	277	6.01	0.048	98
42	23.12.79	04 56 57.44	0.09	49.916	1.696	78.755	1.099	9.09	280	6.18	0.049	94
43	25.04.80	03 56 57.53	0.09	49.973	1.729	78.755	1.121	9.47	220	5.50	0.050	89
44	12.06.80	03 26 57.62	0.09	49.980	1.738	79.001	1.112	9.43	225	5.59	0.054	74
45	29.06.80	02 32 57.69	0.09	49.939	1.749	78.815	1.126	9.60	214	5.74	0.055	69
46	14.09.80	02 42 39.13	0.09	49.921	1.675	78.802	1.095	8.95	325	6.21	0.052	83
47	12.10.80	03 34 14.10	0.09	49.961	1.684	79.028	1.097	9.02	301	5.90	0.050	91
48	14.12.80	03 47 06.40	0.09	49.899	1.688	78.938	1.100	9.06	291	5.95	0.049	94
49	27.12.80	04 09 08.08	0.09	50.057	1.711	78.981	1.114	9.32	245	5.88	0.055	72
50	29.03.81	04 03 50.03	0.09	50.007	1.717	78.982	1.104	9.26	258	5.61	0.052	83
51	22.04.81	01 17 11.34	0.09	49.885	1.684	78.810	1.094	9.00	339	6.05	0.049	96
52	27.05.81	03 58 12.34	0.10	49.985	1.786	78.980	1.140	9.92	184	5.46	0.054	75
53	13.09.81	02 17 18.25	0.09	49.910	1.677	78.915	1.093	8.95	350	6.18	0.048	100
54	18.10.81	03 57 02.64	0.09	49.923	1.709	78.859	1.101	9.17	322	6.11	0.054	77
55	29.11.81	03 35 08.60	0.09	49.887	1.768	78.860	1.122	9.64	255	5.73	0.052	82
56	27.12.81	03 43 14.13	0.09	49.923	1.698	78.795	1.098	9.10	340	6.31	0.050	91
57	25.04.82	03 23 05.37	0.09	49.903	1.730	78.913	1.108	9.35	272	6.1(1)		90

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No.	Date	Origin Time	\pm sec	Latitude, °N	\pm km	Longitude, °E	\pm km	Area of Confidence Region, sq km	n	m _b	$\pm 95\%$ CL	n
58	04.07.82	01 17 14.20	0.10	49.960	1.777	78.807	1.137	9.89	271	6.1		90
59	21.08.82	01 31 00.70	0.10	49.924	1.856	78.761	1.152	10.42	152	5.4		78
60	05.12.82	03 37 12.55	0.09	49.919	1.722	78.813	1.109	9.31	279	6.1		118
61	26.12.82	03 35 14.20	0.09	50.071	1.731	78.988	1.110	9.39	218	5.7		98

(1) The magnitude of explosions from 1982 onwards are those reported by the NEIS/PDE service.

TABLE 2
Station Corrections for Shagan River Explosions

Station	Computed Value	Number in Row	95 Percent Confidence Limits	Variance
1 AAE	-0.418	1	+/- 0.44645	0.051884
2 ASP	0.277	30	+/- 0.08181	0.001742
3 ALE	-0.416	32	+/- 0.07925	0.001635
4 AVF	-0.284	22	+/- 0.09531	0.002364
5 BAG	0.251	15	+/- 0.11521	0.003455
6 BUT	0.036	22	+/- 0.09532	0.002365
7 BDW	-0.780	14	+/- 0.11925	0.003702
8 BKS	0.077	33	+/- 0.07802	0.001584
9 BLA	-0.188	3	+/- 0.25700	0.017194
10 BMN	-0.247	16	+/- 0.11164	0.003244
11 BMO	-0.620	7	+/- 0.16958	0.007485
12 BLC	0.378	11	+/- 0.13500	0.004744
13 BNG	0.341	32	+/- 0.07943	0.001642
14 BNH	0.131	10	+/- 0.14105	0.005179
15 BNS	-0.093	10	+/- 0.14155	0.005215
16 BRG	-0.533	40	+/- 0.07101	0.001313
17 BSF	-0.159	29	+/- 0.08321	0.001802
18 BUD	-0.634	26	+/- 0.08776	0.002005
19 BUL	0.060	44	+/- 0.06782	0.001197
20 CAF	-0.175	6	+/- 0.18197	0.008620
21 CBM	-0.223	10	+/- 0.14100	0.005175
22 CDF	-0.604	31	+/- 0.08050	0.001687
23 CHG	-0.005	20	+/- 0.09993	0.002600
24 CLL	-0.061	42	+/- 0.06932	0.001251
25 CNG	-0.128	7	+/- 0.16841	0.007383
26 COL	0.315	22	+/- 0.09550	0.002374
27 COP	-0.019	36	+/- 0.07480	0.001456
28 CPU	-0.254	7	+/- 0.16940	0.007470
29 CTA	-0.141	7	+/- 0.16853	0.007393
30 CVF	-0.129	26	+/- 0.08780	0.002007
31 CVP	0.288	6	+/- 0.18176	0.008599
32 CWF	0.043	10	+/- 0.14096	0.005172
33 DAG	-0.280	37	+/- 0.07380	0.001418
34 DCN	0.279	18	+/- 0.10529	0.002886
35 DDK	0.178	8	+/- 0.15767	0.006471
36 DKM	0.200	15	+/- 0.11522	0.003456
37 DLE	0.219	10	+/- 0.14109	0.005182
38 DMU	0.167	19	+/- 0.10250	0.002735
39 DUG	0.124	8	+/- 0.15600	0.006499
40 EAB	-0.136	29	+/- 0.08324	0.001603
41 EAU	0.285	27	+/- 0.08622	0.001435
42 EBH	0.132	33	+/- 0.07819	0.001591
43 EBL	0.139	31	+/- 0.08064	0.001693
44 EDI	-0.024	29	+/- 0.08325	0.001804
45 EDM	0.371	30	+/- 0.08185	0.001744
46 EDU	0.544	25	+/- 0.06976	0.002097
47 EGL	0.242	32	+/- 0.07942	0.001642
48 EKA	0.153	39	+/- 0.07186	0.001345
49 ELO	0.297	24	+/- 0.09143	0.002176
50 EMM	-0.120	13	+/- 0.12378	0.003986
51 EPF	0.067	16	+/- 0.11162	0.003243
52 ESK	0.285	24	+/- 0.09127	0.00168
53 EUR	0.216	28	+/- 0.08470	0.001866
54 FBA	0.262	7	+/- 0.16850	0.007390
55 FCC	0.388	19	+/- 0.10265	0.002743
56 FFC	0.347	33	+/- 0.07827	0.001595
57 FLN	0.343	21	+/- 0.09754	0.002477

Table 2 (cont'd)

58	FRB	0.334	26	+/- 0.08786	0.001809
59	F SJ	0.098	12	+/- 0.12924	0.004348
60	FUR	-0.091	34	+/- 0.07699	0.001543
61	GBA	-0.263	30	+/- 0.08181	0.001742
62	GCA	-0.344	3	+/- 0.25687	0.017176
63	GDM	0.031	31	+/- 0.06047	0.001666
64	GOL	-0.234	22	+/- 0.09542	0.002370
65	GIL	0.280	15	+/- 0.11570	0.003485
66	GRF	-0.112	33	+/- 0.07809	0.001588
67	GRFO	-0.316	2	+/- 0.31470	0.025780
68	GRM	-0.388	1	+/- 0.44645	0.051884
69	GRR	-0.097	25	+/- 0.08951	0.002085
70	HAU	0.037	32	+/- 0.07927	0.001636
71	HDM	-0.552	11	+/- 0.13461	0.004717
72	HFS	0.937	43	+/- 0.06867	0.001228
73	HNME	-0.293	4	+/- 0.22279	0.012421
74	MNH	0.476	2	+/- 0.31496	0.025823
75	HOF	-0.106	14	+/- 0.11948	0.003716
76	HYB	0.125	37	+/- 0.07375	0.001416
77	INK	0.393	26	+/- 0.08793	0.002012
78	IPM	0.422	17	+/- 0.10833	0.003055
79	JAY	-0.464	5	+/- 0.19913	0.010322
80	JOS	-0.147	33	+/- 0.07807	0.001587
81	KEV	0.171	42	+/- 0.06937	0.001253
82	KGM	0.279	20	+/- 0.09993	0.002599
83	KHC	-0.329	37	+/- 0.07378	0.001417
84	KKM	0.101	17	+/- 0.10830	0.003053
85	KMU	0.018	6	+/- 0.18254	0.008673
86	KNA	-0.085	8	+/- 0.15762	0.006467
87	KUD	0.220	23	+/- 0.09334	0.002268
88	KRA	0.122	40	+/- 0.07101	0.001312
89	KJF	0.471	43	+/- 0.06870	0.001229
90	KTG	-0.010	27	+/- 0.08628	0.001938
91	KSR	-0.166	9	+/- 0.14865	0.005752
92	LAO	0.319	9	+/- 0.15058	0.005902
93	LBF	-0.293	26	+/- 0.08781	0.002007
94	LD3	-0.064	11	+/- 0.13445	0.004706
95	LEM	-0.402	10	+/- 0.14098	0.005174
96	LFF	-0.101	26	+/- 0.08782	0.002008
97	LGP	0.530	11	+/- 0.13440	0.004702
98	LHC	0.245	23	+/- 0.09324	0.002263
99	LMR	-0.071	27	+/- 0.08618	0.001933
100	LON	-0.242	26	+/- 0.08785	0.002010
101	LOR	-0.071	34	+/- 0.07698	0.001543
102	LPU	0.149	21	+/- 0.09755	0.002477
103	LPF	0.017	20	+/- 0.09996	0.002601
104	LRG	-0.029	30	+/- 0.08181	0.001742
105	LSF	-0.501	26	+/- 0.08774	0.002006
106	MAN	0.719	2	+/- 0.31461	0.025765
107	MAT	-0.762	16	+/- 0.11166	0.003245
108	MBL	0.270	15	+/- 0.11524	0.003457
109	MBC	0.661	30	+/- 0.08209	0.001754
110	MEK	0.080	7	+/- 0.16836	0.007378
111	MIM	-0.289	14	+/- 0.11932	0.003706
112	MFF	0.014	24	+/- 0.09133	0.002171
113	MNT	-0.120	18	+/- 0.10528	0.002885
114	MUX	-0.072	41	+/- 0.07018	0.001282
115	MUN	0.290	11	+/- 0.13445	0.004705
116	MSO	-0.208	19	+/- 0.10261	0.002741
117	MZF	-0.114	17	+/- 0.10831	0.003054
118	NAI	-0.043	14	+/- 0.11923	0.003701
119	NAO	0.137	17	+/- 0.10923	0.003106
120	NB2	0.346	14	+/- 0.11927	0.003703

Table 2 (cont'd)

121	NEW	-0.481	14	+/- 0.11922	0.003700
122	NOR	-0.629	2	+/- 0.31940	0.026555
123	NPA	0.111	9	+/- 0.14853	0.005743
124	NUR	0.691	44	+/- 0.06791	0.001200
125	NWAD	-0.161	10	+/- 0.14099	0.005174
126	OGA	-0.142	10	+/- 0.14105	0.005179
127	OIC	-0.357	14	+/- 0.11944	0.003714
128	OTT	0.167	30	+/- 0.08186	0.001744
129	PCT	-0.304	16	+/- 0.11160	0.003242
130	PIP	0.335	7	+/- 0.16839	0.007381
131	PLP	-0.362	7	+/- 0.16837	0.007379
132	PMG	0.287	22	+/- 0.09527	0.002363
133	PMR	0.264	39	+/- 0.07200	0.001349
134	PNT	-0.211	32	+/- 0.07930	0.001637
135	PUD	-0.020	12	+/- 0.12862	0.004320
136	PPI	0.186	16	+/- 0.11158	0.003241
137	PPK	-0.140	10	+/- 0.14093	0.005170
138	PRE	-0.247	24	+/- 0.09134	0.002172
139	PRU	-0.533	40	+/- 0.07101	0.001512
140	PSI	-0.096	13	+/- 0.12373	0.003985
141	PSZ	-0.297	4	+/- 0.22315	0.012962
142	QUA	-0.159	3	+/- 0.25703	0.017197
143	RES	-0.466	26	+/- 0.06779	0.002006
144	RJF	-0.331	27	+/- 0.08618	0.001433
145	SCH	0.135	16	+/- 0.11164	0.003244
146	SES	0.312	27	+/- 0.08627	0.001937
147	SFA	-0.018	1	+/- 0.44645	0.051664
148	SHK	-0.474	2	+/- 0.31476	0.025791
149	SKD	-0.840	3	+/- 0.25724	0.017225
150	SMF	-0.354	25	+/- 0.08948	0.002664
151	SUP	-0.208	26	+/- 0.08785	0.002009
152	SPF	0.313	17	+/- 0.10847	0.003063
153	SSC	0.183	28	+/- 0.08466	0.001866
154	SSF	-0.274	29	+/- 0.08321	0.001603
155	STU	-0.062	32	+/- 0.07922	0.001633
156	STJ	0.056	7	+/- 0.16830	0.007374
157	SWV	0.596	7	+/- 0.16843	0.007384
158	TCF	-0.334	28	+/- 0.08464	0.001865
159	TRI	-0.178	1	+/- 0.44645	0.051664
160	TRT	0.458	17	+/- 0.10828	0.003062
161	TSK	0.049	8	+/- 0.15766	0.006487
162	TUL	-0.043	41	+/- 0.07025	0.001285
163	UBU	0.346	2	+/- 0.31940	0.026555
164	UCT	0.196	10	+/- 0.14109	0.005181
165	UFP	0.890	28	+/- 0.06464	0.001865
166	VIC	-0.358	1	+/- 0.44645	0.051884
167	WET	-0.165	5	+/- 0.19923	0.010333
168	WES	0.347	3	+/- 0.25736	0.017241
169	WIN	-0.353	14	+/- 0.11936	0.003709
170	WLU	0.092	2	+/- 0.31468	0.025776
171	WOL	0.267	21	+/- 0.09766	0.002483
172	WRA	0.282	22	+/- 0.09534	0.002366
173	WTS	-0.191	7	+/- 0.16849	0.007390
174	YKC	0.523	27	+/- 0.06637	0.001942

TABLE 3

Least Squares Analysis Statistics (Shagan River Explosions)

NUMBER OF READINGS	=	3379
NUMBER OF UNKNOWNS	=	219
SUM OF SQUARES OF RESIDUALS	=	162.851200
MEAN SQUARE OF RESIDUALS	=	0.051535
NUMBER OF DEGREES OF FREEDOM	=	3160
STUDENTS T	=	1.96
SUM OF RESIDUALS	=	0.96E-11
SUM OF SQUARES DUE TO STATIONS	=	341.243306
MEAN SQUARE DUE TO STATIONS	=	1.972505
NUMBER OF EFFECTIVE STATIONS	=	173
SUM OF SQUARES DUE TO EVENTS	=	259.577125
MEAN SQUARE DUE TO EVENTS	=	5.768381
NUMBER OF EFFECTIVE EVENTS	=	45
MEAN STATION-EVENT EFFECT	=	5.741 +/- 0.01263

TABLE 4

JED Epicentres and Least Squares Estimates of m_b for Explosions at Degelen Mountain4 Degelen Mountain

No.	Date	Origin Time	\pm sec	Latitude, $^{\circ}$ N	\pm km	Longitude, $^{\circ}$ E	\pm km	Area of Confidence Region, sq km	n	m_b	\pm 95% CL	n
6	1 17.06.65	03 44 57.61	0.14	49.821	2.476	78.061	1.541	18.24	36	5.2 ⁽¹⁾		10
	2 17.09.65	03 59 57.52	0.13	49.804	2.105	78.176	1.721	17.42	34	5.2		9
	3 24.12.65	04 59 58.22	0.15	49.871	2.890	78.135	1.274	18.04	47	5.0		13
	4 13.02.66	04 57 57.50	0.08	49.804	1.572	78.158	0.864	6.64	178	6.1		51
	5 21.04.66	03 57 57.57	0.08	49.809	1.607	78.135	0.984	7.75	99	5.3		33
	6 7.05.66	03 57 58.07	0.12	49.774	2.398	78.149	1.624	18.86	32	4.8		16
	7 29.06.66	06 57 57.65	0.09	49.847	1.888	78.101	0.970	8.98	96	5.6		34
	8 21.07.66	03 57 57.50	0.08	49.738	1.583	78.140	0.968	7.52	99	5.3		31
	9 26.02.67	03 57 57.37	0.07	49.750	1.447	78.125	0.799	5.66	196	6.0		53
	10 20.04.67	04 07 57.66	0.08	49.731	1.584	78.148	0.980	7.59	105	5.5		37
	11 12.07.68	12 07 57.55	0.09	49.766	1.912	78.139	0.934	8.76	85	5.3		25
	12 29.09.68	03 42 57.44	0.07	49.813	1.474	78.175	0.809	5.84	160	5.8		54
	13 23.07.69	02 46 57.66	0.08	49.817	1.637	78.170	0.805	6.46	129	5.4		46
	14 29.01.70	07 02 57.56	0.07	49.813	1.378	78.185	0.793	5.32	138	5.5		50
	15 6.09.70	04 02 57.56	0.07	49.780	1.452	78.046	0.792	5.62	134	5.4		49
	16 22.03.71	04 32 57.80	0.07	49.791	1.467	78.142	0.718	5.14	196	5.70	0.060	54
	17 25.04.71	03 32 57.54	0.07	49.774	1.402	78.074	0.711	4.87	218	5.94	0.058	60
	18 25.05.71	04 02 58.07	0.10	49.815	1.855	78.197	0.981	8.93	74	5.02	0.086	20
	19 29.11.71	06 02 57.55	0.07	49.758	1.512	78.132	0.838	6.16	113	5.44	0.065	40

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Page 2

No.	Date	Origin Time	\pm sec	Latitude $^{\circ}$ N	Longitude, $^{\circ}$ E	\pm km	\pm km	Area of Confidence Region, sq km	n	m_b	\pm 95% CL	n	
20	30.12.71	06 20	57.80	0.07	49.772	1.451	78.093	0.745	5.28	162	5.78	0.059	51
21	10.03.72	04 56	57.42	0.07	49.752	1.445	78.142	0.775	5.49	157	5.41	0.058	52
22	28.03.72	04 21	57.60	0.09	49.740	1.815	78.130	0.839	7.47	109	5.14	0.068	34
23	7.06.72	01 27	57.43	0.07	49.808	1.459	78.121	0.789	5.58	145	5.40	0.065	39
24	6.07.72	01 02	59.91	0.16	49.781	2.698	78.093	1.959	25.90	21	4.42	0.154	6
25	16.08.72	03 16	57.53	0.09	49.770	1.746	78.113	0.890	7.62	95	5.13	0.073	29
26	10.12.72	04 26	57.66	0.06	49.837	1.319	78.102	0.693	4.44	229	5.6	0.061	62
27	16.02.73	05 02	57.59	0.07	49.822	1.433	78.158	0.746	5.23	153	5.46	0.061	46
28	10.07.73	01 26	57.73	0.07	49.798	1.471	78.087	0.778	5.61	130	5.30	0.065	38
29	26.10.73	04 26	57.74	0.07	49.759	1.507	78.164	0.795	5.87	116	5.24	0.064	38
30	30.01.74	04 56	57.80	0.12	49.837	2.041	78.049	1.216	12.15	55	4.9	0.064	13
31	30.01.74	04 57	02.22	0.08	49.853	1.708	78.087	0.836	7.01	134	5.4	0.060	36
32	16.05.74	03 02	57.65	0.07	49.752	1.470	78.093	0.799	5.75	133	5.25	0.060	46
33	25.06.74	03 56	57.70	0.34	49.840	5.098	78.166	2.297	51.12	28	4.50	0.133	8
34	10.07.74	02 56	57.60	0.09	49.783	1.761	78.130	0.875	7.52	118	5.16	0.060	44
35	13.09.74	03 02	57.61	0.09	49.778	1.737	78.081	0.901	7.67	96	5.17	0.064	39
36	16.12.74	06 22	57.73	0.10	49.793	1.765	78.133	1.055	9.14	70	5.0	0.064	26
37	16.12.74	06 40	57.96	0.10	49.867	1.702	78.087	1.090	9.09	71	4.8	0.064	24
38	20.02.75	05 32	57.63	0.07	49.789	1.414	78.062	0.723	5.65	188	5.65	0.053	64

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No.	Date	Origin Time	\pm sec	Latitude ^o N	\pm km	Longitude ^o E	\pm km	Area of Confidence, sq km	n	m_b	$\pm 95\% CL$	n
39	11.03.75	05 42 57.64	0.07	49.747	1.412	78.146	0.766	5.29	111	5.38	0.056	53
40	8.06.75	03 26 57.55	0.07	49.762	1.794	78.050	0.777	5.31	164	5.50	0.055	59
41	7.08.75	03 56 57.66	0.08	49.812	1.516	78.161	0.829	6.11	116	5.15	0.064	39
42	13.12.75	04 56 57.58	0.09	49.810	1.506	78.157	1.032	7.63	84	5.02	0.061	42
43	15.01.76	04 46 57.57	0.08	49.824	1.433	78.201	0.917	6.49	107	5.25	0.058	48
44	21.04.76	04 57 57.75	0.10	49.776	1.774	78.146	1.004	8.74	77	5.1	42	
45	19.05.76	02 56 57.81	0.12	49.796	2.364	78.058	1.372	15.44	47	4.82	0.075	27
46	23.07.76	02 32 57.79	0.09	49.779	1.648	78.085	0.921	7.43	100	5.04	0.057	49
47	30.10.76	04 57 2.51	0.14	49.821	3.008	78.029	1.732	22.85	33	4.9	15	
48	30.12.76	03 56 57.91	0.10	49.802	1.757	78.069	0.966	8.33	78	5.13	0.062	41
49	29.03.77	03 56 57.56	0.07	49.790	1.438	78.086	0.790	5.54	162	5.4	60	
50	25.04.77	04 06 57.74	0.10	49.813	1.810	78.150	0.971	8.62	91	5.06	0.059	46
51	30.07.77	01 56 57.72	0.08	49.759	1.777	78.097	0.813	7.08	116	5.09	0.055	55
52	17.08.77	04 26 57.57	0.09	49.825	1.705	78.170	1.003	8.36	81	4.99	0.067	35
53	29.10.77	03 06 57.57	0.06	49.833	1.350	78.131	0.694	4.56	245	5.6	68	
54	26.12.77	04 02 57.84	0.13	49.853	2.093	78.115	1.288	13.17	69	4.88	0.064	38
55	26.03.78	03 56 57.55	0.06	49.768	1.253	78.044	0.690	4.21	253	5.61	0.048	90
56	22.04.78	03 06 57.57	0.07	49.761	1.406	78.186	0.751	5.16	184	5.28	0.047	81
57	29.05.78	04 56 57.42	0.16	49.772	3.080	78.141	1.356	20.49	55	4.66	0.066	35

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No.	Date	Origin Time	\pm sec	Latitude, °N	\pm km	Longitude, °E	\pm km	Area of Confidence sq km	n	m_b	$\pm 95\% CL$	n
58	28.07.78	02 46 57.48	0.06	49.756	1.310	78.140	0.702	4.48	230	5.66	0.049	88
59	29.08.78	02 36 57.57	0.08	49.812	1.577	78.142	0.870	6.72	147	5.2		61
60	15.10.78	05 36 57.72	0.08	49.753	1.405	78.165	0.942	6.45	137	5.12	0.050	69
61	31.10.78	04 16 57.77	0.07	49.806	1.390	78.143	0.800	5.40	150	5.22	0.047	80
62	29.11.78	04 32 57.73	0.07	49.810	1.520	78.042	0.735	5.45	176	5.30		75
63	14.12.78	04 42 57.62	0.16	49.813	3.228	78.144	1.519	23.64	33	4.71	0.090	18
64	20.12.78	04 32 57.63	0.12	49.858	2.057	78.089	1.376	13.20	49	4.67	0.074	28
65	6.05.79	03 16 57.65	0.07	49.774	1.485	78.049	0.832	5.94	138	5.19	0.049	76
66	31.05.79	05 54 57.65	0.08	49.835	1.532	78.127	0.860	6.38	133	5.24	0.050	71
67	27.09.79	04 12 57.67	0.16	49.767	2.650	78.120	1.745	22.46	30	4.40	0.088	19
68	18.10.79	04 16 57.70	0.09	49.837	1.679	78.148	0.973	7.85	105	5.19	0.054	59
69	30.11.79	04 52 58.18	0.12	49.789	2.180	78.144	1.546	14.80	41	4.47	0.086	20
70	21.12.79	04 41 57.66	0.13	49.801	2.370	78.173	1.644	17.76	36	4.68	0.086	20
71	10.04.80	04 06 57.81	0.09	49.805	1.676	78.108	0.978	7.86	103	4.98	0.060	46
72	22.05.80	03 56 57.71	0.07	49.784	1.394	78.082	0.721	4.86	172	5.49	0.050	73
73	31.07.80	03 32 57.65	0.07	49.807	1.469	78.148	0.780	5.53	155	5.30	0.049	76
74	25.09.80	06 21 10.65	0.17	49.835	2.522	78.118	1.657	17.31	55	4.77	0.069	32
75	26.12.80	01 07 07.27	0.24	49.941	4.916	78.183	2.124	45.01	19	4.25	0.168	5
76	30.06.81	01 57 12.92	0.08	49.768	1.612	78.119	0.946	7.17	109	5.25	0.055	58

(1) Where no confidence limits are given the magnitude quoted is taken from the ISC Bulletin and (2) from the NEIS.

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No.	Date	Origin Time	\pm sec	Latitude, °N	\pm km	Longitude, °E	\pm km	Area of Confidence Region, sq km	n	m_b	$\pm 95\%$ CL	n
77	17.07.81	02 37 15.76	0.08	49.810	1.645	78.160	0.849	6.73	125	5.16	0.053	62
78	14.08.81	02 27 12.84	0.09	49.791	1.725	78.121	1.040	8.27	92	4.99	0.061	43
79	20.11.81	04 57 02.63	0.09	49.740	1.677	78.160	1.007	8.06	96	5.15	0.061	44
80	22.12.81	04 31 02.88	0.11	49.831	2.081	78.147	1.173	11.74	63	5.06	0.070	32
81	19.02.82	03 56 11.07	0.09	49.824	1.609	78.069	0.974	7.51	117	5.4 (2)		65
82	25.06.82	02 03 04.76	0.11	49.810	1.893	78.132	1.246	11.26	59	4.9		26
83	23.08.82	02 43 04.28	0.15	49.788	2.409	78.092	1.802	20.70	42	4.7		27
84	21.09.82	01 57 00.83	0.08	49.801	1.703	78.151	0.837	6.92	126	5.2		69
85	25.12.82	04 23 05.99	0.23	49.807	4.289	78.068	2.392	49.10	26	4.8		12

TABLE 5
Station Corrections for Degelen Mountain Explosions

Station	Computed Value	Number in Row	95 Percent Confidence Limits	Variance
1 AKU	1.234	13	+/- 0.10627	0.002440
2 ALE	-0.392	26	+/- 0.07555	0.001486
3 ASP	-0.180	6	+/- 0.15623	0.006354
4 AVF	-0.266	19	+/- 0.08848	0.002038
5 BDT	-0.451	2	+/- 0.26939	0.018891
6 BDW	-0.292	5	+/- 0.17044	0.007562
7 BER	-0.232	4	+/- 0.19108	0.009504
8 BHA	-0.482	12	+/- 0.11071	0.003193
9 BKS	0.194	3	+/- 0.21953	0.012545
10 BLC	0.285	12	+/- 0.11149	0.003236
11 BMN	-0.126	11	+/- 0.11595	0.003503
12 BMD	-0.579	19	+/- 0.09184	0.002196
13 BNG	0.421	37	+/- 0.06428	0.001076
14 BNM	-0.105	2	+/- 0.26888	0.018820
15 BNS	-0.209	9	+/- 0.12780	0.004252
16 BRG	-0.447	30	+/- 0.07056	0.001296
17 BSF	-0.180	29	+/- 0.07225	0.001359
18 BUL	-0.302	34	+/- 0.06632	0.001145
19 CAF	-0.512	2	+/- 0.27014	0.018996
20 CBM	-0.086	2	+/- 0.26870	0.018793
21 CDF	-0.570	19	+/- 0.08829	0.002029
22 CHG	-0.125	14	+/- 0.10294	0.002759
23 CIR	-0.542	14	+/- 0.10256	0.002738
24 CLK	-0.530	17	+/- 0.09305	0.002254
25 CLL	-0.051	45	+/- 0.05807	0.000878
26 COL	0.076	33	+/- 0.06736	0.001181
27 COP	-0.019	14	+/- 0.10237	0.002728
28 CPQ	-0.297	10	+/- 0.12127	0.003829
29 CTA	-0.129	1	+/- 0.37989	0.037567
30 CVF	-0.237	12	+/- 0.11059	0.003183
31 CWF	0.341	10	+/- 0.12112	0.003814
32 DAG	-0.166	32	+/- 0.06856	0.001224
33 DAR	-0.169	2	+/- 0.26986	0.018957
34 DCN	0.399	6	+/- 0.15588	0.006325
35 DDK	0.222	4	+/- 0.19068	0.009465
36 DKM'	0.257	7	+/- 0.14447	0.005433
37 DIX	-0.140	23	+/- 0.08081	0.001700
38 DLE	0.251	3	+/- 0.22015	0.012616
39 DMU	0.236	6	+/- 0.15588	0.006325
40 DUG	0.322	13	+/- 0.10659	0.002957
41 EAB	0.014	9	+/- 0.12727	0.004216
42 EAU	0.443	20	+/- 0.08604	0.001927
43 EBH	0.359	21	+/- 0.08432	0.001838
44 EBL	0.371	19	+/- 0.08828	0.002029
45 EDI	0.175	16	+/- 0.09602	0.002400
46 EDM	0.386	23	+/- 0.08021	0.001675
47 EDU	0.524	15	+/- 0.09922	0.002563
48 EGL	0.445	20	+/- 0.08608	0.001929
49 EKA	0.194	35	+/- 0.06560	0.001120
50 ELD	0.412	14	+/- 0.10261	0.002741
51 EPF	0.053	25	+/- 0.07789	0.001574
52 ESK	0.478	5	+/- 0.17064	0.007580
53 EUR	0.305	35	+/- 0.06555	0.001118
54 FBA	0.052	4	+/- 0.19132	0.009528
55 FBC	0.338	4	+/- 0.19111	0.009507
56 FCC	0.185	5	+/- 0.17084	0.007598
57 FFC	0.241	33	+/- 0.06733	0.001180
58 FLN	0.469	23	+/- 0.08110	0.001712
59 FRB	0.527	4	+/- 0.19046	0.009647

Table 5 (cont'd)

60	EUR	-0.169	18	+/- 0.09059	0.002136
61	FSJ	0.268	17	+/- 0.09313	0.002258
62	GBA	-0.395	18	+/- 0.09077	0.002145
63	GDM	-0.098	12	+/- 0.11045	0.003176
64	GIL	0.118	27	+/- 0.07442	0.001442
65	GOL	-0.125	10	+/- 0.12106	0.003815
66	GRF	-0.092	35	+/- 0.06542	0.001114
67	GRR	0.095	29	+/- 0.07231	0.001361
68	GMC	0.361	3	+/- 0.22051	0.012658
69	HAU	0.170	30	+/- 0.07115	0.001318
70	HFS	0.319	44	+/- 0.05921	0.000913
71	HYB	-0.024	16	+/- 0.09584	0.002391
72	INK	0.423	33	+/- 0.06736	0.001181
73	IPM	0.235	7	+/- 0.14460	0.005443
74	JCT	-0.199	1	+/- 0.38158	0.037903
75	JO\$	-0.250	18	+/- 0.09059	0.002136
76	KBS	-0.432	17	+/- 0.09301	0.002252
77	KEV	-0.080	25	+/- 0.07706	0.001546
78	KHC	-0.314	42	+/- 0.06009	0.000940
79	KIR	0.841	17	+/- 0.09318	0.002260
80	KJF	0.037	49	+/- 0.05581	0.000811
81	KLG	0.071	2	+/- 0.26905	0.018843
82	KJN	0.131	6	+/- 0.15849	0.006534
83	KMU	0.036	4	+/- 0.19117	0.009513
84	KOD	-0.034	10	+/- 0.12086	0.003802
85	KON	-0.219	16	+/- 0.09615	0.002407
86	KRA	0.017	27	+/- 0.07419	0.001433
87	KTG	-0.001	26	+/- 0.07561	0.001488
88	KRR	-0.438	20	+/- 0.08631	0.001939
89	LAO	0.236	16	+/- 0.09740	0.002469
90	LBF	-0.192	25	+/- 0.07749	0.001563
91	LD3	0.337	2	+/- 0.26979	0.018946
92	LFF	-0.234	22	+/- 0.08235	0.001765
93	LHC	-0.073	1	+/- 0.37994	0.037578
94	LJU	-0.078	7	+/- 0.14501	0.005474
95	LMR	-0.067	20	+/- 0.08618	0.001933
96	LDR	0.041	47	+/- 0.05727	0.000854
97	LON	0.013	16	+/- 0.09608	0.002403
98	LPF	0.006	26	+/- 0.07610	0.001507
99	LPO	0.071	27	+/- 0.07502	0.001465
100	LRG	-0.130	14	+/- 0.10247	0.002733
101	LSF	-0.370	19	+/- 0.08830	0.002029
102	MAIO	-0.804	8	+/- 0.13499	0.004743
103	MAT	-0.305	3	+/- 0.22010	0.012610
104	MBC	0.651	41	+/- 0.06109	0.000971
105	MBL	-0.339	1	+/- 0.37989	0.037567
106	MFF	0.085	29	+/- 0.07247	0.001367
107	MIM	-0.269	1	+/- 0.37989	0.037567
108	MNY	1.201	1	+/- 0.38158	0.037933
109	MOX	0.116	46	+/- 0.05761	0.000864
110	MUN	0.489	3	+/- 0.22071	0.012680
111	MSO	-0.086	12	+/- 0.11062	0.003185
112	MZF	-0.036	21	+/- 0.08473	0.001869
113	NAI	-0.105	2	+/- 0.26975	0.018941
114	NAO	-0.162	18	+/- 0.39163	0.002186
115	NBZ	-0.269	18	+/- 0.09186	0.002197
116	NDI	0.167	33	+/- 0.06741	0.001183
117	NEW	-0.250	6	+/- 0.15585	0.006322
118	NIE	0.074	29	+/- 0.07167	0.001337
119	NOR	-0.330	6	+/- 0.15644	0.006370
120	NUR	-0.059	35	+/- 0.06545	0.001115

Table 5 (cont'd)

121	OIC	-0.554	5	+/- 0.17134	0.007642
122	DIS	-0.204	2	+/- 0.26986	0.018957
123	OTT	-0.161	2	+/- 0.26903	0.018840
124	PCT	-0.757	5	+/- 0.17070	0.007585
125	PMG	0.219	9	+/- 0.12754	0.004234
126	PMR	-0.089	27	+/- 0.07433	0.001438
127	PNT	-0.039	32	+/- 0.06836	0.001216
128	PDO	-0.026	5	+/- 0.17078	0.007592
129	PRE	-0.464	6	+/- 0.15577	0.006316
130	PRU	-0.520	16	+/- 0.09592	0.002395
131	RES	-0.392	19	+/- 0.08802	0.002017
132	RJF	-0.372	22	+/- 0.08229	0.001763
133	SCH	-0.223	1	+/- 0.37994	0.037578
134	SES	0.317	17	+/- 0.09314	0.002258
135	SHL	-0.170	2	+/- 0.27013	0.018994
136	SMF	-0.195	24	+/- 0.07924	0.001634
137	SOP	-0.326	10	+/- 0.12093	0.003807
138	SPF	0.370	21	+/- 0.08477	0.001871
139	SSC	0.248	25	+/- 0.07794	0.001581
140	SSF	-0.136	32	+/- 0.06903	0.001240
141	STU	0.096	7	+/- 0.14492	0.005467
142	SWV	0.357	1	+/- 0.37994	0.037578
143	TCF	-0.363	17	+/- 0.09317	0.002260
144	TOL	-0.212	4	+/- 0.19054	0.004451
145	TRD	-0.059	2	+/- 0.26987	0.018958
146	TSK	0.425	9	+/- 0.12787	0.004256
147	TUL	0.027	27	+/- 0.07448	0.001444
148	UPP	0.418	9	+/- 0.12729	0.004218
149	UBO	0.337	9	+/- 0.12913	0.004340
150	UCT	-0.136	2	+/- 0.26870	0.018793
151	VAL	0.183	4	+/- 0.19084	0.009481
152	WET	-0.408	1	+/- 0.38122	0.037830
153	WIN	-0.299	1	+/- 0.38114	0.037815
154	WOL	0.682	17	+/- 0.09339	0.002270
155	WRA	-0.115	21	+/- 0.38487	0.001875
156	WTS	-0.011	3	+/- 0.22116	0.012733
157	YKC	0.283	15	+/- 0.09899	0.002551
158	ZUL	0.295	30	+/- 0.07075	0.001303

TABLE 6

Least Squares Analysis (Degelen Explosions)

NUMBER OF READINGS	=	2486
NUMBER OF UNKNOWNS	=	213
SUM OF SQUARES OF RESIDUALS	=	85.427857
MEAN SQUARE OF RESIDUALS	=	0.037584
NUMBER OF DEGREES OF FREEDOM	=	2273
STUDENTS T	=	1.96
SUM OF RESIDUALS	=	0.32E-11
SUM OF SQUARES DUE TO STATIONS	=	229.167277
MEAN SQUARE DUE TO STATIONS	=	1.459664
NUMBER OF EFFECTIVE STATIONS	=	157
SUM OF SQUARES DUE TO EVENTS	=	175.169888
MEAN SQUARE DUE TO EVENTS	=	3.184907
NUMBER OF EFFECTIVE EVENTS	=	55
MEAN STATION-EVENT EFFECT	=	5.105 +/- 0.01518

TABLE 7

JED Epicentre and Least Squares Estimate of m_b for Explosions at KonystanKonystan

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No.	Date	Origin Time	\pm sec	Latitude, °N	\pm km	Longitude E	\pm km	Area of Confidence Region, sq km	n	m_b	+95% CL	n
1	18.12.66	04 57 57.48	0.08	49.922	1.461	77.766	0.959	6.85	165	5.8 ⁽¹⁾		42
2	16.09.67	04 03 57.89	0.08	49.953	1.627	77.756	0.990	7.90	106	5.3		28
3	22.09.67	05 03 57.43	0.09	49.972	1.709	77.726	1.167	9.77	84	5.2		26
4	22.11.67	04 07 57.62	0.16	49.980	2.855	77.777	3.276	42.11	14	4.8		5
5	20.08.68	04 05 57.45	0.16	49.820	2.817	78.078	1.544	21.27	43	4.8		14
6	31.05.69	05 01 56.86	0.08	49.967	1.565	77.728	1.054	8.08	98	5.3		39
7	28.12.69	03 46 57.65	0.07	49.954	1.415	77.748	0.850	5.89	171	5.7		54
78	21.07.70	03 02 57.20	0.08	49.953	1.530	77.701	0.894	6.71	120	5.4		43
	04.11.70	06 02 57.22	0.08	50.007	1.472	77.798	0.894	6.46	143	5.4		45
	06.06.71	04 02 57.23	0.07	49.983	1.358	77.720	0.859	5.72	146	5.48	0.073	43
	19.06.71	04 03 57.74	0.07	49.992	1.373	77.705	0.882	5.93	126	5.41	0.070	50
	09.10.71	06 02 57.42	0.07	49.996	1.361	77.653	0.868	5.78	142	5.32	0.071	44
	21.10.71	06 02 57.41	0.07	50.001	1.479	77.629	0.911	6.60	133	5.51	0.072	46
	15.12.71	07 52 58.96	0.23	50.031	3.505	77.972	2.109	35.20	31	4.9		7
	26.08.72	03 46 57.20	0.08	49.993	1.425	77.773	0.914	6.36	131	5.37	0.077	35
	02.09.72	08 56 57.55	0.13	49.950	2.414	77.660	1.488	17.34	38	4.88	0.120	9
	19.04.73	04 32 57.51	0.08	49.995	1.458	77.647	0.911	6.50	133	5.32	0.073	40
	07.12.74	05 59 57.65	0.21	49.933	2.472	77.636	2.478	30.00	23	4.50	0.172	4

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No.	Date	Origin Time	± sec	Latitude, °N	± km	Longitude, °E	± km	Area of Confidence sq km	n	m _b	±95% CL	n
19	19.03.78	03 46 57.41	0.07	49.959	1.256	77.746	0.871	5.71	128	5.21	0.073	52
20	20.09.78	05 02 56.85	1.76	49.835	4.574	78.416	19.888	363.65	20	4.3	0.070	15
21	16.02.79	04 03 58.10	0.07	49.990	1.469	77.712	0.850	5.99	153	5.47	0.070	68
22	18.07.79	03 17 02.53	0.08	49.937	1.442	77.850	0.961	6.67	132	5.20	0.072	57
23	04.04.80	05 32 57.44	0.12	50.012	2.162	77.856	1.613	15.27	58	5.02	0.092	25
*	20.03.76	04 03 39.30	0.08	50.017	1.495	77.300	0.939	6.88	125	5.1	45	

- (1) Where no confidence limits are given the magnitude quoted is taken from the ISC bulletin.

- * This seismic disturbance has been identified as an earthquake, (Pooley et al (1983 (11)) but is included to provide a relocation which may prove useful to seismologists.

TABLE 8

Station Corrections for Konystan Explosions

Station	Computed Value	Number in Row	95 Percent Confidence Limits	Variance
1 AKU	1.331	1	+/- 0.36655	0.034983
2 ALE	-0.350	5	+/- 0.16467	0.007058
3 ASP	-0.094	7	+/- 0.13969	0.005080
4 AVF	-0.200	4	+/- 0.18506	0.008914
5 BER	-0.135	3	+/- 0.21373	0.011891
6 BHA	-0.397	5	+/- 0.16623	0.007193
7 BKS	0.162	4	+/- 0.18407	0.008819
8 VLC	0.406	5	+/- 0.16773	0.007324
9 BHN	-0.476	1	+/- 0.37313	0.036242
10 BMO	-0.633	7	+/- 0.14184	0.005237
11 BNG	0.362	6	+/- 0.15115	0.005947
12 BNH	0.361	1	+/- 0.36655	0.034983
13 BNS	-0.645	1	+/- 0.37002	0.035641
14 HKG	-0.592	4	+/- 0.18415	0.008827
15 BSF	-0.298	4	+/- 0.18506	0.008914
16 BUL	-0.124	8	+/- 0.13089	0.004460
17 CDF	-0.780	4	+/- 0.18506	0.008914
18 CHG	-0.097	3	+/- 0.21360	0.011876
19 CIR	-0.267	4	+/- 0.18553	0.008961
20 CLK	-0.239	6	+/- 0.15036	0.005685
21 CLL	-0.193	9	+/- 0.12325	0.003954
22 CQL	0.020	2	+/- 0.26221	0.017897
23 CPO	-0.482	2	+/- 0.26112	0.017748
24 CWF	-0.175	3	+/- 0.2124E	0.011752
25 DAG	-0.243	4	+/- 0.18506	0.008914
26 DIX	-0.248	3	+/- 0.21366	0.011884
27 DUG	0.250	2	+/- 0.26094	0.017724
28 EDM	0.205	6	+/- 0.15115	0.005947
29 EMM	-0.328	2	+/- 0.25977	0.017565
30 EPF	-0.089	3	+/- 0.2124E	0.011752
31 EUR	0.186	6	+/- 0.15190	0.006006
32 FBA	0.142	2	+/- 0.25977	0.017565
33 FBC	0.540	2	+/- 0.26119	0.017758
34 FCC	0.442	4	+/- 0.18400	0.008813
35 FFC	0.235	8	+/- 0.13056	0.004437
36 FLN	0.575	3	+/- 0.21240	0.011744
37 FRB	0.576	1	+/- 0.36904	0.035451
38 FUR	-0.182	6	+/- 0.15121	0.005952
39 FSJ	0.089	5	+/- 0.16617	0.007188
40 GBA	-0.023	4	+/- 0.18506	0.008914
41 GDH	0.324	6	+/- 0.15127	0.005956
42 GIL	0.040	3	+/- 0.21304	0.011814
43 GOL	-0.232	5	+/- 0.16610	0.007182
44 GRF	-0.367	9	+/- 0.12317	0.003949
45 GRR	0.118	3	+/- 0.2124E	0.011752
46 GWC	0.860	4	+/- 0.18545	0.008952
47 HAU	-0.103	4	+/- 0.18506	0.008914
48 HFS	0.244	6	+/- 0.15447	0.006211
49 HYB	0.117	9	+/- 0.12325	0.003954
50 INK	0.271	5	+/- 0.16521	0.007105
51 IPM	0.283	1	+/- 0.36732	0.035121
52 JDS	-0.326	4	+/- 0.18470	0.008881
53 KEV	-0.095	7	+/- 0.13969	0.005080
54 KHC	-0.356	8	+/- 0.13068	0.004445
55 KIR	0.836	2	+/- 0.25986	0.017578
56 KJF	0.060	10	+/- 0.11753	0.003596
57 KJN	0.073	3	+/- 0.21359	0.011876
58 KMU	0.105	1	+/- 0.37002	0.035641

Table 8 (cont'd)

50	KUU	-0.054	4	+/- 0.2124E	0.011892
50	KUN	-0.517	6	+/- 0.15121	0.005952
51	KRA	0.083	7	+/- 0.13973	0.005083
52	KTG	0.033	7	+/- 0.13969	0.005079
53	KRR	-0.019	4	+/- 0.18557	0.008964
54	LAO	-0.003	2	+/- 0.26830	0.018739
55	LBF	-0.155	3	+/- 0.21248	0.011752
56	LFF	-0.102	3	+/- 0.2124E	0.011752
57	LJU	-0.008	5	+/- 0.16612	0.007183
58	LMR	-0.005	3	+/- 0.21366	0.011884
59	LOR	0.180	7	+/- 0.1424E	0.005283
70	LON	-0.034	6	+/- 0.15195	0.006010
71	LPF	0.168	3	+/- 0.2124E	0.011752
72	LPO	0.088	3	+/- 0.2124E	0.011752
73	LSF	-0.384	3	+/- 0.21391	0.011912
74	MAT	-0.269	1	+/- 0.36655	0.034983
75	MBC	0.576	6	+/- 0.15552	0.006296
76	MFF	0.215	3	+/- 0.2124E	0.011752
77	MIM	-0.174	1	+/- 0.36655	0.034983
78	MOX	-0.070	9	+/- 0.12325	0.003954
79	MZF	0.007	4	+/- 0.18506	0.008914
80	NAO	-0.247	4	+/- 0.19403	0.009800
81	NB2	-0.401	3	+/- 0.21360	0.011876
82	NDI	0.499	9	+/- 0.12393	0.003998
83	NIE	0.122	8	+/- 0.13135	0.004491
84	NOR	-0.305	4	+/- 0.18545	0.008953
85	NUR	0.215	9	+/- 0.12335	0.003961
86	DIC	-0.277	3	+/- 0.21379	0.011898
87	OTT	0.011	1	+/- 0.36655	0.034983
88	PMG	0.416	6	+/- 0.15195	0.006010
89	PMR	0.114	9	+/- 0.12325	0.003954
90	PNT	-0.063	8	+/- 0.13089	0.004460
91	POO	-0.029	3	+/- 0.21362	0.011879
92	PRE	-0.364	3	+/- 0.21301	0.011811
93	PRU	-0.502	4	+/- 0.18543	0.008951
94	RES	-0.235	2	+/- 0.25996	0.017592
95	RJF	-0.342	3	+/- 0.2124E	0.011752
96	SCH	0.187	1	+/- 0.36845	0.035339
97	SES	0.156	3	+/- 0.21374	0.011892
98	SMF	-0.128	4	+/- 0.18506	0.008914
99	SOP	-0.278	2	+/- 0.25977	0.017565
100	SPF	0.225	4	+/- 0.18506	0.008914
101	SSC	0.238	3	+/- 0.2124E	0.011752
102	SSF	-0.008	4	+/- 0.18506	0.008914
103	TCF	-0.419	3	+/- 0.2124E	0.011752
104	TOL	0.108	2	+/- 0.26112	0.017748
105	TRO	0.093	1	+/- 0.36805	0.035262
106	TSK	0.383	5	+/- 0.16623	0.007193
107	TUL	-0.322	6	+/- 0.15121	0.005952
108	UBO	0.116	5	+/- 0.16612	0.007183
109	WOL	0.048	3	+/- 0.2124E	0.011752
110	WRA	-0.110	1	+/- 0.36774	0.035202
111	YKC	0.393	5	+/- 0.16472	0.007063
112	ZUL	0.165	4	+/- 0.18506	0.008914

TABLE 9

Least Squares Analysis Statistics (Konystan Explosions)

NUMBER OF READINGS = 473

NUMBER OF UNKNOWNS = 123

SUM OF SQUARES OF RESIDUALS = 12.245471

MEAN SQUARE OF RESIDUALS = 0.034987

NUMBER OF DEGREES OF FREEDOM = 350

STUDENTS T = 1.96

SUM OF RESIDUALS = 0.37E-12

SUM OF SQUARES DUE TO STATIONS = 45.670549

MEAN SQUARE DUE TO STATIONS = 0.411446

NUMBER OF EFFECTIVE STATIONS = 111

SUM OF SQUARES DUE TO EVENTS = 8.328130

MEAN SQUARE DUE TO EVENTS = 0.757103

NUMBER OF EFFECTIVE EVENTS = 11

MEAN STATION-EVENT EFFECT = 5.219 +/- 0.02844

TABLE 10

United Kingdom Sponsored Arrays

<u>Station</u>	<u>Code</u>	<u>Location</u>	<u>Element Spacing (km)</u>	<u>Maximum Element Spacing (km)</u>	<u>Date Operational</u>	<u>Date of Digital Recording</u>
Eskdalemuir Scotland	EXA	55°19'59"N 3°09'33"W	0.9	9.8	17 May 1962	14 Nov 1983
Yellowknife Canada	YKA	62°29'34"N 114°36'17"W	2.5	22.5	26 Nov 1962	-
Gauribidanur India	GBA	13°36'15"N 77°26'10"E	2.5	32.0	1 Feb 1966	4 Mar 1979
Warramunga Australia	WRA	19°56'39"S 134°20'27"E	2.5	26.3	1 Mar 1966	7 Jun 1977

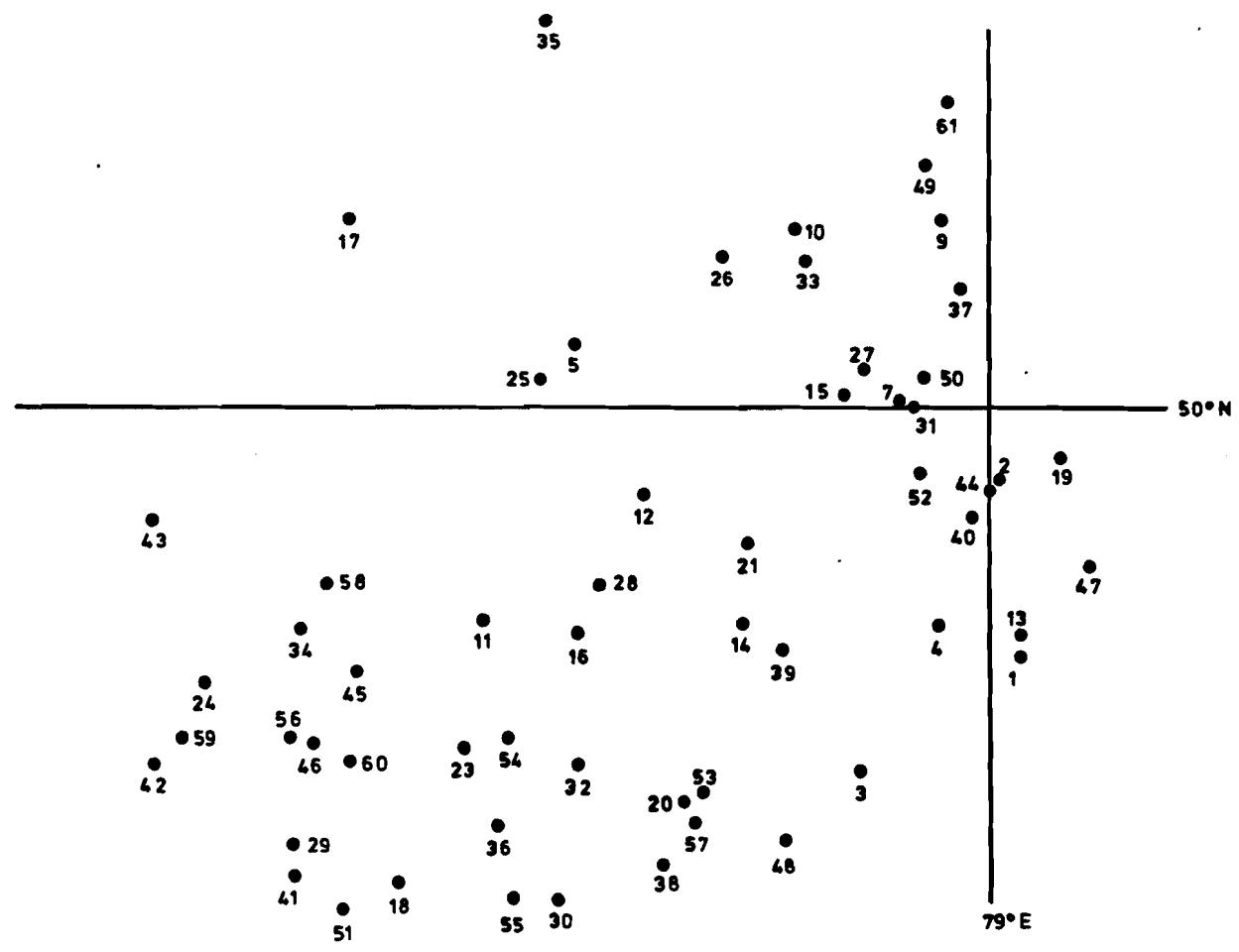


FIGURE 1 The Locations of Shagan River Explosions

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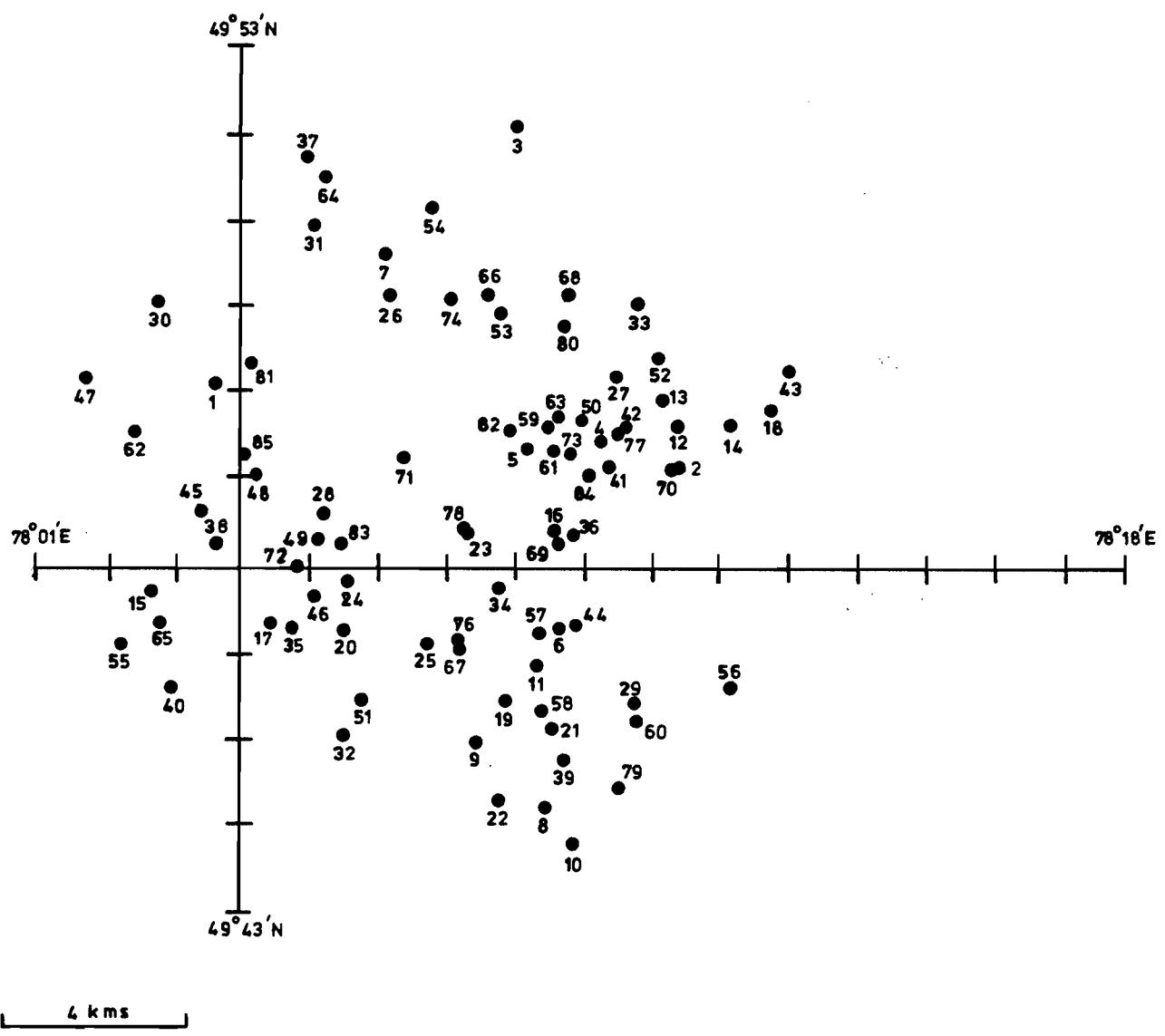


FIGURE 2. Locations of Explosions at the Degelen Test Site

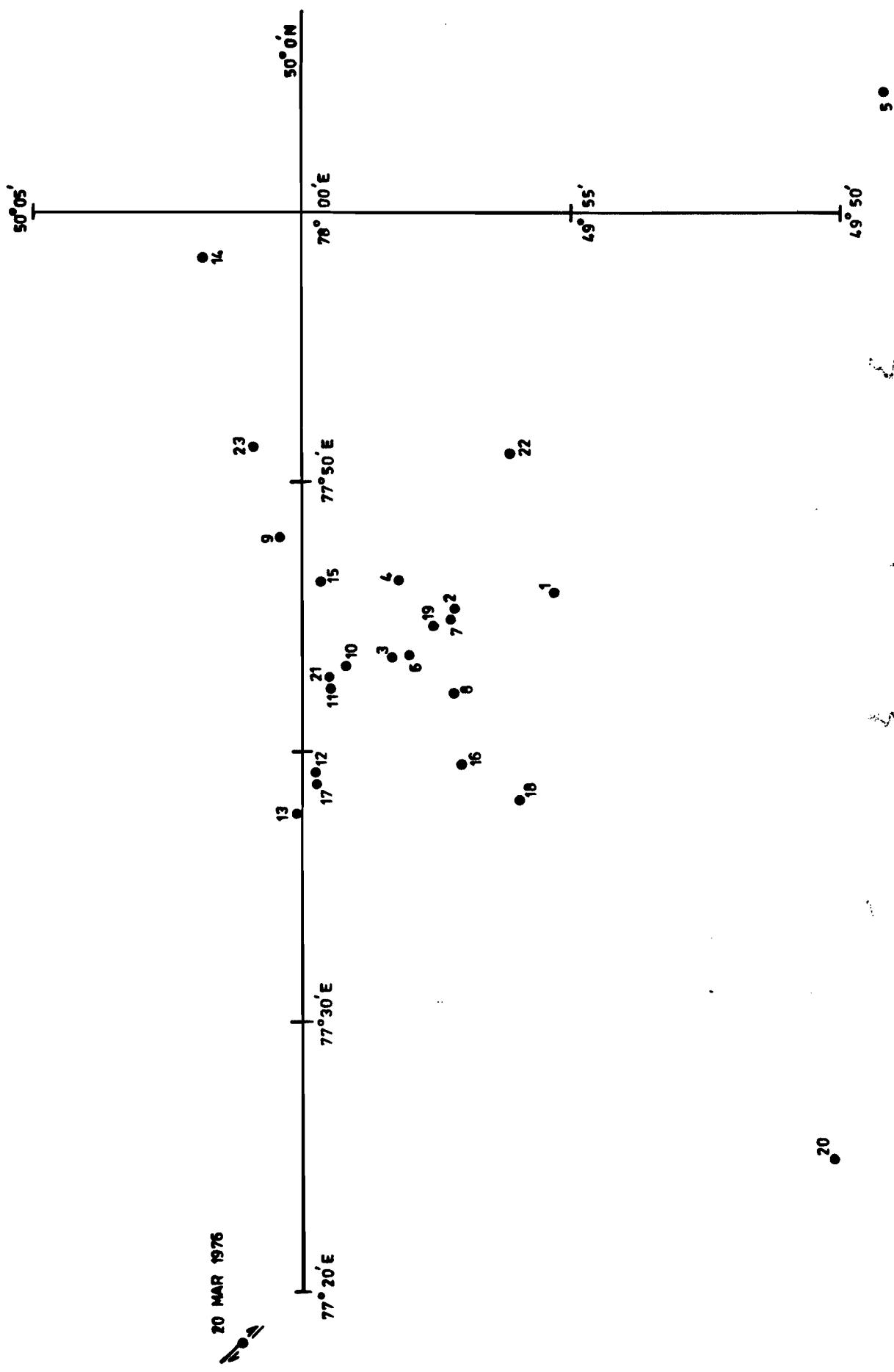


FIGURE 3. Locations of Explosions at the Konystan Test Site

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1. DRIC Reference (if known) —	2. Originator's Reference AWRE Report No. 016/84 (re-issue)	3. Agency Reference —	4. Report Security Classification UK UNLIMITED
5. Originator's Code (if known) —	6. Originator (Corporate Author) Name and Location Atomic Weapons Research Establishment, Aldermaston, Berkshire		
5a. Sponsoring Agency's Code (if known) —	6a. Sponsoring Agency (Contract Authority) Name and Location —		
7. Title Body Wave Magnitudes and Locations of Soviet Underground Explosions at the Semipalatinsk Test Site			
7a. Title in Foreign Language (in the case of Translation) —			
7b. Presented at (for Conference Papers). Title, Place and Date of Conference —			
8. Author 1. Surname, Initials Marshall P D	9a. Author 2 Bache T C	9b. Authors 3, 4 Lilwall R C	10. Date pp ref Oct 1985 87 13
11. Contract Number	12. Period	13. Project	14. Other References
15. Distribution Statement None			
16. Descriptors (or Keywords) (TEST) Underground Nuclear Explosions Seismic Detection Numerical Analysis			
Abstract At their underground nuclear test site near Semipalatinsk in eastern Kazakhstan the Soviet Union detonates explosions in three distinct areas called Shagan River, Degelen Mountain and Konystan. A least squares joint estimate of origin time, epicentre and magnitude is presented for explosions in each of these areas. These are based on data taken from the bulletins of the International Seismological Centre. Further, explosions in the northeast and southwest portions of the Shagan River site write distinctly different waveforms, suggesting that this site can be sub-divided into two test areas characterised by different geophysical properties.			