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Anomalous Seismic Signals from Novaya Zemlya

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CONTENTS

SUMMARY

Broad band seismic signals from several underground explosions on Novaya Zemlya have been analysed to determine the reason for some anomalous broad band signals from the same location.

1. INTRODUCTION

Novaya Zemlya (NZ) has been used as a site for firing underground explosions since 1964. Most of these explosions have been fired in a small area just south of the Matochkin Straits (the northern site), but since 1973 a site at the southern end of Novaya Zemlya on the Kostin Straits (the southern site) has also been used (see figure 1).

The seismic signals from these explosions have been widely recorded by conventional short period (SP) and long period (LP) seismographs and their main features are well known. For some years now, AWRE has been operating seismographs with a broad band (BB) response in addition to SP and LP, and several P signals from NZ explosions have been recorded broad band. The BB signals recorded at Gauribidanur (GBA), India, from NZ explosions are usually remarkably simple and most of the features of the P seismograms can be satisfactorily modelled using simple earth and source models. On two occasions, 18 October (southern site) and 21 October (northern site) 1975, signals from NZ were recorded at GBA which show some unusual features compared to "normal" signals. In this report we analyse these anomalous signals and try to determine the reasons for the anomalies.

In section 2, we briefly describe the BB response and how we interpret "normal" BB signals. In section 3, we give the basic data on the anomalous signals, and for comparison data from a selection of "normal" signals. We list the "normal" and anomalous signals in table 1. In sections 4 to 6, we give an interpretation of the "normal" signals to show why we recognised the anomalous signals, and then attempt to simulate the anomalous signals by taking a "normal" seismogram and adding it to itself with a range of delays and amplitude scaling factors. We also use seismograms computed from simple earth and source models in the same way.

2. THE BROAD BAND RESPONSE (BB)

The advantage of the BB response [1], shown in figure 2, is that it records the complete teleseismic body wave spectrum of explosion signals without distortion. Thus, Marshall, Burch and Douglas [2] show how the BB signals from an explosion and shallow earthquake can be distinguished by their spectral differences, and Marshall and Hurley [3] postulate that these spectral differences are present even for multiple explosions. The disadvantage is the poor signal-to-noise ratio.

In order to determine the value of the BB for test ban monitoring, a four-element array was established near to AWRE in February 1973. Single BB seismometers are also operating at Gauribidanur (GBA), near Bangalore, and Eskdalemuir (EKA), Scotland, but as they were installed in mid-1974 some of the NZ signals were recorded only by SP instruments at these sites. In these cases we can to a degree retrieve the BB signals by dividing the spectrum of the SP signal by the SP instrument response and then multiplying the result by the BB response. The fit of converted and original BB signals is good, although some low frequency noise is introduced. The value of this process is shown in section 5, where we use some of these conversions in the analysis of the anomalous signals.

One way of interpreting BB records is to compare observed and computed seismograms. Here we use the techniques of Douglas, Hudson and Blamey [4] to compute theoretical seismograms. In order to use these techniques, the layered structure of the crust at the source and receiver, and the average absorption factor for the path, must be specified. For some stations the structure of the crust has been determined, and where this has been done, it can be used in the modelling. The structure of NZ is unknown, so we substitute a standard crustal structure [5], and vary the thickness of the layers and depth of emplacement of the explosion until we obtain a satisfactory model. The model is then examined at various stages in the simulation to determine the origin of each pulse.

3. PRESENTATION OF SEISMOGRAMS AND DATA

Before describing and interpreting the BB seismic signals, the signal measurements are given and for each explosion in turn, the SP and LP seismograms from the array stations at EKA, GBA, Warramunga (WRA), Australia, and Yellowknife (YKA), Canada are illustrated. The BB seismograms are from the Blacknest array (BNA) and from single seismographs at EKA and GBA. The locations are given in table 2.

BB measurements include the period of the first half cycle of the signal and a magnitude, defined as $M_{pv} = \log A/T + B(\Delta)$, where A is the amplitude of the first positive pulse in nanometres, T is the period of the first half cycle in seconds, and $B(\Delta)$ is the SP distance normalising term. (We have yet to investigate the decay of low frequency P wave amplitudes with distance.) The results of converting SP to BB response and the associated amplitudes are tabulated. Data from the National Earthquake Information Service (NEIS) of the USA are included for comparison with array results.

A summary of explosion signal parameters is given in table 3, and this is followed by the principal data and seismograms of each explosion in turn. The anomalous BB signals which are the subject of this report are illustrated in figures 14, 15, 25 and 26. The remainder are believed to be "normal".

4. "NORMAL" SIGNALS FROM THE SOUTHERN SITE

The location of the southern site is shown in figure 3. The first BB signals from this site were recorded on 27 October 1973 at BNA, and since the signals are similar across the array (see figure 5), we show only the Headley (HD) signal in figure 28.

The first up-going pulse is the direct P. The first down-going pulse is probably the free surface reflection pP. The large amplitude pulses following pP are difficult to interpret, but may be reverberations generated by receiver geology since the array is situated on a series of Mesozoic sedimentary strata, but equally the unknown shot point structure may also give rise to such reverberations.

Signals from another explosion at the southern site, on 2 November 1974, were recorded on instruments at GBA and EKA as well as BNA. These signals are also shown in figure 28. We observe that the HD signal is similar to the signal from the previous explosion, but EKA differs and is relatively complex after the first cycle, while GBA is very simple. This simplicity makes the GBA record ideal for modelling and subsequent interpretation.

We reproduce the main features of the 2 November GBA seismogram, and show the observed and computed signals in figure 29 before examining the various stages in the model and thereby interpreting the individual pulses. As the modelled signal leaves the source structure, we see that the first positive pulse is of slightly higher frequency than the first negative pulse. This is because the time separation between direct P and the free surface reflection pP is such that these two interfere. Also, the base of the source layer acts as a partial reflector of the P - pP cycle, and we can identify both the direct and reflected cycles in figure 29.

The effect of absorption between the source and receiver is to attenuate preferentially the higher frequencies, or smooth the signal. We measure absorption along a raypath by the quantity t^*, since body waves of angular frequency ω are attenuated by the factor $\exp - \omega t^*/2$, where $t^* = T/Q_{av}$, T being the travel time and Qav being the average quality factor for the raypath. Experience shows that t^* values generally lie between 1.0 and 0.1 s, the former indicating high attenuation. A value of 0.6 fits the NZ-GBA path, and we can observe its effect by comparing the signal shape leaving the source with that entering the receiver structure. Despite the smoothing, we can still identify source reverberations in the signal at the base of the receiver structure.

For the receiver layering, we use a known GBA structure [6]. Comparing the signal at the base of the receiver with the final model signal we observe that the GBA structure has a negligible effect upon the signal shape and we can still recognise the source reverberations. The important conclusion is that the observed GBA signal is a smoothed version of the source function.

Thus, the main features of the simple GBA seismogram can be reproduced. We now model the relatively complex EKA and HD seismograms using the source structure derived for the GBA model, appropriate receiver structures and the best fitting value for t^*. Our simple model successfully reproduces the first 2 cycles of the observed seismograms (figure 30) but not the complex codas. Signal generated noise at EKA and neglect of sedimentary layers under HD explain minor discrepancies.

It is concluded that the GBA signal from the southern site consists of a direct pulse and several identifiable source reverberations, smoothed by travel path absorption.

5. THE ANOMALOUS SIGNALS FROM THE SOUTHERN SITE

Returning to figure 28 and comparing the GBA signal of 18 October 1975 with that of 2 November 1974, we note the large positive pulse after direct P. The signals at EKA and HD are also significantly different to the November signals from the same epicentre.

One possibility is that the 18 October 1975 signal is due to a double explosion. This idea is easily tested by scaling the 2 November 1974 signal and adding it to itself for a variety of time delays to produce a scaled, shifted and summed (SSS) record. The results, with an amplitude scaling factor of 0.8, are shown in figure 31. A good fit occurs at 1.92 ± 0.08 s. Similarly, the signals at HD and EKA can be modelled using the same scaling factor with time shifts of 0.64 ± 0.08 and 0.32 ± 0.08 s respectively. The solutions are in figures 32 - 34.

The simplest interpretation of these BB signals is, therefore, that they were formed by two explosions with spatial separation explaining azimuth dependent time delays. The interpretation may be tested further by means of the converted SP signals at WRA (figures 4 and 13). Because the 27 October 1973 signal resembles the (normal) 2 November 1974 GBA signal, a comparison with the SSS simulation at GBA (figure 31) to explain the shape of the 18 October 1975 WRA signal is justified. There is a close fit corresponding to a time separation of 1.60 ± 0.08 s in the simulation. It is interesting now to use the model derived from the fit with the 2 November 1974 explosion to simulate the 18 October 1975 GBA signal. The best quantitative fit corresponds to a shift of 1.3 s and the best looking shape with a shift of 1.9 s, although in this case the separation of the first two pulses is not correct. Both simulations and the individual models are shown in figure 35. The fits are not as good as those using the real signals, but the shapes are basically similar. Cumulative errors due to initial inaccuracies in the model may explain these discrepancies.

We cannot determine the origin times of the two explosions from the original P wave data using only three stations, but, in principle, it is possible to establish their spatial and temporal distribution from the time separation of other phases such as PcP and LR. "Normal" PcP is present on the 2 November 1974 explosion and it is used to simulate the 18 October 1975 PcP with a scaling factor of 0.8 and a time delay of 0.8 s. The solution which adequately supports the hypothesis is shown in figure 36. Unfortunately, the only other prominent PcP from the double explosion is observed on a single SP seismogram at BNA; it is compared with a normal signal in figure 37. Here the "normal" PcP is almost suppressed by noise and we cannot use it to simulate the 18 October 1975 arrival. The simplicity and abnormally large amplitude, compared to direct P, of the 18 October 1975 PcP suggests constructive interference, and hence negligible time separation, between the individual signals from the double explosion.

Another way to test the double explosion hypothesis is by means of amplitudes. Thus, the BB surface waves at GBA for the two 18 October 1975 explosions (figure 38) show smaller amplitudes relative to "normal" at 18 - 19 s period and relative enhancement at 8 - 9 s period. This would be expected by destructive and constructive interference respectively. At EKA the BB P amplitude is abnormally large compared to the GBA amplitude and the signal shape is almost "normal", so the travel times to that station must be nearly equal.

With these clues to provide a first approximation, we determined the changes in epicentral position of the 2 November 1974 explosion required to generate the observed BB time delays and then predicted the separation of the phases mentioned above. The best solution is obtained when the two explosions are detonated simultaneously about 35 km apart, on a line inclined at 3° east of north with the smaller explosion being most northerly. In table 4, predicted time separations between the signals from each explosion are compared with those we can measure.

A consequence of this hypothesis is that observations of magnitude and arrival time with subsequent estimations of yield, epicentre and origin time (which assume a single signal) will not describe the true situation at source. Thus, in section 3, although we give these estimates on the assumption of a single explosion, the given origin time and epicentre are representative mean values since the station distribution is widespread. Since we believe that the larger signal arrived first at EKA, GBA and WRA, and second at YKA, we can estimate an epicentre for the larger explosion using the measured onset times at EKA, GBA and WRA, and the result of subtracting the predicted YKA separation from the observed YKA onset. This procedure gives co-ordinates 71.1° north and 53.9° east.

6. BROAD BAND SIGNALS FROM THE NORTHERN SITE

Signals from the northern site were recorded at BNA, EKA and GBA on 23 August 1975, and are shown in figure 39. These signals are very similar to normal signals from the southern site. On the other hand, the signals for 21 October 1975 (also shown in figure 39) are anomalous by comparison. The EKA signal might be interpreted as P plus pP. If this is so, then pP corresponds to the first negative pulse on the GBA record and we have shown that the GBA structure does not distort teleseismic BB signals from NZ. So we maintain that the second cycle on the GBA record is generated at the source. Because the second cycle is not present on the EKA record, it follows that the radiation pattern is anomalous; a double explosion with a spatial separation of the epicentres is again a possible interpretation.

This time, however, scaling, shifting and summing the "normal" signals of the 23 August 1975 does not give a good fit to those of 21 October 1975. In this case, the second explosion is much smaller than the first, consequently linear scaling of the normal signal is not justified. Modelling should overcome the difficulty but the resolution at GBA on this occasion was poor and EKA and BNA were too complex to provide a starting model.

As a compromise the southern site modelled pulse was used again. The best quantitative fit to the 21 October 1975 GBA signal is obtained by two signals, one 0.3 times the size of the other, summed with a separation of 1.6 s. The best looking fit has a shift of 1.3 s. Both simulations are shown in figure 40. The time shift discrepancy is understandable, since we have already shown that the summing of computer generated models is susceptible to model inaccuracies.

We believe that the anomalous shapes at EKA and BNA confirm a multiple explosion, since "normal" signals from the northern site are so similar to those we have modelled and interpreted as due to single explosions from the southern site.

7. CONCLUDING COMMENTS

We conclude that the Novaya Zemlya explosions of the 18 and 21 October 1975 were each doubles, separated by a few kilometres.

This is not obvious from the short or long period records considered in section 3. The broad band seismograms not only provided the initial alert, but were also the means of studying each explosion in more detail.

Magnitude estimates and therefore yields should be estimated with this interpretation in mind.

8. ACKNOWLEDGMENTS

Practically every member of the Seismological Research Group at AWRE has been involved in the preparation of this report. In particular I would like to acknowledge the assistance given by Messrs G D L Matthews, J B Young, P G Gibbs and F A Key. Mr G McKenzie and his colleagues were responsible for Eskdalemuir array recordings, while data from the other arrays were provided through the co-operation of the Earth Physics Branch, Department of Energy, Mines and Resources, Ottawa, Canada; the Bhabha Atomic Research Centre, Trombay, India; and the Department of Geophysics and Geochemistry, Research School of Physical Sciences, Australian National University, Canberra, Australia. Finally I would like to thank Messrs P D Marshall, A Douglas and Dr H I S Thirlaway for their encouragement, criticism and advice in the preparation of this report.

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4. A Douglas, J A Hudson and C Blamey: "A Quantitative Evaluation of Seismic Signals at Teleseismic Distances. III: Computed P and Rayleigh Wave Seismograms". Geophys JR Astr Soc, 28, 385 (1972)

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TABLE 1

The Dates of the Explosion Signals Analysed in this Report

Region:

Southern End of South Island	Explosion No. 1	..... 27 October 1973
	2	..... 2 November 1974
	3	..... 18 October 1975
Northern End of South Island	4	..... 23 August 1975
	5	..... 21 October 1975

TABLE 2

The Location of the Five Array Stations Supplying Data for this Report

Eskdalemuir, Scotland	EKA	55	19	59.0	N
		3	09	33.0	W
Gauribidanur, India	GBA	13	36	15.0	N
		17	26	10.0	E
Warramunga, Australia	WRA	19	56	52.0	S
		134	21	03.0	E
Yellowknife, Canada	YKA	62	29	34.3	N
		114	36	16.5	W
Blacknest Array, England	BNA	51	21	50.9	N
		1	11	9.7	W

The cartesian co-ordinates (km) of the 4 BB pits at BNA relative to the above location are:-

Headley	HD	- 5.393	- 0.670
Bucklebury West	BW	- 2.725	+ 5.029
Wolverton	WV	- 2.483	- 5.715
Blacknest	BN	0.0	0.0

TABLE 3

A Summary of Explosion Signal Parameters

Explosion No.	Date of Explosion	Approximate Origin Time GMT, h	4 SP Array Lat. N.	Location Long. E.	Average of SP Array, mb	Average Mpv	Average of Array Ms	Average of NEIS Ms
1	27 October 1973	07.00	70.83	54.47	6.89	6.90	5.69	5.5
2	2 November 1974	05.00	70.89	53.87	6.82	6.76	5.65	5.3
3*	18 October 1975	09.00	70.93	53.79	6.85	6.53	5.47	5.1
4†	23 August 1975	09.00	73.43	54.53	6.50	6.42	5.28	4.9
5*†	21 October 1975	12.00	73.31	55.19	6.54	6.67	5.42	Not given

*Anomalous signals.
†Signals from the northern site.

TABLE 4

The Measured and Predicted Time Separations of Various Seismic Phases from the Two Explosions at Novaya Zemlya on the 18 October 1975

Phase / Station	P(BB) Predicted	P(BB) Measured	PcP(SP) Predicted	PcP(SP) Measured	LR Predicted	LR Measured
EKA	0.20	0.32	0.0	NO	1.10	Very small
GBA	1.90	1.92	1.10	NO	9.80	9.00
YKA	2.40	NO	1.10	0.80	10.50	NO
WRA	0.30	1.62*	-	NO	2.50	NO
BNA	0.60	0.64	0.10	Very small	2.30	Very small

Time separations are in seconds.

NO = not observed.
* = from SPBB conversions.

EXPLOSION NO. 1

Epicentre Estimation from SP Array Data

Date:	27 October 1973
Origin Time GMT:	06.59.57.0
Latitude:	70.83° North
Longitude:	54.47° East

Short Period Array Data

Station	Δ°	Azimuth°	Onset Time	Amplitude, m^{-9}	Period, s	Magnitude, mb
EKA	28.9	267.9	07.05.58.6	2200	0.76	7.06
GBA	58.9	153.7	07.10.00.2	OV		
YKA	46.7	353.1	07.08.28.8	OV		
WRA	105.4	106.1	07.14.08.4	92.7	1.10	6.72

Broad Band Data

Station	Amplitude, m^{-9}	Log A/T	Log A/T + B(Δ)	Period, s	Predicted SP BB Amplitude, m^{-9}
HD	7905	3.59	6.93	2.03	
BW	8402	3.60	6.94	2.12	
WV	7803	3.58	6.92	2.03	
BN	7300	3.46	6.81	2.54	
EKA	NA				8926
GBA	NA				
YKA	NA				
WRA	NA				617

NA = No seismogram available.
OV = Seismometer overloaded.

Surface Wave Data

Station	Amplitude, m^{-9}	Period, s	Ms
EKA	14179	23.08	5.69
GBA	NA		
YKA	OV		
WRA	NA		

EDR Data

Origin Time:	06.59.57.4
Latitude:	70.8° North
Longitude:	54.2° East
mb:	6.9
Ms:	5.5
Data Source:	PDE 65-73

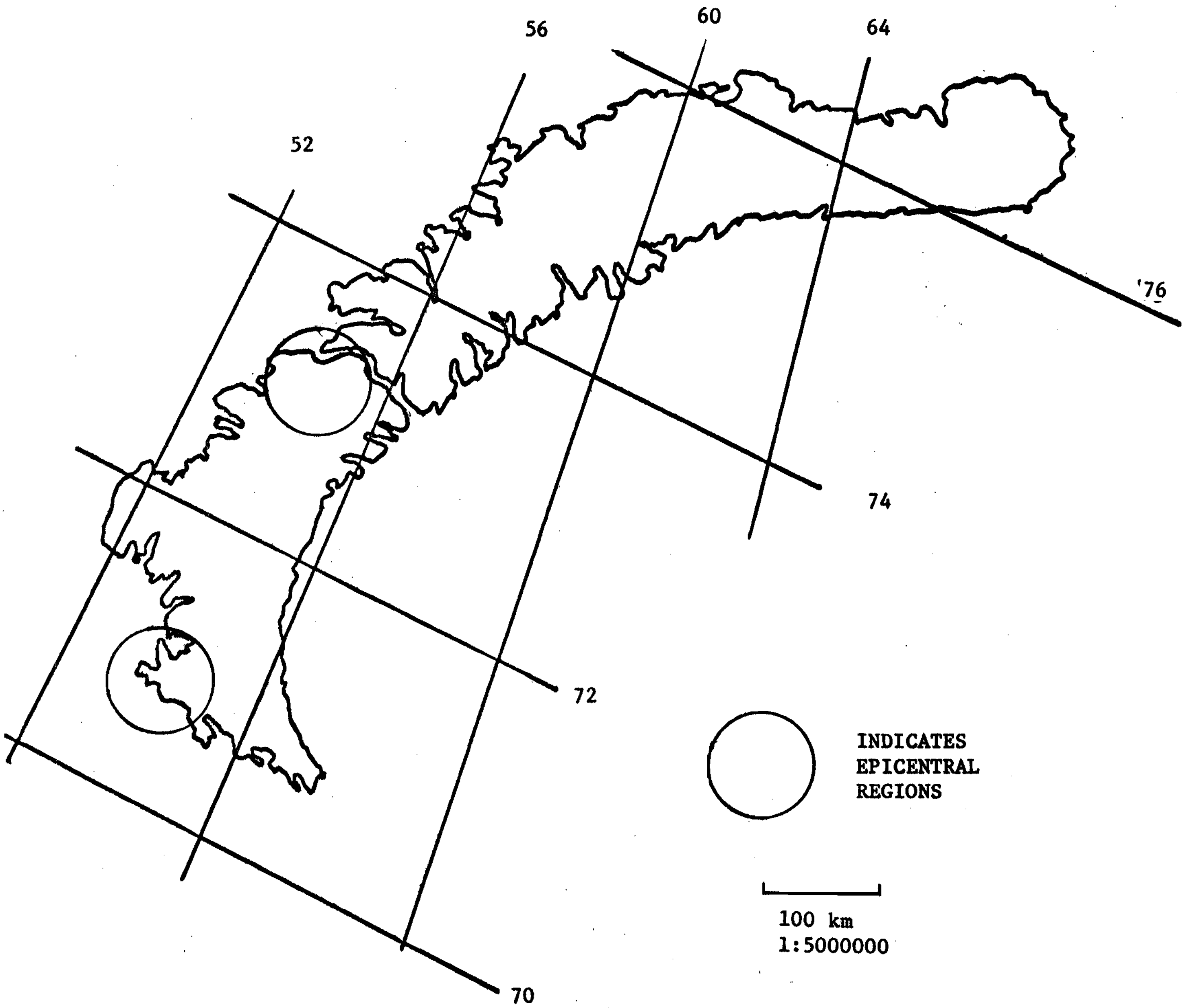


FIGURE 1. A SKETCH MAP OF NOVAYA ZEMLYA INDICATING THE APPROXIMATE EPICENTRAL REGIONS OF THE EXPLOSIONS ANALYSED

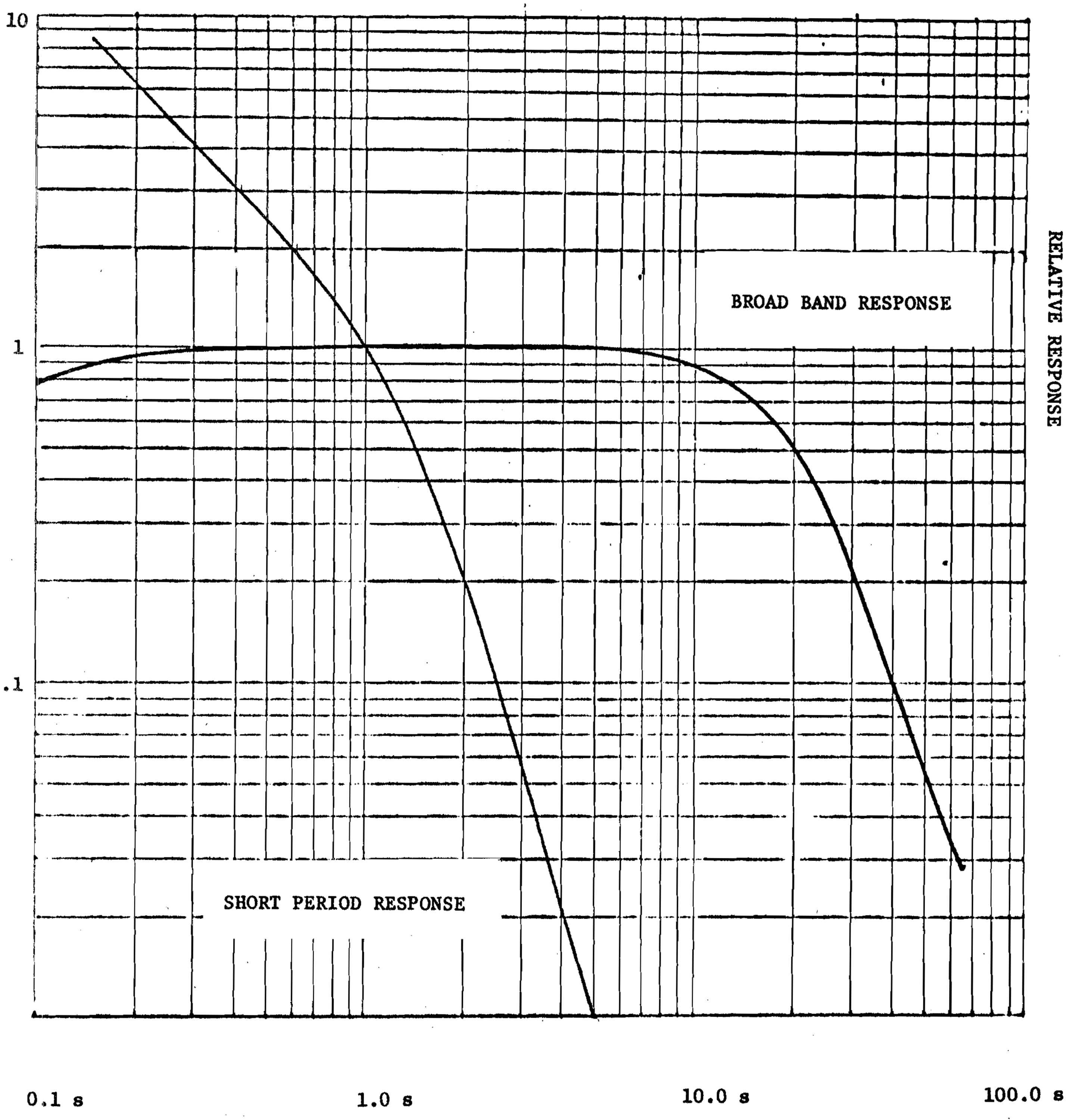


FIGURE 2. RELATIVE FREQUENCY RESPONSE CURVES OF THE BROAD BAND AND SHORT PERIOD RECORDING SYSTEMS

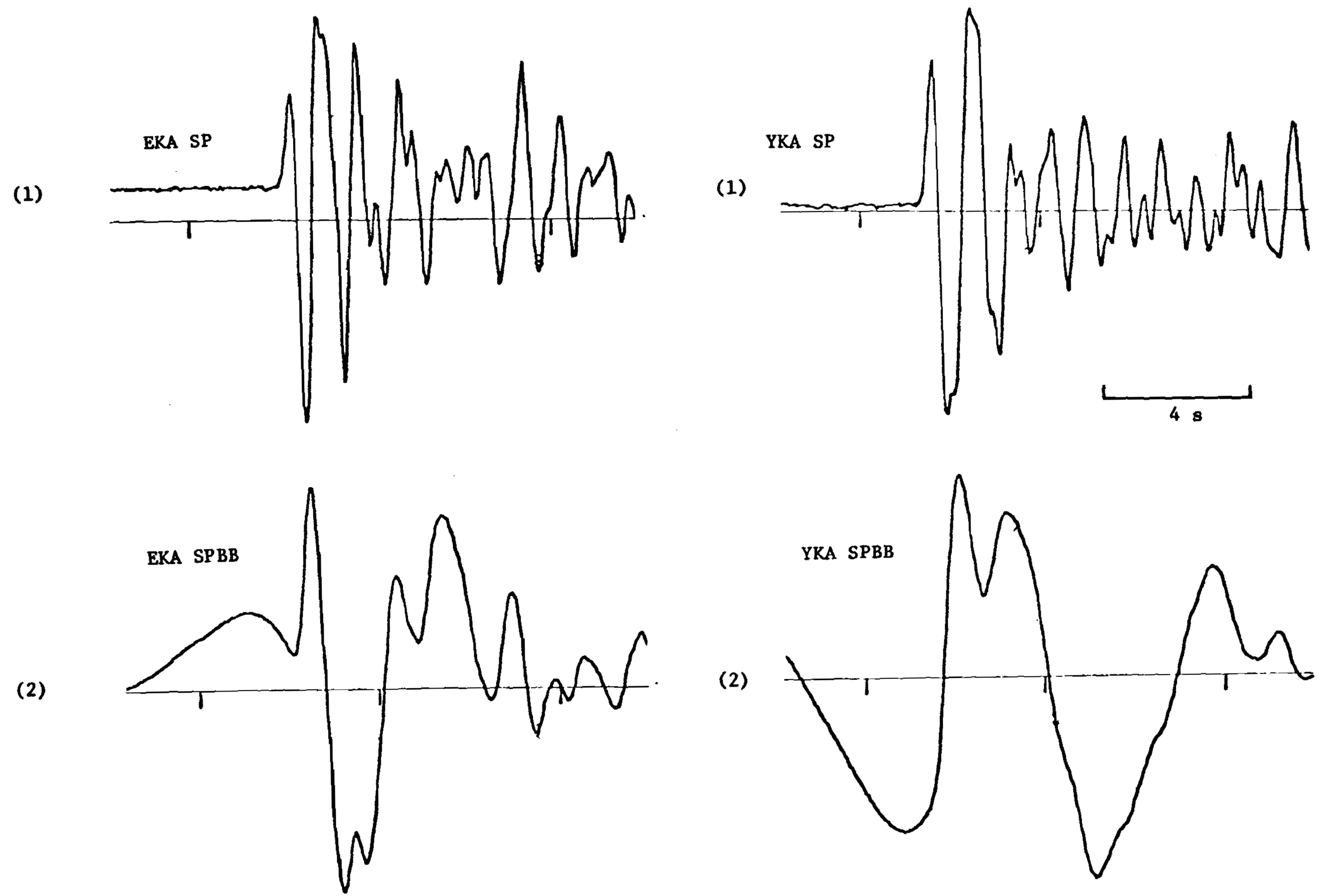


FIGURE 3. 27.10.73. SHORT PERIOD SIGNALS AND SP TO BB CONVERSIONS AT EKA AND YKA

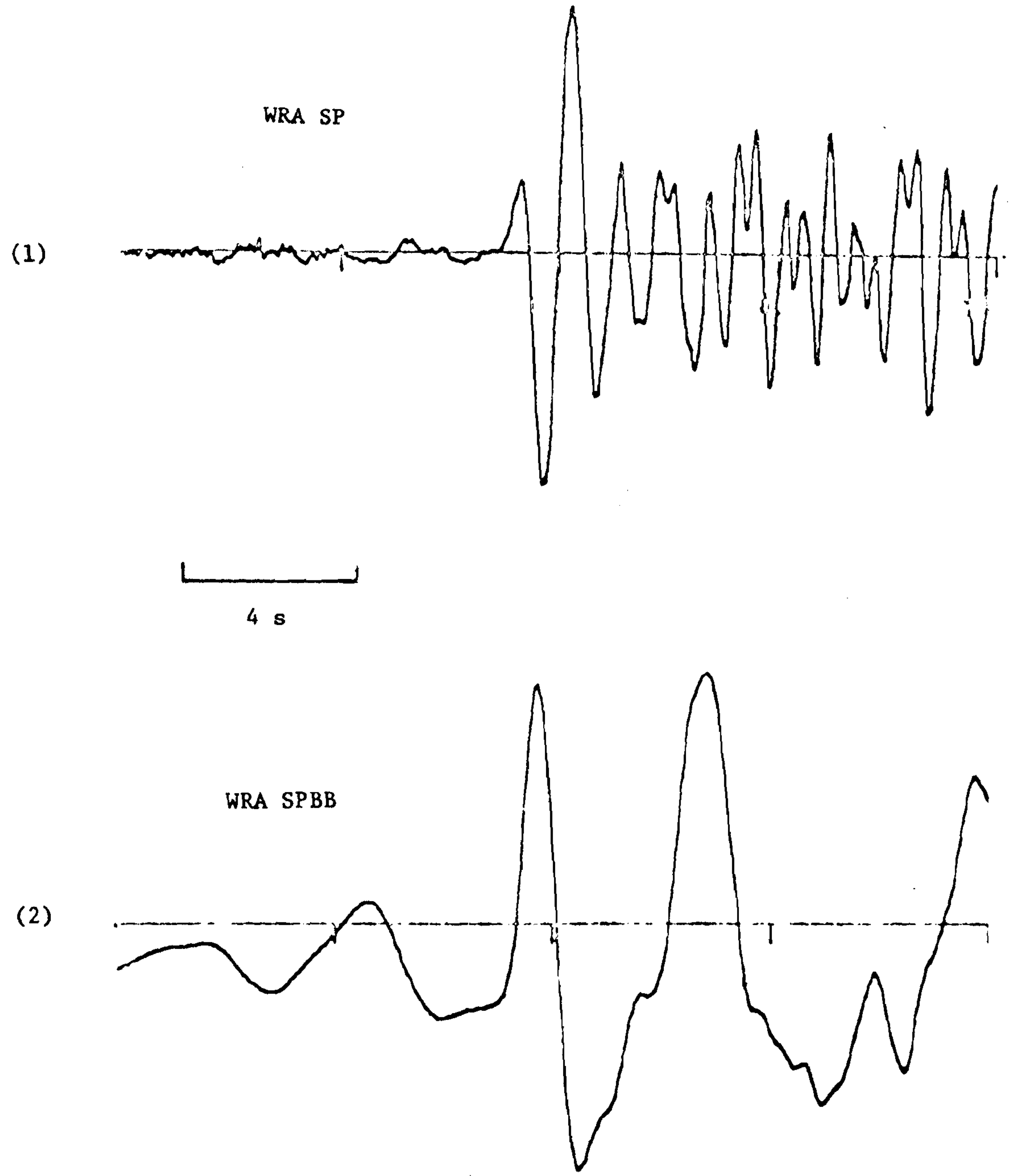


FIGURE 4. 27.10.73. SHORT PERIOD SIGNAL AND SP TO BB CONVERSION AT WRA

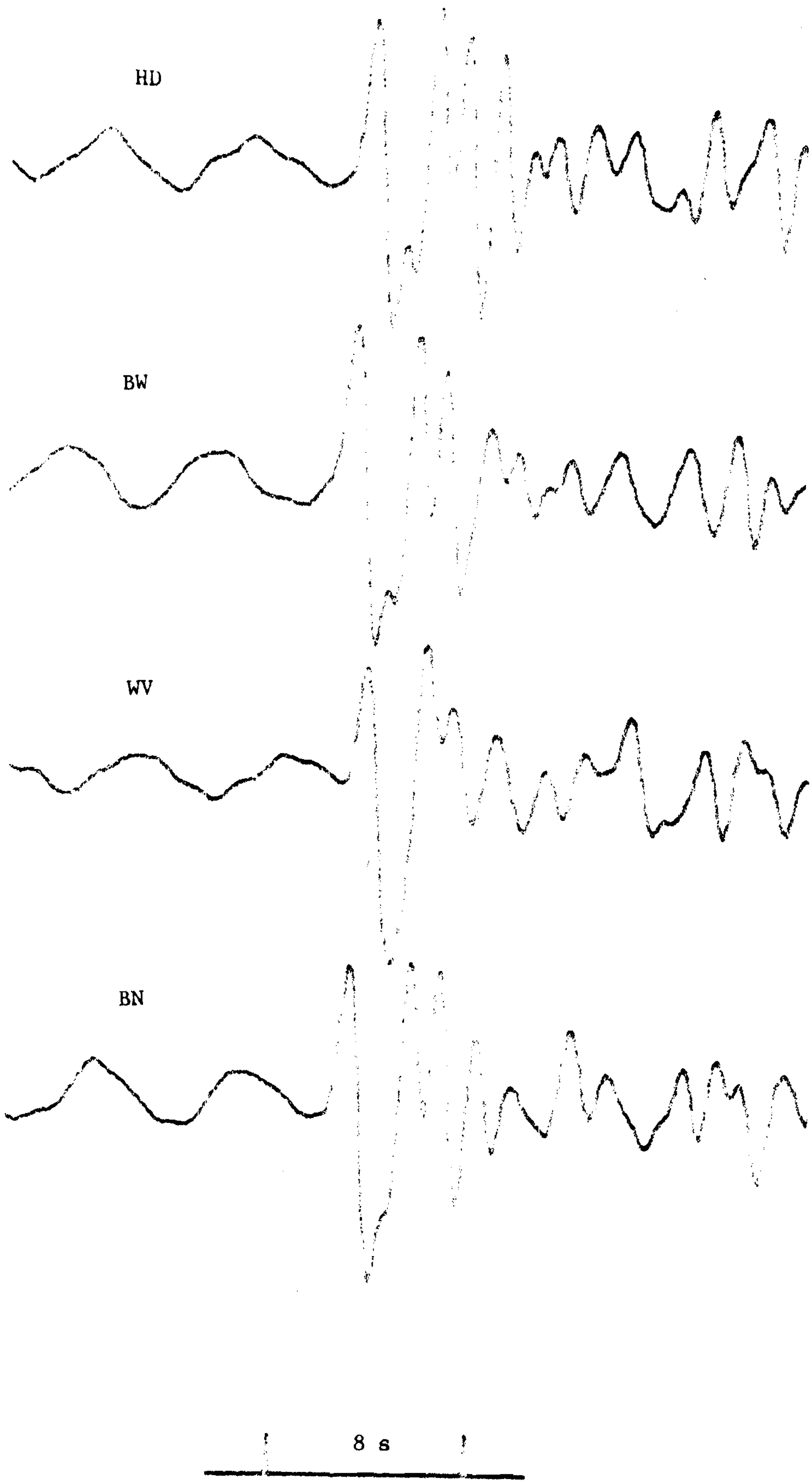


FIGURE 5. 27.10.73. BROAD BAND SIGNALS AT BNA

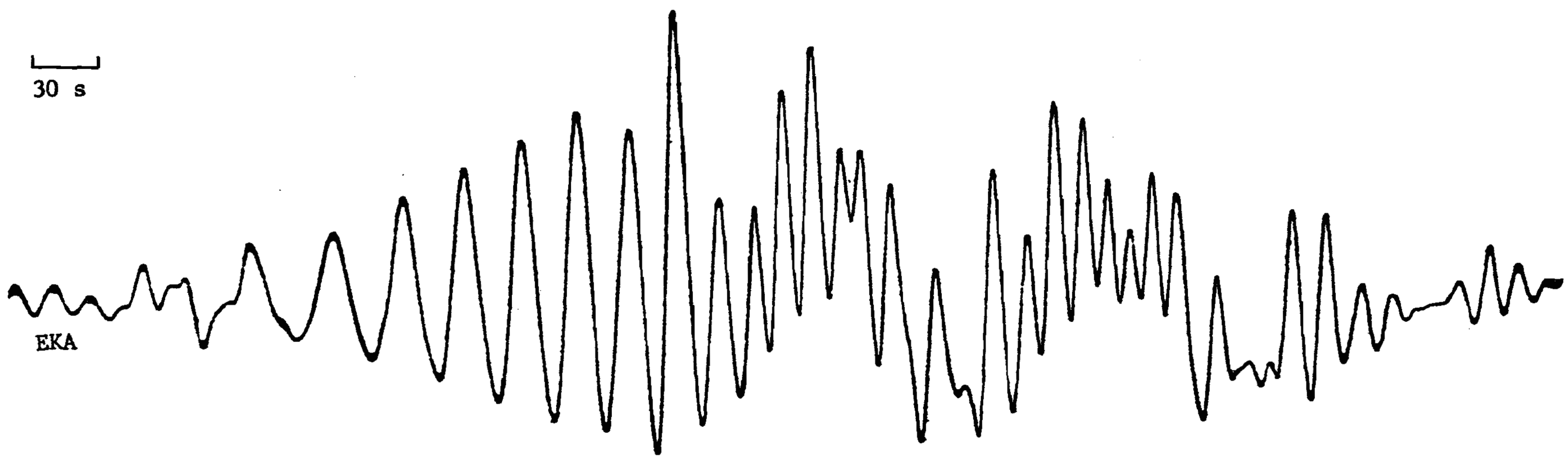


FIGURE 6. 27.10.73. SURFACE WAVES AT EKA

EXPLOSION NO. 2

EPICENTRE ESTIMATION FROM SP ARRAY DATA

Date:	2 November 1974
Origin Time GMT:	04.59.56.7
Latitude:	70.89° North
Longitude:	53.87° East

Short Period Array Data

Station	Δ°	Azimuth°	Onset Time	Amplitude, m^{-9}	Period, s	Magnitude, mb
EKA	28.7	267.2	05.05.56.7	1529	0.65	6.97
GBA	59.1	153.1	05.10.00.6	1353	0.80	7.17
YKA	46.65	352.7	05.08.27.7	416	0.62	6.32
WRA	NA					

Broad Band Data

Station	Amplitude, m^{-9}	Log A/T	Log A/T + B(Δ)	Period, s	Predicted SP BB Amplitude, m^{-9}
HD	5000	3.41	6.76	1.92	
BW	4545	3.37	6.72	1.92	
WV	4242	3.38	6.72	1.76	
BN	4242	3.34	6.69	1.92	
EKA	5151	3.47	6.77	1.75	5111
GBA	5151	3.45	6.90	1.83	4643
YKA	NA				3387
WRA	NA				

Surface Wave Data

Station	Amplitude, m^{-9}	Period, s	Ms
EKA	16666	20.0	5.65
GBA	OV		
YKA	OV		
WRA	NA		

EDR Data

Origin Time:	04.59.56.7
Latitude:	70.8° North
Longitude:	54.1° East
mb:	6.7
Ms:	5.3
Data Source:	PDE 69-74

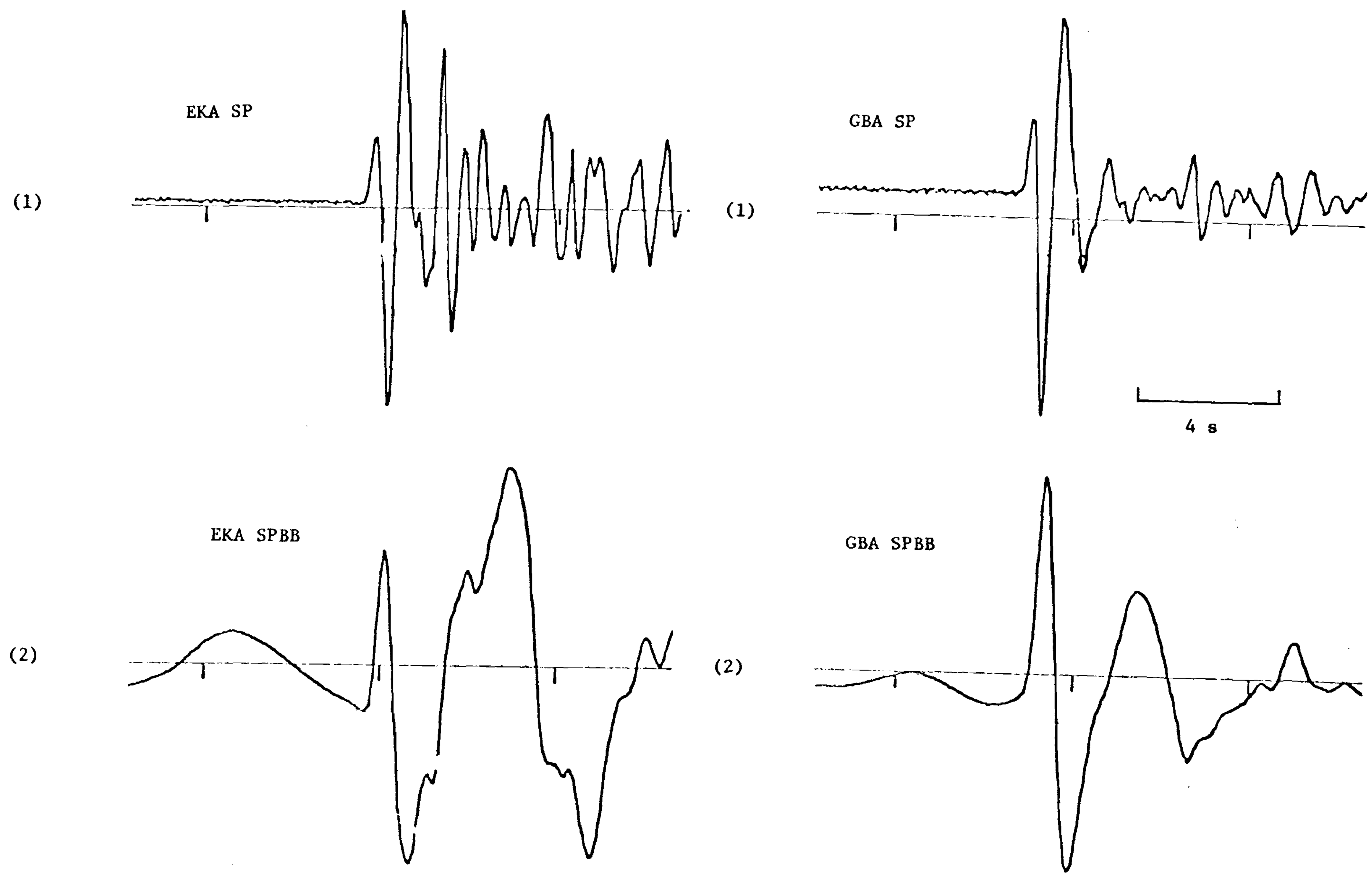


FIGURE 7. 2.11.74. SHORT PERIOD SIGNALS AND SP TO BB CONVERSIONS AT EKA AND GBA

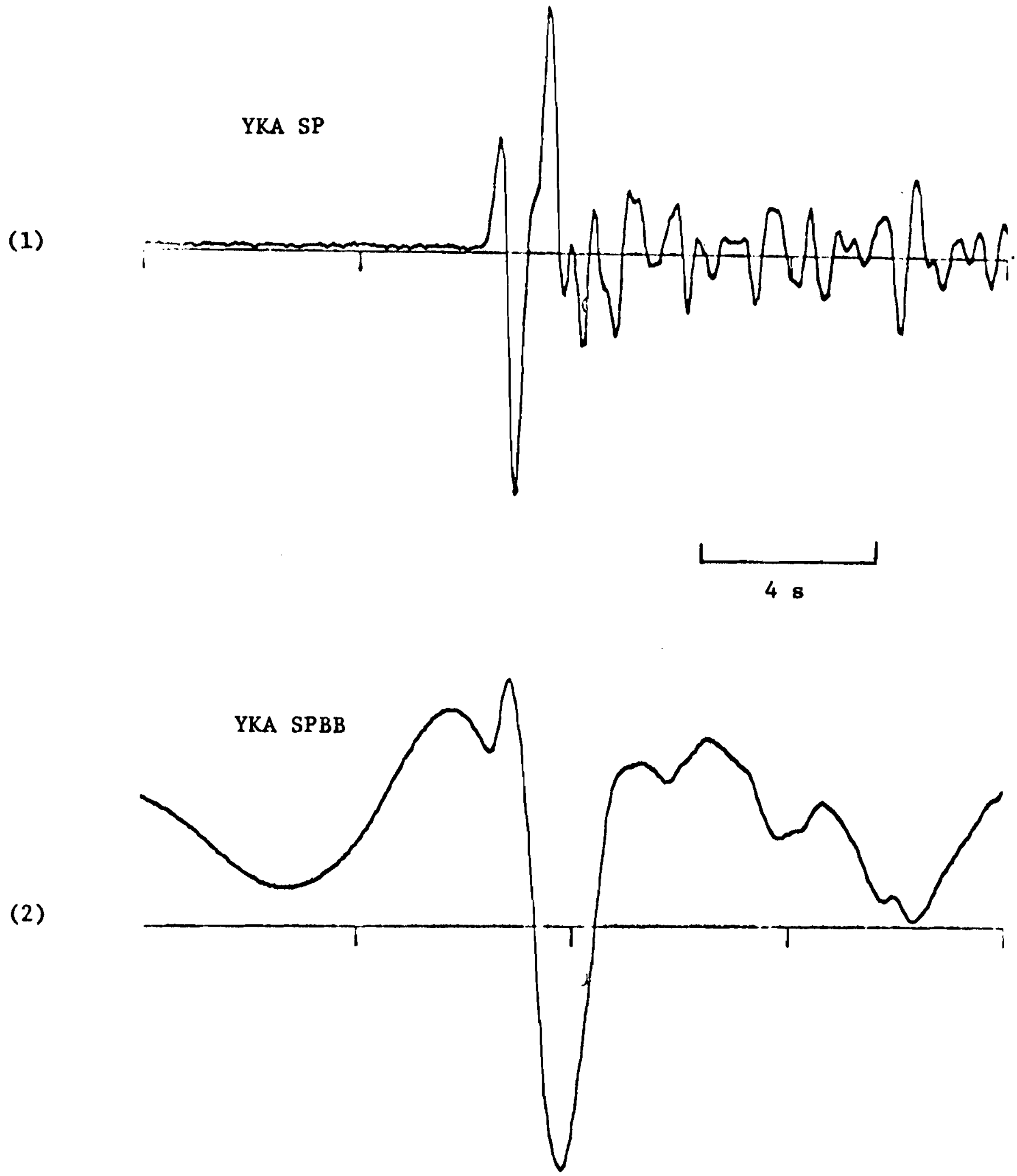
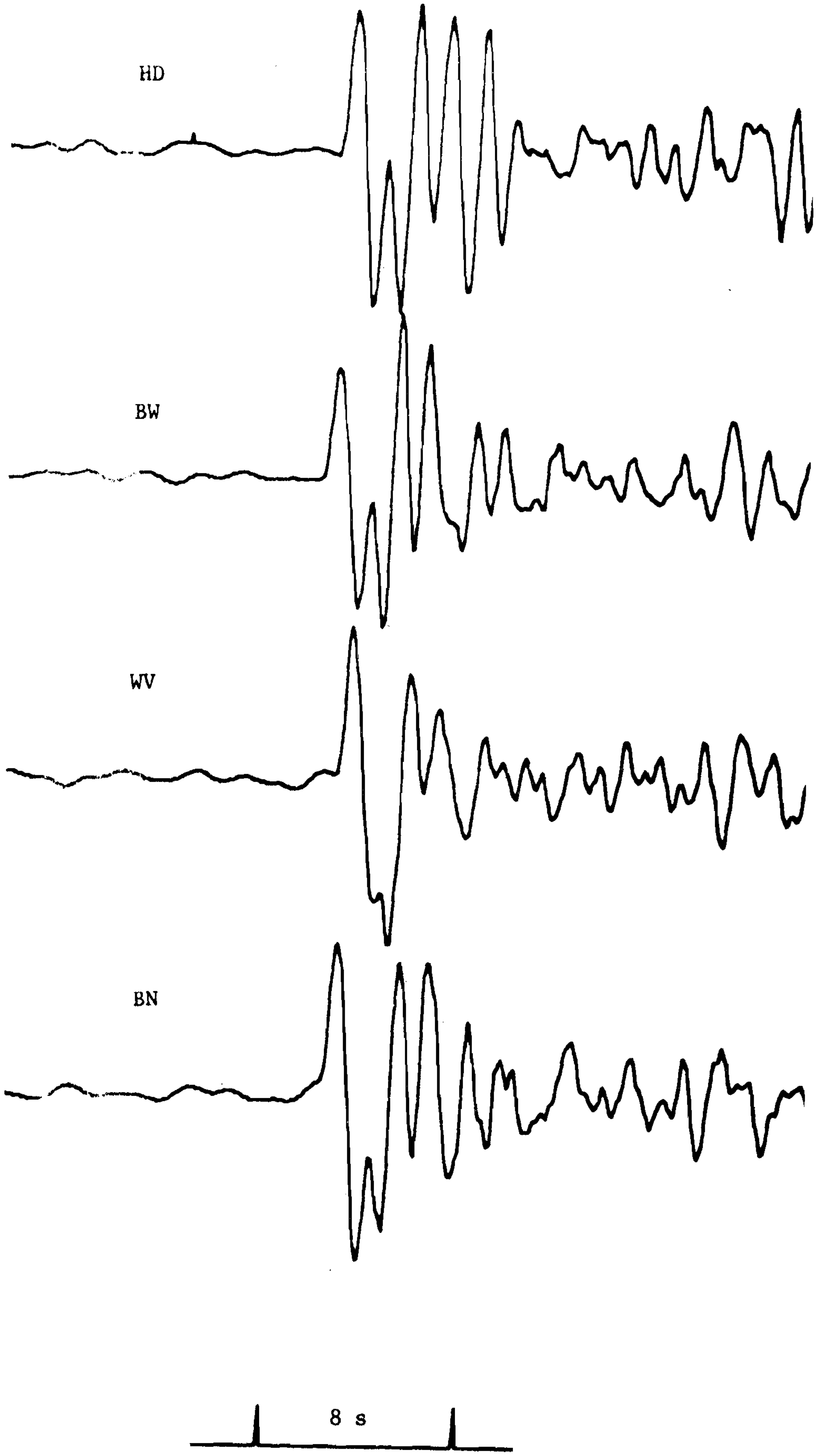


FIGURE 8. 2.11.74. SHORT PERIOD SIGNALS AND SP TO BB CONVERSION AT YKA



<u>FIGURE 9. 2.11.74. BROAD BAND SIGNALS AT BNA</u>

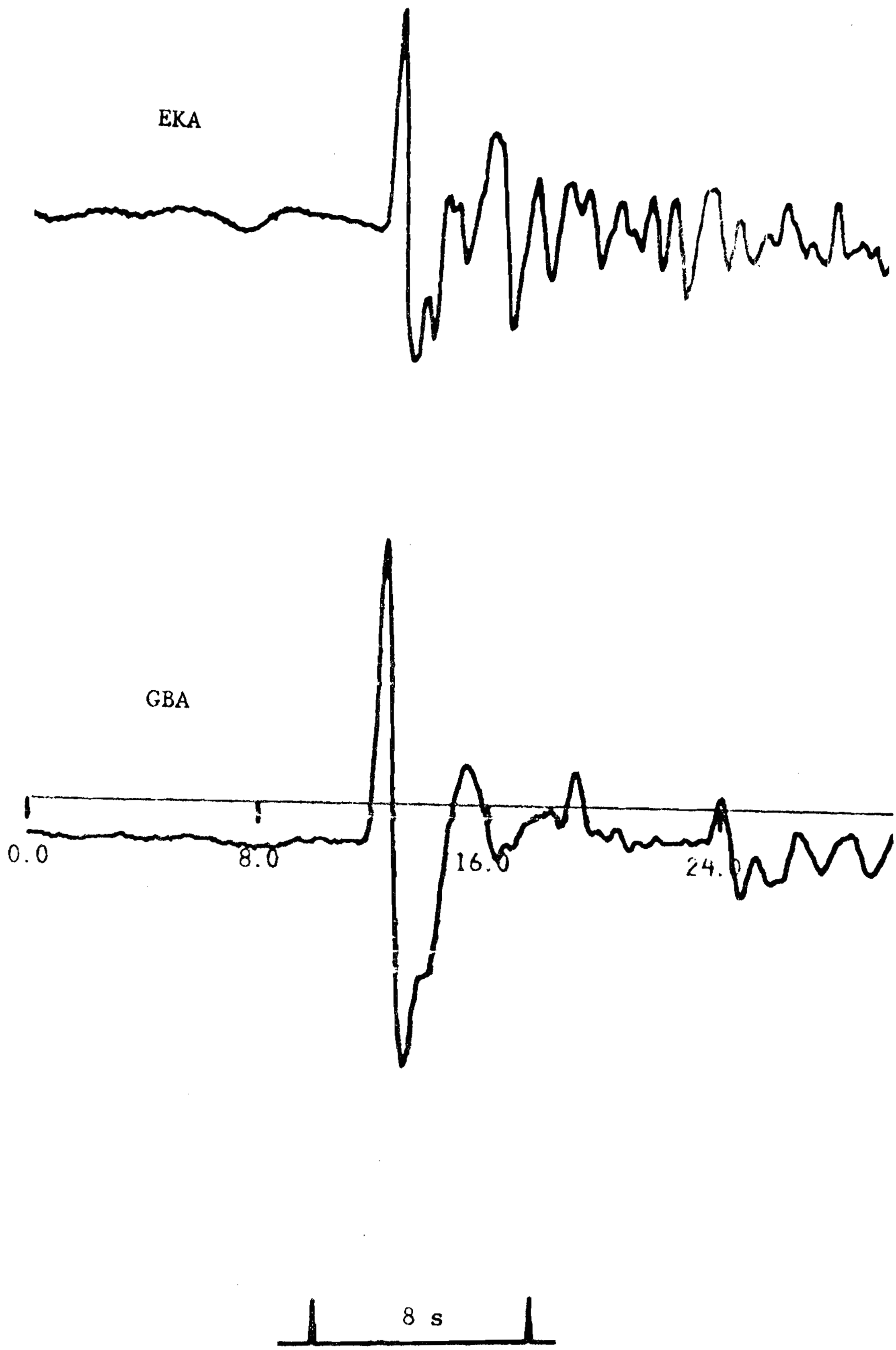


FIGURE 10. 2.11.74. BROAD BAND SIGNALS AT EKA (TOP) AND GBA

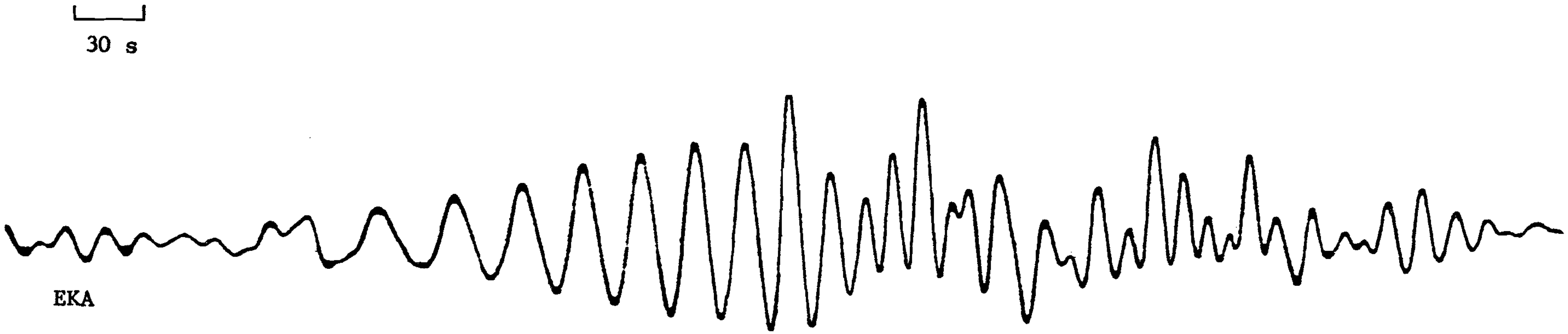


FIGURE 11. 2.11.74. SURFACES WAVES AT EKA

EXPLOSION NO. 3

Epicentre Estimation from SP Array Data

Date:	18 October 1975
Origin Time GMT:	08.59.56.1
Latitude:	70.93° North
Longitude:	53.79° East

Short Period Array Data

Station	Δ°	Azimuth°	Onset Time	Amplitude, m^{-9}	Period, s	Magnitude, mb
EKA	28.7	267.2	09.05.55.9	1590	1.02	6.79
GBA	59.1	153.0	09.10.00.4	OV		
YKA	46.6	352.6	09.08.26.8	557	0.69	6.40
WRA	105.4	105.5	09.14.09.0	101	0.82	6.92

Broad Band Data

Station	Amplitude, m^{-9}	Log A/T	Log A/T + B(Δ)	Period, s	Predicted SP BB Amplitude, m^{-9}
HD	3939	3.16	6.51	2.72	
BW	3787	3.17	6.52	2.56	
WV	NM				
BN	3485	3.10	6.46	2.72	
EKA	4545	3.41	6.70	1.77	7348
GBA	1060	3.02	6.47	1.01	
YKA	NA				2449
WRA	NA				693

NM = Not measured.

Surface Wave Data

Station	Amplitude, m^{-9}	Period, s	Ms
EKA	18333	14.65	5.54
GBA	NA		
YKA	4762	17.05	5.41
WRA	NA		

EDR Data

Origin Time:	08.59.56.3
Latitude:	70.84° North
Longitude:	53.69° East
mb:	6.7
Ms:	5.1
Data source:	PDE 36-75

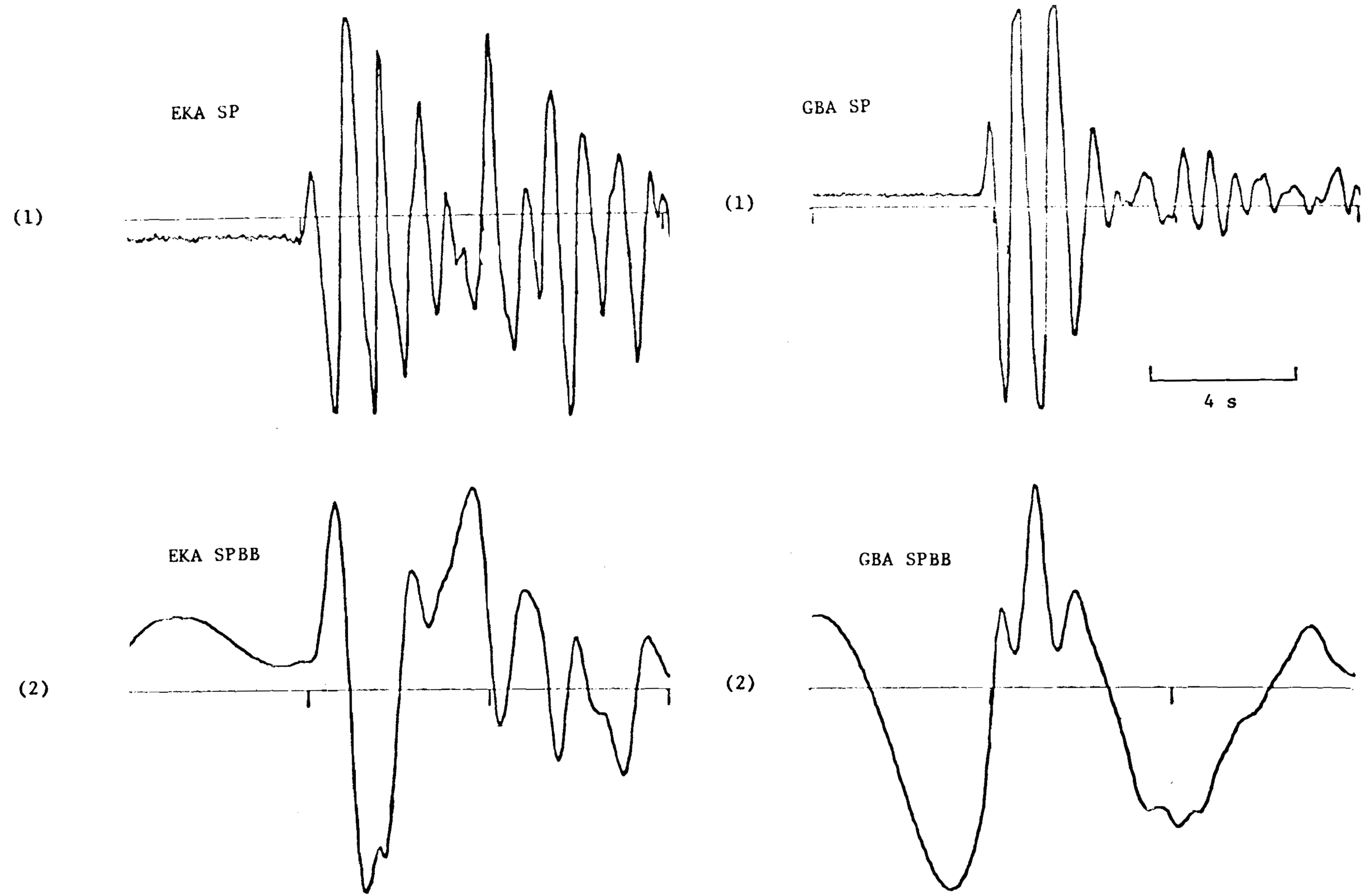


FIGURE 12. 18.10.75. SHORT PERIOD SIGNALS AND SP TO BB CONVERSIONS AT EKA AND GBA

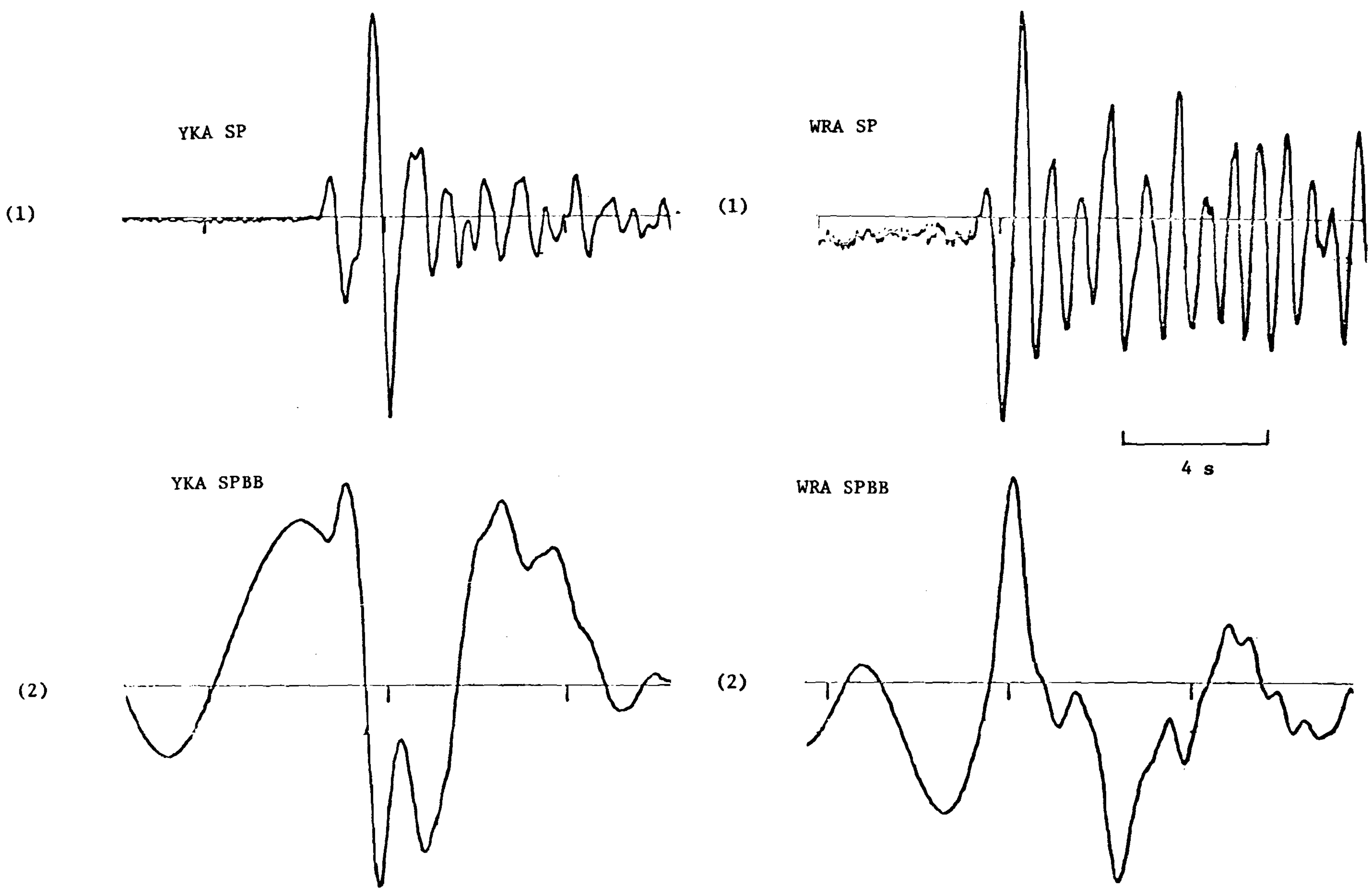


FIGURE 13. 18.10.75. SHORT PERIOD SIGNALS AND SP TO BB CONVERSIONS AT YKA AND WRA

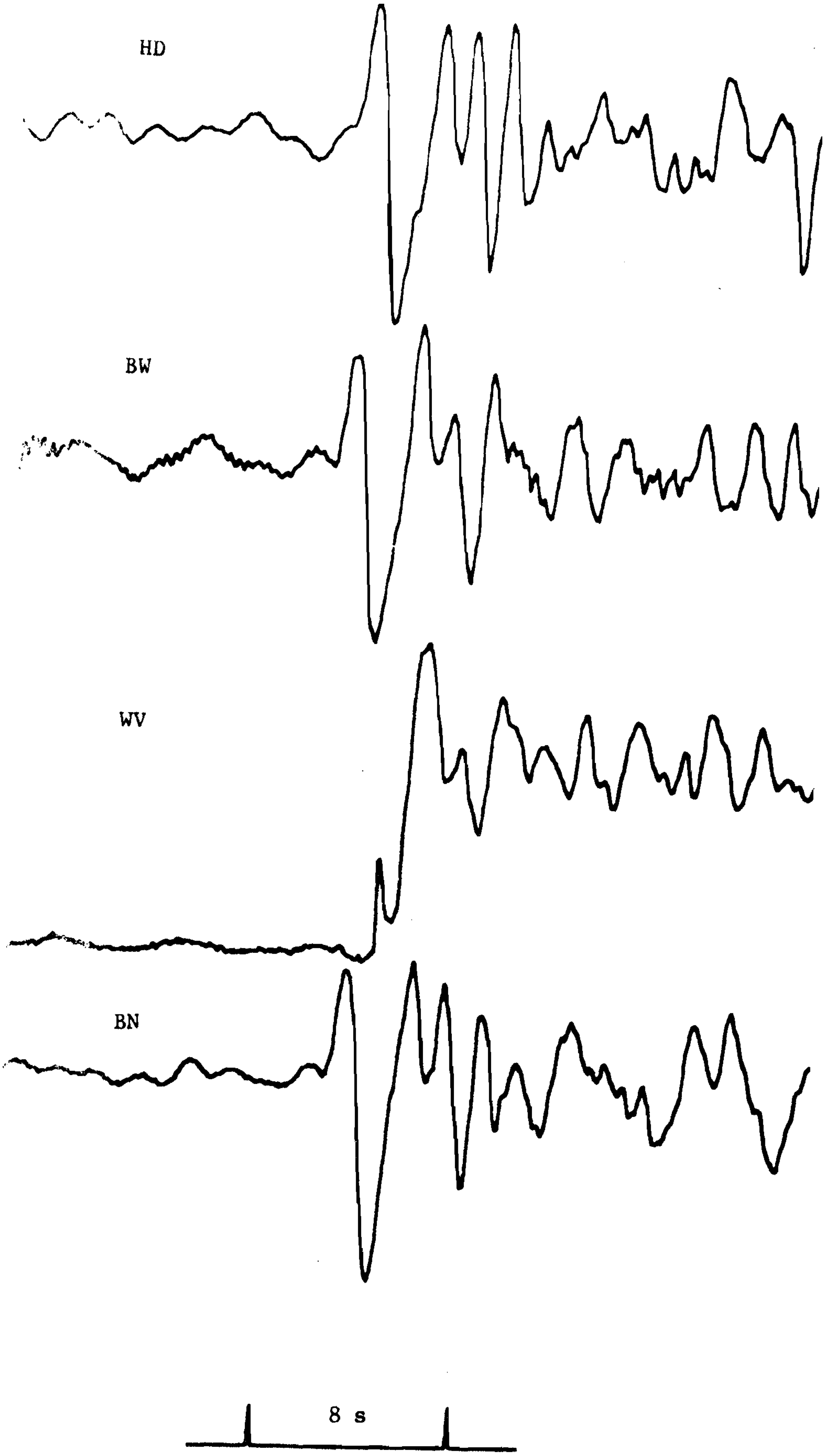


FIGURE 14. 18.10.75. BROAD BAND SIGNALS AT BNA

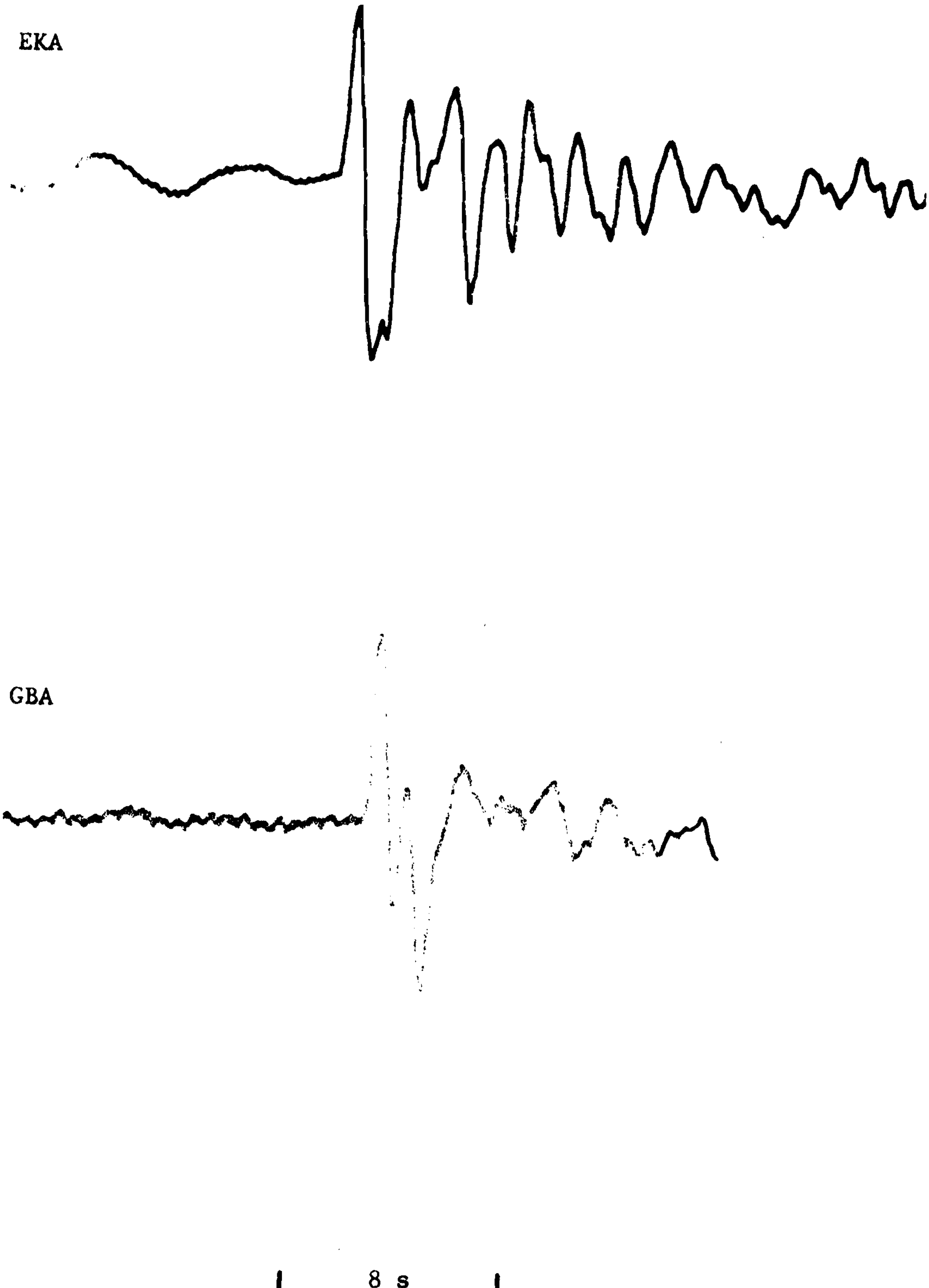


FIGURE 15. 18.10.75. BROAD BAND SIGNALS AT EKA (TOP) AND GBA

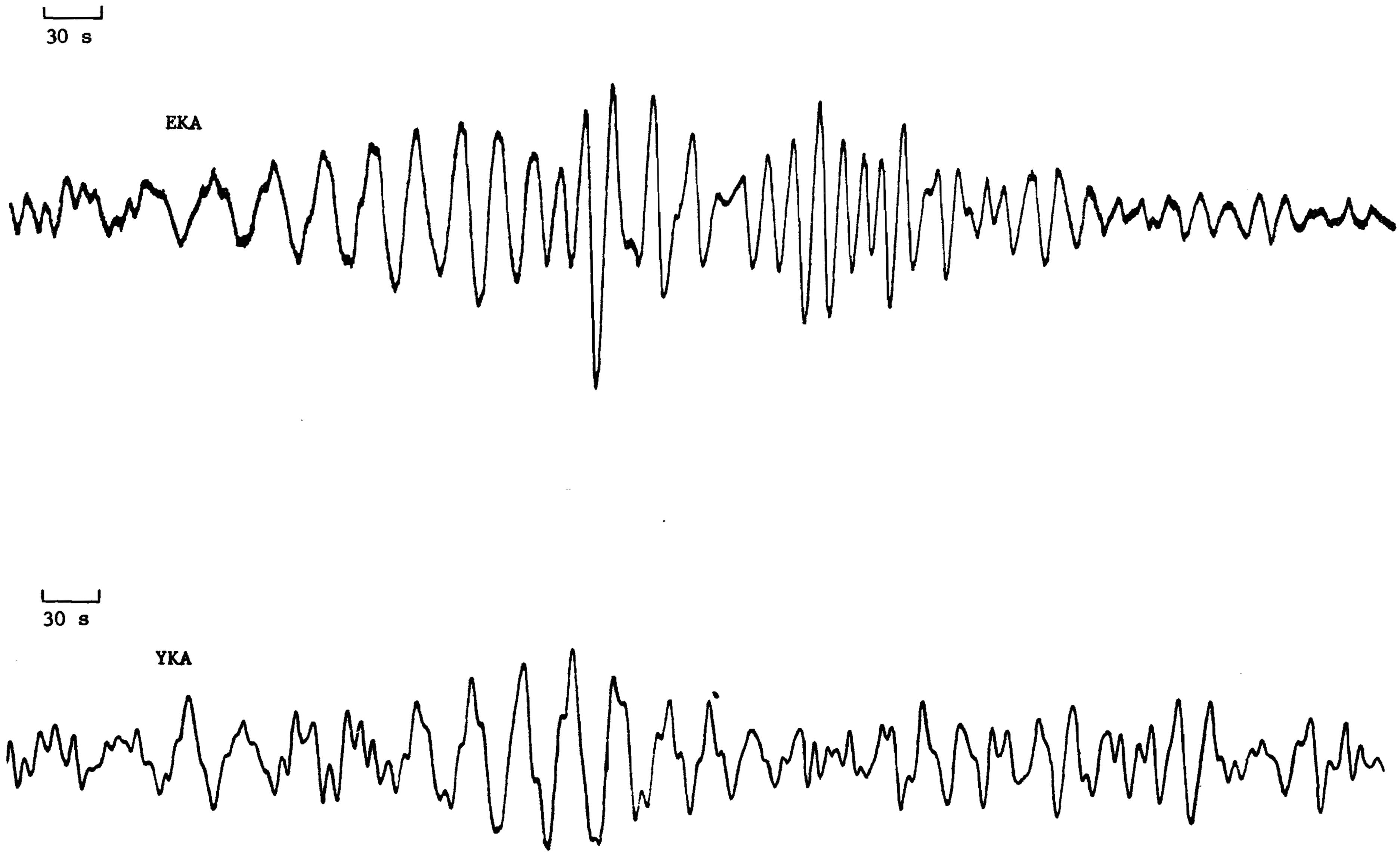


FIGURE 16. 18.10.75. SURFACE WAVES AT EKA (TOP) AND YKA

EXPLOSION NO. 4

Epicentre Estimation from SP Array Data

Date:	23 August 1975
Origin Time GMT:	08.59.58.2
Latitude:	73.43° North
Longitude:	54.53° East

Short Period Array Data

Station	Δ°	Azimuth°	Onset Time	Amplitude, m^{-9}	Period, s	Magnitude, mb
EKA	29.1	263.3	09.06.01.9	725	0.55	6.72
GBA	61.3	154.4	09.10.17.1	1075	0.71	7.12
YKA	44.1	352.8	09.08.09.2	102	0.70	5.66
WRA			NA			

Broad Band Data

Station	Amplitude, m^{-9}	Log A/T	Log A/T + B(Δ)	Period, s	Predicted SP BB Amplitude, m^{-9}
HD	1931	3.08	6.42	1.62	
BW	1856	3.04	6.34	1.70	
WV	1969	3.08	6.43	1.62	
BN	1893	3.05	6.39	1.70	
EKA	2765	3.24	6.54	1.58	1582
GBA	364			NM	2779
YKA	NA				549
WRA	NA				

Surface Wave Data

Station	Amplitude, m^{-9}	Period, s	Ms
EKA	8444	13.07	5.14
GBA	5357	18.0	5.53
YKA	2777	18.75	5.18
WRA	NA		

EDR Data

Origin Time:	08.59.57.9
Latitude:	73.37° North
Longitude:	54.64° East
mb:	6.4
Ms:	4.9
Data Source:	EDR 33-75

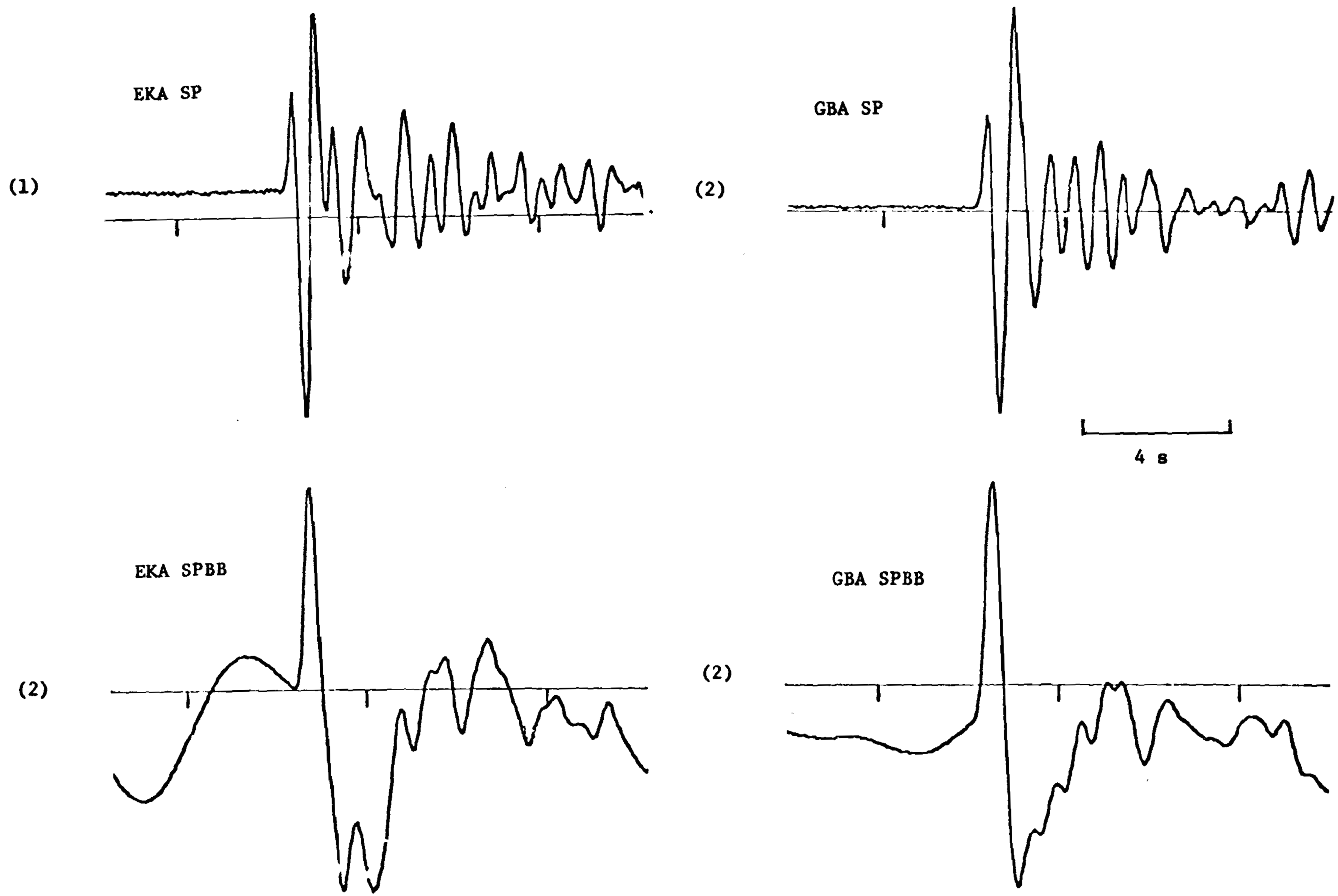


FIGURE 17. 23.8.75. SHORT PERIOD SIGNALS AND SP TO BB CONVERSIONS AT EKA AND GBA

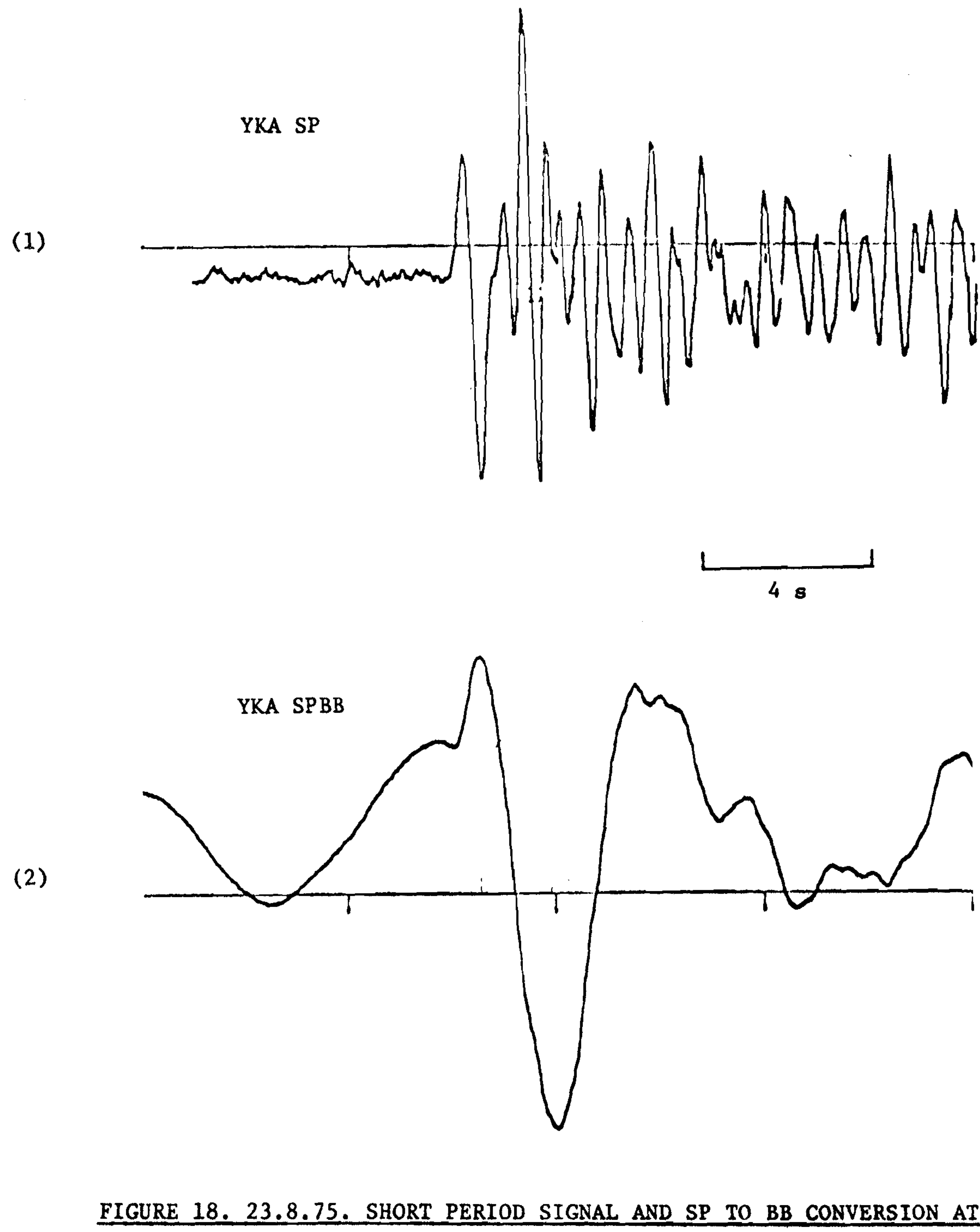


FIGURE 18. 23.8.75. SHORT PERIOD SIGNAL AND SP TO BB CONVERSION AT YKA

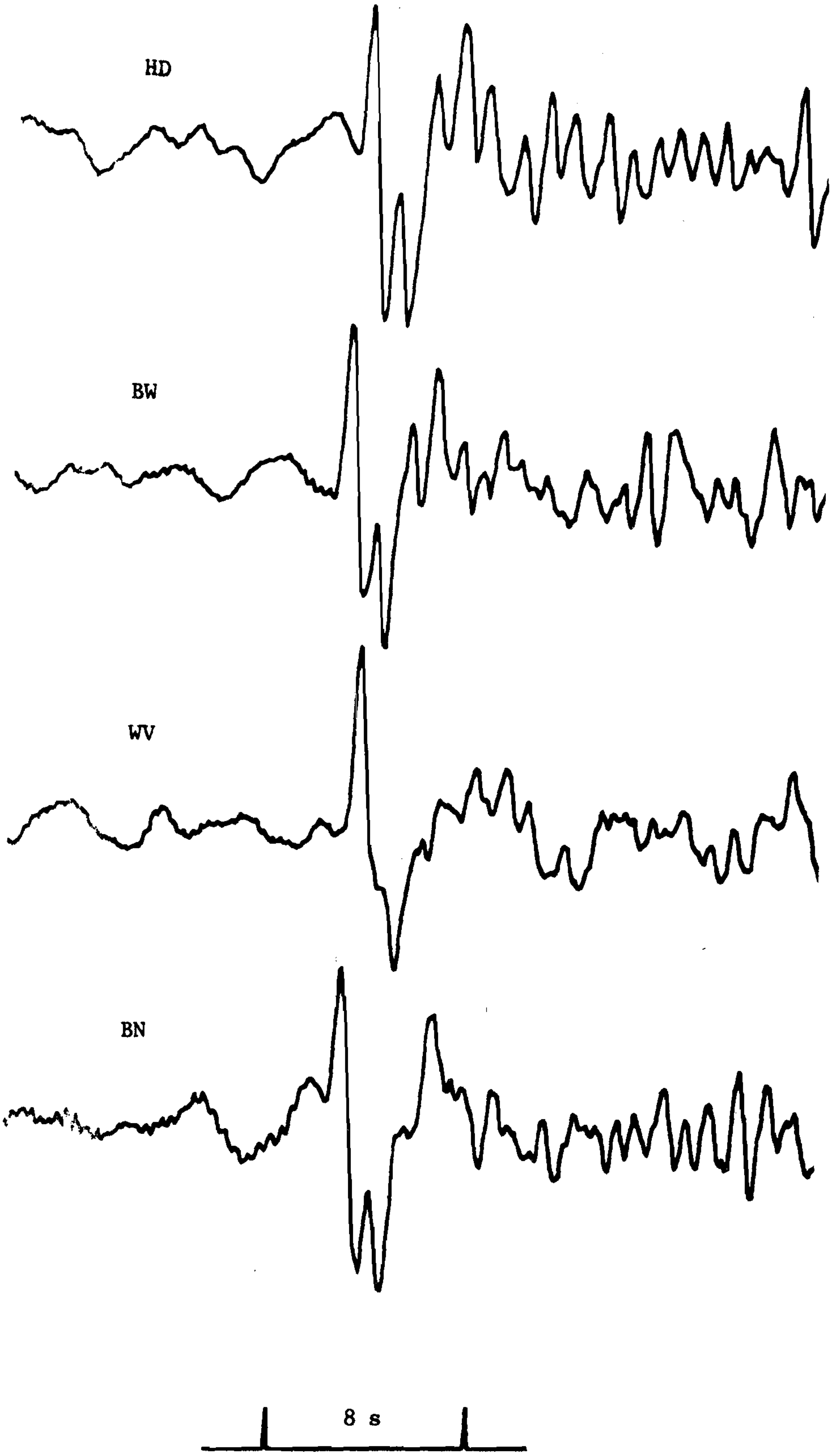


FIGURE 19. 23.8.75. BROAD BAND SIGNALS AT BNA

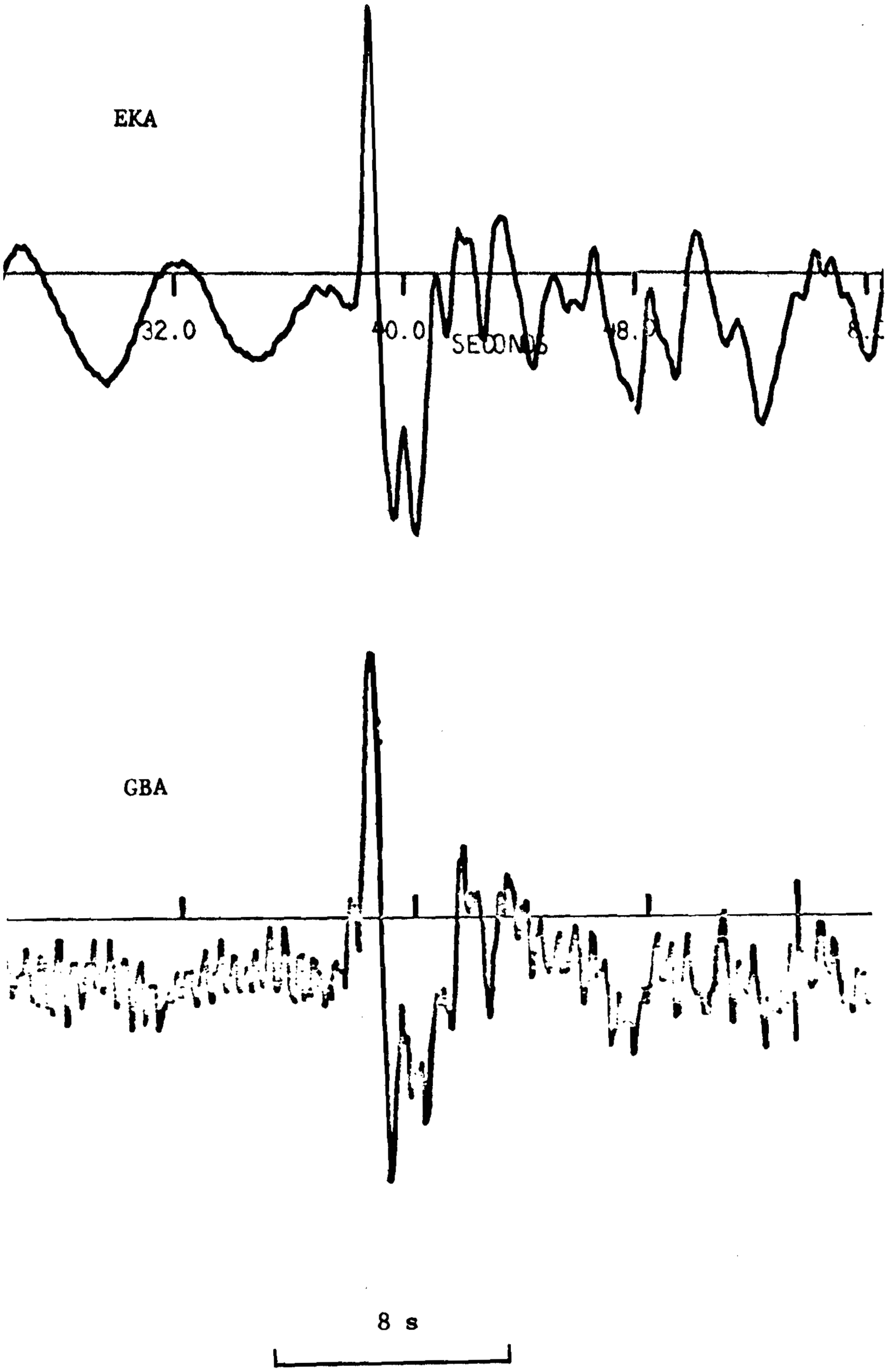


FIGURE 20. 23.8.75. BROAD BAND SIGNALS AT EKA (TOP) AND GBA

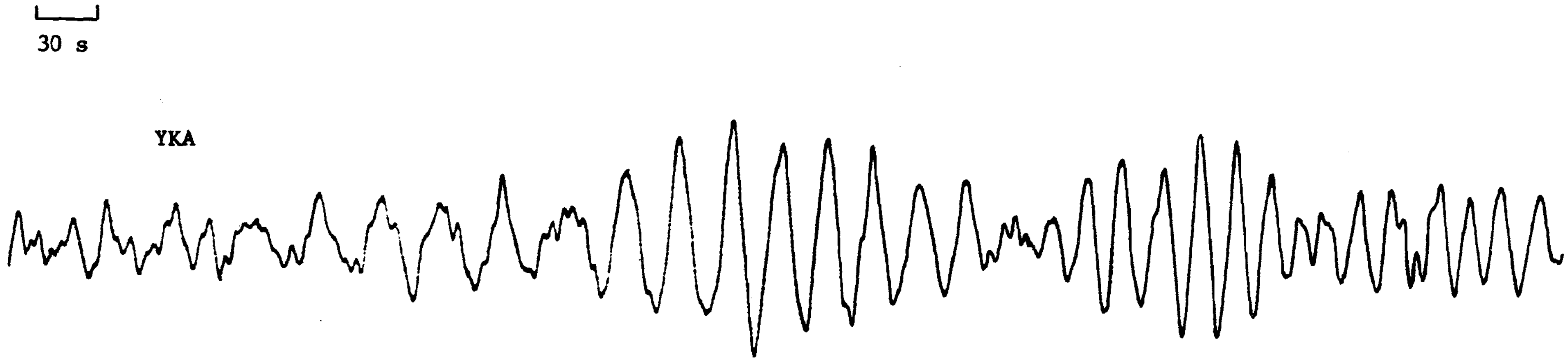


FIGURE 21. 23.8.75. SURFACE WAVES AT YKA

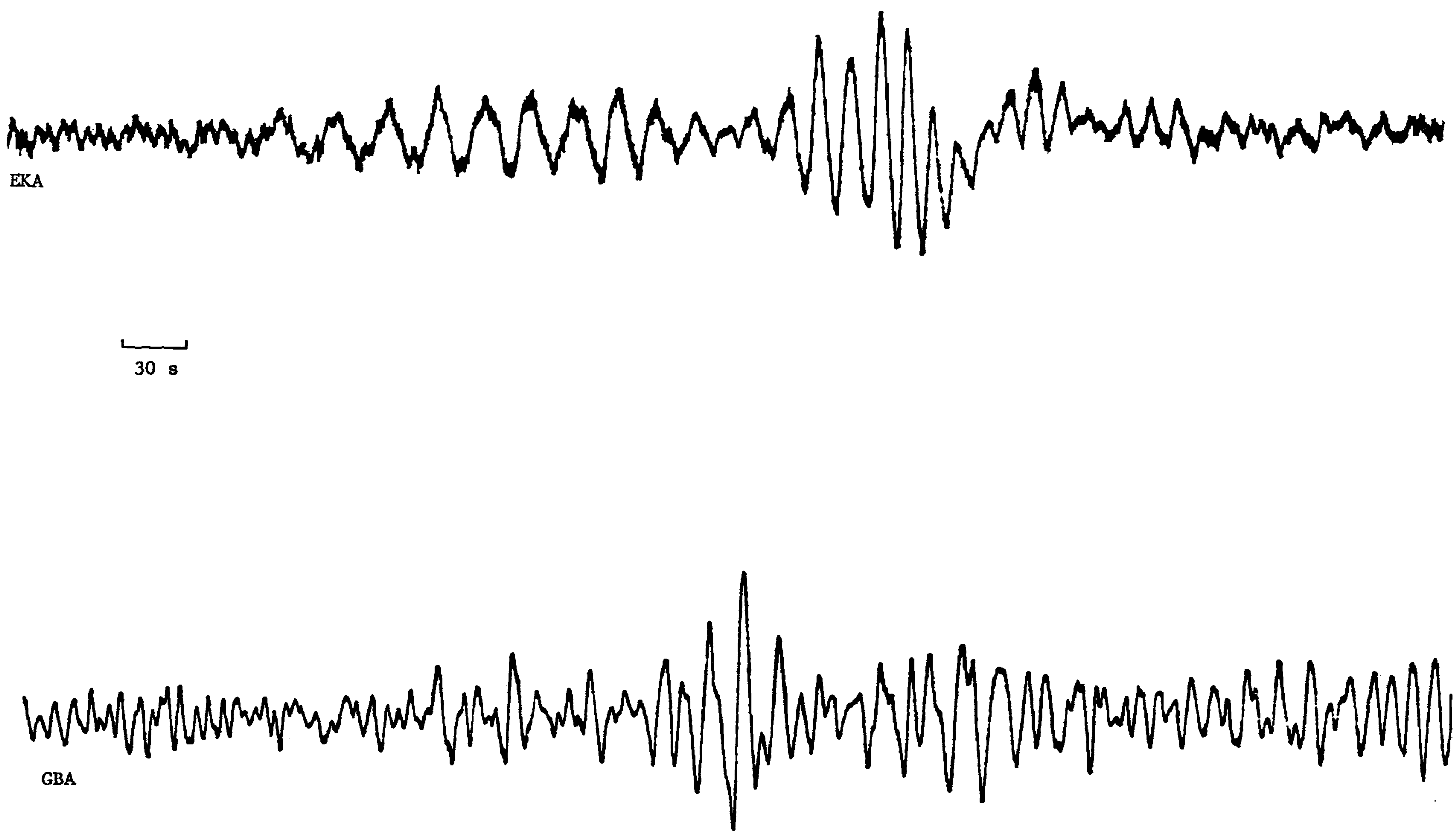


FIGURE 22. 23.8.75. SURFACE WAVES AT EKA (TOP) AND GBA

EXPLOSION NO. 5

Epicentre Estimation from SP Array Data

Date:	21 October 1975
Origin Time GMT:	11.59.57.2
Latitude:	73.31° North
Longitude:	55.19° East

Short Period Array Data

Station	Δ°	Azimuth°	Onset Time	Amplitude, m^{-9}	Period, s	Magnitude, mb
EKA	29.3	264.2	12.06.02.5	1021	0.41	6.99
GBA	61.1	155.1	12.10.14.8	521	0.75	6.78
YKA	106.3	106.1	12.14.09.5	67	0.88	6.71
WRA	44.3	353.2	12.08.09.4	86	0.55	5.69

Broad Band Data

Station	Amplitude, m^{-9}	Log A/T	Log A/T + B(Δ)	Period, s	Predicted SP BB Amplitude, m^{-9}
HD	3484	3.38	6.73	1.44	
BW	2575	3.30	6.65	1.28	
WV	2272			NM	
BN	2424	3.28	6.62	1.28	
EKA	4242	3.40	6.76	1.68	2953
GBA	818	2.71	6.58	1.58	1739
YKA	NA				643
WRA	NA				1225

Surface Wave Data

Station	Amplitude, m^{-9}	Period, s	Ms
EKA	14179	23.08	5.55
GBA	OV		
YKA	3675	17.64	5.30
WRA	NA		

EDR Data

Origin Time:	11.59.57.3
Latitude:	73.35° North
Longitude:	55.08° East
mb:	6.5
Ms:	Not given
Data Source:	EDR 33-75

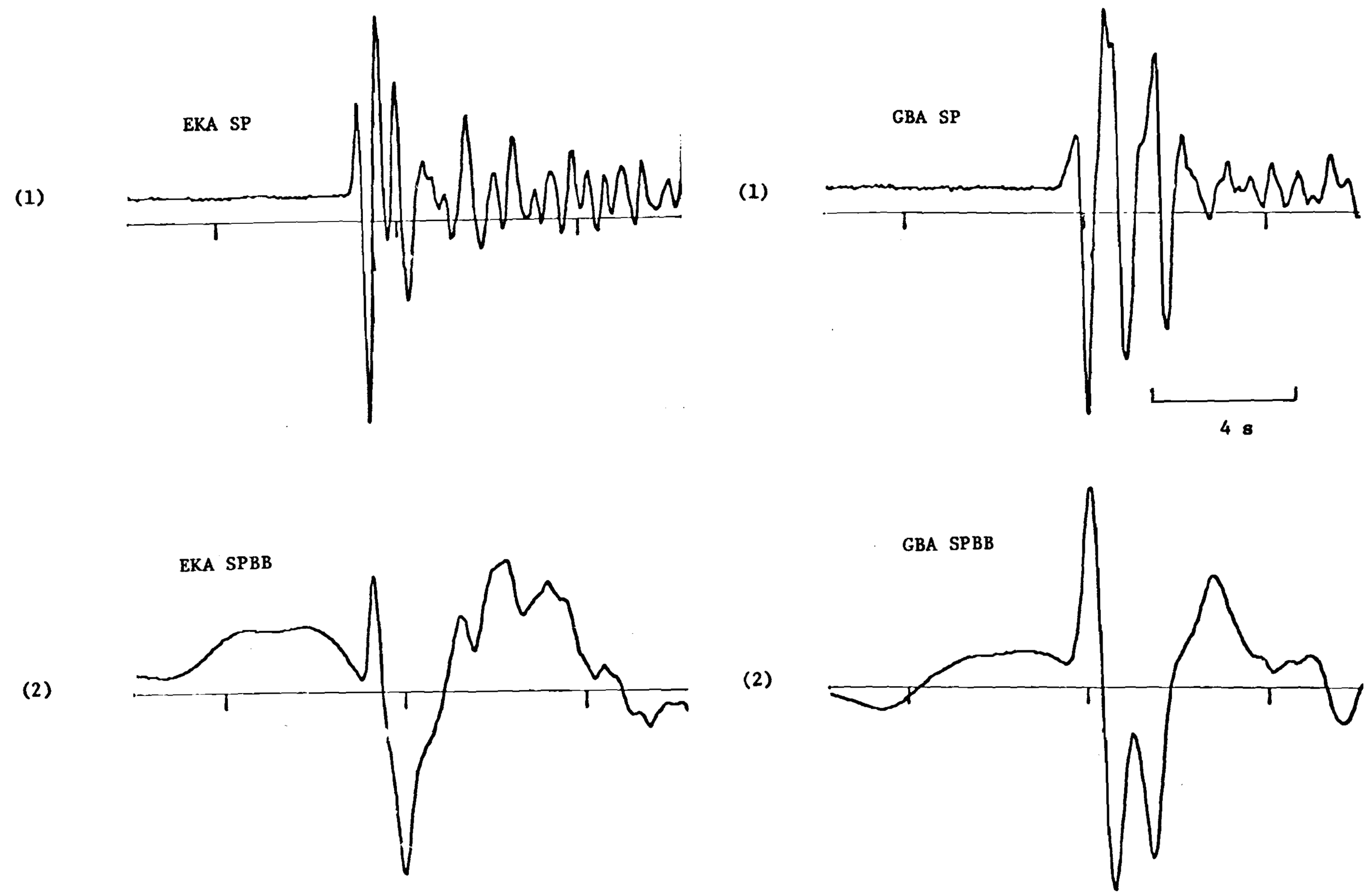


FIGURE 23. 21.10.75. SHORT PERIOD SIGNALS AND SP TO BB CONVERSIONS AT EKA AND GBA

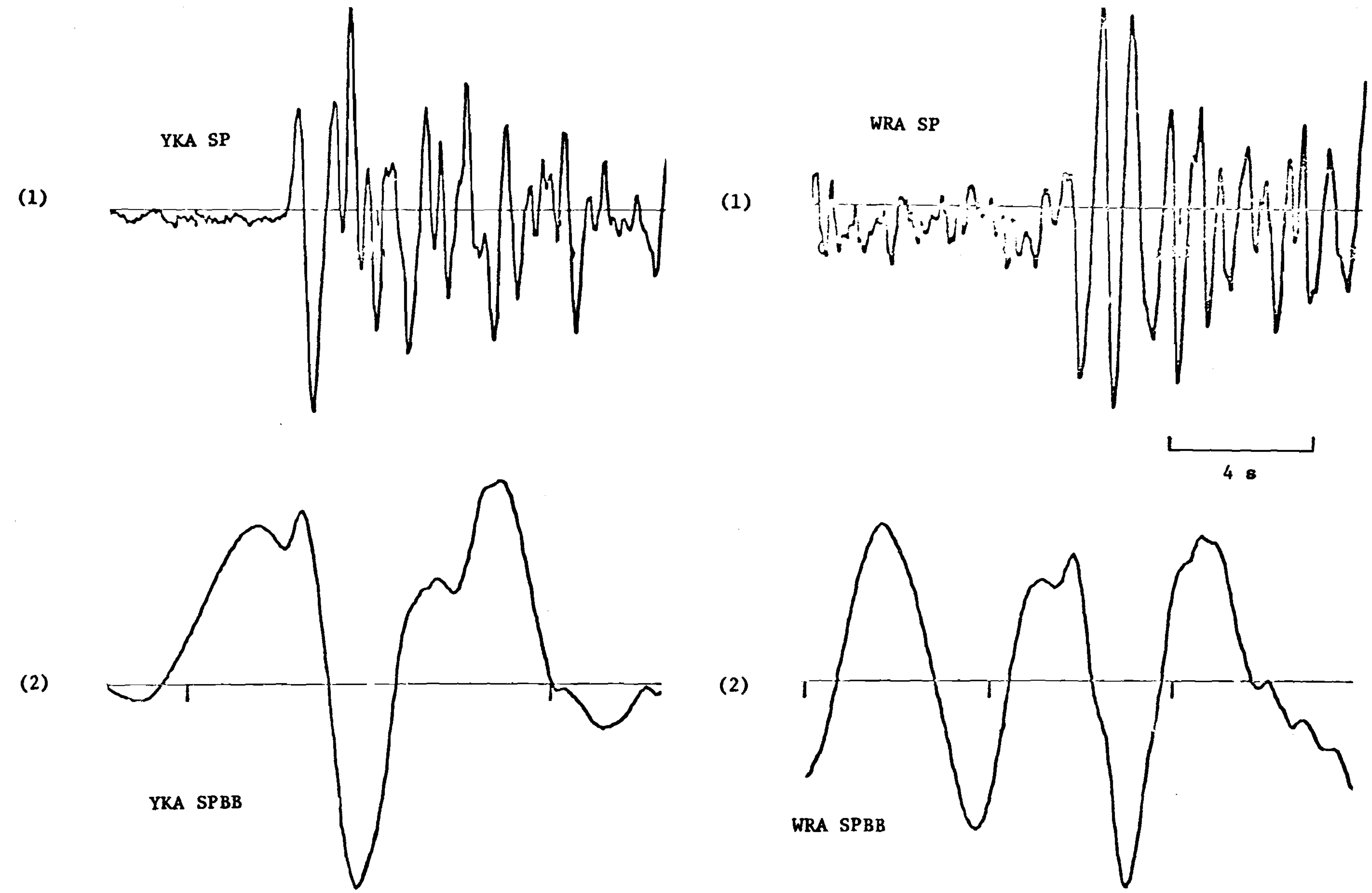


FIGURE 24. 21.10.75. SHORT PERIOD SIGNALS AND SP TO BB CONVERSIONS AT YKA AND WRA

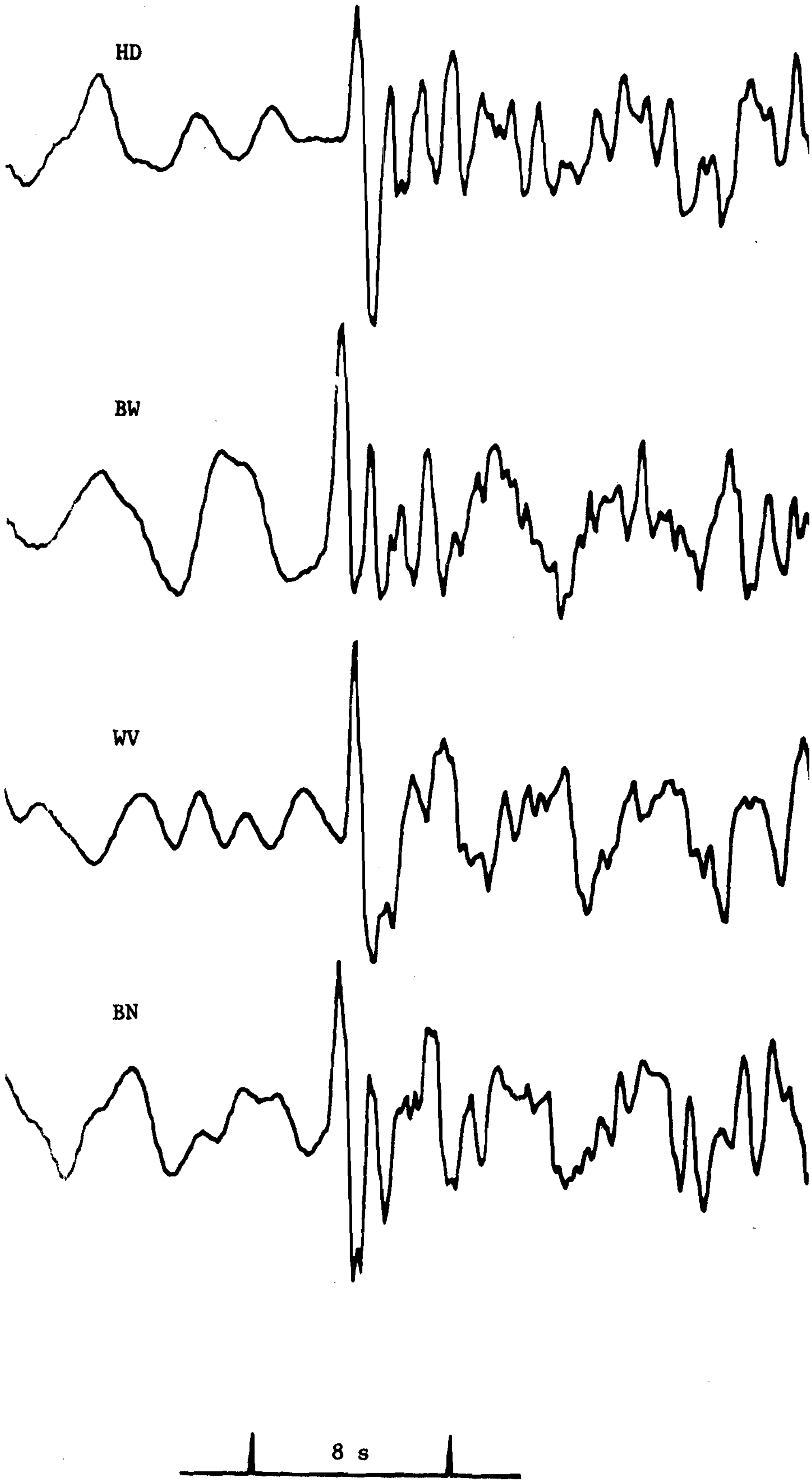


FIGURE 25. 21.10.75. BROAD BAND SIGNALS AT BNA

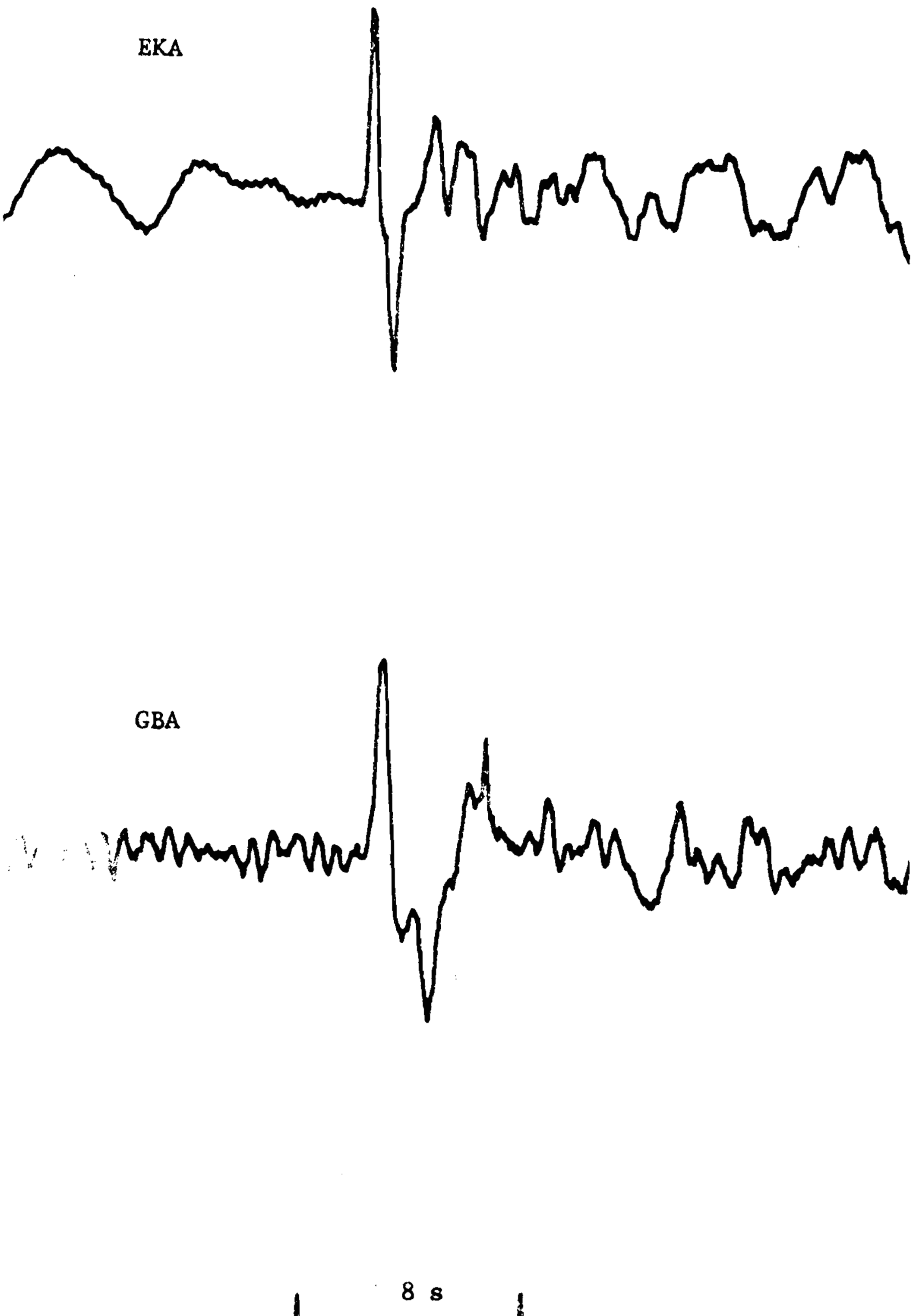


FIGURE 26. 21.10.75. BROAD BAND SIGNALS AT EKA (TOP) AND GBA

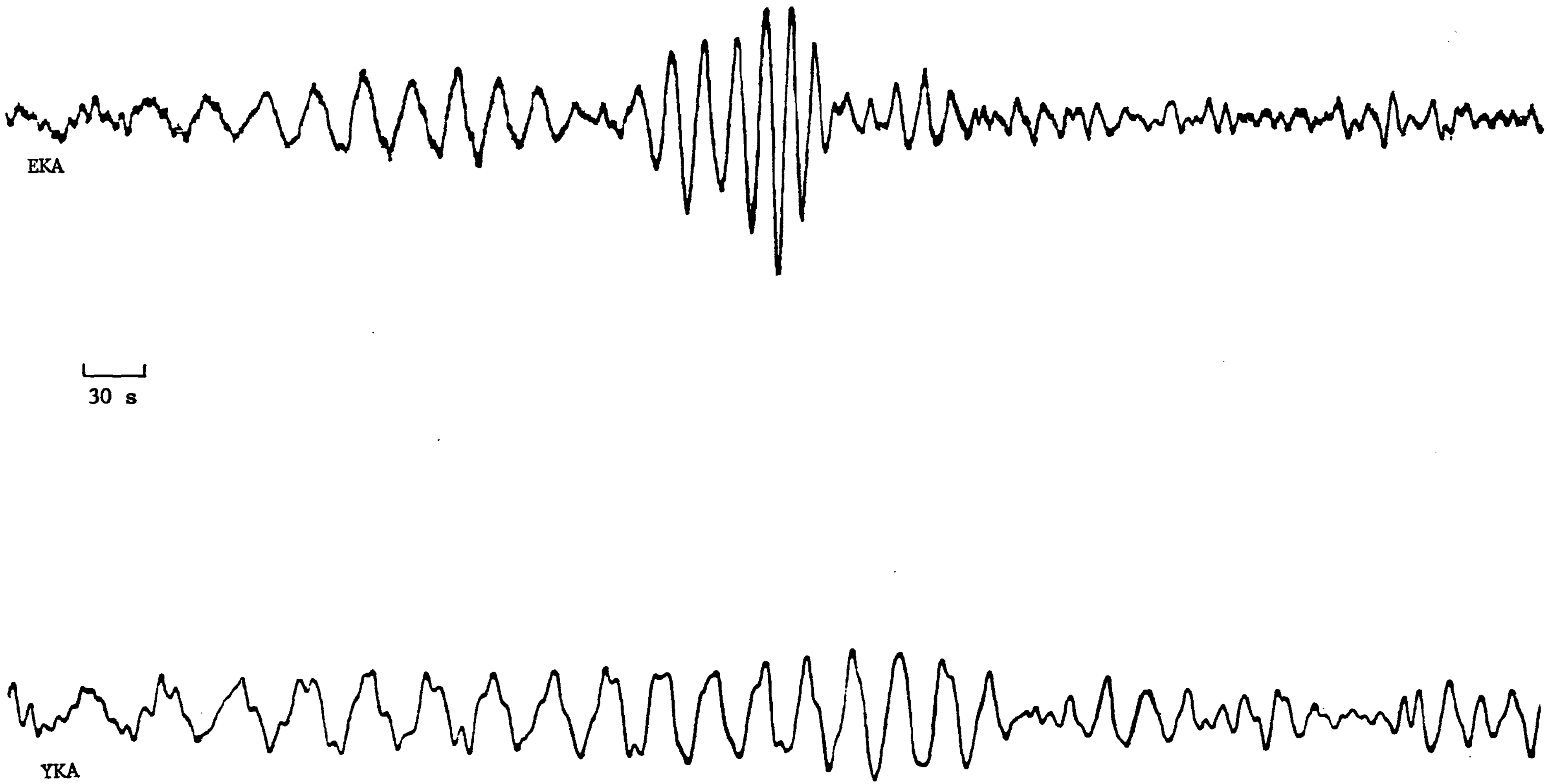
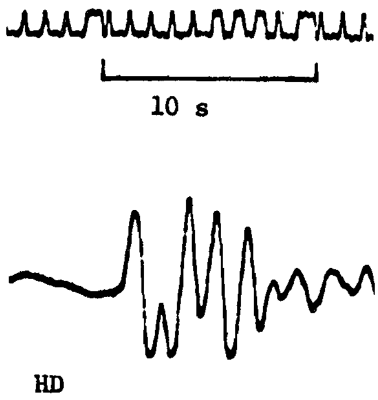
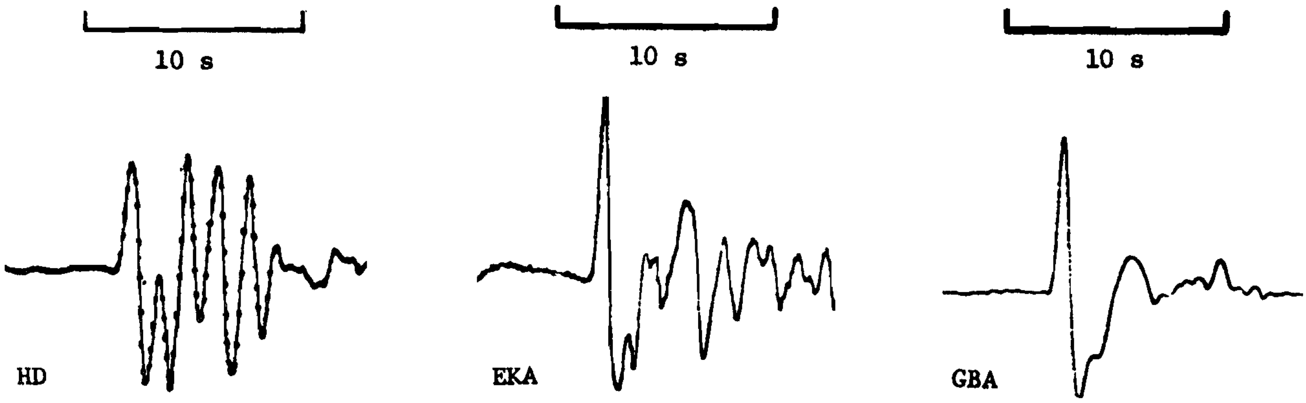


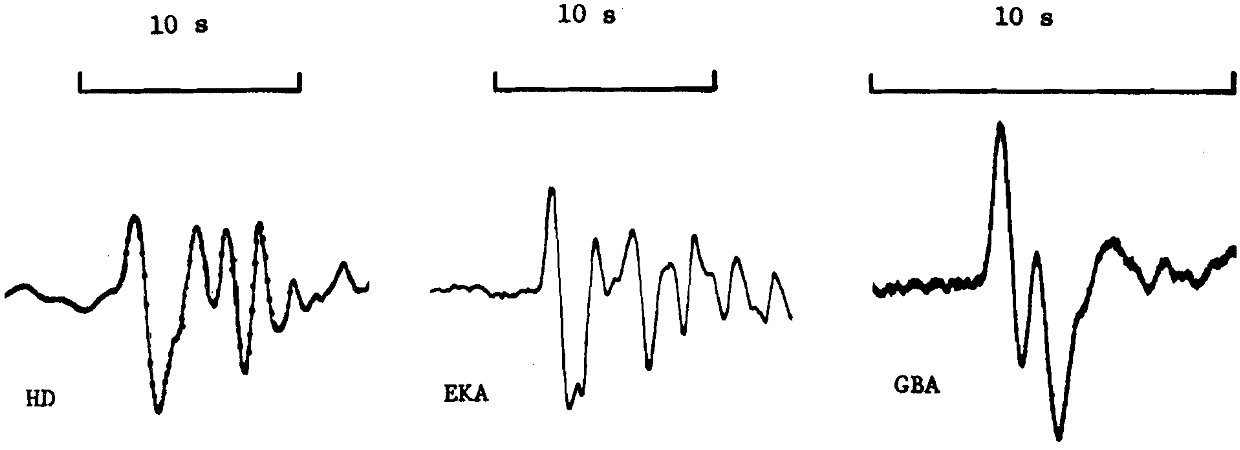
FIGURE 27. 21.10.75 SURFACE WAVES AT EKA (TOP) AND YKA



THE BB SIGNAL FROM NZ RECORDED
AT HD ON 27.10.73



THE BB SIGNALS FROM NZ RECORDED AT HD, EKA AND
GBA ON 2.11.74



BB SIGNALS FROM NZ RECORDED AT HD, EKA AND GBA
ON 18.10.75

FIGURE 28. BROAD BAND SIGNALS FROM THE SOUTHERN SITE, NOVAYA ZEMLYA

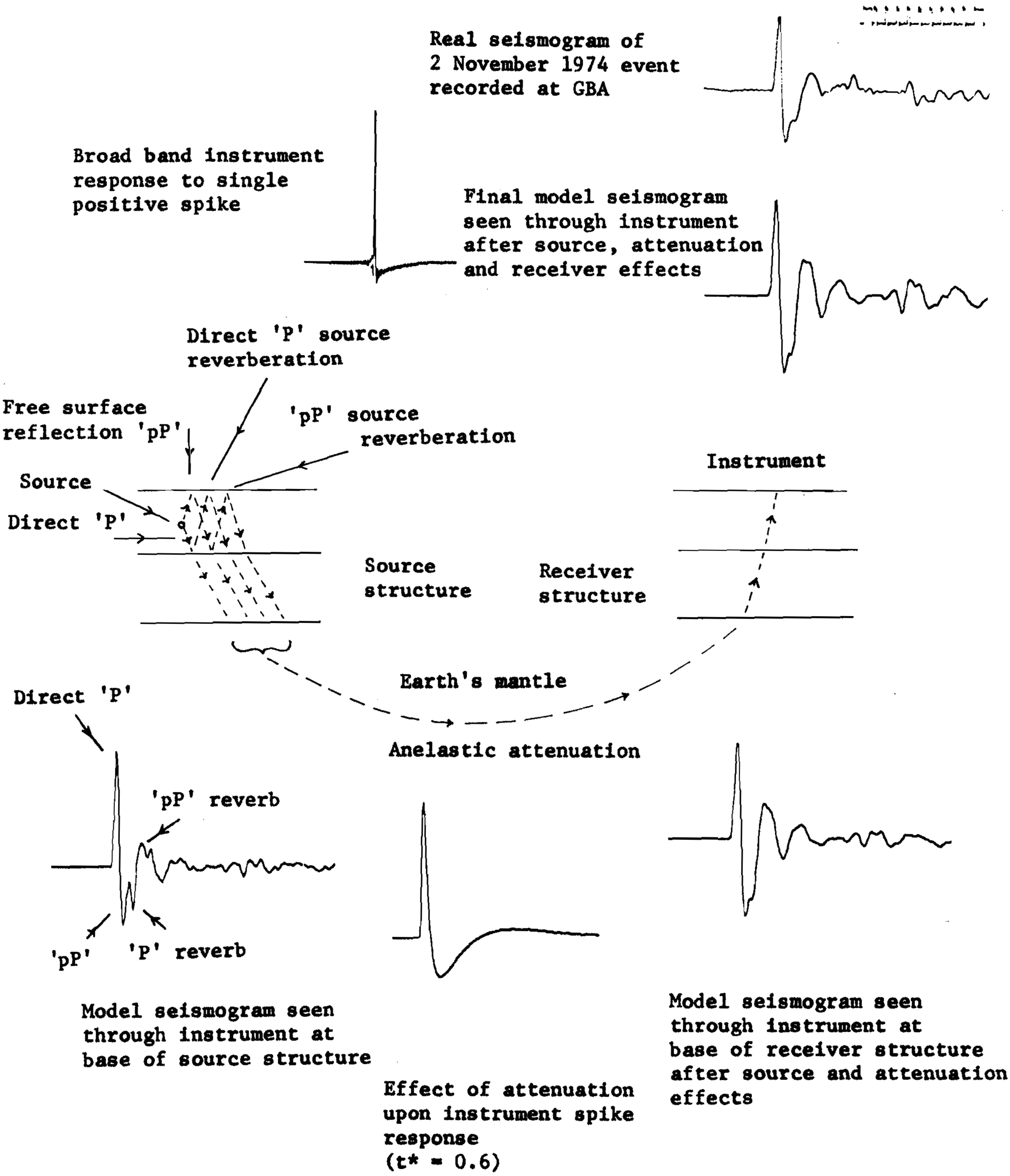
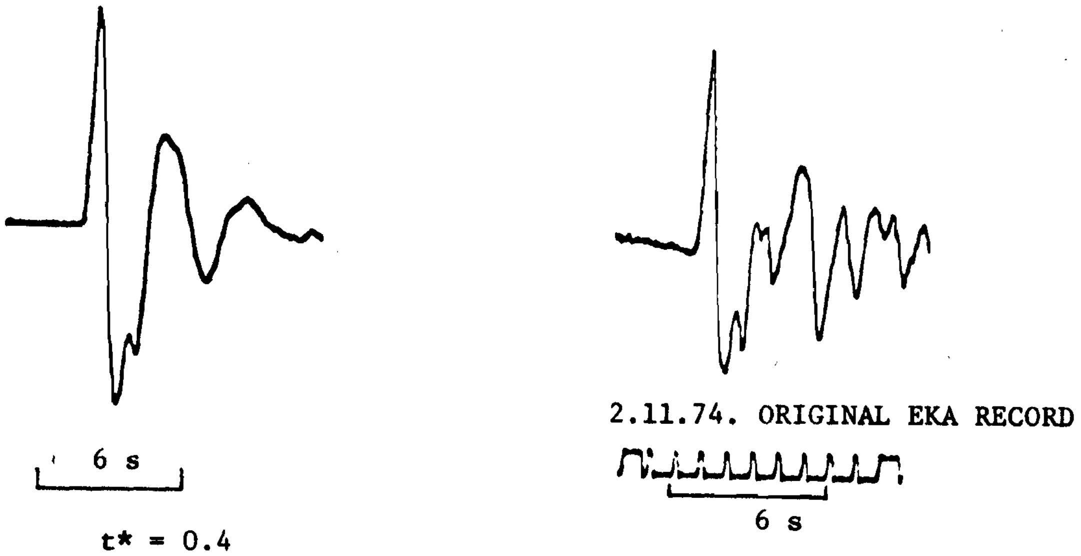
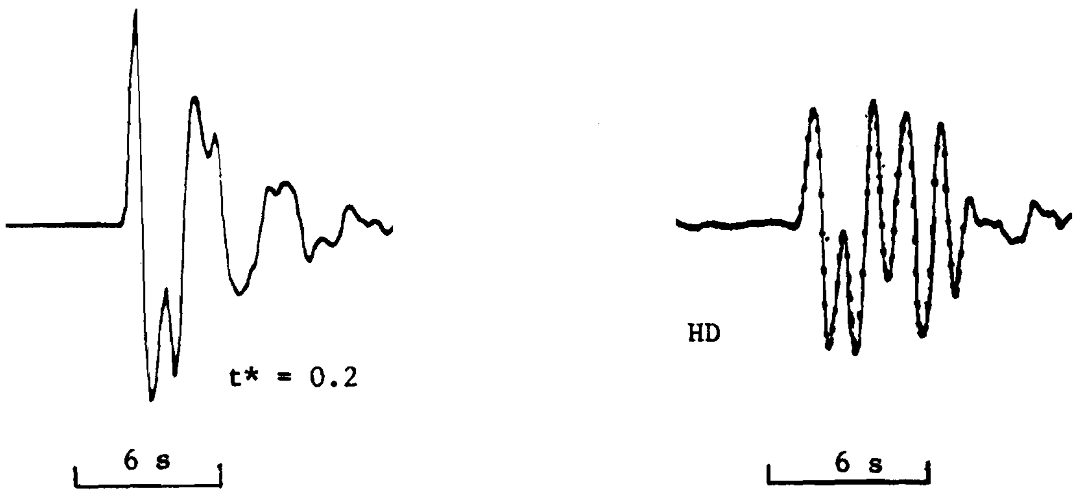


FIGURE 29. THE DEVELOPING MODEL SEISMOGRAM OF THE 2.11.74 BROAD BAND SIGNAL AT GBA



THE OBSERVED (RIGHT) AND COMPUTED SEISMOGRAMS OF THE 2.11.74 BROAD BAND SIGNALS AT EKA



THE OBSERVED (RIGHT) AND COMPUTED SEISMOGRAMS OF THE 2.11.74 BROAD BAND SIGNALS AT HD

FIGURE 30. A COMPARISON BETWEEN OBSERVED AND COMPUTED SEISMOGRAMS AT EKA AND HD

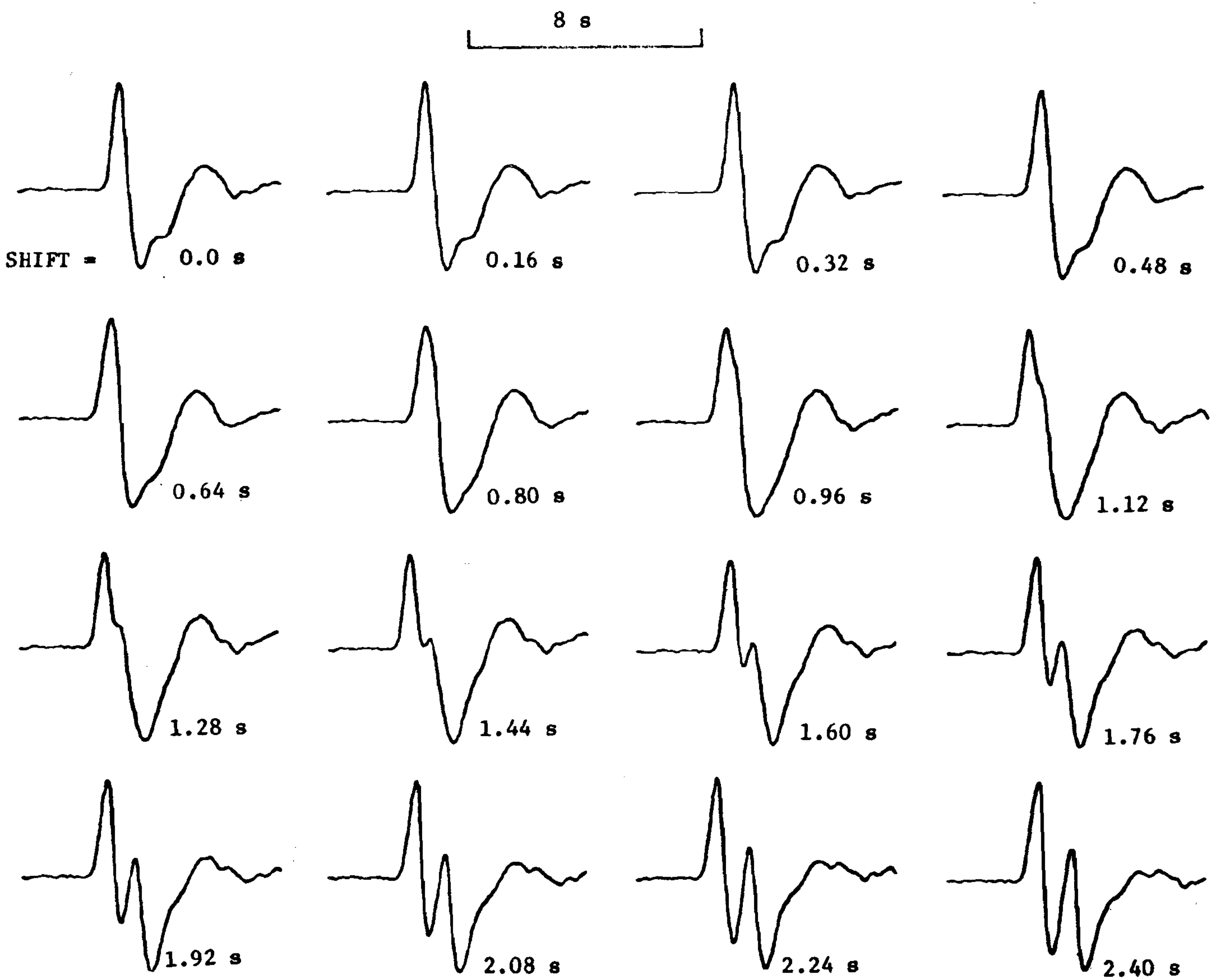
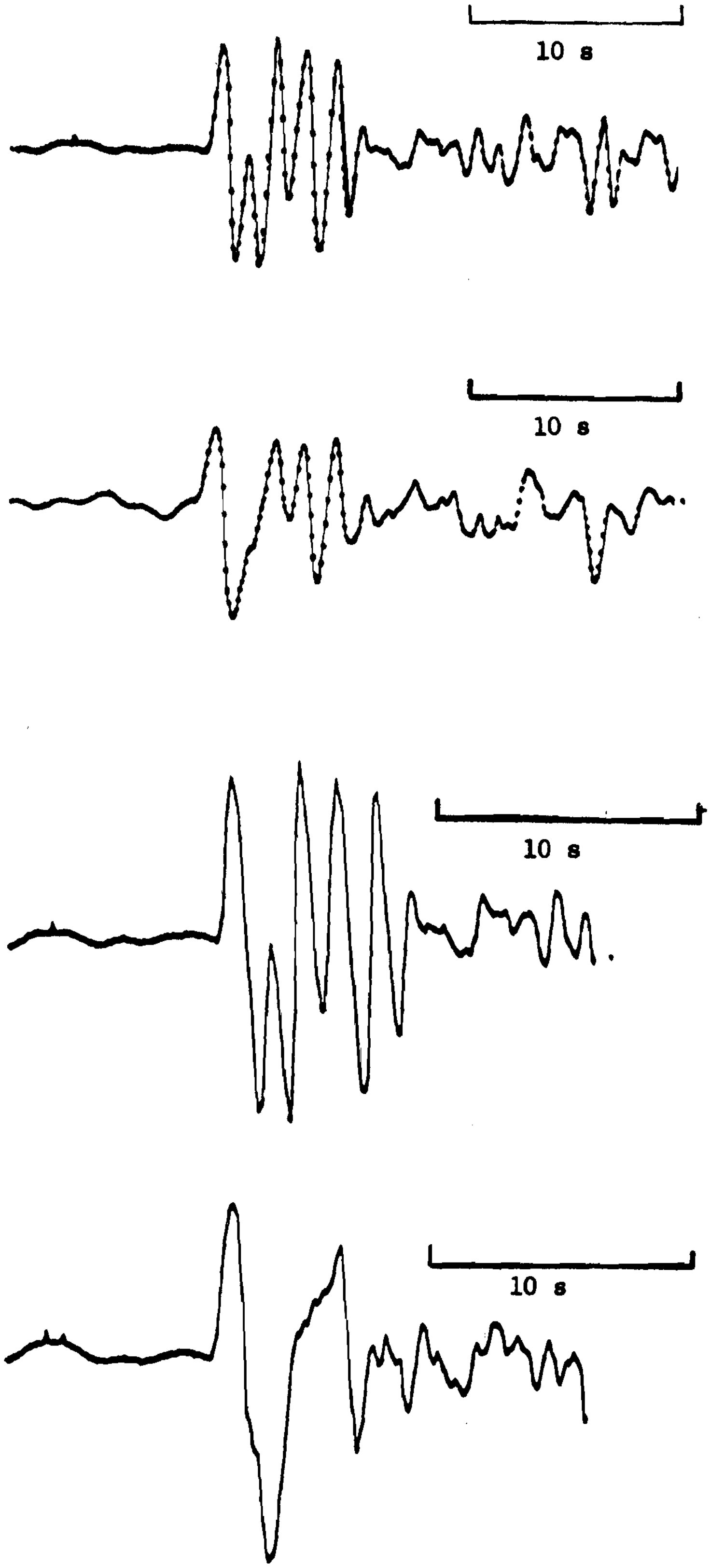


FIGURE 31. THE SIGNAL SHAPES RESULTING FROM SCALING, SHIFTING AND SUMMING THE 2.11.74 GBA BB SIGNAL TO ITSELF FOR A VARIETY OF TIME SHIFTS. (SCALE FACTOR = 0.8)



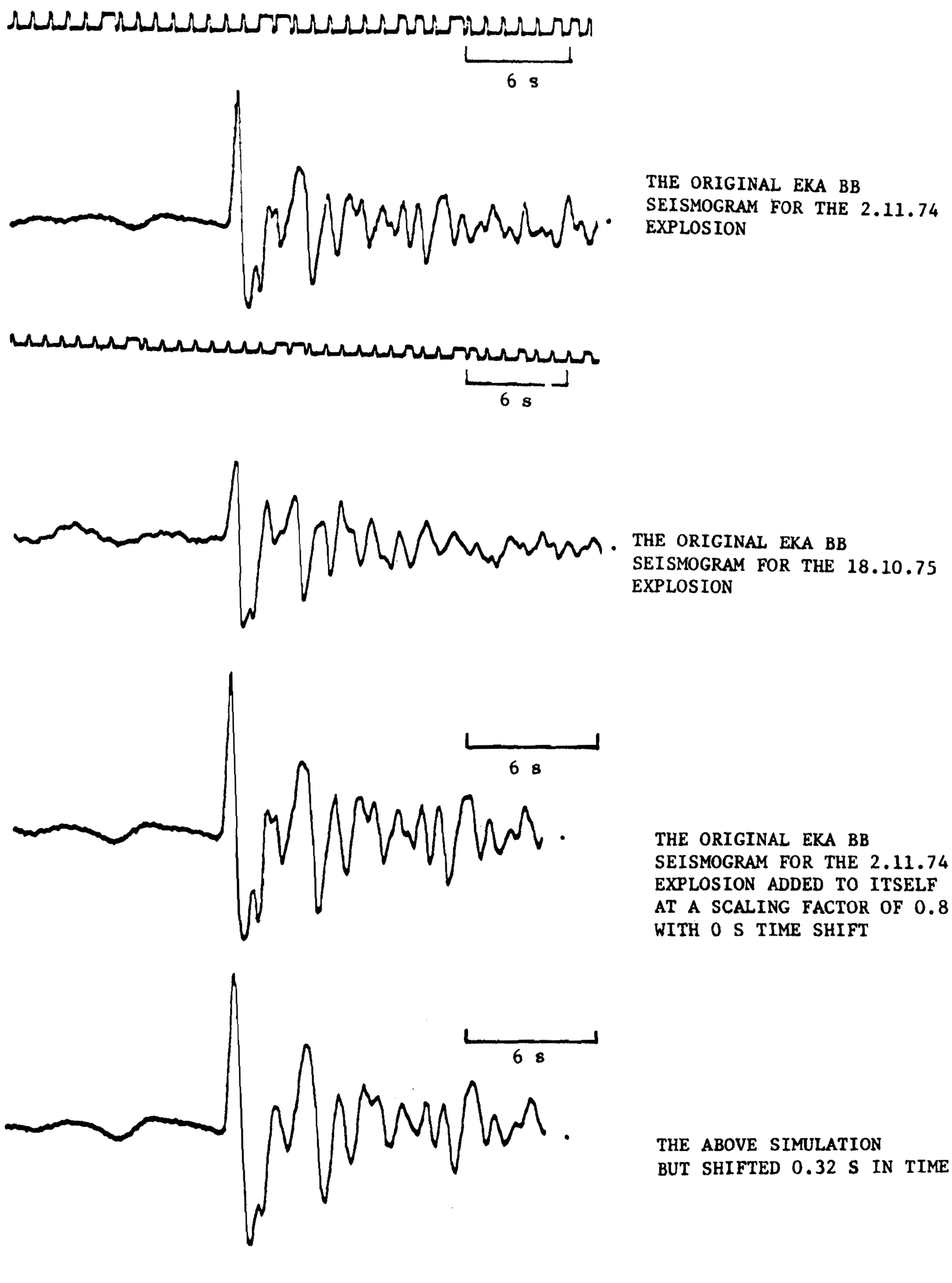
THE ORIGINAL BNA (HD) BB SEISMOGRAM FOR THE 2.11.74 EXPLOSION

THE ORIGINAL BNA (HD) BB SEISMOGRAM FOR THE 18.10.75 EXPLOSION

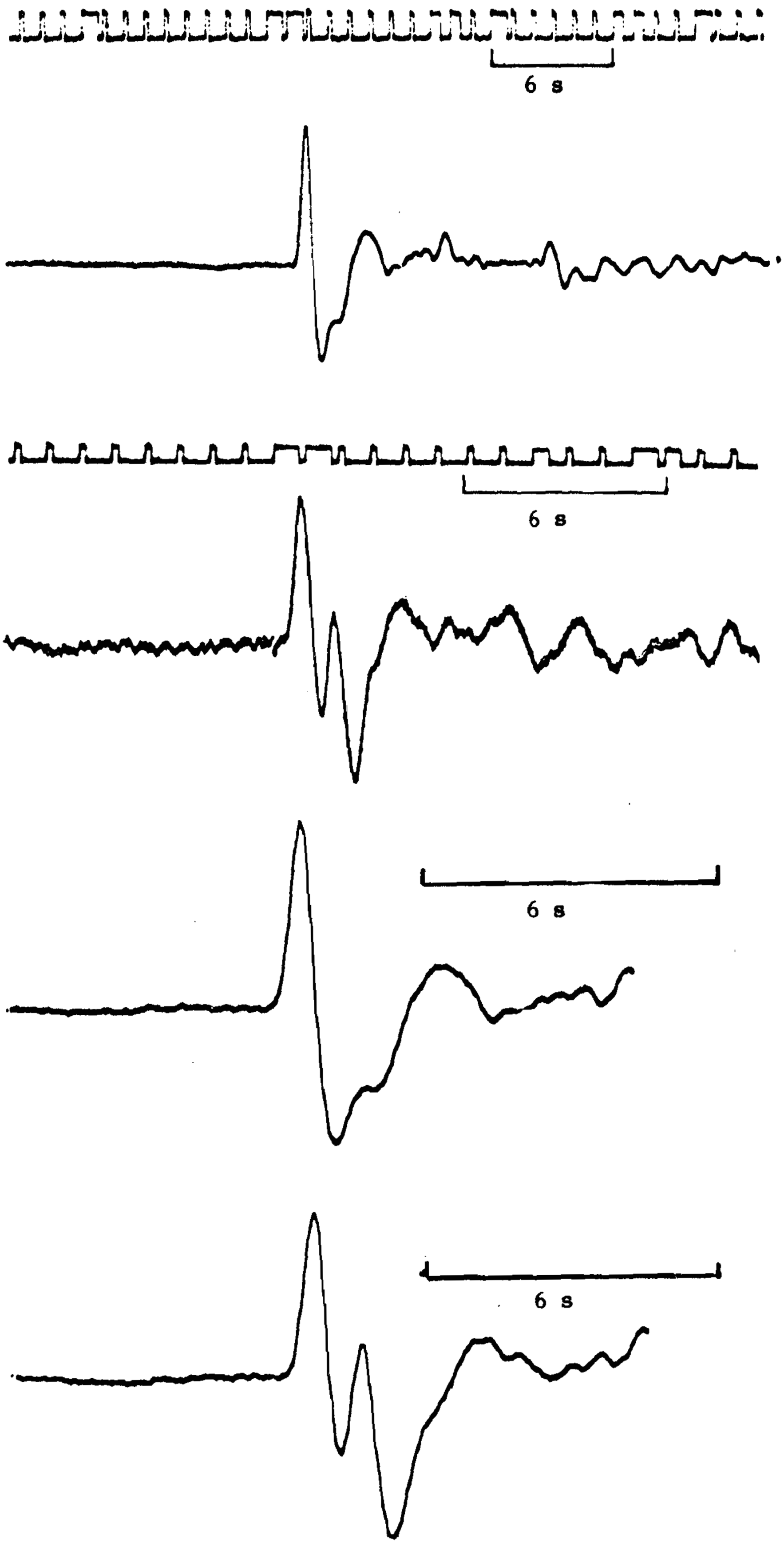
THE ORIGINAL BNA (HD) BB SEISMOGRAM FOR THE 2.11.74 EXPLOSION ADDED TO ITSELF AT A SCALING FACTOR OF 0.8 WITH 0 S TIME SHIFT

THE ABOVE SIMULATION BUT SHIFTED 0.64 S IN TIME

FIGURE 32. A SIMULATION OF THE 18.10.75 BROAD BAND SIGNAL AT HD



<u>FIGURE 33. A SIMULATION OF THE 18.10.75 BROAD BAND SIGNAL AT EKA</u>



THE ORIGINAL GBA BROAD BAND SEISMOGRAM FOR THE 2.11.74 EXPLOSION

THE ORIGINAL GBA BROAD BAND SEISMOGRAM FOR THE 18.10.75 EXPLOSION

THE ORIGINAL GBA BROAD BAND SEISMOGRAM FOR THE 2.11.74 EXPLOSION ADDED TO ITSELF AT A SCALING FACTOR OF 0.8 WITH 0 S TIME SHIFT

THE ABOVE SIMULATION BUT SHIFTED 1.92 S IN TIME

FIGURE 34. A SIMULATION OF THE 18.10.75 BROAD BAND SIGNAL AT GBA

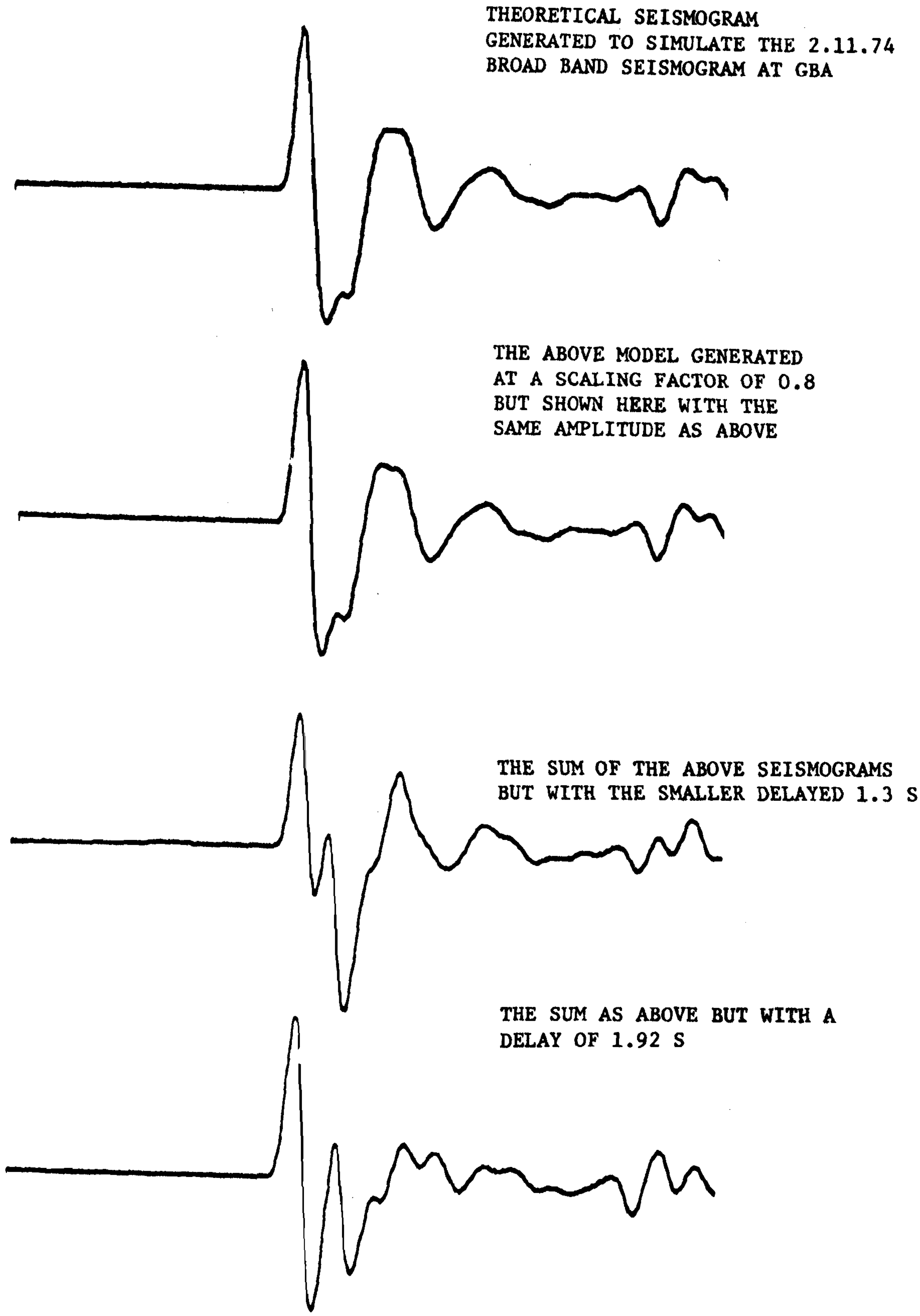


FIGURE 35. A SIMULATION OF THE 18.10.75 BROAD BAND GBA SIGNAL USING MODEL SEISMOGRAMS

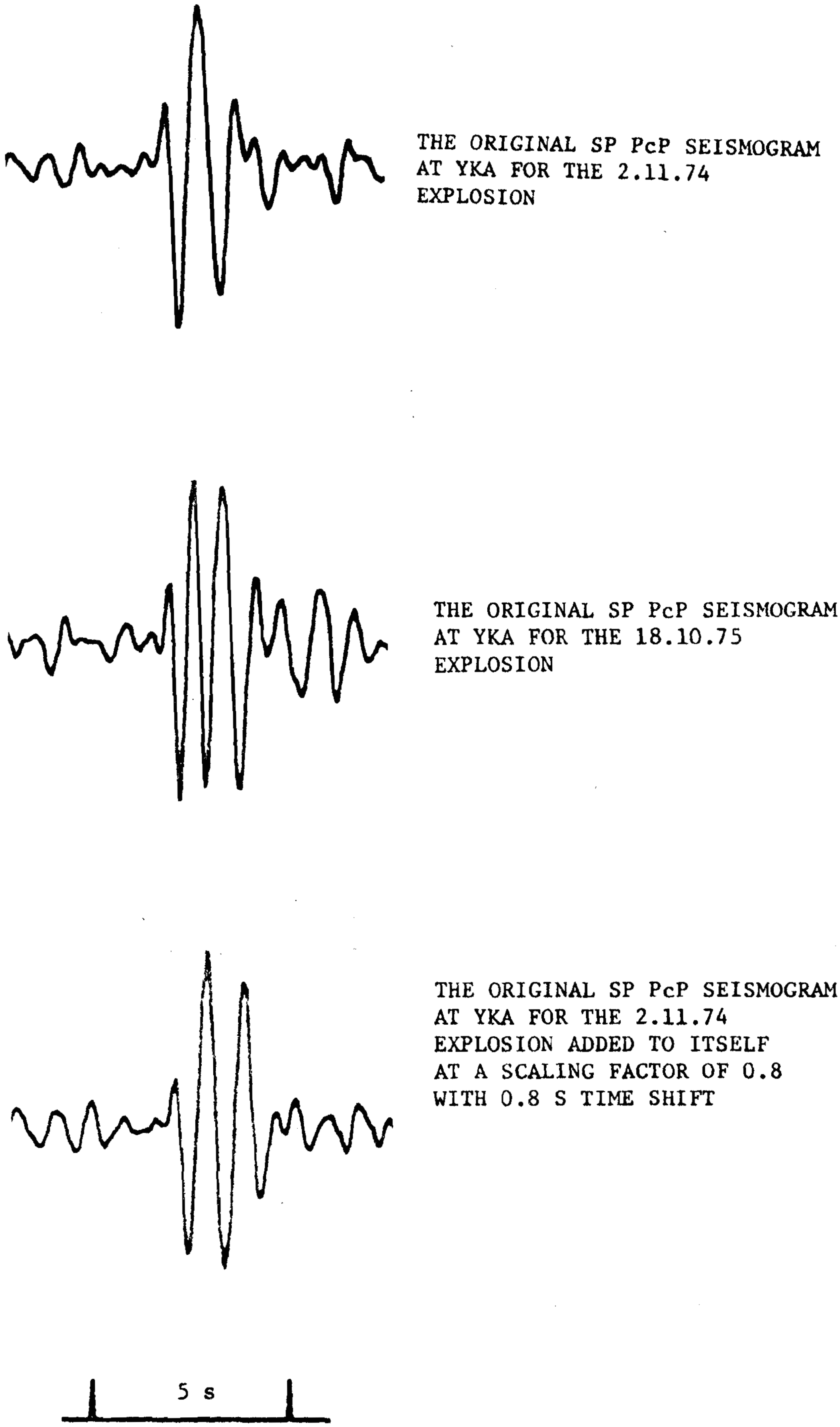


FIGURE 36. A SIMULATION OF THE 18.10.75 SP PcP SIGNAL AT YKA

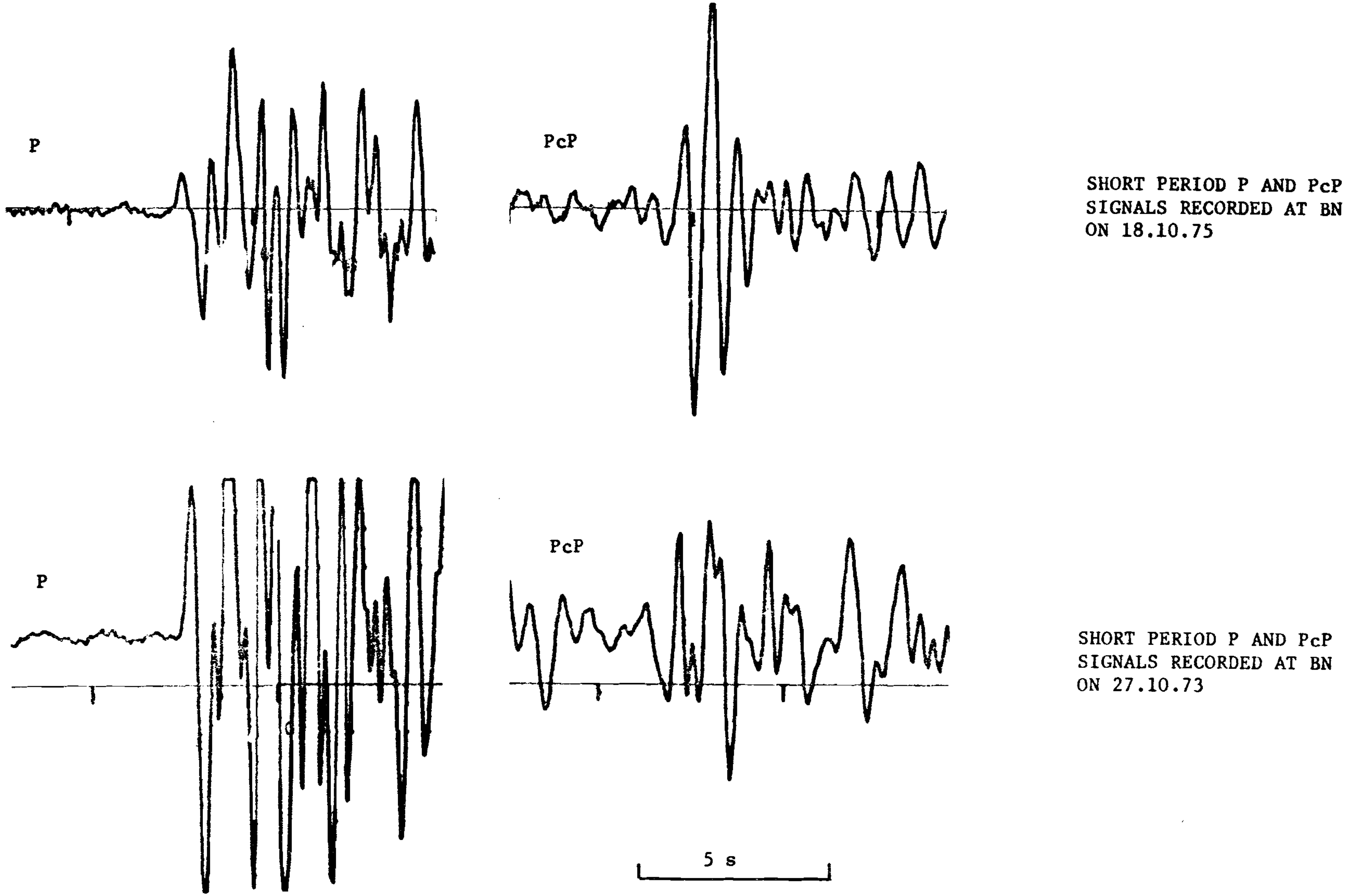


FIGURE 37. SHORT PERIOD P AND PcP SIGNALS FROM NZ AT BN

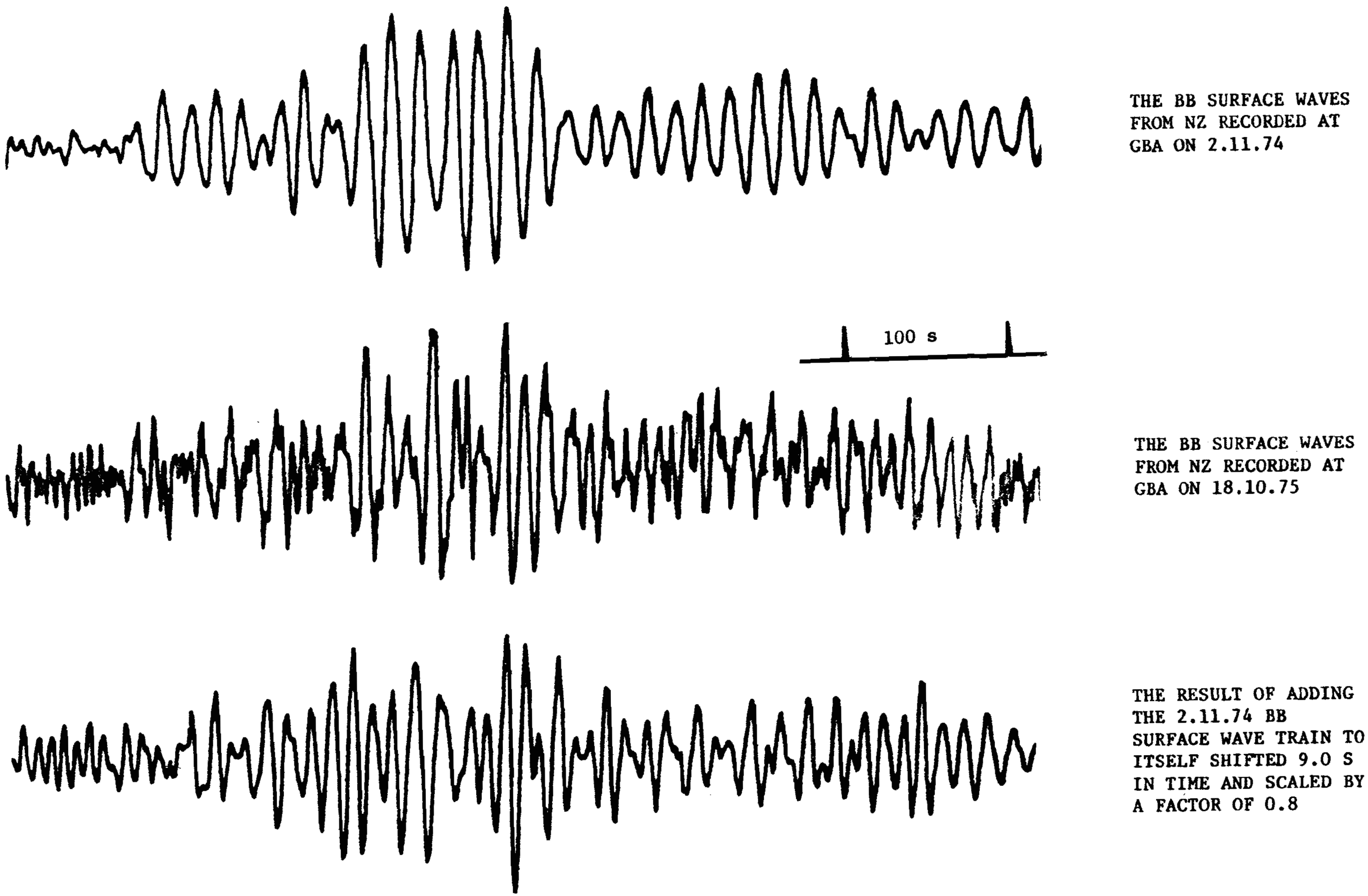
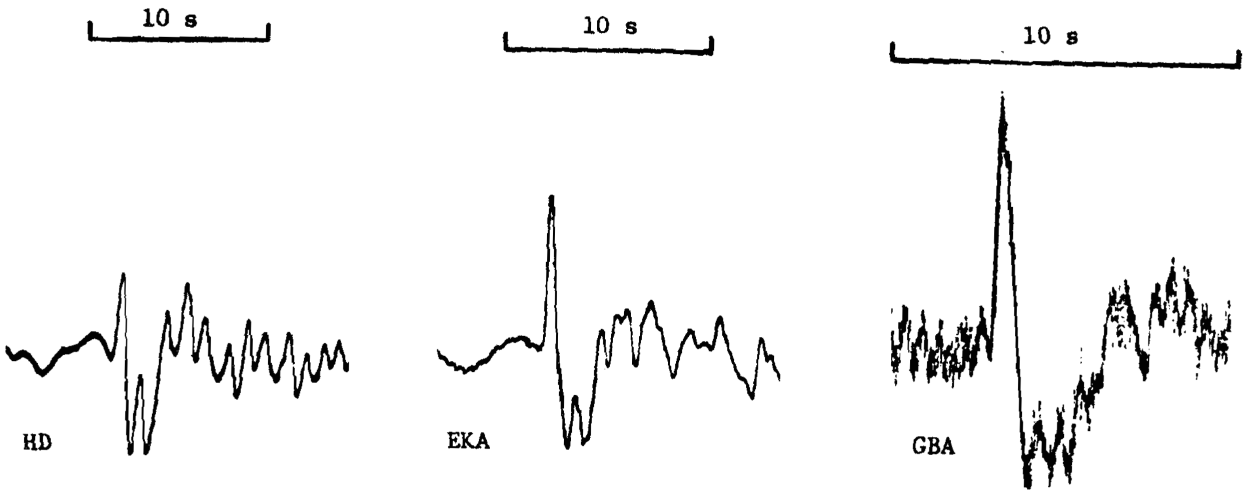
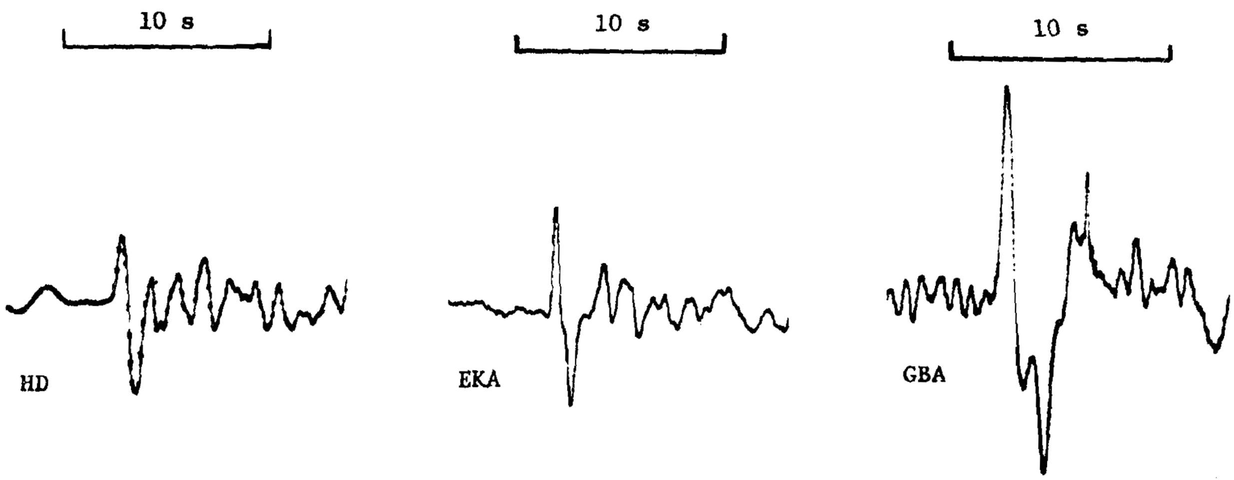


FIGURE 38. A COMPARISON AND SIMULATION OF BB SURFACE WAVES AT GBA

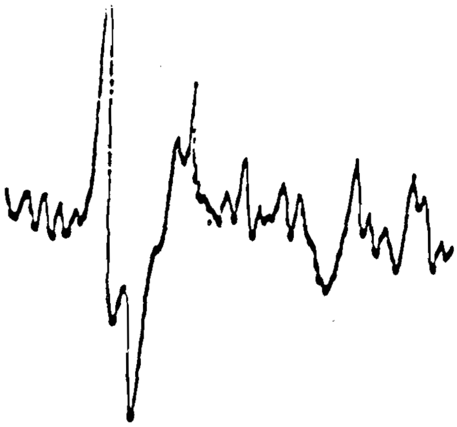


BB SIGNALS FROM NZ RECORDED AT HD, EKA AND GBA
ON 23.8.75

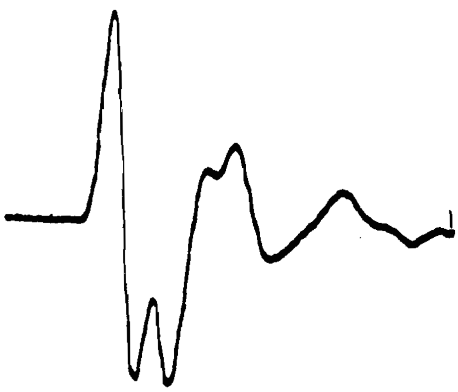


BB SIGNALS FROM NZ RECORDED AT HD, EKA AND GBA
ON 21.10.75

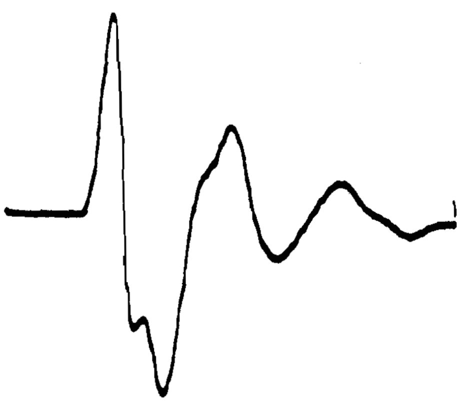
FIGURE 39. BROAD BAND SIGNALS FROM THE NORTHERN SITE, NOVAYA ZEMLYA



21.10.75 AT GBA. THE ORIGINAL SEISMOGRAM. (10 S = 31.5 MM)



COMPUTER MODEL OF 2.11.74 EXPLOSION SEISMOGRAM AT GBA SCALED AT 0.3 RELATIVE TO ITSELF, SHIFTED 1.6 S, AND ADDED TO THE ORIGINAL MODEL. (10 S = 48.8 MM)



THE ABOVE SIMULATION SHIFTED 1.3 S

ORIGINAL 2.11.74 SEISMOGRAM AT GBA, SCALED AT 0.3 RELATIVE TO ITSELF, SHIFTED 2.2 S AND ADDED TO THE ORIGINAL SEISMOGRAM. (10 S = 74.6 MM)

FIGURE 40. SIMULATIONS OF THE 21.10.75 BROAD BAND SEISMOGRAM AT GBA

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-	Atomic Weapons Research Establishment, Aldermaston, Berkshire
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-	-

7. Title

Anomalous Seismic Signals from Novaya Zemlya

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	9a. Author 2	9b. Authors 3, 4	10. Date	pp	ref
Hurley R W	-	-	August 1977	63	6

11. Contract Number	12. Period	13. Project	14. Other References
-	-	-	-

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No restriction

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Seismic arrays
Nuclear explosions
Underground explosions

Abstract

Broad band seismic signals from several underground explosions on Novaya Zemlya have been analysed to determine the reason for some anomalous broad band signals from the same location.