Best
Available
Copy

AD-760 769

DIGITAL ANALYSIS OF MICROBAROGRAPH DATA

J. Kerr, et al

Teledyne Geotech

Prepared for:

Air Force Office of Scientific Research
Advanced Research Projects Agency

9 March 1973

DISTRIBUTED BY:

NTIS
National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

AL-72-6

......contributing to man's understanding of the environment world

DIGITAL ANALYSIS OF MICROBAROGRAPH DATA

BY

J. KERR, P.F. SKEFINGTON, E.A. FLINN and E. SMART

SPONSORED BY
ADVANCED RESEARCH PROJECTS AGENCY

MONITORED BY
AIR FORCE OFFICE OF SCIENTIFIC RESEARCH

ARPA ORDER NO. 1357

9 MARCH 1973

TELEDYNE GEOTECH
ALEXANDRIA LABORATORIES

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Teledyne Geotech Alexandria, Virginia 22313	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. REPORT TITLE

DIGITAL ANALYSIS OF MICROBAROGRAPH DATA

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Scientific Interim

5. AUTHOR(S) (First name, middle initial, last name)

J Kerr
P F Skefington
E A Flinn
E Smart

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
9 Mar 1973	~~66~~ 64	3

8a. CONTRACT OR GRANT NO F44620-69-C-0082	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO AO 1357	
c. 62701D	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) AFOSR - TR - 73 - 0862
d.	

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
TECH, OTHER	AFOSR (NP) 1400 Wilson Boulevard Arlington, Virginia 22209

13. ABSTRACT

In this report we display the results of analysis of microbarograph records from two presumed atmospheric nuclear explosions. The events occurred on 27 December 1968 and 29 September 1969, and were recorded by microbarograph arrays in Boulder, Colorado, College, Alaska, Huancayo, Peru, Tel Aviv, Israel and at LAMA, the Large Aperture Microbarograph Array in Montana. We also show LAMA data and analysis results for eight other presumed explosions. In addition to demonstrating the effectiveness of our digital detector, the purpose of this report is to make the calibrated data and our spectral calculations available to other workers in this field.

DD FORM 1 NOV 65 1473

UNCLASSIFIED
Security Classification

Security Classification

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Nuclear explosions Infrasonics Digital analysis Microbarographs						

Security Classification

DIGITAL ANALYSIS OF MICROBAROGRAPH DATA

ALEXANDRIA LABORATORIES REPORT NO. AL-72-6

Effective Date of Contract:	1 March 1969
Contract Expiration Date:	31 March 1972
Amount of Contract Dollars:	$ 590,572
Program Code:	1F10
Contract Number:	F-44620-69-C-0082
ARPA Order No.:	1357
Principal Investigator:	Carl A. Newton
Period Covered:	1 March 1969 through 31 March 1972

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES (Cont'd.)

LIST OF FIGURES (Cont'd.)

LIST OF FIGURES (Cont'd.)

INTRODUCTION

In this report we display the results of analysis of microbarograph records from two presumed atmospheric nuclear explosions. The events occurred on 27 December 1968 and 29 September 1969, and were recorded by microbarograph arrays in Boulder, Colorado (BC), College, Alaska (CA), Huancayo, Peru (HP), Tel Aviv, Israel (TA), and at LAMA, the Large Aperture Microbarograph Array in Montana. We also show LAMA data and analysis results for eight other presumed explosions. For array coordinates and locations, see Appendix I.

In addition to demonstrating the effectiveness of our digital detector, the pupose of this report is to make the calibrated data and our spectral calculations available to other workers in this field.

The LAMA data were recorded digitally, and calibrations were available for the two dates of the events studied here. However, the other data recorded on analog magnetic tape, and severe difficulty was experienced in locating and processing the signals from these events. First, a time control channel is included among the analog tape channels, but the hour marks were not identified, nor were the days. Each tape contains many days of data, so that locating the desired event requires that the hours be counted from some identifiable point on the tape. After long and frustrating attempts to establish a time base, we finally had to rely on the time notations written at infrequent and irregular intervals in marker pen ink on the back of the analog tape by the station operators.

Counting time marks from such benchmarks, however, assumes continuity of recording, and the records from the stations recording on analog tape are very frequently intermittent. The fact that often the interruptions were not noted on the station logs made it impossible to locate signals on the tapes. The results presented here are those for station records which we were eventually able to locate and identify.

DATA PREPARATION

A great amount of effort was required simply to prepare the data from outlying stations for digital analysis. We will go into some detail about the procedures we used, since the unexpected delay was the major reason why the project ended before meaningful coclusions could be drawn from the data analysis.

A number of steps were involved:

1. Locate events and calibrations on AM tapes. The timing channel on the analog tapes does not distinguish the time marks; every hour mark looks the same as every other hour mark. The tapes run for weeks at a very slow speed, and the station operators occasionally mark the day and hour on the record with a felt-tip pen, often at intervals of many days or weeks. Since the signal-to-noise ratio of the events being sought was often so low that the signals were not visible on the single channels, we had to rely on the timing information. However, the stations frequently stopped operation and started again after an outage of hours or days, and it was not uncommon that the station personnel did not note the outage in the station logs. The signals reported here were finally located with great difficulty.

2. Convert from AM analog tape to FM analog tape. The digitizing equipment at the Seismic Data Laboratory did not have the proper characteristics to digitize the AM analog tapes, so we had to use an intermediate step, in which the AM tape was dubbed onto an FM tape at 30 ips. This shifted the recorded spectrum up from 0.02 cps

(low end) to 144 cps, and from 1.0 cps (high end) to 7200 cps, which the digitizing equipment could handle. When they could be located, calibrations were also dubbed onto the FM tapes.

3. A/D conversion of FM tapes. After applying an anti-aliasing low-pass filter, the FM tapes were digitized at a rate which corresponds to two samples per second on the original frequency scale.

4. Convert digital tape to SDL library tape format. This essentially involved demultiplexing the data channels.

5. Convert SDL library tapes to Subset format. This step put the data in a form accessible to our Fortran programs.

Programs used in preparation and analysis of the data are described by Kerr (1971).

RESULTS

Best beams were computed using program ONE (Kerr, 1971) on the inner five elements of the LAMA array (for details see Flinn, 1972). This process finds by an iterative process the array beam having the largest F-statistic:

$$\frac{(N-1)\ V_B/N}{V_T - V_B/N}$$

where N is the number of channels, V_B is the variance of the beam sum, and V_T is the total variance of all channels within the time window under consideration.

Raw data of the station recordings are shown in Figures 1 through 9. The best beam records are shown in Figures 9 through 16. Power spectra computed for the first 34 minutes of signal in these beam sums are shown in Figures 17 through 22. Time-varying spectrograms (Cohen, 1970) were computed using a two-minute window with 50 percent overlap (Figures 23 through 28). The signal spectral estimates were also computed by following the best beam frequency by frequency through f-k space. The power at each frequency in the estimate was taken to be the maximum power in the wavenumber plane at that frequency. Four spectral plots were generated for each signal: power, F statistic, phase velocity, and azimuth (Figures 29 through 35). See Smart and Flinn (1971) for discussion. The one exception here is the record for Tel Aviv on 29 September 1969, which had only three operating channels that day.

ANALYSIS OF OTHER LAMA RECORDINGS

Microbarograms of eight other presumed atmospheric explosions were recorded at LAMA, and were analyzed by the 'best beam' processor described above. The raw data are shown in Figures 36 through 41, and the spectra in Figures 42 through 49.

REFERENCES

Flinn, E.A., 1972, Seismic and infrasonic waves generated by nuclear explosions in the atmosphere: Alexandria Laboratories Report AL-73-2, Teledyne Geotech, Alexandria, Virginia.

Kerr, A.U., 1971, Digital computer programs for recording and processing infrasonic array data: Geophys. J. Roy. Astr. Soc., v. 26, p. 21-40.

Smart, E. and Flinn, E.A., 1971, Fast frequency-wavenumber analysis and Fisher signal detection in real-time infrasonic array data processing: Geophys. J. Roy. Astr. Soc., vol. 26, p. 279-284.

ACKNOWLEDGEMENTS

This research was sponsored by the Air Force Office of Scientific Research under Contract No. F-14620-69-C-0082.

APPENDIX I

ORIGIN OF SIGNALS PROCESSED*

REPORT DATE	EVENT DATE	ORIGIN TIME	LATITUDE	LONGITUDE
04 Aug 1968	No Report			
25 Aug 1968	24 August 1968	18:29:59.9	22.2S	138.8W
09 Sep 1968	08 September 1968	18:59:59.3	21.8S	139.2W
27 Dec 1968	No Report in by NOS			
29 Sep 1969	No Report in by NOS			
16 May 1970	15 May 1970	13:30:00	37.2N	116.0W
23 May 1970	No Report in by NOS			
31 May 1970	30 May 1970	17:59:58.5	22.2S	138.8W
04 Jul 1970	03 July 1970	18:29:59.1	21.8S	139.2W
07 Aug 1970	07 August 1970	20:17:44.4	4.4N	117.3W

* Information from National Ocean Survey, Preliminary Determination of Epicenters reports.

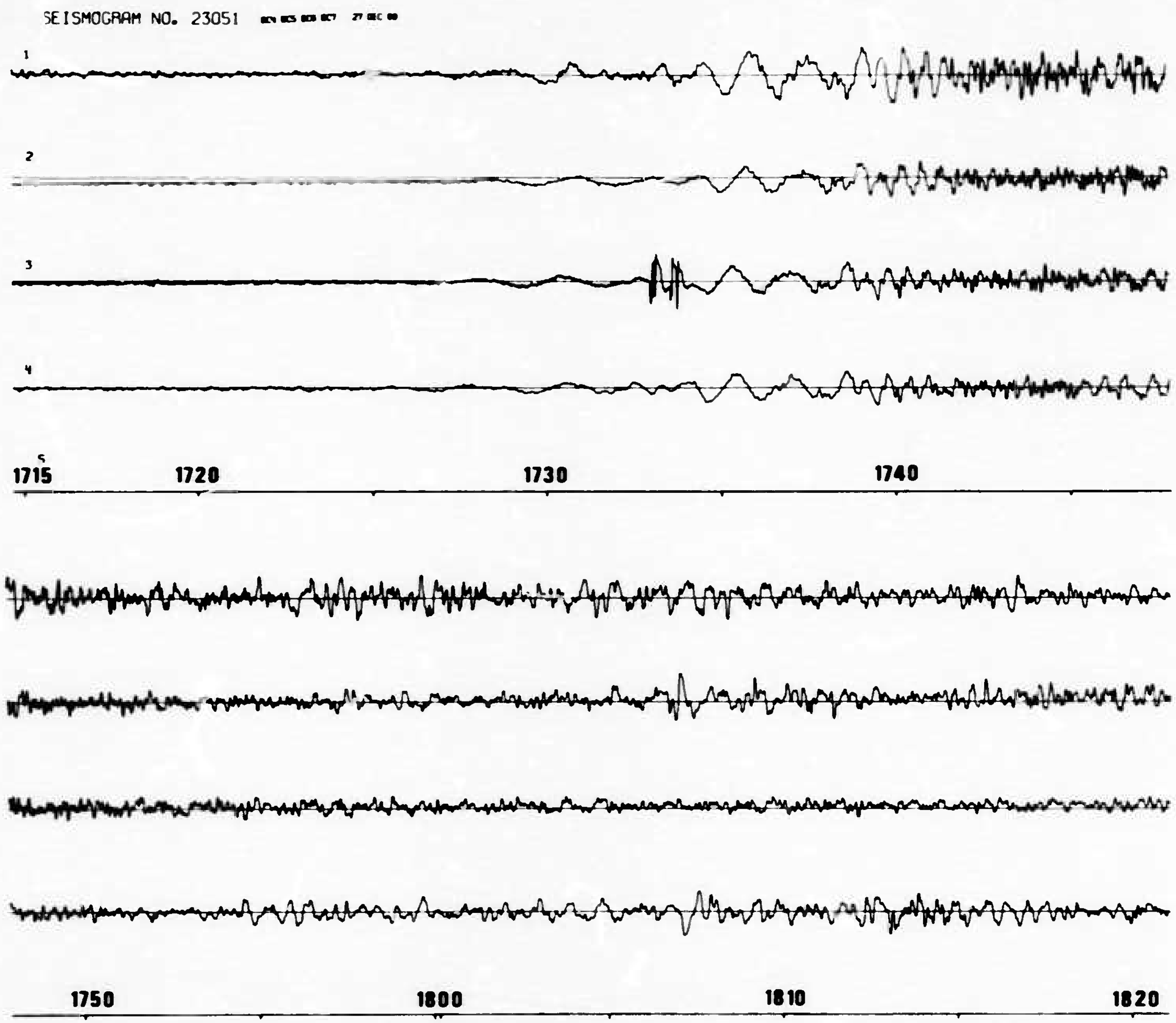

Figure 1. Event of 27 December 1968 recorded at Boulder, Colorado.

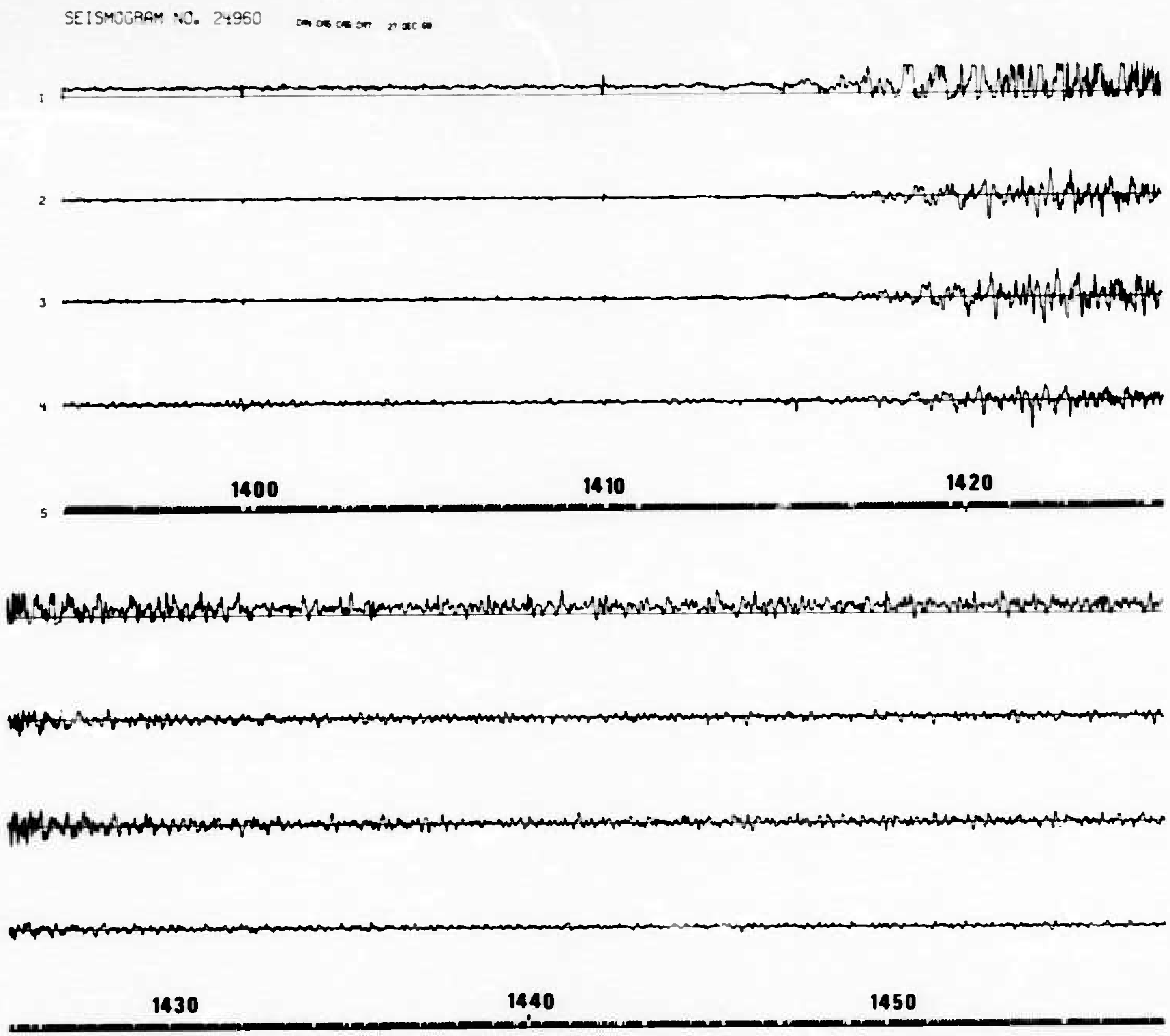

Figure 2. Event of 27 December 1968 recorded at College, Alaska.

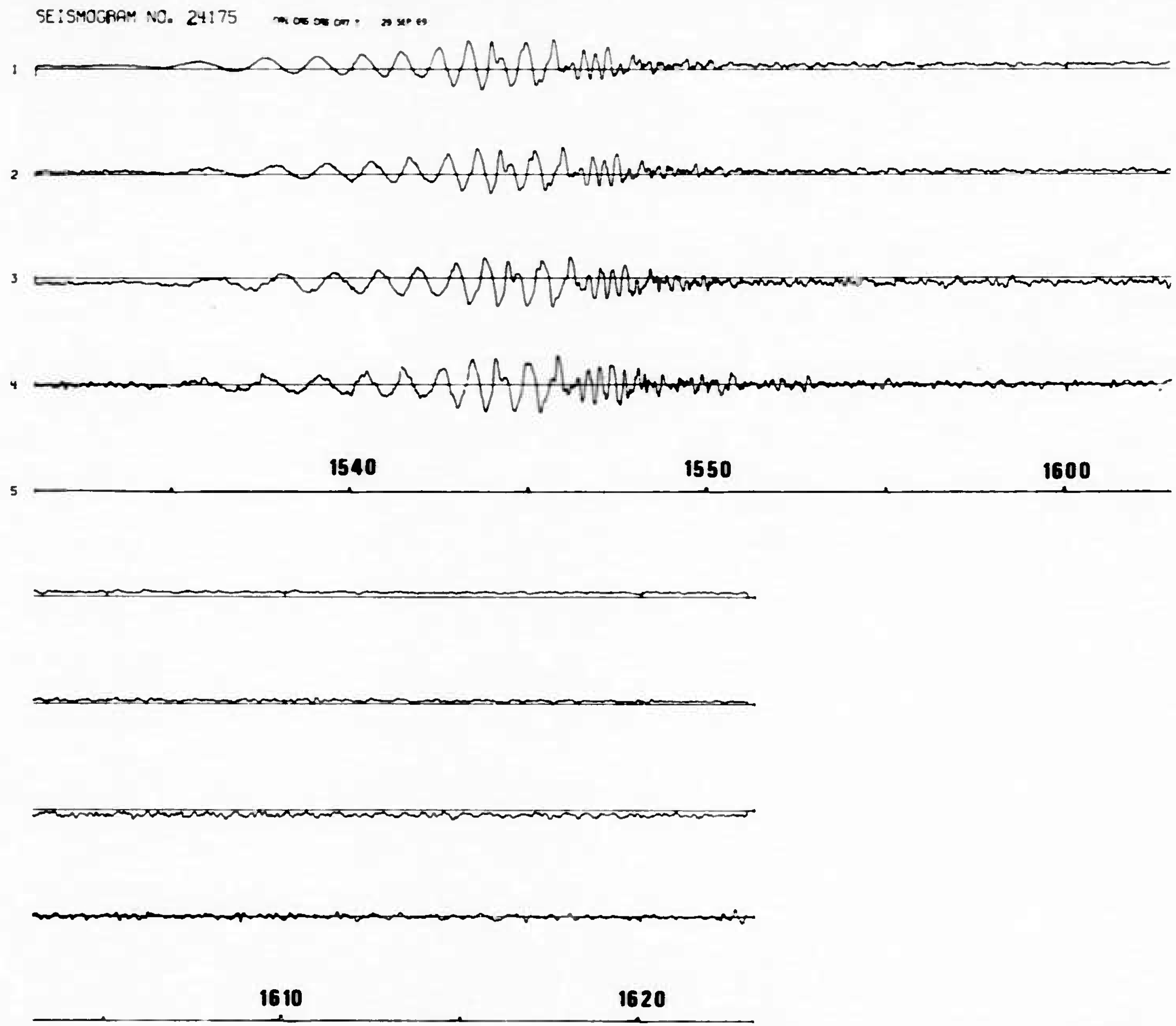

Figure 3. Event of 29 September 1969 recorded at College, Alaska.

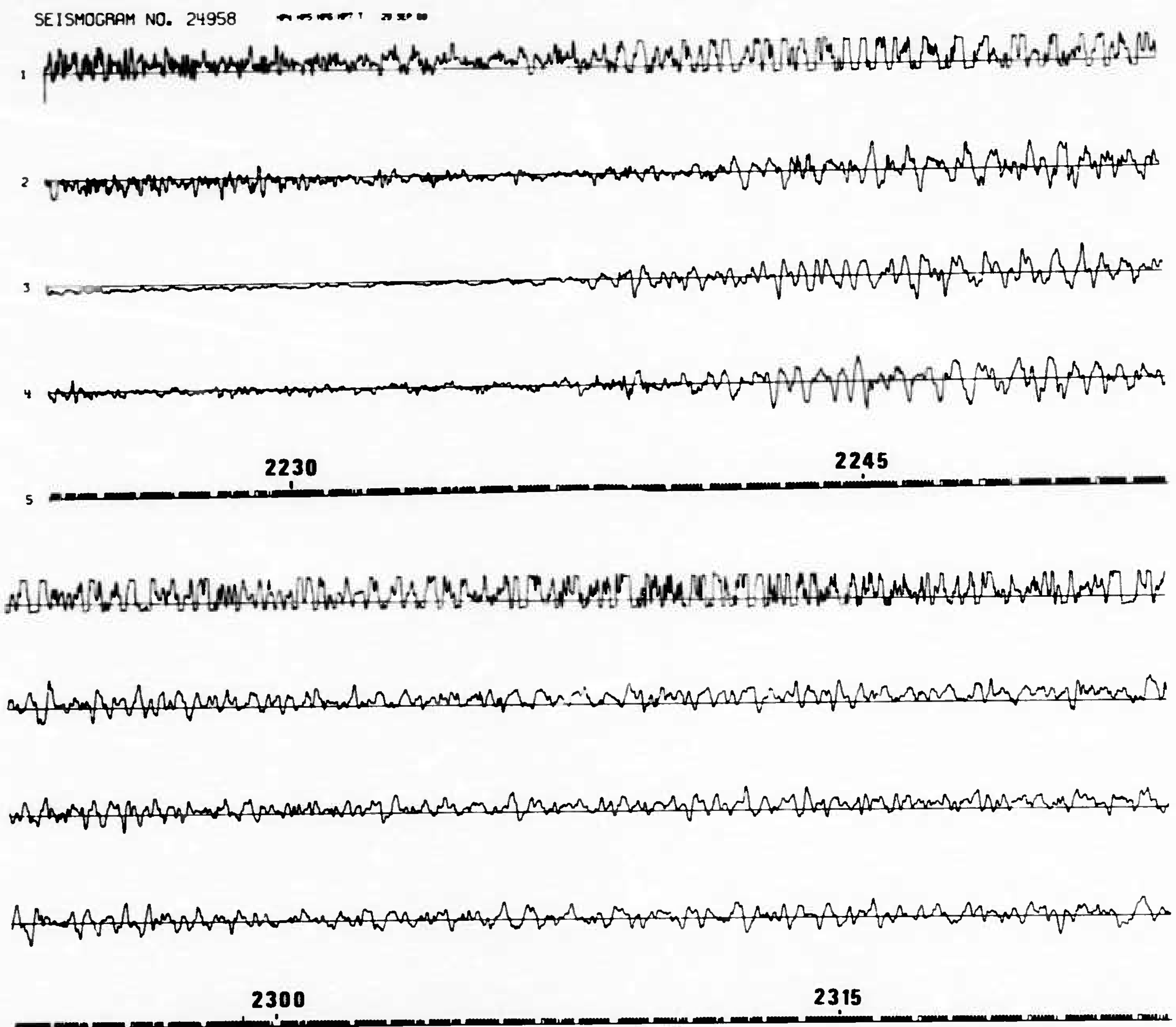

Figure 4. Event of 29 September 1969 recorded at Huancayo, Peru.

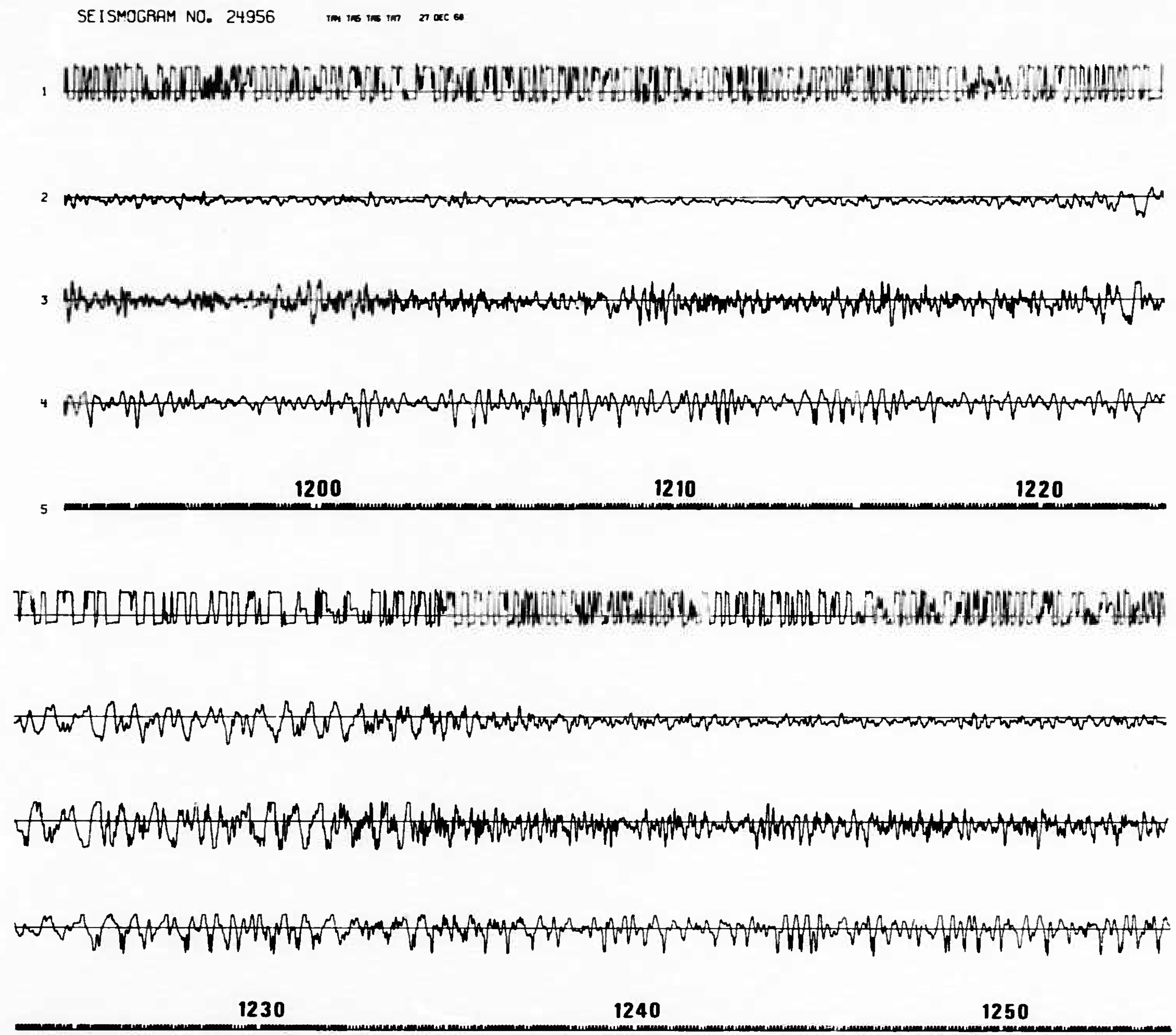

Figure 5. Event of 27 December 1968 recorded at Tel Aviv, Israel.

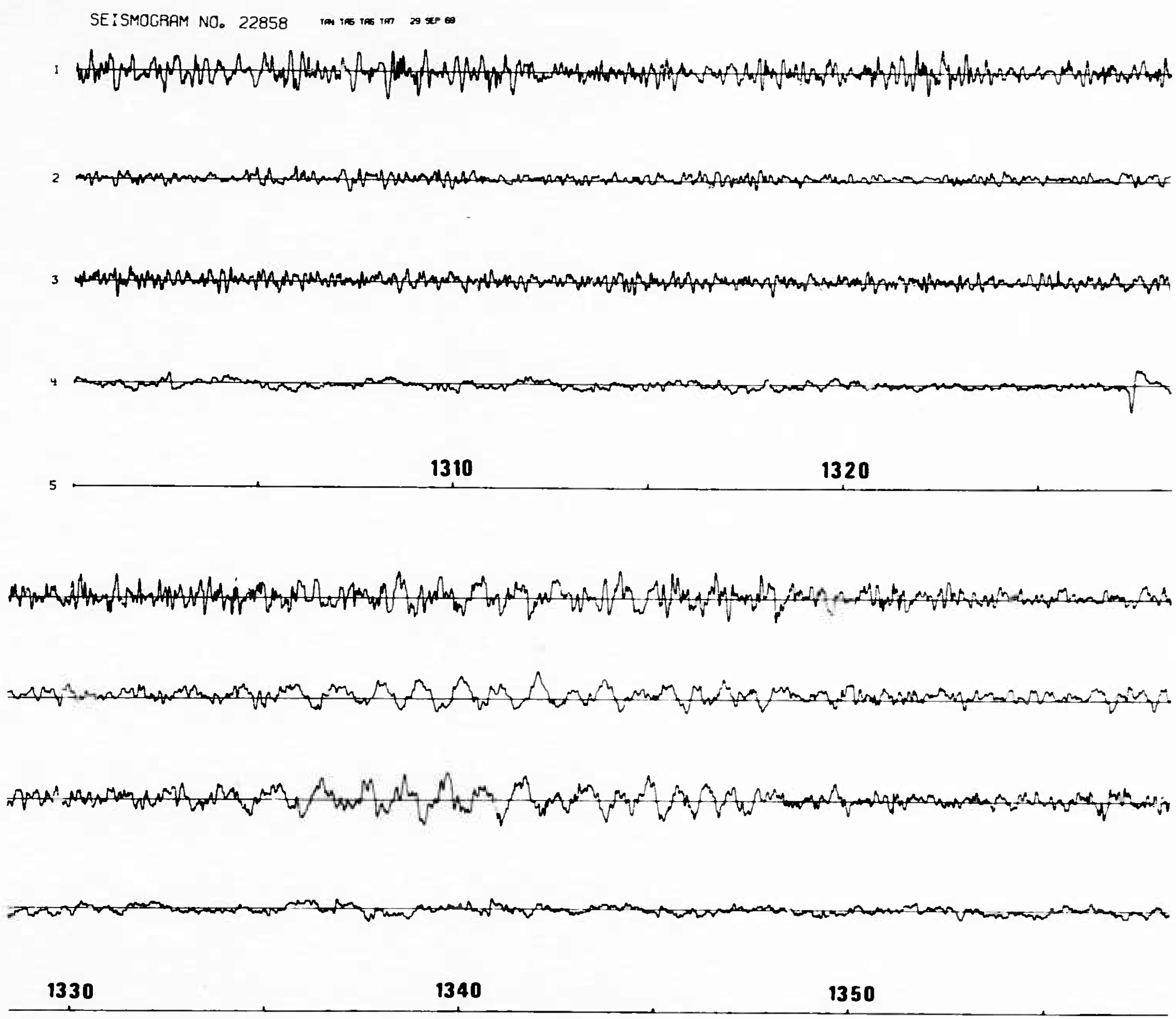

Figure 6. Event of 29 September 1969 recorded at Tel Aviv, Israel.

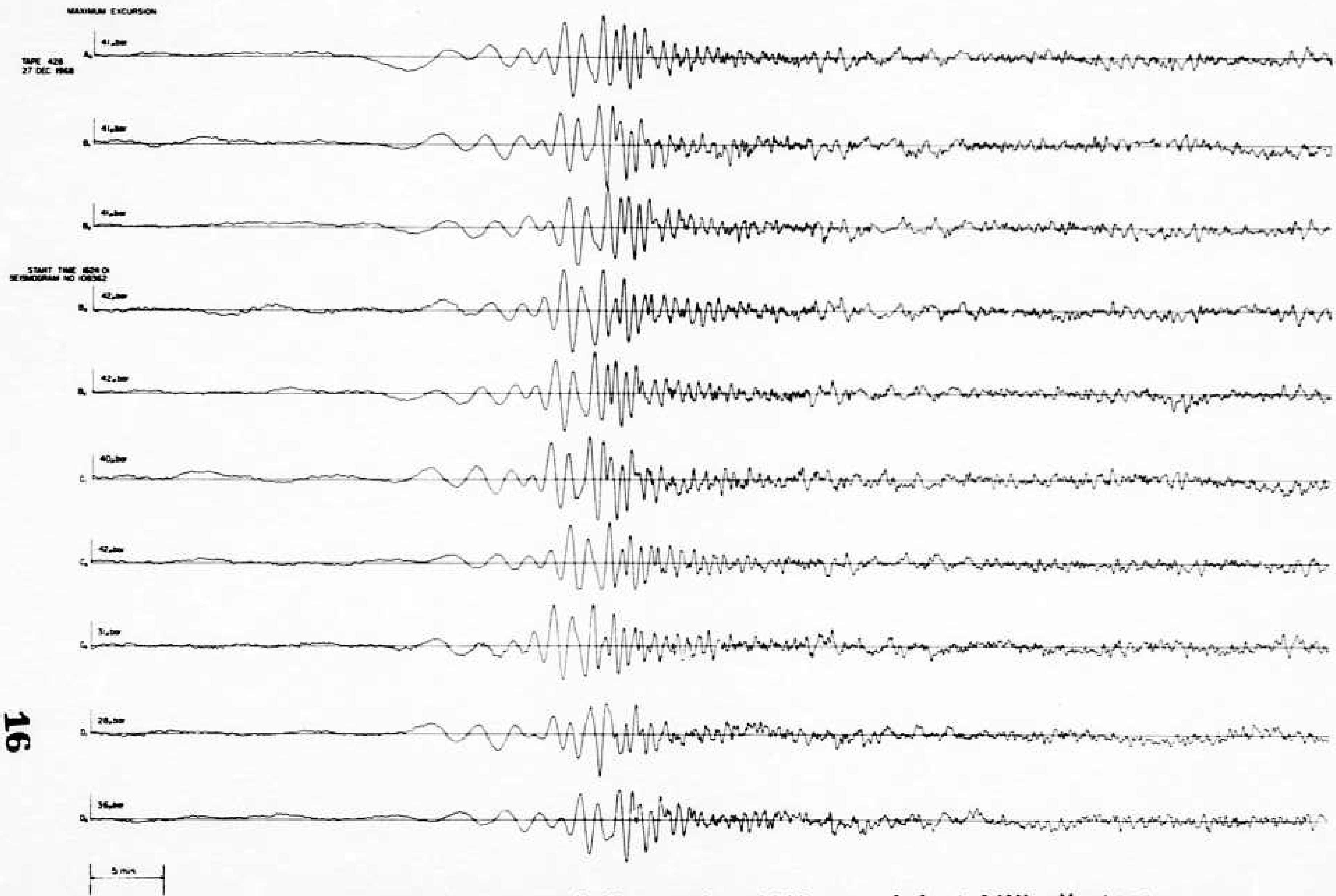

Figure 7. Event of 27 December 1968 recorded at LAMA, Montana.

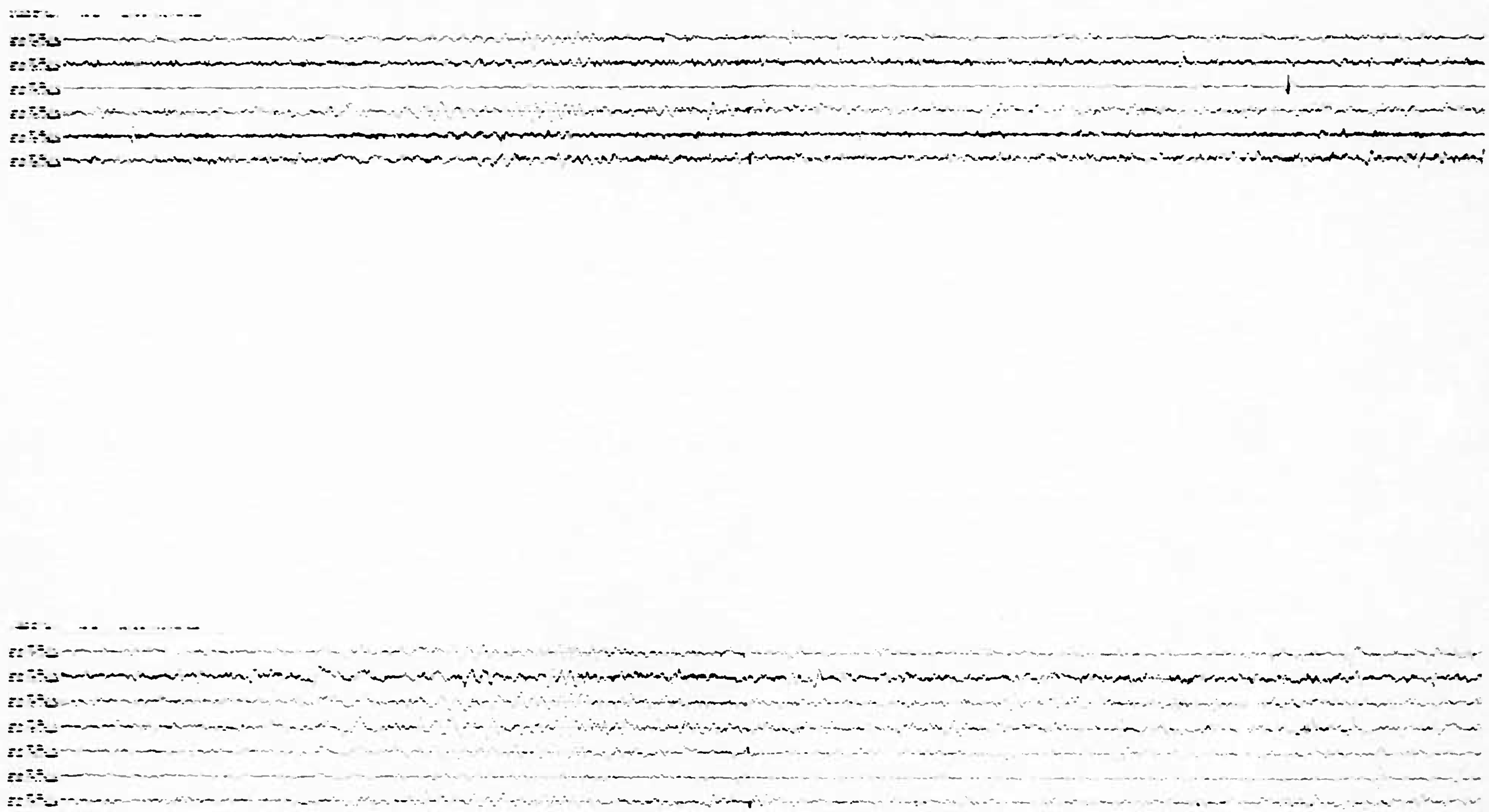

Figure 8. Event of 29 September 1969 recorded at LAMA, Montana.

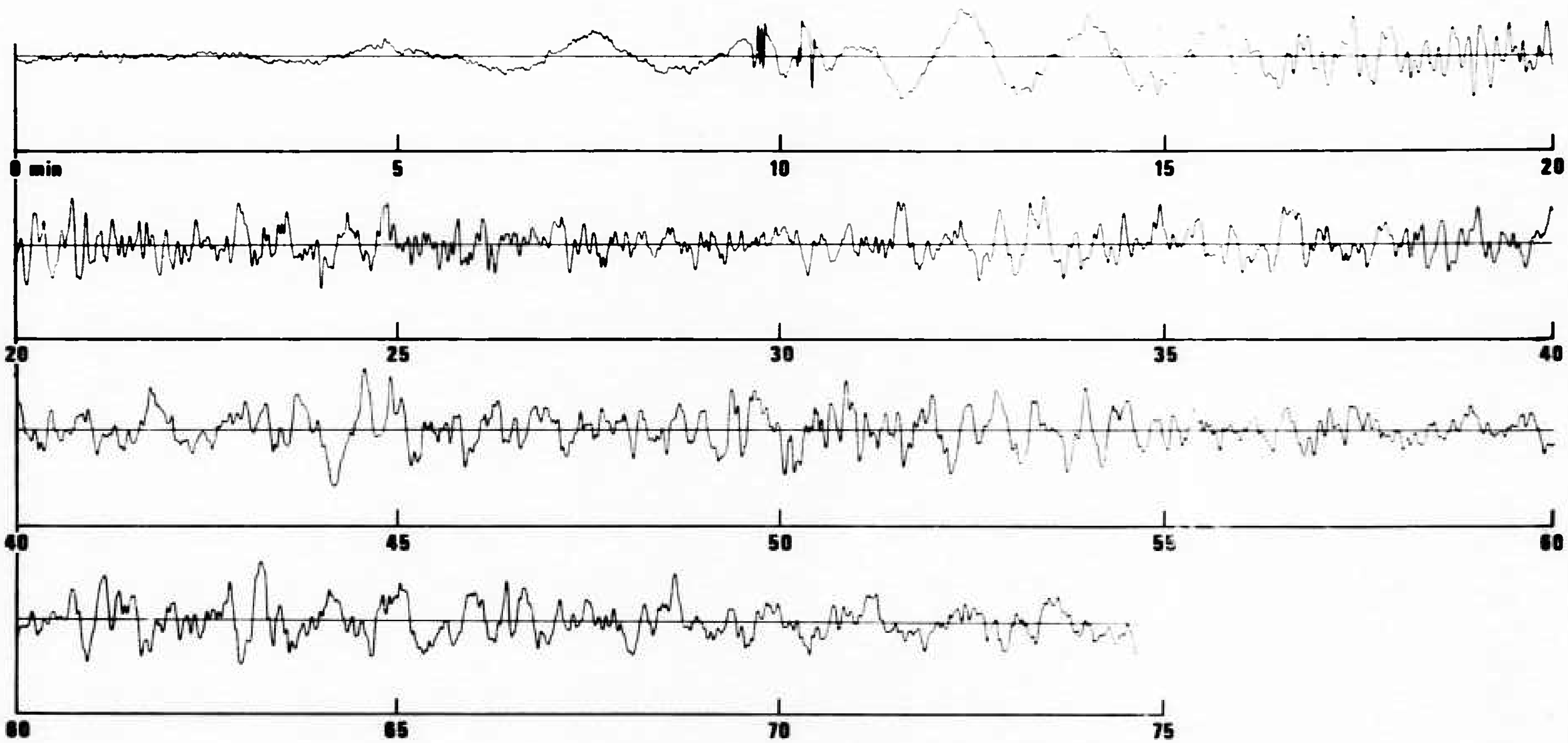

Figure 9. Event of 27 December 1968 recorded at Boulder, Colorado. Beam velocity and azimuth are 339 meter/second and 341° (degrees east of north).

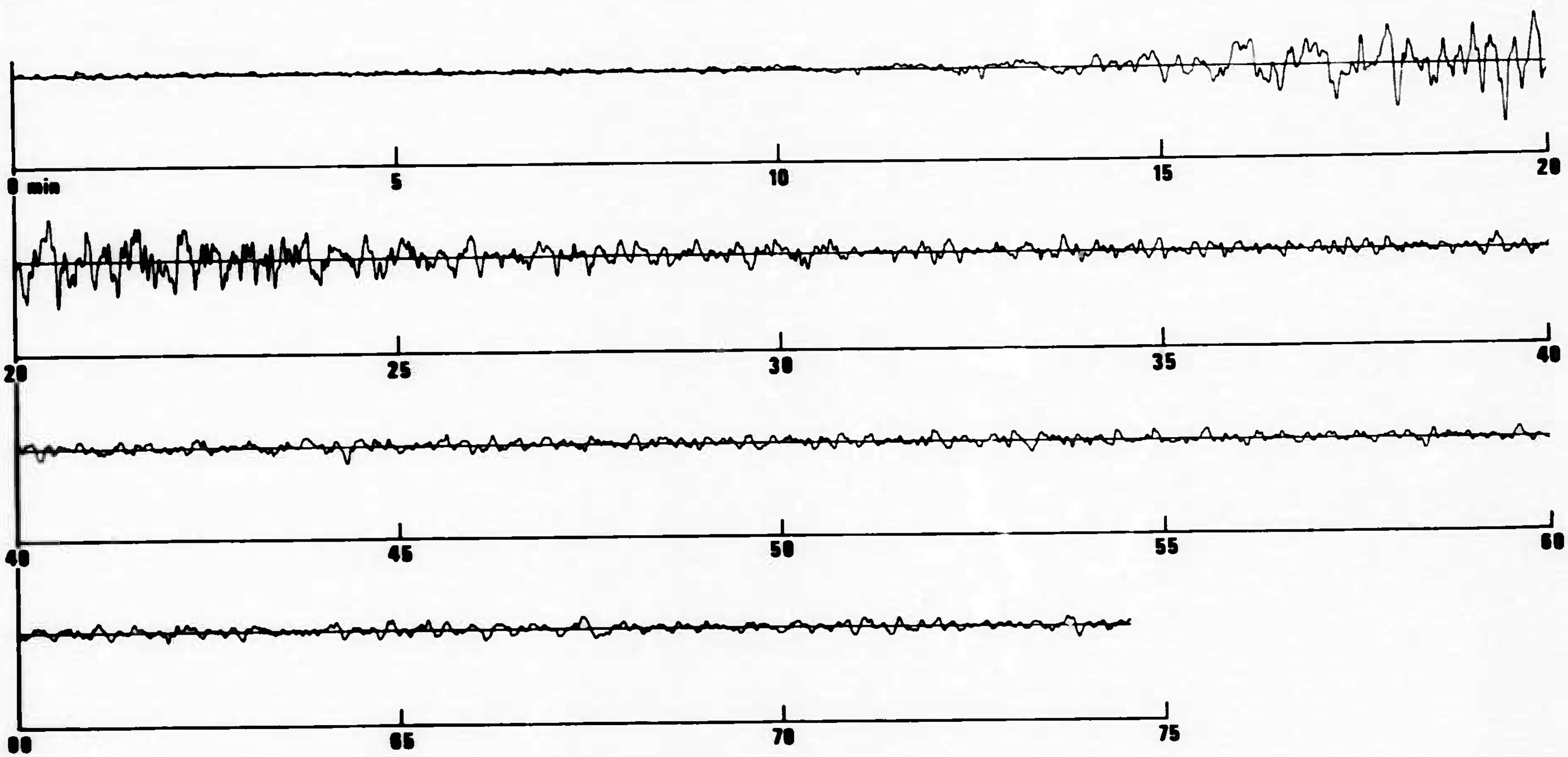

Figure 10. Event of 27 December 1968 recorded at College, Alaska. Beam velocity and azimuth are 316 meter/second and 314°.

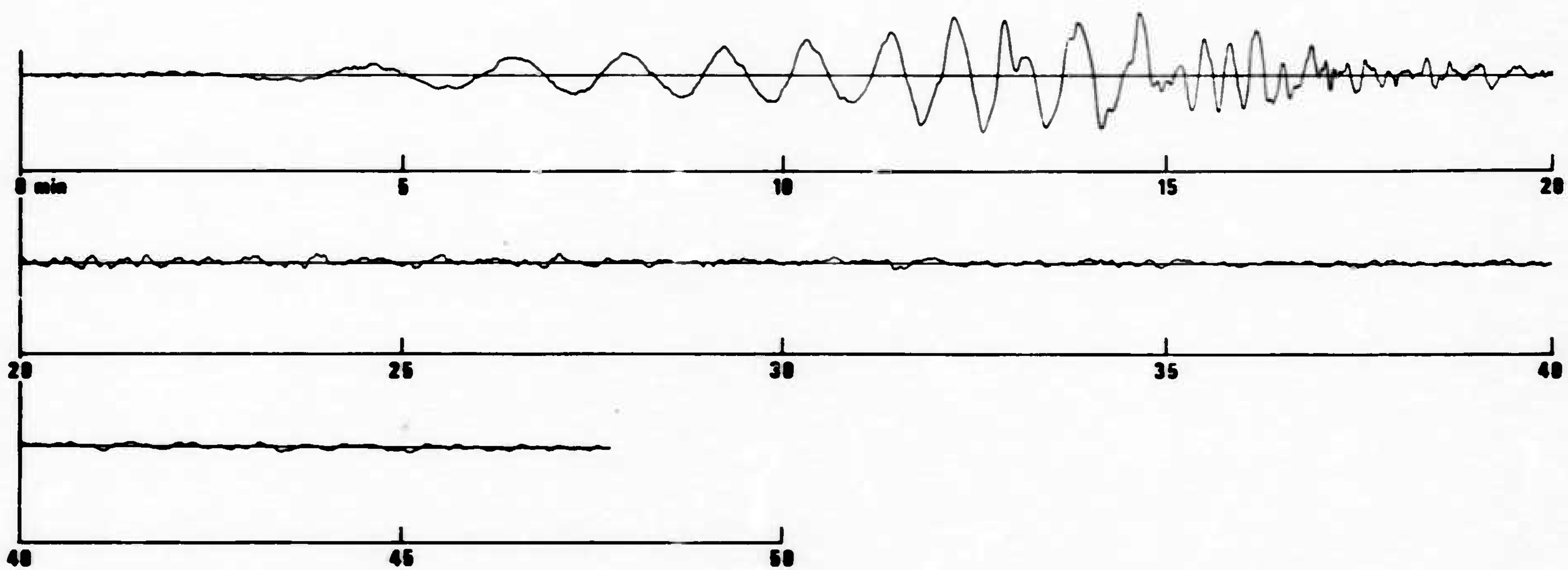

Figure 11. Event of 29 September 1969 recorded at College, Alaska. Beam velocity and azimuth are 330 meter/second and 310°.

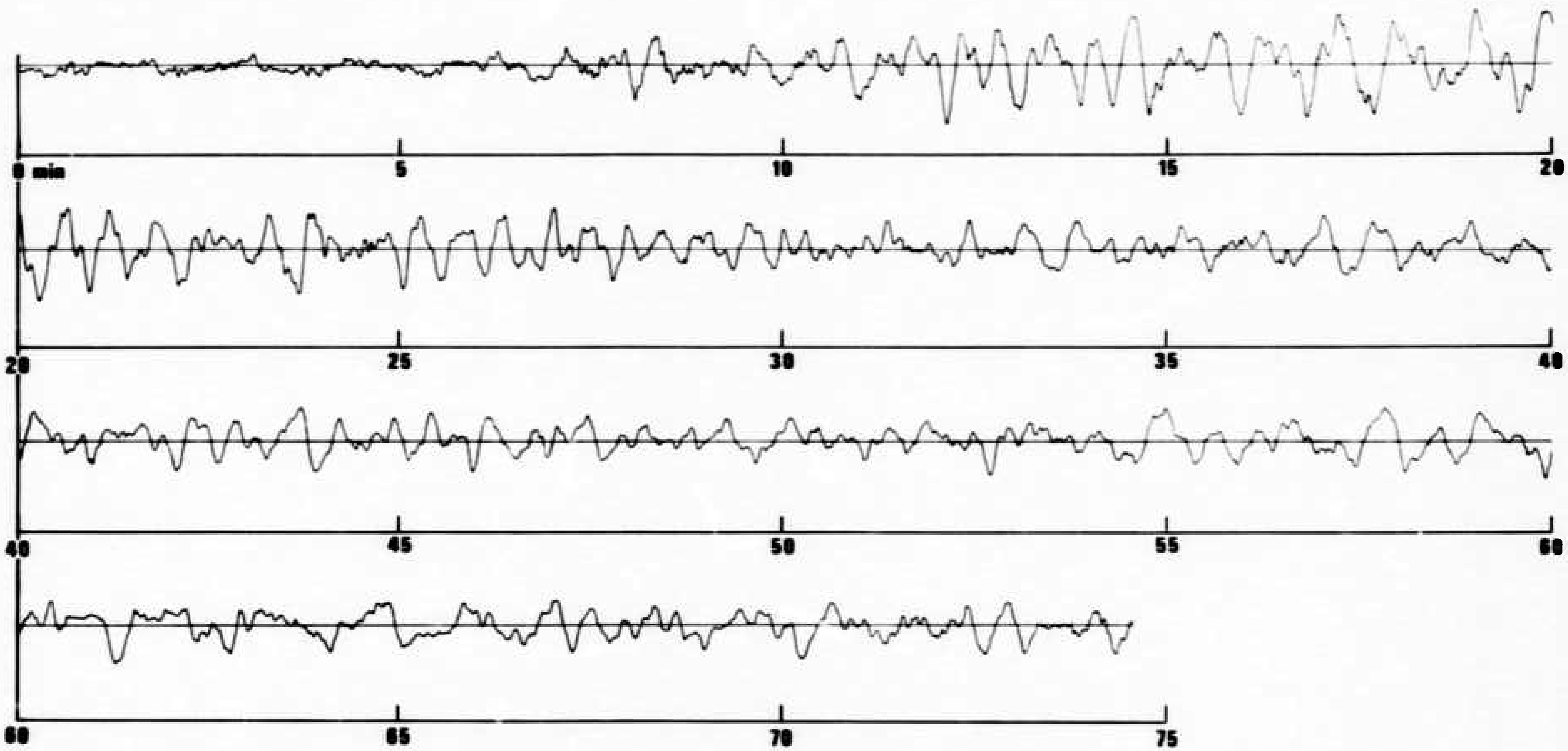

Figure 12. Event of 29 September 1969 recorded at Huancayo, Peru.
Beam velocity and azimuth are 320 meter/second and 28°.

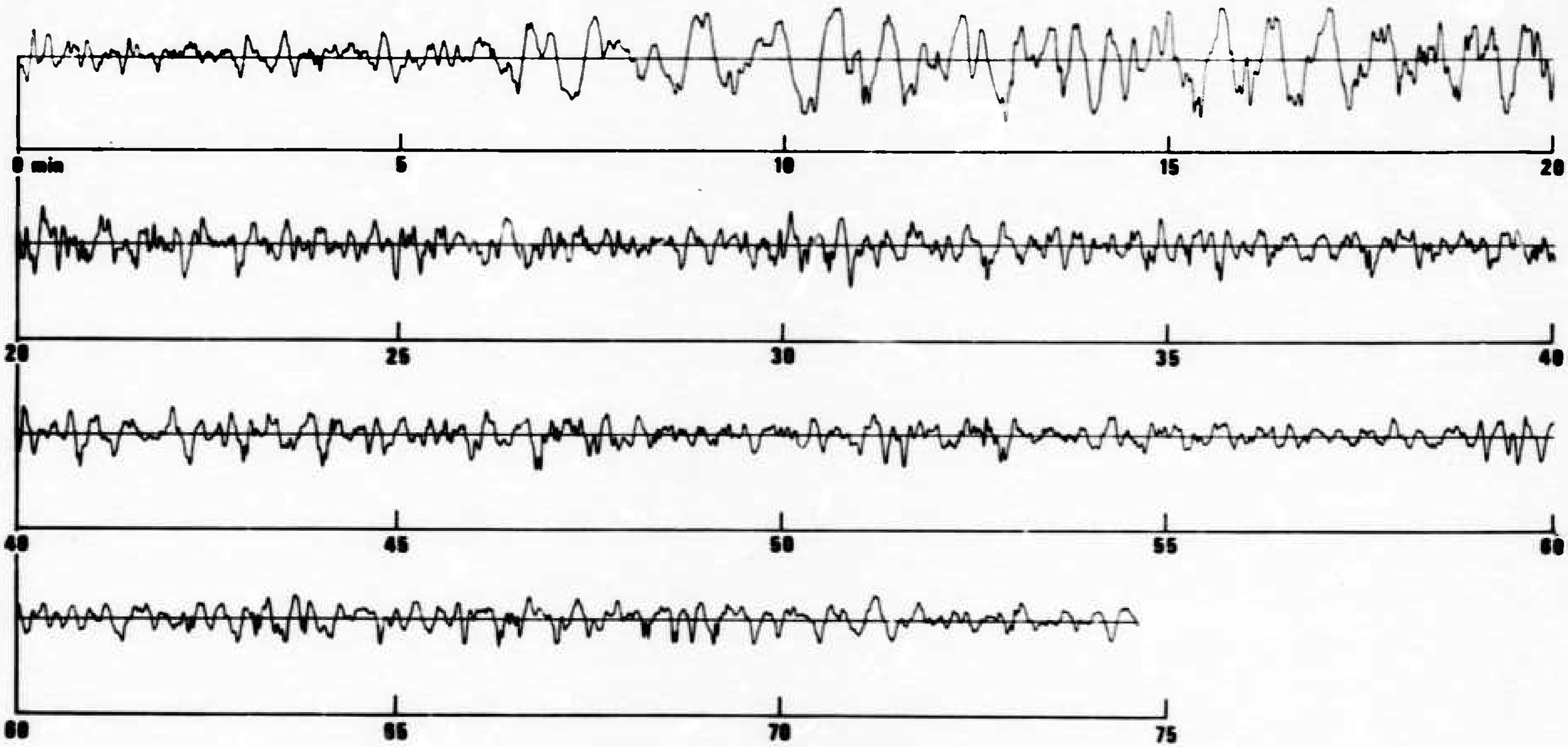

Figure 13. Event of 27 December 1968 recorded at Tel Aviv, Israel. Beam velocity and azimuth are 310 meter/second and 62°.

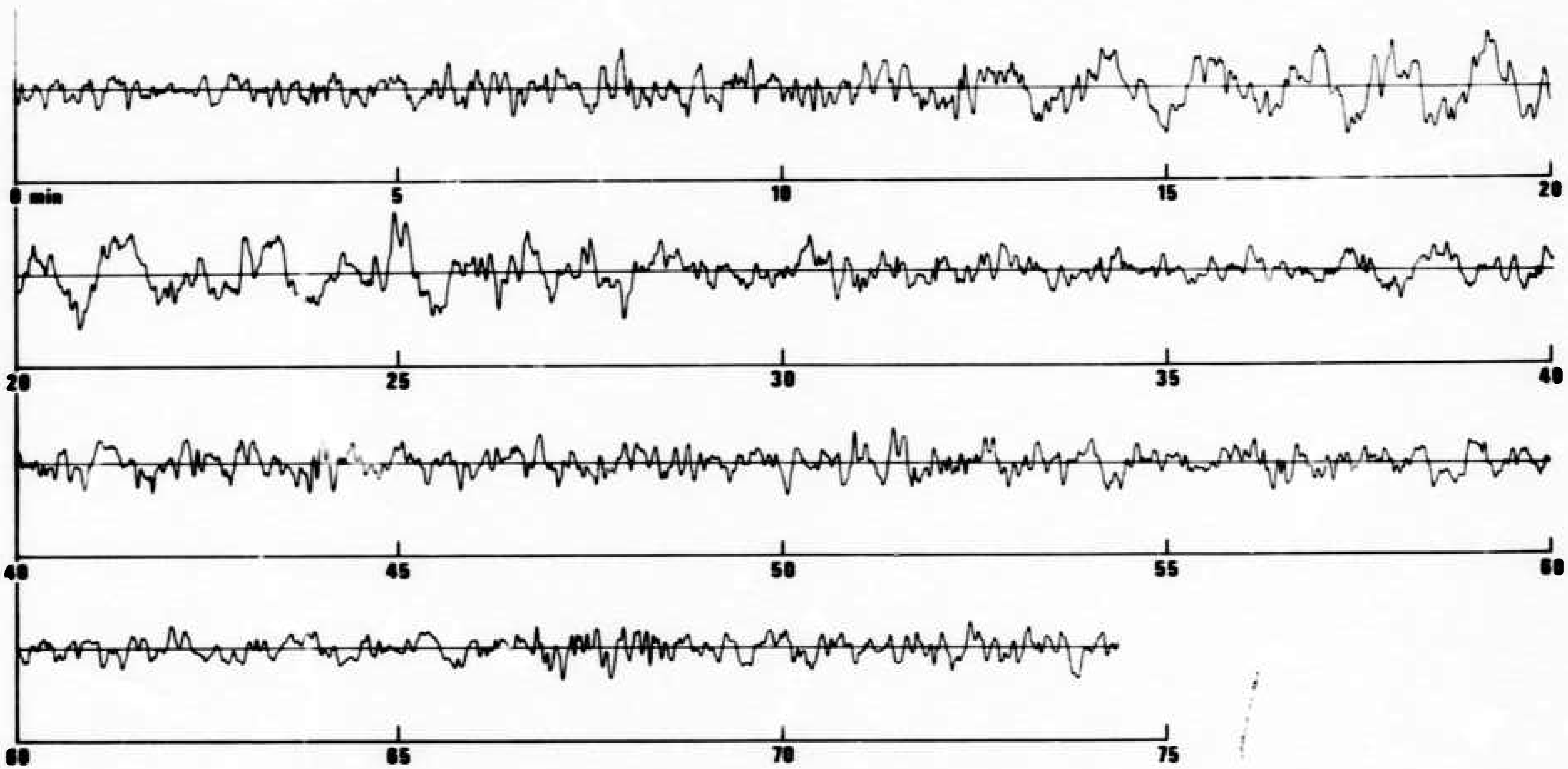

Figure 14. Event of 29 September 1969 recorded at Tel Aviv, Israel. Beam velocity and azimuth are 282 meter/second and 61°.

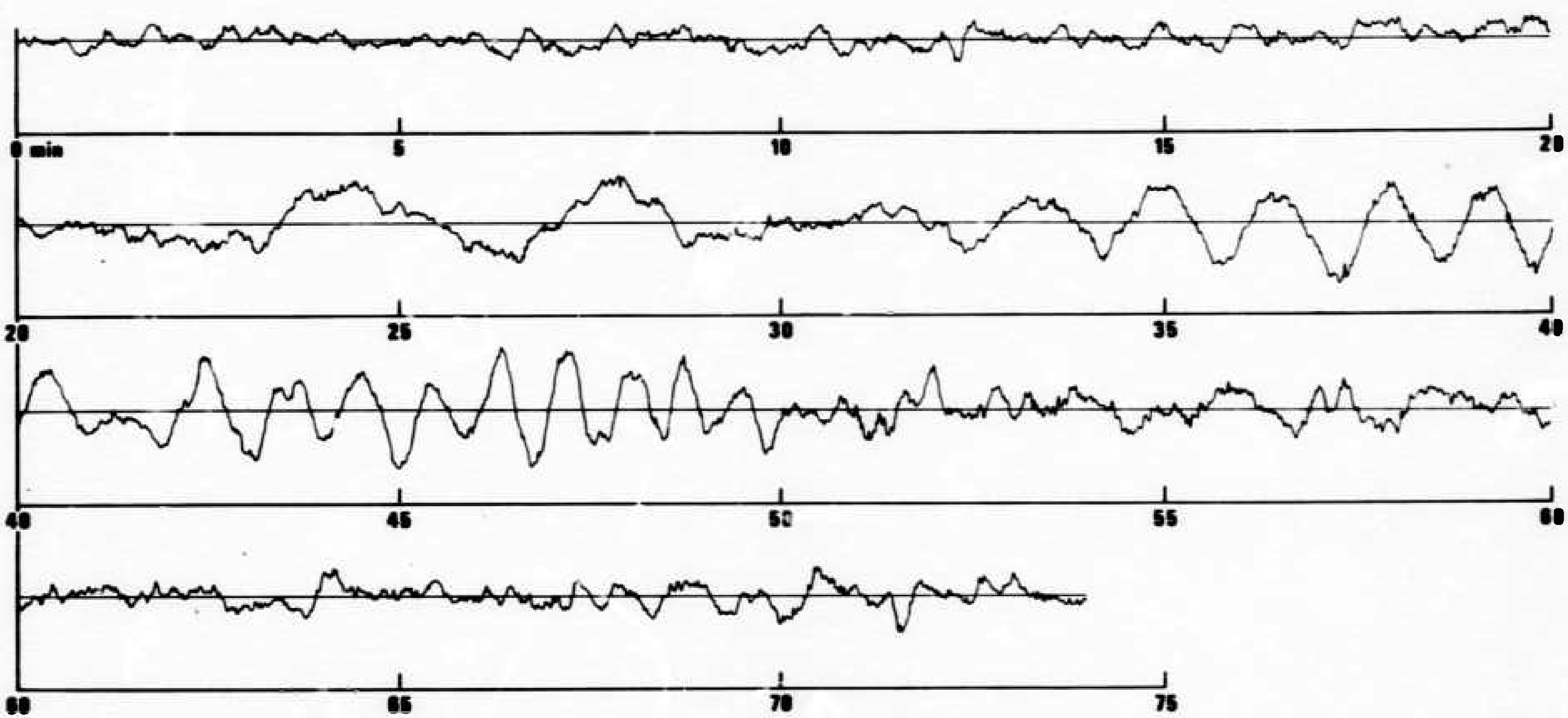

Figure 15. Event of 27 December 1968 recorded at LAMA, Montana. Beam velocity and azimuth are 299 meter/second and 343°.

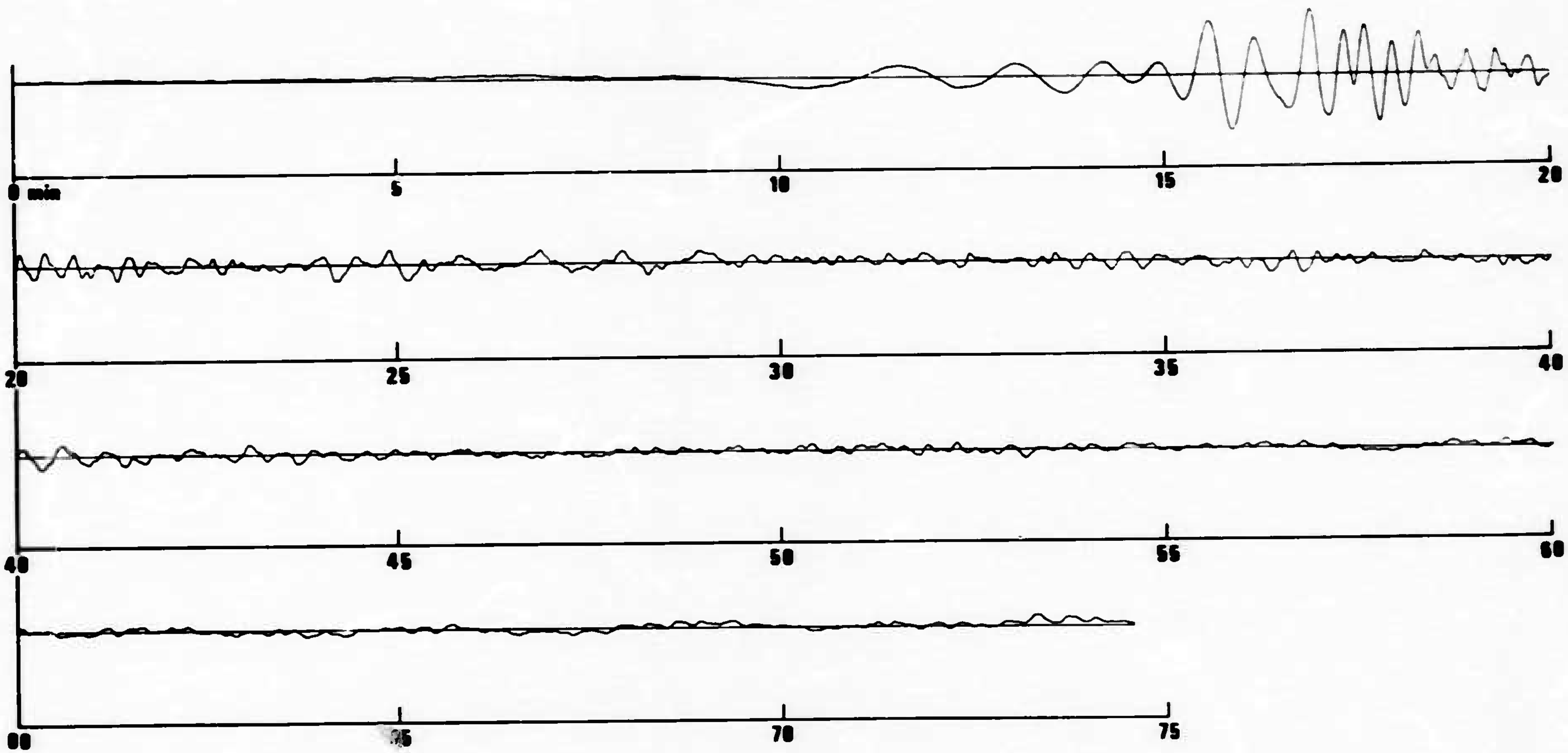

Figure 16. Event of 29 September 1969 recorded at LAMA, Montana.
Beam velocity and azimuth are 313 meter/second and 346°.

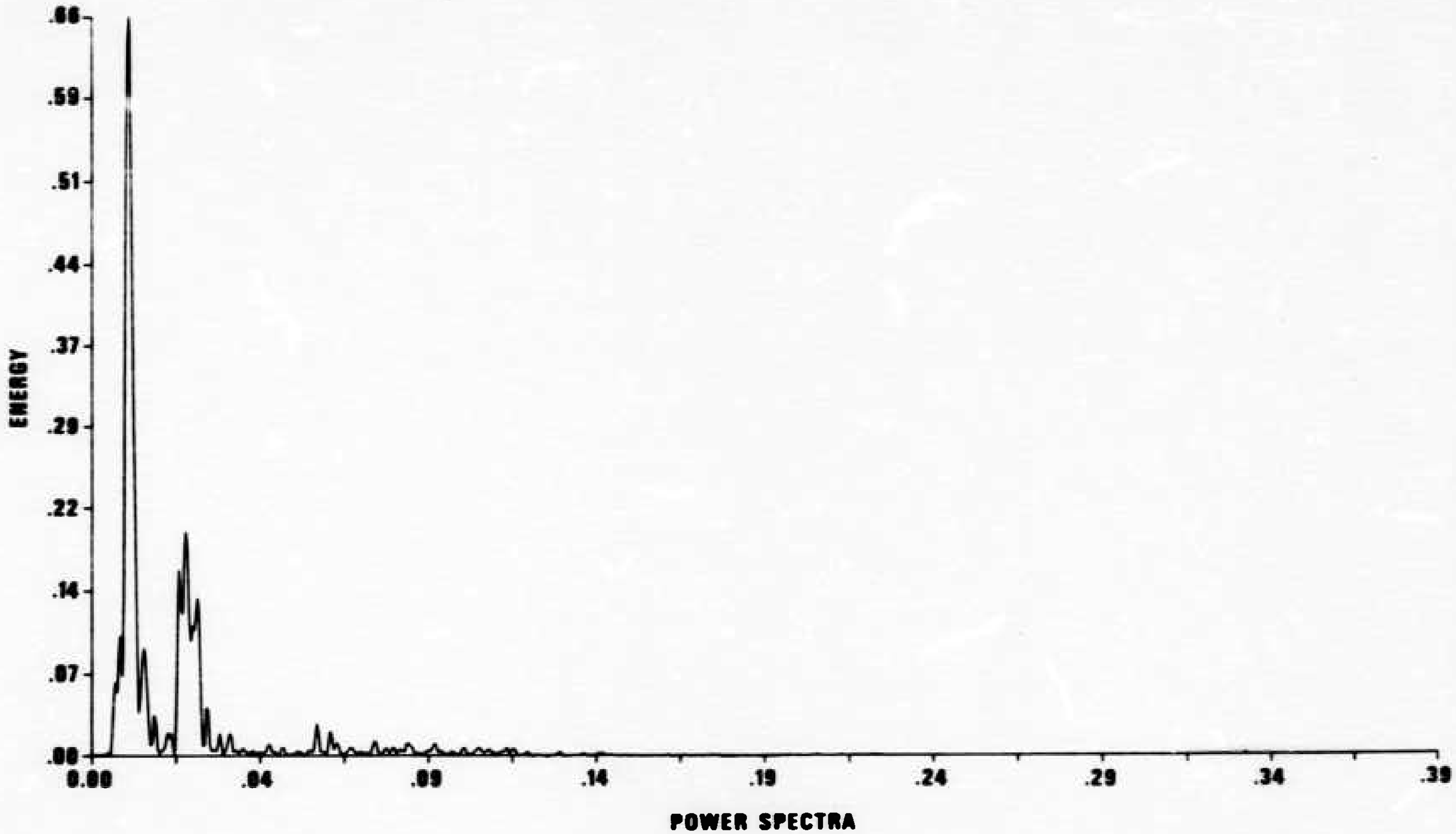

Figure 17. Event of 27 December 1968 recorded at Boulder, Colorado. Power spectrum computed starting at 17 20.

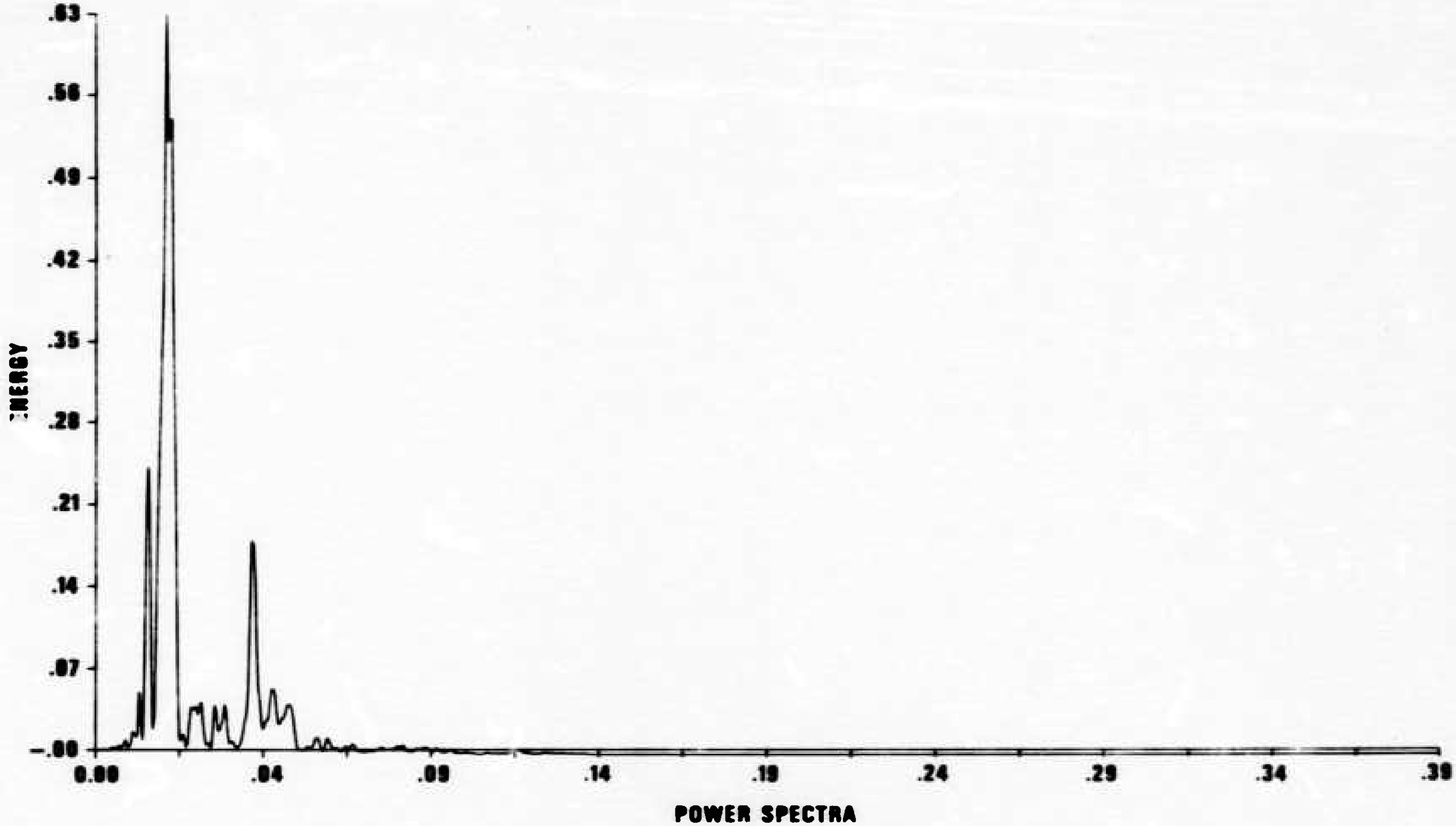

Figure 18. Event of 29 September 1969 recorded at College, Alaska. Power spectrum computed starting at 15 30.

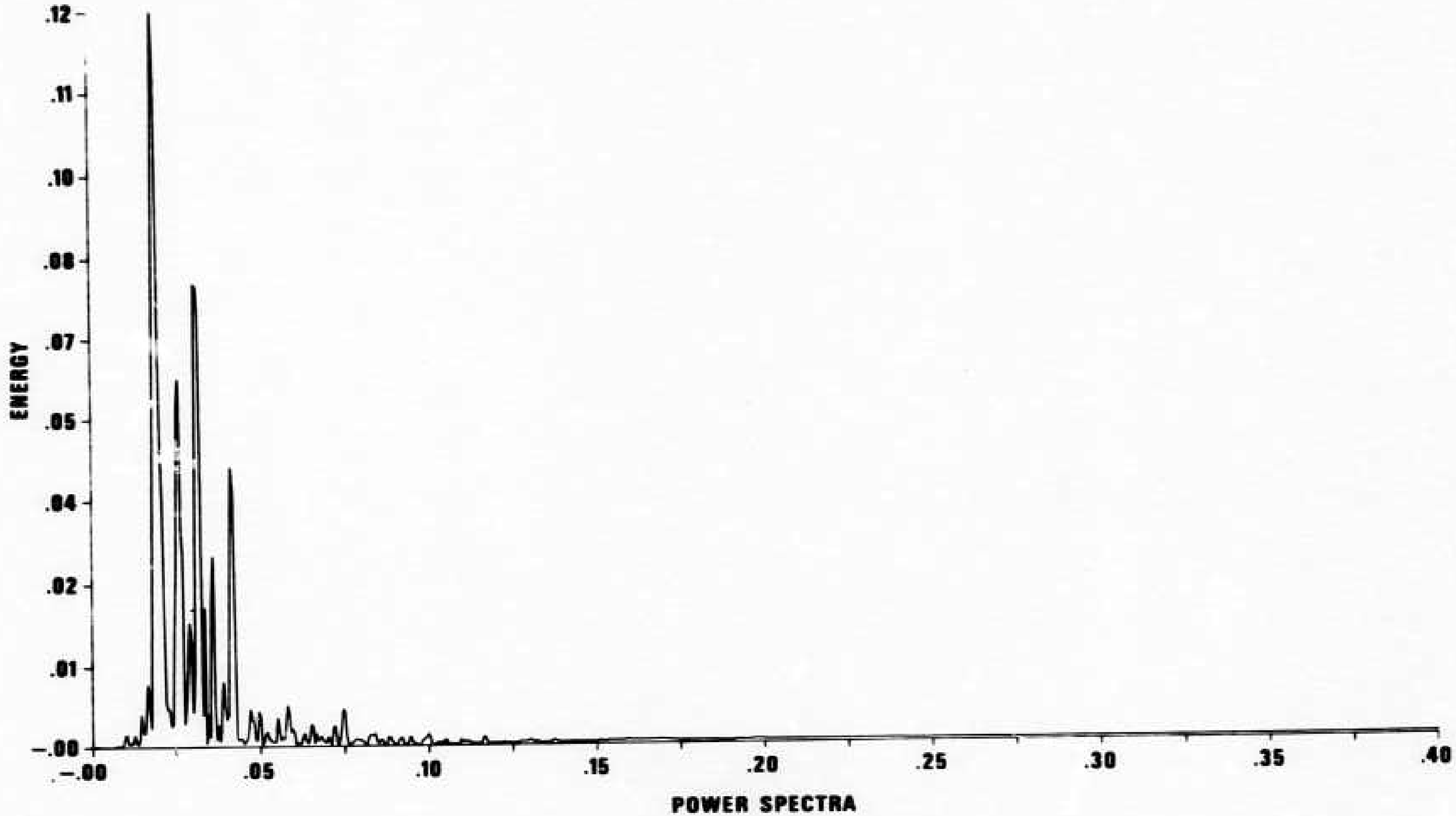

Figure 19. Event of 29 September 1969 recorded at Huancayo, Peru. Powers spectrum computed starting at 22 30.

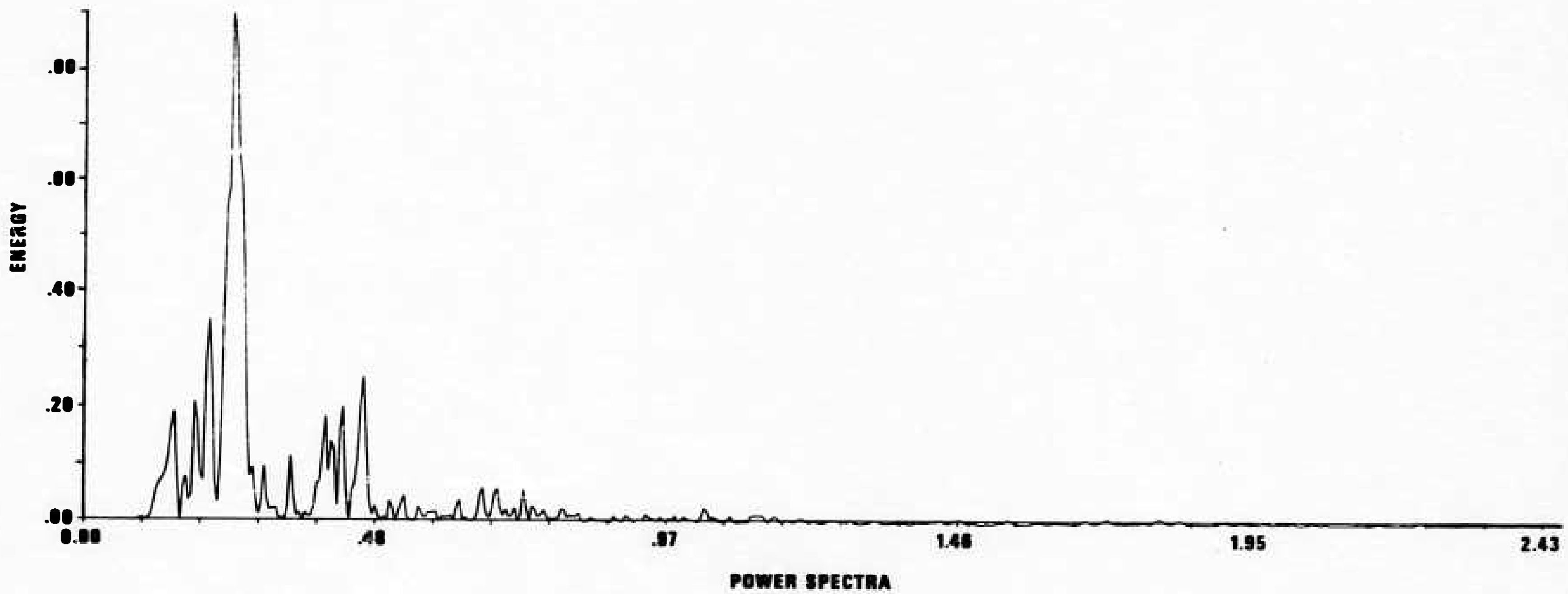

Figure 20. Event of 27 December 1968 recorded at Tel Aviv, Israel. Power spectrum computed starting at 12 10.

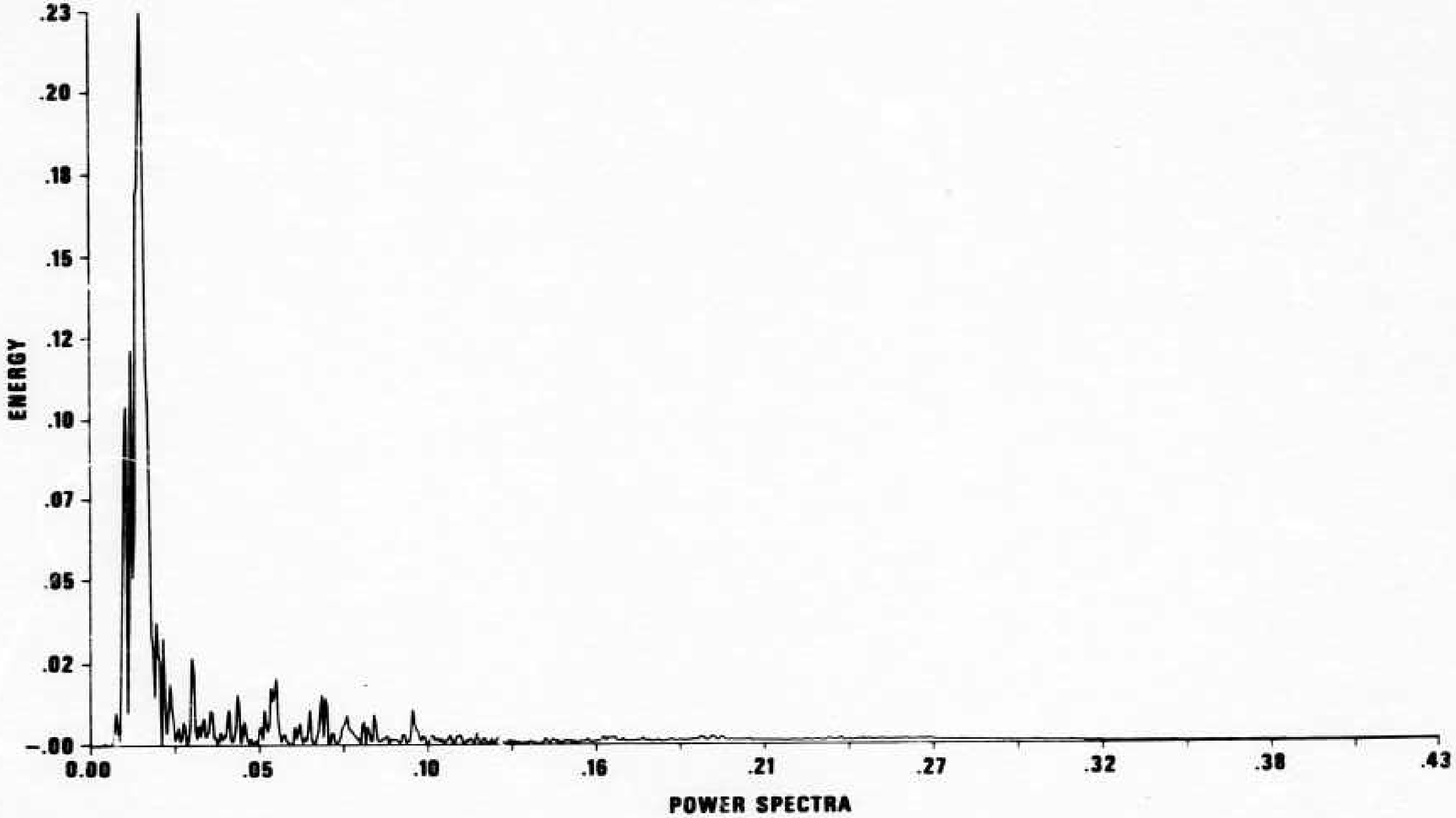

Figure 21. Event of 29 September 1969 recorded at Tel Aviv, Israel. Power spectrum computed starting at 13 20.

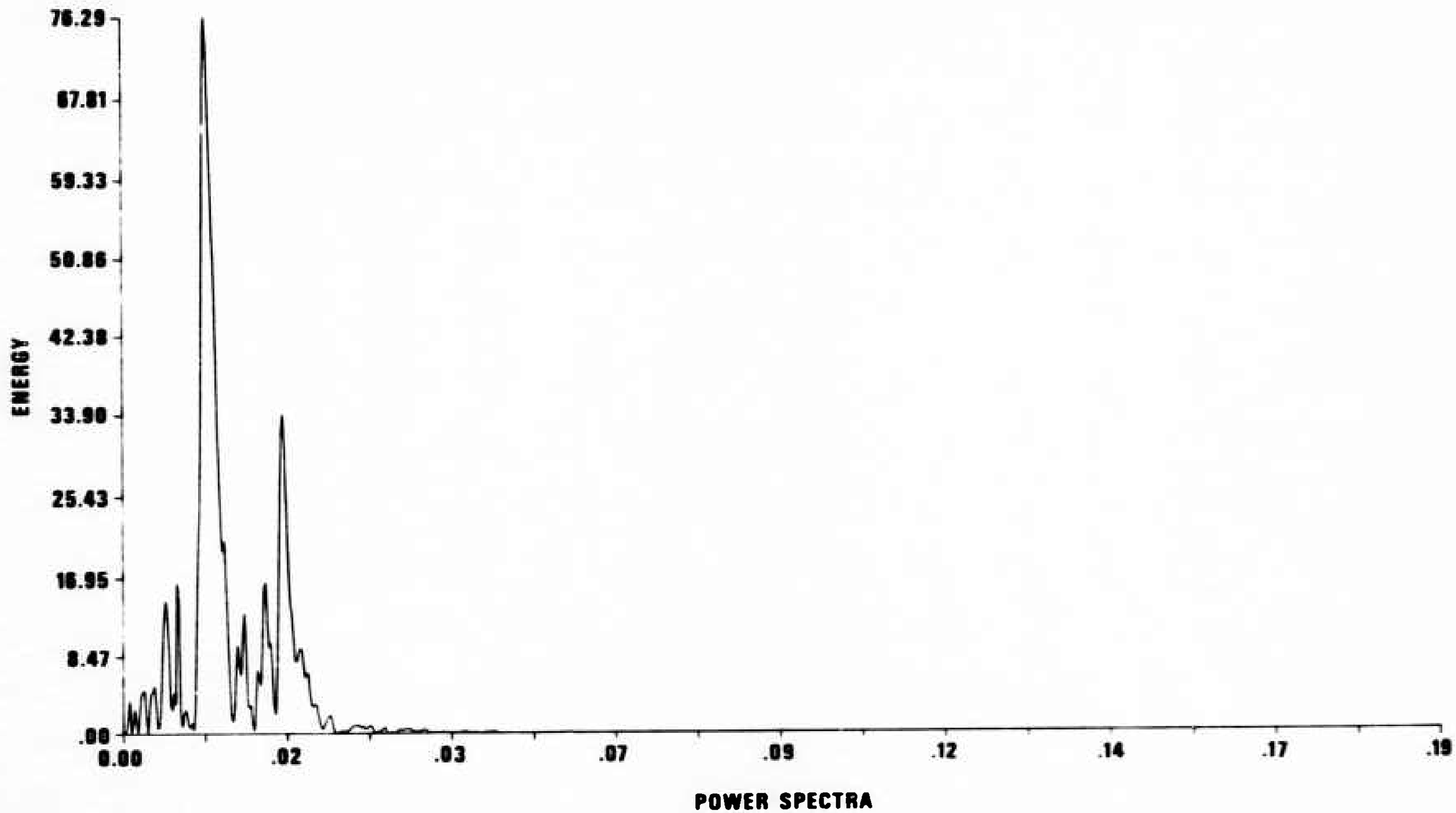

Figure 22. Event of 29 September 1969 recorded at LAMA, Montana. Power spectrum computed starting at 17 50.

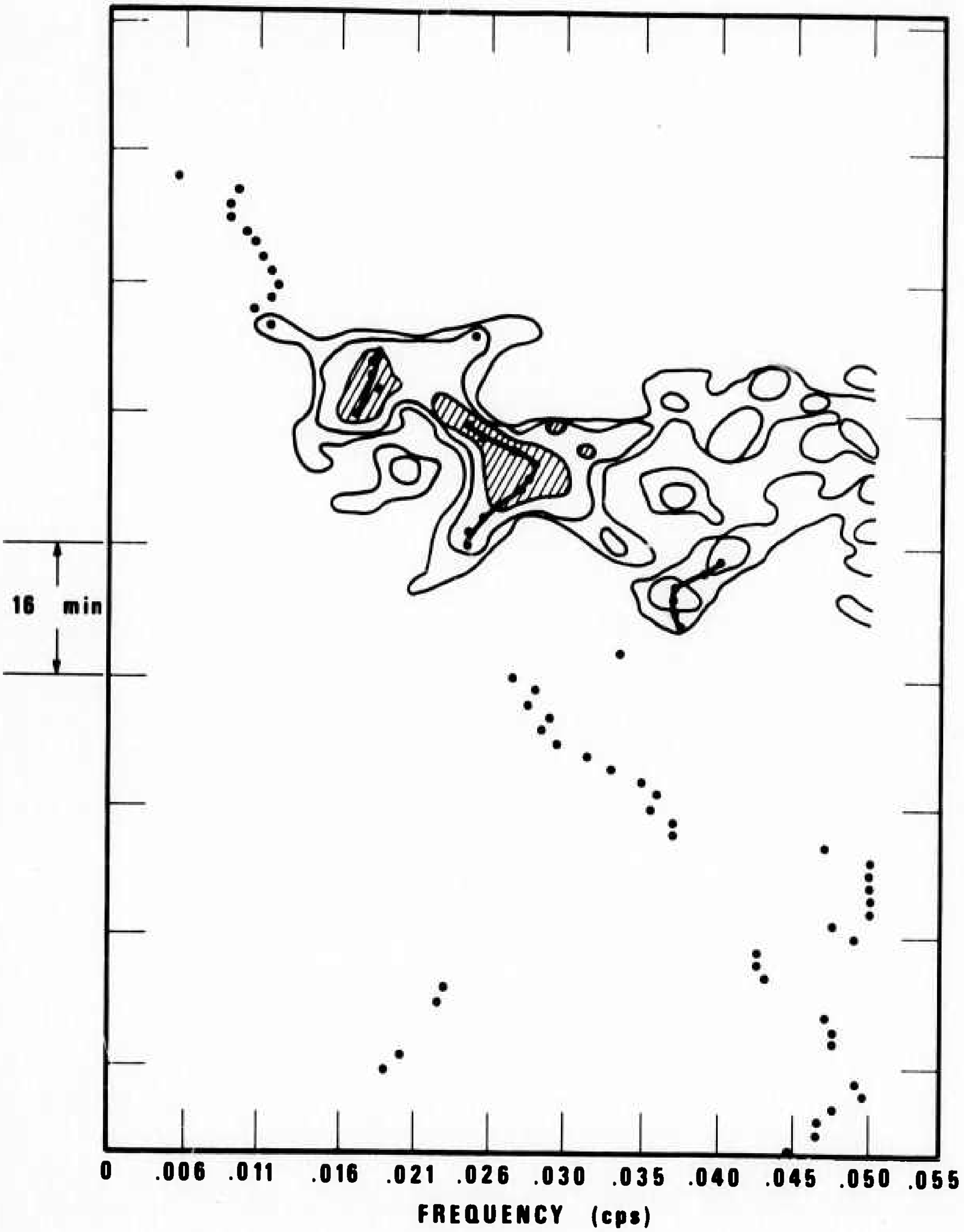

Figure 23. Time-varying spectrum of the event of 27 December 1968 recorded at College, Alaska.

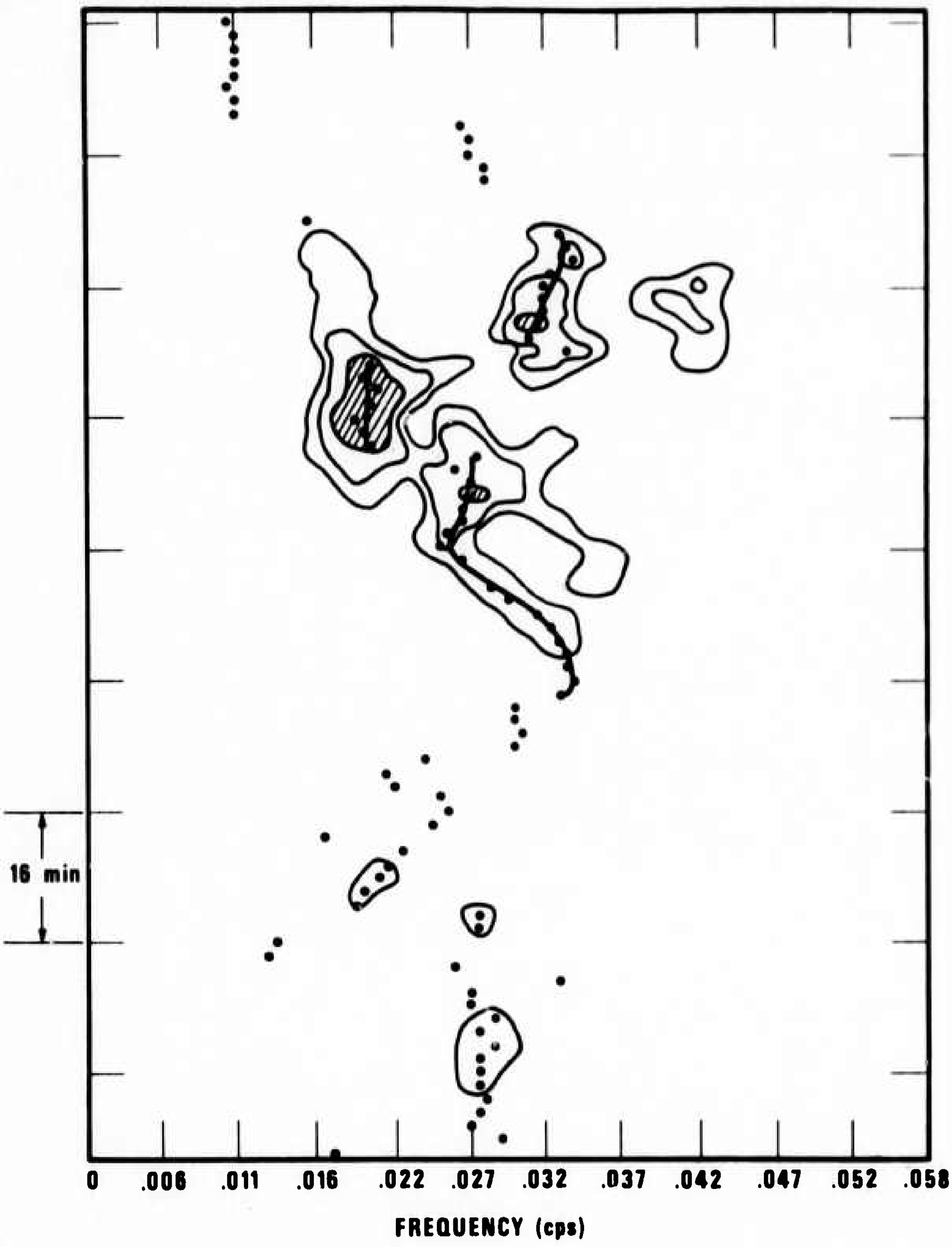

Figure 24. Time-varying spectrum of the event of 29 September 1969 recorded at Huancayo, Peru.

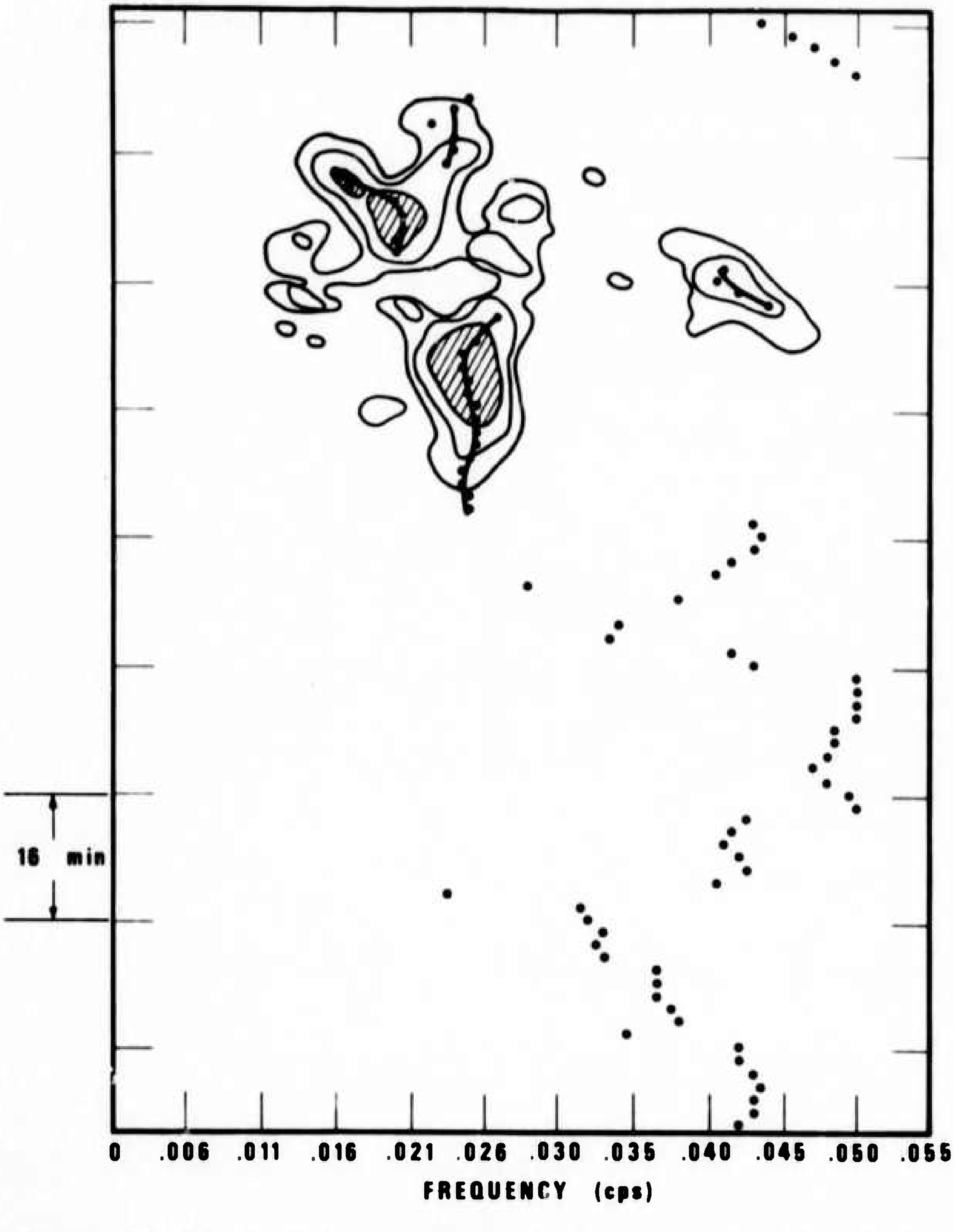

Figure 25. Time-varying spectrum of the event of 27 December 1968 recorded at Tel Aviv, Israel.

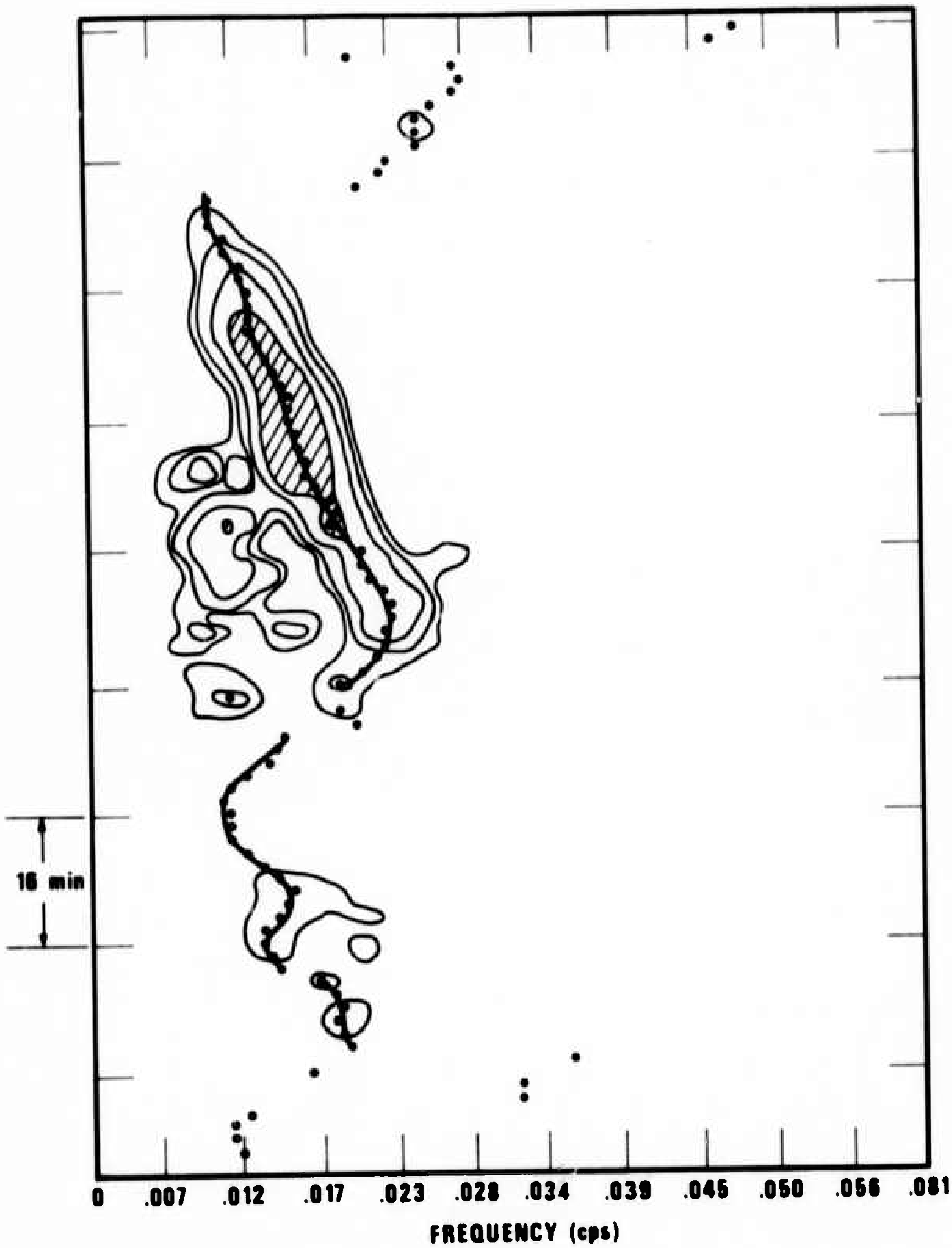

Figure 26. Time-varying spectrum of the event of 29 September 1969 recorded at Tel Aviv, Israel.

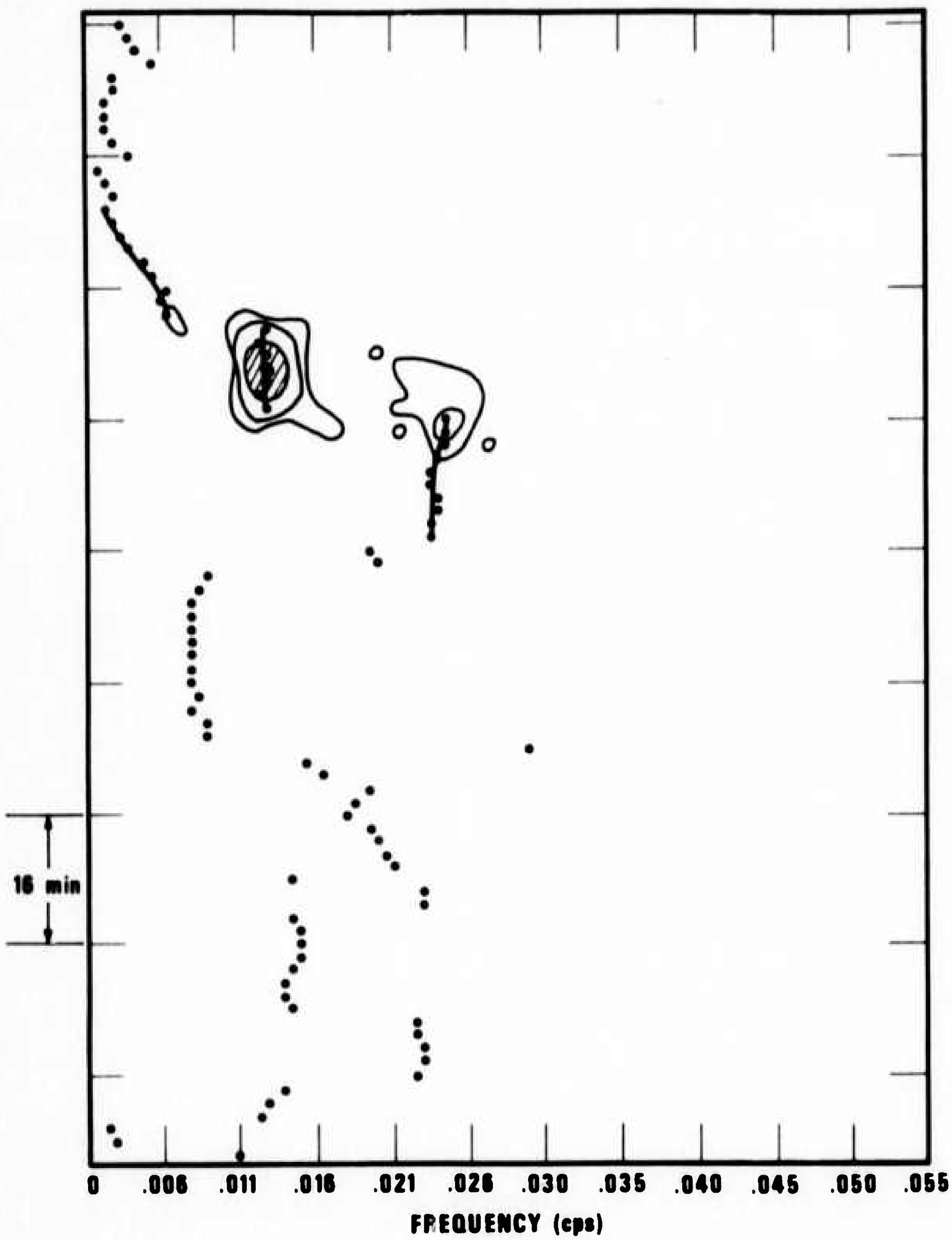

Figure 27. Time-varying spectrum of the event of 27 December 1968 recorded at LAMA, Montana.

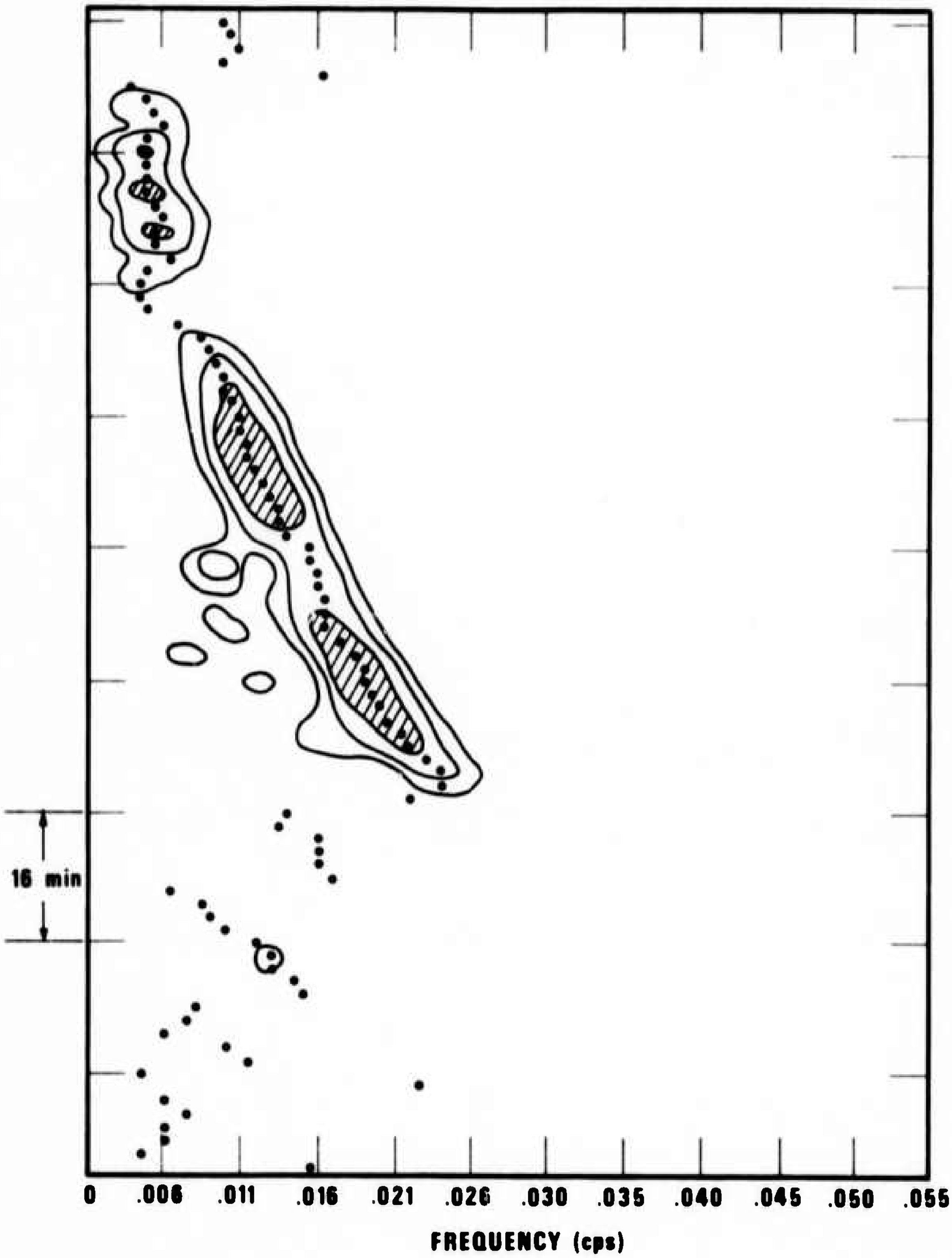

Figure 28. Time-varying spectrum of the event of 29 September 1969 recorded at LAMA, Montana.

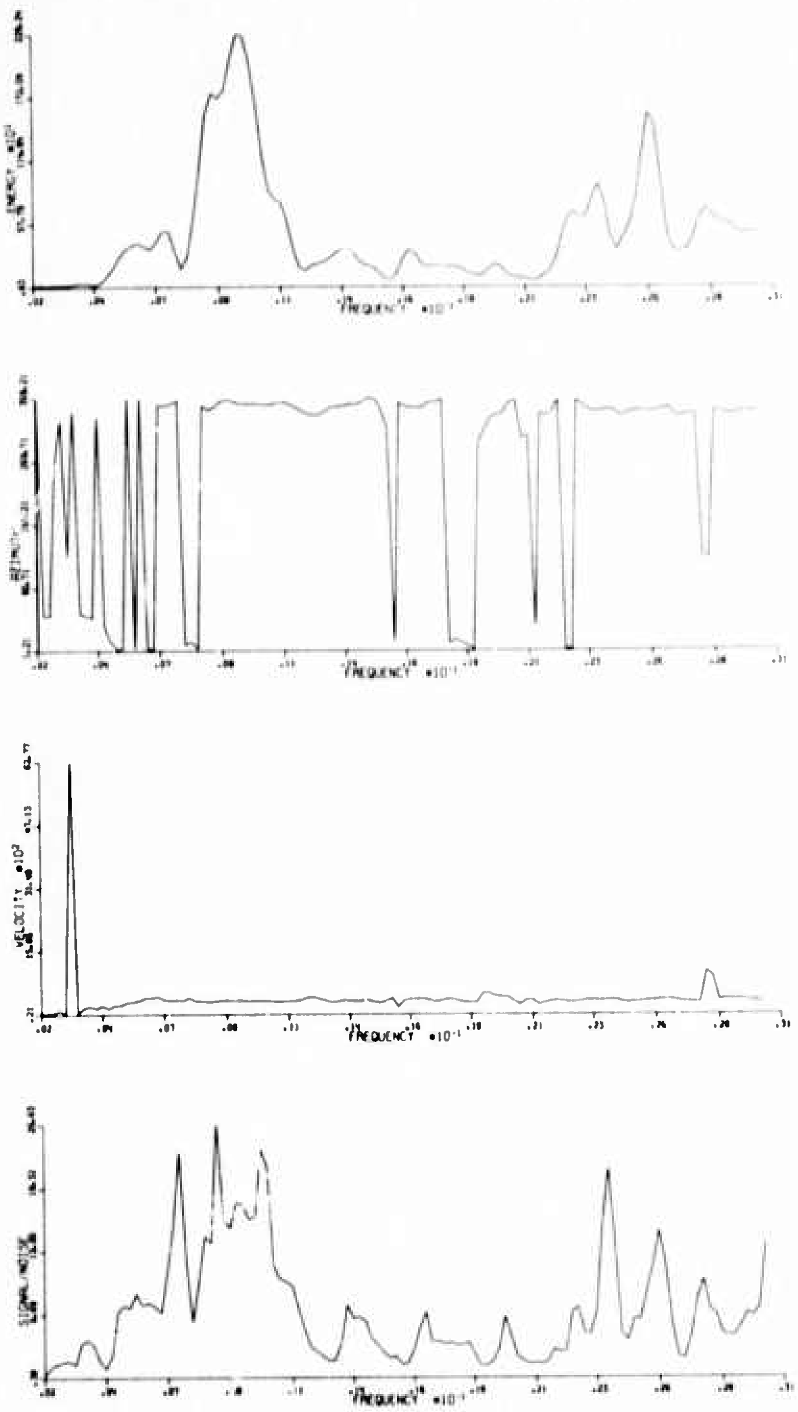

Figure 29. Best-beam spectral estimates for the event of 27 December 1968 recorded at Boulder, Colorado. From top to bottom: power, arrival azimuth, phase velocity, and F statistic. Figures 34 through 39 are arranged in the same way.

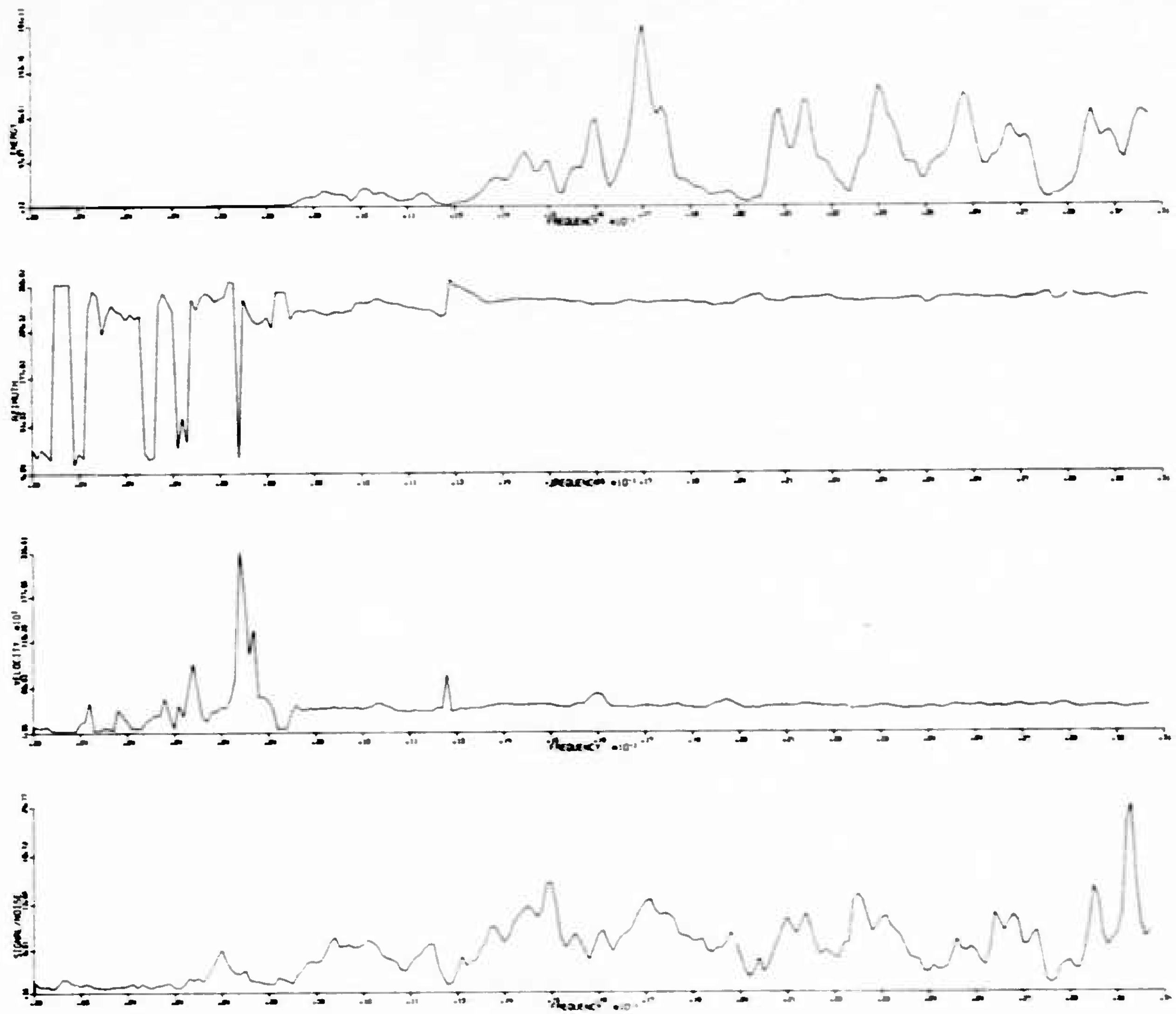

Figure 30. Best-beam spectra for the event of 27 December 1968 recorded at College, Alaska.

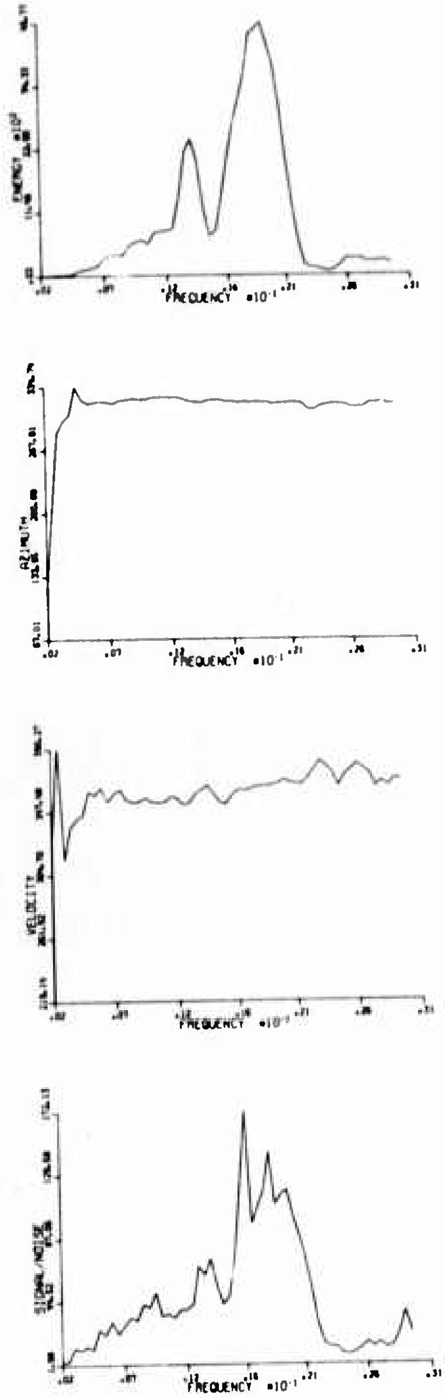

Figure 31. Best-beam spectra for the event of 29 September 1969 recorded at College, Alaska.

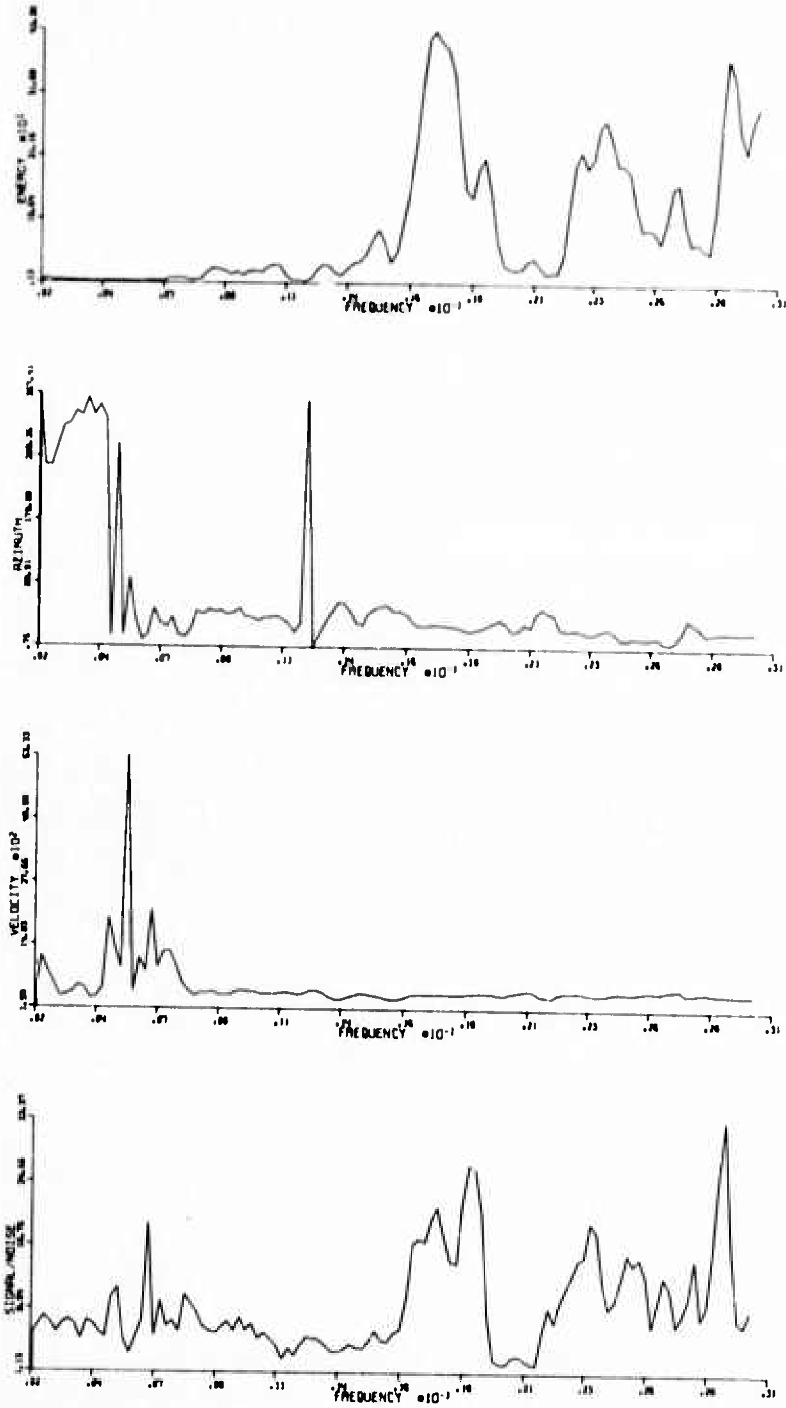

Figure 32. Best-beam spectra for the event of 29 September 1969 recorded at Huancayo, Peru.

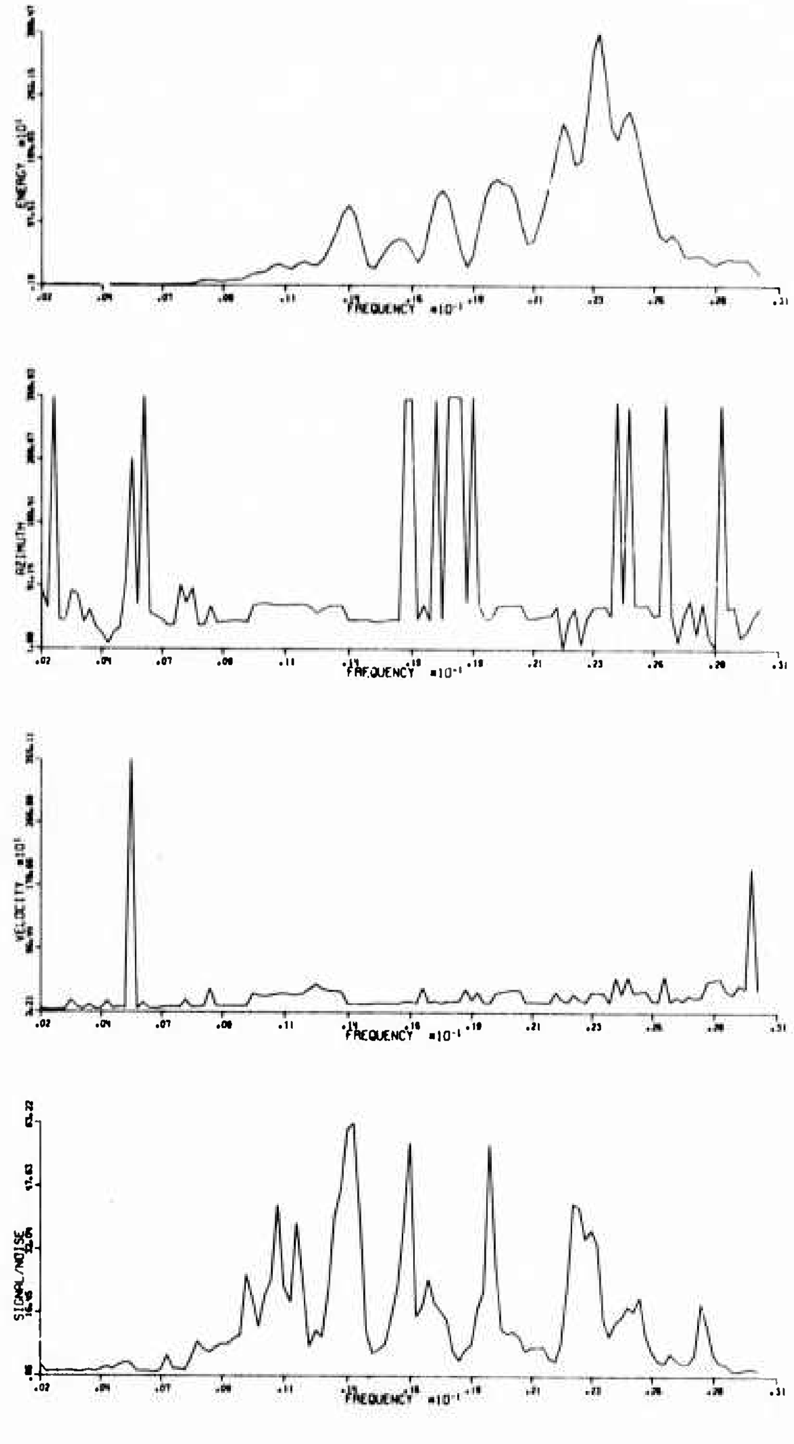

Figure 33. Best-beam spectra for the event of 27 December 1968 recorded at Tel Aviv, Israel.

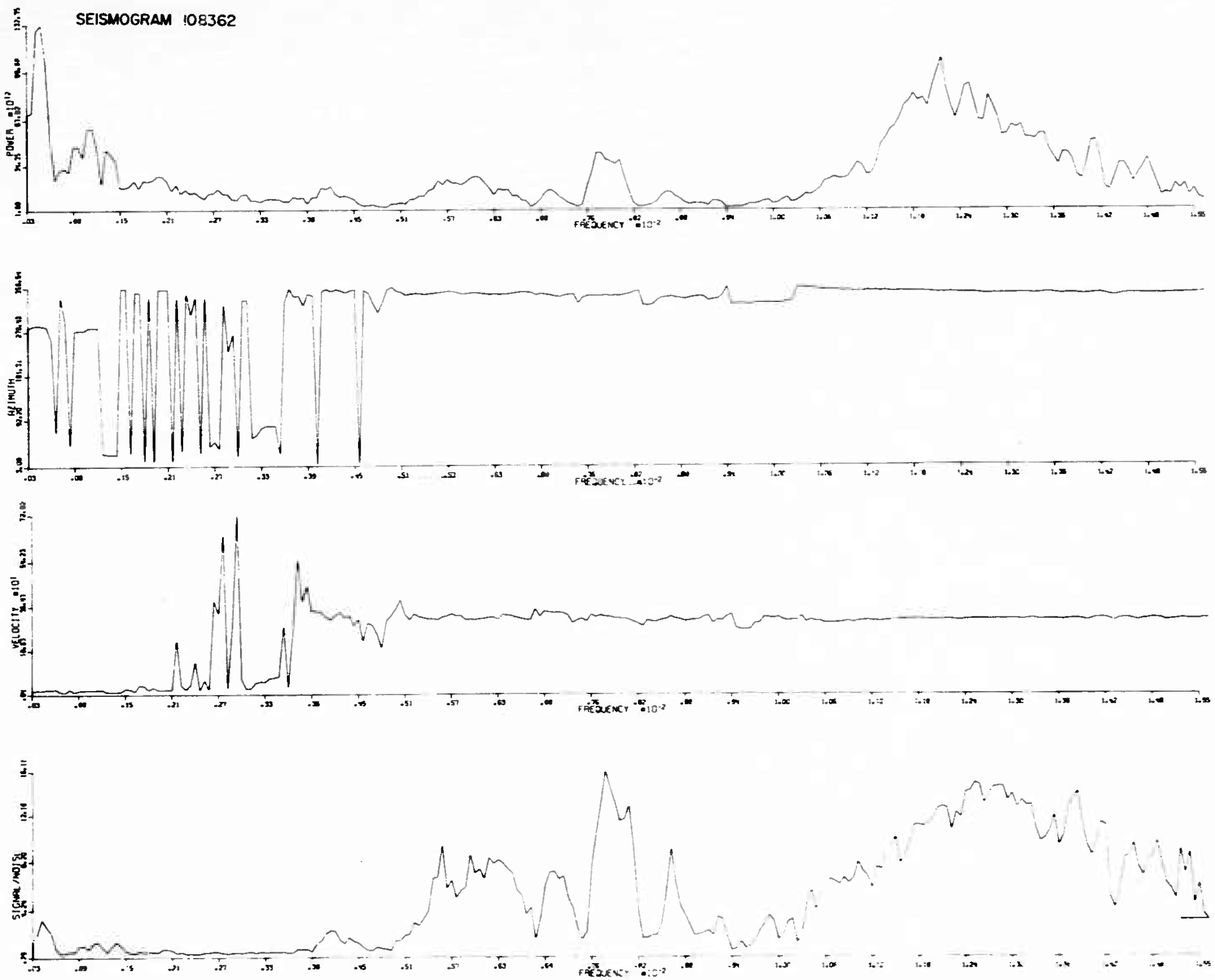

Figure 34a. Best-beam spectra for the event of 27 December 1968 recorded at LAMA, Montana.

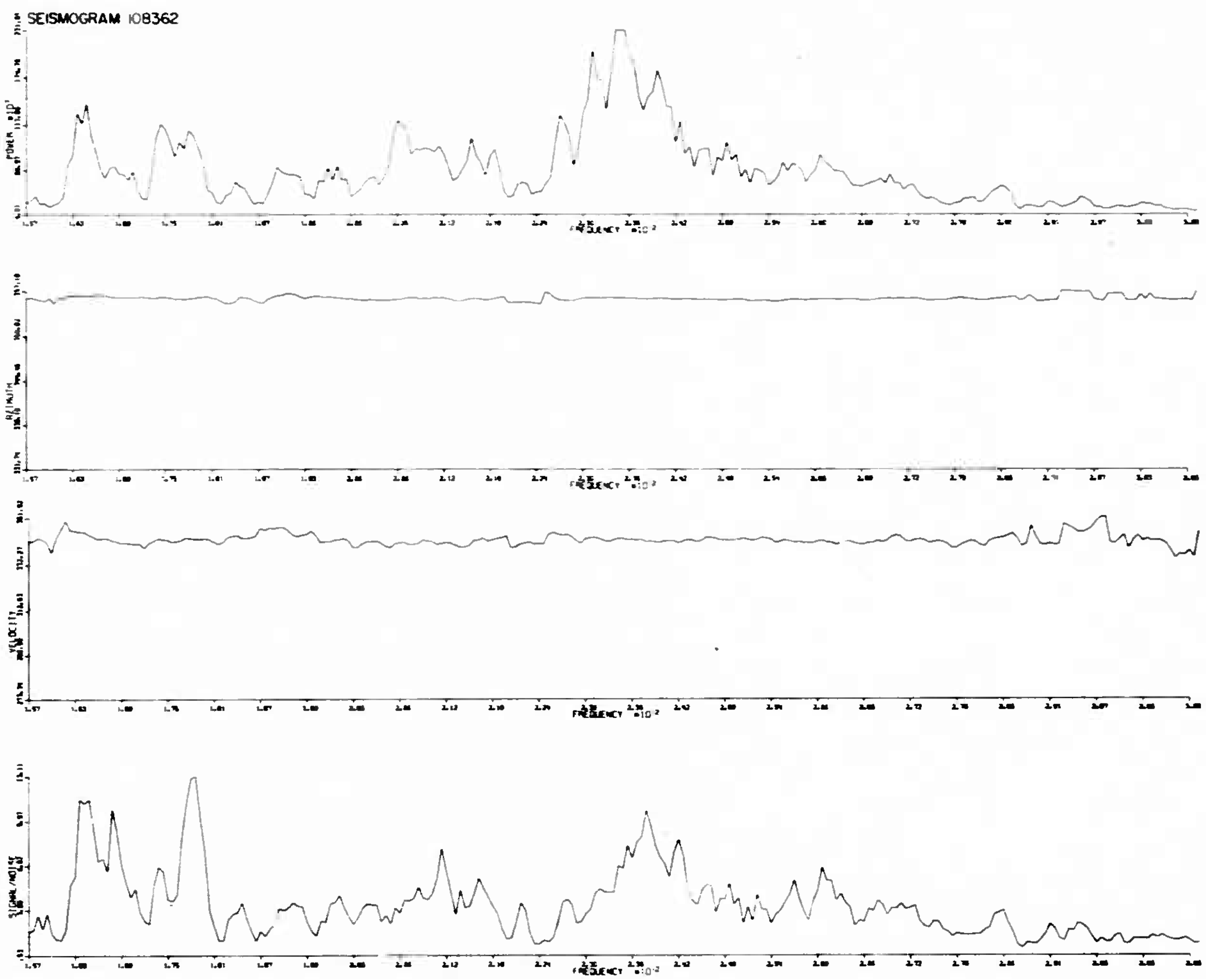

Figure 34b. Best-beam spectra for the event of 27 December 1968 recorded at LAMA, Montana.

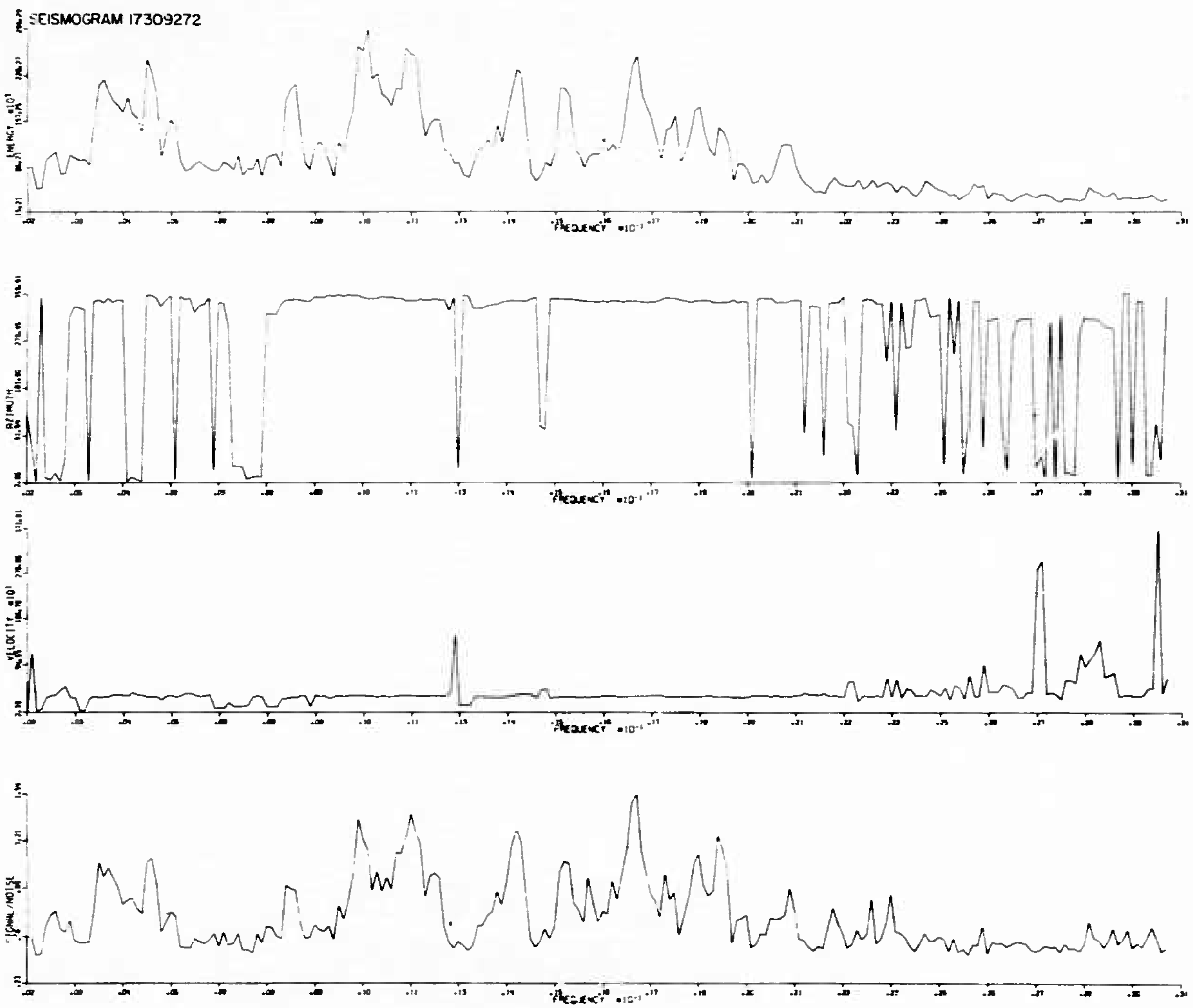

Figure 35. Best-beam spectra for the event of 29 September 1969 recorded at LAMA, Montana.

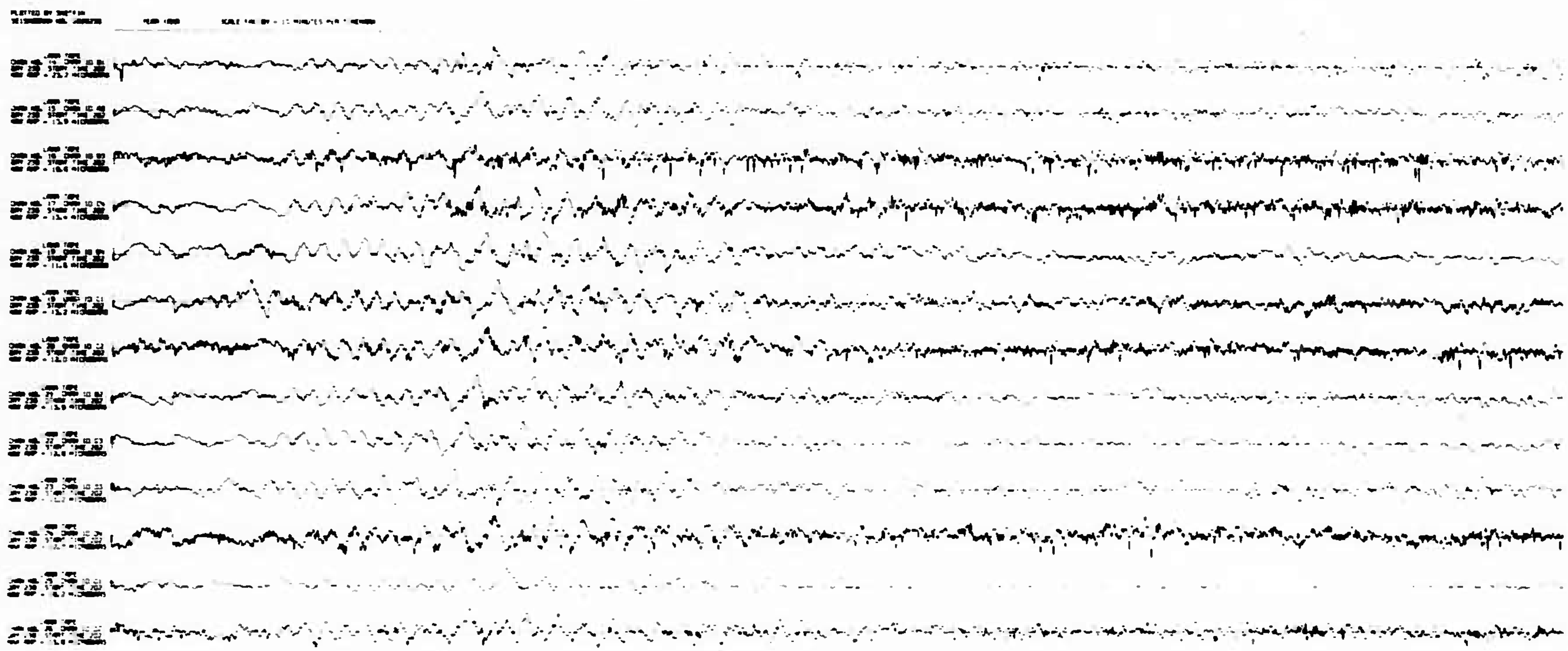

Figure 36. LAMA data channels for 25 August 1968.

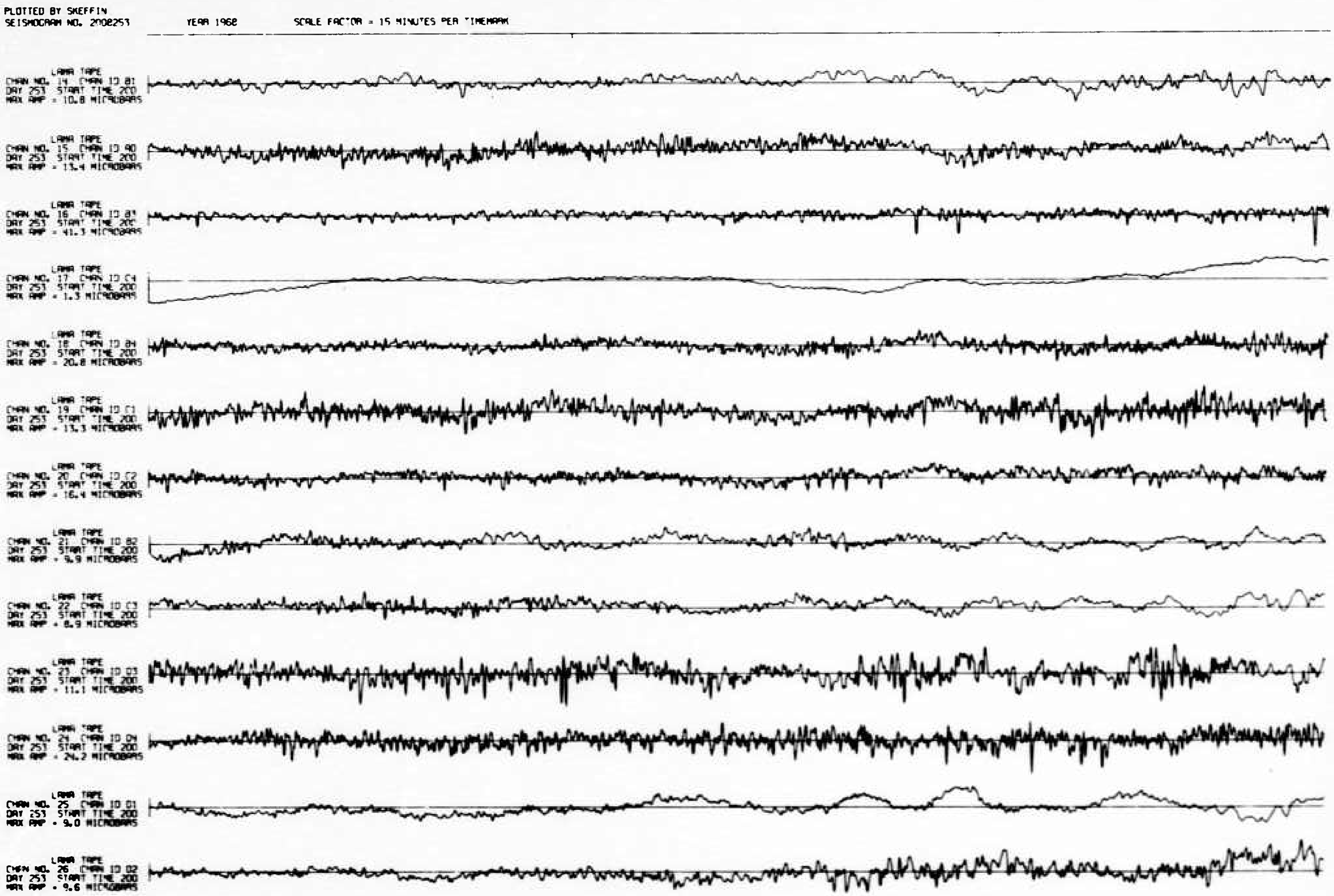

Figure 37. LAMA data channels for 9 September 1968.

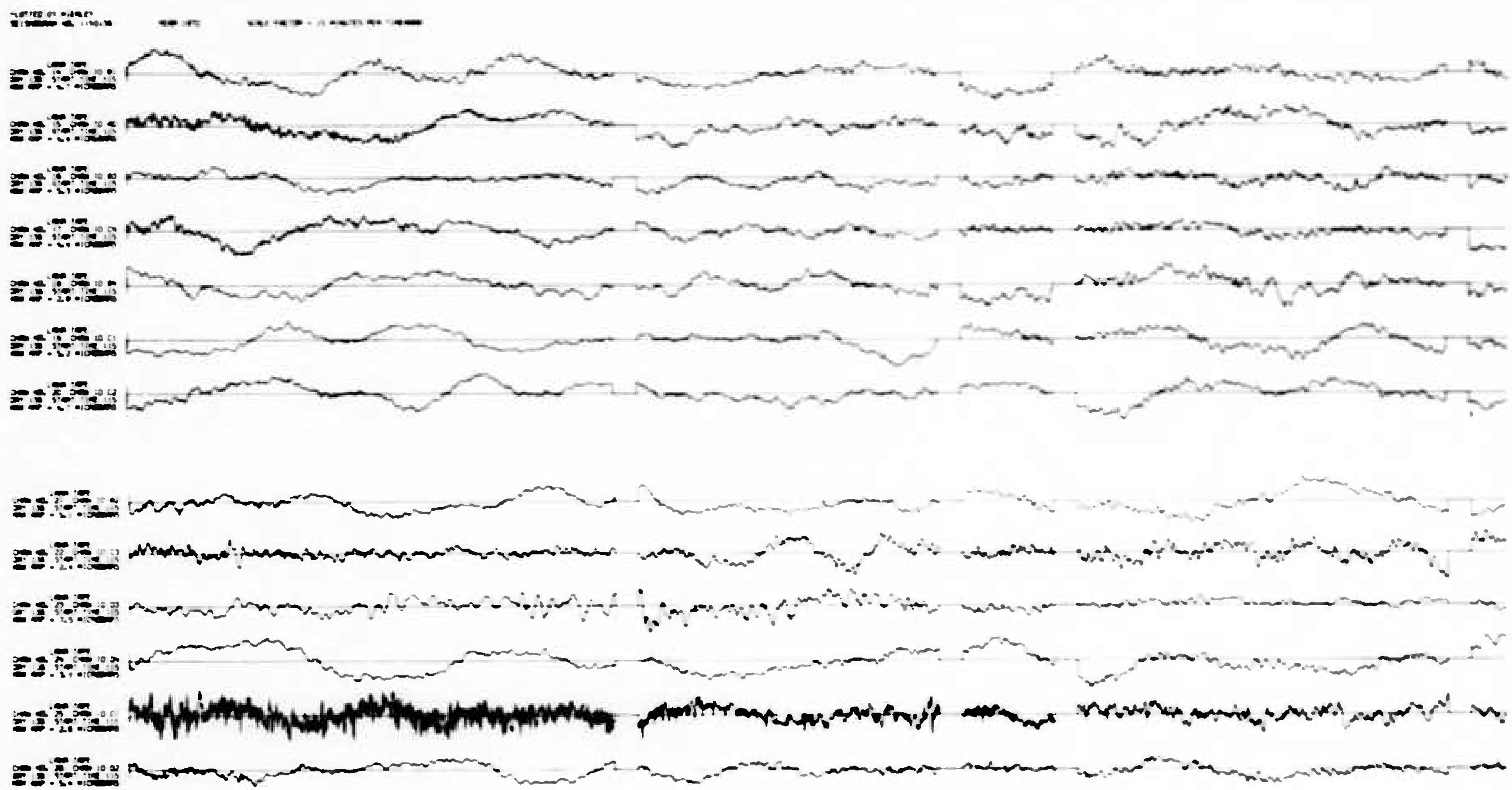

Figure 38. LAMA data channels for 16 May 1970.

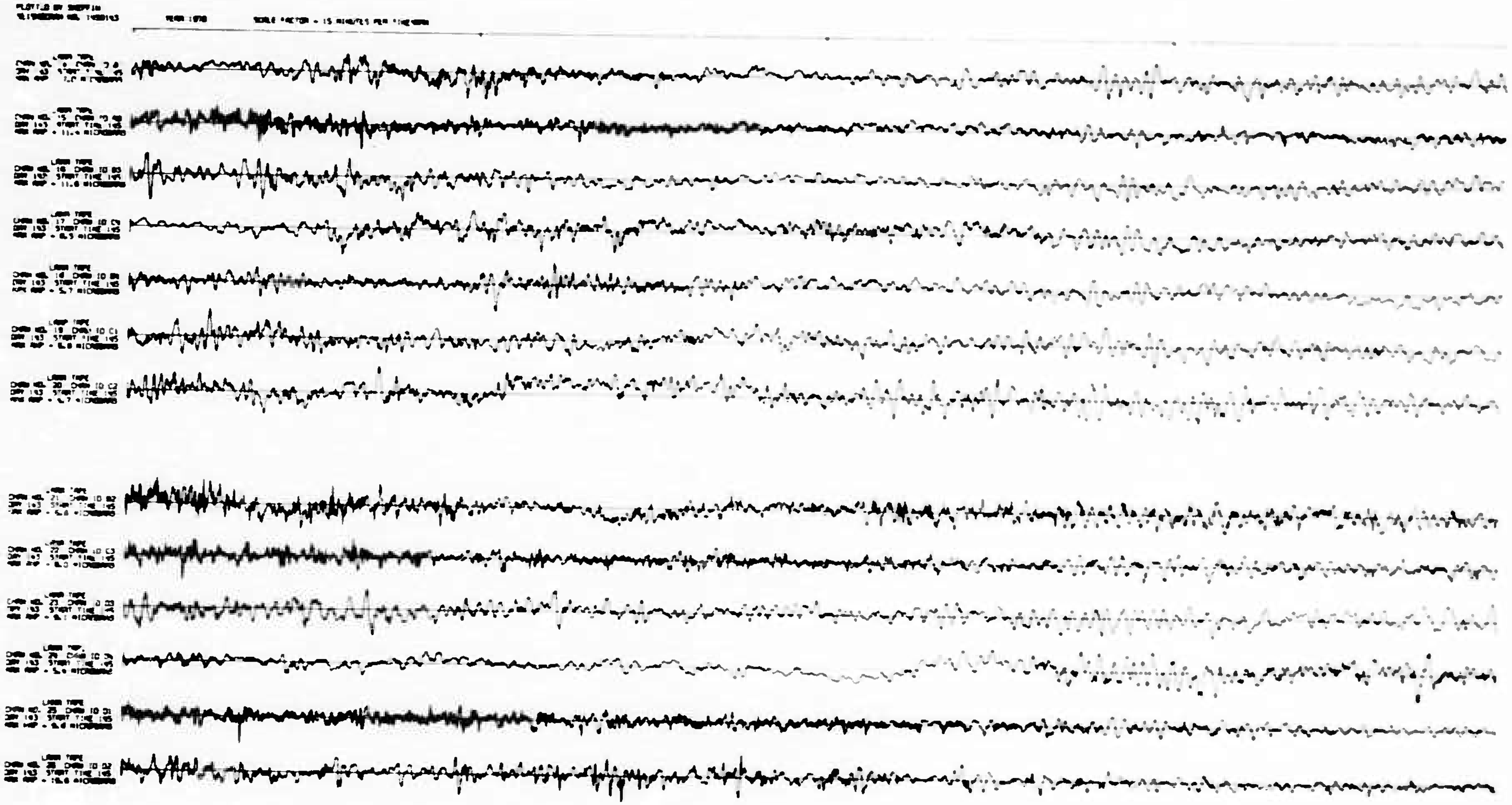

Figure 39. LAMA data channels for 23 May 1970.

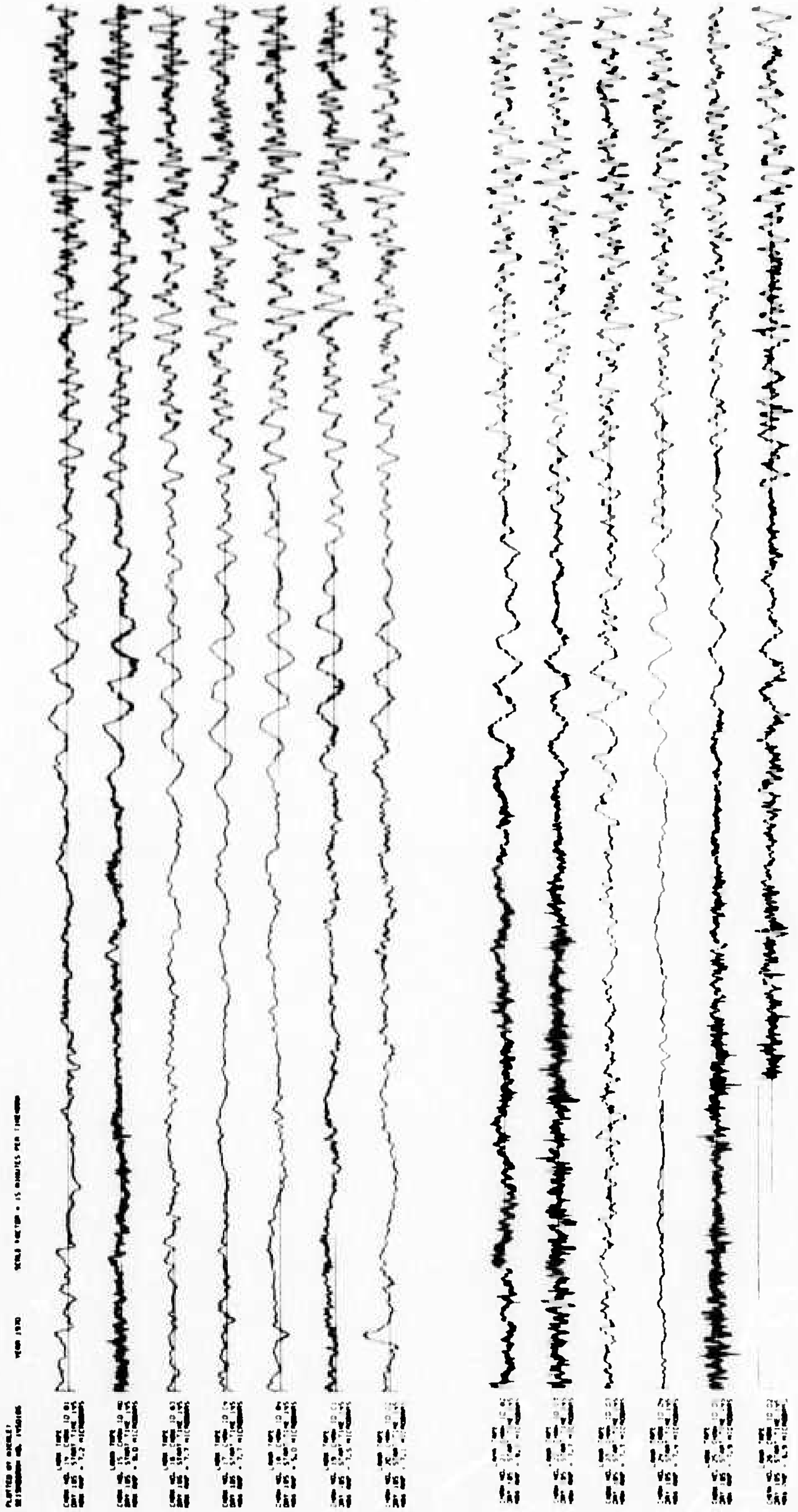

Figure 40. LAMA data channels for 4 July 1970.

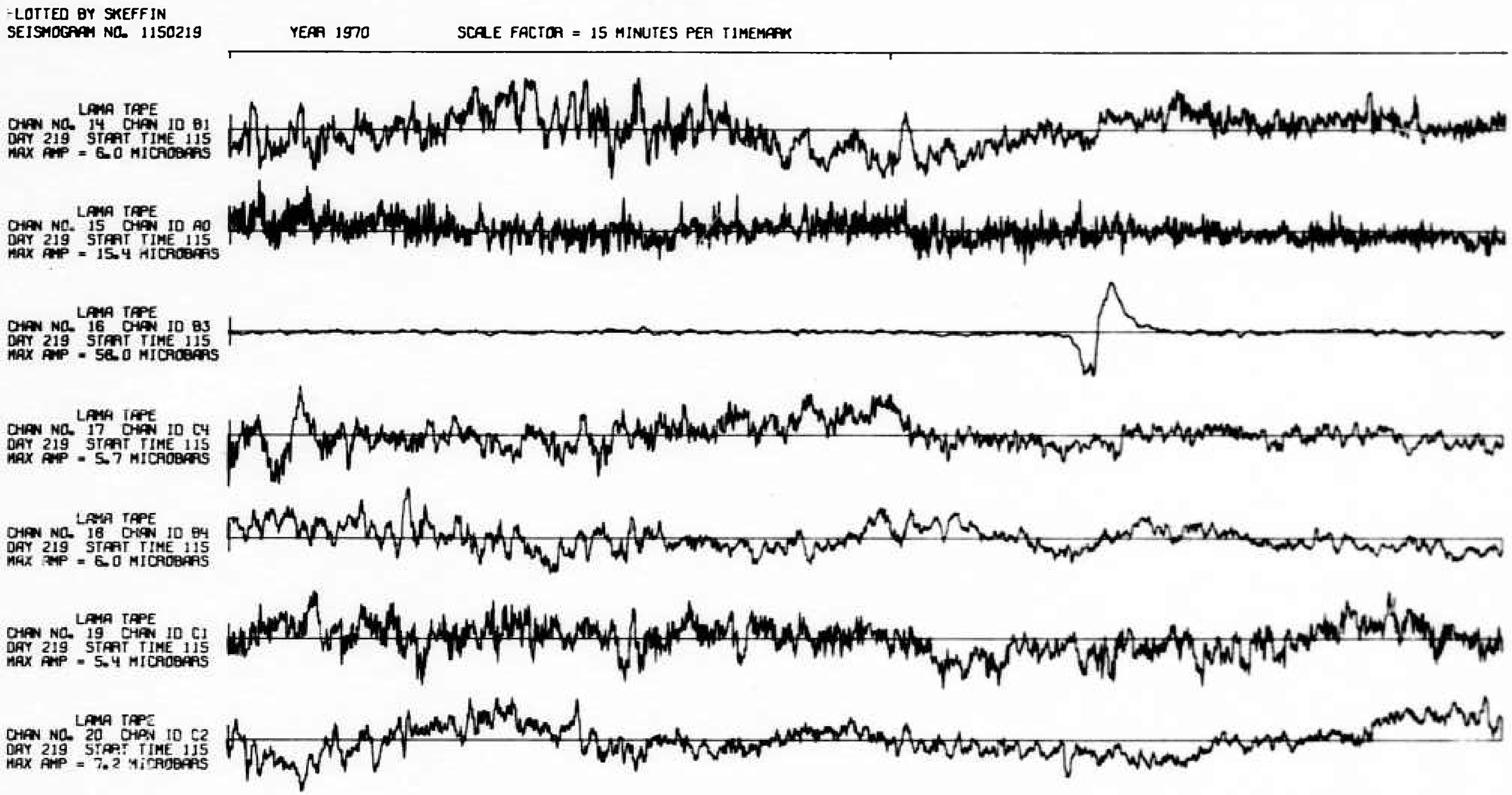

Figure 41a. LAMA data channels for 7 August 1970.

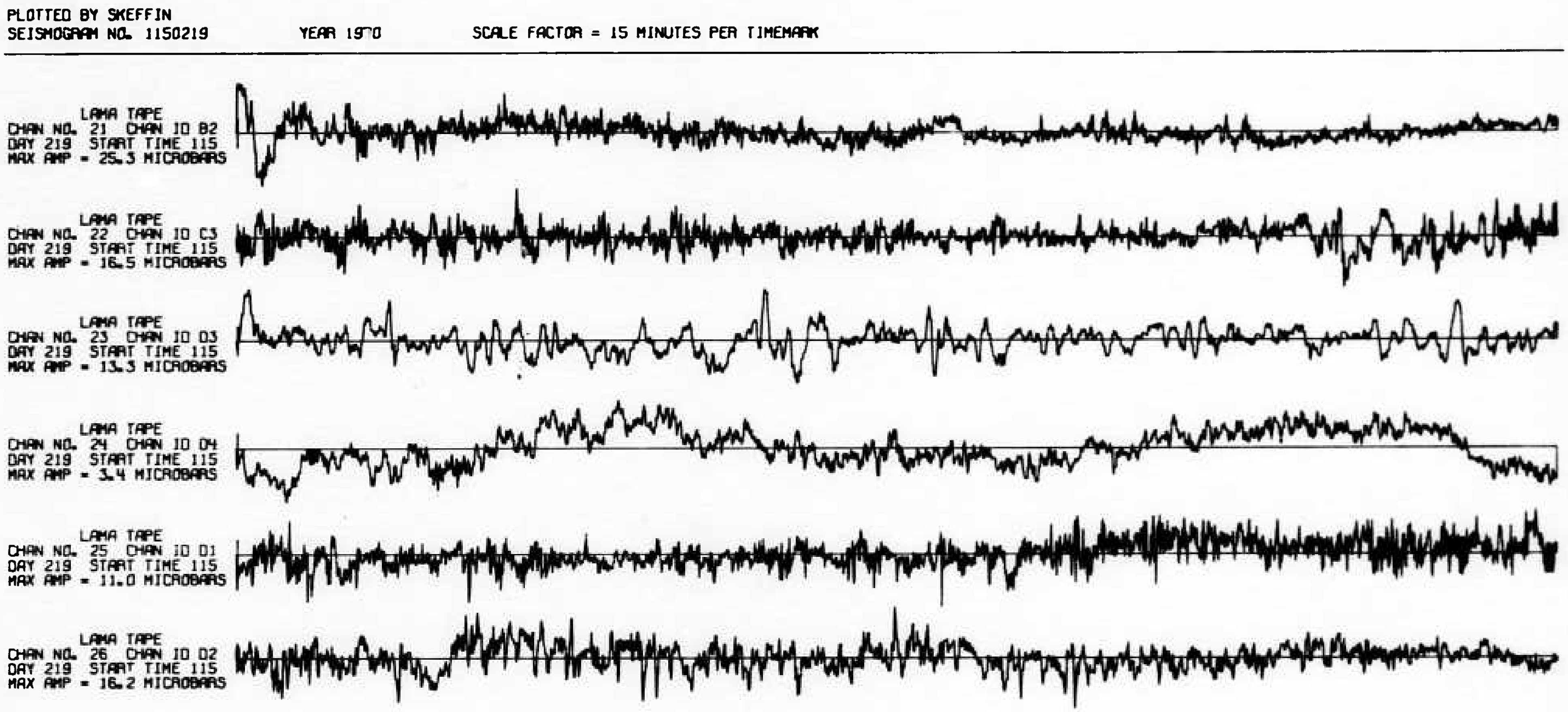

Figure 41b. LAMA data channels for 7 August 1970.

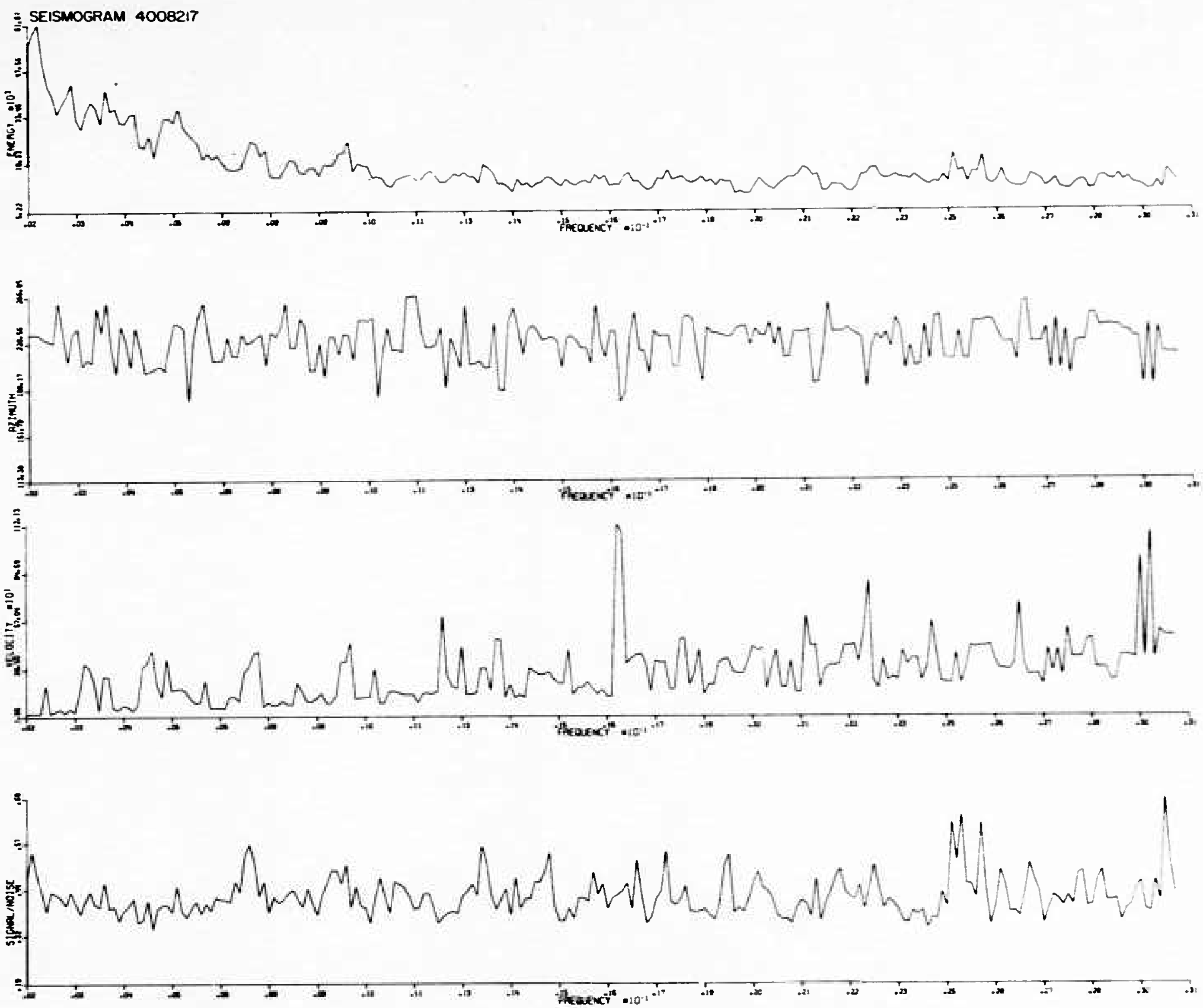

Figure 42. Best-beam spectra for LAMA data, 0400-0508, 4 August 1968.

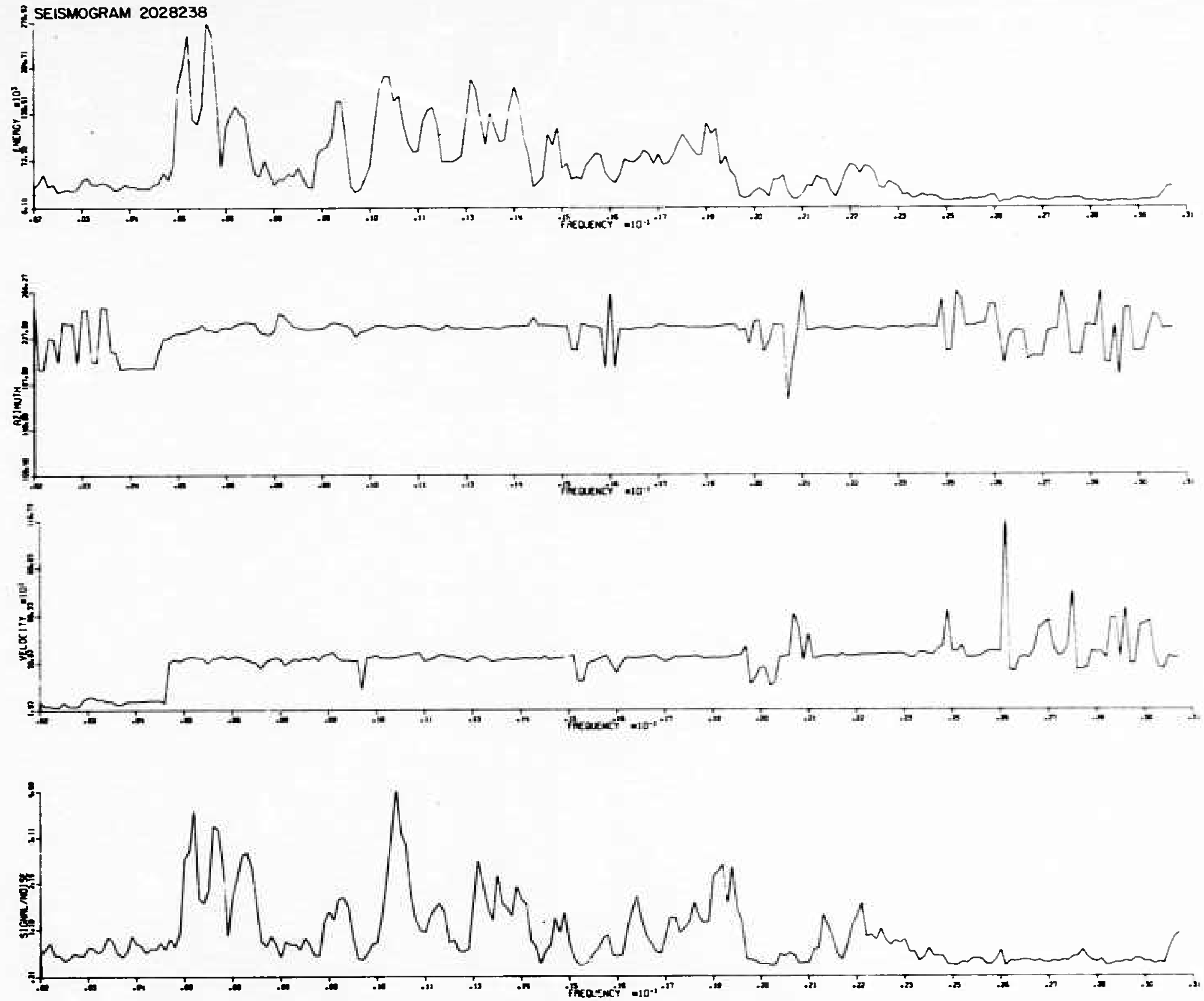

Figure 43. Best-beam spectra for LAMA data, 0202-0310, 25 August 1968.

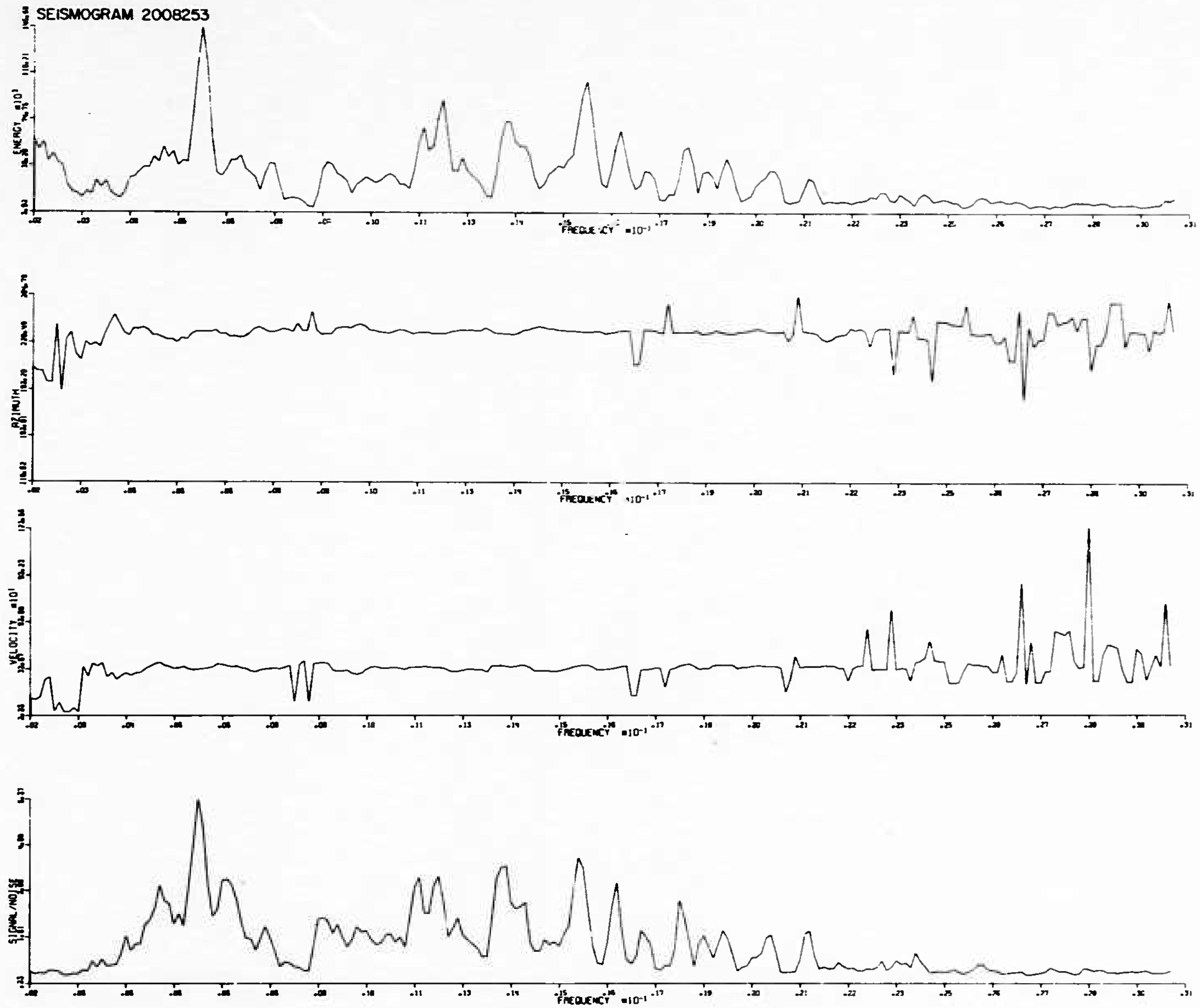

Figure 44. Best-beam spectra for LAMA data, 0200-0308, 9 September 1968.

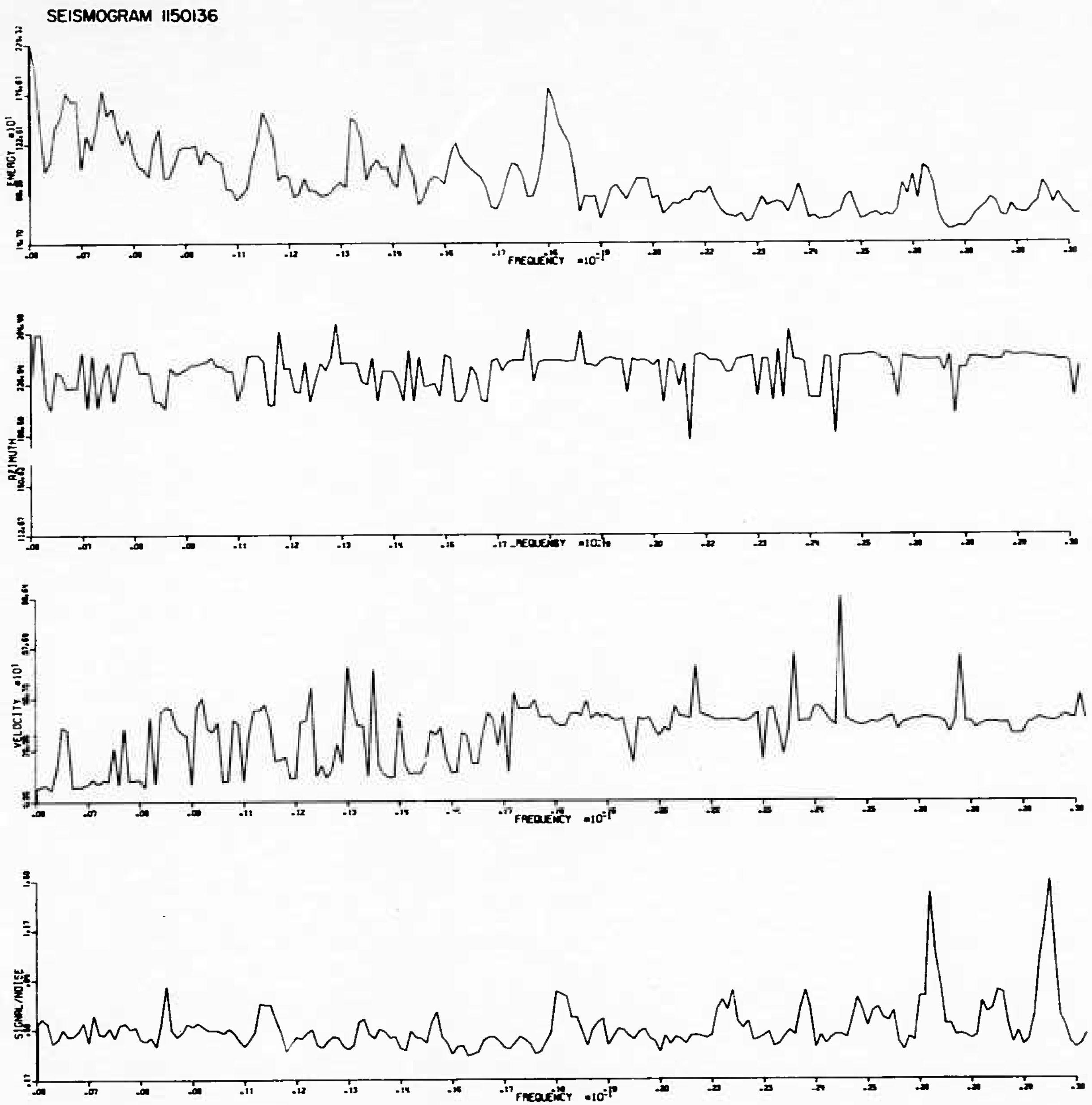

Figure 45. Best-beam spectra for LAMA data, 0115-0223, 16 May 1970.

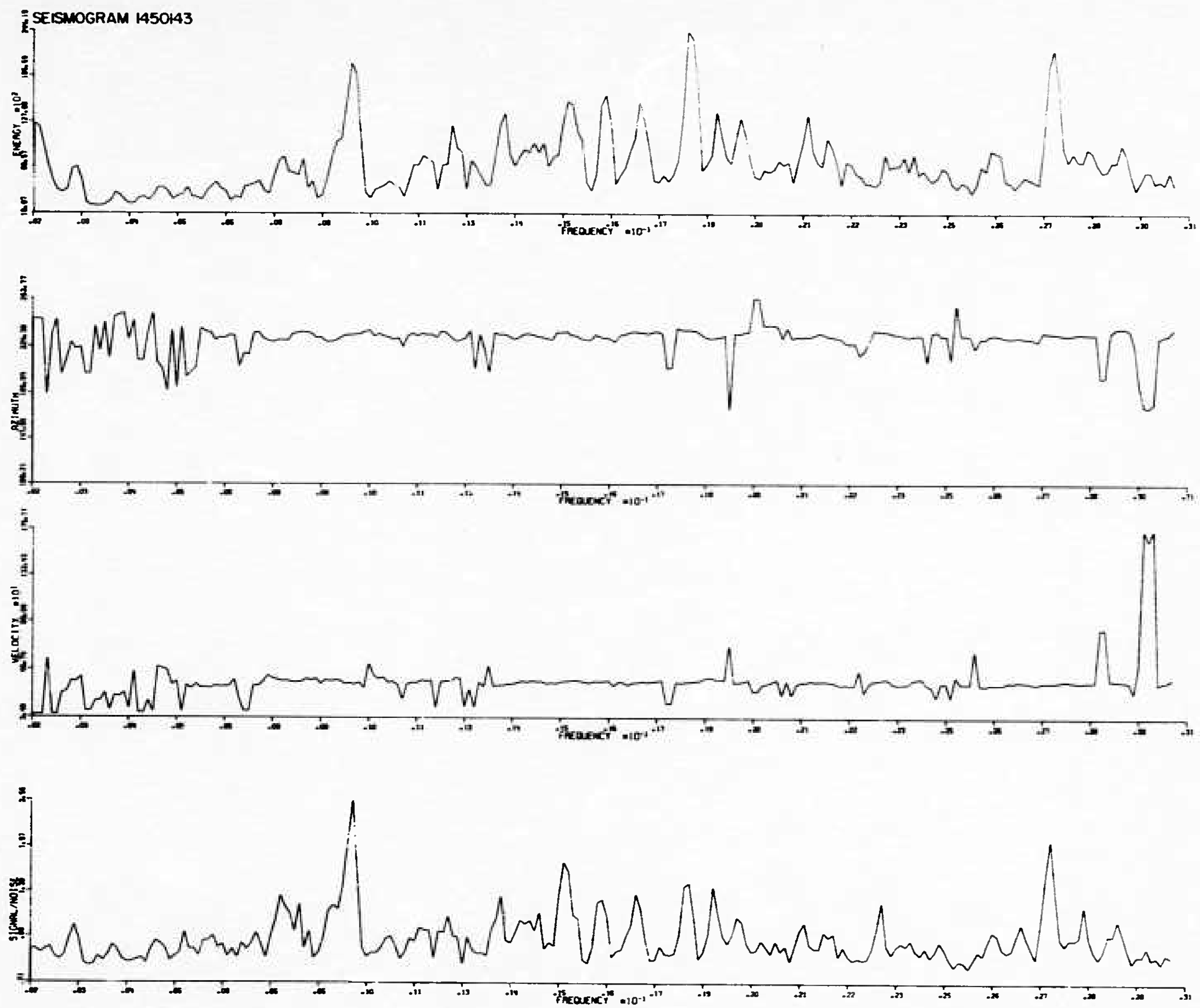

Figure 46. Best-beam spectra for LAMA data, 0145-0253, 23 May 1970.

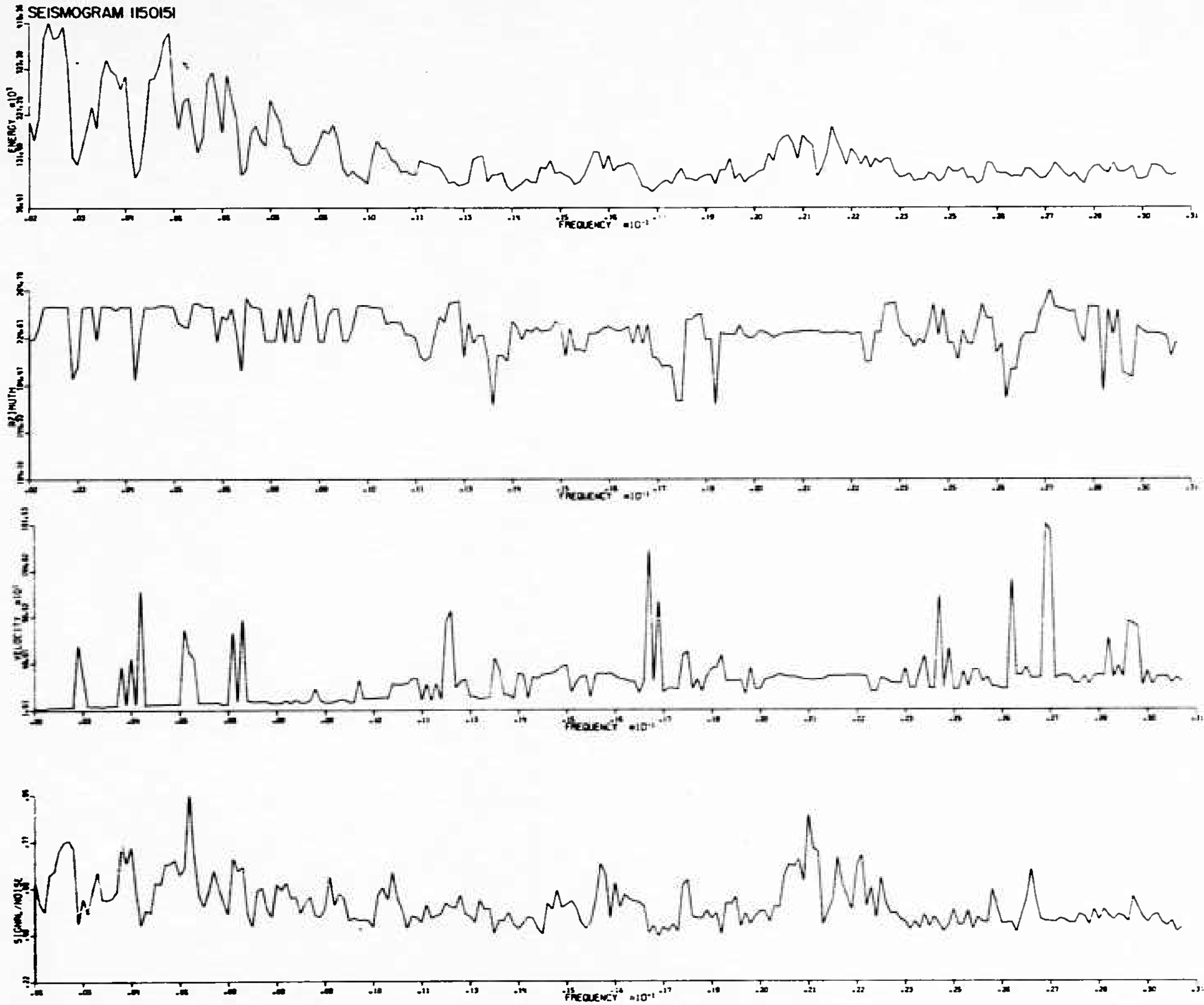

Figure 47. Best-beam spectra for LAMA data, 0115-0223, 31 May 1970.

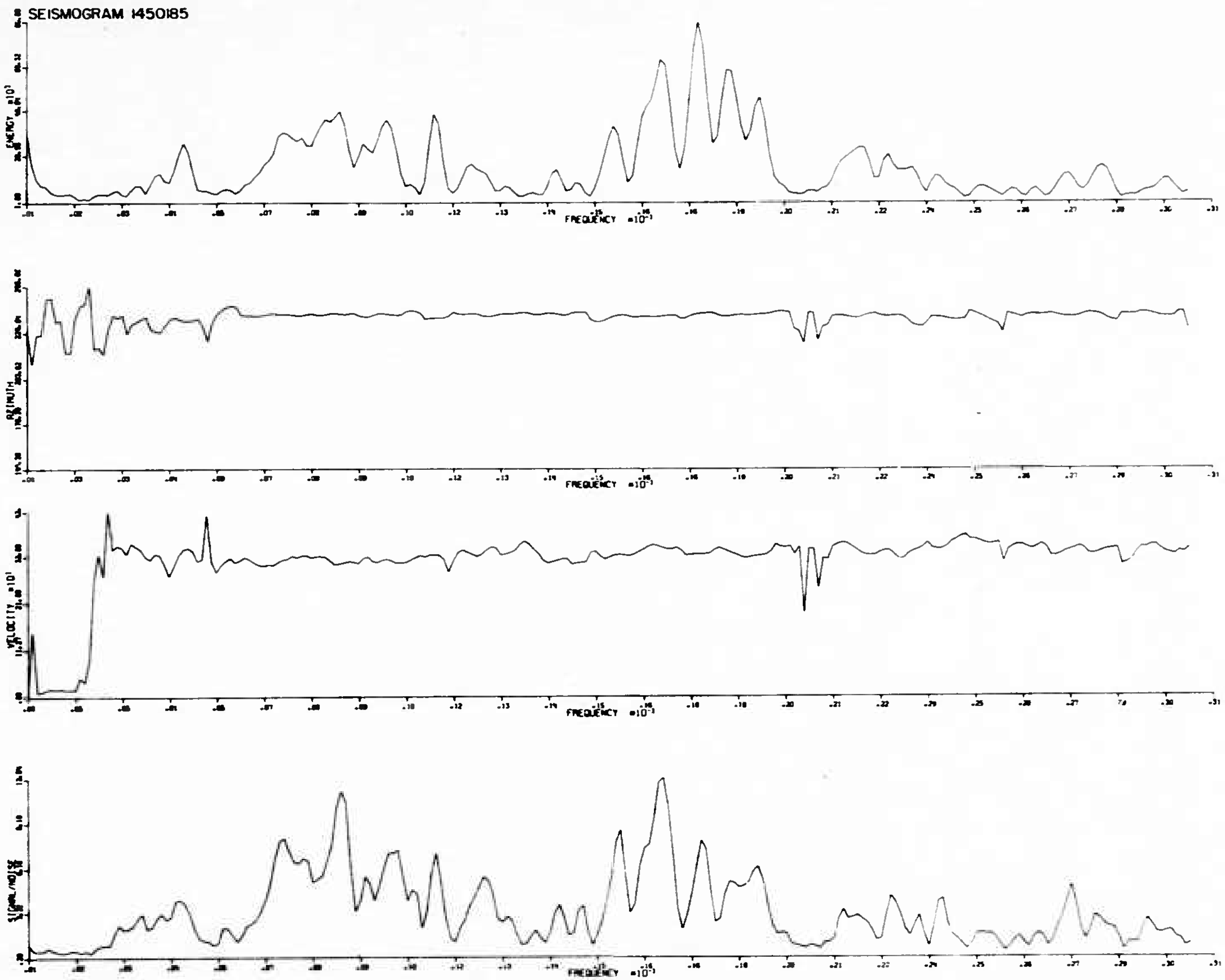

Figure 48. Best-beam spectra for LAMA data, 0145-0253, 4 July 1970.

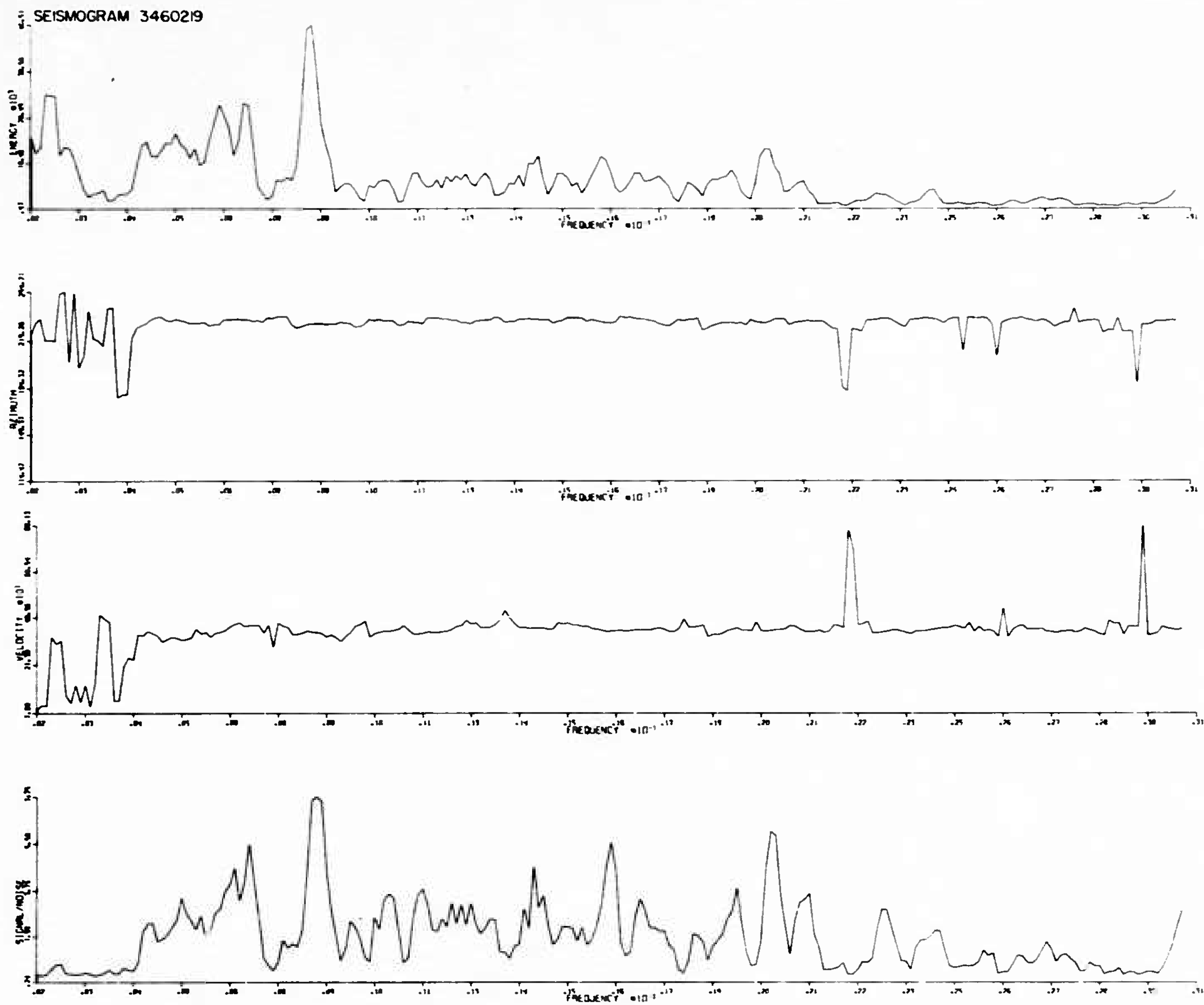

Figure 49. Best-beam spectra for LAMA data, 0346-0454, 7 August 1970.