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LAMONT GEOLOGICAL OBSERVATORY
PALISADES, NEW YORK

Technical Report on Seismology No. 20

[Contract Report No. 19]

Further Study of Atmospheric Pressure Fluctuations Recorded on Seismographs

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(Columbia University)

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by

Maurice Ewing

and

Frank Press

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Abstract

The predominant background disturbance on a long period vertical seismograph is removed by providing compensation for atmospheric pressure fluctuations. A seismically compensated long period microbarograph for study of pressure oscillations in the range 20-2000 seconds is described. Comparison of records from the pressure compensated seismograph and the seismically compensated microbarograph indicates that no significant ground motion is caused by direct coupling of atmospheric pressure fluctuations to the earth. Sample records are shown.

Introduction

Beginning in November 1950 Press and Ewing noticed that simultaneous disturbances were recorded on the long period Benioff seismographs at Palisades and on a newly installed Friez microbarograph.

In a recent paper Crary and Ewing (1952) studied disturbances on the long period vertical Benioff seismograph at Weston, Mass. and a sensitive microbarograph, and concluded that seismograph oscillations accompanying certain barometric disturbances could be accounted for by the effect of changes in atmospheric buoyancy on the inert mass of the seismograph and did not represent earth movements. The present investigation was undertaken to confirm this conclusion and to examine three problems which are affected by it. (1) The development of a buoyancy compensated long period vertical seismograph ($To \cong 10$ sec $Tg = 75$ sec) would eliminate atmospheric pressure fluctuations as a major source of background noise and permit study of weak long period seismic disturbances. (2) The construction of a device for the study of atmospheric pressure fluctuations in the period range 20–2000 seconds, completely compensated for seismic movements, would facilitate study of atmospheric turbulence and wave propagation. (3) The comparison of records from a buoyancy compensated seismograph and a seismically compensated microbarograph offers a direct test of the suggestion made by some investigators that significant ground motion is caused by direct coupling of atmospheric pressure fluctuations to the earth.

The general question of transfer of energy from the atmosphere to the earth is of fundamental importance in all theories of the generation of microseisms. The results of this study confirm the theoretical prediction of very small coupling based on great contrast in acoustical impedance and also the empirical observation that storms over land are relatively ineffectual in producing microseisms.

The uncompensated seismometer had been built a few months before the present study started. Its usefulness was limited by severe background noise, which now has been greatly reduced by buoyancy compensation.

The seismically compensated microbarograph was constructed to measure the atmospheric pressure fluctuations and prove that the indications of the seismograph agreed quantitatively with those calculated from buoyancy effects. Thus, the indications of the uncompensated seismograph were spurious, in that they did not correspond to ground motion.

In the next step, buoyancy compensation was added to the seismograph, and the expected improvement in background noise level was realized. The compensated instrument has proved to be extremely valuable for earthquake study, and details of its performance will be given in a later paper.

Comparison of simultaneous recordings of the microbarograph with first the uncompensated seismograph and later the compensated seismograph form the basic data of the present paper.

The Microbarograph

This instrument (Figure 1) consists of two equal hollow cylinders attached to the ends of a horizontal boom. The boom is free to oscillate about a horizontal axis at midpoint transverse to the length. One of the cylinders is sealed and the other is open to the atmosphere. Consequently atmospheric density changes accompanying pressure fluctuations induce oscillations in the system. The free period of the system is adjusted by varying the distance of the center of gravity below the center of suspension. Recording is accomplished by the use of electromagnetic transducers in push-pull arrangement directly coupled to a Benioff long period galvanometer. Damping of the pendulum and galvanometer and magnification is adjusted by varying the shunt and series resistance of the coupling network between the galvanometer and transducer. Expressions for dynamic magnification and phase changes may readily be derived in a manner analagous to the corresponding expressions for the seismograph (Chakrabarty, 1949). The operating constants for the instrument at the Lamont Geological Observatory in Palisades, New York are pendulum period $T_o = 10.5$ sec, pendulum damping $\epsilon = 3.56$ sec^{-1}, galvanometer period $T_g = 76$ sec, galvanometer damping $\epsilon_g = .10$ sec^{-1}. A calibration curve is shown in Figure 2, in which isothermal pressure variations are assumed. Greater sensitivity is available simply by adjusting the coupling network. Vertical movements of the ground are of course dynamically balanced out, and horizontal movements have negligible effect.

Many investigators have recognized that pressure fluctuations shown by a sensitive microbarograph are useful in aerological studies for identifying various types of air masses. (See for example Bernasconi and Bossolasco, 1951.)

Figure 3A shows a recording made by the microbarograph on March 4-5, 1952. The trace has been widened for emphasis for the hour 2100-2200 EST. Beginning at 21:06 the instrument records large amplitude pressure oscillations of about 10 minute period due to the passage of a pressure jump associated with a squall line. The corresponding record made by the standard Friez microbarograph is shown in Figure 3B. It is seen that the new microbarograph permits more detailed study of the damped oscillations following the pressure jump. It is interesting to note that the prominent short period turbulent pressure fluctuations disappear almost immediately after the passage of the pressure jump. Tepper (1951) proposes that pressure jump phenomena are intimately related to the production of squall lines and tornadoes.

Figure 6B shows trains of long sinusoidal waves of periods up to 10 minutes recorded on the microbarograph. The nature of these waves has not yet been established and is the subject of further investigation.

The Compensated Seismograph

The Columbia University long period seismograph was constructed to provide instrumentation for the study of long period

Rayleigh waves. The seismometer incorporates a design originally suggested by Lacoste (1934) for the use of a zero length spring. It is presently operated with $T_o = 10$ sec and $T_g = 75$ sec, the galvanometer and seismometer being critically damped. Operation of the pendulum at long periods is readily attainable.

Shortly after installation in November 1951, it was noticed that the predominant long period noise level recorded by the instrument was related to atmospheric pressure fluctuations and that the noise level was greater by an order of magnitude than that recorded on the Benioff long period seismograph ($T_o = 1$ sec, $T_g = 76$ sec). It seemed almost certain that these were the buoyancy effects mentioned above and that they were more serious for this instrument than for the Benioff as theory would predict. The microbarograph was built to settle the question.

Comparison of records from the microbarograph and the seismograph verified the calculations. Figure 4 shows recordings from the uncompensated seismograph (A) and microbarograph (B), aligned in time for January 19-20, 1952. Typical pressure fluctuations and the corresponding seismographic disturbances are indicated by letters. It is seen that there is an almost perfect time, wave shape and phase correspondence between the two instruments, pressure increases being accompanied by upward motion of the seismometer boom (downward motion of the ground). Moreover, teleseismic motion recorded by the seismograph, as indicated by the earthquake surface waves, are absent on the microbarograph.

The seismograph was subsequently compensated for pressure fluctuations in a manner similar to the compensation of gravity meters. A sealed one liter chemical flask was attached to an extension of the boom on the side of the hinge opposite the inert mass (Figure 5). The distance from the flask to the hinge was determined so as to exactly balance out the torque of the buoyant force, due to the inert mass, boom, and coil. Simultaneous records from the compensated seismograph and the microbarograph are shown in Figure 6A and B respectively. Unlike the records of Figure 4, atmospheric pressure fluctuations recorded on the microbarograph are absent on the compensated seismograph.

Large amplitude short period pressure fluctuations are recorded occasionally on the compensated seismograph -- in phase with the corresponding disturbance on the microbarograph (ground moves up with increase of pressure). Prior to compensation these disturbances were out of phase on the two instruments. It is believed that the compensated seismograph responds to these oscillations since the center of buoyancy is at the hinge (consisting of two wires in tension), and vertical motion at the hinge introduces an alternative mode of vibration which is pronounced near the free period of the pendulum. This effect can be removed by providing a suitable hinge constrained to rotations only or by placing the seismometer in a case of sufficiently tight construction to exclude the shorter period pressure fluctuations.

Conclusions

1. Great improvement in the performance of a long period vertical seismograph has been obtained by elimination of the effect of buoyancy of the atmosphere. A further report on the performance of this seismograph is in preparation.

2. A sensitive microbarograph suitable for the study of atmospheric pressure fluctuations in the period range 20 to 2000 sec has been constructed. It records the strong turbulence associated with some air masses, and also records trains of sinusoidal waves, periods 3 to 20 minutes, which are the object of future study.

3. Simultaneous operation of the seismograph and the microbarograph confirm the theory that energy transfer between atmosphere and earth is very slight. Properly compensated instruments separate in a perfectly definite way atmospheric disturbances from earth disturbances. The only cases in which energy transfer has been shown to exceed that predicted from simple considerations of acoustical impedance contrast are those of resonant coupling reported by Press and Ewing (1951) and Benioff, Ewing, and Press (1951).

Acknowledgments

The microbarograph was constructed by Angelo Ludas from initial drawings by Bernard Luskin with modifications by Vincent Jennemann. The long period compensated seismograph was constructed by Louis Collyer. Harold Smith aided in the installation and operation of the instruments. We are grateful to the U. S. Weather Bureau for their cooperation in this project.

References

L. J. B. Lacoste, Jr., "A New Type Long Period Vertical Seismograph", Physics, Vol. 5, 178-180 (1934).

S. K. Chakrabarty, "Response Characteristics of Electromagnetic Seismographs and Their Dependence on the Instrumental Constants", Bull. Seism. Soc. Amer., Vol. 39, 205-218 (1949).

M. Tepper, "A Proposed Mechanism of Squall Lines: the Pressure Jump Line", Journ. of Met., Vol. 7 (1950).

H. Benioff, M. Ewing, and F. Press, "Sound Waves in the Atmosphere Generated by a Small Earthquake", Proc. Nat. Acad. Sciences, Vol. 37, 600-603 (1951).

C. Bernasconi and M. Bossolasco, "Le Barovariographe comme Appareil de Sondage Aerologique", Geofisica Pura e Applicata, Vol. XX, 197-202 (1951).

F. Press and M. Ewing, "Ground Roll Coupling to Atmospheric Compressional Waves", Geophysics, Vol. 16, 416-430 (1951).

A. P. Crary and M. Ewing, "On a Barometric Disturbance Recorded on a Vertical Long Period Seismograph", in press Trans. Amer. Geophys. Union (1952).

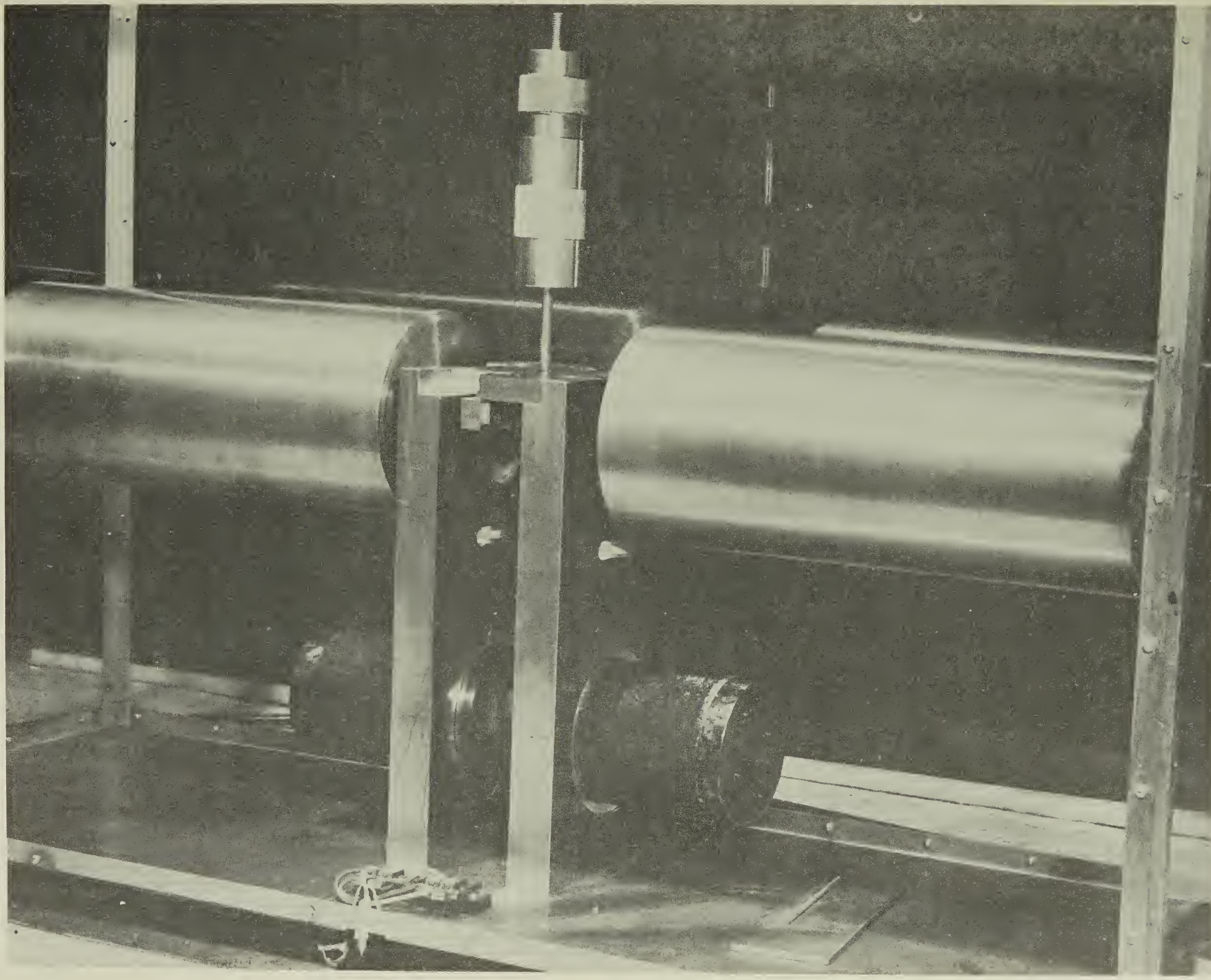


Figure 1 - Seismically compensated microbarograph.

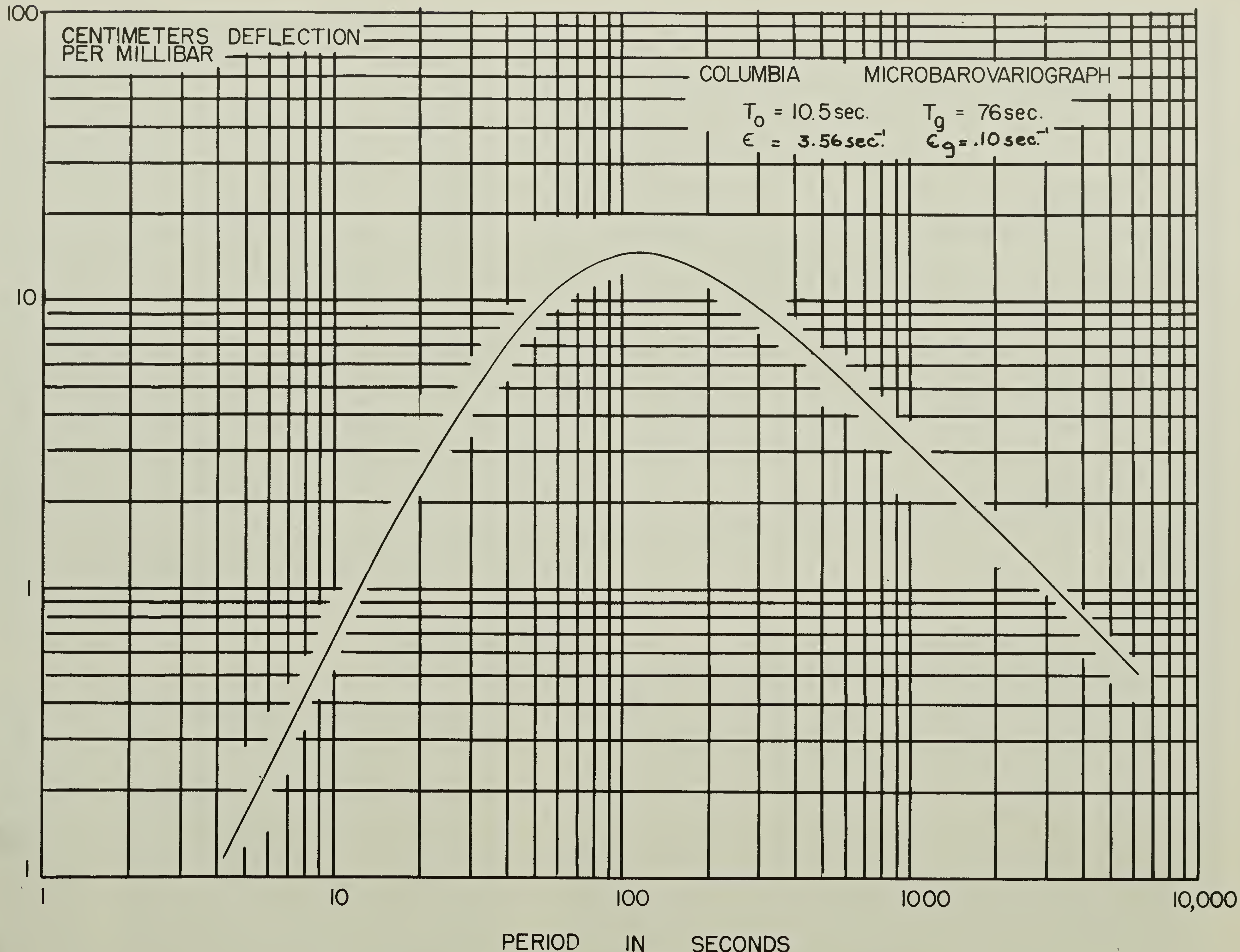
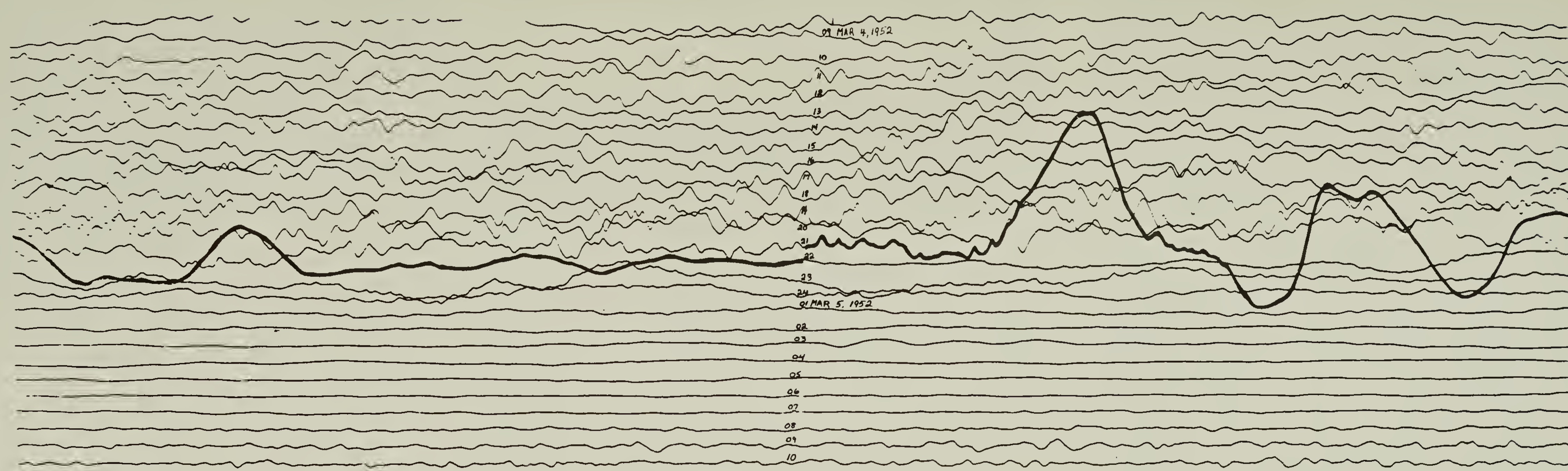
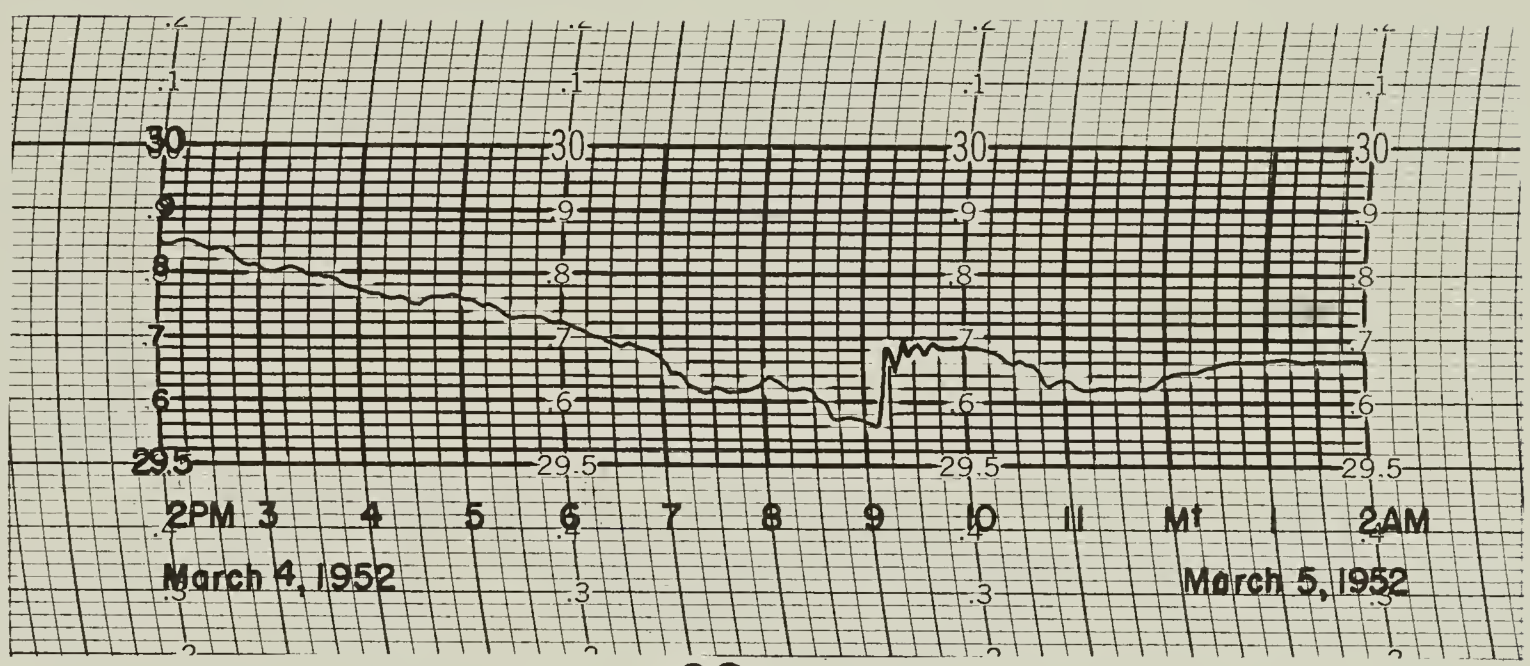


Figure 2 – Calibration curve of microbarograph assuming isothermal pressure variations.



3A



3B

Figure 3 - Recording of pressure jump on new microbarograph (A) and standard Friez microbarograph (B). Time marks are at 1 min. intervals in 3A.

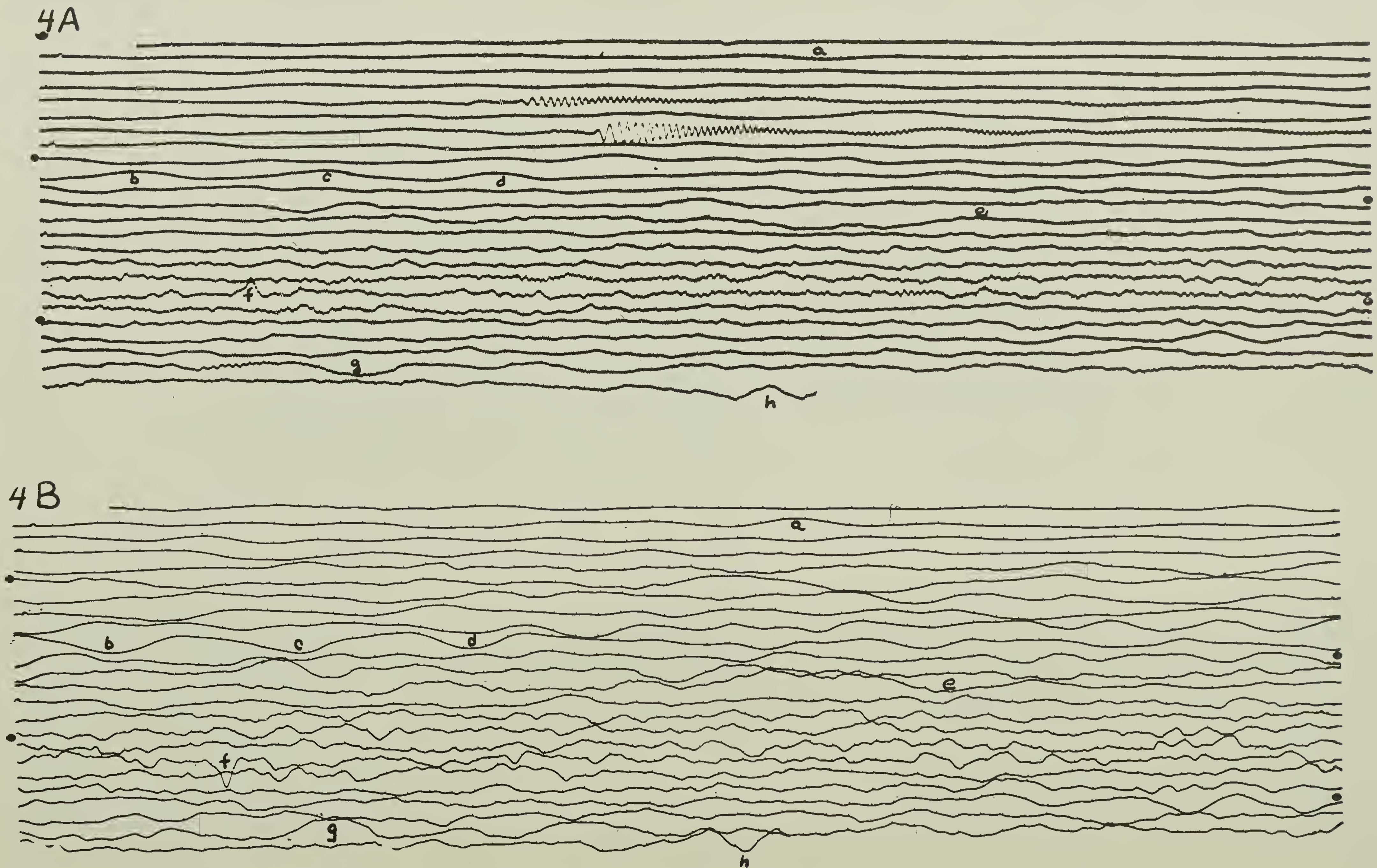


Figure 4 – Simultaneous recordings from the uncompensated seismograph (A) and the microbarograph (B) for Jan. 19–20, 1952. Upward trace motion corresponds to pressure increase and ground up. Time marks are at 1 min. intervals.

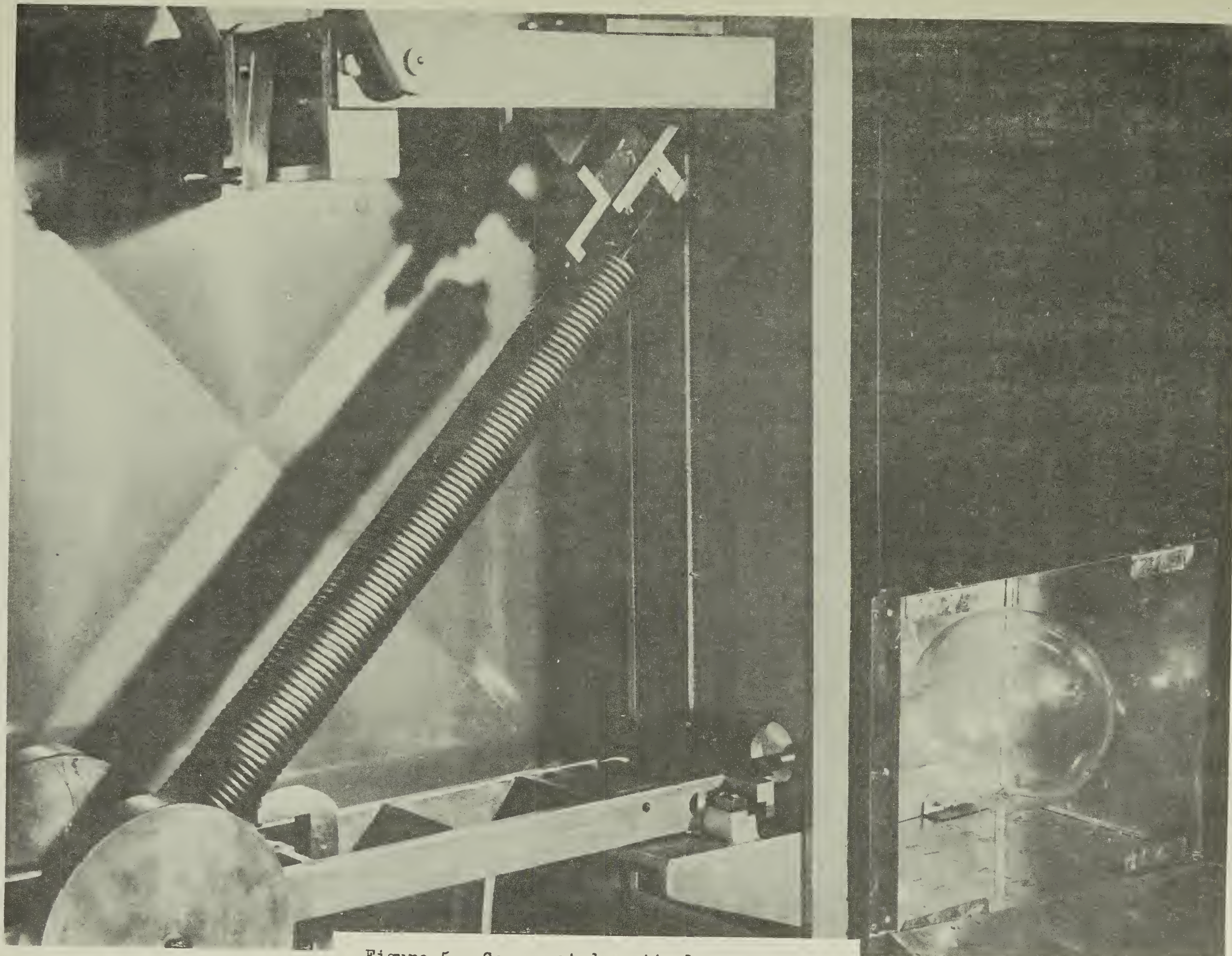
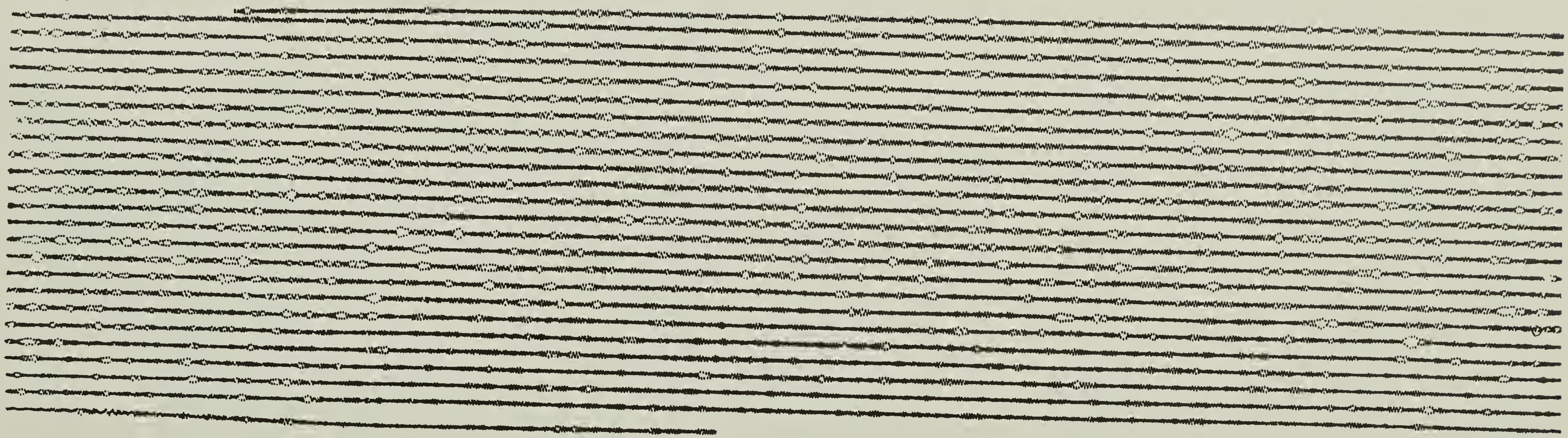


Figure 5 - Compensated vertical seismograph.

6A



6B

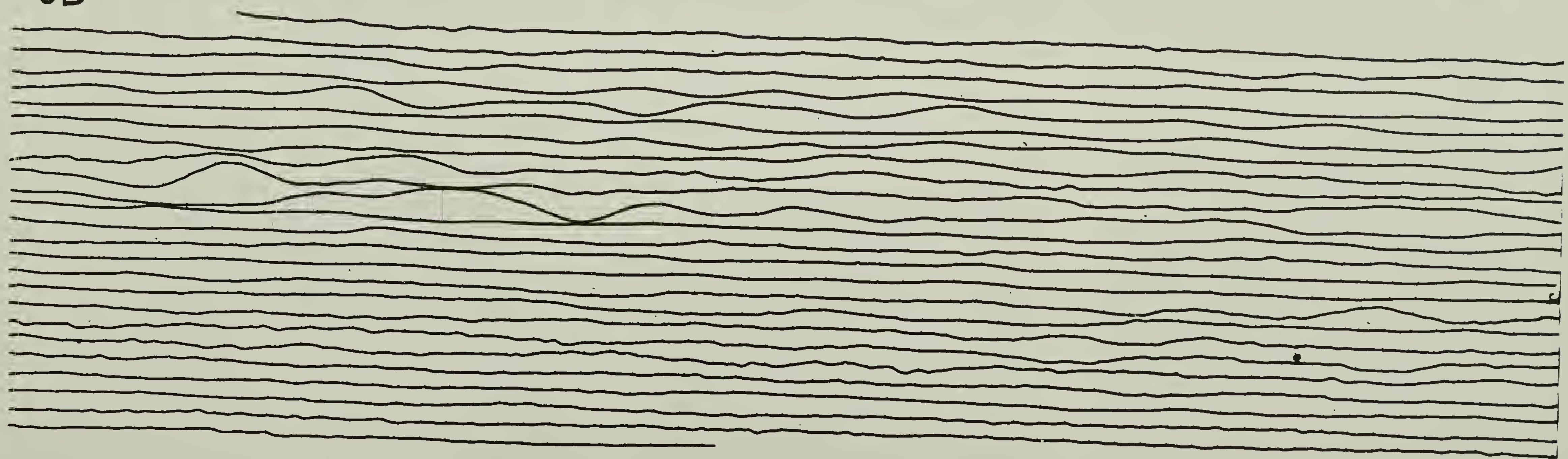


Figure 6 – Simultaneous recordings from the compensated seismograph (A) and the microbarograph (B) for Feb. 20–21, 1952. Time marks are at 1 min. intervals.