THE UNIVERSITY OF MICHIGAN
COLLEGE OF ENGINEERING
Department of Civil Engineering

Progress Report

PUNCHED CARD ACCELEROGRAMS OF STRONG-MOTION EARTHQUAKES

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INTRODUCTION

The strongest U. S. earthquakes for which accelerograms have been obtained to date are:

El Centro, California	December 30, 1934
El Centro, California	May 18, 1940
Olympia, Washington	April 13, 1949
Taft, California	July 21, 1952

The accelerograms of the three components of motion of each of these earthquakes have been reduced to punched card form to enable them to be used in high-speed computers.

ACKNOWLEDGMENT

These punched card accelerograms have been produced from accelerogram prints furnished by the U. S. Coast and Geodetic Survey. Electronic computation was performed in The University of Michigan Computing Center. This work is part of a research project of The University of Michigan Research Institute, under the direction of the Civil Engineering Department, and sponsored by the National Science Foundation.

THE ACCELEROGRAMS

The punched card accelerograms described herein are piecewise linear approximations of recorded accelerograms. A strong-motion accelerogram is essentially a broken line diagram, especially during the strongest part of the ground motion. The error in the piecewise linear approximation is probably not large compared with the error in the accelerogram itself.

To obtain the piecewise linear functions, the time-acceleration coordinates of the intersection points of successive line segments were put on punched cards. The number of points required to describe the significant part (about 30 seconds) of an accelerogram ranged from 380 to 710. An arbitrary zero axis was selected, and the coordinates were scaled from the record using an arbitrary scale of measurement. The resulting data were then processed by computer to introduce appropriate scale factors for time and acceleration and to translate the axis so that with zero initial conditions the terminal velocity would be zero. It was believed at first that this process might yield acceptable accelerograms without further refinement. However, the preliminary ground displacement curves obtained by integrating the accelerograms at this stage left no doubt that other adjustments would be necessary. Maximum displacements ranged all the way from several centimeters to nearly three meters!

The preliminary displacement curves were found to be roughly the shape of a third-degree polynomial. The four conditions which had been arbitrarily assigned, namely, the initial velocity, initial displacement, and location and direction of the axis, would in themselves account for a cubic displacement curve. Therefore, the most logical remedy for the unacceptably large displacements lay in the choice of these conditions.

There is no way to determine the true value of any of these conditions from the accelerogram. The axis can be located approximately, but a minute translation or rotation of the axis can lead to an enormous terminal displacement. The initial velocity and displacement may be nonzero because the ground motion must be strong enough to trigger the recording mechanism before the record starts. The terminal displacement also may be nonzero, as is occasionally evidenced by visible surface displacements at the end of a strong-motion earthquake. Nor can zero terminal velocity be claimed, because only the first 30 seconds or so of the record were used for each punched card accelerogram. Beyond that time the accelerations were not great enough to be of importance in structural analysis.

In keeping with the idea that displacements remain small throughout an earthquake, the four conditions were chosen to minimize the mean square displacement, i.e., to make $\int_0^L y^2\,dt$ a minimum, where y is the ground displacement found by integration, and L is the length of the punched card accelerogram. Admittedly there is no basis for claiming this to be the best approach. Nevertheless, it leads to results which seem acceptable and no better criteria are apparent.

THE PUNCHED CARDS

Figure 1 shows a typical initial card, which specifies the initial velocity, initial displacement, length of the accelerogram, number of cards in the accelerogram, and an index number identifying the earthquake component.

Figure 2 shows a typical accelerogram card. It contains a card number, the time-acceleration coordinates of four successive accelerogram points, and the earthquake index.

RESULTS

The velocity and displacement curves obtained by integrating the final punched card accelerograms are shown in Figs. 3 to 10. Figures 11 to 14 show the ground motion plotted as the horizontal trajectory of a point on the ground surface.

Differences between these results and previously published results can be found. Yet the characteristics of these curves agree reasonably well with those obtained by others. It is believed that these accelerograms are sufficiently accurate for purposes of structural research, and for some aspects of seismological research as well.

The use of punched card accelerograms in research permits comparison of the results of independent research efforts with the certainty that any correlation (or lack thereof) has not been affected by differences in the input data. This in itself appears to be a worthwhile benefit.

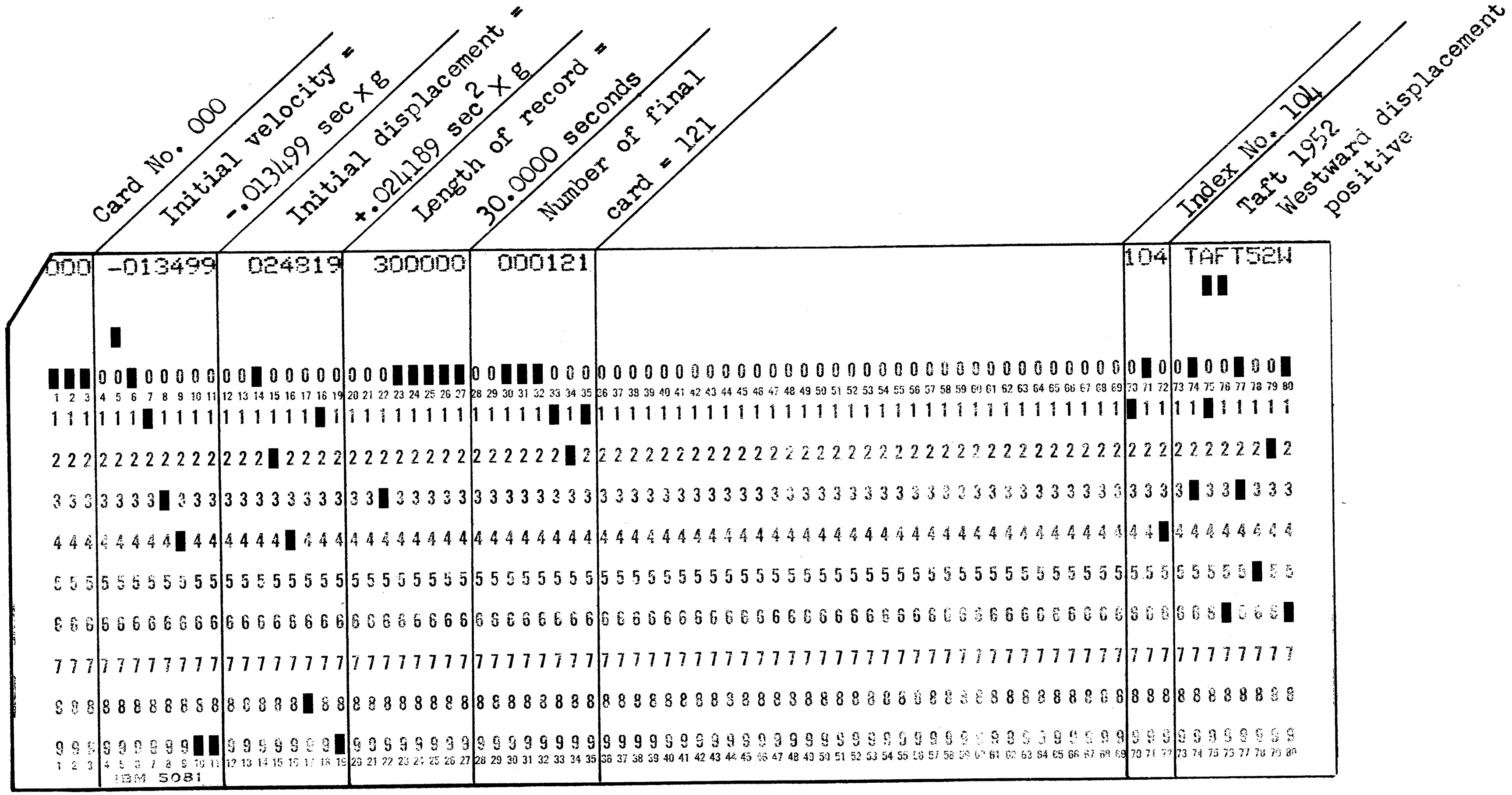

Fig. 1. Initial conditions card.

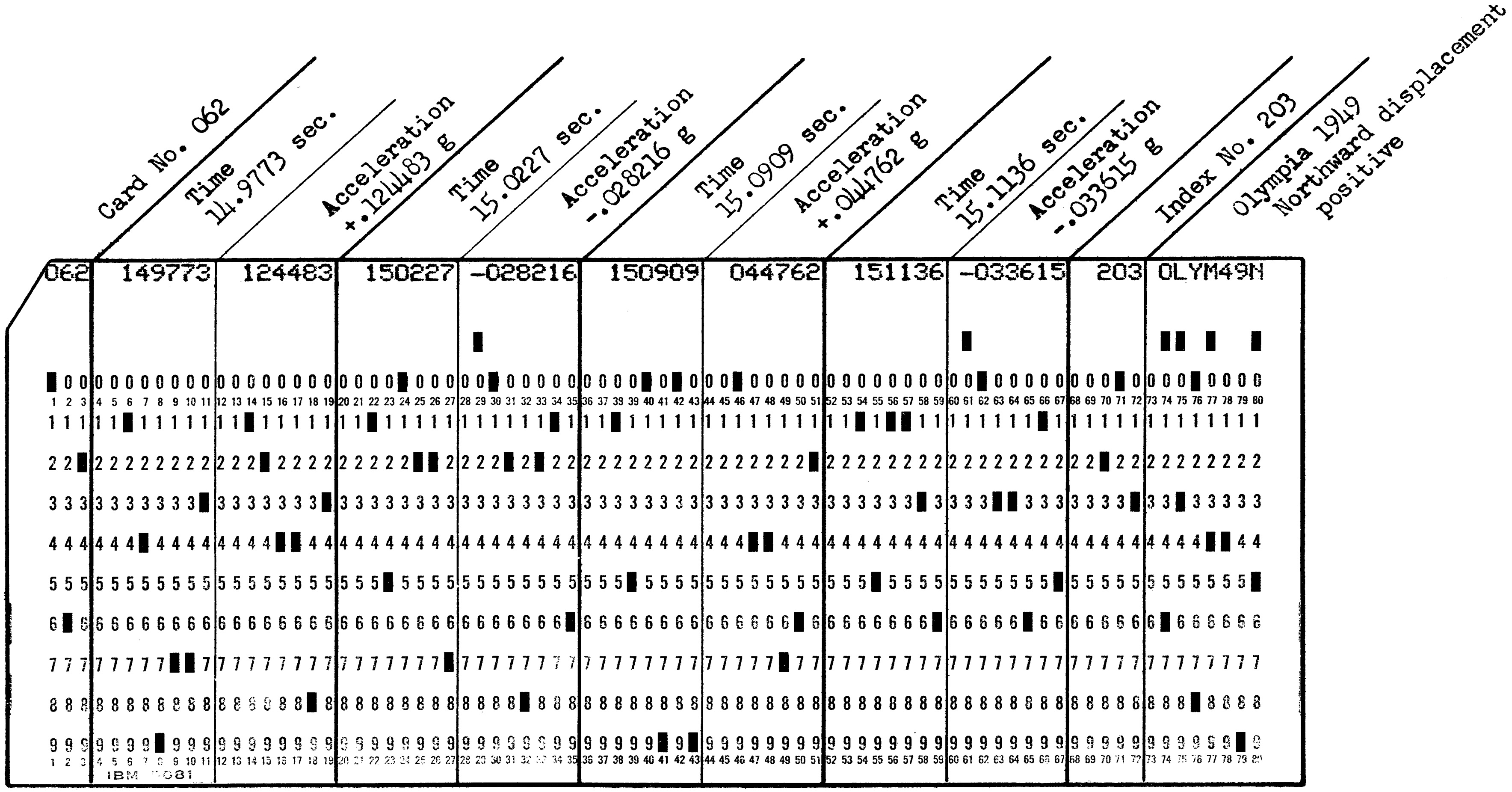

Fig. 2. Accelerogram card.

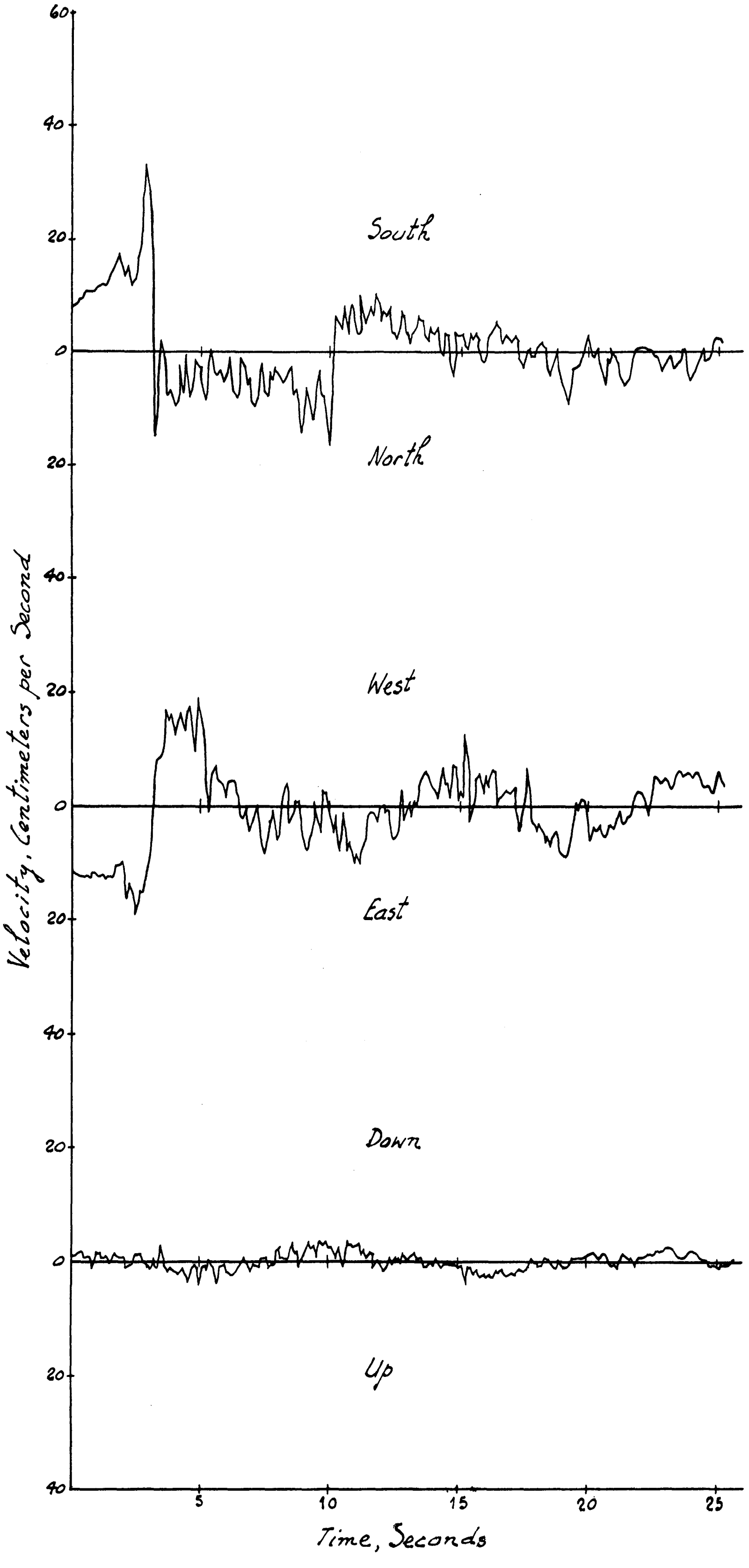

Fig. 3. Ground velocities, El Centro, California, December 30, 1934.

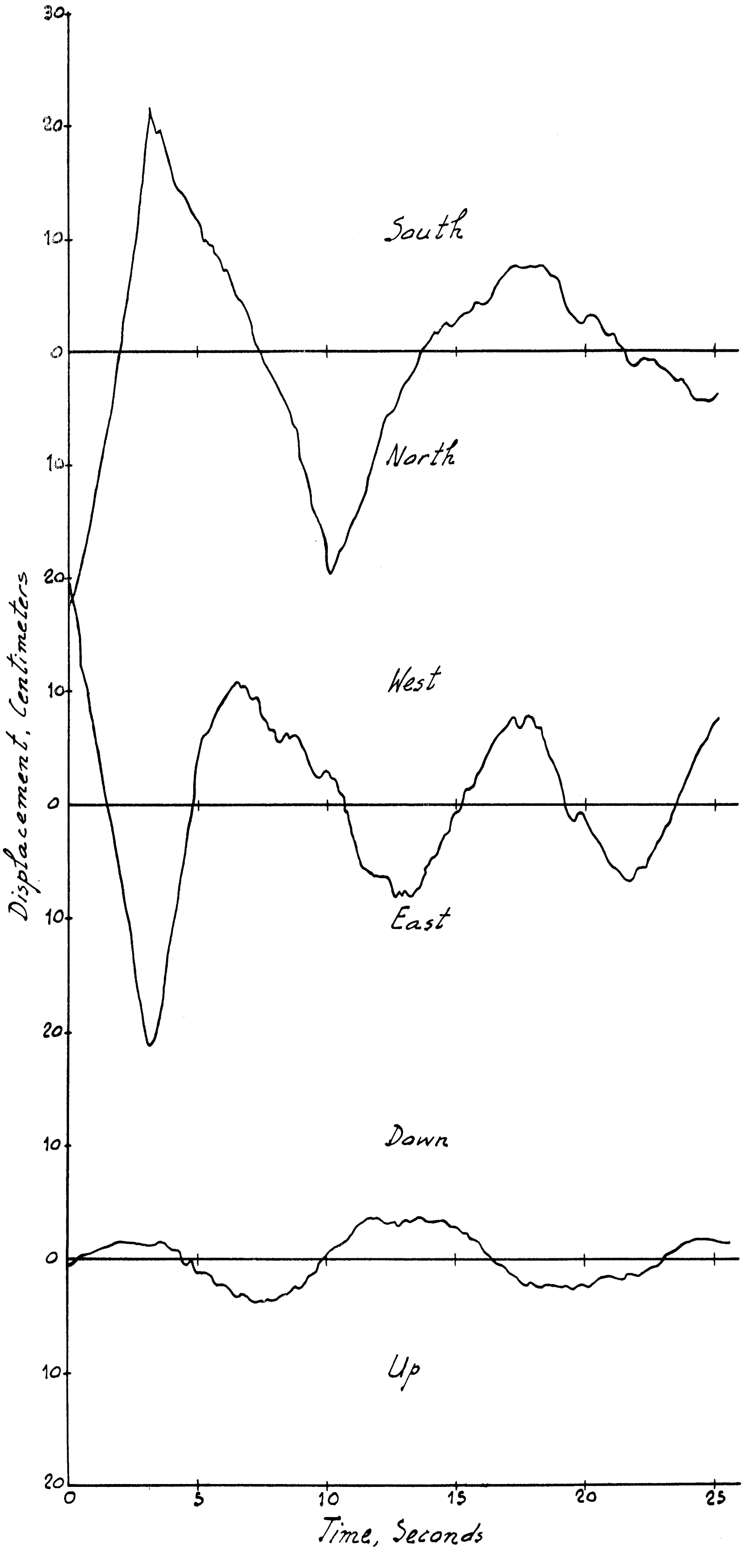

Fig. 4. Ground displacements, El Centro, California, December 30, 1934.

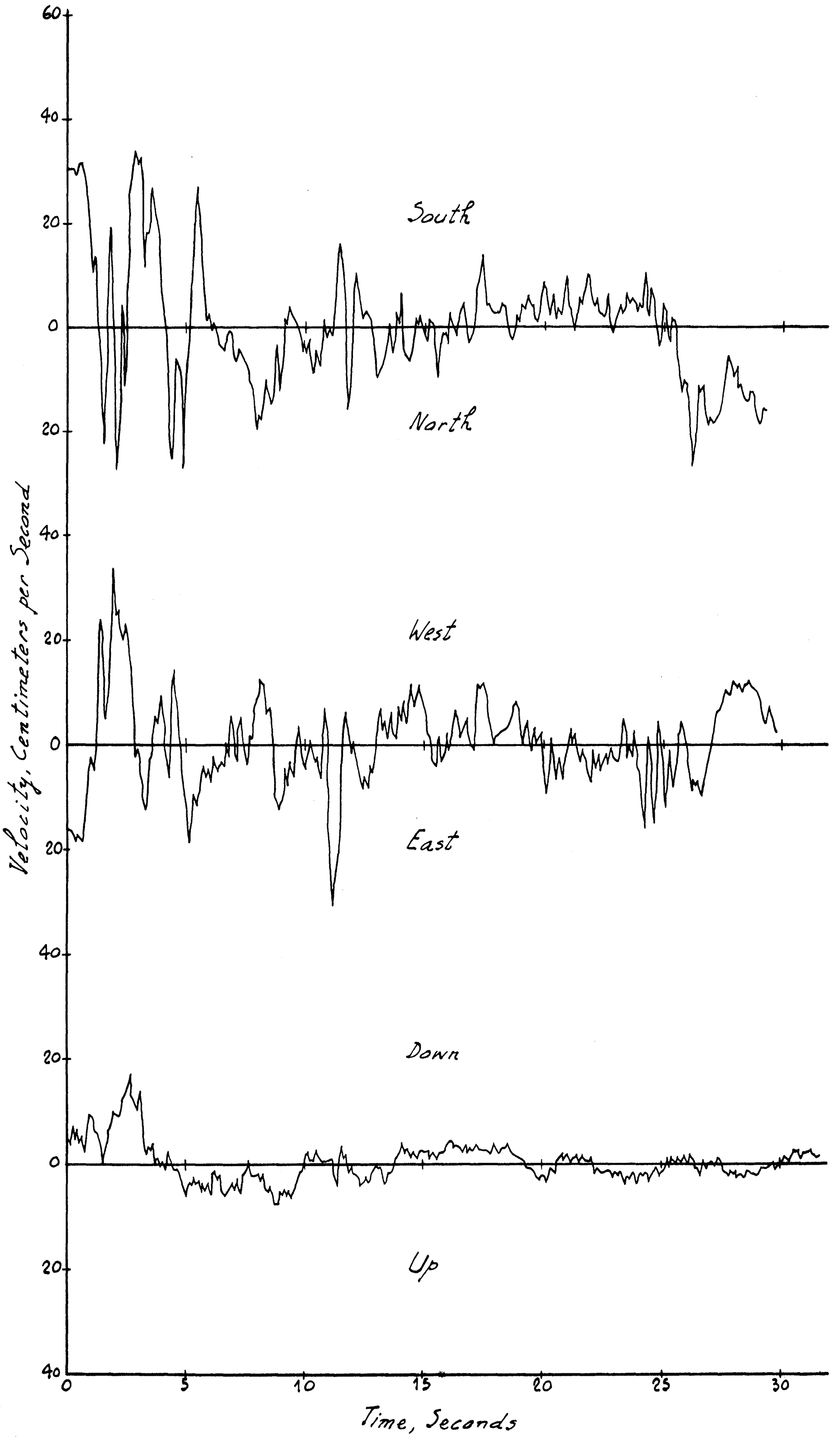

Fig. 5. Ground velocities, El Centro, California, May 18, 1940.

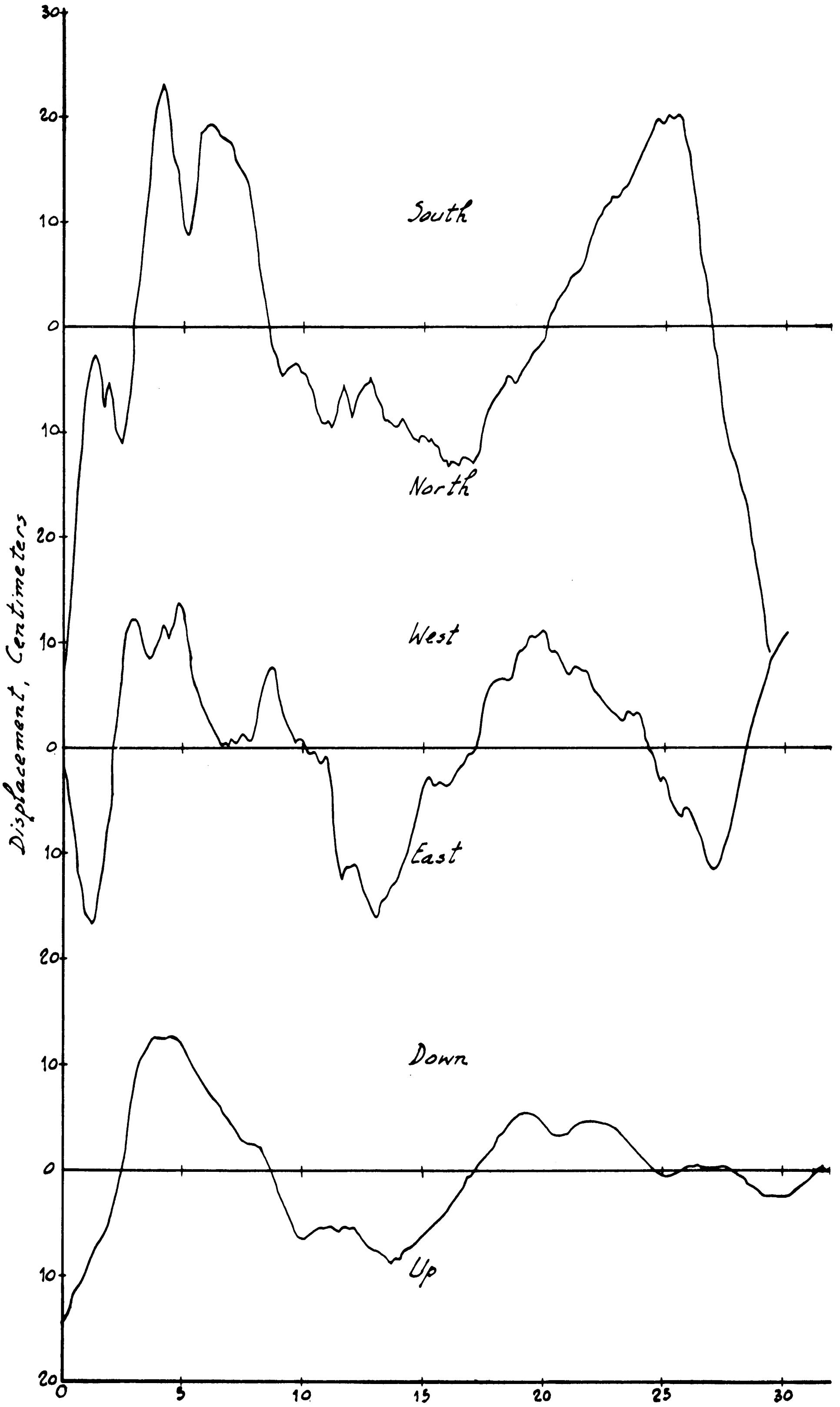

Fig. 6. Ground displacements, El Centro, California, May 18, 1940.

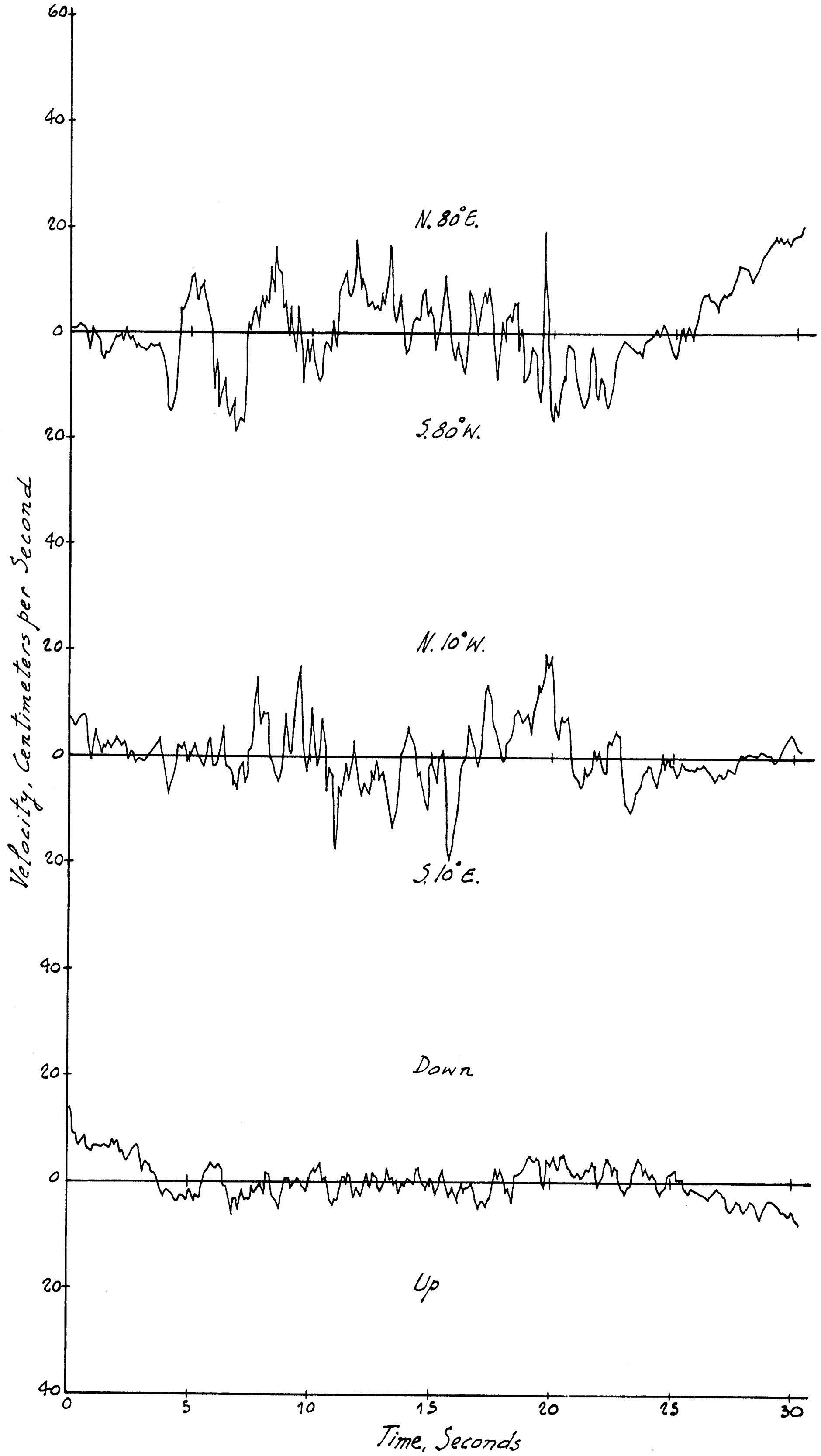

Fig. 7. Ground velocities, Olympia, Washington, April 13, 1949.

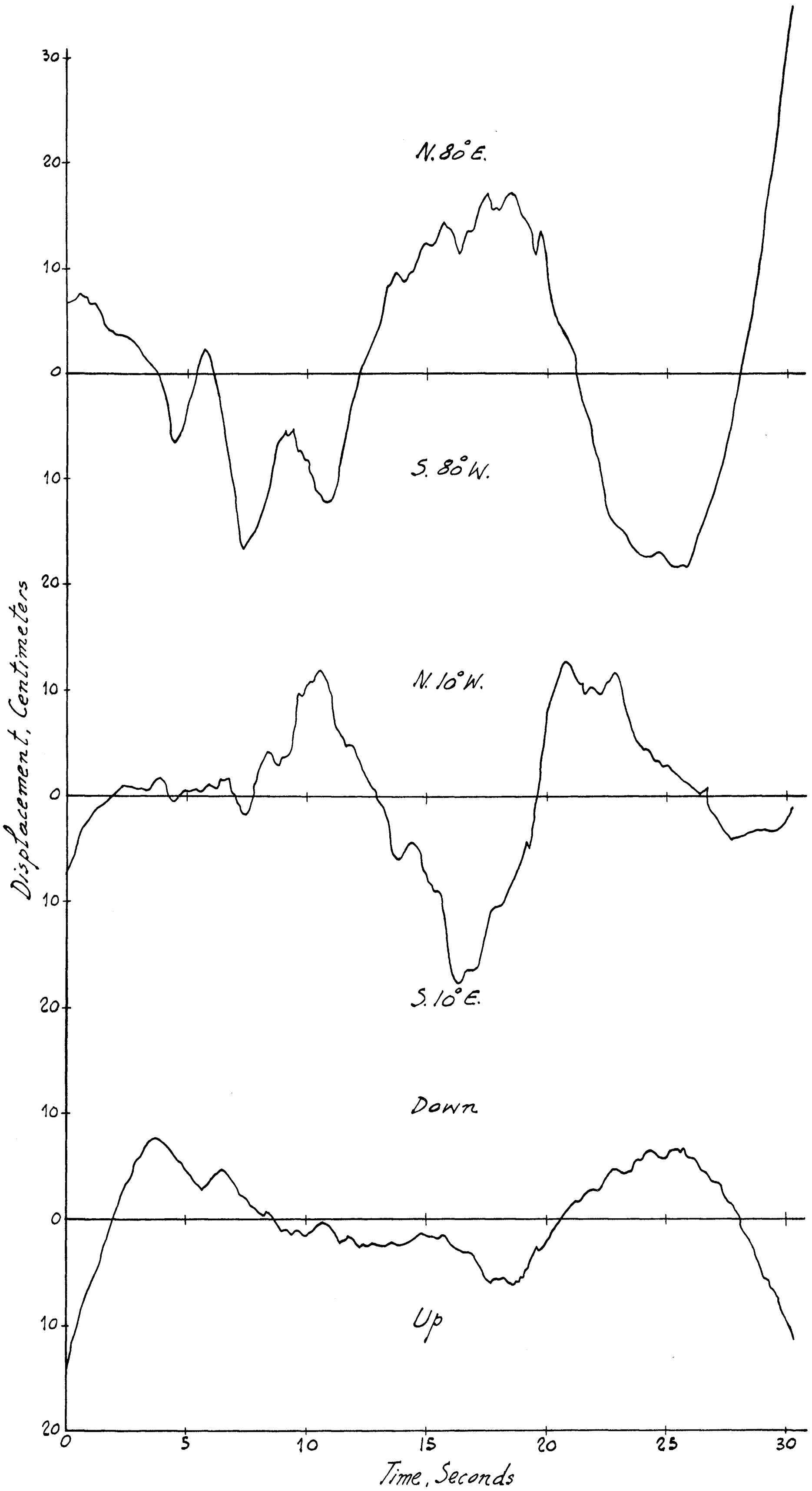

Fig. 8. Ground displacements, Olympia, Washington, April 13, 1949.

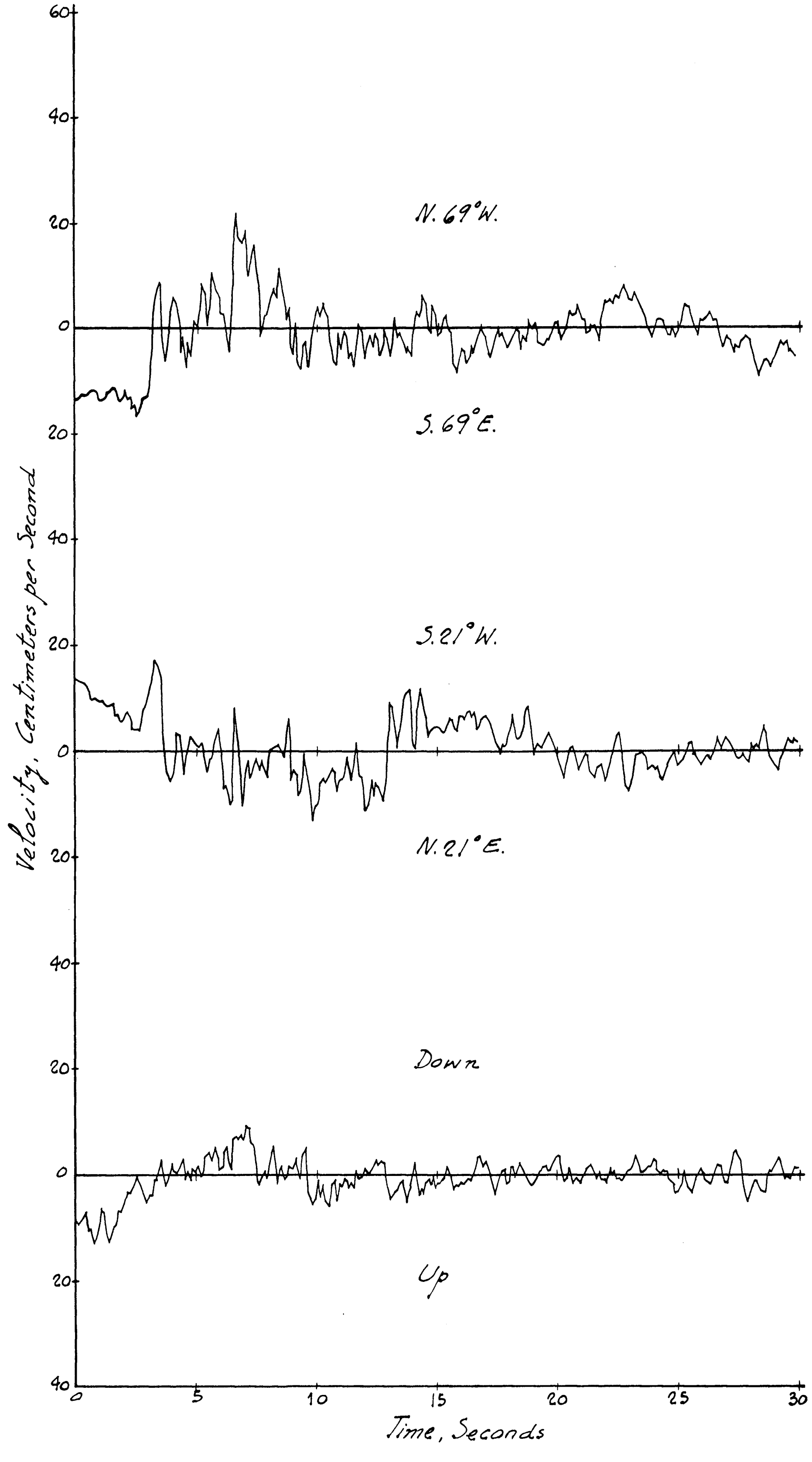

Fig. 9. Ground velocities, Taft, California, July 21, 1952.

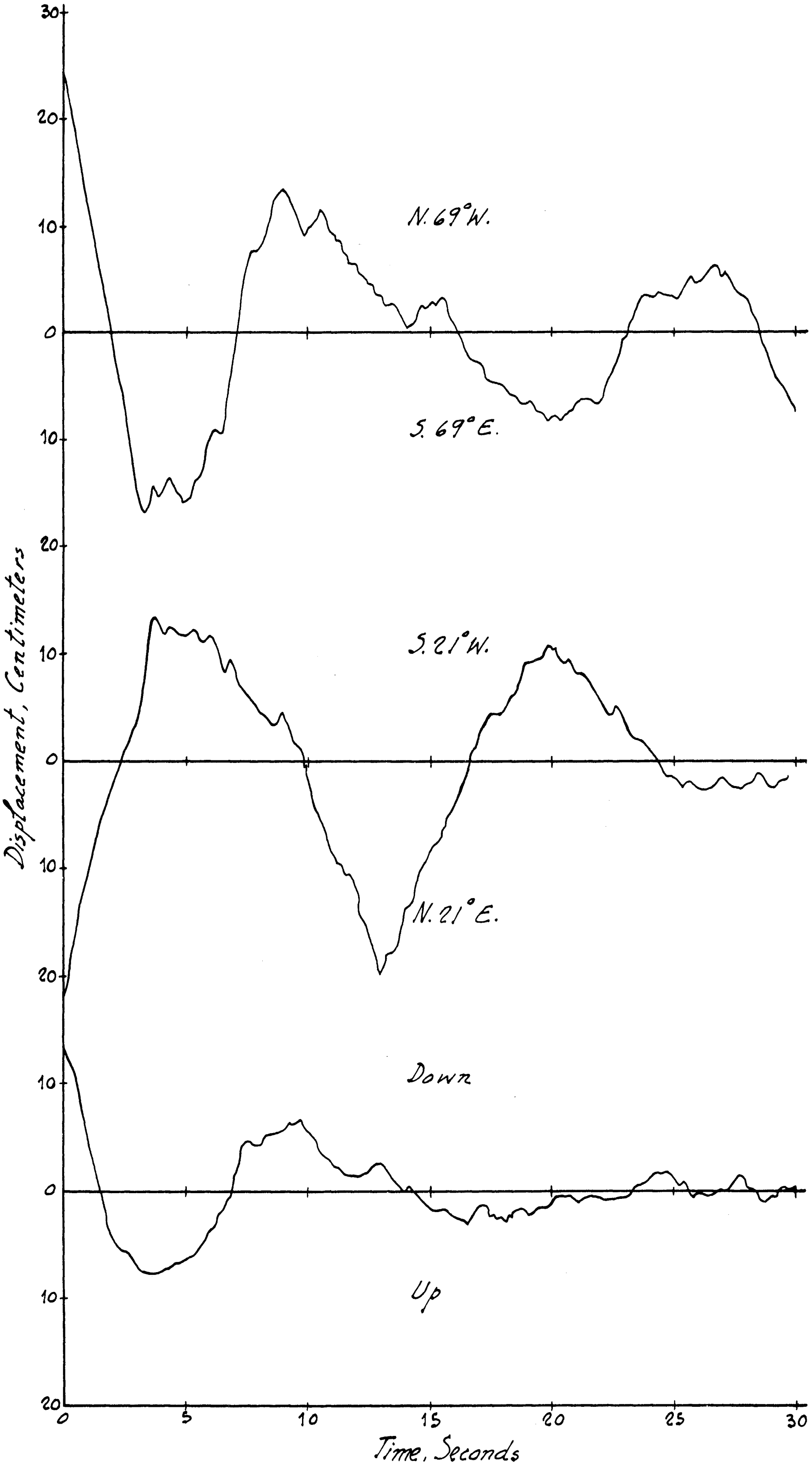

Fig. 10. Ground displacements, Taft, California, July 21, 1952.

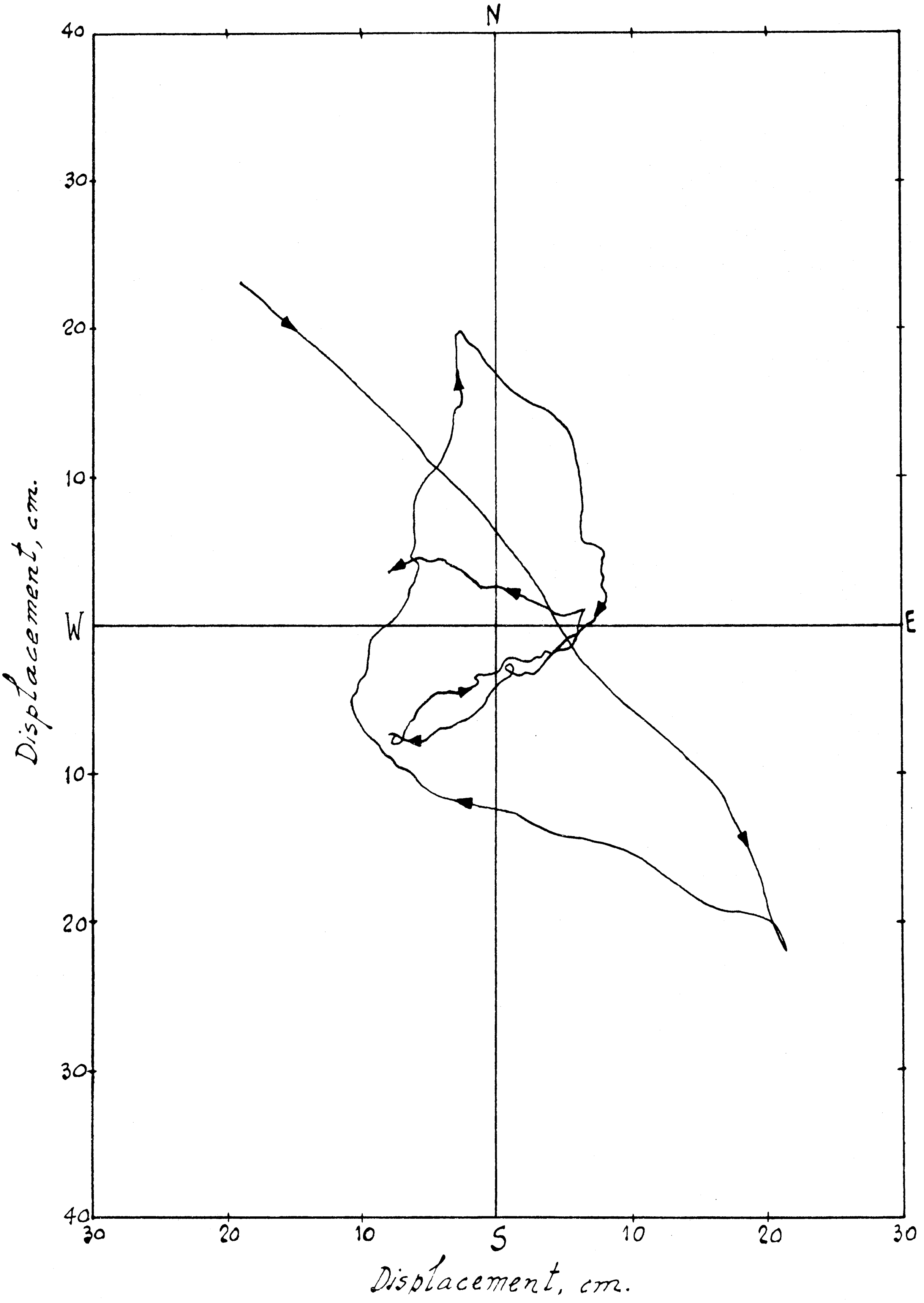

Fig. 11. Trajectory of horizontal ground displacement, El Centro, California, December 30,

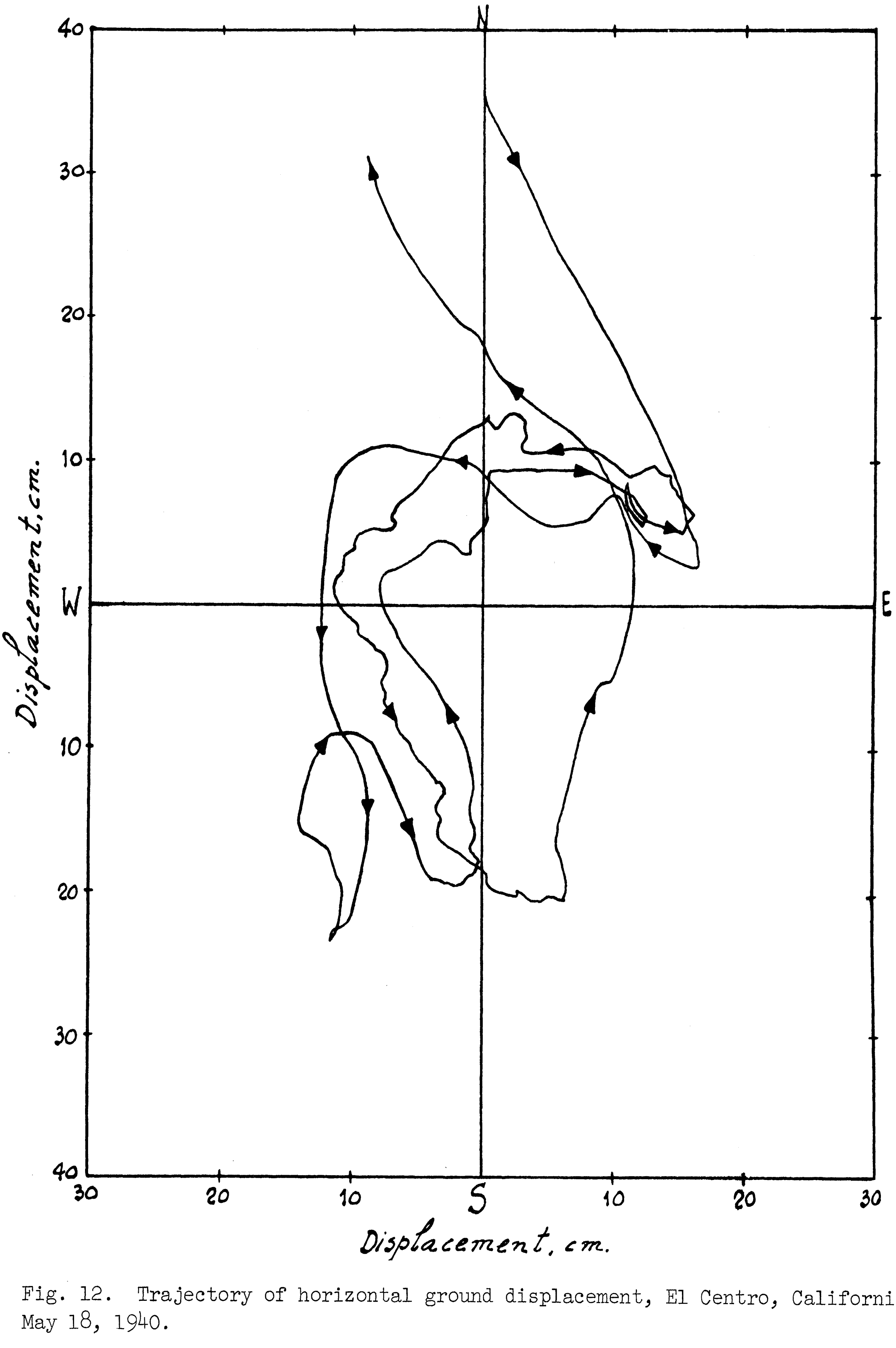

Fig. 12. Trajectory of horizontal ground displacement, El Centro, California, May 18, 1940.

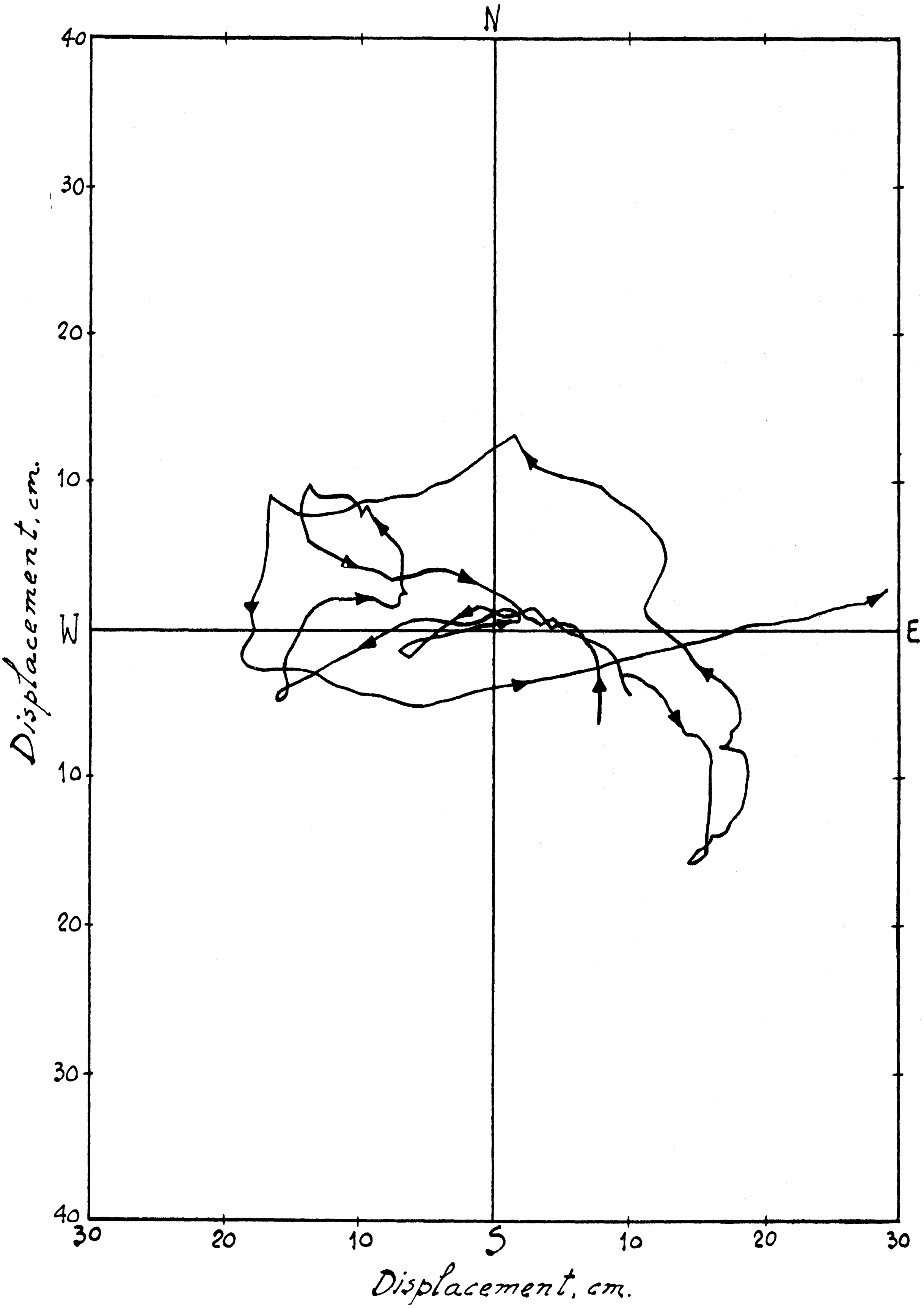

Fig. 13. Trajectory of horizontal ground displacement, Olympia, Washington, April 13, 1949.

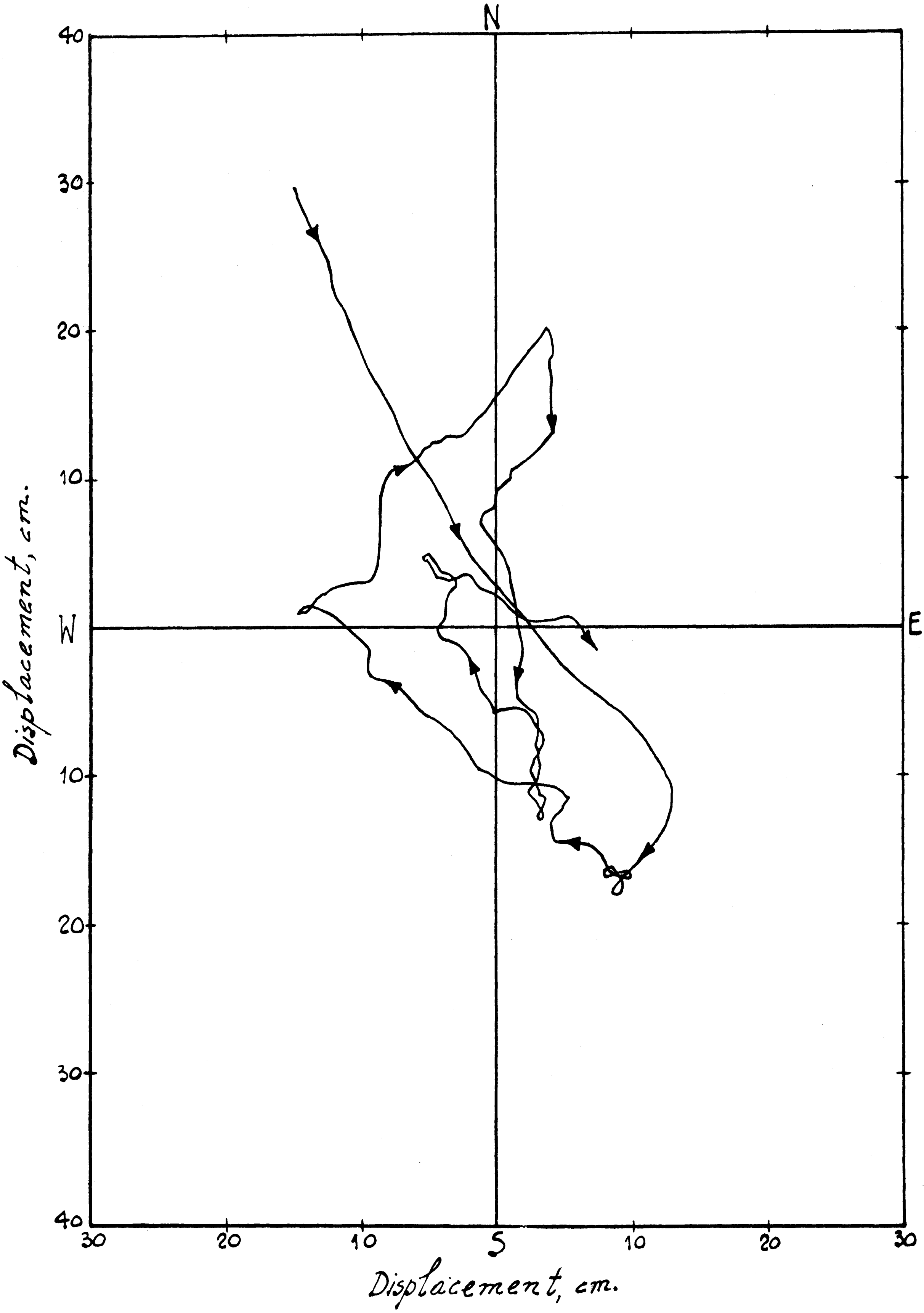

Fig. 14. Trajectory of horizontal ground displacement, Taft, California, July 21, 1952.

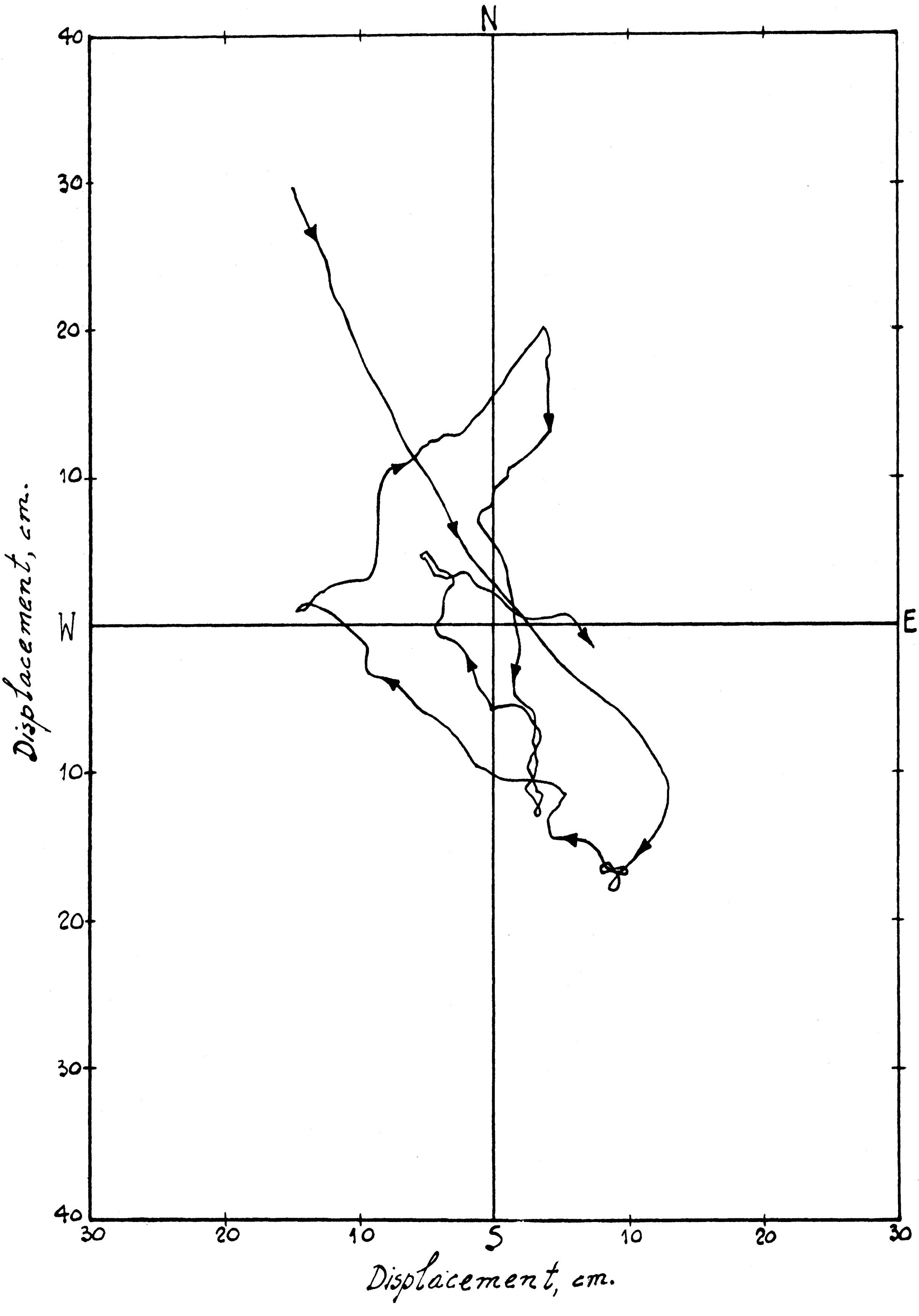

Fig. 14. Trajectory of horizontal ground displacement, Taft, California, July 21, 1952.