STRONG MOTION RECORDS OF THE MILFORD SOUND EARTHQUAKE 1976 MAY 4

S.B. Hodder, R.I. Skinner, R.T. Hefford, P.M. Randal*

SUMMARY

The strong-motion records obtained during the Milford Sound earthquake of 4 May 1976 are of particular interest since the assigned intensities are exceptionally low for an earthquake of magnitude 7. The recorded ground motions are presented here in the general format proposed for publication of significant earthquakes recorded by the New Zealand strong-motion network. It is seen that the ground motions are consistent with the low intensities assigned.

The Milford Sound earthquake was recorded by three-component accelerographs at Milford Hotel, Wanaki, and Te Anau, and by an acceleroscope at Haast. These strong-motion records are of particular interest because the intensities assessed for the region covered by the recorders were exceptionally low for an earthquake with a Richter local magnitude of $M_L = 7$; as described in the accompanying account by G. A. Eiby[1]. The low values of maximum acceleration, from about 0.093 g recorded at Milford Hotel to about 0.033 g at Te Anau, together with the short durations of relatively severe shaking, were consistent with the low intensities assigned.

The peak acceleration components obtained by the strong-motion recorders are shown in Fig. 1(a). These values are generally consistent with the isoseismal map given in Eiby's Fig. 1[1].

GROUND ACCELERATION RECORDS

The accelerogram obtained by the MO2 accelerograph[2] at Milford Hotel is shown in Fig. 2. It was recorded on gently sloping alluvium of unknown depth close to a very steep rocky ridge at the head of Milford Sound, Fig. 1(b). The solution for the epicentre given by Eiby[1] places it at 37 Km $\pm$ 4 Km (closure error) due west from the accelerograph site. The accelerogram traces Fig. 2, in order from the lowest, are the time marks, at 0.02 second intervals, the fixed reference, horizontal accelerations with nominal directions of S4^{o}W and E4^{o}S, and upwards accelerations. It is seen that the approximately east-west accelerations are greatest (the maximum is westward towards the epicentre).

The accelerograms for Wanaka and Te Anau were recorded on type MO1 accelerographs[3] and have not been digitized yet.

The horizontal acceleration of the ground at Haast is given by the acceleroscope[3] record shown in Fig. 3. Points on this record trace give the instantaneous amplitude and direction of the horizontal acceleration. The circle gives a horizontal acceleration of 0.1g. The largest acceleration is towards the general direction of the epicentre, as also occurred in the case of the Milford Hotel accelerogram.

ACCELEROGRAM DIGITIZATION, CALIBRATION AND CORRECTION

The standard procedures[2,4] used for the digitization calibration and correction of the Milford Hotel accelerogram are described briefly to illustrate the type of processing being adopted at PEL.

An enlarged copy of the accelerogram is projected onto the screen of the MO2 record digitizer. For each successive 0.02 second time mark, digital values of the 4 trace positions are punched on paper tape. A computer program then gives an enlarged plot of the accelerogram, as defined by the digital values. As a check on the correctness of the digitization, the original accelerogram is projected onto the digitally generated copy. The digital values are then reduced to trace displacements by scaling with the digitizer constant. Reference levels are then subtracted from trace values and mean values are used to establish zero trace levels.

Each MO1 and MO2 accelerograph has a compact removable accelerometer block, which contains three mirror accelerometers with nominally perpendicular sensing directions, and also a fixed reference mirror. Prior to field installation, each block is calibrated accurately for its three accelerometer sensitivities and for the three pairs of error angles (between the nominated and actual sensing directions). Sets of 9 calibration and error values, for all accelerographs of the New Zealand strong-motion network, have recently been placed in a PEL computer file, for the calibration and correction stage of the automated processing of accelerograms. The accelerometer sensitivity and error angles are formed into a 3 by 3 calibration and correction matrix which transforms the sets of 3 accelerogram trace displacements, for each time value, into acceleration values in the nominated sensing directions. At the same time, an additional correction matrix is used to remove the cross-axis effects which arise with pendulum accelerometers[4]. A

* Physics and Engineering Laboratory, D.S.I.R., Lower Hutt, New Zealand.

further transformation is applied to rotate the horizontal acceleration components into any required pair of perpendicular directions, e.g. the directions north and west. The default directions are along the accelerograph axis and perpendicular to it (90^o anticlockwise).

Corrected values of the ground accelerations recorded at Milford Hotel, for the directions of the accelerograph axes, are plotted in Fig. 4(a), (b) and (c). The corresponding ground velocities and displacements, obtained by successive integration, are also plotted in Fig. (4).

POLAR PLOTS OF GROUND MOTIONS

The horizontal components of Fig. 4 are combined to give the polar plots of Fig. 5. The accelerations of Fig. 5(a) correspond to the record obtained by an acceleroscope, but have a greater accuracy. It is seen that accelerations are somewhat more severe in the general direction towards the epicentre, confirming the impression given by the original accelerogram. Figs. 5(b) and 5(c) give the polar plots of the ground horizontal velocity and displacement respectively. Again it is clear for each of these that the dominant motion is along a line joining the recording station and the epicentre. The polar plots of acceleration, velocity and displacement have dominant periods which are respectively short, intermediate and long, and hence it is evident that a dominant motion along a line connecting the recorder and the epicentre has occurred for a wide range of periods. This increases the likelihood that the directional effect arises from a general characteristic of the propagation of the earthquake motions rather than from the effects of the flexible ground on which the recorder is sited. Futher checks for directional effects will be possible when the Wanaki and Te Anau records are digitized, and plotted in polar form.

ACCELERATION RESPONSE SPECTRA

The acceleration response spectra for the components along the accelerograph axes, S41^{O}E, N49^{O}E and vertically upwards, are each plotted for 5 damping values in Fig. 6. There are no well defined peaks of response for moderately damped resonators for acceleration components S41^{O}E and vertically upwards. However, the peak at about 0.45 seconds for the acceleration component N49^{O}E may be associated with resonances of flexible ground at the accelerograph site. The primary value of response spectra is to indicate the responses to be expected in the resonant modes of structures.

DISCUSSION

The ground motions and spectra given here for the Milford Sound earthquake are representative of the presentation planned for all the significant earthquakes recorded by the New Zealand strong-motion network, both on the ground and throughout structures. However, some further information and refinements will be included.

It is proposed to include Fourier amplitude spectra as well as the above response spectra in the standard presentation of earthquake motion data. The Fourier spectra will give additional information on natural periods of structures and of local ground features. Moreover they can be used to estimate corner frequencies and other source mechanism parameters(5,6).

When presenting and analysing acceleration components it is necessary to select the directions of the components. In the case of accelerations recorded in a structure, components would normally be taken along principal structural axes. The component directions for ground motions may be based on the direction to the epicentre, the orientation of local geological features, the form of horizontal polar plots, and of other criteria.

The polar plots of horizontal ground motions give some useful information. Additional information might be obtained from polar plots in vertical planes. For example, the plane which contains the accelerograph and the epicentre. These and other methods of presenting the earthquake motion data are at present under investigation at PEL.

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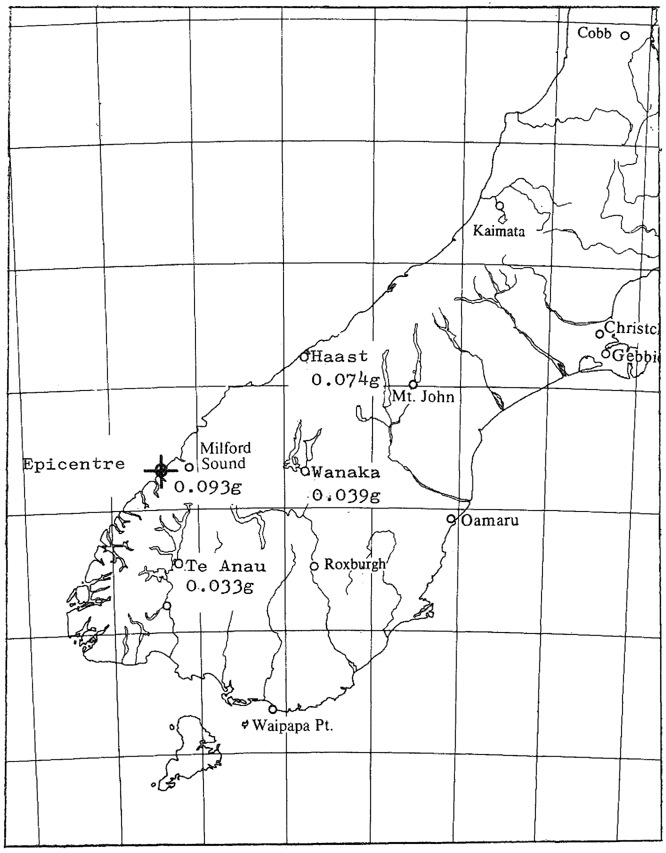

FIGURE 1: (a) PEAK VALUES OF ACCELERATION AT 4 STATIONS DURING MILFORD SOUND EARTHQUAKE, 1976

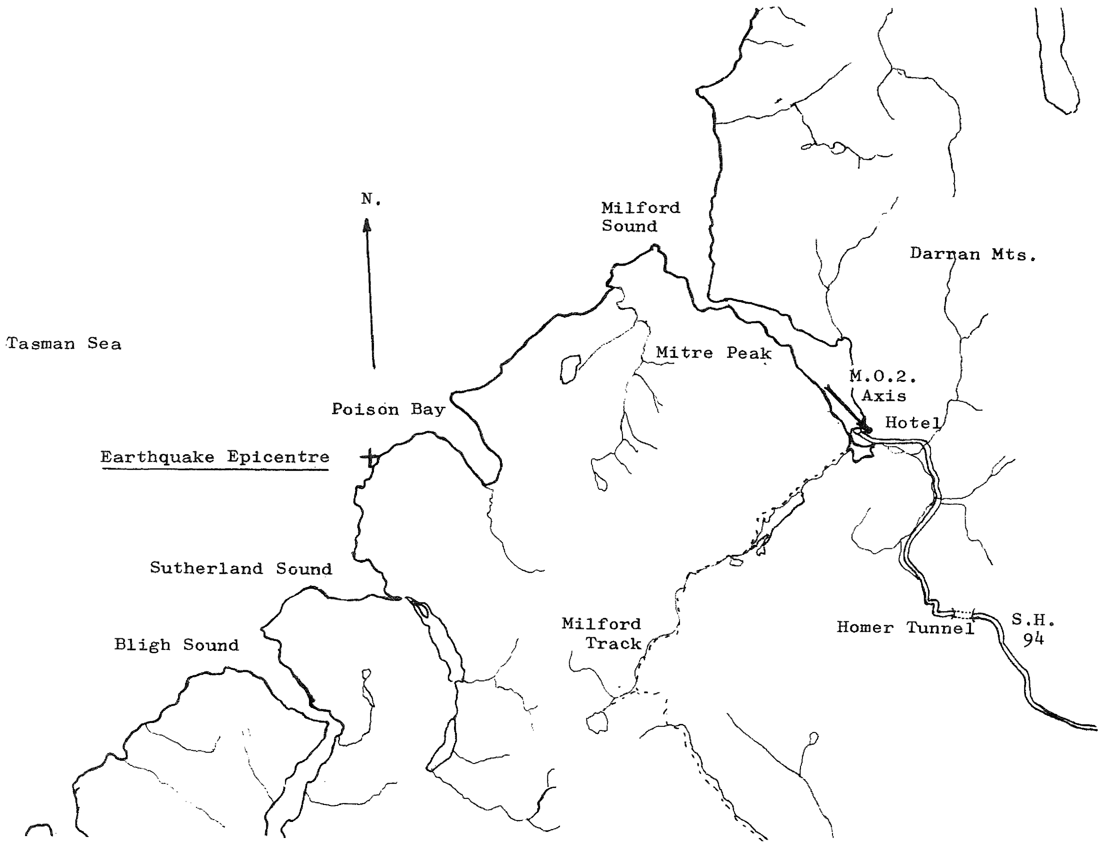

FIGURE 1: (b) ACCELEROGRAPH ORIENTATION AT MILFORD HOTEL AND ASSIGNED LOCATION OF EPICENTRE

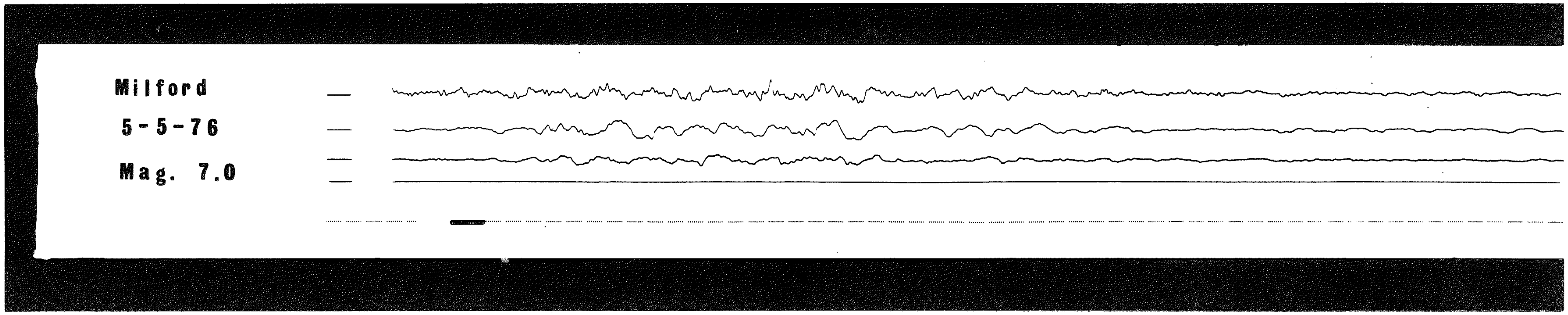

FIGURE 2: ACCELEROGRAM RECORDED AT MILFORD HOTEL. APPROXIMATE SENSING DIRECTIONS, FROM THE LOWEST ACCELERATION TRACE; NORTH, WEST, UP.

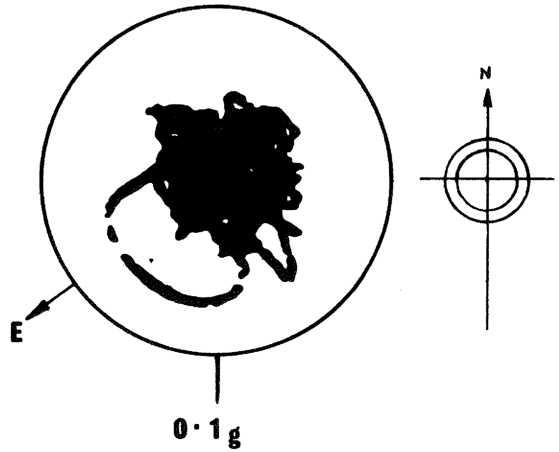

FIGURE 3: ACCELEROSCOPE RECORD OBTAINED AT HAAST.
THE ARROW GIVES THE BEARING TOWARDS THE EPICENTRE

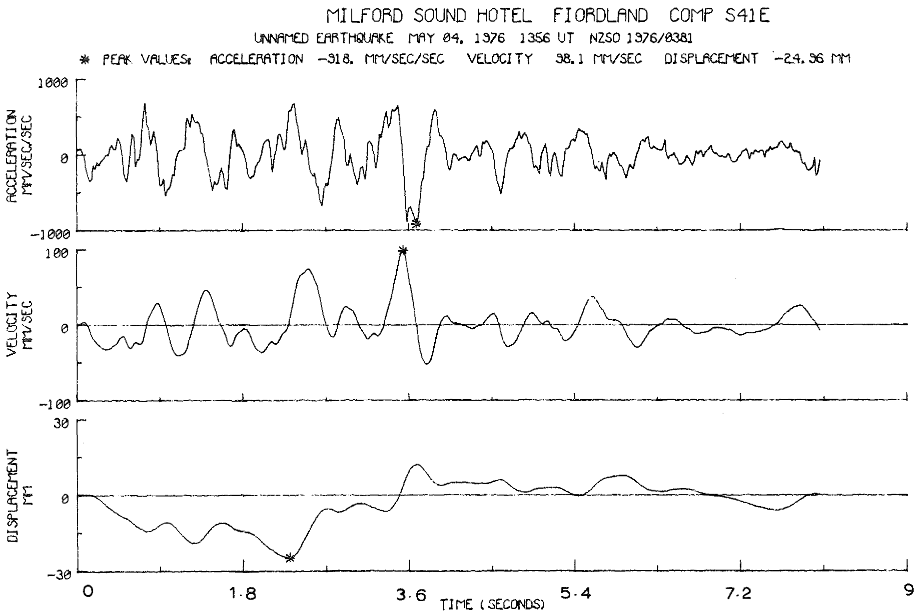

FIGURE 4 (a) PLOT OF CORRECTED VALUES OF GROUND ACCELERATIONS AND DERIVED VALUES OF GROUND VELOCITIES AND DISPLACEMENTS ALONG ACCELEROGRAPH AXIS S 41°E, AT MILFORD HOTEL

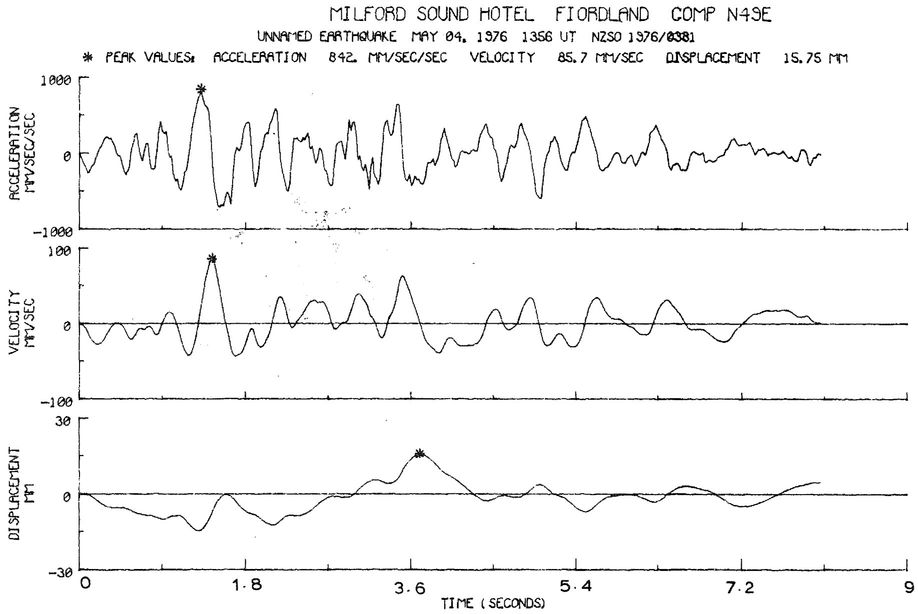

FIGURE 4: (b) PLOT OF CORRESPONDING GROUND MOTIONS ALONG ACCELEROGRAPH AXIS N49°E.

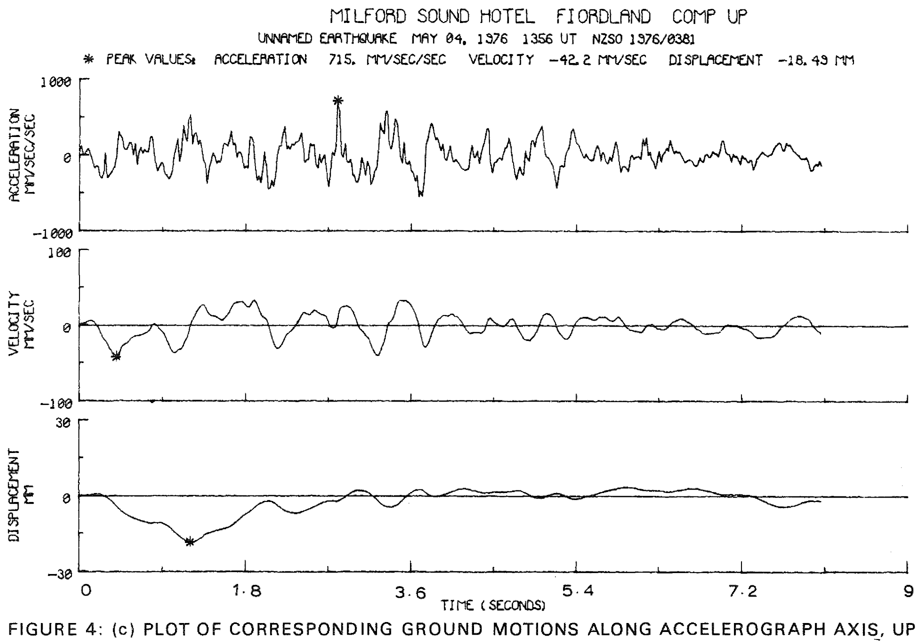

FIGURE 4: (c) PLOT OF CORRESPONDING GROUND MOTIONS ALONG ACCELEROGRAPH AXIS, UP

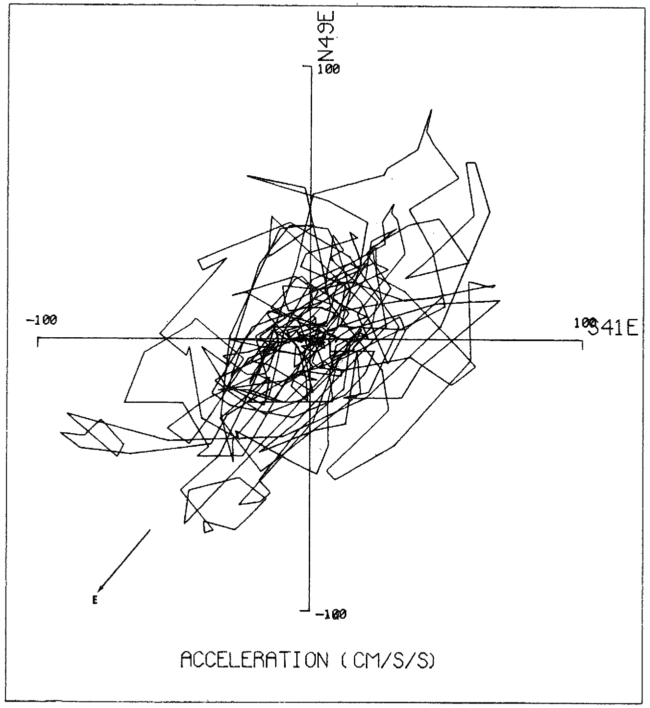

FIGURE 5: (a) POLAR PLOT OF HORIZONTAL ACCELERATIONS. THE ARROW GIVES THE BEARING TOWARDS THE EPICENTRE.

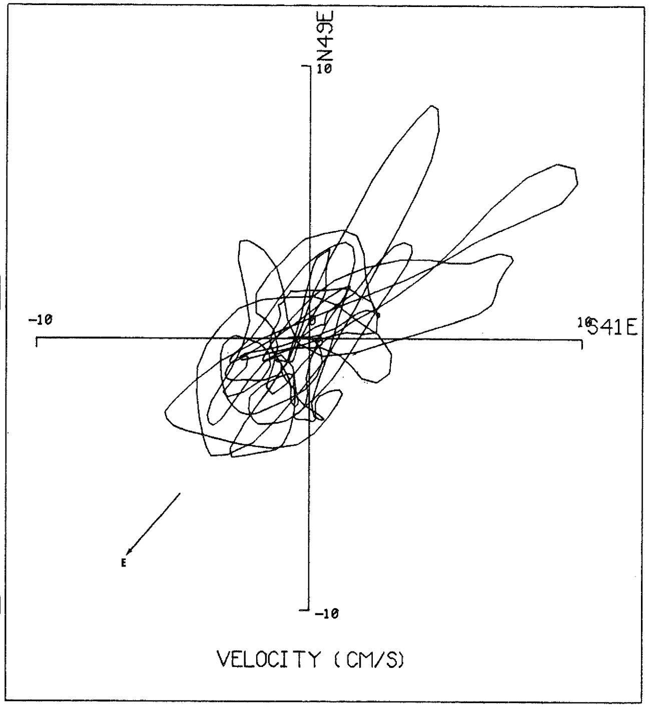

FIGURE 5: (b) POLAR PLOT OF HORIZONTAL VELOCITIES, WITH EPICENTRAL BEARING

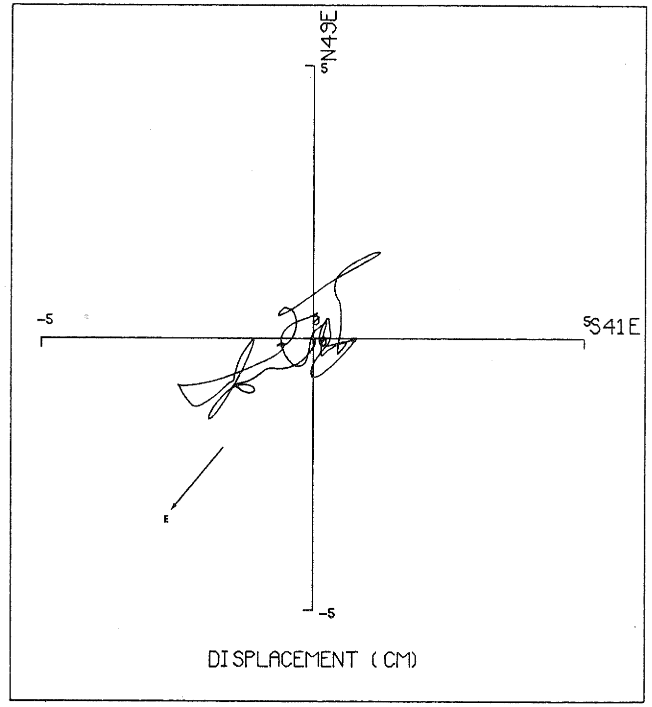

FIGURE 5: (c) POLAR PLOT OF HORIZONTAL DISPLACEMENTS WITH EPICENTRAL BEARING