Some Charts for Studying the Mechanism of Earthquake

著者	Honda Hirokichi, Emura Kinya
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Some Charts for Studying the Mechanism of Earthquake

By HIROKICHI HONDA and KINYA EMURA

Geophysical Institute, Faculty of Science, Tôhoku University

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Abstract

It is shown that the projection similar to "the mechanism diagram" hitherto used in illustrating the mechanism of earthquake can inversely be used to determine the fault and auxiliary planes or the nodal planes for P of an earthquake. Some charts which facilitate the analysis are given, with some examples of their practical application.

1 Introduction

The initial motion of the P waves of an earthquake is generally considered to be alternately compressional and dilatational in the quadrantal areas on the focal sphere bounded by two planes which pass through the focus of the earthquake and are perpendicular to each other. One of the planes is interpreted as the fault plane and the other as the auxiliary plane, or both are called the nodal planes for P. There are several methods for determining the orientation of these planes of an earthquake as explained recently by BYERLY (1955), HODGSON (1957), KEILIS-BOROK et al. (1957) and RITSEMA (1956). These methods are almost equivalent to one another in the assumptions adopted, as already pointed out by SCHEIDEGGER (1957).

In Japan, the pattern on a map of compression and dilatation in the first motion of P could be interpreted in terms of the direction of the forces acting in the focus of the earthquake, and the mechanism of the earthquake was illustrated by the so-called mechanism diagram which is the projection of the focal sphere on a horizontal plane passing through the origin of the earthquake. The relations between the various quantities expressed in the diagram were stated previously (HONDA et al.; 1956, 1957).

In the present paper, we will show that the projection which is similar to the mechanism diagram, can inversely be used to determine the orientation of the nodal planes for P of an earthquake from the observations of the initial motions of P. Some charts which facilitate the analysis, are presented and some examples of the practical application of the charts for the study of the mechanism of the earthquake are given.

2 Charts for Studying the Mechanism of Earthquakes

When the tangent $S_1'FS_2'$ to the seismic ray S_1FS_2 (Fig. 1) at the focus F, is taken in place of the actual ray, the stations S_1 and S_2 on the earth's surface correspond to S_1' and S_2' on the focal sphere i.e. a small sphere constructed around the focus of the earthquake. The initial motion of P at S_1' is considered to be directed just opposite to that at S_2'. The station S_2 corresponds to S_2'' on the surface of the earth stripped to the depth of the focus of the earthquake.

The pattern of the initial motion of P on the upper or lower half of the focal sphere may be illustrated by the vertical projection of the respective half sphere on the horizontal plane passing through the hypocenter. The intersections n_1Qn_1' and

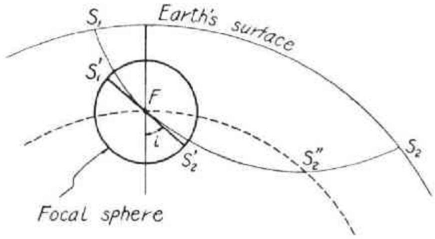


Fig. 1. Focal sphere.

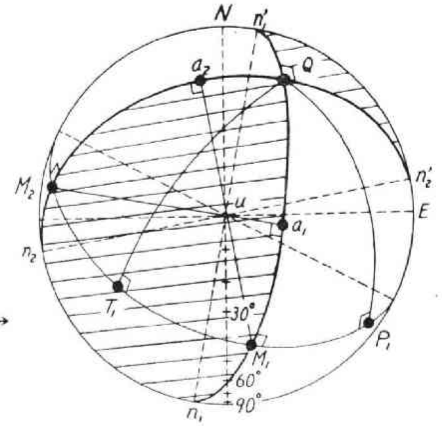


Fig. 2. Mechanism diagram. →
$P_1M_1 = M_1T_1 = \ldots\ldots\ldots = 45°$,
$QP_1 = QM_1 = \ldots\ldots\ldots = 90°$,
$a_2M_1 = a_1M_2 = \ldots\ldots\ldots = 90°$,
⌐ ; 90°.

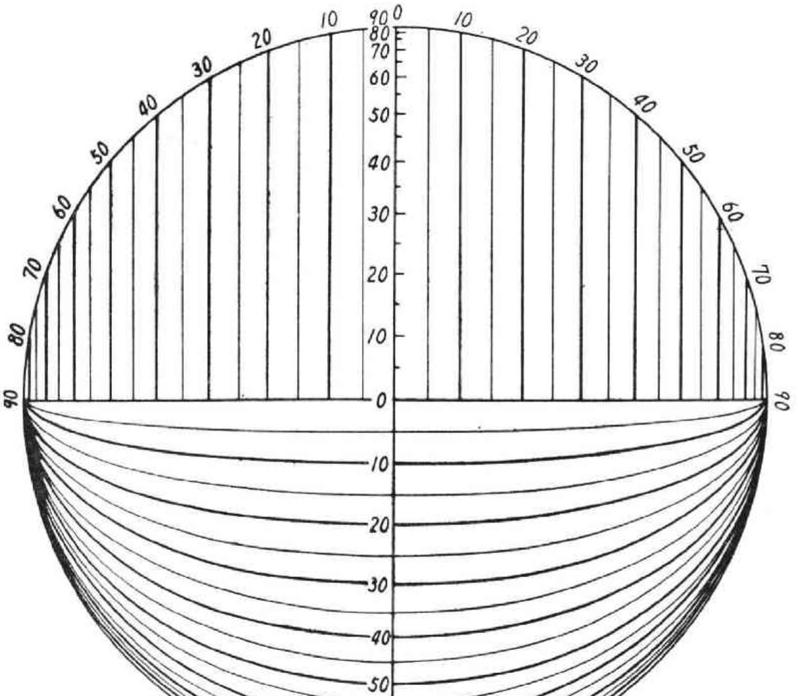


Fig. 3. Chart I.

n_2Qn_2' of the sphere with the nodal planes are represented as ellipses in the figure. (Fig. 2). The pole M_2 of the great circle n_1Qn_1' lies on n_2Qn_2', and the pole M_1 of the great circle n_2Qn_2' lies on n_1Qn_1'. The figure is nothing but the mechanism diagram which has been used to illustrate the mechanism of earthquakes, in Japan. a_1 and a_2 in the figure show the inclination of the nodal planes n_1Qn_1' and n_2Qn_2', M_1 and M_2 the motion directions, and P_1 and T_1 the directions of the maximum pressure and tension respectively.

In Fig. 3 is illustrated the Chart I which gives the ellipses corresponding to n_1Qn_1' and $n_2\ Qn_2'$ of various inclinations, and the lines showing the length of the arc along the ellipse measured from the central vertical plane. The scales on the central line serve to determine the position of the pole of an elliptic curve on the diagram. When the compressions and dilatations of the initial motion of P are entered in the projection, the appropriate nodal lines can be found from the chart, and the corresponding poles are obtained. Once the nodal lines are determined, the positions of P_1 and T_1 in the projection can be obtained graphically by use of the same chart.

Though the method relying on the projection similar to the mechanism diagram has various advantages in facilitating the analysis and interpretation, it has a drawback that the area on the focal sphere is not represented uniformly in the diagram. When it is necessary to avoid the inconvenience, we may adopt the following

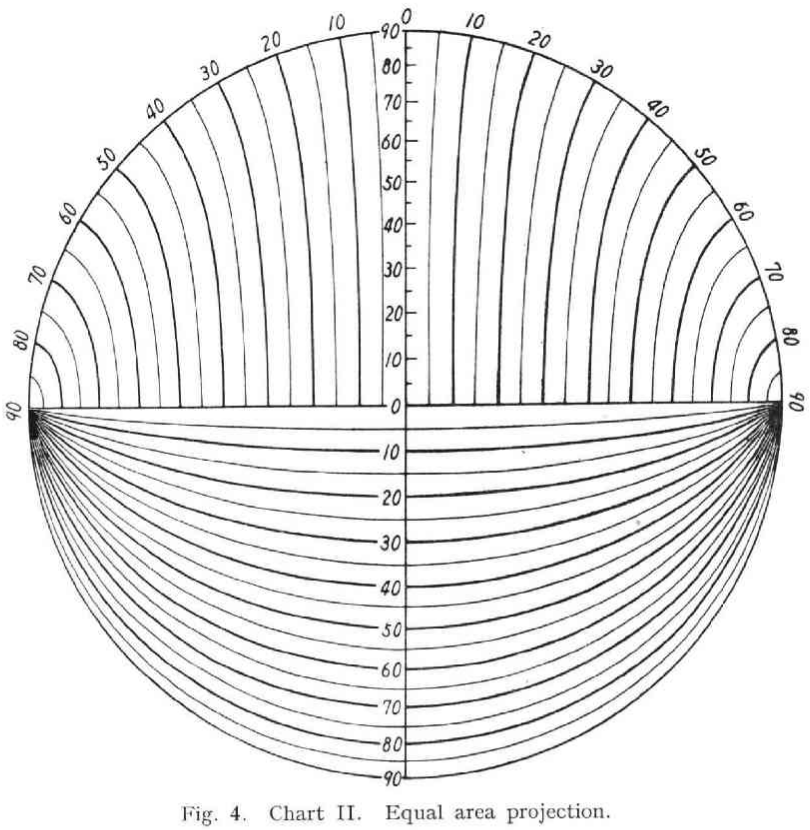
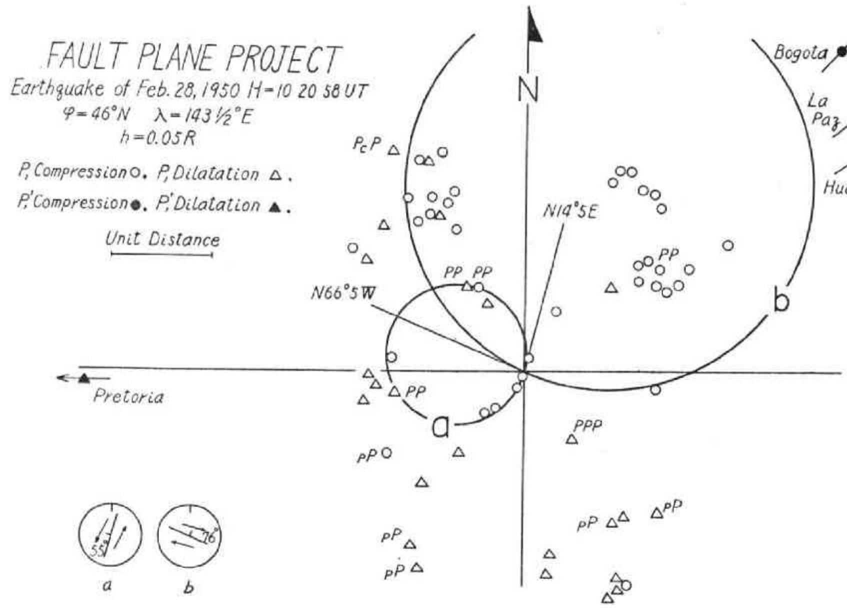


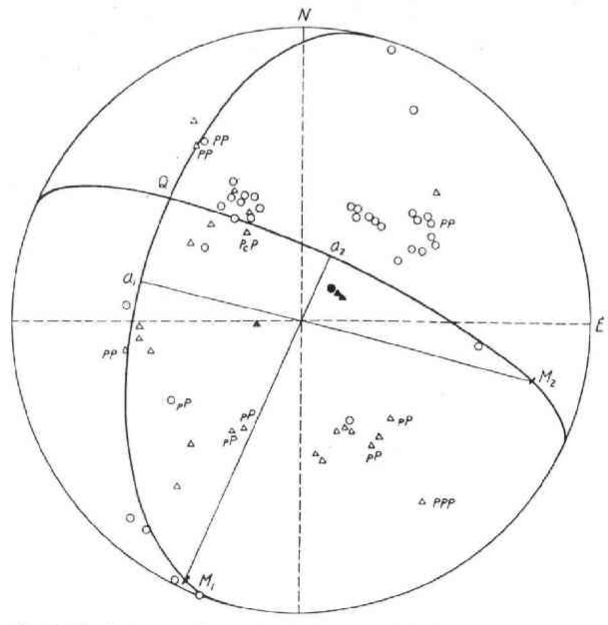
Fig. 4. Chart II. Equal area projection.

method.

Let us take provisionally the radius of the focal sphere as unity. When any point on the focal sphere whose radius vector is inclined by α from the vertical, is represented by a point whose distance from the center of the horizontal circle of unit radius is $\sqrt{2}\sin(\alpha/2)$ in the same azimuth, the figure is known to represent a kind of



(a) Analysis by Hodgson (1956).



(b) Analysis by use of Chart I (lower half of the focal sphere).

Fig. 5. Earthquake of Feb. 28, 1950.

projection of the focal sphere by which the area on the sphere is represented uniformly on the plane figure. We will call the figure the equal area projection of the focal sphere. In Fig. 4, is given the Chart II for the equal area projection, in which the curves corresponding to the nodal lines and those showing the angular distances along the nodal lines are illustrated.

3 Examples

Some examples of the application of the Chart I or Chart II for studying the mechanism of the earthquakes are given below.

(i) Earthquake of Feb. 28, 1950. Sakhalin Island. $\varphi=46°$ N, $\lambda=143\ 1/2°$ E, $h=0.05$ R. The mechanism of the earthquake has been investigated by HODGSON (1956). Fig. 5 (a) shows the results of HODGSON's analysis by use of the stereographic projection method initiated by BYERLY. One of the nodal planes dips at 55° in the azimuth N 75.°5 W and the other one dips at 76° in the azimuth N 23°.5 E. The results of the approximate study basing on the same data as illustrated in Fig. 1 of HODGSON's paper, by our method using the Chart I, are shown in Fig. 5 (b), which shows the projection of the lower half of the focal sphere.

(ii) Earthquake of Apr. 4, 1932. Off the South coast of Japan, $\varphi=30°.5$N, $\lambda=139°.1$E, $h=0.06$R. The mechanism of the earthquake has been studied by HONDA et al. (1932, 1952, 1956). Fig. 6(a) shows the distribution of the initial

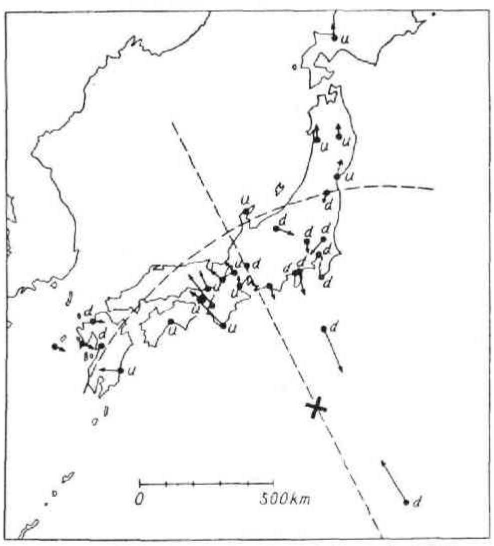
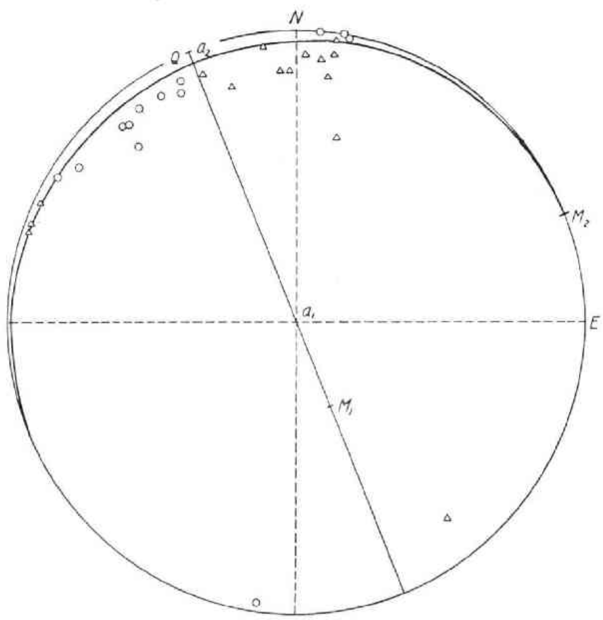


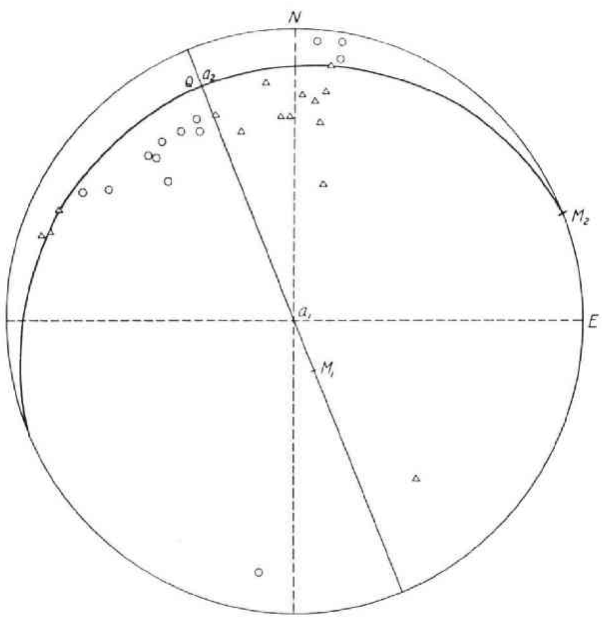
Fig. 6. (a). Earthquake of Apr. 4, 1932. Initial motion of P.

motions of P on a map. The results of the approximate analysis of the data illustrated in Fig. 6 (a), by use of the Charts I and II, are shown in Figs. 6 (b) and 6 (c) where the projections show the upper half of the focal sphere respectively.

The mechanism diagrams of the earthquakes (i) and (ii), are shown in Fig. 7 with various quantities obtained by use of our method of analysis explained in this paper.

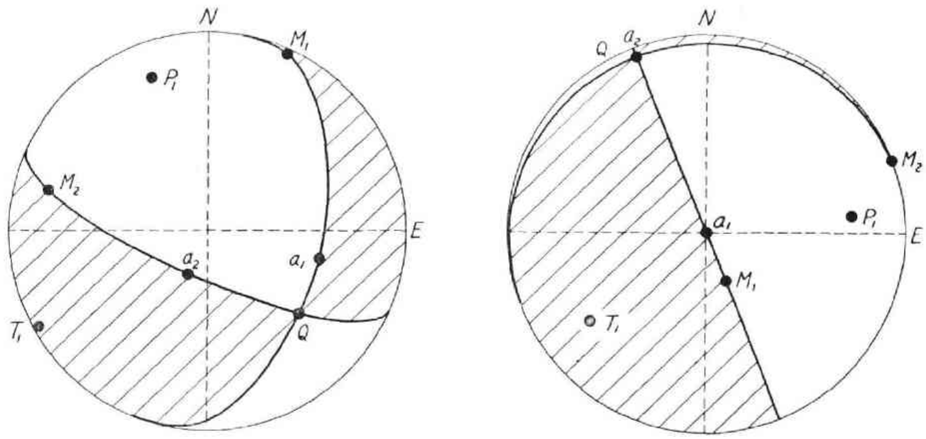


(b). Analysis by use of Chart I.



(c). Analysis by use of Chart II.

Fig. 6. Earthquake of Apr. 4, 1932. Compression : ○. Dilatation : △, (upper half of the focal sphere).



(a) Earthquake of Feb. 28,1950.
a_1 ; S 76°E (35°).
a_2 ; S 24°W (14°).
M_1 ; N 24°E (76°).
M_2 ; N 76°W (55°).
P_1 ; N 20°W (55°).
T_1 ; S 60°W (76°).
Q ; S 48°E (38°).
(Slip angle)$_{1,2}$; 17°,36°.

(b) Earthquake of Apr. 4, 1932.
a_1 ; (0°).
a_2 ; N 22°W (75°).
M_1 ; S 22°E (15°).
M_2 ; N 68°E (90°).
P_1 ; N 83°E (47°).
T_1 ; S 53°W (47°).
Q ; N 22°W (75°).
(Slip angle)$_{1,2}$; 75°,0°.

Fig. 7. Mechanism diagram (upper half of the focal sphere).

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