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Earthquake Focal Mechanism in the East New Guinea Region

by

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SUMMARY

An investigation of the focal mechanism of some New Guinea earthquakes in the period 1962-1964, and a review of the 1922-1962 New Guinea earthquake focal mechanism computer solutions published by Wickens and Hodgson (1967) have shown that:

1. No "dip-slip" solutions have been obtained for New Guinea earthquakes; this is because of an inadequate seismic staton distribution which precluded "dip-slip" solutions and is not a characteristic of New Guinea tectonics.

2. The "strike-slip" solutions are not opposed to the concept of an east-west sinistral shear stress currently active in the New Guinea region.

More stations to the north and to the east of Port Moresby are required to increase the number of focal mechanism solutions, particularly where "dip-slip" motion is involved.

1. INTRODUCTION

Between January 1963 and December 1965, eleven earthquakes with assigned USCGS magnitudes greater than 6.2 occurred in the East New Guinea Region (Plate 1). This study concerns the focal mechanism and tectonic significance of these earthquakes.

The Dominion Observatory in Canada has published computed solutions of earthquake focal mechanism for all cases found in the literature from 1922 to December 1962 (Wickens & Hodgson, 1967). A total of 618 earthquakes throughout the world were used. Unique solutions in which none of the parameters vary by more than a total of 10 degrees were found for only 70 earthquakes. For the East New Guinea Region, the number of events was 20, for which 3 solutions were found. The tolerance has been increased to 34 degrees to allow 8 more earthquakes from the Dominion Observatory report to be included in this study.

2. METHOD OF ANALYSIS

Details of the methods used are contained in a companion Record (Ripper, in prep.) but for completeness a resume is given here. The theory for single couple (fault plane or Model I) and double couple (Model II) types of earthquakes source has been summarized by Stauder (1960, 1962), Hodgson and Stevens (1964), and others.

The following parameters are tabulated for each seismic station which records the earthquake:

Initial P-wave motion;

Epicentral distance; and

Azimuth of the station from the earthquake.

The "angle of incidence" (i_h) of the seismic ray recorded at a seismic station is the angle that the ray makes with the vertically downward direction as it leaves the earthquake focus (Plate 2). The angle is obtained from a knowledge of the earthquake depth, the crust and mantle model in the region of the earthquake, and the epicentral distance to the seismic station. Bessonova et al. (1960) have plotted the angle of incidence against epicentral distance for a series of earthquake focal depths, and their graphs were interpolated to the focal depth values of the earthquakes studied in this Record (Plate 3).

The data, in the form of seismic ray directions at the earthquake focus (angle of incidence and azimuth) and the sense of first motion (polarity; compressional or dilatation) are plotted on a Wulff stereographic projection (Plate 4), which is representative of the bottom half of the focal sphere, an imaginary sphere centred on the earthquake focus.

If the first motion data can be divided into four quadrants on the focal sphere, two of compressions and two of dilatations, by two orthogonal nodal planes through the epicentre, then the earthquake can be described as being either Model I or Model II. The model type can be deduced by an S-wave analysis. The direction of polarization of S is parallel to the fault plane in Model I and converges on the pole (direction) of motion. In Model II the directions of polarization do not favour either nodal plane as the fault plane, but instead converge on their bisectors, which are called the pressure and tension axes as they are the directions of maximum and minimum stress.

The line of intersection of the nodal planes has a special significance. Called the "null vector", or B axis, it is the "roller" about which any fault motion along either nodal plane occurs. If the B axis is vertical, pressure (P) and tension (T) directions and any fault motion are horizontal.

Wickens and Hodgson published their results in terms of the two nodal planes, the B axis, the pressure and tension axes, and the accuracy of the computation. No attempt was made to determine whether the model was I or II, or to establish a fault plane.

S-wave particle motions were analysed where possible for stations with epicentral distances in the range 45-82°. At shorter distances, the critical angle of incidence of S at the free surface is generally exceeded, and particle motion is non-linear or elliptical (Nuttli & Whitmore, 1962). Also, at distances greater than 45°, particle motion in the vertical direction is negligible, and the angle between S horizontal motion azimuth and the plane of incidence approximates the polarization angle of S. To avoid confusion with other phases, epicentral distances less than 82° should be used (Stauder, 1960). Presumably S-wave analysis is permissible at epicentral distances just less than 45° if particle motion is clearly linear.

3. COLLECTION OF DATA

The P-wave data were collected by distributing questionnaires to seismological stations throughout the world. In addition some long-period seismograms of the World Wide Standard Seismograph network were obtained from the World Data Centre for S-wave analyses. The vertical components of these records were included in the P-wave analyses.

Epicentral distances were obtained by a computer programme at the Bureau of Mineral Resources, Canberra (Finlayson & Parkinson, in prep.). Readings of first motions were accepted or rejected on the basis of P-wave residual; phases described as emergent were included in the analysis, but marked as possibly inaccurate.

The station distribution was found to be inadequate to define uniquely the nodal planes of some earthquakes. If a nodal plane is horizontal or nearly so, stations at epicentral distances of about 10° are required to define it. Only three stations operated effectively in this range during the period of the investigation - PMG, RAB, and HNR - so that definition of horizontal nodal planes of New Guinea earthquakes is extremely poor. Where nodal planes are steeply inclined they generally pass between groups of seismic stations and can be well defined.

4. ANALYSIS OF DATA AND RESULTS

Analyses and solutions

Table 1 lists the earthquakes studied at the Port Moresby Geophysical Observatory. The station observations are listed in Table 2; observations discarded for reasons such as incorrect arrival time are not listed. Station codes are those adopted by USCGS. The Wulff stereographic projections of each earthquake except number 6 are shown in Plates 5 to 14, and the S-wave polarization directions in Plates 15 to 20.

Table 3 presents the results of the analysis - the model type, the nodal plane and B axis configuration, the error associated with each nodal plane and the B axis, and the P, T, and motion direction axes. The uncertainty in the position of each nodal plane is expressed as the uncertainty of the position of the pole of the nodal plane on the stereographic projection, given as the long and short axes of an ellipse. The uncertainty of the B axis includes the constraint that the nodal planes must be orthogonal. This constraint considerably reduces the possible nodal plane configurations.

No solution was attempted for earthquake No. 6 because the records were confused by an earlier teleseism and few clear first arrivals were obtained. The readings of earthquakes Nos. 1, 2, and 8 did not conform to an orthogonal nodal plane configuration, and could not be described in terms of conventional single couple or double couple theory. In Nos. 1 and 2, regional stations RAB, GUA, HNR, and DAR did not report impulsive arrivals, and in No. 8 GUA and DAR did not report impulsive arrivals. In earthquakes 3, 4, and 7, only one nodal plane could be described with any degree of accuracy and although it is possible that an orthogonal solution exists in each case the station distribution is inadequate to define it.

Reasonable solutions were obtained for earthquakes Nos. 5, 9, 10, and 11.

Model I is favoured for earthquake No. 5 from S-wave analysis of stations CHG, NDI, COL, and AFI. Station SHL is inconsistent with the results of the other stations. Although AFI is at an epicentral distance less than 40°, its S-wave motion is clearly linear and indicative of Model I.

Eight S analyses in earthquakes No. 9 are unable to distinguish between Models I and II, but station SBA clearly indicates Model II.

Three S-wave analyses were obtained for earthquake No. 10 (Stations SEO, ANP, and MUN) and Model II is indicated. Stations NHA (45°) and SBA (73°) were discarded because their S-wave motions were non-linear.

In earthquake No. 11, TPN in the New Guinea highlands does not conform to the solution. The reason is probably uncertainty in the position of TPN on the stereographic projection owing to anomalous crustal structure. S-wave analyses indicate a Model I solution. Stations SNG, POO, CHG, and SHL can be interpreted as either Model I or II, but station SEO rules out the latter.

Tectonic interpretation

The four fault plane solutions obtained in the analysis Nos. 5, 9, 10, 11 have been combined with the eight solutions obtained by Wickens and Hodgson (Tables 4 and 5) to give a total of twelve earthquakes in the East New Guinea region with nodal plane solutions.

The B-axis configurations are illustrated in Plate 21. In eleven out of twelve cases, the B axis is inclined at an angle greater than 45°, indicating that strike-slip motion predominates. However, well defined dip-slip solutions are difficult to obtain because one nodal plane must be inclined at less than 45° and a large number of close stations are required to define the configuration of this plane. Earthquake No. 7 illustrates this effect. It was recorded by regional stations PMG, RAB, HNR, GUA, and CTA. One nodal plane is well defined, but the position of the second nodal plane, if constrained to be orthogonal to the first, can vary through an arc of 52°, and the corresponding range of dip is 32°-42°. Stations at such places as Goroka in the New Guinea Highlands, Manus Island, Kavieng on New Ireland, and Bougainville would have enabled a much better solution to be obtained. The lack of unique dip-slip solutions in the report by Wickens and Hodgson is probably due to the bad station distribution. There are eight East New Guinea earthquakes included in their report for which no unique solutions have been obtained but which may involve dip-slip motion (Table 6).

Therefore although both dip-slip and strike-slip earthquakes occur in the East New Guinea Region, this analysis can concern itself only with strike slip earthquakes and the corresponding horizontal shear stress fields. There is no indication as to whether the New Britain Trench is a convection downturn or a tensional feature, as both cases would involve dip-slip earthquake motion.

The pressure and tension directions derived from each focal mechanism analysis are shown in Plates 22 and 23 respectively. The preferred pressure and tension directions for the region are shown in the insets. The directions show no obvious correlation with tectonic trends, such as the junction of the New Britain Trench and the Planet Deep, but more results are needed from Bougainville to confirm this observation. The tendency is for the pressure axis to be NE-SW and the tension axis to be NW-SE (although two notable exceptions are No. 11, Table 3, and No. 89, Table 5). This is consistent with either an E-W sinistral shear stress field or a N-S dextral shear stress field. The former has been proposed for New Guinea by Carey (1958) who postulated the existence of a sinistral equatorial shear system passing through New Guinea. The sinistral shear interpretation of the strike-slip solutions is shown in Plate 24, and it is consistent with the theory of a sinistral equatorial shear. The focal mechanism solution of No. 11, Table 3 is a sinistral strike-slip fault parallel to the Markham-Ramu Valley system, which suggests that sinistral shear is currently active along this lineament.

Phase change theory of focal mechanism

Evison has suggested that the dominant first motions (or polarities) of an earthquake are dependent on its environment, and that one polarity is usually strongly dominant over the other (Evison, 1966). He deduced the following "Polarity Rule":

Shallow focus (less than 200 km)

Under land or water	compression
Under ocean trench	dilatation

Deep focus (greater than 200 km) dilatation

Table 7 lists the number of compressions and dilatations of each earthquake except No. 6 in Table 1, and notes whether it conforms to the Polarity Rule. The correlation is poor.

In his derivation of the rule, Evison used one hundred as the minimum number of observations, and it is seen that the numbers in Table 7 fall far short of this figure. But increasing the number of observations, for New Guinea earthquakes, does not proportionally increase the accuracy or reliability of the result. Table 8 shows the number of World Wide Standard

Seismograph stations in different epicentral distance and i_h ranges in July 1966. The majority of stations, being in America and Europe, occupy only 3 percent of the focal sphere. The inclusion of other stations would not improve this distribution significantly, and would mainly increase the number of observations in this region. Such additional readings would be redundant in a nodal plane analysis, and misleading in a polarity rule analysis.

5. CONCLUSIONS

The seismic station distribution in the New Guinea-Bougainville region is inadequate for the determination of fault plane solutions of dip-slip earthquakes.

Nodal plane solutions of strike-slip earthquakes are consistent with the theory of an equatorial shear system through New Guinea.

No evidence was found to support the "Polarity Rule" theory of phase change for earthquake focal mechanism.

6. ACKNOWLEDGEMENTS

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TABLE 1

EARTHQUAKES ANALYSED

Ref. No.	Date	Origin Time			Lat. S	Long. E	Depth (km)	Magnitudes			
		L	M	P				(PAS)	(PAL)	(CGS)	(BKS)
1	28.1.63	12	12	19.8	2.6	149.9	33	6½			-
2	14.2.63	22	07	54.3	5.0	144.6	80	6½	6	6.0	-
3	26.2.63	20	14	08.7	7.5	146.2	171	7¼-7½	6¾-7	7.1	7-7¼
4	27.2.63	04	30	00.8	6.0	149.4	52	6¼	6½-6¾	5.2	-
5	28.6.64	12	51	34.6	1.7	149.6	7	-	-	6.4	5¾-6
6	6.7.64	10	06	02.3	6.3	154.7	49	-	-	6.4	-
7	17.11.64	08	15	39.3	5.7	150.7	45	7¼	-	6.7	7-7¼
8	10.1.65	07	37	35.1	5.8	147.3	113	-	-	6.5	-
9	6.7.65	18	36	47.3	4.5	155.1	510	6-6¼	-	6.5	6¼
10	22.9.65	20	01	49.3	5.4	151.5	57	-	-	6.5	5-5.5
11	7.12.65	22	19	14.8	6.4	146.3	109	-	-	6.4	-

TABLE 2

STATION OBSERVATIONS

Epicentral distance, i_h, and Azimuth are in degrees.

(s) : World Wide Standard Seismograph station

i_h Value in brackets : Upper hemisphere

c : compression

d : dilatation

e : emergent

q : Information obtained from questionnaire

a : Information obtained from a direct examination of the record

b : Information obtained from the station bulletin.

Station	Epicentral distance	i_h	Azimuth	P polarity	Comments
Earthquake No. 1					
AFI(s)	39.5	33	108.7	c	eq
BKS(s)	89.9	19	52.3	d	eq
BRS	24.8	41	173.9	c	q
CAN	32.6	36	181.4	c	q
COL(s)	81.0	21	337.5	c	q
CTA(s)	17.7	55	191.3	c	q
FRU	81.0	21	313.9	c	eq
KOU	22.7	44	142.9	c	q
LAH(s)	79.1	21	302.6	c	ea
MAN(s)	33.3	35	301.8	c	q
MAT(s)	40.5	33	345.5	d	q
MIN	90.5	18	49.8	c	eq
MUN(s)	43.1	33	223.7	d	qa
NHA(s)	43.0	33	290.9	c	a

Station	Epicentral distance	i_h	Azimuth	P polarity	Comments
Earthquake No. 1 (Cont.)					
NOU	25.3	40	141.9	d	q
PMG(s)	7.3	81	201.9	c	a
PVC	23.5	43	131.0	d	q
QUE(s)	85.2	20	300.4	c	a
RIV(s)	31.1	36	178.0	c	q
TAU(s)	40.2	33	182.9	c	qa
TOO	35.0	34	186.1	c	q
WEL(s)	44.5	32	153.1	c	a
Earthquake No. 2					
AFI(s)	43.9	34	104.8	c	q
BKS(s)	95.5	18	52.6	d	eq
BRS	23.6	42	161.6	c	q
CAN	30.4	38	172.9	c	q
COL(s)	85.2	22	23.3	d	q
CTA(s)	15.1	65	174.0	c	q
FRU	78.9	23	315.2	c	eq
KOU	24.6	41	130.7	c	q
LAH(s)	76.0	24	304.1	c	ea
MAT(s)	41.7	35	352.3	d	q
MCQ	50.7	32	169.2	d	q
MIN	96.1	17	50.1	c	eq
MUN(s)	37.8	36	221.3	c	qa
NOU	27.3	40	131.2	c	q
PMG(s)	5.1	90	150.1	c	a
PVC	26.4	40	120.5	c	q
RIV(s)	29.3	39	168.8	c	q

Station	Epicentral distance	i_h	Azimuth	P polarity	Comments
Earthquake No. 2 (Cont.)					
SFA	128.1	8	30.3	c	q
SCH	124.2	8	21.4	c	eq
TAU(s)	37.8	37	176.7	c	q
TOO	32.4	38	178.7	c	eq
WIL	65.6	28	194.5	c	eq
WEL(s)	45.1	34	147.6	c	a
Earthquake No. 3					
AAE(s)	108.3	16	277.0	c	eq
AFI(s)	41.7	37	102.4	d	qa
ADE(s)	28.2	43	193.1	c	q
ALE	104.1	16	3.7	c	eq
APA	106.6	16	338.9	c	q
BAG(s)	34.7	39	313.3	c	q
BAN	101.0	17	39.4	d	eq
BHA	114.5	15	250.5	d	q
BUL(s)	112.8	16	244.6	d	q
BKS(s)	95.8	19	52.7	d	q
BRS	20.7	52	163.3	d	q
CAN	27.8	43	175.1	d	q
CLK	108.1	16	250.9	d	q
COL(s)	86.9	21	23.0	d	q
CTA(s)	12.5	73	179.8	c	q
CUM	110.8	16	315.2	c	q
FRU	81.8	23	315.1	c	q

Station	Epicentral distance	i_h	Azimuth	P polarity	Comments
Earthquake No. 3 (Cont.)					
GDH(s)	117.0	14	7.8	c	q
HNR(s)	13.7	69	99.0	d	q
IRK	69.4	27	334.0	c	q
JER(s)	111.7	16	301.1	c	eq
KEV(s)	106.8	16	341.4	d	q
KIP(s)	61.8	30	61.0	d	a
KIR	109.9	16	340.9	c	q
KOU	21.8	50	18.4	d	q
LAH(s)	78.7	24	304.1	c	ea
MAN(s)	33.2	40	311.7	c	q
MAT(s)	44.4	36	350.8	c	q
MAW	80.6	23	202.7	c	q
MIN	96.5	18	50.3	d	q
MBC	98.3	18	14.0	d	eq
MOS	106.6	16	325.9	c	q
MUN(s)	37.1	39	224.9	c	qa
NHA(s)	41.7	37	297.8	c	a
NOU	24.4	46	129.2	d	q
PPT	63.2	30	105.8	c	q
PMG(s)	2.1	(59)	153.8	c	a
PVC	23.8	47	117.3	d	q
PNT	98.3	18	41.3	d	eq
PUL	109.3	15	331.1	c	eq
QUE(s)	84.5	22	301.3	c	a
RAB(s)	6.8	(85)	61.4	c	eb
RES	104.6	16	13.9	d	eq
RIV(s)	26.6	44	170.8	d	q

Station	Epicentral distance	i_h	Azimuth	P polarity	Comments
Earthquake No. 3 (Cont.)					
SPA(s)	82.5	23	180.0	c	a
TAN	95.7	18	250.1	c	q
TAU(s)	35.3	39	178.6	c	qa
TIF	103.4	17	311.0	c	q
TOO	29.9	42	181.1	c	q
TUC(s)	104.9	16	58.7	d	q
VIC	95.8	19	42.0	d	eq
WIL	63.6	30	195.3	c	q
WEL(s)	42.1	37	148.9	d	eq
YKC	100.8	17	27.8	d	eq
Earthquake No. 4					
AFI(s)	39.0	34	104.6	c	qa
ADE(s)	30.5	37	197.5	d	q
BRS	21.5	46	171.8	d	q
CAN	29.2	38	180.7	c	eq
COL(s)	84.2	20	22.4	c	eq
CTA(s)	14.3	65	192.0	d	q
FRU	83.0	20	314.3	c	eq
HNR(s)	11.0	74	108.7	c	eq
KIP(s)	58.3	30	60.4	c	a
KOU	20.4	49	136.4	d	q
LAH(s)	80.5	23	303.2	c	a
MAT(s)	43.9	33	346.9	c	q
MUN(s)n	40.4	34	226.0	c	qa
NHA(s)	43.9	33	294.4	c	a
NOU	23.1	43	136.2	d	q

Station	Epicentral distance	i_h	Azimuth	P polarity	Comments
<u>Earthquake No. 4</u> (Cont.)					
PPT	60.6	29	106.7	c	eq
PMG(s)	4.1	90	213.2	d	a
PVC	21.8	45	123.9	d	eq
QUE(s)	86.5	20	300.7	c	a
RIV(s)	27.7	39	176.8	d	q
SPA(s)	84.0	20	180.0	c	q
TAU(s)	36.8	35	182.6	d	eqa
TOO	31.6	37	185.9	d	eq
WEL(s)	41.8	33	151.0	d	a
<u>Earthquake No. 5</u>					
BKS(s)	89.6	13	52.3	c	eq
BRS	25.7	27	173.5	d	q
CAN	33.4	25	180.9	c	eq
CHG(s)	53.7	21	294.7	c	eqa
COL(s)	80.2	15	22.6	c	eqa
CTA(s)	18.6	37	189.9	d	q
GUA(s)	15.8	40	343.0	d	a
HKC(s)	42.0	23	306.6	c	a
KOU	23.6	28	143.6	d	q
LPB(s)	138.6	5	117.5	c	eq
LUG	22.1	29	129.4	d	q
MAN(s)	32.6	25	300.9	c	q
MAT(s)	39.5	24	345.5	d	q
MIN	90.2	13	49.9	d	q
NDI(s)	75.4	16	300.1	c	a

Station	Epicentral distance	i_h	Azimuth	P polarity	Comments
<u>Earthquake No. 5</u> (Cont.)					
NOU	26.2	27	142.6	d	q
PHC	86.8	13	39.2	d	eq
PMG(s)	8.0	44	197.6	d	a
RAB(s)	3.6	45	134.1	c	b
RIV(s)	32.0	25	177.6	c	q
SEO(s)	44.3	23	334.0	d	a
SHL(s)	62.0	19	300.1	c	qa
TAU(s)	41.1	24	182.6	c	q
TUC(s)	99.0	13	57.7	d	q
WEL(s)	45.5	23	153.3	d	ea
<u>Earthquake No.</u> 6					
ADE(s)	32.1	36	205.2	d	eq
EDM	96.2	17	37.1	d	eq
ERS	21.1	47	184.8	d	eq
COL(s)	82.6	21	21.3	d	eq
CTA(s)	16.0	61	210.1	d	eq
HNR(s)	6.1	90	121.2	c	eq
LPB(s)	132.0	5	118.8	c	eq
MUN(s)	44.1	33	229.6	d	eq
PMG(s)	8.1	81	247.0	d	a
RIV(s)	27.6	39	186.4	d	q
TOO	32.2	36	193.8	c	eq
WIL	67.2	26	197.9	d	q

Station	Epicentral distance	i_h	Azimuth	P polarity	Comments
Earthquake No. 7					
AFI(s)	37.8	34	105.3	c	qa
ADE(s)	31.2	37	199.3	d	q
ANP(s)	41.8	33	318.5	c	qa
ATH(s)	122.2	5	311.7	c	eq
BAG(s)	37.0	35	306.9	c	q
BKS(s)	91.1	19	52.2	c	eq
BRS	21.7	46	175.0	d	q
CAN	29.5	37	182.8	d	q
CHG(s)	56.5	30	296.8	c	qa
COL(s)	83.5	20	22.2	c	q
CTA(s)	14.9	63	196.4	d	q
GUA(s)	20.0	50	343.3	c	a
HKC(s)	45.3	32	309.1	c	qa
HNR(s)	9.9	77	112.6	d	q
HOW(s)	67.1	26	297.1	c	a
IRK	69.9	25	331.7	c	eq
JER(s)	114.6	14	302.2	c	eq
KJN	109.0	12	337.0	d	q
KIP(s)	57.0	30	60.1	c	ea
KOD(s)	74.6	23	282.2	c	a
KOU	19.8	50	139.5	d	q
LAH(s)	81.4	21	302.9	c	a
LUG	18.8	52	122.4	d	q
MBC	95.5	17	13.9	c	eq
MAT(s)	43.6	33	345.4	c	q
MAW	83.9	20	202.7	c	q

Station	Epicentral distance	i_h	Azimuth	P polarity	Comments
Earthquake No. 7 (Cont.)					
MIN	91.9	18	49.9	c	eq
MUN(s)	41.5	33	226.6	c	qa
NDI(s)	78.4	22	300.7	c	a
NHA(s)	44.9	32	298.5	c	a
NOU	22.5	44	138.8	d	q
PPT	59.4	29	106.9	c	q
PMG(s)	5.1	88	223.4	d	a
POO(s)	79.4	21	290.0	c	ea
PVC	21.0	47	126.3	d	q
PUL	109.9	13	332.3	c	eq
PNT	94.1	18	41.0	c	eq
QUE(s)	87.4	19	300.5	c	q
RAB(s)	2.1	(80)	44.5	d	eb
RIV(s)	28.0	38	179.2	d	eq
SBA(s)	72.6	24	176.5	c	a
SEO(s)	48.4	32	334.7	c	a
SHI(s)	99.9	15	298.8	c	a
SHL(s)	65.0	27	301.5	c	qa
TAN	100.5	15	249.7	c	eq
TAU(s)	37.2	35	184.1	d	qa
TIF	105.6	13	311.6	c	eq
TOO	32.1	36	187.8	d	eq
TUC(s)	100.2	15	58.3	c	q
VIC	91.5	18	41.6	c	eq
UPP	115.3	10	335.9	d	q
WIL	66.5	26	196.6	c	q
WEL(s)	41.4	33	152.3	c	q

Station	Epicentral distance	i_h	Azimuth	P polarity	Comments
<u>Earthquake No. 8</u>					
ADE(s)	30.1	39	194.2	c	eq
BRS	22.1	47	167.0	c	q
CAN	29.4	40	177.2	c	q
COL(s)	84.9	22	22.8	c	q
CTA(s)	14.2	70	184	d	q
HNR(s)	13.1	73	106.8	d	q
MAT(s)	43.0	35	349.2	c	q
MAW	82.5	22	202.7	c	eq
MCQ	49.5	33	171.1	d	eq
MIN	94.5	18	50.1	d	eq
MUN(s)	39.0	36	224.2	d	q
NOU	24.7	43	133.4	c	eq
PPT	62.7	29	106.7	c	q
PMG(s)	3.6	(72)	182.4	c	a
POP	3.0	(67)	162.0	c	a
PVC	23.7	44	121.8	c	q
RAB(s)	5.1	(83)	72.1	d	b
TOO	31.7	39	182.7	d	eq
<u>Earthquake No. 9</u>					
AFI(s)	34.0	50	108.2	d	a
ADE(s)	33.9	50	204.6	d	q
ANP(s)	44.0	45	313.8	c	qa
ATH(s)	124.6	5	313.8	d	eq
BAG(s)	40.0	47	302.1	c	q
BRS	22.9	58	185.3	c	q
CAN	31.2	52	189.7	c	eq

Station	Epicentral distance	i_h	Azimuth	P polarity	Comments
Earthquake No. 9 (Cont.)					
CHG(s)	59.9	38	294.6	c	qa
COL(s)	80.8	29	21.3	c	qa
CTA(s)	17.7	65	208.4	c	q
FRU	86.1	26	313.3	c	eq
GUA(s)	20.6	61	330.7	c	a
HKC(s)	48.1	44	305.3	c	qa
HNR(s)	6.9	(76)	135.8	c	b
KOD(s)	78.7	30	281.3	c	a
KOU	18.3	64	151.5	d	q
MAN(s)	38.7	48	300.1	c	q
MAT(s)	43.7	45	340.2	c	q
MCQ	49.9	43	177.1	d	q
MUN(s)	45.5	45	228.4	d	qa
NOR	102.8	18	358.8	c	q
NOU	20.8	60	149.2	c	q
PPT	55.6	41	108.1	d	q
PMG(s)	9.3	(86)	237.8	c	a
POO(s)	83.1	28	289.2	d	a
PVC	18.5	64	136.6	c	q
RIV(s)	29.4	53	186.7	d	q
SBA(s)	73.6	32	177.4	d	a
SDB(s)	137.4	5	242.4	d	q
SEO(s)	49.4	43	330.4	c	a
SHL(s)	68.1	35	299.7	c	a
TAU(s)	38.9	48	189.1	d	a
TPN	8.9	(85)	244.5	c	a

Station	Epicentral distance	i_h	Azimuth	P polarity	Comments
Earthquake No. 9 (Cont.)					
TOO	34.1	50	193.7	d	q
TUC(s)	95.9	22	58.1	d	q
WIL	69.0	34	197.8	d	q
WEL(s)	40.6	47	157.0	d	a
Earthquake No. 10					
ADE(s)	31.7	37	200.2	c	eq
BAG(s)	37.5	35	305.9	c	q
BUL(s)	118.4	8	243.8	d	q
BHA	120.2	5	250.0	d	q
BKS(s)	90.3	19	52.2	d	q
BRS	21.9	45	177.0	c	q
CHG(s)	57.0	30	296.3	c	qa
COL(s)	82.9	21	22.0	c	q
CTA(s)	15.5	62	198.8	d	q
GSC(s)	35.6	34	321.9	c	q
GUA(s)	19.9	50	340.8	c	a
HKC(s)	45.7	32	308.3	c	qa
HOW(s)	67.6	26	296.7	c	ea
IRK	70.0	20	331.3	c	eq
KIR	109.5	12	342.3	c	q
KOD(s)	75.3	23	282.0	c	ea
LAH(s)	81.9	21	302.8	c	ea
MAN(s)	36.1	35	303.8	c	q
MAT(s)	43.5	33	344.4	c	a
MIN	91.1	19	49.8	d	q
MSH(s)	94.7	17	305.9	c	ea

Station	Epicentral distance	i_h	Jzimuth	P polarity	Comments
Earthquake No. 10 (Cont.)					
MUN(s)n	42.3	34	226.9	d	q
NHA(s)	45.5	33	292.8	c	a
PMG(s)	5.9	87	227.0n	d	q
POP	4.6	89	224.2	d	a
QUE(s)	88.0	20	300.4	c	a
RAB(s)n	1.4	(67)	31.6	d	b
RIV(s)n	28.3	39	180.6	c	eq
SBA(s)	72.9	24	176.6n	c	a
SEO(s)n	48.5	32	333.8	c	a
SHK(s)	43.5	33	337.3	c	eq
SHL(s)	65.5	27	301.1	c	qa
TOO	32.5	37	188.9	c	eq
TUC(s)	99.4	16	58.3	c	eq
WIL	67.1	27	196.8	d	q
Earthquake No. 11					
AFI(f)	41.9	35	103.6	d	q
ADE(s)	29.3	40	192.8	c	a
ANP(s)n	39.6	36	323.4	c	eq
BAG(s)	34.1	38	312.0	d	a
BRS	21.8	48	164.3	c	a
CAN	28.9	40	175.4	c	a
CHG(s)	52.9	32	299.2	d	a
COL(s)	85.8	21	23.0	d	a
CTA(s)	13.6	72	180.2	c	a
FRU	81.1	23	315.0	d	q
GUA(s)	19.8	53	356.0	d	a
HKC(s)	42.5	35	313.1	d	a

Station	Epicentral distance	i_h	Azimuth	P polarity	Comments
Earthquake No. 11 (Cont.)					
HNR(s)	13.8	71	103.4	d	a
KIP(s)	61.2	30	61.4	c	a
KOU	22.4	47	130.6	d	a
LAH(s)n	78.2	24	303.9	d	a
LUG	22.3	47	115.6	d	q
MAN(s)	32.6	38	310.1	d	q
MCQ	37.9	37	224.0		ea
MUN(s)	37.9	37	224.0	c	a
NOU	25.1	42	131.1	d	q
PPT	63.4	29	106.4	d	q
NAI(s)	109.2	13	266.4	c	ea
PMG(s)	3.1	(75)	164.4	c	a
POO(s)	75.6	25	290.9	d	a
QUE(s)	84.0	22	301.2	d	a
RAB(s)	6.2	(88)	69.8	d	b
RIV(s)	27.7	41	171.3	c	a
SEO(s)	47.3	34	339	d	a
SHI(s)	96.4	18	298.9	d	a
SHL(s)	61.6	29	303.4	d	q
SNG(s)	47.6	34	285.8	d	a
STU(s)	124.3	5	326.8	d	ea
TAU(s)	36.4	37	178.7	c	a
TPN	2.0	(55)	160.7	c	A
TRN(s)	152.3	5	79.3	d	ea
WIL	64.7	28	195.2	c	a
WEL(s)	43.1	35	148.2	c	b

TABLE 3

SUMMARY OF FOCAL MECHANISM SOLUTIONS

Earthquake No.	3	4	5	7	9	10	11
Nodal plane 1							
Azimuth	090	165	158	177	336	110	068
Dip	88	60	60	57	76	90	68
Uncertainty (a)	2	28	42	13	15	0	1
(b)	1	12	6	3	10	0	1
Nodal plane 2							
Azimuth	-	-	252	-	228	200	162
Dip	-	-	83	-	42	86	81
Uncertainty (a)	53	90	9	54	25	50	29
(b)	37	32	1	44	2	9	13
B axis							
Azimuth	-	-	173	-	258	200	093
Plunge	-	-	60	-	38	86	65
Uncertainty (a)	36	24	6	56	1	1	11
(b)	1	22	1	13	1	1	1
P axis							
Azimuth	-	-	029	-	116	065	293
Plunge	-	-	26	-	45	3	24
T axis							
Azimuth	-	-	291	-	004	334	203
Plunge	-	-	15	-	21	3	9
Model Type			I		II	II	I
Nodal plane = Fault plane			1				1
Fault motion							
Azimuth			072				342
Plunge			07				09

(a) and (b) are lengths of ellipse axes defining nodal plane pole position.

All values in degrees

TABLE 4

EAST NEW GUINEA REGION EARTHQUAKES SOLVED BY WICKENS AND HODGSON (1967)

(see Table 5)

Date	D.O. Ref. No.	Origin Time			Lat. °S	Long. °E	Depth	Mag.
10.6.36	38	08	23	21	5.5	147	160	6.9
31.8.38	53	17	45	13	4	151.5	350	6.7
4.9.41	72	10	21	44	4.5	154	100	7.1
1.12.43	89	06	04	55	4.5	144	100	7.2
4.12.50	178	16	28	01	5	153.5	100	7.0
23.4.53	307	16	24	17	4	154	33	7.6
3.3.54	343	06	02	55	5.5	142.5	33	7.2
18.6.62	585	23	42	31	4.8	151.8	47	6.7

TABLE 5

FOCAL MECHANISM SOLUTIONS OBTAINED BY WICKENS AND HODGSON

D.O.	Nodal Planes				B axis		P axis		T axis		Total
Ref. No.	Az.	Dip.	Az.	Dip.	Az.	Pl.	Az.	Pl.	Az.	Pl.	variation
38	023.3	65.2	282.3	67.6	335.5	55.5	243.2	01.6	152.2	34.5	34
53	039.6	68.4	306.5	82.3	018.1	66.9	264.9	09.5	171.2	20.8	15
72	012.5	72.1	273.3	63.6	312.6	57.3	051.3	05.6	144.8	32.1	26
89	264.8	89.8	354.9	82.5	353.2	82.5	129.5	05.4	220.0	05.2	11
178	015.2	86.6	106.0	77.0	090.6	76.5	239.7	11.6	331.1	06.7	9
307	343.1	82.5	252.5	85.4	311.2	81.2	207.9	02.0	117.6	08.6	18
343	005.0	76.5	096.8	82.4	035.6	74.4	231.6	15.0	140.5	04.1	7
585	227.7	65.4	136.1	86.4	218.3	65.1	94.5	14.5	359.2	19.8	11

All readings are in degrees

TABLE 6

EAST NEW GUINEA EARTHQUAKES (WICKENS AND HODGSON) WHICH MAY INVOLVE DIP-SLIP FAULT MOTION

Date	D.O. Ref. No.	Origin time			Lat. °S	Long. °E	Depth, km	Mag.	B axis Az.	B axis Pl.	Cone
17.1.46	99	09	39	36	6.2	147.7	100	-	154.1	44.4	47
17.2.51	188 (3 Solns)	21	07	09	7	146	225	7.2	340.8	72.3	1
									144.1	03.8	70
									164.4	09.0	75
28.11.52	295	21	01	27	6.5	155.5	100	6.7	098.5	10.6	64
7.6.54	355 (2 Solns)	10	15	33	3.5	152.5	475	6.7	253.9	13.6	104
									243.1	15.6	100
31.1.56	406	09	17	11	4	152	400	7.1	176.8	05.1	58
22.5.56	415	12	36	12	4	152.5	540	6.7	065.5	15.8	108
5.1.61	554 (2 Solns)	15	53	56	4.1	143.0	108	6.7	167.3	66.4	8
									359.7	02.8	12
30.7.62	591 (3 Solns)	17	16	44	3.3	143.9	25	7	153.0	71.7	4
									153.9	06.4	43
									146.3	01.2	55

All readings in degrees

TABLE 7

POLARITY ANALYSIS

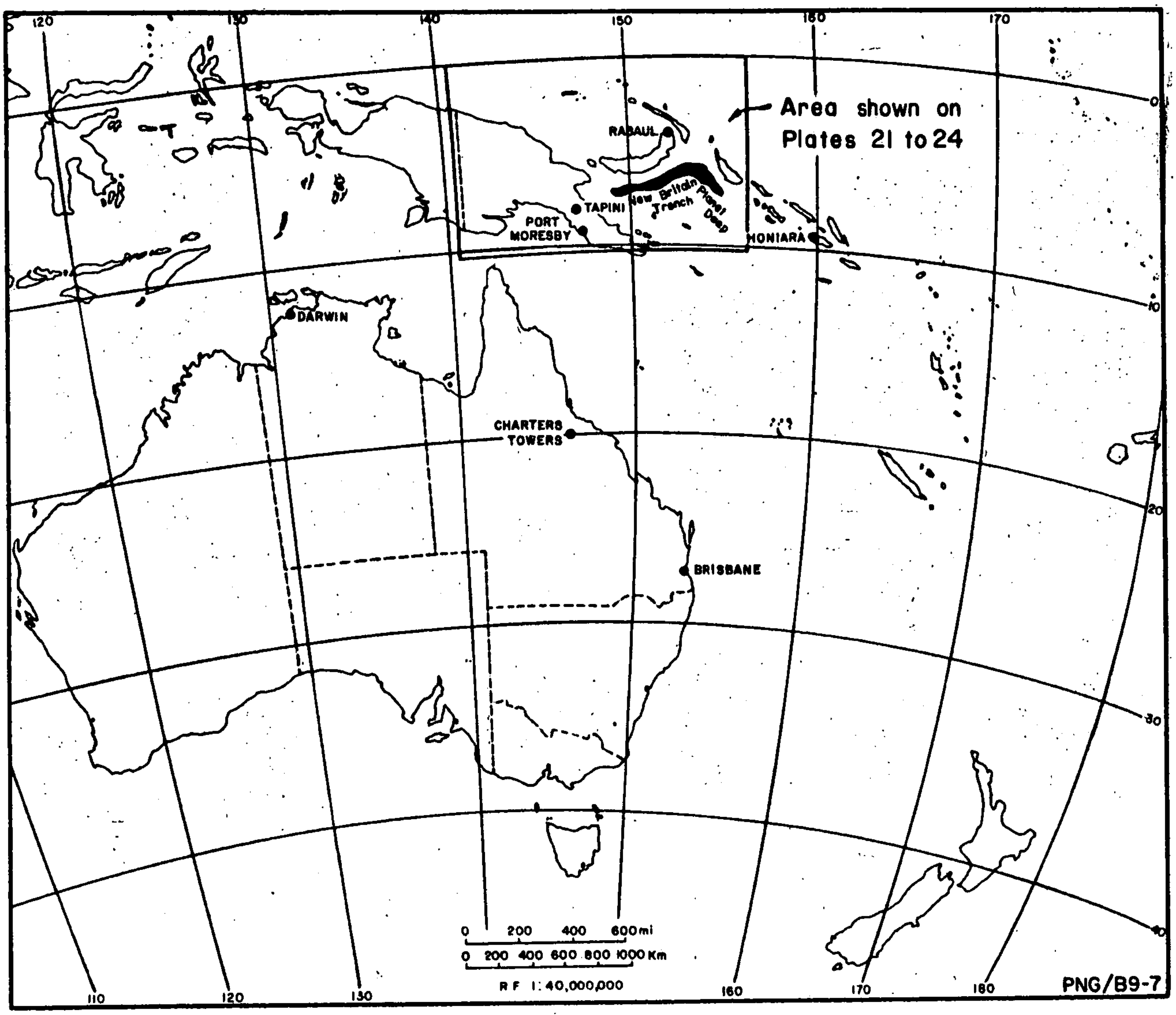
Earthquake No.	No. Compressions	No. Dilatations	
1	17	5	*
2	19	4	*
3	30	24	*
4	12	12	
5	12	13	
7	37	16	
8	11	7	*
9	21	16	
10	25	10	
11	14	23	

* Indicates that the results conform with the Polarity Rule.

TABLE 8

DISTRIBUTION OF STATIONS OF THE WORLD WIDE STANDARD SEISMOGRAPH NETWORK WITH RESPECT TO PMG

Epicentral distances	i_h	Percent of focal sphere	No. of WWSS stations
0-5° (approx)	0-90° (top hemisphere)	50	2
5°-90°	90°-20° (bottom hemisphere)	47	38
90°-180°	20°-0° (bottom hemisphere)	3	72



BASED ON A/BO-27

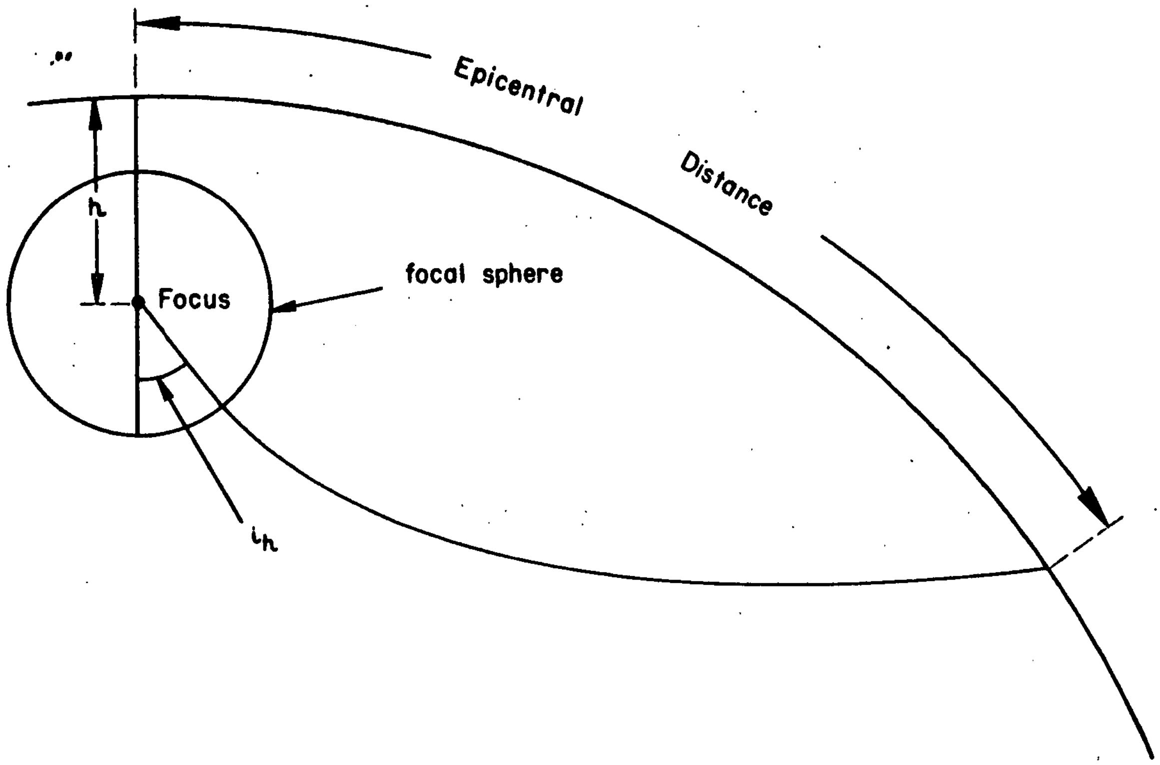
LOCALITY MAP

The East New Guinea Region comprises the Territory of Papua and New Guinea, including New Britain, New Ireland and Bougainville.

- • Darwin – Seismic station
- ⌒ – Deep ocean trench

To Accompany Record No. 1971/27

PLATE 2

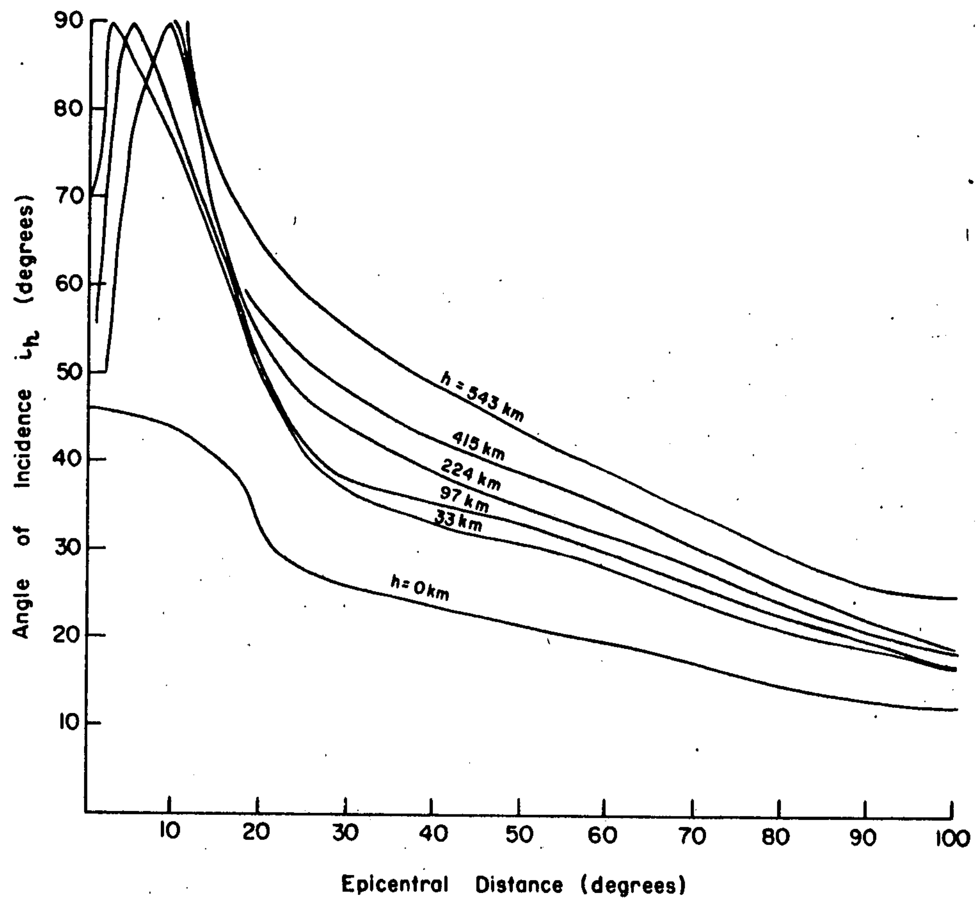


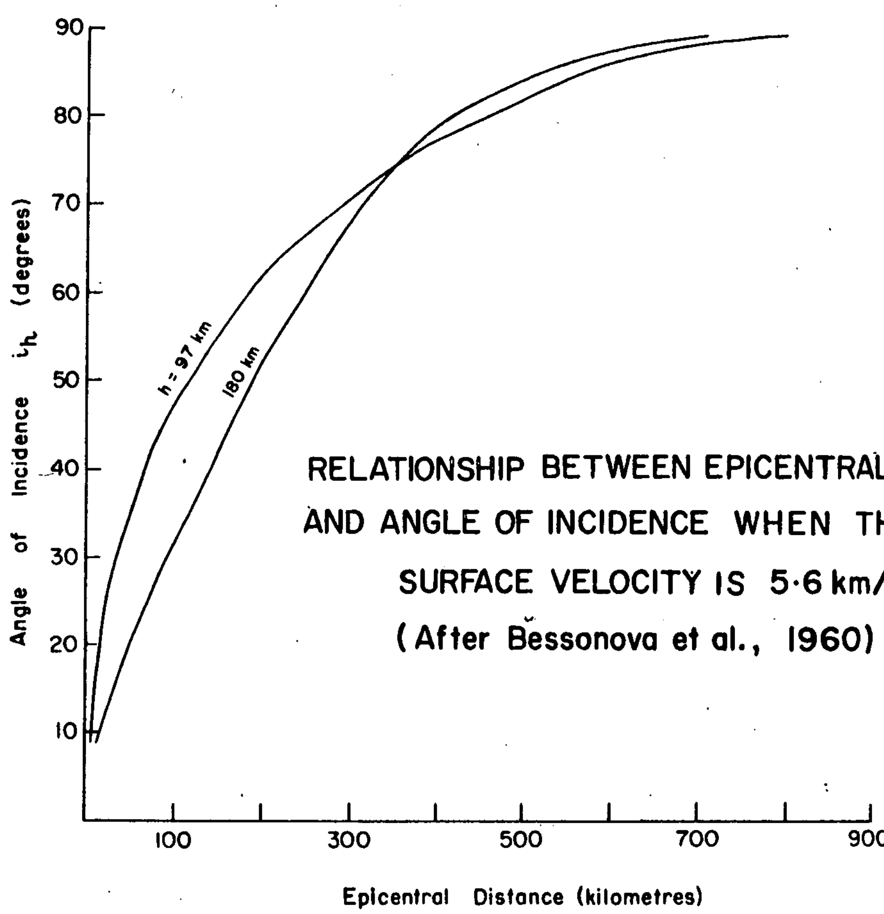
THE THEORETICAL FOCAL SPHERE USED
IN FOCAL MECHANISM INTERPRETATIONS

To Accompany Record No. 1971/27

G82/2-92

PLATE 3



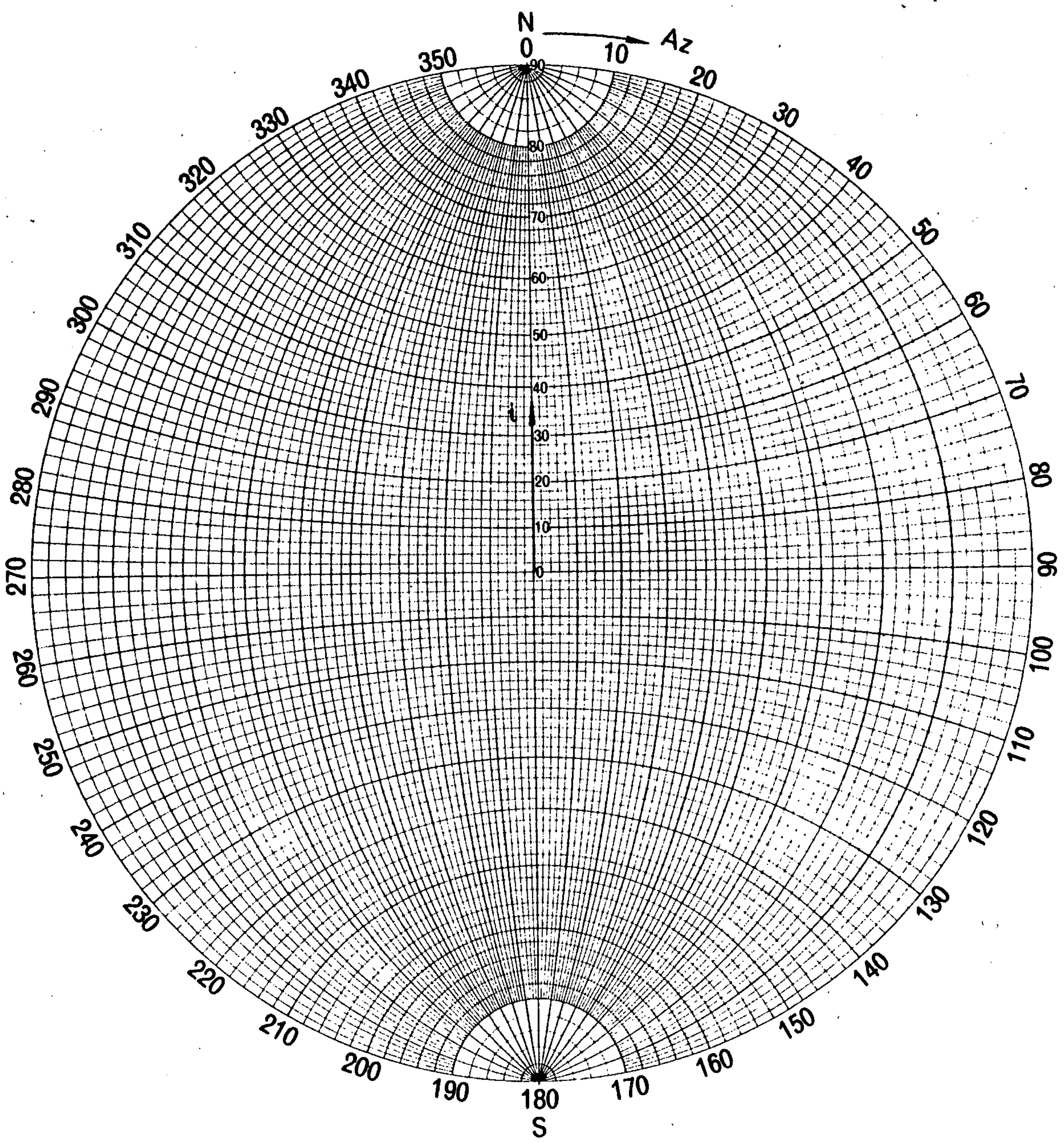


RELATIONSHIP BETWEEN EPICENTRAL DISTANCE AND ANGLE OF INCIDENCE WHEN THE SURFACE VELOCITY IS 5·6 km/s.
(After Bessonova et al., 1960)

To Accompany Record No. 1971/27

G82/2-93

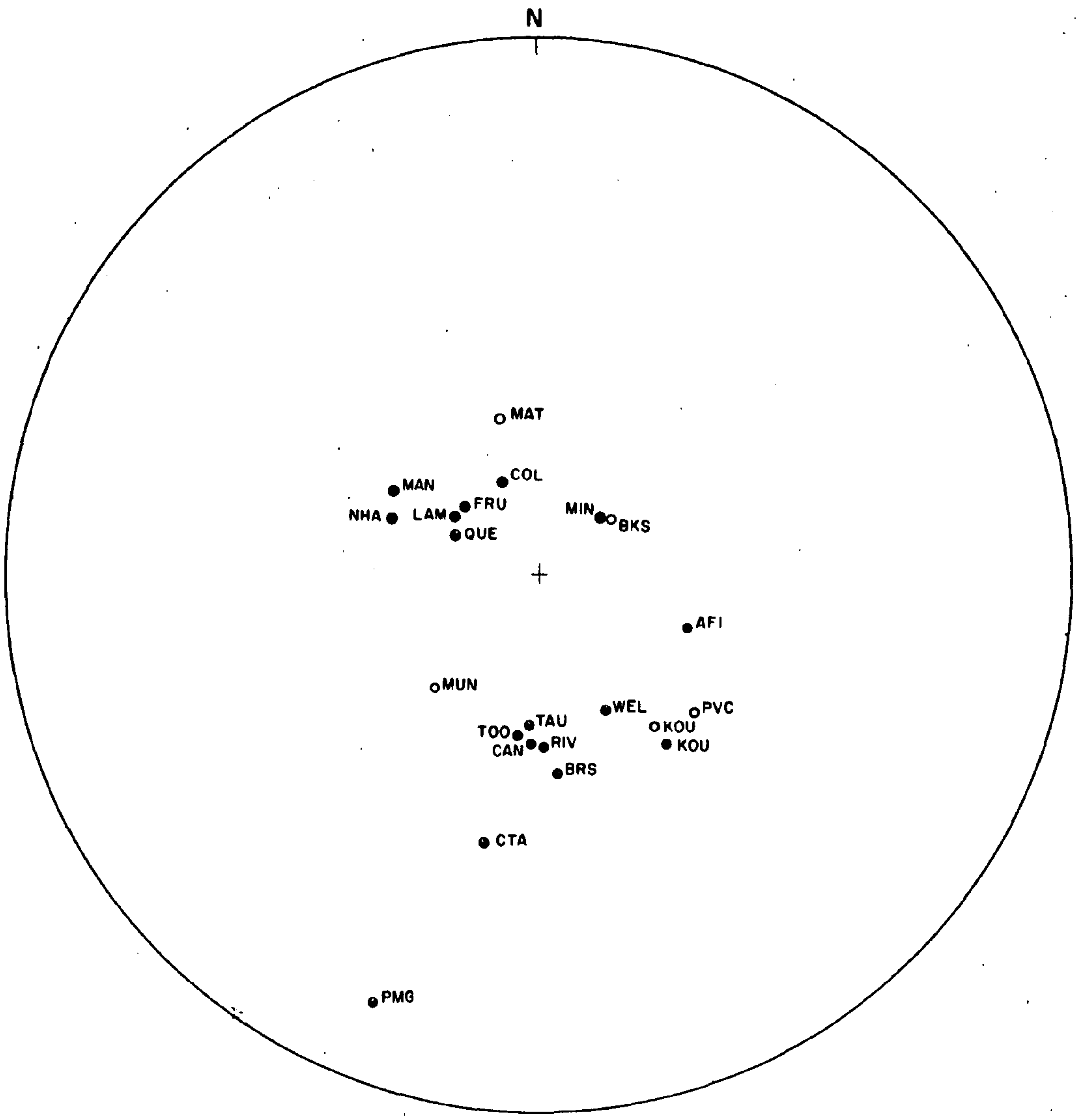
PLATE 4



THE WULFF STEREOGRAPHIC PROJECTION

FOCAL SPHERE STEREOGRAPHIC PROJECTION

EARTHQUAKE No I



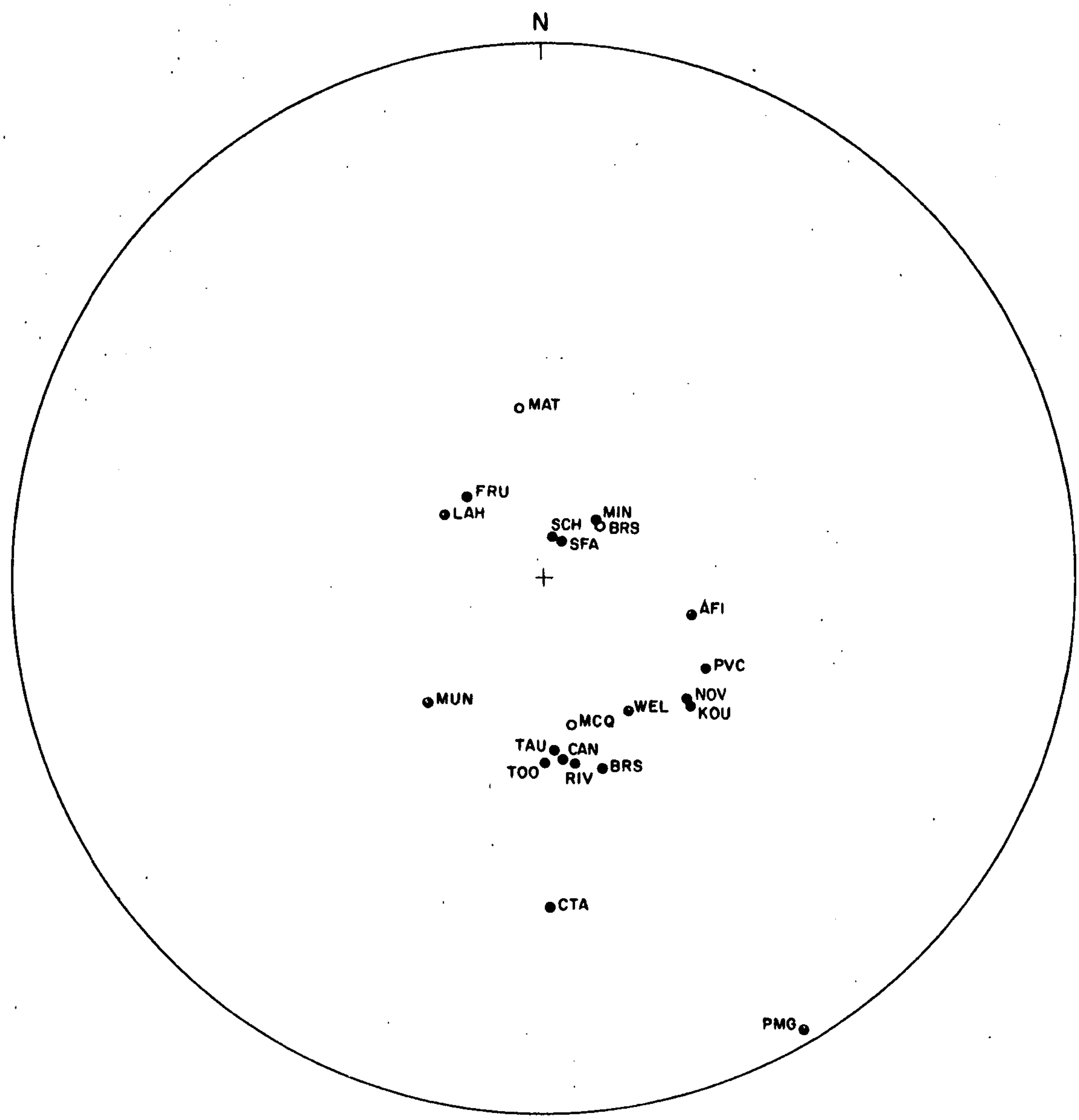
● COMPRESSION

o DILATATION

PLATE 6

FOCAL SPHERE STEREOGRAPHIC PROJECTION

EARTHQUAKE No 2

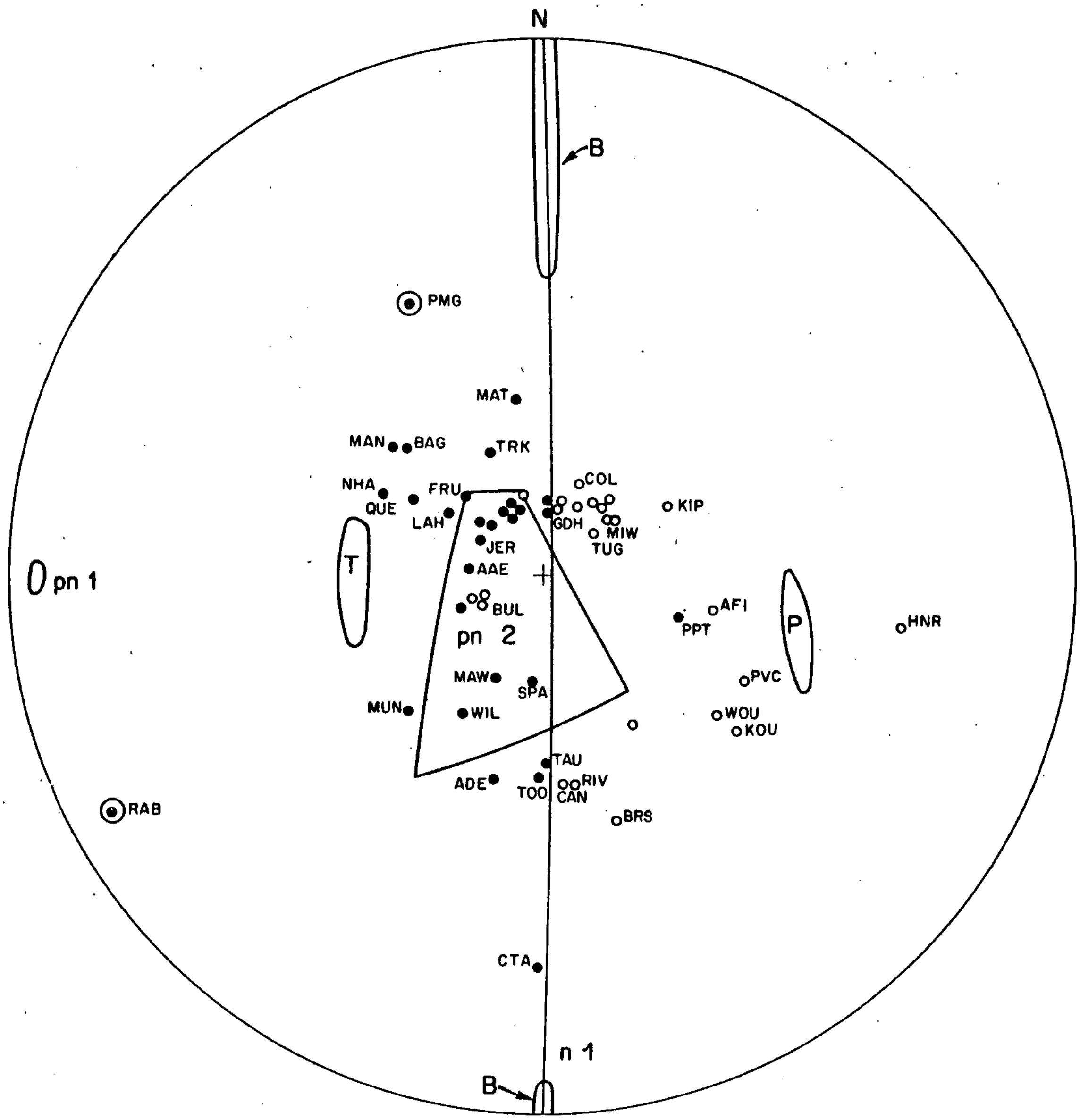


● COMPRESSION
○ DILATATION

PLATE 7

FOCAL SPHERE STEREOGRAPHIC PROJECTION

EARTHQUAKE No 3



● COMPRESSION

o DILATATION

◯ UPPER HEMISPHERE PROJECTION

T TENSION AXIS UNCERTAINTY

P PRESSURE AXIS UNCERTAINTY

pn NODAL PLANE POLE AND ITS UNCERTAINTY

B AXIS

n1 NODAL PLANE

NODAL PLANE 2 IS NOT SHOWN

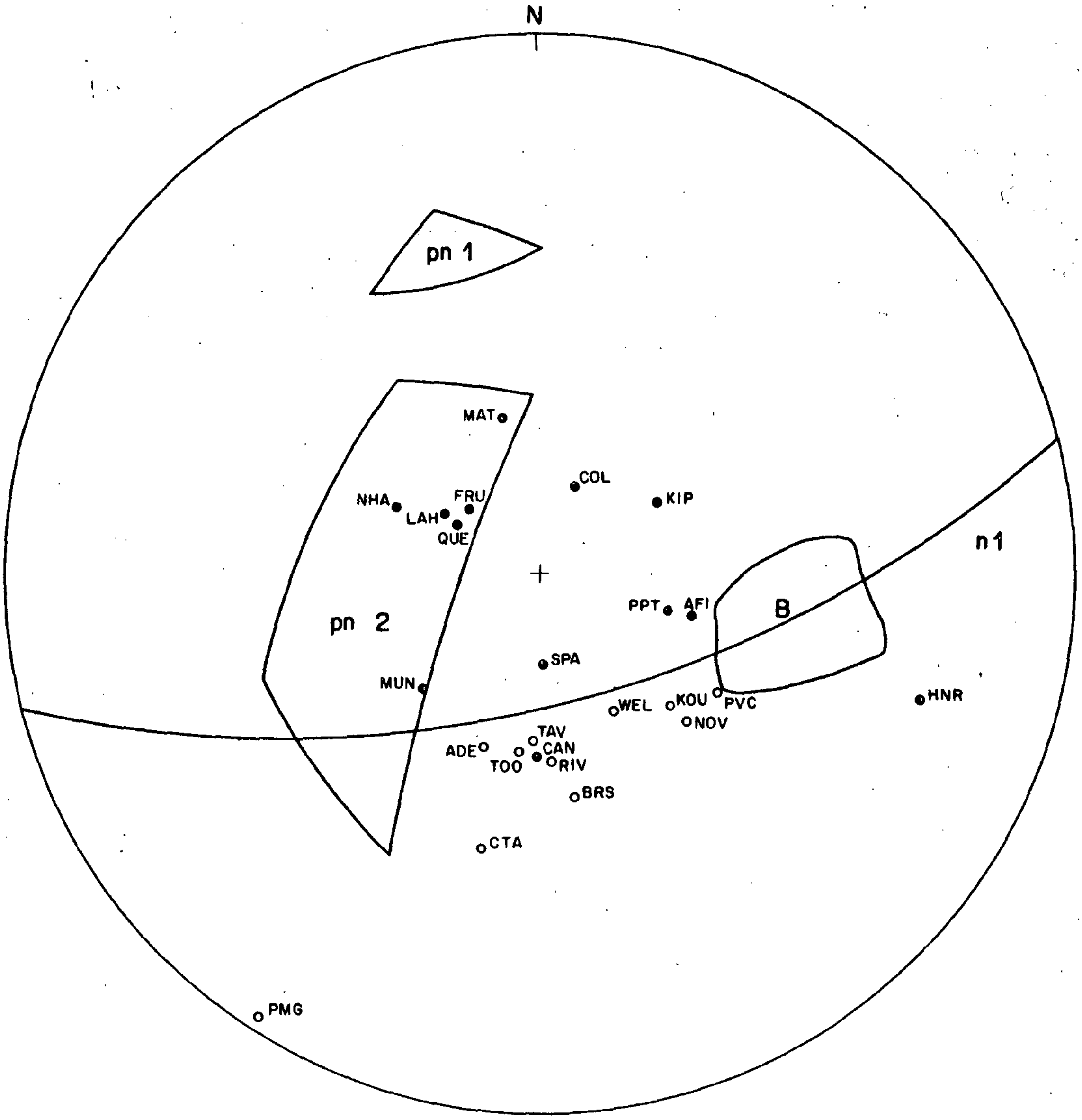
To Accompany Record No. 1971/27

G82/2-96

PLATE 8

FOCAL SPHERE STEREOGRAPHIC PROJECTION

EARTHQUAKE No 4



● COMPRESSION

○ DILATATION

B B-AXIS UNCERTAINTY (ALSO UNCERTAINTY OF THE MUTUALLY PERPENDICULAR NODAL PLANE INTERPRETATION)

n1 NODAL PLANE

pn NODAL PLANE POLE AND ITS UNCERTAINTY

NODAL PLANE 2 IS NOT SHOWN

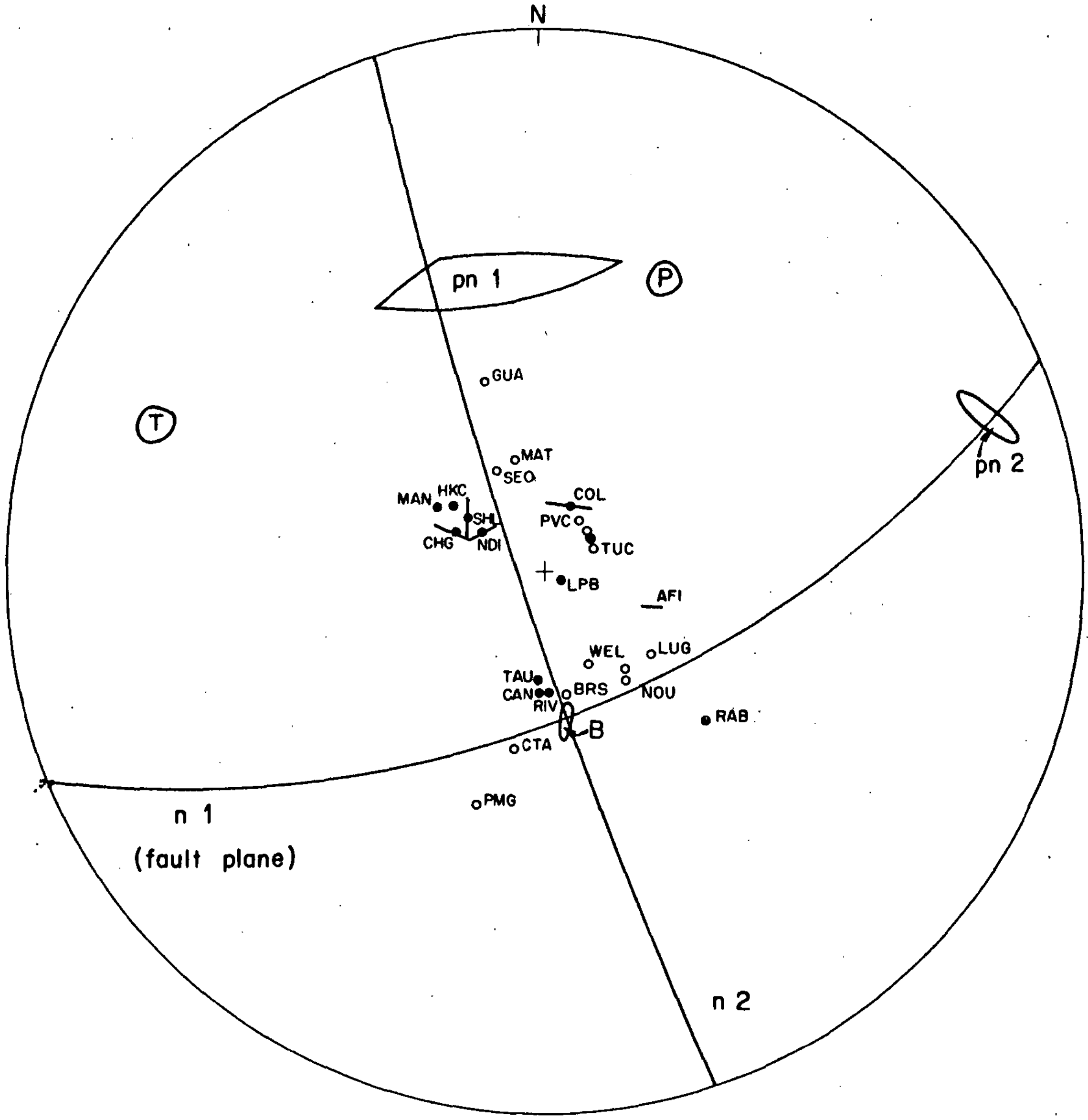
To Accompany Record No. 1971/27

G82/2-97

PLATE 9

FOCAL SPHERE STEREOGRAPHIC PROJECTION

EARTHQUAKE No 5



●	COMPRESSION
o	DILATATION
\	S WAVE POLARIZATION DIRECTION
T	TENSION AXIS UNCERTAINTY
P	PRESSURE AXIS UNCERTAINTY
pn	NODAL PLANE POLE AND ITS UNCERTAINTY
n	NODAL PLANE

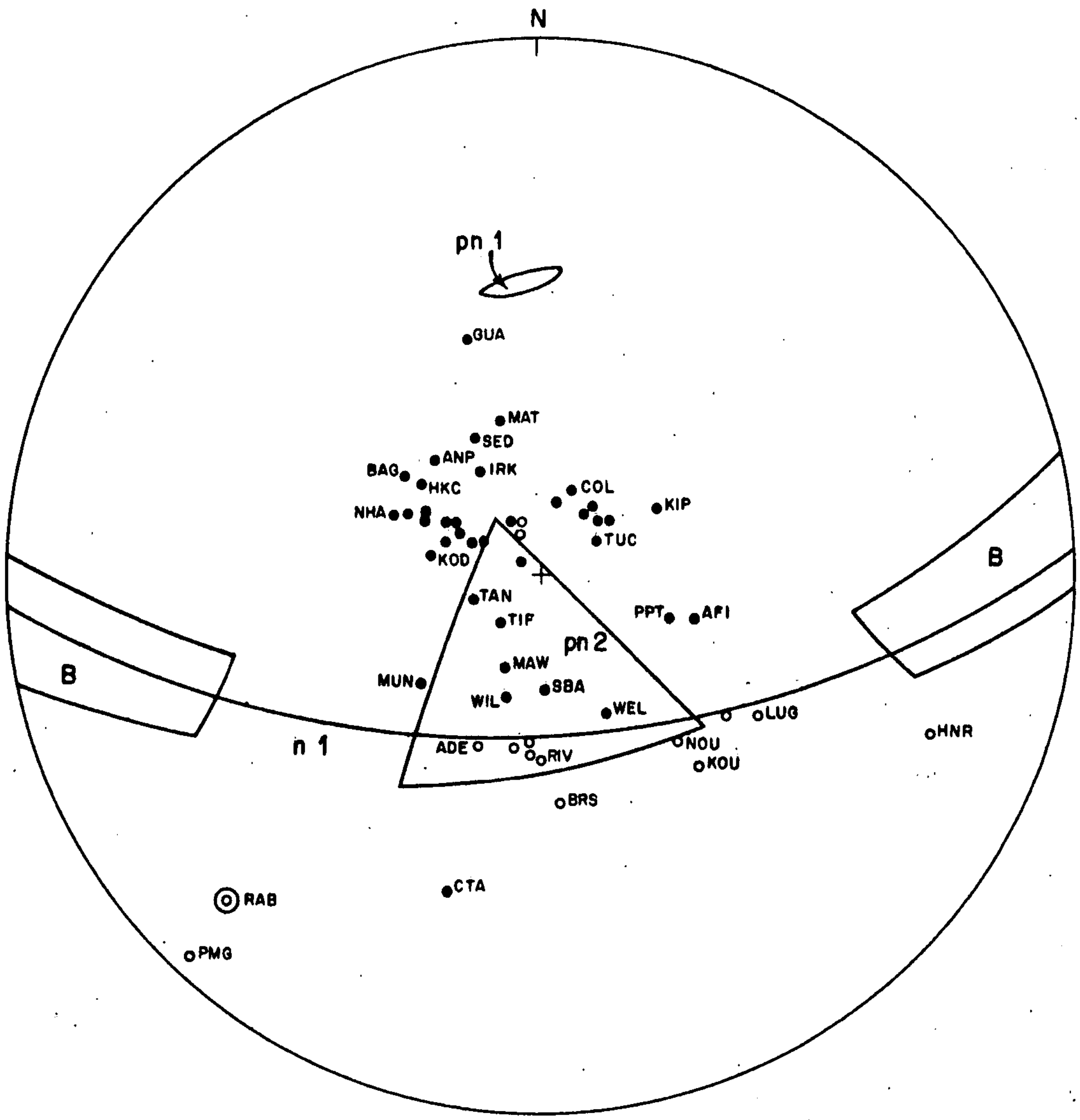
To Accompany Record No. 1971/27

G82/2-98

PLATE 10

FOCAL SPHERE STEREOGRAPHIC PROJECTION

EARTHQUAKE No 7



NODAL PLANE 2 IS NOT SHOWN

●	COMPRESSION
o	DILATATION
B	B AXIS UNCERTAINTY (ALSO UNCERTAINTY OF THE MUTUALLY PERPENDICULAR NODAL PLANE INTERPRETATION)
pn	NODAL PLANE POLE AND ITS UNCERTAINTY
n1	NODAL PLANE
◯	UPPER HEMISPHERE PROJECTION

To Accompany Record No. 1971/27

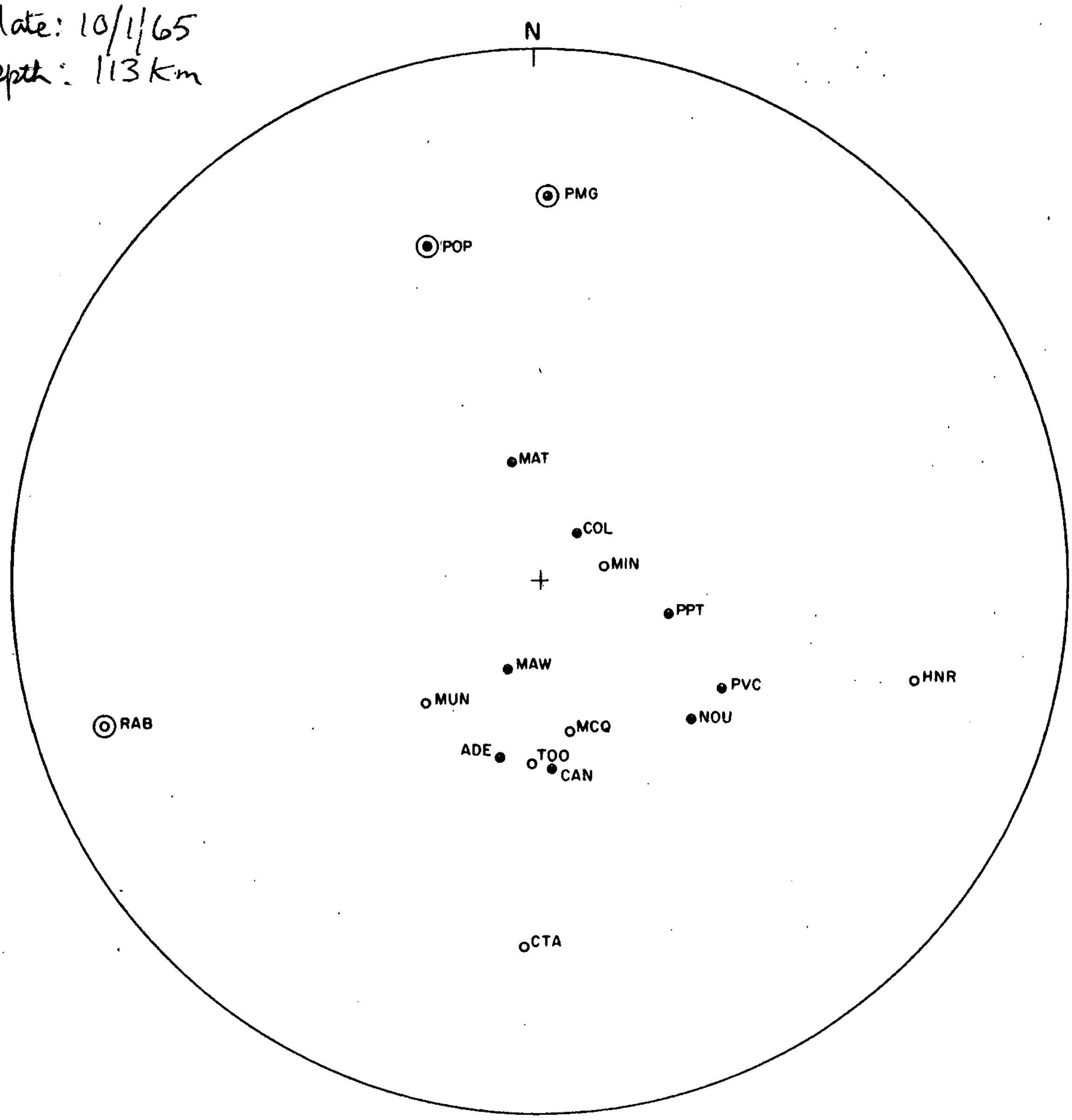
G82/2-99

FOCAL SPHERE STEREOGRAPHIC PROJECTION

EARTHQUAKE No 8

— South of Long Island, does not conform to orthogonal nodal plane model.

date: 10/1/65
depth: 113 Km



● COMPRESSION

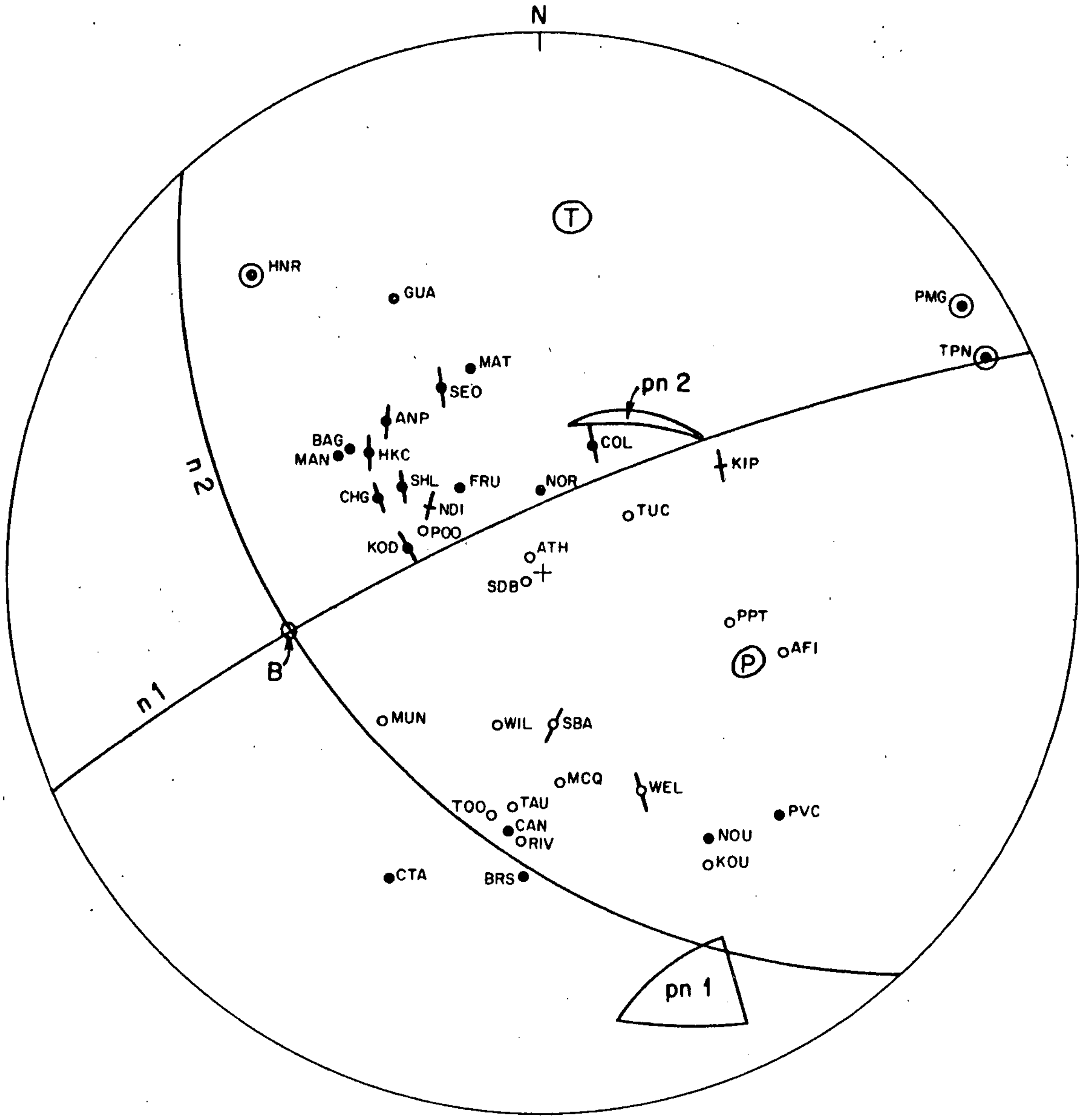
o DILATATION

◯ UPPER HEMISPHERE PROJECTION

PLATE 12

FOCAL SPHERE STEREOGRAPHIC PROJECTION

EARTHQUAKE No 9



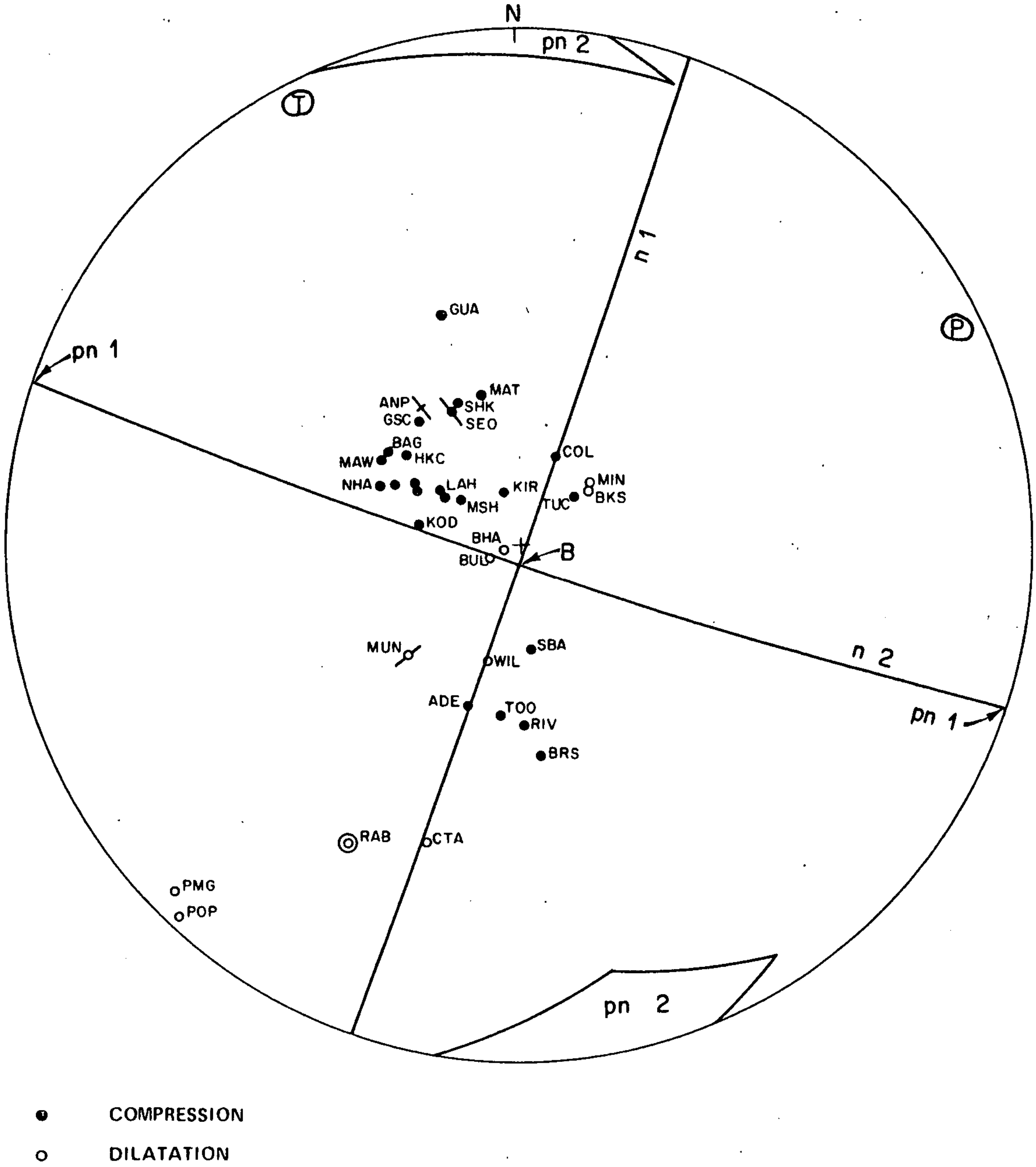
•	COMPRESSION
o	DILATATION
◯	UPPER HEMISPHERE PROJECTION
\	S-WAVE POLARIZATION DIRECTION
T	TENSION AXIS UNCERTAINTY
P	PRESSURE AXIS UNCERTAINTY
B	B-AXIS UNCERTAINTY
pn	NODAL PLANE
n	NODAL PLANE AND ITS UNCERTAINTY

To Accompany Record No. 1971/27

G82/2-101

FOCAL SPHERE STEREOGRAPHIC PROJECTION

EARTHQUAKE No 10



- ● COMPRESSION
- o DILATATION
- ◯ UPPER HEMISPHERE PROJECTION
- \ S-WAVE POLARIZATION DIRECTION
- T TENSION AXIS UNCERTAINTY
- P PRESSURE AXIS UNCERTAINTY
- B B-AXIS UNCERTAINTY
- pn NODAL PLANE
- n NODAL PLANE POLE AND ITS UNCERTAINTY

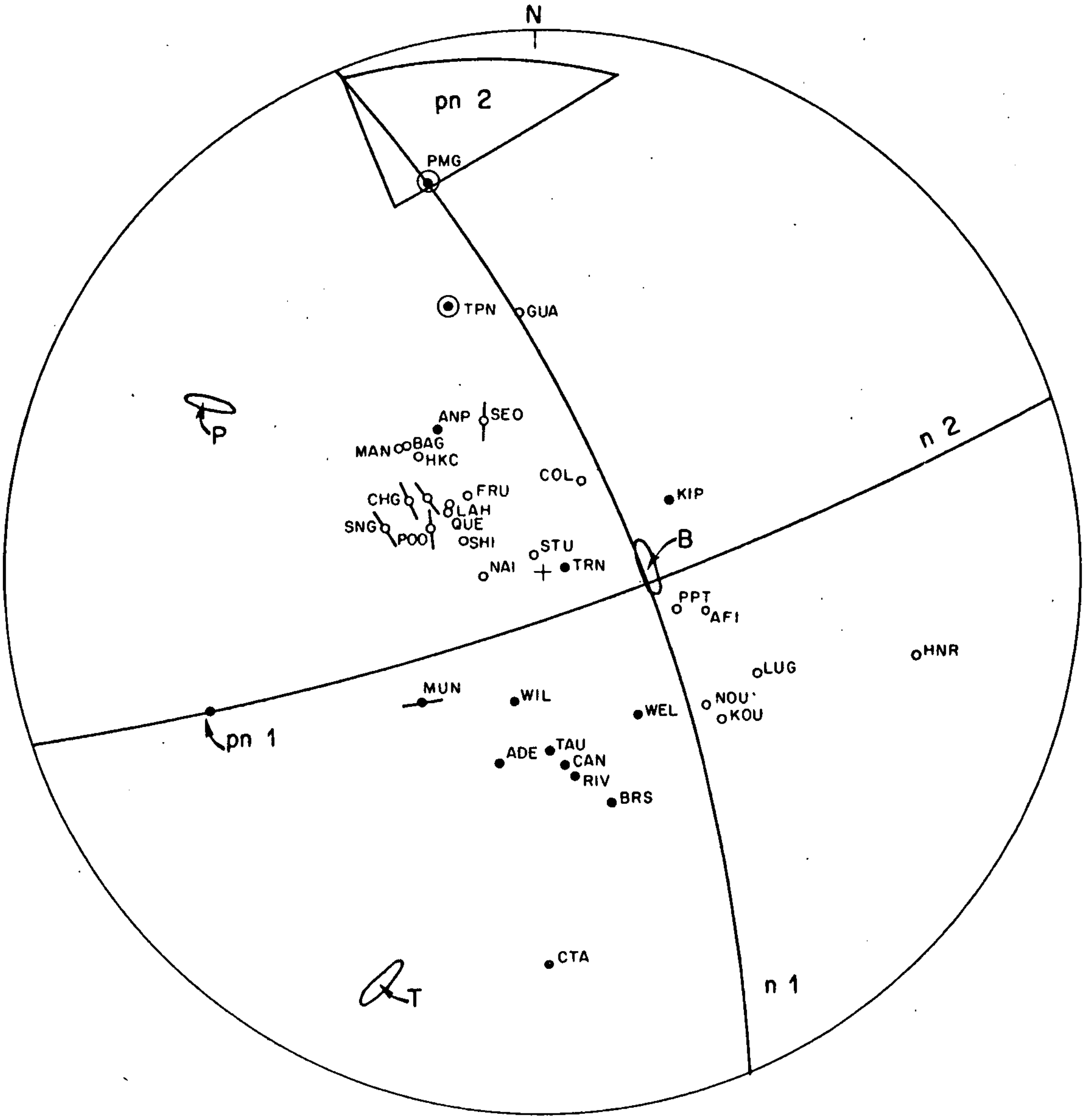
To Accompany Record No. 1971/27

G82/2-102

PLATE 14

FOCAL SPHERE STEREOGRAPHIC PROJECTION

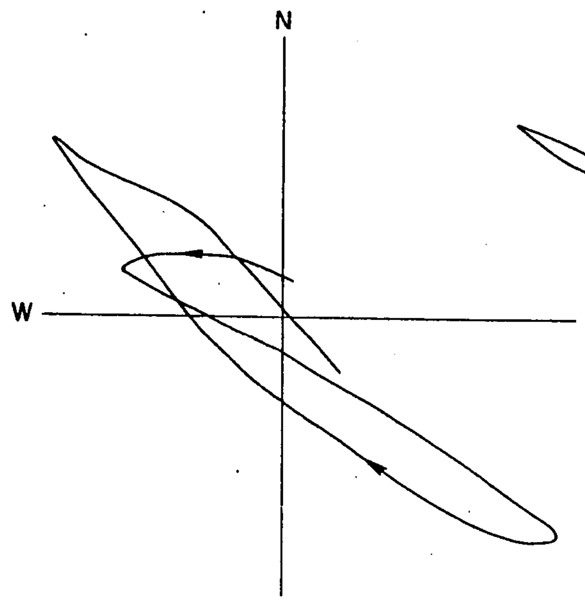
EARTHQUAKE No 11



●	COMPRESSION
o	DILATATION
◯	UPPER HEMISPHERE PROJECTION
╲	S-WAVE POLARIZATION DIRECTION
T	TENSION AXIS UNCERTAINTY
P	PRESSURE AXIS UNCERTAINTY
B	B-AXIS UNCERTAINTY
n	NODAL PLANE
pn	NODAL PLANE POLE AND ITS UNCERTAINTY

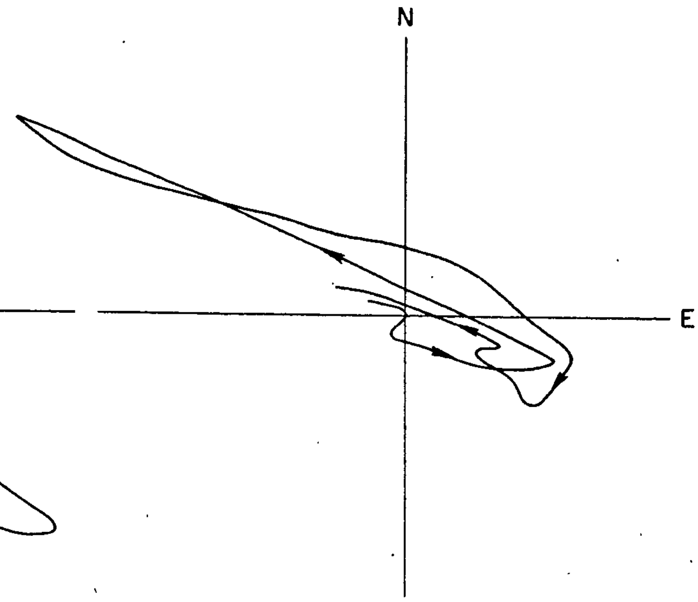
To Accompany Record No. 1971/27 G82/2-103

S-WAVE PARTICLE MOTION ANALYSIS
EARTHQUAKE No5



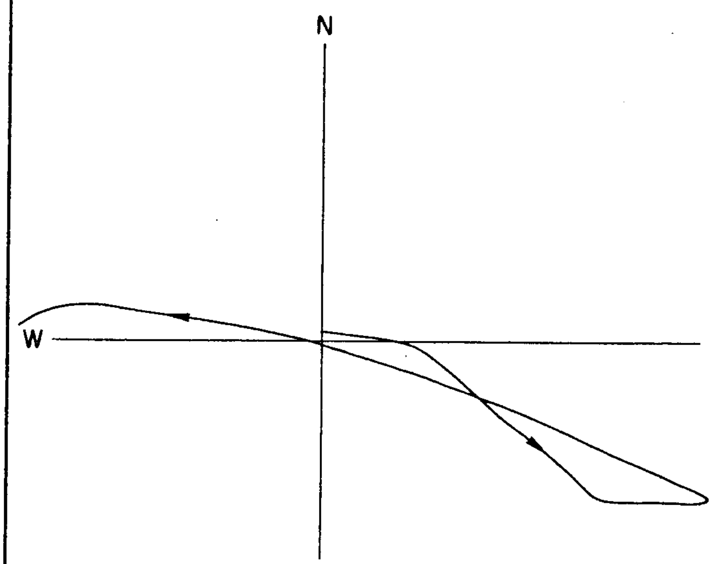
(A)

STATION AFI
Δ = 40°
AZIMUTH OF MOTION = 311°
GREAT CIRCLE AZIMUTH = 284°
ANGLE OF POLARIZATION = 27°



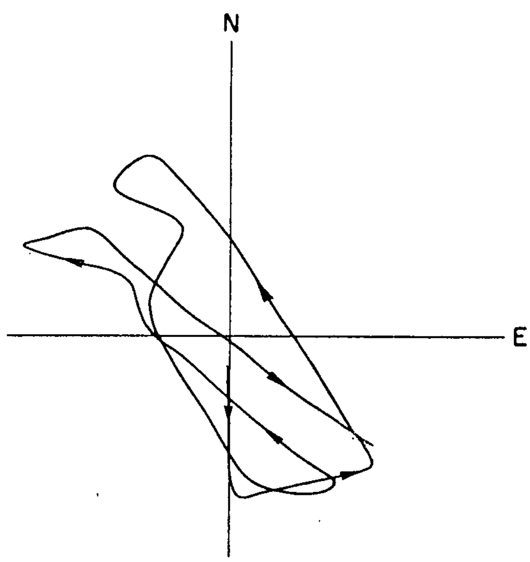
(B)

STATION CHG
Δ = 54°
AZIMUTH OF MOTION = 113°
GREAT CIRCLE AZIMUTH = 106°
ANGLE OF POLARIZATION 7°



(C)

STATION COL
Δ = 80°
AZIMUTH OF MOTION = 106°
GREAT CIRCLE AZIMUTH = 181°
ANGLE OF POLARIZATION = −75°



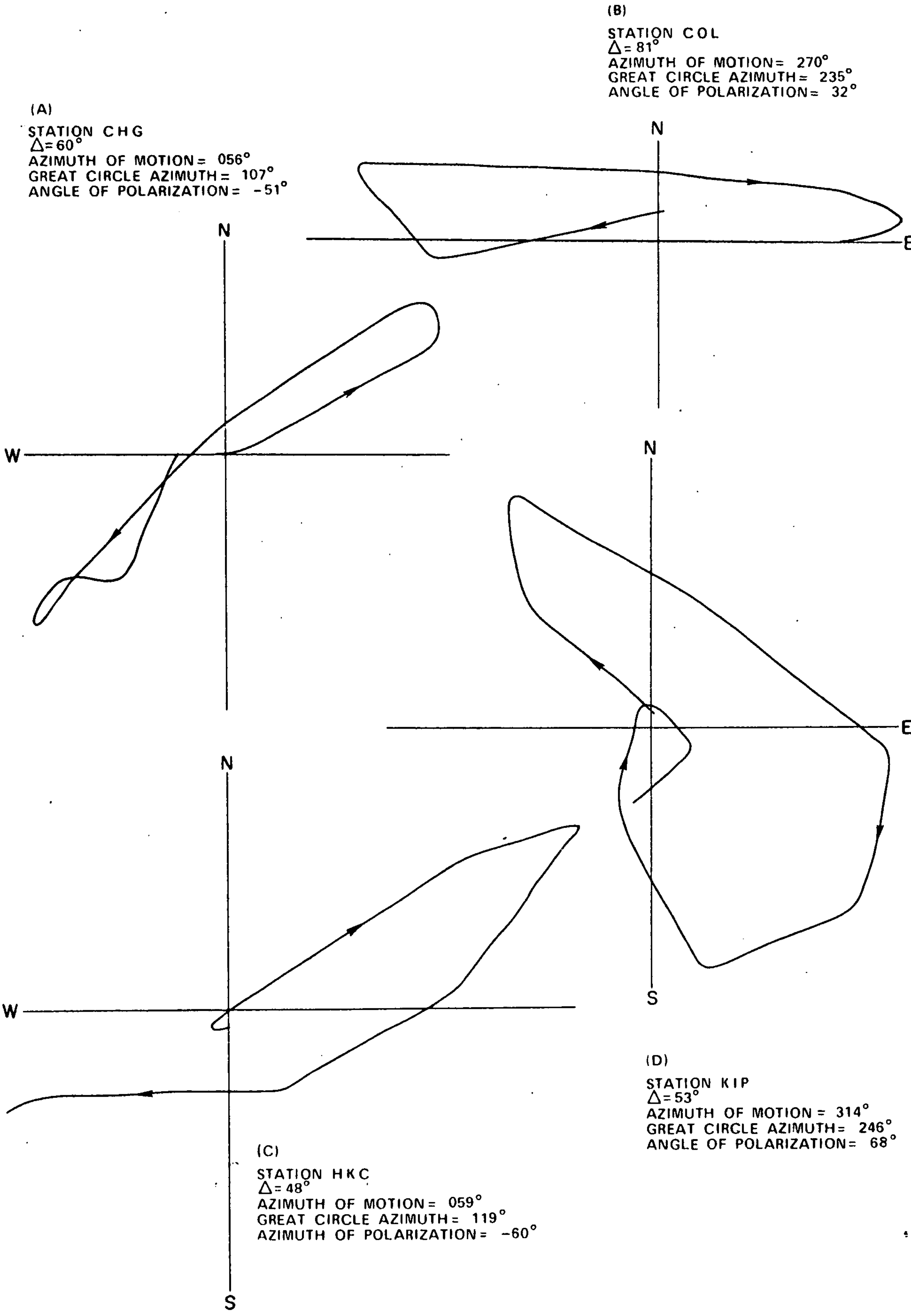
(D)

STATION NDI
Δ = 75°
AZIMUTH OF MOTION = 145°
GREAT CIRCLE AZIMUTH = 100°
ANGLE OF POLARIZATION = 45°

PLATE 16

S-WAVE PARTICLE MOTION ANALYSIS

EARTHQUAKE No 9



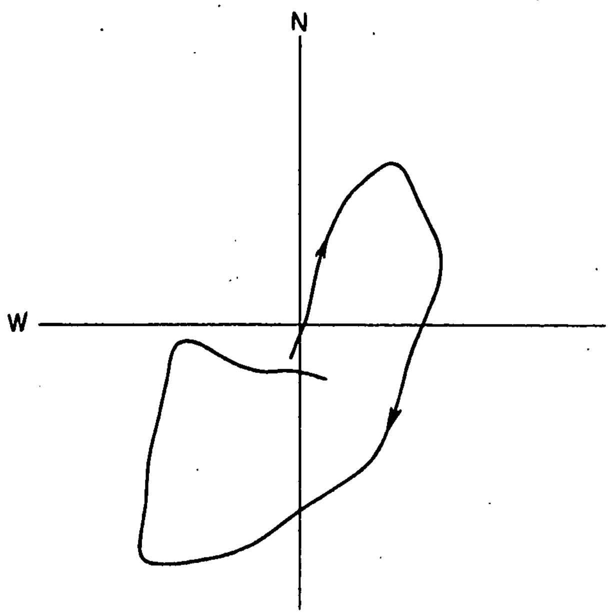
To Accompany Record No. 1971/27

G82/2-105

PLATE 17

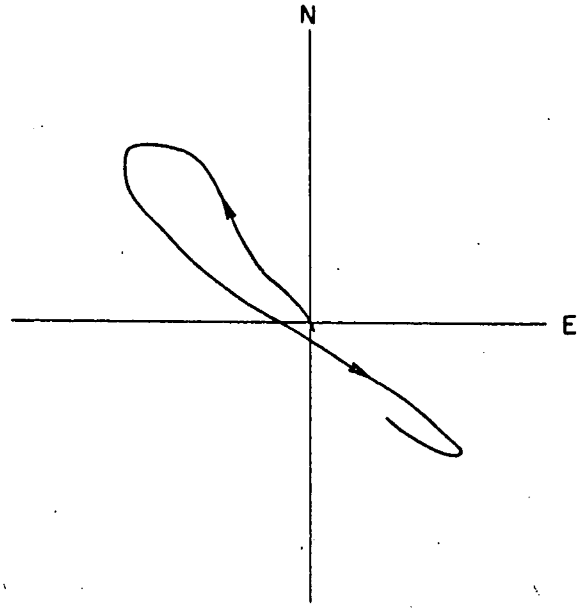
S-WAVE PARTICLE MOTION ANALYSIS

EARTHQUAKE No 9



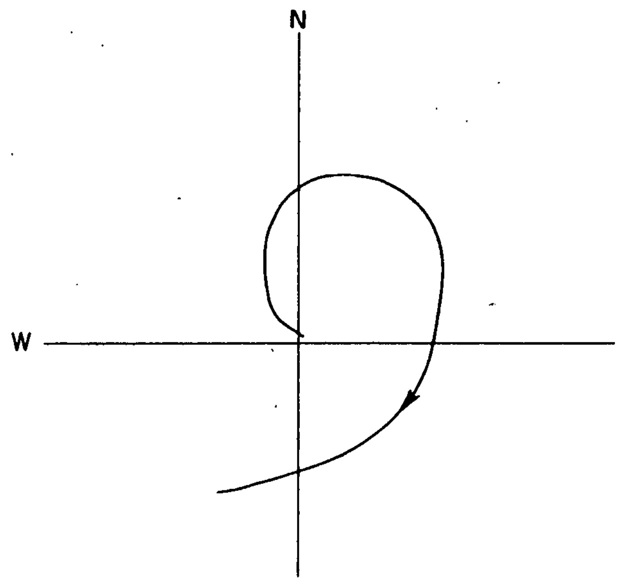
(A)

STATION NDI
$\Delta = 82°$
AZIMUTH OF MOTION = 020°
GREAT CIRCLE AZIMUTH = 100°
ANGLE OF POLARIZATION = -80°



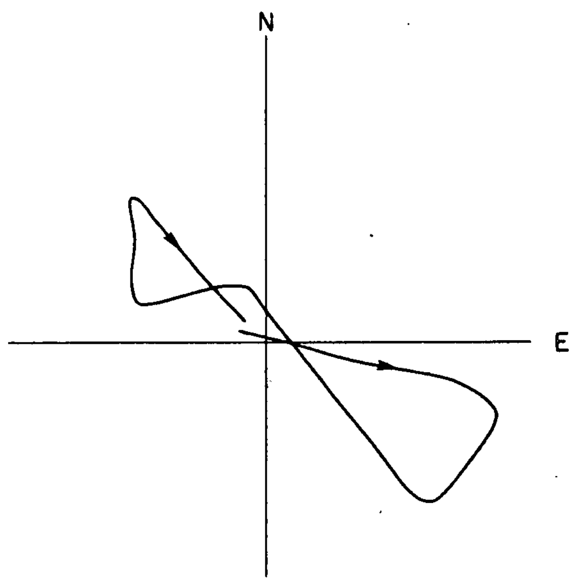
(B)

STATION SBA
$\Delta = 74°$
AZIMUTH OF MOTION = 313°
GREAT CIRCLE AZIMUTH = 348°
ANGLE OF POLARIZATION = -35°



(C)

STATION MUN
$\Delta = 45°$
MOTION IS NON-LINEAR



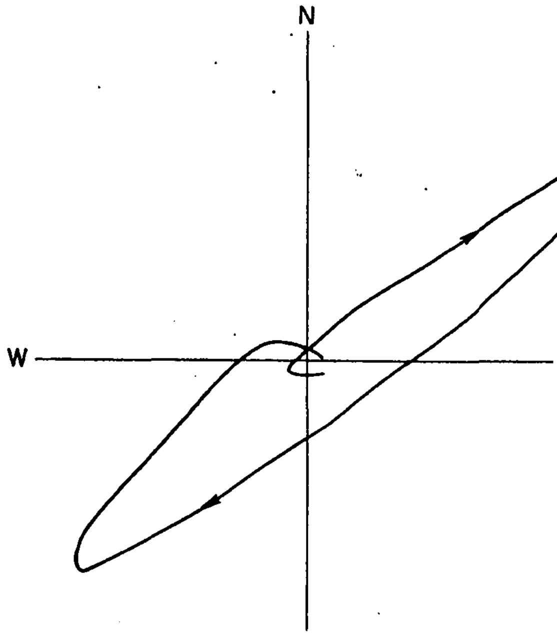
(D)

STATION SEO
$\Delta = 49°$
AZIMUTH OF MOTION = 122°
GREAT CIRCLE AZIMUTH = 142°
ANGLE OF POLARIZATION = -20°

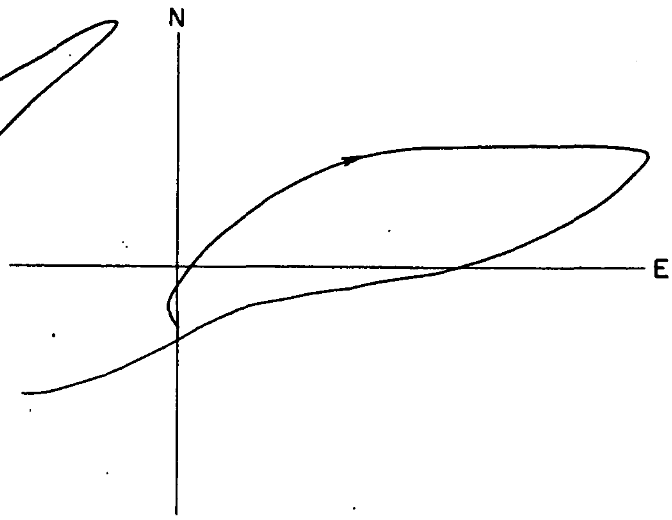
PLATE 18

S-WAVE PARTICLE MOTION ANALYSIS

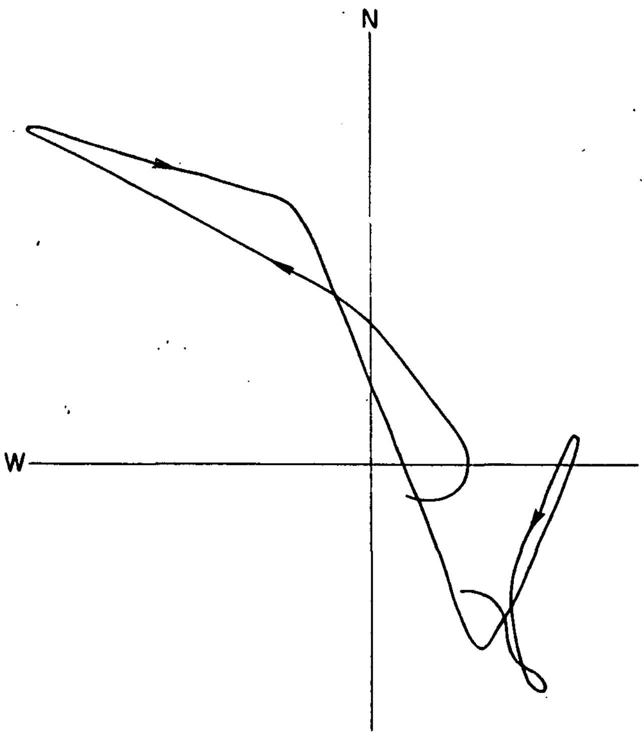
EARTHQUAKE No 9



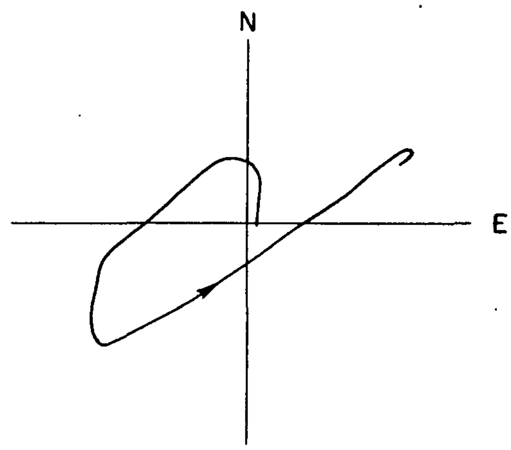
(A)
STATION SHL
Δ = 68°
AZIMUTH OF MOTION = 054°
GREAT CIRCLE AZIMUTH = 106°
ANGLE OF POLARIZATION = −52°



(B)
STATION ANP
Δ = 44°
AZIMUTH OF MOTION = 076°
GREAT CIRCLE AZIMUTH = 127°
ANGLE OF POLARIZATION = −51°



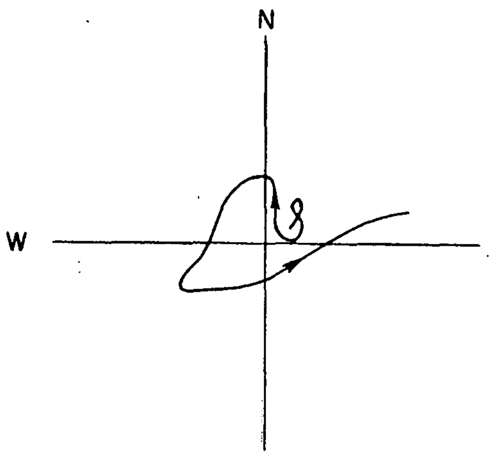
(C)
STATION WEL
Δ = 41°
AZIMUTH OF MOTION = 319°
GREAT CIRCLE AZIMUTN = 329°
ANGLE OF POLARIZATION = −10°



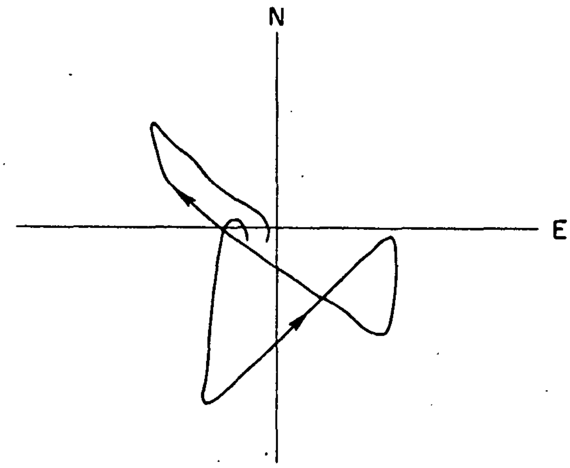
(D)
STATION MUN
Δ = 42°
AZIMUTH OF MOTION = 056°
GREAT CIRCLE AZIMUTH = 059°
ANGLE OF POLARIZATION = −3°

PLATE 19

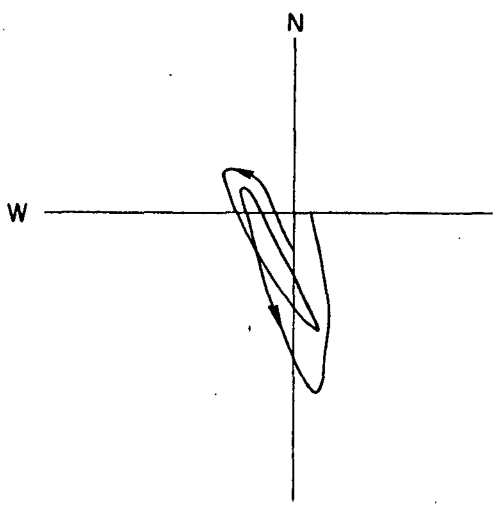
S-WAVE PARTICLE MOTION ANALYSIS
EARTHQUAKE No10



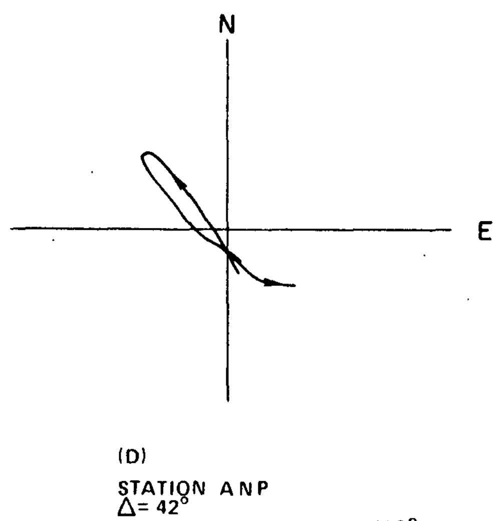
(A)
STATION NHA
Δ= 45°
MOTION NON-LINEAR



(B)
STATION SBA
Δ=73°
MOTION NON-LINEAR



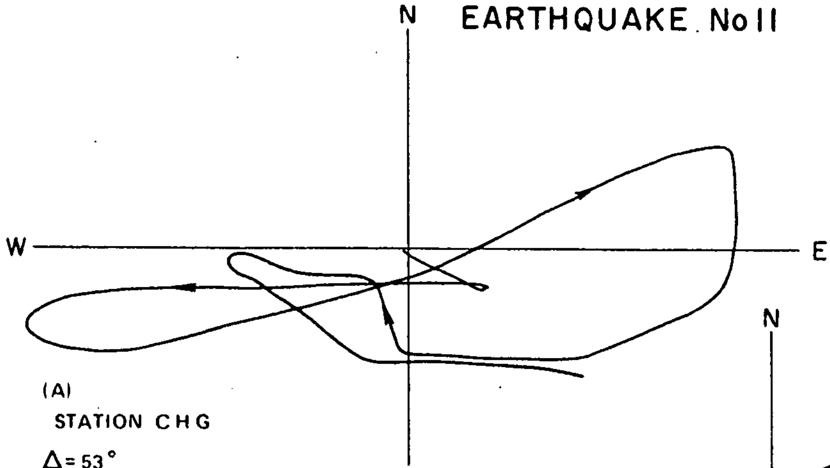
(C)
STATION SEO
Δ= 48°
AZIMUTH OF MOTION = 151°
GREAT CIRCLE AZIMUTH = 146°
ANGLE OF POLARIZATION = 5°



(D)
STATION ANP
Δ= 42°
AZIMUTH OF MOTION = 139°
GREAT CIRCLE AZIMUTH = 132°
ANGLE OF POLARIZATION = 7°

S-WAVE PARTICLE MOTION ANALYSIS

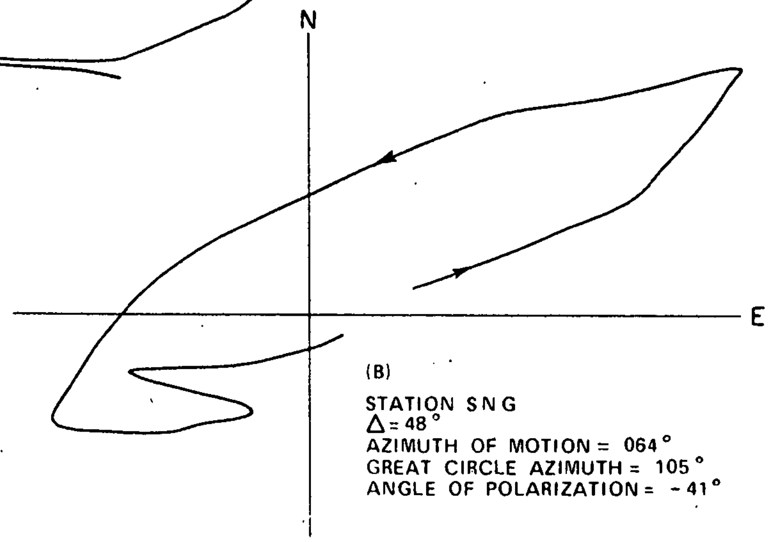
EARTHQUAKE No II



(A)

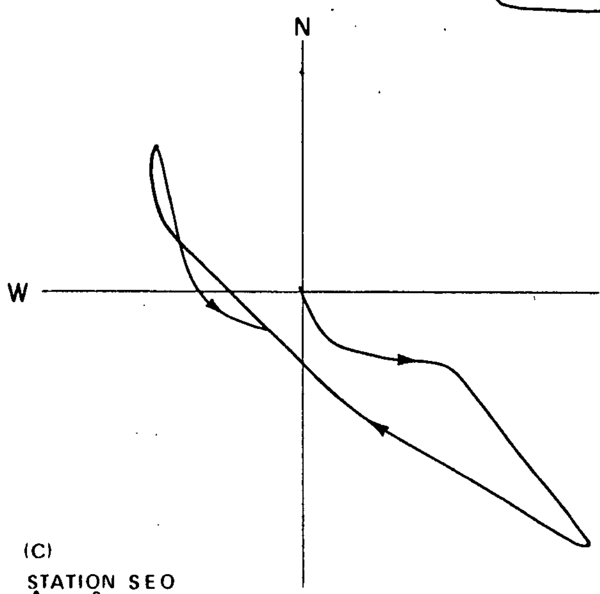
STATION CHG

Δ = 53°
AZIMUTH OF MOTION = 078°
GREAT CIRCLE AZIMUTH = 114°
ANGLE OF POLARIZATION = -36°



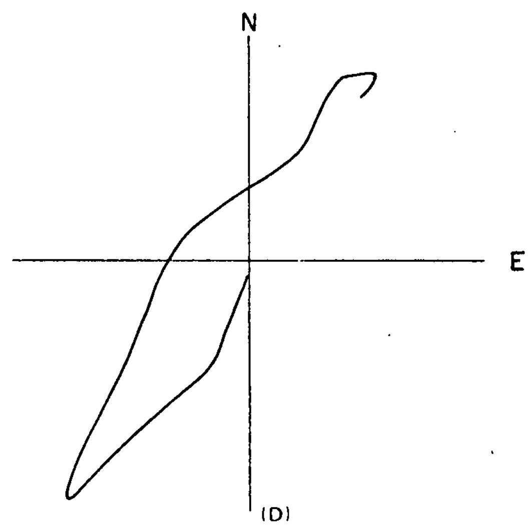
(B)

STATION SNG
Δ = 48°
AZIMUTH OF MOTION = 064°
GREAT CIRCLE AZIMUTH = 105°
ANGLE OF POLARIZATION = -41°



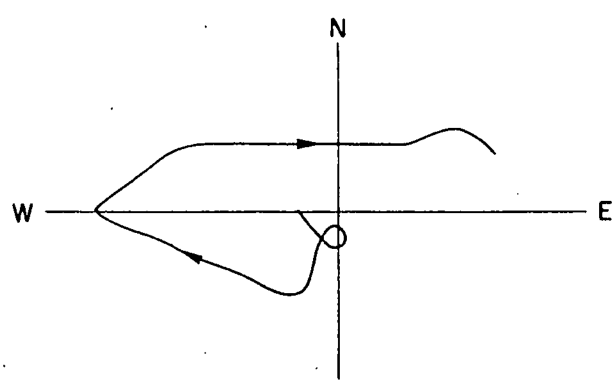
(C)

STATION SEO
Δ 47°
AZIMUTH OF MOTION = 131°
GREAT CIRCLE AZIMUTH = 153°
ANGLE OF POLARIZATION = 22°



(D)

STATION POO
Δ = 76°
AZIMUTH OF MOTION = 036°
GREAT CIRCLE AZIMUTH = 102°
ANGLE OF POLARIZATION = -66°

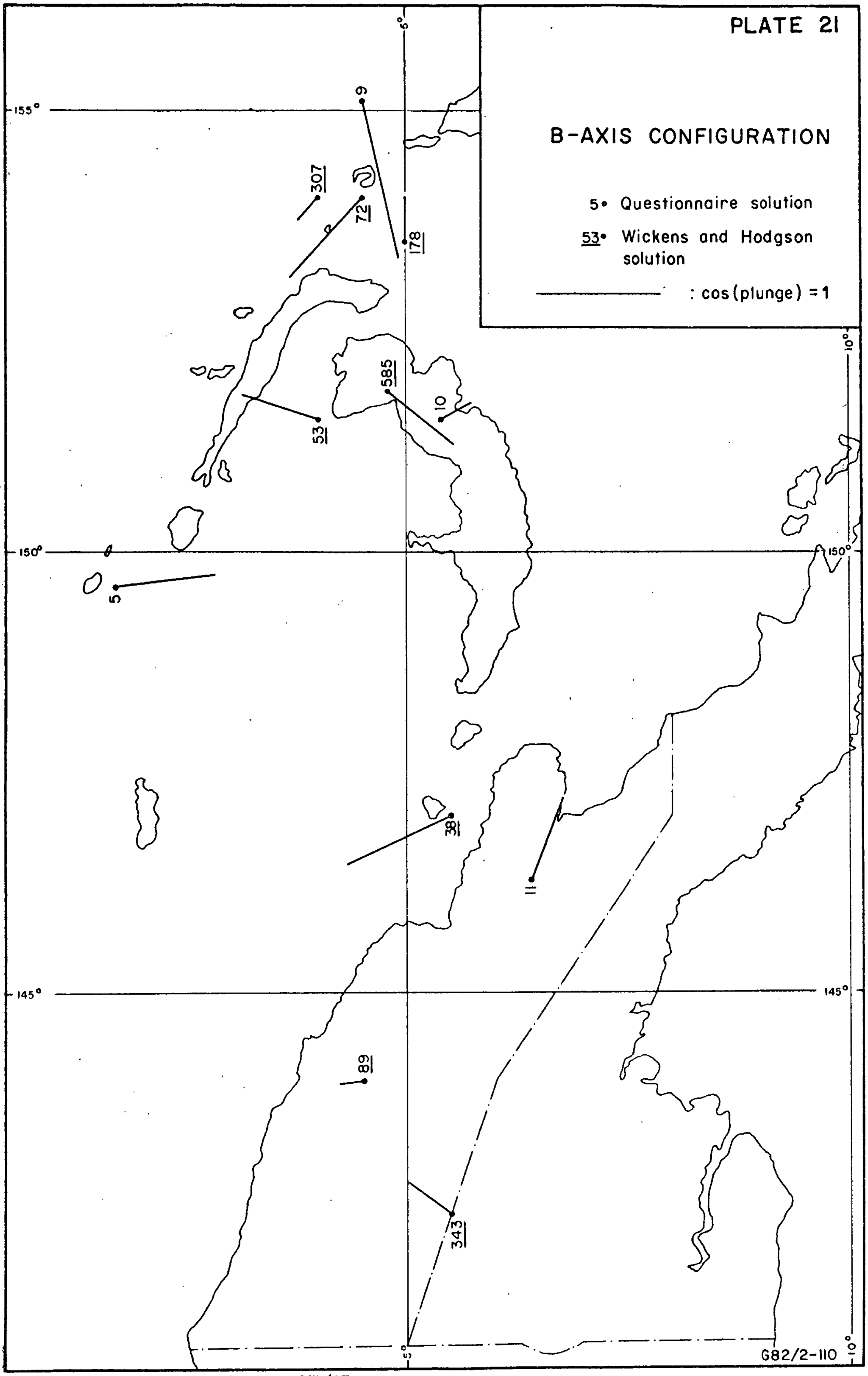


(E)

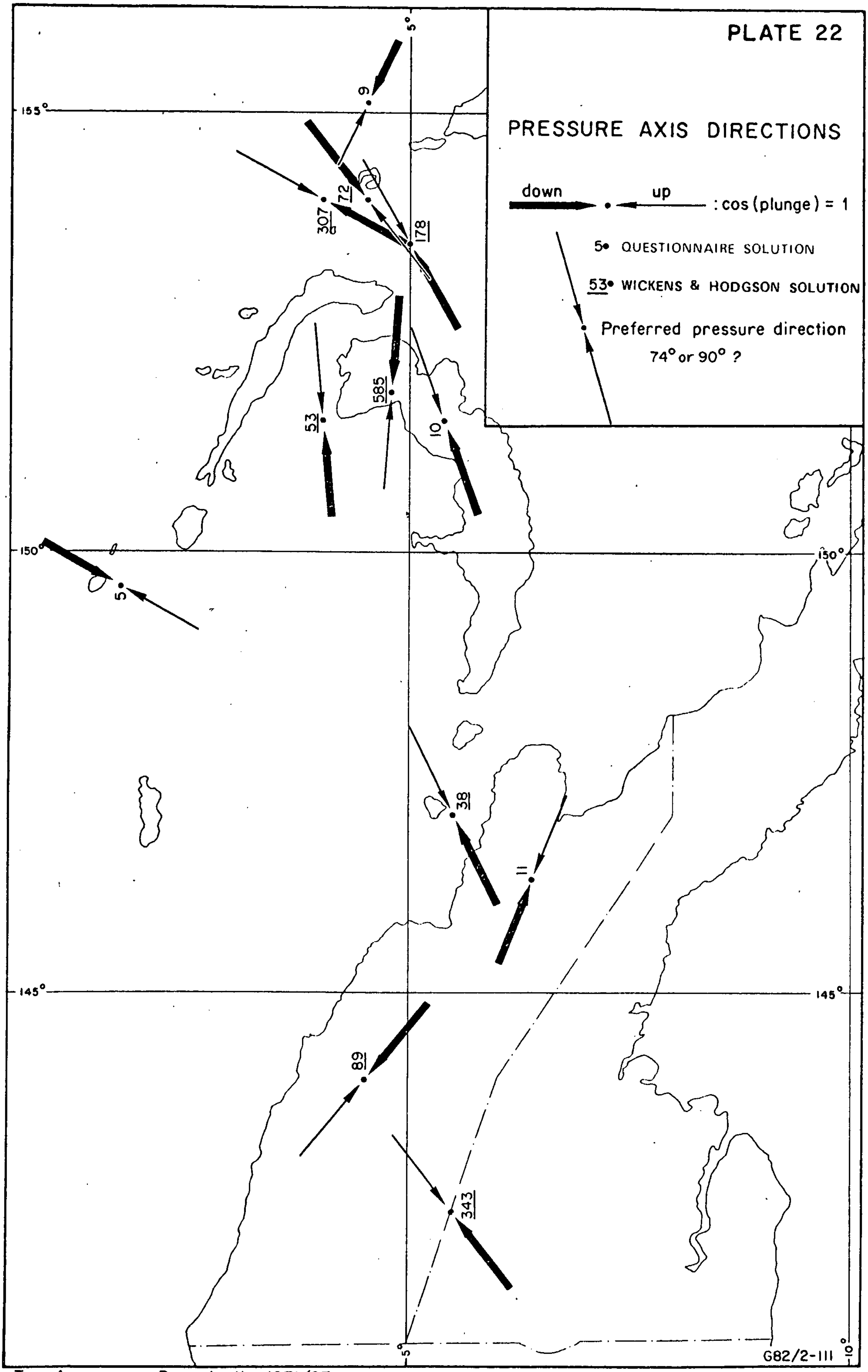
STATION SHL
Δ = 62°
AZIMUTH OF MOTION = 90°
GREAT CIRCLE AZIMUTH = 113°
ANGLE OF POLARIZATION = -23°

PLATE 21

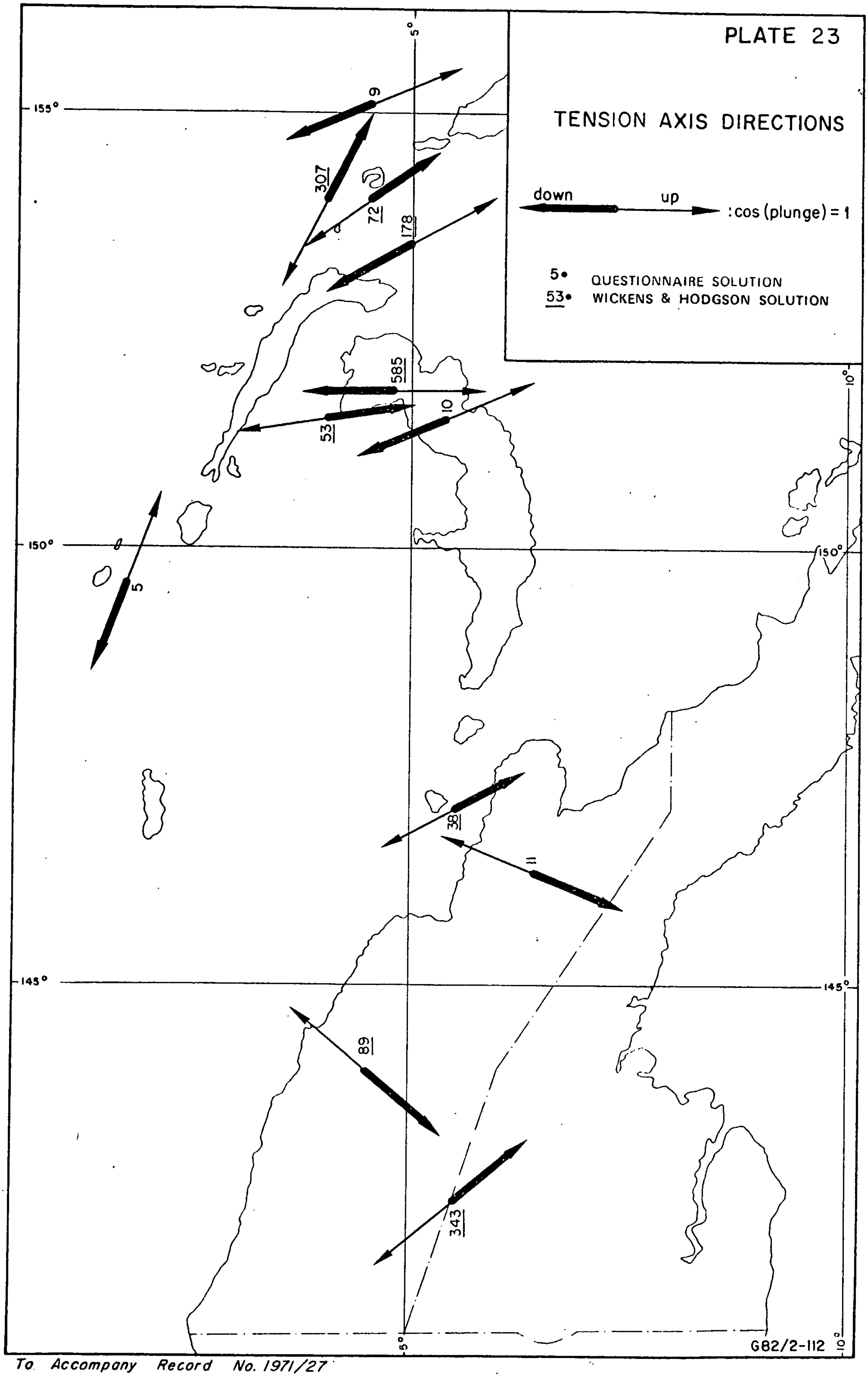
B-AXIS CONFIGURATION



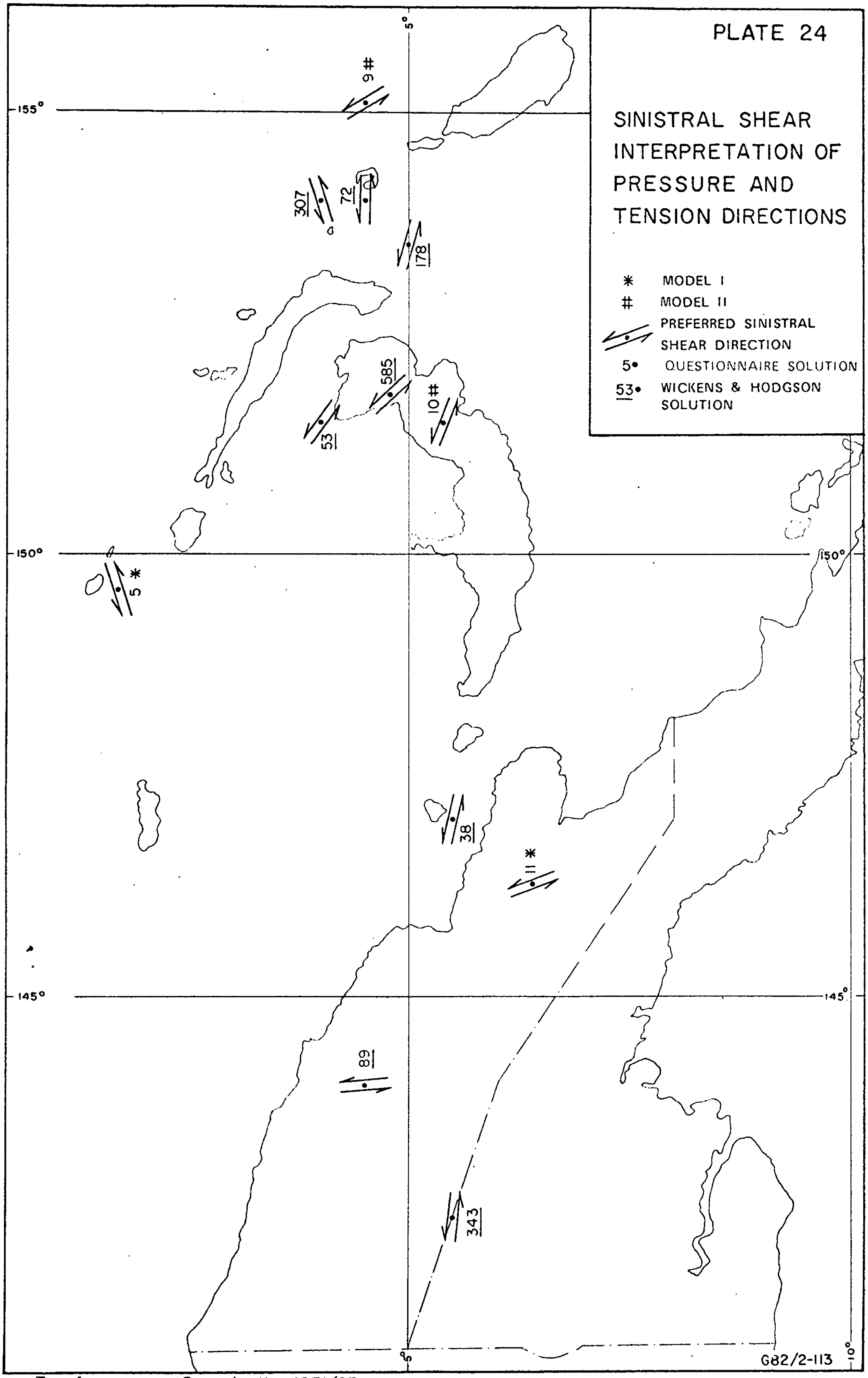
To Accompany Record No. 1971/27



To Accompany Record No. 1971/27



To Accompany Record No. 1971/27



To Accompany Record No. 1971/27