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COMPUTER-DETERMINED P-NODAL SOLUTIONS FOR THE LARGER EARTHQUAKES OF 1959-1962

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COMPUTER-DETERMINED P-NODAL SOLUTIONS FOR THE LARGER EARTHQUAKES OF 1959-1962*

J. H. Hodgson and A. J. Wickens

Abstract:—This paper continues the Dominion Observatory program of attempting P-nodal (fault-plane) solutions for all large earthquakes. In this case the solutions have been determined for 66 of the larger earthquakes of 1959-1962 using a computer program described earlier (Wickens, Stevens and Hodgson, 1963). This program does not define the possible variation of the planes from the "best" position determined by the computer, but an attempt has been made to supply this information by inspection of the solutions.

The solutions are summarized in the tabular form established in earlier papers of the series.

Résumé:—Cette étude fait partie du programme de l'Observatoire du Canada entrepris en vue de déterminer le nœud des ondes P (faille-surface horizontale) pour tous les principaux tremblements de terre. On a effectué ici ces déterminations pour les 66 principaux tremblements de terre enregistrés de 1959 à 1962, à l'aide d'une calculatrice décrite précédemment (Wickens, Stevens and Hodgson, 1963). La programmation ne définit pas la variation possible des plans par rapport à la "meilleure" position déterminée par la calculatrice, mais on a essayé d'introduire cette information en examinant les déterminations.

Les déterminations sont résumées sous la forme de tableaux établis dans les publications antérieures de la série.

INTRODUCTION

For many years this Observatory has published "fault-plane" solutions for all large earthquakes. These solutions have been made graphically, using data collected through questionnaires, and they represent the best fit the investigators could find to the available data. The observations have not been uniformly reliable; for many years reflected phases were used until experience proved that they were producing random observations; many stations were too insensitive or too badly located to produce reliable readings, a fact that could only be learned through experience; some stations had periods during which their galvanometers were reversed, a fact that was normally discovered only when they had produced a long series of observations inconsistent with our solutions. When these sources of error were discovered they explained much of the difficulties of the earlier work, but time never permitted the reappraisal of those earlier solutions. Even if it had been possible to re-work the corrected data, the solutions might still have been suspect because of their lack of objectivity—they merely represented the best fit that the analysist had been able to find.

One of us (Wickens) has recently perfected a program for the I.B.M. 1620 which permits a systematic search for the best position of the nodal planes for any set of data. To test the program it was given the first-motion observations for a large number of earthquakes solved earlier by graphical methods, and its solutions were checked against the earlier graphical ones. In the re-appraisal of 74 earthquakes solved earlier by us and 64 solved earlier by Ritsema, the machine produced as good or better solutions than the graphical ones in 97% of the cases. This establishes the validity of the program. The visual solutions, on the other hand, were sustained only 72% of the time, and only 39% of the solutions were closely defined by the data.

These findings were presented to the I.U.G.G. meetings in Berkeley (Wickens, Stevens and Hodgson, 1963) and to the Symposium on the Results of the I.G.Y. which preceded it (Hodgson and Stevens, 1964). These papers, as well as several others read at the meetings, cast so much doubt on the validity and the closeness of earlier solutions that all present were agreed that some means must be found to express the accuracy of published solutions. This might be done, for example, by giving the possible variation in the strike and dip of each plane, or by giving the solid angle traced out by possible positions of the pole of each plane. Such information is implicit in the computer program and we are currently searching for the best way to express the limitation. It is probable that the program as finally written will require a faster computer than the 1620. When this enlarged program has been perfected we propose to use it to re-analyse every earthquake for which the first-motion information have ever been published, either by ourselves or by someone else.

*Canadian Contribution No. 56 to the International Upper Mantle Project.

In the meantime data are available for the earthquakes from 1959 to 1962, and many people need the solutions in connection with other research. Nodal solutions have therefore been determined using the existing 1620 program. It is possible that these may be modified somewhat by the more sophisticated program being devised, certainly their reliability will be expressed in a more definite way, but the present publication should be useful. The solutions are certainly not less accurate than the graphical ones published earlier in the series.

Not all stations are equally reliable, and some way must be found of expressing this fact. Kasahara (1963) suggested the use of a weighted, running average, using the formula

$$\sigma_{i,j} = \sum_{p=1}^{6} (6 - p)N'_{i,j-p} \Big/ \sum_{p=1}^{6} (6 - p)N_{i,j-p}$$

where $N_{i,j}$ and $N'_{i,j}$ denote, respectively, the total number of reading and the number of proper readings at the i-th station in the j-th year and σ represents the probability that a station will be correct; to translate this probability into a weight, Kasahara proposed the scheme given below.

Predicted Score	Weight
$\sigma \geq 0.95$	5
$0.95 > \sigma \geq 0.85$	4
$0.85 > \sigma \geq 0.75$	3
$0.75 > \sigma \geq 0.65$	2
$0.65 > \sigma \geq 0.55$	1
$0.55 > \sigma \geq 0.0$	0

This system of weighting was used in the early tests of Wickens' program, but experience showed that the few stations of weight 5 were overweighting other stations and distorting the solutions. We now use weight zero to express the weights 0 and 1 of Kasahara, but use weight unity for all other values. This means that stations of proven lack of reliability do not effect the solution; by carrying them along however it will be possible to detect any improvement in the station operation.

Application of the probability formula given above requires a knowledge of the performance of stations over the five years previous to the year for which weight are being computed. Machine solutions are not available for the years 1955-1958; the scores have had to be based on the visual solutions. The weights used here may not be the same in all instances as those which will be used in the final re-appraisal forecast above.

In earlier publications it has been customary to list all the observations on which the solutions are based. In the present publication, which covers a period of four years, this would require a formidable amount of space, and seems unnecessary. All the data are available on punched cards, and a print-out will be sent to anyone who requests it.

Table I lists the earthquakes for which information is available; those for which solutions or partial solutions were obtained are listed separately from those for which no solution was possible. In the latter case an indication of the source of the difficulty has been given. Epicentral data are from the United States Coast and Geodetic Survey. In those cases where several earthquakes occurred on the same day, they have been designated A, B, C – –.

TABLE I – List of Earthquakes Considered

Date	H G.M.T.	Epicentre		Focal Depth, Km	Magnitude	Remarks
		ϕ	λ			
Earthquakes for which solutions have not been obtained						
January 13, 1959	01:15:25	13½ N	146 E	33	6¾	Too few and conflicting data.
February 15A, 1959	03:59:25	59½ S	25 W	33	6½	Too few data.
February 15B, 1959	04:42:35	59½ S	26 W	33	6¾	Too few data.
May 12, 1959	09:46:51	23½ S	64½ W	33	6¾	Conflicting data.
July 6A, 1959	09:10:17	26½ S	61½ W	600	6¾	Conflicting data.
July 6B, 1969	09:23:27	26½ S	61½ W	600	6¾	Too few and conflicting data.
August 17, 1959	21:04:40	7½ S	156 E	33	7¼	Conflicting data.
August 24, 1959	21:30:46	10½ S	161 E	33	7	Conflicting data.
September 7, 1959	04:03:20	1 S	23½ W	33	–	Too few data.
September 15, 1959	05:59:42	28½ S	177 W	33	7	Conflict of data. See text.
November 16, 1959	10:21:17	1 N	26½ W	33	6¼	Too few and conflicting data.
December 14, 1959	23:21:56	59½ S	31 W	33	7	Conflicting data.
January 13, 1960	15:40:34	16 S	72 W	200	7½	Conflicting and poorly distributed data.
March 23, 1960	00:23:22	39½ N	143 E	33	6¾	Conflicting data.
May 22C, 1960	18:55:57	38 S	73½ W	33	7¾	Confusion of data.
May 22E, 1960	19:11:20	38 S	73½ W	33	8½	Too few and conflicting data.
May 24, 1960	14:46:34	44½ S	167½ E	33	6¾	Conflicting data.
June 6, 1960	05:55:44	45½ S	73½ W	33	6¾	Conflicting data, but see text.
June 20B, 1960	12:59:40	39½ S	73 W	33	6¾	Conflicting data, but see text.
November 23, 1960	14:12:21	24.4 S	176.1 W	28	6¾	Too few and conflicting data.

Date	H G.M.T.	Epicentre ø	Epicentre λ	Focal Depth, Km	Magnitude	Remarks
Earthquakes for which solutions have not been obtained						
November 24, 1960	06:52:41	24.4 S	176.1 W	23	7	Conflicting data.
December 2, 1960	09:10:39	24.6 S	69.7 W	19	7	Conflicting data.
December 13, 1960	07:36:16	52.7 S	159.1 E	25	7	Too few data.
January 5B, 1961	17:57:51	21.2 S	169.5 E	53	6¾	Too few and conflicting data.
March 7, 1961	10:10:39	28.3 S	175.7 W	43	7¼	Conflicting data.
March 18, 1961	14:54:59	49.9 S	163.3 E	38	6¾	Too few and conflicting data.
September 8, 1961	11:26:33	56.3 S	27.1 W	125	7¾	Conflicting data.
September 13, 1961	21:19:20	41.7 S	75.2 W	40	7	Too few data.
December 30, 1961	00:39:27	52.3 N	177.6 E	56	6¾	Complete confusion of data.
March 12, 1962	11:40:13	8.1 N	83.0 W	58	6½	Conflicting data.
April 18, 1962	19:14:37	10.0 S	79.0 W	39	6¾	Conflicting data.
May 6, 1962	19:00:10	60.0 S	32.8 W	25	7	Too few and conflicting data.
May 15, 1962	05:23:46	7.3 S	128.3 E	34	7¼	Conflicting data.
May 19, 1962	14:58:13	17.2 N	99.5 W	20	7	Poor distribution of data. See text.
May 21, 1962	21:15:31	20.0 S	177.5 W	379	6¾	Conflicting data.
June 18, 1962	23:42:31	4.8 S	151.8 E	47	6¾	Conflicting data.
Earthquakes for which solutions have been obtained						
January 8, 1959	01:33:48	15½ N	61 W	100	6¾	
January 22, 1959	05:10:25	34 N	142 E	33	6¾	
February 7, 1959	09:36:51	4 S	81½ W	33	7¼	
March 1, 1959	16:49:13	½ S	134½ E	100	7	
April 24, 1959	17:57:58	31 S	178 W	33	6¾	Undefined central circles.
April 26, 1959	20:40:38	25 N	122½ E	150	7½	
April 28, 1959	11:09:30	15 N	93 W	33	6½	Undefined central circles.
May 4, 1959	07:15:42	52½ N	159½ E	60	8	
May 24, 1959	19:17:40	17½ N	97 W	100	7	
May 26, 1959	04:13:01	27½ N	126½ E	100	6½	
June 14, 1959	00:11:57	20½ S	68 W	100	7¼	
June 18, 1959	15:58:38	54 N	161 E	33	6¾	
July 9, 1959	16:05:18	20½ S	68 W	100	6¾	One plane only defined. Poor solution.
July 19, 1959	15:06:10	15 S	70½ W	200	7	One plane only defined. Poor solution.
August 15, 1959	08:57:04	23 N	121 E	33	7	One plane only defined. Poor solution.
August 26, 1959	08:25:30	18 N	94½ W	33	6¾	
September 14A, 1959	14:09:39	28½ S	177 W	33	7¾	One plane only defined.
September 14B, 1959	22:23:53	29 S	177 W	33	6½	One plane only defined.
September 29, 1959	15:31:57	29 S	176½ W	33	6½	
October 5, 1959	18:27:47	83½ N	112½ E	33	6	
January 15, 1960	09:30:24	15 S	75 W	150	7	
March 8, 1960	16:33:38	16½ S	168½ E	250	7	
March 20, 1960	17:07:30	40 N	143½ E	60	7	
May 21, 1960	10:02:50	37½ S	73½ W	33	7¼	One plane only defined. Poor solution.
May 22A, 1960	10:30:39	38 S	73½ W	33	6½	One plane only defined. Poor solution.
May 22B, 1960	10:32:43	37½ S	73 W	33	7¼	One plane only defined. Poor solution.
May 22D, 1960	19:10:47	38 S	73½ W	33	7½	Poor solution.
June 20A, 1960	02:01:08	38 S	73½ W	33	6¾	One plane only defined.
June 25, 1960	11:12:00	54 N	159 E	100	6¾	Only one plane well defined.
July 29, 1960	17:31:40	40.1 N	142.3 E	50	6¾	
October 7, 1960	15:18:31	7.4 S	130.7 E	45	6¾	
October 22, 1960	08:22:01	10.3 S	161.2 E	93	6½	
November 13, 1960	09:20:37	51.1 N	168.8 W	65	7	Undefined central circles.
December 3, 1960	04:24:19	42.9 N	104.4 E	60	7	Undefined central circles.
January 5A, 1961	15:53:56	4.1 S	143.0 E	108	6¾	
January 16, 1961	07:20:19	36.2 N	141.7 E	41	6¾	
January 20, 1961	17:09:16	56.6 N	152.3 W	46	6¾	
February 12, 1961	21:53:44	43.9 N	147.6 E	45	7	
February 26, 1961	18:10:49	31.6 N	131.2 E	54	7¼	
March 28, 1961	09:35:55	0.2 N	123.6 E	83	6¾	
June 1, 1961	23:29:21	10.4 N	39.9 E	33		Only one plane defined.
June 11, 1961	05:10:26	27.9 N	54.6 E	37	6½	
July 18, 1961	14:03:36	29.4 N	131.6 E	21	6¾	
August 11, 1961	15:51:35	43.0 N	145.0 E	50	7	
August 19A, 1961	05:09:50	10.8 S	71.0 W	649	7¼	Only one plane clearly defined.
August 19B, 1961	05:33:31	36.2 N	136.5 E	17	7½	

Date	H G.M.T.	Epicentre ø	Epicentre λ	Focal Depth, Km	Magnitude	Remarks
Earthquakes for which solutions have been obtained						
August 31A, 1961	01:48:38	10.6 S	70.9 W	626	7	Only one plane defined.
August 31B, 1961	01:57:08	10.4 S	70.7 W	629	7¼	
September 1, 1961	00:09:35	59.5 S	27.3 W	131	7¼	Undefined central circles.
February 14, 1962	06:36:01	38.1 S	73.1 W	44	7¼	
March 7, 1962	11:01:00	19.3 S	145.3 E	680	7	
April 12, 1962	00:52:47	38.2 N	142.3 E	68	7	
April 23, 1962	05:58:05	42.9 N	143.4 E	25	7¼	
May 7, 1962	17:39:50	45.3 N	146.7 E	25	6¾	
May 11, 1962	14:11:52	17.0 N	99.7 W	25	7	Only one plane defined. Poor distribution of data.
May 21, 1962	12:02:51	37.3 N	96.0 E	25	7	Undefined central circles.
July 6, 1962	23:05:32	36.6 N	70.4 E	203		See Metzger (1963).
July 26, 1962	08:14:42	7.5 N	82.7 W	21	6¾	One plane only, loosely defined.
July 30A, 1962	17:16:44	3.3 S	143.9 E	25	7	Undefined central circles.
July 30B, 1962	20:18:49	5.0 N	76.3 W	45	6¾	
August 3, 1962	08:56:12	23.2 S	67.5 W	71	7	Undefined central circles.
August 28, 1962	10:59:59	38.0 N	23.1 E	120	6¾	
September 1, 1962	19:20:39	35.6 N	50.0 E	21	7¼	
September 18, 1962	00:29:05	7.5 N	82.3 W	33	7	
December 7, 1962	14:03:37	29.2 N	139.2 E	411	7	
December 8, 1962	21:27:18	25.8 S	63.2 W	580		Epicentre after Espinosa.

NATURE OF THE COMPUTER SOLUTIONS

In the computer program, observations are referred to the focal sphere, and a pair of orthogonal planes in the focus takes up a succession of trial positions. Regarding each trial position in turn as a possible position of the nodal planes, the number of "consistent" and "inconsistent" observations can be added up, and a score established for that particular trial position. In evaluating the score the theoretical radiation pattern is taken into account. Having run its entire gamut of trial positions the machine then selects the ten best of these for up-dating in the second stage of the program; here the neighbourhood of each of the ten is searched to ensure that no maximum has been overlooked in the finite increments of the searching planes.

In the final print-out the machine gives a sheet of information for each of the final ten best solutions; this defines the position of each of the nodal planes and of their line of intersection (the null direction), gives the score of the solution and lists all the stations consistent and inconsistent with it. It would be a simple matter to have the machine print out only the solution with the highest score, but it is usually necessary to examine the other possibilities as well in order to decide on the reliability of the one selected. This may best be illustrated by some examples.

The first, provided by Table II, is for the earthquake of May 24, 1959, at 17.5° N, 97° W. The ten best solutions have been listed in order of decreasing score, with the number of inconsistent observations given in each case. These are out of a total of 111 observations. The table gives the trend and plunge of the null vector and the direction of dip and the amount of dip for each of the two nodal planes. Azimuths are measured in degrees clockwise from north, dips in degrees from the horizontal.

TABLE II

Null Direction		Plane A		Plane B		Number of Inconsistent Stations	Score
Azimuth	Plunge	Azimuth	Dip	Azimuth	Dip		
343	71	343	71	253	90	21	59.10
359	72	336	73	68	83	22	58.99
4	68	354	68	85	86	23	55.58
333	64	5	67	269	78	24	52.90
116	26	178	46	46	55	26	52.00
314	4	232	25	42	65	24	51.69
78	67	164	88	73	67	28	50.90
324	1	232	35	54	55	27	50.71
319	73	335	74	243	86	29	47.97
163	73	107	80	200	76	36	34.62

Examination of the table shows that the first two possibilities have about the same score, and that they represent about the same solution; the azimuth of plane B in the first instance might just as well have been written (253° − 180°) = 73°. As we go away from this optimum position the score decreases steadily and the number of inconsistencies increases. Clearly this is a case of a unique, reasonably well-defined solution.

TABLE III

Null Direction		Plane A		Plane B		Number of Inconsistent Stations	Score
Azimuth	Plunge	Azimuth	Dip	Azimuth	Dip		
250	24	338	85	235	25	10	72.95
252	23	340	84	237	24	11	71.38
249	19	337	86	236	20	11	71.23
63	5	333	85	199	7	12	69.58
243	5	333	85	197	7	12	69.53
42	22	311	87	34	22	15	63.65
358	67	304	76	39	72	15	61.62
359	70	307	77	41	75	15	60.76
17	69	317	79	51	72	15	59.83
293	57	280	56	14	84	18	56.49

Table III gives the results for the earthquake of May 26, 1959, at 27.5° N, 126.5° E. There were 78 observations available. In this solution plane A is very well defined, and the score deteriorates as the plane deviates from this best position. There is certainly a best position for plane B, that given by the best score, and this solution is supported by the next two in order. Note, however, that there follow two solutions, almost identical, with twelve inconsistent observations. This clearly represents a sub-maximum. Considering the fact that even the best stations are inconsistent about one time in nine, are we justified in discarding this alternative solution just because it has two more inconsistent observations than the best one? Probably not. We should list it as an alternative solution, although one with lower probability.

TABLE IV

Null Direction		Plane A		Plane B		Number of Inconsistent Stations	Score
Azimuth	Plunge	Azimuth	Dip	Azimuth	Dip		
347	82	311	84	41	85	13	44.64
9	84	304	88	34	85	13	44.25
343	63	314	66	50	79	13	41.66
27	79	303	89	33	79	14	39.04
23	81	304	88	34	81	14	38.87
279	80	315	82	225	84	14	38.17
297	64	344	72	247	72	14	38.16
27	73	22	73	112	88	14	37.48
81	10	357	61	154	31	15	35.10
261	7	346	55	181	36	16	33.83

The fact that even the best stations may be wrong must keep us from asserting dogmatically any solution defined by too few observations. This is illustrated by the next example which is the earthquake of January 8, 1959, at 15.5 N, 61 W. There were 48 observations in this case; the results are given in Table IV. The first three solutions, all yielding 13 inconsistent observations, are closely similar. Taking an average position between the extremes of the three solutions we might obtain the following values:

Null Direction	
Azimuth	*Plunge*
356° ± 13°	73° ± 10°

Plane A		Plane B	
Azimuth	*Dip*	*Azimuth*	*Dip*
309° ± 5°	77° ± 11°	42° ± 8°	82° ± 3°

they would suggest that the solution was rather closely defined. But note that, by admitting one additional wrong station the next five best solutions are available. This would suggest the following mean positions between extremes, and the following possible variations:

Null Direction	
Azimuth	*Plunge*
336° ± 86°	38° ± 33°

Plane A		Plane B	
Azimuth	*Dip*	*Azimuth*	*Dip*
323° ± 20°	77° ± 11°	40° ± 20°	90° ± 20°

Viewed in this way the solution is much less definite.

This example illustrates another fact—the "best" position is not the mean position between all possible ones. It is arrived at on the basis of the weights of the stations, and this depends on their distance from the nodal planes and the resulting theoretical amplitude. The plus-minus obtained for the average position cannot properly be applied to the best solution, although it certainly indicates the reliability of the solution in a quantitative way. In the following section, where the results of the studies are tabulated, the best position will be given in the Table, the mean position and its possible variations will be indicated in the text.

The kind of considerations discussed in the foregoing remarks are the sort which will be treated analytically in Wickens' new program.

A final example is provided in Table V, which gives the solutions for the earthquake of April 24, 1959, at 31° S, 178° W. There were 97 observations for this shock. Here the solutions range widely, without any very large range in the scores; there is even less variation in the numbers of inconsistent observations. Clearly this is a case where there is no unique solution.

The attentive reader may think to discern some system to the solution for Plane A. The reason for this will be apparent from the plot of the data given in Figure 1. This Figure was produced by the computer, using the Byerly projection. It is produced by the normal computer print-out, not by a plotter, and suffers from the limitations

TABLE V

Null Direction		Plane A		Plane B		Number of Inconsistent Stations	Score
Azimuth	Plunge	Azimuth	Dip	Azimuth	Dip		
44	10	138	67	292	25	20	58.49
112	63	165	73	69	70	20	56.70
63	3	154	73	324	18	21	57.63
85	18	167	67	30	30	21	56.91
92	23	151	39	16	60	21	56.19
107	62	157	71	59	70	21	55.67
144	31	187	40	68	68	21	55.52
152	45	185	50	80	73	21	55.21
351	34	317	43	65	67	21	54.30
319	32	265	47	28	60	22	52.78

of the printer spacing; the points are only approximate and closely grouped points fall on top of each other. To overcome this, the following convention is used:

N	(for negative)	represents one dilatation,
M		represents two dilatations,
L		represents three dilatations;
P	(for positive)	represents one compression,
Q		represents two compressions,
R		represents three compressions.

Where a dilatation and a compression occupy the same printer position this is indicated by *O*; where there are more than three observations of any kind or a mixture of three this is indicated by *J*.

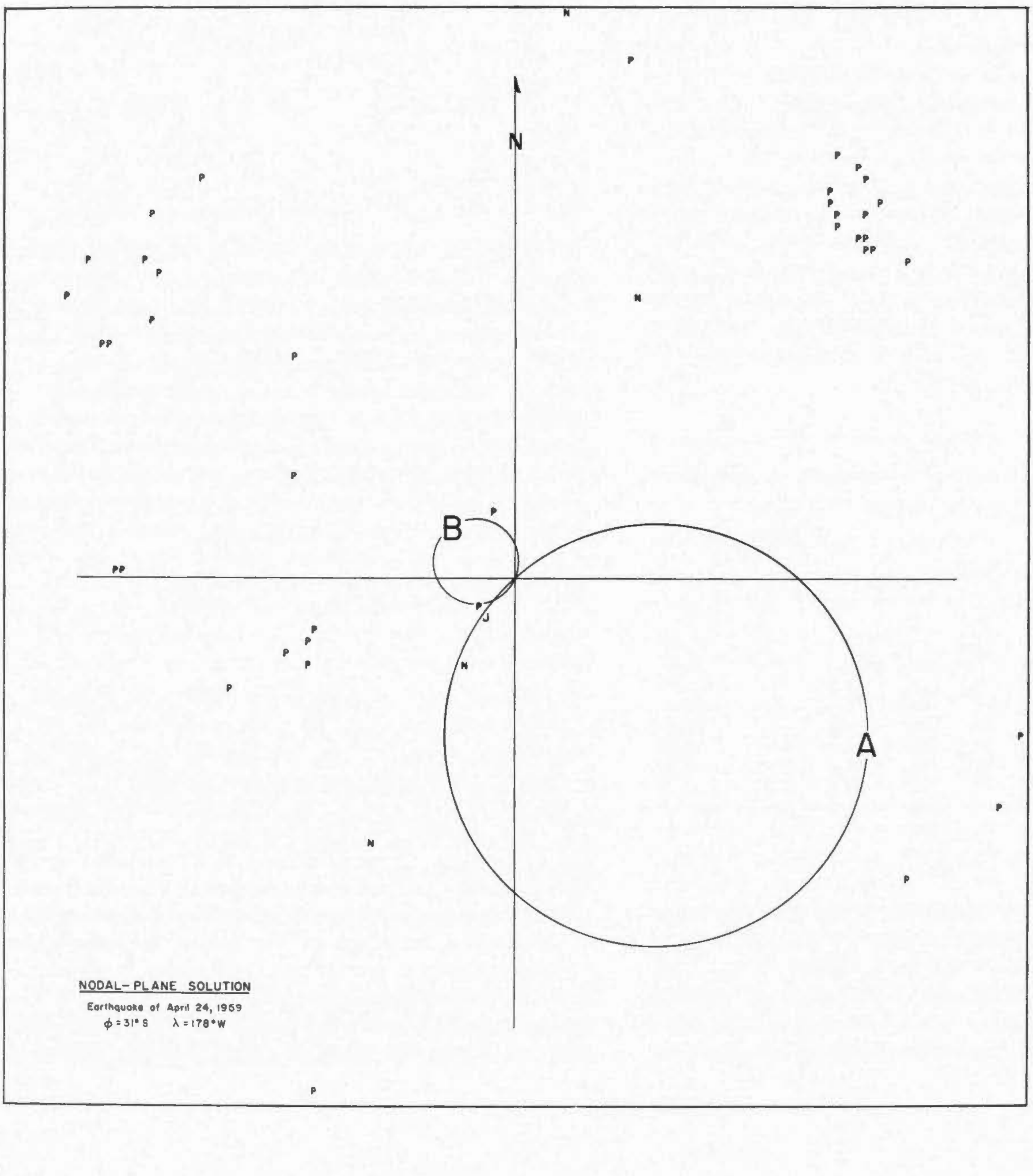

Figure 1

In Figure 1, there is a point marked "J" just south and west of the centre of the plot. This represents the superimposed values of Auckland (compression), Onerahi (compression) and Karapiro (dilatation). All the circles A in Table V (we have plotted the first one in the Table) are attempting to provide a separation of these points. We must ask ourselves whether any one station is sufficiently reliable to warrant this degree of confidence. The situation represented in Figure 1 is one in which almost all the observations are compressional, and there are not enough observations in the epicentral area to define the dilatational circles unambiguously.

Table VI — Summary of Solutions

EARTHQUAKE	NULL DIRECTION		PLANE A		PLANE B		Number of Observations	Number of Inconsistent Observations	Score
	Azimuth	Plunge	Azimuth	Dip	Azimuth	Dip			
January 8, 1959	347	82	311	84	41	85	48	13 (10)	44.64
January 22, 1959	33	10	123	89	28	10	103	23 (18)	67.22
February 7, 1959	136	71	112	73	204	83	110	20 (18)	65.62
March 1, 1959	104	65	119	66	27	84	53	14 (13)	49.98
April 24, 1959	Undefined central dilatational circles						97	20 (16)	
April 26, 1959	294	11	342	16	206	78	200	24 (20)	75.79
April 28, 1959	Undefined central dilatational circles						77	17 (14)	
May 4, 1959	44	30	318	83	60	31	191	30 (22)	70.25
Alternate solution	225	1	315	83	143	7	191	31 (23)	70.95
Balakina solution	230	15	315	35	130	50			
S solution	225	3	314	75	146	15	6		
May 24, 1959	343	71	343	71	253	90	111	21 (15)	59.10
May 26, 1959	250	24	338	85	235	25	78	10 (8)	72.95
Alternate solution	63	5	333	85	199	7	78	12 (10)	69.58
June 14, 1959	13	54	94	83	359	55	102	19 (15)	58.01
June 18, 1959	318	80	350	82	260	85	26	3 (3)	72.44
Balakina solution	310	70	2	76	268	76			
July 9, 1959	143	31	180	37	64	72	60	14 (12)	53.76
July 19, 1959	152	18	174	19	64	83	85	19 (13)	55.08
August 15, 1959			358	86			160	41 (34)	46.12
August 26, 1959	135	15	59	48	210	48	138	25 (19)	65.24
Alternate solution	116	80	111	80	201	89	138	24 (23)	68.30
September 14A, 1959			329	87			99	20 (18)	56.58
September 14B, 1959			329	87			41	9 (9)	58.71
September 29, 1959	287	89	285	89	15	90	44	11 (11)	56.73
Alternate solution	162	81	169	81	79	89	44	10 (10)	57.65
October 5, 1959	207	62	287	85	195	63	35	6 (5)	60.95
January 15, 1960	327	37	257	66	12	47	110	23 (17)	60.97
March 8, 1960	229	57	151	82	245	58	209	24 (20)	83.63
Alternate solution	239	35	165	56	307	41	209	21 (17)	83.00
March 20, 1960	351	2	261	84	62	6	172	36 (29)	57.16
May 21, 1960	189	20	274	76	151	25	135	24 (16)	63.22
May 22A, 1960	225	17	308	68	170	28	105	32 (26)	40.48

EARTHQUAKE	NULL DIRECTION		PLANE A		PLANE B		Number of Observations	Number of Inconsistent Observations	Score
	Azimuth	Plunge	Azimuth	Dip	Azimuth	Dip			
May 22B, 1960	35	2	306	69	120	21	81	19 (14)	49.78
May 22D, 1960	328	71	267	81	360	74	53	17 (13)	37.45
June 20A, 1960	189	71	257	83	165	73	94	21 (16)	55.05
July 25, 1960	212	21	297	78	179	25	161	29 (22)	65.06
Alternate solution	145	48	75	73	178	53	161	28 (20)	64.74
July 29, 1960	27	5	115	69	310	21	166	29 (23)	64.95
October 7, 1960	101	58	148	67	49	69	98	27 (23)	41.08
October 22, 1960	45	62	131	88	39	62	78	15 (15)	58.36
November 13, 1960	Undefined central compressional circles						167	24 (17)	
December 3, 1960	Undefined central dilatational circles						123	24 (18)	
January 5A, 1961	171	67	175	67	85	88	58	13 (10)	51.60
January 16, 1961	45	2	135	87	347	3	135	30 (24)	57.18
January 20, 1961	351	63	301	72	37	71	48	9 (7)	63.76
February 12, 1961	45	5	134	74	332	17	131	25 (18)	64.06
February 26, 1961	189	36	120	64	237	47	172	25 (19)	71.99
March 28, 1961			121	86			121	14 (10)	77.43
Alternate solution	143	55	189	64	87	68	121	16 (12)	74.36
June 1, 1961					246	84	46	14 (9)	35.48
June 11, 1961	98	45	149	58	39	62	65	14 (11)	53.03
Alternate solution	166	15	237	40	87	54	65	16 (13)	50.75
July 18, 1961	25	8	104	36	301	55	161	23 (19)	72.47
August 11, 1961	17	23	92	58	316	41	173	14 (9)	82.67
August 19A, 1961	109	49	87	51	186	79	126	21 (16)	68.43
Alternate solution	147	55	107	62	208	71	126	22 (18)	66.97
August 19B, 1961	359	13	81	60	289	33	116	16 (13)	74.89
Alternate solution	176	16	115	31	258	64	116	17 (14)	74.60
August 31A, 1961	219	65	135	87	227	65	113	20 (14)	66.28
August 31B, 1961			149	84			60	10 (5)	67.03
September 1, 1961	Undefined central dilatational circles						85	18 (13)	56.45
February 14, 1962	351	33	317	38	70	73	59	10 (9)	65.97
Alternate solution	333	82	300	83	30	86	59	11 (9)	61.91
March 7, 1962	135	9	218	54	57	38	142	29 (26)	59.85
April 12, 1962	229	5	139	87	260	6	116	22 (18)	66.03
April 23, 1962	239	23	154	77	272	27	157	26 (21)	67.57
Alternate solution	269	17	358	85	252	17	157	27 (22)	66.63
May 7, 1962	208	36	148	55	267	55	123	14 (11)	78.69
May 11, 1962	128	26	139	26	40	86	85	12 (9)	70.91
May 21, 1962	Undefined central dilatational circles						113	21 (17)	

EARTHQUAKE	NULL DIRECTION		PLANE A		PLANE B		Number of Observations	Number of Inconsistent Observations	Score
	Azimuth	Plunge	Azimuth	Dip	Azimuth	Dip			
July 6, 1962	273	3	352	15	183	75	164	15	
July 26, 1962					262	83	112	25 (22)	56.00
July 30A, 1962	Undefined central dilatational circles						83	17 (16)	
July 30B, 1962	21	76	110	90	20	76	75	16 (13)	53.77
August 3, 1962	Undefined central compressional circles						113	22 (18)	
August 28, 1962	271	20	335	40	194	57	128	21 (17)	66.89
September 1, 1962	150	17	227	53	80	42.	134	19 (14)	71.71
September 18, 1962	63	81	99	83	9	85	74	12 (9)	66.67
December 7, 1962	166	28	160	28	254	87	116	27 (25)	54.00
December 8, 1962	340	21	329	21	69	86	35	3 (3)	85.49

ANALYSIS OF THE DATA

The machine solutions will now be presented. The "best" solution in each case has been listed in Table VI, but each solution will be discussed to show its limitations.

Earthquake of 01:33:48, Jan. 8, 1959.

$\varphi = 15\frac{1}{2}°$ N, $\lambda = 61°$ W

This earthquake was discussed in the previous introductory section. It was shown there that the solution is not well-defined. This is indicated by the possible variations from the mean position:

Plane A		Plane B	
Azimuth	*Dip*	*Azimuth*	*Dip*
323° ± 20°	77° ± 20°	40° ± 20°	90° ± 20°

There were 13 inconsistent observations in the best solution but 3 of these came from stations with zero weight. This has been indicated in the Table by giving the number of inconsistencies as 13(10).

Earthquake of 05:10:25, Jan. 22, 1959.

$\varphi = 34°$ N, $\lambda = 142°$ E

Plane A is an essentially vertical one, for which the strike is defined within ± 5. Plane B is very shallow and depends for its definition on a number of near, Japanese, stations. These seem to define it exactly in the position given in Table VI, but recalling past experience with the tables of extended distances at short distances, one probably should not put too much dependence on this exact value. Certainly however, it cannot be far off.

Earthquake of 09:36:51, Feb. 7, 1959.

$\varphi = 4°$ S, $\lambda = 81\frac{1}{2}°$ W

The machine solutions cluster around the best solution as given in Table VI, but the solution is not at all closely defined. The mean of all the solutions, and the range, is as follows:

Plane A		Plane B	
Azimuth	*Dip*	*Azimuth*	*Dip*
88° ± 24°	65° ± 15°	244° ± 42°	62° ± 21°

Despite the wide range, the score is reasonably good; this simply reflects the lack of observations to control the exact position of the planes.

Earthquake of 16:49:13, March 1, 1959.

$\varphi = \frac{1}{2}°$ S, $\lambda = 134\frac{1}{2}°$ E

The first eight of the machine solutions are essentially the same as the one given in Table VI. Their spread defines the possible variation from a mean:

Plane A		Plane B	
Azimuth	*Dip*	*Azimuth*	*Dip*
107° ± 18°	85° ± 22°	22° ± 17°	84° ± 17°

Earthquake of 17:57:58, April 24, 1959.

$\varphi = 31°$ S, $\lambda = 178°$ W

This earthquake was discussed, as an example, in the introductory section, where it was shown to be a case in which the solution was in terms of undefined dilatational circles in the centre of the diagram. Interpreted in terms of faulting, this means thrust faulting on one of a pair of shallow, non-defined planes. Since this fact has geological significance, the earthquake has been listed as solved in Table I, although no entry can appear in Tables VI or VII.

Earthquake of 20:40:38, April 26, 1959.

$\varphi = 25°$ N, $\lambda = 122\frac{1}{2}°$ E

This earthquake has been treated by Ritsema (1962). Using 144 observations he obtained the following solution:

Null Direction		Plane A		Plane B	
Azimuth	*Plunge*	*Azimuth*	*Dip*	*Azimuth*	*Dip*
297	14	345	18	210	77

The same 144 observations were given to the computer and the following solution was obtained:

287	14	333	20	200	76

This is a reasonably good agreement. However we must present more disquieting figures. Data had been collected for this earthquake through our normal questionnaire. 151 observations so collected yielded the following solution:

217	42	155	68	266	54

This is markedly different than that given by Ritsema.

We combined the data from the two sources, obtaining a total of 200 observations. The two sets of data disagreed in nine cases. Where there were disagreements we took our own observations as correct. The solution was as follows:

222	45	158	66	267	55

We then did the solution once more; where there were disagreements between the two sets of data we this time took Ritsema's observation as the correct ones. We obtained:

294	11	342	16	206	78

which is in excellent agreement with Ritsema's original solution. This solution is given in Tables VI and VII.

It seems clear from the foregoing that the solution is very sensitive to the accuracy of the data and that even a relatively few incorrect observations may distort the solution. It seems certain that Ritsema's observations, which were for the most part based on the study of the actual records, must be more accurate than our own. The implications of these facts to our program of nodal-plane determination will be discussed in a separate paper.

Earthquake of 11:09:30, April 28, 1959.
$\varphi = 15°$ N, $\lambda = 93°$ W

This again is an earthquake in which the solution must be in terms of a pair of undefined, central, dilatational circles, representing thrust faulting on shallow, undefined planes.

Earthquake of 07:15:42, May 4, 1959.
$\varphi = 52\frac{1}{2}°$ N, $\lambda = 159\frac{1}{2}°$ E

In this earthquake there is complete agreement on the position of Plane A among all the solutions, but there is some vagueness about the position of Plane B. As shown in the Table there are two possibilities, one which makes the number of inconsistencies a minimum, the other which gives a maximum score. These more or less run the gamut of possibilities on Plane B.

Balakina, Shirokova and Vvedenskaya (1961) have published a solution for this earthquake; this has been given in Table VI. It will be seen that it agrees quite well with our alternative solution, particularly in regard to the dip directions of the planes; the dips do not agree so well, which probably reflects the limited distances of the stations they used. Stevens (1964) has used her program to determine the mechanism from S-wave data published by Stauder (1962). She finds a Type II mechanism to be appropriate; the directions of the intermediate force and of the nodal planes have been given in Table VI. The agreement with our alternative solution is remarkable.

Earthquake of 19:17:40, May 24, 1959.
$\varphi = 17\frac{1}{2}°$ N, $\lambda = 97°$ W

This solution was discussed in the introductory section. As shown there, it is a unique, closely defined, one.

Earthquake of 04:13:01, May 26, 1959.
$\varphi = 27\frac{1}{2}°$ N, $\lambda = 126\frac{1}{2}°$ E

This earthquake was also discussed in the introduction. It was there shown that, while there was one clearly defined plane, the second plane was less well defined and might be put in either of two positions. These alternative possibilities have been given in the Table; any position intermediate to the two is quite possible.

Earthquake of 00:11:57, June 14, 1959.
$\varphi = 20\frac{1}{2}°$ S, $\lambda = 68°$ W

No other solution of the ten best came close to that given in Table VI in the number of inconsistent observations. Examination of the plot shows the following possible variations from a mean position:

Plane A		Plane B	
Azimuth	*Dip*	*Azimuth*	*Dip*
94° ± 1°	81° ± 2°	358° ± 1°	55° ± 2°

Thus the solution is quite close, despite the rather low score.

Earthquake of 15:58:38, June 18, 1959.
$\varphi = 54°$ N, $\lambda = 161°$ E

There are very few data here; nevertheless Plane A is very closely defined by the observations and Plane B certainly seems to be fixed within ± 4° both in strike and in dip. However, with so few observations one hesitates to place too much credence in the solution.

As shown in Table VI, an independent solution by Balakina et al (1961) agrees closely with the Ottawa one. On the other hand a solution by Stevens (1964), using S-data published by Stauder (1962) shows no agreement whatever.

Earthquake of 16:05:18, July 9, 1959.
$\varphi = 20\frac{1}{2}°$ S, $\lambda = 68°$ W

For this earthquake all the solutions clustered around the value given for Plane B. There was so much variation given for Plane A however that it must be regarded as essentially undefined. The mean for this plane may be given as:

Plane A	
Azimuth	*Dip*
242° ± 82°	52° ± 20°

Even with this limitation, the number of inconsistencies is so high and the score so low, that the solution is on the verge of being classed as a "no solution".

Earthquake of 15:06:10, July 19, 1959.
$\varphi = 15°$ S, $\lambda = 70\frac{1}{2}°$ W

The solution here is almost identical with that for July 9, above. Plane B is closely limited by the data, Plane A may vary as follows:

Plane A	
Azimuth	*Dip*
245° ± 75°	31° ± 20°

Again, the solution is on the verge of "no solution".

Earthquake of 08:57:04, August 15, 1959.
$\varphi = 23°$ N, $\lambda = 121°$ E

All the computer solutions agree on an almost vertical plane striking approximately EW, but it is not possible to give any definite position for the second plane. Possible variations are as follows:

Plane A		Plane B	
Azimuth	*Dip*	*Azimuth*	*Dip*
362° ± 5°	86° ± 5°	182° ± 90°	20° ± 20°

Earthquake of 08:25:30, August 26, 1959.
$\varphi = 18°$ N, $\lambda = 94\frac{1}{2}°$ W

There are two possible solutions for this earthquake, one in terms of large circles (which on a fault interpretation would correspond to strike-slip faulting) the other in terms of small dilatational circles drawn in the central area (which would correspond to thrust faulting). While the former has the higher score, the latter has the fewer "weighted" inconsistencies and seems preferable.

Whatever the relative merits of the two solutions, each is exactly limited by the data.

Earthquakes of 14:09:39 and 22:23:53, September 14, 1959.
$\varphi = 28\frac{1}{2}°$ S, $\lambda = 177°$ W

These earthquakes might have been listed among the "no solutions" except that one plane, the same in each earthquake, was consistently defined. This plane has been listed *in its mean position* in Table VI. It varies from this mean position by ± 15° in azimuth, ± 2° in dip.

The later aftershock of 05:59:42, September 15, was also considered. There was too great a confusion of data to justify publication of even a partial solution, but it may be worth reporting that the best machine solution gave an azimuth direction of 303° and a dip of 88°, very similar to the two earlier shocks.

Earthquake of 15:31:57, September 29, 1959.
$\varphi = 29°$ S, $\lambda = 176\frac{1}{2}°$ W

This earthquake may probably be regarded as an aftershock in the series just considered. There are two possible solutions suggested by the computer. They have been listed in Table VI. Note that the first of these gives, for Plane A, a solution closely related to the ones found earlier in the series. However, this is probably without significance, since the earlier solutions would not have tolerated a second plane with the steep dip found here.

Both of the possible solutions are closely limited by the data, but these are not numerous. The solutions should not be depended on too strongly.

Earthquake of 18:27:47, October 5, 1959.
$\varphi = 83\frac{1}{2}°$ N, $\lambda = 112.5°$ E

Despite the small number of observations for this Arctic earthquake the solution given in the table scored 3.5 points higher than its nearest rival. This suggests a rather strong solution. It is not a tight solution however; Plane B is exactly defined by the data, but Plane A may best be given as:

Azimuth	*Dip*
297 ± 10°	74° ± 11°

Earthquake of 09:30:24, January 15, 1960.
$\varphi = 15°$ S, $\lambda = 75°$ W

The computer solutions are reasonably well clustered around the "best" solution given in Table VI; however, the data do not define the positions of the planes very closely. The mean position, and variations from this mean, may be expressed as follows:

Plane A		Plane B	
Azimuth	*Dip*	*Azimuth*	*Dip*
239° ± 25°	55° ± 15°	6° ± 6°	50° ± 4°

Even with these limitations the circles cannot be regarded as well-defined; the one circle lies in the Pacific, the other in South America, and there are too few stations in these areas.

Earthquake of 16:33:38, March 8, 1960.
$\varphi = 16\frac{1}{2}°$ S, $\lambda = 168\frac{1}{2}°$ E

The observations for this earthquake are almost entirely dilatational; the only consistent groups of compressions come from the New Zealand stations and from Rabaul. There are two ways of satisfying these data, and they have been listed as alternative solutions in Table VI. Each solution is closely defined by the data, but there is not much basis for selecting between them.

Earthquake of 17:07:30, March 20, 1960.
$\varphi = 40°$ N, $\lambda = 143\frac{1}{2}°$ E

There was very good clustering of the machine solutions about the value given in Table VI, and the number of inconsistencies increased very rapidly as the values departed from the "best" position. However, inconsistent observations tended to occur in groups, rather than dispersed throughout the diagram, a phenomenon which is always disquieting. The solution given in the table was exactly limited by the data.

Chilean Earthquakes of May, 1960.

A questionnaire was circulated in June, 1960, seeking first-motion information on six of the earthquakes of this series. An attempt was made to solve the resulting diagrams graphically, but because of confusion of data and because of scarcity of observations in the Pacific and in South America no solutions emerged in which one could have confidence. A number of later aftershocks of the Chilean series were included in the general questionnaire for the years 1959-60; again there was much difficulty in making a pattern from the observations.

However, when the data are fed to the computer a pattern, consistent over the entire series, appears to emerge. This pattern bears considerable resemblance to that established on other grounds and seems to justify the publication of the results, even though they are not well defined. The entire Chilean series will be considered here.

May 21, 1960; 10:02:50

The solution given in Table VI is the computer solution with the highest score. Plane B, given in the Table in its "best" position is in fact almost undefined; the average direction of the dip azimuth is 118° ± 63°, and the average dip is 45° ± 25°. Plane A on the other hand was found repeatedly by the computer in about the position given in the Table, and while the observations defining it are not numerous they lie close enough to limit it within ± 2° in both strike and dip.

St. Amand (1961), from the study of aftershocks has postulated a fault striking N 9° E. Plane A of the computer solution strikes about N 4° E. If the nodal diagram is interpreted in terms of faulting and if Plane A is taken as the fault, the strike direction agrees very well with St. Amand's; the plane dips steeply to the west. Because the second plane is not well defined we can only say that the faulting is thrust with a possible *left-lateral* component which might be very large. This disagrees both with the findings of St. Amand and with the findings of Aki which he reports; they find the lateral displacement to be *right-lateral*.

May 22A, 1960; 10:30:39

As will be seen from Table VI, this solution is quite similar to that given above; Plane A is striking rather more east of north. Again Plane A is closely limited by the data, within ± 6° in azimuth and ± 3° in dip. Again Plane B is almost undefined; the mean azimuth direction is 161° ± 52°, the mean dip is 46° ± 22°. Again, interpreted in terms of faulting, the faulting is thrust with a possible strong left-lateral movement.

May 22B, 1960; 10:32:43

This solution is so poorly defined that it would have been listed among the "no solutions" except for the similarity it bears to the earlier ones in the sequence. The mean azimuth of Plane A is 300° ± 50° the mean dip 52° ± 17°. Plane B is still less well defined than usual; it may vary from a dip azimuth of 47, dip 62 (taken with A as a fault this would indicate right-lateral strike-slip faulting), through an azimuth of 126, dip 21 (indicating pure thrust faulting) to an azimuth of 205, dip of 68 (giving left-lateral strike-slip faulting).

May 22C, 1960; 18:55:57

No solution was possible in this earthquake. The ten different computer solutions all had the same number of inconsistent observations and made about the same score, but they were all completely different.

May 22D, 1960; 19:10:47

The computer found only one possible solution for this earthquake; while the number of inconsistencies is high and the score low the solution is closely limited by the data and one must accept it almost exactly as given in the table, or discard it completely. Again there is a north-south striking plane; regarding this as the fault, a fault-interpretation would insist on left-lateral movement.

May 22E, 1960; 19:11:20

Again the computer did not suggest any unique solution for this earthquake.

June 6, 1960; 05:55:44

The data for this earthquake were very confused, and no reliable solution can be given. Nevertheless it may be worth reporting that the solution which made the minimum number of inconsistent observations had a plane with dip azimuth of 276° and dip of 82°; this is very similar to the north-south striking plane characteristic of the series.

June 20A, 1960; 02:01:08

Plane A is closely limited by the data, but Plane B is not well defined. It can vary from the position shown in the Table, to a position tangential to the large circle. That is to say, the mean azimuth of dip is 121° ± 44° and the mean dip is 40° ± 33°. The similarity of this solution to the earlier ones in the series is remarkable.

June 20B, 1960; 12:59:40

There were several widely differing solutions for this earthquake, all with the same number of inconsistent observations. There was no basis for selecting any particular one. However, one of the possibilities was for a plane with a dip direction of 273°, a dip of 76°, closely analagous to the pattern for the other earthquakes of the series. Another equally plausible solution would be in terms of two undefined dilatational circles drawn in the central region; this would correspond to thrust faulting on a plane of undefined direction.

In summary, none of the Chilean earthquakes has yielded a well-defined solution, but most of them have suggested a plane striking approximately north-south and dipping steeply to the west. The mean strike of the plane, as determined by the several nodal-plane solution, is N 10° E which agrees almost exactly with the over-all fault direction suggested by St. Amand; it is this agreement which has led to the decision to publish the solutions despite their low scores. As has already been pointed out, most of the solutions, interpreted in terms of faulting on a north-south plane, require either thrust or left-lateral movement. The lateral sense does not agree with St. Amand.

Earthquake of 11:12:00, July 25, 1960.
$\varphi = 54°$ N, $\lambda = 159°$ E

It will be seen from Table VI that the computer has suggested two alternative solutions for this earthquake. In the first, Plane A is closely limited although by only two points, but Plane B may have the following range of variations:

Azimuth	*Dip*
40	51
117	12
194	46

The middle position is for the circle tangential to Plane A, and the listing indicates that the plane may vary throughout the entire range.

In the second solution Plane A is again closely limited, but again by only two observations. Plane B is again undefined and may have the following range:

Azimuth	*Dip*
178	53
255	15
332	56

the middle observation again indicates the tangential position for the circle.

It was mentioned in the case of both possible solutions that Plane A was held by very few observations. It should also be noticed that the two planes are not drastically different; in the first solution Plane A strikes N 27° E and dips steeply to the west, in the second it strikes N 15° W and dips steeply to the east. If we admit that two stations are not enough to limit a plane beyond question, then we might take the mean of the two positions of Plane A. This would be a plane striking N 6° ± 20° E and dipping at 90° ± 15°. With this mean position Plane A would have the following gamut:

Azimuth	*Dip*
6	54
–	0
186	47

Earthquake of 17:31:40, July 29, 1960.
$\varphi = 40.1°$ N, $\lambda = 142.3°$ E

The solution given in the table is closely defined by the data; although there is some confusion in the Japanese stations, probably reflecting errors in the extended distance tables at short distances, the position of the planes cannot be much in doubt.

Earthquake of 15:18:31, October 7, 1960.
$\varphi = 7.4°$ S, $\lambda = 130.7°$ E

The score for this solution is low, and the number of inconsistencies is higher than normal, but the computer gives a unique solution. The best position for this is given in Table VI; the mean position may be expressed as follows:

Plane A		Plane B	
Azimuth	*Dip*	*Azimuth*	*Dip*
150° ± 2°	62° ± 5°	48° ± 1°	67° ± 2°

Earthquake of 08:22:01, October 22, 1960.
$\varphi = 10.3°$ S, $\lambda = 161.2°$ E

In this earthquake Plane A is defined within a very few degrees, both in strike and dip, but Plane B is not well defined. In its mean position it may be described as follows:

Azimuth	*Dip*
39° ± 0°	34° ± 34°

Earthquake of 09:20:37, November 13, 1960.
$\varphi = 51.1°$ N, $\lambda = 168.8°$ W

In this case the computer found a number of equally good solutions, all representing compressional circles drawn in the central area of the diagram. This indicates the lack of control in the epicentral area. In a fault interpretation normal faulting on an undefined plane would be indicated.

Earthquake of 04:24:19, December 3, 1960.
φ = 42.9° N, λ = 104.4° E

This solution was in terms of a number of equally valid but loosely defined dilatational circles drawn in the central area of the diagram. On a fault interpretation these would represent thrust faulting, on an undefined, shallow-dipping plane.

Earthquake of 15:53:56, January 5, 1961.
φ = 4.1° S, λ = 143.0° E

This solution is reasonably well-defined in terms of a vertical plane striking north-south, and a second plane striking east-west and dipping steeply to the south. Limits from the mean positions are as follows:

Plane A		Plane B	
Azimuth	*Dip*	*Azimuth*	*Dip*
178° ± 4°	70° ± 10°	90° ± 5°	90° ± 4°

Earthquake of 07:20:19, January 16, 1961.
φ = 36.2° N, λ = 141.7° E

The solution given in the Table provides the best score of a number of approximately similar ones. All of these solutions involve one steeply dipping plane, with a second very shallow one. The mean position may be expressed:

Plane A		Plane B	
Azimuth	*Dip*	*Azimuth*	*Dip*
135° ± 10°	90° ± 3°	358° ± 33°	0° ± 3°

Earthquake of 17:09:16, January 20, 1961.
φ = 56.6° N, λ = 152.3° W

In spite of the small number of observations for this solution, the planes are defined almost exactly in the position given in the table. Even slight deviation from the listed position increased the number of inconsistent observations.

Earthquake of 21:53:44, February 12, 1961.
φ = 43.9° N, λ 147.6° E

Most of the observations in this earthquake were compressional and it was only in the central area that there were consistent dilatations. By good fortune they suffice to define the circles in the positions given in Table VI. Any deviation from the listed position results in increased numbers of inconsistent observations.

Earthquake of 18:10:49, February 26, 1961.
φ = 31.6° N, λ = 131.2° E

The solution given in the Table is almost exactly defined; a variation of even one degree in either the strike or dip of either plane results in a substantial increase in the numbers of inconsistent observations.

Earthquake of 09:35:55, March 28, 1961.
φ = 0.2° N, λ = 123.6° E

There are two possible solutions suggested for this earthquake; because of lack of points in the epicentral area neither is well defined.

The first is in terms of an approximately vertical plane striking north-east; the strike of this plane might vary ± 3° and the dip ± 2°. The second plane is not defined at all; treating the defined plane as a fault, the second circle might be drawn to define anything between strong left lateral and strong right lateral motion, including thrust faulting as an intermediate position.

The alternative solution, which has a poorer score, is somewhat better defined. The mean positions of the planes may be given as

Plane A		Plane B	
Azimuth	*Dip*	*Azimuth*	*Dip*
189° ± 10°	68° ± 5°	75° ± 15°	55° ± 15°

Earthquake of 23:29:21, June 1, 1961.
φ = 10.4° N, λ = 39.9° E

Only one plane can be defined in this earthquake, and even with this limitation the score is very poor. For the one plane defined the dip azimuth has a mean position of 230° ± 15°, and its dip a mean value of 90° ± 5°. If this plane were treated as a fault, the second circle could be drawn to indicate anything between mildly right-lateral to mildly left-lateral faulting, including an intermediate position indicating normal faulting.

Earthquake of 05:10:26, June 11, 1961.
φ = 27.9° N, λ = 54.6° E

Two solutions have been suggested for this earthquake. The preferred solution, listed first in Table VI, is exactly limited by the data. The second solution is less clearly defined. For it:

Plane A		Plane B	
Azimuth	*Dip*	*Azimuth*	*Dip*
220° ± 20°	50° ± 10°	87° ± 1°	54° ± 2°

Earthquake of 14:03:36, July 18, 1961.
φ = 29.4° N, λ = 131.6° E

The solution given in the table is very well defined; the possible variations in the strike are not more than 5° for either plane; for the dips not more than 1° could be tolerated.

Earthquake of 15:51:35, August 11, 1961.
φ = 43.0° N, λ = 145.0° E

The ten best solutions printed out by the computer were all variations on the solution given in the table. Even slight deviation from the published position resulted in decreased score; the mean position and the most variation which could be considered is as follows:

Plane A		Plane B	
Azimuth	*Dip*	*Azimuth*	*Dip*
94° ± 15°	62° ± 5°	321° ± 5°	42° ± 7°

Earthquake of 05:09:50, August 19A, 1961.
φ = 10.8° S, λ = 71.0° W

Two alternative solutions have been given for this earthquake, but these are in fact variations on the same solution and reflect the fact that there are not enough observations in the epicentral zone to define the planes very accurately. One thing that is clear is that the solution demands a plane striking roughly east-west and dipping steeply to the south; its mean position is:

Azimuth	*Dip*
200° ± 15°	75° ± 5°

The second plane is not really defined. While the evidence all points to a circle about as follows:

Azimuth	*Dip*
85° ± 22°	45° ± 20°

the data are not conclusive. A dip azimuth ranging out to 290° cannot be positively excluded.

Earthquake of 05:33:31, August 19B, 1961.
φ = 36.2° N, λ = 136.5° E

Again two alternate solutions have been given; it will be seen that they represent, in each case, a pair of dilatational circles drawn in the central area of the map, each with an approximately north-south strike. They represent two extremes which fit the data, but any pair of planes between would do as well. In terms of a fault interpretation we would say that foulting was thrust on a north-south striking plane of indeterminate dip.

Earthquake of 01:48:38, August 31A, 1961.
φ = 10.6° S, λ = 70.9° W

The epicentre of this earthquake is very close to that of August 19A, and the solution is rather similar. Only one plane is unambiguously defined, an almost vertical one striking somewhat north of east. Its mean position is:

Azimuth	*Dip*
144° ± 10°	90° ± 2°

The second plane has been given in the table in the best position found by the computer, but there is only one point holding it there; if this point is wrong, then there is no control whatever on the position of the plane.

Earthquake of 01:57:08, August 31B, 1961.
φ = 10.4° S, λ = 70.7° W

Again we have a solution in which only one plane can be defined. The mean position of the plane is:

Azimuth	*Dip*
140° ± 10°	83° ± 2°

The similarity to the earthquakes with similar epicentres, of August 19A and August 31A will be noted.

Earthquake of 00:09:35, September 1, 1961.
φ = 59.5° S, λ = 27.3° W

There are too few stations in the epicentral area to permit the definition of the circles in this earthquake; we can say only "undefined central dilatational circles".

Earthquake of 06:36:01, February 14, 1962.
φ = 38.1° S, λ = 73.1° W

There are two possible solutions for this earthquake, each making the same number of weighted stations wrong. In the first solution listed in Table VI, plane B is exactly defined by the data, plane A is almost undefined. It may range from one extreme position: Azimuth 166°, Dip 66°; through a mean position: Azimuth 250°, Dip 17°; to the other extreme: Azimuth 329°, Dip 56°.

In the alternative position the planes are limited within 1°.

Earthquake of 11:01:00, March 7, 1962.
φ = 19.3° S, λ = 145.3° E

There can be no doubt that this solution is in terms of central compressional circles, and any deviation from the position given in the Table results in a greatly increased number of inconsistent observations. However, a disquieting number of inconsistent observations (12) came from stations in the central area of the map. This undoubtedly reflects the errors of the tables of extended distance at short epicentral distances, but must warn against a too exact acceptance of the results.

Earthquake of 00:52:47, April 12, 1962.
φ = 38.2° N, λ = 142.3° E

This solution is in terms of one well-defined vertical plane striking N 49° E; both the strike and dip are defined within 3°. The second plane is almost tangent to the earth and therefore is not very well defined. It might vary both in strike and dip by as much as 10° from the position given in Table VI.

Earthquake of 05:58:05, April 23, 1962.
φ = 42.9° N, λ = 143.4° E

Alternative solution have been given in Table VI, but they do not differ vey much; they might be regarded as the two extremes on a mean position of the solution. This would be given as:

Plane A		Plane B	
Azimuth	*Dip*	*Azimuth*	*Dip*
164° ± 12°	90° ± 12°	262° ± 10°	22° ± 5°

Earthquake of 17:39:50, May 7, 1962.
$\varphi = 45.3°$ N, $\lambda = 146.7°$ E

This solution is in terms of central dilatational circles; fortunately there are enough observations close to the epicentre to define these reasonably well. In their mean positions, the planes given in Table VI assume the positions:

Plane A		Plane B	
Azimuth	*Dip*	*Azimuth*	*Dip*
153° ± 3°	53° ± 2°	276° ± 10°	52° ± 3°

Earthquake of 14:11:52, May 11, 1962.
$\varphi = 17.0°$ N, $\lambda = 99.7°$ W

The score for this solution, as shown in Table VI, is quite high, and the number of inconsistent observations is low. Nevertheless the solution is not a very dependable one, because of the poor distribution of observations. This will be apparent from Figure 2. Plane B represents a plane which runs along roughly parallel to the coast of North America; the stations on the continental side of this plane received initial compressions, but there are too few observations on the Pacific side of the plane to convince us that the plane might not dip in the other direction. Plane A is essentially undefined, although it is constrained by the data to shallow dips. It may range between the extremes, and through the mean position, shown below:

Plane A		Plane B	
Azimuth	*Dip*	*Azimuth*	*Dip*
134°	46°		
220°	4°	40° ± 2°	86° ± 4°
302°	35°		

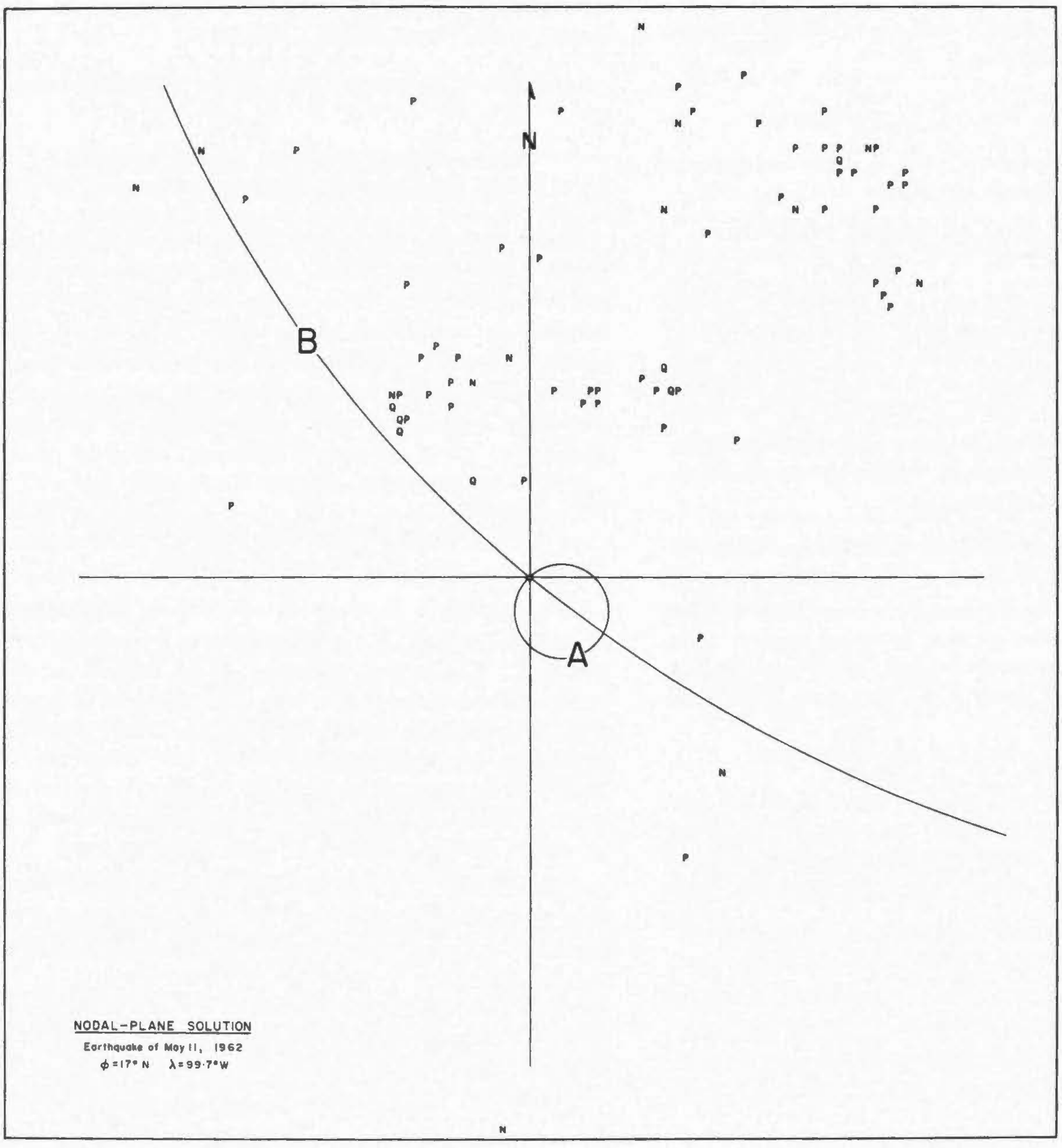

Figure 2

A somewhat analogous problem was created by the earthquake of May 19 (14:58:13), which had about the same epicentre. The computer solution for this earthquake is shown in Figure 3. It is clear that there is really no control on the Pacific side of the large circle; the solution has been listed among the "no solutions".

Earthquake of 12:02:51, May 21, 1962.
φ = 37.3° N, λ = 96.0° E

Almost all the observations in this earthquake are compressional, and the solution must be in terms of small, central, dilatational circles. Unfortunately these are undefined by the data.

Earthquake of 23:05:32, July 6, 1962.
φ = 36.6° N, λ = 70.4° E

This solution has been given by Metzger (1963) but the results have been included here for the sake of completeness. The best computer position has been shown in Table VI. The mean position and possible variation is as follows:

Plane A		Plane B	
Azimuth	*Dip*	*Azumith*	*Dip*
7° ± 55°	15° ± 7°	187° ± 5°	75° ± 7°

Earthquake of 08:14:42, July 26, 1962.
φ = 7.5° N, λ = 82.7° W

This earthquake would have been listed with the "no solution" ones except for the similarity of the pattern to

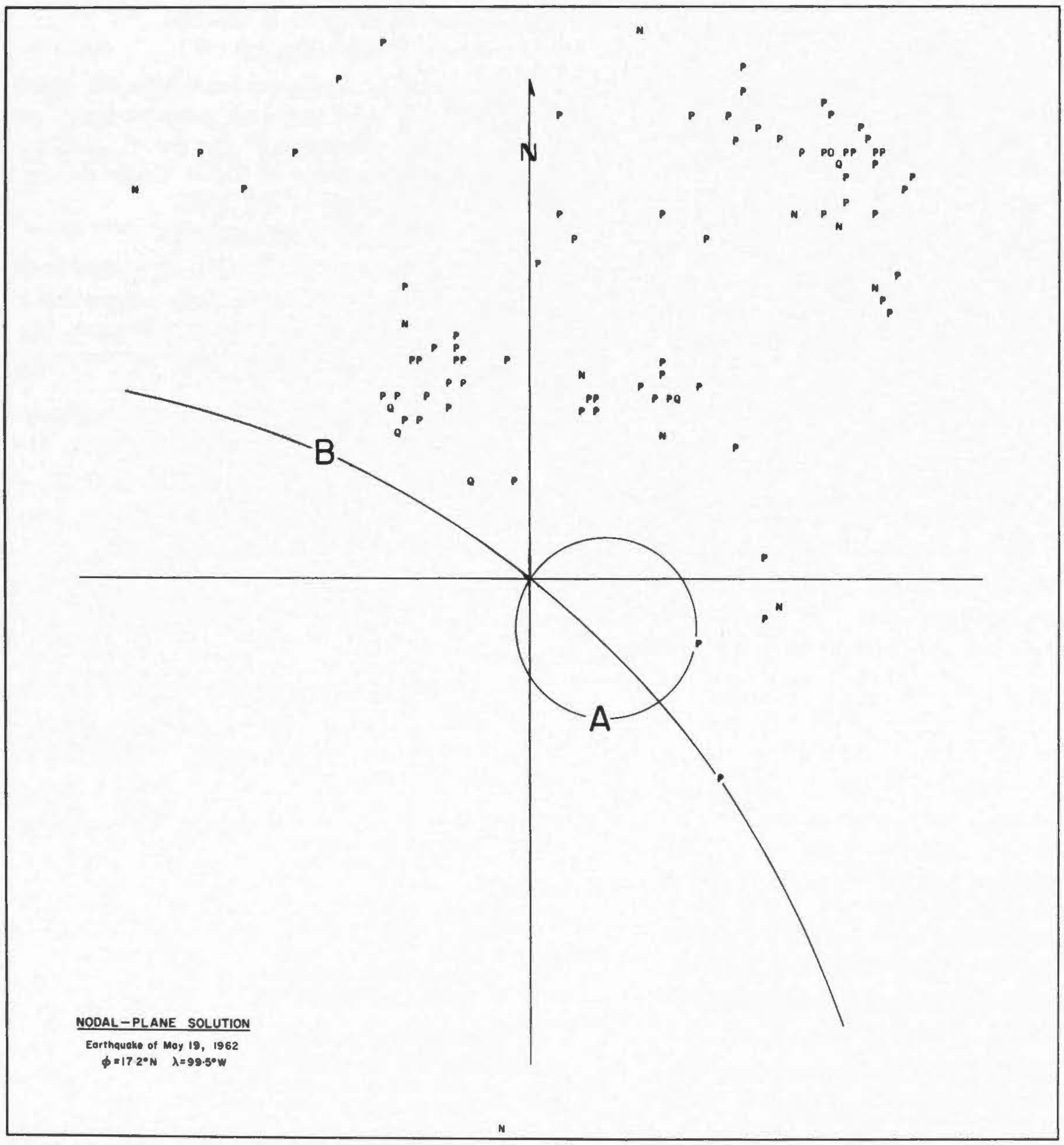

Figure 3

those in the Mexican earthquakes of May 11 and May 21. In those earthquakes the one defined plane ran parallel to the edge of the continent and was poorly defined because of the scarcity of the data on the Pacific side. In the present earthquake there is a similarly oriented plane suggested by all the machine solutions, except that in this case there is disagreement and confusion in the coastal stations so that the position cannot be given better than:

Azimuth	*Dip*
255° ± 7°	81° ± 2°

Earthquake of 17:16:44, July 30A, 1962.
φ = 3.3° S, λ = 143.9° E

Most of the observations in this earthquake were compressional and the best solution is probably in terms of undefined, central dilatational circles.

Earthquake of 20:18:49, July 30B, 1962.
φ = 5.0° N, λ = 76.3° W

Plane A in this solution is almost exactly defined by the data. Plane B is held in the position given in Table VI by only one point; if we were to ignore that point the plane might increase in dip to about 80°. It could not decrease.

Earthquake of 08:56:12, August 3, 1962.
φ = 23.2° S, λ = 67.5° W

The only possible solution for this earthquake is in terms of central compressional circles. The data near the epicentre are not sufficient to define them.

Earthquake of 10:59:59, August 28, 1962.
φ = 38.0° N, λ = 23.1° E

The solution given for this earthquake in Table VI is almost exactly defined by the data.

Earthquake of 19:20:39, September 1, 1962.
φ = 35.6° N, λ = 50.0° E

Most of the first-motion observations for this earthquake are compressional, and they crowd in so close to the epicentre that it is impossible to draw a pair of dilatational circles in the epicentral area; either one must make a number of observations inconsistent or one must ignore the orthogonality criterion.

The solution given in Tables VI and VII chooses the former alternative, making four observations in the epicentral area inconsistent. It had occurred to us that these near stations might have recorded a small foreshock but there is no evidence of this from the travel times. The case should be remembered as one in which a pair of orthogonal planes were not the best solution to the data.

Earthquake of 00:29:05, September 18, 1962.
φ = 7.5° N, λ = 82.3° W

Both planes given in Table VI for the solution of this earthquake are defined within about ± 2° in both strike and dip by the data.

Earthquake of 14:03:37, December 7, 1962.
φ = 29.2° N, λ = 139.2° E

The percentage of inconsistent observations in this solution is rather high, but some solution very like this must be the correct one. The more steeply dipping plane effectively divides the map into two zones, one predominately compressional, the other dilatational. The second plane is also reasonably well substantiated.

If the solution is accepted, then the possible variation on the positions of the planes is very small.

Earthquake of 21:27:18, December 8, 1962.
φ = 25.8° S, λ = 63.2° W

Espinosa is making a study of this earthquake and has collected data on first motion from 35 stations. He kindly supplied this to us for the purposes of a nodal solution. Plane B given in Table VI is exactly defined by the data; Plane A is less well defined. The dip might increase to 40°, with a corresponding variation in azimuth.

SUMMARY

Since it is hoped that the present solutions will shortly be re-worked in the more elaborate program being prepared, we postpone discussion of the results. However, the solutions are summarized in Table VII in the form established in earlier papers of the series.

ACKNOWLEDGEMENTS

We have been assisted by a number of people in the collection of first motion data and in its preparation for the program. To these assitants—Marlene Metzger, Peter Hodgson, Eden Windish and Bruce Compton—we express our thanks.

We are also grateful to those many station operators who, by supplying us with data on first motion, have made this study possible.

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TABLE VII

EARTHQUAKE				PLANE A					PLANE B					NULL VECTOR			
Date	φ	λ	Focal Depth (km)	Strike Direction	Dip Direction	Dip	Strike Component	Dip Component	Strike Direction	Dip Direction	Dip	Strike Component	Dip Component	Trend	Plunge	DEXTRAL Solution	SINISTRAL Solution
January 8, 1959	15.5 N	61 W	100	N 41 E	N 49 W	84°	.996	+.087	N 49 W	N 41 E	85°	.994	+.104	N 13 W	82°	a	b
January 22, 1959	34 N	142 E	33	N 33 E	N 123 E	89°	.172	+.984	N 62 W	N 28 F	10°	.994	+.100	N 33 E	10°	b	a
February 7, 1959	4 S	81.5 W	33	N 22 E	N 112 E	73°	.991	+.127	N 66 W	N 156 W	83°	.955	+.294	N 136 E	71°	a	b
March 1, 1959	0.5 S	134.5 E	100	N 29 E	N 119 E	66°	.993	−.114	N 63 W	N 27 E	84°	.912	−.408	N 104 E	65°	a	b
April 24, 1959	31 S	178 W	33	←				+	Not defined				+				→
April 26, 1959	25 N	122.5 E	150	N 72 E	N 18 W	16°	.656	.754	N 64 W	N 154 W	78°	.185	+.982	N 66 W	11°	b	a
April 28, 1959	15 N	93 W	33	←				+	Not defined				+				→
May 4, 1959	52.5 N	159.5 E	60	N 48 E	N 42 W	83°	.504	−.863	N 30 W	N 60 E	31°	.971	−.236	N 44 E	30°	b	a
Alternative solution				N 45 E	N 45 W	83°	.000	−1.000	N 53 E	N 143 E	7°	.000	−.999	N 135 W	1°	–	–
May 24, 1959	17.5 N	97 W	100	N 77 E	N 17 W	71°	1.000	−.000	N 17 W	N 107 W	90°	.945	−.325	N 17 W	71°	a	b
May 26, 1959	27.5 N	126.5 E	100	N 68 E	N 22 W	85°	.415	+.909	N 35 W	N 125 W	25°	.978	+.206	N 110 W	24°	b	a
Alternative solution				N 63 E	N 27 W	85°	.085	+.996	N 71 W	N 161 W	7°	.698	+.715	N 63 E	5°	b	a
June 14, 1959	20.5 S	68 W	100	N 4 E	N 94 E	83°	.816	−.577	N 89 E	N 1 W	55°	.988	−.148	N 13 E	54°	a	b
June 18, 1959	54 N	161 E	33	N 80 E	N 10 W	82°	.996	+.088	N 10 W	N 100 W	85°	.990	+.139	N 42 W	80°	b	a
July 9, 1959	20.5 S	68 W	100	N 90 E	S	37°	.858	−.513	N 26 W	N 64 E	72°	.542	−.839	N 143 E	31°	a	b
July 19, 1959	15 S	70.5 W	200	N 84 E	N 174 E	19°	.927	−.374	N 26 W	N 64 E	83°	.304	−.952	N 152 E	18°	a	b
August 15, 1959	23 N	121 E	33	N 88 E	N 2 W	86°	←		Not defined								→
August 26, 1959	18 N	94.5 W	33	N 31 W	N 59 E	48°	.355	+.934	N 60 W	N 150 W	46°	.367	+.930	N 135 E	5°	a	b
Alternative solution				N 21 E	N 111 E	80°	.999	+.017	N 69 W	N 159 W	89°	.984	+.173	N 116 E	80°	a	b
September 14A, 1959	28.5 S	177 W	33	N 59 E	N 31 W	87°	←		Not defined								→
September 14B, 1959	29 S	177 W	33	N 59 E	N 31 W	87°	←		Not defined								→
September 29, 1959	29 S	176.5 W	33	N 15 E	N 75 W	89°	.999	+.017	N 75 W	N 15 E	90°	.999	+.017	N 73 W	89°	a	b
Alternative solution				N 79 E	N 169 E	81°	.999	+.017	N 11 W	N 79 E	89°	.987	+.156	N 162 E	81°	b	a
October 5, 1959	83.5 N	112.5 E	33	N 17 E	N 73 W	85°	.890	−.455	N 75 W	N 165 W	63°	.995	−.097	N 153 W	62°	a	b
January 15, 1960	15 S	75 W	150	N 13 W	N 103 W	66°	.665	+.746	N 78 W	N 12 E	47°	.831	+.556	N 33 W	37°	a	b
March 8, 1960	16.5 S	160.5 E	250	N 61 E	N 151 E	82°	.844	−.535	N 25 W	N 115 W	58°	.986	−.164	N 131 W	57°	b	a
Alternative solution				N 75 E	N 165 E	56°	.413	−.910	N 37 E	N 53 W	41°	.522	−.852	N 121 W	35°	b	a
March 20, 1960	40 N	143.5 E	60	N 9 W	N 99 W	84°	.000	−1.000	N 28 W	N 62 E	6°	.000	−.999	N 9 W	2°	b	a
May 21, 1960	37.5 S	73.5 W	33	N 4 E	N 86 W	76°	.357	+.934	N 61 E	N 151 E	25°	.819	+.572	N 171 W	20°	b	a
May 22A, 1960	38 S	73.5 W	33	N 38 E	N 52 W	68°	.305	+.952	N 80 E	N 170 E	28°	.602	+.797	N 135 W	17°	b	a
May 22B, 1960	37.5 S	73 W	33	N 36 E	N 54 W	69°	.000	+1.000	N 30 E	N 120 E	21°	.000	+.999	N 35 E	2°	a	b
May 22D, 1960	38 S	73.5 W	33	N 3 W	N 93 W	81°	.960	−.279	EW	N	74°	.986	−.162	N 32 W	71°	b	a
June 20A, 1960	38 S	73.5 W	33	N 13 W	N 103 W	83°	.955	+.294	N 75 E	N 165 E	73°	.991	+.127	N 171 W	71°	b	a
July 25, 1960	54 N	159 E	100	N 27 E	N 63 W	78°	.376	+.926	N 89 E	N 179 E	25°	.870	+.491	N 148 W	21°	b	a
Alternative solution				N 15 W	N 75 E	73°	.777	−.629	N 88 E	N 178 E	53°	.930	−.366	N 145 E	48°	b	a
July 29, 1960	40.1 N	142.3 E	50	N 25 E	N 115 E	69°	.000	+1.000	N 40 E	N 50 W	21°	.000	+.999	N 27 E	5°	b	a

EARTHQUAKE				PLANE A					PLANE B					NULL VECTOR		DEXTRAL Solution	SINISTRAL Solution
Date	φ	λ	Focal Depth (km)	Strike Direction	Dip Direction	Dip	Strike Component	Dip Component	Strike Direction	Dip Direction	Dip	Strike Component	Dip Component	Trend	Plunge		
October 7, 1960	7.4 S	130.7 E	45	N 58 E	N 148 E	67°	.921	+.389	N 41 W	N 49 E	69°	.908	+.418	N 101 E	58°	b	a
October 22, 1960	10.3 S	161.2 E	93	N 41 E	N 131 E	88°	.882	-.469	N 51 W	N 39 E	62°	.999	-.039	N 45 E	62°	a	b
November 13, 1960	51.1 N	168.8 W	65					-	Not defined				-				
December 3, 1960	42.9 N	104.4 E	60					+	Not defined				+				
January 5A, 1961	4.1 S	143.0 E	108	N 85 E	N 175 E	67°	.999	+.037	N 5 W	N 85 E	88°	.920	+.390	N 171 E	67°	b	a
January 16, 1961	36.2 N	141.7 E	41	N 45 E	N 135 E	87°	.000	+.999	N 77 E	N 13 W	3°	.000	+.999	N 45 E	2°	b	a
January 20, 1961	56.6 N	152.3 W	46	N 31 E	N 59 W	72°	.939	-.342	N 53 W	N 37 E	71°	.945	-.326	N 9 W	63°	b	a
February 12, 1961	43.9 N	147.6 E	45	N 44 E	N 134 E	74°	.101	+.994	N 62 E	N 28 W	17°	.333	+.942	N 45 E	5°	b	a
February 26, 1961	31.6 N	131.2 E	54	N 30 E	N 120 E	64°	.651	+.758	N 33 W	N 123 W	47°	.800	+.599	N 171 W	36°	a	b
March 28, 1961	0.2 N	123.6 E	83	N 31 E	N 121 E	86°		+	Not defined				+				
	Alternative solution			N 81 W	N 171 W	64°	.909	+.416	N 3 W	N 87 E	68°	.881	+.472	N 143 E	55°	b	a
June 1, 1961	10.4 N	39.9 E	33		Not defined				N 24 W	N 114 W	84°						
June 11, 1961	27.9 N	54.6 E	37	N 59 E	N 149 E	58°	.832	+.553	N 51 W	N 39 E	62°	.799	+.600	N 98 E	45°	b	a
	Alternative solution			N 33 W	N 123 W	40°	.404	+.914	N 3 W	N 87 E	65°	.321	+.946	N 166 E	15°	b	a
July 18, 1961	29.4 N	131.6 E	21	N 14 E	N 104 E	36°	.218	-.975	N 31 E	N 59 W	55°	.156	-.987	N 25 E	8°	a	b
August 11, 1961	43.0 N	145.0 E	50	N 2 E	N 92 E	58°	.456	+.889	N 46 E	N 44 W	41°	.589	+.807	N 17 E	23°	b	a
August 19A, 1961	10.8 S	71.0 W	649	N 3 W	N 87 E	51°	.969	-.245	N 84 W	N 174 W	79°	.767	-.641	N 109 E	49°	b	a
	Alternative solution			N 17 E	N 107 E	62°	.929	-.368	N 62 W	N 152 W	71°	.868	-.496	N 147 E	55°	b	a
August 19B, 1961	36.2 N	136.5 E	17	N 9 W	N 81 E	60°	.249	+.968	N 19 E	N 71 W	33°	.396	+.918	N 1 W	13°	b	a
	Alternative solution			N 25 E	N 115 E	31°	.524	+.851	N 12 W	N 102 W	64°	.300	+.953	N 176 E	16°	a	b
August 31A, 1961	10.6 S	70.9 W	626	N 45 E	N 135 E	87°	.906	-.423	N 43 W	N 133 W	65°	.998	-.057	N 141 W	65°	b	a
August 31B, 1961	10.4 S	70.7 W	629	N 59 E	N 149 E	84°		-	Not defined				-				
September 1, 1961	59.5 S	27.3 W	131					+	Not defined				+				
February 14, 1962	38.1 S	73.1 W	44	N 47 E	N 43 W	38°	.880	+.474	N 20 W	N 70 E	73°	.566	+.824	N 9 W	33°	a	b
	Alternative solution			N 30 E	N 60 W	83°	.997	+.070	N 60 W	N 30 E	86°	.992	+.122	N 27 W	82°	a	b
March 7, 1962	19.3 S	145.3 E	680	N 52 W	N 142 W	54°	.226	-.974	N 33 W	N 57 E	38°	.297	-.954	N 135 E	9°	a	b
April 12, 1962	38.2 N	142.3 E	68	N 49 E	N 139 E	87°	.090	+.995	N 10 W	N 100 W	6°	.865	+.500	N 131 W	5°	a	b
April 23, 1962	42.9 N	143.4 E	25	N 64 E	N 154 E	77°	.404	+.914	N 2 E	N 88 W	27°	.868	+.495	N 121 W	23°	a	b
	Alternative solution			N 88 E	N 2 W	85°	.280	-.959	N 18 W	N 108 W	17°	.954	-.298	N 91 W	17°	a	b
May 7, 1962	45.3 N	146.7 E	25	N 58 E	N 148 E	55°	.713	+.700	N 3 W	N 93 W	55°	.713	+.700	N 152 W	36°	a	b
May 11, 1962	17.0 N	99.7 W	25	N 49 E	N 139 E	26°	.987	-.159	N 50 W	N 40 E	86°	.433	-.900	N 128 E	26°	a	b
May 21, 1962	37.3 N	96.0 E	25					+	Not defined				+				
July 6, 1962	36.6 N	70.4 E	203	N 82 E	N 8 W	15°	.000	+1.000	N 87 W	N 177 W	75°	.000	+.999	N 87 W	3°	-	-
July 26, 1962	7.5 N	82.7 W	21						N 8 W	N 98 W	83°	Not defined					
July 30A, 1962	3.3 S	143.9 E	25					+	Not defined				+				
July 30B, 1962	5.0 N	76.3 W	45	N 20 E	N 110 E	90°	.970	+.241	N 70 W	N 20 E	76°	.999	+.017	N 21 E	76°	b	a

EARTHQUAKE				PLANE A					PLANE B					NULL VECTOR			
Date	ϕ	λ	Focal Depth (km)	Strike Direction	Dip Direction	Dip	Strike Component	Dip Component	Strike Direction	Dip Direction	Dip	Strike Component	Dip Component	Trend	Plunge	DEXTRAL Solution	SINISTRAL Solution
August 3, 1962	23.2 S	67.5 W	71	← Not defined →													
August 28, 1962	38.0 N	23.1 E	120	N 65 E	N 25 W	40°	.531	+.847	N 76 W	N 166 W	57°	.407	+.913	N 89 W	20°	b	a
September 1, 1962	35.6 N	50.0 E	21	N 43 W	N 133 W	53°	.366	+.930	N 10 W	N 80 E	42°	.437	+.899	N 150 E	17°	b	a
September 18, 1962	7.5 N	82.3 W	33	N 9 E	N 99 E	83°	.996	-.087	N 81 W	N 9 E	85°	.992	-.122	N 63 E	81°	a	b
December 7, 1962	29.2 N	139.2 E	411	N 70 E	N 160 E	28°	.993	+.111	N 16 W	N 106 W	87°	.467	+.884	N 166 E	28°	a	b
December 8, 1962	25.8 S	63.2 W	543	N 59 E	N 31 W	21°	.980	+.194	N 21 W	N 69 E	86°	.352	+.935	N 20 W	21°	a	b