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Record No. 1969 / 125

Rabaul preliminary Crustal Seismic test, New Britain 1966

by

G. Cifali, G.W. d'Addario, E.J. Polak, and W.A. Wiebenga

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ABSTRACT

This report gives the tentative results of a short preliminary seismic survey in Rabaul, New Britain, to investigate the crustal structure in and around the volcanic zone of the caldera. The survey was proposed to facilitate future interpretations of seismic data to be provided by a volcanic warning system centred on the observatory at Rabaul.

From the seismic travel times plotted as a time-distance diagram a standard time-distance curve and profile was constructed showing three main formations: low velocity layers of about 1.5 and 2.8 km/s velocity, a layer of about 5.0 km/s, and a bottom layer of about 7.0 km/s.

From deviations from the standard time-distance curve, sections and a contour plan of the 5.0-km/s layer were constructed. Reflections were recorded; some are believed to originate from the lowest refractor. Diffractions were used to locate some of the major shear zones.

CONTENTS

ILLUSTRATIONS

1. INTRODUCTION

The Administration of the Territory of Papua & New Guines intends to establish a volcanic eruption warning system at Rabaul, New Britain, centred on the Administration's Rabaul Observatory.

The Observatory is located on the rim of a caldera (Plate 1); the co-ordinates are 4^{o} 11' South and 152^{o} 10' East. The observatory is operated by officers of the Bureau of Mineral Resources, Geology & Geophysics, on loan to the Administration.

The caldera includes Simpson Harbour and Blanche Bay; several dormant and active volcanoes are located in and around the caldera. In 1937 Vulcan's cone rose more than 600 feet during the first 24 hours of an eruption (Williams, 1951); the last major eruption of Matupi (Mount Tavurvur) occurred in 1942.

Volcanic eruptions are preceded and accompanied by swarms of seismic tremors originating within the crust of the upper mantle. From the pattern of earthquakes recorded at the seismograph network being constructed at present, it will be possible to predict volcanic events more precisely. However, to facilitate the interpretation of the seismic records it is desirable to know the distribution of seismic velocities within, and the structure of, the Earth's crust in the volcanic area.

Apart from its specific purpose to assist in the interpretation of vulcanological data, a geophysical survey of this area is of theoretical and international interest (Upper Mantle Project, 1967). The Rabaul area of active volcanoes lies close to the continental shelf and may be in the transition zone between the continental and oceanic crust.

Several surveys on the same lines were carried out in other areas of the Pacific (Officer, 1955; Raitt, 1956; Woollard et al., 1967).

This report covers the results of a preliminary seismic survey during two weeks in August 1966, by W. A. Wiebenga, E. J. Polak and G. Cifali, geophysicists from BMR's Canberra Office, and G. W. d'Addario, BMR's vulcanologist-in-charge of the Rabaul observatory. W. A. Wiebenga and E. J. Polak were generally responsible for the computation and interpretation of the data.

It is especially desired to acknowledge the assistance given by: the Administration, which provided the ship Lahara; Mr G. Bladden, the captain of the Lahara; the staff of the Commonwealth Department of Works, Rabaul; and the staff of the Vulcanological Observatory at Rabaul.

2. VULCANOLOGY AND GEOLOGY

The vulcanology and geology of the Gazelle Peninsula have been described by Fisher (1939). Blanche Bay is an elongated caldera on the north coast of New Britain. It is about 16 kilometres long and 10 kilometres wide. It is open to the sea in the south-east direction (Plate 1). Rabaul is located within the caldera wall on a narrow strip of land. Within the walls of the caldera are located two volcanoes, Matupi (Mount Tavurvur) and Vulcan, which erupted simultaneously in 1878 and in 1937. Matupi erupted again in 1941-42, but now emits only small quantities of steam and gas. Rabalanakaia is a second young crater on the eastern side of the caldera, but its eruption time is not known. The Mother and the North and the South Daughters are older volcanoes on the eastern rim of the caldera. They erupted before the caldera subsided, which probably occurred in 1190 ± 60 years "Before Present" (Grant-Taylor & Rafter, 1963).

The north-east end of the Peninsula is composed of Recent volcanic rocks, which overlie coral limestone of Pleistocene to Recent age. The lavas and pyroclastic deposits of the older volcanoes are basaltic; more recent volcanoes produced lavas ranging from basalt to andesite (Latter, 1966).

Watom Island, an extinct volcano located about 16 kilometres north-west from the observatory, is composed of basalt lava flows.

The present volcanic activity is confined to fumeroles on the Matupi and Rabalanakaia cones and to hot springs and seepages at several places in Blanche Bay. The seepages generally occur below water level and between low and high water mark (Studt, 1961). Higher up the slopes, leakages of steam and hot places on the ground indicate the volcanic activity (Wiebenga & Polak, 1962).

3. METHODS AND EQUIPMENT

The determination of seismic velocities and thicknesses of the Earth's outer layers can be obtained from the travel times of the seismic waves generated by either earthquakes or artificial explosions. From the origin, waves radiate in all directions and are reflected, refracted, or diffracted at discontinuities according to well known laws (Heiland, 1946; Jakosky, 1961). These waves are recorded at the observatory and by portable seismic equipment. If the moment of explosion is known accurately and the information from several recording points is available, time-distance curves may be plotted. From the time-distance curve, the velocities in the layers and their thickness can be calculated.

Charge firing

In the preliminary crustal investigation at Rabaul, the explosive charges were lowered from the ship Lahara to the bottom of the sea. The charges were made of 60% gelignite with a submarine No. 8 detonator. The charges were detonated with an exploder (S.I.E. high-voltage blaster).

A schematic diagram of the shooting and shot-instant timing arrangement is shown in Figure 1, (Plate 6). The moment of explosion is transmitted by radio to the field recording unit and the observatory as a short 1000-Hz signal. The shots were fired exactly 4 seconds after the minute, and the shot moment was also recorded on a multi-channel chronograph. The chronograph also recorded the standard time signal from the radio station located close to the observatory and the one-second and 0.1 second signals from a chronometer. Chronometers were synchronised before each shot.

Observatory recording

The observatory data from the explosions were included in the fortnightly papers issued by the Rabaul Observatory. The papers give the arrival times of seismic waves as recorded by the World Wide Standardised Seismograph and the strong motion Omori Seismograph. For the period of the survey the explosion times (accuracy about ± 0.1 sec) were given as well.

Field station recording

The recording was done on an S.I.E. refraction seismograph. The equipment consists of a bank of twelve P19 amplifiers, a P11 camera with 25 galvanometers of 200-Hz natural frequency, and a power pack. For the test the high tension dynamotors were removed from the power pack and replaced with 270-volt dry batteries. Seismic waves were picked up by eleven T.I.C. geophones of 20-Hz natural frequency spaced 100 feet apart. During recording a high cut filter at 30 Hz was used. Some variable density records were obtained using a "Seismod". The speed of the paper was adjusted to approx. 5 inches per second with timing lines at 10-millisecond intervals.

Three additional recording channels were used:

(i) To record the shot instant by radio, a filter allowed the 1000-Hz signal to pass through.

(ii) One-second and 0.1-second signal from the chronometer was synchronised with the observatory and ship chronometers.

(iii) One-second radio time signal. At the beginning of the test, G.M.T. from Hawaii was used, but owing to the adverse atmospheric conditions the local radio time was substituted.

Accuracy of timing on records

In general the accuracy of the shot instant as recorded by the seismic field equipment is within one to three milliseconds. Where atmospheric interference made the shot instant doubtful the shot instant could be estimated from the cronograph record with accuracy of about 0.1 second. The travel times recorded by the observatory are believed to be accurate to within ± 0.1 second.

Interpretation

In this part only the general method of data interpretation will be given; the detailed explanation will be given in Chapter 4.

Refraction. The time-distance curve is obtained by plotting the time of arrival of the wave at the recording station against the distance between the shot-point and the recording station. Through the points of the graph the best fitting lines are drawn; the slope of these lines equals to the reciprocal of the apparent velocity in the layers. The apparent velocity is related to the true velocity and to the dip of the interface. Intercept times are obtained by extending the lines to the origin. From these and from the true velocities in the refractor, the depth to the refractor can be calculated (Heiland, 1946; Jakosky, 1961).

Reflection. The arrival of a reflected wave at a set of geophones placed approximately in line with the shot-point can be recognised on the seismic record by a line of events crossing the record nearly simultaneously. To determine whether these events on several records came from the same horizon the square of the "shot-point to recording station" distance is plotted against the square of the travel time (Slotnick, 1959, p. 31). Points which lie on the same line or in a group probably represent waves reflected from the same horizon. The depths to the reflecting horizon can be calculated from their arrival time and the velocities found or assumed in the layers above it.

Diffraction. Figure 3 (Plate 6) represents diagrammatically a type of time-distance curvey frequently recorded in complicated areas. Diffraction events have been investigated and used in previous work by BMR (Wiebenga & Polak, 1962).

The two refractors with seismic velocities V_1 and V_2 are intersected by a shear zone which may partly or wholly act as a barrier against waves travelling along the lower refractor. The intersection of the shear zone with the boundary of refractors V_1 and V_2 forms an edge which acts as a secondary radiation source. The corresponding time-distance curve shows a characteristic upward curvature. From the curvature the angle of emergence of the wave can be computed.

4. RESULTS

Data

Tables 1 to 5 give all the data obtained during the survey. The data are divided in groups according to the positions occupied by the field station during the series of shots. Explanatory notes below refer to the numbered line entries in the tables.

1. Shot number consisting of two parts. Part one gives the date in August when the shot was fired; part two is the number of the shot in this day.

2. The distance in kilometres between the shot-point and first geophone of the field spread.

3. First arrival refraction a. time of arrival in seconds
b. corrected apparent seismic velocity in km/sec. recorded by spread, (the velocity is corrected for the angle between the spread line and line joining first geophone with the shot-point.

Seismic velocities

Plate 2 shows the time-distance curves plotted from explosions. In plotting, the observatory and field stations were considered as the origin of a composite time-distance curve, and the distance to the shot-points is plotted along the horizontal axis, irrespective of azimuth. The data were divided into two groups; Figure 1, Plate 2 gives the data from shots fired north-west of the caldera; Figure 2, Plate 2, is concerned with the data inside the caldera and on the south-east rim of the caldera.

Through the points the best fitting lines were drawn; the slopes of these lines equal the reciprocal of the apparent seismic velocity in the refractors. The apparent velocities in the upper layers towards the south-east are lower than those towards the north-west, indicating that the interfaces are sloping to the south-east. From the apparent velocities in opposite directions the true velocities were calculated. The distribution of seismic velocities suggests the following refractor velocities:

Top layer, with a seismic velocity of about 1.5 km/s, which consists of water and unconsolidated sediments below the sea bottom.

Second layer, with a seismic velocity of about 2.8 km/s, consisting of lava flows, tuffs, coral limestone, etc.

Third layer, with a seismic velocity of about 5.0 km/s, which may consist of lava flows and older metamorphosed sedimentary rocks. There is a suggestion of a fourth layer, with a velocity of about 7 km/s, however this was recorded from shots in one direction only, and over a small distance. The velocities shown in Plates 4 and 5 for the deeper layers have been deduced from a later survey in 1967; a separate report is being prepared on this.

It is not proposed to discuss the possible implications resulting from the refractor velocities found, because the data are insufficient (see also Talwani, 1964).

During engineering surveys in the area (Wiebenga & Polak, 1962; Cifali, Milsom & Polak, 1968), wide velocity variations were found for the near-surface layers. The difficulties of predicting geological formations from seismic velocities were well illustrated at Warangoi (Cifali et al., op. cit.): in a drill hole a body or dyke of olivine basalt with a seismic velocity of more than 6.0 km/s was found overlying a formation with a seismic velocity of 1.7 km/s.

Standard section

Using the time intercepts of the time-distance curve and the velocities mentioned above ("Seismic velocities") a standard section was prepared. The data used for preparation are shown in Figure 3, Plate 2. The actual result in the form of a section is shown in Figure 4, Plate 2.

Column 1 of the Table in Figure 3 gives the velocities in the refractors; Column 2 contains the intercept times read on the zero distance of the time-distance curves. In the interpretation an assumption is made that the layers are horizontal and therefore the average of intercept times from shots coming from opposite directions is considered. From columns 1 and 2 the thickness of the layer is calculated and shown in column 3. Column 4 gives the depth of the top interface of each layer, while column 5 gives the conversion factor, which is obtained by dividing the depth to the interface by half the intercept time of the same interface. The full explanation of the procedure of obtaining the conversion factor may be found in Heiland (1946) or Wiebenga and Polak (1962).

Sections

The results of the interpretation of data are included in Plates 3 to 5. Plate 3 indicates the positions of the shots, recording stations, contours of the bottom of the 2.8-km/s velocity horizon, and the positions of shear zones. Plates 4 and 5 give three sections shown in Plate 3.

To plot the sections refraction, reflection, and diffraction data were considered.

Refraction. The method of interpretation of the data, with an example, is explained in Figure 3, Plate 2. Each point on the time-distance curve was to determine from which refractor the signal came. The displacement of the point of the actual time of arrival of the wave from the standard curve is called the residual time. The sign of the residual time indicates whether the interface is deeper (plus) or shallower (minus) than the standard section. The residual time multiplied by the conversion factor for this horizon (see table in Fig. 3) is added to the standard section to give the depth to the interface. These depths were plotted on sections.

Reflection. The depth to a reflecting horizon was calculated after ascertaining that it is a true reflection in the way indicated in Chapter 3 above. In the computation of depths the conversion factors in seismic refraction work were used as average velocities to the interface. The depths were plotted in Plates 4 and 5, with a letter "R" to distinguish them from other data.

On some locations very late reflections (about 15 seconds) were recorded. When plotted they did not fit into the pattern. After investigation it was concluded that these events may be multiple reflections between the 7.0-km/s horizon and the surface. Where a shear zone was located between shot-point and recording station, multiple reflections may sometimes be recorded but not direct reflections, owing to loss of reflectivity in the shear zone itself.

Diffraction. The diffraction events were instrumental in determination of the shear zone pattern of the area. As mentioned before, some of the shear zones were indicated by double reflection, and in some places where the shot was fired over a shear zone, a great attenuation in seismic energy was noted on the records in the observatory and at the field station.

Detailed examination of the sections

Section A-B (Plates 2 and 4 illustrate the structure of the 5.0-km/s layer). The section starts at Watom Island, an extinct volcano. There was no recording station on the island, and the two shots fired near the island are not sufficient to prepare a detailed section, but there is a clear indication that the depth to the 5.0-km/s layer is approximately 3 to 4 km; total depth is 5 km. The depth to the 5.0-km/s layer decreases sharply between the shear zone (about 3½ km north-west from the observatory) and the observatory. The shear zone located about 2½ km soth-east from the observatory is believed to be related to the North Daughter, Sulphur Creek, and Vulcan craters. Seven kilometres south-east from the observatory a very pronounced shear zone coincides with the Mother and Matupi craters.

The South Daughter is located near or between the two shear zones 9 to 10½ km south-east from the ovservatory, near Praed Point. South-east from the last shear zone the 5.0-km/s layer is probably 4 to 5 km deep. Further south-east, no data are available to draw up the section in detail. The 7.0 ± km/s layer dips about 7 degrees towards south-east underneath the Gazelle Peninsula, and reaches a depth of about 10 km 25 km south-east from the observatory.

Section C-D (Plate 4). The section shows a graben in the 5.0-km/s material. This section is important because it indicates that the movement in the area is in the form of blocks and not in strips as could be wrongly suggested by the pattern of shear zones in Plate 3. This erroneous conclusion could have been reached because all available data are grouped in a narrow band stretching from north-west to south-east.

Section E-F (Plate 5). The section is similar to Section A-B. The only difference is in the south-eastern part of the section, where considerable accumulations of 1.5-km/s and 2.8-km/s seismic velocity material are shown. Possibly these accumulations were formed by volcanic eruptions of Vulcan.

5. CONCLUSIONS

The results of this survey give some idea of the structure of the area, mainly in terms of seismic velocity and depth. But these results are subject to confirmation by the 1967 Rabaul seismic crustal investigation.

To complete the picture it is desirable to programme for shipborne and airborne magnetic surveys to map old and new volcanoes, for sonar boomer surveys to map the sea bottom, and for a temperature survey to trace the heat flow.

6. REFERENCES

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APPENDIX

In interpreting the 1966 survey data some events on the time-distance curves were interpreted as belonging to a deeper layer with a velocity of about 7.0 km/s. Since this layer was obtained by shooting in one direction only it was not considered to be reliable and therefore was not used in the construction of Plates 4 and 5 (1966 Survey).

However as a result of the 1967 survey, where reverse shooting was carried out, the deeper velocities obtained can now be considered reliable and are added to Plates 4 and 5.

TABLE 1. Field station at Turanguna Bay (Praed Point)

1. Record Number		19	20	21	40	41	42
2. Shot number		22/1	22/2	22/3	29/1	29/2	29/3
3. Distance shot-field station		21.0	8.70	8.29	5.5	5.8	4.55
4. Explosive charge (lb)		200	100	100	50	30	15
5. Depth of water (ft)		168	210	150	132	144	
6. First arrival	a. time (sec)		4.79	491	2.18	1.24	0.45
refraction	b. velocity (km/s)		4.3	3.5	5.5	2.0	2.0
7. Second arrival	a. time			10.49	2.48	2.55	0.51
refraction	b. velocity			4.8	3.2	2.7	2.8
8. Third arrival	a. time						
refraction	b. velocity						
9. Fourth arrival.	Reflection		9.0			6.26	1.30
	Diffraction	5.62			7.58		
10. Fifth arrival.	Reflection						3.25
	Diffraction					7.25	
11. Sixth arrival.	Reflection						
	Diffraction					9.73	
12. Seventh arrival.	Reflection						
	Diffraction						
13. Distance shot-observatory		31.0	13.0	10.70	5.7	4.7	
14. First arrival		6.1	3.5	3.6	2.2	2.3	
15. Second arrival			8.0				
16. Third arrival							

TABLE 2. Field stations at Raluana

1. Record Number		35	36	37	38	39
2. Shot number		26/1	26/2	26/3	26/4	26/5
3. Distrance shot-field station		15.2	6.9	1.0	0.7	10.85
4. Explosive charge (lb)		300	50	30	20	50
5. Depth of water (ft)		180	120	12		126
6. First arrival	a. time (sec)	2.25		0.71	0.64	
refraction	b. velocity (km/s)	2.6		2.4	1.5	
7. Second arrival	a. time					
refraction	b. velocity					
8. Third arrival	a. time					
refraction	b. velocity					
9. Fourth arrival.	Reflection					
	Diffraction	5.26		1.4		
10. Fifth arrival.	Reflection	5.5		4.5		
	Diffraction					
11. Sixth arrival.	Reflection					
	Diffraction					
12. Seventh arrival.	Reflection					
	Diffraction					
13. Distance shot-observatory						2.4
14. First arrival						1.0
15. Second arrival						10.5
16. Third arrival						

TABLE 3. Field station at Matupi Island

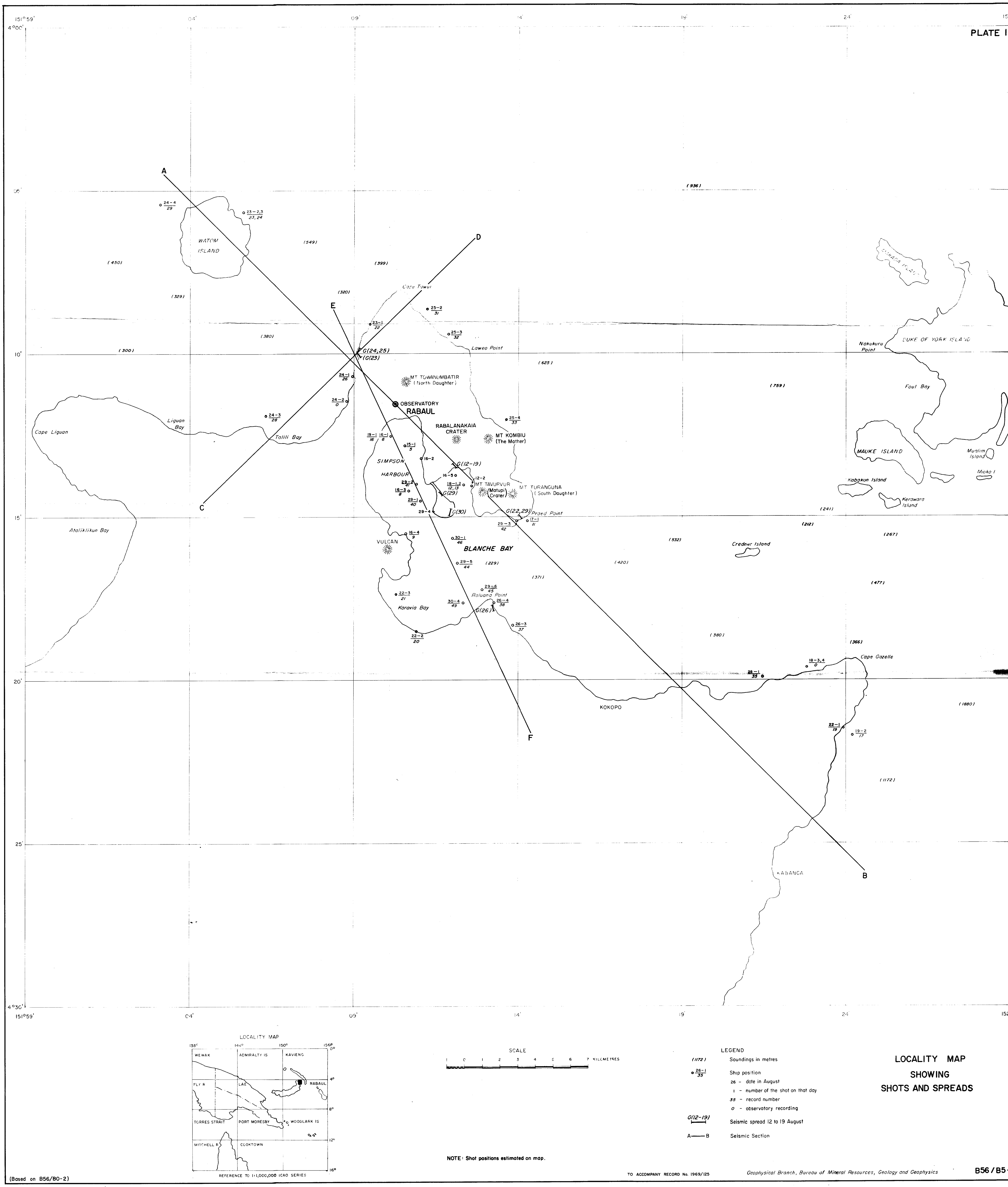
1. Record Number	43	44	45	46	47	48	49
2. Shot number	29/4	29/5	29/6	30/1	30/2	30/3	30/4
3. Distance shot-field station	1.07	4.0	5.7	1.7	2.4	3.3	5.0
4. Explosive charge (lb)	10	30	100		50	100	100
5. Depth of water (ft)			156		240	420	48
6. First arrival a. time (sec)	1.18	3.13	4.25	1.11			2.62
refraction b. velocity (km/s)	2.8	2.95	42	2.2			2.2
7. Second arrival a. time	1.35	3.65	4.37				3.8
refraction b. velocity	4.3	4.3	2.2				1.7
8. Third arrival a. time							4.5
refraction b. velocity							6.5
9. Fourth arrival. Reflection							
Diffraction	2.7	36					9.6
10. Fifth arrival. Reflection							11.8
Diffraction							
11. Sixth arrival. Reflection							
Diffraction							
12. Seventh arrival. Reflection							
Diffraction							
13. Distance shot-observatory	6.53	9.7	11.6	8.25	8.8	9.95	11.9
14. First arrival	2.6		2.9				3.5
15. Second arrival	4.1						
16. Third arrival							

TABLE 4. Field station at Airport

1. Record Number	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
2. Shot number	12/2	12/3	12/4	15/1	16/1	16/2	16/3	16/4	16/5	17/1	18/1	18/2	18/3	18/4	19/1	19/2	19/3
3. Distance shot-field station	1.5	0.6	1.9	2.90	3.94	1.89	2.56	4.2	2.2	5.0	.78	.78	22.2	28.7	3.94	27.0	
4. Explosive charge (lb)	15	20	60	10	20	20	20	25	50	100	50	50	150	150	25	200	275
5. Depth of water (ft)	80	80	100	116	74	28	144	132	60	90	168	168	204	240	60	300	300
6. First arrival a. time (sec)	2.38	0.21	1.84	1.27	2.22		1.57	2.65		2.44	0.61	0.55			2.15	6.3	
refraction b. velocity (km/s)	1.37	1.3	2.63	2.2	2.6	2.4				2.0	1.2	1.5			2.0	2.5	
7. Second arrival a. time	2.45	1.3		1.29								0.81				6.7	
refraction b. velocity	2.14	3.0		4.3	5.2							5.5				3.7	
8. Third arrival a. time																	
refraction b. velocity																	
9. Fourth arrival. Reflection		1126															
Diffraction	2.70		2.41	1.87						2.66						7.3	
10. Fifth arrival. Reflection	3.50																
Diffraction			2.57	2.46													
11. Sixth arrival. Reflection																	
Diffraction																	
12. Seventh arrival. Reflection																	
Diffraction																	
13. Distance shot-observatory				2.42	1.80	6.0	4.99	7.4	5.40	10.00	5.99	5.99	26.0	26.0	1.80	32.0	32.0
14. First arrival				1.8	2.6	3.5	4.5	5.0	2.0		2.1	2.2	5.9	6.5	0.9	6.5	7.1
15. Second arrival				9.0	7.2	13.0	6.0	7.9	10.0		4.6	4.8	10.9	11.0	3.7		
16. Third arrival											6.6	8.8	13.9				

TABLE 5. Field stations at Nonga

1. Record Number	22	23	24	25	26	27	28	29	30	31	32	33
2. Shot number	23/1	23/2	23/3	23/4	24/1	24/2	24/3	24/4	25/1	25/2	25/3	25/4
3. Distance shot-field station	1.57	11.1	11.1		1.49	2.79	6.47	6.47	1.55	4.46	5.0	9.1
4. Explosive charge (lb)	20	50	100	100	20	30	100	100	20	30	100	100
5. Depth of water (ft)	180	240	240	180	12	18	240	270	30	360	300	180
6. First arrival a. time (sec)	0.55	1.82	3.46	2.09	0.60		3.5		0.83	1.75	1.75	
refraction b. velocity (km/s)	1.2	2.6	1.5	1.7			2.2		2.8	3.3	5.3	
7. Second arrival a. time	1.48		4.79	2.71			2.2		0.97		2.0	
refraction b. velocity	3.0		3.0	3.0					1.7			
8. Third arrival a. time												
refraction b. velocity												
9. Fourth arrival. Reflection	2.2						4.48					
Diffraction		3.1	3.85									
10. Fifth arrival. Reflection							5.0					
Diffraction												
11. Sixth arrival. Reflection							10.3					
Diffraction												
12. Seventh arrival. Reflection												
Diffraction												
13. Distance shot-observatory	4.8	13.8	13.8		2.88	2.79	6.19	17.49	2.8	5.7	4.97	6.3
14. First arrival	2.3	3.8	4.0		3.4	2.0	2.0	4.0	1.2	2.2	2.1	2.0
15. Second arrival							2.5		2.5	3.0		6.5
16. Third arrival									4.0	7.5		

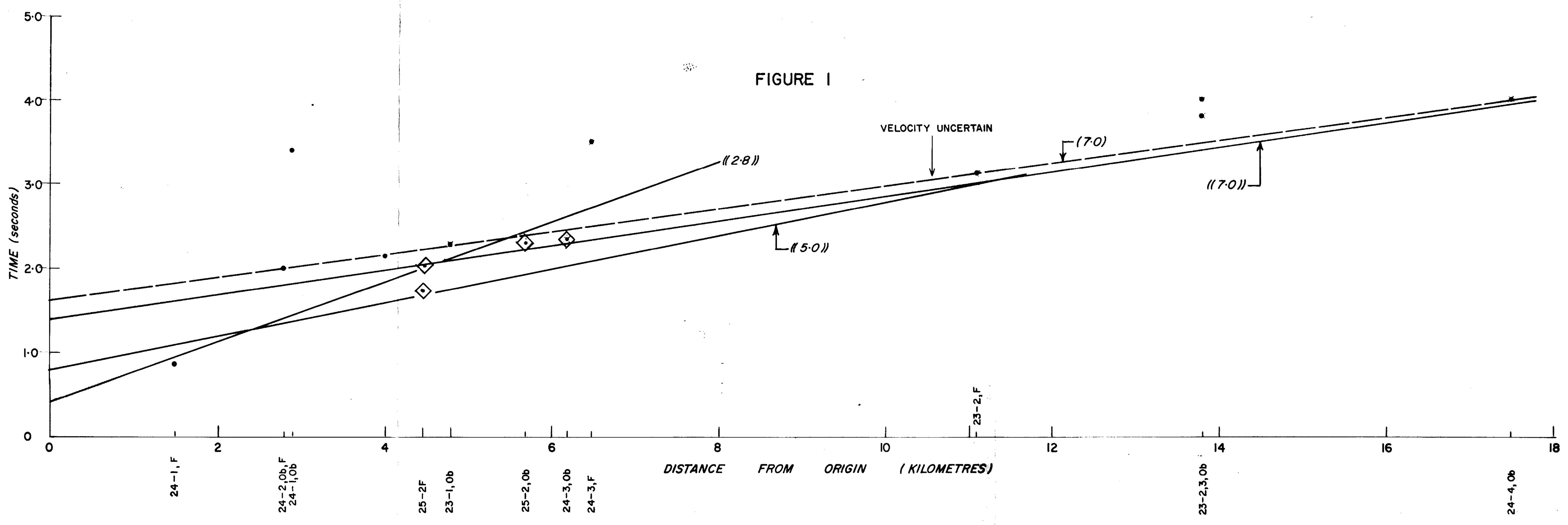


LOCALITY MAP
SHOWING
SHOTS AND SPREADS

B56/B5-7

PLATE 2

FIGURE 1



LEGEND

• 23-1, Ob	Shot 1 on 23 August recorded at observatory and located in general direction NW from observatory
◇ 25-2, F	Shot 2 on 25 August recorded at field station located in zone perpendicular to direction NW/SE
((5·0))	Seismic refractor velocity (km/s) used for standard model
(7·0)	Apparent seismic refractor velocity (km/s)

FIGURE 2

FIGURE 3

STANDARD CRUST MODEL RABAUL AREA

COMPUTED BY AVERAGING DATA ON COMPOSITE TIME / DISTANCE CURVES

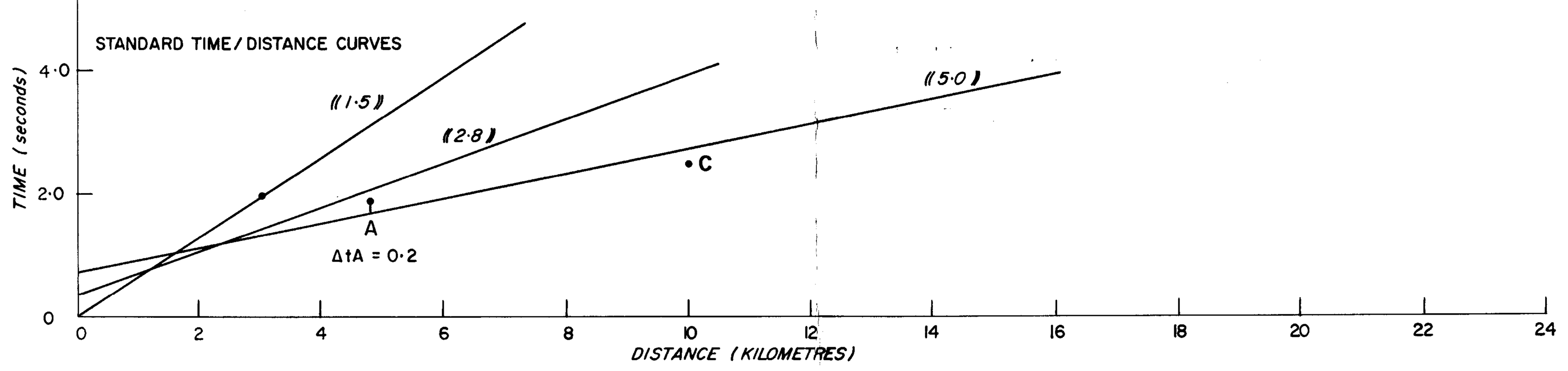


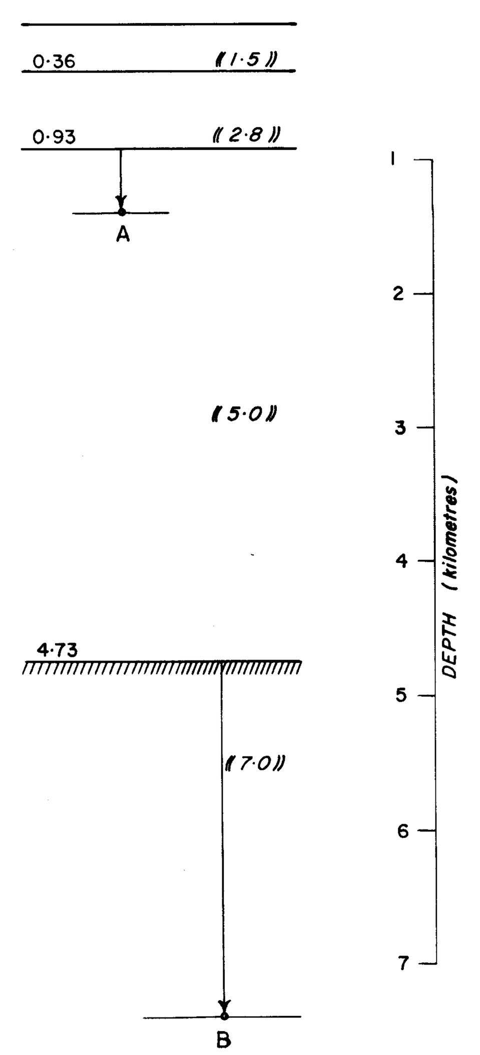
TABLE GIVING DATA USED IN COMPUTATION OF STANDARD MODEL				
REFRACTOR VELOCITY (km/s)	INTERCEPT TIME (seconds)	THICKNESS (km) (D)	DEPTH (km) (H)	CONVERSION FACTOR (CF)
1·5±		0·36		
2·8±	0·4	0·57	0·36	1·8
5·0±	0·8		0·93	2·33

EXAMPLES ILLUSTRATING USE OF CONVERSION FACTORS

Travel time "A" of 5·0 km/sec refractor is 0·2 seconds higher than standard ($\Delta tA = 0{\cdot}2$) hence: depth is $\Delta tA \times 2{\cdot}33$ higher than standard or depth 5·0 km/s refractor is $0{\cdot}93 + 0{\cdot}2 \times 2{\cdot}33 = 1{\cdot}4$ km

FIGURE 4

STANDARD MODEL

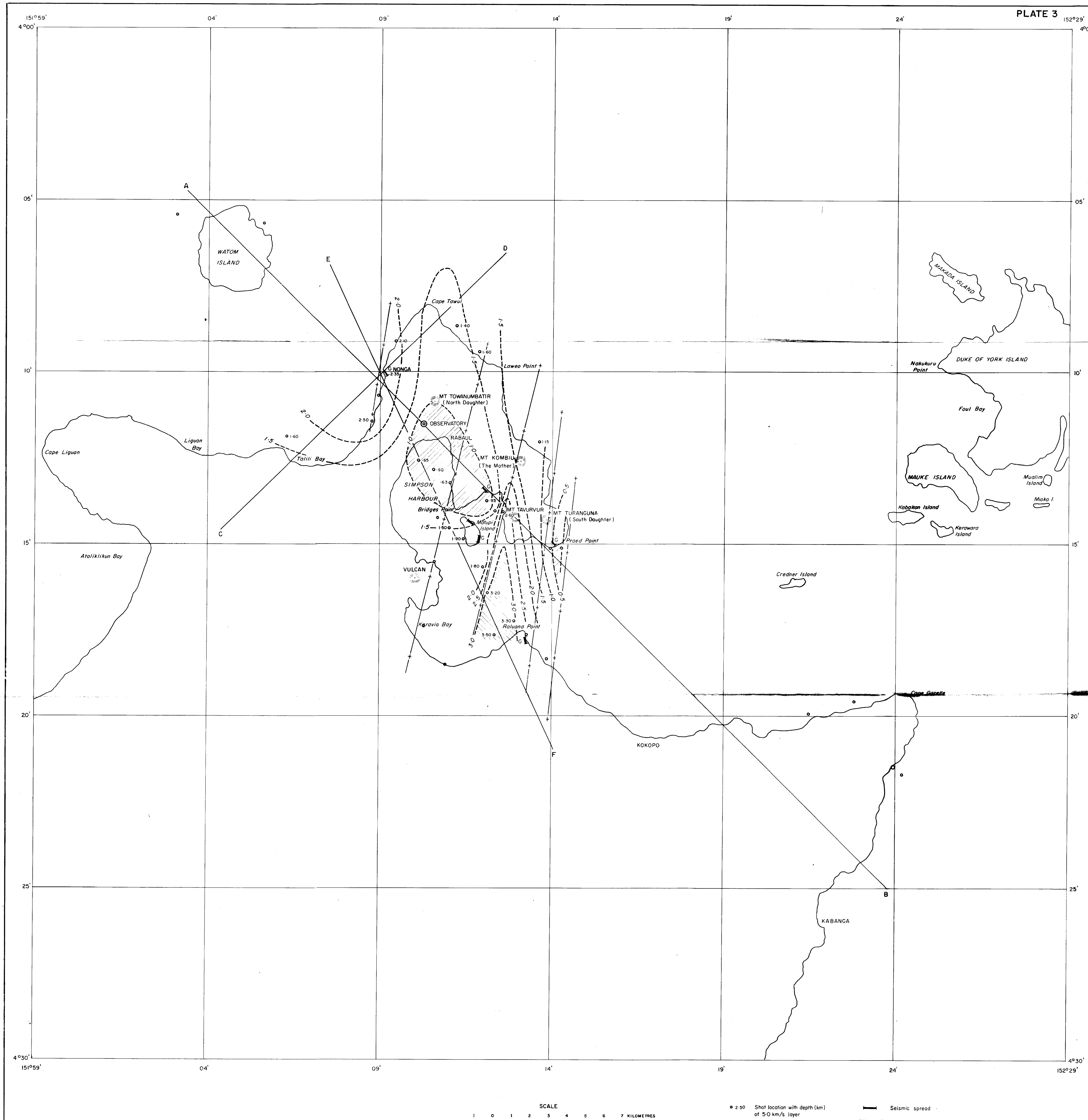


TIME – DISTANCE CURVES AND STANDARD SEISMIC MODEL

TO ACCOMPANY RECORD No. 1969/125

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

B56/B5-8



2·50 Shot location with depth (km) of 5·0 km/s layer

C—D Section

Contour indicating depth of 5·0 km/s layer (in km)

+—+ Shears indicated by seismic diffraction events

Seismic spread

Area where 5·0 km/s layer is shallowest

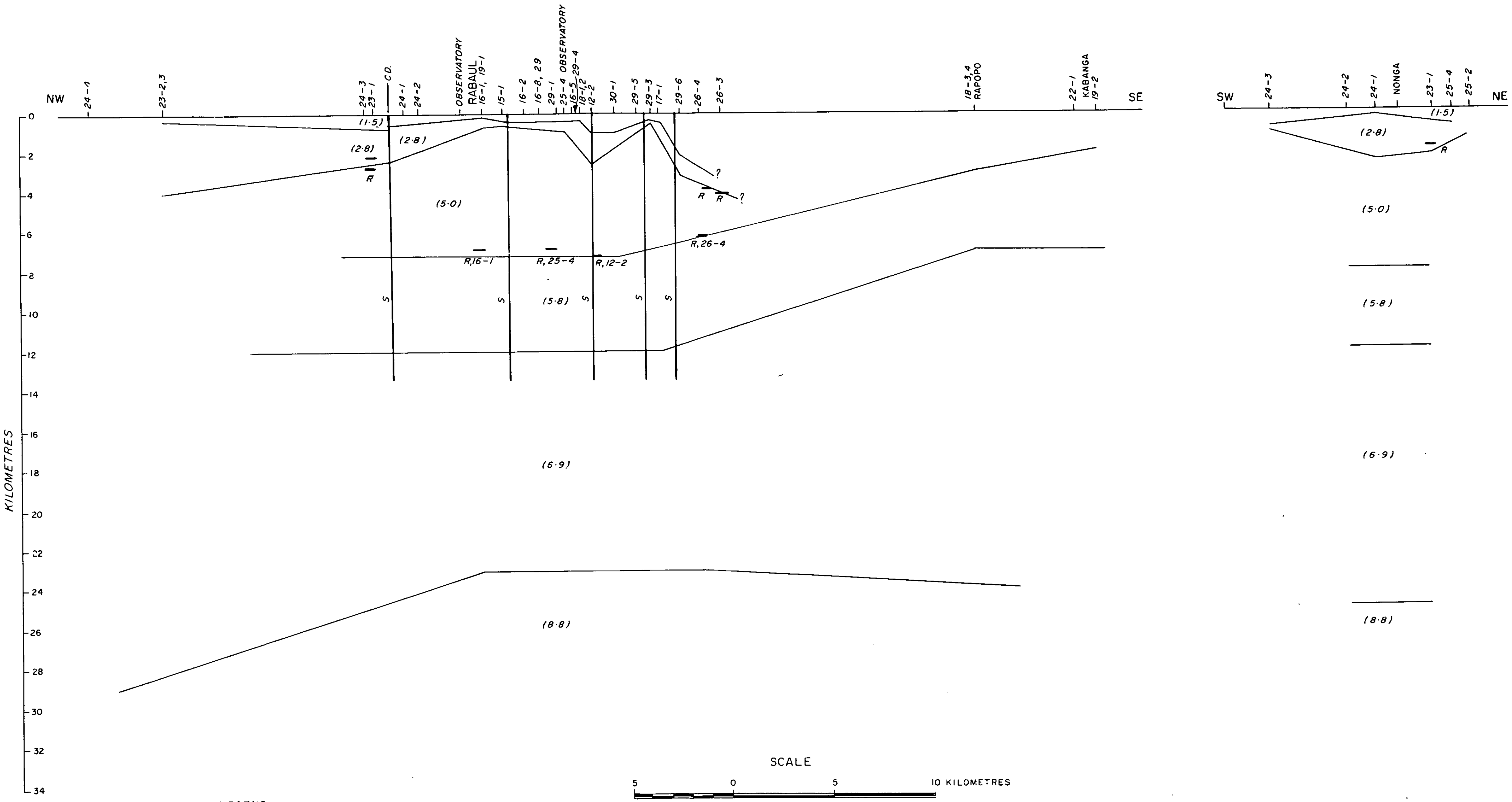
Area where 5·0 km/s layer is deepest

APPROXIMATE CONTOUR PLAN SHOWING DEPTH OF 5·0 KM/S LAYER

TO ACCOMPANY RECORD No. 1969/125

B56/B5-11

PLATE 4



LEGEND

24-2	Station number : Shot 2, 24th August
(6·9)	Seismic velocity (km/s)
S	Shear or fault
R	Reflection

SECTION A-B

SECTION C-D

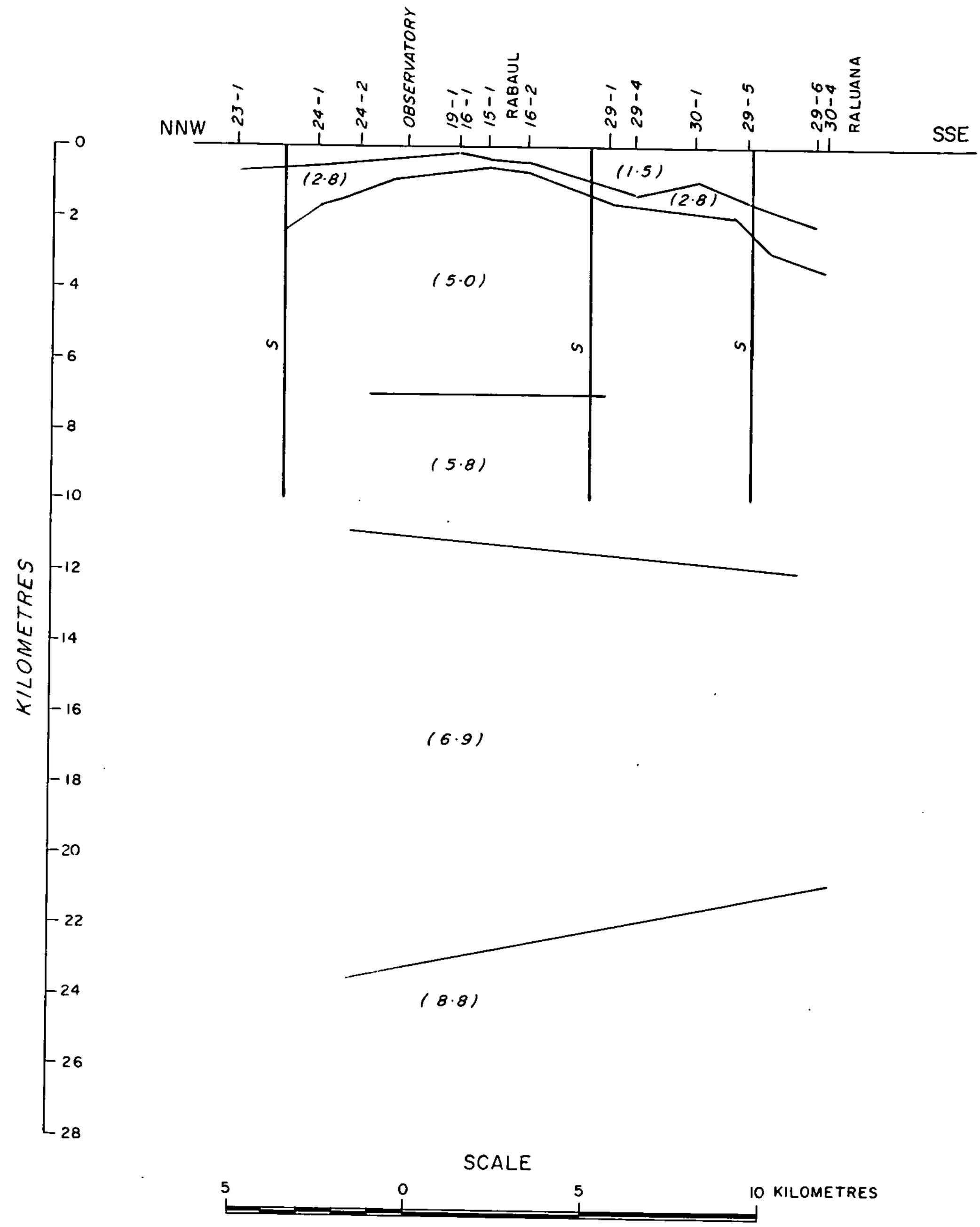
NOTE: Lower crust information obtained in 1967 survey.

TO ACCOMPANY RECORD No. 1969/125

B56/B5-41

RABAUL CRUSTAL INVESTIGATION, 1966

PLATE 5



LEGEND

24-2 Station number: Shot 2, 24 August

(6·9) Seismic velocity (km/s)

S Shear or fault

NOTE: Lower crust information obtained in 1967 survey

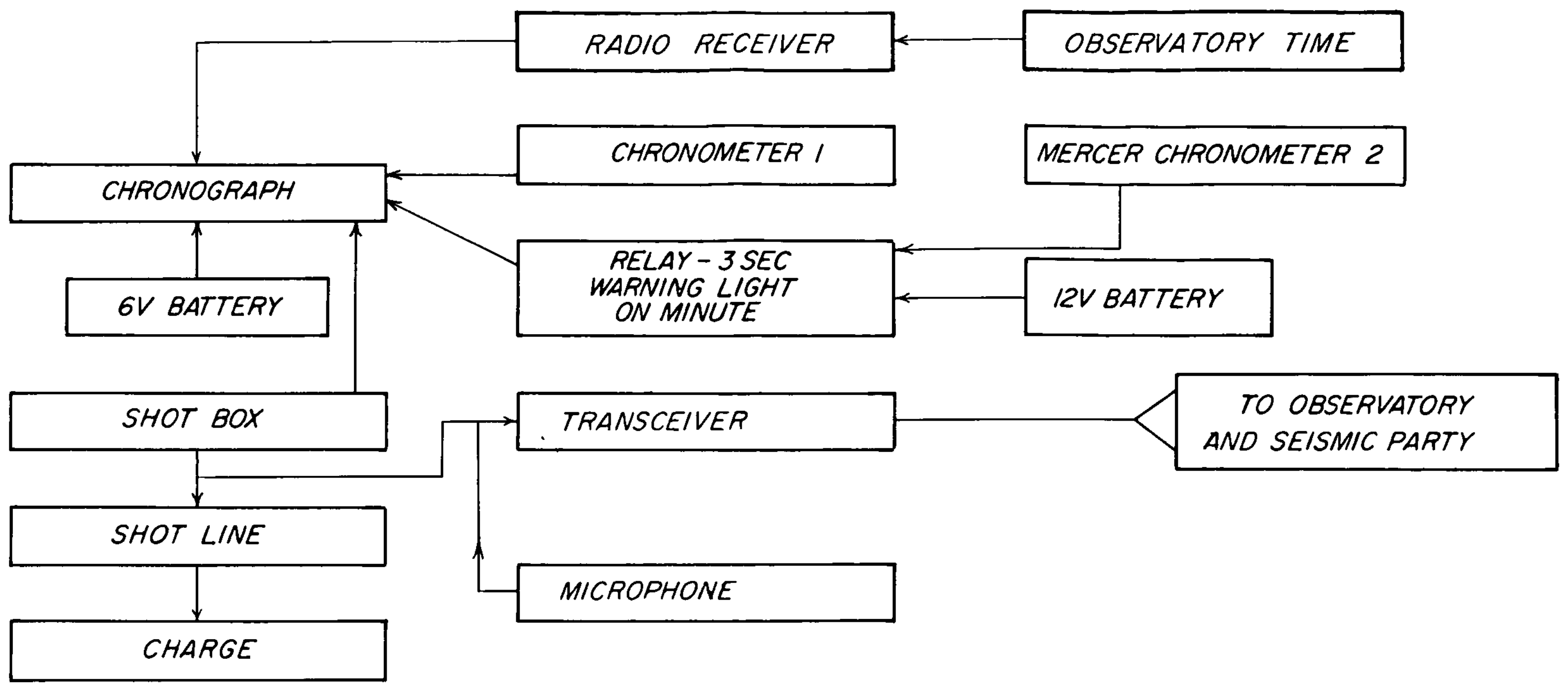
SECTION E-F

TO ACCOMPANY RECORD No. 1969/125

B56/B5-42

RABAUL • CRUSTAL INVESTIGATION, 1966

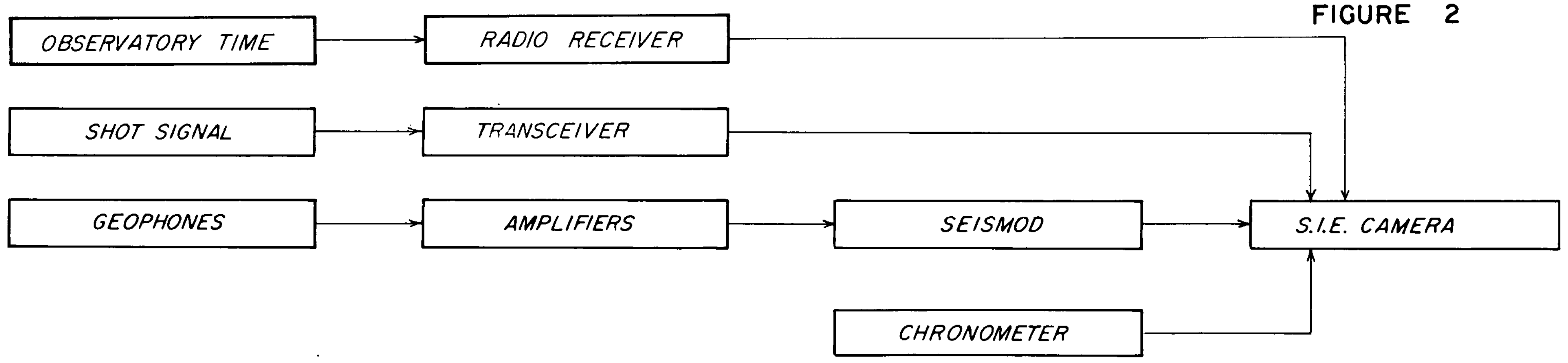
FIGURE 1



Chronograph record tape shows 0·1 sec. and 1 min. time marks, with shot instant mark

BLOCK DIAGRAM - OPERATION SHOOTING - SHIP "LAHARA"

FIGURE 2



Seismod not used when recorded events were of low energy

RECORDING SEISMIC FIELD STATION

FIGURE 3

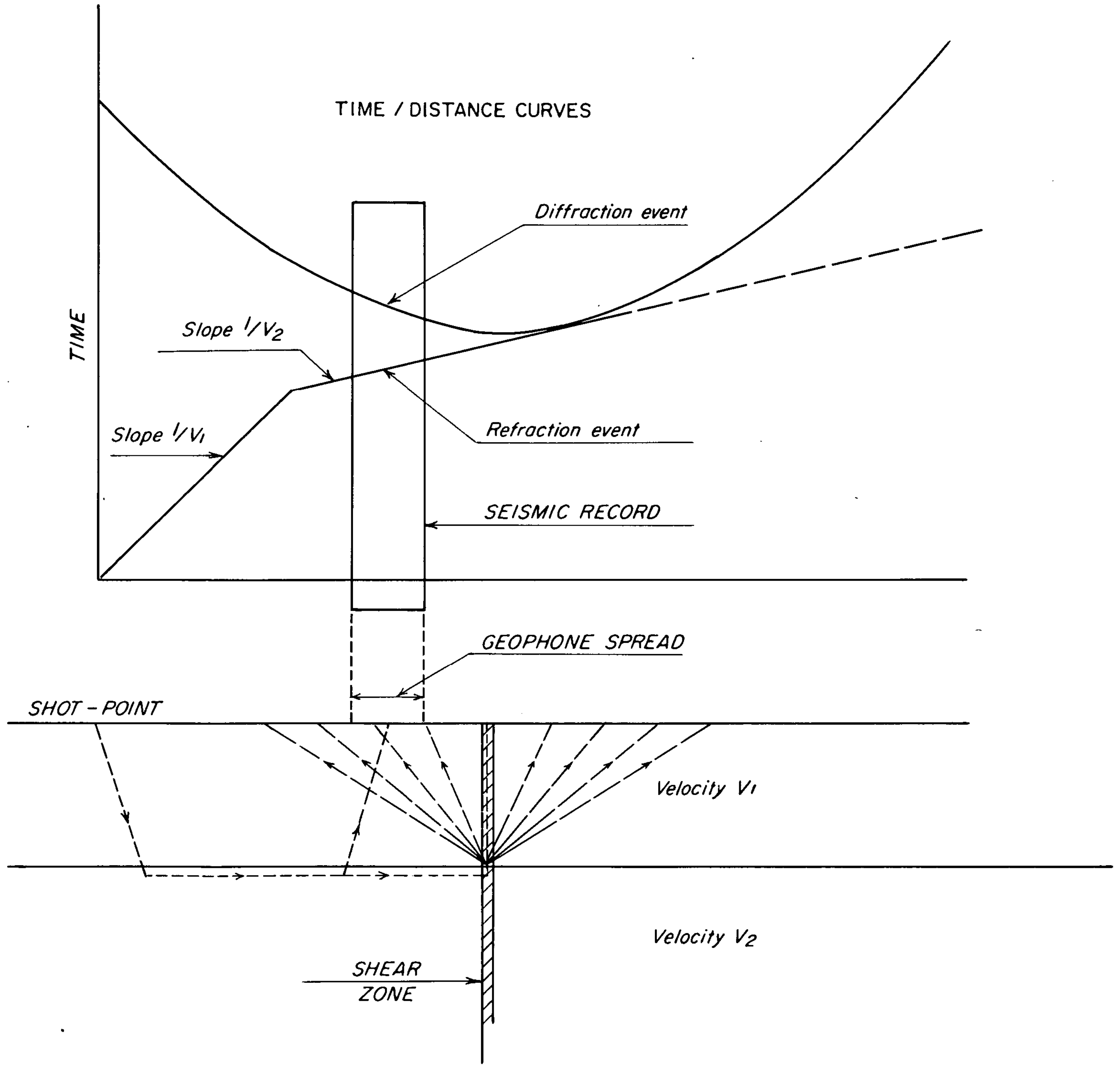


DIAGRAM EXPLAINING DIFFRACTION EVENTS
IN SEISMIC REFRACTION SHOOTING

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics

B56/B5-9