COMMONWEALTH OF AUSTRALIA.

DEPARTMENT OF NATIONAL DEVELOPMENT.

BUREAU OF MINERAL RESOURCES

GEOLOGY AND GEOPHYSICS.

RECORDS.

1957/14

VOLCANO - SEISMIC PHENOMENA IN EASTERN PAPUA SINCE 1939

by

M.A. Reynolds.

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SUMMARY

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Canberra
May, 1957.

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An unusual number of earthquakes, ~~two Pelean type eruptions~~, and other events of possible tectonic significance have occurred in Eastern Papua since October 1953. Most of these took place at times of maximum luni solar influence. The main earth tremors felt were all of shallow focus. Near Dobu passage between Normanby and Fergusson Islands, craters which cannot yet be certified extinct exist - Lamonai, Oiau and Dobu Island. Earthquake swarms have been felt in this area.

The most logical inference to be drawn from the facts presented in this report is that another eruption may be expected in eastern Papua and that it will probably be centred in the eastern Fergusson Island - Dobu Island area. Other conclusions however, are also possible. One is that the events in eastern Papua are comparable with those of the volcano-seismic crisis at Montserrat, 1933-1937, described by Perret (1939); another is more hypothetical and implies that strain adjustments in the eastern part of the region after release of energy by eruptions to the west may be the cause of events since late 1953.

I. INTRODUCTION

Since 1953 there has been a series of disturbing events in the area of eastern Papua which forms the Northern and Milne Bay Administrative Districts. The frequency and nature of earthquakes and other phenomena in the area, so soon after the catastrophic eruption of Mt.Lamington in 1951, have alarmed local inhabitants and government officers responsible for the welfare of the people.

For this reason, and to answer specific questions asked by the District Commissioner, Milne Bay District, events since 1939 were listed and carefully examined. Although results of the examination were not very conclusive, some possibilities as to the significance of recent events did present themselves. They were discussed in letters to the Assistant Administrator of the Territory of Papua and New Guinea and tothe District Commissioner, Milne Bay. The list of events and details of discussion form the basis of this report.

The helpful criticism of Dr. J. Smythe of Rabaul, who has lived in the area, is gratefully acknowledged.

II. LIST OF EVENTS

According to available information, no major earthquakes or other unusual phenomena occurred inthe eastern Papua area between 1919 and 1939. Locations of the more important events listed hereunder are plotted on the accompanying map.

1939, November 10. Earthquake -

Epicentre: 9°S., 148°E., shallow depth, Magnitude 6¼ (Gutenberg and Richter 1949) or 9.4°S., 148.9°E., Recorded by 49 stations (International Seismological Summary ?).

1940, June 7; Earthquake -

Epicentre: 9½°S., 151½°E., shallow depth, M 6¼, (G. & R. 1949) or 9.7°S., 151.5° E., Recorded by 37 stations (I.S.S.?)

1940, July 31; Earthquake -

Epicentre: 9½°S., 149½°E., shallow depth, M d*, G. & R. 1949)

1941, September 24; Earthquake -

Epicentre: 9°S., 153°E., Recorded by 26 stations (I.S.S.)

1943, 1944 - Eruption of Goropu (9°34'S., 149° 04½' E.) -

Glowing cloud type of eruption; devastation area extended 3 miles down slope from crater (Fisher, 1956)

* Magnitude "d" is given by Gutenberg and Richter; d = 5.3 to 5.9

1947, October 22; Earthquake -

Epicentre: 9° S., 153° E., Recorded by 38 stations (I.S.S.), or 10° S., 151½°E., - other details and authority unknown; Wellington determined a depth of 200 kms. for the focus of this shock.

1951, 1952; Eruption of Mount Lamington (8° 56½' S., 148° 10½'E.) -

Pelean (glowing cloud) type eruption; nearly 3,000 people killed; devastation over area 6 to 7 miles radius (Fisher, 1956).

1953, October 6; Earthquakes, Woodlark Island -

Epicentre: 9° S., 152½° E. "somewhat unusual epicentre" (Pasadena Seismological Bulletin, 1953). Numerous shocks were felt on Woodlark Island from 6th until 9th; only three of those on 6th were recorded on Omori seismograph, Rabaul. (These earthquakes were previously incorrectly stated as felt at Esa'ala - slight tremors were felt at south-east Fergusson Island on 9th and 11th.)

1954, April 9 - Shoal area or submarine disturbance at 10° 02½' S., 151° 42' E.; reported by Master of M.V. "Theresa May".

1954, July - Vague report of new fissures at Deidei thermal area, Fergusson Island (Monthly vulcanological return, Esa'ala.)

1954, October 8; Earthquake -

Felt: Intensity 6, Bwagaoia (10° 40' S., 152° 50' E.)
Intensity 5, Sawataitai (10°S., 151° E.)
Epicentre: "Off east coast of New Guinea", United States Coast and Geodetic Survey Preliminary Determination of Epicentre No.S40-54b, or 10° S., 152°E., "B.C.I.S." * (Pasadena Seis. Bull., 1954).

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* B.C.I.S. - Bureau Central International de Seismologie, Strasbourg.

1955, March 9; Earthquake -

Epicentre: $9\frac{1}{2}^{o}$ S., $154\frac{1}{2}^{o}$ E., (U.S.C.G.S. P.D.E. No.21 - 55)

1955, June - Taylor (1955) noted change in position and nature of geyser activity since last visit in June 1951 and slightly abnormal temperatures at Deidei thermal area.

1955, July-September; Earthquakes, Gomwa Bay -

July 31; Epicentre: 9^{o} 41' S., 150^{o} 49' E. Surface, $M4\frac{1}{2}$. Main shocks at 1230, 1314 hours (local time.) Some damage; numerous aftershocks (Reynolds, 1956).

August 14; 12 tremors felt on Woodlark Island.

1956, February, March - New thermal activity near Salamo reported (Thomas, 1956)

1956, March 27 - Small explosion Mt.Lamington; vent opened south-east of cone. (Monthly vulcanological return, Popondetta.)

1956, May-July - "Red tide" reported from d'Entrecasteaux Islands area; water near shore at Kedidia, Gomwa Bay, reported warm in June.

1956, August - "Numerous slight tremors" felt throughout month, at Popondetta (Monthly vulcanological re return).

1956, October; Earthquakes, Ward Hunt Strait -

Epicentres: 22nd -, $9\frac{1}{2}^{o}$S., 150^{o} E., (U.S.C.G.S. P.D.E.86-56)
23rd - $9\frac{1}{2}^{o}$S., 150^{o} E., Depth of focus about 100 kms. (U.S.C.G.S. P.D.E. 89-56).

Numerous other small shocks felt Goodenough Island and Gomwa Bay; earthquakes felt until November 4th at Goodenough Island. Small faults occurred near Lake Diodio, Goodenough Island (Hastings 1956).

Continuous ground movement reported near Lake Diodio in January, 1957 (vulcanological return, Esa'ala).

1957, February 13: Earthquake and disturbance in water between Budoia and Sebulugowa, Gomwa Bay, (vulcanological return, Esa'ala.)

Since the commencement of monthly vulcanological reporting by out-stations in November 1953, and the establishment of regular recording at the Rabaul Observatory with the Benioff seismograph, much information has become available. There have been many earthquakes reported from Esa'ala which have not been recorded on seismographs at Rabaul or other seismological stations; lists of these until September 1955 have been placed on record (Taylor 1955, and Reynolds 1956a). For purposes of future reference, earthquakes since then are listed hereunder -

Date	Intensity	Type of Movement	Felt at	Remarks
2.10.55	2	Short, sharp	Esa'ala	
8.10.55	3 at 2-3		Ubuia	
8.10.55	2	Sharp, NE-SW	Esa'ala Salamo Ubuia	
22.10.55	2	Short, sharp	Esa'ala	
12.11.55	2		Watalumo	Epicentre 5°S., 152°E., Depth 60 km. USCGS
29.12.55	2		Budoia	
29.12.55	2		Esa'ala	
20. 3.56	2	"As though person hurrying up stairs"	Salamo	?Epicentre 6°S., 150°E. U.S.C.G.S.
7. 4.56	2	Heavy thump	Esa'ala	
7. 4.56	2	Rumble from E. to W.	Esa'ala	
7. 4.56	1	" "	Esa'ala	
1. 5.56	2	Triple jerk from E. to W.	Esa'ala	
5. 5.56	2	Single thump	Esa'ala	
11. 5.56	2	Bump and rattle	Esa'ala	
2. 6.56	1	One wave from S.N.	Esa'ala	
30. 6.56	2 4-5 3	Quiver from S to N.	Esa'ala Salamo Salamo	
30. 6.56	2	Settling	Salamo	
17. 7.56	2 2-3	Heavy rocking SE-NW	Salamo Esa'ala	
22. 8.56	2	Quiver	Esa'ala	
22. 8.56	1	Settling quiver	Esa'ala	
22.10.56		3 small shocks	Esa'ala	
22.10.56	3 4	Shaking E-W. Heard from E.	Esa'ala Salamo	Epicentre 9½°S., 150°E. USCGS. Felt over wide area.
22.10.56	7 at 1-3	7 small shocks	Esa'ala Salamo	2 recorded Rabaul, Brisbane
23.10.56	2 at 1		Salamo	
23.10.56	2		Salamo	Epicentre 9½°S., 150°E. Depth about 100 km. U.S.C.G.S.
23.10.56	3		Salamo	Recorded Rabaul Brisbane.

Date	Intensity	Type of movement	Felt at	Remarks
23.10.56		2 small shocks	Esa'ala	
23.10.56	3	Shaking E-W	Esa'ala	
23.10.56	4	Violent shake E-W then sharp from NE to SW	Esa'ala	
23.10.56	6 at 1-2		Salamo	
30.10.56	4	Solid knock from SE	Esa'ala	
30.10.56	2	Quiver	Esa'ala	
1.11.56	1-2	Quiver	Esa'ala	
1.11.56	1-2	Quiver	Esa'ala	
1.11.56	1-2	Quiver	Esa'ala	
4.11.56	"severe"		Nuatutu, Goodenough Island.	Recorded Rabaul, Brisbane.
7.12.56	2	Short, sharp	Sebulugomwa	
9.12.56	1	Light	Sebulugomwa	
17.12.56	2	Short, sharp	Esa'ala	
13.2.57	2	Moderate shake	Budoia	
18.2.57	2	Rattled the house	Budoia	

III. GEOTECTONIC POSITION OF EASTERN PAPUA

1. The area in which the events listed have occurred forms part of the Structural Zone No.11, "Morobe arc and Owen Stanley folded Zone" of Glaessner (1950). The strike of fold axes "swings from northeast Bear Lae to southeast in the vicinity of Mt.Yule" and "this arcuate trend continues without a break into the high ranges of the Owen Stanley Mountains;" at the northern end, the zone appears to be linked to the Bismarck Archipelago arcuate structure. The lines drawn on the accompanying map to show the main directions of elongation of isoseismic lines for six widely-felt earthquakes are roughly parallel to either the structural trends or the two components of the Planet Deep shown in Figure 1 of Glaessner's paper; four of the earthquakes, as indicated by extension of the lines, were felt in the Northern District. These facts support the idea of the linkage of the two zones. There is, however, no apparent relation between seismic events in the two zones in the period since 1939; the sources of volcanic activity are also unrelated, the volcanoes of eastern Papua being mainly of the Pelean type with intermediate to acid type lavas, while those of the Bismarck Sea are yield basic-type lavas.

2. Another link suggested by Glaessner from eastern Papua through Woodlark Island to the Solomon Islands has been discussed previously, (Reynolds, 1955); evidence given in favour of the suggestion was based on similarity of volcanic rock types and eruptions. Subsequently, information available on the volcanoes of Melanesia has been catalogued by Fisher (1957). The more acidic types of volcanic rocks such as trachytes and acid andesites are confined to eastern Papua and the Solomon Islands; basic-type lavas are recorded from the New Hebrides, Mt.Balbi (northernmost of Bougainville volcanoes), Anir Island and volcanoes of the Bismarck Sea Arc. Baker and Coulson (1948) have also described

basalts from Goodenough Island in eastern Papua. Since the Catalogue of the volcanoes of Melanesia has been prepared, Dr.Fisher has identified Savo volcano (British Solomon Islands) as a definite Pelean type. This is further evidence in support of a possible genetic relationship between the volcanoes of eastern Papua and the Solomon Islands. No evidence based on isoseism patterns, however, can be presented for a link between the two zones. Earthquakes originating near Bougainville, although often widely felt in eastern New Britain, have never been reported from eastern Papua. Also, the possibility that earthquakes reported from Eastern Papua over the last three years originated in the British Solomon Islands is excluded by the fact that most of them were not recorded on Rabaul seismograms; the Benioff seismograph at Rabaul records most of the widely felt tectonic earthquakes of the south-west Pacific region.

IV. PERIODICITY OF VULCANISM IN PAPUA AND NEW GUINEA

Unfortunately the history of volcanic eruptions in the Territory of Papua and New Guinea is inadequate to suggest any regional trend or periodicity of vulcanism. Information available has been collected from reports of early explorers and navigators, legends and stories of native people (an unreliable source particularly in regard to dating) and from Europeans since their settlement near volcanoes. There are, however, two interesting episodes:

(1) 1878 Eruptions of Matupi and Vulcan near Rabaul were followed by eruptions at Mt.Victory ("about 1880") and a "great explosion" (Guppy) in December 1883 or January 1884 at Bagana (apparently, however, it was in more or less continual eruption for at least 15 to 20 years before this). This information is taken from Fisher (1957), who also records eruptions at about that time at ?Sakar - 1878, Langila, some time between 1878 and 1900, ?Tuluman - 1883, Ritter - 1887,8, and at Benda, Pago and Lolobau early in the 20th century; there was a severe eruption in 1915 at Ulawun (The Father).

(2) Eruptions since 1937 which are listed chronologically hereunder -

1937	Matupi amd Vulcan in May; Bagana in September * (no record of activity between 1884 and 1937; minor activity at Ulawun.
1938	Bagana in May
1941, 2	Matupi, Ulawun
1943, 4	Goropu
1945, 6	Bagana (light explosions)
1948-50	Bagana (spasmodic activity increasing in frequency and violence until most violent eruptions, June-Sept. 1950).
1951	Lamington, Bagana
1952	Lamington, Bagana
1953	Bagana from June to August; new crater formed.
1953-57	Long Island, Tuluman and Langila.

It should also be noted that there were eruptions at Manam, Bam (1877) and Manam (1936-37), but as these volcanoes have been spasmodically ctive for at least 100 years including times between the above two periods they have not been included.

* Mrs.Wallace-Brown of Kieta stated that the 1937 eruption of Bagana was the first for a considerable number of years (see Best, 1956).

These two episodes suggest that extensive regional stresses embracing both Papua and New Guinea have developed twice in the last 100 years. The renewed activity of Matupi and Vulcan in 1937 and the strong activity at Bagana which followed in 1937-38 were therefore possibly related and resulted from the same regional stresses which subsequently caused the first major earthquake in eastern Papua (1939) for 20 years.

V. LUNI-SOLAR INFLUENCES

The effects of Luni-solar influence on volcanic activity have been discussed in recent reports of eruptions in New Guinea; it has been shown that where strain already exists, this force often acts as a triggering mechanism. Perret (1939) also found that the majority of earthquake crises at Montserrat occurred at times of syzygies.

The relation of seismic events in eastern Papua since November 1953 to the movements of the moon and sun and dates of syzygies, apogee and perigee is shown in Figure 1. Events are grouped and numbered hereunder so that the relation can be discussed more easily.

Group A. Seismic storms (strong earthquakes, sometimes preceded by foreshocks, with numerous aftershocks, or, several small tremors felt during a long period).

(1) Nov.6-9, 1953, Woodlark Island.
(2) Dec.25-26, 1953.)
(3) June 18-19, 1954)
(4) Dec. 14-19, 1954) Gomwa Bay
(5) Mar. 9-10, 1955)
(6) Jul.31 - Sept.20, 1955)
(7) August, 1956, Popondetta - probably volcanic.
(8) Oct.22 - Nov.4, 1956, Goodenough Is. (also Gomwa Bay).
(9) January, 1957, Goodenough Island.

Group B. Brief periods of earthquakes (total of Intensities from 5 to about 10 - Modified Mercalli Scale).

(10) May 30-31, 1954)
(11) Sept.1 1954) Gomwa Bay
(12) Apr.6-7, 1955)
(13) Aug. 14, 1955, Woodlark Island.
(14) Sep. 13-15, 1955, Sewataitai.
(15) Oct. 8 1955)
(16) Apr. 7 1956) Gomwa Bay
(17) June 30, 1956)

Group C Earthquakes (greater than Intensity 2).

(18) Aug.26, 1954, Gomwa Bay.
(19) Oct. 3, 1954 Gomwa Bay.
(20) Oct. 8, 1954, Sewataitai, Bwagaoia.
(21) Mar.24, 1955, Gomwa Bay
(22) Jul.17 1956, Gomwa Bay.
(23) Nov. 4 1956, Duatutu (Goodenough Is.).

Group D. Small shocks (Intensity 2 or less).

(24), (25) Oct.9, 11, 1953)
(26) -(31) Ap.16, 19, Oct.2, 22, Nov.12, Dec. 29, 1955.) Gomwa
(32) -(40). Mar.20, May 1, 5, 11, June 2, Aug.22, Dec.7,9,17,1956.) Bay.
(41) -(42) Feb.13,18, 1957.)

Figure 1 shows that most of the above occurred when the sun was at, or within, 2^{o} of its maximum declination (North or South), between 0^{o} and 12^{o} S., (near the zenith of eastern Papua), or when the Moon was between 0^{o} and 12^{o} S. Combinations of the sun and moon in these positions are listed in Table I together with the seismic events occurring at those times. Two other divisions have been added for periods when there were no obvious combinations.

TABLE I.

Division No.	Sun's Position	Moon's Position	Group A	Group B	Group C	Group D
1	Within 2^{o} of, or at Maximum Declination (North or South)	Max. Declination opposite to sun	(2)-o (3)-o		(22)	(31)-o (40)-o
2		Near same zenith as sun	(9)-c	(10)-c		
3		Between 0^{o} and 12^{o} S		(17)		(36), (38) (39)
4	Between 0^{o} and 12^{o} S.	Near same zenith as sun	(1)-c (5)-o		(20)	(42)
5		At max. declination (N. or S.)	(8)-o	(15)	(19)	(29), (32)
6	Between 0^{o} and 12^{o} S.		(4)			(24), (25) (28)-o
7		Between 0^{o} and 12^{o} S		(11), (12) -o, (16)		(27), (34) (37)-o

Note: "-c " = sun and moon in conjunction;
"-o " = sun and moon in opposition.

Divisions 1, 2 and 4 represent conditions when strongest luni-solar influences applied; strong tidal forces could also be expected for Divisions 6 and 7. The influence of combinations 3 and 5 is not known.

Although a complete statistical analysis of Table I is beyond the scope of this paper, a brief analysis shows that Divisions 1, 2, 4, 6 and 7 contain the following numbers of events for each Group:

Group A:- 6 (Note also that event (6) commenced when sun only 5^{o} south of its northernmost declination and in opposition to moon at its southernmost declination);

Group B:- 4;

Group C:- 2;

Group D:-9 (Event (35) occurred when sun 5° south of northernmost declination and in conjunction with moon also at northernmost declination).

Therefore, a total of 21, possibly 23, events occurred at times of strong luni-solar influence. Three other events, B(14), C(21) and C(23), also occurred when luni-solar influences were strong: when sun and moon were in conjunction.

The most significant feature of the analysis is that 6, possibly 7, of the 9 Group A events occurred when luni-solar influence was very strong; also, more than half of the events listed could be attributed to this influence. This strong response suggests that eastern Papua has become very unstable since October 1953.

The periods when seismic events are most likely to occur in Eastern Papua due to luni-solar influence are late February-March, June, late September-October, and December; activity in October and December has been very common.

VI. SIGNIFICANCE OF EVENTS SINCE LATE 1953.

Apart from details of earthquakes which were registered at seismological stations and were accorded epicentres, and the two major eruptions, little is known of activity in eastern Papua before the vulcanological reporting system commenced in November 1953. It is considered, however, that after the catastrophic eruption of Mt.Lamington in January 1951, volcanic and seismic events, even of a minor nature, would have been reported from the eastern Papua area had they occurred. This has been evidenced by the apparent anxiety resulting from the October 1953 earthquakes in the Woodlark Islands and subsequent seismic storms in the d'Entrecasteaux Islands. Events since late 1953 therefore probably represent another phase of the regional unrest in eastern Papua which first manifested itself in 1939.

This report is now concluded with a discussion of the possible significance of these events.

1. Possibility of another eruption.

Since volcanic activity declined in eastern Papua in 1952, there has been a series of events which is strongly indicative of another impending eruption. Although there have been only five strong earthquakes, they have all had foci at very shallow depths, and therefore have not been felt over large areas. The earthquake of 23rd October 1956 was given a depth of about 100 kms. by the United States Coast and Geodetic Survey; this also was only felt close to the epicentre, and although its record on Rabaul seismograms is slightly different from the earthquake of 22nd October 1956, there is no indication of a deep focus. In addition to these earthquakes there have been numerous aftershocks and other small earthquakes of shallow focus; these were rarely recorded by Rabaul seismographs. Apart from the small local tremors felt during August 1956 at Popondetta which were probably caused by a slight adjustment of Mt. Lamington, two series of seismic events have originated near volcanic areas which have been quiescent for a long time; these occurred at Gomwa Bay and near Goodenough Island in the d'Entrecasteaux Island group. The pattern and nature of seismic activity, therefore, could easily be attributed to a volcanic source. Events other than seismic which also suggest manifestations of vulcanism have been reported. These include the submarine disturbance seen on April 9th, 1954, a vague report of new fissures at Deidei in July 1954, new thermal activity at Salamo in February, March 1956, the advent of "red tide" in in May and the report of warm water near Kodidia in June 1956.

The slightly abnormal temperatures and change in geyser activity at Deidei reported by Taylor (1955) might also be significant; however, temperatures and activity were normal when examined later the same year. (Reynolds, 1956b.)

The report by Hastings (1956) on the Lake Diodo area, Goodenough Island, where ground movements have been reported as recently as January 1957, suggests that the lake itself is an old crater. Samples from the "crater" area forwarded to Rabaul were not of volcanic origin, but this does not necessarily imply that explosive activity has not occurred at this centre - the volcanoes of Goropu, Balbi and Bagana have all been reported as having broken through metamorphic rocks (Fisher 1946; Baker 1949). However, the facts that the initial earthquakes of October 1956 were centred very close to this area and caused minor faulting near Lake Diodio and also that the most recent volcanic activity on Goodenough Island has consisted of basaltic lava flows suggest that the continuous recent movements were due to aftershocks rather than being symptomatic of impending eruption at that centre.

As additional thermal activity has been reported from Gomwa Bay before and since the strong earthquakes in July-August 1955, and as local shocks are still being felt, eastern Fergusson Island-Dobu Island area is the most suspect as a centre for renewed volcanic activity. The craters in this area are Lamonai, Oiau and on Dobu Island, and revival of these centres would probably cause violent eruptions; it has been stressed previously that the possibility of a new submarine vent developing should not be overlooked (Taylor, 1955). Slight thermal activity in a small crater on the south-east side of Dobu Island indicates that the most recent activity in the area might have been there (Reynolds, 1956b.)

The obvious conclusion to this discussion is that events since late 1953 have been symptomatic of impending eruption; the most logical centre suggested is the eastern Fergusson Island - Dobu Island area. However, certain other facts, although their significance is not yet perfectly understood, do suggest that there may be alternative explanations for the phenomena. These facts are as follows -

(1) Activity in eastern Papua has extended to the eastern-most part of the region, including Woodlark and Misima Islands, where there is no historical evidence of vulcanism. The area is almost certainly related to the eastern Papua structure because -

(a) it was stable for a long period before 1939;

(b) there have been earthquakes near Woodlark Island in the pre-eruption period and between eruptions ⁂ at Goropu and Mt.Lamington; and near Woodlark and Misima Islands since 1952.

Although the nature of earthquakes before 1953 is not known, it may be significant that the October 1953 and August 1955 earthquakes near Woodlark Island were similar to the seismic storms in the d'Entrecasteaux Islands.

(2) The present series of seismic events and other phenomena has been fairly long.

(3) There were large energy releases from eruptions at Goropu and Mt.Lamington prior to this activity.

⁂ The I.S.S. epicentre for the 22.10.47 earthquake is accepted because I.S.S. determinations are made only when maximum information from other stations is available.

(4) Although new thermal activity has been reported, there have been no significant increases in activity at well established thermal areas.

(5) Apart from the decadent fumarolic activity at the small crater on the south-east side of Dobu Island, there are no fumaroles in other craters.

(6) The eruption of Mt. Victory "about 1880" was followed in 1895 by three days of intense earthquakes at Dobu Island; * these may have been tectonic or similar to present activity. There was apparently no culminating eruption.

2. Similarity to Volcano-Seismic Phenomena at Montserrat, 1933-1937:

Another possible explanation for the phenomena in eastern Papua can be given on the basis of Perret's monograph on "The Volcano-Seismic Crisis at Montserrat 1933-1937" (1939). There is at least one perhaps very significant similarity between the Lesser Antilles Arc of which Montserrat is a part (see Fig.2) and eastern Papua; they are both structural arcs with intermediate to acid lava volcanoes of the Pelean type (Mt.Pelee from which this type gains its name is at the centre of the Lesser Antilles Arc.)

The most active seismic period at Montserrat was between May 1934 and November 1935, when there were 28 earthquakes of sufficient magnitude to cause destruction of buildings (mostly brick,) "1175 strongly sensible shocks, and innumerable tremors". During his investigation at the end of 1934, Perret recognised three potential dangers:

"(1) the possibility of a much stronger shock;
(2) a break through to the surface, with resulting volcanic eruption; and
(3) a possible phenomenal outrush of gas from a fissure or from a pocket opened by a shock."

The last possibility did eventuate, but fortunately was not of sufficient scale to cause any harm.

His final conclusion on causation of the crisis was based on a theory of gas-liquid differentiation in subterranean magma and variations in the gaseous pressure on overlying strata by rise and fall of the magma; both vertical and horizontal movements of gas were envisaged and also pressures of sufficient magnitude to disrupt strata. In addition "we may imagine that such a rushing through subterranean galleries (of gas) gives rise to the rumbling and rolling sound-effects heard, and to the horizontal translation of pressures to new accumulations at a distance." The theory explains the phenomena which occurred at Montserrat, andcould also be used to explain recent events in eastern Papua; such gas-liquid differentiation is more plausible for eastern Papua where the lava is of a highly viscous nature than for volcanic areas with more fluid basaltic lavas. Another fact which Perret mentioned was that volcano-seismic crises in the Lesser Antilles Arc occurred near times of eruptions elsewhere in the arc. There was a previous crisis at Montserrat between 1897 and 1900, a catastrophic earthquake at Guadeloupe in 1897 followed by high mortality eruptions at Mt.Pelee and St.Vincent in 1902 and a series of earthquakes at St.Lucia in 1906. Also, the 1929 eruption of Mt.Pelee was followed by a small earthquake series at Nevis in 1930, the 1933-37 crisis at Montserrat and moderate earthquakes at Dominica in 1937. He made the additional observation that the culminating earthquakes at Montserrat of November 10-12, 1935, were preceded on 8th November by an increase of pressure "in the primary fumaroles on the new dome of Pelee."

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* This information was obtained from an old native, Pani, aged about 75, and supplied by a Methodist Missionary of Dobu Island, the Rev.H. Robinson.

From the above information it seems possible that the cause of the volcano-seismic crisis in Montserrat was similar to that producing the disturbing events in eastern Papua. The results in eastern Papua (particularly in the d'Entrecasteaux Islands), although not as severe, are similar in many aspects to those at Montserrat:

(1) the shallow foci of earthquakes
(2) their frequency
(3) type of noise accompanying earthquakes
(4) many shocks described as "short and sharp".
(5) additional thermal activity etc.

The distribution of events since 1939 in eastern Papua has been widespread, and although over a longer period, similar to the 1897-1906 and 1930-1937 episodes in the Lesser Antilles Arc. Also, the 1933-37 crisis at Montserrat commenced 4 years after an eruption at Mt.Pelee. A comparable interval, almost 3 years, elapsed after the initial eruption of Mt.Lamington in January 1951 before the seismic storms at Woodlark Island and the commencement of activity in the d'Entrecasteaux Islands. It should be remembered, however, that the seismic events at Montserrat in 1897-1906 preceded the catastrophic eruptions of Mt. Pelee and St.Vincent in 1902. Nevertheless, the inter-relationship of events seems to be well established in both the Lesser Antilles Arc and eastern Papua, particularly in view of the previous relative stability of eastern Papua.

Perret's theory of subterranean magmatic pressures for this inter-relationship is limited in eastern Papua by the fact that the easternmost part of the region shows no historical evidence of vulcanism. It could, however, possibly explain recent events in the d'Entrecasteaux Islands area and earthquakes may have resulted from large gas movements caused by -

(1) transmission of magmatic pressures from other regions or
(2) a local release of pressure producing activation of subterranean magma.

3. An alternative hypothesis:

Recent volcanic and seismic events in eastern Papua may have resulted from adjustments of regional strain. Such adjustments would cause earthquakes, and also gas movements by alteration of the configuration of "channels". Because events cited pertaining to thermal activity involve new or changed foci but no increase in intensity, alteration of "channels" seems a more logical cause for gas movements than magmatic pressures.

The hypothesis was developed from the following ideas -

(1) Extensive regional stresses probably caused the earthquakes from 1939 onwards in eastern Papua and may have played a predominant part in initiating the development of the eruptions of Goropu and Lamington.

(2) Expansion as lava changed into a fluid state, the upward movement as a prelude to eruption, and the release of pressure by eruption probably caused widespread effects on stresses in the region, particularly as:

(a) the lavas were viscous, and

(b) in the case of Goropu, eruption burst through metamorphic rock.

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Stresses developed before the eruption of Goropu must have been particularly strong- pre-eruption earthquakes which lasted for two years, were felt over such wide areas that Taylor (1955, p6) suspected them to be tectonic. The effect of strain release by eruption may even have augmented the development of activity at Mt. Lamington.

(3) Although both the magnitude of energy release and the depth of focus are generally regarded as much greater for tectonic earthquakes than for volcanic eruptions, the following facts suggest that the difference has been less marked for events in eastern Papua.

(a) The majority of, if not all, large earthquakes which have occurred in the region and which have been recorded on seismographs in other parts of the world have had very shallow foci -

(a) they were felt only over small areas
(b) foreshocks and numerous aftershocks accompanied them, and
(c) some were reflected at the surface by landslides or small faults;

(b) Volcanic earthquakes before the Goropu eruption were apparently felt over a wider area than is normal for volcanic earthquakes.

(4) The eastern Papua region appears to have become highly unstable since October 1953, judging by the coincidence of earthquakes and luni-solar maxima, and may have responded to fairly small stresses since then.

On the basis of these suggestions the possibility arises that events in eastern Papua since October 1953 are at least in part due to Mt.Lamington's activity;

(a) the build-up to the eruption added extra stresses to those existing in the region,

(b) there was a period of great release of pressure by explosions in 1951 and further activity in 1952;

(c) although energy is still being expended - e.g. partial dome collapse in June 1954 (significance somewhat doubtful without other information), March 1956 explosion, August 1956 tremors - it was apparent that activity was waning by 1953. Taylor (1954) made observations in 1952 which suggested a periodicity in the activity of Lamington, and that there would be a gradual decline (with peak periods of activity becoming less intense) to the dormant state;

(d) strains developed in other parts of the region would be relieved to some extent as Lamington moved towards the dormant state;

(e) this implies that the eastern part of the region is undergoing a type of rebound as the western part returns to equilibrium and that events since 1953 are due to the region returning to a normal stable condition.

The above argument is based primarily on the assumption that in this case, the magnitude of energy involved in vulcanism and the depth of focus have been more nearly equivalent to the energy and depth factors of tectonic earthquakes than usual, the evidence, however, is very scant and other conclusions, based on more substantial evidence, must be accepted until more proof of the validity of the hypothesis is presented. Because the lives

and welfare of many people are involved, the conclusion that events since October 1953 manifest impending eruption should be tentatively accepted and careful observations maintained particularly in the eastern Fergusson Island - Dobu Island area.

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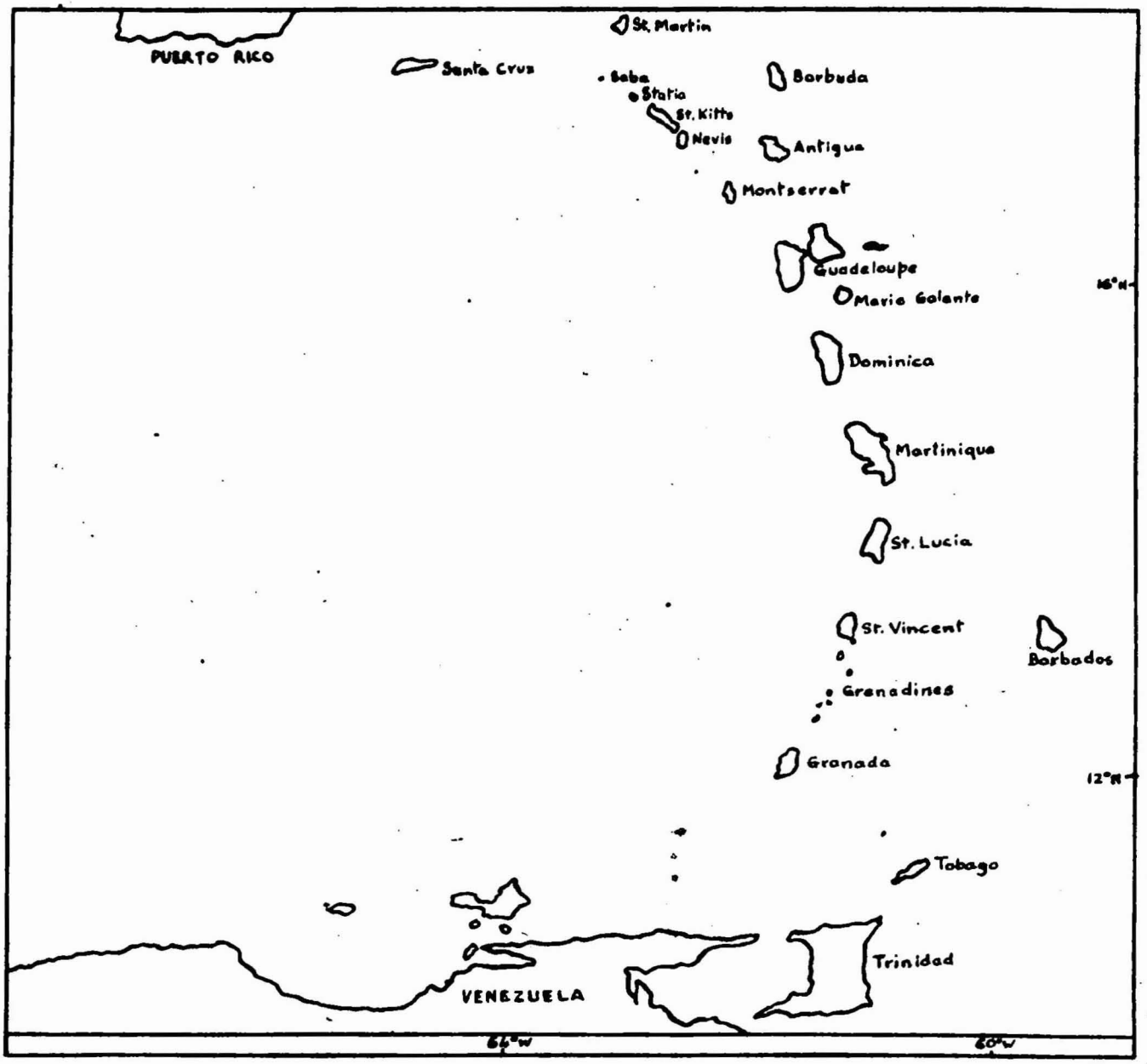

FIG. 1: Sketch of Lesser Antilles Arc.

2

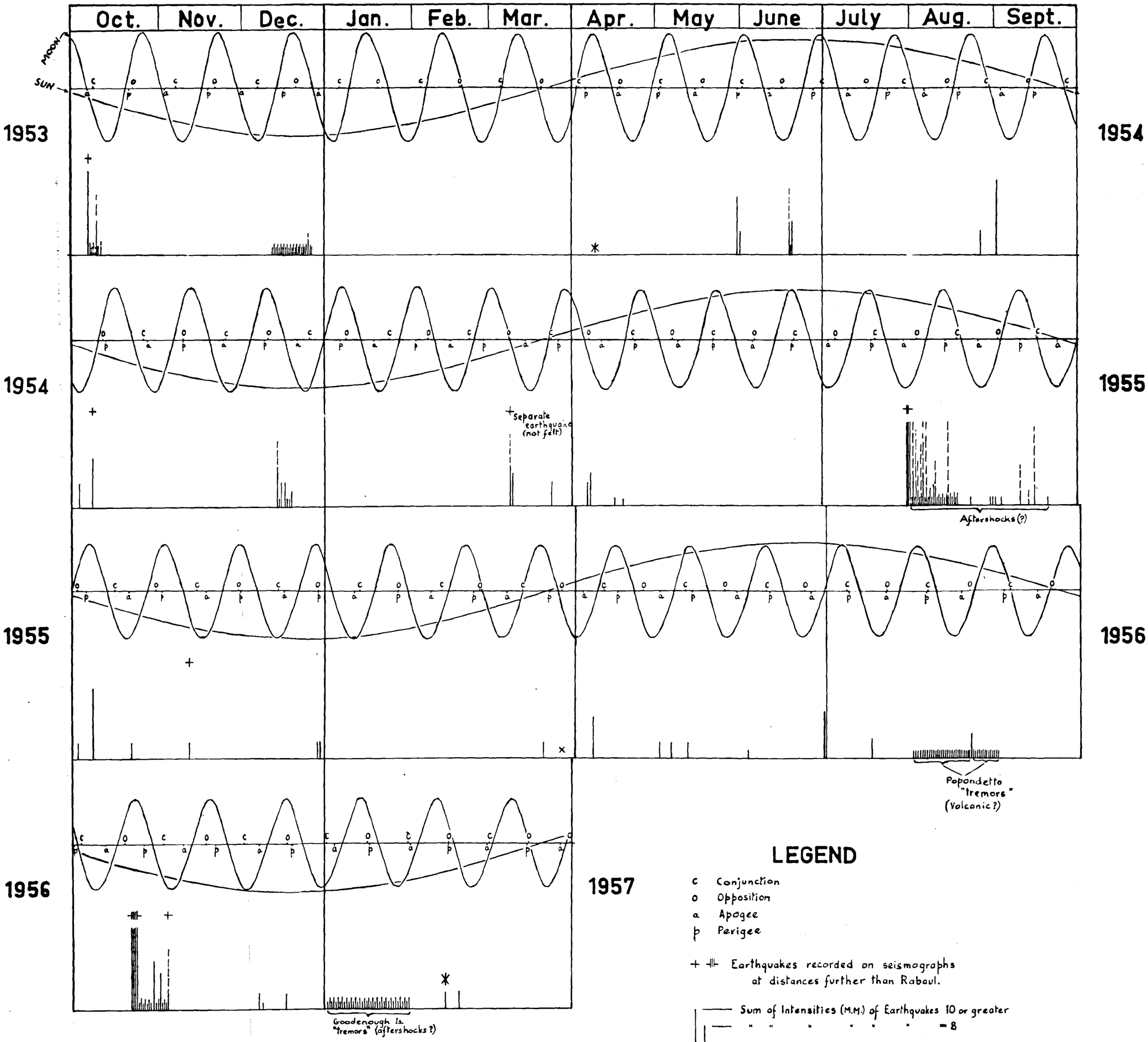

FIGURE 1: Luni-Solar Chart with Seismic and Volcanic Events in Eastern Papua since October, 1953.

LEGEND

c Conjunction
o Opposition
a Apogee
p Perigee

\+ ⊣ Earthquakes recorded on seismographs at distances further than Rabaul.

— Sum of Intensities (M.M.) of Earthquakes 10 or greater
— " " " " " " = 8
— Intensities of some shocks not reported
— Numerous tremors or small shocks

✳ Submarine Disturbance
× Small explosion - Mt. Lamington

MANUS

NEW IRELAND

Tuluman

Lihir

SEPIK

Bam

N E W G U I N E A

Manam

Ambitle

Rabaul

MADANG

BOUGAINVILLE

Karkar

Narage

Garove

Lolobau

Benda

Ulawun

Bamus

Bola

Garua Hbr.

Galloseulo

Garbuna

Walo

Pago

Long I.

Talo

Sakar

Ritter I.

Langila

WESTERN HIGHLANDS

3-3-54 M7 (Pasadena)

13-10-56 h=150kms (U.S.C.G.S.)

10-10-55 (U.S.C.G.S.) M 7¼ (Pasadena)

Trend of isoseismic lines

Balbi

Bagana

Loloru

24-1-57 h=100kms (U.S.C.G.S.)

19-3-56 (U.S.C.G.S.) M 6·4 (Uppsala)

16-8-55 h=200kms (U.S.C.G.S.) M 7¼ (Pasadena)

SOUTHERN HIGHLANDS

EASTERN HIGHLANDS

NEW BRITAIN

MOROBE

WESTERN

GULF

Trobriand I.

Popondetta.

NORTHERN

Lamington

10-11-59 M 6¼ (G & R) or

Musa R.

Victory

Goodenough I.

Tamalete

Fergusson I.

D'ENTRECASTEAUX ISLANDS

6-10-53 (Pasadena)

Woodlark

22-10-47 (I.S.S.)

24-9-41 (I.S.S.)

9-3-55 (U.S.C.G.S.)

31-7-40 M 6¼ (G & R)

22-10-56 (U.S.C.G.S.)

Deidei

Goropu

Dobu

7-6-40 M 6¼ (G & R)

P A P U A

MILNE BAY

9-4-54 Submarine Disturbance

Normanby I.

8-10-54 Strong earthquake felt Bwagaoia, Sewataira (B.C.I.S.)

Misima I.

Bwagaoia

CENTRAL

QUEENSLAND

LEGEND

- Volcanoes with recorded eruptions
- Volcanoes in solfataric stage - no recorded eruptions } Fisher, 1956.
- \+ Solfatara fields
- * Shallow focus earthquakes
- ▽ Intermediate depth of focus earthquakes

SCALE: 50 0 50 100 miles