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AN INVESTIGATION OF TREMOR, AT BAGANA VOLCANO USING TELEMETERED EQUIPMENT

MAY 1970

by

M.G. Mancini

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MOUNT BAGANA SEISMIC INVESTIGATION

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CONTENTS

SUMMARY

A portable seismograph station was established on the flanks of Mount Bagana, Bougainville Island, during May, 1970. Data comparison with a similar instrument operating at Piva, 16 km distant, shows that over a period of two days, twenty volcanic shocks were recognizable. Three types of shocks can be distinguished; strong impulsive, impulsive and emergent. The interpretation suggests an origin for the tremors 2 to 12 km distant from the Bagana station. The average travel time between Bagana and Piva stations is 8.5 seconds, correspondent to an apparent velocity of 2 km/s. Several weak, early arrivals suggest the possibility of an underlying 3.5 km/s refractor.

Because no volcanic explosions were observed during the investigation, the tremors could be caused by hydrostatic pressure variations. Activity since 1966 has been confined to the continuous emission of a white vapour cloud with rare, grey, ash-laden vapour ejections and summit glows. A small lava flow, several hundred metres in length, has recently occupied the southeast breach.

INTRODUCTION

A report of increased activity at Mount Bagana and Mount Balbi, Bougainville Island, was received at the Rabaul Observatory on the afternoon of 2nd May, 1970. An inspection party consisting of W.D. Palfreyman (Acting Senior Resident Geologist), M.G. Mancini (Seismologist) and E. Ravian (Technical Assistant) left Rabaul for Sohano (northern Bougainville) on 3rd May. An aerial inspection of both volcanoes made early on the 4th showed little change in the level of activity at either centre since the last inspections were made in July, 1968 and December, 1969 respectively.

It was decided however, to establish a portable seismic station on the flanks of Mount Bagana for a short period for the purpose of, firstly, ascertaining the nature of seismic activity which may originate from the volcano, and secondly, to test in the field the newly developed radio telemetry equipment. W.D. Palfreyman returned to Rabaul from Sohano on 4th and M.G. Mancini and E. Ravian proceeded to Torokina by boat to carry out the seismic investigation.

METHODS AND EQUIPMENT

The party arrived at Piva Catholic Mission and Hospital which is situated 16 km southwest of Mount Bagana (Plate 1A) on the afternoon of the 5th. A portable Willmore seismograph station was installed in a small shed, used by the Observatory to house a pair of bubble tube tiltmeters, and was operational by 2245 hrs (LT) on the 5th.

On 16th May, a seismometer, together with the transmitting portion of the telemetry link, was installed on the southern slopes of the volcano at a point approximately 750 metres above sea level and 1600 metres from the crater (see Plate 1A). Transport and installation took about three hours; the setting up of the seismic equipment took less than one hour.

A small 12 volt lead/acid battery provided power for the transmitter until the evening of the 20th May. A strong radio signal was received at Piva; however, the records were marred at times by a recurring technical fault and by sporadic overseas radio interference.

Both Piva and Bagana stations were equipped with Willmore Mark 1 vertical components. The telemetring unit was designed and built at the Rabaul Observatory workshop (see Myers, N.C. 1969). Simultaneous recording for the two stations was effected using two galvanometers in the single Willmore recorder. Drum speed was 55 mm/minute. An approximate x400 relative magnification at 1 second for the Bagana telemetry system was estimated by direct comparison of regional earthquakes at both stations. Piva relative magnification at 1 second was x1320. Further workshop tests confirmed the estimate value (see also Appendix 1A).

RESULTS

The events registered at the two stations during the telemetry test period can be classified as follows:-

1) Man-made disturbances: Mostly due to the Hospital Land Rover which was parked a few yards from the seismometer shed; these were absent from night-time records. Also people walking around the shed and the operator checking the station left their signatures on the record. This type of event was totally absent from the Bagana records.

2) Tectonic tremors: Events with nearly simultaneous onsets on the Piva and Bagana records. These also show a similarity in their envelope trend. The difference in amplitude allowed a rough estimate of the telemetry magnification to be made.

3) Volcanic tremors: These show clearly on the Bagana records but are weak or absent on the Piva records. Their duration does not exceed one minute; S-P interval is constant, when readable, and Piva's first arrival is nearly 8 seconds later than Bagana's.

The 20 events recognised as volcanics are tabulated in Table 1A. They were classified as: strong impulsive, (Si), impulsive (i), and emergent, (e) (Plate 2A). The characteristics of the three types can be summed up as follows:-

a) Type Si

Bagana: strong impulsive first movement; ground motion either up or down; duration more than 40 sec; period of P wave (within 1 second of the beginning) 0.4 sec and amplitude more than 2 mm; clear S phase after 2 seconds, always recorded at Piva as an "i" or a clear "e" 8 sec later.

b) Type i

Bagana: clear beginning; ground motion either up or down; duration around 30 sec; period around 0.4 sec and amplitude less than 2mm; S phase after 2 sec; sinusoidal tremors with smoothly fluctuating amplitude. Sometimes it shows at Piva as an "e" 8 seconds later. At Piva this type could hardly be distinguished from background noise.

c) Type e

Bagana: no clear beginning; duration less than 20 sec and sometimes without coda; probably only M (Maxima) of surface waves recorded. This type is not recorded at Piva.

DISCUSSION

The following points of interest can be made about the volcanic tremors:-

1) First motion: The compressions are not predominant as would be expected from volcanic tremors originating from the same area. A linear distribution of sources (e.g. a volcanic vent) may explain the compression-dilatation balance.

2) S-P interval: S phases can be masked by the well developed surface waves. When recognizable, the S-P interval averages from 1 to 2½ seconds. Assuming a maximum velocity of 3.6 km/s in the crater material, this would correspond to a distance to the focus of up to 12 km for the most distant tremor. Assuming a lower velocity in the volcanic material the distance to the focus would be 2 km for the nearest ones.

3) Piva-Bagana difference in arrival: The difference in arrival between Piva and Bagana averages 8.5 seconds. This gives an apparent velocity of 2 km/s between the two stations.

Three of the Si type tremors present at Piva an emergent beginning which is followed about four seconds later by the impulsive movement which has been accepted as onset for this type of tremor.

The period of the emergent beginning is slightly greater and the amplitude is about a third than that of the impulsive movement.

If it is assumed the emergent beginning to be the onset of the tremor the difference in arrival between Piva and Bagana stations would be reduced to 4.9 seconds corresponding to an apparent velocity of 3.0 km/sec between the two stations.

The true seismic velocity for the bedrock should then be higher than 2-3 km/sec. This cannot be excluded at the present stage of knowledge of the area.

4) No depth interpretation was attempted, but an origin deeper than 12 km must be excluded. The very small ratio between P and S amplitudes suggests a very large angle of emergence, thence a

shallow origin. Also the well developed surface waves are typical of shallow origin tremors.

5) No volcanic explosions were observed, heard or reported during the investigation. This suggests an "inground" origin for the tremors. The (Si) type could be originated by small hydrostatic pressure variation inside the vent and/or gas explosions within the vent. The different shapes of (i) and (e) types can be a function of smaller magnitude or greater distance. They could also be originated by small scale laminar effect of the volcano layers under variation of magmatic pressure.

6) The Bagana station recorded on average of one tremor per hour. The useful recording was only 19 hours out of 72 and no trend in the frequency of events could be detected. There is not enough information at this stage to assess whether the tremors represent a pre or post eruption trend, or whether they are characteristic of a quiescent period.

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APPENDIX 1A

CONVERSION TABLE WILLMORE-TELEMETRY-SPREGNETHER

Calibration test carried out at Rabaul Central Observatory Workshop, June 1970.

T = seismometer period

A = amplitude in mm from Willmore recorder at 1/10 attenuation setting for a test current of 2 mamp x 1 mm seismometer mass deflection.

B = idem from Spregnether recorder coupled to telemetry system.

C = idem from Willmore recorder coupled to telemetry system.

D = ratio B/A.

E = ratio C/A.

F = Willmore relative magnification.

G = Spregnether-telemetry system relative magnification obtained as F x D.

H = Willmore-telemetry system relative magnification obtained as F x E.

T	A	B	C	D	E	F	G	H
1 sec	54.0	18.0	10.0	1/3.00	1/5.40	13.200	4.450	2.400
0.83	82.5	28.0	18.0	1/2.94	1/4.58	16.000	5.300	3.050
0.67	63.6	21.0	15.0	1/3.03	1/4.23	19.000	6.300	4.500
0.50	33.0	8.5	7.8	1/3.88	1/4.18	23.000	5.900	5.400
0.40	21.9	6.5	5.2	1/3.36	1/4.20	27.800	8.300	6.600
0.33	17.4	5.0	4.0	1/3.48	1/4.35	30.000	8.600	6.900
0.25	12.9	4.0	2.4	1/3.23	1/5.20	25.000	7.700	4.800
0.20	6.9	3.0	1.4	1/2.30	1/4.93	17.900	7.700	3.600
0.167	3.3	2.0	0.9	1/1.65	1/3.78	15.000	9.900	3.900
0.143	1.8	?1.8	0.5	1/1.00	1/3.60	12.000	12.000	3.300
0.125	0.6	?1.5	0.2	1/0.4	1/3.00	10.000	25.000	3.300

? covered by trace thickness

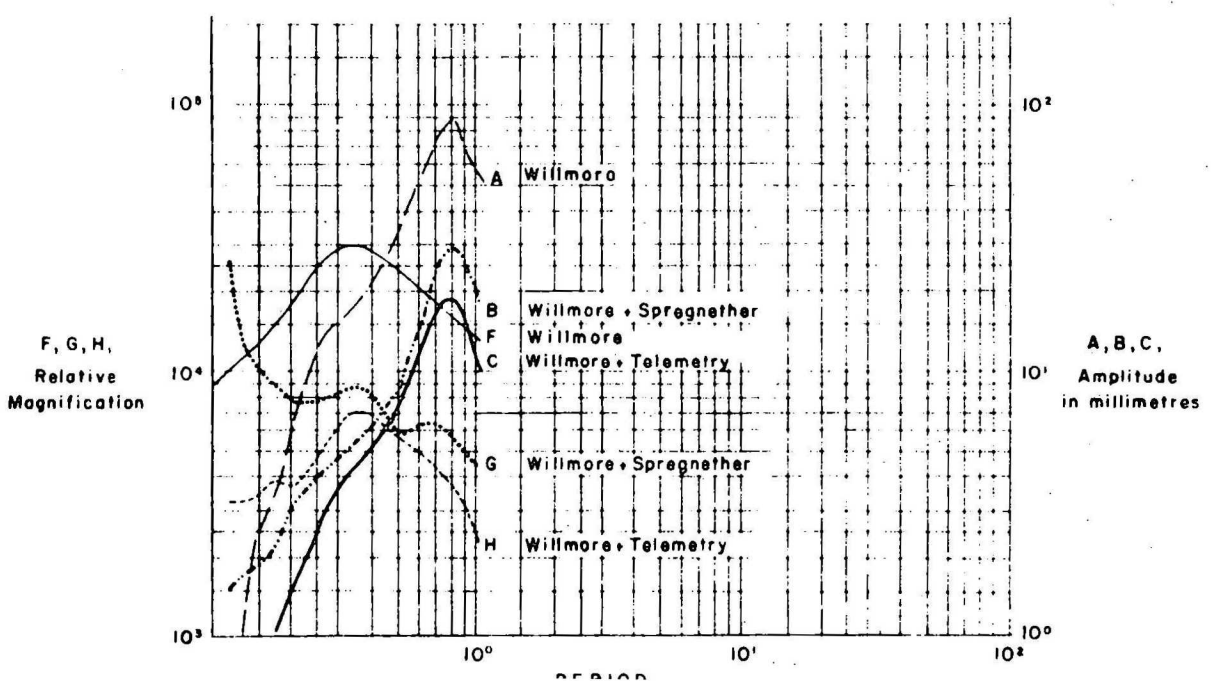


TABLE 1A

ANALYSIS OF VOLCANIC EVENTS, BAGANA & PIVA STATIONS, 17TH - 19TH, MAY, 1970

	BAGANA						PIVA					
NT	FIRST MOTION	TYPE	PERIOD (SECONDS)	AMPLITUDE (MM)	DURATION (SECONDS)	S-P (SECONDS)	TRAVEL TIME PIVA - BAGANA	INITIAL MOTION	TYPE	PERIOD (SECONDS)	AMPLITUDE (MM)	DURATION (SECONDS)
	d	Si	0.4	2.0	43.5	2	8.1	-	e	0.5	0.2	16
	d	Si	0.4	5.0	54	2½	8.3	u	i	0.5	2½	23
	u	i	0.3	1.0	26	1½						
	not clear /u reading	Si	0.4	2.0	44	2	8.8	u?	e	0.5	0.6	8?
		e	0.2	0.8	13							
	not clear /u reading	Si	0.3	2.2	40	1½	9	d?	e	0.6	0.8	7?
	u?	e										
	u	i	0.3	2½	26	1						
	not clear /u reading	i	0.4	3.0	44		8½	d	e	0.5	0.8	10
	not clear /u reading	i	0.4	1.0	32	1.8	7½	d?	e	0.6	0.4	7
	d	e	0.2	0.4	22	2.0						
	d	i	0.35	1.2	33	1.5	7½	d	e	0.5	0.3	9
	d	Si	0.4	1.8	43	1.8	*4.7 8.5	*u d	i	*0.6 0.5	2	*50 45
	d	i	0.3	1.5	23	2	8.7	d	e			22
	u	Si	0.5	3.0	44	2	*4.1 8.6	*u d	*e i	*0.6 0.6	*2 2.5	
	d	e	0.4	0.6	33	2					0.5	
	not clear /u	Si	0.4	2.5	43	2	*5.9 10.7	*u u	*e e	*0.6 0.5	1.0	*42 37
	?	e										
		e										
	u	Si	0.5	5.0	53	1½	8.0	u	i	0.5	2.5	43

*Doubtful Early Arrivals.

Plate IA

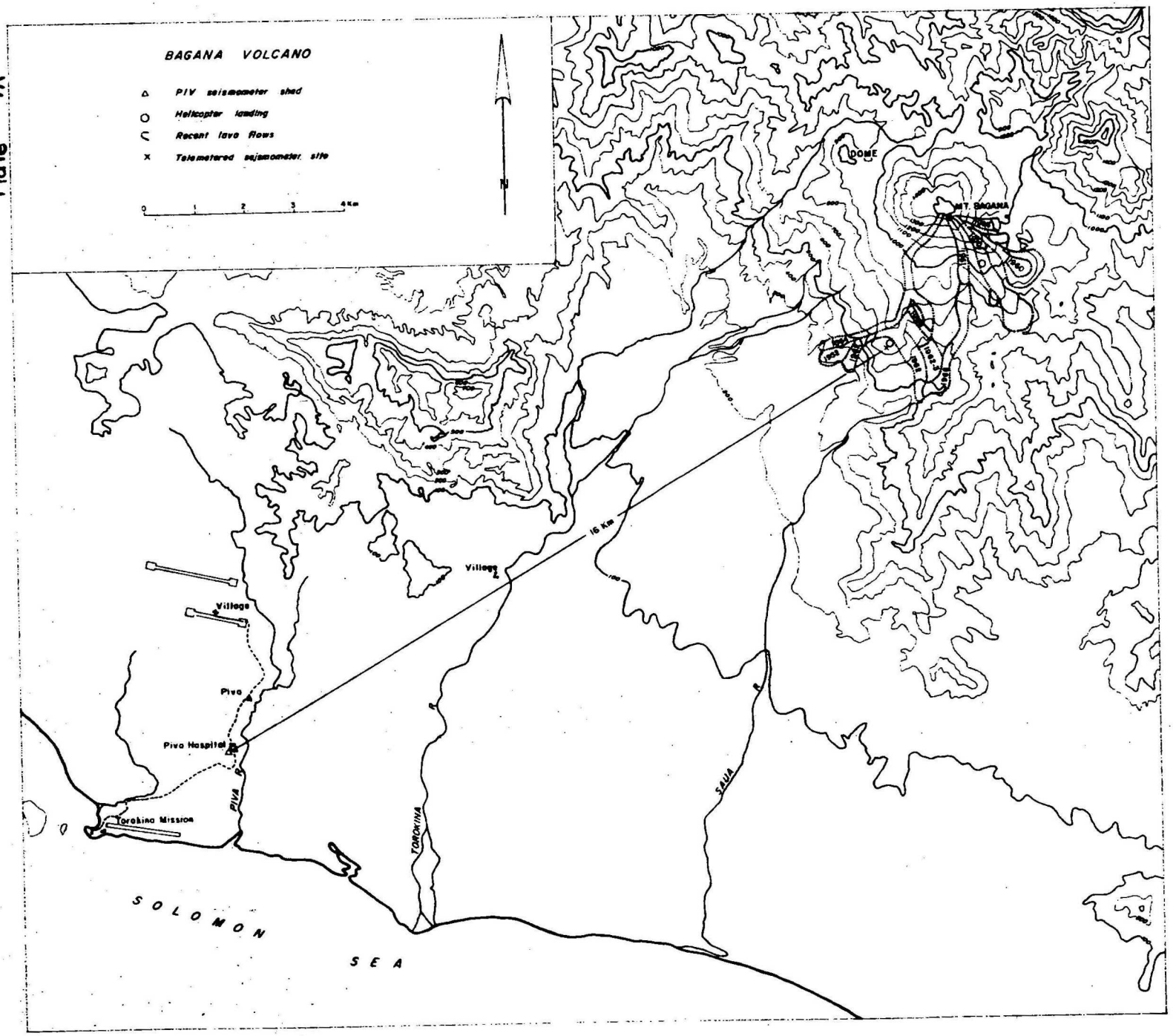
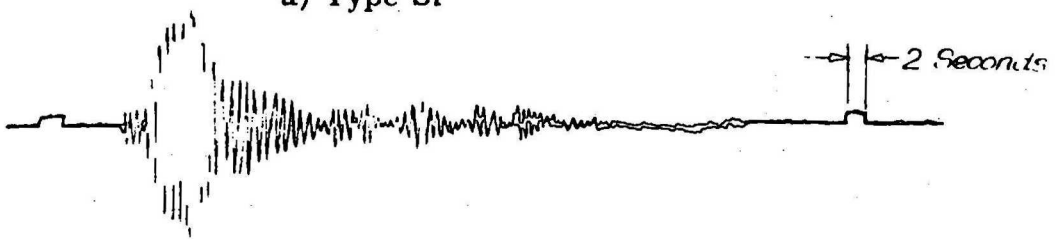

BAGANA VOLCANO
PIV seismometer shed
Helicopter landing
Recent lava flows
Telemetered seismometer site
0 1 2 3 4Km
N
DOME
MT. BAGANA
16 Km
Village
Village
Piva
Piva Hospital
Torokina Mission
PIVA R.
TOROKINA
SAUA
SOLOMON
SEA

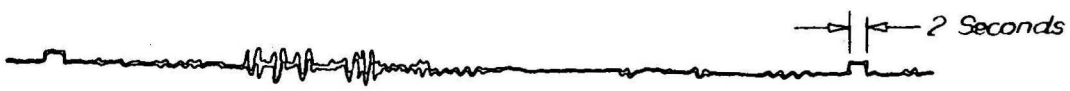
Plate 2A

a) Type Si

Bagana:



Piva:



Bagana: strong impulsive first movement; ground motion indifferently up or down; duration more than 40 sec.; period of P wave (within one second from beginning) 0.4 seconds and amplitude more than 2 mm; clear S phase after 2 seconds; always recorded at Piva as an "i" or a clear "e" 8 seconds later.

b) Type i

Bagana:

Bagana: clear beginning; ground motion indifferently up or down; duration around 30 seconds; period around 0.4 seconds and amplitude less than 2 mm; S phase after 2 seconds; sinuisoidal tremors with smoothly fluctuating amplitude. Sometimes it shows in Piva as an "e" type 8 seconds later, where it can hardly be recognized from the background noise.

c) Type e

Bagana:

Bagana: uncertain beginning; duration less than 20 seconds and sometimes without coda; S phase after 2 seconds, seldom readable. It never shows at Piva.