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44. *Volcanological Survey of Indonesian Volcanoes. Part 2. Seismic Observation at Merapi Volcano.*

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Summary

Seismic observation was made during the period of August 22 and September 30, 1968 at Merapi Volcano, Central Java, Indonesia. The monitor seismographs were set up at the southern foot and northern flank with the use of smoked paper recording. A data recorder with magnetic tape recording was used as mobile seismic observation. The observation period was characterized by the minimum number of occurrences of lava avalanches, however, seismic activity showed a relatively high level.

Most of the volcanic earthquakes indicated typical B-type earthquakes. Tape recorded seismograms obtained just beneath the lava dome showed high frequency oscillation which seems to be the oscillation of a part of the lava dome associated with gas emission. Ground vibration associated with the lava avalanche was observed. Amplitude of earthquakes was abnormally large at Plawangan where the seismic waves of the period 0.4 sec. appear to be selectively amplified. Type of earthquakes observed at Selokopoduwur, just beneath the lava dome, was classified into four according to the vibration period and duration time. High frequency vibration was not observed at Babadan and at Plawangen. Period increase of B-type earthquake with distance was found to be similar to that observed during the development of the lava dome of Showa Shinzan. During the observation, at least ten earthquakes were observed of which epicenters were located near Jogjakarta.

1. Introduction

In Japan, there are no such volcanoes as Merapi in Central Java which have an active lava dome in its summit crater. Therefore, it would be very interesting to investigate the seismic activity of such a volcano and to compare it with that of andesitic volcanoes in Japan. From this point of view, we carried out seismic observations at Merapi Volcano from August 22 to September 30, 1968.

Geological Survey of Indonesia has six observatories surrounding Merapi Volcano, namely, Plawangan, Selo, Djrakah, Krindjng, Babadan and Ngepos. Among them, Plawangan and Babadan observatories are equipped with two component Wiechert seismographs[1]. These observatories report surface events to the central office in the city of Jogjakarta.

In the first place, we must briefly outline the recent activity of Merapi Volcano. The 1967 lava dome which extruded in April in the upper breach of Batang river (SW slope) slid down in October, 1967. Immediately after, a new lava dome started to extrude and continued to make growth. At the end of May, 1968, the length of "lava tongue" was estimated as 875 m. The number of lava avalanches originated from this lava tongue was counted as being 1432 in June and 1370 in July. During the following two months, the number decreased strikingly, viz., 329 in August and 12 in September[2].

Renewed activity of Merapi Volcano commenced in October 1968 with an increasing number of lava avalanches. In December, the seismic activity increased in spite of the decreasing number of lava avalanches. On January 7, eruptive activity started which accompanied nuèe ardente

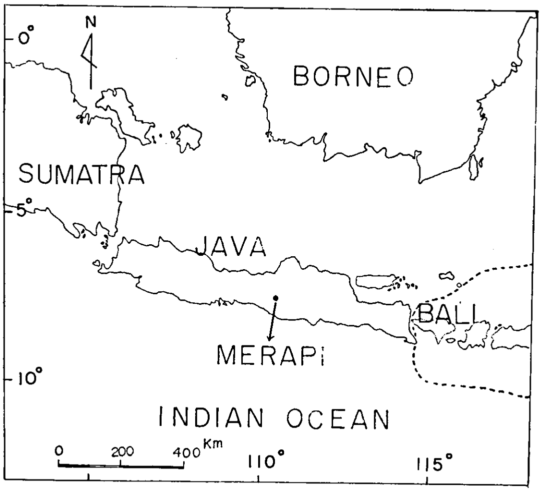

Fig. 1. Map of central Java and locality of Merapi Volcano.

1) Plawangan Observatory is now being supplied with an electrical power line which makes it possible to operate a high magnification seismograph.

2) D. HADIKUSUMO, "Preliminary Report of Mt. Merapi Volcanic Eruption, Indonesia, 7 January 1969," *Smithsonian Inst., Center for Short-lived Phenomena, Publication*, **10**, Feb. (1969).

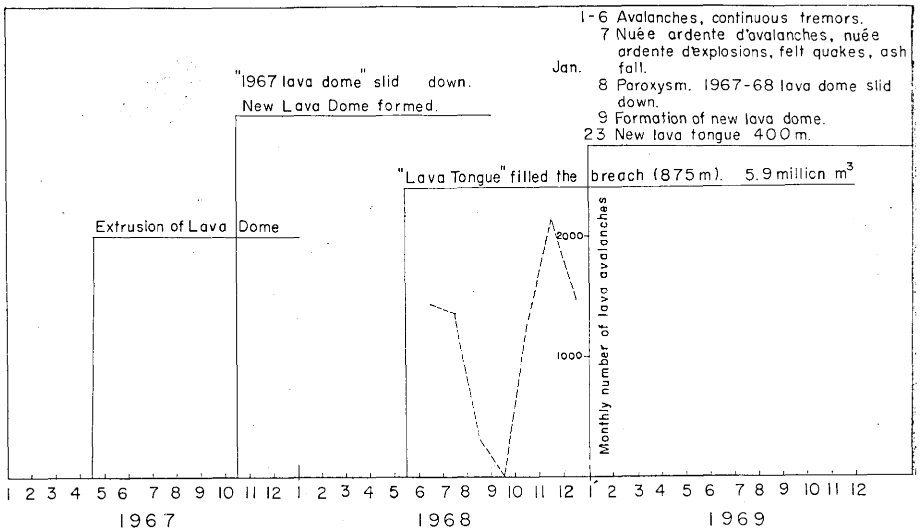

Fig. 2. Chronological illustration of the recent activity of Merapi Volcano.

d'explosion, felt quakes and ash falls. On January 8, the 1967-1968 lava dome slid down and the formation of a new lava dome commenced.

A chronological diagram of the recent events described above is shown in Fig. 2. Our seismic observation, August 22—September 30, 1968 was made when the number of lava avalanches was extremely small. It is most interesting to compare the seismic activity during our observation with that during the period of frequent occurrence of lava avalanches.

In this article, we describe the results of our seismic observation and include some discussions upon the nature of volcanic earthquakes which originated in Merapi Volcano.

2. Method of Observation

Seismographs brought from Japan are listed below.

1) Monitor seismograph for continuous observation.
   - 3 horizontal 1 Hz transducers
   - 3 transistorized amplifiers
   - 3 pen-galvanometers
   - 1 smoked-paper recorder for 3 component
   - 2 crystal clock
2) Data recorder for mobile observation.
   - 3 vertical 4 Hz transducers
   - 1 (V and H) 3 Hz transducers
   - 4 transistorized pre-amplifiers

4 transistorized main-amplifiers
1 data recorder (SONY PFM 15, 4 channels)
1 power amplifier (4 channels)
1 pen recorder (4 channels)
1 A. C. generator (Honda 300 W)

Considering the availability of electrical power supply and other environmental conditions, we selected Kaliurang, 30 km north of Jogjakarta, as the base station and stayed there during the entire period.

One monitor seismograph recorder was placed at Kaliurang and 3 horizontal transducers were set up at Plawangan and Kaliurang which were connected by cables to the Kaliurang station. This observation began on August 22, just one week after we arrived at Djakarta.

On September 5, we began another monitoring observation at Selo Observatory which is located at the southern foot of Merbabu Volcano. Two horizontal transducers were located at the northern flank of Merapi Volcano. Seismographs were operated by battery at Selo Observatory since no electrical power supply was available there.

The Kaliurang seismograph was operated from August 22 to Sep-

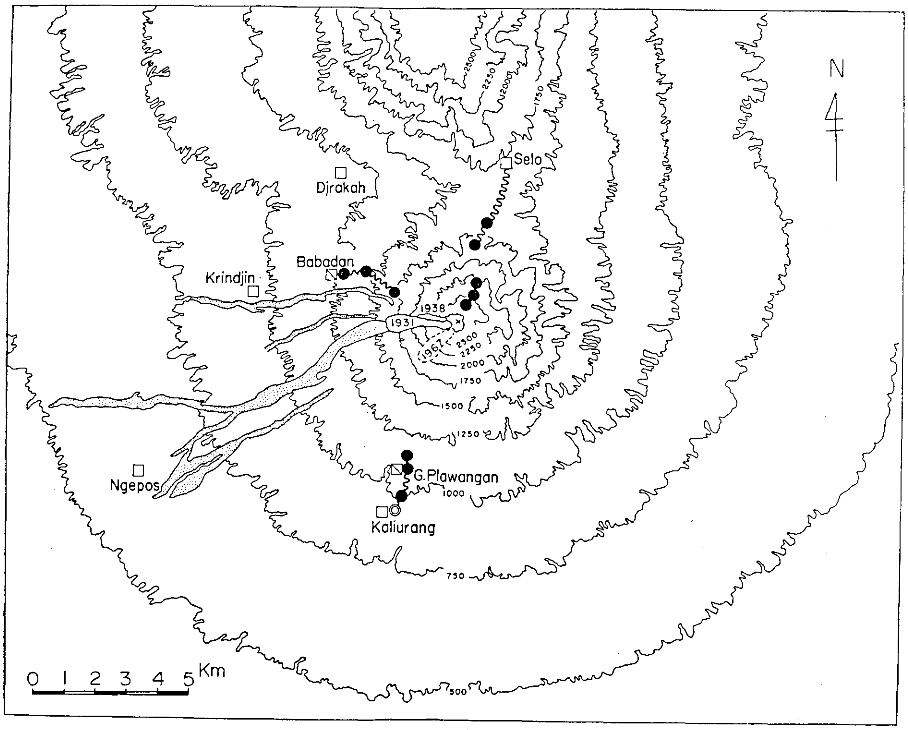

Fig. 3. Topographic map of Merapi Volcano and location of observatories and seismometers.

tember 27 and that at Selo from September 5 to September 22.

Both monitoring observations were occasionally interrupted by thunder and a consequent stoppage of electrical power supply. The crystal clock of which time marks are fed to the recorder was checked by WWVH and JJY time signal.

Besides these monitor seismographs, mobile seismic observation was made by use of a 4-channel data recorder. Electrical power for driving the data recorder, power amplifier and pen recorder was obtained by a A. C. generator. As it can be seen in Fig. 3, temporary observation by the data recorder was made at Selokopoduwur (Sept. 7-9), Babadan (Sept. 14-16) and at Plawangan (Sept. 18-22), successively. At each station, 4 Hz vertical transducers were placed along the steepest slope so that the attenuation of seismic waves could be estimated. For comparison of ground amplitude with other stations, one 3 Hz horizontal transducer was occasionally used.

At Selokopoduwur, a small underground shelter which belongs to the Geological Survey of Indonesia, was used for observation and accomodation. Based on the different ground noise for each station, magnification of seismographs was selected accordingly 15,000 at Selo, 5,000 at Kaliurang and Plawangan No. 1, and 8,000 at Plawangan No. 2. Ground noise at Plawangan was relatively large compared with other stations. During the observation by data recorder, a pen recorder was operated as a monitor.

Merapi Volcano is characterized by the frequent occurrence of lava avalanches. In order to distinguish the ground vibration caused by lava avalanches from B-type earthquakes, observation by tape recorder was made at Plawangan where observatory officials watched the lava avalanches in night and day shifts. Throughout the observation at Plawangan, we found one ground vibration which was associated with a small-scale lava avalanche.

3. Discussion of the Results.

1) Results of monitoring seismic observation.

Daily number of earthquakes recorded by seismographs at Kaliurang, Plawangan and at Selo is illustrated in Fig. 4. Daily number of lava avalanches which were observed at Plawangan Observatory is also plotted. Among these seismic stations, Plawangan is the nearest to the summit crater, while Kaliurang is the most distant station. Magnification of Plawangan seismograph is the smallest and that of the Selo seismograph the largest. It is striking that the daily number of recorded earthquakes at Plawangan is almost double those recorded at Kaliurang. The reason for this fact cannot be interpreted as due only to the attenuation of seismic

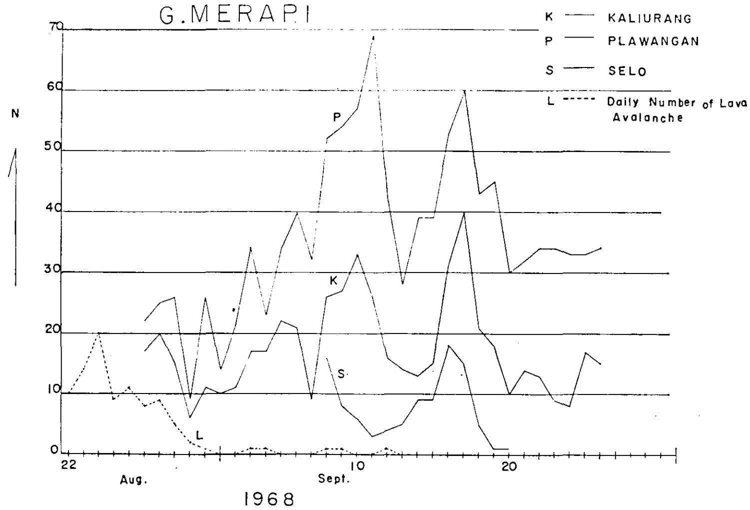

Fig. 4. Daily number of earthquakes recorded at Plawangan, Kaliurang and at Selo. Dotted line is the daily number of lava avalanche.

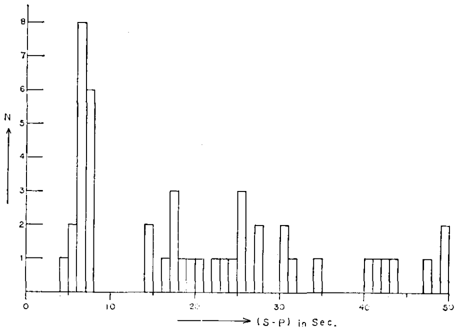

Fig. 5. Frequency of (S-P) time interval at Plawangan.

waves with distance. It is also noticable that the number of recorded earthquakes is smaller at Selo than at Kaliurang.

Daily number of lava avalanches decreased towards September, while seismic activity increased. This opposed tendency between seismic activity and lava avalanche was observed during the past and also at the time of the recent activity. The causal dependence between the occurrence of volcanic earthquake and lava avalanche is not known. But, it should be noted that seismic activity becomes high with the decreasing number of lava avalanches. This means, on the other hand, that earthquakes acting as a trigger for the occurrence of a lava avalanches, or at least earthquakes which are associated with lava avalanche are quite few or too small to be detected.

It is very difficult to read (S-P) time interval of most of the recorded earthquakes. This indicates that the recorded earthquakes are mostly of volcanic origin of which the focal depth is extremely shallow.

It is remarkable that no earthquake of A-type has been observed. (S-P) time interval of earthquakes recorded by Plawangan seismograph is shown in Fig. 5. Between the period of September 16–21, a swarm of local shocks occurred of which (S-P) interval was 6.6–7.1 seconds. Epicenters of these shocks were estimated to be located near Jogjakarta.

The reason why the Plawangan seismograph shows a large amplitude even for tele-seisms is considered to be the consequence of the selective amplifying effect at Plawangan. Frequency distribution of the average period of seismic waves observed at Plawangan and at Kaliurang is shown in Fig. 6.

Frequent occurrence of 0.4 sec. period is conspicuous at Plawangan. Earthquake motion which was recorded at Plawangan sometimes behaved as a free oscillation with the period of 0.4 seconds. This result implies that the observation site at Plawangan amplifies the seismic waves of 0.4 seconds. Plawangan seismographs were placed on a relatively narrow ridge extending towards the southern foot of Merapi Volcano. It is not clear whether 0.4 seconds is the natural period of transverse vibration of the ridge or not.

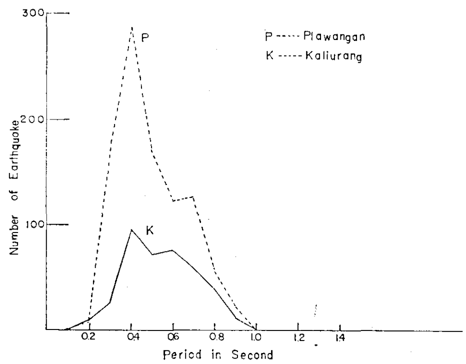

Fig. 6. Frequency of average period of seismic waves recorded at Plawangan and at Kaliurang.

From this view-point, good attention should be paid when we discuss the amplitude and period of seismic waves observed at Plawangan. During our observation, five seismographs placed at Selo (1, 2), Plawangan (1, 2) and at Kaliurang recorded many B-type earthquakes from which the amplitude-distance relation of seismic waves can be plotted.

Horizontal transducers of the above five seismographs were placed so that the direction of pendulum oscillation could be normal to the slope of the volcano. Maximum horizontal ground amplitude in the above direction for each B-type earthquake are plotted as shown in Fig. 7. An abnormally large amplitude was found at Plawangan. The Kaliurang seismogram shows a slightly larger value than that at Selo. The Kaliurang seismograph was placed nearly at the end of the ridge. Therefore, the amplifying effect of the ground vibration at Kaliurang can easily be expected.

It is incorrect to conclude that most of the B-type earthquakes occur near to Plawangan judging only from the amplitude-distance relation. The dotted line in Fig. 7 is the amplitude of a B-type earthquake observed at Selokopoduwur (Selo 3 in the figure) and simultaneously ob-

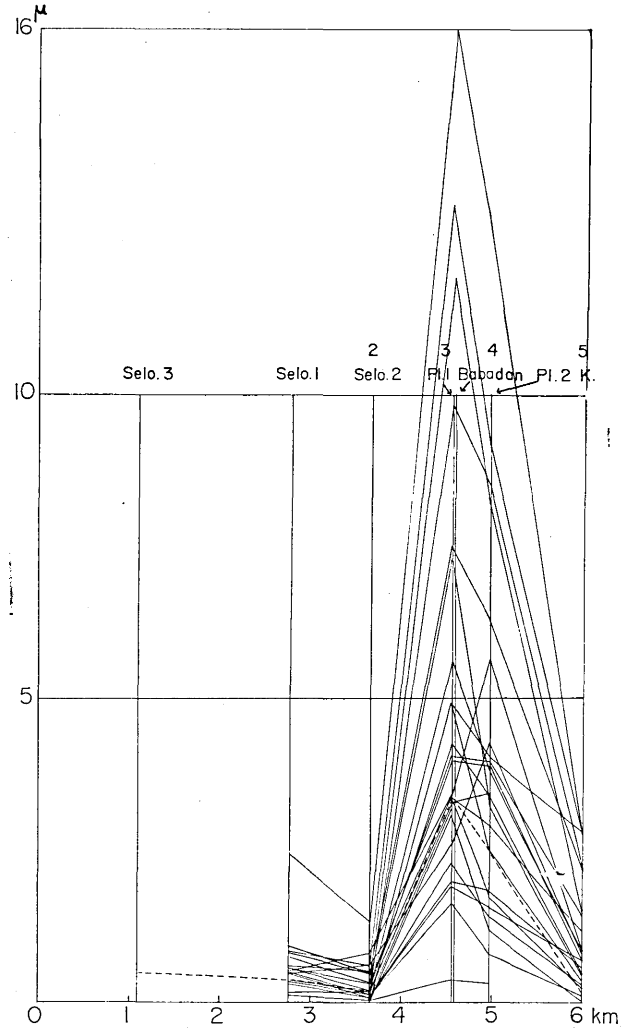

Fig. 7. Vertical ground amplitude of earthquake at Plawangan, Selo and Kaliurang.

served at other monitoring stations. The amplitude decreases monotonously with distance along the northern slope of the volcano, whereas it increases at Plawangan.

It is most likely that the ground vibration may be observed to be associated with the lava avalanche though the frequency of lava avalanche decreased during our observation. The Plawangan seismograph recorded many spindle shaped earthquakes which apparently seem to be B-type earthquakes. But, we have to distinguish vibration associated with lava avalanche, if it exists, from B-type earthquakes.

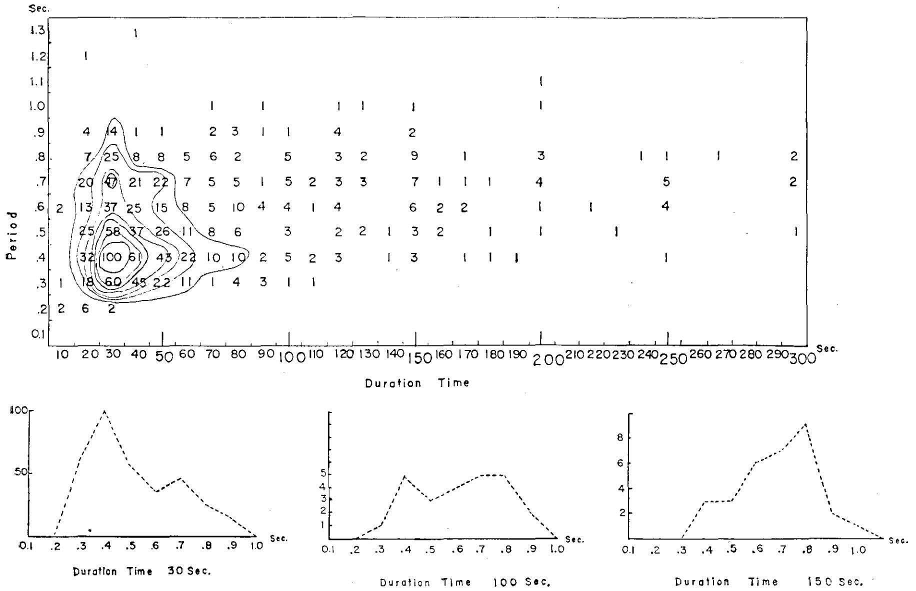

Fig. 8. Relation between the average period and the duration time. Lower figures show the average period for the duration time of 30, 100 and 150 sec., respectively.

As a first step, we read the duration time and average period of earthquakes recorded by the Plawangan seismograph which are shown in Fig. 8. In the upper part of the figure we can see that the duration time of many earthquakes is 30 seconds of which the period is 0.4 seconds. It is very likely that if the duration time became longer, the short period waves would disappear. This relation can be recognized from the lower part of the figure. Besides this general tendency, a considerable number of earthquakes have a longer period than 0.4 seconds even though their duration time is less than 30 seconds. These are the earthquakes of extremely shallow origin at the summit region.

From the relation of period-duration time, it seems to be impossible to distinguish the vibration associated with lava avalanche from B-type earthquakes. This matter will be discussed later on from the stand-point of spectral studies.

As mentioned here, amplitude decay could not become a measure of estimating the source region of volcanic earthquakes of Merapi volcano.

We shall, therefore, discuss the period increase of earthquakes with epicentral distance. Elaborate work carried out by T. Minakami during the growth of the new lava dome "Showa Shinzan" showed a remarkable difference between the period increase for A-type and B-type earth-

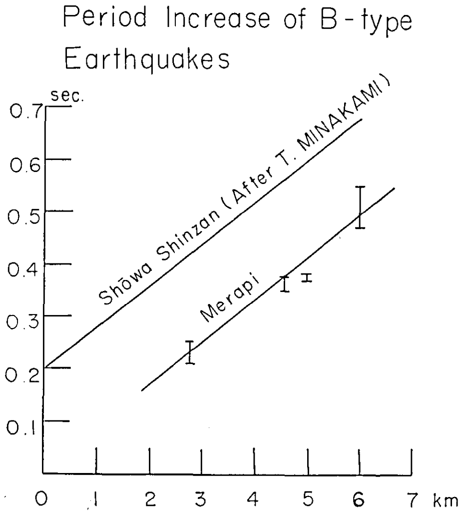

Fig. 9. Period increase of B-type earthquakes. Horizontal distance is taken from the summit.

quakes[3]. In order to compare his result with ours, the average period of seismic waves which seems to be the volcanic origin was read which were recorded by monitoring seismographs. The result is shown in Fig. 9. together with the result obtained by T. Minakami.

Period increase with epicentral distance at Merapi volcano showed almost the same feature as the B-type earthquake observed at "Showa Shinzan". Period increase depends both on the focal depth and the attenuative character of the medium through which seismic waves are propagating.

2) Results of mobile observation by use of tape recorder.

As mentioned above, many ambiguities remained concerning the detailed nature of volcanic earthquakes. Monitoring seismographs were located only at the northern and southern slopes of the volcano. The nearest transducer was placed at nearly 3 km away from the summit crater. No seismographs were operated at the eastern side of the volcano. In this connection, it was necessary to observe earthquakes very close to the summit and also at the eastern and western slopes. It was difficult to make seismic observation at the eastern side of the volcano because of the environmental circumstances and the lack of accommodation facilities. Therefore, observation by a tape recorder was carried out successively at Selokopoduwur and at Babadan. As it was also necessary to make simultaneous observation with monitoring seismograph,

Table 1. List of Observation by tape recorder

Station	Period in hours	Number of recorded earthquakes	Hourly number
Selokopoduwur	22.9	291	12.6
Babadan	22.4	208	9.3
Plawangan	49.7	304	6.1

3) T. MINAKAMI, T. ISHIKAWA and K. YAGI, "The 1944 eruption of Volcano Usu in Hokkaido, Japan", *Bull. Volcanologique*, **11** (1951), 45-157.

observation by tape recorder was made at Plawangan where transducers were placed side by side with the monitoring transducers.

Period of observation and recorded earthquakes are listed in Table 1.

Though the seismic activity varies with time (c.f. Fig. 4), the hourly number of recorded earthquakes seems to be proportional to the distance from the summit crater.

We shall discuss the results obtained by mobile observation by use of the tape recorder one by one.

a) Amplitude distribution at Selokopoduwur

The transducer nearest to the summit was placed just at the foot of the summit dome. The second transducer was placed at Gadjahmungkur (elephant back) and the third transducer near to the underground shelter at Selokopoduwur. The distance between each transducer was approximately 300 meters. During the half period of observation, the third transducer was replaced with a 3 Hz horizontal transducer. The maximum trace amplitude on the monitoring ink recorder for three vertical component is plotted in Fig. 10. The uppermost line is the amplitude of distant earthquake. This does not show any appreciable difference in amplitude at the three stations. Most of the lines show a different degree of amplitude decrease. The steepest slope corresponds to the earthquake of which average period is slightly less than 0.1 second while the lowest line corresponds to the period of 0.4 seconds. It can be re-

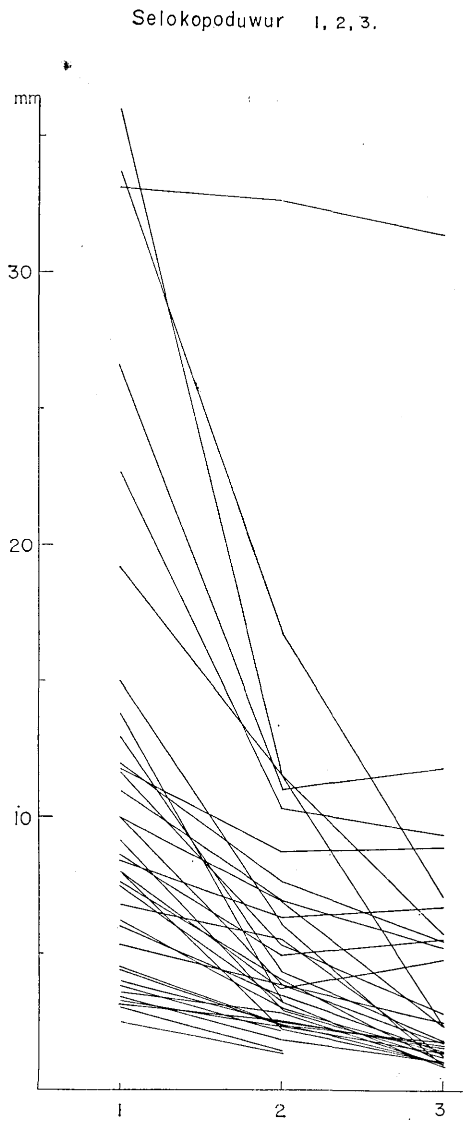

Fig. 10. Maximum trace amplitude of earthquakes recorded at Selokopoduwur by use of the tape recorder.

cognized that we observed various types of earthqukes of which period covered a considerably wide range.

Earthquakes characterized with short period waves as observed at Selokopoduwur could not be found at Babadan and Plawangan, this resulting from the dissipation of short period waves with distance.

b) Spectral studies

Typical earthquakes were selected on their shape from the records at Selokopoduwur, Babadan and at Plawangan. These earthquakes were played back with high paper speed and Fourier analyses were made for each earthquake.

An effort has been made to identify the ground vibration associated with lava avalanche by observation by eyewitnesses as well as from the operation of the tape recorder at Plawangan Observatory. At 08 h 30 m, Sept. 22, we observed a small-scale ash explosion caused by a lava avalanche from the lowest part of the lava tongue. At the same time, we recorded ground vibration of which the seismogram is slightly different from usual valcanic earthquakes. This was the last opportunity to clearly recognize a vibration associated with lava avalanche. We do not believe that the lava avalanche was followed by vibration but, conversely, the vibration seemed to have been caused by a lava avalanche. Fourier analysis was also made for this earthquake.

At a glance, monitored tape recording seismograms showed various type of earthquakes, especially at Selokopoduwur. The purpose of the spectral study was to compare the spectra of these earthquakes and, if possible, to classify the earthquakes observed at Merapi Volcano.

In the following, we shall describe the nature of earthquakes which were classified based mainly on the spectral features.

i) *Type 1 (double spindle, high frequency.)*

This type of earthquake was observed at Selokopoduwur, nearest station to the summit dome. Earthquakes of the three different shapes and their spectra are shown in Figs. 11, 12 and 13.

Apparently, these earthquakes seem to be due to a different mechanism. But, three of the earthquakes are characterized by a broad spectrum in the high frequency range. The shape is also impressive looking like a double spindle. Judging from the large dissipation of amplitude with horizontal distance, sources of this type of earthquake seem to be located at a very shallow depth, very likely located in the summit dome. From a comparison with other types of vibration and also from its peculiar shape, the writers consider that this type of earthquake might have been generated by a different mechanism from the ordinary volcanic earthquakes of A-type or B-type. It is difficult, of course, to interprete

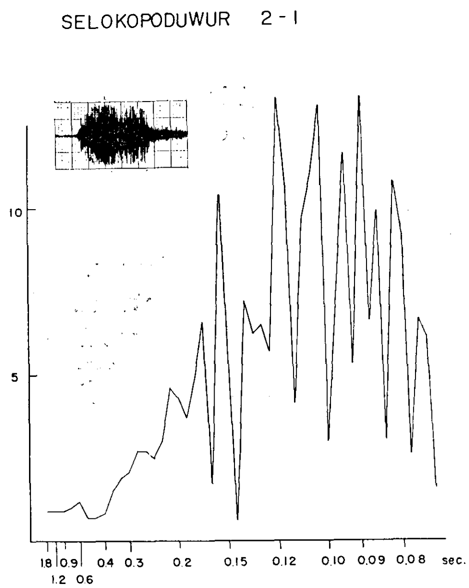

Fig. 11

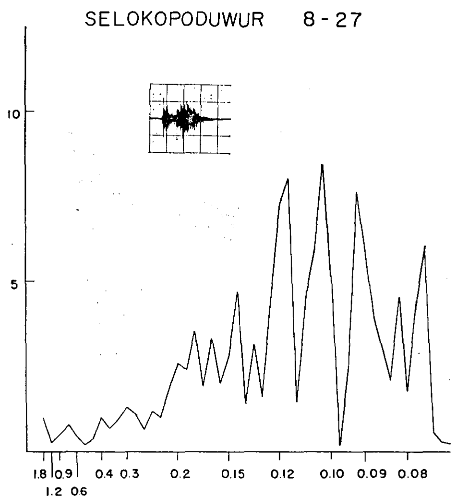

Fig. 12

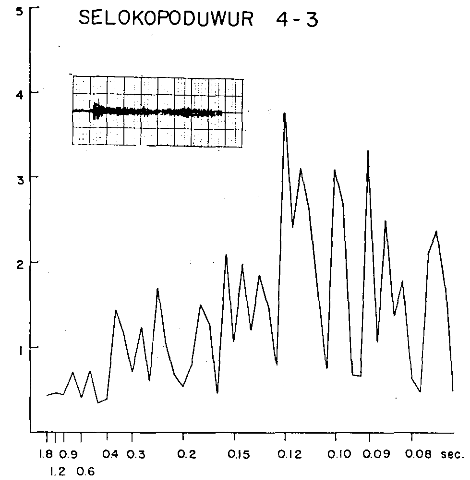

Fig. 13

Fig. 11–13. Monitored seismograms and spectra for Type 1.

the generation mechanism of this type of vibration only from the present observation. We can presume that the vibration of a part of the lava dome may be possible by a hammering action caused by the sudden emission or sudden stoppage of gas from the inner part of the lava dome. We can easily imagine the surging effect in a hydraulic system where a self-exciting vibration is generated in the system.

For instance, if we lift up the valve of a blowing machine, a strong sound occurs. This sound energy acts as a hammer to excite vibration of the system concerned.

We are not sure whether the vibration of Type 1 is generated with a similar mechanism as cited above, however, it may be one of the possible causes.

ii) *Type 2 (double spindle, high frequency, low frequency)*

This type of earthquake was observed only at Selokopoduwur. The typical seismogram is shown in Fig. 14 together with the spectrum. At a glance, the shape is quite similar to the third example of Type 1 (Fig. 13). But, if we execute Fourier analyses for each spindle separately, we can find a different spectral feature from Type 1. In Fig. 14, spectrum 1 corresponds to the first spindle and spectrum 2 to the second one. We observed several examples of this type of vibration. The mechanism of generation of the first spindle seems to be the same as that of Type 1 since spectrum 1 covers almost the same frequency range with that of Type 1. The only difference of this type of vibration from Type 1 is the spectrum of the second spindle, where the predominant peaks shift to a longer period. The spectrum of the second spindle is similar to that of a lava avalanche.

iii) *Type 3 (B-type)*

This type of earthquake is the so-called "B-type" earthquake of which the focal depth is shallow. The spectrum has significant peaks between 0.17–0.27 sec.

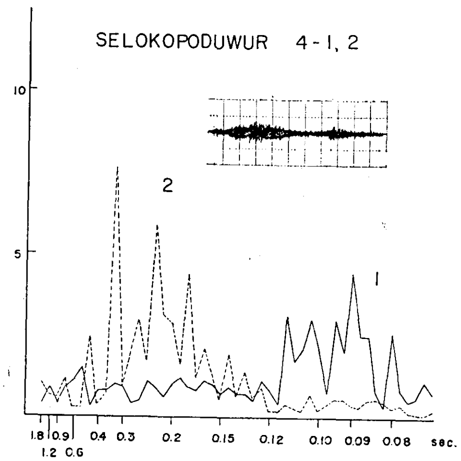

Fig. 14. Monitored seismogram and spectrum for Type 2.

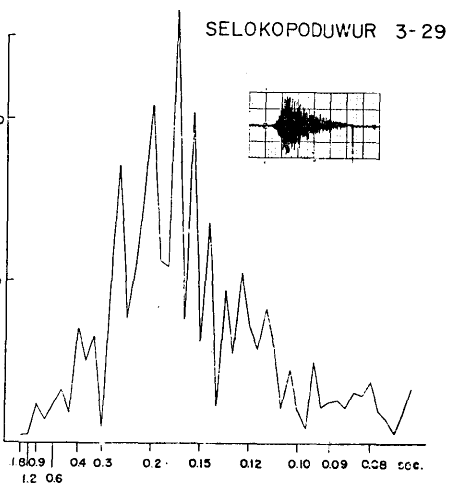

Fig. 15. Monitored seismogram and spectrum for Type 3.

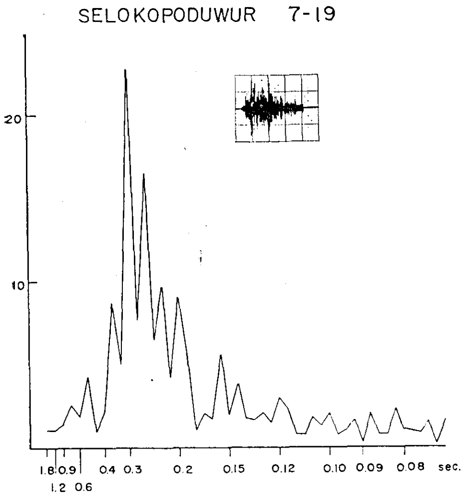

Fig. 16

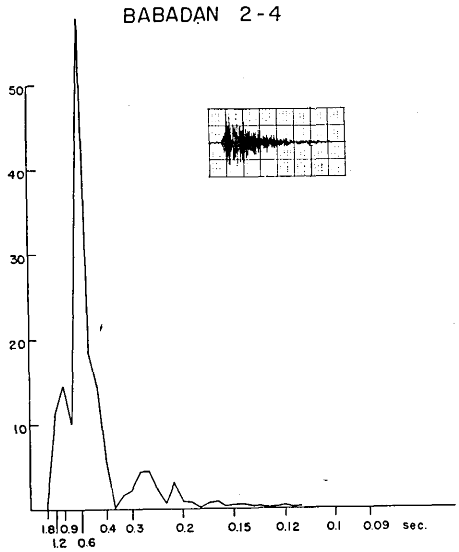

Fig. 17

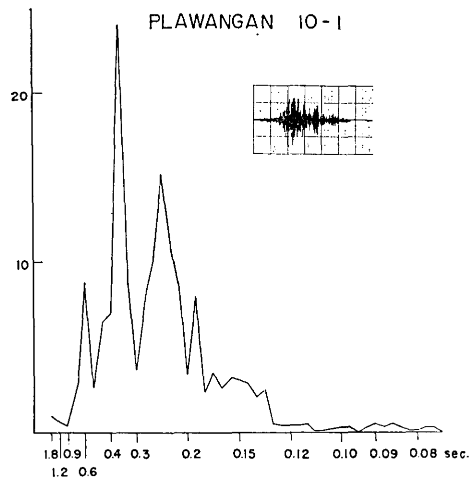

Fig. 18

Fig. 16–18. Monitored seismograms and spectra for Type 4.

Most of the earthquakes which we recorded by monitor seismographs were of this type. Hence, seismic activity as shown in Fig. 4 indicates almost the frequency of occurrence of B-type earthquakes.

iv) *Type 4* (*Many phases*)

We observed many earthquakes of this type both by the tape recorder and the monitor seismographs. The difference in shape of type of earthquake from that of B-type earthquake is the occurrence of several distinct

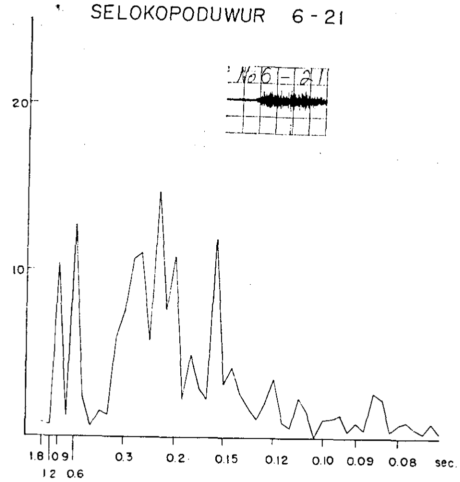

Fig. 19

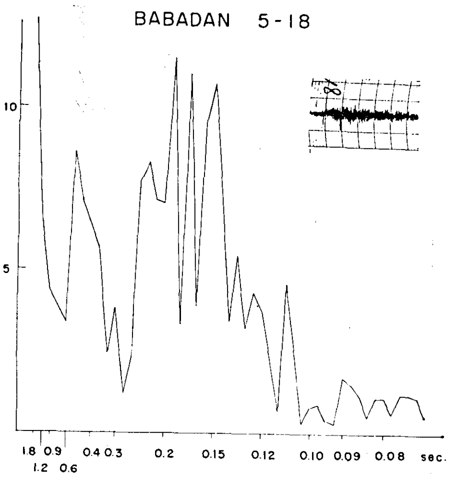

Fig. 20

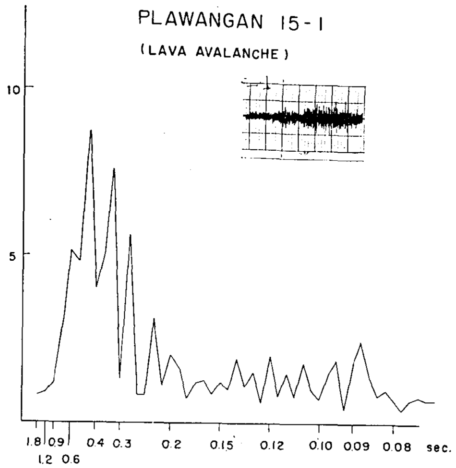

Fig. 21

Fig. 19-21. Monitored seismograms and spectra for Type 5.

phases during the entire duration time, while the B-type earthquake is more or less a monotonous decrease of amplitude.

Comparison of spectra of this type and with type 3 which were both recorded at Selokopoduwur yields that the spectrum of Type 4 has the predominant peaks at a longer period than those of Type 3.

At Babadan, the predominant period is 0.6 sec. which is longer than that of the remaining two stations. This may be due to either the ground condition of the observation site or the dissipation of the short period waves during the passage, since the western slope of the volcano is covered by thick pyroclastic deposits.

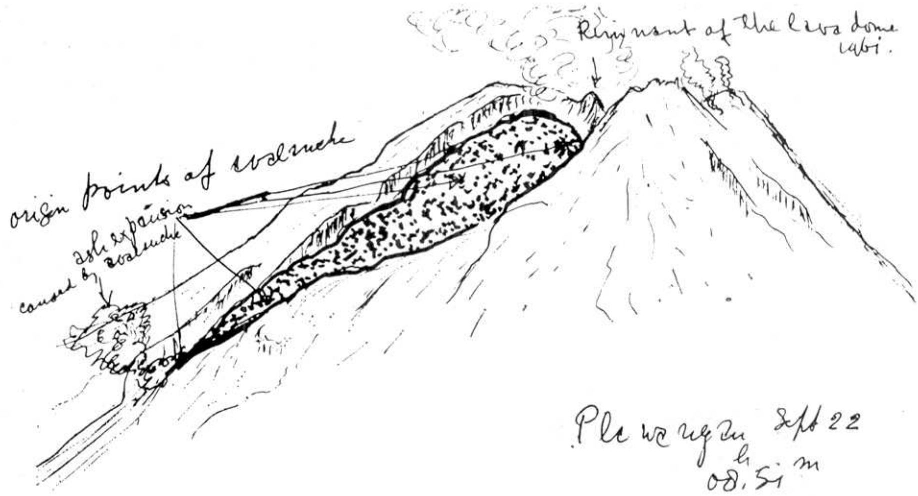

Fig. 22. A sketch from the Plawangan Observatory at 08 h 30 m, September. This lava avalanche caused the ground vibration as shown in Fig. 21.

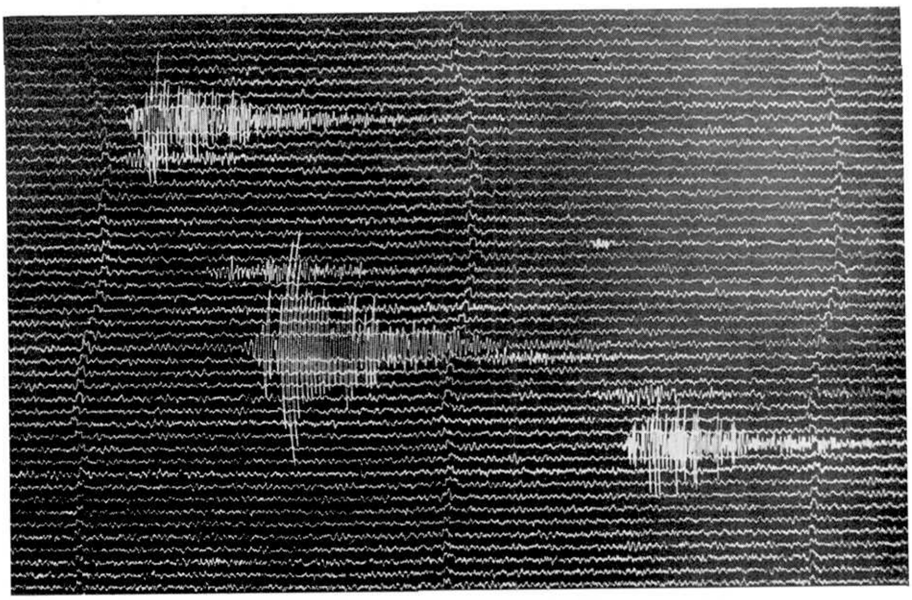

Fig. 23. B type earthquakes recorded at Plawangan.

The mechanism of generation of this type of earthquakes is not known. During the formation of the lava dome of Showa Shinzan, T. Minakami[4] observed numerous earthquakes which showed peculiar fea-

4) *loc. cit.*, 3)

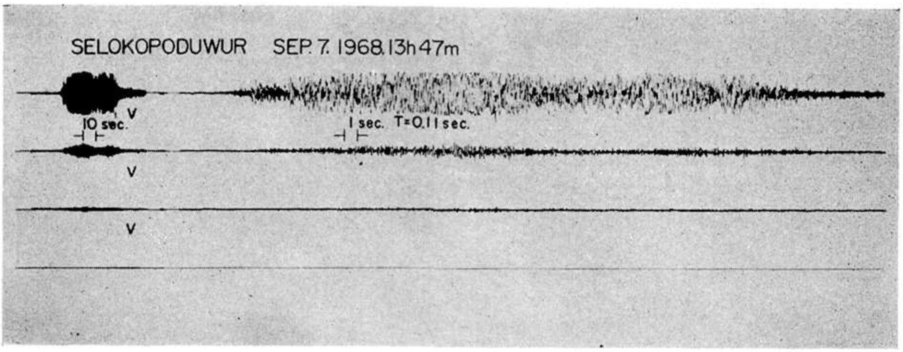

Fig. 24. An example of seismogram of Type 1.

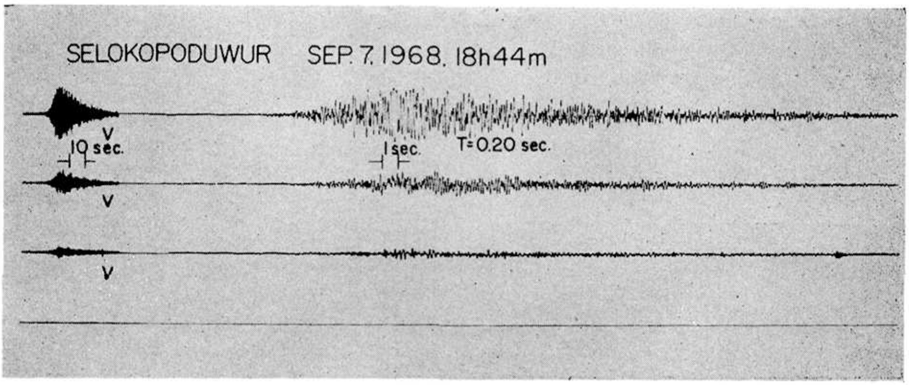

Fig. 25. An example of seismogram of Type 3.

tures. This type of earthquake was classified as "C-type" earthquakes having several distinct phases. He stated that "C-type" earthquakes have intermediate characteristics between A and B types.

Apparently, though it is not quite similar in shape, the earthquake of Type 4 seems to belong to the same category of the C-type earthquakes observed at Showa Shinzan.

If this is so, it is most interesting that we observed a similarity of type of the earthquakes at Merapi and Showa Shinzan during the active stage of their lava dome.

v) *Type 5 (spindle, associated with lava avalanche)*

As mentioned before, ground vibration associated with lava avalanche was observed at 08 h 30 m, Sept. 22 at Plawangan. The seismogram on this occasion is shown in Fig. 21 together with its spectrum.

Similar types of seismograms were selected from the records obtained at Selokopoduwur and at Babadan, their spectra being shown in Fig. 19 and 20, respectively. A common feature of the three seismograms is an elongated spindle shape and their spectra having a predominant numbers of peaks covering a low frequency range. The seismogram shown at Fig. 21 is the only example of ground vibration associated with lava avalanche. But, eye-witness observation of the lava avalanche could not clarify the difference of time of the occurrence of the events between the lava avalanche and the ground vibration.

A sketch of the lava avalanche observed from up-stairs of the Plawangan Observatory is shown in Fig. 22.

4. Concluding Remarks

Seismic observation at Merapi Volcano, though short in period, and being of relatively low seismic activity, yielded interesting results. Based on the tape-recorded seismograms observed at Selokopoduwur, volcanic earthquakes at Merapi Volcano were classified into five types. These are briefly described and listed in Table 2.

Table 2. Type of volcanic earthquakes at Selokopoduwur.

Type	Apparent feature	Period	Remarks
1	double spindle	0.09–0.12 sec.	high frequency
2	double spindle	0.09–0.12 0.24–0.36	high frequency is followed by low frequency
3	B-type	0.15–0.25	
4	distinct phases	0.25–0.30	
5	elongated spindle	0.16–0.90	associated with lava avalanche

Besides Type 3, four types of earthquakes are very uncommon ones of volcanic origin. In Japan, we do not have any volcano like Merapi who keeps repeating the growth and collapse of the lava dome. As far as we were concerned for Merapi Volcano, the four types of earthquakes were the first finding and classification of volcanic earthquakes. It should also be mentioned that no earthquake of A-type has been observed. Most of the earthquakes of volcanic origin are of very shallow origin and presumed to be even located in the lava dome.

From the stand-point of the prediction of volcanic eruption, it is necessary to observe the frequency of occurrence of these types of earthquakes and to examine the correlation of each type with the volcanic activity. For this purpose, seismic observation should be made very near to the summit, otherwise Types 1 and 2 could not be observed.

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Appendix

Earthquake observation by two component Wiechert seismographs (mass 200 kg) has been continued over a long time at Plawangan and Babadan observatories. Merapi Volcano erupted on January 7-8, and as

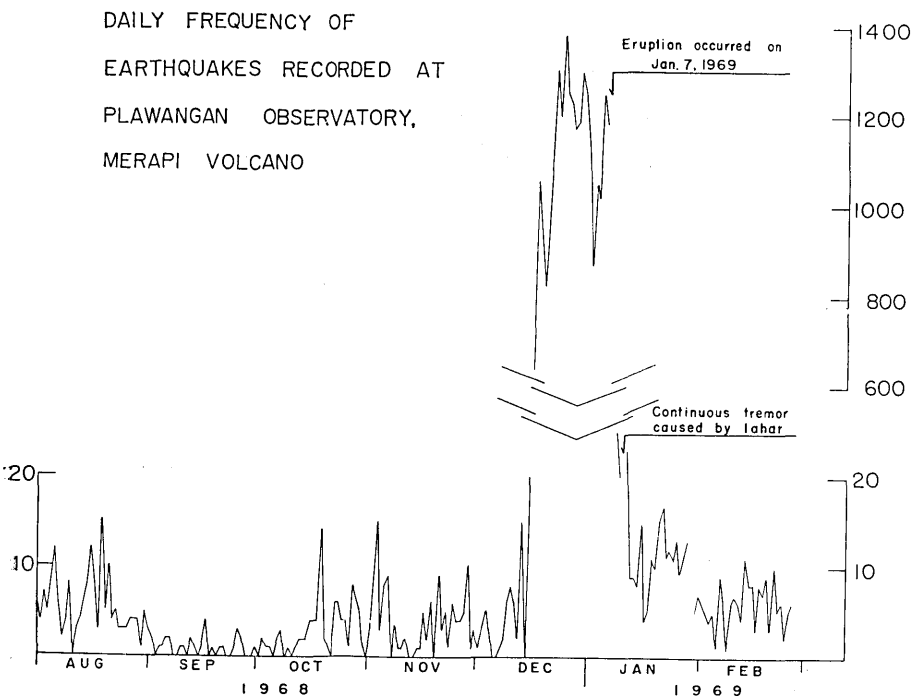

Fig. 26. Daily number of earthquakes recorded by a Wiechert seismograph at Plawangen Observatory.

a result the summit dome slid down accompanying the nuèe ardente of lava avalanche.

Daily frequency of earthquakes recorded by Plawangan Wiechert seismograph is plotted in Fig. 26, during the period of August 1968–February 1969. It is noticiable that the number of recorded earthquakes suddenly increased from December 17, some 3 weeks before the eruption. Culmination of the seismic activity was reached on December 25 counted at 1376 for a day. On January 2, the number decreased to 870 followed by a sharp increase again and on January 5 it reached 1248. During the eruption, the number of earthquakes could not be counted because of a continuous tremor. Thus, the eruption took place after the first culmination of seismic activity. This tendency of the eruption is not a peculiar feature of Merapi Volcano, for we find similar cases in many andesitic volcanoes.

It is also a remakable fact that, comparing the number of lava avalanches, in Fig. 2, seismic activity and the occurrence of lava avalanche seem to be in an opposed sense. During our observation, the same relation was noticed.

At a glance, seismic activity of Merapi Volcano during our observation was at its lowest level.

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44. インドネシア火山の調査

その 2 メラピ火山の地震観測

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1968年8月22日—9月30日の期間，インドネシア，中部ジャワにあるメラピ火山において地震観測を行った．モニター地震計は煤書き水平動3成分をメラピ火山南麓のプラワンガンとカリウランに置き，カリウランで連続観測を行った．また，9月7日より，メラピ北麓のセロ観測所に煤書き2成分記録計を設置し，水平動地震計を2台，北側山腹に設置した．モニター観測の結果の主要なものは次の通りである．

1. lava avalanche の数が減少するに従って，火山性地震の数が多くなる．
2. A 型地震は全く観測されなかった．
3. プラワンガンでは 0.4 秒の波が選択的に増幅されて振幅が極めて大きい．
4. 9月16日頃から数日にかけ少くとも 15 ケの地震がジョクジャカルタ附近に群発した．
5. 観測された火山性地震の殆んどはその震源が極めて浅く，(S—P) も明瞭ではない．

次ぎに，テープレコーダーによる移動観測は，山頂近くのセロコポドゥールおよび，ババダン観測所，プラワンガン観測所で行った．主要結果は次の通りである．

1. 山頂ドーム直下での観測では5つのタイプの火山性地震が観測された.

Type 1. 2つのスピンドル型の震動で，スペクトルは高周波部分に広い. このタイプは，その発震機構が明瞭でないが，工学でいうサージング効果の類推から，おそらく火山ガスの噴出が急激に止ったり，突然始まったりした時に生ずる強い音の衝撃によって，lava dome の一部に振動が励起されるのであろう. このタイプは高周波のため，波の減衰が大きく，山頂附近でのみ観測される.

Type 2. 型は Type 1 に似ているが，2番目のスピンドルの周期が長いのが特徴で，1番目のスピンドルは，そのスペクトルから判断すると Type 1 と同じメカニズムに因ると思われる. 2 番目のスピンドルは B 型地震かあるいは lava avalanche による振動であろう.

Type 3. これはいわゆる B 型地震であって，それの距離による周期の伸びの割合いは昭和新山の lava dome 生成の際観測された B 型地震のそれとほぼ一致する.

Type 4. この型の地震は B 型地震と似ているが，震動型式が異なり，途中に，いくつかの極めて明瞭な相が現われる. これは. 昭和新山の場合に現われた C 型地震ほど特徴的ではないが，lava dome の生長に関係していると思われる.

Type 5. これはプラワンガンにおいて唯一つ観測されたもので lava avalanche に伴って生ずる震動で，スペクトルが周期の長い方にいくつかのピークを持っているのが特徴である. プラワンガン以外の観測点でもこの種の震動は観測されている.

以上，観測結果の概要を述べたが，メラピ火山で観測された地震には，活動している lava dome に特徴的と考えられる地震が数種発生していることが明瞭になった. 将来，火山噴火予知の立場からも重要なことは，これらの種類の異った地震が，火山活動の推移に伴ってどのように発現するかを見出すことであろう.