Vibrations of the Aso Volcanological Laboratory Building and its Surrounding Ground

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1. Introduction

In November 1931, and in greater detail in September 1935, studies were made of the ordinary micro-tremors caused by wind, waterfalls, and disturbances of volcanic origin as they affect the building and ground of the Aso Volcanological Laboratory to find the properties of the vibrations peculiar to the building. Observations were made at a number of selected points with micro-seismographs of very high magnification. These instruments were five sets of the horizontal component and two sets of the vertical component of the short period micro-seismographs. The former sets were prepared by Assist. Prof. K. Sassa for his investigations on volcanic micro-tremors of the volcano[1] and the latter by the present writer. In the observations of Nov. 1931, the following instrumental constants were used:

Instruments	Set	T_0 sec.	μ_0^2	T_1 sec.	μ^2_1	k	l cm.	V_m	s cm.
Horizontal component micro-seismograph S_A	2	0.55	0	0.55	0	16100	7.5	12300	30
Horizontal component micro-seismograph S_B	3	0.55	0	0.55	0	25600	7.5	19300	30

In Sept. 1935:

Instruments	Set	T_0 sec.	μ_0^2	T_1 sec.	μ_1^2	k	l cm.	V_m	s cm.
Horizontal component micro-seismograph S_A	2	0.55	0	0.55	0	20100	7.5	15400	30
Horizontal component micro-seismograph S_B	2	0.55	0	0.55	0	25100	7.5	19000	30
Vertical component micro-seismograph S_V	2	0.58	0	0.58	0	31200	10.7	17500	30

1. K. Sassa: Volcanic Micro-Tremors and Eruption-Earthquakes, Mem. Coll. Sci., Kyoto Imp. Univ., Ser. A, **18** (1935).

The symbols have the following denotations :—

T_0, T_1 : Periods of free oscillation of the pendulum and the galvanometer respectively.

μ_0^2, μ_1^2 : Damping constants of the pendulum and the galvanometer respectively.

k : Uebertragungsfaktor of the seismograph.

l : Length of the equivalent simple pendulum.

V_m : Maximum magnification.

s : Speed of the recording paper per minute.

The vertical component seismographs used are similar to the Galitzin seismographs of galvanometric registration, except that the lower suspension point of the main spring is near the center of the mass of about 1.5 kgr. wt. to get the short period of free oscillation of the pendulum. The other parts such as the coils of the pendulum and the galvanometer, etc., are similar to those of the horizontal component seismographs, the instrumental details of which will be found in Mr. Sassa's paper above cited. These seismographs were compared by setting up all the pendulums on a single concrete basement facing all those of the horizontal component seismographs in the same direction, and registering the movements of their galvanometer mirrors on a single recording drum. As shown in Fig. 3, Plate I, the recorded curves were satisfactorily similar even in details. The pendulum parts were set at various positions in and outside the building, the galvanometers and the recording drum being left untouched and the pendulums placed as shown by the small circles in Fig. 1 (i) and (ii). An account of the observations follows.

2. Oscillations observed on the foundational volcanic rock

The reinforced concrete building of the Aso Volcanological Laboratory stands on a hill of volcanic rock covered with a layer of volcanic ashes ca. 20 m. thick as shown in Fig. 1 (iii). To study the oscillations of the foundational volcanic rocks, observations were made at the positions, P and L, the former being a pit of ca. 20 m. in depth and ca. 60 m. horizontally NE from F_0 (the basement room directly under the tower in the building). At the bottom of this pit the pendulums were set directly on volcanic rock. The latter, L, is an adit ca. 50 m. long excavated near the middle of the northern slope of the hill for tiltometric observation and will be further lengthened in future. Its entrance is horizontally ca. 200 m. N from the building, and its end 20 m. below the surface of the ground in volcanic rock. The pendulums were set at four positions along the length of the adit to study the transitive changes in the oscillations observed in the ground at various depths. On calm days irregular oscillations of periods ranging from 0.4^s to 1.0^s and about 0.1μ in double amplitudes were observed on volcanic rocks, and when the surface of the ground was excited by wind, regular oscillations of about 0.55^s became conspicuous and had double amplitudes of about 0.3μ as shown in Fig. 15, Plate IV, being accompanied by oscillations of about 0.32^s which were especially noticeable on the surface of the ground rapidly decreasing in amplitudes with increasing depths, while the oscillations of 0.55^s above stated suffered no considerable decrease with increasing depths. We often observed micro-tremors of about 0.5^s periods which are thought to be disturbances upon the bed-rock caused by the waterfalls near the laboratory. These were fully discussed in Mr. Sassa's paper already cited. Further, in the tails of local earthquakes of shallow origin we always observed regular oscillations of about 0.55^s whose amplitudes in the horizontal component were three times those of the vertical ones. From these observations the writer considers that the oscillations of period of about 0.55^s seem to be the proper oscillations of this underlying layer composed of volcanic rock, lapilli, etc..

3. Oscillations of the volcanic ash-layer

As shown in Fig. 1 (iii), the superficial layer of volcanic ash is about 20 m. in thickness. Its oscillations were observed at various points outside the building. On calm days regular oscillations of about 0.32^s with double amplitudes of about $0.2u$ were observed on the surface of the ground and when the ground was excited by wind, these 0.32^s period oscillations became more and more predominant, sometimes reaching about 0.5μ in double amplitudes, mingled with irregular oscillations which are supposed to be those forced by the wind. The vertical amplitudes of the oscillations of 0.32^s observed on the surface of the ground are one-third of the horizontal. It is interesting to note that there exists a slight preponderance in amplitude and frequency of occurrence in the N-S component as compared with those in the E-W component of these 0.32^s period oscillations on the surface of the ground. This tendency becomes more and more notable as the oscillations are observed at deeper points. When observed on the foundational volcanic rock the differences between the N-S and E-W components are quite conspicuous both in amplitude and frequency of occurrence. The cause of these peculiarities is at present unexplainable, though it seems to be attributable to the shape of the ash-layer and the character of the underlying layer, which do not come within the scope of the present investigation.

Mingled with these 0.32^s period oscillations were observed others of about 0.10^s periods, the amplitudes and frequencies of occurrence of which were rapidly increased by wind excitations, sometimes reaching even 0.5μ in double amplitudes. The amplitudes of the vertical components of these oscillations are in the same degree as the horizontal ones. There is no doubt that these 0.10^s period oscillations were not caused by the direct action of wind upon the covers of the pendulums of the seismographs or the concrete basements, for the observations at various points outside the building were all made in small rectangular pits, about 1 m. deep, with good lids which protected the covers of the pendulums and the concrete basements from the direct action of the wind and other disturbances. Moreover, we observed these 0.10^s period oscillations at the observing points in the adit, L, already described where suffer no direct action of wind even in stormy weather. Further, it may be noticed that the periods of oscillations of the ground generated by the falling of a stone were also about 0.10^s. In each observation, a stone weighing ca. 160 kgr. was allowed to fall from the height of 1.5 m. above the surface of the ground at the point S, having a horizontal distance of ca. 22 m. W from the end of the north-wing of the building, a somewhat detailed description of which will be found in a later paragraph. From these observed facts it may be concluded that the superficial ash-layer possesses in general two modes of oscillation; one is the oscillation of about 0.32^s whose vertical motions are less than one-third of the horizontal, the other is the oscillation of about 0.10^s whose motions are of nearly the same in both the vertical and the horizontal components.

Simultaneous observations made at points outside the building which were not influenced by the vibrations of the building showed that ground motions observed at two points within a few meters of each other were nearly the same, but as the two observing points became further apart, the similarity in the motions decreased. When the distance between the two observing points became 20 m. or more

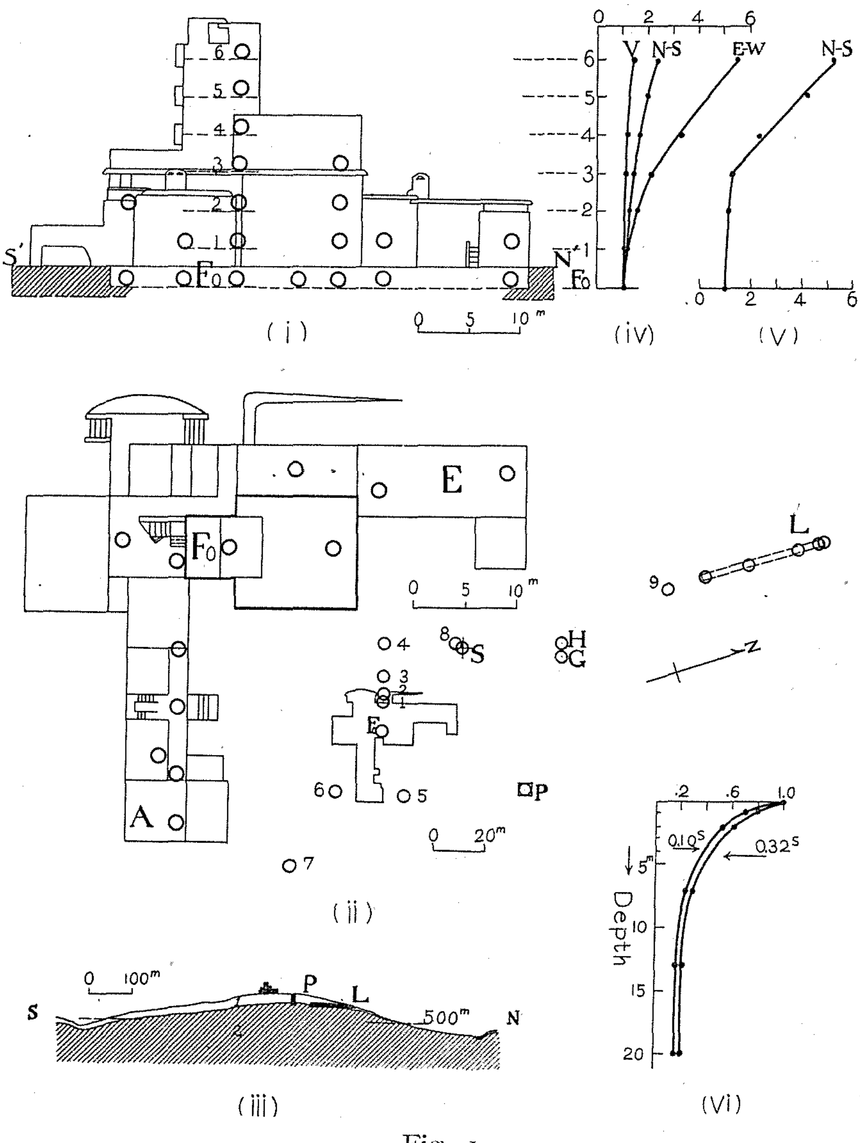


Fig. 1

(i). Side-view of the building of the Aso Volcanological Laboratory.

(ii). Plan of the building. (Small circles in the Figures show the positions where the pendulums of the seismographs were set.)

(iii). Profile of the building and its neighbouring ground. (In the Figure, 1 denotes the superficial ash-layer and 2 denotes the foundational layer of volcanic rocks. P and L are the pit and the adit respectively.)

(iv). Amplitude-height relations of the prevailing vibrations of the building.

(v). Amplitude-height relation of the 0.13^s period vibrations of the tower.

(vi). Amplitude-decrease with increasing depth of the oscillations of the ground in the horizontal components.

the similarity completely disappeared. Thus, speaking of oscillations of such periods as were discussed above, motions of the ground may be compared to the ripples on the surface of the water in a gentle breeze. The interaction of the motions between the building and the near-by ground will be treated in a later paragraph.

4. Amplitude-decrease of the oscillations with increasing depth

Simultaneous observations were made at points of various depths in the volcanic ash-layer to ascertain the degree of amplitude-decrease of the oscillations at increasing depths. These points were as follows: at point H the pendulums were set on a surface concrete basement especially constructed to observe the oscillations of the surface of the ground; at G on a concrete basement in a pit 2 m. deep; at many small pits 1 m. deep already described; at the bottom of pit, P, 20 m. deep; at four points at depths of 2 m., 7 m., 13 m., and 20 m. respectively in the adit L as all shown in Fig. 1 (ii). After careful comparisons in mode and amplitude of the oscillations of the same periods in the records obtained at the above described positions, we ascertained the relations between the depths of the observed places and the horizontal amplitudes observed at those places for oscillations of 0.32^s and 0.10^s periods as given in Fig. 1 (vi), taking the amplitude of the oscillations observed on the ground surface as a unit. The amplitudes of the oscillations observed on the ground surface decrease rapidly, in nearly exponential forms, at increasing depths. To illustrate this, portions of the records are given in Fig. 4, Plate I and Fig. 15, Plate IV. As for the relations between the depths of the observed positions and the vertical amplitudes of the oscillations observed at those places, we have no detailed comparison, for the vertical components were not as fully observed as the horizontal components were. But from several observations we are able to say that the amplitude-decrease of the oscillations at increasing depths are in general not so rapid in the vertical components as in the horizontal components; and the amplitudes of the oscillations of 0.32^s observed at a depth of 20^m are about 40 % in the vertical components and about 20 % in the horizontal components as compared with those observed on the surface of the ground.

5. Vibrations of the building

The Aso Volcanological Laboratory, standing on the top of a hill of volcanic rock covered with a layer of volcanic ashes 20 m. thick, is a reinforced concrete L-shaped building with a tower 25 m. high in the center. The pendulum parts of the seismographs were set at various positions in the building as shown in Fig. 1 (i) and (ii) to study the vibrations of the building, and the following is the result of the observations obtained.

(1) *Predominating vibrations of the building*

The vibrations observed at various positions in the building differ considerably between the motions of the N-S and E-W directions both in period and in mode of vibrations, and also between the horizontal and the vertical components; the predominating periods of vibration observed being 0.37^s and 0.50^s or longer in the motions of the E-W direction, 0.34^s and 0.43^s in the N-S direction, and 0.32^s or shorter in the vertical component. The vibrations observed at different positions in one direction are quite similar to one another especially in the horizontal component. But it should be mentioned that the vibrations observed at the extremities of the wings of the building are more or less disturbed in their lateral directions by vibrations ranging from 0.30^s to 0.33^s periods. This phenomenon will be discussed later in greater detail in connection with the lateral vibrations of the wings of the building. The amplitudes of the corresponding vibrations observed at various positions on the same floor in the building are equal. The higher the floor, the larger the amplitudes of the corresponding vibrations become, as shown in Fig. 1 (iv). This figure shows the relations between the heights of the observing positions and the relative amplitudes of the corresponding vibrations of periods of 0.37^s in the E-W component, 0.34^s in the N-S component, and 0.32^s in the vertical component, in terms of the amplitudes at the basement. As for the vibrations of the other periods, similar relations to the above selected vibrations were obtained, and in general the shorter the periods of vibration, the more rapidly the amplitudes increase with heights. On calm days the mean amplitudes of these selected vibrations were observed at the basement to be of nearly the same magnitude in both direction, N-S and E-W, and the vertical components were one-fourth or less of the horizontal. The rates of increase of amplitude of the vibrations at increasing heights are far greater in the E-W direction than in the N-S direction. This is not due to the direction of wind at the time of observations—NE wind—but probably to the dimension and structural configuration of the tower: in the shorter direction of the sectional plan of the tower (the portion illustrated by thick lines in Fig. 1 (ii)), i. e. in the E-W direction the tower vibrates more easily—the amplitude is larger and the period longer—than in the N-S direction. When the building was excited by strong wind, the 0.37^s period vibrations became more and more predominant, especially in the E-W direction, the amplitudes of which became, independent of the direction of the wind, twice as large as those in the N-S direction in the basement; and sometimes their double amplitudes reached even 4μ or more. The rate of increase of amplitude of 0.32^s period vibrations in the vertical component is very small compared with those in the horizontal component as already seen in Fig. 1 (iv). This is probably due to the mode of these vibrations; that is, the tower moves rigidly in the vertical component, differing from the case of the horizontal motion. These 0.32^s period vibrations in the vertical component observed in the building are perhaps generated by the free-oscillations of the volcanic ash-layer under the building without changes of period and mode of the original oscillations.

(2) *Beatlike vibrations*

Simple beatlike vibrations of 0.35^s periods, given as examples in Fig. 6, Plate I, and Fig. 7, Plate II, were occasionally observed in the tower and its adjoining rooms. The relations between their observed amplitudes and the heights of the observing positions are quite similar to those of the ordinary vibrations of the building already described in the preceding pages. These beatlike vibrations differed from the ordinary in the following respects: first, the corresponding vibrations simultaneously observed were so small (shown in Fig. 7, Plate II) at the observing positions A_0, which are at the end of the east-wing of the building and in a room next to it, that they were utterly masked by the other vibrations, while beatlike vibrations were very conspicuous at F_0, the basement room directly under the tower and its adjoining position. This fact shows that these beatlike vibrations belong only to the tower. Second, in the basement the amplitudes of these beatlike vibrations in the vertical component were of nearly the same magnitude as those in the horizontal component, while the amplitudes of the ordinary vibrations of the building in the vertical component were one-fourth or less of those in the horizontal component in the basement as already described. From these two highly characteristic features, these beatlike vibrations are supposed to belong only to the tower, and may be regarded as vibrations made by the tower in bounding up and down, the ends of the two wings being fixed points, a phenomenon probably caused by the sudden sinking of the ground underlying the tower in as much as it is much heavier than the other portions of the building. Moreover, it is interesting to note that the beatlike vibrations were generally, though not always, accompanied by preceding or succeeding regular vibrations of about 0.50^s periods with durations of several seconds (see previously mentioned figures), having almost the same amplitudes in the vertical component as in the horizontal one in the basement and generally attended by the vibrations of a shorter period. These vibrations of 0.50^s seem likely to exert a direct or indirect effect upon the generation of the beatlike vibrations, but their nature and the mechanism of their actions not being clear at present, their detailed study will be postponed to the future.

(3) *Elastic vibrations of the tower*

As shown in Fig. 5, Plate I, short period vibrations of about 0.13^s were observed in the tower, especially marked in the N-S direction, mingled with the ordinary rocking vibrations. These were sometimes about 0.5μ in double amplitudes at the top of the tower on windy days. These vibrations are thought to be elastic vibrations of the tower, for they are suddenly increased in amplitudes beginning at the third floor, at the place where the tower is joined to the main building. It must be mentioned that this tendency of predominance in the N-S direction of the vibrations of shorter period plays a significant rôle in the vibrations of the tower generated by the dropping of a stone upon the surface of the ground outside the building, the accounts of which will be described in a later paragraph.

(4) *Lateral vibrations of the wings of the building*

In comparing the records obtained by simultaneous observations at F_0, the basement room directly under the tower, and at A_0, the end position of the east-wing of the building, we notice that the motions in their longitudinal direction along this wing (the E-W component) are exactly the same, even in details, while in the lateral direction (the N-S component) show different appearances at both positions, especially marked during excited states, as shown in Fig. 7 and 8, Plate II, and Fig. 12, Plate III. Similar relations are observed by comparing the motions observed simultaneously at two positions F_0 and $_nE_0$, the end position of the north-wing of the building: that is, in this case, the motions in the E-W lateral direction of the wing, observed at $_nE_0$ are disturbed by different vibrations as compared with those observed at F_0 as shown in Fig. 8, Plate II, while in the N-S longitudinal direction, the motions observed at these two positions are quite similar both in amplitude and phase. These complexities of the motions observed in the lateral direction of the wings of the building become more and more marked as the building and the ground are excited by wind and some other disturbances, and the same tendencies are observed quite similarly on every floor of the building. The transitive changes of vibrations along the wings of the building in their lateral directions were recorded as shown in Fig. 10, Plate II, by simultaneous observations with several seismographs placed along the passage-way of the wing. And the motions observed even in the north room next to F_0 showed a somewhat different appearance in their lateral direction (the E-W component) as compared with those observed at F_0 when the building and the ground were excited by wind. (See Fig. 11, Plate III.) These facts lead us to conclude that the phenomena are caused by the lateral elastic vibrations of the wings of the building. This conclusion was further ascertained by the following observations: The simultaneous observations made at such positions as F_0, A_0, the pit No. 5 (outside the building and 8 m. N apart from A_0), and the pit No. 6 (outside the building and 8 m. S apart from A_0), show that the motions observed at A_0 in the lateral direction of the wing (the N-S component) resemble those observed at the pits No. 5 and 6 rather than those observed at F_0, as shown in Fig. 12, Plate III. The same phenomena were also found in a slight degree between the motions in pits No. 1 and 2, and in the north-wing of the building. Thus it may be concluded that the interaction between the horizontal motions of the building and those of the surrounding ground are more marked in the lateral direction of the wing of the building, in which direction the wing is more flexible than in the longitudinal direction.

6. Interactions between the motions of the building and those of its surrounding ground

To study in detail the interactions between the motions of the building and those of the near-by ground, simultaneous observations were made at various points in and outside the building when the building and the ground were excited by a severe wind, about $30^{m.}/_{sec.}$, caused by the typhoon of Sep. 24, 1935 which passed along the east coast of Kyûshû. This typhoon was advantageous to us in determining the limit of the effects of the motions of the building upon those of the surrounding ground. The motions observed at pit No. 1 (1.4 m. apart from the building and shown together with the other pits in Fig. 1 (ii)), are nearly the same in the horizontal component as those observed at F_0 (the basement room directly under the tower), excluding the short ground oscillations of 0.10^s which are not observed in the building. But in this case the vertical motions observed at both places show considerable differences. Almost identical vibrations are observed at pit No. 2 (4 m. apart from the building) as are observed at F_0, but when we proceed to pit No. 3 (11 m. apart from the building), the difference of the motions between this pit and F_0 becomes conspicuous even in the horizontal component as shown in Fig. 13, Plate III, and the motions observed at the former show closer resemblance to those observed at pit No. 4 (24 m. apart from the building) than to those observed at F_0. The simultaneous observations made at pit No. 4, pit G (at a horizontal distance of ca. 75 m. NNW from F_0), and at pit No. 8 (the middle point of pit No. 4 and G), show that the motions observed at G are quite different from those observed at pit No. 4. At G, only the proper oscillations of the ground are observed, unaccompanied by the vibrations of the building which are yet notably observed at pit No. 4. The motions of pit No. 8 more closely resemble those observed at G than those of pit No. 4. The above facts lead us to the conclusion that, with reference to horizontal oscillations of periods ranging from 0.3^s to 0.5^s, the ground a few meters from the building moves with it, and the effect of the vibrations of the building upon the motions of the surrounding ground gradually decreases with the increase in distance from the building, and that no effect of the vibrations of the building can ordinarily be observed at a distance beyond 30 m. from F_0, or beyond a distance of about 50 m., a value comparable to the length of the building, even on days when the speed of wind is ca. $30^{m.}/_{sec.}$ or more. As to the vertical motions, the oscillations proper to the ground being observed with no considerable variation in periods and modes of oscillations at every point in the building, the vertical motions observed at two positions somewhat separated on a horizontal plane in the building, owing to the random oscillations of the ground, show considerable differences. That is, the building shows flexural vibrations in the vertical component as well. By this may be elucidated the observed facts that the vertical motions observed even at pit No. 1 (1.4 m. apart from the nearest wall of the building and 10 m. apart from F_0) differ considerably from those observed at F_0, while the horizontal motions observed at both positions are quite similar. But it ought to be noticed that the vertical motions observed at every position on one *vertical projection are all similar on every floor in the building*. Thus, from obtained facts, the building rocking to and fro on the restless ground may be likened to a wooden block floating on the surface of a disturbed body of water.

7. Vibrations generated by the falling of a stone

In connection with each observation the vibrations generated by the falling of a stone of 160 kgr. wt. was recorded. The stone was dropped from a height of 1.5 m. above the surface of the ground at the point S shown in Fig. 1 (ii), by cutting the suspension wire connected with a chain block hung from the supporter with three legs of log. The instant the suspension wire was cut was also recorded by the extinguishing of a light spot on a fixed mirror illuminated by a lamp which used the suspension wire as a part of its electric circuit. The period of the vibrations generated by the falling of the stone were observed to be about 0.10^s at the ground outside the building and about 0.16^s at the positions in the building shown as examples in Fig. 4, Plate I and Fig. 9, Plate II; and the propagating velocity of the first impulse observed was $280\ ^{m.}/_{sec.}$, the wave-length thus being about half the length of the building. The first impulses observed both in and outside the building are thought to be waves generated by the collision of the stone with the surface of the ground which were transmitted in the ash-layer directly to the observing stations. This judgment is based on the differences in the time of commencement, their emergent angles and azimuths. It is important to notice that the vibrations generated by the falling of the stone showed a rapid decrease, especially marked in the horizontal component, at every observation point inside the building, as compared with those observed on the ground outside the building. In Fig. 2, the loci of the horizontal vibrations generated by the falling of the stone observed at various points in and outside the building were traced from the first to the fourth motions. The azimuths of vibra-

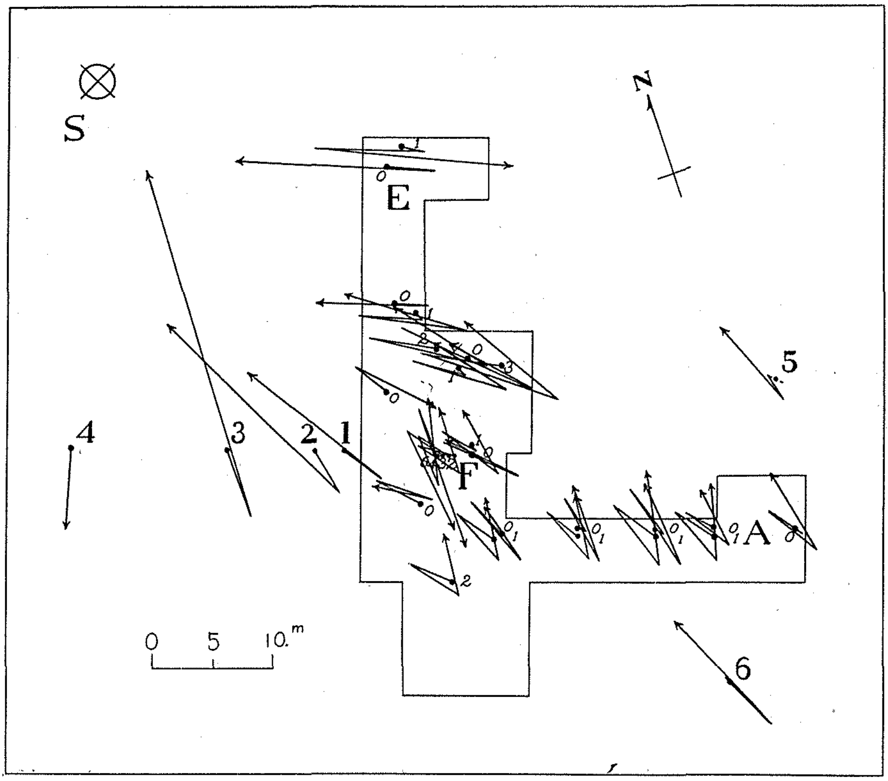


Fig. 2

Movements in the horizontal component generated by the falling of the stone. (*S* is the position where the stone was freely let fall. The black circular spots show the position where the pendulums of the seismographs were set, and their annexed figures indicate the numbers of the pits outside the building and the floors in the building.)

tions observed at pits No. 4 and 3 (24 m. and 11 m. apart from the building respectively) point to *S* (the point where the stone was dropped), but those observed at pits No. 2 and 1 (4 m. and 1.4 m. apart from the building respectively) show a considerable deflection from the direction of *S*. The vibrations observed at every position in the north-wing of the building are all polarized in the E-W direction, while those observed at every position in the east-wing are gradually polarized in the N-S direction. Thus the vibrations generated by the falling of the stone observed at every position in the building and at its near-by ground were all somewhat disturbed by the lateral vibrations of the wings of the building. And really the new phases of the westward motions, regarded as being caused by the vibrations of the building, were observed at pits No. 1 and 2, 0.08^s after the time of commencement of first motion. The vibrations observed in the tower higher than the third floor, (at which level the tower rises above the main building), are all polarized in the N-S direction following the second or third motions, thus differing from the vibrations observed at other near-by positions on lower floors. This fact corresponds to the partial predominance of the tower vibrations in the N-S direction with respect to the 0.13^s period vibrations already described, the periods of which are in nearly the same as those of vibrations generated by the falling of the stone. Furthermore, the polarization in the N-S direction of the vibrations observed at pit No. 5 (8 m. N apart from A_0) can be explained by the effect of the lateral vibrations of the east-wing of the building, but the vibrations observed at pit No. 6 (8 m. S apart from A_0) maintain the true azimuths, being undisturbed by the building. The reason why the motions of the two ground positions both being equally distant from and symmetrically situated with respect to the east-wing of the building are different, seems to be due to the fact that pit No. 5 is situated inside while pit No. 6 is outside the domain of the L-figure of the building. Next, at the positions near S, micro-vibrations of about 0.10^s periods on the ground and of somewhat longer periods inside the building were observed, preceding the main shocks generated by the falling of the stone. (Shown as examples and denoted for the sake of convenience as *r*-waves in Fig. 4, Plate I.) Calculating from the time they began, these micro-vibrations were sent forth from point S before the falling stone reached the ground. These vibrations are thought to have been generated by the sudden relieving of the ground tension by the cutting the wire suspending the stone. The mean amplitude of these micro-vibrations was estimated to be one-twelfth of that of the main shocks. From this fact it can be calculated that several per cent of the kinetic energy of the free falling stone was transformed into elastic waves.

8. Volcanic micro-tremor of the first kind

The volcanic micro-tremors with periods of about 1.0^s are fully discussed in Mr. Sassa's paper.[1] These oscillate with the same amplitudes and modes at all positions in and outside the building as shown

1. K. Sassa: loc. cit.

in Fig. 14, Plate III; that is, in the case of these tremors, the building moves horizontally as a unit. The ratio between the amplitudes observed directly on volcanic rock (at pit P, 20 m. in depth) and those observed on the surface of the ground is 0.85/1.00.

9. Summary

The ordinary vibrations of the building of the Aso Volcanological Laboratory and its surrounding ground were observed with five horizontal and two vertical component micro-seismographs of very high magnification (about 20,000 maximum), and the following results were obtained:

1. The periods of prevailing vibrations observed are as follows:

the foundational volcanic rock		0.55^s
the superficial volcanic ash-layer		0.32^s and 0.10^s
the building	N-S	0.34^s and 0.43^s
	E-W	0.37^s and 0.50^s
	V	0.32^s and 0.20^s

2. The amplitudes of oscillations observed in the superficial ash-layer suffer a rapid decrease in nearly exponential form with increasing depths. The shorter the period of oscillation, the greater the decrease of the amplitude. The amplitudes in the vertical component decrease less than those in the horizontal component.

3. The ordinary vibrations observed in the tower of periods ranging from 0.34^s to 0.37^s show considerably larger amplitudes in the E-W direction than those of the N-S direction. On the other hand, the shorter elastic vibrations of the tower of 0.13^s periods are conspicuous in the N-S direction. Thus the building behaves differently in different directions, its motions being characterized by its structural configuration.

4. Simple beatlike vibrations of 0.35^s periods were observed in the tower and at positions adjoining it. These vibrations are regarded as bounding vibrations of the tower, probably generated by the sudden sinking of the ground beneath the tower of the building.

5. It was observed that the building vibrates somewhat elastically in the lateral and the vertical directions.

6. The motion of the ground immediately surrounding the building is influenced by its vibrations, but beyond such distances from the building as are comparable to its length the motions are not even slightly influenced by the vibrations of the building even when excited by a severe wind.

7. A stone weighing 160 kgr. was dropped at a ground position near the building, and vibrations generated by it were observed in and outside the building. The azimuths of these vibrations, their wave-length being about half the length of the building, were strongly deflected from their normal planes of vibration by the effects of the lateral vibrations of the wings of the building, the elastic vibrations of the tower, and other disturbances.

In conclusion the writer wishes to express his cordial appreciation to Assist. Prof. K. Sassa for his kind guidance and advice throughout the course of this study.

Plate I

Fig. 3

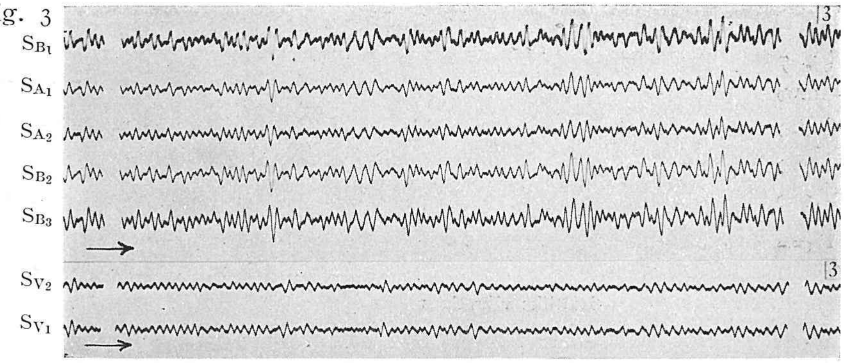
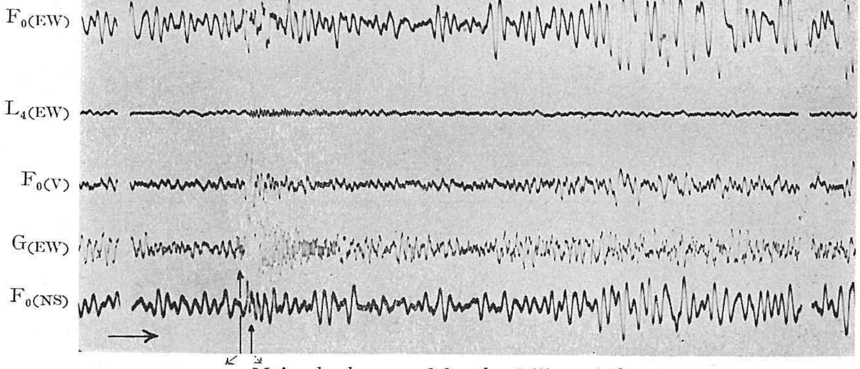


Fig. 4



r-wave, Main shocks caused by the falling of the stone

Fig. 5

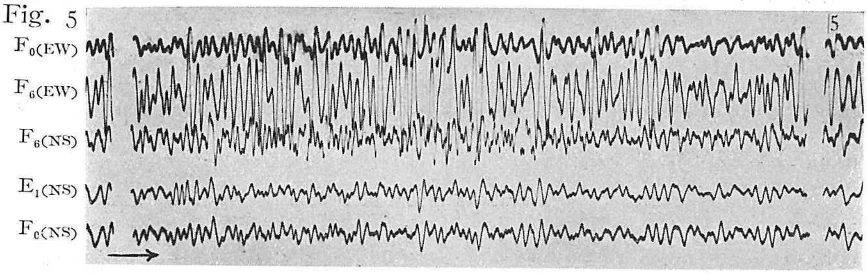
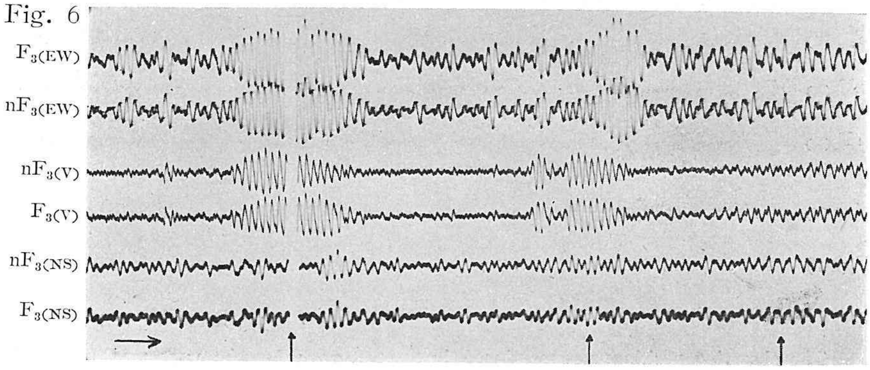


Fig. 6



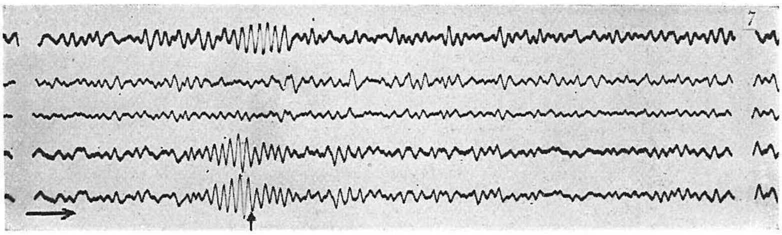
Beatlike vibrations Beatlike vibrations, 0.50^s period vibrations

(3/5 × the original records)

In all records in Plates I, II, and III, the interval between two consecutive time marks is 30^s, and the upward movements on the records correspond to the north-, east-, and upward motions of the ground respectively. The observing positions not mentioned in the text are L_4 (the end of the adit L) and nF_3 (the north next room of F_3).

Plate II

Fig. 7



Beatlike vibrations

Fig. 8

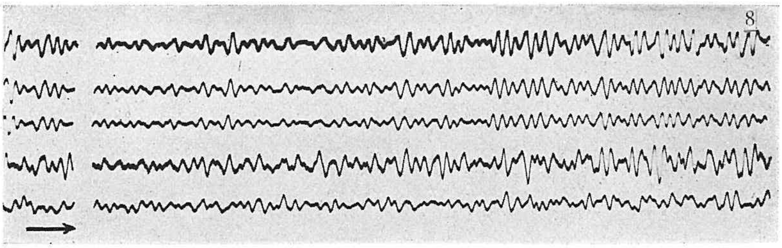
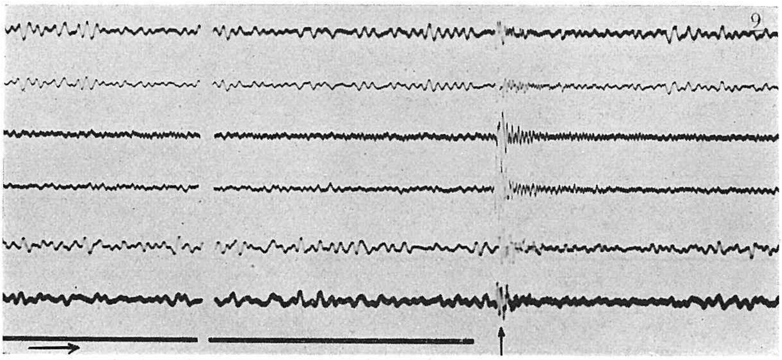
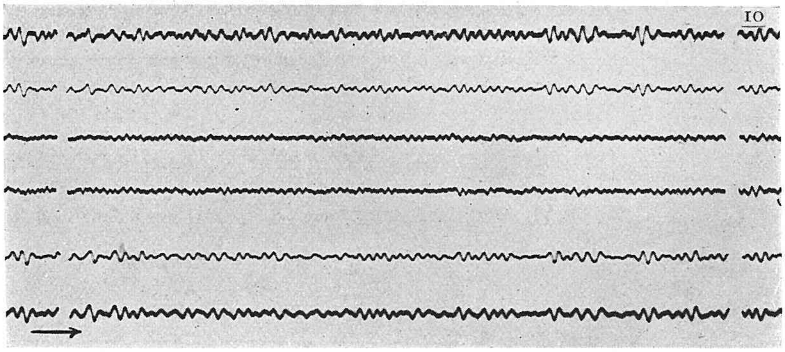


Fig. 9



Vibrations generated by the falling of the stone

Fig. 10



(3/5 × the original records)

The observing positions not mentioned in the text are wA_0 (the west next room of A_0), sF_0 (the south next room of F_0), nE_0 (the north end of E_0), sE_0 (the south position of E_0), and nW_0 (the middle of the passage-way of the north-wing of the basement floor).

Plate III

Fig. 11

Fig. 12

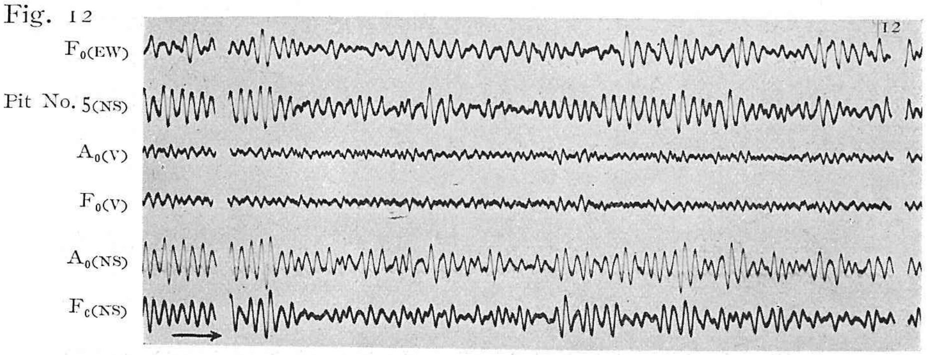


Fig. 13

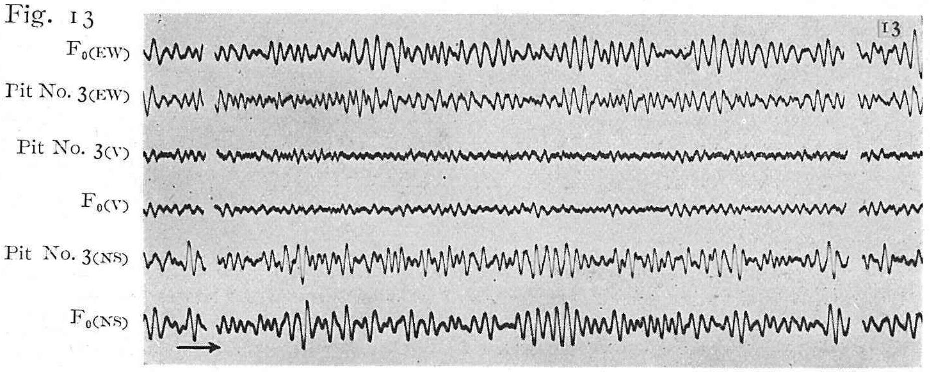
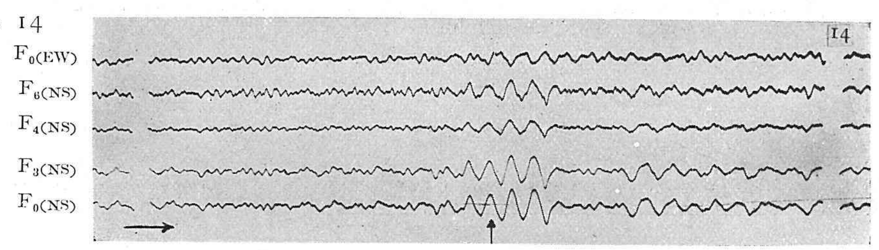


Fig. 14



Volcanic micro-tremors of the first kind.

(3/5 × the original records)

The observing position nF_0 is the north next room of F_0.

Plate IV

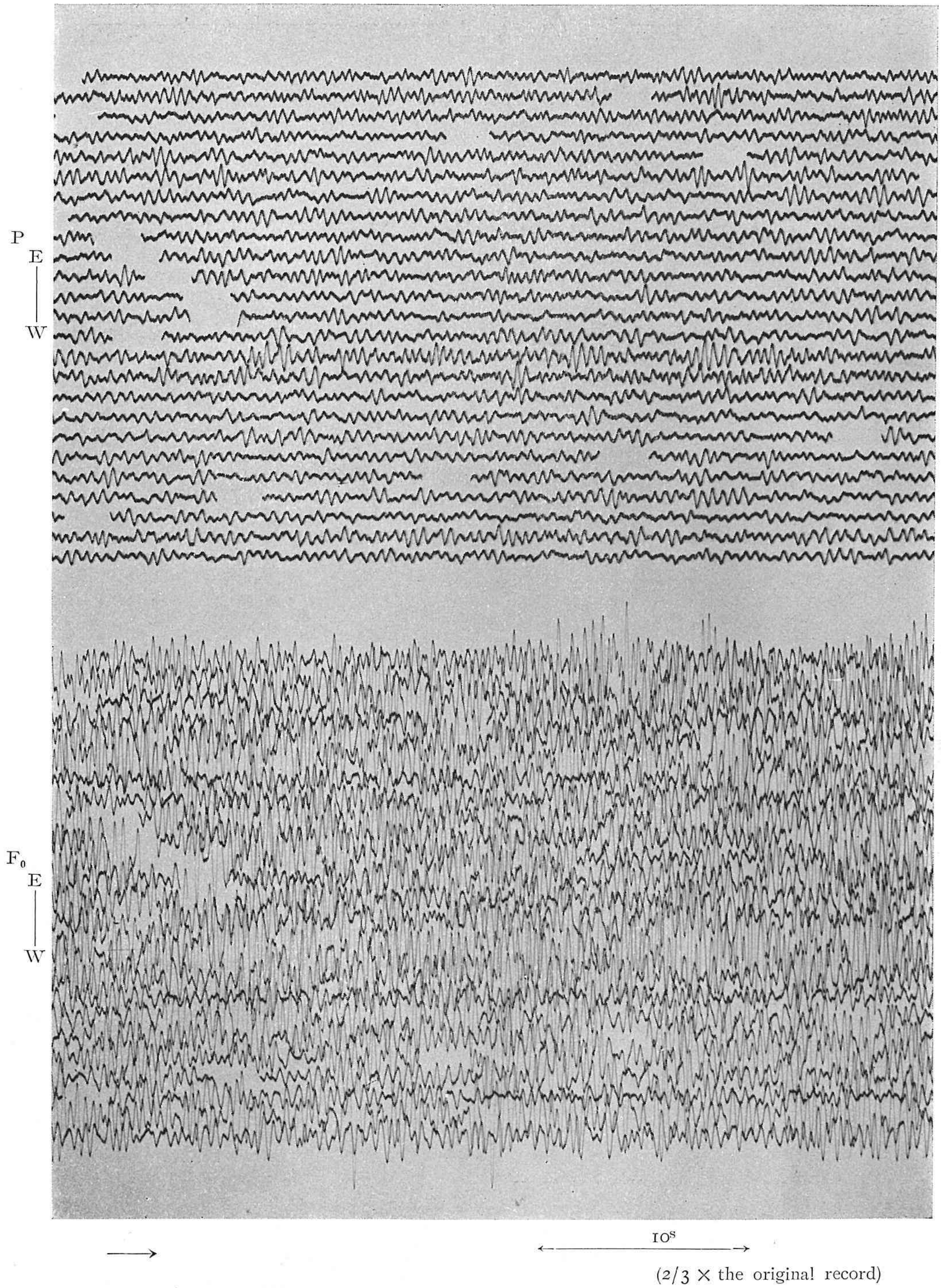


Fig. 15

Comparison of the amplitudes of the oscillatory motions excited by strong wind (about $15^{m.}/_{sec.}$) observed on volcanic rock in the pit P of about 20m in depth outside the building with those observed at the basement room F_0 in the building. Both were observed with S_B-type micro-seismographs.