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NATURE OF THE VOLCANIC MICRO-TREMORS AT THE VOLCANO ASO PART 2

BY

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Part 2. Some Natures of the Volcanic Micro-Tremors of the 1st kind at the Volcano Aso

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Abstract

Some observations was carried out to examin the natures of the volcanic micro-tremors of the 1st kind at the Volcano Aso, that is, tripartite method with horizontal seismographs for determining the velocity and the direction of propagation of the tremors and observation with three components seismographs for examining oscillatory modes of the tremers. The results obtained in this observation are compared with that given by Sassa in 1933. The mechanism of origin generating the tremors is discussed. It is confirmed that the volcanic micro-tremors of the 1st kind, found by Sassa at the Volcano Aso, is generated near or at the crater. The period of the tremors is predominant in 0.8～2.0 sec. and the propagation speed (corresponding to phase velocity) is about 1.2～1.35 km./sec.. The distribution of oscillatory modes obtained in the Caldera are compatible with the mechanism suggested by Sassa. It is pointed out that a close relation exists between the oscillatory mode and the direction of valley or cliff near the observing station, namely the longer axis has a tendency to predominate along the direction of valley or cliff.

1. Introduction

According to Sassa's geophysical studies[1], the volcanic micro-tremors associated with the activity of the Volcano Aso are clssified into four kinds of tremors. Among them the micro-tremors of the 1st kind with the period range from 0.8 to 2.0 sec. did not occur in continuous wave-trains, but intermittently, several groups per hour, each of which consisted of five to ten somewhat regular waves of 1 μ or less in double amplitude. The vertical component is defect or very small and the amplitude observed in a pit is small in comparison with that on surface, and hence the tremors are polarized in horizontal plane and are waves of Love type. Furthermore, Sassa[2)] examined the oscillatory modes of the tremors to suggest the mechanism of origin. Frequency of occurrence, amplitude and period of the tremors were likely to be closely related with the activity of the volcano, and moreover the mechanism of origin seems to change its mode with variation of activity. Henceforth, Sassa pointed[3)] out a possibility of predicting an eruption of volcano by observing this kind of tremors as well as the other kinds of tremors. The writer aimed to observe the tremors of the 1st kind in more detail than made hitherto.

2. Instrument

Since the period of the tremors of the 1st kind is generally predominant in 0.8 to 2.0 sec., a seismograph with the peak of its magnification curve in about 1 sec. is suited for our purpose. Two vertical and three horizontal components were prepared, of which all are electromagnetic seismographs of moving-coil type. Their constants and characeristic curves are listed in Table 1 and shown in Fig. 1, respectively. The constants were precisely calibrated, since one of our aims is determination of the oscillatory mode by drawing the locus (as seen in Fig. 2). These seismographs will be

Table 1. Constants of seismographs.

Component	T_1 (sec)	T_2 (sec)	h_1	h_2	V_{max}
Horizontal (SH-2)	2.0	2.0	1.0	1.0	12000
Vertical (SH-3)	2.0	2.0	1.0	1.0	7000
Vertical (SH-2)	0.85	3.4	1.0	1.0	16300

T_1 : Period of pendulum
T_2 : Period of galvanometer
h_1 : Damping constant of pendulum
h_2 Damping constant of galvanometer
V_{max} : Maximum magnification

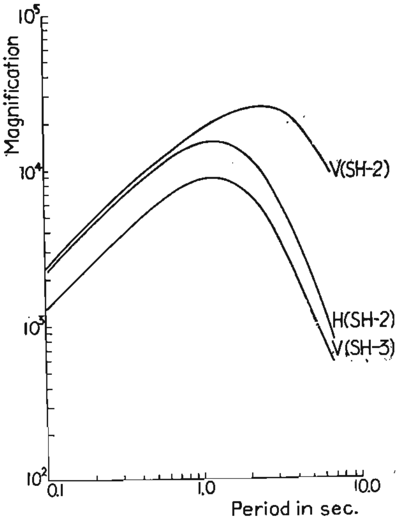

Fig. 1. Chracteristic curves of seismographs.

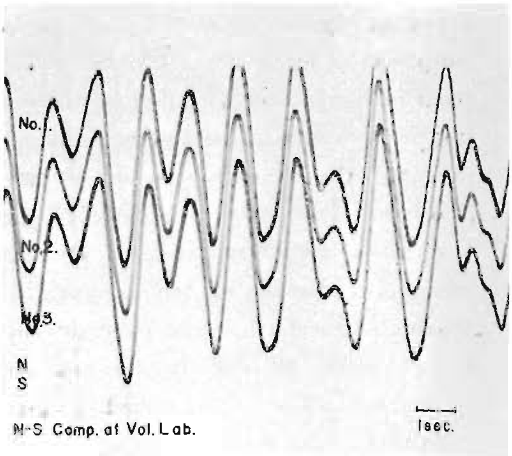

Fig. 2. A portion of the seismogram of comparison of the three horizontal seismographs (SH-2).

described for abbreviation by SH-2 horizontal, SH-2 vertical and SH-3 vertical (as shown in Table 1 and Fig. 1).

3. Determination of propagation direction and velocity by tripartite method

According to Sassa's paper[4], it is reported that the propagation velocity of the tremors of the 1st kind is 0.99 km./sec., assuming that the origin of disturbance is just below the bottom of the 1st crater. The value, however, was obtained from only two observing data, that is, at the Aso Volcanological Laboratory and Hondô observing room near the crater, and hence the accuracy is not always well. The propargation velocity of microtremor is usually determined by tripartite method, since, generally speaking, the initial phase can not be recognized. At the Aso Volcanological Laboratory, a tripartite net was spanned, which was a regular triangle with its length of side of 580 m. and of which one side was deviated in 6° northwards from the line drawn from the Laboratory to the 1st crater. On the other hand, at Koborimaki situated in NE direction from the crater (the Laboratory westwards from the crater as seen in Fig. 3), another tripartite net was spanned, which was an scalene with the following different lengthes

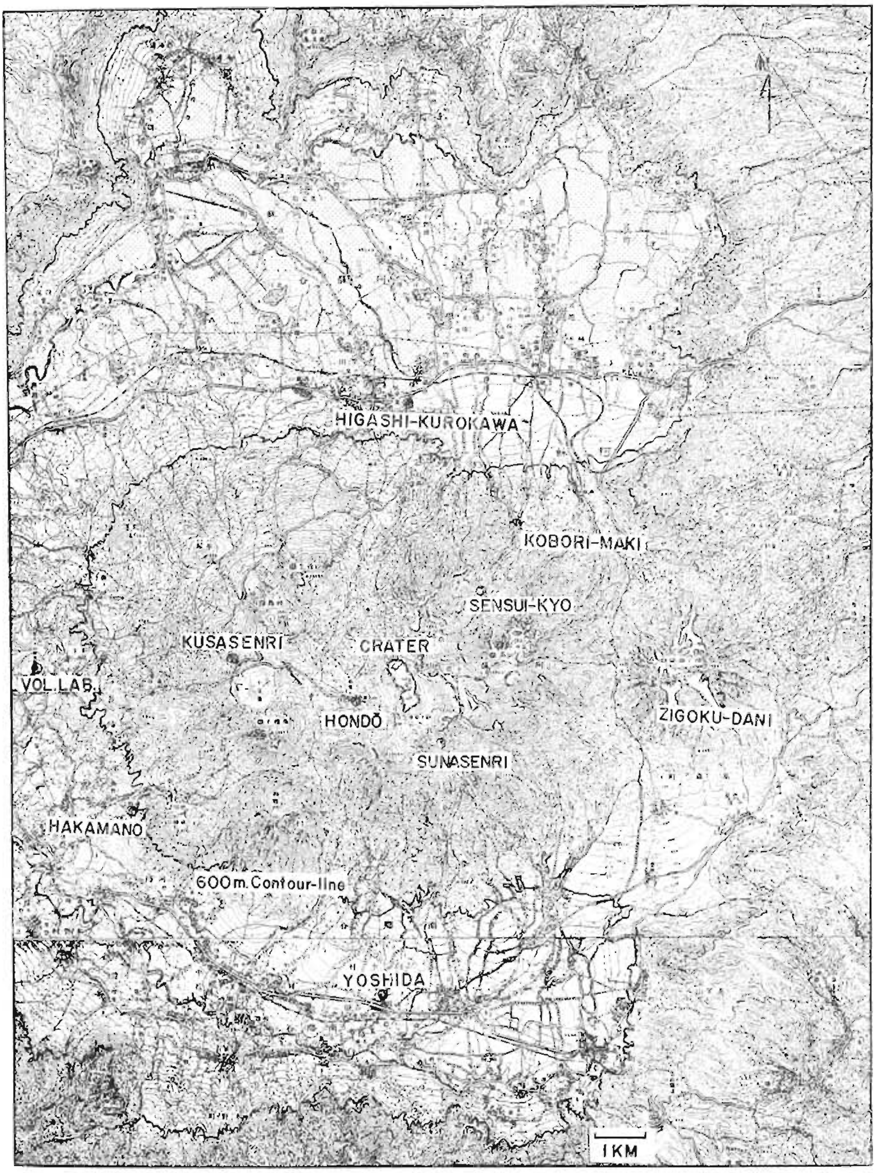

Fig. 3. Map of the observing station in the Aso-caldera.

of sides ; 700, 550 and 480 m., respectively, and of which the side of 480 m. was deviated in 21° northwards from the line drawn from Kobori-maki to the 1st crater. Three seismographs of SH-2 horizontal component were set for each observing system. An example of records obtained at the Volcanological Laboratory is shown in Fig. 4, in which regular sinusoidal waves with period of about 1 sec. are the tremors of the 1st kind. Picking up such clear phases as marked by arrow in Fig. 4, time difference of each pair was read.

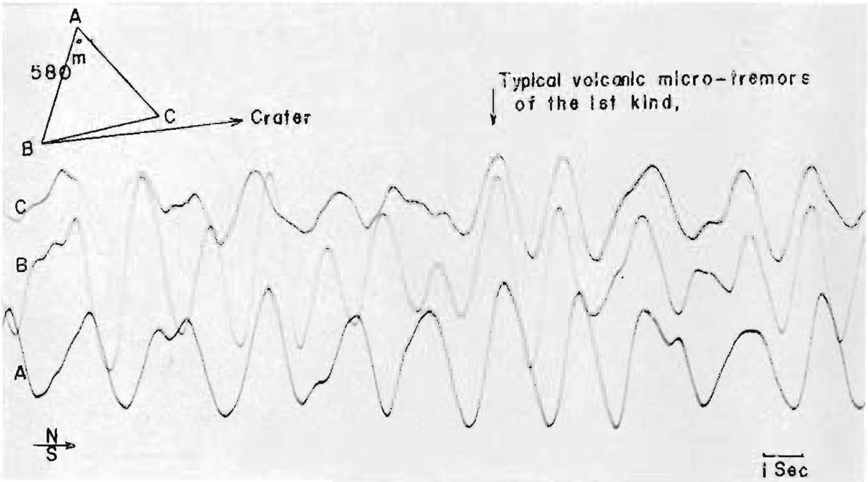

Fig. 4. An example of record obtained by tripartite method, at the Vol. Lab. on Mar., 10, 1961.

Number of phases identified amounts to about 180 for the records obtained at the Laboratory, while only 10 for those obtained at Koborimaki. The ditribution of propagation direction does not have enough sharp peak to determine uniquely the most probable direction. At the Laboratory, the directions distribute in the range from E20°N to E80°S., and the average direction corresponding to the peak of distribution curve points to E20°S.. On the other hand, at Kobori-maki, number of fully regular waves to be used for analysis are not over about 10, and all directions distribute in the range from S7°W to S73°W. These results are shown in Fig. 5 and Fig. 6. From the latter figure, it may be suggested that the origin of the tremors of the 1st kind appears to be situated near the place of about 1 km. southwards from the 4th craters (the craters are named the 1st, 2nd, 3rd

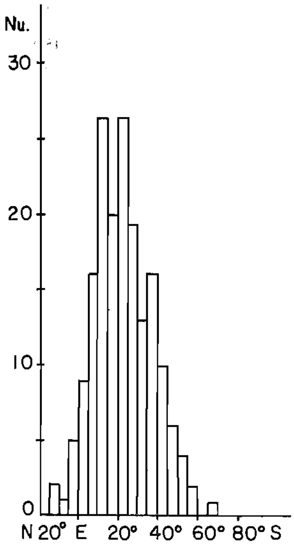

Fig. 5. Graph showing the frequency distribution of arrival direction of the volcanic micro-tremors of the 1st kind observed at the Vol. Lab..

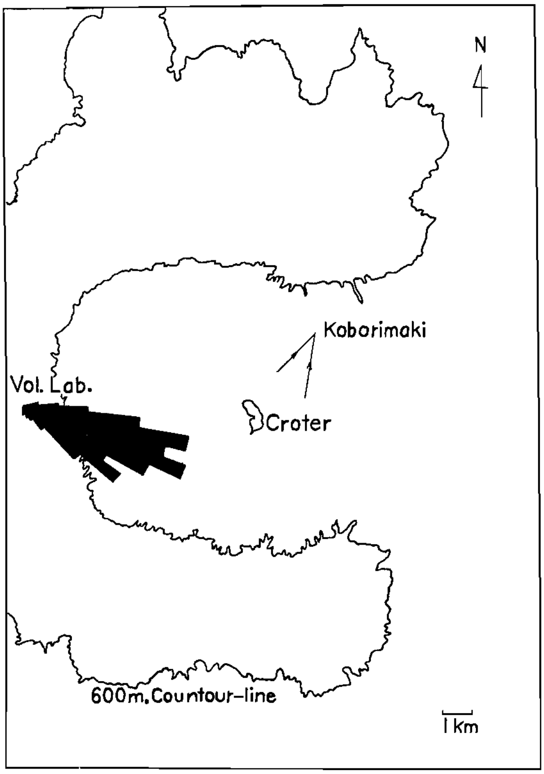

Fig. 6. Arrival direction of the volcanic micro-tremors of the 1st kind at the Vol. Lab..

Table 2. The list of observing station.

Station	Azimuth from the crater	Distance from the crater	Elevation	Method of observation
The Laboratory	W	7.3 km	568 m	Tripa. & 3-comp.
Hakamano	W27.7°S	5.7	580	3-comp.
Yoshida	W87.5°S	5.1	480	3-comp.
Zigoudani	S80.0°E	6.6	1040	3-comp.
Higashi-kurokawa	S 8.6°E	5.3	548	3-comp.
Kusasenro	W 9.2°N	3.2	1100	3-comp.
Sensui-kyo	E46.5°N	2.4	900	3-comp.
Hondô	W41.5°S	1.0	1170	3-comp.
Sunasenri	S34.0°E	1.8	1280	3-comp.
Kobori-maki	E48.0°N	3.7	700	Tripa.

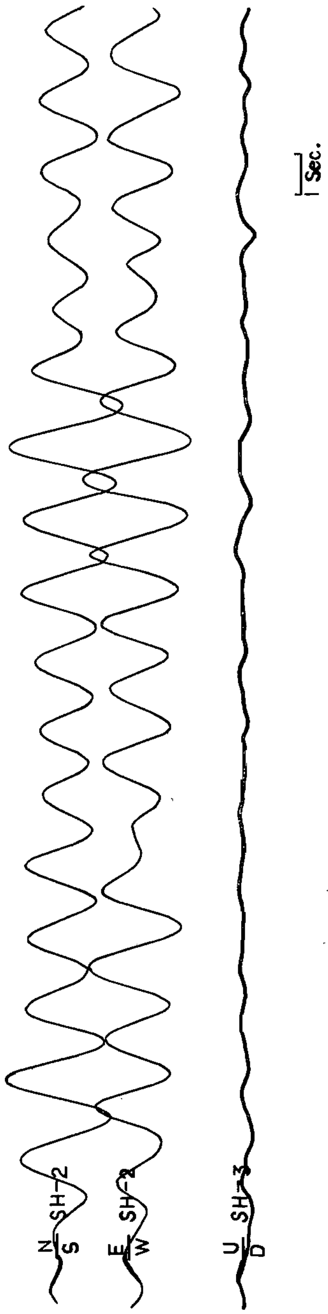

Fig. 7. A protion of record obtained at Zigoku-dani on Mar., 17, 1961, showing the most typical volcanic micro-tremors of the 1st kind.

and 4th consecutively from the north). However, this suggestion seems to be optimistic. For example, owing to exsistence of any anormaly in geological structure, deflection of wave causes the deviation of its propagating direction. In fact, Sassa[5] reported that the deflection of earthquake waves were found at the Laboratory and there might be an anormaly in geological structure of upper crust.

The propagation speeds also distribute in the range from 0.6 to 5.0 km./sec.. The average speed of propagation is 1.2 km./sec. for the data obtained at the Laboratory and 1.35 km./sec. at Koborimaki, respectively. These values are regarded as phase velocity and if the tremors of the 1st kind are a kind of surface waves of Love type, the variation of velocity with period may be found. In fact, such variation can be found, at least tentatively, but the quantitative estimation can not be possible, notwithstanding the fact that appreciably regular waves were recorded. At any rate, it is thought reliable that the tremors of the 1st kind are originated near or at the crater. The southwards deflection, dispersive property and etc., as above described, will be examined in the further study prepared at our Laboratory.

4 Oscillatory mode

According to Sassa's paper[6], the tremors of the 1st kind are of Love type, that is, horizontally polarized. And that he determined the distribution of oscillatory mode by observing the tremors in three components at several observing stations in the Aso-Caldera. Moreover, he suggests that the mechanism of origin is a doublet in active stage of the volcano while a singlet in quiescent stage, situated at the north wall of the 1st crater, and each oscillator is polarized in horizontal plane.

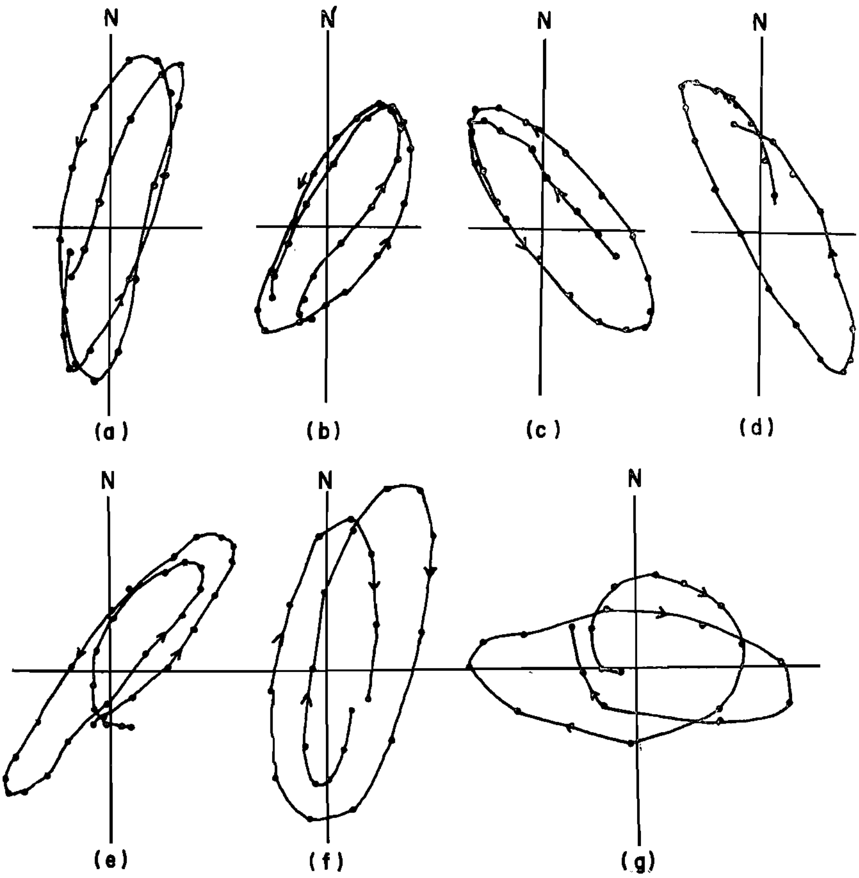

Fig. 8. Typical orbits on horizontal plane of the volcanic micro-tremors of the 1st kind. (a) : Vol. Lab., (b) : Hakamano, (c) : Zigoku-dani, (d) : Higashi-kurokawa, (e) : Kusasenri, (f) : Sensui-kyo, (g): Hondô.

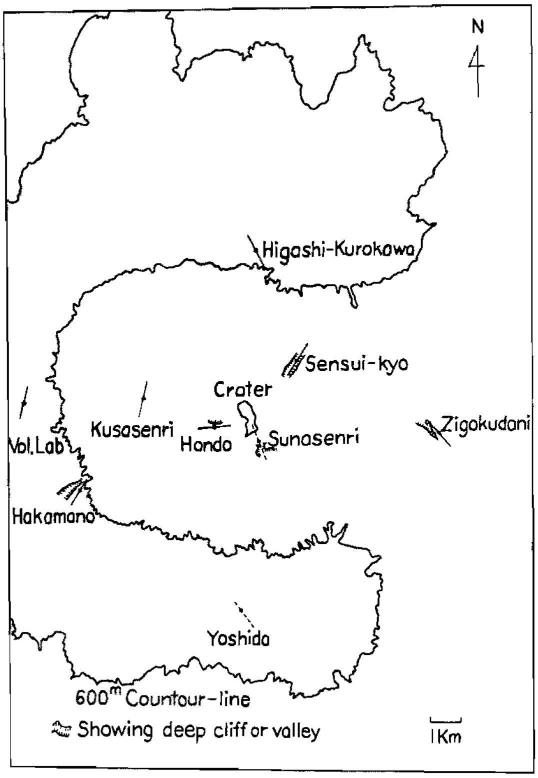

Fig. 9. Direction of the major axes of the volcanic micro-tremors of the 1st kind.

To examine more precisely the mode of the tremors, the writer carried out observation with three components of seismographs at nine observing stations in the Aso-Caldera, of which the locations are shown in Fig. 3 and Table 2. A typical example of records obtained at Zigoku-dani is shown in Fig. 7. In the other records as well as this record, the vertical component is slightly found, but examining them in detail, the vertical component increases somewhat with decreasing of the distance between the station and the crater, but

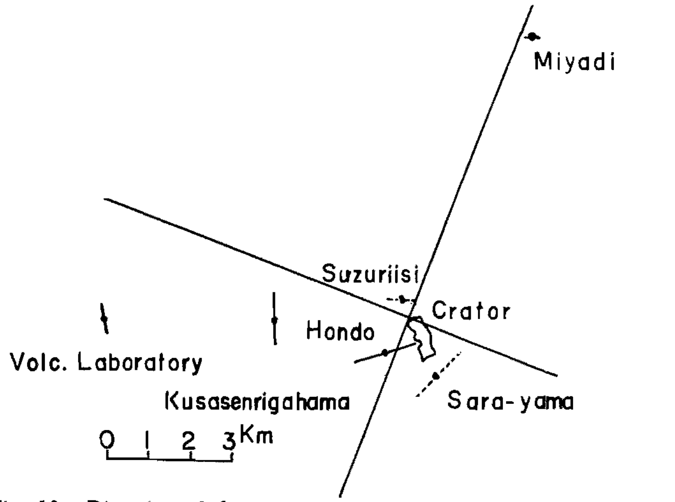

Fig. 10. Direction of the major axes of the volxanic micro-tremors of the 1st kind (after Sassa, 1933).

not over 1/10=amplitude of vertical comp./amplitude of horizontal comp.. Picking up as regular waves as possible, the locus in horizontal plane was drawn. Some examples are shown in Fig. 8. Most loci obtained show appreciably regular elliptic forms, and hence those waves may be thought undisturbed by noise caused from any unknown force. The longer axes of those loci also coincide with each other almost on each wavelet in a single-wave train. The average directions of these axes obtained at the observing points are indicated in Fig. 9, in which the directions obtained at Yoshida and Sunasenri are indicated by dashed lines, since the observed waves at the both stations were not regular so that the loci were appreciably distorted.

Let us compare these oscillatory modes with the previous results obtained by Sassa[7] (see Fig. 10). Since the results obtained by Sassa express the condition in Aug. 1933, and the writer's in Mar., 1960, the both results would be not always same. In fact, if the location, dimension and physical properties of origin change, the period, amplitude and mode of the tremors of the 1st kind shoud be forced to change. In other words, examining the variation of the oscillatory mode enable us to obtain some informations on the development of the origin. From this point of view, several interesting suggestions can be deduced from comparing both data. The ocillatory modes at the Laboratory and Kusasenri seem to be almost unchanged, while the mode at Sunasenri is appreciably different from the previous one at Sarayama, of which location is deviated about 10° from the former observing point when the each observing point is connected by straight line with the origin suggested by Sassa, and the distance between both points about 600 m., but the difference between both directions of oscillatory mode amounts to 50°. This discrepancy in the directions appears to be untenable to the mechanism given by Sassa, but the variation of oscillatory mode is extremely large near the origin, especially in close vicinity to an axis. That is, oscillatory mode is remarkably distorted by the slight difference of distance from origin, or angle between observing point and axis. The oscillatory modes found at the Laboratory, Kusasenri, Hondô, Sunasenri and Sensui-kyo are likely to be compatible with the mechanism (in the case of $n=2$[8]) of the origin, adopted previously by Sassa, excepting the slight removing of origin and the rotating in some degree of of the axes, on which the azimuthal displacement alone appears and the tangential disappears. On the other hand, the oscillatory modes found at Hakamano, Yoshida, Zigokudani and Higashi-kurokawa can not be reconciled with the mechanism. To find the effect of irregularity in surface structure on the mode, cliff or valley closely situated at the observing points are shown in Fig. 10. From the figure, the tendency of predominating of oscillatory direction along the valley or cliff seems to be recognized. The modes at Hakamano and Zigokudani may be deviated due to such a effect, and those at Higashi-kurokawa and Yoshida may be so, if there are any anomalous structure beneath the observing points. Of course, those at Hndô, Sensui-kyo and Sunasenri, must be influenced by the existence of cliff or valley near the observing point, those points are situated relatively near the nodal axes and hence the deviations do not appear to be conspicuous, since the cliff and valley is pointed to the favourable direction.

However, the effect of structure on propargation of Love Wave is at present not studied enough to be dealed with quantitatively and hence it must be remenbered that the explanation, as above described, is simply a suggestive one. Since the further observations are aimed by the writer, the more information on this problem may be obtained.

5. Conclusion

In the present paper, the location of origin of the volcanic micro-tremors of the 1st kind is mainly dealed with. From the observations at two points by tripartite method, it is deduced that the origin is situated southwards in 1~2 km. from the south end of crater, in spite of our expectation that the origin may be near the 1st crater, the north end of crater. However, considering each value obtained on propagation velocity and direction is considerably different from the other, and remenbering the suggestion of existence of anomalous structure, causing the deflection of of wave, it is probable that such deflection is recognized in the propagation of the volcanic micro-tremors of the 1st kind.

On the other hand, the observations in three components of the volcanic micro-tremors of the 1st kind were carried out at nine stations in the Aso-Caldera. From their orbital motions, this tremors are horizontally polarized and of Love type as pointed out previously by Sassa. The distribution of the oscillatory modes also seems to support Sassa's opinion on the mechanism of origin, disregarding the slight removing of the location of origin and the rotation of the axes in some degree. Of course, a question whether this slight change of coordination of origin expresses any true change of mechanism or not, could not be resolved without the further observation and analysis. To increase number of observing points in the Caldera in future enable us to resolve the question, whereas the effect of structure beneath path of propagation on oscillatory mode should be fully considered not only experimentally but also theoretically. At any rate, it is suggested that the longer axis of orbit predominates along valley or cliff near the observing station.

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