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Visit to Japanese Volcano Observatories

by

M. G. Mancini

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SUMMARY

The main volcano surveillance installations in Japan were visited from the 3rd to the 29th August, 1970. The tour included 8 volcanic complexes and 16 observatory stations. Seismic methods for surveillance and detection of volcanic eruptions were discussed with leading Japanese volcanologists. The most outstanding points were:

- Focus determinations of volcanic tremors and applications of the Omori formula
- Field Investigations to improve the knowledge of seismic characteristic for each volcano
- VHF equipment and solar cell batteries employment in remote stations
- Volcanic tremor classifications
- Seismic activity before and after a volcanic eruption
- Light table reading and ink pen recording

Rotation of professional staff between field investigations and Headquarters has been observed also as the best arrangement for the effective use of available personnel.

ACKNOWLEDGEMENTS

All the information included in this report has been provided by Japanese scientists and Institutions. The writer is particularly indebted to Professor D. Shimozuru of the Earthquake Research Institute (Tokyo University) who worked out final details of the time-table for the visit. He wishes to express sincere thanks also to Professors Kubotera, Miyazaki, Yoshikawa and Yokoyama who accompanied him on his visits.

The tour was partly sponsored by the B.M.R. and took place while the writer was in Japan on a vacational visit.

INTRODUCTION

The writer intended to collect information on instrumentation and interpretation from the established various Japanese volcano surveillance networks.

Volcanic tremors have been studied in Japan since 1910 (Omori 1912) and the first volcano observatory was established in Asama in 1911. The Japan Meteorological Agency (JMA) and Universities are both concerned with volcano surveillance in Japan. JMA has established a country-wide volcanic observation network since 1942. Tokyo and Kyoto Universities maintain permanent observatories in a limited number of particularly interesting active volcanoes. They, as well as Hokkaido University, carry out volcanological research in the fields of geology, geochemistry, seismicity, geomagnetism, geogravimetry, geothermy.

VISIT DETAILS

The centres visited were:

Earthquake Research Institute	(E.R.I.)	Tokyo University	3rd August
Japan Meteorological Agency	(J.M.A.)	Tokyo	4th August
Taruzawa Weather Station	(J.M.A.)	Asama Volcano	10th August
Asama Volcano Observatory	(E.R.I.)	Asama Volcano	10th August
Kusatushirane Field Station	(E.R.I.)	Kusatushirane Volcano	11th August
Volcanological Laboratory	(Kyoto Univ)	Aso Volcano	14th August
Kirisima Volcano Observatory	(E.R.I.)	Kirisima Volcano Complex	15th August
Onamiike Field Test	(E.R.I.)	Kirisima Volcano Complex	15th August
Kakuto Caldera Network	(E.R.I.)	Kirisima Volcano Complex	16th August
Sinmoedake	(E.R.I.)	Kirisima Volcano Complex	16th August
Sakurajima Observatory	(Kyoto Univ)	Sakurajima Volcano	17th August
Kaimon Dake (Unzen caldera field station)	(Kyoto Univ)	Kaimon Volcano	18th August
Kirokami Station Visit	(Kyoto Univ)	Sakurajima Volcano	19th August
Kagoshima Meteorological Observatory	(J.M.A.)	Sakurajima Volcano	19th August
OKI Electric Co.		Tokyo	22nd August
Hokkaido University Geophysical Inst.	(Hokkaido Univ)	Sapporo	25th August
Tarumae-Tomakomai Weather Station	(J.M.A.)	Tarumae Volcano	25th August
Toya Caldera	(Hokkaido Univ)	Toya Caldera	27th August
Usuzan-Muroran Meteorological Observatory	(J.M.A.)	Toya Caldera	27th August
JMA Sapporo Branch	(J.M.A.)	Sapporo	27th August
Sharp Co.		Tokyo	29th August

Several visits were paid to the Earthquake Research Institute during stop overs in Tokyo between trips. In the first call on 3rd August a time-table of visits was arranged and contacts were made with the other centres included in the tour.

EARTHQUAKE RESEARCH INSTITUTE

The Earthquake Research Institute Research Program includes work in theoretical and observational Seismology, Geomagnetism, Geoelectricity and Geothermy, Geodesy, Tsunami Studies, Volcanology, Petrology, Prevention and Reduction of Earthquake Disasters.

JAPAN METEOROLOGICAL AGENCY

The Japan Meteorological Agency carries out and processes meteorological, terrestrial and hydrological observations. Since 1942 the J.M.A. has been using its network for the routine observation of Japanese volcanoes. The Agency classifies volcanoes as

Class A: Active volcanoes with damaging eruption and located in a largely populated area.

Class B: Active volcanoes with damaging eruption and located in a sparsely populated area, or dormant volcanoes in populated area.

Class C: Active volcanoes with no damaging eruption, or dormant volcanoes in sparsely populated area.

Table 1 shows the volcanoes' classification and their activity and Plate 1 shows their distribution with J.M.A. stations.

At present 15 (4 class A, 11 class B) volcanoes are checked by the J.M.A. with wire or wireless telemetered seismometers. Table II shows instrument characteristics.

ASAMA VOLCANO
Karuizawa Weather Station (J.M.A.)
and Asama Volcano Observatory (E.R.I.)

Karuizawa Weather Station maintains a seismic network only on the southern flank of Asama Volcano at one to three kilometres distance from the volcanic centre. J.M.A.'s instrumental characteristics of seismographs are shown in Table II (Figures 1 & 2). The Asama Volcano Observatory (E.R.I.) was established in 1911. During 1933 it became a branch of E.R.I.. Its network completely encircles the volcanic centre. The Asama Volcano Observatory station characteristics are shown in Table III Figure 1. The distribution of the two networks is shown in Plate 2 Figure 1.

Interpretation

The Characteristic trends of Asama Volcano activity have been studied since 1910. The number of volcanic tremors rises sharply before an eruption. They reach a peak before the eruption and they decrease slowly while the eruption is still in progress. The Asama tremors are normally of very shallow origin, within 2 km depth. They have very weak P phase and strong transversal waves. The radial component seismometers are the best in recording such tremors.

Minakami (1910) classified 4 types of volcanic tremors after a long experience of observations at Asama, Usu and other active volcanoes:

A type: Clear P and S phases. Characteristic of pre-eruptive activity. Origin 1-10 km depth. Observed at all volcanoes.

B type: Shallower hypocentre within 1 km radius from the active crater. S phase masked by surface waves. Observed at Vulcanian type volcanoes.

Explosion earthquake type: It accompanies individual explosive eruptions. First motion compressional at all stations. Hypocentre near crater floor. Magnitude larger than B type.

Continuous microtremor type: Mainly surface waves. Characteristic of Hawaian or Strombolian eruptions.

Confusion between various classifications may occur.
Omori's (1912) A type, includes both Minakimi's A and B types.
Omori's B type corresponds to the Minakami's explosion earthquake type.
Sassa's (see chapter in Aso visit) 1st, 2nd and 3rd kind refer to Minakami's continuous tremor type.

Minakami observed in Asama a slight increase of B type earthquakes starting two months before some eruptions. During the explosive eruption the tremor frequency and explosion frequency follow a parallel trend. Minakami computed an empirical formula to predict Asama eruptions. He calls "N" the total number of B earthquakes in 5 days.

N_1 = total tremors frequency from day 1 to day 5
N_2 = " " " " " 2 " " 6
N_3 = " " " " " 3 " " 7

"N" is approximated to the next hundred unit, the frequencies are divided in this way into groups of a hundred. He calls "F" the frequency distribution of each group in a large interval of time (i.e. one month). N^1 and F^1 are e the frequencies actually observed for the previous Asama eruptions. The ratio between F and F^1 gives the eruption probability $\frac{F}{F1}$ 100 = P. Plate 2 Figure 2 shows an example of eruption and its prediction at Volcano Asama. A continuous tape recording at Asama Volcano Observatory triggers a recording tape for tremors of pre-described characteristics (e.g. a given amplitude, or duration).

KUSATU SHIRANE VOLCANO

During the writer's visit an E.R.I. field party was operating a temporary seismic network around the summit of this volcano. Distance between stations was 2 km. The moving coil seismometers, with 3 sec. and 1 sec. periods, had their output telemetered by cable to a 9 + 2 channel oscillograph and a visual smoked paper recorder.

Interpretation

During the 1967 Survey of Kusatu Shirane (Minakami et al. (1969) the volcanic tremor hypocentres were determined using S-P intervals and a constant P wave velocity of 3 km/sec. The foci were also determined using a different P velocity computed graphically for each tremor. The two methods yield similar epicentres but marked differences in depth. This error is mainly due to the assumption of the constant P wave velocity 3 km/sec.

ASO VOLCANO

Aso Volcanological Laboratory. The Disaster Prevention Research Institute (DPRI) of the Kyoto University maintains the Aso Laboratory. Plate 3 (Figure 1, 2 & 3) shows the configuration and the instruments characteristics of the Laboratory seismic network. The writer was particularly interested in this installation because three of the stations are linked to the Laboratory, by VHF. The wave length adopted is 60 MHz. The equipment is not transistorized. Transmitter and receiver are 7 kilometres distant and not in line of sight, nevertheless the signal received is perfect. No explanation is given for this unexpected performance, but the station personnel believes the good reception is given by a lateral reflection on the caldera wall.

Ancillary equipment includes a sound recording microbarometer, a bench mark network for the caldera precise levelling, portable moving coil seismometers, continuous tape recording and triggered events recording. Gravity research is also carried out by the D.P.R.I. personnel.

Interpretation

A few local explosions were used by the laboratory to compute a crustal model for the caldera. An average P wave velocity of 3.2 km/s was assumed inside the caldera area. The velocity was determined using the time-distance plot (Kamo & Kituchi 1968).

Kubotera & Kikuchi (1970) estimated the thickness of pyroclastic deposits in the Atrio region from the attenuation of numerous tremors. They assumed a shear wave velocity of 1 km/sec for these deposits. The Love wave attenuation is supposed to vary sharply from the bedrock to the pyroclastic deposits and it is also function of the strata inclination. Consequently the variation in amplitude of Love waves at different stations gives the relative thickness deposits and the inclination of bedrock.

Sassa (1933) noticed for Aso an increase in microseismic activity before the eruption. A sharp peak is reached just before the eruption. In 1935 he classified 4 kinds of volcanic tremors.

The 1st kind has a period around 1 second and it is best recorded on the N - S component (tangential to the source). Its movement is thus dominantly transverse.

The 2nd kind has a longer period, around 5 seconds, and it is well recorded on the E - W component. Rayleigh type waves are predominant.

The 3rd kind of tremor is also predominantly a Rayleigh wave. The average period is 0.5 sec and is best recorded on the vertical component. Kubotera (1962) assigns it a phase velocity of about 1.2 km/sec.

The 4th kind is recorded in all components with a period around 0.2 sec. Plate 4 shows a reproduction of the 4 kinds of Tremors registered in Aso Laboratory. The JMA Aso Observatory was not visited due to a volcano warning alert.

KIRISIMA VOLCANO COMPLEX

Kirisima Observatory

Average height of the Kirisima massif is 1000 m and numerous cones reach 1800 m height. The Kirisima volcano observatory was established in 1964 with an initial array of 6 stations. Each station is within 1 kilometre distance from each individual main cone. Kakuto basin and Sinmoe Dake cone networks were later installed respectively NW and SE of the Observatory. Plate 5 figure 1 shows the location of the networks.

Seismographs are linked by telephone-type cable to the recording sites and arrester tubes had to be installed to protect amplifiers, transducers and cables from lightning.

Interpretation

Kirisima's earthquake swarms occurred originally in an area 10 km beneath the Kakuto basin and an auxiliary network was installed there. Since 1968 the hypocentral area is getting shallower and migrating toward the most dangerous cone, Simmoe Dake, to the southeast, following the major axis of the mountain system. All three seismic networks are distributed in a 20 km strip, NW-SE, in order to detect the progressive migration of microtremors foci. No assumed crustal model was available for the Kirisima area and the hypocentres were determined by analytic methods.

In an early survey (Minakami et al 1968) the following Omori formula was applied: $S - P = \quad /K$
where S-P is the arrival time difference between transverse and longitudinal waves, is the focal distance, K is a constant expressed in km/s entirely depending on the medium. A geometrical plot of at least four S-P gives a K between 6.5-6.8 km/s for Kirisima.

A more accurate determination (Minakami op. cit.) is done using the observed apparent velocity $\overline{V}_p$.

$$\overline{V}_p = \frac{d - \cos}{t}$$

Where is azimuth of the approaching wave
$\overline{V}_p$ is the P wave apparent velocity
d is the distance between two given stations
t is the time interval of P arrival between the two stations

Assuming a true velocity V_p in the upper layer the emergent angle "e" is given by:

$$e = \sin^{-1} \frac{V_p}{\bar{V}_p}$$

Thus, epicentral distance and focal depth "h" can be computed for each station (i)

$$_i = K(S-P)_i \sin \ e_i$$

$$h_i = K(S-P)_i \cos \ e_i$$

Onamiike Field Test

A successful test of VHF (400 MHz) transmission was observed at Kirisima. A contact had to be established on opposite sides of Onamiike volcano. Yagi directional antennas were used. As expected no contact could be made on direct line but a very good link was obtained using Sakurajima mountain 60 km south as a reflecting surface with both receiver and transmitter aerials orientated in that direction. The equipment was not transistorized and the transmitter had 10 watts power output.

Kakuto Basin

Following the 1968 earthquake swarm and the seismic network installation a levelling route was established in the Kakuto Basin. Crustal deformation is measured in all the principal Japanese Calderas and Volcanoes. The visit to Kakuto Basin network was followed by an exercise in levelling measurement using a Laser geodimeter in which the writer took part.

Sinmoe-Dake

Sinmoe-Dake was the last cone of Kirisima complex to be active in 1959. Before the eruption no seismometers were operating in the Kirisima area. The nearest stations were Sakurajima and Myazaki, at a distance of 60 km and they were too far to register any tremor related to the eruption. ERI and JMA seismic stations are now installed on the Flanks of Sinmoe.

SAKURAJIMA VOLCANO

Sakurajima has been one of the most active volcanoes in Japan during this century. The Kyoto University's Disaster Prevention Research Institute (DPRI) maintains the Sakurajima Observatory and the Kurukami networks. Plate 6 (Figures 1 & 2) shows the networks configuration. In Plate 7 the frequency response for each station is given.

Continuous recording of slow ground motion by means of Reservoir type water tube tiltmeters has been developed and built at the Sakurajima Observatory (Eto 1966).

Yoshikawa-Nakamura (1970) determined a Regional Model from swarms of Local Earthquakes. The standard deviation of the S wave can be used for the location of the magmatic chamber.

Interpretation

Precise levelling permits the recognition of two connected magmatic chambers. The principal one is located under the Sakurajima Caldera and the secondary one, smaller and shallower, is located under Sakurajima Volcano (Yoshikawa 1961, 1962 Eto 1965, 1966).

A crustal Model for Seismic interpretation is not available because Sakurajima Island is a National Park and explosions, are banned. The focus depth of volcanic tremors is estimated using the Omori formula S-P= /K with an experimental value of "K". The interpretation is facilitated by the regular pattern followed by the volcanic activity and by the complementary disposition of the two networks.

Yosikawa and Nishi (1965) note a sharp increase in the trace amplitude and number of the small earthquakes in the two hours preceding the eruption. The seismic activity reaches a peak a few minutes before the eruption, decreasing slowly afterwards. These volcanic tremors are recorded as Minakami's B type (shallow depth). A swarm of microtremors took place during the writer's visit. The swarm was accompanied by emission of abundant ash laden vapour from the summit crater and fall out of thin ashes on Sakurajima city.

Kirokami auxiliary network and Sakurajima Volcano Excursion

Plate 6 Figure 1 shows the Kirokami auxiliary network location. This seismic installation was required to improve the hypocentre determination because of the lack of a seismic model for the volcano. During the visit the writer noted that a light table is used as viewer for smoked paper records. (The Japanese volcano observatories equipped with smoked paper recording widely use light tables to improve the seismogram reading).

Kagoshima JMA Observatory

The visit to this Observatory was particularly interesting because it is connected to the seismic network on Sakurajima Volcano by a VHF FM radio link (Plate 6 Figure 2). The network operates on the 400 MHz wavelength with 0.5 watts power output and it is fully transistorized.

10 km in-line-of-sight separate transmitter and receiver. Although most of the path is over the sea no interference is produced because of the high frequency used.

KAIMON DAKE VOLCANO AND UNZEN FIELD STATION

Kaimon is a dormant volcano at the southern tip of Kyushu Island (see Plate 1). In 1967 the DPRI set a seismic field station in the nearby Unzen Caldera and recorded seismic activity at shallow depth. A temperature increase in the local thermal areas is also causing concern. A permanent station will now replace the field installation.

OKI ELECTRIC TOKYO

A visit was paid to OKI Electric Co., the JMA electronic supplier. Enquiries were made on the seismograph-radio telemetering equipment. Booklets on the system characteristics and performances were collected (see Appendix I). No maximum range was tested by OKI, but a satisfactory transmission is expected at least up to 60 km distance.

HOKKAIDO UNIVERSITY, GEOPHYSICAL INSTITUTE

Professor Y. Yokoyama, Director, is involved in volcanology through his seismic, gravimetric and geomagnetic studies.

Yokoyama (1969) correlates local anomalous geomagnetic changes with volcanic eruption.

Interpretation

In 1962 after 37 years quiescence, Tokaty volcano, Hokkaido, showed a clear increase in the thermal area temperatures and on the rate of sublimate deposition. Seismic observations of the 1962 eruption at Tokaty volcano are given by Yokoyama (1964). 12 shocks were felt in the area in the month preceding the eruption, but a seismometer 1.2 kilometres from the crater registered a daily number of volcanic shocks relatively small. Only 19 small shocks were recorded the day preceding the first explosion. The number and trace amplitudes of the tremors reached a peak of 100 per day several days after the first eruptive outburst.

Because of the low level of seismicity no warning of danger was given and five miners working the sulphur near the summit were killed by the first explosion.

Not all volcanic eruptions are preceded by marked seismic activity. The UNESCO will shortly issue a paper analysing the different cases (D. Shimozuru personal communication).

TARUMAE VOLCANO

Also in Tarumae Volcano (see Plate 8, Figure 1) the JMA maintains a radio telemetered seismic equipment. The transmitter unit located on the south eastern slope of the volcano, is similar to that operating at Kagoshima (see Appendix 1). At Tarumae volcano there was no electric power available. (This condition is usual in the T.P.N.G. field operation and the writer was interested to see the Japanese solution to the problem).

The Tarumae station is 1 kilometre from the volcano's central dome and 18 km in line of sight from the Tomakomai recording station (Plate 8, Figure 2). The power at Tarumae is produced by a solar cell* apparatus. Ni-Cd alkaline batteries are also charged during day time hence supplying sufficient power for night or bad weather station operation. The three seismometers, the radio transmitter and batteries are fully operated by two plates of 1 m^2 surface each. Each plate is composed of 180 cell units. The current output is double of the requirement of the Tarumae station. The cost in Japan of each plate is about $A4.500. No maintenance is required at the remote station except for the checking of Ni-Cd batteries. The Tarumae Station was installed in 1967 and has not produced any technical problems.

Strong motion seismometers with ink pen visual recording were seen in operation in Tomakomai Station. The ink recording method has an unreliable magnification factor due to the pen friction on the paper. This factor would increase with the high humidity of the territory clima. In other hand it does not require record processing.

USU AND SYOWA SINZAN (TOYA CALDERA)

Usu and Syowa Sinzan are two lava domes at the border of Toya Caldera (Hokkaido Is.).

Usu is the most recent of the Toya Caldera domes and was formed in the period 1944-45. "A" type earthquakes occurred before the extrusion. A gradual transition from A type to B type tremors accompanied the development of the lava dome (Minakami 1960).

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* The solar cells convert directly solar energy, proportionally to the incident illumination intensity, into electric energy. No consumption or chemical change in the cells is required by this conversion. Hence the cell life is practically indefinite.

Muroran Station

The JMA maintains a three component seismic station 1½ km from Usu and Syowa Sinzan. The seismic data are transmitted to Muroran Station 28 km away (see Plate 8, Figure 3). The telemetering equipment is the same as already described for Kagoshima and Tomakomai (details and specification in Appendix I).

SAPPORO (JMA HEADQUARTERS). JMA VHF SYSTEM

At Sapporo, Muroran records were examined. The seismic records do not present any trace of radio interference. The Japanese VHF system was observed in operation in many different conditions: over sea water (Kagoshima), on long distance range (Usu), between points not in line of sight (Aso, Kirishima), with solar cell electric power supply (Tarumae). The records produced were always perfect and there were no traces of radio interference. The frequency used (400 MHz) is a major factor in these successful performances.

SHARP SILICON

Solar cell batteries supplier Sharp Silicon Co. was visited in Tokyo. Enquiries were made on solar cell performances and characteristics. Booklets in English were collected.

CONCLUSIONS AND SUGGESTIONS

In Japan the writer inspected various methods of volcano surveillance. The slow ground motion study by means of tiltmeter appear relatively neglected and more emphasis is given to the other methods.

- Different methods for focus determination of volcanic tremors have been described from Asama, Aso, Kirisima and Sakurajima visits. A knowledge of the volcano-crustal model and/or of the usual seismic trends are always necessary. The Omori formula S-P = /K is most useful where a local crustal model is not available. In order to obtain the "K" values a preliminary survey with a seismic network sufficiently sensitive to detect the smallest tremors has to be done on each volcano. The plotting of the S-P for near tremors would give "K" in km/s.

- Seismic Investigations and permanent observations are most useful when carried out within few km from the active centres. Three component-stations disposed around the volcano improve the hypocentre determination and reduce the error introduced by inaccurate assumptions of: "K", average wave velocity, strata uniformity, layer inclinations, etc. A single seismometer is of no use for the hypocentre determination and it should be placed within 1 km from the volcano crater to monitor the level of seismic activity.

- VHF telemetering equipment will solve most of the problems involved in seismic volcano surveillance in T.P.N.G.. In Japan perfect results in all field conditions are obtained using the 400 MHz frequency range.

The installation of solar cell batteries would satisfy the power supply requirement at the remote station.

- Examples of the classification of volcanic tremor is given from the Asama visit. Type references are necessary to prevent confusion between classifications. The Rabaul Central Observatory uses at present a different one for the D'Entrecasteaux Islands seismic activity (see Rabaul Central Observatory: Preliminary Earthquake Analysis Bulletin 1969 No. 19).

Classifications are based on characteristics such as S-P intervals and on the shock signature. The appearance of volcanic tremor signatures is governed by instrument response and the location of seismometers. (Seismometers with different frequency response or set in other positions can change noticeably these aspects of the microtremors). The Japanese classifications are based mainly on results from moving coil seismometers with frequency of 1 and 3 cycle/sec., placed in and around epicentral areas.

- The sole use of seismic equipment to predict eruptions is inadequate. An eruption is not necessarily preceded by a peak in seismic activity (see Hokkaido Geophysical Institute visit). The UNESCO will shortly issue a paper discussing various examples.
The UNESCO will shortly issua a paper discussing various examples.

- A light table as described in Kirokami visit would be very useful with the new Sprengnether smoked paper recorders adopted by the Volcanological Branch at Rabaul.

- Record processing will still be a problem in the Territory for many years to come. An ink pen recording does not require processing but the paper would be affected by the Territory high humidity, (see Tarumae visit). It could be adopted for the routine surveillance in the most remote stations if air conditioned.

- The T.P.N.G. seismic surveillance equipment appears up to date but it has not been put to full use. The effectiveness of the Japanese volcano surveillance is given by the complex and original studies the professional staff have done using their instruments.

The Japanese Volcanologists and Geophysicists spend only a few weeks a year in their Volcano Observatories or Field Investigations. Back at their headquarters they work out results and methods. Seismic routine and station maintenance are left to the technical staff. Analogous system should be adopted by the B.M.R. for the T.P.N.G. volcanic surveillance with the creation of an "Active Volcanoes Group" including Geologists, Petrologists, and Geophysicists with headquarters in Canberra. Group members could rotate for short terms (e.g. a year) as Rabaul Observatory Residents. Emergencies and routine investigations would be carried out by staff solely involved in this delicate field of activity. Eventual political problems would have less repercussions in the Canberra based Group.

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APPENDIX I

RADIO TELEMETERING SEISMOGRAPH SYSTEM FOR VOLCANIC TREMORS (USED BY J.M.A.)

1. DESCRIPTION

The Radio Telemetering Seismograph System measures the earth tremors caused by volcanic activities and telemeters the output signal to a distant, safe site for the continuous monitoring of active volcanoes.

Developed by the JMA's (Japan Meteorological Agency) project for the improvement of volcanic observations, a number of these systems have been installed by OKI near the Volcanoes, Usuzan, Komagatake in Hokkaido, Azumasan, Adatarayama, Bandaisan, and Nasudake since 1965 and provides important data for the constant watch of active volcanoes. The announcement of "Volcano Information" was initiated in January, 1965, based on the data from these radio and cable telemetering stations.

This system can also be applied to general seismic and meteorological observations. In seismic observations, for instance, high gain transducers are placed in quiet, but remote sites away from city noise and ocean microseisms, and the telemetered output signals can be recorded and interpreted in large cities where many other facilities are available.

2. FEATURES:

(1) Continuous observations all the year round are possible.

(2) Three-component record is obtained simultaneously.

(3) The present system can be easily employed between any two points on a line of sight.

(4) The observation site (transmitting side) can be run unattended.

(5) The function of the entire system can be checked by the calibration signal automatically applied once a day.

(6) The devices at the observation site are tightly sealed and made moisture- and drip-proof. Main circuits consist of units molded in plastics for a higher reliability.

(7) All electronic parts are transistorized and function stably in an environmental temperature range of -15° to $+40^{\circ}$C.

(8) Two recorders can be switched automatically from one to the other for continuous observation.

3. <u>SPECIFICATIONS:</u>

(1) Component:	3 (N-S, E-W, Vertical)
(2) Maximum Overall magnification:	5,000
(3) Minimum Detectable Ground Displacement:	0.1 u at 2 Hz
(4) Frequency Range of Displacement Response:	about 1 - 15 Hz
(5) Transducer:	
Type:	Moving Coil
Natural Period:	1 sec
Sensitivity:	2 V/cm/sec
(6) Transmitting Mode:	FM - FM
(7) Sub-carrier:	
Center Frequencies:	960 Hz, 1,700 Hz, 3,000 Hz
Maximum Frequency Deviation:	$\pm$ 7.5%
(8) Transmitter:	
Transmitting Frequency:	Any preset frequency in the 400-MHz band
Output:	0.5 W
Maximum Frequency Deviation:	$\pm$ 12 kHz
(9) Recorder:	
Recording Method:	Smoked Paper
Recording Drum Speed:	60 mm/min
Galvanometer Lateral Translation:	1.6 mm or 6.4 mm/revolution
Natural Period of Galvanometer:	about 0.07 sec
(10) Power Requirements:	AC 100 V $\pm$ 20 %, 20 VA at observation site and 200 VA at recording base

TABLE I

The Volcanic Activities detected in JAPAN
during the period from 1945 to 1969

Year (A.D.)

Name of volcano	Class	1945					1950					1955					1960					1965				
3. Atosanupuri	C							□								□						□				
4. Meakandake	B							□	□		O	O	●	O	O	O	O		O		O	O	O	□		
6. Tokatidake	B								O	□	□	□	O	O	O	O		□	●	□					□	□
7. Tarumaeyama	B							O			O	O						□	□						□	
8. Ususan	B	●																								
9. Hokkaido-Komagatake	B				□	□					□						□									
12. Osoreyama	C																								□	
15. Akita-Yakeyama	C					O		O																		
17. Iwatesan	B																□			□			□			
18. Akita-Komagatake	C																		□							
20. Kurikomayama	C																			□						
22. Zaozan	B																		□				□	□		
23. Azumayama	B						O		□														□		□	
26. Nasudake	B									O							O	□	□	O						
27. Nikko-Siranesan	C								□																	
29. Kusatu-Siranesan	B							□							□											
30. Asamayama	A	O	O	●		O	●	O	O	O	O	O		□	●	O	□	●	□		□	O		□		
31. Niigata-Yakeyama	C					O													O	O						
34. Yakedake	B									□					□				●	O						□
39. Hakoneyama	C								□	□						□	□						□			
41. Izu-Osima	A				□	□	●	●	□	O	O	□	O	●	O	O	O	O	O	O	O	O	O	O	O	O
42. Niizima	C													□					□	□			□	□	□	
43. Kozusima	C																					□	□	□	□	
44. Miyakezima	B									□			□			□			●	□						
47. Beyoneisu-Retugan (Myozin-syo)	C		O						●	O	O	O		□			O									
49. Izu-Torisima	C								□			□	□	□	□	□		□	□	□	□	□				
52. Asosan	A	O	O	●	O	O	O	O	O	●	O	O	O	O	●	O	O	O	O	O	O	●	O	O	O	□
53. Unzendake	B							□			□	□	□		□	□			□		□		□		□	□
54. Kirisimayama	B											□			□	●	□	□	□						□	□
55. Sakurajima	A		●		O		O				□	●	O	O	O	O	O	O	O	O	●	O	O	O	O	O
56. Kaimondake	C																							□	□	
58. Kutierabusima	C	O																					O	□	O	O
59. Nakanosima	C					O																				
60. Suwanosezima	C					O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
62. Iezima	C	□												O										O		O
63. Submarine volcano off Minami-Iozima	C									□			□	□											□	

● Eruption with great damage

O Eruption with little damage

□ Volcanic Extra-ordinary Phenomena only

(swarm earthquakes, inccrease in fumarolic activity, etc.)

TABLE II

Instrumental Constant of the JMA Seismographs

T: Period of seismograph, h: Damping constant of seismograph,

v: Damping ratio, V: magnification

Volcano	Type of seismograph	T	h(v)	V
Asamayama	JMA-62A JMA-56 P S	1.0 s 1.0 2.0 5 6	0.5 (8) (6 8) (8)	5000 300 50 1
Izu-Osima	JMA-62A JMA-56 W S	1.0 1.0 4.5~5.0 5~6	0.5 (8) (7~8) (4~8)	500 300 60 80 1
Asosan	JMA-62A JMA-56 S	1.0 1.0 5~6	0.5 (8) (8)	3000 300 1
Sakurajima	JMA-62A JMA-62C JMA-56 JMA-59 S	1.0 1.0 1.0 5.0 5~6	0.5 0.5 (8) 0.5 (8)	2000 2000 300 100 1
Meakandake	JMA-56	1.0	(8)	300
Tokatidake	JMA-62A JMA-56	1.0 1.0	0.5 (8)	5000 300
Tarumaeyama	JMA-62E JMA-56	1.0 1.0	0.5 (8)	3000 300

Volcano	Type of seismograph	T	h(v)	V
Ususan	JMA-62E JMA-56	1.0 s 1.0	0.5 (8)	2000 300
Hokkaido-Komagatake	JMA-62E JMA-56 S	1.0 1.0 5~6	0.5 (8) (8)	2000 300 1
Azumayama	JMA-62E	1.0	0.5	5000
Adatarayama	JMA-62E	1.0	0.5	5000
Bandaisan	JMA-62E	1.0	0.5	5000
Nasudake	JMA-62E JMA-56	1.0 1.0	0.5 (8)	3000 300
Miyakezima	JMA-62A JMA-56	1.0 1.0	0.5 (7)	1000 300
Unzendake	JMA-62A JMA-56	1.0 1.0	0.5 (8)	2000 300
Kirisimayama	JMA-62A JMA-56	1.0 1.0	0.5 (8)	5000 300
Temporary observation*	JMA-62B JMA-62D JMA-62P	1.0 1.0 1.0	0.5 0.5 0.5	500~30000 500~30000 500~10000

* The seismological section of J.M.A.

Type of seismograph

- JMA-62A, JMA-62B, JMA-62D: Electromagnetic seismograph for wire telerecording.
- JMA-62C, JMA-62E: Electromagnetic seismograph for wireless telerecording.
- JMA-62P: Portable electromagnetic seismograph for wire telerecording.
- JMA-56: Mechanical seismograph.
- JMA-59: Electromagnetic seismograph.
- W : Wiechert's seismograph.
- P : Portable seismograph.
- S : Strong motion seismograph.

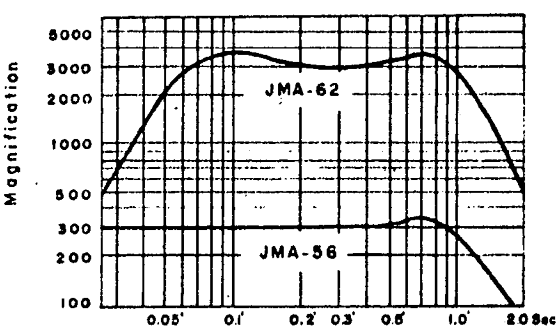


Figure 2 Period of ground movement.

Period characteristics of the main seismographs

JMA-62 Electromagnetic seismographs of JMA-62A, JMA-62B, JMA-62C, JMA-62D, JMA-62E and JMA-62P type.

JMA-56 JMA-56 type seismograph

TABLE III

Figure 1 Seismograph constants at the Asama Volcano Observatory

(a) Electromagnetic seismographs (transducer-galvanometer at ASAMA Observatory)

Station of transducer	Period of transducer	Period of galvanometer	Magnification	Component
No. 2	1 sec	0.2 sec	4,000	V
No. 2	1 sec	0.2 sec.	4,000	H
No. 3	1 sec.	0.2 sec.	4,000	H
No. 7	1 sec.	0.2 sec.	4,000	H

(b) Electromagnetic seismographs (transducer-amplifier pengalvanometer at ASAMA Observatory)

Station of transducer	Period of transducer	Magnification	Component	Amplifier
No. 1	1 sec.	4,000	H	transistor
No. 2	"	"	V	"
No. 2	"	"	H	tube
No. 3	"	"	V	transistor
No. 3	"	"	H	tube
No. 4	"	"	H	"
No. 5	"	"	H	"
No. 6	"	"	H	transistor
No. 7	"	"	V	"
No. 7	"	"	H	"
No. 8	"	"	H	"
No. 9	"	"	H	tube

Figure 2 Seismograph constants at the Kirisima Volcano Observatory

Stn. No.	Place of transducer	Component	Magnification on smoked paper	Magnification on oscillo-graph paper
1	Kirisima V. O.(1)	2 horizontal	15,000	100,000-200,000
"	"	1 vertical	"	"
2	Kamimonzen	1 horizontal	"	"
3	Oonami-ike W.	1 vertical	"	"
4	Kurino-dake	1 horizontal	"	"
5	Simmoe crater N	1 vertical	"	"
6	Karakuni-dake NE	1 vertical	"	"
7	Suwa-zinzya	1 horizontal	15,000	100,000-200,000
8	Okamoto P. S.	1 horizontal	-	"
"	"	1 vertical	-	"
9	Okamoto-ura	1 horizontal	15,000	-
10	Kawazoe	1 horizontal	"	100,000-200,000
11	Miyosi	1 vertical	-	"
12	Momogasako	"	-	"
13	Deguti	"	-	"
14	Makiba	"	-	"
15	Mizunomi	"	-	"
16	Yunono	1 vertical	15,000	100,000-200,000
"	"	2 horizontal	"	"
17	Yunono-ura	1 vertical	-	"
18	Ebosi-dake	1 "	-	"
19	Simmoe-Naka-dake	1 "	-	"
20	Simmoe crater S.	1 "	-	"
21	Oonami-ike S.	1 "	-	"
22	Takatiho	1 "	-	"

PLATE I

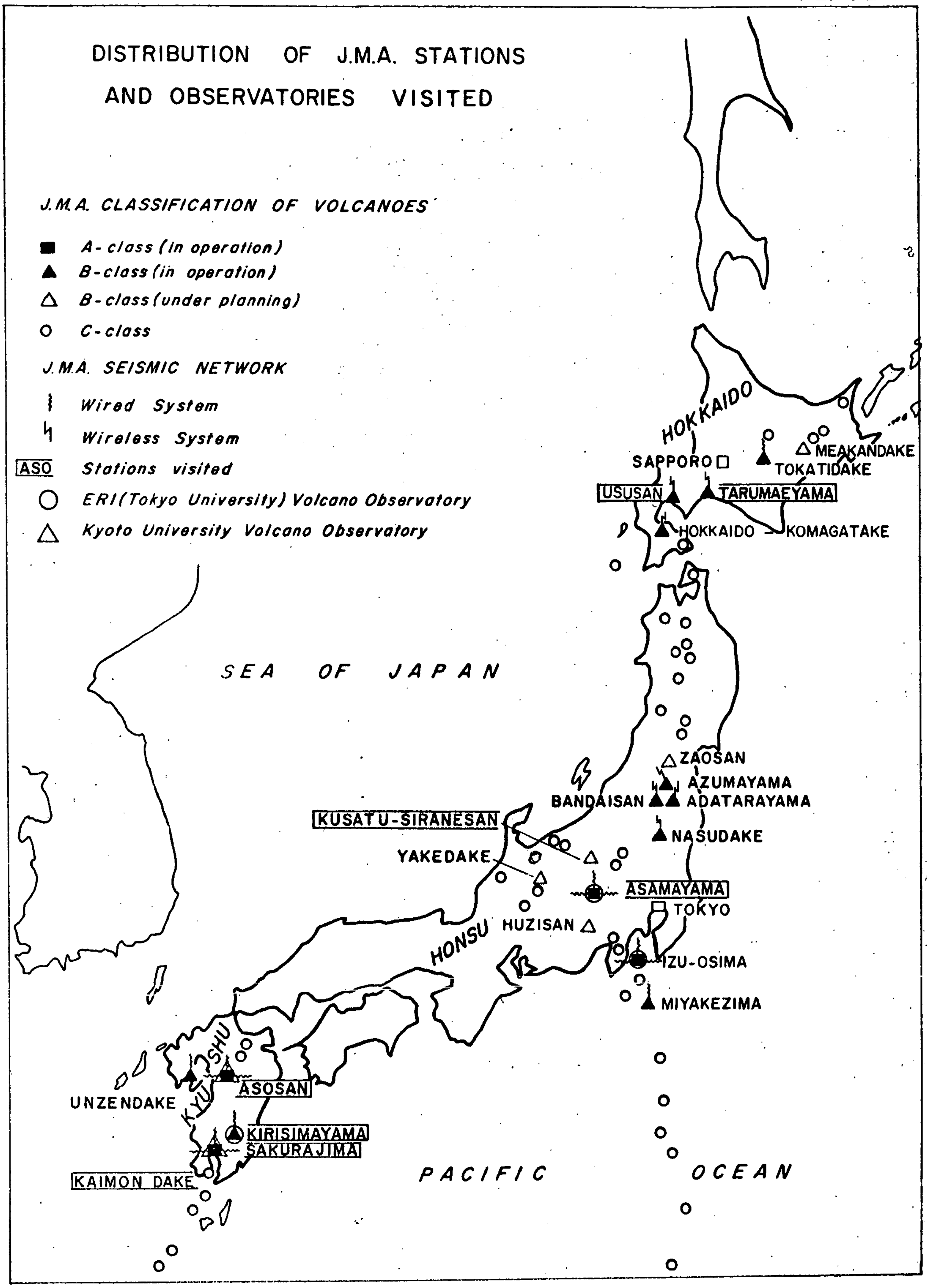
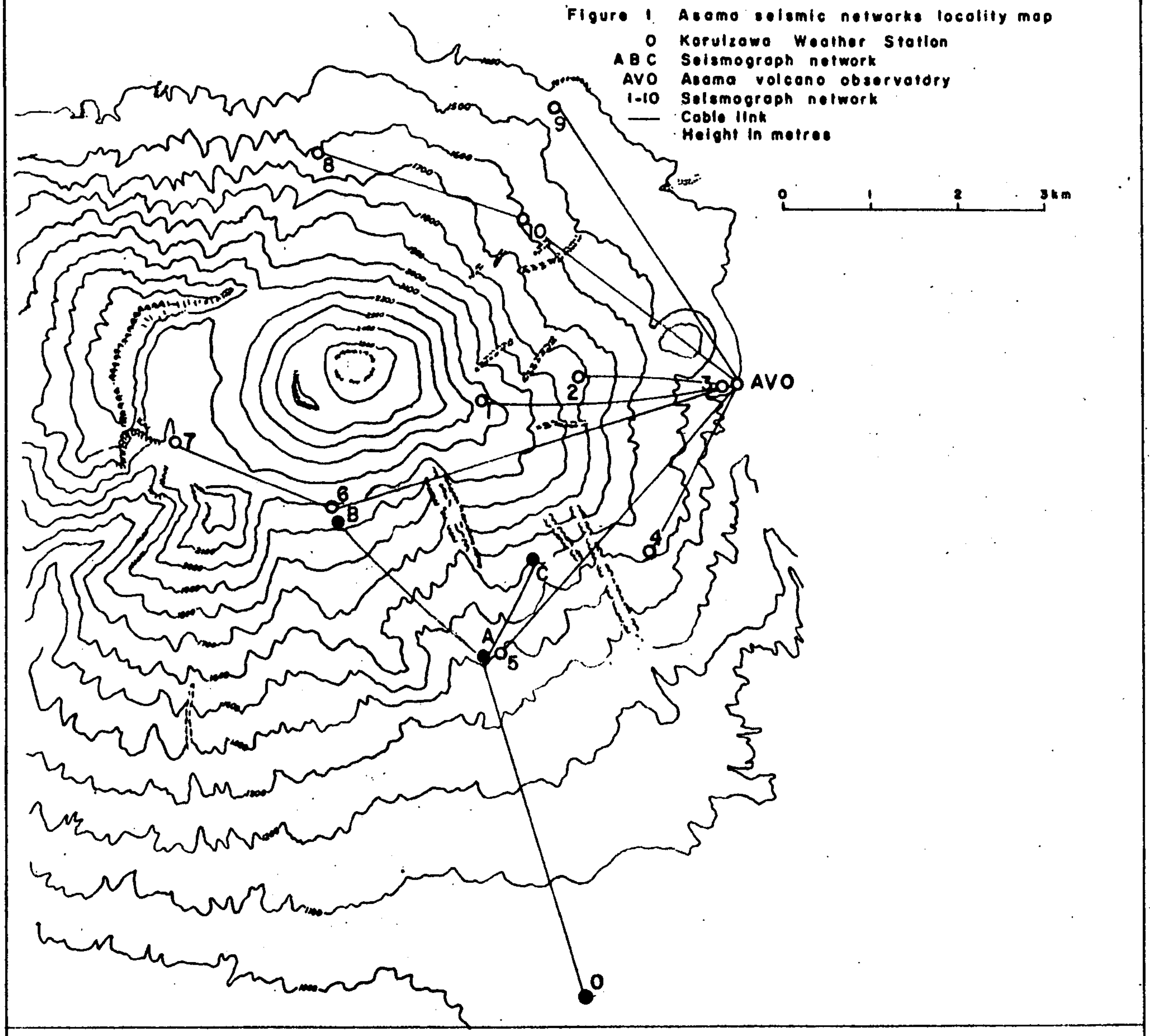

DISTRIBUTION OF J.M.A. STATIONS
AND OBSERVATORIES VISITED
J.M.A. CLASSIFICATION OF VOLCANOES
A-class (in operation)
B-class (in operation)
B-class (under planning)
C-class
J.M.A. SEISMIC NETWORK
Wired System
Wireless System
ASO Stations visited
ERI (Tokyo University) Volcano Observatory
Kyoto University Volcano Observatory
SEA OF JAPAN
PACIFIC OCEAN
HOKKAIDO
SAPPORO
MEAKANDAKE
TOKATIDAKE
USUSAN
TARUMAEYAMA
HOKKAIDO
KOMAGATAKE
ZAOSAN
AZUMAYAMA
BANDAISAN
ADATARAYAMA
NASUDAKE
KUSATU-SIRANESAN
YAKEDAKE
ASAMAYAMA
TOKYO
HUZISAN
HONSU
IZU-OSIMA
MIYAKEZIMA
KYUSHU
ASOSAN
UNZENDAKE
KIRISIMAYAMA
SAKURAJIMA
KAIMON DAKE

PLATE 2

Figure 1 Asama seismic networks locality map



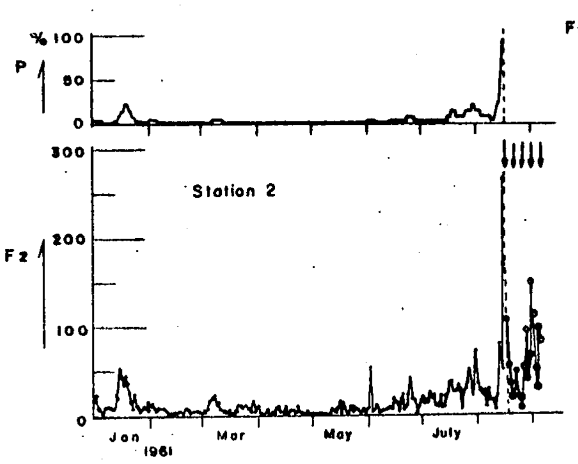
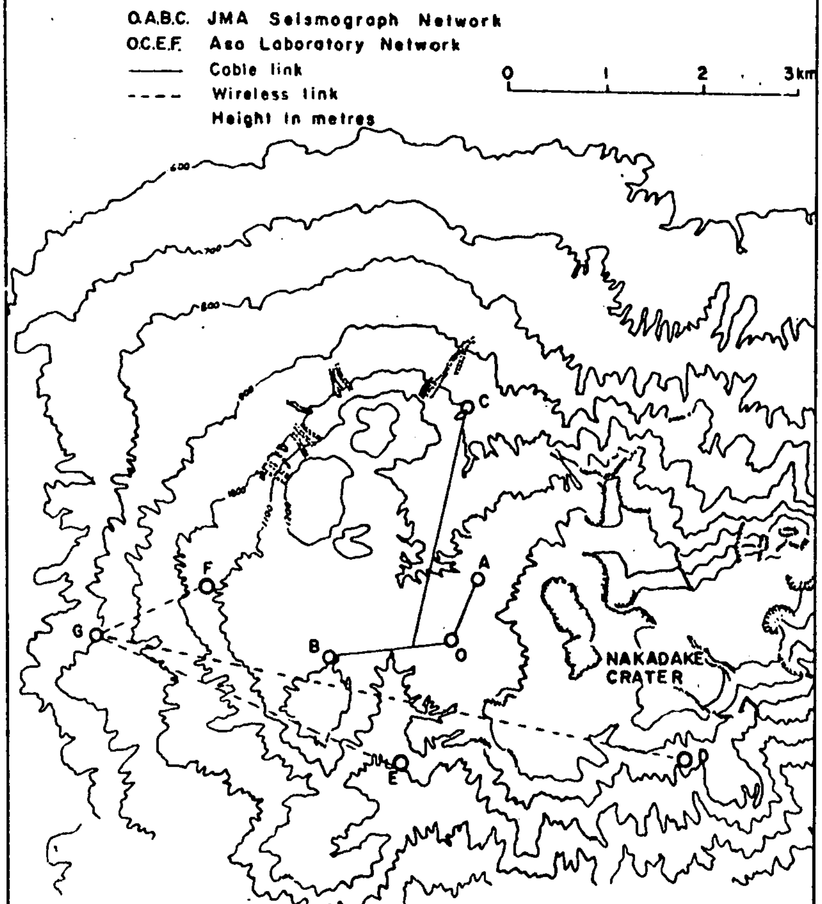


Figure 2 Eruption and its prediction at Volcano Asama.

P Probability of eruption computed from the empirical prediction formula on the basis of the observed frequency of small earthquakes.

F2 Daily frequency of small earthquakes. Small arrows indicate the occurrences of eruptions.

Figure 1 Aso Seismic Network Locality map



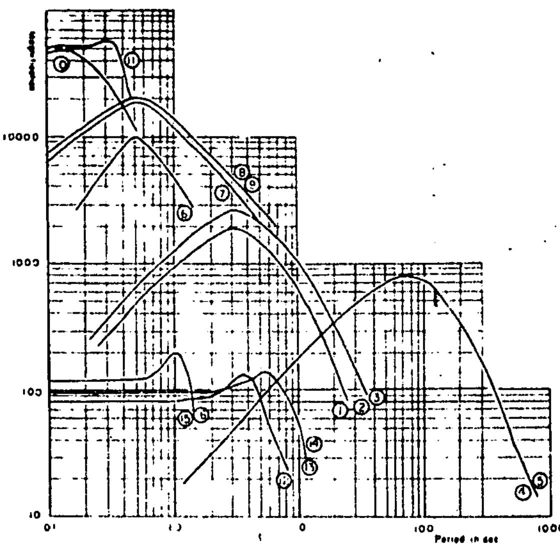


Figure 2. Magnification curves of Seismographs used for the Volcanological Laboratory Network. Curve numbers refer to instruments in Fig. 3

Figure 3 Constants of Aso volcanological seismograph laboratory

Station	Instruments No. Name	Comp.	Vmax.	T_1 sec.	T_2 sec.	h_1	h_2	σ	ρ mm.
D	1. Golitzin B-type Seismograph	UD	1,950	6.0	4.0	1.0	1.0	0.1	
D	2. Ditto.	EW	2,580	6.0	4.0	1.0	1.0	0.1	
D	3. Ditto.	NS	2,600	6.0	4.0	1.0	1.0	0.1	
D	4. Long-Period Seismograph	EW	780	180.0	100.0	1.0	1.0	0.1	
D	5. Ditto.	NS	750	180.0	98.6	1.0	1.0	0.1	
D	6. High Sensibility Seismograph*	UD	10,000	1.2	0.8	1.0	0.5	0.0	0.2
D	7. High Sensibility Electro-magnetic Seismograph**	UD	22,000	0.75	1.06	1.0	1.0	0.1	
D	8. Ditto.	EW	19,000	0.71	1.16	1.0	1.0	0.08	
D	9. Ditto.	NS	19,500	0.70	1.10	1.0	1.0	0.09	
E	10. Short-Period Seismograph	UD	46,000	0.33	0.11	0.51	1.0	0.28	
E	11. Ditto.	Hor.	57,000	0.38	0.11	0.28	1.0	0.42	
F	12. Wiechert Seismograph	UD	130	4.0		0.3			0.3
F	13. Ditto.	EW	150	6.0		0.35			0.3
F	14. Ditto.	NS	140	6.0		0.35			0.3
G	15. S-300 Seismograph	EW	200	1.0		0.4			0.5
G	16. Ditto.	NS	200	1.0		0.4			0.5

*Seismograph recording on smoked paper with transistor amplifier.

**Seismograph recording on 35mm. wide film.

T_1 : Period of pendulum

T_2 : Period of galvanometer

h_1 : Damping constant of pendulum

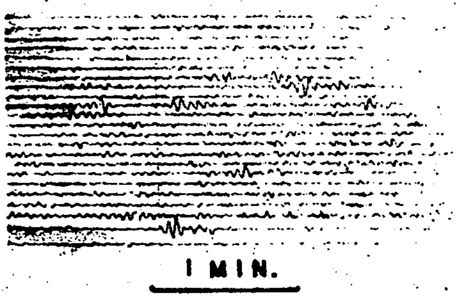
h_2 : Damping constant of pendulum

σ : Coupling factor

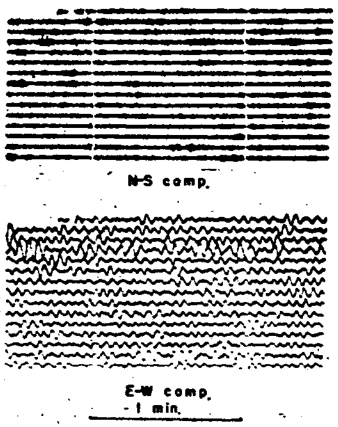
ρ : Solid friction

Station letters refer to Fig. I

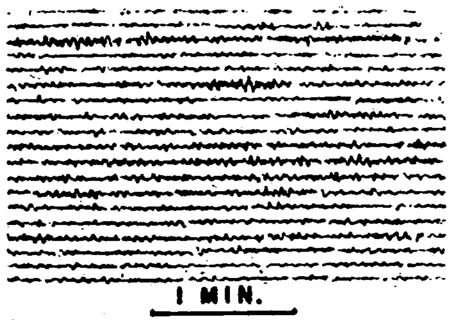
Aso Network records showing various kinds of tremors



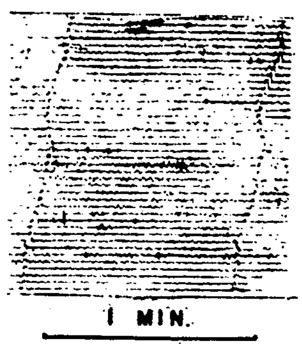
17 1st-kind volcanic micro-tremor
Instrument. Wiechert Seismograph
Component. E.W. (Raleigh wave)
Date Jan. 1st-2nd 1962



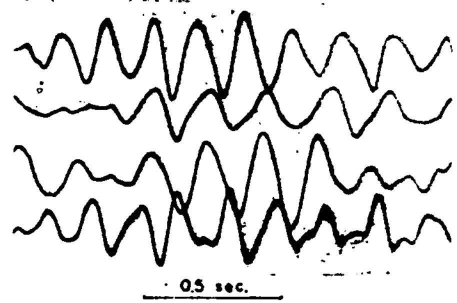
18. N-S Com. 1st-kind volcanic microtremor
E-W Com. 2nd-kind volcanic micro-tremor
Instrument. Galitzin E-type Seismo graph
Component. N-S E-W
Date. Sept. 5-6th 1959



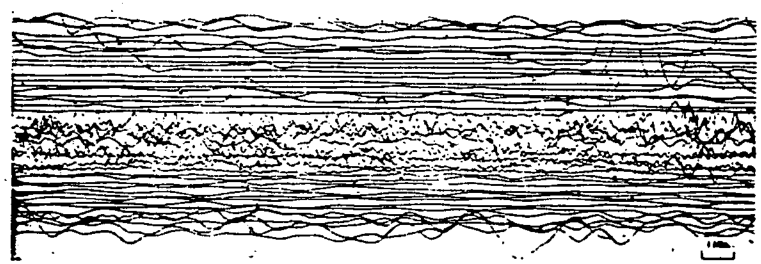
19 2nd-kind volcanic micremor
Instrument. Wiechert Seismograph
Component. N.S. (Transversal wave)
Date Jan. 1st-2nd 1962



20.. 3rd-kind volcanic micro-tremor
Instrument. High Sensibility Seismograph
Component. U-D
Date. Jan. 16-17th 1962



21. 4th-kind volcanic micro-tremor
Instrument. Short-Period Seismograph
Component. U-D N-S E-W
Date. Sept. 9th 1960



22. A Record by Long-Period Seismograph. (Apr. 7th. 1958)

PLATE 4

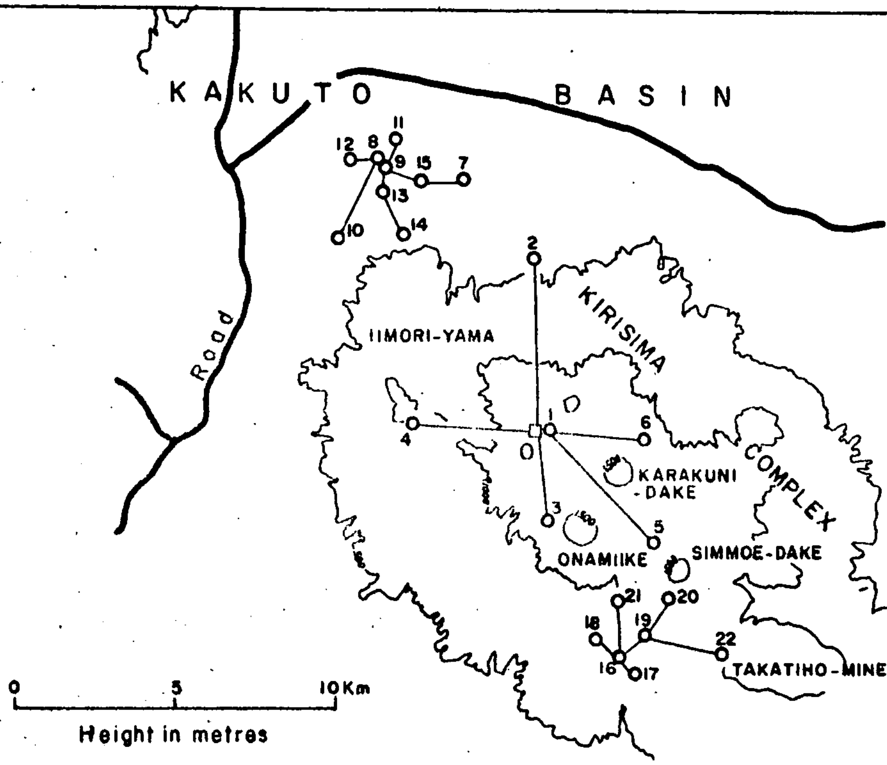


Figure 1 Kirisima Seismic Networks locality map
0 Kirisima Observatory
1-6 Kirisima Observatory Network
7-15 Kakuto Basin Network
16-22 Simmoe - Dake Network
—— Cable link

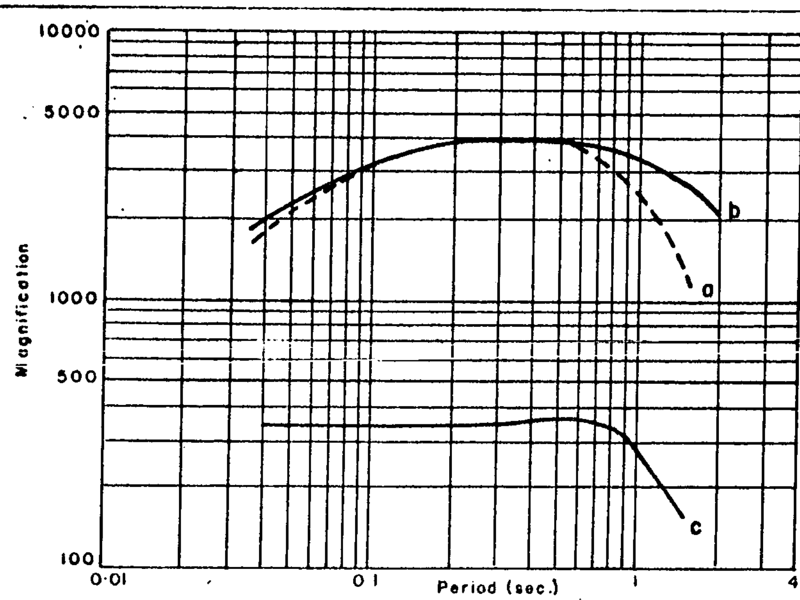


Figure 2 Asama Volcano Observatory and Kirisima Volcano Observatory Seismograph Frequency Response Curves.

a Electromagnetic Seismograph (transducer galvanometer)

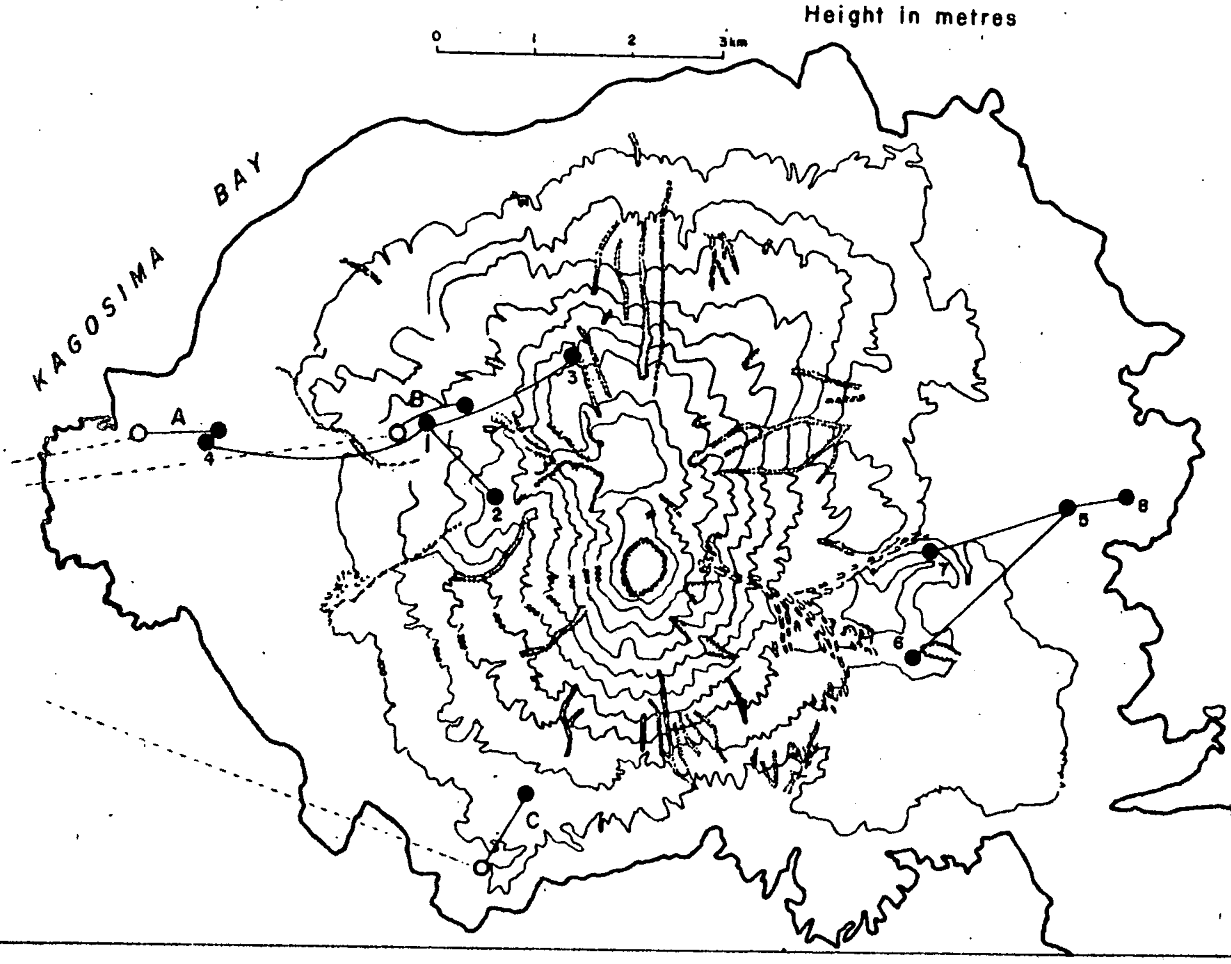
b Electromagnetic Seismograph (transducer-amplifier-pen-galvanometer)

c Ishimoto Seismograph

Figure I Sakurajima Seismic Networks locality map

I	Sakurajima Volcano Observatory
I-4	Sakurajima Seismograph Network
5	Kirokami Station
5-8	Kirokami Auxiliary Network
A,B,C ●	JMA Seismograph
O	JMA Telemetering Station
———	Cable link
- - - - - -	Wireless link

Height in metres



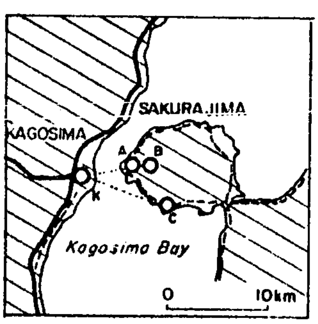
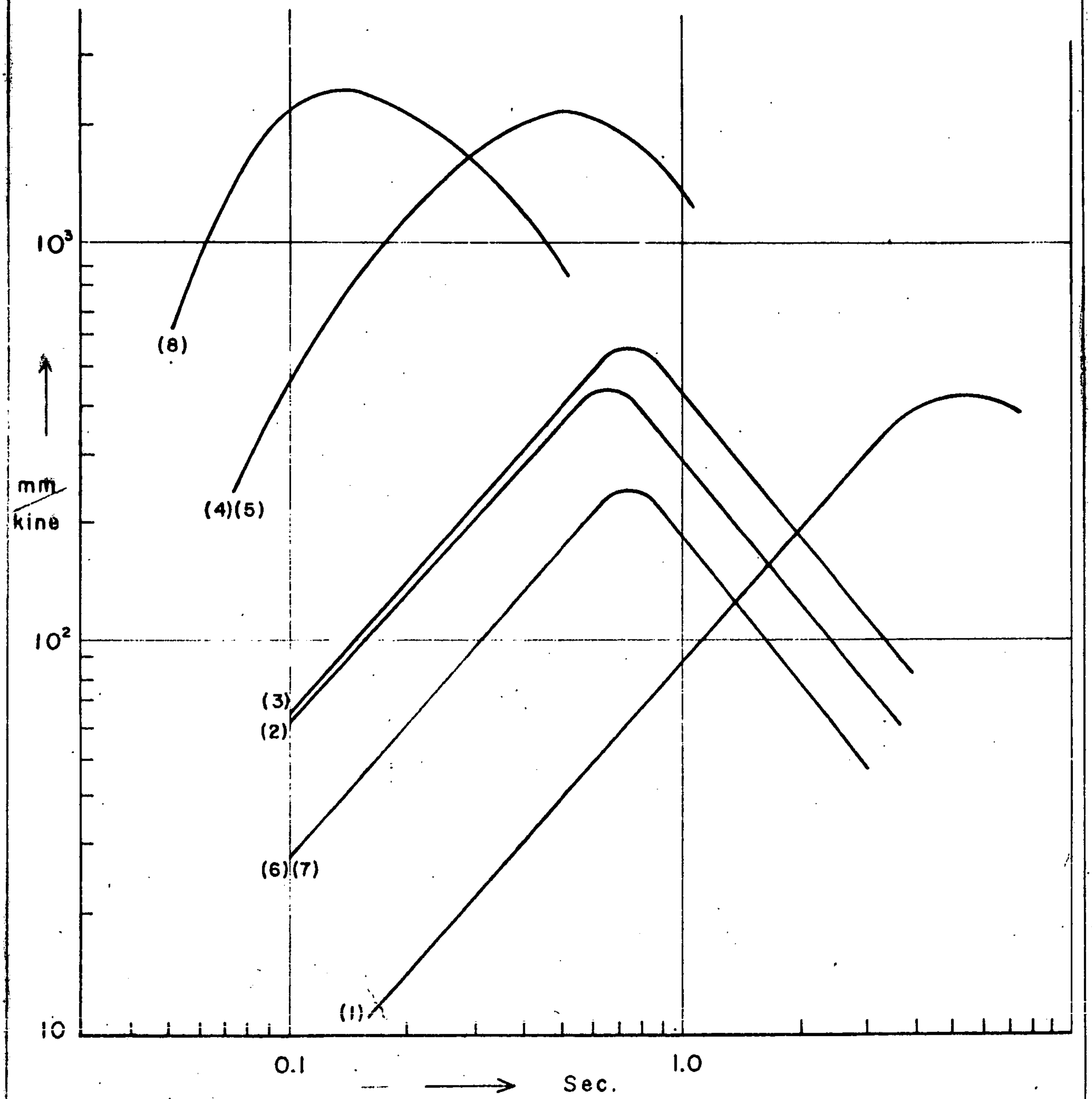


Figure 2 Locality map

K	Kagosima local Meteorological Observatory
A,B,C	JMA Seismograph
- - - - - -	Wireless link

PLATE 7



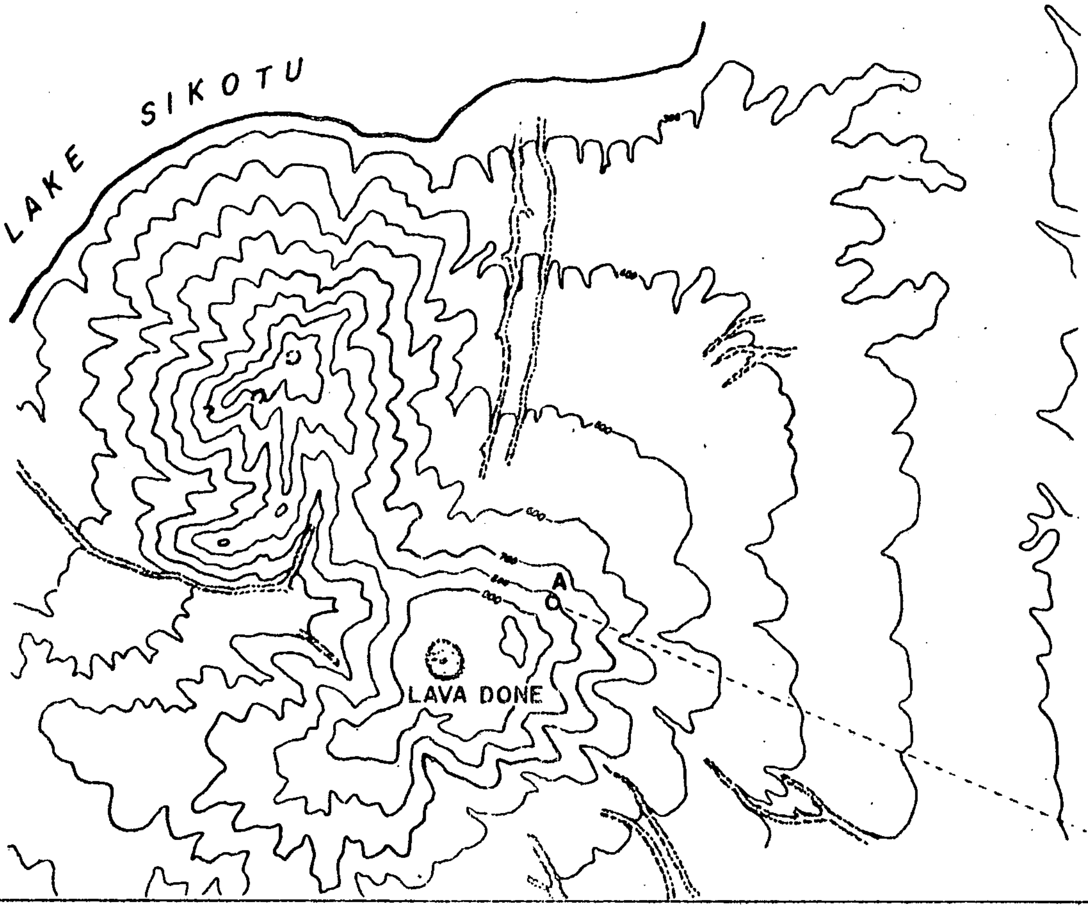
Sakurajima Volcano Observatory Seismographs frequency response curves

1-4 Sakurajima Observatory Seismograph Network
5-8 Kirokami Auxiliary Network

PLATE 8

Figure 1 Tarumae Volcano locality map
A Tarumae Seismic Station
----- Wireless link
Height in metres

0 1 2 3 km



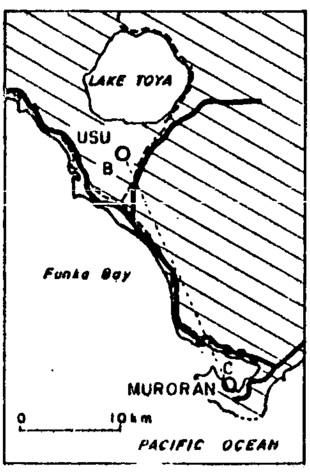


Figure 3 Usu Volcano Locality map
B Usu Volcano Seismic Station
C Muroran Weather Station
-.-.- Wireless link

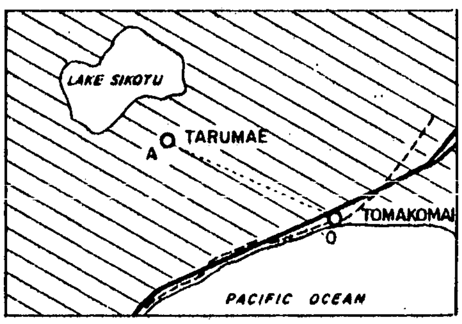


Figure 2 Tarumae Volcano Locality map
A Tarumae Seismic Station
O. Tomakomai Weather Station
---- Wireless link

0 10 20km