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VOLCANO SURVEILLANCE IN JAPAN

by

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SUMMARY

Japan has 48 active volcanoes which range in distribution from Hokkaido to the small islands south of the country. The Japanese Meteorological Agency is the official body responsible for volcano surveillance and a specialist cell within this organisation maintains 13 permanent volcanological stations. The station activities include seismic, tilt, topographic, exhalation, temperature, sound and petrological studies. Their seismic equipment at this stage consists predominantly of mechanical low magnification instruments. Steps are being taken to replace them with modern high magnification electronic instruments.

Several of the Universities undertake fundamental research in volcanic behaviour and have made major contributions to knowledge in this field. The most notable institutions are the Universities of Tokyo and of Kyoto which have a number of permanent observatories in operation. Tokyo University's observatory at Asama has revealed that eruptions are preceded by tumescence of the structure and an increase in the frequency of shallow focus earthquakes. It has developed a telemetered seismic array which enables precise plotting of foci at depth. At Aso volcano where seismic activity is almost exclusively continuous micro-tremor Kyoto University has obtained promising results for prediction purposes by extending its "seismic window" to include long period waves. At Sakura-zima pre-eruption seismic events have ranged from strong earthquake swarms to barely detectable micro-tremor. Here much attention is given to measurement of topographic changes, tilt, and strain. Topographic measurements suggest a gradual increase in deep seated pressures since the great eruption of 1914. Tilt changes have preceded the lesser eruptions of 1946 and 1955 and extensometer readings indicate greater crustal compliance with tidal forces during the pre-eruption period of high volcanic pressures. In Japan studies of seismic activity and crustal deformation have yielded the most promising material for predicting volcanic eruptions and most research is going into the refinement of techniques in these fields.

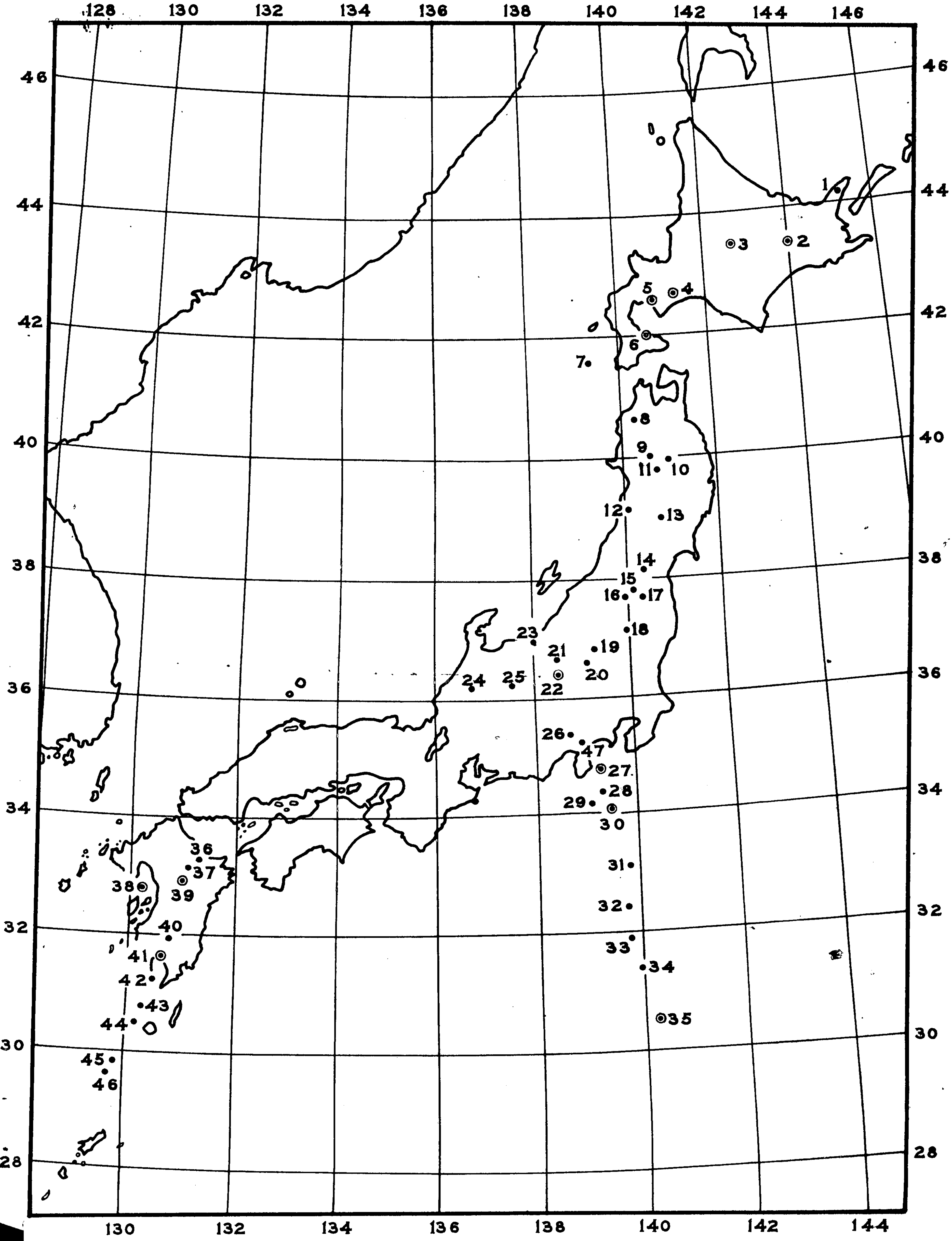
TABLE I

LIST OF THE ACTIVE VOLCANOES IN JAPAN

No.	Volcano	Height	Latitude (N)	Longitude (E)
		m	°	°
1	Shiretoko-Iozan	1563	44.2	145.2
2	Meakandake	1053	43.5	144.0
3	Tokachidake	2077	43.5	142.7
4	Tarumaeyama	1024	42.7	141.4
5	Ususan	725	42.5	140.8
6	Komagatake in Hokkaido	1140	42.0	140.7
7	Oshima-Oshima	714	41.5	139.4
8	Iwakiyama	1625	40.6	140.3
9	Yakeyama in Akita Prefecture	1366	40.0	140.8
10	Iwateyama	2040	39.8	141.0
11	Komagatake in Akita Prefecture	1637	39.8	140.8
12	Chokaizan	2230	39.1	140.1
13	Kurikomayama	1628	38.9	140.8
14	Zaosan	1841	38.1	140.5
15	Azumasan	2024	37.7	140.1
16	Bandaisan	1818	37.6	140.0
17	Adatarayama	1760	37.6	140.2
18	Nasusan	1917	37.1	140.0
19	Nikko-Shiraneyama	2578	36.8	139.4
20	Akagiyama	1828	36.6	139.2
21	Kusatsu-Shiranesan	2162	36.6	138.5
22	Asamayama	2542	36.4	138.5
23	Yakayama in Niigata Prefecture	2400	36.9	138.0
24	Hakusan	2702	36.2	136.7
25	Yakedake	2458	36.3	137.6
26	Fujisan	3776	35.3	138.7
27	Miharatama	755	34.7	139.4
28	Niijima	285	34.3	139.2
29	Kozujima	571	34.2	139.1
30	Miyakejima	815	34.1	139.5
31	Hachijojima	858	33.1	139.8
32	Aogashima	424	32.4	139.8
33	Bayonnaise Rocks	-	31.9	139.9
34	Smith Reef	-	31.4	140.0
35	Torishima	403	30.5	140.3
36	Tsurumidake	1375	33.3	131.5
37	Kujusan	1764	33.1	131.2
38	Uuzendake	1360	32.7	130.3
39	Asosan	1592	32.9	131.1
40	Kirishimayama	1700	31.9	130.9
41	Sakurajima	1118	31.6	130.7
42	Kaimondake	924	31.2	130.5
43	Iojima	716	30.8	130.3
44	Kuchinoerabujima	1043	30.5	130.2
45	Nakanoshima	1032	29.8	129.8
46	Suwanosejima	825	29.6	129.7
(47)	Hakoneyama	1439	35.2	139.0
(48)	Kimpozan	666	32.8	130.6

47, 48 : Volcanoes which had not erupted in historic time.

FIG. 1.



◉ THE VOLCANOES WITH PERMANENT OBSERVATION STATIONS OF JAPAN METEOROLOGICAL AGENCY

• THE OTHER VOLCANOES

' Mineral Resources,
and Geophysics.

ACTIVE VOLCANOES IN JAPAN

To accompany Record 1964/16
O/13/1

INTRODUCTION

A meeting of the International Association of Vulcanology was held in Japan in 1962. Some 200 delegates from many countries presented formal papers on a wide range of subjects connected with prediction and the nature of eruptive activity. The sessions were arranged to allow visits to some of the notable Japanese volcanic areas and the main institutions responsible for the study of local vulcanism.

Japan is vitally concerned with its volcanoes; about 300,000 people live within 10 kilometres of active centres and tourist visitors to individual craters number as many as 2,000,000 per annum. Thus Japanese vulcanologists are presented with special problems and prediction studies are being closely pursued. It is proposed in this report to outline broadly their approach to volcanic surveillance with particular attention to instrumentation.

DISTRIBUTION OF VOLCANOES

Japan possesses at least 46 active volcanoes whose locations range from Hokkaido in the north to the islands south of Kyushu. (Fig.1; Table 1) Three or four of these centres are always active; according to statistics made available by the Meteorological Agency, seven or eight eruptive outbursts occur each year and 20 reports of abnormal conditions are received annually.

SURVEILLANCE

The official body for the surveillance of volcanic activity in Japan is a specialist cell within the Japanese Meteorological Agency. It maintains thirteen permanent observation stations on the volcanoes of Japan (Fig.1) and the nature of their observations is detailed in the table below:-

Table II

Meteorological Agency Observatories

Permanent observations of activity are maintained at volcanoes listed in the following table; the type of observation and the meteorological observatories or weather stations, concerned, are given below.

A. Routine Observations.

1. Seismological observation
   a. Volcanic earthquake
   b. Volcanic tremors
2. Visual observations from distance
   a. Volcanic fume or smoke.
   b. Other volcanic phenomena such as rumbling.
3. Field observations
   a. Topography
   b. Temperature of the ground, fume and hot springs.
   c. Chemical compositions and quantity of fume.
   d. Other volcanic phenomena such as rumbling and sublimation.

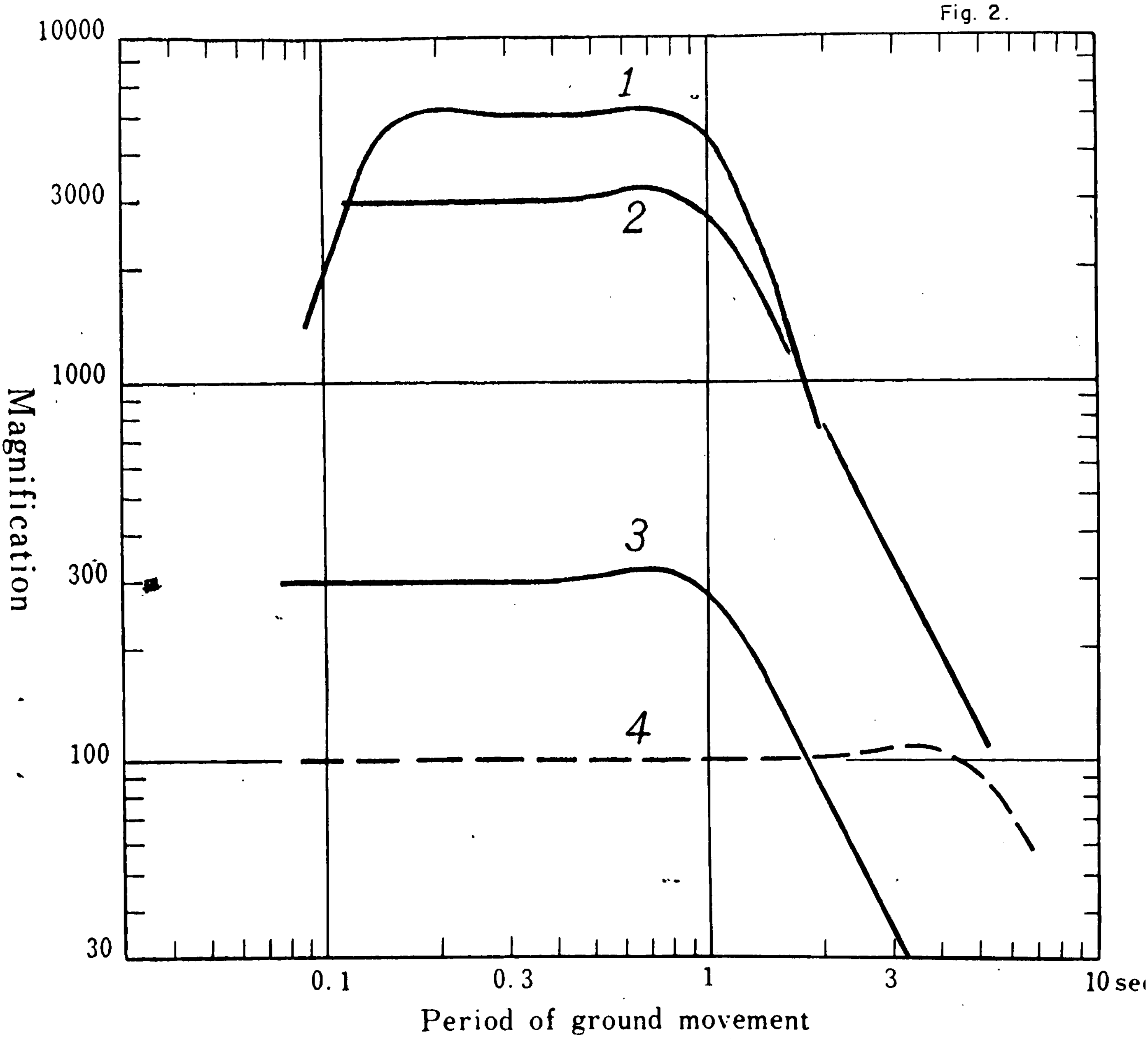
B. Special observation - The following phenomena are observed during eruptive activities in addition to the above-mentioned observations.

1. The course of eruption
2. Physical proportion of the lava and ejecta
3. Petrological properties or mineral constituents of the lava and ejecta.
4. Distribution of the ejecta, lava flow, etc.
5. Other volcanic phenomena such as explosive sound and air vibration.

Volcanoes	Height; Latitude Longitude	Observation station and its branch station.	Distance and Direction from the volcano or crater.	Seismograph
Sakurajima	118m 31.6°N 130.7°E	Kagoshima Local Meteroological Observatory (a.b.c.)	10 km W of Minamidake Crater	W.S.
		Sakurajima Volcano Observatory (a)	5 km W of Minamidake Crater	I_1 E
Asosan	1592m 32.9°N 131.1°E	Asosan Weather Station (a,b,c)	1 km. W of Nakadake Crater	I_1 T, E
		Bochu Branch Station	5 km. NNW of Nakadake Crater	
Unzendake	1360m 32.7°N 130.3°E	Branch Station of Unzendake Weather Station (a.c.)	Near the field of hot springs	W, P, I_1
Torishima	430m 30.5°N 140.3°E	Torishima Weather Station (a.c.)	1 km. W of the central cone "Ioyama"	I_1 P
Miyakejima	815m 34.1°N 139.5°E	Miyakejima Weather Station (a,b,c)	5 km N of the central cone "Oyama"	I_1
Miharayama	755m 34.7°N 139.4°	Oshima Weather Station (A,b,c,)	5 km.N of the crater	W.S.
		Somma Branch Station (a)	1.5 km. NW. of the central cone	I_1
Asamayama	2542m 36.4°N 138.5°E	Karuizawa Weather Station (b.c.)	9 km. SE of the crater	
		Oiwake Branch Station (a)	8 km. SSE of the crater	I_1T,X
		Chinotaki Seismograph Station (a)	3.5 km SSE of the crater	E.

Volcanoes	Height Latitude Longitude.	Observation station and its branch station.	Distance and Direction from the volcano or crater.	Seismograph
Nasusan	1917m 37.1°N 140.0°E	Shirakawa Weather Station (b)	20 km.E of the volcano	
		Utsunomiya Local Meteorological Observatory (c)	63 km.S. of the volcano	
		Nasusan Seismograph Station (a)	1.3 km ENE of the top of the volcano.	I_1
Komagatake in Hokkaido	1140m 42.0°N 140.7°E	Mori Weather Station (a,b,c)	9 km.NW of the crater	W.S.
		Komagatake Seismograph Station (a)	4.5 km. SW of the crater.	I_1
Ususan	725m 42.5°N 140.8°E	Muroran Local Meteorological Observatory (b,c)	25 km. SE of the volcano	
		Sobetsu Seismograph Station (a)	2.3 km. NE of Sowashinzan of Ususan	I_1
		Niskikohan Seismograph Station (a)	1.5 km NNW of Sowashinzan of Ususan	I_1
Tarumaeyama	1024m 42.7°E 141.4°E	Tomakomai Weather Station (b,c.)	20 km. E of the Volcano	
		Morappu Seismograph Stn.(a)	6 km. NE of the volcanic dome	I_1
Tokachidake	2077m 43.5°N 142.7°E	Asahikawa Local Meteorological Observatory (b,c.)	50 km. SE of the volcano	
		Tokachidake Seismograph station	0.9 km. NW of Taiso crater	I_1
Meakandake	1503m 43.5°N 144.0°E	Kushiro Local Meteorological Observatory (b,c)	60 km. NW of the volcano	
		Meakandake Seismograph Station (a)	1.1 km. NNW of Pommachineshiri Summit Crater of Meakandake	I_1

Fig. 2.



1. Electromagnetic seismograph.
2. Mechano-optical seismograph.
3. 450 times seismograph.
4. Wiechert's seismograph.

Period characteristics of the main seismographs

Notations - (a) Seismological Observations.
(b) Visual observations from distance
(c) Field observations
E. Electromagnetic seismograph
I_1 450 x seismograph
I_2 150 x seismograph
W Wiechert's seismograph
P Portable seismograph
S Strong motion seismograph
T Omori's tromometer
X Mechano-optical seismograph

It will be noted in Table II that the majority of Agency stations are equipped with mechanical seismographs which are inherently low magnification instruments (fig.2). The Agency staff were aware of the limitations of this equipment and a programme of replacement with electromagnetic instruments was under way. The new equipment was being constructed in their own workshops. Mobile observatory teams with suitable equipment were also planned for special investigations of eruptive activity.

The Agency is not legally bound to warn the public of impending eruption. This point was made quite clearly to visiting vulcanologists. They do, however, issue an immediate report on any change in conditions of a volcanic centre. Recently voluntary disaster prevention organisations have been formed in regions near active volcanoes. These organisations may act on the recommendations made by the local observatory or weather station and demarkate danger areas, arrange evacuation and restrict movement in these areas.

The Japanese Meteorological Agency began publishing their routine volcano observations in a separate quarterly Vulcanological Bulletin in 1961 since it was realised that the specialist field of vulcanology covered a wide range of studies which could not be adequately presented in the Bulletins of the seismological section. Most of the professional papers written by the Japanese Meteorological Agency staff are published in the Quarterly Journal of Seismology in Japanese, and in the Geophysical Magazine in English.

RESEARCH

Research on volcanic activity is carried out for the most part by Universities some of which have established permanent observatories on the more active volcanoes. The chief institutions interested in this field of study are the Universities of Tokyo and of Kyoto. Some idea of the scope of their work is given by considering the instrument installation at Asama and Aso which are probably the best equipped vulcanological stations in Japan.

Asama Volcano Observatory

Asama erupted in 1783 and produced nuées ardentes which were responsible for the death of 1300 people. Serious study of this volcano began in 1933 when Professor T. Minakami of the Earthquake Institute of Tokyo started observations. In the following year an observatory was constructed 4 kilometres east of the crater and observations have been maintained until the present day. Minakami's work at this centre has made a major contribution to knowledge of volcanic behaviour.

Fig. 3

Schematic plans of
Asama Volcano Observatory

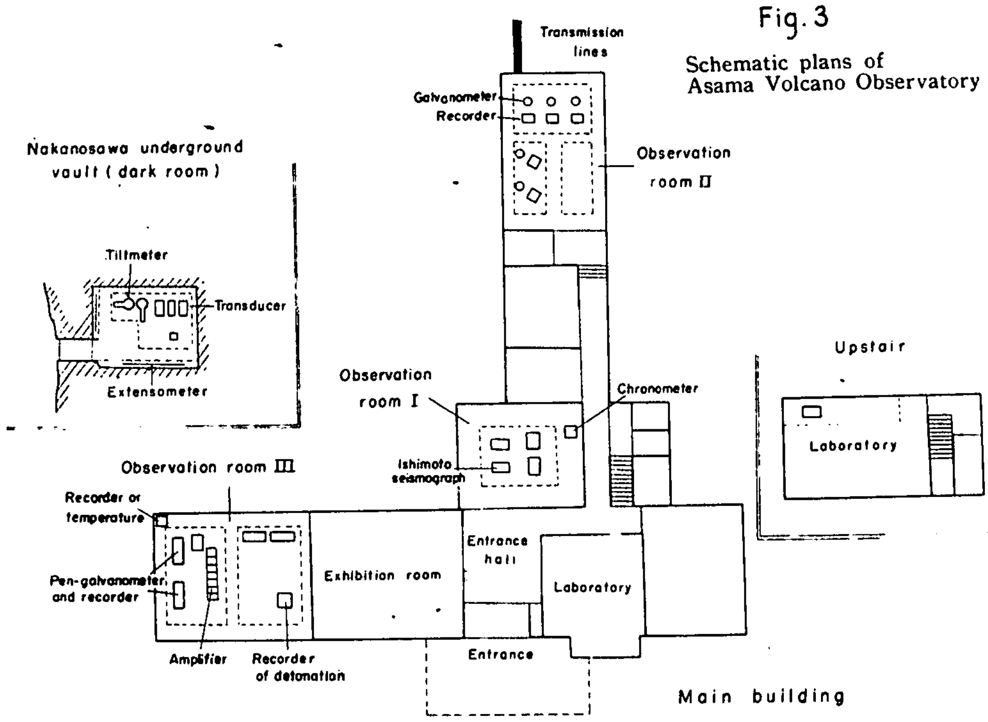
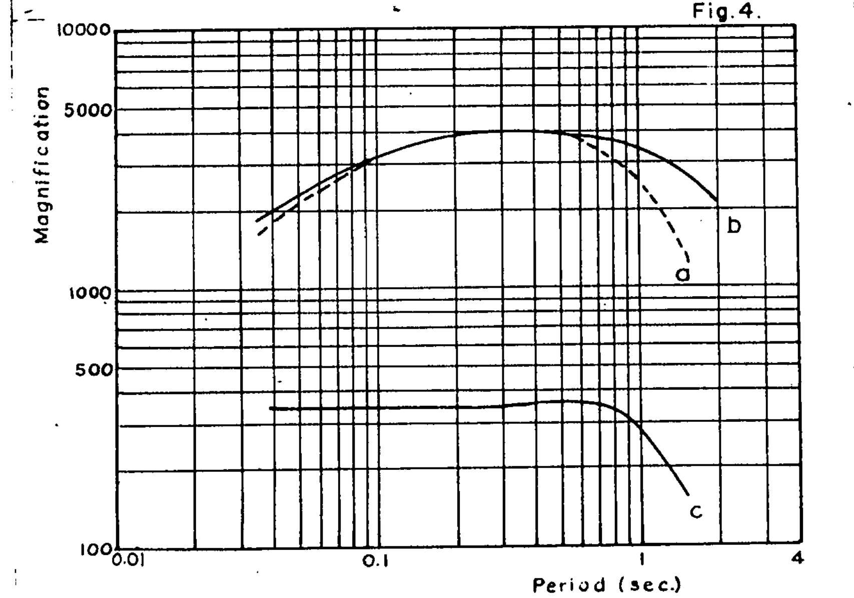


Fig. 4.



Characteristic Curves of the Seismograph, Installed at the Asama Volcano Observatory

a: electromagnetic Seismograph (transducer galvanometer.)

b: electromagnetic Seismograph (transducer - amplifier - pen-galvanometer.)

c: Ishimoto Seismograph.

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Current instrumentation at Asama is listed below (Table III) and the layout of the Observatory is shown in Figure 3. Response characteristics of the seismic equipment is illustrated in Figure 4.

TABLE III

INSTRUMENTS OPERATED AT THE ASAMA VOLCANO OBSERVATORY

1. Seismographs
(Routine observations)

(a) Electromagnetic seismographs (transducer-galvanometer at 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 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

(c) Ishimoto seismographs

Station	Period	Magnification	Component
Volcano Observatory	1 sec.	350	H(EW)
"	"	350	H(NS)
"	"	350	V
"	"	50	H(EW)

(Temporary observation)
Electromagnetic seismographs (transducer—electromagnetic oscillographs at Observatory.

Station of transducer	Period of transducer	Period of galvanometer	Sensitivity	Component
No.1	1 sec.	0.033 sec.	4×10^2 mm/kine	V
No.2	"	"	"	V, H, H.
No.3	"	"	"	V
No.5	"	"	"	V
No.6	"	"	"	V
No.7	"	"	"	V
No.8	"	"	"	V
No.10	"	"	"	V

2. Apparatus for measurements of sound waves accompanying explosive eruption.

3. Thermometer (thermister—recorder at Observatory)

Station of geothermal measurement	Depth
Volcano Observatory	1.3 m.
Onioshidasi	30 m.
Sannotorii (No.2)	4.5 m.
Sengataki	(Spring)
Gippayama	(Spring)

4.

Tiltmeter and extensometer	Component	Station
Horizontal pendulum tiltmeter	N S, E W	No.3
Silica-tube extensometer	N S, E W	No.3

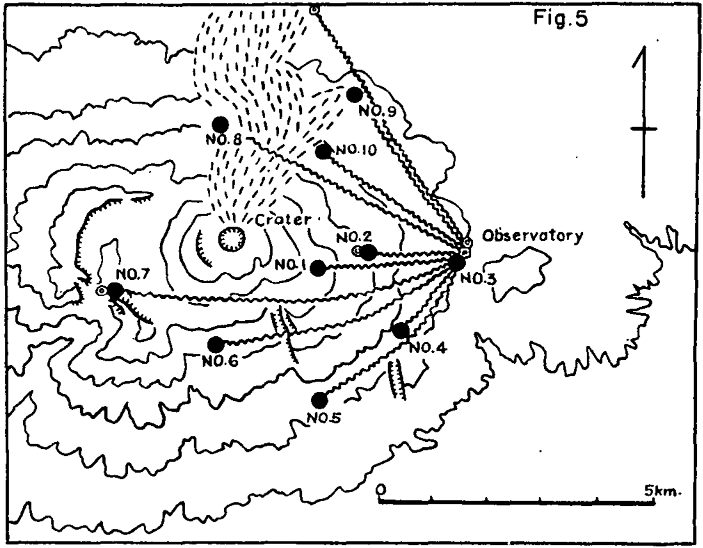


Fig.5
Crater
Observatory
NO.1
NO.2
NO.3
NO.4
NO.5
NO.6
NO.7
NO.8
NO.9
NO.10
0
5km.

0/13/6

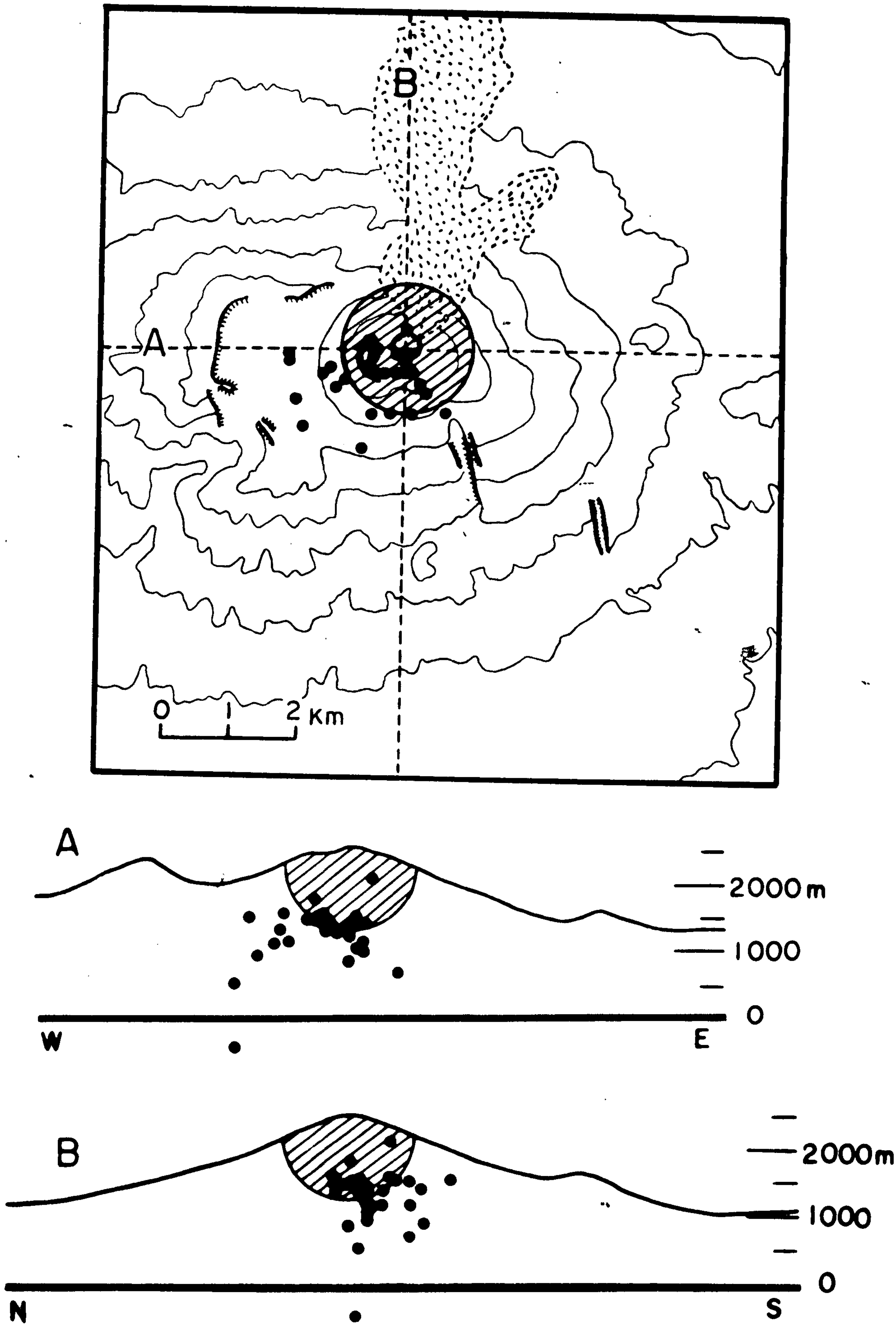


Fig. 6. Hypocentral distribution of earthquakes originating from Asama. Hatched area indicates the hypocentral domain of extremely shallow earthquakes.

A conspicuous feature of the instrumental layout is the use of line telemetering for seismic, sound and temperature data (Fig. 5). This system makes possible recording on a common time base which greatly facilitates accurate reading and interpretation of seismograms and also brings in data from locations on the volcano which would be quite impracticable to occupy with separate stations. Continuous recorders at the observatory have a drum speed not exceeding 60 mm/minute. A high speed recorder, 3 cm/minute, is used for sampling earthquake arrivals with sufficient accuracy to plot hypocentres with a small margin of error.

Investigations have revealed a good correlation between the frequency of occurrence of shallow focus earthquakes and explosive activity. Professor Minakami has been able to calculate an experimental formula which has been useful in predicting eruptions. One point of particular interest which the detailed seismic work over the last 25 years has brought to light is the predominantly shallow focus nature of Asama's earthquakes. Disturbances deeper than 2 kilometres rarely occur. Hypocentres are illustrated in figure 6.

Tilt measurements have indicated marked movement preceding and accompanying eruptions. Precise levelling surveys have indicated that eruptions are associated with a dome-shaped upheaval and a related subsidence of surrounding country. A similar pattern of deformation has been observed at other Japanese volcanoes.

No positive results for prediction work have been achieved at Asama with temperature and geomagnetic studies.

<u>Aso Volcano Observatory</u>

Aso volcano on Kyushu is a caldera structure which occupies an area of 397 square kilometers. In addition to its large size the caldera is notable for the welded tuffs which form part of its walls and extend for many miles on the surrounding slopes. The centre of the structure is occupied by at least a dozen strato volcanoes. One of them, Naka-dake, has produced about 90 eruptions since 769 A.D. All have been explosive in type.

A sudden eruption during the night in 1958 killed a number of workmen who were repairing the overhead trolley line which carries up as many as 20,000 tourists a day to the crater rim. The bus terminal and souvenir store were destroyed by the same eruption.

Kyoto University established an Observatory 7.3 kilometers from Naka-dake in 1928 and three years later the Meteorological Agency followed suit with a station at the foot of Naka-dake. The type of equipment used at the observatories and the instrument constants are listed below in Table IV. The response range of the seismographs is illustrated in Figure 7.

TABLE IV

CONSTANTS OF SEISMOGRAPHS

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

* Seismograph recording on smoked paper with transistor amplifier.
** Seismograph recording on 35 mm. wide film.

T_1 Period of pendulum

T_2 Period of galvanometer

h_1 Damping constant of pendulum

h_2 Damping constant of pendulum

o– Coupling factor

P Solid friction

Kyoto University has expanded its facilities to include four additional stations: one has radio telemetry equipment which transmits seismic signals back to the central observatory. This system provides three continuous channels covering the seismic frequencies from 0.1 to 35 cps. Transmitting on 62.90 Mc. with subcarrier frequencies of 1.3, 1.7, and 2.3 Kc. Frequency and pulse modulation is used. A transmitting power of 5 watts sends the signal over a distance of 6.2 kilometres which is not line of sight. Signal to noise ratio is greater than 40 decibells. This equipment has been operating continuously

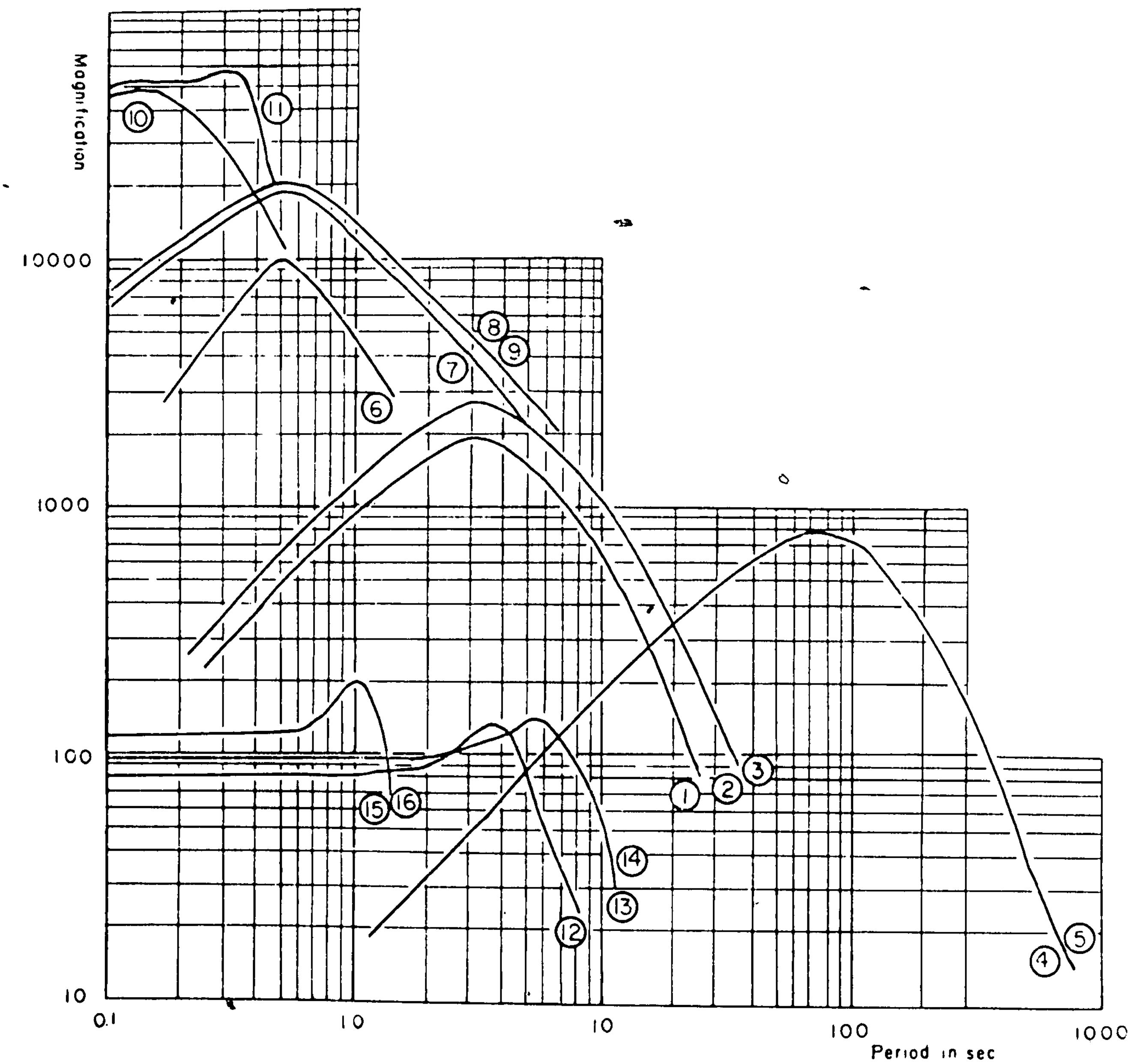


Fig. 7 . Magnification curves of Seismographs used at the Volcanological Laboratory.

since 1960 except for periods of electrical storms. Cloud fog causes marked attenuation of the signal. Other equipment includes magnetic recorders, tiltmeters and a tape recorder with associated filter recorders for analysing seismic wave characteristics.

The seismic activity at Aso has affinities with the Territory's Manam volcano in that it commonly takes the form of a continuous micro-tremor. Discrete earthquakes are rare: in only one instance during the last 30 years has an eruption been preceded by earthquake swarms.

The micro-tremor has been studied in great detail and four classes of movement have been recognized by Sassa. They have the following periods:

1st type 0.8 - 1.5 seconds.

2nd type 3.5 - 7 seconds

3rd type 0.4 - 0.6 seconds

4th type 0.2 seconds

The first is identified as a Love wave, the second as a Rayleigh andthe remaining two as body waves. The existence of a wave of a much longer period has been established by Kamo. This wave has a period of 40 - 55 seconds and it is thought to be of the Rayleigh type.

Seismic refraction surveys have been used to obtain information on structure and travel time velocities. These have revealed a surface layer with a P velocity of 1.4 - 1.6 km/sec. and a lower layer with a P velocity of 2.5 - 3.5 km/sec.

For a close study of temperature trends in Naka-dake thermistors have been buried in the ground on the floor of the crater and connected by line to recorders at one of the nearby stations.

Changes in seismic activity, tilt and temperature have been associated with some of the eruptions of Naka-dake. Perhaps the most diagnostic event which preceded the 1958 eruption was the appearance of long period tremor (40-55 secs.) two days before the eruption. A marked fluctuation in the amplitude of the 2nd type of micro-tremor also preceded this eruption.

Thermister investigations of the crater temperatures have indicated that seismic fluctuations occur at temperature peaks and that the strongest explosions usually occur about one week after temperature peak.

Tilt changes over a range of 100 seconds were detected near the crater before the eruptions of 1934 and of 1958. Levelling surveys have indicated that an increase in the height of bench marks near the crater is associated with a change in the amplitude of micro-tremor of the 1st type (0.8 - 1.5 seconds).

Continuous recording of the magnetic field is maintained but no positive relationship has been established between magnetic changes and the activity of the volcano.

Sakura-zima Volcano

Sakura-zima is one of Japan's most active volcanoes. Twelve eruptions have occurred since the beginning of the century. Its location in a caldera which has been invaded by the sea gives it affinities with Rabaul's volcanic situation. Some of the observations made there may have relevance to our problems.

Although Professor Omori's study of Sakura-zima at the time of the great eruption of 1914 made singular contributions to knowledge of volcanic behaviour, it was not until the eruptions of 1946 and 1955 that further study of the centre was undertaken when scientists from Tokyo and Kyushu Universities carried out goedetic and seismological investigations. Recently both the Meteorological Agency and Kyoto University established permanent observatories on the island.

Short-term investigations of the seismic activity which was associated with the eruptions of 1946 and 1955 yielded observations of modest value for prediction purposes. No earthquakes preceded or accompanied the lava outpouring of 1946. Micro-tremor accompanied explosions from the crater. Microtremor and Minakami's B type (shallow) earthquakes predominated during the 1955 eruption. Some A type, deeper, shocks occurred only during the early part of the eruption suggesting that the energy migrated towards the surface as the eruption developed.

Crustal Deformation

Particular attention has been given to the study of crustal deformation using precise levelling, triangulation, tide gauges, tiltmeters and extensometers.

Apparently there is evidence in strand line changes to suggest a gradual rise in land elevation of the Kagoshima Bay area from the middle of the 19th century up to 1914, the year of the great eruption. Extensive subsidence followed the eruption. F. Omori checked the nature of this subsidence and found the volume of a roughly circular depressed area to be 1.27 cubic kilometres with a centre near the middle of the caldera. Large horizontal displacements of triangulation points were found on Sakura-zima itself.

Subsequent surveys have indicated gradual upheaval of the depressed area and very interesting evidence of differential movement. The inside and outside of the caldera move independently suggesting that the structure is still in an active stage of formation. Successive surveys on Sakura-zima have indicated uplift in the north and subsidence in the south of the cone, with a hinge line coinciding with the line of the 1914 craters. This deformation is attributed to changes in a lava reservoir which is assumed to be situated 10 kilometres below the centre of Kagosima Bay. The positions of this reservoir is further indicated by tilt changes which precede eruption. Pressure appears to originate from the bay north of the volcano, not from the crater area.

Both tilt and extensometer installation have indicated a sinusoidal movement which is attributed to tidal loading. A phase lag of 4½ to 5 hours exists between high water and the tilt or strain movement. This phase lag shortens when the volcano becomes more active suggesting that elastic compliance is greater under conditions of high volcanic pressure.

Special attention is being given to the development of water tube tilt meters. These instruments offer several advantages which include the avoidance of spurious localised movements, relative freedom from temperature effects and almost limitless refinements of accuracy. Its main disadvantage is that it does not produce a record. One of the projects under study at Sakura-zima was the development of a recording device for this instrument. The approach being used at that time was to float an object attached to a strain gauge on one of the water pots. A change in tilt was recorded as a change in strain. I have been advised recently that this method has been abandoned in favour of an optical system because of electronic instability in the strain gauge recorder.

CONCLUSIONS AND RECOMMENDATIONS

The study of earthquakes and crustal deformation yields the most promising material for prediction of volcanic activity. This conclusion is recognised in the basic equipment of Japanese vulcanological stations. Although the potential value of the study of temperature, vent chemistry, magnetic fields and gravity is clearly acknowledged in current work, much of the present research goes into refining techniques in the study of seismic disturbances and crustal deformation.

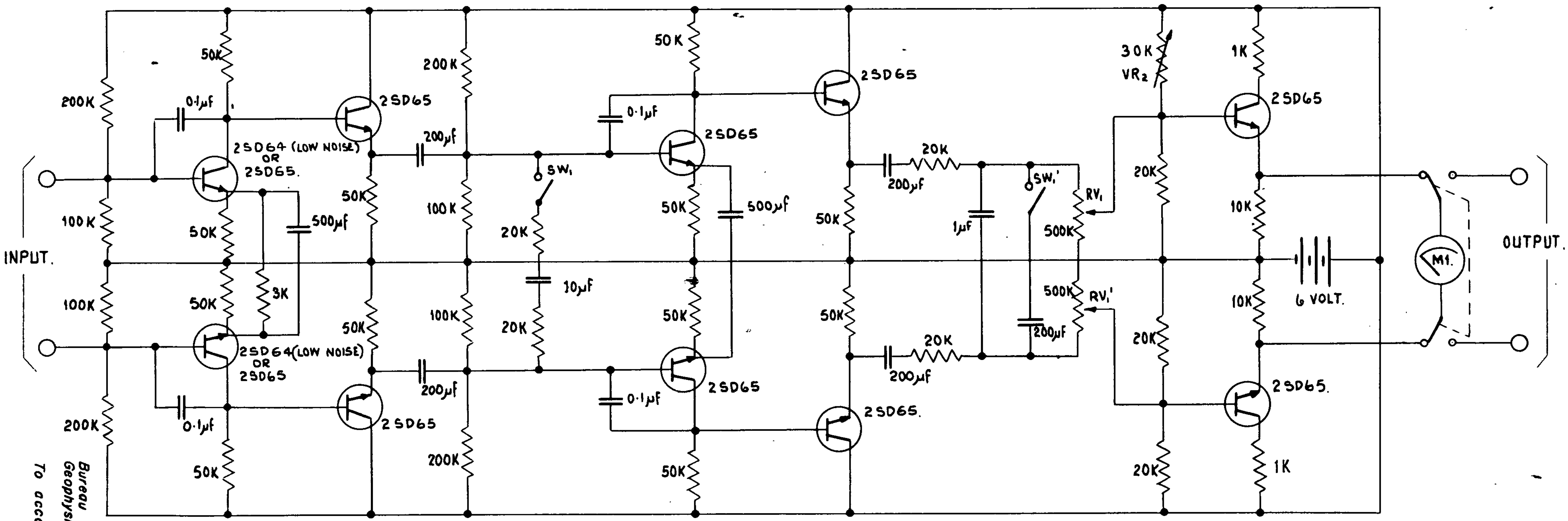
An outstanding development in this regard is the growing adoption of telemetering, particularly for seismic recording. This technique increases the volume and variety of information available on any disturbance and at the same time greatly increases its accuracy. This facilitates the location of disturbances and enables study of their migration of earthquake foci. Ground lines are normally used for connecting the remote seismometers to central recorders. The signal is boosted on some lines by an inexpensive amplifier of the valve or transistorized type (fig.8) which has a maximum gain of about 3000.

Some success has been achieved with radio telemetering but it is not being widely adopted. Interference with the signal by atmospheric electricity and attenuation by cloud fog may be factors in its lack of popularity.

I was particularly interested to see that the "seismic window" at the Aso observatory had been extended to include long period waves and also to find that diagnostic waves of this type preceded the 1958 eruption. The study of eruptions in the Territory has indicated the presence of such waves at two volcanic centres. Witnesses of the preliminary seismic activity of the Mount Lamington eruption experienced long period disturbances and I have seen clear evidence of them at Manam at times of high eruptive potential.

Due regard has been paid to Japanese experience in the recommendations which have been made covering equipment for volcano observatories in the Territory. Priority has been given at all observatories to installation of seismic and tilt equipment as initial instrumentation. A telemetered system has been recommended for Rabaul. A radio link was suggested for only one of the Rabaul network stations because its reliability seemed less certain than cable - a view which was later supported by Professor Newstead.

Equipment now on hand will enable three of the Territory volcano stations to record seismic signals covering the frequency range from short period to medium long period (30-40 seconds). Considerable research is going on at present in the development of long period instruments. Instruments with the requisite stability and an extended long period response will undoubtedly soon become available.



M1: 50μA FULLSCALE D.C. METER.
(FOR BALANCING CHECK).

JAPANESE · AMPLIFIER.

DISASTER PREVENTION INSTITUTE.

Fig 8.

Bureau of Mineral Resources, Geology and Geophysics Dec. 1964
To accompany Record 1964/16
M(E)56

Most field investigations of volcanic activity in the Territory have been carried out with portable Willmore seismographs which have rather heavy current requirements. The associated batteries and charging equipment often present a transport problem particularly since Department of Civil Aviation are insisting on strict conformity with the regulations on the transport of batteries. The processing of photographic records under field conditions also presents a recurrent problem.

Consideration is being given to the practicability of adapting Japanese equipment to avoid some of these difficulties. If we can use clockwork driven recording drums, smoked paper, pen galvanometers and low drain amplifiers, power requirements can be reduced to a few dry batteries which are easily transported.

The results of precise levelling surveys in the Sakura-zima region suggests that more attention should be given to studies of this kind at Rabaul. It seems advisable to check the levels of the post-war survey line at regular intervals and extend it well beyond the confines of the caldera. The installation of one or more tide gauges at points remote from Rabaul, say Kleenwater and Kokopo, would ensure detection of movement of the caldera as a whole. Level changes following the 1914 eruption at Sakura-zima were detected as far as 100 kilometres from the centre. Our present system of tide gauge and level marks are all on the floor of the caldera and will only detect relative movements within this structure.

All Japanese volcanoes on which detailed seismological recording studies are carried out are investigated for travel time velocities and general structure by seismic refraction methods. This information is essential to proper interpretation of records. Seismic refraction surveys should be carried out in the Territory at Rabaul, Manam, Esa'ala and Mount Lamington.