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Research on Akita-Komaga-take (I)
—*Summary of its eruptions in 1970–1971*—

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Abstract: Volcano Akita-Komaga-take went into sudden eruptions on September 17, 1970 after 38 years' silent period and the Strombolian type eruptions were continued until January 25, 1971.

The geothermal survey was conducted immediately before the outburst and also the seismic observation was carried out throughout the period of the volcanic eruptions. The only one forerunning phenomenon of the eruptions was the appearance of a high ground temperature area with many fumaroles. About 33,000 explosion earthquakes were observed from September 18, 1970 to January 25, 1971. However, volcanic tremor was observed only on the late stage of activity and no B-type earthquake was recorded. The relationship between frequency and maximum amplitude for the explosion earthquakes was consisted of two parts and the m value in the part of smaller amplitude was 2.7–2.9, while that for larger amplitude was 4.4.

1. Introduction

Akita-Komaga-take is a volcano located on the boundary between Akita and Iwate Prefectures in Northeastern Japan. It is a double stratovolcano with a caldera of which the central cone is called Me-dake (1,540 m). The highest peak, Oname-dake (1,637 m), which is located at 140°47.9'E and 39°35.0'N, is a parastic volcano of the somma. This volcano seems to have had three eruptions in 1890, 1902 and 1932 according to historical records. It was reported that the volcano rumbled and ejected "hot stones" in 1890: The emission of fumaroles was observed in 1902 at "Oyake-suna", the eastern part of somma: In 1932 the phreatic explosions occurred at "Ishipora", the southwestern foot of Me-dake and eleven small craters and a small amount of mud flow were observed (Otsuka, 1932; Kunitomi and Sagisaka, 1932; The Central Meteorological Observatory, 1932). Epicenters of earthquakes occurring in and around Komaga-take from 1926 to November 1970 are shown in Fig. 1. Recently, four earthquakes were felt near Komaga-take during December 10–12, 1962.

The seismological observation of volcanic micro-earthquakes was carried out during two weeks in 1969 at a distance of 6.0 km to the north of Me-dake by Tanaka

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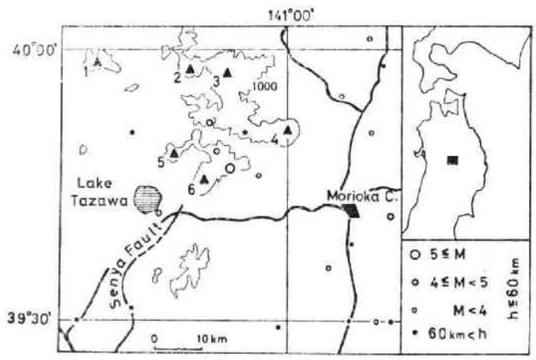

Fig. 1. Map of volcanoes and faults. The epicenters of earthquakes from 1926 to 1970 determined by JMA are also shown. The shallow earthquakes are indicated by open circles and full circles are those deeper than 60 km. Numerals correspond to the volcanoes of 1; Moriyoshi, 2; Akita-Yake-yama, 3; Hachimantai, 4; Iwate, 5; Kayo, 6; Akita-Komaga-take.

and Hori (1969). Then only four shallow micro-earthquakes were detected but none of them was located just beneath Me-dake.

Akita-Komaga-take suddenly became active on August 30, 1970 after 38 years' dormancy, when the emission of water vapor was observed. An eruption occurred at the top of Me-dake on September 18 and the eruptions of Strombolian type were continued until January 25, 1971. The geothermal survey was conducted by the authors immediately before the eruption. The seismological observation has been also made since September 3, 1970. About 33,000 explosion earthquakes were observed during the whole period of eruptions.

The investigation of volcanic earthquakes is an essential source of the valuable information on the mechanism of volcanic eruption and the state of magma situated in the deep interior under the volcano. The observations and analyses of volcanic earthquakes, therefore, have been carried out at many volcanoes with a great deal of fruitful results. For example, the present authors have investigated the volcanic earthquakes occurring around the volcanoes of Iwate, Hachimantai, Akita-Komaga-take, Akita-Yake-yama and others. Although these studies gave some fruitful results, many problems remain unsolved, because the feature of volcano is different from one to another. The seismological study of individual volcano is still necessary for further progress in volcanology. In this paper the outline of the present eruptions of Akita-Komaga-take and the results of the geothermal survey and the seismological observation will be described.

2. Description of Volcanic Activity and Geothermal Survey

On August 29, 1970 the emission of vapor was discovered at Me-dake by a climber and the appearance of new fumaroles was confirmed on August 30 by the mountain patrolmen, Kimura and Hara. They reported that the water vapor with sulfur gas

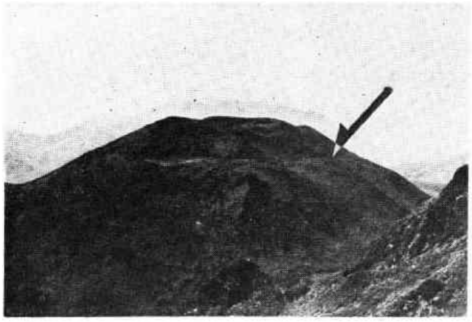

Photo. 1. Me-dake before eruption. The area of fumaroles is indicated by an arrow.

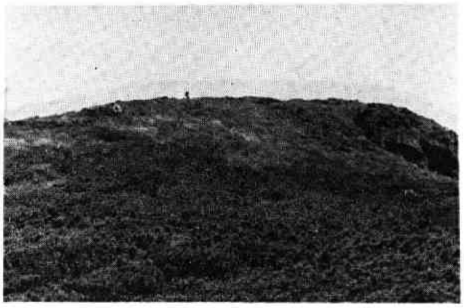

Photo. 2. The area of fumaroles. Vapor is not so clearly seen because of weak emission.

was emitted from the fumaroles and the sublimate of sulfur was found at one of the fumaroles, while no sublimate was seen after August 31. The maximum ground temperature was about 90°C.

On September 15 the activity became higher: A new fumarole was found some tens meters distant from the former ones, the ground temperature near the new fumarole being 82°C. It is interesting that this time is just after the occurrence of big earthquake (M=6.2) off the coast of Miyagi Prefecture. The amount of water vapor and the sound of emission increased on September 16 and a new crack was found near the former fumaroles.

Since the first eruption was observed from Tazawako Town at night on September 18, the eruptions of Strombolian type occurred successively with a rate of 20–30 times per hour and the lava was ejected. The lava flowed down to the west of Me-dake and turned to the south at the caldera walls (Photos. 3 and 4). Osaka and Takahashi (1971) surveyed the area covered by lava on September 19 and 21, October 2, November 3 and January 20, 1971, the area being 2,000 m^2, 12,400 m^2, 29,000 m^2, 49,100 m^2, 82,000 m^2 respectively.

The eruptions were clearly seen from O-dake, about 500 m north of the crater, and the details of eruptions could be observed. The crater, of which the size is about 10 meters in diameter, was situated at the summit of Me-dake. The overflow of magma

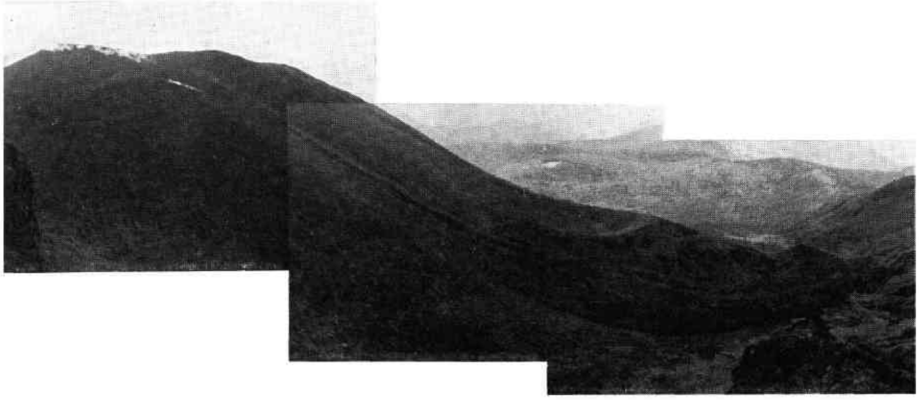

Photo. 3. Lava flow.

Photo. 4. Caldera and lava flow. Photographed from the hericopter in the case of the aeromagnetic survey by Takagi et al. on Nov. 17, 1970.

was seen in every eruption. The ejecta were consisted mainly of smoke, volcanic cinders, magma and others. When the ash content was rich, the color of smoke was rather black, while it was rather white in the cases where the content of water vapor was large (Photos. 5 and 6). The eruptions repeated periodically with explosive sound in

Photo. 5.

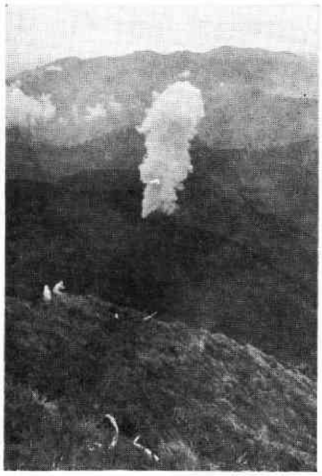

Photo. 6.

Photo. 5. Example of eruption with black smoke.
Photo. 6. Example of eruption with white smoke.

most cases. From these features, this activity may be called the eruptions of Strombolian type. In some eruptions, however, only new magma was ejected without smoke and sound. The smoke and cinders usually reached a height of about 300 and 400 m respectively, the maximum being about 600 m.

The underground temperature in and around the fumaroles was surveyed on September 3 and a part of the area was again surveyed on September 6. The measurement was done at the depth of 10 cm deep under the ground and the number of the measurement points was 53 in total. The results is shown in Fig. 3, in which the areas of fumaroles found on August 30 were shown by the marks of A and B. The crack observed on September 16 is on the line connecting the points of D and D'. The isothermal lines are contoured at an interval of 20°C. The dashed line for the ground temperature of 20°C roughly indicates the area in which the temperature was abnormally high. Although the measurement outside of this area was not carried out, it is certain that the abnormally high ground temperature was limited in this contour line. The size of abnormal area is about 1,500 m^2 and the highest temperature is 88°C. The alpine plants were dead in the region where the ground temperature was higher than 60°C. The comparison of observations on September 3 and 6, as well as the report by patrolmen, indicates that the maximum ground temperature decreased but the abnormally high area increased as the time lapsed.

In relation to the change in ground temperature, the temperature and quantity of water at nearby hotsprings of Kunimi Spa, Mizusawa Spa, Ganiba Spa, Kuro-yu Spa, Magorokuno-yu Spa, Ogama Spa and Tsuruno-yu Spa were studied early in September. These springs are located within the distances of 2–6 km from Me-dake. A change in temperature was observed at Kunimi Spa and the quantity of deposit in water was slightly increased at Mizusawa Spa. No considerable change was observed

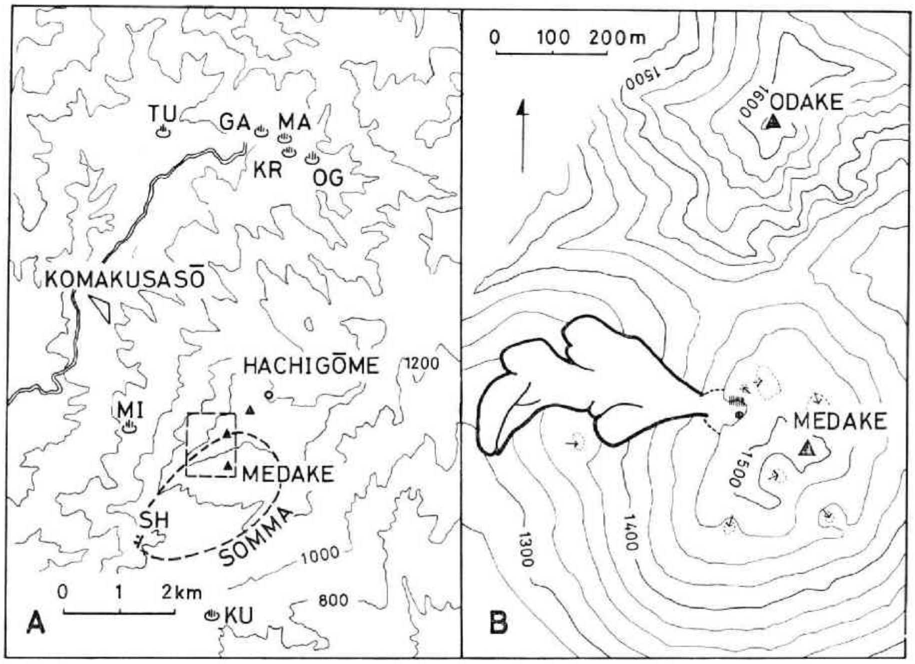

Fig. 2. (A) The location of Komaga-take, observation station and tripartite array. Hot springs and falls researched are also indicated. TU; Tsurunoyu Spa, GA; Ganiba Spa, MA; Magorokuno-yu Spa, KR; Kuro-yu Spa, OG; Ogama Spa, MI; Mizusawa Spa, KU; Kunimi Spa, SH; Shira-taki Falls.
(B) The locations of the new crater, fumaroles before eruption and lava flow. A full circle represents the new crater, hatched region does area of fumaroles and area enclosed with a bold stroke line indicates lava flow, which is drawn from air photograph of the aeromagnetic survey over this volcano on Nov. 18, 1970 by Takagi et al..

at other springs. Moreover, there is no difinite evidence that the above mentioned change at the two springs was directly connected with the volcanic activity of Komaga-take. The water temperature of the spring at the upper stream of Shira-taki Falls, about 2 km southwest of Me-dake, was measured on September 4 and October 3, but no change was found between the two measurements.

3. Seismic Observation

A temporary station (KMK) was set up on September 3 at "Komakusaso", Tazawako Town, on a plateau of volcanic ash about 4 km northwest of Me-dake. On September 21, when the volcanic activity increased, the station was developed to the tripartite station net and another temporary station was installed in an abandoned sulfur mine at "Hachigome" (HAC) about 1.8 km north of Me-dake. The locations of stations, as well as the size and shape of tripartite station, is seen on the map of Fig. 2. The single station observation at KMK started on September 3 and has been carried out until now. The tripartite station observation was made from September 21

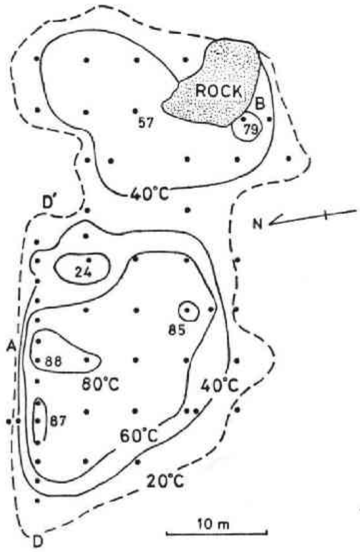

Fig. 3. The distribution of ground temperature. Full circles represent measurement points at the depth of 10 cm under the ground.

Table I

STATION	PICKUP	PERIOD	RECORDER
KMK	1Hz One vertical	Sept. 3–21	Pen recorder*
	4Hz Horizontal two comps.	Sept. 3–10	
	1Hz Horizontal one comp.	Sept. 23–Oct. 16	
	1Hz Three vertical	Sept. 21–Oct. 14	Magnetic tape recorder***
	1Hz One vertical 4Hz Two vertical	Oct. 14–Nov. 13	Pen recorder**
	1Hz One vertical	Nov. 13–Dec. 23	Pen recorder*
		Dec. 23–	Smoked paper recorder*
HAC	4Hz One vertical	Sept. 20–23 Oct. 8–22	Smoked paper recorder*
	1Hz Horizontal one comp.	Sept. 23–Oct. 7	

The running speed of paper or tape
* 2 mm/sec ** 2 or 4 mm/sec *** 9.5 cm/sec

to November 13. The station HAC was operated during the period of September 20–October 7. All the seismometers used in this observation were of moving coil type. The pickups, the recorders and the periods when they were used are listed in Table I. The amplifiers were unchangeable during the whole period of the observation.

In the tripartite station system, a vertical component pickup with the natural frequency of 1 Hz was set at each station. At one of the stations, a horizontal

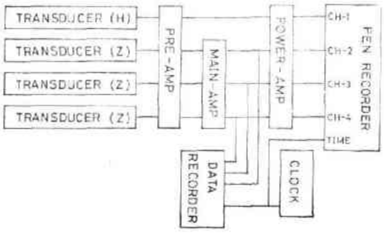

Fig. 4.

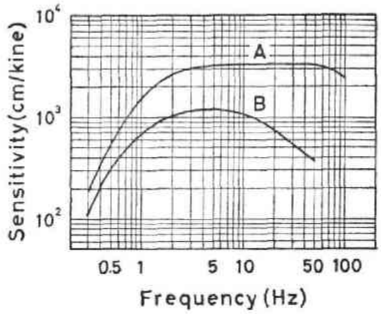

Fig. 5.

Fig. 4. Outline of instrumentation.
Fig. 5. Over all frequency response curve. A denotes that of 1Hz vertical seismometer at KMK. B denotes that of 1Hz horizontal seismometer at HAC.

component of 1 Hz was also used. For 3-6 hours in the midnight the sensitivity of each station was kept on nearly the same level and the magnetic tape recorder, as well as the pen recorder, was used for registration. Then the instrumentation had the system illustrated in the block diagram in Fig. 4. In other time the sensitivities of two pickups was reduced by 10 and 20dB to obtain a wide dynamic range and only the pen recorder was operated. The over-all frequency response of 1 Hz vertical seismometer at KMK is shown by the curve A in Fig. 5, the maximum sensitivity being 3.3 $\times 10^3$ cm/kine. In September and October, however, the sensitivity was reduced by 10dB from this curve. The curve B in Fig. 5 indicates the frequency response of 1Hz horizontal seismometer at HAC station.

The earthquakes associated with volcanic activity are classified into several types, i.e., A and B types of volcanic earthquake and volcanic tremor. Besides these three, the ground motion directly connected with eruption is sometimes called explosion earthquake. It has been often reported that the activity of B type earthquake increase just before the volcanic eruption (for example Minakami, 1960; Y. Tanaka, 1969). Since our observation started before the first eruption on September 17, the change in earthquake activity, if any, can be examined in relation to the eruption activity. During the two weeks from September 3 to 17 only three earthquakes with P-S times of 1.3, 1.3 and 3.0 sec were observed. These earthquakes may be called A type according to classification by Minakami judging from their wave forms having clear and sharp phases of P and S, and they were estimated to occur in a rather deep region under the volcano. As mentioned previously, Tanaka and Hori made the observation of volcanic earthquake around this volcano in 1969 and they reported that four earthquakes of A type took place near the volcano during two weeks. The frequency of occurrence of A type earthquake, therefore, did not change significantly even in the present observation just before the eruption. The daily number of A type volcanic earthquakes with the P-S times smaller than 3.0 sec is seen in Fig. 6, which indicates that the frequency of occurrence did not vary so much by the increase of

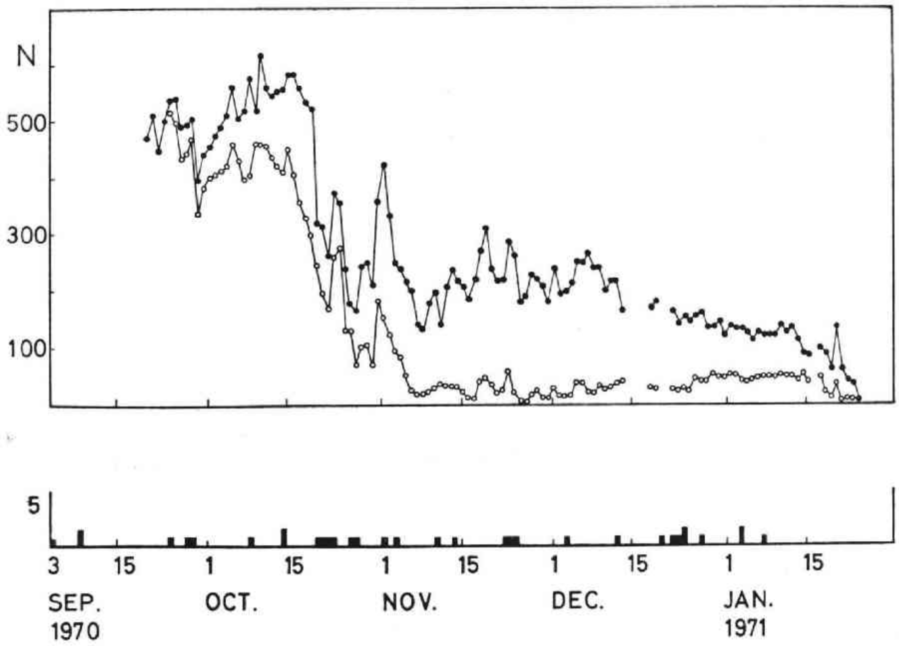

Fig. 6. Daily number of explosion earthquakes is shown at the upper row. Open circles represent the number of earthquakes with maximum amplitude larger than 200 μkine. That of A type with the P-S times smaller than 3.0 sec was shown at the lower row.

eruption activity. The frequency distribution of P-S times at KMK is shown in Fig. 7. The earthquakes with the P-S times smaller than 3.0 sec are thought to be located near Komaga-take and somehow related to the volcanic activity. Eight events with the P-S times between 3.9–4.0 are the micro-earthquakes occurring about 20km southeast of the volcano, according to the report by the Reseach Group for Micro-earthquakes, Tohoku University.

It is a feature of the present activity that very few earthquakes preceded the eruption. In general activity is very low before the eruption in the basaltic volcano and it is generally thought to be due to the low viscosity of basaltic lava. The new lava, however, is andesitic with SiO_2 contents of 58.6% according to the analyses by several authors (Aramaki and Haramura, 1971; Kano, 1971; Osaka and Takahashi, 1971), although the analysis of rocks made by Kawano and Aoki in 1959 gave the SiO_2 contents of 49.98%, which meant the lava was basaltic. Moreover, the temperature of new lava was 1,030°–1,060°C, which was not so high as to decrease sufficiently the viscosity of andesitic lava. The reason why the preceding earthquakes were so few in the present activity of andesitic type is still open to question, though the high value of Fe contents (Fe_2O_3 and FeO) may be the cause as pointed out by Aramaki and Haramura.

Most of the events detected in the present observation are the so-called explosion earthquakes directly connected with eruptions. The first event of this type was

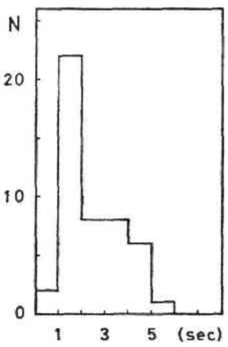

Fig. 7.

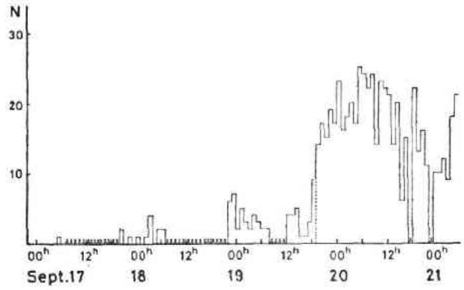

Fig. 8.

Fig. 7. P-S time distribution of A type earthquakes. (Sept. 3, 1970–Jan. 25, 1971)
Fig. 8. Hourly number of explosion earthquakes at early stage of the eruptions.

observed at 05^h24^m on September 17. Although the sensitivity of seismometer at that time is not high enough, this may be safely assigned to the explosion type judging from the wave form. The first eruption in the present activity, therefore, is thought to take place in early morning of September 17, though the eruption was first found on September 18 by people. Some examples of seismograms are seen in Photos. 7, 8 and 9.

The hourly number of explosion earthquakes in the early stage of activity is represented in Fig. 8, which shows the number increased gradually in this period. The daily number of earthquakes having the larger amplitude than 200 μkines is seen in Fig. 6 for the whole active period. As seen in this figure, the daily number exceeded 500 on September 21 and reached the maximum value of 614 on October 10. The number decreased suddenly on October 17 and it reached down to 314 on October 20. It is noteworthy that the time of sudden decrease corresponds to the occurrence of a big earthquake ($M=6.2$) in southeastern part of Akita Prefecture, the epicenter being about 60 km distant from Komaga-take. The comparison of daily numbers of explosion earthquakes and aftershocks of the above mentioned earthquake is seen in

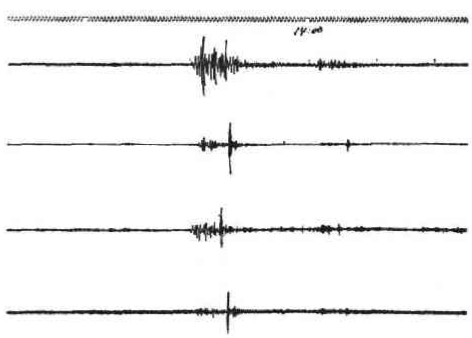

Photo. 7. The explosion earthquakes registered on the ink writing oscillograph at "Komakusaso" (KMK) on Sept. 27, 1970.

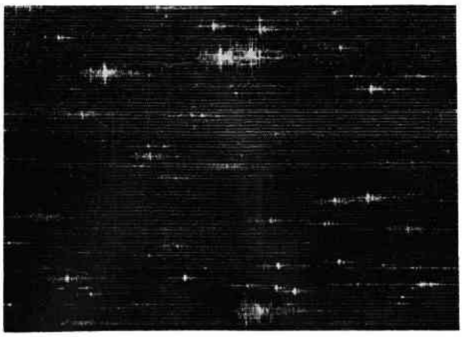

Photo. 8. The explosion earthquakes registered on the smoked paper recorder at "Hachigome" (HAC) on Oct. 9, 1970.

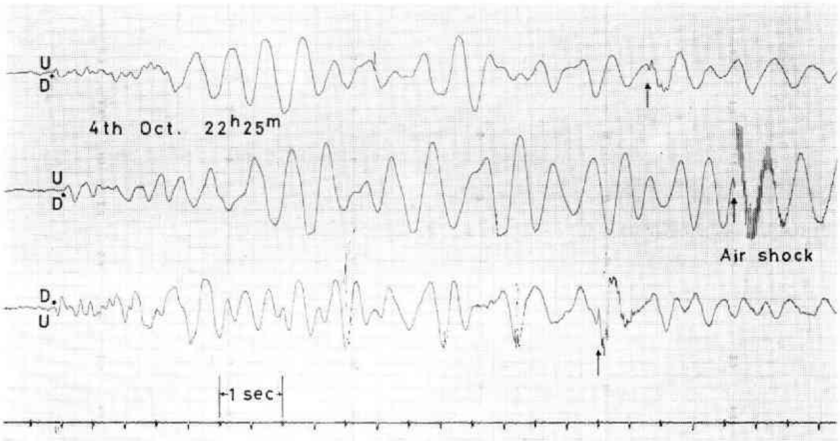

Photo. 9. Seismograms of the explosion earthquakes reproduced from magnetic tape for the tripartite observation. The initial motion shows compressional direction. An air-shock is seen as a later phase.

Fig. 9, which shows a good correlation between them. The daily amount of energy release is estimated from the sum of squares of maximum velocity amplitude of every events. The daily energy release thus calculated is shown in Fig. 10 for the two groups of explosion earthquakes and aftershocks. The positive correlation is clearly seen at least until early November. The Rikuu Earthquake occurred in 1896 and its epicenter was estimated to be nearly at the same location as that of the earthquake mentioned above. The former earthquake caused the appearance of the Senya Fault which extended up to the Tazawako Town, where the Komagatake was situated (see Fig. 1). Moreover, the eleven craters of Komaga-take found in 1932, as well as the new crater at Me-dake and a fumarole at Hachigome in the present activity, were located on the extension of the Senya Fault. It may be suggested from these points and the clear correlation seen in Fig. 10 that the activity of

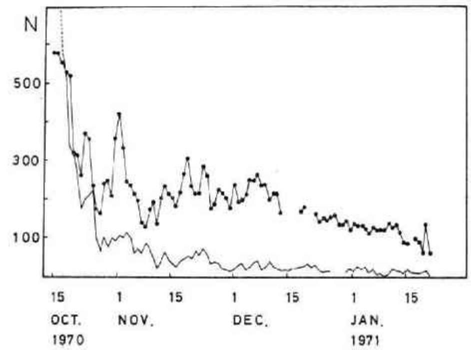

Fig. 9.

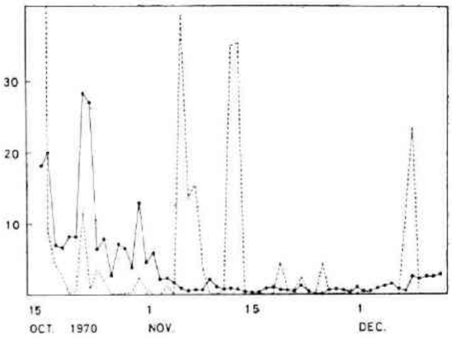

Fig. 10.

Fig. 9. Daily numbers of explosion earthquakes and aftershocks of the earthquakes on Oct. 16. Explosion earthquakes are shown by the full circles. Aftershocks which were observed at Honjo Seismological Observatory, Tohoku University are shown by the solid line.

Fig. 10. Relative energy releases. Explosion earthquakes; solid line. Aftershocks; broken line.

Komaga-take is somehow correlated with the occurrence of the earthquake in south-eastern part of Akita Prefecture.

The volcanic tremors which are characterized by the sinusoidal and regular wave forms were observed in the later stage of eruption. This is similar to the so-called "later tremors" at O-shima (Y. Tanaka, 1969 and 1970).

The relation between number and amplitude of volcanic earthquakes is usually represented by the Ishimoto-Iida's formula:

$$n(a)\,da = ka^{-m}\,da\,,$$

where $n(a)$ is the number of earthquakes of which the maximum amplitudes are between a and $a+da$, and m and k are numerical constants. The values of m in many cases are 1.4–2.6 for A type earthquakes, 2.8–4.1 for B type ones and 2.9–3.4 for volcanic tremors, and they are scattered from 2.7 to 4.0 in many cases of explosion earthquakes (Kubotera, 1965). The relation of observed explosion earthquakes is seen in Fig. 11. The whole period of observation is divided into four sections according to the state of volcanic activity. As seen in Fig. 11, the amplitude-frequency relation in every section may be consisted of two parts. The Ishimoto-Iida's relation holds good in each part and the values of m in both parts being denoted by m_1 and m_2. The periods of four sections are listed in Table II as well as the values of m_1 and m_2. The values of m_1 are between 2.7 and 2.9, which may be normal compared to the values obtained for other volcanoes, while m_2 differs much from the normal values. The abnormal value of m_2 in D section is reliable, because the cumulative number of events at the boundary of two parts is as large as 100. There are several reports that the amplitude-frequency relation is consisted of two parts. Yoshikawa and Nishi (1966) reported on B type earthquakes of Sakura-jima and Y. Tanaka (1967 and 1970) reported on eruption earthquakes and airshocks of Sakura-jima and on eruption-tremors of O-shima.

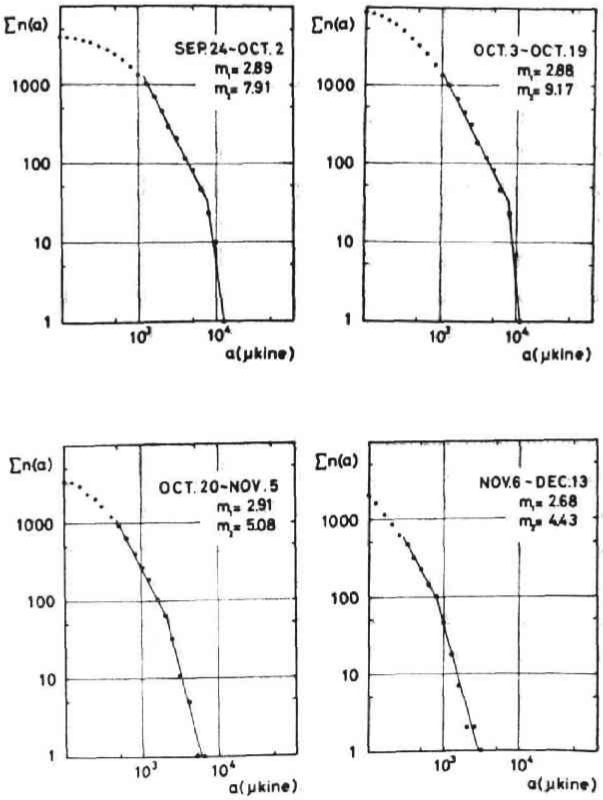

Fig. 11. The relation between frequency and maximum amplitude of explosion earthquakes.

Table II

		m_1	m_2
A	Sept. 24–Oct. 2	2.89	7.91
B	Oct. 3–Oct. 19	2.88	9.17
C	Oct. 20–Nov. 5	2.91	5.08
D	Nov. 6–Dec. 13	2.68	4.43

4. Conclusions

The eruption of Akita-Komga-take in 1970 is discussed in this paper based on the special observations of volcanic earthquakes and ground temperature. The results of the present study are summarized as follows:

1) The only one phenomenon that preceded the eruption was the appearance of high ground temperature with several new fumaroles on the top of Me-dake. The size of high temperature area was about 1,500 m^2. Neither the earthquake of B type nor the volcanic tremor was observed before the outburst.

2) The earthquake of B type was not observed even after the first eruption. No significant change in the number of A type earthquakes was seen between the observa-

tions in 1969 and 1970. The observations before and after the first eruption did not show any change in the number of A type earthquakes. The volcanic tremors were observed on the late stage of activity. Almost all the events observed during the activity were the explosion earthquakes.

3) The eruption was of basaltic type though the lava was andesitic. This may be due to the low viscosity because of high contents of iron.

4) The relation between number and amplitude of explosion earthquakes is represented by two linear parts on doubly logarithmic scale diagram. The Ishimoto-Iida's relation holds good in each part. The value of m for the part of smaller amplitude was normal, while that for larger amplitude range was abnormally large.

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