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Observation Results of Low Frequency Electromagnetic Emissions as Precursors of Volcanic Eruption at Mt. Mihara in November, 1986

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At the time of the major volcanic eruptions on November 15 and 21, 1986 at Mt. Mihara, Izu-Ohshima Island, Tokyo territory, Japan, a detector from a multipoint direction-finding network to detect electromagnetic emissions was operating. Since October 20, 1986 impulsive noises at 82 kHz were recorded, and these anomalous burst-like noise observations increased after November 3. At 10–16 JST (Japanese Standard Time, UT+9 hours) on November 14, several strong noise bursts were observed, and the first major eruption occurred at the main summit crater of this volcano at 16 JST on November 15. At 10–12 JST on November 21, noise bursts were observed and four hours later, 19 new craters erupted suddenly on the side slope of the mountain, both in and outside the caldera, simultaneously with the intrusion of dykes in the mountain body. These records are the first observations of electromagnetic emissions as precursors to volcanic eruptions ever recorded. The authors present this paper in the form of a short note for data presentation, because analysis of these data and comparison with other observations is still continuing.

1. Introduction

In 1980, the Japan and Soviet co-operative Project for the study of electromagnetic emission phenomena related to earthquakes began. The first anomalous emission was observed at 16:33 JST (UT+9 hours) on March 31, 1980 at Sugadaira Space Radio Observatory, University of Electro-Communications, Sugadaira, Nagano prefecture, Japan. The magnitude of the earthquake was about 5.9, with a depth of focus of approximately 360 km. The epicenter was located in Kyoto prefecture, approximately 250 km from the Sugadaira observatory. The noise level recorder for 81 kHz recorded an anomalously high background noise level. The noise level exceeded the usual level by more than 15 dB for a 50 minute period before the main shock, and then dropped sharply back to the previous level at exactly the moment of the earthquake. The noise level data of the VLF whistler recorder at the Sugadaira Observatory also recorded these unusual impulsive emissions at frequencies below 1.5 kHz before the earthquake. Similar 81–82 kHz emissions were observed prior to other earthquakes of magnitudes between 5.5 and 6.5 on September 25, 1980 and on January 28, 1981, located in the Tokyo area (GOKHBERG *et al.*, 1982).

Since 1981, the authors have observed several emission events in the 81–82 kHz range just prior to earthquakes (YOSHINO, 1986b). Based on these measurements, the authors installed a network of new multipoint observation stations, with direction-finding functions, in the Tokyo area. The purpose of the network is to investigate the possibility of locating the epicentral region prior to an earthquake, and to eliminate man-made noise interference to improve instrument accuracy. One of the most successful results of epicenter locating by means of this network was in the case of a typical "underfoot" type of earthquake which occurred around the southwest of Ibaraki prefecture at 21:14 JST on February 27, 1983. The magnitude of this earthquake was 6.3 at a depth of approximately 79 km. The predicted results of direction finding of the epicenter location were successfully obtained by the following three observation points: Suginami in Tokyo, Sugito in Saitama prefecture, and Yatsugatake in Nagano prefecture. Using the forecasting results of the epicenter location system, the epicenter was located in the small predicted area which was determined from the measurements collected from the above-mentioned observation points (YOSHINO *et al.*, 1985).

Since 1984, the authors installed a multipoint direction-finding network of eight observation stations in the Tokyo region (Fig. 1). Presently, we are building a data telemetry system to enable realtime computation of cross-correlation between each station (YOSHINO, 1986a, 1986b). One of the stations in this earthquake prediction network operated on Ohshima Island near an active volcano, Mt. Mihara.

A major volcanic eruption occurred at Mt. Mihara in November, 1986, and the direction finding detector operating on Ohshima Island recorded several impulsive noise emissions prior to a major eruption and an intrusive sequence of lava. In this paper, the authors will present the data in short note form, because investigative work is still ongoing.

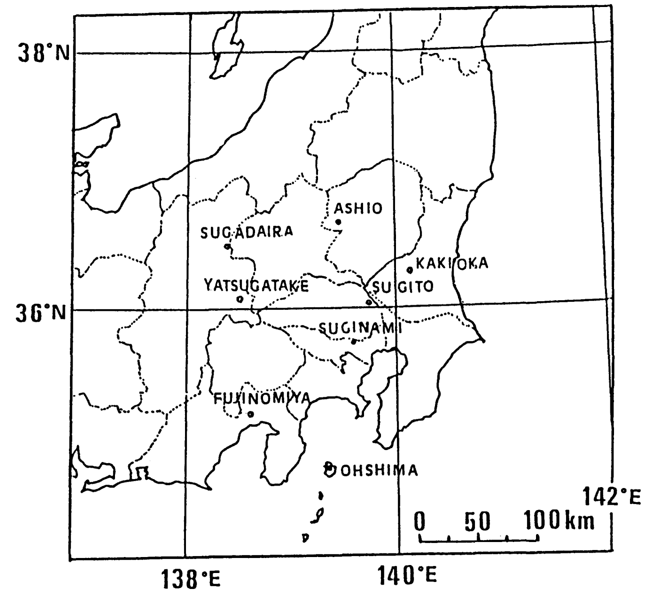


Fig. 1. Station locations of a multi-point observation network around the Tokyo area.

2. Equipment for Detection of Electromagnetic Emission

Figure 2 illustrates in a block diagram the standard receiver unit of our multipoint system and the data processing for the prediction of epicenter bearings by means of electromagnetic emissions as precursors. Sensors consisting of two loop antennas are set up perpendicular to each other in a north-south and east-west direction. Each loop consists of a 50-turn coil with static shielding tuned to 82 kHz.

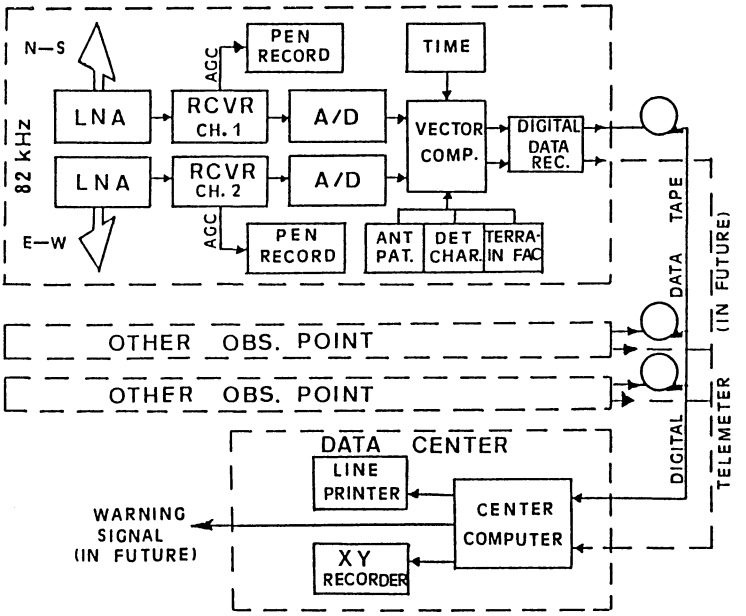


Fig. 2. Block diagram of a standard receiver and data analysis system for the observation of electromagnetic earthquake precursors.

The diameter of the loops is 85 cm. The output level for the north-south and east-west sensors are automatically transferred as digital signals into the microprocessor circuit through a 16 bit analog-to-digital converter and onto digital tape. The computer-calculated results of composite vector direction from each station are telemetered to a central computer. When the calculations of the central computer indicate some small area and its correlation factors are high, the probability of an earthquake in the small area is increased. The receiver output levels automatically compensate for the direction pattern of each antenna, the detection characteristics of each receiver, and other local terrain factors. The detection equipment was set up in the Ohshima Volcano Observatory of Tokyo University, east of the town of Motomachi, the largest population area in Ohshima Island as shown in Fig. 3. Recording of the seismo-electromagnetic noise detection started in November 1984.

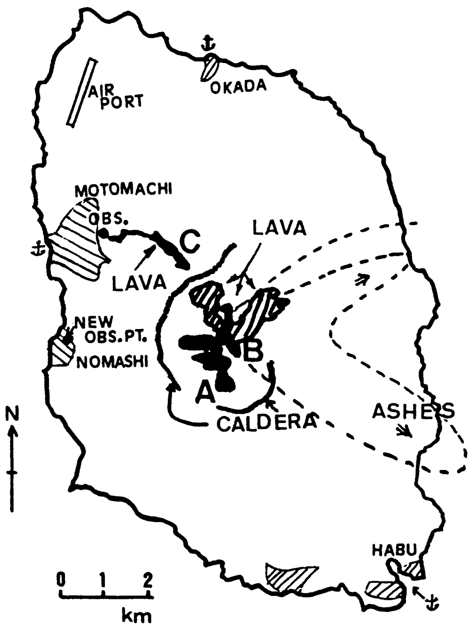


Fig. 3. Map of Izu-Ohshima illustrating the locations of the main and the new craters and station locations. The covered areas indicate lava flows during the eruptions in November, 1986. Point A is the location of the summit crater on Mt. Mihara, which erupted on the 15th of November. Point B is the location of the new craters which erupted inside the caldera. Point C is the location of new craters on the side slope of the mountain, outside the caldera, which erupted on November 21.

3. Observation Results at the Eruption of Mt. Mihara

Before July 1986, the volcanic activity at Mt. Mihara (673.2 m) had been quiet for the previous 12 years. A typical example of monthly noise conditions for 82 kHz data, recorded by the above-mentioned equipment located at Ohshima, is as shown in Figs. 4(a) and 4(b). Figure 4(a) shows the north-south data, and 4(b) is the east-west data; the data are compensated by using the monthly average natural background noise level. The sampling rate is 10 seconds. The natural background noise levels in the night-time is usually 8–10 dB higher than the day-time levels due to the effect of lightning noise from the southern tropical regions and the good propagation conditions of the night E layer in the ionosphere. The average noise level of the north-south direction is always a few dB higher than that of the east-west, because Ohshima Island is located south of the large man-made noise emission areas of Tokyo, Yokohama and the large industrial areas in Kanagawa prefecture.

Volcanic micro-vibrations had been observed at Ohshima observatory since July 1986, but the anomalous impulsive noise emissions at 82 kHz did not appear until after October 20. Observations of several clear burst-like emissions were recorded between November 3 and the 22. The plots of one-second data at Ohshima in November are shown in Fig. 5(a) and 5(b). Figure 5(a) shows the data between November 1 to 13, the two-week period just before the eruption, and Figure 5(b)

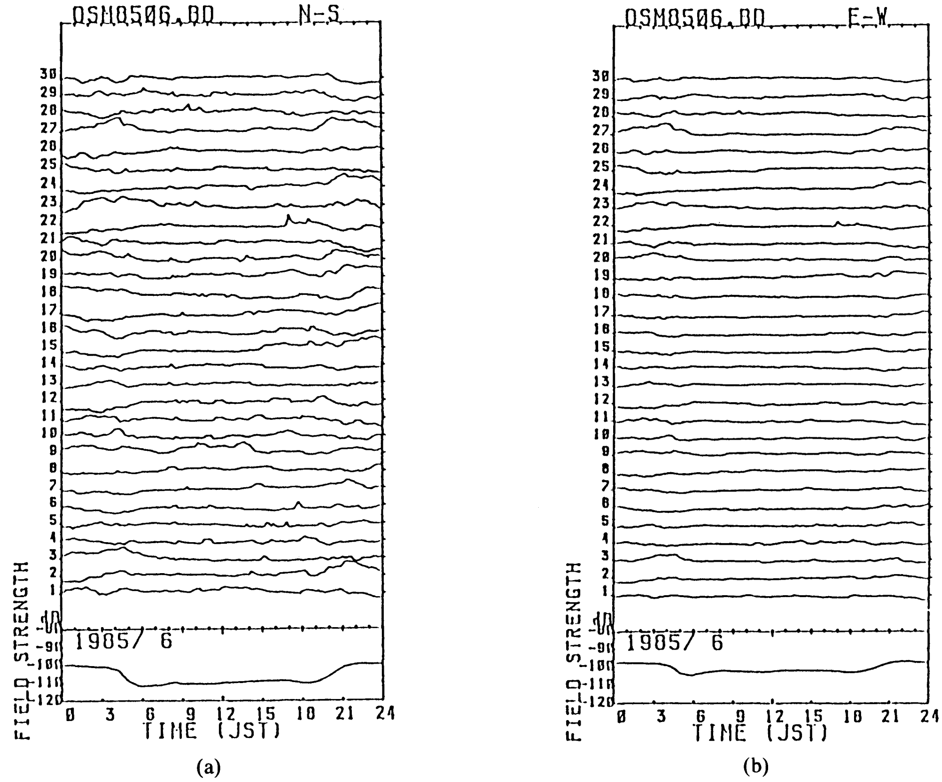
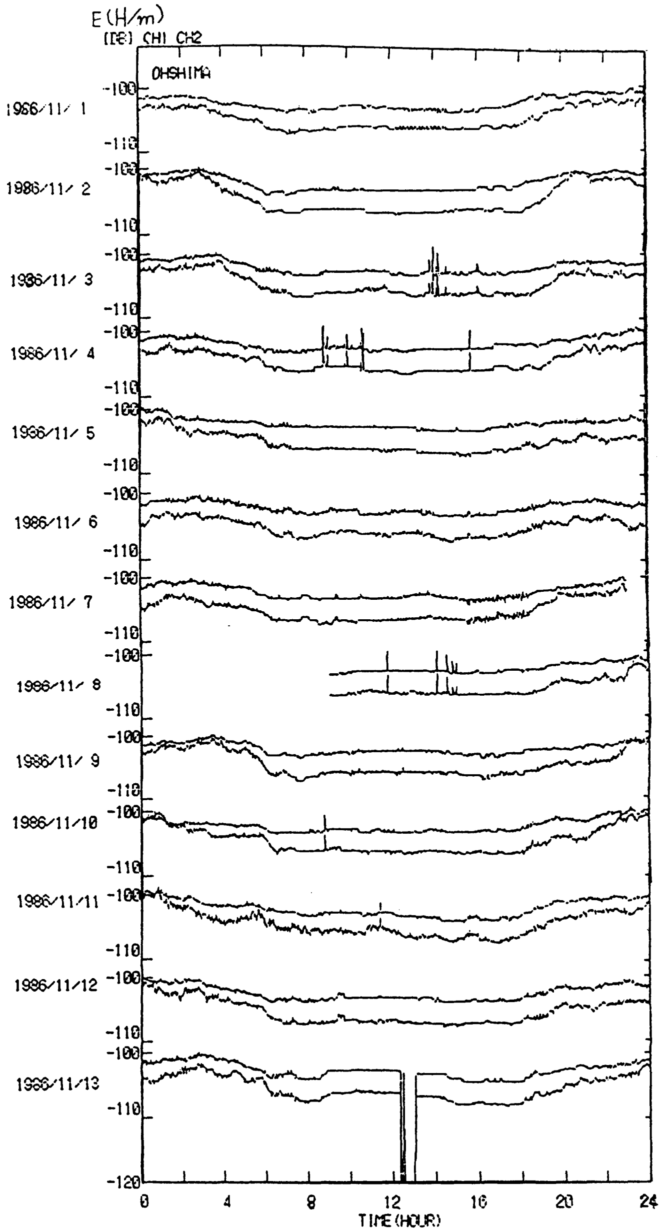


Fig. 4. Typical example of the noise level in the quiet term one year before the eruption. (a) shows the north-south directional data and (b) shows the east-west directional data.

shows the data for the eruption period between November 14 and 23. The upper plots show the noise levels of the north-south sensor and the lower plots the level of the east-west sensor. As noted above, the noise level during the night is usually 6 to 10 dB higher than the daytime level due to interfering lightning discharge noise propagated from the southern tropical region.

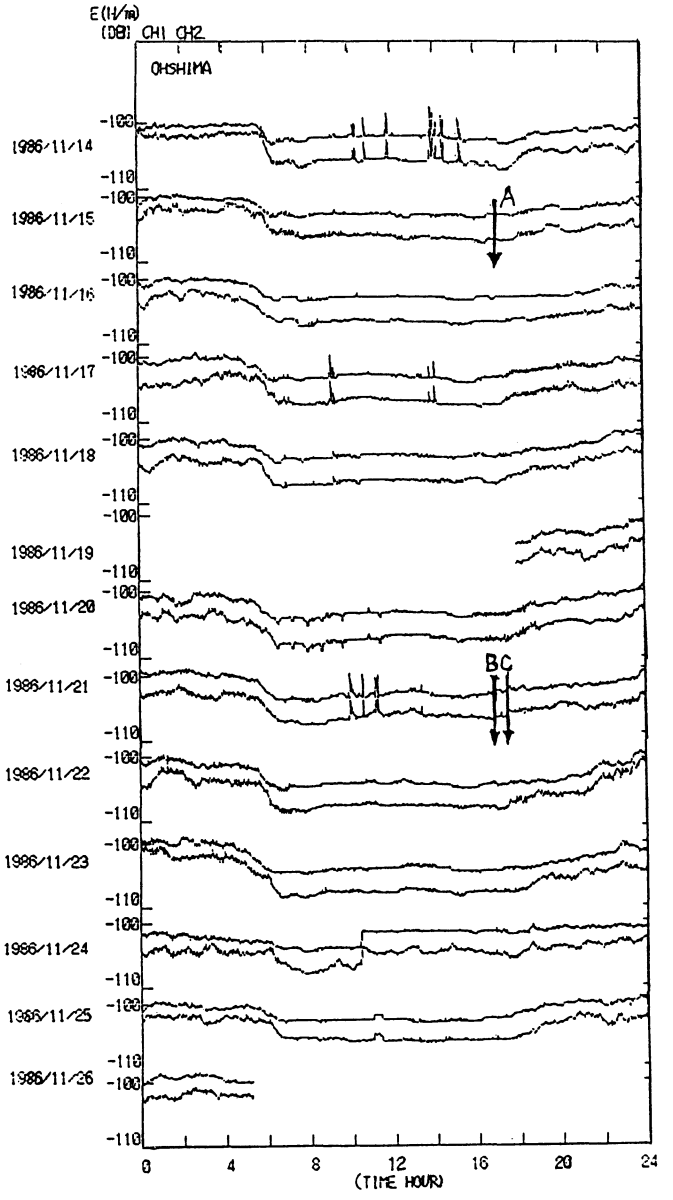
As shown in Fig. 5(a), the observation of burst-like emissions occurring two weeks prior to the eruption are as follows: at 14–16 JST on November 3, at 09–11 JST on November 4, at 11 JST and 14–16 JST on November 8, at 09 JST on November 10, and at 11 JST on November 11.

At 17:25 JST on November 15, the first major eruption occurred at the main crater of the summit. The location of this crater is indicated as A in Fig. 3. Anomalous burst-like emissions were observed at 10–16 JST on November 14, one day before this major eruption, but were not observed at the time of eruption. The volcanic activity continued with a violent eruption and the lava fountain reached heights over 100 meters. Lava flowed out from the summit crater A to the caldera at 10:35 JST on November 19, as shown in Fig. 3. The earthquakes and volcanic micro-vibrations during the eruption of crater A continued violently, and burst-like emissions were only observed at 08–09 JST and 14–15 JST on November 17, but the



(a)

Fig. 5. (a) 82 kHz data between November 1 and 13 at Ohshima. The upper plots show the north-south directional data and the lower plots show the east-west directional data. (b) Data between November 14 and 25 at Ohshima. The arrow on the 15 is the start time of the eruption at summit crater A, and the arrows on the 21 are the start times of the eruptions at craters B and C.



(b)

Fig. 5. (continued).

average background noise levels at night were 6 to 10 dB higher than usual. At 23 JST on November 19, the eruption activity of crater A quickly decreased.

At 10–12 JST on November 21, several strong burst-like emissions were observed as shown in Fig. 5(b); the strongest peaks during these emissions reached 15 dB higher than the background noise level. At the same time, strong local earthquakes started and continued until evening. At 16:15 JST, four hours after the emissions at 10–12 JST, new eruptions occurred at 19 new craters which appeared along a line trending northwest to southeast in the bottom of the old caldera along with violent earthquakes. The location of these craters are labeled B in Fig. 3.

At 16:15 JST, the summit crater A again erupted violently, and at 17:46 JST new craters suddenly appeared in the virgin fields outside the main crater on the northwestern side slope of the mountain body, and started major eruptions. The location of this group of craters is labeled C in Fig. 3. Lava flowed down quickly towards our station at Motomachi, as shown in Fig. 3. The major eruptions at craters B and C were almost completely stopped by 4 JST on the morning of November 22. Our data recording had to be stopped after November 25, because the quick increase of strong background noise levels from many digital processors installed in many pieces of observation equipment set up quickly after the eruption without any noise check in the laboratory, interfered. Then our observation station was moved to a safe area of Nomashi village, located 2 km south of Motomachi as shown in Fig. 3, and the equipment resumed operating at Nomashi observatory.

4. Discussions on the Source Mechanism

The observations of anomalous burst-like emissions at 82 kHz do not directly correspond to the time or the duration of the most active eruptions as shown in Fig. 5(b). The observed anomalous emissions at 10–16 JST on November 14 occurred about 24–28 hours prior to the first major eruption from the old summit crater A, and the observed anomalous emissions at 10–12 JST on November 21 occurred 4–6 hours prior to the first major and violent eruptions from the new craters, which erupted on the virgin fields inside the caldera at point B and on the mountain side slope outside the caldera at point C, Fig. 3. The direction finding results for both periods of anomalous emissions indicated location A in the former case and the approximate location B in the latter case, as shown in Fig. 6. These values were obtained from the digital output of a vector composition algorithm developed from the various receiver outputs recorded on magnetic tape. The horizontal bearings were found not to be clearly directed because of the fact that the direct wave from the source region arrives with a large dip angle.

Geological studies after the eruption indicated the mixture ratio of silica in the lava and scoria which erupted from the summit crater A differed from the lava extruded from locations B and C. These results suggest the magma extruded at the summit crater had a different source than that extruded at location B and C. The basalt at the old summit crater had a higher viscosity and a lower ratio of silica, while the basalt from the new craters had a high mixture ratio of silica. The duration of the active eruption at the new crater groups B and C was on the order of only a few hours, and the lava extrusion ceased completely early the next morning.

A model developed by Prof. Aramaki, of the Earthquake Research Laboratory

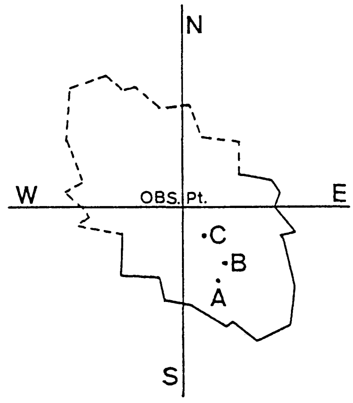


Fig. 6. Direction finding results for the eruption at crater A and craters B and C. The data were recalled from the digital output of the vector composition circuit of receivers. Bearings are not clearly determined due to the direct wave having a large dip angle.

of Tokyo University, was used to explain the observed results. Figure 7 illustrates the movement of magma based on the Aramaki model. The generation mechanism of these anomalous burst-like emissions can be explained by this model as follows: (1) the magma flow at the eruption of summit crater A is supplied directly from the base mantle as primary magma, Y, (2) the eruptions at the new craters B and C are

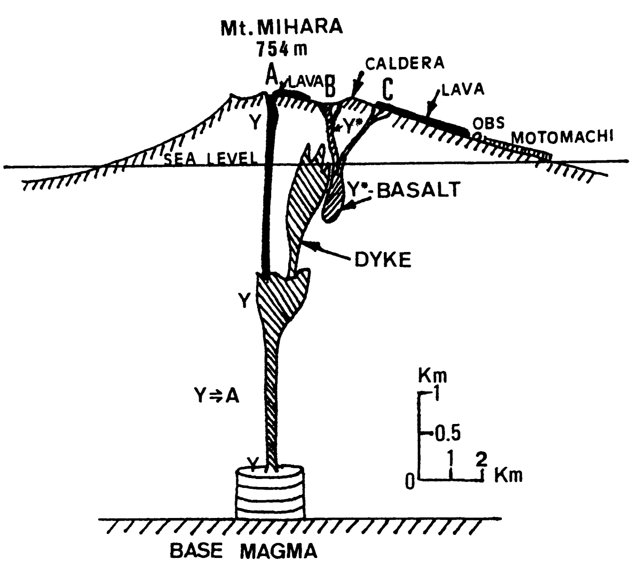


Fig. 7. Vertical profile of Mt. Mihara, illustrating the mechanism of magma flow in the mountain body based on the Aramaki model. Summit crater, A, erupted due to the insertion of the primary magma, Y, and new craters B and C erupted due to basalt, Y, which was heated by a dyke of primary magma. The time of the dyke insertion corresponds to the time of the burst-like emission observed between 10 and 12 JST on November 21, 1986.

created by new magma flows forced up as a result of dyke insertion into the mountain body on the morning of November 21, as shown in Fig. 7.

The quantity of this dyke seems to have been approximately equal in size to the magma volume for the total eruption of this volcano. The lump of basalt with a high mixture ratio of silica under craters B and C melted from the heating effect of this dyke, and this molten basalt extruded violently from craters B and C. The height of the lava fountain of this eruption extended 600 meters from the mouths of the craters, due to the very high back-pressure of the internal gas which was created as a result of the high density of silica. The eruption from craters B and C stopped a few hours after it began, and the duration of this short but violent eruption fits the Aramaki model well. The emission mechanism of this model shows good correlation with the instant when the dyke started its insertion into the mountain body. At the same time, measurement data obtained from other kinds of observations suggested the time of commencement of dyke insertion at around 10–12 JST on November 21 (Yukutake *et al.*, private communication); and the results of our direction finding approach also suggested a source in the south-eastern "underfoot" of the mountain body. From the data of the anomalous burst-like emissions prior to the volcanic eruptions of Mt. Mihara at 10–12 JST on November 21, the source mechanism of the 82 kHz electromagnetic impulse emission can be explained as radiation induced along a crash line or gap running in the rocks.

The results of laboratory experiments by Mizutani (MIZUTANI and YAMADA, 1987; CRESS *et al.*, 1987), observed several clear emissions when various rock specimens were crushed by strong compression forces. The emission field intensities and frequencies depended on the kinds of rocks, size of the specimens and the dry or wet conditions of the rocks. The authors believe the observed emissions on November 21 were generated when the rocks were crushed by strong pressures from the insertion of dykes. The electromagnetic impulses propagate through the rocks of the mountain body and are recorded by the sensors. The average distance from the source region to sensor is approximately 2.5 km, as shown in Fig. 7. At this distance a reasonable value would be a few microvolts per meter at 82 kHz as a near-field induction.

The emissions at 10–16 JST on November 14, 10–14 JST on November 17 and many which were observed before the eruption from the old summit crater, A, suggest that the source mechanism of the burst-like emissions can be well explained as impulse emissions induced at the intervals when cracks run in the rocks as a result of the movement of magma or dykes prior to eruption. These phenomena can be explained, and the developed model proven, by means of the ongoing laboratory experiments by Cress and Mizutani. The results of direction-finding by our observation systems were always directed to the summit crater during this time, as shown in Fig. 7.

5. Conclusion

In this paper, the authors present the results of observed electromagnetic emissions related to volcanic eruptions at Mt. Mihara in Izu-Ohshima Island near Tokyo in November 1986. These are the first observations of electromagnetic emissions during a volcanic eruption ever recorded. The data recorded at Ohshima used a 82 kHz direction-finding detector, one unit in a multi-point receiving network around the Tokyo area designed for the detection of electromagnetic emissions as precursors to earthquakes. This earthquake prediction experiment was started by the authors in 1982.

Seismologists and volcanologists are continuing their active investigation and analysis of the eruption mechanisms of Mt. Mihara on November 15 and 21, 1986. Presently, a model developed by Dr. Aramaki, of the Earthquake Research Laboratory of the University of Tokyo, best explains the observed data for this eruption.

The observation of burst-like emissions on November 14 and 21 were observed 24 hours and 4 to 6 hours before major eruptions, respectively. Geological studies determined that the magma extruded from summit crater A and the mountainside craters B and C contained different ratios of silica. The movement of magma for the major eruptions from new craters B and C at 10–12 JST on November 21 can be explained by applying the Aramaki Model. The large number of data sets obtained by other kinds of field observations during the above-mentioned time interval, such as DC and VLF conductivity, telluric currents, total magnetic flux density, gravity, seismometer, volcanic tremors etc. (Yukutake *et al.*, private communication) indicate large insertions of dykes which branched off from the primary magma, Y, as shown in Fig. 7. These phenomena suggest that the source mechanism of emissions can be well explained by means of the Aramaki model and by the results of the ongoing laboratory experiments by Cress and Mizutani.

The investigation and the data analysis of the phenomena of electromagnetic emission related to earthquakes and volcanic eruptions are also continuing vigorously, and the authors will publish a full paper version in the near future. Moreover, noise detection observation is also continuing at Nomashi, Ohshima, at present and into the future.

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