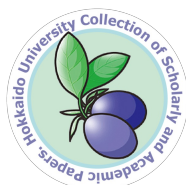




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Human Response and Adjustment to the 1977 Eruption of Usu Volcano, Hokkaido, Japan

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1977年有珠山噴火に対する住民の意識と対応

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Summary

From mid-November to early December, 1977, a questionnaire research on human response and adjustment to the 1977 Eruption of Usu Volcano, Central-South Hokkaido was carried out for the areas within 20 km from the crater, which include both hit by serious damages and slight damages. The respondents, totalling 1763, were chosen chiefly among the parents of pupils of lower secondary schools. The analysis of the answers was made by using settlement units in order to examine the spatial patterns of human response and adjustment. The main results are as follows:

(1) Human response and adjustment to the volcanic hazards vary in relation to the experiences with past eruptions, occupation, sex, etc. of the respondents, as well as the location of settlements.

(2) The distance from the crater, the amount of ash fall, and the extent of damages are the main factors controlling the spatial patterns of human perception and adjustment.

(3) Clear spatial differences are found in the foreseeing of both eruption and ash fall, psychological response and emergency self-adjustments during eruptions, and the evaluation of emergency self-adjustments and the danger in living from future eruptions.

(4) On the contrary, little choice has been found in the desirable precautionary measures demanded to the local and national governments, regardless of the location of settlements and the personal attributes. By the people living in the hazardous zone, timely warning based upon the accurate prediction of eruption is believed to be the only limited basic precautionary measures to cope with the volcanic hazards.

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Introduction

After a long silence since the 1943-45 activity which produced "Showa-shinzan" (406.9 m), Usu Volcano (727 m) which is situated in the Shikotsu-Toya National Park, Central-South Hokkaido, erupted suddenly on August 7, 1977. During the first week from the first burst, some fifteen explosive eruptions were recorded and a large amount of ashes, pumices and lapillies, amounting $8.3 \times 10^7 \text{ m}^3$ (Katsui *et al.*, 1978), were ejected from the new craters which were formed within the summit somma. Although the explosive eruptions have not been reported since that time, small-scale phreatic explosions have occurred intermittently until now. In addition vigorous crustal movement, which indicates the upheaval of magma from underneath of the summit crater, have continued.

The most important damages have hitherto resulted from the ash and pumice falls to agriculture. Total amount of damages reaches to ca. 31.7 billion yen, 80 % of which is shared with agricultural losses. About 35,000 inhabitants at a total living in the areas close to the volcano were evacuated to the adjacent safety areas. Because of immediate escape and other emergency adjustments, no human lives were lost by the direct impact of ejectas. However, a serious damage hit hot spa villages, *i.e.*, Toyako-onsen and Sobetsu-onsen, because the people could not carry on business of hotels, souvenir shops and others relating to sightseeing industry for a month and more. This is another marked characteristic feature of the damages caused by the eruption.

A survey on the damages and human perception to the eruption was carried out for the ash-stricken areas, in order to make clear the relationship between spatial distribution of damages and human adjustments. The main purpose of this paper is to describe the outline of the volcanic hazards and the results of a preliminary analysis of the data obtained by a questionnaire research on human perception and adjustment to the 1977 Eruption of Usu Volcano.

Regional Setting

The area stricken by the 1977 Eruption of Usu Volcano is the center of Shikotsu-Toya National Park, within which Usu Volcanic Group including Showa-shinzan, a lava dome born during the 1943-45 activity, and Lake Toya, a caldera lake are harmoniously blended to produce an attractive volcanic landscape. On the lake shore, Toyako-onsen spa, one of the most famous spas in Hokkaido, is situated (Fig. 1). This hot spa,

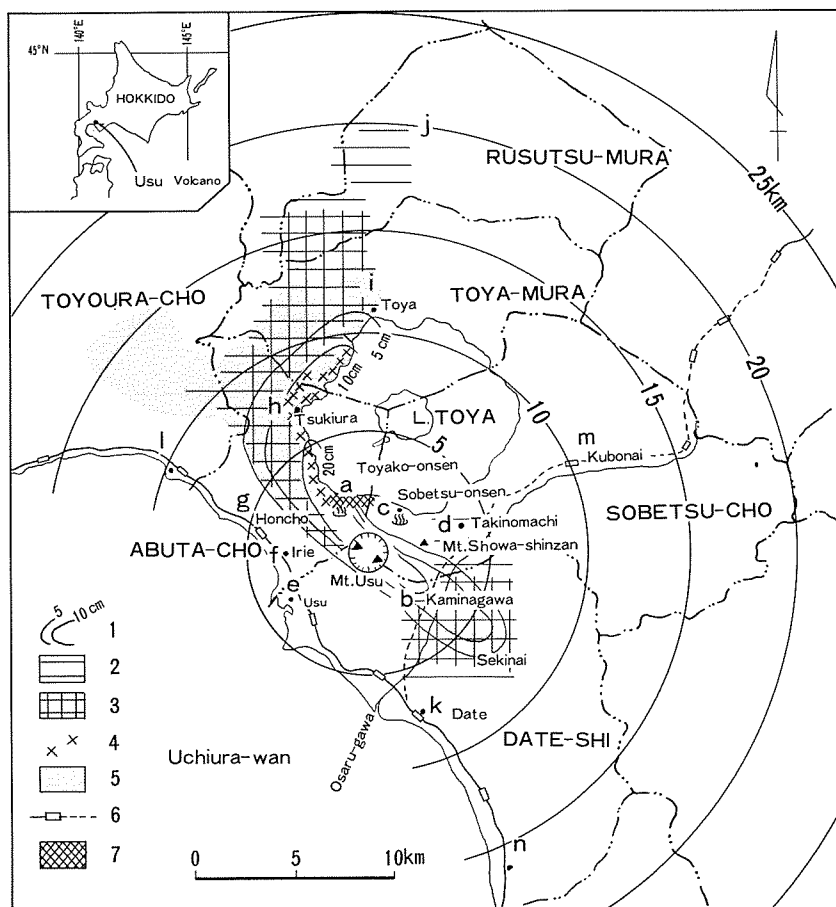


Fig. 1. Geographical setting of the region investigated and the distribution of damages caused by the 1977 Eruption of Usu Volcano

1: Isopach of fallen ash, 2: Area of slight damage to agriculture, 3: Area of severe damage to agriculture, 4: Cut off of the current, 5: Area of blacked out, 6: Damaged section of railway, 7: Area of slight damage to houses and buildings. For the symbols a~n see Table 3.

standing on the compound alluvial fans consisting mainly of mudflow deposits, was found after the 1910 Eruption, and has developed as a core town of the national park. The number of visitors to this spa has increased rapidly after the World War II, and exceeded one million a year for these 5 years in average. This spa, with a population of 4,300 and with the accommodations for 6,500 guests, is located very close to the summit crater, within 1.5–2.0 km.

The region surrounding Usu Volcano is one of the most intensively cultivated land in Hokkaido, the main products being sweet corns, sugar beets, red beans, haricots and potatoes as well as such vegetables as asparagus, cabbages, Chinese cabbages, radishes, pumpkins, etc. Uplands and gentle foot-slopes of volcanoes, which are mostly covered with pyroclastic deposits, are the main cultivated lands in the region.

Past Eruptions and Disasters

Usu Volcanic Group is geologically composed mainly of andesite lavas and dacites, and geomorphologically consists of a summit somma topped with a crater having a diameter of 1.5 km, domes and protodomes formed on the summit crater and flank slopes. This volcanic group has been conceived to be formed during the Holocene (Oba, 1966), and has made repeated eruptions since the historical times. Six explosive eruptions are known to have occurred since the 17th century (Table 1). Among these

Table 1. Historical eruptions of Use Volcano

Age	Type of Eruptions	Main Losses
1663	Summit eruption Formation of protodome Ejection of ash and pumice	5 deaths
1769	Summit eruption Nueé ardente? Ejection of ash	Destroyed houses? (Southeastern foot)
1822	Summit eruption Nueé ardente Ejection of ash	1 village destroyed, 50 deaths, 53 injureds (Southwestern foot)
1853	Summit eruption Formation of protodome Nueé ardente	(Eastern flank)
1910	Flank eruption Phreatic eruption Mudflows	1 death (Northern foot)
1943~45	Flank eruption Phreatic eruption Formation of protodome and lava dome (Showa-shinzan)	(Northeastern foot)

Compiled after Hokkaido Council for Disaster Prevention, 1973.

historical eruptions the most destructive disaster was caused by the 1822 Eruption, which produced a nueé ardente rushing at a village situated on the southwest foot and destroying the village completely, resulting in 50 deaths and 53 injureds. Apart from the occasion of this eruption, the loss of human life was minimum, partly because of the slow occurrence of causative factors such as the formation of protodomes and, pumice and ash falls, and partly because of little inhabitants in the danger areas. However, agriculture and forestry in the region have been repeatedly

damaged by ash and pumice falls in a greater degree.

Among 79 active volcanoes of Japan, Usu Volcano has been classified as Class B by the Japan Meteorological Agency, for which continuous observations have to be made. Before the 1977 Eruption, however, there was no observatory and only one seismometer was in operation within Usu Volcanic Group. Since the beginning of the eruption, continuous and systematic observation has been carried out for monitoring the activities.

Progress of the 1977 Eruption and Occurrence of Disasters

On 6 August, 1977, one day before the first eruption, lots of earth tremors were felt in the areas surrounding the volcano since early morning. At the night of this day, a Fire Festival was held on the eastern foot of the volcano in commemoration of the birth of Showa-shinzan, a lava dome 406.9 m high born during the 1943-45 activity, and about 30,000 visitors took part in this festival. Although the repeated occurrence of earth tremors seemed to be a symptom of the eruption, no official warnings were made before the first eruption. The first eruption suddenly came at 09 h 12 m on 7 August, 1977, 30 hours after the beginning of the felt tremors. The time interval from the first occurrence of the earth tremors to the first eruption is shorter as compared with the past eruptions. This interval for the past eruptions was usually 3 to 10 days except for the 1943-45 activity which made the first burst six months after the occurrence of earth tremors (HCDP, 1973). Therefore, the 1977 Eruption may be said an abnormal case in this regard.

Among the municipalities located in the areas surrounding the volcano, only two had established the headquarters for disaster prevention before the first burst. However, the order of evacuation had never been issued before the first burst, the first order being issued immediately after the eruption. During the first week in which a series of explosive eruptions occurred, the order of evacuation was repeatedly issued to the inhabitants living in the areas close to the volcano, in correspondence to the progress of volcanic activities.

Ashes and pumices fell on and attacked the areas southeast and northwest to north-northwest of the volcano, due to the prevailing wind direction during the eruptions. The depth of ashes including pumices exceeded 50 cm on the foot-slopes and 5 to 10 cm in the area about 5 to 10 km from the crater (Fig. 1). The damages to crops and trees were caused in the areas which hit by the ashes more than 1–2 cm deep. So the agricultural and forestry damages occurred in a large area and the total damaged area reaches 16,200 ha. The agricultural damages, above

all, were most serious where ashes fell with rain waters. This event happened at the night on 8 August, 1977 in the northwest to north-northwest areas.

The damages to houses and buildings were not so serious as compared to the agricultural damages, because the settlements were not hit by a great amount of ashes and pumices. However, slight damages were recorded to the houses and buildings in Toyako-onsen spa, which is situated within 1.5–2 km from the active craters. Breaks of windows and roofs were the main damages caused by the hit of pumices, the diameter of which sometimes exceeded 20 cm, and volcanic bombs. The damages to the windows and roofs of the vehicle were also happened in this spa. The electricity was failed and total number of houses blacked out exceeded 5,000. The cut off of the current was caused mainly by the heavy ash falls accompanied by rain waters, because the destroyed trees leaned against electric poles and wires. In Sobetsu-onsen spa, situated east to Toyako-onsen spa, due to land deformation one hospital building was already destroyed completely and the destruction of houses, water pipelines and roads has been found elsewhere.

Roads were also covered with ashes and pumices and removal of those materials was done repeatedly. A railway which runs east side of the volcano was also buried and was tied up for a month. In addition, traffic regulation was enforced on the roads running through the foot of the volcano, and the order of evacuation to some settlements was not released until 23 September, 1977. Because of these conditions, in Toyako-onsen and Sobetsu-onsen spas the people could not carry on business of hotels, souvenir shops and other works relating to sightseeing industry for a month and more, and number of visitors was not recovered even after the release of traffic regulation. If the danger from explosive eruptions is to be expected, the amount of economic loss for sightseeing industry may be inevitably accumulated day by day. This is another marked characteristic feature of the disaster caused by the eruption.

Fine-grained particles in the deposited ashes were scattered in the wind. Scattering was also caused by the motor traffic. This phenomenon resulted in impediments to the health such as bronchial, eye and nose troubles. These troubles to the health were frequently found in the area where the depth of ash fall was more than 1–2 cm. Deposited ashes and pumices on the hillslopes have also been redistributed by the shock of earth tremors as well as by water erosion, and are liable to remove as torrential mudflows due to the impact of downpours and rapid snow melt in early spring.

In Toyako-onsen spa, the houses occupying the areas close to the hillslopes and the mouths of valleys are in danger from the attack of such mudflows and 26 houses were abandoned by the end of August, 1977. Moreover, about 100 houses were designated as danger houses by the local government. Although no serious damages to the houses have occurred hitherto, on the southern foot-slopes, large-scale mudflows were triggered four times by rains during August and September, 1977, causing damages to farms, orchards, chicken farms, etc.

Contents and Methods of the Research

After preliminary field surveys for the stricken areas, which included general survey on the disasters and an interview research on the percep-

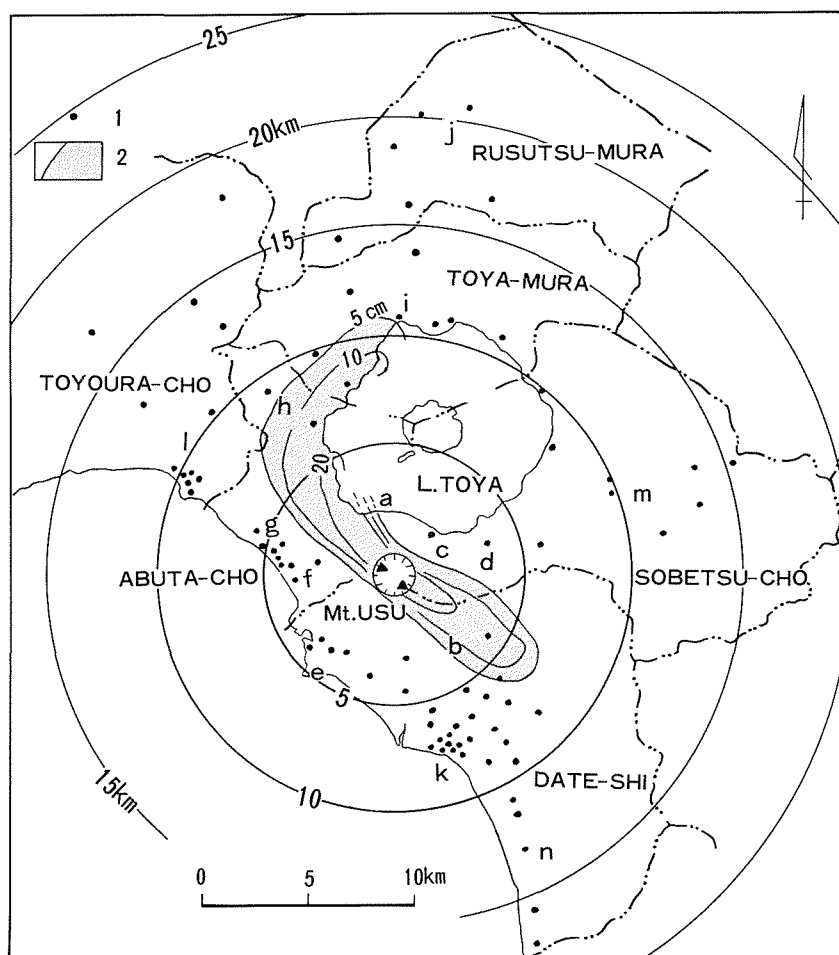


Fig. 2. Settlements investigated by the questionnaire survey
 1: Location of settlement unit "aza", 2: Areas stricken by ash fall with the depth of more than 5 cm, a~n: Settlement groups used for the analysis (see Table 3).

tion and adjustment of the inhabitants to the eruption, a questionnaire research was carried out from mid-November to early December, 1977. The area covered by the research is within about 20 km from the summit crater and includes both hit with serious damages and little damages (Fig. 2).

Method of the Research

The questionnaire research was undertaken with the cooperation of Hokkaido Council for Disaster Prevention, Board of Education, and primary and lower secondary schools of the local governments concerned. Respondents were chosen chiefly among the parents of pupils at primary and secondary schools. Questionnaires were sent out and gathered through pupils by schools. Numbers and abstraction rates of sampling respondents are shown in Tables 2 and 3. As shown in Table 2, the percentage of gathering is high, exceeding 80 % for most of the administrative units. But it must be noted that the ages of the respondents concentrate to forties.

Table 2. Number of questionnaire sheets distributed and collected and rate of sampling respondents by administrative units

	Number of householders	Questionnaire sheets		Rate of collection	Effective samples ²⁾	Rate of sampling ³⁾
		Distributed	Collected ¹⁾			
1. Date-shi	9,280	1,142	888	77.8	891	9.6
2. Abuta-cho	3,889	607	509	83.9	480	12.3
3. Sobetsu-cho	1,201	216	185	85.6	198	16.5
4. Toyoura-cho	1,948	60	50	83.3	50	2.6
5. Toya-mura	713	100	100	100.0	100	14.0
6. Rusutsu-mura	453	50	44	88.0	44	10.3
Total	17,484	2,175	1,776	81.7	1,763	10.1

1) Numbers collected through pupils by schools.

2) Numbers adjusted according to the address of parents.

3) Rate to the total number of householders.

Contents of the Questionnaire

The questionnaire designed for the research includes 48 questions, and two to seven optional answers have been prepared for each questions except for four freely answered ones. Based on the purposes and contents, the questions can be divided into eight groups:

1) to know awareness and experiences of the 1977 Eruption(4),

Table 3. Settlement units for the analysis grouped by the distance from the summit crater and the extent of damages

Settlement Units and Groups	Number of Respondents	Sampling Rate ¹⁾
A. Within 5 km and hit by serious damages	400	% 19.3
a: Toyako-onsen	326	21.0
b: Kaminagawa/Sekinai	51	14.6
c: Sobetsu-onsen/Showashinzan	23	13.9
B. Within 5 km and hit by slight damages	269	7.3
d: Takino-machi	84	13.9
e: Usu	79	9.5
f: Irie/Izumi	23	4.9
g: Abuta-honcho	83	4.7
C: Between 5 and 25 km and hit by serious damages	192	15.3
h: Tsukiura/Hanawa	48	53.3
i: Toya-mura	100	14.0
j: Rūsutsu-mura	44	10.3
D: Between 5 and 20 km and hit by slight or very slight damages	902	8.6
k: Urban area of Date-shi	625	9.0
l: Toyoura-cho	50	2.6
m: Kubonai and its environs	91	21.2
n: Kogane/Mareppu ²⁾	136	12.0
Total	1,763	10.1

1) Rate to the total number of householders.

2) All the respondents are school boys and girls.

- 2) to know the magnitude and distribution of destructive forces, particularly the depth of ash fall(4),
- 3) to know the human response during the eruptions(6),
- 4) to know the emergency self-adjustments including evacuation taken by the inhabitants(10),
- 5) to know the extent and distribution of damages(12),
- 6) to know the experiences and knowledges with the past eruptions(8),
- 7) to know the demands for the future precautionary measures to the local and national governments(2), and

8) to know the lessons learnt from the volcanic hazards(1).

Numbers in the parenthesis indicate the number of questions included in the given categories. Freely answerable questions have been prepared in order to know the types of emergency self-adjustments to the personal properties, kinds and extent of health troubles, the lessons learnt from the 1977 Eruption, and the demands for the future precautionary measures to the national and local governments.

Some Results

Hypothesis and Units of the Analysis

It is expected that the perception and adjustments to the eruption may vary from the past experiences of the inhabitants, the extent of damages, distance from the crater and other factors. Therefore, the add up and frequency analysis of the answers have been made by settlement units "azas" or group of "azas", so as to observe the areal differences of the human response resulting from past experiences, the distance from the crater, the amount of ash fall and the extent of damages. The classification and distribution of analytical units are shown in Fig. 2 and Table 3. The characteristics of the settlement units are presented

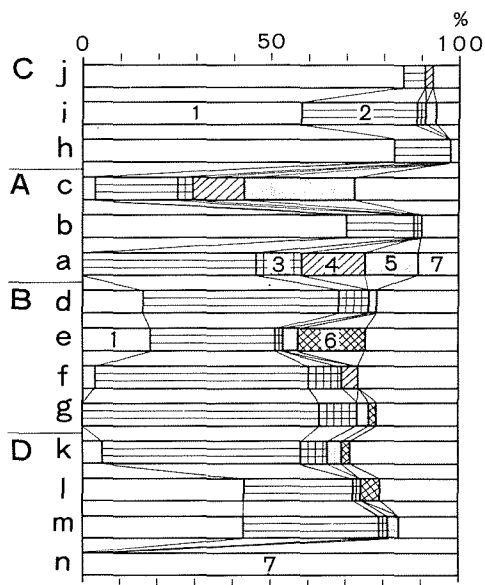


Fig. 3. Occupation of respondents
1: Agriculturalist, 2: Salary-earner,
3: Merchant, 4: Hotel or inn manager,
5: Transportation and service,
6: Fisherman, 7: Others.
For symbols A-D and a~n
see Table 3.

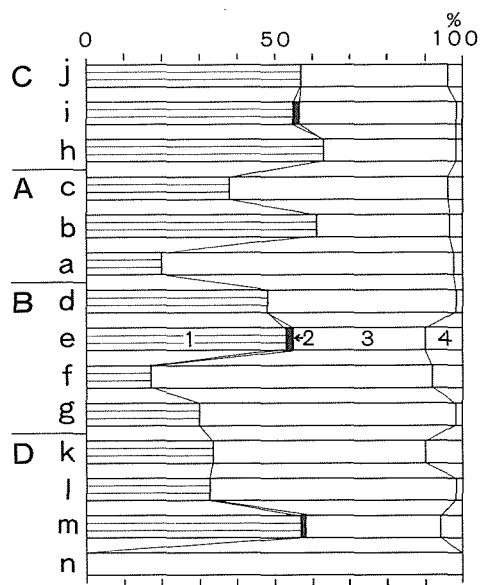


Fig. 4. Experience with past eruptions
1: With experience of the 1943~45
activity, 2: With experience of the
1910 Eruption, 3: Without experi-
ence, 4: No answer.

in Figs 3–5. Some results derived from the simple frequency analysis will be presented below.

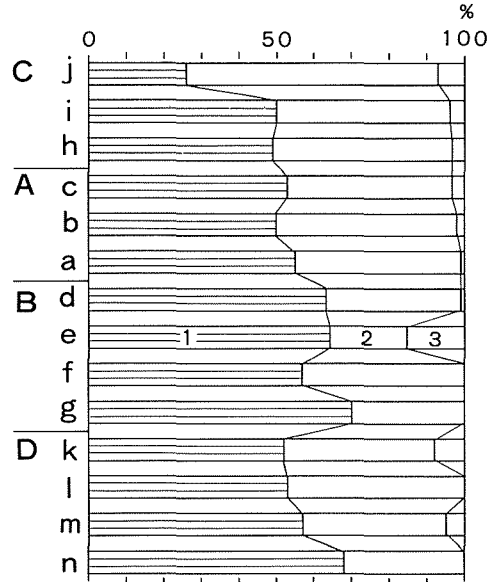


Fig. 5. Knowledges on the past eruptions before Meiji era (1868)
1: With knowledges, 2: Without knowledges, 3: No answer.

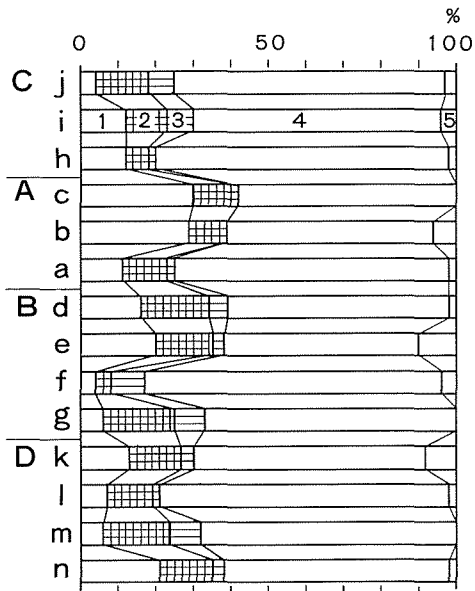


Fig. 6. Foreseeing of eruption
1: Near future, 2: After several years, 3: After ten years and more, 4: Unexpected, 5: No answer.

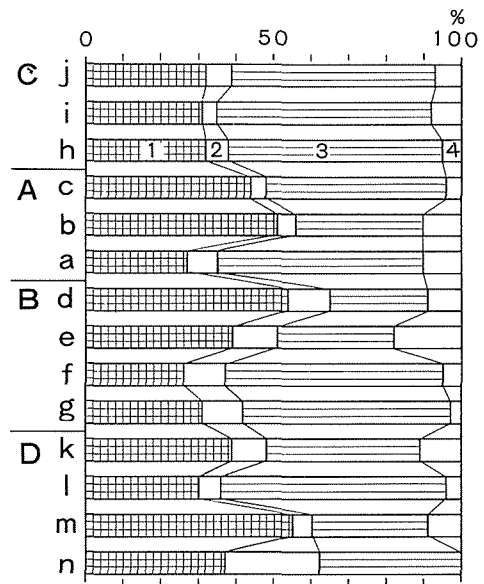


Fig. 7. Foreseeing of ash fall
1: Expected, 2: Don't know, 3: Unexpected, 4: No answer.

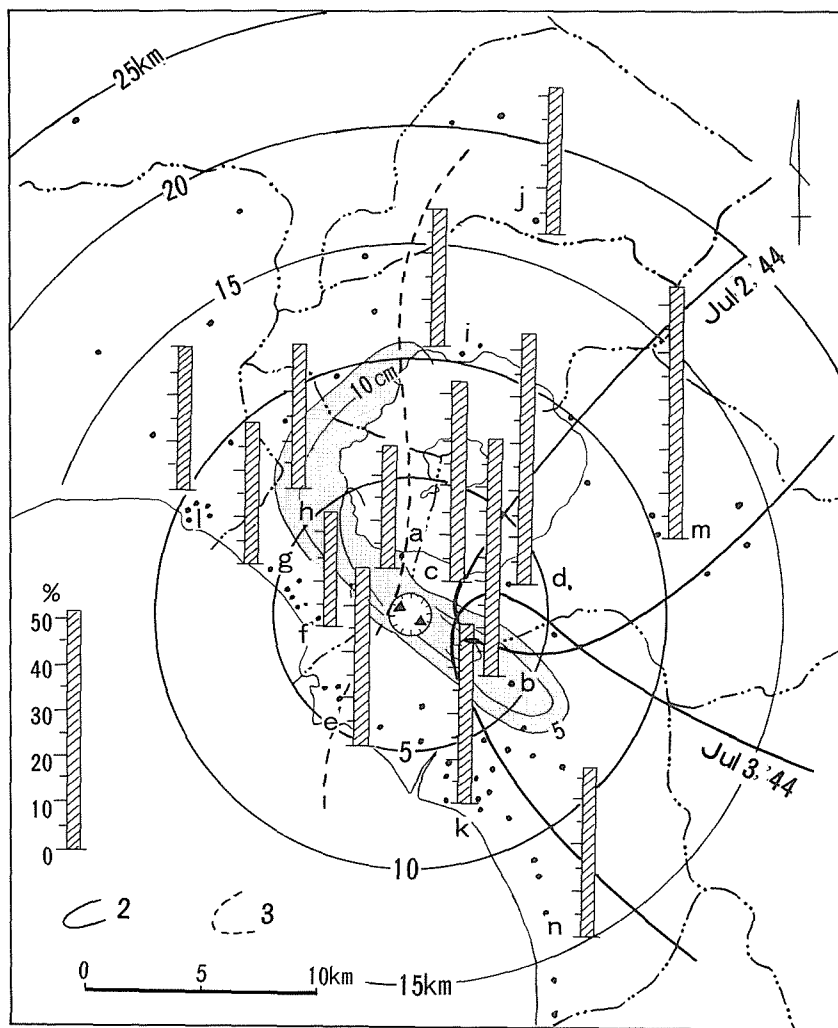


Fig. 8. Distribution of the respondents who answered "ash fall was expected"
 1: Percentage of respondents who expected ash fall, 2: Areas covered by ash fall of July 2 and 3, 1944 (after Ishikawa, 1950), 3: Western limit of ash falls produced during the 1943~45 activity (after Ishikawa, 1950).

Foreseeing of Eruption

The 1977 Eruption was an expected event for most of the people who lived in the areas surrounding Usu Volcano. In the settlement groups *a*, *f*, *i*, *j*, and *l*, more than 70 % of the respondents answered that the eruption was an unexpected event. On the contrary, in the east and southeast sides of the volcano, the respondents who foresaw near future eruption reach 30 to 40 % (Fig. 6). The latter settlements were hit

by the land deformation and ash falls during the 1943-45 activity, and about the half of the respondents experienced the events caused by that activity(Fig.4). In Toyako-onsen spa, where the number of respondents who experienced the past eruptions was only 20%, those who foresaw the near future eruption were also 20 % of the total respondents.

Similar perception pattern is also observed in the foreseeing of ash fall. While 40 to 50 % of the respondents expected to be hit by ashes and pumices in the settlements which were attacked by the ash falls during the 1943-45 activity, in Toyako-onsen spa, though situated very close to the active craters, over 50 % of the respondents did not expected ash fall at all. This difference in the expectation of both future eruption and ash fall may be explained by the difference in the past experiences (Figs. 6, 7 and 8; also *see* Fig. 22).

Response During Explosive Eruptions

Psychological effects of explosive eruptions and ash falls on the behavior were investigated in the case of surprise and fear. As shown in Figs. 9 and 10, the degree of surprise and fear is generally high in the ash-stricken settlements. Among those, the higher percentage of the re-

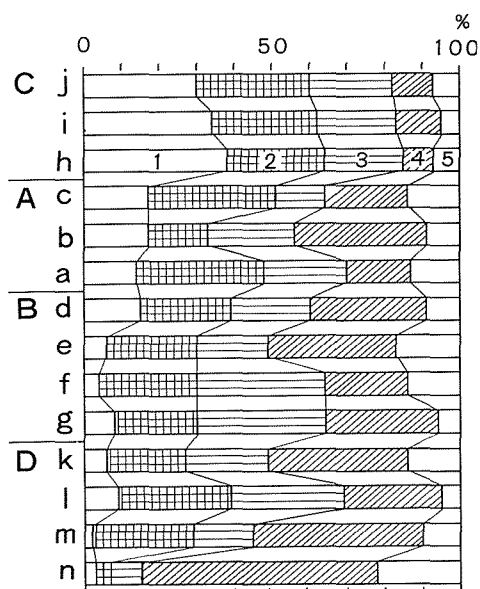


Fig. 9. Surprise
1: Extremely suprised, 2: Very surprised, 3: Surprised, 4: A little surprised, 5: Not surprised and no answer.

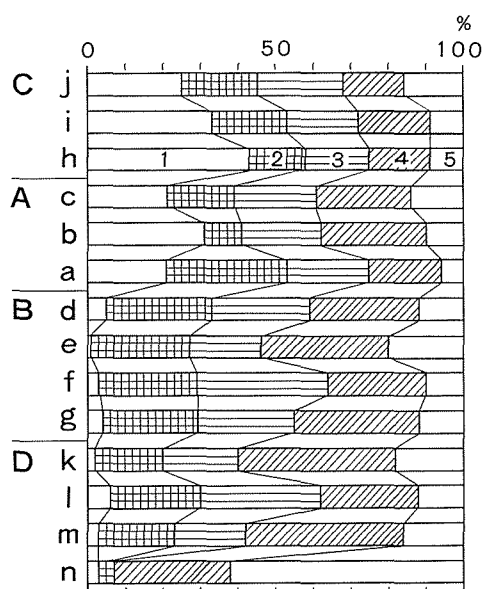


Fig. 10. Fear
1: Lost mind, 2: Very feared, 3: Feared, 4: A little feared, 5: Not feared and no answer.

spondents in group C, which is situated between 8 and 20 km northnorth-westward from the crater, is noted. Although the depth of fallen ashes was not so large and was 3 to 10 cm, most of the crops in this area were completely destroyed by the heavy and sticky ashes fallen with rain waters. Moreover, as previously mentioned, ashes mixed with rain waters fell at night, accompanying thunders and lightnings. These phenomena might have increased the degree of fear and surprise among the agriculturalists in such settlements. This also represents that the great destructive force of fallen ashes to the crops was explicitly recognised by many inhabitants.

It must be noted that most of the respondents living within 5 km from the summit somma, except those living on the southern foot-slopes, *i.e.*, settlements groups *e* and *f*, took some emergency self-adjustments to guard their bodies with composure (Fig.11). The respondents include those who were living in the areas very close to the crater and were hit by heavy ash and pumice falls. Even in the settlement unit *b* (Kaminagawa and Sekinai), which was attacked by the ash and pumice fall produced from the first explosive eruption of August 7, 1977, at unware-

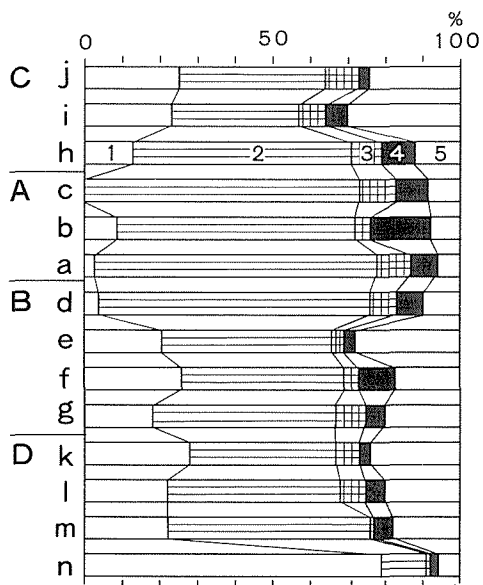


Fig. 11. Self-adjustment for protecting life during eruption and ash fall

1: No need, 2: Took some emergency adjustments to guard one's body such as escape into houses with composure, 3: As above, without composure, 4: Lost one's mind, 5: Others and no answer.

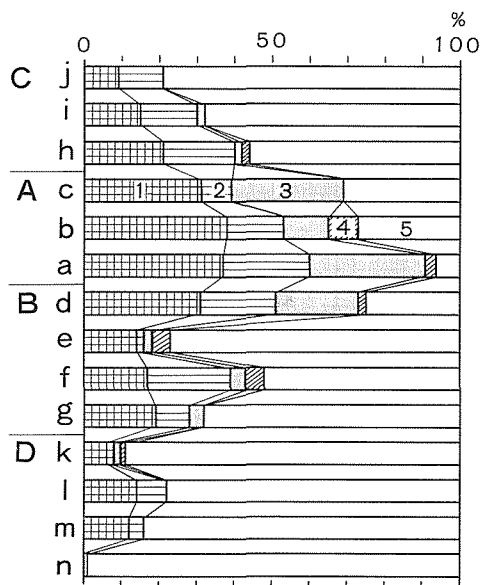


Fig. 12. Self-adjustment for protecting individual properties

1: Took some adjustments, 2: Wanted to take but could not take, 3: Escaped without time to take any adjustment, 4: Others, 5: Not necessary to take and no answer.

ness. The respondents who lost their balance were only 16%. Generally speaking, a greater proportion of the people living in the ash-stricken areas adjusted to the repeated eruptions composedly. It is evaluated that this would play a most important role in minimizing the loss of human life.

On the contrary, those who took any emergency countermeasure to protect their properties such as crops, houses, vehicles, goods, etc., were not so many. The percentage of the respondents who took some emergency adjustments is the highest in the settlement groups *a* (Toyako-onsen spa) and *b* (Kami-nagawa and Sekinai), but both showing only 37% and decreasing with the increase of the distance from the crater. Most of other inhabitants escaped to the safety places without time to take any protective measures to their properties (Fig.12). This suggests that the first consideration during the eruptions was not the properties but human life for most of the people.

Evacuation: Motivations and Means

Evacuation is the only effective way to cope with volcanic violence. Immediately after the first eruption on August 7, 1977, the order to evacuate from the danger areas was issued to the inhabitants living in the areas close to the volcano, and on August 9 the order was also issued to the whole inhabitants of Toyako-onsen spa (*a*), 4,300 in total, by the local governments concerned. Most of the people, therefore, evacuated in obedience to the order. Besides such passive evacuation, some other people made several times of self-evacuation according to circumstances. The motivations and means of the evacuation which were done at the first evacuation regardless of the day and time are shown in Figs. 13

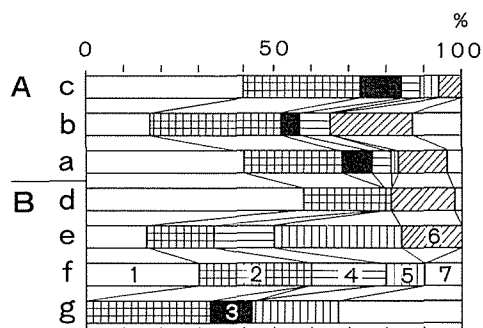


Fig. 13. Motivation of escape

1: In obedience to the order of evacuation, 2: By seeing eruption and/or approaching smokes. 3: Heavy ash fall, 4: Horror, 5: Strong earthquakes, 6: Others, 7: No answer.

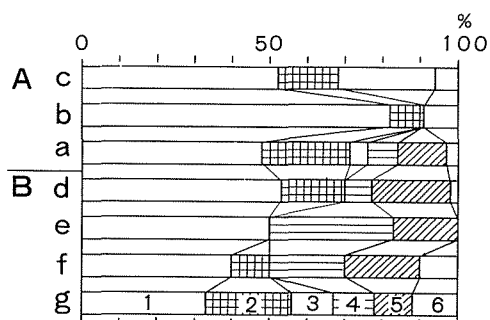


Fig. 14. Means of escape

1: By own vehicle, 2: Buses prepared by the local government, 3: Buses on regular operation, 4: On foot and by bicycle, 5: Others, 6: No answer.

and 14, respectively. The day of the first evacuation concentrated between 7 and 9 August when a series of violent eruptions happened.

In the settlements for which the order to evacuate was issued to the inhabitants, the percentage of the evacuees to the total respondents in each settlement was over 70 %. Excepting the people who evacuated in obedience to the order, some other people evacuated according to their self-decision. The main motivation of such evacuation was to perceive the eruption, to see approaching smokes or to receive heavy ash and pumice falls. It is worthy to note that the percentage of these respondents was 20 to 30 % in each settlement units.

The most common means of evacuation were using their own vehicles (Fig. 14). Most of the respondents think that the use of private vehicles would be convenient to the immediate evacuation on the basis of self-decision. However, an utter confusion of the traffic may resulted from scramble for roads. This problem has been perceived both by some respondents and the authorities concerned as one of worries in the emergency adjustments during the eruptions.

Evaluation of Emergency Adjustments

Fortunately, no human lives were lost by the direct impact of the eruptions and/or ash and pumice falls, and the injured was also very limited as previously mentioned. How did the people evaluate this? The evaluation differs from the location of the settlements (Fig. 15). In the two settlements situated closest to the crater, *i.e.*, *a* (Toyako-onsen spa) and *b* (Kami-nagawa and Sekinai), and hit by the heavy ash and pumice falls, the immediate escape into houses and buildings was evaluated as the most effective measures to minimize the casualties. Apart from these two settlements, the evaluation differs one from the others. In some settlements, especially which did not suffered from heavy ash falls, the wind direction at the time of the eruptions, together with small amount of ash and/or pumice falls, was believed to be the most leading reason. This was the common view among the people afflicted by slight or no damages. In other words, it may be said that the people learnt that the spatial pattern of damages caused by ash and pumice falls may depend on the wind direction at the time of eruption.

Evaluation of Danger

Although the degree is variable one settlement unit from others, over 80 % of the respondents in each unit thought that their living sites would be in danger from the future eruptions of Usu Volcano (Fig. 16). The

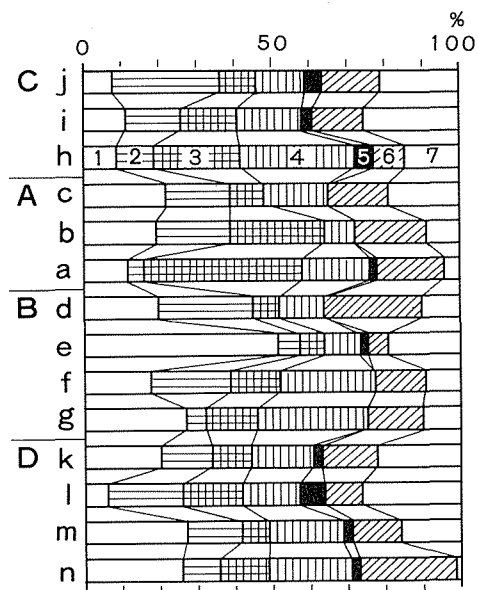


Fig. 15. Reason of no causalities due to direct impact of eruptions

1: Because of wind direction, 2: Little ash fall, 3: Immediate self-defence such as to escape into houses, 4: Appropriate induction of evacuation made by the local government, 5: Appropriate prediction and quick delivery of information, 6: Others, 7: No answer.

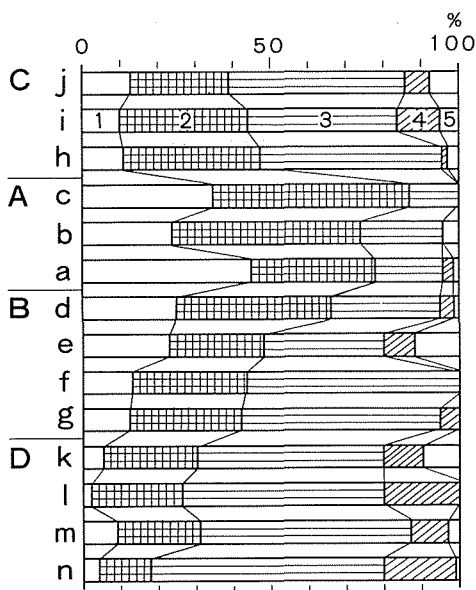


Fig. 16. Degree of danger of the living place from future eruptions

1: Very danger, 2: Danger, 3: A little danger, 4: Not danger, 5: No answer.

percentage of the respondents who chose the answer "very danger" and "danger" is higher in the settlement groups A and d (Takinomachi), exceeding 66 %. The percentage is generally decreasing with the increase of the distance from the crater in the case of slightly afflicted areas (Figs. 16 and 18).

Fig. 17 shows how many people among those who answered "very danger" had an intention to remove to other places. It is emphasized that within the 5 km zone, except for *f* (Irie and Izumi) and *g* (Abutahoncho), 37–59 % of the respondents wanted to remove with conditions attached. In the two hot spas, namely *a* and *c* settlements, there are about 10 % of respondents who hoped immediate removal.

The number of people who felt strong hazard reaches 46 % in Toyakoonsen spa which suffered from direct hit of ash and pumice falls. The relationship between the dwelling duration and the desire of removal for those felt that their living sites may be very danger from future eruptions is shown in Fig. 19. As observed in this figure, the percentage of those

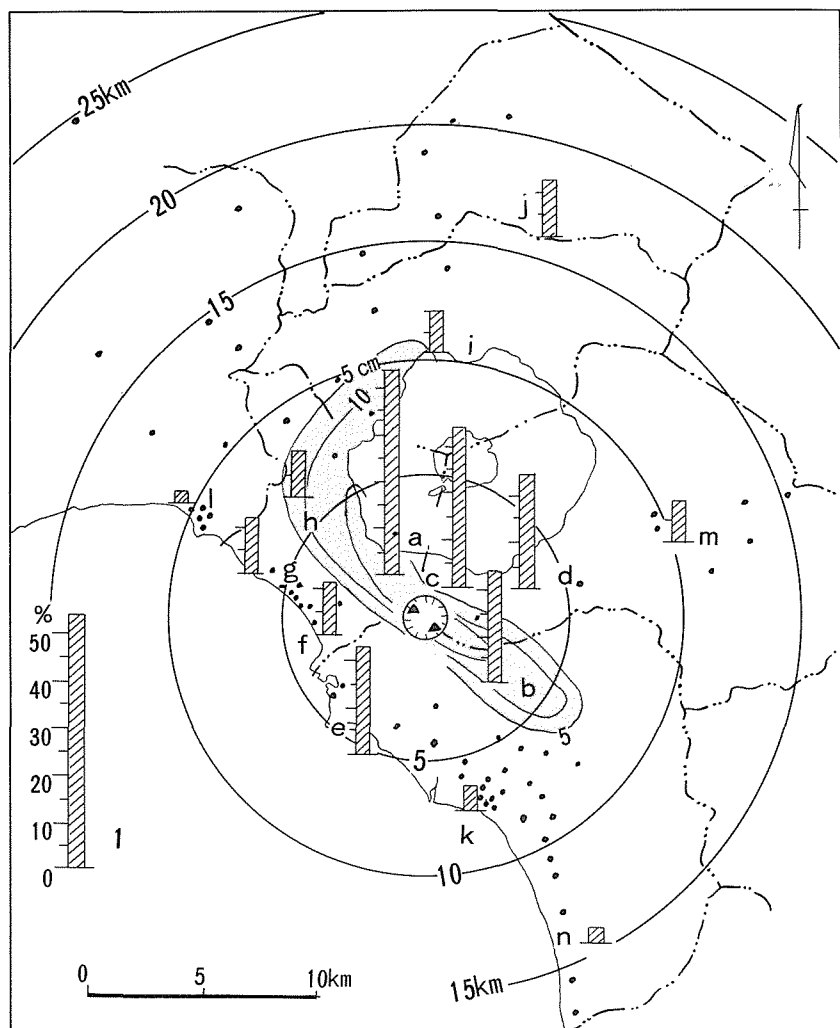


Fig. 17. Distribution of respondents who answered "very danger"
 1: Percentage of respondents who answered "very danger".

who desire to remove into other places is higher among the people living for shorter duration, except for those living for more than 31 years. From the analysis of the results of questionnaire research, it is unable to explain the reason of different response among the people living for more than 31 years.

In Toyako-onsen spa, 10 houses with 26 households were abandoned since mid-August, 1977 because these houses have been in danger from mudflows which might be generated from fallen ashes. Moreover, about 250 people, 5 % of the whole population already removed from

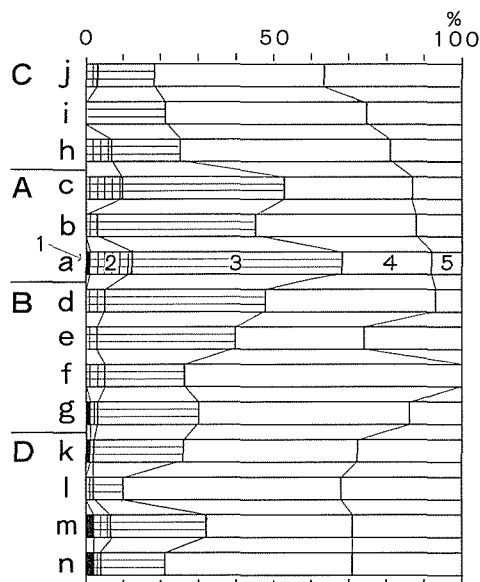


Fig. 18. Desire of removal

1: Already decided to remove, 2: Want to remove immediately, 3: Want to remove with conditions attached, 4: No need, 5: No answer.

this spa until the end of January, 1978, partly because of danger from repeated eruptions and partly because of business depression of the hot spa. In fact, the number of visitors to this spa, above all those staying at the spa, has greatly decreased since the beginning of the eruption. Even after the removal of the order of evacuation and traffic control, the number of visitors has not recovered soon. These conditions inevitably accelerated the removal of inhabitants, particularly employees of the sight-seeing industry such as hotels, inns, etc.

Desirable Public-Adjustments

Through the experience of the eruptions, most of the inhabitants have learnt some lessons and have known the problems for preventing volcanic hazards, as well as future problems of emergency self-adjustments, relief, and reconstruction works.

Throughout the areas investigated, the most desirable emergency public-adjustment to cope with volcanic hazards is believed to be "the delivery of accurate information about the volcanic activity" (Fig. 20). This was demanded by 40 to 50 % of the respondents, except *n* where the answers were made by school boys and girls. Exception is also found in *h*, where the desire for secure of food supply and road transportation shows a little higher percentage in comparison with other settlements.

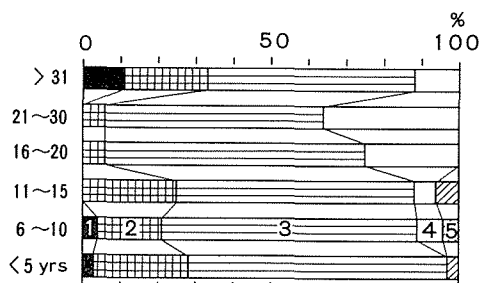


Fig. 19. Relationship between dwelling duration and desire to remove, in the case of Toyako-onsen spa(a)
1~5: see Fig. 18.

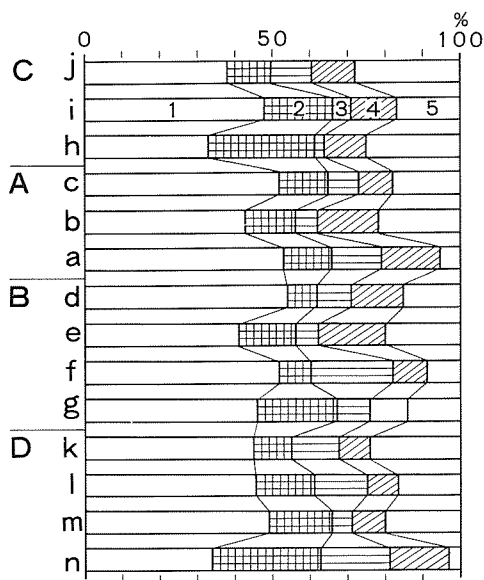


Fig. 20. Most desirable emergency public-adjustment immediately before and during eruptions

1: Delivery of accurate information, 2: Secure of food supply and road transportation, 3: Induction of evacuation, 4: Others, 5: No answer.

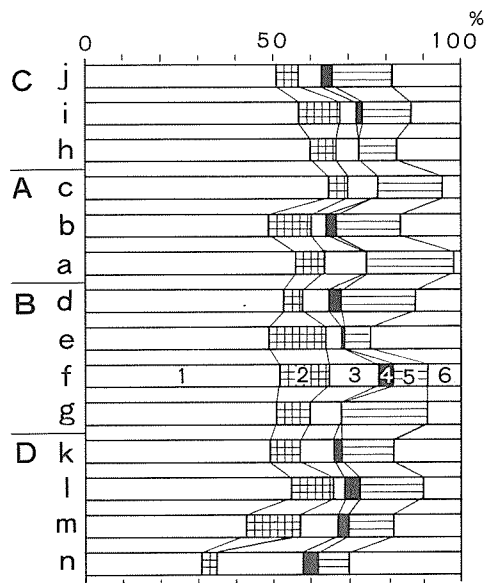


Fig. 21. Most desirable long-term public-adjustment

1: Prediction of eruption, 2: Land use regulation of hazard zone, 3: Preparation of safety refuges, 4: No entry to hazard zone, 5: Others, 6: No answer.

This is an example which reflects the demand for not only immediate removal of fallen ashes from the roads but also the relaxation of the strict traffic controls enforced during the rest of eruption.

Of the long-term public-adjustments, the strengthening of the prediction is believed to be most desirable (Fig. 21). 50 to 65 % of the respondents, excluding those of *m* and *n* settlements in *D* group, believe this would be the most effective long-term adjustment. Together with the demand for the above-mentioned emergency adjustments, this response clearly shows that the quick delivery of appropriate information necessary for emergency adjustments based on the accurate prediction has been conceived to be the foundation of disaster prevention.

Although the percentage is not so high, land use control or construction of refuges and shelters for emergency comes second or third in the selected answers for most of the settlement units.

Lessons

The lessons learnt by the people are too many to mention by details, and show a great variety in relation to the location of settlements, and ages, sex and occupation of the respondents. Therefore, only an outline of

the answers will be given below.

The first five lessons from the whole areas investigated are:

1. The grandeur and the horror of the Nature.
2. The necessity for self-provisions against emergency such as food, etc.
3. Response with composure during the eruptions.
4. Unreliable information makes one anxious.
5. Orderly life and unity in the refuges.

Among these lessons, 'orderly life and unity in the refuges' has been derived from the experience during the evacuation at public refuges.

Some Considerations

As previously mentioned, clear spatial patterns are found in human response and adjustments to eruptions. Some of these may result from the differences of personal attributes of the respondents such as ages, sex, occupation and past experiences. In order to examine the differences of perception to the hazards which are expected to be derived from such

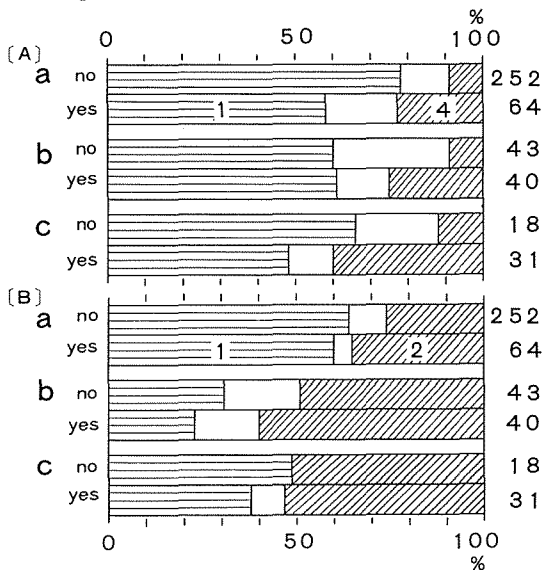


Fig. 22. Relationship between experiences of past eruptions and foreseeing of eruption and ash fall, in the case of settlement groups a, b and d (A) Foreseeing of eruption – 1: Unexpected, 4: After several years. (B) Foreseeing of ash fall – 1: Unexpected, 2: Expected.

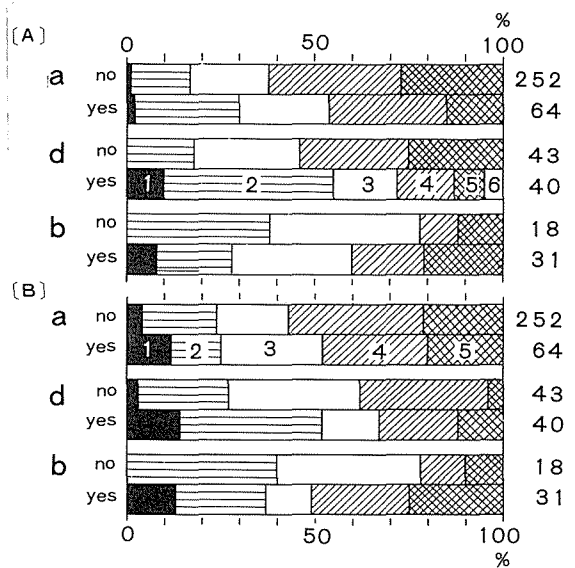


Fig. 23. Relationship between experience of past eruptions and psychological response, in the case of settlement groups a, b and d. (A) Surprise – 1: Not surprised, 2: A little surprised, 3: Surprised, 4: Very surprised, 5: Extremely surprised, 6: No answer. (B) Fear – 1: Not feared, 2: A little feared, 4: Very feared, 5: Extremely feared.

personal attributes, some considerations will be made below.

Past Experiences

As has been stated above, different response to the eruptions and ash falls is found between the respondents with the experiences of past eruptions and without such experiences. Fig. 22 compares the answers replied by two respondent groups in the case of the settlement groups *a*, *b* and *d*, all of which are located within 5 km from the summit somma. Although over 50 % of respondents answered that the eruption was an unexpected event, the percentage of respondents who foresaw near future eruption is two to three times larger in the group having past experiences. A similar response pattern may also be observed in the answer of foreseeing of ash fall.

From these examinations, it becomes more clear that the past experiences have greatly contributed to the making of perception on expectation of both coming eruption and ash fall.

Fig. 23 shows the differences found in the psychological response. Except for the settlement unit *b*, which attacked by the ash and pumice fall produced by the first burst, the degree of surprise and fear is high in the respondents without experience of past eruptions. On the contrary, the relation is reversed in the case of *b*, both for surprise and fear. However, respondents who responded to the eruptions without surprise and fear appear only in the experienced group. This suggests that the degree of psychological effects may also be controlled in a great degree by the experiences with past eruption.

Occupation

The most desirable public-adjustment chosen by the respondents of settlement unit *a* (Toyako-onsen spa) is compared by occupation (Fig. 24). As the number of sampled respondents is small in free laborers and manufacturers, the reliability of answers made by those people may be small. However, as long as the first answers, *i.e.*, "delivery of appropriate information" as the emergency adjustment, and "accurate prediction of eruption" as the long-term adjustment, no differences are to be found regardless of occupation.

Slight differences are found in the second answer. In the most desirable emergency adjustment, "secure of road traffic" chosen as the second answer by the people engaging in businesses relating to sightseeing industry may be noted. Of the most desirable long-term adjustment, merchants chose "land use regulation of hazard zone" as the second

answer, and “preparation of safety refuges” was believed to be the second important measures by the people engaging in transportation, service business and manufacture.

Sex

The differences in the perception, adjustment, and desire for the disaster prevention which are observed between in the male respondents and female respondents are compared in the case of Abuta-cho (Fig. 25). Little difference is found in the answers concerning the most desirable public-adjustments (E and F). The difference is also small in the fore-seeing of ash fall (G). In contrast to these, clear differences are observed for other five items. The degree of both surprise and fear is higher in

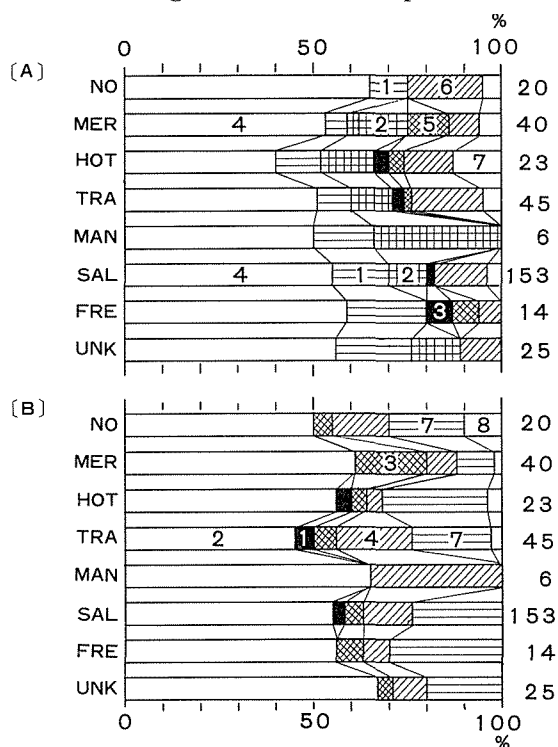


Fig. 24. Comparison of most desirable public-adjustment demanded by each occupation group

NO: No occupation, MER: Merchant, HOT: Hotel or inn manager, TRA: Transportation and service, MAN: Manufacturer, SAL: Salary earner, FRE: Free, UNK: Unknown.

(A) Emergency adjustment – 1: Induction of evacuation, 2: Secure of road transportation, 3: Secure of food supply, 4: Delivery of appropriate information, 5: Others, 6: Two answers and more, 7: No answer.

(B) Long-term adjustment – 1: Training of evacuation, 2: Prediction of eruption, 3: Land use regulation of hazard zone, 4: Preparation of safety refuges, 5: No entry to hazard zone, 6: Others, 7: Two answers and more, 8: No answer.

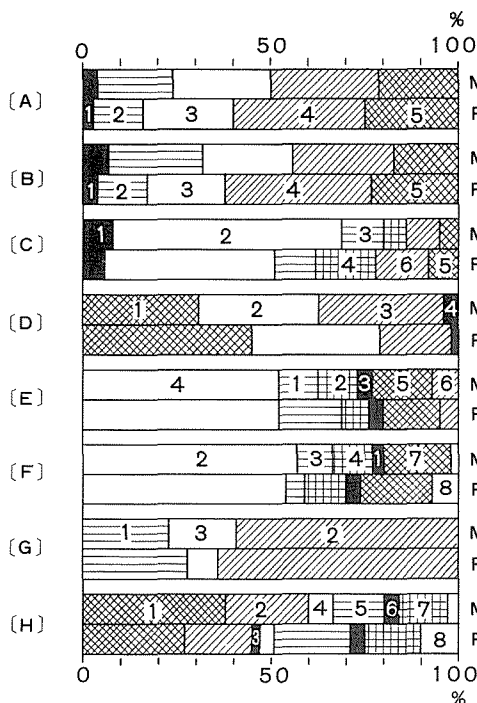


Fig. 25. Comparison of perception, adjustment and desire between male respondents and female respondents, in the case of Abuta-cho (M: Male, 364; F: Female, 116).

(A) Surprise – 1: Not surprised, 2: A little surprised, 3: Surprised, 4: Very surprised, 5: Extremely surprised.

(B) Fear – 1: Not feared, 2: A little feared, 3: Feared, 4: Very feared, 5: Extremely feared.

(C) Self-adjustment for protecting life – 1: No need, 2: Took some emergency adjustments to guard one's body with composure, 3: Escaped into houses at once, 4: As above, without composure, 5: Lost one's mind, 6: Others.

(D) Degree of danger of living place – 1: Very danger, 2: Danger, 3: A little danger, 4: Not danger.

(E) Emergency adjustment – 1: Induction of evacuation, 2: Secure of road transportation, 3: Secure of food supply, 4: Delivery of appropriate information, 5: Others. 6: Two answers and more.

(F) Most desirable long-term adjustment – 1: Training of evacuation, 2: Prediction of eruption, 3: Land use regulation of hazard zone, 4: Preparation of safety refuges, 5: No entry to hazard zone, 6: Others, 7: Two answers and more, 8: No answer.

(G) Foreseeing of ash fall – 1: Expected, 2: Unexpected, 3: Don't know.

(H) Reasons of no causalities due to the direct impact of eruptions

1: Immediate self-defence such as to escape into houses, 2: Appropriate induction of evacuation made by the local government, 3: Appropriate prediction and quick delivery of information, 4: Because of little ash fall 5: Wind direction, 6: Others, 7: Two answers and more, 8: No answer.

the female group. The degree of danger in living from future eruptions is also high among the female group. The number of respondents who

took some self-adjustments to guard their bodies with composure is larger in the male group. The percentage of the respondents, who believed that the immediate self-defence such as to escape into the houses was successful for minimizing the casualties, is 11% higher in the male group(H).

Conclusion

Human response and adjustment to the 1977 Eruption of Usu Volcano, Hokkaido were investigated by means of a questionnaire survey for the areas within 20 km from the summit crater, from mid-November to early December, 1977. The questionnaire designed for the survey contains 48 questions and the respondents, totalling 1763, were chosen chiefly among the parents of pupils of lower secondary schools.

The results have shown that human response and adjustment to the volcanic hazards vary in relation to the experiences of past eruptions, occupation, sex, etc. of the respondents, as well as the location of settlements. The distance from the crater, the amount of ash fall and the extent and type of damages are the main factors controlling the spatial patterns of perception and adjustments. Clear spatial differences are found in the foreseeing of both eruption and ash fall, psychological response and emergency self-adjustments during the eruptions, and the evaluation of emergency adjustments and the danger from future eruptions. On the contrary, little choice has been found in the desirable precautionary measures demanded to the local and national governments, regardless of location of settlements and personal attributes. By the people living in the hazardous zones, timely warning based upon the accurate prediction of eruption is believed to be the only limited basic public-adjustments to cope with the volcanic hazards. The patterns of choice for the desirable public-adjustments are similar those reported for the volcanic hazard in Puna District, Hawaii (Murton and Shimabukuro, 1974), and may be common to the developed regions (White, 1974).

It should be emphasized that the results obtained by this research have made clear the human perception to the risks involved in the physical environment of the region as well as the problems of the disaster-prevention, with their spatial patterns. From the point of view, the results described in this paper together with the data derived from the questionnaire survey should be effectively applied for improving and strengthening the regional disaster prevention project.

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