Technical Note of the National Research Institute for Earth Science and Disaster Prevention, No. 380 ; July, 2013

Volcanic Hazard Maps of Japan, Second Edition

Japan is one of the most volcanic countries on earth with more than 100 active volcanoes. Many scenic tourist destinations and hot spring resorts are located near active volcanoes, and residential areas have been approaching the volcanic summits. This has made it urgent for local governments and disaster mitigation organizations adjacent to active volcanoes to implement effective disaster management systems for dealing with volcanic threats. After the eruption of Unzen Fugendake in 1991, the National Land Agency of Japan published a national guideline for volcanic eruption disaster hazard maps based on lessons learned from casualties caused by the disastrous eruption of Nevado del Ruiz in South America in 1985. This was followed by publications of volcanic hazard maps (disaster mitigation maps) as well as disaster mitigation plans by many local governments adjacent to volcanic areas. Efforts to update volcanic hazard maps and prepare other refuge handbooks were stepped up significantly after Usuzan and Miyakejima erupted in 2000.

Meanwhile, the Commission on Mitigation of Volcanic Disasters of the Volcanological Society of Japan (VSJ) had been investigating effective methods for developing the best suited mitigating systems for volcanic disasters in Japan. Also, the Disaster Information Laboratory of the National Research Institute for Earth Science and Disaster Prevention (NIED) had been working on efficient ways to collect and disseminate disaster prevention related materials and information resources. Working together, these two organizations developed a volcanic hazard map database that provides basic information resources to local government authorities, disaster mitigation organizations, and researchers who are concerned with volcanic hazards. After building on these collaborations, the first edition of the Volcanic Hazard Maps of Japan (on two DVDs) was published in 2006, followed by an English supplemental DVD (on a single disk) in 2007. In addition, the NIED made the database system of volcanic hazard maps widely available to the public by putting up an online version on their website, which they regularly update as new information becomes available. Since the first edition of the Volcanic Hazard Maps of Japan was published six years ago, the Japan Meteorological Agency (JMA) has revised the number of active volcanoes upward from 108 to 110, and the new Volcanic Warning and Volcanic Alert Levels System has been incorporated into many areas near active volcanoes. Several hazard maps have therefore been revised by local governments, and numerous publications with new information have been published.

One valuable lesson we learned from the recent Great East Japan Earthquake of March 11, 2011 is that we must be prepared to respond to major natural disasters no matter how infrequent and unlikely, and we must deal with such disasters as a national challenge and not simply rely on local governments and local disaster management organizations. In order to implement a wide-area disaster management system that can handle these kinds of large-scale disasters, we must bolster hard countermeasures with soft countermeasures while continuing to explore other novel ways of thinking. Indeed, reassessment of how people should respond to disasters based on these new ways of thinking has already begun.

Taking this into consideration, the second edition of Volcanic Hazard Maps of Japan was planned and has now been released with new updated content, based on recent studies and reviews by national agencies, disaster management organizations and commissions, and local governments, some of which have faced volcanic threats in the recent past. We have tried to incorporate a great deal of new data about the current state of disaster management and future disaster mitigation efforts into this second edition. By including the latest version of volcanic hazard maps and other relevant information resources, we hope that the recent initiatives and information coming out from local governments, other relevant organizations and agencies, media organizations, volcanologists and disaster mitigation scientists will be put to widespread use in developing even better ways of mitigating volcanic disasters in Japan.

Finally, we would like to express our appreciation to the members of the Disaster Information Laboratory, NIED, and the Commission on Mitigation of Volcanic Disasters of VSJ for publishing this paper.

Yoichi Nakamura, Toshikazu Tanada, and Shigeo Aramaki

March 2013

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Challenges of Dealing with Large-Scale Volcanic Disasters

Shigeo ARAMAKI*

Japan has not made much progress in dealing with large-scale volcanic eruptions that wreak devastation across several prefectures, and as we just witnessed in the Great East Asia Earthquake in March 2011, this is a challenge of great urgency. Indeed, we have been rather slow to mount a comprehensive response even in the face of relatively small volcanic disasters. It would be a very significant development if we could come up with a viable scheme for dealing with large-scale volcanic disasters across an extensive area, for of course this would enable us to deal with the whole range of volcanic hazards. The biggest failing of disaster management personnel at the local level is their inability to envision a volcanic disaster in concrete detail. This lack of vision can be attributed to the fact that very few people have really experienced a volcano first hand, and the fact that there is far greater range of physical volcanic disaster models compared with other kinds of natural disasters. In order to get beyond this lack of vision, it is absolutely essential to move experts—mainly volcanologists—into positions of authority in organizations that deal with volcanic hazard mitigation and management. Unfortunately, the government officials sitting on these councils and other organizations are only dimly aware of the necessity and importance of volcano experts, so the experts tend to be marginalized. Involvement and input from the volcanologists must be vigorously encouraged at the national level, the prefectural level, and the municipal level. In order to deal effectively with large-scale volcanic hazards, it is necessary to bring together different administrative entities and organize some kind of joint disaster management headquarters. Again, the volcanologists should be the key players in gathering and assessing data about volcanic activity, while offering reports and advice to the administrative personnel. For their part, seismologists and volcanologists must learn how to work within disaster management organizations, so that they know who to talk to and who they should offer their information and advice to. Volcanologists involved in basic research tend to be uninterested in this kind of administrative activity, or think that they lack the basic skills and knowledge to play such a role. But considering how poorly informed most working-level disaster managers are regarding volcanic activity, basic science volcanologists must get directly involved so they can explain and assess what is going on and offer advice to their less-knowledgeable colleagues. Volcanic activity has very different characteristics from earthquakes and other types of natural disasters. For all its devastation, the Great Tohoku-Kanto Earthquake of March 2011 was a wakeup call. It woke people up to the urgency of establishing effective countermeasures to deal with major volcanic disasters. Following the Tohoku-Kanto earthquake, three prefectures—Shizuoka, Yamanashi, and Kanagawa—banded together and organized a countermeasures council to consider what to do in the event of a large-scale eruption of Mount Fuji. Here we will discuss the range of activities and just what these onsite joint countermeasure headquarters do. This promises to be a very substantive discussion that will go into some depth about the actual state of volcanoes and eruptions. There are many major volcanoes straddling prefectures that cut across jurisdictional boundaries in Japan, yet so far there has been very little progress in setting up joint inter-prefectural conferences to think through and develop effective countermeasures. Clearly we must pursue this approach in the years ahead.

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Volcano Disaster Prevention Work of the Cabinet Office

Hideaki FUJIYAMA*, Shinichi TOKUMOTO*, Kiyotaka KOCHI*, and Toshiki SHIMBARU*

1. Introduction

Our country, the volcanic islands of which are among the world's most famous, has suffered from volcano disasters since the dawn of history. Over the past decade, volcano disasters such as the eruptions and volcanic activity of Unzen-Fugendake from 1990 to 1995 and the eruptions of Usuzan and Miyakejima in 2000 have caused great damage to people and property. In 2011, Kirishimayama (Shinmoedake) resumed full-scale volcanic activity for the first time in about 300 years.

To prevent these volcano disasters, the central government has designated areas with volatile volcanoes as areas requiring emergency provision of refuge facilities under the Act on Special Measures for Active Volcanoes. The central government is thus supporting local government projects (improvement of roads or ports and of shelter and other evacuation facilities) in the designated areas. As part of its efforts during non-emergency periods, in 1992 the Disaster Prevention Bureau of the National Land Agency developed "principles for drafting maps that forecast dangerous areas at the time of a volcanic eruption." Under these principles, preparation of volcano hazard maps has been promoted.

After the reorganization of the central government, the Cabinet Office, which was established to plan and coordinate important issues related to ensuring public safety (such as disaster prevention), took over volcano disaster countermeasure operations. In 2000, the Office established the Fujisan Volcano Disaster Management Council and, in collaboration with related prefectural and municipal governments and government agencies, prepared a Fujisan Hazard Map following low-frequency earthquakes directly under the mountain. In addition, the Office's Central Disaster Management Council developed basic policies that should be followed by central and local government in the event of an eruption of Fujisan.

As described above, the Cabinet Office develops the policies for volcano disaster countermeasures in our country. It also works on measures to improve and strengthen these countermeasures under the policies, in collaboration with related ministries and agencies.

2. Establishment of a Volcano Disaster Management System for Each Volcano

The important thing for volcano disaster countermeasures is to implement entry restriction and evacuation beforehand in areas predicted to be at risk from the volcanic phenomena associated with an eruption (e.g. ballistic projectiles, pyroclastic flows, and snowmelt and volcanic mudflows). To achieve this, it is necessary to establish a system in which suitable eruption alerts can be announced to residents and the residents can be evacuated immediately and smoothly.

In 2006 and 2007, the Cabinet Office and other relevant agencies held meetings to commission a review of disaster management countermeasures on the basis of volcanic information. The aim was to investigate essential factors for establishing an effective evacuation system for use during the eruption of each volcano. Under the Policy on Volcano Management Related to Evacuation in the Event of an Eruption (the Policy) compiled at the meeting, relevant ministries and agencies, including the Cabinet Office, are working jointly to establish a volcano disaster management system. The details of their efforts are introduced below (**Fig. 1**).

2.1 Establishment of Volcano Disaster Management Councils and Formation of Core Groups

Volcanoes are often sited at the boundaries of several municipalities or prefectures. For this reason, the relevant prefectural and municipal governments need to implement consistent evacuation measures so as not to interfere with the residents' evacuation in the event of an eruption. Consequently, the prefectural and municipal governments and relevant agencies and authorities must share information during non-emergency periods and establish Volcano Disaster Management Councils for the joint study of evacuation measures. To run disaster management conferences, prefectural governments must collaborate with the relevant agencies and authorities.

Core groups, which consist of prefectural and local government officials, meteorological observatory personnel, the Sabo (Soil Erosion Control) Department and volcanologists deeply involved in establishing evacuation timing and areas, play an important role in allowing

* Disaster Management. Cabinet Office

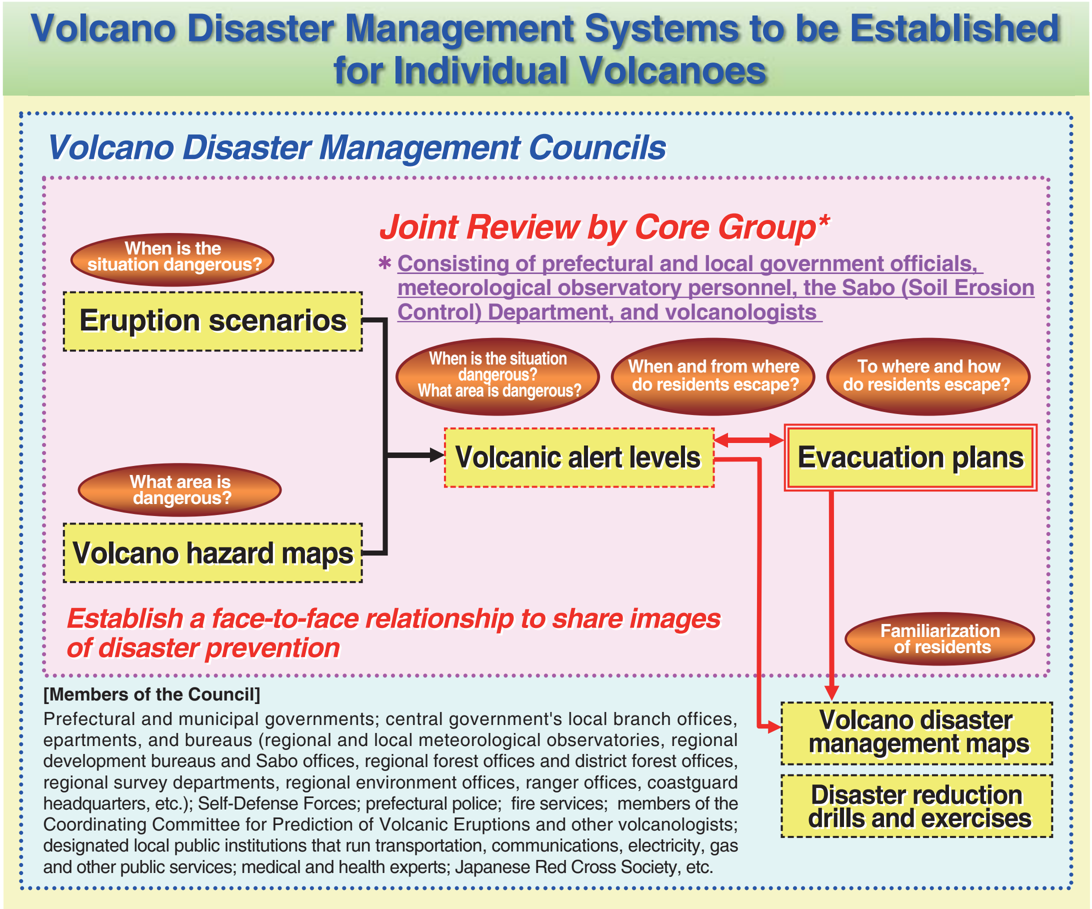

Fig. 1 Volcano disaster management systems to be established for individual volcanoes.

such conferences to examine evacuation measures in an efficient manner.

2.2 Eruption Scenarios, Volcano Hazard Maps, and Volcanic Alert Levels

In any examination of evacuation in the event of an eruption, core groups need to take the initiative in developing several eruption scenarios and preparing volcano hazard maps that indicate the likely areas affected by the eruption. Gradual evacuation in response to different scales of eruption requires several volcano hazard maps to be prepared according to each scale.

By mapping a variety of eruption phenomena (ballistic projectiles, pyroclastic flows, and snowmelt and volcanic mudflows), the volcano hazard maps point out danger areas that are at risk of eruption phenomena. The maps form a basis for volcano disaster countermeasures.

By preparing eruption scenarios and volcano hazard maps, the Volcano Disaster Management Councils' related agencies and authorities can share information on the likely areas affected by an assumed disaster in each phase of volcanic activity. They can also determine the timing criteria for disaster prevention measures (e.g. road and trail regulation, or issuances of evacuation preparation information and evacuation orders and advisories). The disaster countermeasure criteria that are agreed to by the Volcano Disaster Management Councils are used to determine the volcanic alert levels that will trigger disaster countermeasures.

In response to an increase in volcanic alert levels, the agencies and authorities can take disaster countermeasures in an immediate and smooth manner. This should help to reduce the extent of volcano disasters.

2.3 Drafting of Specific and Practical Evacuation Plans

For a volcano with a certain volcanic alert levels, a level in the "alert" range (e.g. between 4 and 5) implies that certain areas must be evacuated. On the basis of this range, specific and practical evacuation plans for residents in the relevant areas are developed. Information includes when residents evacuate, from where they evacuate, who evacuates, to where they evacuate, and how they evacuate.

It is necessary to identify residents (including people requiring assistance during a disaster) in evacuation areas and to then draft specific and practical evacuation plans that will enable immediate evacuation. The plans need to consider a variety of phenomena in the event of an eruption (e.g. earthquakes associated with volcanic activity, traffic congestion caused by evacuation in cars, and evacuation means, routes, and times).

To familiarize residents with the need for evacuation, it is also necessary to prepare volcano disaster management maps. These maps will include the disaster prevention information required for volcano hazard maps (e.g. descriptions of eruption alerts, evacuation centers and routes, evacuation methods, and how to disseminate disaster information to residents) and will be based on the details of the evacuation plans that have been developed. It will also be necessary to execute disaster reduction drills and exercises based on the evacuation plans and to validate the evacuation plans on the basis of the results of the drills.

2.4 System of Experts in Volcano Disaster Management

Volcanic disasters occur at a lower frequency than other natural disasters. Only a few prefectural and municipal governments have suffered volcano disasters, and there are only small numbers of staffers across Japan that have experience in working in disaster prevention in the event of an eruption. Therefore, in July 2009 the Cabinet Office initiated a system of experts in volcano disaster management. The Office designates as experts in volcano disaster management those staff members in prefectural and municipal governments who have taken the initiative in responding to volcano disasters in recent years. These members support the drafting of disaster countermeasures in volcanic areas.

3. Support for Establishment of a Disaster Management System

As a result of the Cabinet Office's survey, however, it has become obvious that volcano disaster countermeasures under the Policy are not being implemented as smoothly as desired. Prefectural and municipal governments and the Volcano Disaster Management Councils need various types of support from the central government and relevant agencies (e.g. manuals and advice). The state of disaster countermeasure efforts for different volcanoes as of January 2013 is shown in **Table 1**.

Table 1 State of efforts to implement disaster countermeasures for 47 volcanoes.

State of efforts for disaster management countermeasures for 47 volcanoes

State of efforts for disaster management countermeasures for 47 volcanoes requiring strengthening and improvement of monitoring and observation systems (selected by the Coordinating Committee for Prediction of Volcanic Eruptions)

Name of volcano	Establishment of Volcanic Disaster Management Councils	Establishment of volcano hazard maps	Introduction of volcanic alert levels	Drafting of specific and practical evacuation plans	Name of volcano	Establishment of Volcanic Disaster Management Councils	Establishment of volcano hazard maps	Introduction of volcanic alert levels	Drafting of specific and practical evacuation plans
Atosanupuri		○			Yakedake	○	○	○	
Meakandake	○	○	○		Norikuradake				
Taisetsuzan					Ontakesan	○	○	○	
Tokachidake	○	○	○		Hakusan				
Tarumaesan	○	○	○		Fujisan	○	○	○	
Kuttara		○			Hakoneyama	○	○	○	
Usuzan	○	○	○		Izu-Tobu Volcanoes	○	○	○	
Hokkaido-Komagatake	○	○	○		Izu-Oshima	○	○	○	
Esan		○			Niijima				
Iwakisan		○			Kozushima				
Akita-Yakeyama		○			Miyakejima	○	○	○	
Iwatesan	○	○	○		Hachijojima				
Akita-Komagatake		○	○		Aogashima				
Chokaisan		○			Ioto				
Kurikomayama					Tsurumidake and Garandake		○		
Zaozan		○			Kujusan	○	○	○	
Azumayama		○	○		Asosan	○	○	○	
Adatarayama		○	○		Unzendake	○	○	○	
Bandaisan		○	○		Kirishimayama	○	○	○	○
Nasudake	○	○	○		Sakurajima	○	○	○	○
Nikko-Shiranesan					Satsuma-Iojima	○	○	○	
Kusatsu-Shiranesan	○	○	○		Kuchinoerabujima	○	○	○	
Asamayama	○	○	○		Suwanosejima	○	○	○	
Niigata-Yakeyama	○	○	○		**Total**	**25**	**37**	**29**	**2**

○ Twenty-five volcanoes established Volcanic Disaster Management Councils.
○ Twenty-nine volcanoes introdued volcanic alert levels.
○ Thirty-seven volcanoes established volcano hazard maps.
○ Two volcanoes drafted specific and practical evacuation plans.

For this reason, the Cabinet Office clearly indicated the need to establish Volcano Disaster Management Councils in the Basic Disaster Management Plan that was revised in December 2011. Furthermore, during the period from January 2011 to March 2012, a Review Committee for the Promotion of Disaster Management Measures was created to help further promote volcano disaster countermeasures. The committee discussed possible assistance measures that could be taken by the central government in order to promote the development of evacuation plans, the preparation of volcano hazard map, the establishment of Volcano Disaster Management Councils, and revitalization of the Councils.

3.1 Guide for Drafting of Specific and Practical Evacuation Plans in the Event of an Eruption

Following the eruption of Kirishimayama (Shinmoedake) in January 2011, the central government dispatched to Miyazaki and Kagoshima prefectures a government assistance team that consisted of staff from relevant agencies and authorities. Guidelines for the drafting of evacuation plans in the event of volcanic eruptions and sediment disasters were also prepared (described later).

On the basis of these guidelines, the review committee analyzed and collated issues and important points to be noted when the evacuation plans were drafted. It prepared a Guide to Drafting Specific and Practical Evacuation Plans in the Event of Eruptions and other Natural Phenomena (Inland Volcano and Island Volcano Editions) (“the Guide”). This acts as a manual for the drafting of evacuation plans in the event of eruptions of any of the volcanoes across the country, in reference to the evacuation plans that have already been prepared for Sakurajima, Shinmoedake, and other active volcanoes.

Since the start of fiscal year 2012, the Cabinet Office has been helping prefectural and municipal governments to draft evacuation plans on the basis of the Guide and in cooperation with the relevant agencies and authorities.

3.2 Policy for Preparation of Volcano Disaster Management Maps

Preparation of volcano hazard maps has been promoted so far under “principles for drafting maps that forecast dangerous areas at the time of a volcanic eruption.” This policy was developed by the Review Committee for Disaster Management Measures (Secretariat: Disaster Prevention Bureau, National Land Agency) in 1992. However, there are some volcanoes for which hazard maps have still not been prepared. To promote the development of these maps, it has been decided that this 20-year-old policy should be revised on the basis of new findings about volcano disaster management and volcanology.

In addition, the Policy for Preparing Volcano Disaster Management Maps was developed in 2012. The aim of the policy is to determine whether existing volcano hazard maps are effective for preparing evacuation plans and also to promote the development of volcano disaster management maps that can be utilized in actual evacuations.

3.3 Meetings of Volcano Disaster Management Councils

Volcano Disaster Management Councils form a basis for the review of measures for evacuation in the face of eruptions of different volcanoes, but establishment of the councils has not been promoted. Some existing Volcano Disaster Management Councils do not promote the review of evacuation measures. This is because Council meetings are not held often, or because the Councils do not form core groups or do not have input from volcanologists.

Therefore, since fiscal year 2012, representatives of Councils for different volcanoes and prefectural and municipal governments in volcanic areas have gathered at the Meetings for Volcano Disaster Management Councils. Through discussions and the exchange of opinions, information, and the issues confronting Volcano Disaster Management Councils, the meetings aim to promote the establishment and revitalization of these Councils.

4. Support in the Event of an Eruption

4.1 Establishment of Major Disaster Management Headquarters

In the event of a large-scale volcano disaster, the central government will establish a Headquarters for Major Disaster Management, headed by a Minister, in accordance with the Disaster Countermeasures Basic Act. For liaison and coordination with relevant agencies and local municipalities, or for the immediate establishment of a local disaster response system, if required, the central government will set up a local disaster management base to take countermeasures. In the event of an unusual and severe volcano disaster, the government will set up a Headquarters for Extreme Disaster Management that is headed by the Prime Minister. If required, the Headquarters for Extreme Disaster Management will also establish a local extreme disaster management base for countermeasures. In the event of any disaster not requiring a Headquarters for Major Disaster Management, the government may set up a local organization (local liaison base) and take measures in coordination with local relevant agencies.

In the event of the eruption of Usuzan in 2000, the Usuzan Local Liaison and Coordination Conference was set up in response to information announced by the Japan Meteorological Agency immediately before the eruption.

A Headquarters for Major Disaster Management and local disaster management base were set up after subsequent eruptions of the mountain

4.2 Support under the Act on Special Measures for Active Volcanoes

In the event of the eruption of a volcano, support for projects related to emergency provision of refuge facilities, removal of volcanic ash and minimization of ash damage, and improvement of agricultural facilities for disaster prevention and farming facilities is provided under the Act on Special Measures for Active Volcanoes.

Areas designated under the Act as requiring the emergency provision of refuge facilities can receive financial support for the establishment and improvement of facilities required for immediate evacuation of residents (improvement or construction of roads or ports, squares and shelters; and fire-proofing and ruggedization of schools and community centers).

Municipalities designated under the Act as requiring removal of volcanic ash can receive financial support for improving or establishing facilities for removing volcanic ash and for educational and social welfare facilities.

In the event of the eruption of Kirishimayama (Shinmoedake) in 2011, the central government designated affected areas as those requiring emergency provision of refuge facilities and those requiring removal of volcanic ash. It conducted various projects based on the designation of the relevant areas.

4.3 Response in the Case of the Eruption of Kirishimayama (Shinmoedake) in 2011

Full-scale volcanic activity occurred at Shinmoedake in Kirishimayama in January 2011. Volcano hazard maps had already been prepared, and volcanic alert levels had been introduced for the mountain. However, specific and practical evacuation plans had still not been developed. Because of the continuous explosive eruption of Shinmoedake, an evacuation advisory was issued to areas 8 to 12 km from the crater (1,158 people in 513 households), although the volcanic alert level was 3 (regulated entry within a distance of 3 km from the crater). There was a discrepancy between the meteorological observatories' responses to this volcano disaster and the municipalities' responses.

In light of these circumstances, the central government dispatched to both Miyazaki and Kagoshima prefectures a government assistance team of relevant agency officials to help deal with the eruption. The government reestablished the Volcano Disaster Management Council (Core Member Conference for Kirishima Volcano Disaster Management Liaison Committees; Miyazaki and Kagoshima prefectures as the secretariat) as a system in which the central government's local agencies, as well as the prefectural and municipal governments and the volcanologists, jointly examined the residents' evacuation in an integrated manner. Furthermore, the government compiled Guidelines for Drafting Evacuation Plans in the Event of the Eruption of Kirishimayama (Shinmoedake). On the basis of these guidelines, evacuation plans in relation to pyroclastic flows and ballistic projectiles were developed for the town of Takahara in Miyazaki Prefecture and the city of Kirishima in Kagoshima Prefecture. Evacuation plans in relation to sediment disasters from volcanic ash were developed for the city of Miyakonojo in Miyazaki Prefecture. All of these plans were developed through joint review by the Volcano Disaster Management Council.

Experts in volcano disaster management were dispatched to Takaharu and Miyakonojo in Miyazaki Prefecture. They held an explanatory meeting with local residents to disseminate information and educate the public about sediment disasters, for example in relation to the debris flows associated with rain after ash fall.

5. Future Movements

The Cabinet Office will continue to support efforts to establish disaster management systems for individual volcanoes. The relevant Review Committee for the Promotion of Disaster Management Measures has collated data on those issues that occur in any large-scale volcano disasters and that cannot be dealt with within the framework of the Volcano Disaster Management Councils alone. This includes volcano disasters that greatly and broadly affect society in the long term. On the basis of this review, at the start of fiscal year 2012 the Cabinet Office and other related agencies created a Committee to Review Wide-ranging Disaster Management Measures and have been examining specific disaster countermeasures.

The Japan Meteorological Agency's Volcanic Disaster Mitigation Initiatives

Hitoshi YAMASATO*, Jun FUNASAKI*, and Yasunobu TAKAGI*

1. Active Volcanoes in Japan

Japan is one of the most volcanic countries in the world, and has suffered many volcanic disasters in the past. In Japan, the definition of *active volcanoes* by the Japan Meteorological Agency (JMA) and the Coordinating Committee for Prediction of Volcanic Eruptions (CCPVE: private advisory body to the Director-General of the JMA that was established by the volcanic eruption prediction plan: Fujii, 2013) is widely used. According to this definition, there are 110 *active volcanoes* in Japan (see Figure 1). The definition of active volcanoes has fluctuated over the years, but in 2003 the JMA defined *active volcanoes* in Japan as "volcanoes which have erupted within 10,000 years or volcanoes with vigorous fumarolic activity" (Yamasato, 2007).

Active volcanoes range widely in the degree of activity - they exhibit from constant eruptive displays such as one sees at Sakurajima to volcanoes that are relatively quiescent over long periods. This led the CCPVE to refine the 2003 definition of active volcano (until then defined as a volcano that had erupted within 2,000 years) into three ranks—A, B, and C—depending on degree of past volcanological activity. Because this ranking is based on degree of volcanic activity in the past, it may not reflect eminence of eruption or the potential impact on society or need to respond to volcanic disasters. The CCPVE thus followed up with a project to identify volcanoes that could erupt over the next 100 years, that call for close monitoring and observation to mitigate any potential impact on society, and in 2009 they came up with a list of 47

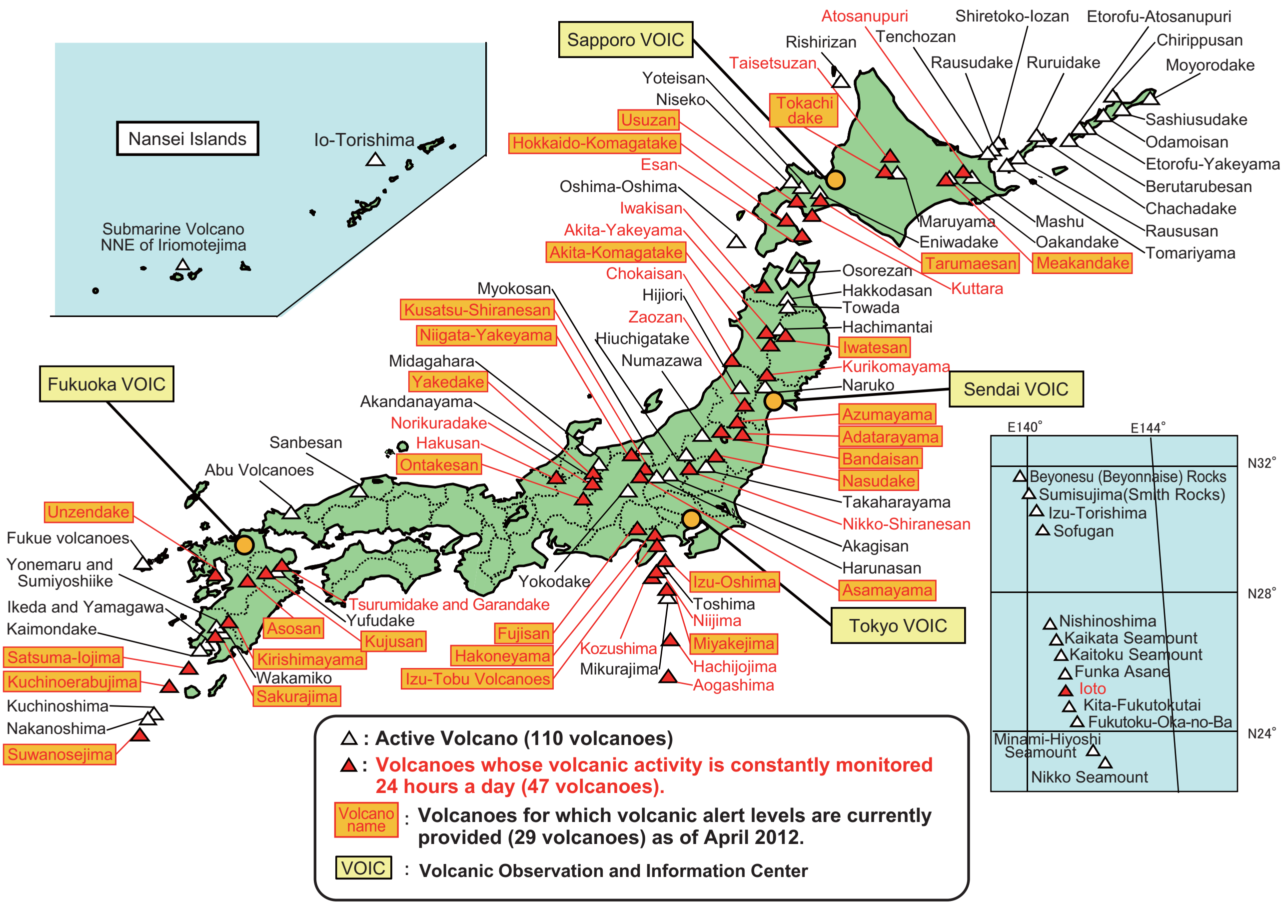

Fig. 1 Japan's active volcanoes and volcano monitoring system.

* Volcanological Division, Seismological and Volcanological Department, Japan Meteorological Agency

volcanoes that met these new criteria. The JMA's constant monitoring system has been in effect to the present day, and we will describe this system in detail which is based on this same list of 47 active volcanoes. In light of the fact that the volcanoes on this watch list were selected based on different criteria than the rank system and that many of the 47 were classified as Rank C volcanoes in 2003, the JMA no longer uses the older ranking system.

2. Japan Meteorological Agency Responsible for Monitoring Volcanoes

In Japan, the JMA, an affiliate agency of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT), is responsible for monitoring volcanic activity. Another affiliate agency of the MLIT, the Japanese Coast Guard monitors volcanoes on the seafloor and remote islands, while the Geospatial Information Authority of Japan (GSI) is in charge of monitoring crustal deformation using a nationwide crustal deformation observation network. In addition, the MLIT and prefectural erosion control departments monitor mudflows (lahars) as part of their erosion control responsibilities. Finally, universities and research institutes have their own volcanic observation networks for research purposes, and conduct research with the goal of refining eruption prediction capabilities. This paper will be primarily concerned with the JMA's Volcanic Monitoring System.

The JMA had kept a close eye on the main active volcanoes using meteorological observatories and weather stations that are located in close proximity to the volcanoes. A mechanical seismograph was deployed at Kagoshima weather station is 1888, and this marked the beginning of constant onsite seismic observation near an active volcano. The seismograph recorded the major eruption of Sakurajima in 1914. Japan set up its first volcano observatory on Asamayama in 1911 in a team effort between the Ministry of Education's Imperial Earthquake Investigation Committee and the Nagano Weather Station.

In the 1960s, the JMA made a serious effort to implement a constant volcano observation system nationwide, and initially designated 17 active volcanoes for constant monitoring using high-sensitivity seismographs deployed at meteorological observatories and weather stations on or near the volcanoes. Other volcanoes not on this watch list were checked periodically by mobile volcano observation teams.

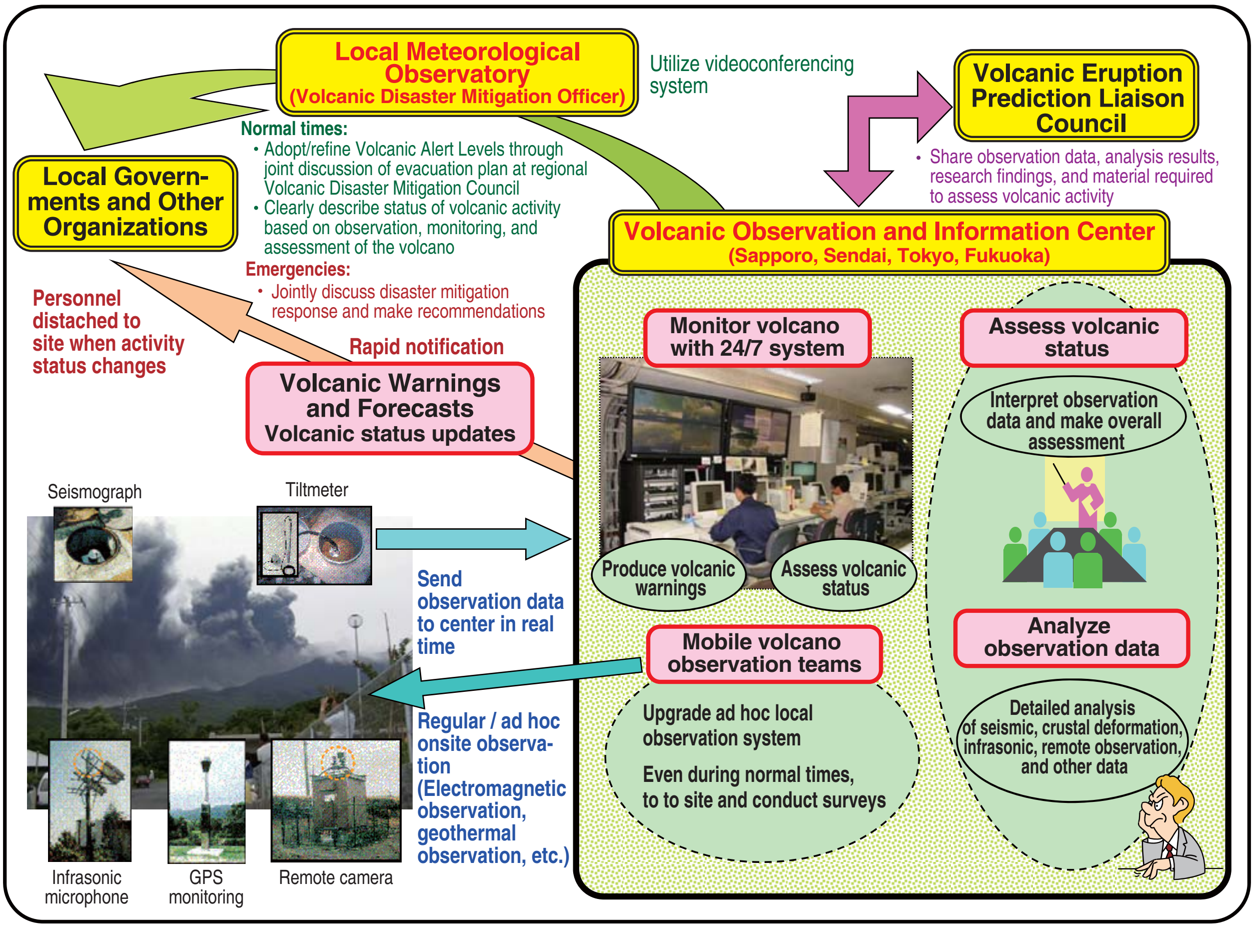

Fig. 2 JMA's volcano monitoring and warning advisories.

Beginning in 2002, a series of Volcano Observation and Information Centers (VOICs) was erected in Sapporo, Sendai, Tokyo, and Fukuoka to collect and monitor data 24 hours a day from equipment installed close to the volcanoes (Yamasato, 2005). By 2009, the 47 active volcanoes identified by the CCPVE as requiring monitoring and observation were being monitored by VOICs using borehole seismographs and tiltmeters in combination with existing equipment (**Fig. 2**).

In addition to seismic observation, GPS, and crustal deformation observation by tiltmeter, the VOICs provide a 24-hour centralized surveillance including visual monitoring by high-sensitivity cameras and camera installed on the walls of craters and infrasonic observation. More recently, we have made good progress exploiting the observational data of universities, research institutes, erosion control departments, and other relevant organizations to dramatically upgrade the monitoring system. This goes well beyond telemetry observation, for every VOIC sends mobile observation teams out to the volcanoes on a regular basis to repeatedly check geothermal temperatures, volcanic gas, GPS, geomagnetic total intensity, in order to enhance our understanding of volcanic activity. Mobile observation teams are also sent out on an ad hoc basis to improve our understanding when volcanoes act erratically or abnormally.

When volcanoes exhibit heightened or escalating unrest, staff are dispatched to the site to monitor, observe, and conduct mobile tests and measurements. Sakurajima is one of the most active volcanoes in Japan, and it is closely monitored by the Kagoshima Local Meteorological Observatory in conjunction with the Fukuoka VOIC. Resident Offices for Volcanic Disaster Mitigation have been set up at Asamayama, Izu-Oshima, Miyakejima, and Asosan. These offices pursue hazard mitigation work in collaboration with local governments, while also taking charge of the mobile observation teams.

3. JMA Volcanic Disaster Mitigation Information

At the same time JMA was building a constant volcano observation system during the 1960s, the agency began disseminating volcanic information to the public in 1965, and soon began providing disaster prevention information with the goal of mitigating damage and destruction caused by volcanoes.

The nature of volcanic information held by JMA has changed somewhat over the years, but beginning in December 2007 the agency began releasing volcanic warnings and forecasts in order to further mitigate volcanic disasters.

Volcanic information had a clear legal position of importance for disaster prevention before 2007, and the basic idea of releasing volcanic warning and forecasts led to the creation of *Volcanic Alert Levels*.

Deep low-frequency earthquakes around Fujisan in 2000 boosted momentum to produce volcanic hazard maps for the area, set up a Fujisan Volcanic Hazard Map Review Committee, and other countermeasures, and the idea of Volcanic Alert Levels took hold through a series of meetings that determined JMA volcanic information could be used to trigger specific disaster prevention countermeasures at critical moments when the need arises. This approach came into focus a bit later during study sessions covering "disaster prevention countermeasures corresponding to specific volcanic information" (Fujiyama *et al.*, 2013). Essentially, the scheme works as follows. Before a volcanic anomaly occurs, relevant organizations get together and share projections based on the volcano's past history of volcanic unrest (eruption scenario) and hazardous areas (volcanic hazard maps). They come to agreement on what criteria to use in deciding when to start evacuating people, when to prohibit people from hiking or climbing in the area, and other disaster responses. Note that these procedures are done during normal times when the volcano is quiescent. Later, if the volcano shows signs of unrests, the JMA issues a Volcanic Alert Level reflecting the current state of volcanic activity based on its 24-hour volcano surveillance system.

The Volcanic Alert Levels are divided into five stages depending on "areas that must be warned" and "responses that should be taken" for the volcano's current state of unrest: Level 1 signifies that no particular response or action is required; Levels 2-3 indicate that, while residential areas are not threatened, the volcano is off limits for hiking or climbing; Levels 4-5 reveal that residential areas are starting to be threatened by the danger of eruptions (**Table 1**). Levels 2 and 3 are differentiated by the degree to which hiking and climbing are prohibited in hazardous areas, with the exact definitions decided in advance through consultation among local relevant organizations. Level 4 is the stage where people with special needs are evacuated and other local residents prepare to evacuate, and at Level 5, all local residents are subject to mandatory evacuation from threatened areas. Each Volcanic Alert Level is associated with specific keywords—"evacuation", "prepare for evacuation", "do not approach the volcano", "do not approach the crater", "normal" etc.—and this helps ensure response compliance of local residents, mountain climbers, sightseers, and so on.

Joint deliberations regarding of Volcanic Alert Levels for volcanoes subject to constant monitoring continue among local relevant organizations in the Volcanic

Disaster Mitigation Councils (discussed below), and "areas that must be warned" and "responses that should be taken" commensurate with the Volcanic Alert Levels are being defined in the regional disaster prevention plans of local governments for volcanoes throughout Japan. The Volcanic Alert Level scheme is gradually being implemented, and as of the end of 2012, has been put into effect for 29 volcanoes (**Fig. 1**).

When the Volcanic Alert Level changes (that is, the response for an area that must be warned changes), a new *volcanic warning and volcanic forecast* is issued that is commensurate with the new level. So, for example, if the level is moved up to Levels 2-3, a *near-crater warning* is issued. If the level is moved up to Levels 4-5, a *warning* is issued. At Level 1, a *volcanic forecast* is issued. If a warning is explicitly issued for an area, the local governments responsible for evacuating and preparing to evacuate people know exactly where these evacuation areas are.

Even if a volcano is not yet incorporated in the Volcanic Alert Level system, *near-crater warnings* and *warnings* will be issued, but since specific response measures have not been formulated for volcanoes outside the system and JMA warnings are tied to these response measures, there is still work to be done. Specifically, evacuation plans must be drawn up through collaboration of relevant organizations in the Volcanic Disaster Mitigation Councils (discussed below), and these volcanic districts must be successively brought into the Volcanic Alert Level system.

Volcanic warnings and forecasts are immediately transmitted to all relevant organizations and stakeholders including affected prefectures, and conveyed to local residents through municipalities, news media, and JMA's website. In addition, warnings for submarine volcanoes are issued in the form of *near sea area warnings*.

4. Collaboration Through the Volcanic Disaster Mitigation Councils

The Volcanic Alert Level framework is outlined in the Basic Plan for Disaster Prevention (the Volcano Disaster Countermeasure Volume) that was revised by the Central Disaster Management Council on December 27, 2011 and September 6, 2012. The scheme was further elaborated through linkage to evacuation plans (who, how, where, and when) drawn up through collaboration among members of Volcanic Disaster Mitigation Councils that are established in all prefectures with active volcano. The Volcanic Disaster Mitigation Councils are made up of all interested bodies and stakeholders in the prefecture including prefectural authorities, municipalities, meteorological

Table 1 Volcanic warnings / forecasts and Volcanic Alert Levels.

Abbreviated Term	Target area	Levels & Keyword			Explanation: Expected volcanic activity	Explanation: Action to be taken by inhabitants	Explanation: Action to be taken by climbers
Warning	Residential areas	Level 5	Evacuate		Eruption that may cause serious damage in residential areas, or imminent eruption.	Evacuate from the danger zone. (Target areas and evacuation measures are determined in line with current volcanic activity.)	
		Level 4	Prepare to evacuate		Possibility or increasing possibility of eruption that may cause serious damage in residential areas.	Prepare to evacuate from alert areas. Let disabled persons evacuate. (Target areas and evacuation measures are determined in line with current volcanic activity.)	
Near-crater Warning	Non-residential areas near the crater	Level 3	Do not approach the volcano		Eruption or possibility of eruption that may severely affect places near residential areas (threat to life is possible in these areas).	Stand by, paying attention to changes in volcanic activity. Let disabled persons prepare to evacuate in line with current volcanic activity.	Refrain from entering the danger zone. (Target areas are determined in line with current volcanic activity.)
	Around the crater	Level 2	Do not approach the crater		Eruption or possibility of eruption that may affect areas near the crater (threat to life is possible in these areas).	Stay as usual.	Refrain from approaching the crater. (Target areas around the crater are determined in line with current volcanic activity.)
Forecast	Inside the crater	Level 1	Normal		Calm: Volcanic ash emissions or other related phenomena may occur in the crater (threat to life is possible in these areas).		No restrictions. (In some cases, it may be necessary to refrain from approaching the crater.)

observatories, erosion control departments, and volcanologists. Thus, the local evacuation plans (who is evacuated when and from where) are closely integrated with the Volcanic Alert Level system (**Fig. 3**).

JMA has stationed Volcanic Disaster Mitigation Officers, the primary in charge of volcanic disaster mitigation efforts, at most of the meteorological observatories adjacent to the 47 active volcanoes under constant surveillance that were mentioned earlier. During normal times, the Volcanic Disaster Mitigation Officers work to encourage local relevant organizations and volcanologists to organize and convene Volcanic Disaster Mitigation Councils to ensure the Volcanic Alert Level system interworks seamlessly with the local evacuation scheme if an eruption actually occurs. The officer also reconciles inconsistencies between the two schemes—areas that must receive volcanic warnings in the Volcanic Alert Level scheme and areas that must receive evacuation orders and designated off-limits in the evacuation plans—and reconcile any local problems with the Volcanic Alert Level system through joint discussions regarding the evacuation plan. Working together with local relevant organizations in the Volcanic Disaster Mitigation Councils in normal times ensures that evacuation plans integrate smoothly with the Volcanic Alert Level system. The face-to-face contact enables stakeholders to share different visions of how disaster mitigation (share knowledge regarding specific disaster mitigation responses tailored to Volcanic Alert Levels), and is absolutely essential for cooperating with other organizations and mounting an effective evacuation plan-based response.

One specific local government initiative based on the revised Basic Plan for Disaster Prevention brought together relevant organization centered mainly around disaster management departments from Yamanashi, Shizuoka, and Kanagawa prefectures in establishing the Volcanic Disaster Mitigation Council of Fujisan on June 8, 2012. Local meteorological observatories and JMA Headquarters also participate on the Fujisan Council as a core group. In setting up the council, participants agreed to the following four conditions to ensure the Volcanic Disaster Mitigation Council would continue to serve as an substantive Evacuation Alliance System—promoting joint discussion of evacuation plans during normal time, and solid advice to evacuation sites during emergencies—in line with the Basic Plan for Disaster Prevention:

(1) Clear legal position

To eliminate differences in commitment among constituent organizations of Volcanic Disaster Mitigation Councils and to ensure adequate funding for organizations to participate in council meetings (mainly providing travel expenses to attend meetings), it is important that

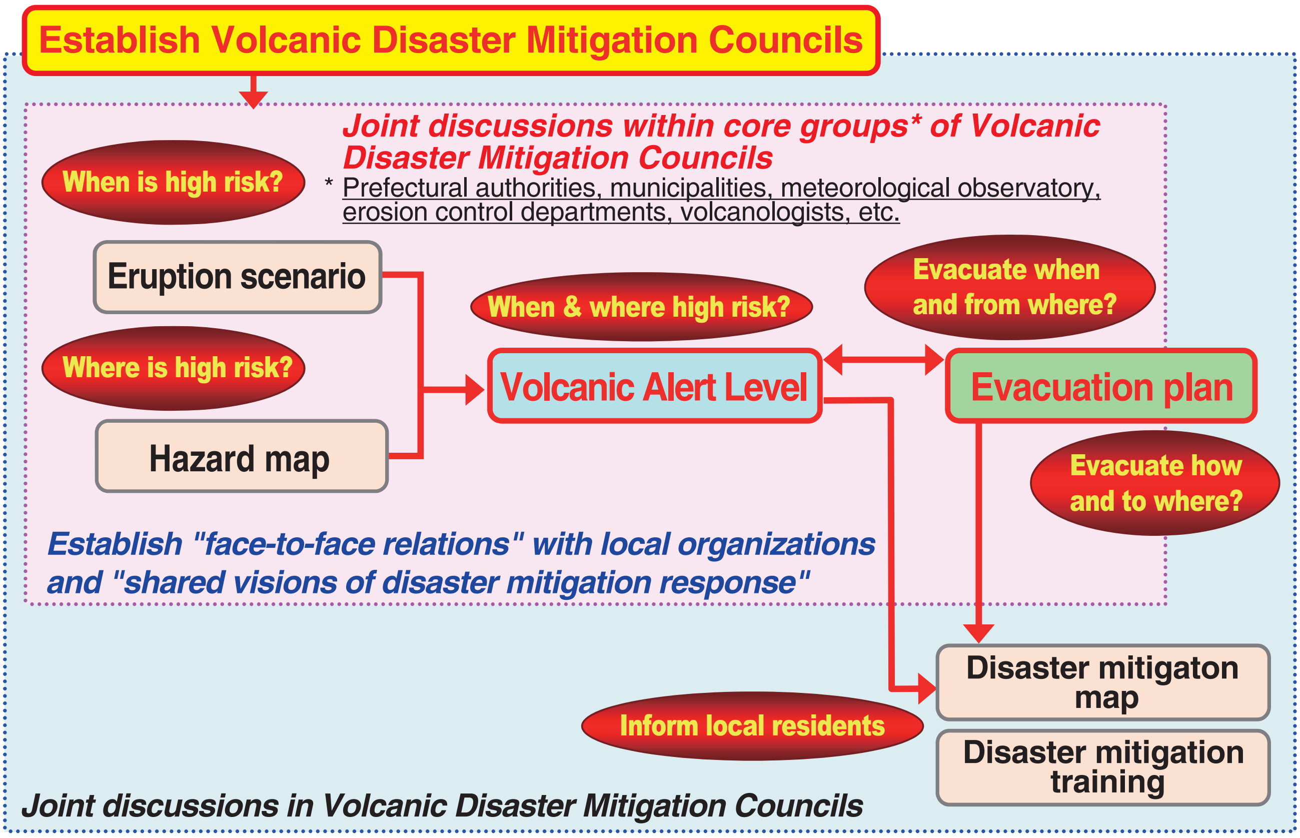

Fig. 3 Role of Volcanic Disaster Mitigation Councils based on the Basic Plan for Disaster Prevention.

councils are established based on "local disaster management plans" as defined in Article 40 of the Disaster Countermeasures Basic Act.

(2) Jurisdiction in advising target evacuation areas

To ensure proper evacuation orders based on professional consideration of volcanic risk, target evacuation areas must be defined through collaboration of constituent organizations who are members of the Volcanic Disaster Mitigation Council, and advice is given to mayors of towns and municipalities from the council. If local authorities were to make these evacuation calls on their own, there is a tendency for target evacuation areas to expand as the safety coefficient gradually increases during the process of conveying volcanic risk information to the public (warnings → hazard maps → evacuation orders), thus requiring more people to be evacuated than necessary (a phenomenon known in business administration as the bullwhip effect). Moreover, repeatedly calling for evacuation diminishes people's trust in disaster management information, which makes it harder to get people to evacuate in the event of a real or imminent danger. Indeed, a desultory response to volcanic warnings could hinder smooth and rapid evacuation, and even increase the number of victims if warnings are not taken seriously (the so-called *cry-wolf effect*).

(3) Establish core group to conduct technical study of evacuation timing and target evacuation area

In order for Volcanic Disaster Mitigation Councils to advise mayors of evacuation timing and target evacuation areas, it is essential that the core groups most deeply involved in establishing when and what areas should be evacuated—prefectures, municipalities, meteorological observatories, erosion control departments, professional volcanologists, and so on—can work together flexibly when required.

(4) Involvement of volcanologists

To ensure smooth technical consideration of evacuation timing and target evacuation areas, members of the Coordinating Committee for Prediction of Volcanic Eruptions and other professional volcanologists must serve as regular members (i.e., not observer status) and participate in the joint discussions.

These four conditions are essential and should be carefully considered in all of Japan's volcanic areas in order for the Volcanic Disaster Mitigation Councils' Evacuation Alliance System based on the Basic Plan for Disaster Prevention to work efficiently and smoothly.

5. Other Information Besides Volcanic Warning and Forecasts

Besides volcanic warnings and forecasts, JMA has also been issuing forecasts for the following types of volcanic phenomena since March 2008.

First, Ash Fall Forecasts are issued for eruptions exceeding a certain scale, and forecast areas likely to be affected by ash fall up to about six hours after an eruption. Assuming a plume model based on the scale of the eruption being observed, results are calculated based on JMA's Tracer Transport Model using numerical weather prediction data and released to the public. So far, these forecasts have been issued for three volcanoes: Sakurajima,

Table 2 Various kinds of volcano-related information other than warnings and forecasts.

情報等の種類 Volcanic Information	概要及び発表の時期 Details
●火山の状況に関する解説情報 Details of Volcanic Activity	火山性地震や微動の回数、噴火等の状況や警戒事項について、必要に応じて定期的または臨時に解説する情報。 Details of Volcanic Activity specify the number of volcanic earthquakes or tremors and the situation regarding eruptions. They are issued as often as needed.
●火山活動解説資料 Bulletins on Volcanic Activity	地図や図表を用いて、火山活動の状況や警戒事項について、定期的または必要に応じて臨時に解説する資料。 Bulletins on Volcanic Activity specify the current status of volcanic activity. They are issued once a month or as often as needed.
●週間火山概況 Weekly Volcanic Activity Reports	過去一週間の火山活動の状況や警戒事項を取りまとめた資料。 Weekly Volcanic Activity Reports specify the volcanic activity status for the previous week. They are issued every Friday.
●月間火山概況 Monthly Volcanic Activity Reports	前月1ヶ月間の火山活動の状況や警戒事項を取りまとめた資料。 Monthly Volcanic Activity Reports specify the volcanic activity status for the previous month. They are issued at the beginning of each month.
●噴火に関する火山観測報 Observation Reports on Eruption	噴火が発生したときに、発生時刻や噴煙高度等をお知らせする情報。 Observation Reports on Eruption specify event times and plume heights. They are issued as soon as eruption occurs.

Kirishimayama (Shinmoedake) and Asamayama. When Asamayama erupted in 2009, the small amount of ash-fall over western Tokyo was accurately predicted using this approach. However, current Ash Fall Forecasts only predict areas likely to experience ash fall. A more sophisticated forecast model is currently under consideration that would incorporate qualitative data based on the disaster response that should be taken.

Second, *Volcanic Gas Affected Area Outlooks* are issued when large volumes of volcanic gas are emitted that might adversely affect residential areas over a long period of time. Current forecasts clearly indicate an area subject to risk of high concentrations of volcanic gas in association with high atmospheric winds forecast two times a day as large volumes of sulfur dioxide continue to be emitted from Miyakejima.

In addition to warnings and forecasts, JMA also puts out various other types of information listed in **Table 2** either periodically or as required.

The JMA's *Details of Volcanic Activity* provide text-based information about the status of volcanic activity, that, like volcanic warnings and forecasts, are available through an online system. In addition to the regular *Bulletins on Volcanic Activity* that come out monthly with figures, charts, photos, and other detailed information, special reports are issued for volcanoes not included on the constant observation watch list when circumstances dictate. Finally, *Weekly Volcanic Activity Reports* and *Monthly Volcanic Activity Reports* are also released weekly and monthly, as indicated.

When an eruption occurs, *Observation Reports on Eruption* are released as breaking news. *Observation Reports on Eruption* deliver the minimum information necessary as quickly as possible—the time of eruption, ash-plume height, and so on—so even in the case of volcanoes such as Sakurajima that erupt quite frequency, a report is issued within minutes of each eruption.

As part of a worldwide network for monitoring and disseminating information on atmospheric volcanic ash clouds that may endanger aviation, the JMA also puts out Airway Volcanic Ash Advisories, but we will save that for another report (Shirato, 2013).

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Volcanic Ash Advisories

Shomei SHIRATO*

Volcanic ash adversely affects the aviation industry by causing engine failure, abrasion of windshields that reduces visibility, and ashfall on runways that prevents takeoff and landing. To mitigate such effects, the International Civil Aviation Organization (ICAO), working together with the World Meteorological Organization (WMO), recommended establishment of Volcanic Ash Advisory Centers (VAACs) and designated nine centers covering the world (**Fig. 1**). The VAACs are in charge of issuing Volcanic Ash Advisories (VAAs) that predict the extent and movement of volcanic ash. Tasked with monitoring movement of volcanic ash for East Asia and the Northwest Pacific airspace, the Tokyo VAAC was established at the Japan Meteorological Agency (JMA) and commenced operations in 1997 (Sawada, 1997).

When the Tokyo VAAC receives information about an eruption or ash plume from a volcano observatory or pilot in its area of responsibility, or observes an ash cloud from a meteorological satellite (e.g., **Fig. 2** shows satellite images recorded when Kirishimayama (Shinmoedake) erupted in 2011), the center issues a VAA to meteorological watch offices that provide meteorological information throughout their own Flight Information Regions (FIRs), aviation weather stations, aviation authorities, and other VAACs throughout the world (**Fig. 3**).

The VAAs are written in a special abbreviated format and include information about the erupting volcano (name, summit elevation, location), time of eruption, horizontal and vertical extent of the ash cloud at the time of observation, as well as its movement, and forecast ash distributions in six-hour intervals for the next 18 hours. Also included is a graphic, so one can easily visualize the content of the VAA (**Fig. 4**). When a volcano erupts in Japan, the Tokyo VAAC also provides Japan's civil aviation authorities and other aviation related organizations with its own information consisting of ash distribution

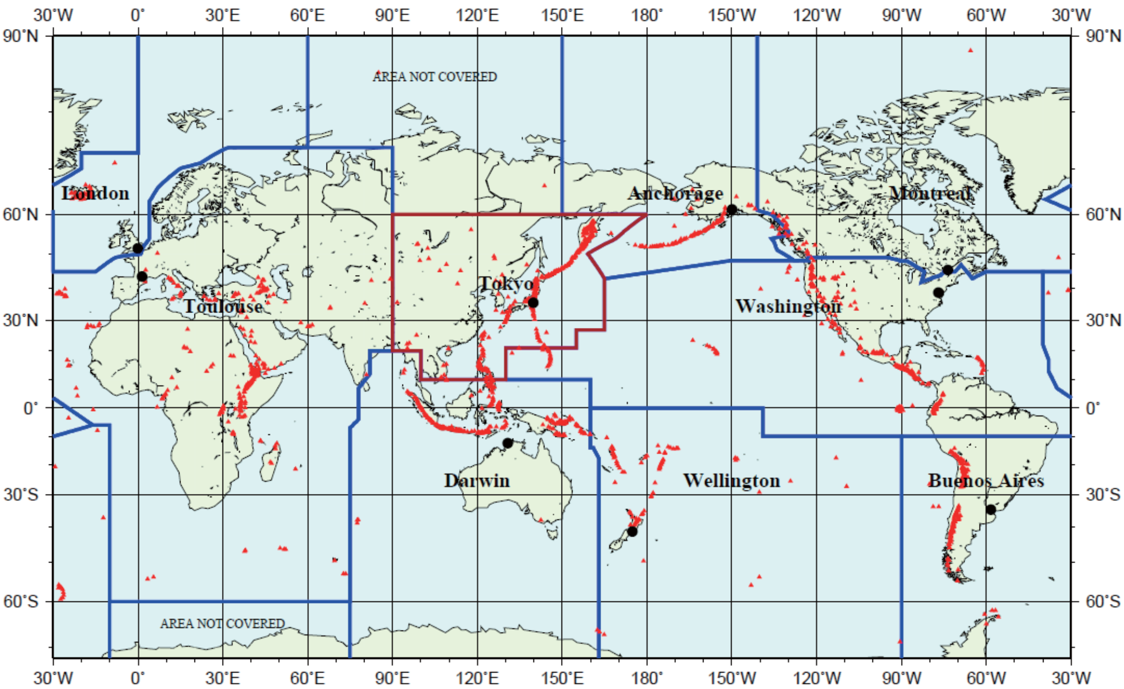

Fig. 1 The nine Volcanic Ash Advisory Centers (VAACs) around the world and their areas of responsibility. (●: VAAC ▲: Active volcanoes The red boundary indicates the Tokyo VAAC's area of responsibility.)

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maps in hourly intervals for up to six hours. For especially active volcanoes in Japan, assuming they erupt on a certain scale, ash distribution maps in hourly intervals up to six hours ahead are issued at 3:00 AM (JST), 9:00 AM, 3:00 PM, and 9:00 PM.

When the Tokyo VAAC began operations in 1997, full-time staff at the Haneda Aviation Weather Service Center carried out the center's services during the day when air traffic was busy. During the night when there was little air traffic, staff at the Seismological and Volcanological Department, JMA at Otemachi in Tokyo conducted VAAC operations along with their own tasks. Volcanic activity in Tokyo VAAC's area of responsibility was relatively calm in the early years, so few VAAs were issued and there were no major organizational problems. But more recently, Sakurajima and several volcanoes on Kamchatka peninsula have become active and this has caused the number of VAAs to soar. Since 2009, more than 1,000 VAAs have been issued annually, which is roughly ten times the number issued when the Tokyo VAAC was first established. In order to handle the increased work load, separate operations were consolidated at the JMA Seismological and Volcanological Department in March 2006, and full-time staff were added in June 2011 to monitor ash clouds and issue VAAs 24 hours a day.

In April 2010, airspace all across northern Europe was affected—planes were grounded and enormous financial losses incurred—by volcanic ash contamination in the upper atmosphere for well over a week from the eruption of the Icelandic volcano Eyjafjallajökull. In response to this, the European Organization for the Safety of Air Navigation, EUROCONTROL, rushed through an air traffic control scheme based on calculated concentration of volcanic ash. To underpin such efforts, the ICAO is currently investigating the extent to which aircraft engines can tolerate concentrations of volcanic ash and drafting new standards for safe navigation. One challenge is that it's not easy to accurately determine the concentration of volcanic ash using current meteorological satellite technology, so we are considering adding information to VAAs: specifically, whether the ash cloud is clearly discernible in satellite images and a confidence level.

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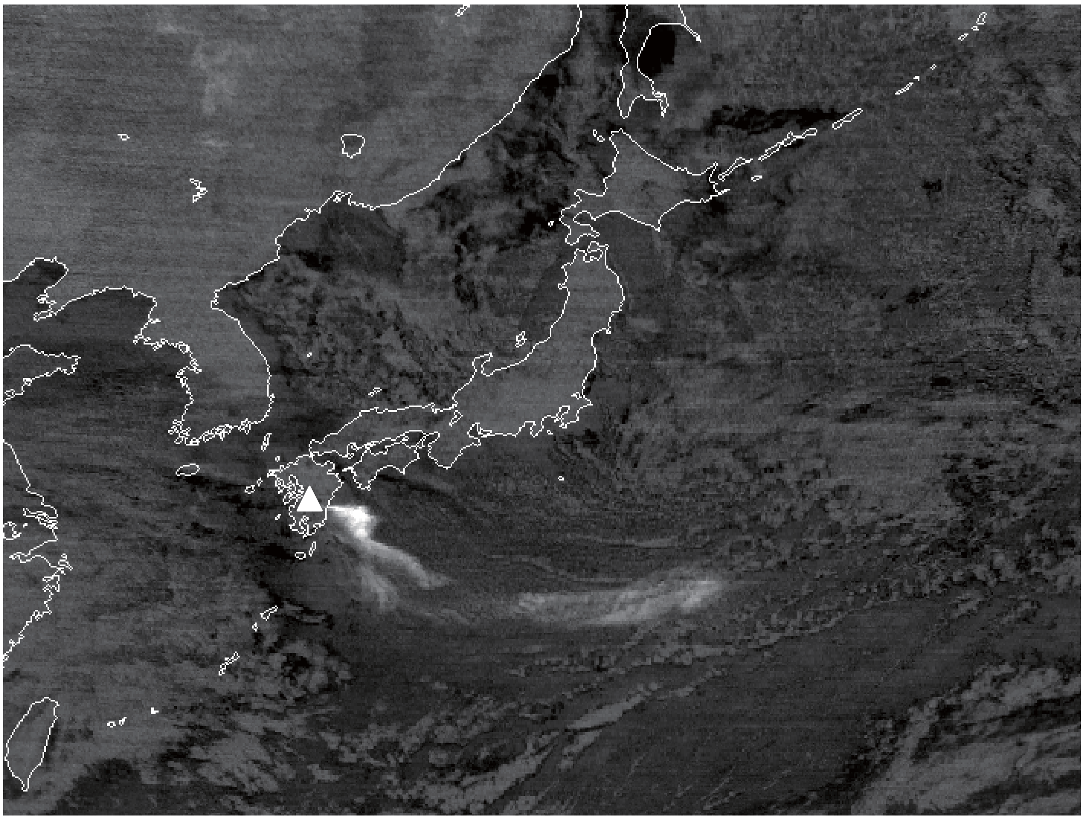

Fig. 2 Infrared differential image of volcanic ash plume over Kirishimayama (Shinmoedake) observed by meteorological satellite (Himawari 7) at 5:00 AM January 27, 2011.

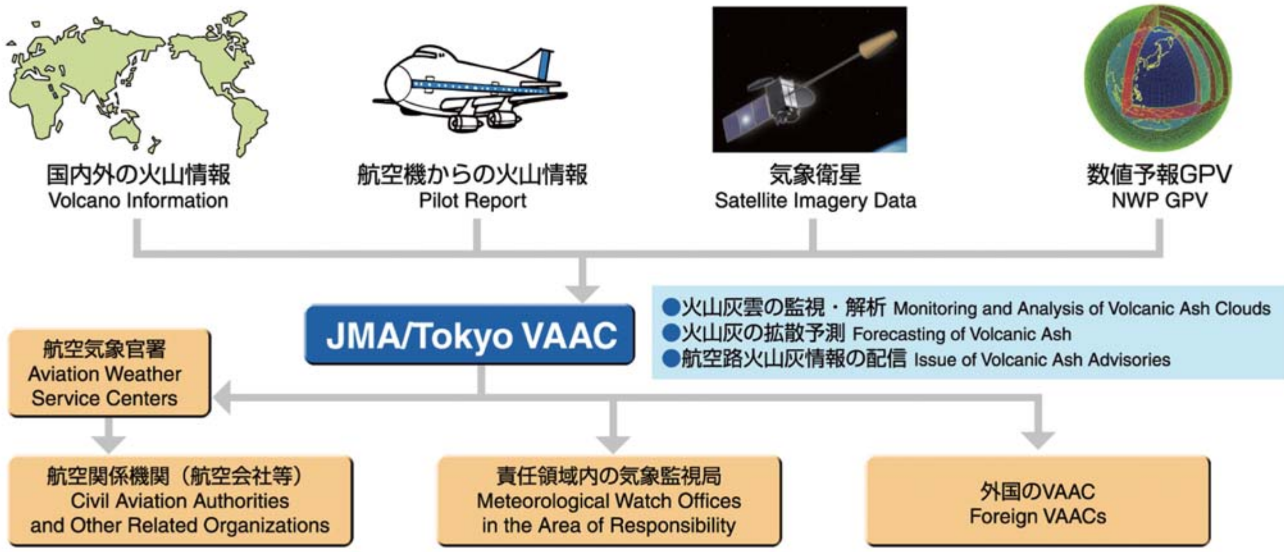

Fig. 3 Information Flow of Volcanic Ash Advisory.

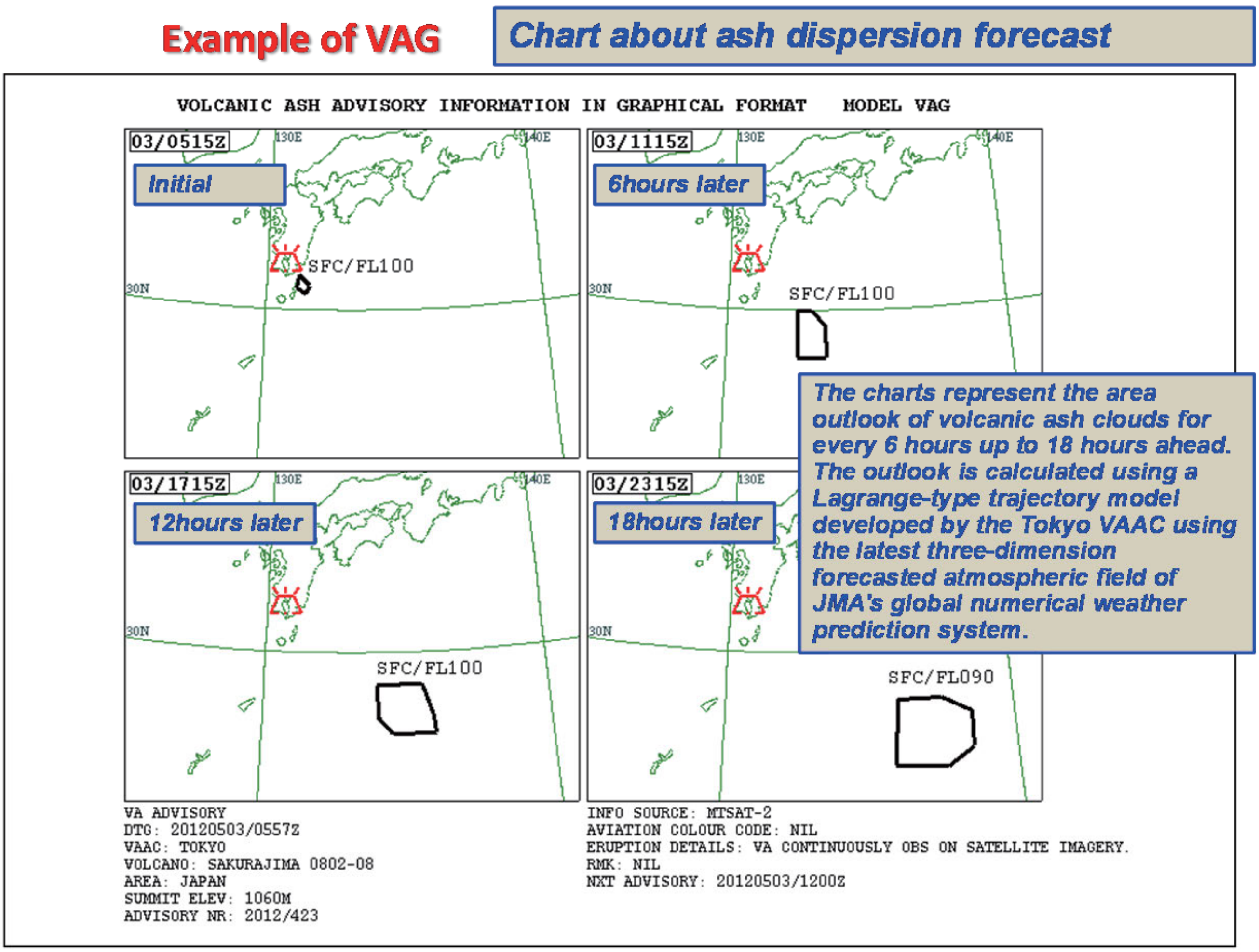

Fig. 4 Volcanic Ash advisory information in Graphical format model (VAG).

Technical Note of the National Research Institute for Earth Science and Disaster Prevention, No. 380 ; July, 2013

The Japanese Coordinating Committee for Prediction of Volcanic Eruptions and its Contribution to Volcanic Disaster Mitigation

Toshitsugu FUJII*

1. Introduction

The Coordinating Committee for Prediction of Volcanic Eruptions (CCPVE) was established in 1974 when the National Plan for the Prediction of Volcanic Eruption was formulated. It is a private advisory organ of the Director General of the Meteorological Agency and has ambiguous responsibility and authority; nevertheless, it has been playing a major role in predicting volcanic eruptions in Japan. To discuss the contributions of the Committee to the mitigation of volcanic disasters we need to look back on the history of the National Plan for the Prediction of Volcanic Eruption.

2. Actions taken to formulate the Volcanic Eruption Prediction Plan

The history of studies of the observation of volcanic activities in Japan can be traced back to 1911, when Fusakichi Omori monitored earthquakes in a volcano observatory established on Asamayama by the Imperial Earthquake Investigation Committee and Nagano Weather Station. Systematic studies on volcanoes by university researchers started in 1928, when Kenzo Sassa of the Faculty of Science at Kyoto Imperial University investigated the relationship between volcanic tremor and eruption at an Aso Volcanological Laboratory affiliated with the Faculty.

In 1933, Takeshi Minakami started geophysical observations at Yunodaira Observatory, which was the predecessor of the Asamayama Volcano Observatory of the Earthquake Research Institute of the University of Tokyo. His studies of the relationship between earthquakes and eruption led the world's volcanic observation research. Showashinzan of Usuzan erupted from 1943 to 1945. During the eruption, Minakami *et al.* of the Earthquake Research Institute of the University of Tokyo, by monitoring earthquakes and conducting leveling at the slope of the mountain, observed the process of the formation of a new volcano caused by dacite magma intrusion. The studies formed the foundations of volcanic activity observational studies in Japan, which were developed on the basis of physical monitoring by university researchers. These studies were quite different from observational studies in other countries, such as those by the US Geological Survey, which is part of the Department of the Interior, or by national volcanic observatories in Italy at, for example the Vesuvius Observatory, which involve physical and chemical observations and geological surveys.

Volcano observation requires physical observations of various kinds over a long period of time, and universities have established observatories for volcano studies. Before the formulation of the National Plan for the Prediction of Volcanic Eruption, the University of Tokyo established the Izu-Oshima Geo-electromagnetic Observatory (1959) and Kirishimayama Volcano Observatory (1964); the Disaster Prevention Research Institute of Kyoto University constructed Sakurajima Volcano Observatory (1960); and the Faculty of Science of Kyushu University established Shima bara Institute of Volcanology and Balmeology (1962), which was reorganized into Shimabara Volcano Observatory in 1971.

In 1963, a Priority Research Areas system was established for Grants-in-Aid for Scientific Research, and "disaster science" was included in four of the priority areas. In 1965, the Volcanic Eruption Prediction Team was established as an organization for the study of disaster science. The group consisted of 6 research groups from 5 universities and conducted intense observations of earthquake activity on Fujisan. This joint observation led to the nationwide organization of studies to predict eruptions. Observation studies progressed mainly at university observatories at Asamayama, Sakurajima, and Asosan, where volcanoes had been active, enabling eruptions to be predicted with relatively high accuracy. Activity at Minamidake on Sakurajima, which had been active since 1955, intensified still further after an explosive eruption on 2 October 1972, leading researchers to suggest that the eruptions could become large-scale and lateral, as had occurred in the Taisho and Showa eruptions.

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3. Start of the National Plan for the Prediction of Volcanic Eruption

Against this background, Takeshi Nagata, the then president of the Geodesy Council of the Ministry of Education, proposed that earthquake prediction researchers assimilate research into volcanic eruption prediction so as to promote such prediction. This was because the Second National Plan for Earthquake Prediction had finished in fiscal year 1973, and the next plan was scheduled to start. However, the consent of the earthquake prediction study group could not be obtained, and it was decided that the new plan would start independently of any Earthquake Prediction Plan. In June 1973, a proposal entitled "Promotion of Volcanic Eruption Prediction Studies" was formulated by the Geodesy Council and put forward to the relevant ministers. In the face of active volcanic activity at Sakurajima, the Act on Special Measures for Active Volcanoes was enacted on 24 July of the same year.

The preceding First National Plan for Earthquake Prediction was centered on "studies" of earthquake prediction, but the word "study" was omitted from the Second Plan in response to social demand for practical earthquake prediction. In response to this, the succeeding "National Plan for the Prediction of Volcanic Eruption" ruled out the word "study" from its title.

On the basis of the proposal of the Geodesy Council, the Plan for the Prediction of Volcanic Eruption was implemented in 1974 as a national project. The First Plan aimed to construct monitoring systems appropriate to the characteristics of each volcano and collect the necessary monitoring data for volcano studies and eruption prediction. Therefore, the mainstays included increasing and strengthening volcano monitoring systems, constructing observatories, organizing mobile observation teams, promoting research to develop prediction methods, establishing a coordinating committee, and developing human resources.

On the basis of the plan, the CCPVE was established as a private advisory organ of the Director General of the Meteorological Agency, with its head office in the Meteorological Agency. Members of the Committee included not only university professors and other people of learning and experience but also executive officers of the Ministry of Education, National Land Agency, Science and Technology Agency, and other relevant authorities. This situation was quite different from that of the preceding Coordination Committee for Earthquake Prediction, because administrative power was judged necessary to ensure fast mobilization and judgments during volcanic eruptions. Since it was first established, the main objective of the Committee has been disaster prevention. Takeshi Nagata, the then president of the Geodesy Council, became the first president of the Committee.

4. The National Plan for the Prediction of Volcanic Eruption and Volcano Observatories

In 1974, when the First Plan started, volcanoes on Izu-Oshima and Sakurajima had become active and were intensively observed by mobile observation teams from universities. Initially, construction of observatories was not included in the Plan, but the Geodesy Council revised the First Plan soon after its formulation and decided to include construction of a new university-owned observatory on Usuzan in the proposal. This was because there was no university-owned volcano observatory in Hokkaido (although there are many active volcanoes in the prefecture) and Usuzan was thought to erupt soon: it had erupted at intervals of about 30 years and more than 30 years had passed since its eruption in 1943. At that time, on Usuzan there was only one set of seismometers, which belonged to the Meteorological Agency. The fact that Toyako Onsen resort was located near the volcanic crater aroused social interest and propelled the revision. It was also decided that an annual and systematic practice of intensive and comprehensive volcano observation would be included in the revised plan. The Geodesy Council produced a summary document called "Partial Revision of the National Plan for the Prediction of Volcanic Eruption" and sent the proposal and request to the relevant ministries and agencies.

In 1977, the construction of an observatory by Hokkaido University on Usuzan was approved, but before the observatory started operating a large number of earthquakes that could be felt, and had hypocenters near Usuzan, occurred on 6 August. At 7:50 on 7 August, the Meteorological Agency dispatched Special Notice No. 6 on volcanic activity to warn people of the eruption. Immediately after the announcement, at 9:21, the volcano issued ash plume from the southeastern slope of Kousu on the top of Usuzan; the ash plume reached an elevation of 1,200 m.

Backed by the start of the National Plan for the Prediction of Volcanic Eruption, the Meteorological Agency renewed and modernized observation devices and systems at those of the 16 observatories considered most important. In 1977, it constructed a constant observation station on Kusatsu-Shiranesan as its 17th observatory.

The Second Plan, which started in 1979, aimed to strengthen observational studies toward practical implementation and took a step forward from the First Plan's central objective of observation system construction. To achieve the Plan's goals, the volcanoes to be monitored were classified into 1) particularly active ones (Usuzan, Asamayama, Izu-Oshima, Asosan, Kirishimayama, and Sakurajima) and 2) others. Besides upgrading of the observation system, the priority items chosen were construction of systems for predicting eruption, basic studies for understanding volcanic phenomena, and development of methods for predicting eruption. There were university observatories on active volcanoes (i.e. those in the first category). The numbers of earthquake observation stations were increased around these observatories so as to cover large areas, and telemetric systems for intensive recording of various data were introduced. Hokkaido University's volcano observatory on Usuzan was chosen to monitor also Tarumaesan, Tokachidake, and Hokkaido-Komagatake, and observation stations were constructed in these areas.

Since the initiation of the Second Plan, the Ministry of International Trade and Industry's Geological Survey of Japan has participated in the Plan and joined CCPVE to work together with the universities, the Meteorological Agency, the Geographical Survey Institute (now the Geospatial Information Authority of Japan), the National Research Center for Disaster Prevention (now the National Research Institute for Earth Science and Disaster Prevention), and the Hydrographic Department of the Marine Safety Agency to prepare annual volcanic geology maps, which are needed for understanding the history of volcanic activity.

Two volcanoes erupted as if in anticipation of the start of the Second Plan. One was Asosan, which erupted from June 1979 over a period of 6 months. Because the study team at the Aso Volcanological Laboratory, Faculty of Science, Kyoto University, predicted activation of the volcano and a resultant increase in the frequency of volcanic earthquakes and tremors, the local weather bureau dispatched frequent volcanic activity notices, and municipal governments ordered evacuation of the area 1 km from the crater. However, the Crater East Side Ropeway Station was left out of the order even though it was located no farther than 1 km from the crater, and some tourists at the station were killed or injured. The other volcano was Ontakesan, which unexpectedly erupted at its summit on 28 October 1979. At the time, it was believed that Ontakesan had erupted for the first time since the dawn of history. The volcano was located in the area to be covered by Nagoya University, which was not yet participating in the Plan, and had therefore not been observed. With the revision in circumstances, Nagoya University joined the Plan and started monitoring Ontakesan, but this did not occur until the time of the Fourth Plan.

During the period of the Second Plan, the Faculty of Science and Technology of Hirosaki University asked the Ministry of Education for permission and funds to construct a new observatory on Iwakisan to monitor its volcanic activity, and construction was approved in 1981. The Faculty of Science of Tokyo Institute of Technology started geochemical observations of Kusatsu-Shiranesan which at the time was becoming active.

In the Third Plan, which aimed to strengthen and enhance the observational studies based on the characteristics of volcanoes and promote basic studies of the eruption mechanisms of volcanoes, Japanese active volcanoes were classified into 1) 12 particularly active ones that needed to be intensively observed (Tokachidake, Tarumaesan, Usuzan, Hokkaido-Komagatake, Kusatsu-Shiranesan, Asamayama, Izu-Oshima, Miyakejima, Asosan, Unzendake, Kirishimayama , and Sakurajima); 2) active volcanoes and those with the potential to erupt (Fujisan and 22 other volcanoes and submarine volcanoes); and 3) others.

Construction of a system for promoting comprehensive observation of Izu Oshima was advised. On the basis of this advice, in 1985 the Earthquake Research Institute of the University of Tokyo integrated its geomagnetic observatory and tsunami observatory on Izu-Oshima into Izu-Oshima Volcano Observatory. To strengthen observations of Unzendake, which had been newly selected for intensive monitoring, in 1984 the existing Shimabara Volcano Observatory of the Faculty of Sciences, Kyushu University, was enlarged and reorganized into Shimabara Earthquake and Volcano Observatory, with an increase in staff and upgrading of the facility.

With the aim of strengthening observations of those volcanoes scattered in the Tohoku Area that had the potential to erupt, such as Iwatesan, Azumayama, Chokaisan, and Akita-Yakeyama, in 1987 a division in charge of volcano studies was added to the Observation Center for Earthquake Prediction of the Faculty of Science, Tohoku University, and the facility was reorganized into the Observation Center for Prediction of Earthquakes and Volcanic Eruptions.

In July 1989, during the Fourth Plan, a submarine volcano erupted off the coast of the city of Ito and the Teishi submarine knoll was formed. Against this background, the Izu-Tobu Volcanic Group was added to the group of particularly active volcanoes to be intensively monitored (Group 1), increasing the number of such volcanoes from 12 to 13. Introduction of basic studies, such as high-pressure experiments, alongside observation studies was also stressed. In response to this, a division of volcanic studies was added to the earthquake prediction observation facility of Nagoya University, which joined the National Plan for the Prediction of Volcanic Eruption. The facility was reorganized into the Research Center for Seismology and Volcanology. The Nansei-Toko Observatory for Earthquakes and Volcanoes of the Faculty of Science, Kagoshima University, also joined the Plan.

In 1990 earthquakes were observed near Tachibana Bay, and in July of the same year earthquakes started to occur directly beneath Fugendake (Unzendake). The mobile observation team of the Meteorological Agency started mobile observations, and the Shimabara Earthquake and Volcano Observatory attached to Kyushu University established several temporary observation stations. On 17 November, immediately after a mobile observation team of the universities had established temporary observation stations, phreatic explosions occurred from two of Fugendake's craters. In April 1991, magmatophreatic explosions became active, and in early May notable expansion of the volcano was observed, suggesting magma intrusion. On 20 May, the top of a lava dome appeared in the Jigokuato Crater, and the dome continued growing following the intrusion of magma. On 25 May, the lava dome collapsed, and the first pyroclastic flow was confirmed to have flowed down the Mizunashigawa River. Many pyroclastic flows followed, reaching farther and farther. On 3 June, 43 persons were killed, including firemen and journalists; the latter were taking videos of pyroclastic flows within the controlled area.

During the 6-year eruption period, Kyushu University's Shimabara Earthquake and Volcano Observatory served as the base for volcano researchers from all over the nation and provided space for liaison officers from the Self-Defense Forces, police, and other people engaged in disaster prevention. It also played a central role in disaster prevention in the region. The CCPVE dispatched its deputy president to be stationed at the site for a month in June 1991 to control the observation systems of the various organizations and establish a network among them.

In the Fourth Plan the active volcanoes were re-classified into 1) 13 particularly active volcanoes that needed to be intensively observed; 2) active volcanoes and those with the potential for erupting (Fujisan and 22 other volcanoes and submarine volcanoes); and 3) others. In the Fifth and subsequent Plans the classifications were not revised.

At the end of March 2000, during the period of the Sixth Plan, Usuzan erupted for the second time after the start of the Plan; this put the Plan to the test for its ability to predict eruptions. After observing the occurrence of an earthquake swarm, the research team of the Usu Volcano Observatory suggested to evacuate 16,000 people. People were evacuated following the suggestion, and no one was killed or injured by the eruption. During the eruption, the central members of the research committee for volcanic eruption prediction, which was composed of university researchers and in charge of planning and conducting explorations of the volcano's structure, stayed by turn in Hokkaido University's volcano observatory on Usuzan. They maintained observation points, collected observation data, and coordinated and selected the workshifts of personnel, working with the observatory staff.

In June, Miyakejima, which had erupted in 1983, erupted for the second time since the start of the Plan. Initially, the movement of the magma was estimated from the results of tilt and earthquake observations. The submarine eruption on 27 June was correctly predicted, and this was praised as a successful result of the National Plan for the Prediction of Volcanic Eruption. However, in July the difficulty in predicting eruptions was manifested by of the fail to predict the change of the mode of eruption when the explosive eruptions from the summit crater started following the subsidence of the summit. On 29 August, a low-temperature and slow pyroclastic flow occurred, requiring the entire island to be evacuated. Because of subsequent emissions of sulfur dioxide gas, the island had to remain unpopulated over a period of 4 and a half years.

During this period, there were no passenger ships or any other ordinary means of transport to the island. It was therefore difficult for university staff to independently monitor the volcano, and the observation team had to rely on transfers provided by the Meteorological Agency. After the island was evacuated, the commercial power supply was shut down. Not only the university but also national research institutes such as the Geographical Survey Institute and National Research Institute for Earth Science and Disaster Prevention faced temporary data gaps.

From 1992 to 2000, nine former imperial and other national universities were restructured so as to prioritize their graduate schools. The research centers constructed throughout Japan under the National Plan for the Prediction of Volcanic Eruption belonged to undergraduate schools and not the newly intensified graduate schools. Therefore, in and after the Sixth Plan, the observation centers shifted their affiliations to graduate schools, with the exception of the Earthquake Research Institute of the University of Tokyo and the Disaster Prevention Research Institute of Kyoto University, both of which stayed as they were.

In 2004, when the Seventh Plan started, Asamayama began magmatic explosions after a lapse of 21 years. Observation was made mainly by the Earthquake

Research Institute of the University of Tokyo, which has an observatory on Asamayama. The explosion was on a relatively small scale and caused almost no damage to residential districts. Damage to farm products was also relatively small because the eruption occurred from September to November.

5. Incorporation of National Universities and Volcano Observation

When the Seventh Plan started in 2004, national universities were incorporated under the Act of General Rules for Incorporated Administrative Agencies. The incorporations ushered in a period in which volcano observation by universities has been difficult. It was decided that Management Expenses Grants would be paid to each university in sums determined on the basis of the expenses paid in the previous fiscal year (2003), thus impeding universities from requesting funds for constructing or renovating volcano observatories and observation points. It has therefore become difficult to renovate observation points, even when they have deteriorated.

The former Geodesy Council was disbanded because of integration of the Ministry of Education and the Science and Technology Agency; the Council became the Subdivision of Geodesy and Geophysics, Council for Science and Technology. In December 2002, the volcano section of the Subdivision summarized a proposal called “Temporary Strategy for Volcanic Observations and Research by universities, etc”. It proposed to choose 16 most active volcanoes out of 34 that had been studied by universities, enhance the observation network infrastructure for those 16 volcanoes via research institutes such as the National Research Institute for Earth Science and Disaster Prevention, share observation data among universities and institutes, and use the data for predicting eruptions.

Although the National Research Institute for Earth Science and Disaster Prevention started to improve and reinforce volcano observation points on the basis of the proposal, budgeting has not been enough, and the initial construction plan has not been completed. However, two observation points on Kirishimayama that had been installed on the basis of the proposal, together with an observation point newly constructed under the Meteorological Agency’s upgrading project associated with 47 volcanoes, were quite useful to monitor a series of eruptions that started as a sub-Plinian eruption on 26 January 2011. These stations played a very important role in helping us to understand the nature of the eruptions. Observational data from the National Research Institute for Earth Science and the Disaster Prevention and Meteorological Agency have been available to the public via the web site of the National Research Institute for Earth Science and Disaster Prevention since 2012.

6. Integration with the Earthquake Prediction Plan

The Great Hanshin-Awaji Earthquake occurred during the Seventh National Plan for the Prediction of Earthquake. Therefore, the eighth plan was not drawn up, but a new Observation and Research Plan for Earthquake Prediction was formulated in 1999. The new plan was succeeded thereafter by the “Second Observation and Research Plan for Earthquake Prediction.” On the basis of reviews and outside evaluations of the Second Observation and Research Plan for Earthquake Prediction and the Seventh National Plan for the Prediction of Volcanic Eruption, both Plans were integrated into the “Program of Research and Observation for Earthquake and Volcanic Eruption Prediction” in fiscal year 2009.

In the second year of the integrated plan, a magmatic eruption occurred in Kirishimayama (Shinmoedake) after a lapse of about 300 years. On 26 and 27 January, 2011 a sub-Plinian eruption occurred, spewing out pumice. After subsequent inflow and accumulation of magma in the summit crater, intermittent Vulcanian eruptions occurred. These eruptions, which resulted in over 50 million tonnes of ejecta and lava, were among the largest in recent years, but no explosive eruptions have been observed since 7 September 2011. The observation team could not detect signs of the sub-Plinian eruption but successfully detected premonitory phenomena of the Vulcanian eruptions, such as slope changes and increased tremors, and predicted the eruptions after February 2011. The borehole-type monitoring system of the Meteorological Agency, built in 2010, played an important role in the predictions.

The Volcano Observatory at the Earthquake Research Institute of the University of Tokyo on Kirishimayama had been left unmanned as a result of the government policy of reducing staff numbers to cut costs. Therefore, data were monitored and transmitted to the Research Institute, but the team could not communicate with local government and could not give sufficient advice on disaster prevention.

The Great East Japan Earthquake occurred on 11 March 2011. The National Program of Research and Observation for Earthquake and Volcanic Eruption Prediction is being partly revised; the revision was completed by the end of 2012. The progress of the present plan, which will end in fiscal year 2013, is to be reviewed in 2012 by an outside third party. On the basis of this outside evaluation the next plan will be drawn up, but its development is difficult to predict because the Council for Science and Technology, in its Interim Report on the Science and Technology Policy, proposed that earthquake research systems be revised. Because the Plan for the Prediction of Volcanic Eruption has been integrated with that of earthquake prediction, the National Plan for the Prediction of Volcanic Eruption will surely be changed.

7. Coordinating Committee for Prediction of Volcanic Eruptions

7.1 Roles of Coordinating Committee for Prediction of Volcanic Eruptions

As described above, the CCPVE was organized on the basis of the First National Plan for the Prediction of Volcanic Eruption, which started in 1974. The Committee is made up of university scholars, experts from research institutes, and representatives of administrative organizations such as the Ministry of Education, Culture, Sports, Science and Technology and the Cabinet Office in charge of disaster prevention, which are also members of the Volcanic Eruption Prediction Plan. The term of service is 2 years, and the members are commissioned by the Director General of the Meteorological Agency. The members are to:

(1) exchange information on the results of studies and work by related institutes and organizations; promote research on volcanic eruption prediction; and develop technologies at each institute;
(2) during volcanic eruptions, make comprehensive judgments on the phenomena of eruption and improve the quality of information about the volcano, thus contributing to disaster prevention activities; and
(3) comprehensively investigate measures for enhancing systems for studying volcanic eruption prediction and monitoring.

There are three regular meetings in an ordinary year, but the Committee may be urgently summoned during eruptions. Upon predicting a volcanic eruption, CCPVE used to announce collective opinions or the comments made by the Chair, but today its announcements mainly include the results of investigations of a specific volcano and evaluations of the activities of other volcanoes in Japan. The literature references investigated by CCPVE, and the Committee's proceedings, are published in CCPVE bulletins three times a year. Recently, most of the references have been published almost in real time on the web pages of the Meteorological Agency.

An executive board has been established to discuss the operations of the Committee. There have also been Subcommittees for predicting the activity of specific volcanoes and in specific regions. Working groups have been established to investigate specific topics, such as activity levels and approval of new active volcanoes, but today they serve as investigative commissions. The Usuzan Subcommittee was established during the eruption of Usuzan in 2000, and the Izu Subcommittee was formed during the eruption of Miyakejima. The latter is the only remaining Subcommittee as of 2012.

To support information transmission by the Meteorological Agency, CCPVE working groups have investigated approvals of the classification of volcanoes as active and information about volcanic activity. In 1975, CCPVE published "Nihon Kakkazan Soran" (Complete Guide to Active Volcanoes in Japan) as its first project, which included 77 volcanoes. In 1991, the definition of active volcanoes was revised from "volcanoes with a historical record(s) of eruption" to "volcanoes that have erupted in the past 2000 years," thus increasing the number of active volcanoes from 77 to 83. In 1996, three volcanoes were newly listed as those with eruption records in the past 2000 years, making the total number 86. In 2003, the definition was revised again into an internationally accepted one of "volcanoes that have erupted in the last ~10,000 years or those in which fumaroles are active." Using the new definition, the volcanoes in Japan were revised; 108 were acknowledged to be active.

The Assessment and Investigative Commission on Volcanic Activity, which was subsequently established, investigated the long-term activity of volcanoes in Japan and listed 47 volcanoes as those to be intensively monitored for the time being. On the basis of the results, the Meteorological Agency increased the number of volcanoes to be monitored on a 24-h basis from 34 to 47 in 2010, and it constructed and improved observation points. The Commission is also in charge of investigating the basic data for approval of volcanoes as active. In 2011, CCPVE approved more volcanoes as active on the basis of the results of the Commission, and the number of active volcanoes in Japan was increased from 108 to 110.

The Investigative Commission on volcano observation systems is investigating monitoring systems and is exchanging and integrating observational data from the Meteorological Agency and other related organizations. The results of the Commission were used to increase the number of observation points when the Meteorological Agency increased the number of volcanoes to be monitored around the clock. The Investigative Commission on fume research in volcanic areas has been preparing a database on gases.

7.2 Contingency Plans

In contingencies, the executive board or expanded board may judge an eruption, and sectional meetings and special

CCPVE meetings are to be held when necessary to assess the activity of the volcano. When the eruption is predicted to last for a long time, a comprehensive observation team is to be formed under CCPVE to estimate changes in volcanic activity, establish new observation points, and conduct mobile observations. Because the team may need to enter control areas and other dangerous zones as occasion demands, the Meteorological Agency is to serve as the head office and engage in negotiations with local governments, etc.

The comprehensive observation team is to consist mainly of people from member organizations of the National Plan for the Prediction of Volcanic Eruption but may also include researchers from other institutes when necessary. Approval by the team leader, who is also a member of CCPVE, needs to be obtained for a person to become a member of the team. However, the member's expenses will not be paid by CCPVE but will need to be covered by the institute to which he or she belongs, and the institute that dispatches the person will also be responsible in the case of accidents, etc. Luckily, no accidents have occurred since the establishment of the National Plan for the Prediction of Volcanic Eruption, mainly because only small-scale eruptions have occurred. However, such a calm period cannot last forever, and urgent improvement measures are needed.

7.3 Problem of the Term, "Eruption Scenarios"

Since 2007, the Meteorological Agency has been in charge of issuing eruption predictions and warnings for Japan's active volcanoes. At the same time, the Agency has introduced and deployed an eruption alert level system for volcanoes, starting with those that are ready for introduction of the system. To introduce the alert level system for a volcano, a time-sequence diagram of the expected eruption called an eruption scenario should be prepared to help establish judgment standards for deciding on alert levels and clarify when changes in level should be made. Because there are no established methods available today for predicting the scale and modes of eruption, the scenario must be prepared on the basis of a particular recorded past eruption event, assuming that the eruption will progress as in the past, but this can never be taken as the exact future scenario. More than one scenario may be prepared, but not all cases can be assumed. Thus, in a manner of speaking, the scenarios are just for emergency drills.

The Izu Subcommittee of CCPVE prepared an event tree showing the divergences at which decisions were made during an eruption of Izu-Oshima. It was called "the eruption scenario for Izu-Oshima". The Volcano Group of "the Program of Research and Observation for Earthquake and Volcanic Eruption Prediction", organized the phenomena involved in the eruption, which occur in time sequence, into an event tree and is developing methods to determine the probability of each divergence. However, it must be noted that the probabilities that are expressed as divergences are only the frequencies observed in the past and may differ from the actual probabilities in the future. Probability prediction of low-frequency events, such as volcanic eruptions, has not been statistically established, so care should be taken not to rely on unreliable numbers.

Another problem is that the event trees are also called "eruption scenarios." Giving two different concepts (i.e. that of JMA and those of the Izu Subcommittee and the Volcano Group of the Program of Research and Observation for Earthquake and Volcanic Eruption Prediction) the same name may cause confusion in real scenarios of disaster prevention; this issue needs to be resolved urgently.

8. Conclusions

Unlike earthquake prediction, for which there is a government authority called the Headquarters for Earthquake Research Promotion, there is no government body for predicting volcanic eruption. The CCPVE is the sole organization that evaluates volcanic activity and predicts activity progress on the basis of monitored data. The comprehensive observation team is responsible for monitoring and collecting data, which are indispensable for predicting the progress of volcanic activity during eruptions. Although team members may have to expose themselves to danger, their legal security is not covered by CCPVE but must be covered by the institutes to which they belong. This is because the CCPVE is a private advisory organ of the Director General of the Meteorological Agency, which has no legal responsibility or authority over the CCPVE, although it serves as a head office.

In Japan, where volcanic activity could be intensified in the near future, radical strengthening of disaster prevention organizations is essential. Particularly, CCPVE—the organization for assessing volcanic activity—should be an official organization of the government instead of being a private advisory organ of the Director General. A centralized authority such as a Volcano Agency should be ideally created to monitor, assess, and study volcanic activity, but this may be difficult to actualize given the recent trends in administrative reform.

Therefore, headquarters in charge of volcanic eruption research promotion, such as Headquarters for Earthquake Research Promotion, should be immediately established. Under such headquarters, the national government should be responsible for unifying related ministries and agencies and preventing volcanic disasters.

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Actions for Volcanic Disaster Management

Shinji YAMAGUCHI*

1. Introduction

There are currently 110 active volcanoes in Japan. Disasters induced by volcanic eruptions are frequent and have recently included the eruption of Unzendake in 1991 and the eruption of Usuzan and Miyakejima in 2000. Such disasters are caused by various events, such as volcanic cinder falls, ash falls, pyroclastic flows, lava flows, volcanic mudflows, debris flows, and debris avalanches. They have a tremendous impact on people's lives if the scale is large. In particular, large-scale volcanic mudflows or debris flows, which are generally triggered by rainfall on deposited volcanic ash, affect wide areas for a long time. The Sabo departments (sediment-control departments) of the central and prefectural governments conduct volcanic sediment and erosion control projects to prevent or mitigate the damage from sediment-related disasters associated with volcanic eruptions.

2. Volcanic Sediment and Erosion Control Project and Volcanic Sediment and Erosion Control Plan

A Volcanic Sediment and Erosion Control Project (hereinafter "Volcano Sabo Project") should be conducted as a comprehensive measure that combines the development or improvement of sediment-control facilities and the establishment of warning and evacuation systems. A Volcanic Sediment and Erosion Control Plan (hereinafter "Volcano Sabo Plan") should be formulated to rationally and effectively implement a Volcano Sabo Project. A Volcano Sabo Plan is composed of two programs: a volcano sabo program for rainfall, which addresses sediment movement phenomena attributable to rainfall over fragile geology in a volcanic region, and a volcano sabo program for eruption, which addresses sediment movement phenomena attributable to volcanic eruptions.

The Sabo departments of the central and prefectural governments implement rational and effective structural measures based on comprehensive reviews of the local topographic conditions, regional plans, landscape, and environment according to the corresponding Volcano Sabo Plans. They also implement nonstructural measures, including installing sensors to monitor abnormal sediment flows, and send the information to the relevant organizations to help establish warning and evacuation systems for the public.

To take appropriate measures to deal with volcanic eruptions, such as the implementation of structural works, it is necessary to know the types of volcanic phenomena and the extent of the damage. Volcanic hazard maps are produced as part of these efforts. They show the possible extent of the damage, as estimated by numerical simulations or other means, in the case of volcanoes that are expected to cause serious social and physical damage once they erupt. On the basis of these volcanic hazard maps, volcanic disaster prevention maps, which show evacuation sites and disaster-prevention information and describe eruption phenomena, are prepared by municipalities to promote public response and evacuation activities (**Fig. 1**).

3. Sabo Plan for Urgent Measures for Volcanic Disaster Reduction

3.1 Outline of the Plan

It is difficult to fully prevent sediment-related disasters resulting from volcanic eruptions, even if appropriate measures—including the development of facilities—are systematically taken on the basis of volcanic sediment and erosion control plans. This is because it is difficult to determine the occurrence of volcanic eruption activity or its scale, which can become very large. Therefore, Sabo Plans for Urgent Measures for Volcanic Disaster Reduction (hereinafter "Volcano Disaster Sabo Plans") are formulated by the sediment control personnel of the central and prefectural governments to minimize the damage caused by volcanoes that are highly likely to erupt and for which a high risk of sediment-related damage is associated with the volcanic eruption.

A Volcano Disaster Sabo Plan should be produced for each volcano that is expected to have serious social impacts if it erupts. As of 2012, twenty-nine volcanoes are the targets of this planning. The volcanoes are:

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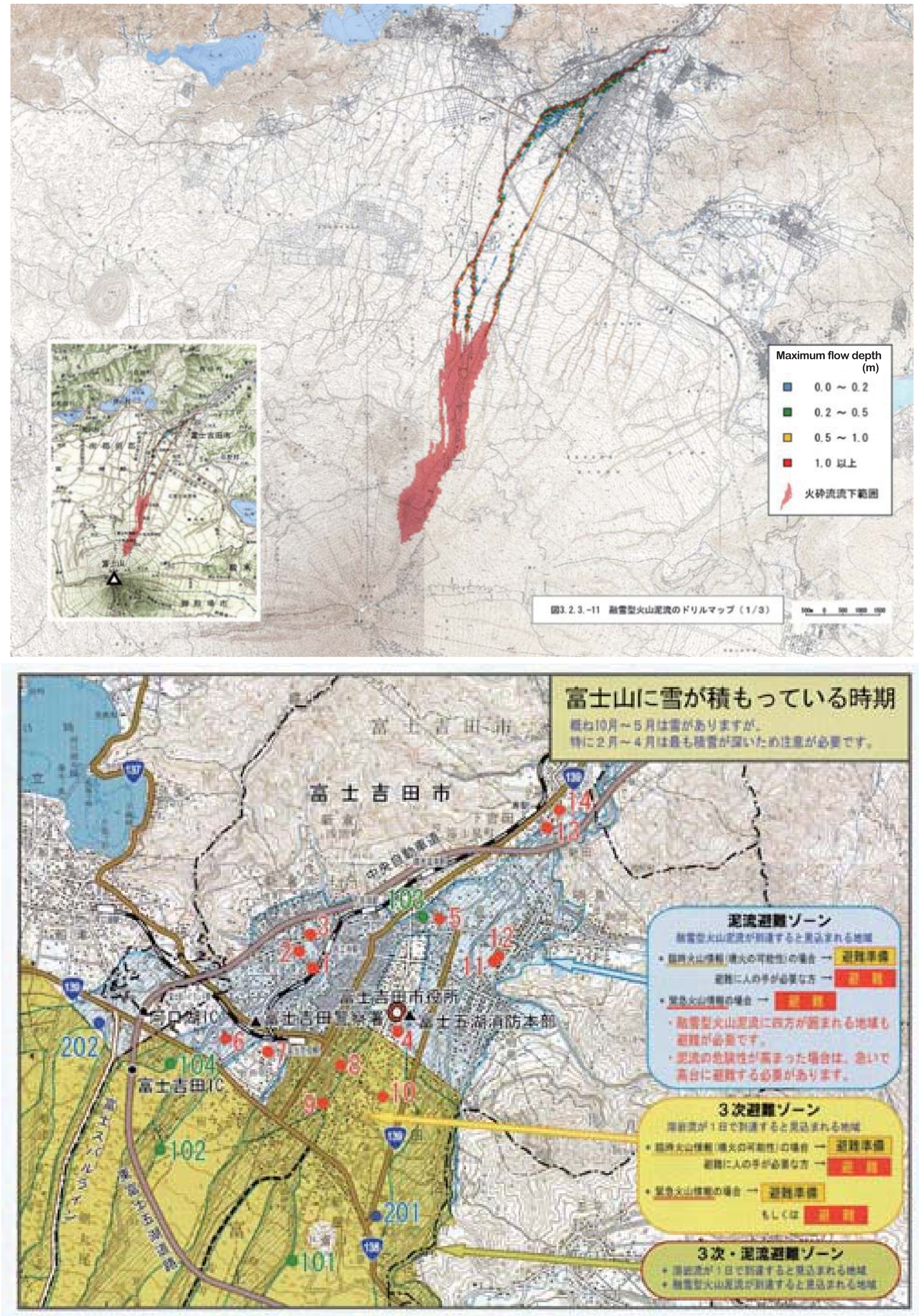

Fig. 1 (Top) Example of a volcano hazard map (results of a simulation of snowmelt-type volcanic mudflows on Fujisan). (Bottom) Example of a volcanic disaster prevention map (for the city of Fujiyoshida).

Meakandake, Tokachidake, Tarumaesan, Usuzan, Hokkaido-Komagatake, Iwakisan, Akita-Yakeyama, Akita-Komagatake, Iwatesan, Chokaisan, Zaozan, Azumayama, Adatarayama, Bandaisan, Nasudake, Asamayama, Kusatsu-Shiranesan, Izu-Oshima, Miyakejima, Niigata-Yakeyama, Yakedake, Ontakesan, Fujisan, Tsurumidake and Garandake, Kujusan, Unzendake, Asosan, Kirishimayama and Sakurajima.

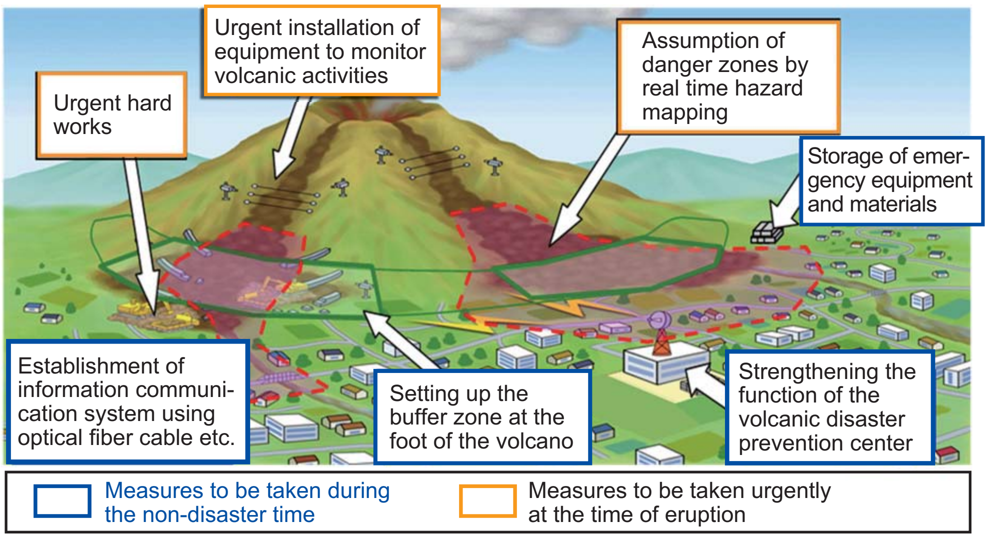

Fig. 2 Outline of the Sabo Plan for Urgent Measures for Volcanic Disaster Reduction.

3.2 Position of the Sabo Plan for Urgent Measures for Volcanic Disaster Reduction, and Study System

Disaster-prevention measures should be implemented through the coordinated action of relevant organizations, as they involve a variety of activities, including monitoring and observation of volcanic activity, provision of volcano-related information, protection of residents' lives by promoting evacuation or setting restricted zones, and prevention or mitigation of damage to social assets or housing. Therefore, it is important to prepare a Volcano Disaster Sabo Plan through the coordination of measures from relevant organizations and of disaster-prevention plans from relevant municipalities. Given their importance, Volcano Disaster Sabo Plans are examined by a study group composed of members of relevant organizations, including the Meteorological Agency, the Self Defense Forces, fire departments, and police; administrative agencies, including prefectures and municipalities; and volcano specialists. The sediment-control sections of The Ministry of Land, Infrastructure, Transport and Tourism's Regional Development Bureaus and prefectural governments take the initiative.

3.3 Contents of the Sabo Plan for Urgent Measures for Volcanic Disaster Reduction

Designed to produce the maximum effect in case of emergency, a Volcano Disaster Sabo Plan consists of two sections, namely actions taken in emergency situations and actions taken in times of non-disaster to prepare for emergency situations. Emergency actions include emergency structural measures, such as reinforcement of sediment-control weirs or construction or improvement of sand pockets or training dikes, and emergency nonstructural measures, such as urgent installation of equipment to monitor volcanic activity or the assumption of danger zones through real-time hazard mapping. Preparatory actions include stockpiling of necessary materials and equipment, such as concrete block, or strengthening of the functions of volcanic disaster prevention centers (**Fig. 2**).

4. Emergency Survey Based on the Sediment Disasters Prevention Act

4.1 Outline of the Survey

Appropriate advice based on advanced technology is essential for a municipality to make an appropriate judgment on the evacuation of residents in a situation where a large-scale sediment-related disaster is imminent owing to, for example, a volcanic eruption. The Act for Partial Revision of the Act on Promotion of Sediment Disaster Countermeasures for Sediment Disaster Prone Areas (herein the "Revised Sediment Disasters Prevention Act") was approved by the 176th Cabinet (Extraordinary Diet) on 17 November 2010. This revision specifies that the central government must conduct emergency surveys on the debris flows that could be caused by a volcanic eruption and notify relevant municipalities and the general public of the estimated extent and timing of the damage.

4.2 Case Example: Emergency Survey of the Eruption of. Kirishimayama (Shinmoedake)

Kirishimayama (Shinmoedake), which started erupting on 19 January 2011, had a full-scale magma eruption on the 26th of the same month and began explosive eruptions on the 27th.

The Kyushu Regional Development Bureau, Ministry of Land, Infrastructure, Transport and Tourism had its sediment control personnel survey the amount of fallen volcanic ash on 27 January. The survey team identified those mountain streams that satisfied the emergency survey requirements as those likely to be damaged by debris flows torrent

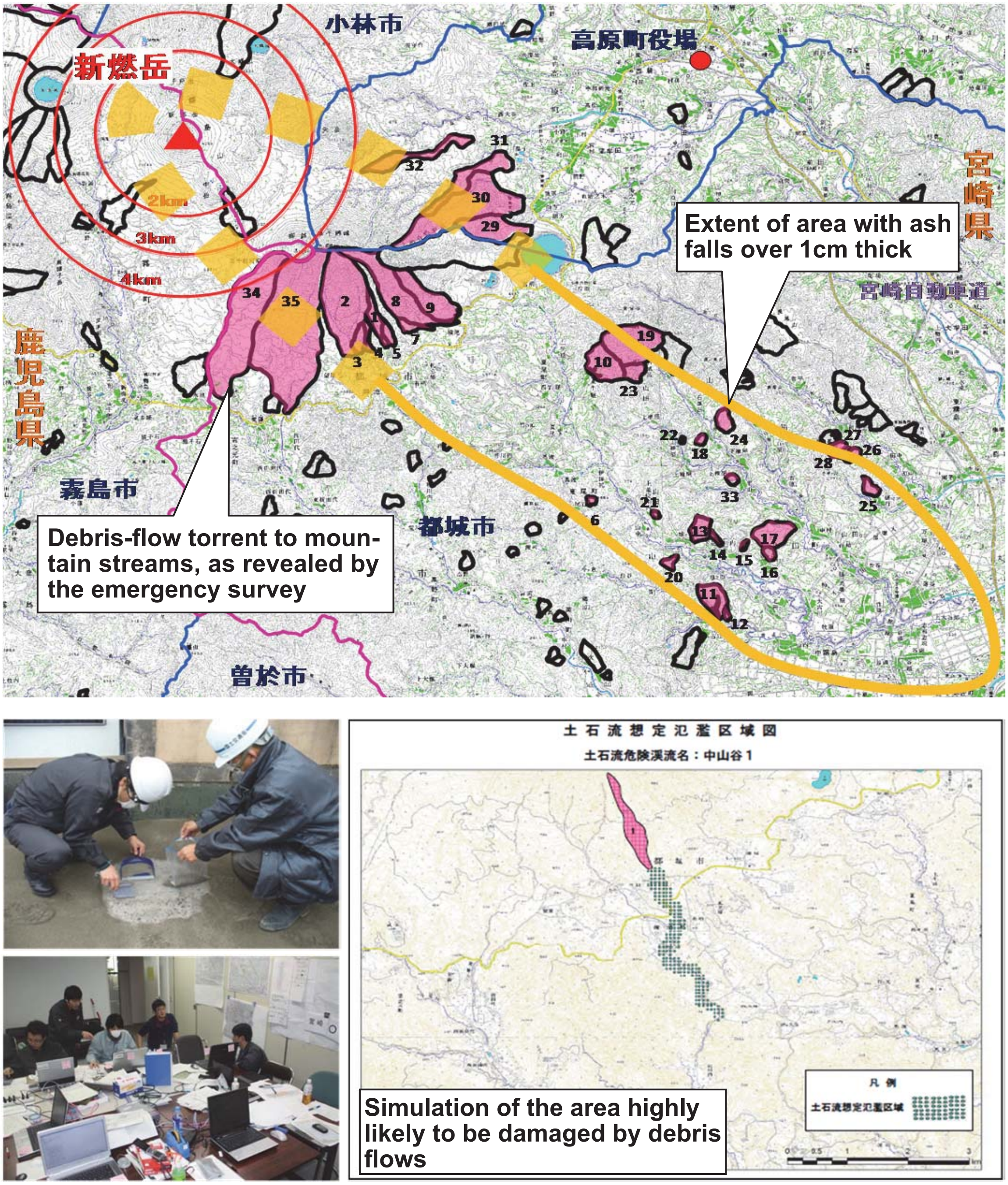

Fig. 3 Example of the status of emergency survey and sediment-related disaster emergency information.

and started an emergency survey ahead of the official enactment of the Revised Sediment Disasters Prevention Act. The emergency survey was conducted by the Bureau with technical support from the Public Works Research Institute. It included an analysis of the extent of the area highly likely to be damaged by the flood of debris flows. On the basis of data on the debris flows that occurred following the eruption of Miyakejima, the Bureau also proposed a criterion of an hourly rainfall of 4 mm as the trigger for a debris flow. Information on the analyzed extent and timing was provided to Miyakonojyo City, Takaharu Town, and Miyazaki Prefecture as reference information to help issue evacuation advice to municipalities. With the official enactment of the Revised Sediment Disasters Prevention Act on 1 May, the survey was officially designated a regulatory emergency survey, and the emergency information on sediment-related disaster was then provided to the relevant municipalities. The rainfall criterion was revised on a timely basis by considering the actual rainfall data and the status of sediment movement (**Fig. 3**).

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Technical Efforts to Prepare Volcanic Hazard Maps

Nobuo ANYOJI*

1. Erosion Control in Volcanic Areas and Volcanic Hazard Maps

Volcanic eruption hazards are caused by movement of ash fall, pyroclastic flows, lava flows, or other volcanic ejecta. If a mountain slope is covered with pyroclastic material, the hydrologic environment will change. As a result, even a small amount of rain can easily cause debris flows or mudflows. Furthermore, repeated debris flows may damage inhabited areas downstream in the long term.

The Erosion Control Works in Volcanic Areas is a disaster prevention project aimed at preventing or reducing sediment hazard in volcanic areas. In this project, a volcanic hazard map is made to delineate those areas estimated to be affected by sediment disasters associated with volcanic eruptions. The maps can be used to provide basic information for examining the structural and non-structural measures needed to prevent and minimize disasters [1]. To determine the specific areas where disaster prevention measures need to be taken, assumptions need to be made about the areas that could be affected by each phenomenon. It is also necessary to examine the types and details of measures that should be implemented according to the damage level expected. Consequently, the Project's volcanic hazard maps need to enable users to change their predictions according to preconditions and also to quantify these predictions. A numerical simulation that is based on a kinetic model of each phenomenon and that meets these requirements is therefore applied to each map.

2. Technical Background to Preparation of Volcanic Hazard Maps

The numerical simulation uses a 1-D calculation that tracks the sequential change in a flow's profile and a 2-D calculation that can express planar spread with changes in a transverse direction. The simulation basically employs phenomena that can be modeled as "water flow" and "sediment transport" by using sediment hydraulics, namely bed load by flood flows, mudflows created by applying a turbulence model, and debris flows (aggregate flows). In the wake of the Izu-Oshima and Unzendake eruptions, a lava flow based on a rheology model and a pyroclastic flow (main body) model based on solid-gas multiphase flow were added.

The dominant element of the flow characteristics of a lava flow is a constant of a function of temperature and viscosity that determines viscosity; the dominant element of the flow characteristics of the main body of a pyroclastic flow is a coefficient of dynamic friction related to concentration. As these constants cannot be measured, approximate values determined by calibration calculations are used.

Because the kinetic models for some types of sediment transport have not been fully developed, the constants can be approximated on the basis of empirical rules. For instance, phenomena such as large-scale debris avalanches and pyroclastic surges, the interior structures of which are difficult to reproduce in detail, are subject to this kind of approximation.

These numerical calculations are largely attributable to progress in computer calculation techniques over the last 20-odd years and in microtopography survey techniques. If the initial conditions are not set properly for a numerical simulation model, however, the expected results cannot be obtained. Therefore, when a volcanic hazard map is prepared the following items need to be properly established as initial conditions for each phenomenon (**Fig. 1**).

The position of the crater (particularly in a lateral eruption that generates a new crater), the scale of the eruption (total volume of ejecta), and the eruption rate are preconditions for making a volcanic hazard map, rather than initial conditions for numerical simulation. These settings are largely attributable to the findings obtained in volcanology. In volcanic geology, the phenomena generated from each eruption event, their scales, and the distribution of the ejecta have been investigated in surveys of eruption history. These results present various potential conditions for volcanoes when their hazard maps are under consideration. First, a literature survey of the various eruption events gives an outline of the events. A field survey is then conducted to supplement the literature survey. At this stage, capitalization on the expertise

* Sabo and Landslide Technical Center

of volcanologists, together with consultant engineers who have majored in volcanology, provides a wealth of information that is useful for the Erosion Control in Volcanic Areas project.

Various surveys of Fujisan and analyses of this volcano with the aim of developing a volcanic hazard map[2] have been conducted as part of this cooperative effort. Importantly, these tasks were performed extensively. Specific activities include: (1) estimation of sources, and calculation of volumes, of airborne tephra and lava flows that had not been surveyed; (2) estimation of the distributions and sources of pyroclastic flow deposits that had not been fully surveyed; and (3) and confirmation of records of the eruptions of peak craters. These activities yielded substantial results in terms of volcanology[3]. Through a survey of historical documents, data on the volcanic ash emitted by the 1707 Hoei eruption of Fujisan and the damage it caused were compiled in terms of time and space, and records on the movement of debris flows and other deposits were checked. These activities gave good results in terms of disaster management, and the basic surveys were intensive. The results of the investigations were incorporated into Fujisan Hazard Map.

3. State of Preparation of Erosion Control Plans for Volcanic Areas and Volcanic Hazard Maps

As mentioned above, the Sabo (Erosion Control) Department examines and develops volcanic hazard maps to work out plans for erosion control in volcanic area and other measures. Erosion Control Plans for Volcanic Areas and Sabo plan for urgent measures for volcanic disaster reduction during Volcanic Eruptions are currently under consideration for 29 active volcanoes in Japan, where the constant volcanic activity affects wide-ranging settlements, built-up areas, and public facilities. Volcanic hazard maps for all of these volcanoes were examined, and their data were submitted to risk management departments. As a result, many volcanic disaster management maps have now been published. The Erosion Control Plans for Volcanic Areas are now being reviewed to serve as master plans for the Sabo plan for urgent measures for volcanic disaster reduction during Volcanic Eruptions, which will

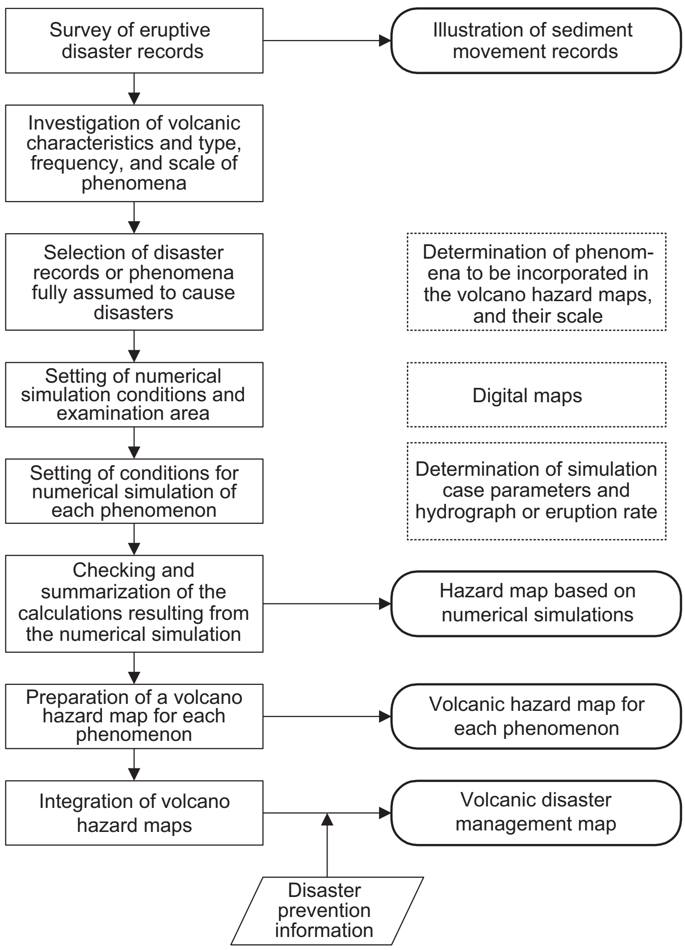

Fig. 1 Procedure for preparation of volcanic hazard maps.

be prepared to formulate emergency measures in the event of eruptions.

Volcanic disaster management maps for the following volcanoes[4)] have been made public on the basis of information provided under the Erosion Control project:

- Hokkaido: Meakandake, Tokachidake, Tarumaesan, Usuzan, and Hokkaido-Komagatake
- Tohoku region: Iwakisan, Iwatesan, Akita-Komagatake, Zaozan, Chokaisan, Bandaisan, Azumayama, and Adatarayama
- Kanto region: Nasudake, Kusatsu-Shiranesan, Asamayama, Izu-Oshima, and Miyakejima
- Hokuriku and Chubu regions: Niigata-Yakeyama, Fujisan, and Ontakesan
- Kyushu: Asosan, Kujusan, Tsurumidake and Garandake, Yufudake, Kirishimayama, and Sakurajima

The volcanic disaster management maps for Asosan and Asamayama are being revised to meet the volcanic alert levels announced by the Japan Meteorological Agency.

4. Future Volcanic Hazard Maps: Issue of Real-time Hazard Maps

The preparation and release of volcanic hazard maps and disaster management maps for our country's major active volcanoes are almost completed. Some of the maps have been revised, but the volcanic hazard maps for those volcanoes that erupt infrequently remain unrevised. Volcanic disaster management maps are closely linked to the upgrading of evacuation plans and other disaster management strategies. For this reason, we need to discuss how to use the maps to provide appropriate information to local residents and tourists. Consequently, a hazard map that reflects various scenarios without the constraints imposed by conventional forms of hazard map is required.

Real-time hazard maps are expected to be the next-generation of volcanic hazard maps. The concept of the real-time hazard map has been derived from recent progress in techniques for observing the meteorological, hydrological, and terrestrial phenomena leading to hazards. These advances allow immediate acquisition of observed data and faster numerical calculations based on these data. The quick publication of hazard areas on the basis of the latest data is expected to be used to tackle various natural hazards.

Volcanic real-time hazard maps have been examined particularly in the field of the erosion control in volcanic areas and have been classified into pre-analysis and real-time-analysis types (**Fig. 2**).

The pre-analysis system stores calculated results as a database and searches for a hazard map with similar conditions on the basis of eruptive and sediment movement. The system has been developed to reduce the time required for numerical simulations.

If an eruptive event or sediment movement is predicted, then the real-time analysis system will execute a calculation based on the conditions of the predicted and will prepare a hazard map. **Fig. 3** shows the procedure used to prepare real-time hazard maps.

Real-time hazard maps are used for structural and non-structural emergency measures. As the representative conditions and the precision required vary with the types and details of the measures taken, it is efficient to determine in advance the representative conditions that will be required by the end-users of the real-time hazard map[5)] (**Table 1**).

5. Future Development

The volcanic hazard maps that were prepared under the Erosion Control project are to be revised with changes such as new eruptions or drastic changes in topography. The volcanic hazard maps for Usuzan and Miyakejima, where eruptions occurred after volcanic hazard maps were instituted, have been reassessed in light of the changes occurring after these eruptions. To furnish the information appropriate to such reassessment work, we need to further improve the quality of the hazard maps by studying the

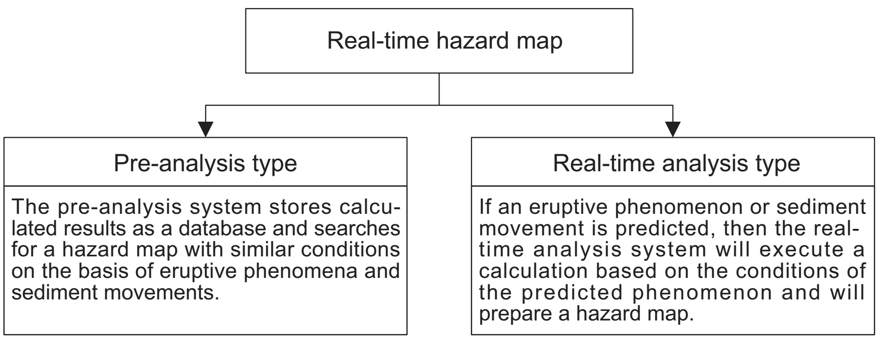

Fig. 2 Types of real-time hazard maps.

results of volcanological research and reviewing the kinetic models of sediment movement.

It is important to ensure that reexamination of conventional volcanic disaster management maps on the basis of volcanic hazard maps promotes further improvement of the volcanic disaster prevention schemes.

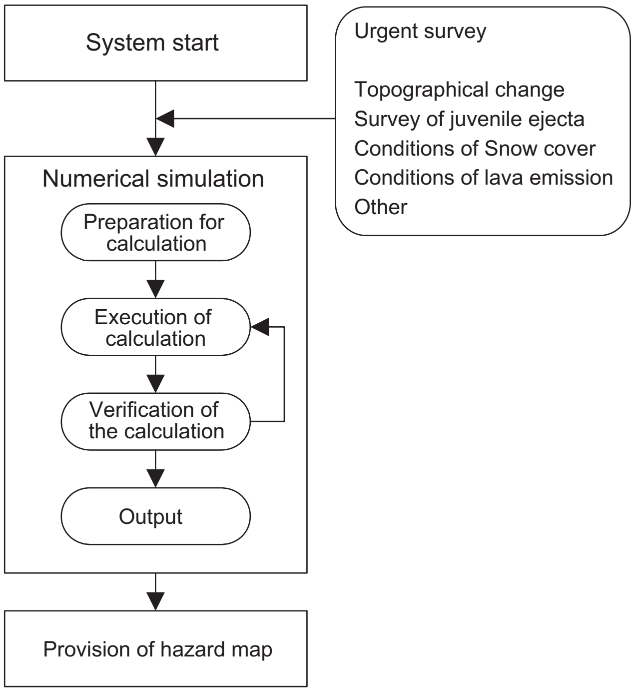

Fig. 3 Procedure for review of real-time hazard maps [4].

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Table 1 Application of real-time hazard maps for disaster prevention schemes, and their required precision[5].

Applications	Details	Representative item of RTHM	Required precision
Emergency evacuation	Evacuation implementation and cancellation with changes in the phases of volcanic activity.	Extent of impact from hazardous events. Arrival time of the phenomenon.	Evacuation (all-clear) areas must be set to order or lift of evacuation area, a size of digital map of about 50 m that can mark a township boundary is needed.
			The arrival time of the phenomenon is expressed in minutes.
			The results of calculations are required Immediately.
Declaration off-limits	Restriction of Access to areas at risk of dangerous eruption phenomena; road blocking; cancellation of these measures.	Extent of impact from hazardous events.	The outer boundary of the affected area is expressed, and a road map is superimposed on it.
Emergency erosion control works	Removal of Sediment from Sabo dams to prevent inundation with sediment and water, and construction of emergency training levees etc.	Extent of impact from hazardous events. Arrival time of the phenomenon.	The affected area varies with the planar shape of the structure. The mesh size that can express the structure is normally 10 to 20 m.
			The time of a phenomenon’s arrival at a construction site is a critical element for construction safety. Consequently, it must be expressed in minutes. The time of a slow phenomenon such as lava flow must be expressed in days.
			Because the mesh size becomes very small, the calculation time sometimes increases to about 1 day.

Volcanic Disaster Measures of the Geospatial Information Authority of Japan

Tetsuro IMAKIIRE*

1. Volcanic Activity Observation by the Geospatial Information Authority of Japan

Charged with monitoring active volcanoes throughout Japan, the Geospatial Information Authority of Japan (GSI) analyzes observational data from GEONET (a GNSS-based continuous monitoring system), GPS-based control points, and a remote GNSS-based volcano deformation monitoring system (REGMOS) to continuously monitors the earth's crust in 3D with millimeter accuracy. In 2008, GSI began conducting integrated analysis of GPS data incorporating the GPS observations of other institutions, and this gives us the ability to monitor crustal deformation around volcano with even greater accuracy. With this system, GSI is able to monitor the process of buildup to an eruption, and should be able to anticipate movements of magma with a high degree of temporal and spatial accuracy.

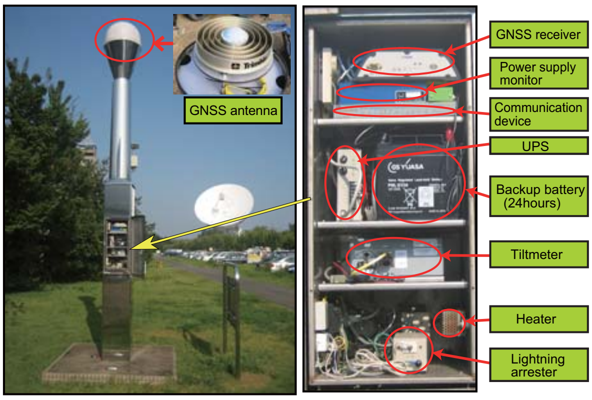

Fig. 1 GPS-based control points.

Fig. 2 External view of REGMOS.

Izu-Oshima is continuously monitored by a geodetic monitoring system, and crustal deformation measurements (leveling, GNSS surveying, gravity surveying) are periodically performed for 15 key volcanoes. GSI has also been continuously monitoring of geomagnetism around Fujisan since December 2001.

In areas where volcanic activity is intense due to contraction of the volcanic cone or large accumulations in the crater, surface deformation is estimated using SAR interferometric analysis from a satellite or aircraft. Finally, in order to detect crustal deformation around volcanoes or movements of magma deep underground, GSI conducts volcanic deformation modeling using GNSS and other observational data.

Fig. 3 Automatic observation station (Izu-Oshima).

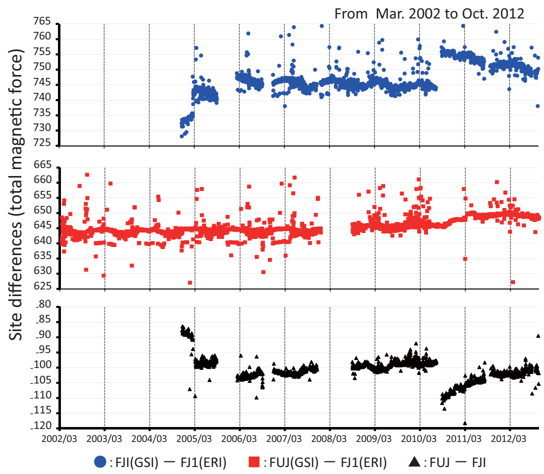

Fig. 4 Magnetic total force intensity observation results (Fujisan).

* Geospatial Information Authority of Japan

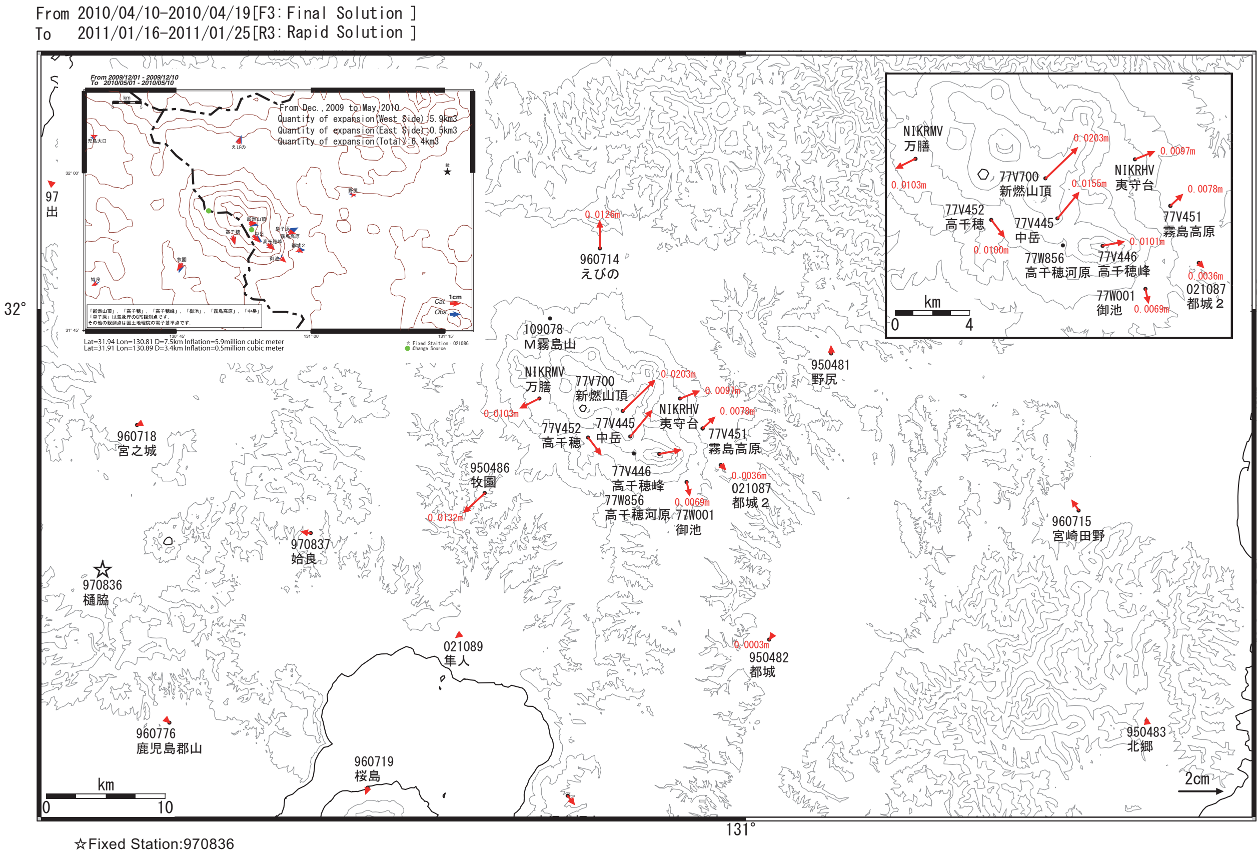

Fig. 5 GPS integrated analysis results and volcanic deformation model (upper left) (Kirishima volcano complex).

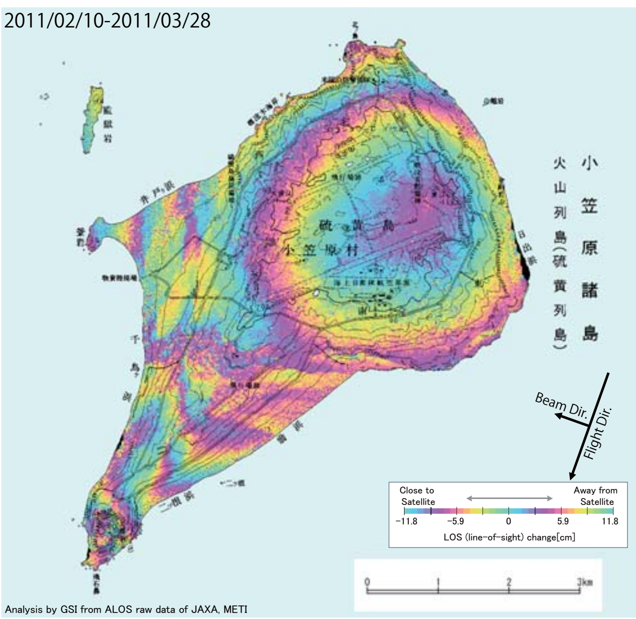

Fig. 6 Crustal deformation at Ioto detected by SAR interferometric analysis.

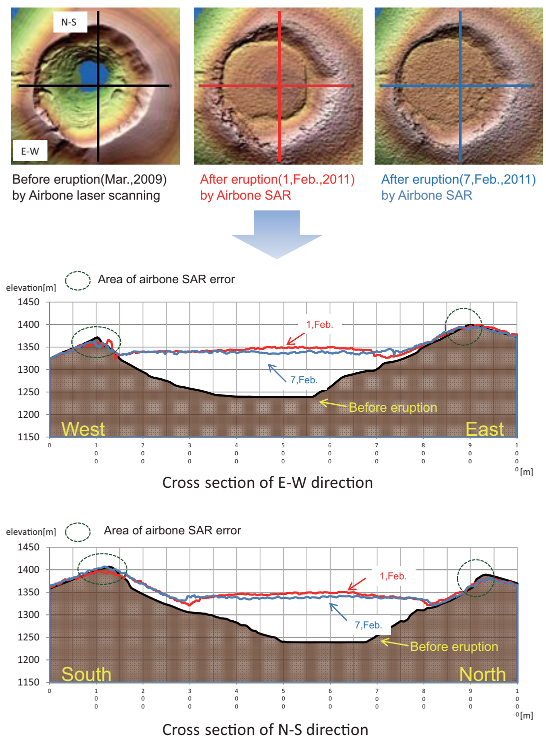

Fig. 7 Airborne SAR observation results of Kirishimayama (Shinmoedake).

The GNSS and other observational data and estimated crustal deformation results are reported to the Meteorological Agency's Volcanic Eruption Prediction Liaison Council and are also made available to the public on the GSI's website. We continue to monitor recent volcanic activity such as the spectacular magma eruption in January 2011 of Kirishimayama (Shinmoedake), volcanic activity on Ioto, and elsewhere.

2. Creating Basic Volcano-Related Information and Making it Available to the Public

GSI is committed to preparing hazard maps and other basic disaster management information and making this information available to the general public. Thus far, GSI has published Volcanic Base Maps for 33 volcanoes as well as Volcanic Land Condition Maps for 19 volcanoes based on volcanic land condition surveys. In addition, the GSI also conducts rapid-response field surveys in the event of an actual eruption, and quickly produces Ejecta Distribution Maps and Damage Condition Maps.

The Volcanic Base Maps are large-scale topographical maps drawn to 1/5,000 or 1/10,000 scale, with contour lines at 5-meter intervals. They include detailed features—summit craters, lateral cones, slopes, ridges, valleys, and so on—and highlight mudslide control dams and other disaster prevention facilities. The Volcanic Base Maps are a basic resource (base map) used to predict mudslide damage in volcanic areas, debris flows associated with volcanic activity, help formulate countermeasures to protect observation facilities from damage, conceive emergency measures in the event of eruptions, and provide valuable resources for studying volcanoes and predicting volcanic eruptions.

The Volcanic Land Condition Maps are easy-on-the-eyes multicolor printed maps with scales ranging from 1/10,000 to 1/50,000. They show the topology shaped by past volcanic activity, distribution of ejecta (lava flows, pyroclastic flows, scoria cones, debris avalanches, and so on), and the present state of the volcano (state of river dissections, artificial deformed ground, disaster-related facilities and institutions, locations of river construction projects).

All of these resources—Volcanic Base Maps, Digital Elevation Models, Volcanic Land Condition Maps, and other Volcanic Topology Classification Data that quantifies land features and distribution of ejecta caused by volcanic activity—are readily available to the public under the heading "Volcanic Maps" on GSI's website.

Volcanic Maps URL: http://www1.gsi.go.jp/geowww/Volcano/volcano.html

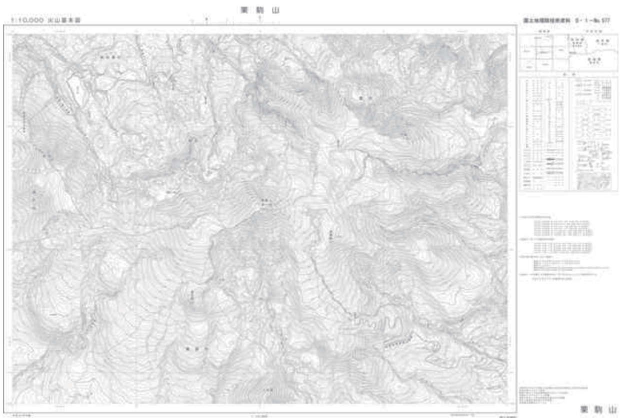

Fig. 8 Volcanic Base Map (Kurikomayama).

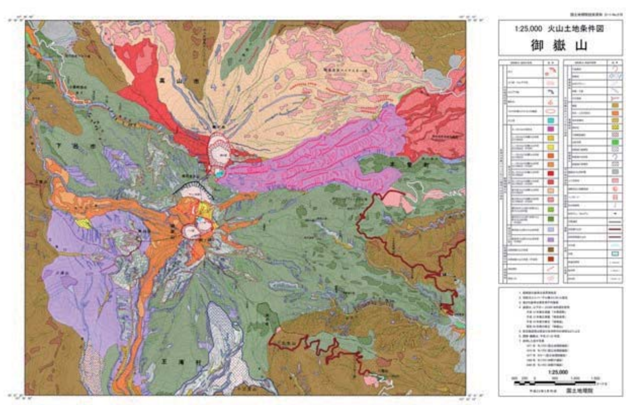

Fig. 9 Volcanic Land Condition Map (Ontakesan).

Fig. 10 Current availability of Volcanic Base Maps (left) and Volcanic Land Condition Maps (right).

Observation of Volcanoes in the Seas around Japan by the Japan Coast Guard

Koji ITO*

1. Introduction

Many volcanic islands and submarine volcanoes are distributed in the seas around Japan. These volcanoes, given the abundant volume of water surrounding them, can trigger phenomena different from those associated with terrestrial volcanoes; such phenomena may include phreatomagmatic explosions, the rise of floating pumice to the sea surface, and tsunamis and may threaten islanders' lives and nearby ships. To secure the safe passage of ships, the Japan Coast Guard has monitored and observed such volcanoes since its inauguration in 1948. This report provides general information about the monitoring activities of the Japan Coast Guard.

2. *Daigo Kaiyomaru* Accident at Myojinsho Reef

Myojinsho Reef includes an active volcano located about 400 km south of Tokyo. The post-caldera volcano developed along the edge of the north-eastern side of the Myojinsho Caldera. Volcanic activity has been noticed a couple of times throughout recorded history. A new island with a long axis of about 200 m was formed in 1946, but it later disappeared through wave erosion. In September 1952, upon receiving from the fishing boat *Daijyuichi Myojinmaru* a radio communication about submarine volcanic activity, the survey ship *Daigo Kaiyomaru* of the Hydrographic Department of the Maritime Safety Agency (the predecessor of the Japan Coast Guard), with university researchers on board, put to sea to identify the location of another new island (or reef) in the same area (**Fig. 1**). However, radio contact with *Daigo Kaiyomaru* was later lost. Analysis of debris floating around Myojinsho Reef indicated that *Daigo Kaiyomaru*, with a total of 31 souls on board, had been capsized by the blast of the volcanic explosion. Later, the U.S. Navy's SOFAR (Sound Fixing and Ranging) channel data suggested that the explosion had occurred at 12:21 on 24 September. Observing active volcanic islands and submarine volcanoes was therefore extremely dangerous when survey ships were the only means available.

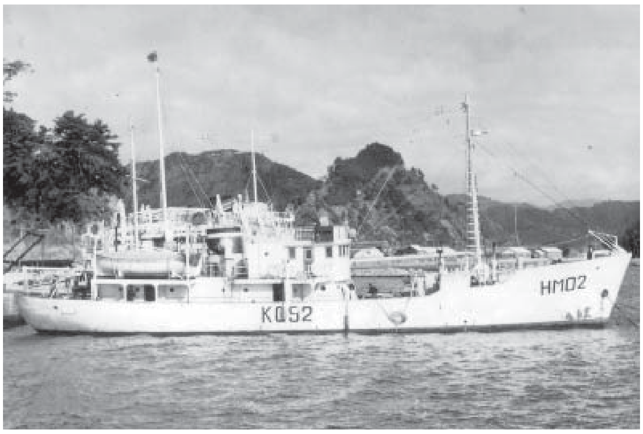

Fig. 1 *Daigo Kaiyomaru*. It is 34 m long, weighs 280 t, and was completed in 1943. As a survey vessel for the Maritime Safety Agency of Japan it helped to restore Japanese marine transportation. It was destroyed in a volcanic accident near Myojinsho Reef in 1952.

Thereafter, volcanic activity in the seas of the southern Japanese islands remained relatively calm. However, in the 1970s, volcanic activity in such areas as the Minami-Hiyoshi Seamount, Fukutoku-Oka-no-Ba Volcano, and Nishinoshima Island increased and was observed by the YS-11-based airplanes newly introduced by the Maritime Safety Agency.

3. Regular and Extraordinary Airborne Observations

Airborne observations are extremely important for learning the current status of volcanic activity in real time. The Japan Coast Guard monitors about 30 major volcanic islands and submarine volcanoes (**Fig. 2**). It has the capacity to observe the volcanoes of the southern Japanese islands on a once-a-month basis; this includes the regular biannual observations and other regular observations by the 3rd Regional Coast Guard Headquarters and the Self-Defense Forces. In the southwestern Japanese islands, the 10th and 11th Regional Coast Guard Headquarters make airborne observations of volcanic activity during their airborne patrols. This is in addition to the Japan Coast Guard's regular annual observations. The Japan Coast Guard makes extraordinary observations when

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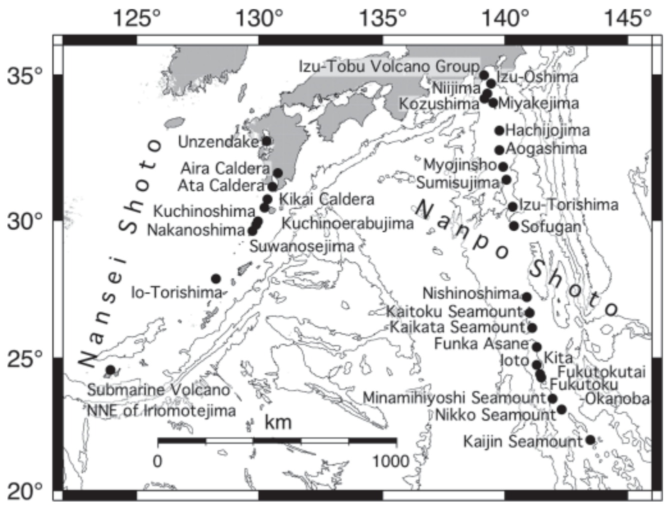

Fig. 2 Volcanic islands and submarine volcanoes to be monitored by the Japan Coast Guard.

any volcanic activity is spotted during these regular observations or is reported by fishing boats. In recent years, it has started to monitor volcanoes by using satellite images through joint study with JAXA (the Japan Aerospace Exploration Agency).

Major airborne observation methods include visual, geomagnetic, and thermal-infrared. Visual observations include eruption clouds, volcanic gases, and extent and color of discolored water. Thermal-infrared observations include the temperature inside craters and help to reveal the current status and activity of the magma. These data are sent as part of various navigational warning messages, including NAVAREA messages, and are also reported to the Coordinating Committee for Prediction of Volcanic Eruptions.

4. Basic Surveys by Survey Vessels

The Japan Coast Guard performs basic surveys by using survey vessels to collect basic data on volcanic islands and submarine volcanoes, including volcanic topography, the nature of volcanic ejecta, geomagnetic and gravitation anomalies, and crustal structure. It has surveyed 10 volcanoes since 1998. The survey data are used to compile the Basic Information Map of Submarine Volcanoes and are also used for the Database of the Maritime and Submarine Volcanoes in Japan.

By understanding volcanic topography, we can estimate the eruptive style, the eruption history, and the scope of the eruption impact. The recent rapid development of the multi-beam echo sounder has contributed greatly to our detailed understanding of the volcanic topography of the volcanic islands and submarine volcanoes (**Fig. 3**). By accumulating data on geomagnetic and gravitation anomalies when volcanoes are quiescent and comparing them with data collected during eruptions, we can predict the locations and movements of the magma and fluids inside the volcanoes.

Vessels used for the surveys include the survey vessels such as *Shoyo* and *Meiyo*. We also use survey boats *Manbo II* and *Jinbei* (**Fig. 4**), which are available for remote, unmanned navigation or pre-programmed navigation in shallow seas or where manned survey ships cannot enter because of volcanic activity. These boats are equipped with echo sounders and water-sampling bottles for studying topography and taking samples of discolored water.

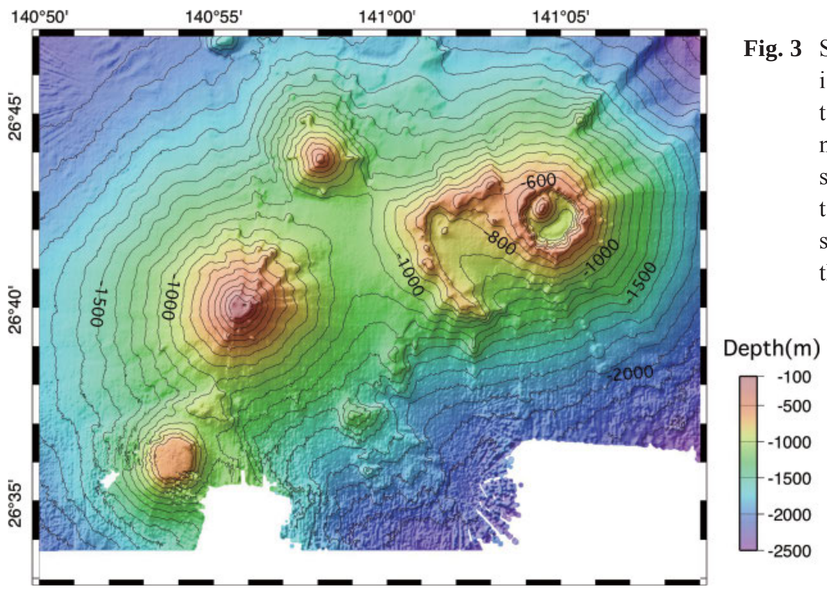

Fig. 3 Shaded relief map of the Kaikata Seamount in the Ogasawara Islands Chain. Note the horseshoe caldera on the eastern mountainside and the small caldera at the summit. By understanding the volcanic topography, we can estimate the eruptive style and the type and scale of the disaster that may result from an eruption.

Fig. 4 The manned/unmanned survey boat *Manbo II*. It is usually mounted on a large survey ship and used in places the mother ship cannot enter.

5. Future Issues

The future issues surrounding the observation of volcanic islands and submarine volcanoes include, first and foremost, increasing observation activities. Japan has many volcanic islands and submarine volcanoes, but the Japan Coast Guard currently observes only those volcanoes that are most active and highly likely to erupt in the near future. As volcanic eruptions can subside within a couple of days, some may begin and end without anyone's knowledge. Establishing an undersea cable-based real-time monitoring system is one way to solve such a problem and expand the scope of observations in space and time. Under the VENUS Project led by the Science and Technology Agency in the 1990s, an attempt was made to monitor the Earth's environment by connecting various items of observation equipment to the undersea coaxial cable laid from Guam to Okinawa. The Maritime Safety Agency also participated in the project and deployed hydrophone arrays to capture the eruption sounds of submarine volcanoes. Unfortunately, because of equipment troubles, the project finished before achieving its goal. This technology needs to be put to practical use in the near future.

Aerial observations of submarine volcanoes are often hampered by the presence of the sea: the status of the areas around craters and eruption phenomena often cannot be directly observed. In such cases, the discolored water is observed instead to evaluate volcanic activity. Observation activities currently include keeping records of the presence of discolored water and of the extent and color of the change. However, the influence of subjective views on the observation results cannot be ruled out because of the heavy dependence on visual observation. An attempt has begun to capture images of the water with multi-band cameras and thus determine the levels of volcanic activity by quantifying the color changes. However, this system is yet to be put into practical use in predicting eruptions. As a first step, we need to collect sufficient quantitative data on these color changes for each volcano so as to identify their relationship with the level of volcanic activity.

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AIST's Research on Volcanology

Hiroshi SHINOHARA* and Yoshihiro ISHIZUKA*

1. Introduction

The National Institute of Advanced Industrial Science and Technology (AIST) produces and compiles geological information to enhance our society's safety and security. AIST also works on technological development to create solutions to various problems. These solutions include mitigation of damage by natural disasters, preservation of the global environment, and development of resources and energy on the basis of the compiled information. Among these fields, geological research to mitigate damage by volcanic disasters is the major research theme. To reduce volcanic damage it is indispensable to evaluate and predict changes in volcanic activity and eruptions. In this respect, AIST conducts geological surveys to understanding and evaluating past eruption history, frequency of eruption, and changes in volcanic activity and modeling of magma supply systems, magma ascent and eruption sequences, which are the causes of the activity changes, by using geophysical observations and materials science analyses of rocks and volcanic gas with the aim to refine the techniques to predict volcanic activity changes. This paper focuses on the three research activities currently conducted by AIST: (2) geological maps of volcanoes; (3) researches for prediction of volcanic activity changes; and (4) database of active volcanoes.

2. Geological Maps of Volcanoes

Each volcano has its own characteristics, and eruptions often follow a similar pattern. Study of the history of past activity of a volcano is therefore important to infer the style and scale of possible future eruptions. AIST conducts regular detailed field surveys and compiles the results into geological maps to reveal the past histories of volcanic activity. These geological maps are useful to understand the possible eruption sites, eruptions styles and areas affected by the future eruptions (**Fig. 1**). There are two series of geological map of volcanoes. The Geological Map of Volcanoes focuses on active volcanoes and the 1:50,000-scale Quadrangle Series covers the entire country. The first Geological Map of Volcanoes was published in 1981 for Sakurajima, issued for 16 volcanoes and was revised. Since 2000, seven maps have been added to the series, namely Kirishima, Miyakejima, Iwate, Kuchinoerabujima, Usu (2nd edition), Tarumae, and Tokachidake. All of the rank A volcanoes (the most active ones) will be covered by the Geological Map of Volcanoes with the issue of the map of Suwanosejima, scheduled for fiscal year 2012. Since 2000, the 1:50,000-scale Quadrangle Series of the area including active volcanoes were issued for Midagahara, Hakkodasan, Numazawa, Kaimondake, Ikeda and Yamagawa, Nishinoshima, and Harunasan.

To determine the history of activity and growth of a volcano it is essential to establish an accurate time axis of eruption dates. AIST developed a method to date the young volcanic rocks and applied to various volcanoes These results are indispensable for production of geological maps and improve the accuracy of the geological maps and systematic compile of the eruption data.

We combine various techniques such as drilling, trench and sea bottom surveys, in addition to the conventional surface geologic surveys, to understand the history of volcanic activity. For example, the eruption history of Izu-Oshima obtained by ground surface survey as revised based on the results of the drilling and trench surveys. The comparison of the geological surveys on the island and in the sea revealed the long-distance movement of magma. These are very important outcomes for improvement of future geological maps.

3. Researches for Prediction of Volcanic Activity Changes

We are systematically conducting various researches based mainly on materials science so that we can determine the magma supply system that controls a volcano's history of activity or eruption changes and the progress in magma rise and eruption. The major research topics are as follows.

Lithological analysis of ejecta is effective in clarifying the composition of the magma that characterizes the volcanic activity, the evolution and differentiation of the magma before eruption, and magma mixing. The analysis conducted by AIST is based particularly on analytical studies of major components and volatile materials in

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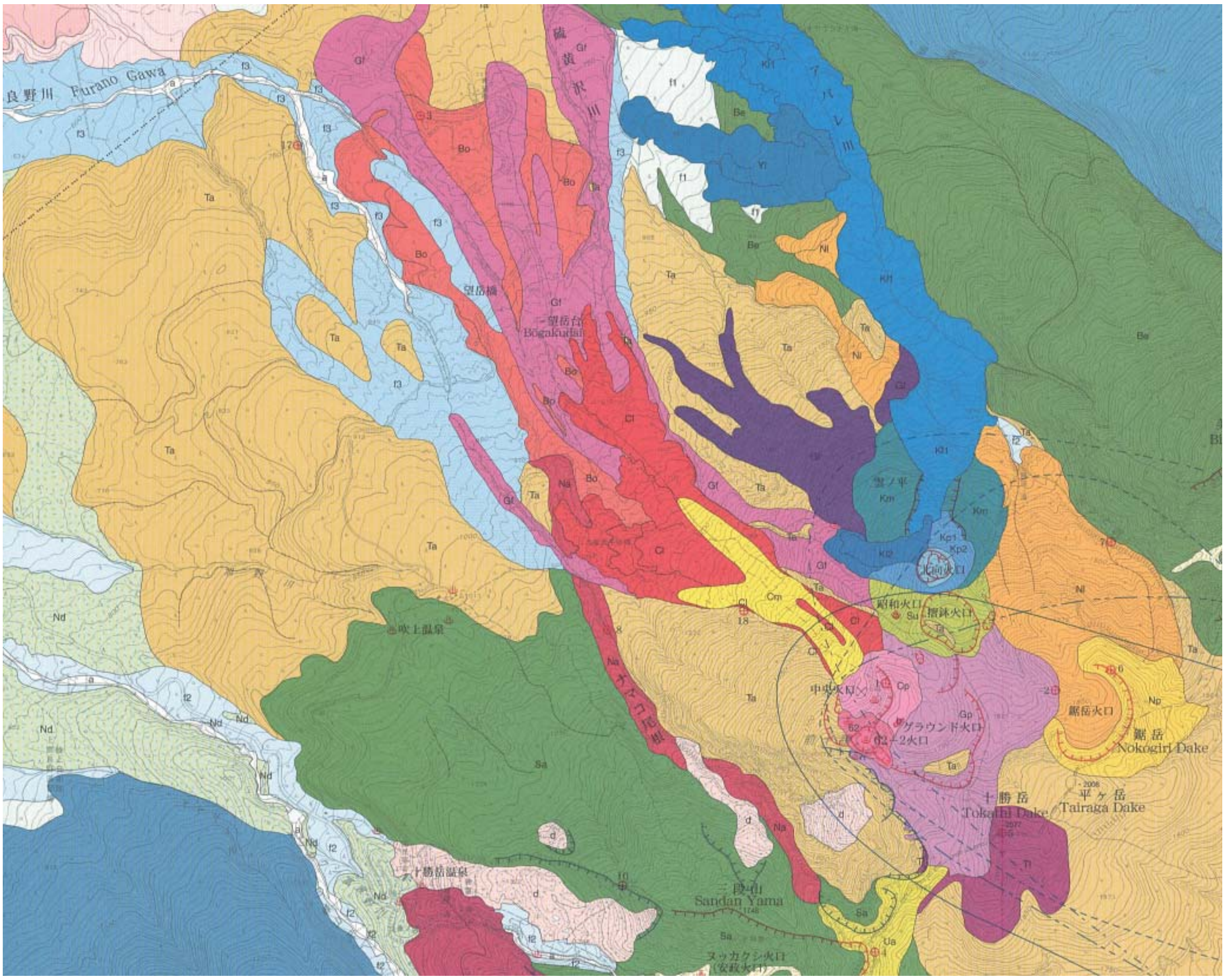

Fig. 1 Geological map of Tokachidake Volcano (Ishizuka *et al.*, 2010).

the melt inclusions in the phenocrysts in volcanic rock or the microstructures of the phenocrysts. Because these samples are very small, they are analyzed by using an electron microprobe or secondary ion mass analyzer. In addition, magma reaction experiments are conducted with an internally heated gas pressure high-temperature high-pressure apparatus to quantitatively evaluate the results obtained. This analysis provides us with various findings such as follows;

For an example, the magma ejected by the eruption of Kirishimayama (Shinmoedake) in 2011 was mixed repeatedly for a long time in the magma chamber and underwent another mixing immediately before eruption, and this final mixing triggered the eruption.

Volatile components in the magma are the major driving force of explosive eruption. At the same time, the emission of volcanic gas onto the ground reflects the degassing process of the magma underground.

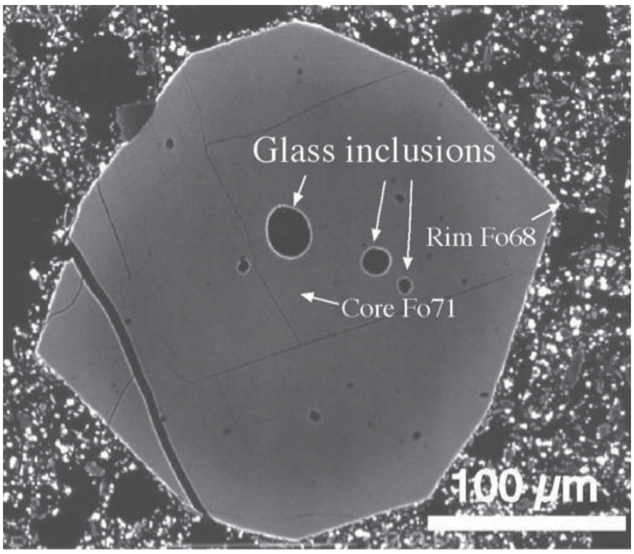

Fig. 2 Melt inclusions of basaltic magma in an olivine phenocryst in Miyakejima ejecta emitted on 18 August 2000 (photo taken by Genji Saito).

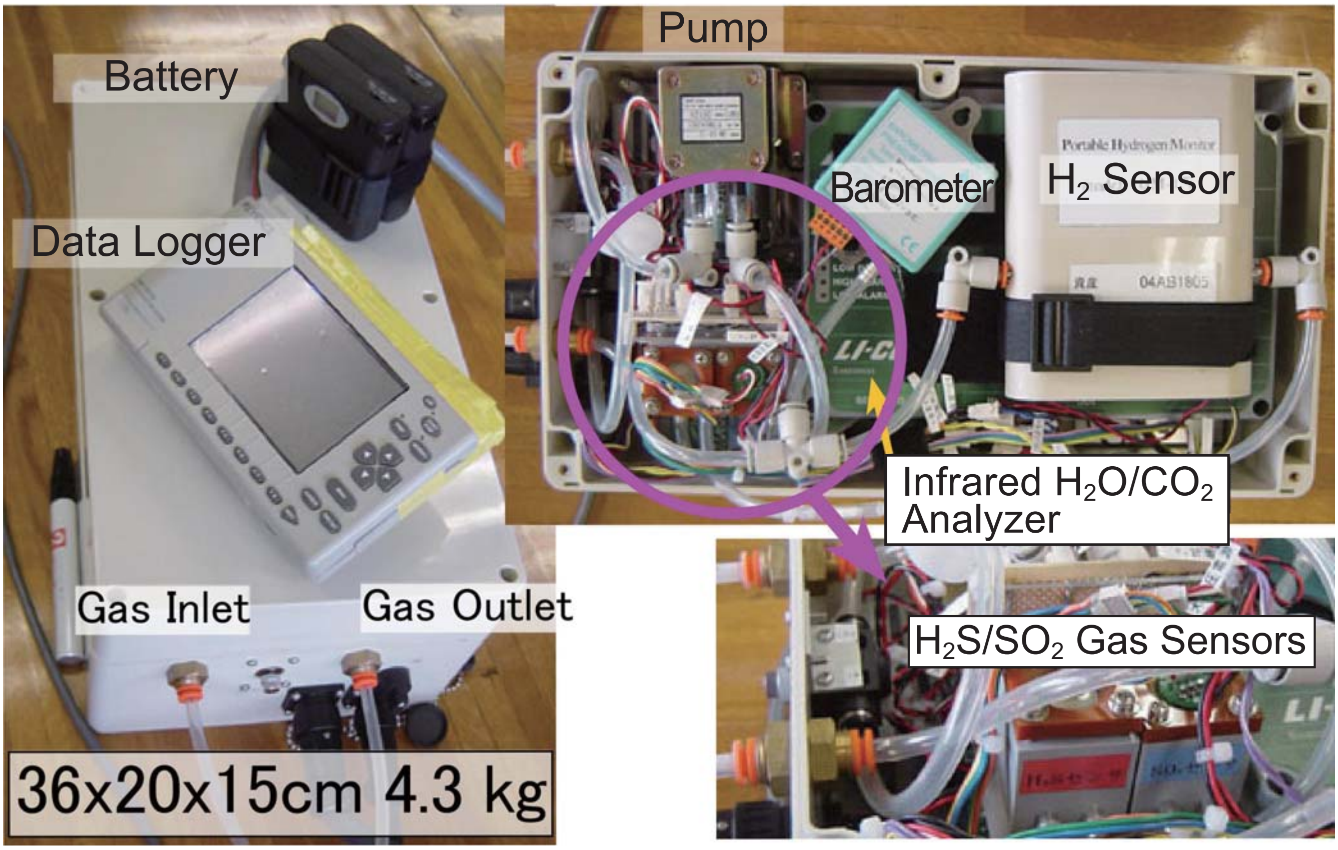

Fig. 3 Multi-GAS (multi-component gas analyzer system).

We observe the gases from active volcanoes to monitor volcanic gas discharge activity and analyze the degassing process of magma and changes in hydrothermal systems. Conventionally, the major means of observing volcanic gas components is direct sampling and analysis; the subject of observation is therefore limited to fumarolic activity. However, we have newly developed an apparatus and method for observations of volcanic smoke to measure volcanic gas components (**Fig. 3**). This system enables us to observe the gases from various volcanoes within and outside Japan. It also allows us to quantify the components of large-scale volcanic gas discharges, such as that in the case of Miyakejima. Thanks to this new technique, advances are being made in evaluating changes in the process of volcanic gas supply as a result of changes in volcanic activity. As the apparatus is designed to conduct automatic measurements, it can be installed on a volcano for long-term observations. Various improvement of the apparatus and techniques are being performed to realize continuous observation of volcanic gas.

Changes in volcanic activity—including increased underground thermal activity, increased supply of volcanic gas, and intrusion of magma—initially cause changes in the underground hydrothermal system. These changes can be detected on the surface as the changes in thermal activity on the ground surface or in spontaneous potential or resistance in the volcanic edifice. AIST conducts continuous observations of spontaneous potential and repeated observations of surface temperature distribution to detect changes in volcanic activity by observing hydrothermal activity. We also conduct hydrothermal system simulations to quantitatively evaluate these changes. Based particularly on comparisons between the simulation results and observation results, we develop quantitative models of hydrothermal systems that can reproduce those of actual volcanoes to quantitatively predict changes in hydrothermal systems under various conditions caused by magma intrusion or supply of volcanic gas.

4. Database of Active Volcanoes

The histories, the scales and styles of eruption of active Japanese volcanoes are compiled and published as a database to facilitate the understanding and usage of the geological information. The database includes 10,000-year eruption event data, geological maps of volcanoes, detailed volcano data, and researches on active volcanoes. Collection and editing of information is still under way.

The 10,000-year eruption event data contains the eruption date, eruption styles, types of sediments, sources of supply, and scale of eruption, taken from the documents so far published, and those data are chronologically compiled in standardized format. The geological maps of volcanoes and detailed volcano data explain in detail the relevant geology of particularly active volcanoes with the aid of drawings and photos. Researches on active volcanoes overviews the studies on a volcano from an interdisciplinary viewpoint covering geology, geophysics, and geochemistry, so that readers can obtain a general understanding of volcanoes and is published for Satsuma-Iojima and Usuzan.

Reference

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Fire and Disaster Management Agency and Local Government Volcanic Disaster Countermeasures

Hirobumi KOBAYASHI* and Noriko URATA*

1. Fire and Disaster Management Agency Volcanic Disaster Countermeasures

Today there are 110 active volcanoes in Japan. A diverse range of volcanic phenomena have high risk for destruction of life and property including volcanic cinders, pyroclastic flows, lahars, lava flows, falling ash, debris flows, volcanic gas, landslides, and are sometime accompanied by tsunami tidal waves. Various measures have been taken in line with Act on Special Measures for Active Volcanoes and other statutes to minimize the impact of volcanic hazards, and the Fire and Disaster Management Agency is charged with administering government support to defray the infrastructure costs of maintaining evacuation facilities in towns and cities in areas where volcanoes are present. In light of volcanic disasters that occurred in 2000—one at the base of Usuzan and the other involving Miyakejima—the Fire and Disaster Management Agency began holding Volcano Disaster-related Prefectural Liaison Council meeting in 2001 to promote sharing of the latest information regarding volcano disaster countermeasures and information held by the various council member organizations.

Then in March 2008, the Cabinet Office, the Fire and Disaster Management Agency, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT), and the Japan Meteorological Agency drafted the “Volcano Disaster Prevention Guidelines for Evacuation when Eruptions Occur” based on discussions of volcano-related information and evacuation plans with the aim of constructing an effective volcano disaster management system. The agencies called on all affected prefectures and municipalities to hold council meetings during normal times in order to set up Joint Countermeasure Headquarters to deal with abnormal situations that arise when eruptions occur, to develop specific and practical evacuation plans, to educate their local populations, and to formulate volcano management countermeasures based on the guidelines.

2. Local Government Volcanic Disaster Countermeasures

2.1 Organize Communication and Cooperation Framework with Adjacent Local Governments and Relevant Institutions

It is critically important that local governments located near volcanoes establish wide-area communication and collaboration systems in order that they implement consistent evaluation polices, mountain climbing restrictions, and other measures. Currently as of April 1, 2011, Councils have been established covering 25 volcanoes, and a coordination system has been put in place for deliberating and coordinating regarding information sharing, evacuation response policies, and other concerns. Of these, municipalities in the shadows of 9 volcanoes—Tokachidake, Usuzan, Hokkaido-Komagatake, Tarumaesan, Meakandake, Kusatsu-Shiranesan, Unzendake, Asosan, and Kujusan (Ioyama)—have already formed local disaster prevention councils in line with the Basic Act on Disaster Control Measures, and cities near 7 of these volcanoes have already developed a regional disaster plan covering contingency measures and other polices related to eruptions.

In order to implement volcanic disaster response measures in a timely and accurate manner, local governments near volcanoes are cooperating through their Volcano Disaster Management Councils with local weather stations that monitor volcanoes, erosion control departments, volcanologists and other specialists, police and fire departments, the Self-Defense Forces, Coast Guard, and other support organizations.

2.2 Preparing and Distributing Volcanic Hazard Maps

Volcanic Hazard Maps are detailed maps showing the risks and vulnerabilities faced by different communities in the event of an eruption. The maps are prepared by the Volcano Disaster Management Councils and others, and are extremely helpful to the local councils in drafting evacuation plans. Another type of map called Volcanic Disaster Mitigation Maps have also been prepared that explain eruption warnings, evacuation planning, and other disaster-related information to the local population. By widely distributing these maps to local residents under

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normal conditions, it helps raise peoples' awareness of what they are supposed to do in the event of a disaster. As of April 1, 2011, Volcanic Hazard Maps have been created for 41 volcanoes across Japan. Following the eruption of Usuzan and volcanic activity at Miyakejima, the Fire and Disaster Management Agency has called on local governments near volcanoes to step up their efforts to create hazard maps, while stressing the importance of raising peoples' awareness and getting disaster prevention information into the hands of all their local residents before a major eruption occurs.

2.3 Planning for Volcano Disaster Management

Local governments near volcanoes must also implement detailed disaster management strategies dealing with different level eruption warnings as part of their local disaster management planning that take the characteristics of volcanoes, the geographic conditions, and the social conditions of different communities into account. Currently as of April 1, 2011, some 14 prefectures and 115 municipalities have drafted volcanic hazard countermeasure plans as a separate section or chapter of their comprehensive regional disaster prevention plans, or have updated their plans to incorporate the latest resources and information about volcanoes[*1)].

2.4 Practical Disaster Reduction Drills and Exercises

Local governments in the shadow of volcanoes should conduct regular disaster reduction drills and exercises in close cooperation with the local fire department and other local disaster-prevention organizations, and in 2010 four prefectures conducted drills five times while municipalities conduced volcanic hazard drills 48 times. In cases where local governments are linked, the drills were conducted as joint exercises[*1)].

2.5 Establish System for Conveying Information to Citizens and Tourists

A disaster PA (public address) radio network is most effective for conveying disaster-related information such as eruption warnings and evacuation advisories to the local population quickly and reliably. As of March 31, 2011, some 78.3 % of municipalities that are vulnerable to volcanoes have deployed PA radio networks. Moreover, volcanic areas frequented by tourists and mountain climbers have started to impose hiking/climbing and access regulations based on eruption warnings that reflect volcanic activity, and are taking proactive steps to keep local tourists informed of volcanic hazards.

***1)** That data from Iwaki, Miyagi, and Fukushima Prefectures have been excluded from the figures used in this report due to the devastating impact of the Great East Japan earthquake in March 2011.

Technical Note of the National Research Institute for Earth Science and Disaster Prevention, No. 380 ; July, 2013

Volcanic Disaster Management at Unzendake

Shinichi SUGIMOTO*

1. Introduction

It has been 21 years since the pyroclastic flow disaster that followed the volcanic eruption of Unzendake on 17 November 1991. Volcanic activity continued for 4 years and 3 months, from November 1990 to February 1995. On the Shimabara Peninsula there has been steady progress in the process of restoration after the disaster. As part of the lessons to be learned from the disaster, volcanic disaster management, including volcano monitoring, sediment disaster countermeasures, victim management, and restoration measures, was thoroughly reviewed. After the eruption had subsided, efforts were made to investigate the eruption mechanism by digging into the volcanic vents at Unzendake and facilities such as the Mt. Unzen Disaster Memorial Hall, where people can learn about and experience volcanic disasters, were established. These efforts resulted in the hosting of the 5th Cities on Volcanoes Conference in November 2007, approval of the Unzen Volcanic Area Geopark as a Global Geopark in August 2009, and the hosting of the 5th International UNESCO Conference on Geoparks in May 2012.

In this report, I look at the history of volcanic disaster management from the perspective of my experience of responding to the volcanic disaster as a Shimabara City employee; I also describe new efforts that have been initiated in the restoration process and possible future issues.

2. Volcanic Eruption and Specifying of No-entry Zones

The volcanic eruption of Unzendake started on 17 November 1990 and caused a series of sediment and pyroclastic flow disasters beginning in May 1991. The pyroclastic flows reached some 100 °C in temperature and their downward flow speed exceeded 100 km/h, suggesting that the flows could reach the urban area in 3 to 4 min. At the time of the eruption it was difficult to provide accurate volcano information in the form of predictions of pyroclastic flows. It was also technically impossible to erect any physical barriers to prevent disaster from lava collapse. As a result, 43 people died or were listed as missing in the pyroclastic flow that occurred on 3 June 1991. An urban area densely populated with residential houses, stores, and factories was specified for the first time as a "no-entry zone" under Article 63 of the Disaster Countermeasures Basic Act of Japan to protect lives from the pyroclastic flow; no one was permitted to enter the zone without a permit from the authorities. However, prolonged living under evacuation made it difficult for people to engage in their agricultural, commercial, or industrial business activities; they could not go to work or school, and it was also impossible for them to take care of their houses or farmland. Establishment of the zone also made it impossible to maintain the transportation systems and other infrastructure and to implement such strategies as sediment disaster countermeasures. The disaster affected not only the areas directly hit but also the entire Shimabara Peninsula: commercial and industrial revenue declined because of a reduction in the numbers of tourists and shoppers. The population also declined, as many citizens left the city.

3. Publicizing the Predicted Volcano Disaster Area Map

The (then) Sabo (Erosion and Sediment Control) Department of the Construction Ministry, together with the Nagasaki Prefectural Government, explained to the Shimabara City Government the effectiveness of a hazard map in swiftly enhancing warning and evacuation systems. At the request of Shimabara City on 1 June 1991, the Nagasaki Prefectural Government asked the Sabo and Landslide Technical Center (STC) to create a hazard map. A predicted volcanic disaster area map was rapidly produced. However, the pyroclastic flow that caused so many casualties occurred a little past 4 pm on 3 June, just when an STC staff member was waiting to board a plane at Haneda Airport to deliver the map to the city.

On the basis of the assumption that the downward flow distance of the pyroclastic flow could extend because the lava dome could collapse, the area upstream from the Mizunashigawa Bridge along National Route 57 was specified on 6 June as a no-entry zone under the Disaster Countermeasures Basic Act. Shimabara City, on the same day, publicly released the first edition of the predicted volcanic disaster area map of the Mizunashigawa River, created by the STC. A total of 8 such maps, including the first edition, were created as the volcanic activity changed.

* Mt. Unzen Disaster Memorial Hall Assistant Director

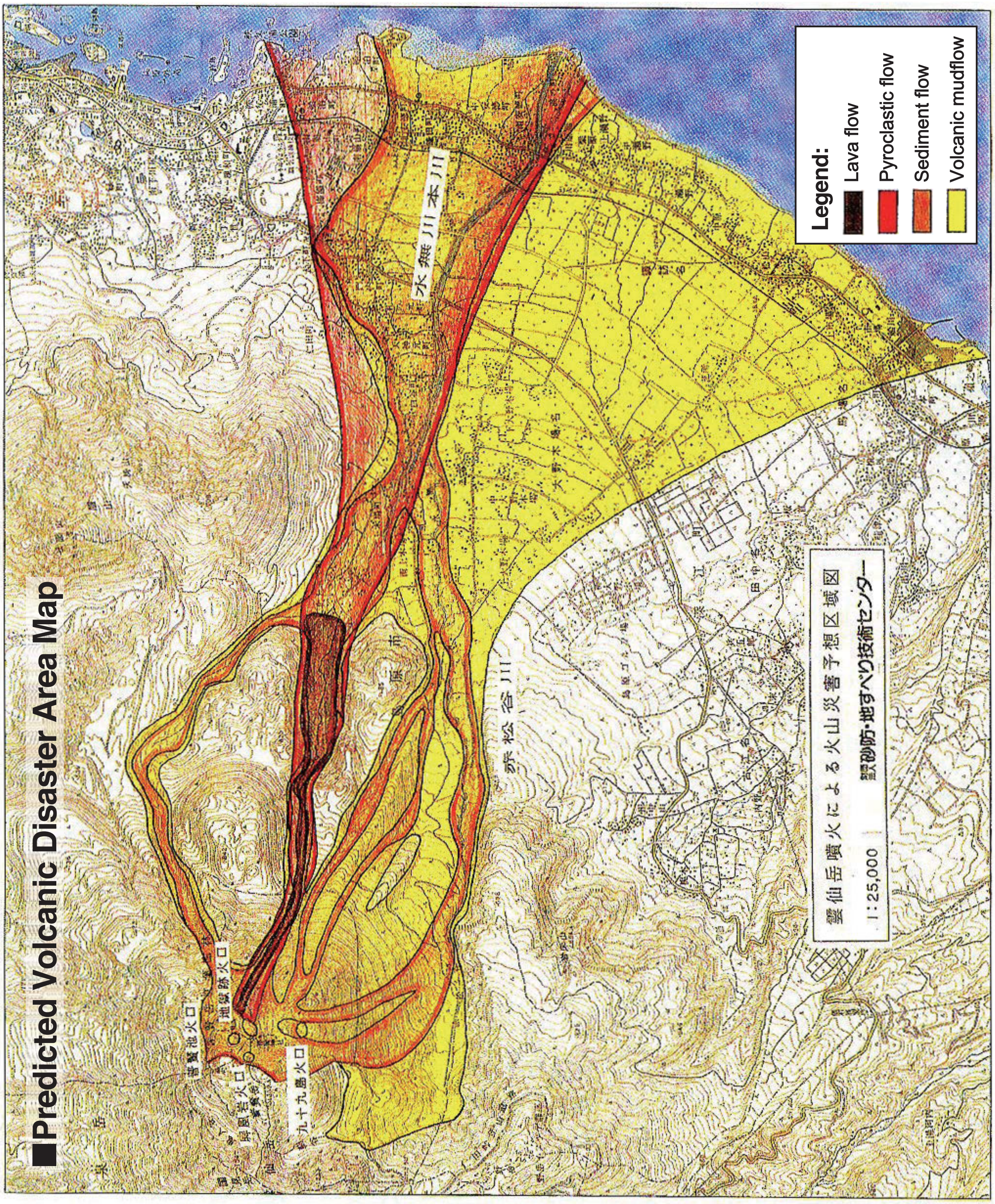

Fig. 1 First edition of the predicted volcanic disaster area map (June 1991) [Sabo and Landslide Technical Center] (reduced by 55 % from the original).

The Unzendake volcanic disaster made many Japanese people aware for the first time of the dangerous pyroclastic flow phenomenon. The Unzendake disaster made both the public and administrative officials throughout Japan keenly aware of the importance of creating volcanic hazard maps as part of disaster management.

4. Joint Volcano Monitoring and Information Supply by Self-Defense Forces and University

The Self-Defense Forces (SDF) dispatched for disaster-relief efforts deployed a communications unit at the Shimabara Earthquake and Volcano Observatory of Kyushu University to monitor the status of the pyroclastic flows with an oscillatory wave monitor equipped with a seismometer. It also set up a 24-h monitoring post equipped with field-information-gathering devices such as ground radar. The initial purpose of such monitoring activities was to provide logistical support for such activities as searching for missing persons or collecting bodies. Because the volcano observation organizations lacked functional monitoring devices designed for disaster management, a warning and monitoring network was established by using high-tech devices owned by reconnaissance and communications units of the SDF.

However, because its reconnaissance, monitoring, and warning activities are primarily targeted at military moves by enemy forces in combat, the SDF lacked volcanological knowledge. For this reason, the SDF needed advice from volcano researchers. The Shimabara Earthquake and Volcano Observatory of Kyushu University, in turn, required support from the SDF to install and manage monitoring devices in dangerous areas, because frequent aerial photography of the lava dome and the pyroclastic flow was indispensable for the observatory's research and for giving disaster management advice to local governments. For these reasons, the volcano monitoring system was established jointly by the SDF and the university.

The SDF immediately reported by radio real-time information about the pyroclastic and sediment flows captured by seismic wave monitors, visual monitoring, and radar observation, and the disaster management organizations used the data received for their respective activities. The SDF provided real-time pictures of the captured pyroclastic and sediment flows to the disaster management organizations. The information was made publicly available to the public via privately run cable TV stations, effectively preventing any panic caused by rumors.

5. Coordination Meetings for Specifying No-Entry Zones

Article 63.1 of the Disaster Countermeasures Basic Act stipulates that the head of each municipal government, who has comprehensive responsibility for disaster management in each area of the municipality, has the right to specify no-entry zones. However, although municipal heads know the situations and human relationships in their own municipalities well, they are totally unfamiliar with volcanic activities. This raises questions about the wisdom of leaving the responsibility to declare or nullify no-entry zones to the municipal heads and about coordination among individual municipalities. The town of Fukae, like the city of Shimabara, specified a no-entry zone, but it made the zone specification on 8 June 1991, one day after Shimabara City did so (7 June), because Fukae sustained no human casualties. Nagasaki Prefecture sponsored a meeting on 27 June to coordinate no-entry zone specification before the first specification expired.

The meeting, which was headed by the Nagasaki governor, was attended by heads of municipalities, fire-fighting headquarters, police stations, the SDF, the Japan Coast Guard, and the Kyushu University Observatory. The attendees decided on a basic guideline based on comprehensive discussions of the status of the volcano and the residents. The coordination meeting was not legally backed by ordinances, but the proposals coordinated and decided at the meeting were discussed and approved by the disaster management headquarters of each participating organization. The next step to take was for the municipal heads to specify no-entry zones under the Disaster Countermeasures Basic Act. Coordination meetings continue to be held as of December 2011 and have been joined by new members, including representatives of the Nagasaki Construction Office of the Construction Ministry, the Unzen Restoration Work Office, and the Unzen Weather Station.

6. Volcanic Disaster Management and Geopark

Restoration after the volcanic disaster is progressing steadily on the Shimabara Peninsula, thanks to support from the central government, the prefecture, and many people throughout Japan. We are now working on regional development. However, a decline in disaster awareness as time passes is apparent and is revealing a new issue of the need to provide disaster education in preparation for the next disaster. Under such circumstances, three cities on the Shimabara Peninsula are attempting to revitalize the region and provide new disaster education programs by promoting Geopark activities jointly with various groups and institutions in the region.

A Geopark is a natural park that features the heritage of the Earth's activities as a major sightseeing attraction. The Global Geoparks Network, established in 2004 under the auspices of UNESCO, promotes Geopark activities worldwide. Currently five regions— Unzen Volcanic Area, Toya Caldera and Usuzan, Itoigawa, Sanin Kaigan, and Muroto—have been approved as global Geoparks in Japan.

Geopark activities are focusing increasingly on disaster management efforts. The declaration adopted at the 3rd International UNESCO Conference on Geoparks, held in Osnabrück, Germany, in June 2008, included a phrase to the effect that "Geoparks help share knowledge about geological disasters with society."

Many of the 20 Geoparks approved by the Japanese Geoparks Network have associations with volcanic activity, and six of them (Unzen Volcanic Area, Toya Caldera and Usuzan, Aso, Kirishima, Izuoshima, and Bandaisan) are centered around volcanoes. Active volcanoes in the Japanese archipelago constitute an important natural heritage, and their eruptions create additional geological values and benefits, such as diversity of terrain, vegetation, culture, and society. Regional volcano education programs can be positively incorporated into Geopark activities, turning the existing volcanic disaster management network into infrastructure to support Geopark activities.

Each volcano has a unique terrain based on differences in eruption patterns and providing splendid scenic views and an abundance of local hot springs. The foot of each volcano has fertile farmlands with plentiful underground spring water, making it possible for residents to make their living through tourism and agriculture.

However, although quiescent volcanoes attract many people with their beauty, they can inflict tremendous damage on people once they erupt. To coexist with volcanoes, residents must be fully prepared for swift evacuation in emergencies such as eruptions, while taking full advantage of the benefits of the volcanoes when they are inactive.

The "Volcanic Disaster Management Guideline for Evacuation after Eruption," created in March 2008, includes a provision for "efforts for volcanic disaster management by using volcano tourism." This provision is aligned with the Geopark principle.

Fig. 2 Geo-tour to the relics of the pyroclastic flow disaster.

7. International UNESCO Conference on Geoparks

The 5th International UNESCO Conference on Geoparks was held in Shimabara from 12 to 15 May 2012, with about 600 registered participants from a record 31 countries and territories. A total of about 5,300 people—well exceeding the initial estimate—participated in the Conference, including the civic forum.

The biennial international conference, which is sponsored by the Global Geoparks Network, provides an opportunity for a broad range of people, including researchers, administrative officials, Geopark operators, and the public, who come from various fields such as earth science, environmental protection, disaster management, tourism, and the regional economy, to discuss a broad range of Geopark-related topics. It is never an "academic conference" on geology and volcanology.

The Shimabara Conference was aimed at sharing and achieving the goal of the Geopark to "achieve sustainable regional development by protecting important earth-scientific heritage, using the heritage for education, scientific development, and regional tourism as well as for revitalizing regional economies." It was further aimed at improving the quality of each Geopark by communicating and exchanging information through the reporting of activities by Geoparks of the world.

Many children and students, from kindergartens to elementary, junior high, and senior high schools, who bear the responsibility for the future, played important roles in making the Shimabara International Conference an exciting one. The Shimabara Declaration adopted at the closing ceremony stated that "the experience of the Great East Japan Earthquake should be utilized effectively at Geoparks all over the world as an educational tool for people living in regions under threat from nature." The Declaration stressed that "educational programs utilizing Geoparks, which are the Earth's heritage, are the most effective means of understanding how regional societies should live together with nature." The Conference closed by announcing in summary that "the lively discussions at the Conference can be used to further develop global Geoparks and to develop disaster-resilient nations."

We were able to convey to many participants from Japan and abroad the attractive features of Shimabara as a new type of Geopark where people can learn the geological heritage of the Unzendake, including life with the volcano, the culture, the disasters, and the benefits.

Volcanoes bring disasters, but when they are inactive they bring many benefits to people. Geopark activities put together the disasters and the benefits, as well as the history and the culture of the people, to revitalize these regions. However, Geoparks are not only for tourism promotion. Japan is located in a mobile belt and its geology is dynamic. The people of Japan cannot escape from natural disasters, but I believe that Geoparks can act as tools to reduce the damage these disasters can cause.

Practical Example of the Use of a Volcano Hazard Map in 2000 Eruption of the Usu Volcano

– Efforts by the town of Sobetsu for coexistence with ever-changing Earth –

Toshiya TANABE*

1. Introduction

On March 31, 2000, at 13:07, a new crater opened near the national road at the western foot of Usuzan, a volcano in Hokkaido, Japan, and the mountain started to erupt. This was its fourth volcanic eruption in the 20th century.

There were no casualties due to a number of factors; namely, the strong motivation of local residents to learn lessons from past eruptions and prepare for future eruptions, the presence of volcanologists who had been trying to identify Usuzan's eruption characteristics and thus predict eruptions and develop regional disaster management plans, and the launching of educational programs using an Usuzan Volcano Hazard Map published and distributed to all local residents five years before the eruption.

In this report, I describe the first practical case in which a hazard map actually helped to mitigate a volcanic disaster in Japan, in the hope that the lessons from the 2000 eruption can assist in disaster management and mitigation in other regions.

2. Historical sketch of Usu Volcano, and Regional Status

Usuzan is relatively a new volcano formed about 20,000 years ago on the southern rim of the Toya Caldera. The collapse of the volcanic edifice some 7,000 to 8,000 years ago created countless hummocks around the southern foot of the mountain down to Funkawan Bay. As of 2000, nine eruptions had occurred since the mountain resumed erupting in 1663.

Table 1 General history of Usuzan eruptions.

Year (Era)	Eruption location	Pre-eruption tremors	Major activity/ disaster	Dormant period
1663 (Kambun 3)	Summit	3 days before	Ko-Usu lava dome was created. Houses collapsed and were burnt down by heavy ash fall. 5 deaths.	Thousands of years?
Pre-Meiwa eruption	?	?	Unknown	40 years?
1769 (Meiwa 5)	Summit	Yes. Time uncertain	Houses were burnt down by a pyroclastic surge at the S.E. foot.	70 years?
1822 (Bunsei 5)	Summit	3 days before	Ogariyama crypt-dome was formed. A village was destroyed and burnt down by pyroclastic surge at the S.W. 103 deaths, many missing.	52 years
1853 Kaei 6	Summit	10 days before	O-Usu lava dome created, Pyroclastic flow, residents evacuated	31 years
1910 (Meiji 43)	Northern foot	6 days before	Meiji-Shinzan crypt-dome was formed, Steam explosion, crustal movement, 1 death (from volcanic mud flow), ash-fall damage	57 years
1944–1945 (Showa 19-20)	Eastern foot	Half a year before	Showa-Shinzan lava dome was formed. Destruction of houses and railways due to crustal movements. 1 death (infant: suffocated by ash fall, digestive organ ailment), damage from eruption products	33 years
1977–1978 (Showa 52-53)	Summit	32 hours before	Usuzan-Shinzan crypt-dome was formed. Destruction of fertile lands, forests and constructions by pyroclastic falls, crustal movemens . People were 3 deaths (including 1 missing) from volcanic lahar.	32 years
2000 (Heisei 12)	Western foot	4 days before	2000 crypt-dome was formed, Destruction of houses and roads by crustal movements and volcanic rocks. Low-temperature pyroclastic flow.	22 years

* Sobetsu Town Board of Education.

Photo 1 Left: The Showa-Shinzan Eruption Reenactment Fireworks Festival.
August 6, 1977 (Saturday) From 20:30
Right: The eruption occurred about half a day after the festival.
Photo by Saburo Mimatsu at 9:12 on Sunday, August 7

Before the eruption in 1977, local people tended to shun disaster management discussions because they regarded such discussions as alarmist. On August 6, the night before the eruption in 1977, the Sobetsu Town Office, amid volcanic tremors, held the Showa-Shinzan Eruption Reenactment Fireworks Festival (Showa-Shinzan, literally, “Showa New Mountain,” is a volcanic lava dome adjacent to Usuzan). Fortunately, at 9:12 the next morning, when the eruption began, there were few tourists in the area and there were no casualties in the initial stages. However, there is no doubt that a disaster could have easily occurred. The lessons learned from the eruption served as the initial step in promoting education programs in normal times.

3. Efforts during Normal Periods: Disaster Prevention Education and Hazard Map

In 1982, immediately after the volcanic activity that had started in 1977 subsided, the Sobetsu Town Board of Education, with the cooperation of Hokkaido University, sponsored the establishment and operation of the Hokkaido Citizens’ College jointly with the Hokkaido Prefectural Board of Education.

A social education project, entitled Learning from Regional Disaster Environments, was inaugurated in 1983. This included a Local History Seminar for Children (sponsored by the Sobetsu Town Board of Education). Project participants went into the field near active volcanoes to hear experts’ views and opinions on the gifts of nature and on the disasters.

From 1993 to 1995, a series of events commemorating the 50th anniversary of the formation of Showa-Shinzan were held by local volunteers. As part of these events, the Sobetsu Town Office, a town with a population of only 3,500, sponsored an International Workshop on Volcanoes

Photo 2 Local History Seminar for Children, held by Sobetsu Town Board of Education.

Fig. 1 Usuzan Volcano Hazard Map
(Date City, Abuta Town, Sobetsu Town, etc., published in September 1995)

(1995 Volcano Conference). A hazard map was published and distributed to all local residents in September 1995.

The Usuzan Volcano Hazard Map is printed on both sides of an A1 sheet of paper and folded to A4 size. Printed on the front are the cover, the eruption history, signs of an eruption, volcano information, and rules of conduct after an eruption, while the back contains the hazard map and information on types of disasters.

In 1998, the Sobetsu Town Office published its own hazard map, called “Preparation for Disasters,” and distributed it to all of the town’s residents. It also provided administrative information, including a series of tips on volcanic disasters, in the monthly town gazette.

Through these projects including the publication of hazard maps, the local residents gained an accurate understanding of Usuzan and bonds of trust were forged between the experts and government and among local residents, thus facilitating the evacuation of the residents before the eruption.

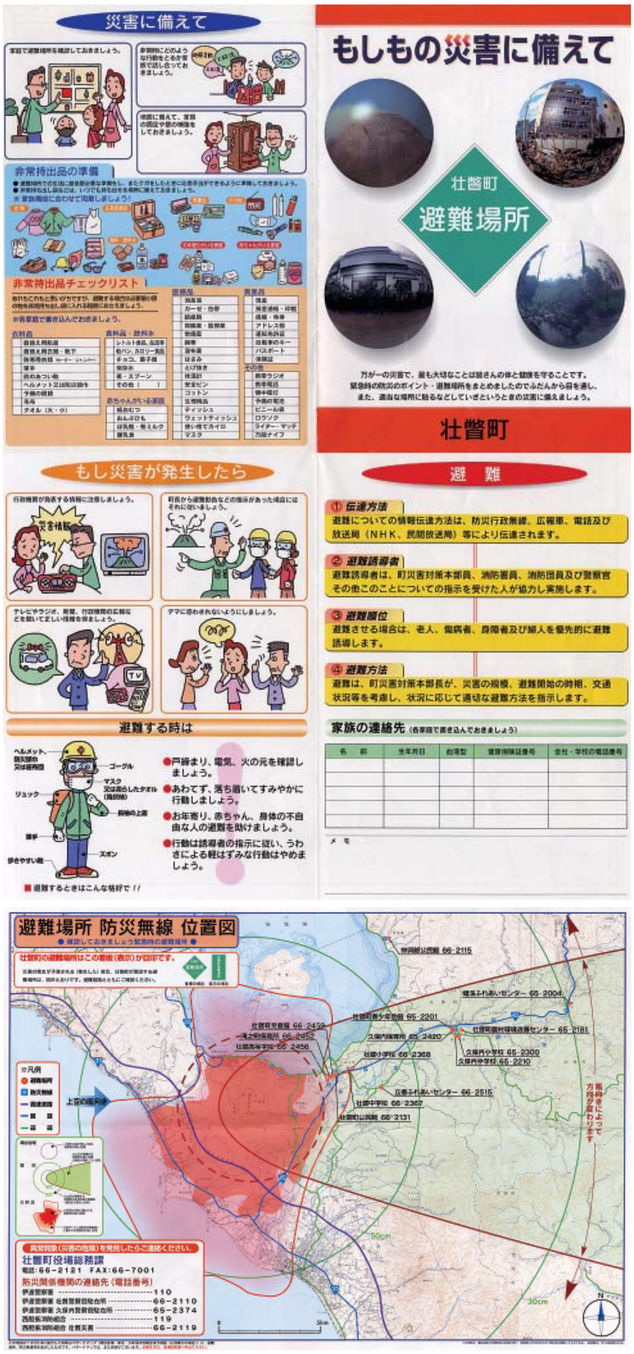

Fig. 2 Sobetsu Town Hazard Map, “Preparation for Disasters” (Published in March 1998 by Sobetsu Town Office).

4. Emergency Response of 2000 Eruption of the Usu Volcano

The crater at the western foot of Usuzan started to erupt on March 31, 2000. A group of craters was formed the following day (April 1) at the northwestern foot of the mountain. Volcanic activity was observed from the very beginning of the volcanic tremors on March 27 by the Japan Meteorological Agency and the Usu Volcano Observatory of Hokkaido University and was reported to the relevant local governments. On March 28, each local government established a disaster management headquarters.

When the emergency volcanic alert (i.e., warning) was issued at 11:10 on March 29, three local governments, on the basis of expert advice, rapidly instigated a series of measures, including issuing evacuation orders, providing evacuation guidance, and installing evacuation shelters. About 10,000 residents were evacuated before the eruption without any casualties, thanks to proper explanations and information on volcanic activity provided by the experts.

Photo 3 Apartments close to the crater (Photo by Dr. Hiromu Okada).

4.1 Roles of Hazard Map and Evacuation Recommendation/ Order

Volcanic activity is a phenomenon that occurs underground and is difficult to predict. The expert advice and the hazard map, which was created from an aggregation of scientific knowledge, played important roles in the implementation of a series of evacuation measures and in providing information to local residents while the local governments were having difficulty making administrative decisions.

The evacuation measures were taken in stages and were based on volcanologists advice and hazard map. The stages encompassed the period from calling for voluntary evacuation to recommending and ordering evacuation.

As the first eruption, at 13:07 on March 31, occurred at the crater at the western foot of the mountain, a decision to expand the evacuation order zone was made on the basis of the hazard map.

Photo 4 Volcano expert using the hazard map.

4.2 Hazard Evaluation and Flexible Lifting of Evacuation Order

Experts from the Usu Subcommittee of the Coordinating Committee for Prediction of Volcanic Eruptions and Hokkaido University evaluated the hazardous areas and made decisions regarding brief visits home by residents and the gradual and flexible lifting of the evacuation order.

It was extremely difficult to predict and depict on the map the hazard (or safety) levels. This was implemented by taking into consideration the predicted volcanic activity, the terrain, the weather, and the wind direction according to the changes in volcanic activity.

Henceforth, it will be necessary to develop a real-time hazard map that can quickly display the results of predictions entered into a computer. It is also necessary to construct an information technology-based information-sharing system.

4.3 Resumption of Tourism and Development of Safety Guidelines

The evacuation order zone was gradually changed as the volcanic activity of Usuzan repeatedly intensified and subsided. Safety guidelines were developed for the resumption of tourism, and the Usuzan Volcano Information Map was published by Sobetsu Town Office in Japanese and English for tourists on May 2000.

Fig. 3 "Usuzan Volcano Information Map by Sobetsu Town" for tourists.
Two versions were created: an A4 map for guest rooms and a B2 map for building entrances (published in May 2000 by Sobetsu Town Office).

4.4 Revision of Hazard Map

The predictions of the eruptions at the foot of the mountain were reviewed on the basis of the experience of the 2000 eruption, and in 2002 a revised hazard map was published and distributed to all residents in the vicinity of Usuzan. The map is printed on both sides of a sheet of A3 paper. The volume of information provided has been kept to a minimum. Detailed volcanic information is supplied in guidebooks published on the same time.

Fig. 4 Usuzan Volcano Hazard Map, 2002 Edition
(Date City, Abuta Town, Sobetsu Town, etc., published in 2002).
Printed on both sides of A3 paper (left: front, right: back).

5. Development of the Town by Determining Land Use According to the Hazard Map

The 2000 eruption was very small, but many public facilities, including the core disaster management base (fire station headquarters), were damaged.

On the basis of the hazard map, the municipal governments incorporated land use into its reconstruction plans and promoted measures aimed at developing a town in which a potential disaster would be mitigated by relocating service facilities such as elementary schools and hospitals to safer areas; this had been a major issue since the 1977 eruption.

In addition, the municipal governments are developing a volcanic disaster-resilient social infrastructure. This includes the establishment of transportation networks and core disaster-management bases using the hazard map information as an important decision-making tool.

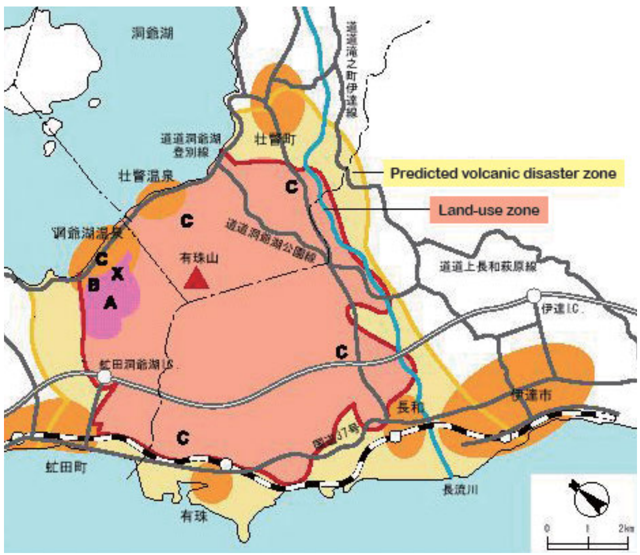

Fig. 5 Land-Use Zone Map (Basic Guidelines for Reconstruction Planning) March 2001.

6. Conclusion: For Making a Culture of Social Safety

In this report, I mainly describe the usefulness of the hazard map on the basis of my experience, as an official of local municipality office who has actually used the map to respond to a disaster. It is also important to understand that people should take actions based on their own proactive decisions, because true disaster management cannot be achieved by leaving one's own safety to others.

The development of human resources through education emphasizing an understanding of nature and the long history of the Earth is the only way to develop a sustainable society that can coexist with natural disasters on the Japanese archipelago, where many types of natural disaster occur frequently.

Many of the cases in which risks were averted in large-scale disasters, including the evacuations before the 2000 Usuzan eruption and the 2011 Great East Japan Earthquake, were the result of educational programs implemented thoroughly and repeatedly and the outcome of efforts by the academic experts, teachers, and regional leaders involved in such programs.

I believe it is important to establish a culture of safety in which, in addition to the social education field, schools can provide more systematic and well-prepared disaster education programs based on the National Curriculum Standards for Schools.

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Photo 5 The Local History Seminar for Children, sponsored by the Sobetsu Town Board of Education, was inaugurated in 1983 to impart accurate knowledge of volcanoes and natural disasters through experience-based learning.

Problems Associated with Activity Assessment, Dissemination of Information, and Disaster Response During the 2000 Eruption of Miyakejima

Hidefumi WATANABE*

1. Introduction

Volcanic hazard mitigation requires mobilization of observational data and volcanological knowledge to achieve accurate assessment of volcanic activity, dissemination of volcanic information, and rapid response. We saw serious problems in achieving all of these objectives during the explosive eruptions associated with the formation of a caldera and large volumes of volcanic gas emissions in the Miyakejima 2000 eruption. That year I was closely involved in volcanic activity assessment as Chairman of the Izu Subcommittee, Coordinating Committee for Prediction of Volcanic Eruptions. In this paper, I will detail the challenges and the lessons learned by working through these steps of activity assessment, dissemination of information, and response in dealing with the major activity of Miyakejima that was beyond reckoning.

2. History of Volcanic Activity on Miyakejima

A volcano erupted on Miyakejima some 2,500 years ago that formed a caldera at the summit, followed by eruptions from flank and summit craters that spewed out a vast amount of tephra and ash. However, since 1469 there has been little evidence of explosive emissions of ash from the summit crater, although flank fissure eruptions continued to occur every few decades or so. In recent times, eruptions continue to occur on Miyakejima about every 20 years, including an eruption in 1983, the most recent eruption prior to 2000. None of these eruptions in recent centuries have been particularly explosive, and whatever damage occurred was mostly caused by lava flows.

3. Advance Preparation for the 2000 Eruption

3.1 Detection of Precursors to the Eruption

Repeated leveling measurements in the years since the 1983 eruption revealed that, after subsiding during the 1983 eruption, the southwest part of the Miyakejima island had continued to uplift. Miyakejima was subjected to intensive comprehensive observation in 1990, including the first use of GPS, in order to identify the location of the deformation source. Systematic re-measurement by intensive observation in 1995 revealed the summit had inflated significantly, particularly on the south flank, and the source of the deformation was estimated at a depth of 9.5 km (Mikada, *et al.*, 1996). GPS observations continued, and an inversion of the GPS and leveling data in 1997-99, revealed the source of the inflation as estimated to be 2 km southwest of the summit and 9.5 km below the surface (Nishimura, *et al.*, 2002). These results were in line with relative uplift of the southwestern part of the island found by leveling measurements after the 1983 eruption, and clearly captured the process of magma accumulation in the Miyakejima for the first time. We also learned from a network for observing geomagnetic total intensity covering the island that shallow subsurface temperatures were rising on the south flank of the summit (Sasai, *et al.*, 2001). While we could have detected these precursors, no one anticipated the 2000 eruption until the sudden intrusion of magma that began on June 26, 2000, accompanied by a swarm of earthquakes and ground deformation.

3.2 Creating Hazard Maps and Disaster Management

Many of the residents of Miyake Village have experienced eruptions in the past and are thus well aware of the need for preparedness for volcanic disasters. Based on areas affected in the past, Miyake Village produced “Miyakejima volcanic hazard map” in 1994 and distributed copies to all the local residents. I would note that the 1994 hazard maps make no mention of the kinds of high-risk phenomena that occur infrequently such as caldera formation, volcanic bombs reaching to the volcano foot, heavy ash falls causing mudflows, and large gas emissions.

The community remembers the disastrous eruption of October 3, 1983 as Miyake Village Disaster Prevention Day, when the entire community participates in evacuation exercises and drills. The well-organized evacuation of residents from harm’s way after the magma intrusion of June 26, 2000 can largely be attributed to these drills. After the 1983 eruption, a four-party council consisting of key local entities with an interest in disaster

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prevention—Miyake Village, Miyake Subprefecture, Miyakejima Weather Station, and Miyakejima Police Department—was established and continued to meet regularly over the years. Thanks to the four-party council, the communication system was well developed, so the initial response to the eruption in 2000 went smoothly.

4. Activity Assessment and Dissemination of Information during the Eruption Developments

The Izu Subcommittee of the Coordinating Committee for Prediction of Volcanic Eruptions (CCPVE) met frequently as the volcanic situation on Miyakejima unfolded to update our activity assessments based on comprehensive consideration of observation and survey results. The Izu Subcommittee met a total of 19 times between June 26, 2000, the day the Miyakejima came to life, and October 6, 2000, and the Subcommittee's observation results are published in the form of a Comment advisories. In the rest of this section, I present an overview and some of the problems associated with the Izu Subcommittee's assessment of the eruption sequence and information dissemination.

4.1 From Seismic Precursors to Magma Intrusion on West Side of the Island

The initial phase of seismic activity began on June 26, 2000 when we detected, by tracking the hypocenter and ground deformation, that magma had migrated from deep beneath the island up within the south flank of the volcano , and sometime between 10:00 PM that night and the next day (June 27), magma had migrated to the northwest side of the mountain. Sea surface discoloration was observed off the west coast on June 27, which was attributed to small eruptions on the seabed. Then there was a prolonged lull when seismic activity and crustal deformation on the island tapered off, so on June 29 the Subcommittee announced that there was low probability of an eruption on the island or in coastal waters, and some residents who had been evacuated from the southern part of the island began to go home. This seemed like a reasonable assessment at the time considering that, aside from some shallow phenomena directly below the summit that were apparently related to the collapse of the summit, all signs pointed to a weakening of seismic activity: seismicity of the island as a whole had decreased and the north-south extension associated with contraction in the east and a dyke intrusion on west had leveled off.

4.2 Summit Collapse and Large-Scale Phreato / Phreatomagmatic Explosions

Shallow earthquakes, first detected on July 4 below the summit, had become significantly larger by July 8. Tremors also gradually increased from around noon, and that evening there was a small eruption at the summit. The next day, on July 9, an onsite survey team confirmed that a large pit crater had opened up inside the summit caldera. It was thought that the pit crater marked an empty cavity that was left when magma migrated from the summit area and intruded to the west, a conclusion supported by later analysis of magnetic and gravity observation data.

The weakening contraction of the island from June 27 to July 7 accelerated just before the collapse on July 8, then continued at about the same rate until the climactic eruption on August 18. The massive collapse might have resumed the magma flow beneath Miyakejima to the west, but the significance of these events was not fully recognized at the time. Even today, the mechanical causal relationship between the prolonged deflation of Miyakejima after the collapse of the summit and opening deformation that occurred between Miyakejima and Kozushima is poorly understood. A better quantitative understanding of the mechanical causal relationship between the magma migration from under Miyakejima to the west and the opening deformation, should contribute to our understanding and ability to predict such phenomena in future at Miykejima and other volcanoes exhibiting similar events.

Another aspect difficult to understand at the time was the recurrent phreato and phreatomagmatic explosions as the collapse of the summit caldera continued. The continuing volcano contraction and the decreasing gravity would normally indicate that magma is descending, but in this case, eruptive activity from the caldera became more intense, a climactic eruption occurred on August 18, and a pyroclastic flow-like phenomena occurred on August 29. Consequently, we were not able to make public helpful information that would have certainly supported a rapid response before the event occurred. This can be attributed to the fact that eruption prediction (volcanology) research as well as surveillance systems are still inadequate.

Generally, we assume that magma migrates upwards via a volcanic conduit or into shallow subsurface and produces a phreato/phreatomagmatic explosion when the magma comes into contact with groundwater or seawater. As in the Izu-Oshima summit eruption in 1986, we suppose that a large-scale phreato or phreatomagmatic explosion rarely happens when “drain-back” of magma occurs. Yet the examples of Kilauea (1790, 1924) and Izu-Oshima (5th century) show that large-scale phreato/phreatomagmatic explosions are more likely to occur when linked to a massive collapse. In the case of Miyakejima, it is thought the phreatomagmatic explosions resulted from continued large-scale collapse beneath the summit caldera, which opened the way for high-temperature material deep below the summit to come in contact with groundwater. If we had not only a general understanding of fundamental processes of phreatic explosion but a better understanding of the mechanisms and nature of these large-scale events, we might have been able to recognize in advance the potential danger of massive phreato and phreatomagmatic explosions as large-scale collapse continued after July 8. On August 21, the Subcommittee held discussions focusing exclusively on explosive phenomena accompanying a large-scale collapse. Another factor preventing a correct assessment of the eruption of August 18 and subsequent quick response was that the eruption occurred at night, and aside from the local weather station, we did not have an observation and research station onsite to quickly assess the situation. This meant that we could not verify whether volcanic rock fragments might fall on villages at the foot of the volcano, with all the potential risk to life that entails. Local residents of the island posted valuable information on the Internet, but we were not able to use these sources. Considering that volcanologists may not be physically present at volcano sites (especially in the recent years when Japan Meteorological Agency and university observation facilities are being consolidated), we must put systems in place that will enable us to quickly gather informations from local people on the scene, and to verify and assess them.

4.3 Large-Volume Degassing

Ironically, all the observational data collected after the climactic eruption on August 18, including ground deformation, gravity, and volcanic gas data, suggested that magma had begun to migrate up the summit conduit after the eruption. Large amounts of volcanic gas discharge have continued from September 2000 to the present, which are thought to be maintained by conduit magma convection, but since we have little idea of the source of the gas supply (depth and size of the magma chamber directly beneath the island or a magma pool that may exist at even deeper lower crust), we are unable to predict how long the large amount discharge of volcanic gas might continue.

5. Volcanic Information and Disaster Response

Table 1 shows a summary overview of the sequence of volcanic activities of Miyakejima starting on June 26, 2000, volcano related information, and the disaster response.

On June 26, a comment from the Izu Subcommittee advising that “volcanic activity had begun on Miyakejima and there was a possibility of an eruption” was released by the Japan Meteorological Agency as an emergency volcano advisory. Upon receiving this advisory, Miyake Village and Tokyo Metropolitan Government convened Disaster Response Headquarters, which immediately began organizing disaster response measures. Subsequently, upon receiving an “activity end” advisory from the Izu Subcommittee on June 29, Tokyo Metropolitan Government and Miyake Village disbanded their Disaster Response Headquarters.

In dealing with the progressive collapse of the caldera and succession of summit explosions after July 8, the Miyake Village Disaster Response Headquarters reconvened to organize repeated evacuations from the dangerous parts of the island in response. However, Tokyo Metropolitan Government did not reconvene its Disaster Response Headquarters until after the summit explosions and low-temperature pyroclastic flow on August 29. During this period, the dissemination of volcano information and the response both came after volcanic activity had already begun, but fortunately there were no casualties.

6. Problems with Disseminating Volcano Information and Disaster Response

When Miyakejima erupted in 2000, a number of serious problems were evident in the assessment of volcanic activity, the dissemination of information, and the response. Here we will take a closer look at the three main causes of these problems.

First, the lack of an onsite observation station except for the local weather station and insufficient manpower caused a delay in gathering information, and this made it impossible to rapidly assess volcanic activities on the island (this was particularly true for the climactic eruption on August 18). In the recent major eruptions in Japan (Uszan 1977-78, Unzendake 1990-95, Uszan 2000, and so on), the onsite volcano observatories of national universities played major roles in conducting extensive observation and gathering of information. This raises concern that it may be difficult to grasp rapidly the developments of volcanic activity associated with future major eruptions in the Izu Islands or the Ryukyu Islands (Nansei-shoto) where there are no nearby observation-research stations.

Second, the relevant eruption reference scenarios (diagrams showing longitudinal progression of volcanic events that could occur) needed to accurately assess volcanic activity based on observational surveys had not been created. This was a factor in our inability to predict the escalation of the eruptive activity accompanying the collapse of the summit caldera from July 8 to August 29, 2000. Scenarios including theoretically possible events that can be referenced as needed would be especially useful for unexpected styles of eruptions that are infrequent throughout volcano history but cause severe disasters.

Third is the structural problem of the system linking dissemination of volcano information and disaster response. The Coordinating Committee for Prediction of Volcanic Eruptions (CCPVE) is a private advisory body of the Director-General of the Japan Meteorological Agency, and its specific duties as stipulated in the committee's operating guidelines are to “make an overall assessment of volcanic events when eruptions occur, and contribute to disaster prevention by improving the quality of volcano information.” The primary emphasis of the committee's work so far has focused on assessment of volcanic activity based on observational data. Most members of the committee are professional volcanologists, intensely interested in volcanoes per se, but not so well trained to provide information on how best to respond to volcanic disasters. Especially when we have a succession of unexpected events such as the eruption of Miyakejima in 2000, volcanologists are keen to focus all their efforts on prediction of volcanic eruptions based on monitoring volcanic events and understanding of eruption mechanisms, and this takes a great deal of time. They are less inclined to address important issues of disaster response.

While a number of non-volcanologists from disaster management organizations and other disaster management personnel currently sit on the Coordinating Committee for Prediction of Volcanic Eruptions, there is no guaranteeing that they will play their own roles adequately in the committee. We should at least provide a certain amount of time to consider the disaster response implications of observation data as part of the overall assessment of volcanic activity toward the end of meetings.

Up to now, important roles in disaster response have been held by personnel from local volcano observatories (so-called home doctors) from a sense of personal responsibility, by the local Disaster Response Headquarters consisting of various disaster management organizations, and various committees of professionals organized by local governments as required. After the Miyakejima eruption in 2000, Tokyo Metropolitan Government and Miyake Village organized a number of committees to assist with disaster response (Tokyo Metropolitan Government: the Miyakejima Volcanic Activity Research Committee, September 26, 2000; Investigative Committee Regarding Miyakejima Volcanic Gas (established in cooperation with the Cabinet Office), September 30, 2002; Miyake Village: Miyake Village Volcanic Gases Safety and Countermeasures Research Committee, March 28, 2003; Miyake Village Experts Council for Security and Countermeasures, July 1, 2004).

Also required are people whose primary role is to make decisions from a disaster response perspective as well as a system for including those opinions. In the future, we expect to see marked improvement in volcanic activity assessment capabilities of personnel associated with the Meteorological Agency’s Volcano Monitoring Information Center, as well as mastery of disaster response issues through experience and exchanges with local government disaster management personnel from communities located near volcanoes. Accumulation of experiences and regular exchanges between personnel in the Volcano Monitoring Information Center (Japan Meteorological Agency) and personnel in disaster management organizations and local government hold the key to success or failure of rapid volcanic activity assessment and disaster response. For this reason, it is extremely important that the “Volcano Disaster Management Councils” (consisting of the Japan Meteorological Agency, local government disaster management personnel, related disaster management organizations, volcanologists, and so on), as detailed in Japan’s “Basic Plan for Disaster Prevention,” become firmly established and fulfill their intended capabilities.

Table 1 Miyakejima eruption sequence in 2000, volcano information dissemination and disaster response.

Date	Phenomena	Volcano information (Japan Meteorological Agency, CCPVE)	Disaster response (Tokyo Metropolitan Government and Miyake Village)
June 26	Earthquake swarm and ground deformation began	High probability of eruption on south Miyakejima Magma migrated from summit to southwest	Miyake Village convened Disaster Response Headquarters Evacuation advisory to south Miyakejima
June 27	Small seabed eruptions west of Miyakejima	Probability of eruptions in west sea area and west flank of volcano Low probability of eruptions in east Miyakejima	Tokyo Metropolitan Government convened Disaster Response Headquarters Evacuation advisory to west Miyakejima
June 28		Probability of eruptions in sea to the west and on the coast	
June 29		Volcanic activity declined, no probability of eruptions	Cancel evacuation advisory
		Warning of earthquake activity in sea to the west	Tokyo Metropolitan Government and Miyake Village disbanded Disaster Response Headquarters
July 4	Summit seismic tremors began		
July 8	Summit small eruptions, caldera collapses	Probability that summit small eruptions will continue	Miyake Village convened Disaster Response Headquarters (disbanded on the June 29)
July 14	Summit explosion, volcanic plumes 1.5 km high	Summit phreatic explosion, ashfall warning downwind	Miyake Village convened Disaster Response Headquarters Evacuation advisory for east Miyakejima
July 15	Summit explosion		
August 10	Summit explosion, volcanic plumes 3 km high	Probability of future summit explosions, ashfall and mudflow warnings	Evacuation advisory for eastern part of Miyakejima
August 18	Summit explosion, volcanic plumes 14 km high	Largest explosion so far	Residents elect to evacuate on their own
	Volcanic bombs reached foot of the mountain	Probability of future summit explosions, ashfall and mudflow warnings	Evacuation advisory for west, north, and east parts of Miyakejima
August 21		Probability of future summit explosions, volcanic bombs and ashfall warnings	
August 24		Prediction of eruptions is difficult during this period Probability of future summit explosions, volcanic bombs and ashfall warnings	
August 29	Summit explosion, volcanic plumes 8 km high		Tokyo Metropolitan Government convened Disaster Response Headquarters
	Low-temperature slow pyroclastic flow to foot of the volcano		Establish national Major Disaster Management Headquarters Children and elderly evacuated from the island
August 31		Probability of larger eruptions, pyroclastic flows Volcanic bombs, mudflow and volcanic gas warnings	
September 1-3, 2000			Order to evacuate entire island
End of August	Beginning of large amounts of volcanic gas emission from summit		
October 6		Volume of volcanic gas emissions increased from late August	
		Low probability of explosive eruptions and pyroclastic flow	
		Volcanic gas alarms required	

Volcano Disaster Mitigation Research Initiatives at National Research Institute for Earth Science and Disaster Prevention

Toshikazu TANADA* and Motoo UKAWA**

1. Introduction

Since becoming an independent agency in 2001, the National Research Institute for Earth Science and Disaster Prevention (NIED) has followed five-year medium-term research plans in addressing the safety and security of Japan's citizens.

The NIED is pursuing three key research initiatives with the goal of developing a reliable way to predict volcanic eruptions and contribute to volcanic disaster mitigation: strengthen the nation's volcanic observation network for monitoring volcanic activity, upgrade remote sensing capabilities to track volcanic activity, and develop simulation techniques to predict volcanic activity and volcanic hazards.

This report provides an overview of these initiatives and the progress achieved so far over the past seven years (i.e., during the 2nd five-year research plan (2005-2010) and the first two years of the 3rd five-year research plan (2011-2016)). For more detailed descriptions of these developments, please refer to the individual websites of the NIED researchers that can be accessed here: http://vweb2.geo.bosai.go.jp/intra/member/index.html).

2. Strengthen the Volcanic Observation Network for Monitoring Volcanic Activity

Based on the volcanic eruption prediction plan, NIED extended the Volcano Observation Network to cover Ioto in the early 1980s; Izu-Oshima in the late 1980s; and Miyakejima, Fujisan, and Nasudake in the 1990s. Deployment plans for the volcano observation research stations were carefully considered by the Volcano Subcommittee of the Geodesy Division of the Science and Technology Council in 2008, and basic observational facilities were built up at volcanoes with high research potential by the NIED: volcanoes showing a high degree of activity, volcanoes that are currently appear dormant but show signs of explosive activity, and so on. In accordance with this policy, NIED constructed volcano observation stations at eight sites on a total of five volcanoes between 2009 and 2010—Asosan, Uszan, Iwatesan, Asamayama, and Kirishimayama—and one station at Kusatsu-Shiranesan in 2011. In 2013, NIED will continue to observe and monitor a total of 11 volcanoes including the six just mentioned (**Fig. 1**).

Fig. 1 Volcano Observation Stations deployed by NIED.

Fig. 2 illustrates a typical volcano observation station. As one can see, stations are equipped with short-period seismographs, tiltmeters, GPS, broadband seismographs, barometers, and precipitation meters. The combination of short-period seismograph and tiltmeter is functionally equivalent to a high sensitivity seismograph with a tiltmeter, and successfully picked up precursory signals of the recent eruptions on Izu-Oshima and Miyakejima. All these seismic and volcano-related data are continuously transmitted back to NIED 24 hours a day by using an IP

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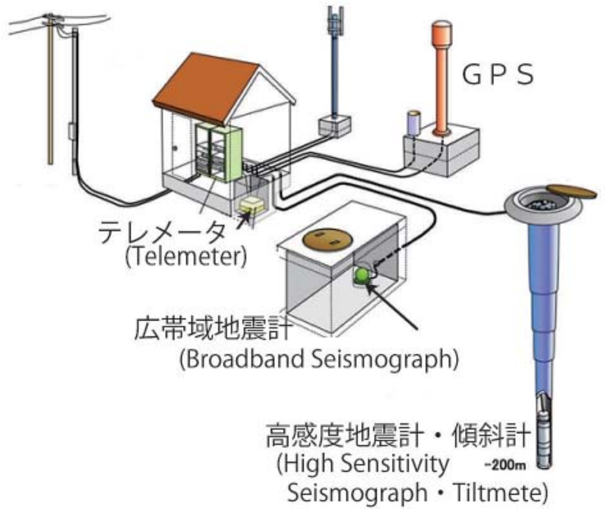

Fig. 2 Schematic of Volcano Observation Station.

virtual private network (IP-VPN) over NTT circuits.

The integrated data are processed continuously 24 hours a day for automatic hypocenter detection, automatic anomaly detection of crustal deformation data, and automatic modeling on systems developed by NIED. This processing system performs very well as evidenced by its success in detecting crustal deformation anomalies and modeling the Kirishimayama and the Izu-Tobu volcano group, and the observational data are periodically reported to the Japan Meteorological Agency's Volcanic Eruption Prediction Liaison Council for use in evaluating volcanic activity. All this observational data—continuous waveform images, average short-period seismograph amplitude changes at 1-minute intervals, and tiltmeter change charts—can be viewed on line at the Visualization System for Volcanic Activity (VIVA) website (http://vivaweb2.bosai.go.jp/viva/v_index.html). Moreover, beginning in January 2013, earthquake and tiltmeter data will be assessable on the Volcanic Observation Network (V-net) site (http://www.vnet.bosai.go.jp/), including a statement of purpose and download instructions. At present in August 2012, both of these sites are getting between 2,000-4,000 page visits a day.

The volcano observation data are sent directly to the Japan Meteorological Agency, the agency responsible for monitoring volcanic activity, over an IP-VPN link in accordance with an agreement signed on February 1, 2011 to exchange volcano observation data. The data are also provided to academic volcano research institutes through the University of Tokyo Earthquake Research Institute. In addition, the NIED periodically conducts geochemical analysis of ground water and thermal water around volcanoes, and measures hydrogen and oxygen isotope ratios to check for the presence of magmatic water.

3. Remote Sensing Capabilities to Track Volcanic Activity

The NIED has developed remote sensing technologies and new analytical methods for monitoring and assessing volcanic activity. Starting with the development of a remote high-spatial-resolution thermal imaging system to assess volcanic thermal activity in the 1980s, the 1st generation VAM-90A, a scanning spectrometer with nine spectral bands, was completed in 1990, and operated until 2007. This was followed by a 2nd generation Airborne Radiative Transfer Spectral Scanner (ARTS) for volcano observation that was put into service in 2008. The spatial resolution of ARTS is capable of identifying features measuring 0.5-to-1 square meter from altitudes ranging from 700 to 6,500 meters. The ARTS imaging spectrometer detects light energy (radiance) from visible to infrared covering wavelengths for up to 421 bands, which enables ARTS the measure surface temperatures from -20 to 1,200 °C as well as volcanic gas (SO2 gas) concentrations (**Fig. 3**). Through 2010, ARTS was used to successfully measure approximately 50 scenes from Asamayama and six other active volcanoes. For example, just after Asamayama eruption on February 2, 2009, we were able to evaluate the thermal activity, that is, it had not expanded inside the crater by comparing measured results before the eruption (November 2008) and after the eruption (February 21, 2009). ARTS was also used to successfully estimate the surface concentration density of volcanic gases (sulfur dioxide gas) for three volcanoes: Sakurajima, Asosan, and Miyakejima.

Another valuable tool is synthetic aperture radar (SAR) for obtaining high-density crustal deformation data, which are invaluable for evaluating complex behavior of magma. This research employs a new time-series-based method of analysis called InSAR that combines SAR images obtained using multiple satellite passes to form interferograms. By reducing noise caused by phase propagation through the atmosphere and troposphere, very high resolution maps of crustal deformation were obtained around the craters of Kirishimayama and Miyakejima volcanoes (**Fig. 3**). Radar is also used to monitor and observe volcanic plumes. Working together with NIED's Storm, Flood and Landslide Research Unit, we employed X-band weather radar operated by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) to analyze the explosive eruption of Sakurajima in 2008 and the eruption of Kirishimayama (Shinmoedake) in 2011. We found that X-band weather radar was fully capable of observing explosive eruptions.

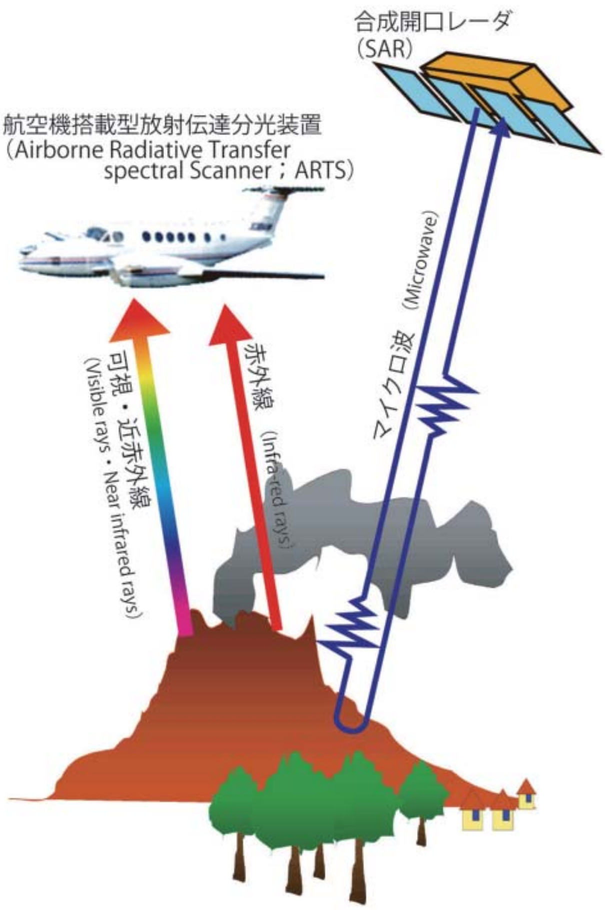

Fig. 3 Volcanic observation by remote sensing.

4. Simulations to Predict Volcanic Activity and Hazards

The NIED has made excellent progress in developing and exploiting simulation methods for assessing volcanic activity and predicting volcanic hazards. For example, we performed a simulation using the distinct element method to model crack growth and magma intrusion in 3D stress fields caused by magma movement, and were thus able to evaluate elastic deformation, plastic deformation (breakage), and stress field changes around the magma. We also developed a method for simulating static stress field changes near volcanoes caused by plate boundary earthquakes in a subduction zone, and an approach that proved very fruitful for evaluating the effects of the magma chamber under Fujisan. Conducting a numerical analysis of the process of gas-liquid two-phase magma moving up the volcanic conduit, we were able to analyze the movement of magma from the magma chamber up the conduit to erupt on the surface by employing a hydrodynamic numerical model. In other words, by developing this time-development model that replicates the transition process from a non-explosive eruption to an explosive eruption, we can successfully simulate the process of pressure change within the volcanic conduit (**Fig. 4**). Simulation is a powerful tool for predicting volcanic hazards. For example, by evaluating mesh-size dependence of topology data and large-scale lava flows, we successfully simulated a scenario lava flow from Sakurajima Showa crater.

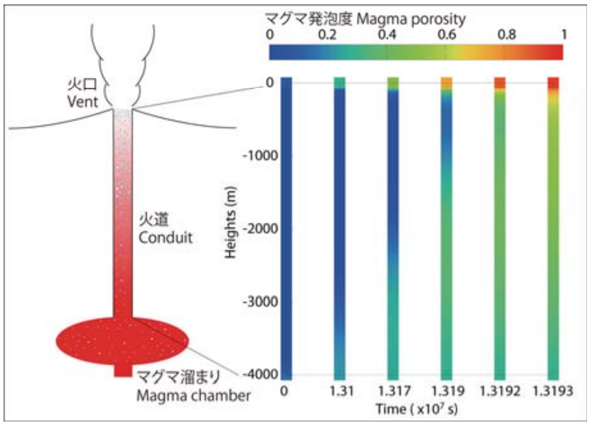

Fig. 4 Simulation of the upward flow of magma in conduit.

5. Research Results and Giving Back to Society

Kirishimayama (Shinmoedake) erupted on January 26, 2011, and is still active as of October 2012. The Volcano Observation Network (V-net) stations mentioned earlier in Section 1 that were deployed on Kirishimayama in 2010 based on the policy outlined in 2008 by the Volcano Subcommittee, Subdivision on Geodesy and Geophysics, Council for Science and Technology proved very useful for capturing the entire process from magma accumulation to eruption. At the same time, analytical results regarding occurrence of earthquakes and location and size of magma chambers that expand as magma accumulates and contract with eruptions are provided to the Coordinating Committee for the Prediction of Volcanic Eruptions and are highly useful for evaluating volcanic activity. The East Shizuoka earthquake (M_{JMA} 6.4) struck at the foot of Fujisan on March 15, 2011. When the earthquake occurred, we were able to infer a fault model from the coseismic crustal deformation and hypocenter distribution observed by NIED's tiltmeter and GPS. Using the simulation program described earlier, we were also able to assess the impact of the Fujisan magma chamber.

6. Pursuing Domestic and International Collaborative Research

When drilling boreholes for tiltmeters and other observation equipment at Volcano Observation Network sites, the entire length of the geologic core samples are collected. These samples are extremely useful for investigating the past history of volcanic activity at sites that cannot be discerned from surface outcrop topography, and are therefore shared with local universities and research labs for further assessment of the geology and petrology of the volcano.

In terms of international collaboration, NIED shares its observational data with the World Organization of Volcano Observatories (WOVO) international database WOVOdat with the goal of sharing knowledge that contributes to the prediction of volcanic eruptions. NIED also collaborates with sister organizations in Indonesia, the Philippines, and Ecuador in building earthquake and volcano observation networks, by archiving data and research about earthquakes and volcanic eruptions, and pursues collaborative studies with the goal of mitigating earthquake and volcanic hazards.

7. Outreach Activities

The NIED is committed to disseminating information that raises peoples' awareness and helps mitigate volcanic hazards. Working together with the NIED Disaster Information Laboratory (DIL) and the Commission on Mitigation of Volcanic Disasters, the Volcanological Society of Japan, a compilation of volcanic hazard maps for Japan was published in 2006. Later, a DVD version of volcanic hazard map collection was created and widely distributed to academic groups and workshops throughout Japan and the world.

The NIED holds an annual Science and Technology Week Open Institute event every April. In order to promote greater understanding and interest in volcanoes among the general public, the event features a video presented by the Volcano Research Group showing an active volcanic eruption, an indoor display of cinder, lava, and other forms of volcanic rock, and an outdoor experiment enabling visitors to experience first-hand what an eruption is like. The NIED also hosts a number of disaster prevention educational events for elementary and middle school age children including Tsukuba Chibikko Hakase (for younger children) and a Summer Science Camp.

In addition, since 2003 the NIED has cosponsored an biennial International Workshop with the Yamanashi Institute of Environmental Sciences that focuses on polices and measures for mitigating volcanic hazards. As one can tell from the themes covered at the last few workshops—"Learn from attempted eruption events" (2007), "Crisis management in the event of large-scale eruptions (level 4-5)" (2009), and "Real-time assessment and government response to volcanic disasters" (2011)—the International Workshop is not just for professional volcanologists from Japan and elsewhere. Recently a local government official was invited to speak at the Workshop, and discussion usually centers on the current state and challenges of volcanic hazard mitigation.

NIED has also put up a website called Learn more about volcano hazards! (http://www.bosai.go.jp/realtime/volcano/detail01.html) for relative beginners that introduces a wide range of references and resources organized into three subsections: Books, Instructional Materials, and Professional websites. Here I would call attention to two pamphlets available in the Instructional Materials section that are offered in collaboration with the International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI) and other organizations: "Health consequences of volcanic ash" and "Prepare for falling ash." These two brochures were widely distributed through local government and mass media channels after Kirishimayama (Shinmoedake) erupted in 2011, and are filled with useful and practical advice.

8. Conclusions

This paper has provided a broad overview of the volcano preparedness and management initiatives and research achievements at NIED over these past ten years. Over the decade, NIED deployed a Volcanic Observation Network that circulates data based on remote sensing capability, developed innovative new methods of analysis, and introduced simulation techniques used to validate eruption theories. At the same time, the NIED developed observational techniques that markedly improve our ability to predict and explain volcanic phenomena. NIED remains committed to mitigate volcanic hazards, and will continue to gather observational data, develop new technologies for tracking and studying volcanic activity, refine volcanic eruption theory, and develop innovative simulation models.

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Japan's Volcanic Disaster Mitigation Initiatives: Activities of the Commission on Mitigation of Volcanic Disasters, the Volcanological Society of Japan

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1. Introduction

The Commission on Mitigation of Volcanic Disasters was organized by the Volcanological Society of Japan (VSJ). This commission was set up as a public forum for members and other stakeholders to exchange ideas and views on wide-ranging topics relating to the mitigation of volcanic disasters, to explore possible solutions to various issues pertaining to volcanic disasters and their mitigation, and to put forward recommendations for the benefit of society. In this paper, we present a broad overview of the objectives of this commission, highlighting some of the activities and achievements of the commission to date. The paper also provides an overview of disaster mitigation topics that have been taken up for consideration by the commission.

2. Activities of the Commission on Mitigation of Volcanic Disasters

Establishment of the Commission on Mitigation of Volcanic Disasters was approved at the 2004 General Meeting of the VSJ. The primary objectives of this commission are summarized as follows (Establishment Proposal, Aramaki, 2004): (1) Assess basic deficiencies regarding preparedness and mitigation of volcanic disasters, explore appropriate measures and methods to solve the shortcomings, and recommend the findings for implementation. (2) Recommend suitable candidates from public and private sectors as disaster mitigation advisors, and promote educational activities by sending these advisors out to lecture upon request. (3) The VSJ itself is also very much involved in developing human resources, instructional materials, and educational activities with the goal of educating people and raising awareness regarding volcanic disaster mitigation.

Adopting the "commission organization" of the International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI), a number of charges were appointed—Shigeo Aramaki, Yasuyuki Miyake, Yoichi Nakamura— to pursue free-reign activities in an easy-going management style. Three subcommittees were initially set up: the Strategy Subcommittee managed by Shigeo Aramaki, the Public Awareness Subcommittee headed by Yasuyuki Miyake, and the Hazard Maps Subcommittee directed by Yoichi Nakamura. In 2008, Eisuke Fujita replaced Yasuyuki Miyake as facilitator. Then in 2012, Hiroshi Yamasato, Kazutaka Mannen, and Koji Ishimine joined the management team. The VSJ holds two regular meeting during the year—one in the spring and the other in the fall—and the fall meetings are a symposium held on site in a district where there is an active volcano and are open to the general public.

Table 1 presents a list of the topics addressed by the commission thus far. As shown on **Table 1**, the themes on mitigation of volcanic disasters range widely including (1) systems for monitoring and observing active volcanoes, (2) volcanic warning and alert levels, (3) disaster management systems in areas with active volcanoes, (4) eruption scenarios and disaster risk assessment, and (5) large-area disaster mitigation when large-scale eruptions occur. Other current topics relating to volcanic disaster mitigation are also taken up from time to time. The fall meetings are public symposiums addressing themes related to the active volcanic areas in which the meetings are held, and the agenda allows as much time as possible for an exchange of ideas and opinions. Diverse opinions and feedback are received from local residents, local government officials, and members of local disaster management organizations, and the discussions are always animated. Abstracts of the recent public symposiums are put up on the VSJ website.

One major achievement of the commission was to hold a symposium on "Volcanic Hazard Map Methodology." The 2004 symposium, supported by Earthquake Research Institute, University of Tokyo, offered a good overview of the process of creating Japan's volcanic hazard maps (disaster mitigation maps) that are made available to the public, and stirred a great deal of discussion. We followed up the next year by putting out a two-volume edition of "Volcano Hazard Maps of Japan." The Commission on Mitigation of Volcanic Disasters then collaborated with the National Research Institute for Earth Science and Disaster

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Table 1 List of Session Topics of the Commission on Mitigation of Volcanic Disasters: from 2004 to 2012.

Monitoring active volcanoes and the role of volcanic information
Active volcano monitoring/observation and volcanic disaster mitigation: Recent initiatives.
Active volcano monitoring/observation and volcanic warnings: What roles do these have in mitigating volcanic disasters?
How evacuation systems related to volcano management countermeasures should be implemented in the event of an eruption
Implementation of volcanic monitoring, eruption predictions, and warnings by the Japan Meteorological Agency (JMA)
Evacuation systems with new volcanic warning and volcanic alert levels when eruptions occur
How well do the new volcanic alarm levels and volcanic warnings work?
Action assignments pertaining to volcanic warning and alarm levels
Reviewing Japan's volcanic disaster mitigation strategy
New framework of volcanic disaster mitigation from the standpoint of current eruption prediction levels
Operation and exchange of information among on-site disaster management headquarters when volcanic disasters occur
Review of the "Volcano Disaster Prevention Guidelines for Evacuation when Eruptions Occur" and efforts to upgrade the Volcano Disaster Management System
Japan's volcanic disaster prevention initiatives and volcanic disaster expert system
Volcanic Eruption Emergency Mitigation Countermeasure Plan of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT)
Role of the Volcanic Eruption Emergency Mitigation Sabo Plan
What is an effective mitigation system for a large-scale volcanic disaster?
How to implement large-area volcanic disaster mitigation when a large eruption occurs
Super-volcanic eruptions and the mitigation strategy
Volcanic disasters from a historical perspective in Japan
What we have learned from the response of the national government to the Great East Japan Earthquake on preparing for large-scale volcanic disasters that exceed expectation
Eruption scenario of Izu-Oshima submitted by the Izu-subcommittee, Coordinating Committee for Prediction of Volcanic Eruptions
Recent progress of discussions on Nasudake eruption scenario
Review of Italy's Bayesian Event Tree (BET) for eruption forecasting
Proposal of Volcanic risk assessment for active volcanic areas in Japan
Study of nationwide volcanic disaster threat assessment
Volcanic disaster mitigation initiatives in the construction industry: Introducing the volcanic hazard risk assessment map system
Volcanic disaster mitigation after the Unzendake 1991 eruption
Unzendake conduit boring project: implementation and lessons
Overview of Kirishima (Shinmoedake) eruption in 2011
Sakurajima activity 2006: Response initiatives and residents' awareness
Volcanic gas safety measures at Miyakejima Island
How has volcanic mitigation changed in Hakoneyama through introduction of volcanic alert levels?
Recent volcanic activity and current volcanic mitigation in Asamayama
Simulation exercises and evacuation drills with map assuming Nasudake eruption
Thoughts on lessons learned based on experience and eruption crisis response in Iwatesan
Historical eruption and disaster mitigations in Hokkaido-Komagatake:
Lessons from Usuzan eruption in 2000
Lessons from volcanic disaster and mitigations of active volcanoes in Hokkaido
Activities of the Crisis & Environment Management Policy Institute
Rebirth of the Aso Volcano Museum
Volcanic observation by Advanced Land Observing Satellite "DAICHI"
Publication of Volcanic Hazard Maps of Japan database, DVD edition
Cities on Volcanoes 5, Shimabara 2007
Aircraft and volcanic ashes at the 2010 eruption of Eyjallajokull
Eruptions of Mt. Vesuvius in Italy and the remains
The 1783 eruption of Asamayama and the remains of volcanic disaster

Prevention (NIED) to develop a database system giving access to high-resolution images of Japan’s volcanic hazard maps (disaster mitigation maps) along with other relevant materials, and has kept the maps and other content regularly updated. A DVD version came out in 2006 entitled “Volcanic Hazard Maps of Japan” that can also be accessed by the general public on the NIED website.

3. Volcanic Disaster Mitigation Issues Addressed Through Commission on Mitigation of Volcanic Disasters Topics

In this section we will introduce some of the discussions relating to topics raised in the Commission on Mitigation of Volcanic Disasters, with additional comments provided by Yoichi Nakamura, one of the Commission charges. Topics covered in other papers are not considered here.

3.1 Volcanic Activity and Disasters in Japan

Since volcanic phenomena are caused by the movement or action of magma, they exhibit a diverse range of characteristics: site locality, precursory signs, diversity and scale of activity, term or length of activity, periodicity of activity, and so on. Therefore, a historical record of volcanic activity and volcanic disasters in the past can serve as a very useful basic resource for disaster mitigation. Studying how best to respond to volcanic disasters based on these historical materials certainly helps implement an effective disaster mitigation system.

A summary overview of the history of volcanic activity and disasters for Japan's 110 active volcanoes over the past 2,000 years has been compiled (Nakamura and Ito, 2012). A total of 1,160 eruptions over the past 2,000 years (a series of eruptions within a short time frame are treated as a single event) have been recorded. Of these, it is found that the 47 active volcanoes constantly monitored by the Japan Meteorological Agency (JMA) account for close to 87% of total eruptive events. Much of the volcanic activity in Japan involves debris that is explosively ejected into the air, so the scale of volcanic eruptions can be measured on the Volcanic Explosivity Index (VEI). **Fig. 1** shows the amount of volcanic activity for different scales of VEI. There is a pronounced increase in the number of recorded VEI 3 and VEI 2 scale events over the past 500 years, and the number of VEI 1 events over the past 150 years. Turning to frequency distribution of volcanic events as a function of eruption scale (**Fig. 2**), the VEI 3 scale events are the most common, and in fact this trend is apparent for active volcanoes the world over for about the past 10,000 years (Siebert *et al.*, 2010). Japan accounts for roughly 15 % of recorded VEI 5 to VEI 2 scale eruptions in the world. Estimating the average frequency of eruptions in Japan for different scale volcanoes, we find that VEI 5 eruptions occur about every 200 years, and VEI 4 scale eruptions take place approximately every 50 years, with little fluctuation over time. VEI 3 and VEI 2 scale eruptions occur at intervals of 18 years and 4 years, respectively, but here we see far greater fluctuations in the intervals between eruptions.

Examining recorded fatalities from Japan's volcanic disasters over the past 2,000 years, we obtain a total of approximately 20,000 victims (excluding people who died of starvation in the aftermath of an eruption), with slightly over 80 % of fatalities due to volcanic tsunami and the next largest toll due to mudslides (lahars) (**Fig. 3**). Most volcano-related fatalities are attributed to pyroclastic fall debris (including cinders), mudslides, and pyroclastic flows, in that order. The number of fatalities due to pyroclastic fall debris and pyroclastic flows tend to increase with the scale of the eruption. The number of casualties per volcanic incident is highest for volcanic

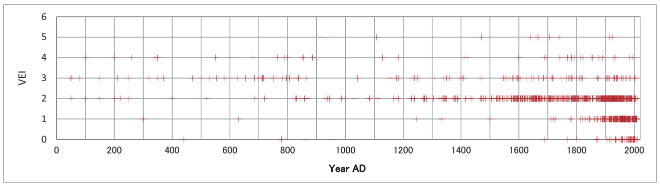
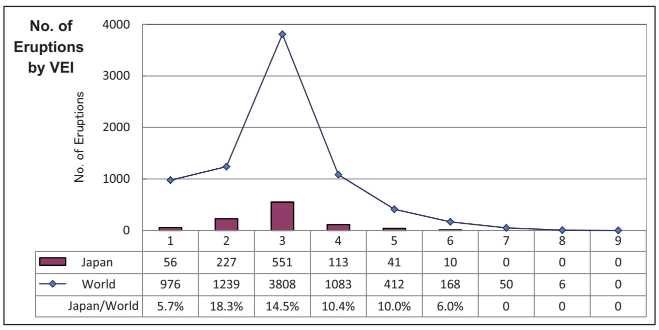


Fig. 1 Scale (VEI) of volcanic activity occurring in Japan over the past 2,000 years.



	1	2	3	4	5	6	7	8	9
Japan	56	227	551	113	41	10	0	0	0
World	976	1239	3808	1083	412	168	50	6	0
Japan/World	5.7%	18.3%	14.5%	10.4%	10.0%	6.0%	0	0	0

Fig. 2 Scale (VEI) of volcanic activity occurring in Japan over the past 2,000 years and in the world over the past 10,000 years. Data of volcanic activity in the world are from Smithsonian Inst. (2010).

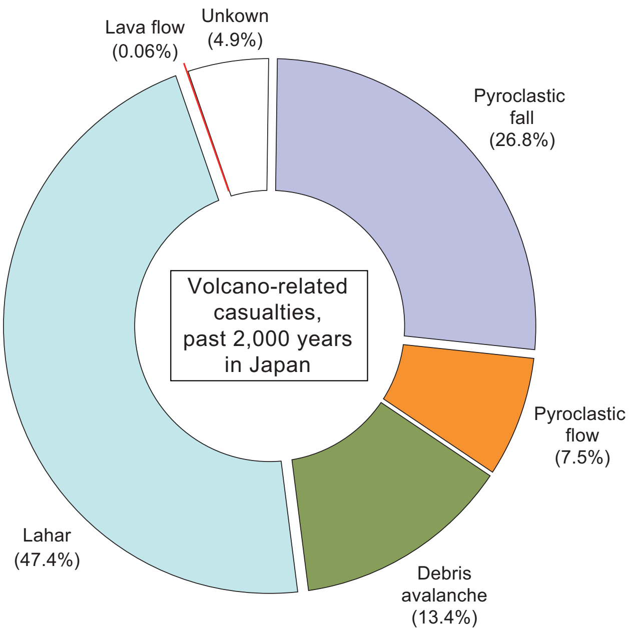


Fig. 3 Volcano-related casualties by cause over the past 2,000 years in Japan (excluding deaths due to volcanic tsunami).

tsunami followed by debris avalanches, but these events are extremely infrequent. These trends are consistent with the breakdown of volcano-related fatalities worldwide over the past 100 years (Tilling, 1989, and others).

Lahars and debris flows continue to occur for some intervals after an eruption, so it is not surprising that much discussion on the mitigation of lahar disasters at most public symposia in areas of active volcanism tend to focus on effective measures to counter this type of hazard.

3.2 Volcanic Hazard Maps and Disaster Risk Maps

Japan's first volcanic hazard map (disaster mitigation maps) was published for Hokkaido-Komagatake in 1983, followed by a map created for the Tokachidake Volcano that was made available in 1987. Following the eruption of Unzendake in 1991, there was a marked increase in production of hazard maps after the Japan Meteorological Agency (JMA) published "Guidelines for Drafting Hazard Maps of Areas Threatened by Volcanic Eruptions" in 1992, and hazard maps were published for most of the highly active volcanoes classified as Rank A (a ranking system based on degree of activity defined by the JMA). Then, following the eruption of Miyakejima and Usuzan in 2000, hazard maps were produced for many areas associated with Rank B and some of Rank C active volcanoes (Nakamura *et al*., 2006). Currently as of 2012, some 160 hazard maps and 110 other relevant references have been published for a total of 40 volcanoes on the JMA's list of 110 active volcanoes (**Table 2**). More recently, an effort has been made to revise hazard maps and other references to make them more intuitive and user friendly for local residents (Local governments in volcanic areas have been especially active in creating these revised hazard maps).

Volcanic hazard maps are produced by examining the history of past volcanic activity and disasters in a region, assuming what a local disaster would be like based on climactic and typical volcanic activity for the area (in most cases based on a deterministic approach), then producing a map that anticipates or predicts the result of a volcanic disaster in the area (**Table 2**). To ensure the most effective use of hazard maps for a particular area, the disaster mitigation information must be presented as clearly as possible. Many of Japan's active volcano areas have become tourist destinations, and in some cases residential areas have encroached close to craters. The risk (threat) to natural and social environments caused by volcanic disasters in these areas is evaluated, and the results are made widely available as basic information to local communities.

The concept of risk assessment has been applied in various sectors over the years: application of risk assessment to oil tanker accidents in the 1970s led to application of the concept to financial derivatives in the 1980s, and to catastrophic accidents and natural disasters since the 1990s. It is proposed that assessing the risk of natural disasters involves risk analysis (analysis of risk factors), risk assessment (assessing potential losses or damages to an object, an area, etc.), and risk management, ie: processes to mitigate risk (UN/ISDR, 2004; NVEWS, 2006, and others).

It has also been suggested that developing these kinds of risk assessments would have a significant mitigating effect as a basic volcanic disaster mitigating infrastructure. Applying this approach to assess potential risk to natural and social environments posed by a volcanic disaster essentially involves calculating a numerical risk factor, then performing an assessment based on the risk factor (Tiling, 1989; Blong, 2000, and others). By casting the risk assessment results in the form of a disaster risk map (assumed disaster threat map), it becomes a very easy-to-use disaster mitigation resource for communities living in the shadow of active volcanoes. It is also recommended that these localized risk assessment results be incorporated in projects to upgrade disaster mitigation systems with immediate and medium-to-long-term perspectives.

The Commission on Mitigation of Volcanic Disasters has discussed a wide range of issues—disaster mitigation responses to volcanic eruptions in the past, how to implement volcanic mitigation approaches in Japan based on probabilistic methods developed in other countries—but so far, risk assessment of volcanic areas has been seldom tried, and there are no cases of actually testing the effectiveness of this probabilistic method approach on past volcanic eruptions in Japan.

3.3 Probabilistic Disaster Mitigation using Eruption Event Trees and Scenarios

Volcanic warnings and volcanic alert levels were introduced by JAM in 2007, and it became necessary for local governments near volcanoes to formulate regulations, evacuation plans, and other countermeasures corresponding to the alert levels. However, until the volcanic alert levels were introduced, very few local governments had done anything to reassess their own regional disaster prevention plans (Nakamura, *et al*., 2007).

Because volcanic activity exhibits progression and change over time, coming up with a disaster mitigation system that can anticipate this progression in advance is highly effective for mitigating hazards. The current mitigation systems in Japan based on regional disaster prevention plans that have been put in place so far assume volcanic factors and scale based on a deterministic approach, then formulate countermeasures accordingly.

Table 2 Monitoring and observation system for volcanic areas in Japan, drafting hazard maps, and volcanic disaster mitigation system based on Local Disaster Management Plans.

No.	Volcano name	Volcanic rank	Constant monitoring system in place	Volcanic alarm system	Year of hazard map published	Integrated map	Name of Regional Disaster Mitigation Plans dealing with Volcanic Disasters (Prefetural name), as of 2011
1	Shiretoko-Iozan	B			2007		Volcanic Disaster Countermeasure Plan (Hokkaido)
2	Rausudake	B			2007		Volcanic Disaster Countermeasure Plan (Hokkaido)
3	Atosanupuri	C	+		2001	+	Volcanic Disaster Countermeasure Plan (Hokkaido)
4	Meakandake	B	+	+	1999	+	Volcanic Disaster Countermeasure Plan (Hokkaido)
5	Taisetsuzan	C	+				Volcanic Disaster Countermeasure Plan (Hokkaido)
6	Tokachidake	A	+	+	1986		Volcanic Disaster Countermeasure Plan (Hokkaido)
7	Tarumaesan	A	+	+	1994	+	Volcanic Disaster Countermeasure Plan (Hokkaido)
8	Kuttara	C	+		2006		Volcanic Disaster Countermeasure Plan (Hokkaido)
9	Usuzan	A	+	+	1995	+	Volcanic Disaster Countermeasure Plan (Hokkaido)
10	Hokkaido-Komagatake	A	+	+	1983	+	Volcanic Disaster Countermeasure Plan (Hokkaido)
11	Esan	B	+		2001	+	Volcanic Disaster Countermeasure Plan (Hokkaido)
12	Iwakisan	B	+		2002	+	Wind and Flooding Countermeasure Volume (Aomori)
13	Akita-Yakeyama	B	+		1996	+	Volcano Disaster Countermeasures (Akita)
14	Iwatesan	B	+	+	1998	+	Volcanic Disaster Countermeasures Volume (Iwate)
15	Akita-Komagatake	B	+	+	2003	+	Volcanic Disaster Countermeasures Volume (Akita), Volcanic Disaster Countermeasures Volume (Iwate)
16	Chokaisan	B	+		2001	+	Wind and Flooding Disaster Countermeasures Volume (Yamagata), General Disaster Countermeasures Volume (Akita)
17	Kurikomayama	B	+				None
18	Zaozan	B	+		2002	+	Wind and Flooding Disaster Countermeasures Volume (Miyagi), Wind and Flooding Disaster Countermeasures Volume (Yamagata)
19	Azumayama	B	+	+	2002	+	General Disaster Countermeasures Volume (Fukushima)
20	Adatarayama	B	+	+	2002	+	General Disaster Countermeasures Volume (Fukushima)
21	Bandaisan	B	+	+	2001	+	General Disaster Countermeasures Volume (Fukushima)
22	Nasudake	B	+	+	2002	+	Volcanic Disaster Countermeasures Volume (Tochigi)
23	Nikko-Shiranesan	C	+				Volcanic Disaster Countermeasures Volume (Tochigi)
24	Kusatsu-Shiranesan	B	+	+	1995	+	Volcanic Disaster Countermeasures Volume (Gunma), Volcanic Disaster Countermeasures Volume (Nagano)
25	Asamayama	A	+	+	2001		Volcanic Disaster Countermeasures Volume (Nagano), Volcanic Disaster Countermeasures Volume (Gunma)
26	Niigata-Yakeyama	B	+	+	2002	+	Wind and Flooding Countermeasures Volume (Niigata)
27	Yakedake	B	+	+	2002	+	Volcanic Disaster Countermeasures Volume (Nagano), Volcanic Disaster Countermeasures Volume (Gunma))
28	Norikuradake	C	+				None
29	Ontakesan	B	+	+	2002		General Countermeasures Plan (Gifu), Volcanic Disaster Countermeasures Volume (Nagano)
30	Hakusan	C	+				None
31	Fujisan	B	+	+	2001	+	Volcanic Disaster Countermeasures Volume (Yamanashi), Volcanic Disaster Countermeasures Volume (Shizuoka), Volcanic Disaster Countermeasures Volume (Kanagawa)
32	Hakoneyama	B	+	+	2004	+	Volcanic Disaster Countermeasures Volume (Shizuoka), Volcanic Disaster Countermeasures Volume (Kanagawa)
33	Izu-Tobu Volcanoes	B	+	+			Volcanic Disaster Countermeasures Volume (Shizuoka)
34	Izu-Oshima	A	+	+	1994	+	Volcanic Disaster Countermeasures Volume (Tokyo)
35	Niijima	B	+				Volcanic Disaster Countermeasures Volume (Tokyo)
36	Kozushima	B	+				Volcanic Disaster Countermeasures Volume (Tokyo)
37	Miyakejima	A	+	+	1994	+	Volcanic Disaster Countermeasures Volume (Tokyo)
38	Hachijojima	C	+				Volcanic Disaster Countermeasures Volume (Tokyo)
39	Aogashima	C	+				Volcanic Disaster Countermeasures Volume (Tokyo)
40	Ioto	B	+				Volcano Disaster Countermeasures Volume (Tokyo)
41	Tsurumidake and Garandake	B	+		2003	+	Volcanic Disaster Countermeasures (Oita)
42	Yufudake	C			2003	+	Volcanic Disaster Countermeasures (Oita)
43	Kujusan	B	+	+	2004	+	Volcanic Disaster Countermeasures (Oita)
44	Asosan	A	+	+	1995	+	General Disaster Countermeasures Volume (Kumamoto)
45	Unzendake	A	+	+	1991		Basic Plan Volume (Nagasaki)
46	Kirishimayama	B	+	+	1996	+	Volcanic Disaster Countermeasures Volume (Miyagi), Volcanic Disaster Countermeasures Volume (Kagoshima)
47	Sakurajima	A	+	+	1994	+	Volcano Disaster Countermeasures Volume (Kagoshima)
48	Satsuma-Iojima	A	+	+	1996	+	Volcanic Disaster Countermeasures Volume (Kagoshima)
49	Kuchinoerabujima	B	+	+	1996	+	Volcanic Disaster Countermeasures Volume (Kagoshima)
50	Nakanoshima	B			1996	+	Volcanic Disaster Countermeasures Volume (Kagoshima)
51	Suwanosejima	A	+	+	1996	+	Volcanic Disaster Countermeasures Volume (Kagoshima)

However, because there are factors not assumed and scales for which no countermeasures have been considered in advance, if a disaster of this magnitude actually does occur, local authorities would find themselves scrambling to come up with an effective mitigation response—evacuation plan, countermeasures, and so on—on the scene at the site of the disaster.

In order to promote discussion of disaster mitigation responses that encompass volcanic phenomena and activity that progress beyond expectation, responses that incorporate a probabilistic approach are necessary. Shifts in activity to be forecast could be small-scale disaster factors that have a high probability of occurring or large-scale or multiple disaster factors with a low probability of occurring. We are thus exploring probability event tree algorithms (e.g. 1996 eruption, Sourfriere Hills) that can predict various types and scales of volcanic phenomena over time that are associated with progressions or shifts in volcanic activity. Improving the predictive accuracy of event tree algorithms requires estimates of the probability of events occurring (numerical estimates and ranking), and creation of a probabilistic event tree. Examining the kinds of monitoring and observational data needed for the various end branches of probability tree algorithms for forecasting would also be a useful exercise. If we could develop event trees along these lines, we could derive high-probability activity progressions as well as typical progressions, explore disaster response measures required over time, and create realistic eruption scenarios. By pursuing a disaster mitigation response that incorporates this kind of probabilistic approach, we could reduce volcanic phenomena that until now have been beyond the scope of assumptions, put in place mitigation responses that are tailored for a wide range of disaster factors and scales, and implement real-time disaster mitigation systems that are highly effective in their mitigating effects (Nakamura, 2009).

The Commission on Mitigation of Volcanic Disasters has addressed how mitigation plans and systems should be implemented with the introduction of volcanic warning and volcanic alert levels, how to develop volcanic event trees and scenarios, disaster mitigation based on probabilistic event trees that have been introduced in other countries, and a range of other topics. So far, however, probabilistic real-time disaster mitigation systems have not been sufficiently deployed in Japan.

3.4 Large-Area Disaster Mitigation Systems for Large-Scale Eruptions

The 1961 Disasters Countermeasures Basic Act directs that prefectural and municipal governments draft local disaster management plans that cover disaster preparedness and proactive countermeasures, disaster emergency response, and disaster recovery and reconstruction countermeasures. Then, these plans are to be made widely available to local communities. For dealing with natural disasters, the local plans contain separate volumes for earthquake countermeasures, wind and flood countermeasures, volcanic disaster countermeasures, and snow damage countermeasures. The 1973 Act on Special Measures for Active Volcanoes (Active Volcano Act) stipulates that if an active volcano erupts, prefectural and municipal authorities shall establish local Disaster Management Headquarters to carry out emergency response measures based on the regional disaster prevention plans. If necessary—say, if a catastrophic disaster occurs—the Cabinet Office of the national government shall establish Major Disaster Management Headquarters and Headquarters for Emergency Disaster Control to orchestrate a comprehensive emergency response.

Current compliance of Japan's local governments in developing regional disaster prevention plans for volcanic disasters is shown in **Table 2**. One can see that, while many of the 26 prefectures with active volcanoes have drafted general disaster countermeasure volumes and wind and flood countermeasure volumes, remarkably few have drafted volcanic disaster countermeasure volumes (Nakamura *et al.*, 2007; and others). Examining the volcanic disaster-related content, we find that much is written about disaster preparedness, but little is written about post-evacuation recovery and reconstruction, and content about post-evacuation support measures is inadequate. Local governments that have actually experienced a volcanic disaster focus attention of volcanic disaster-related discussion, but most have not drafted specific procedures for volcanic disasters and seem to think that the general disaster countermeasure volume is adequate. We would also note that most prefectures and local governments have drafted earthquake countermeasure volumes as part of their regional disaster prevention plans.

As we observed earlier, large-scale volcanic uprest (VEI 4 and VEI 5) of Japan's active volcanoes occurs with some probabilistic regularity. These larger scale events commonly involve multiple secondary factors, and history shows that they often extend over a large area and persist over long periods. Looking back further into the geological record, there is plenty of evidence that VEI 6 and above super-volcanoes and catastrophic eruptions have occurred in Japan.

Many of Japan's active volcanoes straddle administrative borders, so there are many cases where multiple administrative units fall victim to the same disaster factor even though the eruption may be small in scale. When local governments and disaster mitigation organizations are inevitably slow to join forces and cooperate, this results in volcanic disasters being counted more even for relatively small scale disaster factors. Since local governments bear responsibility for dealing with local disasters, several local governments may draft their own regional disaster prevention plans and consider disaster mitigation systems in response to one target volcano. Because of this redundancy, there are actually some districts in which prefectures or local authorities give out hazard maps that are not integrated or unified even though they cover the same volcano. But when large-area volcanic disasters occur that involve multiple administrative units, if all the local governments attempt to implement their own disaster mitigation systems, their efforts tend to fall short. This led to the recommendation to establish Volcanic Disaster Mitigation Councils that could mount a more effective response to large-area volcanic disasters by bringing all the local governments together that are affected by volcanic uprest from the target volcano. Yet there are still many districts with active volcanoes where Volcanic Disaster Mitigation Councils have not been set up. In fact, the district around Fujisan is the only example so far of several prefectures coming together to form a Volcanic Disaster Mitigation Council in the country. Other districts should certainly consider drafting a large-area disaster management plan that encompasses the local disaster plans of multiple administrative units in order to respond more effectively to large-area disasters, and deploying large-area disaster mitigation systems in which the prefecture or even the national government assumes responsibility (i.e., the responsible entity behind the Volcanic Disaster Mitigation Councils).

Serious discussions have been held among constituent members of the Commission on Mitigation of Volcanic Disasters—local residents, local governments and disaster prevention stakeholders, the media, volcanologists and disaster professionals—regarding the need for large-area disaster mitigation that encompasses multiple administrative districts and/or multiple disaster factors, and how large-area disaster mitigation should be implemented. In addition to exploring how several local governments can work together to achieve a close-knit disaster mitigation system, members of the Commission on Mitigation and Volcanic Disasters exchange views and provide feedback on radical reform of disaster mitigation systems that goes far beyond the existing localized disaster mitigation systems.

4. Conclusions

The Great East Japan Earthquake of 2011 taught us the valuable lesson that we cannot ignore the possibility of large-scale volcanic disasters simply because they happen infrequently and are beyond the scope of our assumptions. Rather, we must continue to discuss and explore not only the more tangible "hardware" elements of disaster response, but also the less tangible "software" aspect of response such as raising disaster mitigation awareness, promoting disaster mitigation education, conducting evacuation training and drills, maintaining accurate disaster information, making the reliable information assessable to the public, and so on. Volcanic disaster mitigation in the past generally focused on the volcanic activity or history of disasters that occurred over the past 2,000 or 10,000 years. The problem is that large-scale disaster factors that occur infrequently are often excluded from discussion because they exceed the realm of "hardware" response in terms of cost-effectiveness, and as a result, "software" responses also tend to be excluded from discussion.

In order to establish a more robust disaster mitigation system for dealing with volcanic disasters, a new volcanic disaster mitigation framework is called for, and the Commission on Mitigation of Volcanic Disasters of the Volcanological Society of Japan provides the ideal forum for vigorous discussion among the many stakeholders as to what this new framework should look like.

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- Explanation of “Volcanic Hazard Maps of Japan – Second Edition”
- List of Database on Volcanic Hazard Maps and Reference Material
- Location Map on Volcanoes

Explanation of "Volcanic Hazard Maps of Japan – Second Edition"

Yayoi HOTTA*, Hinako SUZUKI *, Katsue SAWAI *, and Toshikazu TANADA*

1. Outline

This database, "Volcanic Hazard Maps of Japan," covers almost all hazard maps and disaster prevention maps published from 1983 to March 2013 for 40 active volcanoes in Japan. It also includes the old versions of the maps and explanatory references.

The enclosed DVD contains 319 reference materials, including those covered by the first edition, which was published in 2006, and those collected thereafter. The DVD also contains 56 hazard maps plus 27 related reference materials for which approval has been newly obtained from the institutions and committees that prepared them, and it contains regional disaster prevention plans and volcanic disaster prevention plans for which usage permission has been obtained. Y. Hotta controlled the entire process of preparing the references and edited illustrations and papers. K. Sawai collected the maps and references and prepared the "List of Database on Volcanic Hazard Maps and Reference Material", and H. Suzuki supervised the creation of the html files and web pages.

2. How to Use the DVD-ROM

The English opening screen automatically opens the file "index_eng.html" from the disk. There are two search portals on the English opening screen, from which users can choose:

a) "Search from a list of Volcanic Hazard Maps"

b) "Search by Volcano Location Map"

For Google Earth, we have experimented with providing location information on active volcanoes in Japan by using a KML (Keyhole Markup Language) Network Link. In every case, the user finally arrives at the "List of Database on Volcanic Hazard Maps and Reference Material."

A digital image file for screen browsing can be opened by selecting and clicking on a hazard map or a reference material from the list in the "Name of hazard map / Reference material" column. The resolution of data files for printing is about 300–400 dpi. Some maps and references have no separate data files for printing, either because they were not available or because we needed to save on disk capacity.

On the opening screen there are also links to regional disaster prevention plans and volcanic disaster prevention plans.

3. "List of Database on Volcanic Hazard Maps and Reference Material"

The methods used to organize the maps and reference materials and the definitions of the terms in the "Name of hazard map / Reference material" list are described below.

3.1 Organization of Maps and Reference Materials

(1) Hazard maps and reference materials

In the database, published hazard maps and disaster prevention maps, regardless of their form (e.g. maps or booklets) are collectively called hazard maps (HMs). Explanatory and related materials and trial HMs are collectively called reference materials (RMs).

(2) Whole and regional editions

Because most volcanoes (except e.g. those on small islands) extend across municipal borders, volcanic HMs are often prepared by two or more municipalities and relevant institutions through mutual collaboration. Therefore, there are various kinds of volcanic HM, even for a single volcano. In this database, HMs and RMs are classified into whole and regional editions.

The whole editions aim at the residents in all municipalities subject to hazards posed by the volcano, whereas the regional editions aim at some municipalities. For example, HMs and RMs that provide information on evacuation centers, publishers, and emergency points of contact mainly in a single municipality are classified as regional editions, even though the hazardous area may be relevant to all municipalities.

(3) Versions

Some HMs and RMs have the same titles and formats but differ slightly in content. In this database, such HMs and RMs are regarded as:

a) separate HMs or RMs when they differ in content such as year of publication, contact address, and authorization number from the Geospatial Information Authority of Japan—regardless of the version numbers, which may be identical

* National Research Institute for Earth Science and Disaster Prevention

b) the same HM or RM when they differ in terms of only the year of issue, not the contents, and the publication year of the first edition is cited in second and subsequent editions as the original year of issue

c) In the case of HMs or RMs reprinted because of a misprint, only the correct version is included in the database

(4) Naming of files

The files have been named in the following manner:

Example: \05atosa_1h01-H.pdf

[Volcano ID + name of the volcano]_[1: whole; 2: regional][h: hazard map; m: reference material][two-digit serial number] -[L: low resolution, H: high resolution]

3.2 Order in which HMs and RMs are Arranged

(1) In the "Name of hazard map / Reference material" list, HMs and RMs are arranged in order of volcano number. The volcano numbers and names in the list are based on the "National Catalogue of the Active Volcanoes in Japan, 4th Edition" (Japan Meteorological Agency, 2012). The rank of volcanic activity is based on the "National Catalogue of the Active Volcanoes in Japan, 3rd Edition" (Japan Meteorological Agency, 2005).

(2) For each volcano, HMs and RMs are arranged in order from the whole to the regional editions. In each class of information, HMs are listed first and then RMs.

(3) RMs and HMs of the same edition type are each arranged in the reverse chronological order in which they were published.

(4) If there are two or more regional editions for a single region, the HMs and RMs are arranged in the order of the relevant publisher, i.e. from national, through prefectural, to municipal governments. HMs and RMs published by different municipal governments are placed in random order.

(5) Reference numbers were newly assigned for this second edition of the database and are different from those in the first edition.

3.3 Explanation of Columns

(1) Common: Description in parentheses indicates information not shown in the original text but added in the second edition for clarification.

(2) Regions: Japan is divided into four blocks: Hokkaido, Tohoku, Kanto and Chubu, and Kyushu. Volcanic hazard maps have not been prepared for other regions.

(3) Volcano number and name of volcano: Based on the "National Catalogue of the Active Volcanoes in Japan, 4th Edition" (Japan Meteorological Agency, 2012)

(4) Rank (Rank of volcanic activity): Based on the "National Catalogue of the Active Volcanoes in Japan, 3rd Edition" (Japan Meteorological Agency, 2005)

(5) Name of hazard map/Reference material: The file you wish to browse will open when you click on the name of the HM or RM.

(6) Pagination: Information on pagination for reassembling separately scanned image sections (if any) into an entire image is displayed below the name of the HM or RM. Please see "Notes for printing," which can be reached via a link on the opening screen, for methods of image reassembly.

(7) Size and/or kind of reference material: Indicates the original size and/or form of the reference material.

(8) Kind of materials: Expressed as a combination of a number and a letter, i.e. 1: entire edition or 2: regional edition + h: hazard map or m: reference material.

(9) File size for print: Represents the size of the file in Mb, with resolutions of 300–400 dpi. The file size is prefixed with a ▼ mark if the file includes images at resolutions below 300 dpi. Files for which resolution is unidentified are marked with △, showing that printing quality is not guaranteed.

(10) Publisher/reference: If the publisher or reference has their own website, click on the publisher/reference column to access the website.

(11) Date of publication: The notation of the date of the publication has been standardized by using the Western calendar. If the date of publication is not written on the HM or RM, "not written" is shown in the column and any additional information or materials obtained from the publishers by our clerical staff is added in parentheses.

(12) Explanation of volcanic alert levels: A link is provided to a leaflet on volcanic alert levels on the website of the Japan Meteorological Agency.

4. Regional Disaster Prevention Plans

The database covers the regional disaster prevention plans cited by municipal governments as of December 2012. Many municipal governments revise their regional disaster prevention plans annually and make frequent changes to them. In principle, links are posted to the disaster prevention plan pages of those municipalities that have such plans posted on their websites. In the case of those municipalities that do not have plans on the web but have given us their plans and permission to use them, the plans are included in the database as PDF files. These PDF plans are not the latest versions, and users should ask the relevant municipality for the latest version every time they want to use it. In the case of plans that we did not obtain permission to use, only the names are listed in the database.

5. Volcanic Disaster Prevention Plans, Emergency Sabo Plans for Mitigating Volcanic Eruption Disasters, etc.

Volcanic disaster prevention plans, emergency sabo plans for mitigating volcanic eruption disasters, and other relevant plans as of December 2012 have been collected and included in the database. In the case of those plans that we were unable to get permission to use, only the plan names are listed.

Acknowledgments

We thank the municipal governments and institutions involved in volcanic disaster prevention for helping us to collect volcanic HMs, RMs, regional disaster prevention plans, and information on Volcano Disaster Management Councils. We are also grateful to Ms. N. Hiyama of the National Research Institute for Earth Science and Disaster Prevention for her help in editing papers.

List of Database on Volcanic Hazard Maps and Reference Material

No.	Rank	Name of Volcano	Data No.	Name of hazard map : HM / reference material :RM	Size	Kind	Date of Publication	Publisher or Reference [As of March, 20013]
Hokkaido								
1, 2	B, B	Shiretoko-Iozan, Rausudake	1	HM 01-02sire-rau_2h02	A4-book, Attached A2-B map	2h	2011.4	Shari
			2	HM 01-02sire-rau_2h01		2h	2007.4	
1, 2, 3	B, B, –	Shiretoko-Iozan, Rausudake, Tenchozan	3	RM 01-02-03-sire-rau-ten_2m01	A4-book	2m	2012.6	Rausu
5	C	Atosanupuri	4	HM 05atosa_1h01	A2-B	1h	2001.12	Teshikaga
7	B	Meakandake	5	HM 07meakan_1h01	A4-book	1h	2012.8	Kushiro
			6	HM 07meakan_1h02	A4-book	1h	2012.8	Kushiro
			7	HM 07meakan_1h03	A4-book	1h	2012.8	Ashoro
			8	HM 07meakan_2h03	A4-book	2h	2012.3	Ashoro
			9	HM 07meakan_2h02	A2-B	2h	2000.1	Ashoro
			10	HM 07meakan_2h01	A1-S	2h	1999.8	Kushiro
			11	RM 07meakan_2m01 [in Japanese and English]	A3-S	2m	2000.9	Kushiro
10	A	Tokachidake	12	RM 10tokachi_1m08	A4-book	1m	2009.3	Asahikawa development and construction dept. Hokkaido Regional Development Bureau, MLIT
			13	RM 10tokachi_1m07	A4-book	1m	2009.3	
			14	RM 10tokachi_1m06	A4-B, four-page spread	1m	2012.2	Asahikawa Local Meteorological Observatory
			15	RM 10tokachi_1m05	A4-book	1m	2003	
			16	RM 10tokachi_1m04	A4-book	1m	2002.1	
			17	RM 10tokachi_1m03	A4-B, four-page spread	1m	2000.3	
			18	RM 10tokachi_1m02	[A4-book]	1m	1998	Asahikawa District Public Works Management Office, Hokkaido Goverment Kamikawa General Subprefectural Bureau
			19	RM 10tokachi_1m01	[A4-book]	1m	[1993.5]	[Kamihurano]
			20	HM 10tokachi_2h08	A1-S	2h	2010.3	Biei
			21	HM 10tokachi_2h02	A1-S	2h	[2002]	Biei
			22	HM 10tokachi_2h01	B2-S	2h	1987	Biei
			23	HM 10tokachi_2h04	B2-S	2h	2006	Kamihurano
			24	HM 10tokachi_2h03	B2-S	2h	2001.3	Kamihurano
			25	HM 10tokachi_2h05	B2-S	2h	1999.6	Kamihurano
			26	HM 10tokachi_2h07	B2-S	2h	1992.12	Kamihurano
			27	HM 10tokachi_2h06	B2-S	2h	[1986.5]	Kamihurano

[Legend]

(1) No. [Volcano number] and name of volcano: Based on the "National Catalogue of the Active Volcanoes in Japan, 4th Edition" (Japan Meteorological Agency, 2012).
(2) Rank [Rank of volcanic activity]: Based on the "National Catalogue of the Active Volcanoes in Japan, 3rd Edition" (Japan Meteorological Agency, 2005), but currently unused in JMA.
(3) Name of hazard map/ reference material: The file you wish to browse will open when you click on the name of the HM or RM.
(4) Size [Size and/or form of materials]: Indicates the original size and/or form of the material. "S" is Single side print, "B" is Double sides print.
(5) Kind [Kind of materials]: Expressed as a combination of a number and a letter, i.e. 1: entire edition or 2: regional edition + h: hazard map or m: reference material. The whole editions aim at the residents in all municipalities subject to hazards posed by the volcano, whereas the regional editions aim at some municipalities.
(6) Others: Please note that these maps and materials are not always the latest.

No.	Rank	Name of Volcano	Data No.	Name of hazard map : HM / reference material :RM	Size	Kind	Date of Publication	Publisher or Reference [As of March, 20013]
12	A	Tarumaesan	28	HM 12taru_link_01	A4-B, four-page spread	1h	2003.8	Muroran Development and Construction Dept., Hokkaido Regional Development Bureau, MLIT
			29	HM 12taru_1h02 [in English]		1h	2003.8	
			30	HM 12taru_link_02 [*1]	Web only	1h	2006.4	
*1: These two hazard maps are made by Adobe Flash. If you can not open these files, please install Adobe Flash Player.								
12	A	Tarumaesan	31	HM 12taru_1h01	A1-B	1h	1994.3	Hokkaido,Tomakomai, Chitose, Eniwa, shiraoi
			32	RM 12taru_link_03	Web only	1m	2006.4	Muroran Development and Construction Dept., Hokkaido Regional Development Bureau, MLIT
			33	RM 12taru_1m04	A4-book	1m	[2003]	
			34	RM 12taru_1m03	A4-book	1m	[2003]	
			35	RM 12taru_1m02	A4-book	1m	2009.4	[Muroran Development and Construction Dept., Hokkaido Regional Development Bureau, MLIT]
			36	RM 12taru_1m01	A4-book	1m	2008.8	Muroran Development and Construction Dept., Hokkaido Regional Development Bureau, MLIT
			37	HM 12taru_1m06	A4-book	1m	2007.11	[Muroran Development and Construction Dept.], Hokkaido Regional Development Bureau, MLIT
			38	HM 12taru_1m05	A4-B, four-page spread	1m	2007.1	Muroran Development and Construction Dept., Hokkaido Regional Development Bureau, MLIT
			39	HM 12taru_2h04	A4-book	2h	2005.8	Chitose
			40	HM 12taru_2h03	[A4-book]	2h	2001.5	Chitose
			41	HM 12taru_2h02 [*2]	A4-book	2h	[1999.4 [*2]]	Eniwa
			42	HM 12taru_2h05 [*2]	A4-book	2h	[1999.4 [*2]]	Eniwa
*2: These two materials seem the same, but the information was slightly modified. We treat them as another edition by our database classification.								
12	A	Tarumaesan	43	HM 12taru_2h01	A4-book	2h	[1998.4]	Tomakomai
14	C	kuttara	44	HM 14kuttara_2h01	A4-book	2h	2006.12	Noboribetsu
15	A	Usuzan	45	HM 15usu_1h02	A3-B	1h	2002.2	Date, Soubetsu, Toyoura, Toyako
			46	HM 15usu_1h01	A1-B	1h	1995.9	Date, Soubetsu, Toyoura, Toyako
			47	RM 15usu_list_only_01	CD-ROM	1m	2000	Muroran Development and Construction Dept., Hokkaido Regional Development Bureau, MLIT
			48	RM 15usu_1m04	A4-book	1m	2004.3	
			49	RM 15usu_1m05	A4-book	1m	[First Ed. 2003.3]	
			50	RM 15usu_1m06	CD-ROM	1m	2005.3	
			51	RM 15usu_1m07	CD-ROM	1m	2005.3	
			52	RM 15usu_1m03	A4-book	1m	2003.3	Date, Soubetsu, Toyoura,Toyako
			53	RM 15usu_1m02	A4-book	1m	2001.3	Muroran District Public Works Management Office, Hokkaido Goverment Iburi General Subprefectural Bureau Corporation；Mimatsu Saburo [Mimatsu Masao Volcano Memorial Museum]
			54	RM 15usu_1m01	A4-book	1m	1997	Mimatsu Masao Volcano Memorial Museum
			55	HM 15usu_2h03	A4-book	2h	2010.1	Toyako
			56	HM 15usu_2h02	B3-B	2h	1999.3	Soubetsu
			57	HM 15usu_2h01	B3-B	2h	[1998]	Soubetsu
			58	RM 15usu_2m05	A4-book	2m	2002.5.29	Soubetsu

No.	Rank	Name of Volcano	Data No.	Name of hazard map : HM / reference material :RM	Size	Kind	Date of Publication	Publisher or Reference [As of March, 20013]
15	A	Usuzan	59	RM 15usu_2m01	A4-S	2m	2000.5	Soubetsu
			60	RM 15usu_2m02 [in English]	A3-S	2m	2000.5	Soubetsu
			61	RM 15usu_2m03 [in English, Chinese, Korean]	[A4-S]	2m	2000.5	Soubetsu
			62	RM 15usu_2m04	A2-S	2m	1999.2	Toyako-onsen Elementary School
18	A	Hokkaido-Komagatake	63	HM 18hokkai-koma_1h05	A4-book	1h	2010.3	Mori
			64	HM 18hokkai-koma_1h04	A0-B	1h	[2000.3]	Mori
			65	HM 18hokkai-koma_1h03	A1-B	1h	1998.8	Mori
			66	HM 18hokkai-koma_1h02	B2-B	1h	[1992]	Mori
			67	HM 18hokkai-koma_1h01	B2-S, 2 sheets	1h	[1983.11]	Mori
			68	RM 18hokkai-koma_1m12	A3-S	1m	[2005.9.22]	Mori
			69	RM 18hokkai-koma_1m11	CD-ROM *3	1m	2005.3	Mori
*3: This reference material is not in PDF but quotes the contents of CD-ROM, just as they are, by the consent of the publisher.								
18	A	Hokkaido-Komagatake	70	RM 18hokkai-koma_list_only_01	CD-ROM	1m	2005.1.31	Mori
			71	RM 18hokkai-koma_list_only_02	CD-ROM	1m	2004.6	Mori
			72	RM 18hokkai-koma_list_only_03	CD-ROM	1m	2004	Mori
			73	RM 18hokkai-koma_1m10	A4-book	1m	2002.3	Mori
			74	RM 18hokkai-koma_1m09	A4-B	1m	[2001.3.30]	Mori
			75	RM 18hokkai-koma_1m08	A3-B	1m	[1998.10.1]	Mori
			76	RM 18hokkai-koma_1m07	A4-book	1m	[1998.8]	Mori
			77	RM 18hokkai-koma_1m06	A4-book	1m	[1997]	Mori
			78	RM 18hokkai-koma_1m05	A4-book	1m	[1995.3]	Mori
			79	RM 18hokkai-koma_list_only_04	VHS	1m	1995	Mori
			80	RM 18hokkai-koma_1m04	A4-book	1m	[1990.9]	Mori
			81	RM 18hokkai-koma_1m03	A4-book	1m	1989.1	Mori
			82	RM 18hokkai-koma_1m02	A3-S	1m	[1986.9]	Mori
			83	RM 18hokkai-koma_1m01	A2-S	1m	[1984.11]	Mori
			84	RM 18hokkai-koma_2m04	A4-B, three-page spread	2m	[1999.1]	Shikabe
			85	RM 18hokkai-koma_2m03	A4-book	2m	[1996.7]	Shikabe
			86	RM 18hokkai-koma_2m02	A4-B	2m	1998	Mori
			87	RM 18hokkai-koma_2m01	A3-S	2m	1996	Mori
19	B	Esan	88	HM 19esan_1h01	A3-S	1h	2001.2	Hakodate
			89	RM 19esan_1m01	A4-book	1m	2001.2	Hakodate
Tohoku								
22	B	Iwakisan	90	HM 22iwaki_1h01	A1-B	1h	2002.2	Aomori
25	B	Akita-Yakeyama	91	HM 25akita-yake_1h02	A1-B	1h	2002.1	Akita, Kazuno Public Works of Akita Pref.
			92	HM 25akita-yake_1h01	A1-B	1h	[1996]	

No.	Rank	Name of Volcano	Data No.	Name of hazard map : HM / reference material :RM	Size	Kind	Date of Publication	Publisher or Reference [As of March, 20013]
27	B	Iwatesan	93	HM 27iwate_link_01	Web only	1h	[2006.2.24]	Iwate Office of River and National Highway, MLIT
			94	HM 27iwate_1h01	A1-S	1h	1998.1	Iwate Office of River and National Highway, MLIT, Iwate, Morioka, Shizukuishi, Hachimantai, Takizawa
			95	HM 27iwate_1h02 [in English]	A1-S	1h	1998.1	
			96	HM 27iwate_1h03 [in Chinese]	A1-S	1h	1998.1	
			97	RM 27iwate_1m04	A4-book	1m	2005.5	
			98	RM 27iwate_1m01	[A4-book]	1m	1998.1	
			99	RM 27iwate_1m02 [in English]	[A4-book]	1m	1998.1	
			100	RM 27iwate_1m03 [in Chinese]	[A4-book]	1m	1998.1	
			101	HM 27iwate_2h04	A0-S	2h	2000.3	Morioka
			102	HM 27iwate_2h02	A0-S	2h	2000.2	Shizukuishi
			103	HM 27iwate_2h06	A0-S	2h	[2000.4]	Hachimantai
			104	HM 27iwate_2h05	A0-S	2h	[2000.4]	Hachimantai
			105	HM 27iwate_2h03	A0-S	2h	2000.3	Morioka
			106	HM 27iwate_2h01	A0-S	2h	1999	Takizawa
28	B	Akita-Komagatake	107	HM 28akita-koma_1h03	A3-B	1h	2011.3	Yuzawa Office of River and National Highway, MLIT
			108	HM 28akita-koma_1h04	A3-B	1h	2010	
			109	HM 28akita-koma_1h01	A1-B	1h	2003.2	Semboku, Shizukuishi, Akita, Iwate, Yuzawa Office of River and National Highway, MLIT, Iwate Office of River and National Highway, MLIT
			110	HM 28akita-koma_1h02	[A3-B, fold in three]	1h	2003.2	Semboku, Shizukuishi
			111	RM 28akita-koma_1m01	A4-book	1m	2003.2	Semboku, Shizukuishi
29	B	Chokaisan	112	HM 29chokai_1h01	A2-S	1h	2004.3	Yamagata
			113	RM 29chokai_link_01	Web	1m	2003.9	Yamagata, Hayakawa Lab. Faculty of Education, Gunma Univ.
			114	RM 29chokai_1m03	A4-S, 11 sheets	1m	2002.3	Yamagata
			115	RM 29chokai_1m01	A5-book	1m	2002.3	Yamagata
			116	RM 29chokai_1m02	A4-book	1m	2002.3	Yamagata
			117	HM 29chokai_2h10	A4-book	2h	2006	Yurihonjo, Nikaho
			118	HM 29chokai_2h11	A4-book	2h	2006	Sakata, Yuza
			119	HM 29chokai_2h01	A1-B	2h	2001.3	Sakata, Yuza
			120	HM 29chokai_2h02 *4	A1-B	2h	2001.3	Akita
			121	HM 29chokai_2h07 *4	A1-B	2h	[2001.3]	Yurihonjo, Akita
			122	HM 29chokai_2h08 *4	A1-B	2h	[2001.3]	Yurihonjo, Akita
			123	HM 29chokai_2h03 *4	A1-B	2h	[2001.3]	Yurihonjo, Akita
			124	HM 29chokai_2h04 *4	A1-B	2h	[2001.3]	Yurihonjo, Akita
			125	HM 29chokai_2h05 *4	A1-B	2h	[2001.3]	Nikaho, Akita
			126	HM 29chokai_2h06 *4	A1-B	2h	[2001.3]	Nikaho, Akita
			127	HM 29chokai_2h09 *4	A1-B	2h	[2001.3]	Nikaho, Akita
*4: The new hazard map was prepared in 2006. Therefore be careful in handling these old version maps.								
29	B	Chokaisan	128	RM 29chokai_2m01	[B6-book]	2m	2002.3	Yamagata, Sakata, Yuza

No.	Rank	Name of Volcano	Data No.	Name of hazard map : HM / reference material :RM	Size	Kind	Date of Publication	Publisher or Reference [As of March, 20013]
33	B	Zaozan	129	HM 33zao_1h01	A1-B	1h	2002.3	Miyagi, Kawasaki, Zao, Shiroishi, Shichikashuku, Yamagata Pref., Yamagata, Kaminoyama
34, 35, 36	B, B, B	Azumayama, Adatarayama, Bandaisan	130	RM 34_35_36azu_ada_ban_1m02	A5-book	1m	2012.3	Fukushima Office of River and National Highway, MLIT
34	B	Azumayama	131	HM 34azuma_1h01	A1-B	1h	2002.2	Fukushima, Inawashiro, Kitashiobara
			132	RM 34azuma_1m01	B2-S	1m	2002	Yonezawa
35	B	Adatarayama	133	HM 35adata_1h01	A2-S	1h	2002.3	Nihonmatsu, Fukushima, Koriyama, Motomiya, Otama, Inawashiro
			134	RM 35adata_1m01	A4-book	1m	2002.3	
36	B	Bandaisan	135	HM 36ban_1h02	A1-S	1h	2012.1	Bandai、Kitashiobara、Inawashiro
			136	HM 36ban_1h01	A1-S	1h	2001.5	Koriyama, Aizuwakamatsu, Kitakata, Bandai, Kitashiobara, Inawashiro
			137	RM 36ban_1m01	A4-book	1m	2001.5	
Kanto / Chubu								
39	B	Nasudake	138	HM 39nasu_1h01	A1-S	1h	2002.3	Nasushiobara, Nasu, Tochigi
			139	HM 39nasu_1h03	A3-S	1h	2010.3	
			140	HM 39nasu_1h02	A3-S	1h	2002.3	
			141	RM 39nasu_1m01 [in English] *5	A3-S	1m	2002.3	
*5: The publisher makes the following statement: The map is prepared not for publication but on a trial basis.								
39	B	Nasudake	142	RM 39nasu_1m03	A4-book	1m	2010.3	Nasushiobara, Nasu, Tochigi
			143	RM 39nasu_1m02	A4-book	1m	2002.3	
44	B	Kusatsu-Shiranesan	144	HM 44kusatsu_1h01	B2-B	1h	1995.3	Kusatsu, Tsumagoi, Naganohara, Nakanojo
			145	RM 44kusatsu_1m01	B5-book	1m	1997.5	Gunma
			146	RM 44kusatsu_1m02	A4-book	1m	1996.3	Gunma
45	A	Asamayama	147	HM 45asama_1h01	A3-B	1h	[2011.8.16]	Gunma
			148	RM 45asama_1m04	A4-book	1m	2003.11	Komoro, Saku, Karuizawa, Miyota, Naganohara, Tsumagoi
			149	RM 45asama_1m03	A1-B	1m	2003.3	Tone River System Sabo Work Office, MLIT, Nagano, Gunma
			150	RM 45asama_1m02	A4-book	1m	1999.3	Nagano
			151	RM 45asama_1m01	B5-book	1m	1997.5	Gunma
			152	RM 45asama_1m05	A4-book	1m	1997.3	Gunma
			153	HM 45asama_2h22 [in Japanese, English, Chinese, Thai]	Cover page: A4 wide, Other page: A4, Attached map: A1-B	2h	2013.3	Saku
			154	HM 45asama_2h23 [in Japanese, English, Chinese, Thai]		2h	2013.3	Saku
			155	HM 45asama_2h24 [in Japanese, English, Chinese, Thai]		2h	2013.3	Saku
			156	HM 45asama_2h25 [in Japanese, English, Chinese, Thai]		2h	2013.3	Saku
			157	HM 45asama_2h26 [in Japanese, English, Chinese, Thai]		2h	2013.3	Saku
			158	HM 45asama_2h27 [in Japanese, English, Chinese, Thai]		2h	2013.3	Saku

No.	Rank	Name of Volcano	Data No.	Name of hazard map : HM / reference material :RM	Size	Kind	Date of Publication	Publisher or Reference [As of March, 20013]
45	A	Asamayama	159	HM 45asama_2h28 [in Japanese, English, Chinese, Thai]		2h	2013.3	Saku
			160	HM 45asama_2h04	A1-B	2h	2003.11	Saku
			161	HM 45asama_2h03	A1-S	2h	1995.3	Saku, Komoro, Karuizawa, Miyota, Tsumagoi
			162	HM 45asama_2h21	A3-B	2h	2010.3.1	Komoro
			163	HM 45asama_2h12	A1-B	2h	2003.11	Komoro
			164	HM 45asama_list_only_01	A1-S	2h	1995.3	Saku, Komoro, Karuizawa, Miyota, Naganohara, Tsumagoi
			165	HM 45asama_2h20	A3-B	2h	[2011.12]	Karuizawa
			166	HM 45asama_2h19	A3-B	2h	2010.3.1	Karuizawa
			167	HM 45asama_2h06	A1-B	2h	2003.11	Karuizawa
			168	HM 45asama_2h05	A1-S	2h	1995.3	Saku, Komoro, Karuizawa, Miyota, Naganohara, Tsumagoi
			169	HM 45asama_2h18	A3-B	2h	[2013.8]	Miyota
			170	HM 45asama_2h17	A3-B	2h	2010.3.1	Miyota
			171	HM 45asama_2h10	A1-B	2h	2003.11	Miyota
			172	HM 45asama_2h09	A1-S	2h	1995.3	Saku, Komoro, Karuizawa, Miyota, Naganohara, Tsumagoi
			173	HM 45asama_2h16	A3-B	2h	[2012.7]	Naganohara
			174	HM 45asama_2h15	A3-B	2h	2010.3.1	Naganohara
			175	HM 45asama_2h08	A1-B	2h	2003.11	Naganohara
			176	HM 45asama_2h07	A1-S	2h	1995.3	Saku, Komoro, Karuizawa, Miyota, Naganohara, Tsumagoi
			177	HM 45asama_2h14	A3-B	2h	[2012]	Tsumagoi
			178	HM 45asama_2h13	A3-B	2h	2010.3.1	Tsumagoi
			179	HM 45asama_2h02	A1-B	2h	2003.11	Tsumagoi
			180	HM 45asama_2h01	A1-S	2h	1995.3	Saku, Komoro, Karuizawa, Miyota, Naganohara, Tsumagoi
47	B	Niigata-Yakeyama	181	HM 47nii-yake_1h02	A1-B	1h	2004.5	Itoigawa
			182	HM 47nii-yake_1h03 [in English]	A1-B	1h	2004.5	Itoigawa
			183	HM 47nii-yake_1h01	A1-B	1h	2001.3	Itoigawa
			184	RM 47nii-yake_1m01	A4-book	1m	2004.5	Itoigawa
50	B	Yakedake	185	HM 50yake_1h02	A4-book	1h	2003.9	Takayama, Jintsu River System Sabo Work Office, MLIT
			186	HM 50yake_1h01 *6	A2-B	1h	2002.3.28	Gifu
*6: The publisher makes the following statement: This map shows the areas threatened by the hazards of volcanic cinders, pyroclastic flows, pyroclastic surges, volcanic mudflows caused by snow melting, and avalanches of rocks and earth that should be given particular attention in the case where Mt. Yakedake erupts on the same scale [30 million m3 in one direction] as the Nakao pyroclastic flow, or the latest magmatic explosion [about 2,000 years ago.] In addition, the map shows the range of volcanic cinders caused by phreatic explosion. [The range of ash fall is not shown on the map.] However, not all the areas shown on the map are hazardous depending on a volcanic crater. If the eruption lasts a long time, the hazardous areas may be broadened. In addition, be careful about other possible hazards, such as debris avalanches and volcanic gas flow.								
50	B	Yakedake	187	RM 50yake_1m01	A4-book	1m	2002	Gifu
53	B	Ontakesan	188	RM 53ontake_1m02	A5-book	1m	2009.3	Gifu
			189	RM 53ontake_1m01	A4-book	1m	2002	Gifu
			190	HM 53ontake_2h04	A4-B, four-page spread	2h	2009.2	Gifu
			191	HM 53ontake_2h02	A2-B	2h	2005.3	Gifu
			192	HM 53ontake_2h01	A2-B	2h	2002.3.29	Gifu
			193	HM 53ontake_2h03	A2-B	2h	2002.3.29	Kiso, Otaki, Nagano

No.	Rank	Name of Volcano	Data No.	Name of hazard map : HM / reference material :RM	Size	Kind	Date of Publication	Publisher or Reference [As of March, 20013]
55	B	Fujisan	194	RM 55fuji_1m03	A2-S *7	1m	2004.6	Cabinet Office, Government of Japan.
			195	RM 55fuji_1m04	A4-B	1m	[2004]	
			196	RM 55fuji_1m05	A3-book	1m	2004.6	
			197	RM 55fuji_link_01	[A4-book]	1m	2004.6	
			198	RM 55fuji_link_02	[A4-book]	1m	2004.6	
			199	RM 55fuji_1m06	[240× 109 mm, book]	1m	2007.11	Sabo Works at Mt.Fuji, MLIT
			200	RM 55fuji_1m07		1m	2005.1	
			201	RM 55fuji_1m08	[A4-B, fold in three]	1m	2006.3	
			202	RM 55fuji_1m09 [in English]		1m	2006.3	
			203	RM 55fuji_1m02	B1-B	1m	2001.6	Sabo Works at Mt.Fuji, MLIT, Yamanashi, Shizuoka
			204	RM 55fuji_1m10	[A4-book]	1m	2006.1	
			205	RM 55fuji_1m11	[A4-book]	1m	2005.2	
			206	RM 55fuji_1m01	[A4-book]	1m	2000.11	
			207	HM 55fuji_2h14 [in English]	A3-B	2h	2007.6	Mt. Fuji Volcanic Disaster Prevention Conference [Fujiyoshida, Fujikawaguchuko, Nishikatsura, Yamanakako, Oshino, Narusawa, Minobu]
			208	HM 55fuji_2h26	A1-B	2h	2010.3	Mt. Fuji Volcanic Disaster Prevention Conference [Fujiyoshida, Fujikawaguchiko, Nishikatsura, Yamanakako, Oshino, Narusawa, Minobu], Yamanashi
			209	HM 55fuji_2h07	A1-B	2h	2006.3	
			210	HM 55fuji_2h25	A1-B	2h	2010.3	
			211	HM 55fuji_2h08	A1-B	2h	2006.3	
			212	HM 55fuji_2h24	A1-B	2h	2010.3	
			213	HM 55fuji_2h08	A1-B	2h	2006.3	
			214	HM 55fuji_2h23	A1-B	2h	2010.3	
			215	HM 55fuji_2h10	A1-B	2h	2006.3	
			216	HM 55fuji_2h22	A1-B	2h	2010.3	
			217	HM 55fuji_2h11	A1-B	2h	2006.3	
			218	HM 55fuji_2h27	A1-B	2h	2012	Oshino
			219	HM 55fuji_2h21	A1-B	2h	2010.3	Mt. Fuji Volcanic Disaster Prevention Conference [Fujiyoshida, Fujikawaguchiko, Nishikatsura, Yamanakako, Oshino, Narusawa, Minobu], Yamanashi
			220	HM 55fuji_2h12	A1-B	2h	2006.3	
			221	HM 55fuji_2h20	A1-B	2h	2010.3	
			222	HM 55fuji_2h13	A1-B	2h	2006.3	
			223	HM 55fuji_2h04	A4-book	2h	2004.11	Mt. Fuji Volcanic Disaster Prevention Conference [Fujiyoshida, Fujikawaguchuko, Nishikatsura, Yamanakako, Oshino, Narusawa, Minobu]
			224	HM 55fuji_2h19	A2-B	2h	2004.3	Gotenba
			225	HM 55fuji_2h01 [in Japanese and English]	A4-book	2h	2004.3	Gotenba
			226	HM 55fuji_2h18	A2-B	2h	2009	Fujinomiya
			227	HM 55fuji_2h02	A2-B	2h	2004.3	Fujinomiya
			228	HM 55fuji_2h17	A2-B	2h	[2007]	Fuji
			229	HM 55fuji_2h16	A2-B	2h	[2007]	Fuji
			230	HM 55fuji_2h15	A4-book	2h	2010.3	Fuji
			231	HM 55fuji_2h03	A1-B	2h	[2004.3]	Fuji
			232	HM 55fuji_2h06	A2-B	2h	[2005]	Susono
			233	HM 55fuji_2h05	A2-B	2h	2004.11.12	Oyama

<table>
<tr><th>No.</th><th>Rank</th><th>Name of Volcano</th><th>Data No.</th><th>Name of hazard map : HM / reference material :RM</th><th>Size</th><th>Kind</th><th>Date of Publication</th><th>Publisher or Reference [As of March, 20013]</th></tr>
<tr><td rowspan="5">55</td><td rowspan="5">B</td><td rowspan="5">Fujisan</td><td>234</td><td>RM 55fuji_2m03</td><td>A2-S *7</td><td>2m</td><td>2004.6</td><td rowspan="5">Cabinet Office, Government of Japan.</td></tr>
<tr><td>235</td><td>RM 55fuji_2m04</td><td>A2-S *7</td><td>2m</td><td>2004.6</td></tr>
<tr><td>236</td><td>RM 55fuji_2m05</td><td>A2-S *7</td><td>2m</td><td>2004.6</td></tr>
<tr><td>237</td><td>RM 55fuji_2m02</td><td>A2-S *7</td><td>2m</td><td>2004.6</td></tr>
<tr><td>238</td><td>RM 55fuji_2m01</td><td>A2-S *7</td><td>2m</td><td>2004.6</td></tr>
<tr><td colspan="9">*7: The publisher makes the following statement: A2-size, A3-size, one-side, double-side editions [with whole edition printed on the back], and a combination of various editions are available.</td></tr>
<tr><td rowspan="3">56</td><td rowspan="3">B</td><td rowspan="3">Hakoneyama</td><td>239</td><td>HM 56hakone_1h02</td><td>A4-book</td><td>1h</td><td>2009</td><td>Hakone</td></tr>
<tr><td>240</td><td>HM 56hakone_1h01</td><td>A4-book</td><td>1h</td><td>2004</td><td>Hakone</td></tr>
<tr><td>241</td><td>RM 56hakone_1m01</td><td>A2-S</td><td>1m</td><td>2004</td><td>[Hakone]</td></tr>
<tr><td>57</td><td>B</td><td>Izu-Tobu Volcanoes</td><td>242</td><td>RM 59izutoubu_1m01</td><td>A4-book</td><td>1m</td><td>2011.1</td><td>Shizuoka</td></tr>
<tr><td rowspan="3">58</td><td rowspan="3">A</td><td rowspan="3">Izu-Oshima</td><td>243</td><td>HM 58izu-o_1h01</td><td>A1-S</td><td>1h</td><td>[1994.3]</td><td>Oshima</td></tr>
<tr><td>244</td><td>RM 58izu-o_1m02</td><td>B5-book</td><td>1m</td><td>1994.7</td><td>Oshima</td></tr>
<tr><td>245</td><td>RM 58izu-o_1m01</td><td>B5-book</td><td>1m</td><td>1991.11</td><td>Oshima</td></tr>
<tr><td rowspan="10">62</td><td rowspan="10">A</td><td rowspan="10">Miyakejima</td><td>246</td><td>HM 62miyake_1h06</td><td>A2-B</td><td>1h</td><td>2012.4</td><td>Miyake</td></tr>
<tr><td>247</td><td>HM 62miyake_1h05</td><td>A4-book</td><td>1h</td><td>2012.3</td><td>Miyake</td></tr>
<tr><td>248</td><td>HM 62miyake_1h04</td><td>A4-book</td><td>1h</td><td>2008.3</td><td>Miyake</td></tr>
<tr><td>249</td><td>HM 62miyake_1h03</td><td>A2-B</td><td>1h</td><td>2005.1</td><td>Miyake, Tokyo</td></tr>
<tr><td>250</td><td>HM 62miyake_1h02</td><td>A2-B</td><td>1h</td><td>2003.4</td><td>Miyake, Tokyo</td></tr>
<tr><td>251</td><td>HM 62miyake_1h01</td><td>[B2-S]</td><td>1h</td><td>1994</td><td>Miyake</td></tr>
<tr><td>252</td><td>RM 62miyake_1m04
CD Vol. 1, Vol. 2 *8</td><td>A4-book with two CD -ROMs</td><td>1m</td><td>2007.3</td><td>Tokyo</td></tr>
<tr><td>253</td><td>RM 62miyake_1m03 *8</td><td>A4-book with a CD-ROM</td><td>1m</td><td>2008.2</td><td>Miyake</td></tr>
<tr><td>254</td><td>RM 62miyake_1m03 *9</td><td>A4-book</td><td>1m</td><td>2008.2</td><td>Miyake</td></tr>
<tr><td>255</td><td>RM 62miyake_1m03
[in English] *9</td><td>A4-book</td><td>1m</td><td>2008.2</td><td>Miyake</td></tr>
<tr><td colspan="9">*8: Because the attached CD-ROM contains information other than that printed in the booklet, the contents of the CD-ROM are included in this database. The data files for browsing and those for printing are linked.</td></tr>
<tr><td colspan="9">*9: Because data files Nos. 254 and 255 are recorded on the same CD-ROM (enclosed) as file No. 253, they are linked to file No. 253.</td></tr>
<tr><td rowspan="3">62</td><td rowspan="3">A</td><td rowspan="3">Miyakejima</td><td>256</td><td>RM 62miyake_1m02</td><td>A4-book</td><td>1m</td><td>2005.12</td><td>Miyake</td></tr>
<tr><td>257</td><td>RM 62miyake_1m01</td><td>A4-book</td><td>1m</td><td>2005.1</td><td>Miyake</td></tr>
<tr><td>258</td><td>RM 62miyake_2h01</td><td>A3-book</td><td>2h</td><td>2005.5</td><td>Miyake, Tokyo</td></tr>
<tr><td colspan="9">Kyushu</td></tr>
<tr><td rowspan="8">81, 82</td><td rowspan="8">B, C</td><td rowspan="8">Tsurumidake and Garandake, Yufudake</td><td>259</td><td>HM 1-82tsuru-yufu_1h02</td><td>A1-S</td><td>1h</td><td>2006.6</td><td rowspan="2">Oita, Beppu, Yufu, Usa, Hiji</td></tr>
<tr><td>260</td><td>HM 1-82tsuru-yufu_1h03</td><td>A4-book</td><td>1h</td><td>2006.6</td></tr>
<tr><td>261</td><td>HM 1-82tsuru-yufu_1h01</td><td>A1-S</td><td>1h</td><td>[2003]</td><td>Oita</td></tr>
<tr><td>262</td><td>RM 1-82tsuru-yufu_1m01</td><td>A2-S</td><td>1m</td><td>[2006]</td><td>Oita</td></tr>
<tr><td>263</td><td>HM 1-82tsuru-yufu_2h01</td><td>A4-S</td><td>2h</td><td>2006.6</td><td rowspan="4">Oita, Beppu, Yufu, Usa, Hiji</td></tr>
<tr><td>264</td><td>HM 1-82tsuru-yufu_2h02
[in English]</td><td>A4-S</td><td>2h</td><td>2006.6</td></tr>
<tr><td>265</td><td>HM 1-82tsuru-yufu_2h03
[in Chinese]</td><td>A4-S</td><td>2h</td><td>2006.6</td></tr>
<tr><td>266</td><td>HM 81-82tsuru-yufu_2h04
[in Korea]</td><td>A4-S</td><td>2h</td><td>2006.6</td></tr>
<tr><td rowspan="2">83</td><td rowspan="2">B</td><td rowspan="2">Kujusan</td><td>267</td><td>HM 83kuju_1h01</td><td>A1-S</td><td>1h</td><td>2004.3</td><td>Oita</td></tr>
<tr><td>268</td><td>HM 83kuju_2h01</td><td>A4-book</td><td>2h</td><td>2010.6</td><td>Takeda</td></tr>
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No.	Rank	Name of Volcano	Data No.	Name of hazard map : HM / reference material :RM	Size	Kind	Date of Publication	Publisher or Reference [As of March, 20013]
84	A	Asosan	269	HM 84aso_1h02	A4-book	1h	2008.3	Kumamoto
			270	HM 84aso_1h01 *10	A1-B	1h	1995.3	Aso, Minamioguni, Oguni, Ubuyama, Yamato, Takamori, Minamiaso, Nishihara, Aso broader-based local government clerical work union

*10: The publisher makes the following statement: The reference material was published on 1995 and includes many differences from the present state because of the consolidation of municipalities in 2005, and therefore care is needed in handling the material.

No.	Rank	Name of Volcano	Data No.	Name of hazard map : HM / reference material :RM	Size	Kind	Date of Publication	Publisher or Reference [As of March, 20013]
84	A	Asosan	271	HM 84aso_2h02	A4-book	2h	2012.4	Aso
			272	HM 84aso_2h01	A4-book	2h	2010.4	Aso
			273	HM 84aso_2h03	A4-book	2h	2012.3	Takamori
85	A	Unzendake	274	RM 85unzen_1m01	A4-book	1m	2004.3	Unzen Restoration Work Office
			275	RM 85unzen_1m02	A4-book	1m	2004.3	
			276	HM 85unzen_2h05	B2-B	2h	2007.3	Shimabara
			277	HM 85unzen_2h02	A2-S	2h	2002	Shimabara
			278	HM 85unzen_2h06	B2-S	2h	1999	Shimabara
			279	HM 85unzen_2h01	B2-S	2h	1994	Shimabara
			280	HM 85unzen_2h03	B2-S	2h	1997	Shimabara
			281	HM 85unzen_2h04 *11	B2-S	2h	[1993]	Minamishimabara

*11: The publisher makes the following statement: The map was prepared during the disaster of Mt. Fugendake in 1993, and therefore mudslide-control and other dams on the map are completely different from the present state after completion of the dams in 2006.

No.	Rank	Name of Volcano	Data No.	Name of hazard map : HM / reference material :RM	Size	Kind	Date of Publication	Publisher or Reference [As of March, 20013]
85	A	Unzendake	282	RM 85unzen_2m01	A4-book	2m	1994	Shimabara
			283	RM 85unzen_2m02	A3-S	2m	[1991]	Shimabara, Sabo Technical Center
87	B	Kirishimayama	284	HM 87kiri_1h01	A1-B	1h	2009.3	Miyakonojo, Kobayashi, Ebino, Takaharu, Yusui, Kirishima, Soh
			285	RM 87kiri_1m05	A3-B	1m	2012.3	Kyushu Regional Environment Office
			286	RM 87kiri_1m04 [in English]	A3-B	1m	2012.3	
			287	RM 87kiri_1m03	A4-book	1m	2008.3	Miyazaki Office of River and National Highway, MLIT
			288	RM 87kiri_1m02	A4-book	1m	2005.8	
			289	RM 87kiri_1m01	A4-book	1m	1996.3	Miyakonojo, Kobayashi, Ebino, Takaharu, Yusui, Kirishima
			290	HM 87kiri_2h07	A3-S	2h	1996.3	Miyakonojo
			291	HM 87kiri_2h06	A1-S	2h	1996.3	Miyakonojo, Kobayashi, Ebino, Takaharu, Yusui, Kirishima
			292	HM 87kiri_2h11	A1-B	2h	2012.3	Kobayashi
			293	HM 87kiri_2h04	A1-S	2h	1996.3	Miyakonojo, Kobayashi, Ebino, Takaharu, Yusui, Kirishima
			294	HM 87kiri_2h02	A1-S	2h	1996.3	
			295	HM 87kiri_2h05	A1-S	2h	1996.3	
			296	HM 87kiri_2h09	A1-S	2h	1996.3	
			297	HM 87kiri_2h08	A1-S	2h	1996.3	
			298	HM 87kiri_2h10	A1-S	2h	2011	Kirisima
			299	HM 87kiri_2h03	A1-S	2h	1996.3	Miyakonojo, Kobayashi, Ebino, Takaharu, Yusui, Kirishima
			300	HM 87kiri_2h01	A1-S	2h	1996.3	
			301	RM 87kiri_2m02	A2-S	2m	1991	Takaharu
			302	RM 87kiri_2m01	A2-S	2m	−	Takaharu

No.	Rank	Name of Volcano	Data No.	Name of hazard map : HM / reference material :RM	Size	Kind	Date of Publication	Publisher or Reference [As of March, 20013]
90	A	Sakurajima	303	HM 90sakura_1h03	B2-S	1h	2006.3	Kagoshima
			304	HM 90sakura_1h02	B2-S	1h	2002	Kagoshima, Tarumizu
			305	HM 90sakura_1h01	B2-S	1h	1994	Kagoshima, Tarumizu
			306	RM 90sakura_1m02	A4-B	1m	2007.1	Osumi Office of River and National Highway, MLIT
			307	RM 90sakura_1m01	B6-book	1m	1994	Kagoshima, Tarumizu
			308	HM 90sakura_2h02	B2-S	2h	2010	Kagoshima
			309	HM 90sakura_2h01	A3-B	2h	2011	Tarumizu
			310	RM 90sakura_2m02	A4-book	2m	2012.3	Kagoshima
			311	RM 90sakura_2m01	A3-S	2m	2006.6.14	Kagoshima
93	A	Satsuma-Iojima	312	HM 93satsuma-io_1h01 *12	A3-S, 2 sheets	1h	[First Ed. 1996]	Kagoshima
			313	RM 93satsuma-io_1m01 *12	A4-book	1m		Kagoshima
94	B	Kuchino-erabujima	314	HM 94kuchino_1h01 *12	A3-S, 2 sheets	1h	[First Ed. 1996]	Kagoshima
			315	RM 94kuchino_1m01 *12	A4-book	1m		Kagoshima
96	B	Nakanoshima	316	HM 96nakano_1h01 *12	A3-S, 2 sheets	1h	[First Ed. 1996]	Kagoshima
			317	RM 96nakano_1m01 *12	A4-book	1m		Kagoshima
97	A	Suwanosejima	318	HM 97suwanose_1h01 *12	A3-S, 2 sheets	1h	[First Ed. 1996]	Kagoshima
			319	RM 97suwanose_1m01 *12	A4-book	1m		Kagoshima

*12: These materials are extracted from "Kagoshima prefecture regional plan for disaster prevention".

Location Map on Volcanoes