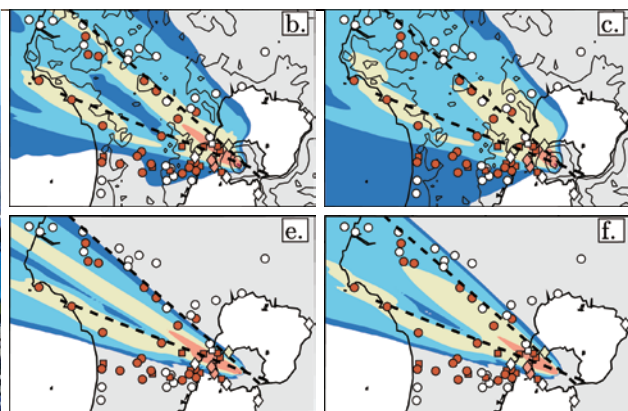


Integrated Program for Next Generation Volcano Research and Human Resource Development



Simulated ashfall



MEXT

MINISTRY OF EDUCATION,
CULTURE, SPORTS,
SCIENCE AND TECHNOLOGY-JAPAN

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火山の未来を観る
次世代火山研究・人材育成
総合プロジェクト
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Introduction

The Ministry of Education, Culture, Sports, Science and Technology (MEXT) launched the “Integrated Program for Next Generation Volcano Research and Human Resource Development” in light of the eruption disaster at Mt. Ontake in September 2014, with the aim of advancing Japan’s volcano research and contributing to mitigation and disaster resilience countermeasures for volcanic hazards. The aims of this project are “Promotion of integrated volcano research encompassing observation, forecasting and countermeasures with unifying volcano observation data” and “Nurturing human resources with the qualities to become highly accomplished volcano researchers with specialized knowledge and skills regarding volcanoes.” Working closely with all stakeholders involved in volcano disaster risk reduction, we would like to promote this project strongly.

Ministry of Education, Culture, Sports, Science and Technology
Research and Development Bureau
Earthquake and Disaster-Reduction Research Division

Messages

Integrated Program for Next Generation Volcano Research and
Human Resource Development
Project Leader: Toshitsugu Fujii

Forecasting volcanic eruptions is a big issue for countries with many active volcanoes, such as Japan, where volcanic eruptions are on-going and expected in future. Therefore, we have promoted the Volcanic Eruption Prediction Plan since 1974 although the allocated budget has not been sufficient. Its main entity is basic research by universities and research institutes, the results of which have been utilized for volcanic monitoring by the Japan Meteorological Agency (JMA). It was considered until the Ontake eruption in September 2014 that the number of victims of eruptions has been limited due to these efforts.

Although 44 people became casualties of pyroclastic flows during the Unzen eruption from 1990 to 1995, they were inside the zone subject to entry restrictions where a pyroclastic flow hazard was expected. Conversely, in the Ontake disaster, the eruption was not expected and 63 people lost their lives in the area where entry was not restricted. Small-scale phreatic eruptions such as the Ontake eruption are difficult to study due to their scale and short duration, and have not been taken up as a central research theme in the Volcanic Eruption Prediction Plan. To prevent further loss of lives by volcanic eruptions in future, it was reaffirmed that it was an urgent issue to promote not only basic research but also research with the explicit aim of mitigating volcanic disasters.

As a volcanic eruption, the Ontake eruption was extremely small in scale. It demonstrated that being in the vicinity of the eruption site would result in a serious catastrophe even if the scale of eruption is small. In the case of large-scale eruptions, a major disaster would affect not only the area around the crater but also residential areas. For the past 100 years, Japan has not experienced a large-scale eruption. This was fortunate. Since the previous large-scale eruptions occurred just before the development of modern observation equipment such as seismometers, we do not have enough data on what sort of precursor phenomena can be detected before a large-scale eruption. There is also an urgent need for research on the forecasting a large-scale eruption, including the development of methods to measure the eruption.

Furthermore, unless we nurture the next generation of volcano researchers, it will not be possible to respond to the expected future volcanic eruptions. After the Ontake disaster, the Act on Special Measures for Active Volcanoes was revised, and the Volcano Disaster Prevention Councils assigned to 49 volcanoes have been established throughout the country. Each council needs volcano experts as the official members. Experts of the councils are expected to be able to understand volcanological areas, but also social science and humanities areas because the transmission of information and the way of evacuation are involved as the task of the councils. However, at present, the number of professors engaged in volcano research, who are expected to nurture the next generation of volcano researchers and volcanic experts, is small at each university, and their research field is limited. For this reason, it is not efficient for each university to nurture independently volcano researchers and experts. It is vital that volcano researchers scattered throughout the country form consortium that can transcend the bounds of universities in educating students with volcano expertise.

From the above perspectives, this project is currently underway as a ten-year plan. Aiming to contribute to volcanic disaster mitigation that society expects, we will dramatically raise the level of volcano observation research in our country and develop human resources for volcano research with a broad range of knowledge

Messages

Integrated Program for Next Generation Volcano Research and
Human Resource Development
Chief Project Advisor: Dr. Takashi Nishigaki

I serve as the Chief Project Advisor of the Integrated Program for Next Generation Volcano Research and Human Resource Development. This project is for implementing unified and multidisciplinary research encompassing observation, prediction and countermeasures in order to establish the research structure that will underpin Japan's volcano research in future. As well as the rapid development of this apparatus, the project nurtures human resources for volcano research that can be active throughout society. In implementing this integrated project, as Chief Project Advisor I will closely liaise with the project leader (PL) and provide various forms of advice to researchers from a comprehensive viewpoint, with the aim of smoothly leveraging the project and obtaining excellent results.

This is a ground-breaking initiative, a first for Japan, under which researchers in many different fields from many organizations will work collaboratively toward achieving highly-set objectives. Accordingly, for promoting its implementation, I am consulting with each researcher regarding the progress of the project and endeavoring to forge close linkages to support its development. The promotion of collaborative activities/joint research relies upon the underpinning systems from which research develops, and we are creating such systems accordingly. We are steadily constructing a data network which will provide a major foundation for coordinated deployment of the project. Starting from our field experiment at Izu Oshima, we are in the process of constructing an Emergency Observation System (flexible and centralized planning system for volcano observation) that contributes in the promotion of forecast research through capturing the precursor signs of volcanic activity and observing the transition of volcanic activity from an early stage. Based upon these systems, we will promote close linkages with stakeholders in municipalities. Enlisting the cooperation of researchers and all persons involved in volcano disaster preparedness, I will strive to be a catalyst for furthering Japan's volcano research and enhancing resilience to volcano disasters

Integrated Program for Next Generation Volcano Research and
Human Resource Development
Project Advisor on Risk Communication: Naoya Sekiya

I am the Project Advisor in charge of risk communication in the Integrated Program for Next Generation Volcano Research and Human Resource Development. For the last two decades, I have been involved in disaster prevention research with a focus on the relay of information, the psychology, and social phenomena during natural disasters such as volcanic eruptions and flooding as well as man-made disasters.

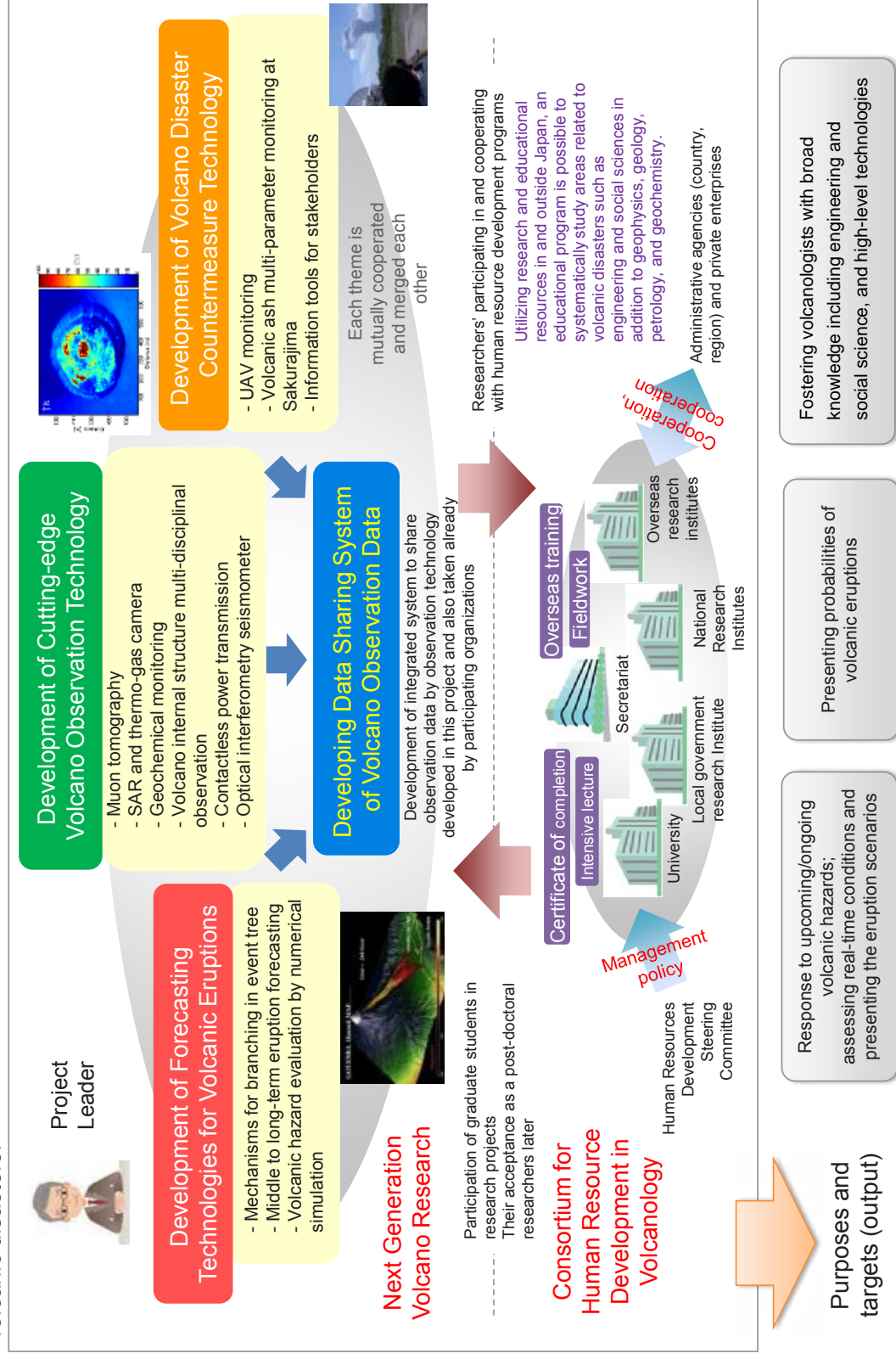
Researchers of disaster prevention make the distinction between the critical phenomena (hazard) and the ensuing disaster. In the same way that "basic medical science" that researches the human body does not amount to "medical care" that underpins the health of humans, the research of volcanic phenomena with observation of volcanoes alone does not amount to volcano disaster prevention. While understanding natural phenomena is of course indispensable, reducing and preemptively avoiding damage caused by disasters on society is a different matter.

Mitigating and protecting against volcanic disasters rely upon promoting research on volcano phenomena, volcanic observation and the development of countermeasure technologies. It is also essential that residents in the vicinity of volcanos, media, related government agencies, disaster prevention organizations and the people as a whole can first understand the current state of volcano research as a starting point, before coming together to deliberate how they should engage with volcanic hazards, and then to proceed with volcano disaster preparedness. In addition to comprehending disaster-related laws/systems as well as research in peripheral domains related to disasters, volcano researchers should develop a common understanding of volcano disasters with other researchers and practitioners involved in disaster prevention, and consider together the systems for volcanic disaster prevention and the countermeasures.

In this project, I consider it my role to foster relationships and to facilitate communication among the various entities involved in researching volcanic phenomena, volcano observation, developing countermeasure technologies and fostering the next generation of human resources in this field. I will do whatever I can to further the efforts of everybody involved in implementing the project, with the sincere hope of contributing to Japan's preparedness against volcano disasters.

Project Outline

The “Integrated Program for Next Generation Volcano Research and Human Resources Development” promotes research on observation, forecasting and countermeasures by creating the volcanic data sharing system, and nurtures the next generation of volcano researchers with wide-area knowledge and high-level technologies. This program aims at contributing to mitigating volcanic disasters.



Development of Volcano Observation Data Sharing System

Manager: Hideki Ueda, Volcano Monitoring Laboratory, Network Center for Earthquake, Tsunami and Volcano, National Research Institute for Earth Science and Disaster Resilience

Introduction

The National Research Institute for Earth Science and Disaster Resilience (“NIED”) is the organization responsible for Theme A, “Development of Volcano Observation Sharing System.” Under its stated goal of, “Realizing a Disaster-Resilient Society,” NIED carries out basic research and foundational research and development regarding science and technology for disaster resilience. NIED’s remit also includes maximizing R&D results for the country as a whole including those of other organizations including private companies and universities. It does this through promoting joint usage of its facilities and equipment such as the volcano observation network and through linkages and collaborations with other organizations. In light of these missions, and in order to mitigate damage from volcano disasters by invigorating volcanic research and promoting linkages with other organizations, Theme A will focus on developing systems that will form the foundation for further research on systems for sharing volcano observation data.

The Volcano Observation Network and its Role

NIED carries out volcano observation at observation facilities installed in 55 locations at the 16 active volcanos across Japan (photo 1). These observation facilities house high-precision seismometers and tilt meters installed at the bottom of wells that are 100 ~ 200m deep, with GNSS (Global Navigation Satellite System) devices above ground, which provide observational data in real-time, 24 hours a day. These observation devices can capture the very slight swelling that occurs in volcanos due to magma building up underground before an eruption, as well as the small earthquakes and slight tilting of the ground surface that occurs when magma is rising up through the bedrock just before an eruption.

Precise analysis of observational data allows us to estimate the movements of magma, so observational data is used in research for elucidating the mechanism of volcanic eruptions, and is fed in real-time to the JMA to be used in its volcano monitoring. When it a major disaster caused by a volcanic eruption seems imminent, JMA issues eruption warnings based on the analysis of observational data, and each municipality issues evacuation advisories.



Photo 1: Observation Facilities of Mt.Iwate Volcano.

As such, observational data is extremely important for volcano research and volcano disaster preparedness.

Shearing of Observational Data

NIED is not the only organization carrying out volcano observation. The JMA also carries out volcano observation at 50 active volcanos across Japan, as do other organizations including universities, the Geospatial Information Authority of Japan, National Institute of Advanced Industrial Science and Technology, local governments, and others.

There are many examples where multiple organizations are observing one volcano. The mutual exchange of this observational data allows more precise estimation of the movement of magma, and can also lead to discovering phenomena that had been hitherto undetected. Knowledge and experience are also shared alongside observational data, which paves the way for more sophisticated research and monitoring of volcanos. Pursuant to this, each organization has concluded a treaty for exchanging data, and also for exchanging information related to joint research and volcanic activity. Data is also provided through NIED’s website (<http://www.vnet.bosai.go.jp/>). This allows researchers in universities that do not conduct volcano observation to utilize the data for their own research.

However, the current sharing of data is limited to certain organizations and researchers, and data restricted to certain types; there is insufficient sharing of information regarding who is observing what, and where. Furthermore, the current method for sharing this data is difficult to use for people who have not been involved in volcano research before. In order to contribute to volcano disaster preparedness through volcano observation, as well as the existing approach to volcano research, it will be increasingly important to create linkages with other research fields, industries, private companies and local governments. If we can provide an environment where anybody can provide data and anybody can use data, it will be a lot more accessible both to those involved in volcano observation up until now and those who are new to the field. This is the “Centralization of Various Observational Data” (Fig. 1).

System Development

Pursuant to promoting the centralization of various volcano observational data, in FY2017, 18 members representing 16 organizations formed the “Data Distribution Working Group” in order to hold intensive deliberations regarding the systems for distributing data in the volcano domain. This working group established that the centralization of observational data is not limited to the actual sharing of the data, but should also contribute to invigorating volcano research, promoting the usage and application of observational data in research and disaster preparedness, strengthening linkages between research domains and organizations, strengthening volcano disaster preparedness, and developing human resources. The group also agreed that data distribution will basically be implemented in the manner of Fig. 2.

In light of this basic policy, and toward commencing operations at the end of 2018, a system is being developed to allow the down-

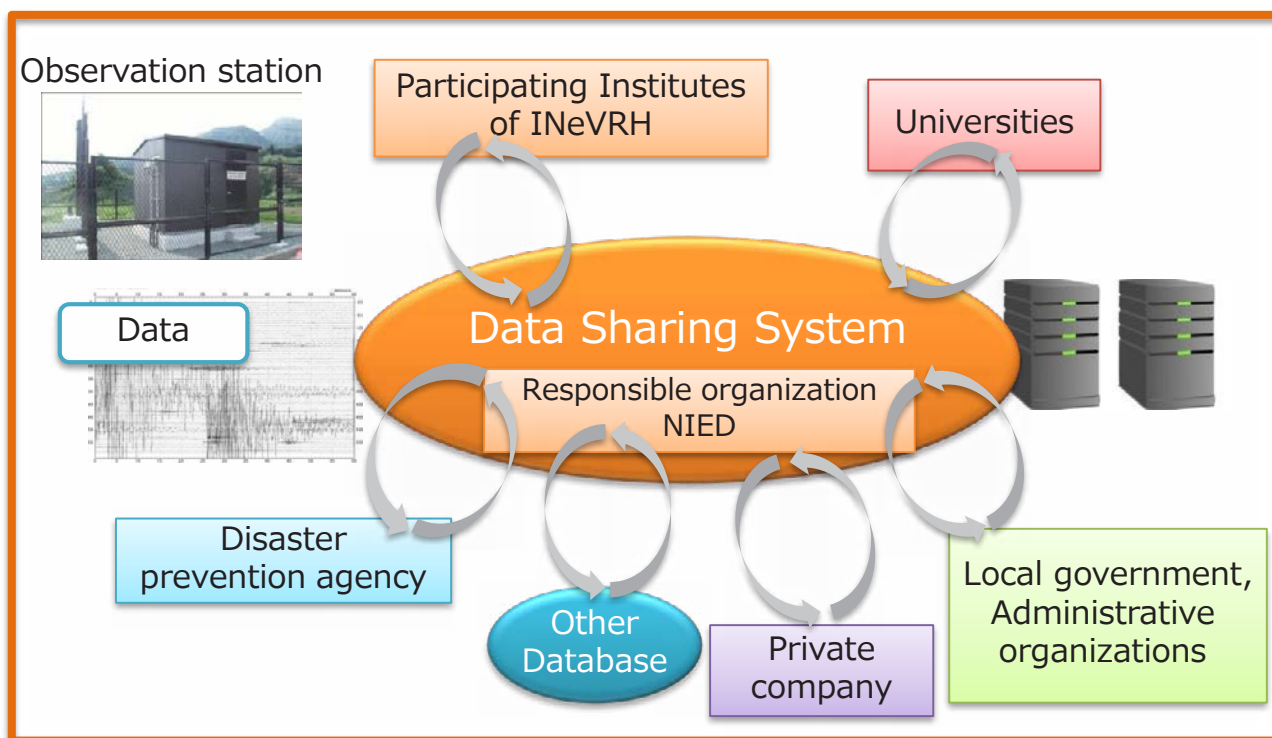


Fig. 1: Schematic diagram of "Centralization of Various Observation Data."

loading of visualization tools such as GIS and graph tools, as well as data. A portal site was also launched for the publication of data (<https://jvdm.bosai.go.jp>) (Fig. 3).

Promotion of Volcanological Research and Contributing to Volcano Disaster Preparedness

By applying the visualization tools that are currently in development and the systems for data distribution, it is expected that it will be easier than ever before to utilize data and to promote link-

Image of data sharing in volcanological research field

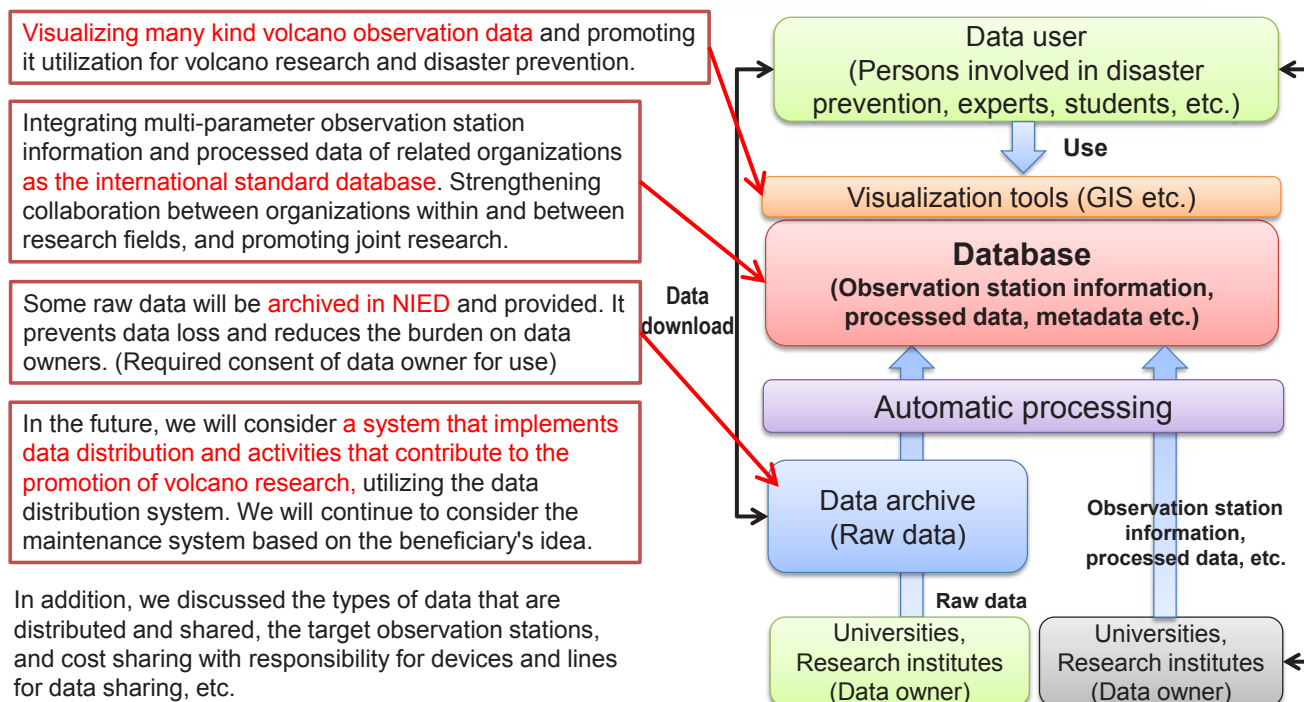


Fig. 2: Schematic diagram showing distribution of data in volcano field.

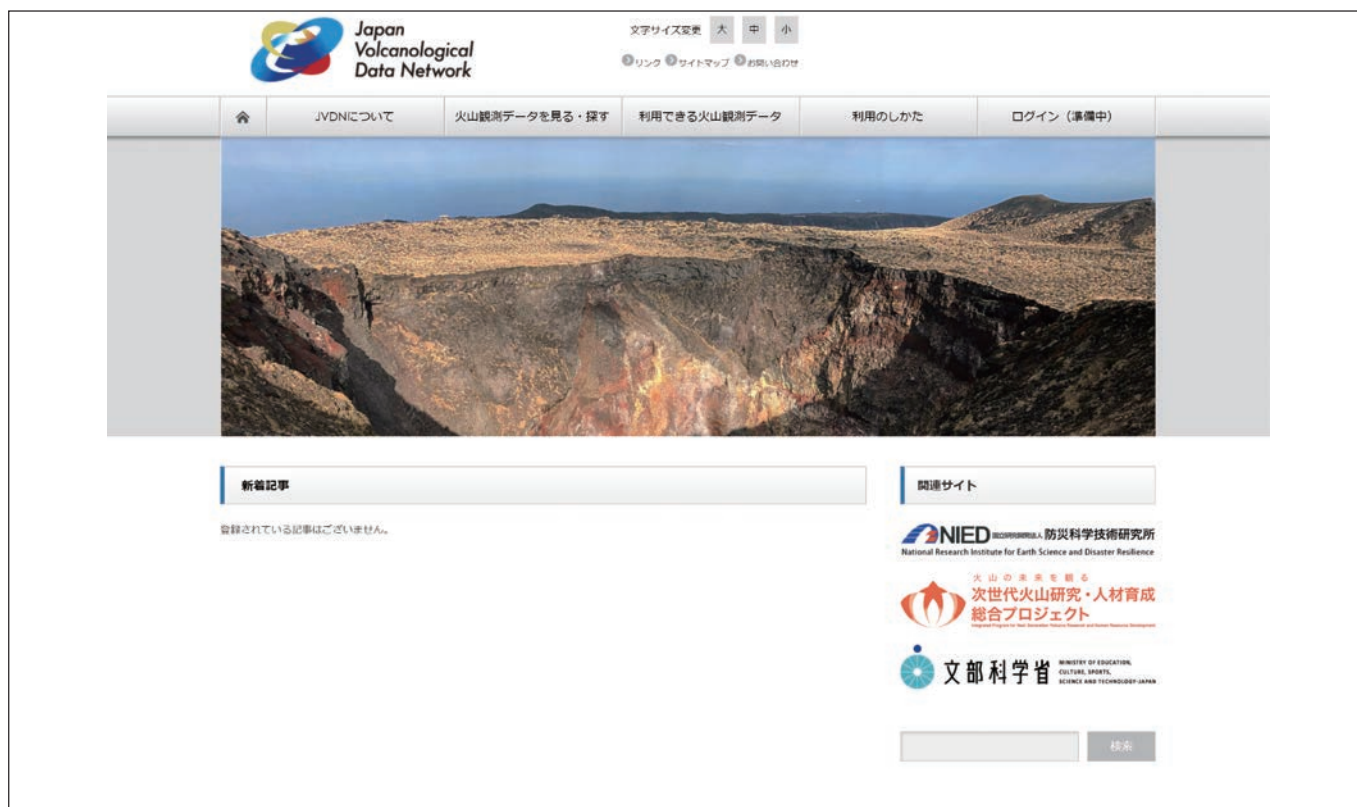


Fig. 3: Portal site for data shearing system.

ages between different research domains and between organizations, and to implement joint research. However, it is not the case that volcano research can be invigorated merely by constructing systems. While this system will initially be used mainly by participants in the Integrated Program for Next Generation Volcano Research and Human Resource Development, it is hoped that researchers other than project participants and disaster preparedness practitioners outside of these researchers will also come to use the system. To this end, it will be necessary to link Theme A with other themes, and to promote joint research and initiatives that utilize this system.

One such initiatives is the “Development of a Quantitative Hazard Assessment and Risk Assessment Method.” A quantitative hazard and risk assessment method is a technique that involves using observation data to forecast when, where and what kind of volcano disaster could occur (including probability of occurring). Although research institutions in various countries are developing such a method, it is still extremely problematic and as such no practicable technology has so far been realized. If such information can be relayed to the populace and disaster preparedness organizations in a timely and easily understandable manner, it could be utilized for effective disaster countermeasures and for decision-making during disaster response, and as such could make a major contribution to mitigating damage wrought by volcano disasters.

There are basically 2 types of technological development required to expedite a quantitative hazard and risk assessment method: one of these is the quantitative forecasting of volcanic eruptions. To realize this technique, it is first of all necessary to understand the mechanisms that trigger volcanic eruptions. To do so will require analysis of observation data in many categories,

as well as collaborative research between different fields, and collaboration with overseas research institutions on comparative research of many different volcanos. The system to be formulated under Theme A will prove to be an indispensable system for implementing such research. Another is the forecasting of volcano disasters. Forecasting volcano disasters relies upon understanding the mechanisms that cause them. To do so, technological development is required to make forecasts by quickly grasping the scale of eruption and eruption site from real-time observational data and carrying out numerical simulations.

Furthermore, it is necessary to visualize this kind of forecasting information in order to share it with local governments, disaster preparedness organizations and researchers so that they can utilize it for protecting against disasters. The visualization tools developed in Theme A can be utilized for information sharing, and research into what sort of information should be relayed will be conducted in tandem with Theme D-3. While such technological development is no simple matter, with regard to the “observation/forecasting/countermeasure” unified volcano research being implemented by the Next Generation Volcano Researcher Development Program, we are confident that the system developed under Theme A will be effectively utilized and will contribute to invigorating volcano research and to volcano disaster preparedness.

Summary

Theme A is concerned with developing systems for the centralization of observation data and for coordination among related institutions; we aim for the system to be online by the end of FY2018. Through operating this system, we aim to help invigorate volcano research, contribute to disaster preparedness, and to deliver results that live up to the expectations of society.

Development of Cutting-edge Volcano Observation Technology

Manager: Yuichi Morita, Earthquake Research Institute, The University of Tokyo

Mitigation Volcano Disasters for Japanese People

Since a long-term volcanic activity relating to plate subduction has created the Japanese lands, the Japanese people have never been released from threats of mega-earthquakes and volcanic eruptions even though technologies are advancing in many fields. The number of victims by volcanic eruptions is still high even at the modern time in Japan. We, Japanese, should never forget the threat of volcanic eruptions to save our lives. On the other hand, we can usually enjoy beautiful landscapes composed of volcanoes unless large volcanic eruptions happen. Mt. Fuji is a symbol of Japan for tourists from foreign countries as well as Japanese. Actually, many volcanoes are registered as national parks and attract a lot of tourists. A terrible disaster of Mount Ontake in 2014 reminded us the above situation. After this event, the Japanese government revised the special measures law for countermeasures against volcano disasters and make local governments located close to all active volcanoes establish “Volcano Disaster Prevention Council” (see Fig. 1). In this framework, the “Volcanic Alert Level” issued by the JMA (Japan Meteorological Agency) became playing an important role. If the volcanic alert level was as reliable as the weather forecast, and if it could be announced with ample lead time before eruptions, it would be sufficient as a preparatory measure. However, in reality, the volcanic alert level is still unreliable and there are many problems in this framework. In this program, we aim at volcanology research and its application to develop and further improve the precision of the Volcanic Alert Level using “Cutting-edge Volcano Observation Technology”.

Required Items to Improve Evaluation of the Volcanic Alert Level

Before the 2014 Mount Ontake eruption, several abnormal phenomena were observed in various time scale (see Fig. 2). Mount Ontake had erupted on Oct. 28, 1979 after a long quiescence of more than several hundred years and it was the first event which links to the present activity. After 1979, small eruptions occurred in 1991 and 2007. It was fortunate that there were no deaths and no injured persons in these three eruptions as they occurred out of tourism seasons, few climbers visiting around the summit. From long-term stand of view, Mount Ontake was awake from a long sleep and we should recognize that it has a potential to erupt every around 10 years. Moving to the middle time scale, the seismicity gradually increased a half month before the eruption and gradually decreased with time. A slight inflation of volcanic edifice was depicted by the GNSS measurement that may show the inflation at the depth. Other kinds of signals were not reported explicitly. Unfortunately the above observation data were missed not to be used for evaluation of the Volcanic Alert Level because of the lack of understanding on a precursor of the phreatic eruption. Just before 30 minutes of the eruption, the amplitude of the volcanic tremor began to increase drastically and large ground tilts were recorded as showing the inflation at the shallow part beneath the summit. Although the latter strong abnormal signals make JMA staff to perceive a high possibility of eruption, there was a very short time to notice the occurrence of the eruption. Considering the above situation, the most requisite items in the volcanological application is to find out slightly abnormal signals considered as the precursor

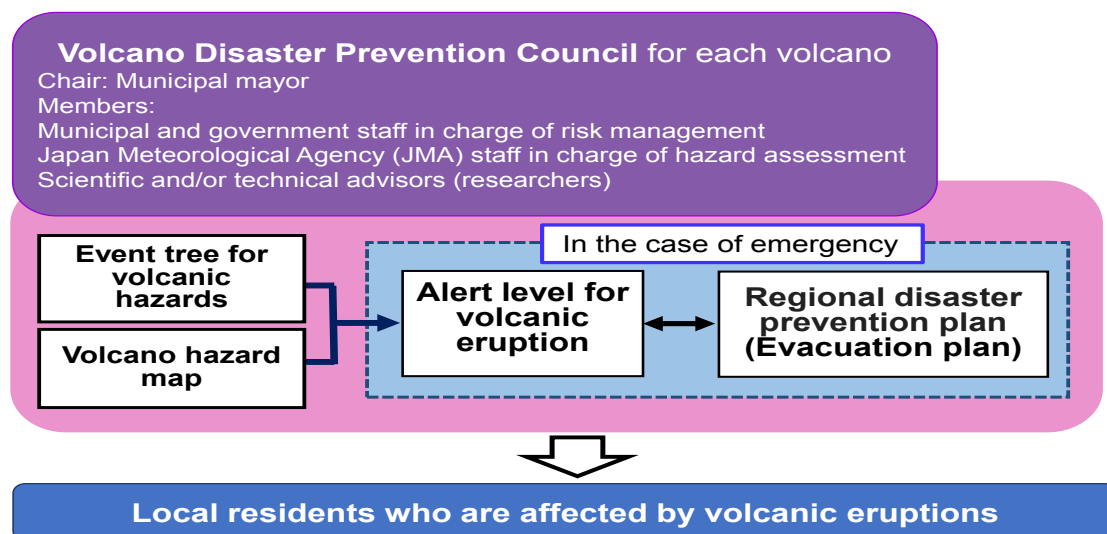


Fig. 1: Extract from outline of Act on Special Measures for Active Volcanoes.

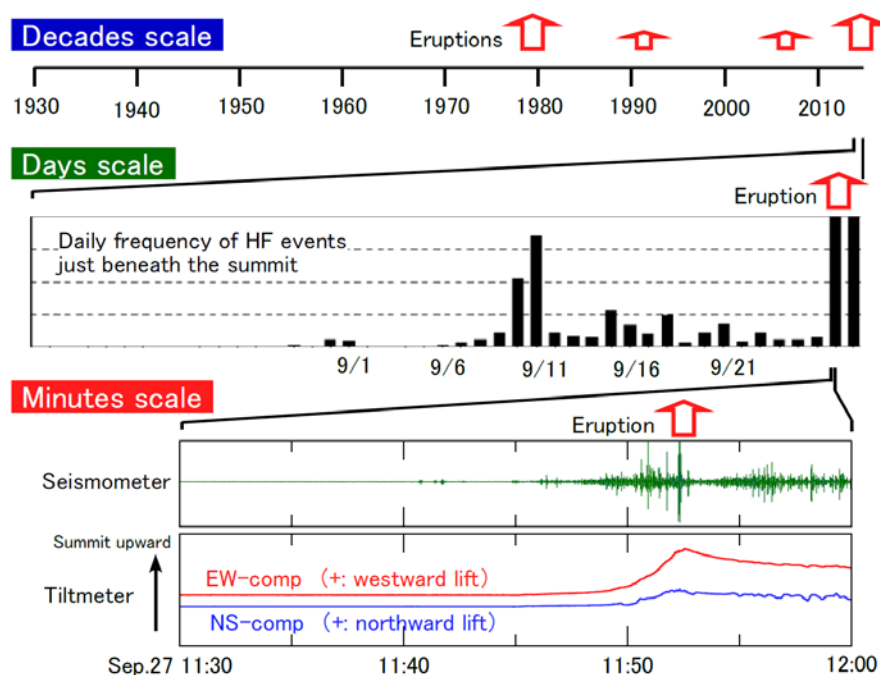


Fig. 2: Schematic diagram of time sequences prior the 2014 Ontake eruption.

to a volcanic eruption enough before the eruption (at least a few days). For this purpose, we should find out new observable parameters from multidisciplinary and various kinds of measurements as well as understating the precursory process to volcanic eruptions from perdurable research. Advancing research needs new findings in observation, and new techniques in volcano observations sometimes are introduced from other fields through hints from such the findings. The both are complementary to mitigate volcanic disasters.

The target of “Development of Cutting-edge Volcano Observation Technology”

To improve the evaluation method of the Volcanic Alert Level, we propose two approaches in this program from scientific points of view. In the first, we will develop new technology to monitor volcanic activities and find out abnormal phenomena prior to eruptions. We will develop the technology for imaging inside of volcanic edifice by cosmic ray, surveying ground deformations by In-SAR and in-situ measuring volcanic gases. In the second, we will carry out intense and temporally observation at active volcanoes using multi-disciplinary methods to reveal the detailed structure and condition inside of the volcanic edifice. From the above two approaches, we will try to improve the precision of the Volcanic Alert Level. Even if each signal is unclear, we may be able to find out abnormality in multi-parameters from multi-disciplinary observations. In addition, we need evaluation criteria on “degree of abnormality”, many of these are based on past experiences that are still very few, meaning that the scientific basis is insufficient. More highly precise forecasting will require enhanced ability to detect abnormalities, as well as scientific analysis of the degree of the abnormality, tracing back to the cause of the abnormality, and

numerical quantification of the degree of abnormality.

Specifically, the project theme B will be divided into four sub-themes (Subtheme 1 to 4).

Subtheme 1: In order to detect the correlation between volcanic activity and perspective images of the shallow conduit part of volcanoes using cosmic ray “muons”, images will be collated in a database, compared with actual volcanic activity, aiming for the usage of a new method for evaluating volcanic activity.

Subtheme 2: Through increasingly precise remote sensing techniques (development of Ground-based synthetic aperture radar (GB-SAR) and miniaturization of optical spectrum image measurement devices), this subtheme aims at detecting local and microscopic deformation of the earth’s crust and the remote measurement of volcanic gas.

Subtheme 3: This subtheme will increase the sophistication of volcanic gas isotope analytic techniques in order to develop a method for instantaneously determining whether volcanic gas collected at the surface emanated from magma, or it was released from heated groundwater.

Subtheme 4: To reveal the detailed structure and the present condition inside of volcanoes, this subtheme will involve well-designed temporally installed observations using multi-disciplinary methods. Obtained observation data will be used as the standard for comparison when precursory signs become active. It will also aim to develop tools and techniques for carrying out real-time processing of observation data.

The contents of each subtheme are described below. We will undergo the above approaches for technological development to give the scientific and technological bases, and try to improve the evaluation method of the Volcanic Alert Level in this project.

Using New Techniques to Enhance the Sophistication of Volcano Observation

Leader: Hiroyuki Tanaka, Earthquake Research Institute, The University of Tokyo

Japan is ahead of the world in successfully seeing through the superficial part of volcanos using the elemental particle muons (muography), and while limited to the area in the vicinity of the crater, has succeeded in imaging the internal construction of the superficial part of volcanos at a resolution not achieved up until now. For example, the visualization of the upper part of the magma channel under the now frozen lava that was released during the 2004 eruption at Mt. Ontake (Fig. 1, left). Similarly, magma foam was visualized in the upper part of the magma column at Satsuma Iwo Jima. Although these are static images, around the time of 2009 Asama Volcano eruption, part of the lava that hardened around the base of the crater was lost due to the eruption, and this was visualized as chronological change in fluoroscopic imaging (Fig. 1, right). More recently, during the small-scale eruption at Satsuma Iwojima in 2013, fluoroscopic images were obtained indicating the rising and falling of magma (Fig. 2). These results indicate that

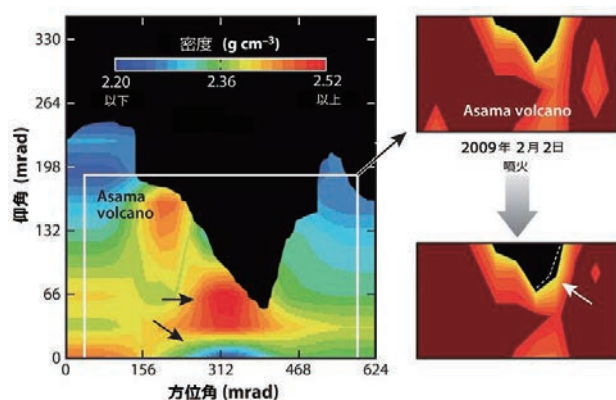


Fig. 1: Left: Muography fluoroscopic image taken of Mt. Asama. The red section is high density, while the blue is lower density. Right: Muography fluoroscopic image taken around the time of the eruption of Mt. Asama in 2009. There is a dotted line showing the position of the base of the crater prior to the eruption.

Muography has the potential to grasp the dynamic construction of the superficial part of volcanos, and can provide information for forecasting the eruptive style and for forecasting the eruption transition. However, at present, Muography data analysis takes time, and even if Muography data with sufficient statistical precision could be obtained in a few days of observation, it is not yet possible to swiftly provide this data in the form of fluoroscopic images. Also, at present, not all volcanologists are in a position to access fluoroscopic images. This is merely due to the fact that fluoroscopic images generated through analysis are saved within the calculators of Muography researcher groups, and other volcanologists are unable to access them. If volcanologists can make strides in interpreting fluoroscopic images, and if it becomes possible to systematically evaluate the link between volcanic activity and Muography fluoroscopic images, there is no doubt the understanding of volcanic eruptions would deepen considerably. Thus, this sub-theme will develop software capable of automatically processing Muography data and promptly providing it as fluoroscopic images; by creating an online data base of the fluoroscopic images generat-

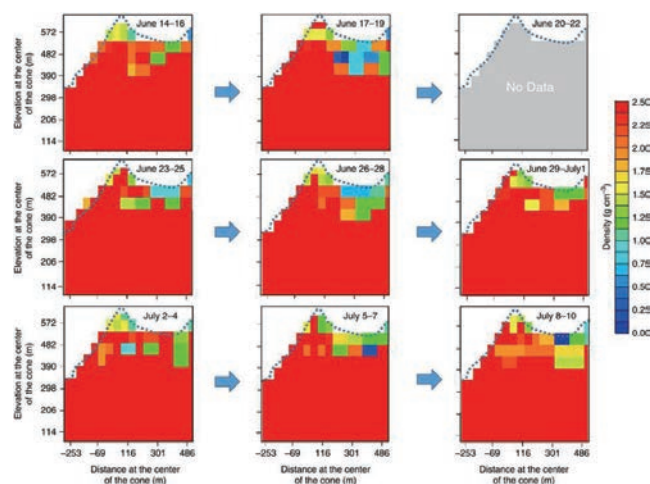


Fig. 2: Chronological muography fluoroscopic image captured at Satsuma Iwojima. The red part is high density, while the blue area is lower density. Volcanic glow was observed on June 16th and 30th, 2013.

ed of volcanic edifices, we can consolidate an environment where volcanologists can in real time freely obtain fluoroscopic images of a period that they wish to view. Furthermore, in order to grasp the constriction of the superficial part of the volcanic body, we will enhance the resolution of the muography observation device. Fig. 3 shows a high-resolution image of Sakurajima Volcano taken using a high-resolution muography observation device that was completed under this technological development.

A comparison with existing fluoroscopic images (Fig. 2) shows how the resolution has been significantly improved. As with the leap from hi-vision to 4K, by providing over 10x the number of pixels than was previously possible, it will be possible to provide much clearer transfer imaging of volcanos. By combining these two elements of R&D, we will aim to provide information for forecasting eruptive style and eruption transition that was not attainable using existing muography technology. We will also implement activities to communicate to society the correct understanding of muography.

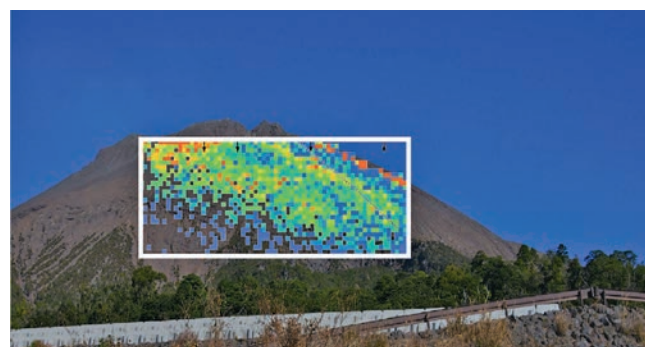


Fig. 3: High definition muography fluoroscopic image captured at Sakurajima. The section within the white box is the field of vision of the observation device.

Development of Remote Sensing Techniques for Volcano Observation

Leader: Taku Ozawa, Center for Integrated Volcano Research, National Research Institute for Earth Science and Disaster Resilience

To mitigate volcano disasters, it is essential to observe various phenomena associated with the volcanic activity, and to connect these observed information with assessing its activity with a high degree of certainty. In particular, noticeable phenomena often occur in and around the crater. If such phenomena are observable, it will connect to deeper understanding of the volcanic activity. However, such observation is usually difficult, because approaching to the active crater is difficult. To resolve this problem, this subtheme aims to develop remote-sensing techniques capable of observing crustal deformation, thermal activity, volcanic gas, and so on.

Crustal deformation is a useful information for understanding the behavior of magma beneath the volcano. Then observation networks for monitoring crustal deformation have been conducted at many volcanoes, but denser observation is necessary to understand its causing mechanism in more detail. Synthetic aperture radar (SAR) is an effective tool to detect the dense information of crustal deformation. SAR can obtain ground surface images with spatial resolution at the meter level, and can detect crustal deformation by comparing SAR images acquired at different periods as shown in Fig.1. This subtheme

will create a database of crustal deformation obtained from SAR in order to utilize efficiently in volcano research and for evaluating volcanic activity.

On the other hand, spaceborne SAR has a disadvantage that observation frequency is limited by the recurrence period of the satellite. When volcanic activity increases, rapid crustal deformation often occurs within a few days, and then, satellite SAR is insufficient to detect such the fast crustal deformation. Therefore, in this subtheme, we also develop a portable radar interferometer capable of observing crustal deformation from the ground. When the volcanic activity increases, we carry out emergent observation using the developed sensor, and add spatially and temporally detailed crustal deformation information obtained into the database.

Measurement of the geothermal temperature distribution in volcanoes, volcanic gas, volcanic ash etc. makes it possible to obtain vital information that is instrumental in grasping the level of activity of a volcano and the current state of a volcano disaster. A technique used for measuring these phenomena is the optical remote sensing. In recent years, large spectrum devices mounted in aircraft are used to measure the optical characteristics (light spectrum) of the observation target, which has made it possible to obtain observation information regarding diverse ground surface phenomena (temperature, gas concentration, distribution of volcanic product etc.) as shown in Fig. 2. However, it is difficult to have this technology widely adopted and used because the device is bulky and requires a special observation aircraft. On the other hand, recently, a portable handheld camera-type device (infrared camera) has become widely adopted, which can be used from a helicopter or at ground level survey to easily grasp the surface temperature of a volcano. However, due to single band wavelength measurement, it is not capable of measuring SO_2 gas or estimating temperature accurately. In order to realize a practical device that combines the various strengths of these techniques, this subtheme will conduct research for integrating a large-scale spectrum device into a portable camera-type device.

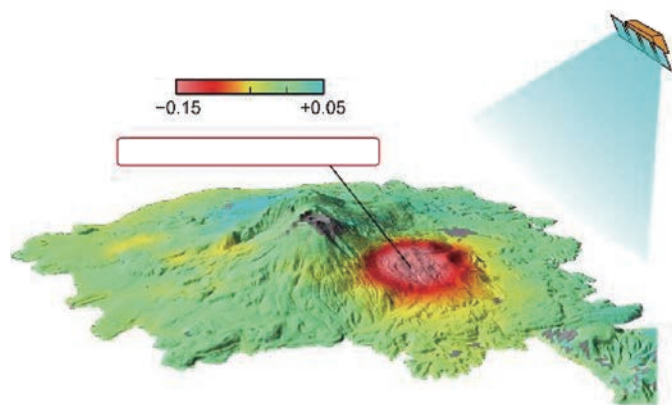


Fig. 1: Crustal deformation in Sakurajima volcano obtained from satellite SAR data (ALOS-2/PALSAR-2). The colors represent the change in distance from the satellite to the ground surface that occurred in the period from August 10, to August 14, 2015.

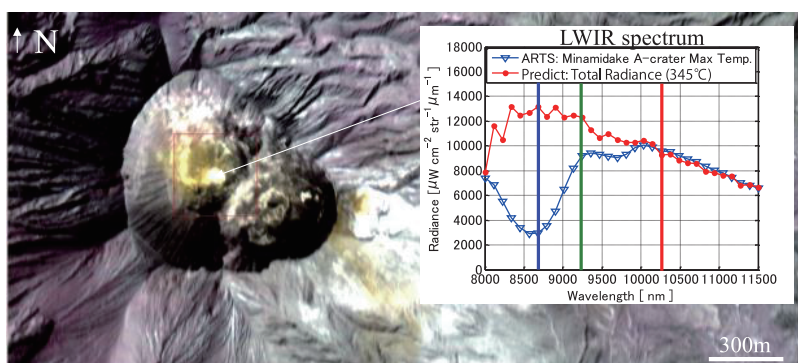


Fig. 2: Pseudo color images around the Minamidake A-crater and Showa crater at Sakurajima, acquired by the Airborne Radiative Transfer Spectral Scanner (ARTS). R/G/B = 10260/9243/8678 nm. Because the SO_2 gas infrared absorption band exists around 8670 nm, the yellow coloring area (blue (B) is weak) indicates the existence of SO_2 gas. The graph shows the infrared spectrum at a point inside the crater.

Development of Geochemical Monitoring Techniques

Leader: Hirochika Sumino, Department of Basic Science, Graduate School of Arts and Sciences,
The University of Tokyo

When a volcano erupts, large amounts of gas (volcanic gases) are released from the crater. The volcanic gas consists of water vapor, carbon dioxide, sulfur dioxide, hydrogen sulfide, hydrogen, and other minor gases including helium. While a volcano has no eruption, volcanic gases are released as fumaroles, hot spring gases dissolved into ground water heated by magma, and soil gases diffusing out from the surface of the volcano body. These, however, also include components not derived from magma, but from the atmosphere, meteoric water, biological processes, and volcanic and basement rocks, which have no relation to volcanic activity.

When the activity of magma increases before an eruption, the ratio of magmatic components within the volcanic gas can change. Given that such geochemical indices provide insights that differ from those obtained with the existing geophysical observations, we can look forward to much more precise evaluation of the likelihood of an eruption by adapting them into volcano monitoring. However, the quantitative evaluation of the magmatic contribution within volcanic gas is not at all straightforward.

Thus, this subtheme will employ isotope ratios of some elements in volcanic gases. Because the isotope ratio of helium ($^3\text{He}/^4\text{He}$ ratio) and the ratio of helium to neon ($^4\text{He}/^{20}\text{Ne}$ ratio) differ in magma, crustal rocks, and the atmosphere, we can quantitatively figure out magmatic contributions in volcanic gases from their $^3\text{He}/^4\text{He}$ and $^4\text{He}/^{20}\text{Ne}$ ratios (Fig.1). Similarly, it is possible to clarify the origin of carbon dioxide from its carbon isotope ratio ($^{13}\text{C}/^{12}\text{C}$ ratio). Also, the isotope ratios of hydrogen (D/H ratio) and oxygen ($^{18}\text{O}/^{16}\text{O}$ ratio) of the water vapor within fumarolic gases can indicate the eruption type (phreatic explosion or magma explosion). Also, as the water isotope ratio reflects the temperature of fumarole at the vent, it can be a useful geochemical indicator for volcano monitoring.

Because up until now measurement of isotope ratios requires the complicated procedures for separation and purification of chemical components as well as a large-sized mass spectrometer optimized



Photo 1: Collecting volcanic gas.

for the isotopes of interest, it has not been possible to carry out onsite analysis in the vicinity of the volcano, making it difficult to trace dynamic volcanic activity moment by moment. Thus, this subtheme will incorporate state-of-the-art spectroscopic and mass spectrometric techniques to develop methods for measuring (with a portable instrument) the chemical compositions of volcanic gases, the magma-derived helium, the $^{13}\text{C}/^{12}\text{C}$ ratio of carbon dioxide, and the D/H and $^{18}\text{O}/^{16}\text{O}$ ratios of water vapor and hydrogen. We will also investigate onsite the temporal and spatial variations of the discharge rate of magmatic components, with the aim of achieving higher precision evaluation of the likelihood of eruptions, and to contribute to swiftly diagnosis of the eruption type.

In the meantime, volcanoes are alive, and will not wait for the new techniques to come into practical use. Thus, at some volcanoes we will collect and analyze samples using conventional methods, in order to figure out the current level of volcanic activity and the distribution of volcanic gas emanations in and around volcanoes (Photo 1). Furthermore, we will establish a new remote measurement method of the temperature of fumaroles from the isotope ratio of hydrogen/oxygen in volcanic plumes collected using aircraft. The release of hot water and gas from submarine volcanoes threatens the safe travels of ships. We will thus develop extraction and analysis techniques for water and gas samples from inshore submarine volcanoes for continuous observation.

The shortage of human resources researching volcanoes from a geochemical point of view has been a serious problem. We will thus endeavor to educate the next generation of volcanologists/geochemists who master cutting-edge analytical methods and then go on to develop new technologies by themselves.

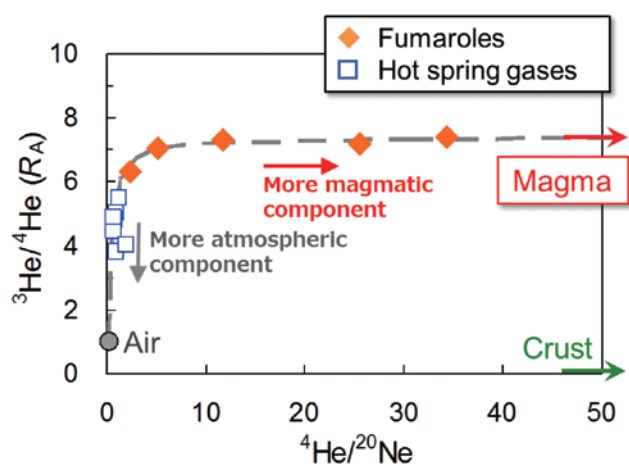


Fig. 1: $^3\text{He}/^4\text{He}$ and $^4\text{He}/^{20}\text{Ne}$ ratios of fumaroles and hot spring gas at Kusatsu-Shirane volcano.

$^3\text{He}/^4\text{He}$ ratio is shown as relative ratio to the atmospheric $^3\text{He}/^4\text{He}$ ratio = 1.4×10^{-6} . Sample data are plotted on the mixing line (broken line) between magmatic and atmospheric components depending on their relative contributions.

Development of Techniques for Revealing Internal Structure and Conditions of Volcanoes

Leader: Yuichi Morita, Earthquake Research Institute, The University of Tokyo

The major importance of well-designed temporally installed observations to complement stationary observations

The 2014 phreatic eruption of Ontake volcano reminded us that even moderately active volcanoes, most of which are tourist attractive places in Japan, can sometimes exhibit unpredictable and hazardous behaviors, taking away the lives of those who do not fully recognize their threat. Most of highly active volcanoes have been fully recognized their risks and we prepared for them. On the other hands, moderately active volcanoes often cause conflicts between tourism and risk management. In this case, precise forecasting of volcanic eruptions is important and a powerful tool for saving lives of tourists and the touristic activity. In order to forecast volcanic activities of moderately active volcanoes, we need to know the structure beneath the summit and internal condition in advance, and, then, anticipate probable and observable measures, and prepare to deploy instruments before they become more active. The above procedure is like health care for human. Even if we consult our home doctor to care our slight disease monthly, we also need detailed and fully physical examination at well-equipped general hospital once a few years. The former is equivalent to permanent observations at each volcano, the latter is temporally dense-installed and multi-disciplinary observations carrying out on the schedule. In this subtheme we design and conduct temporally installed observations to obtain and multi-parameter data for revealing internal structure and condition of volcanoes. In addition, we try to develop techniques for comprehensively evaluating abnormal fluctuations in volcanic activity from the observed data. In this program, we have plan to undergo temporally installed observations for 10 volcanoes during these 10 years.

Table 1: Volcanoes for densely/temporally installed observation with the subjects

Kirishima	Internal structure and occurrence of a phreatic eruption
Hakone	Deep magma source and shallow steam activity
Kuttara	Hot ground water system and phreatic eruptions
Miyakejima	Seismicity at and electroconductivity structure
Kusatsu-Shirane	Internal structure and phreatic eruption
Zao	Seismic activity and electroconductivity structure
Izu-Oshima	Magma accumulation and eruption preparatory
Usu	Magma accumulation and eruption preparatory
Niigata-Yakeyama	Hot water system and electroconductivity
Fuji	Hot water system and volcanic gas

A stunning example revealed in this subtheme

We would like to depict a stunning example of the importance of temporally installed observations that is conducted in this subtheme. Fig. 1 shows the subsurface structure and precise hypocenters around Kirishima Ioyama (Ebino highland), where a phreatic eruption occurred on April 19, 2018. We are carrying out multi-disciplinary mobile observations including magnetotelluric (MT) survey, seismic observations and ground deformation observations, from the time of this project launching until the present. The result of the MT survey shows a distinct region of very high electric conductivity with the flatten cap shape near the surface. This region is considered as an un-permeable layer composed by thermal altered material (clay). The structural feature shown here is common in geothermal areas. The cap is considered with a high potential for phreatic eruptions. As well as electric conductivity structure, active seismic zone locates just beneath the high electric conductive region, which can be explained by what upwelling groundwater stored beneath the un-permeable top layer increase the inner pressure. Actually, the pressure source estimated from geodetic data during the inflation event locates just beneath this region (star in the figure). Just before the phreatic eruption, the seismicity at there increased remarkably. Especially N type earthquake, that is caused by the vibration of volcanic fluid along the crack within host rock, occurred intensely two days before the eruption. As shown here, the internal structure suggests us a hint on the place and type of future eruption, and the seismicity and ground deformations give us the fundamental information for evaluating the imminence of it.

Observation Plans

Many volcanoes in Japan are moderately or less active, some having a high potential of a phreatic eruptions. The latter, as well as active ones, should be monitored with multi-disciplinary observational methods to reveal their internal structures and conditions of the eruption potential, effectively. Therefore, it is essential to systematically implement and schedule temporally installed observations for those volcanoes, and to accumulate the accurate and precise information on the volcanic activity in advance. Researchers in universities and national institutions from all over Japan join this subtheme and will collaborate in conducting mobile observation on 10 volcanoes shown in Table 1. To analyze the observation data obtained, we will also develop several tools for processing volcanic earthquakes and tremors, for evaluating electric conductivity regarding the heated underground water behavior, and for detecting thermal anomaly using drones. All the data acquired in this subtheme will be stored in the data base system designed in Theme A in this project, and will be shared by all researchers joined in this project.

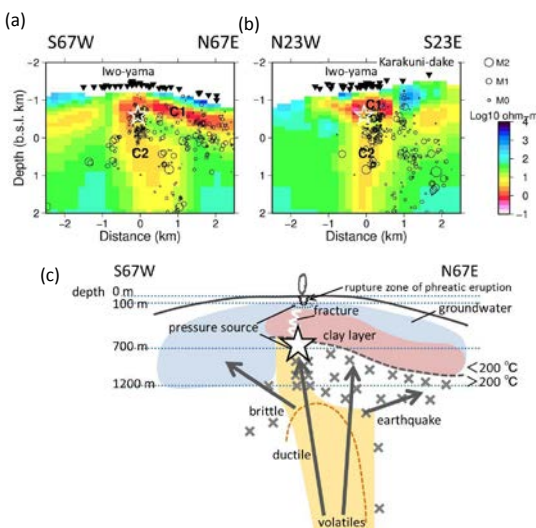


Fig. 1: Vertical cross-sections of electric conductivity (resistivity) structure along (a) S67W–N67E and (b) N23W–S23E lines which pass through the summit of Kirishima Iwo-yama. Black circles represent relocated hypocenters within ± 1 km of each section. The red color indicates the region with high electric conductivity. The stars denote position of pressure sources. (c) Schematic diagram of the hydrothermal system at Iwo-yama. The bottom of the clay layer coincides with the 200°C isotherm. Dashed line indicates the pressure source determined for the ground deformation, which may reflect a liquid–gas phase transition. A white star indicates the pressure source determined by a leveling survey, which was generated by the accumulation of hydrothermal water beneath the clay layer. Orange dashed line represents the possible brittle–ductile transition. (Refer to Tsukamoto et al., 2018)

Development of Volcano Monitoring System using Aerial Microwave Power Transmission Technology

Leader: Takeshi Matsushima, Faculty of Science, Kyushu University

Out of the 111 active volcanos in the Japanese archipelago, approximately 50 are subject to constant monitoring using seismometers, tiltmeters and video cameras, while the remaining volcanos are not permanently monitored. One of the main reasons for this is that in areas where active volcanos are located, it is difficult to provide the power cables and telephone infrastructure required for observation equipment. Furthermore, observation equipment installed around the craters of active volcanos rely mainly on solar panels for their power source, and for data transmission rely on wireless communications such as mobile telephone communication. If a major eruption occurs at such a volcano, the solar panels are destroyed by volcano bombs, and accumulation of volcanic ash causes power outages, rendering it impossible to collect the vital observation data from the time of eruption.

Given this situation, we can use drones – for which technological development is advancing rapidly – to transmit electricity from the sky using a microwave power transmission device to observation equipment on the ground, and in tandem with this we are developing a device that can collect the precious volcano observation data that was stored inside the observation equipment.

Microwave power transmission is the mainstay behind the “Space-based solar power station” concept, which involves positioning giant solar cell panels in space, and from there converting energy into microwaves and sending that electricity to devices on the earth’s surface. Japan is a world-leader in conducting this research.

Currently, development engineers of drones, experts in microwave transmission technologies, and volcano observation researchers – who up until now did not have much cross-pollination – are now working collaboratively on developing “volcano observation/monitoring devices employing mid-air microwave transmission technology”, which is indispensable for next-generation volcano research.

Microwave Electric Power Transmission Technology

In terms of methods for contactless transmission of electrical energy, there is currently the electromagnetic induction method that is used to charge mobile phones, and the electromagnetic resonance method which uses the resonance vibration method of coil and condenser; however, each of these can only transmit electricity to areas in close proximity, and the antenna position needs to be carefully adjusted. In contrast, the microwave electricity transmission method – which can send and receive through an antenna after it has converted electrical energy into magnetic energy – is capable of transmitting large amounts of electrical energy even to far-off locations.

Development of Autonomous Unmanned Aerial Vehicles

Volcanic ash emitted from volcanos negatively impacts the engines of aircraft, meaning that once a volcanic eruption occurs, aircraft are subjected to flying restrictions in the vicinity

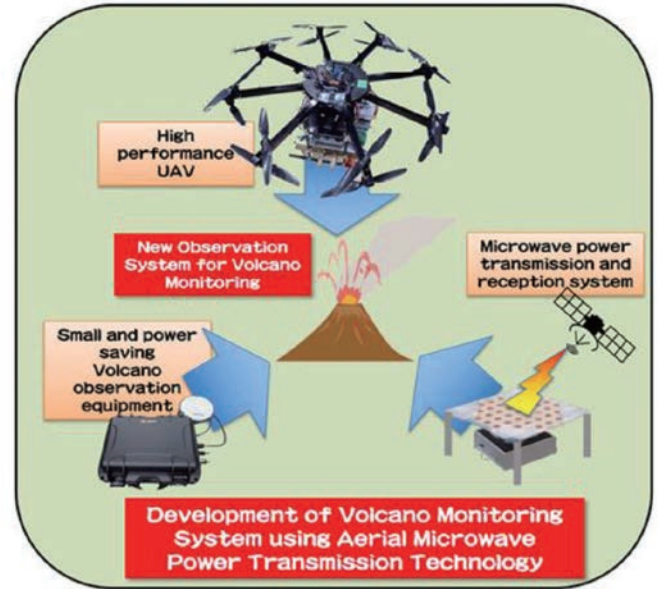


Fig. 1: Development system for volcano monitoring/observation device employing airborne microwave electricity transmission technology.

of the crater. Given this fact, industrial unmanned helicopters designed for spraying fertilizer have been appropriated for the use of observing active volcanos. In recent years, technology has rapidly progressed for drones that are electric and have multiple rotary wings. Similarly, major advances have been made in “self-contained navigation systems” which, if programmed with coordinates, can automatically navigate to the target area while avoiding obstacles, which is paving the way for observation within volcano craters and other places where the pilot radio cannot reach.

Development of Low-energy Consumption Volcano Observation Equipment

At active volcanos, volcanic activity is measured using sensors for earthquakes, crustal alteration and electromagnetism. Currently, solar power cells and mobile phone lines are used for power provision and data collection, but once volcanic activity intensifies the power source is lost, and it becomes problematic to collect data. Faced with this conundrum Kyushu University and Kyoto University are collaborating to develop observation devices that can transmit data using a tiny amount of electricity supplied by airborne microwave transmission, and which can also collect the precious observation data. Due to deploying a great amount of equipment around craters, the price of the equipment as well as development costs need to be kept as low as possible. To this end, we are deliberating a system which would involve connecting up to existing volcano observation equipment, and designing a data collection host device quipped with a wireless LAN device, which could then automatically collect data from mid-air. Another vital point with regard to developing equipment will be to devise a com-



Photo 1: Flight experiment for 16-blade large-scale unmanned aerial vehicle. It is able to fly for 7 minutes with a 10kg load. To extend the flight time, lighter machine parts will be indispensable.

pact and low-loss antenna (rectenna) for receiving microwave electricity.

The Ultimate Aim of This Research Theme

To mount a microwave electricity transmission device within an autonomous unmanned aerial vehicle, and while supplying electricity from 2-3 meters up in the air to volcano observation equipment installed on the ground, develop a device that can wirelessly collect data from the observation equipment.

Once the device has been developed, as well as testing it out in indoor experiments, we intend to fly the unmanned aerial vehicle in volcano regions (such as Sakurajima), and to conduct experiments for transmitting electricity and collecting data. By



Photo 2: Experimental device for sending and receiving electricity inside an anechoic chamber.

2.5 GHz 50 W microwaves are transmitted from 32 element antennas in the upper part, and received by 37 element rectennas below.

continually improving the transfer technology and stable navigation of the unmanned aerial vehicle, we will aim to achieve a transceiver efficiency of at least 10%, and in the near future aim for the practical implementation of “airborne microwave electricity transmission technology”.

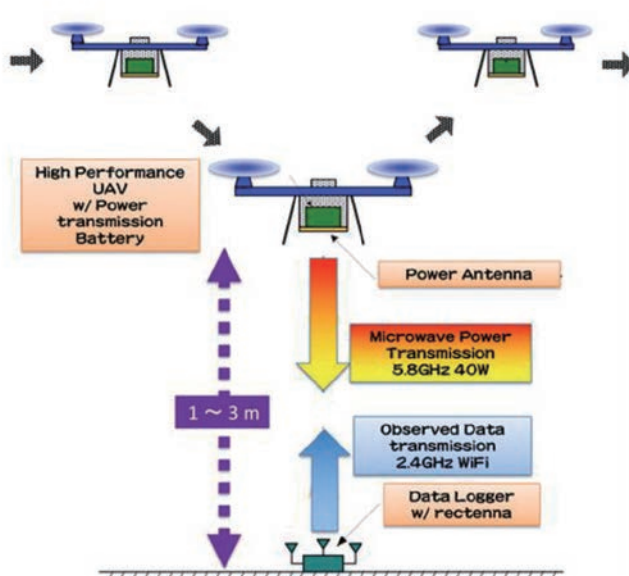


Fig. 2: Schematic diagram of system for microwave power transmitting and receiving, and observation data retrieving using a high performance UAV.

Development of New Observation Techniques for Volcano Observation

Deliberation and Development of Multi-channel Volcano Observation System using Phase-Shifted Optical Interferometry

Leader: Haruhisa Nakamichi, Disaster Prevention Research Institute, Kyoto University
Sub-leader: Yoshiharu Hirayama, R&D Department, Hakusan Corporation

In this theme, we are constructing a practical-use model of the “vibration observation system using Phase-Shifted Optical Interferometry”, which is a new vibration sensor system (hereinafter “optical sensor system”) that uses laser beams for volcano observation. We will also hold a series of field tests and improvements, in order to cultivate a new and practicable observation system.

On-site observation is essential for volcano research and volcano disaster mitigation. Seismic waves, i.e. volcanic earthquakes and volcanic microtremors, constitute valuable information that informs us what is going on beneath a volcano. Vibration sensors (seismometers) that capture these seismic waves perform the role of “ears” that hears the interior of a volcano. If we are to swiftly detect abnormalities in volcanic activities that are invisible to the naked eye, then sensors that can be “ears” must be placed at the flank of a volcano where lightning regularly strikes, full of corrosive volcanic gases lay, and high temperature occurs (Fig. 1). It is in these such places that an optical sensor system presents a major advantage.

The optical sensor system does not have an electrical circuit in its sensor unit (Photo 1). The optical sensor detects surface motions caused by seismic waves as phase differences in op-

Sensor

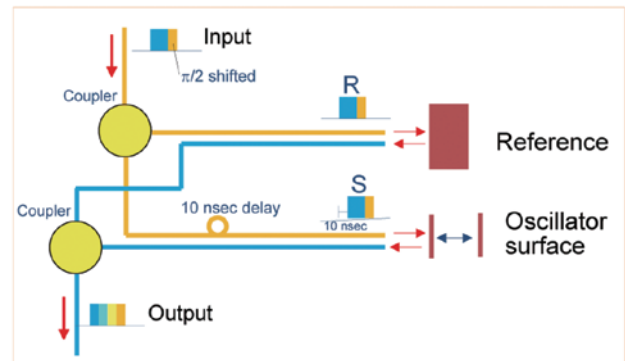


Fig. 2: Principle of the optical sensor system.

tical pulses (Fig. 2). The phase differences come directly at the processor as optical signals through an optical fiber in the optical sensor system. Because of non-electric basis, optical sensors can withstand electric shocks such as those caused by a lightning surge and can also withstand high temperatures and corrosive gases.

In FY2016, the prototype model for optical sensor system was operated for approximately 1 month at Mt. Sakurajima. It compared favorably to the conventional system used at Mt. Sakurajima in terms of obtaining a high-quality record of volcanic earthquakes (Fig. 3). In FY2017, we conducted an extended period field test at Mt. Asama. In 2018, we assembled and tested new longer-period sensors suitable for volcano observation. Under this theme, by continually improving on the new model and carrying out field tests, we will build practical-use sensor system that can capture volcanic phenomena quicker than ever before and contribute to ever-more precise volcanic research and volcano disaster mitigation.



Photo 1: A sensor unit of the optical sensor system.

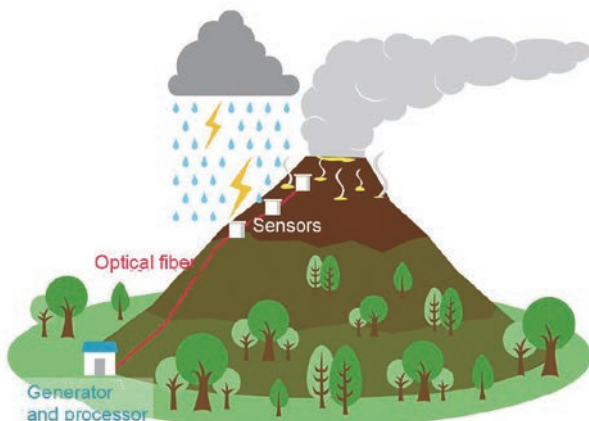


Fig. 1: Volcano observation in a harsh environment.

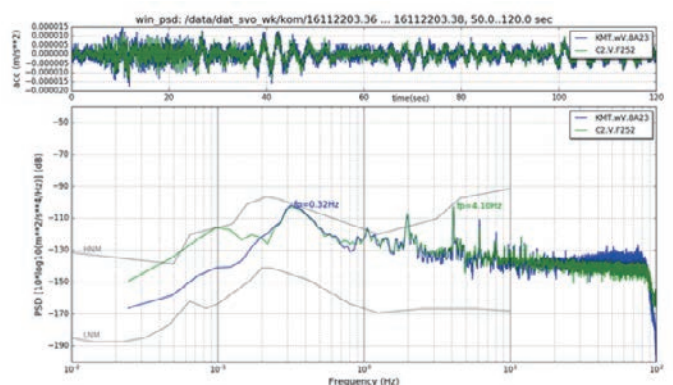


Fig.3: Volcanic tremor at Sakurajima recorded by the optical sensor system.

Development of Forecasting Technologies for Volcanic Eruptions

Manager: Mitsuhiro Nakagawa, Graduate School of Science, Hokkaido University

Outline of Theme

Theme C will elucidate the eruption history for major active volcanos in Japan and analyze their eruption events. By analyzing the information obtained with numerical simulations, we will develop forecast technologies for volcanic eruptions. Then, while consolidating “eruption event trees” that accompany event divergence evaluation criteria, we will examine the calculation of probability of eruption occurrence. This theme is composed of three subthemes (C-1 to -3), which will be promoted in a closely interlocking manner: C-1: “Development of a Method for Forecast of Branching in Eruption Event Tree through Analysis of Volcanic Pyroclasts”; C-2: “Medium-to-long term forecasting of volcanic eruptions through investigation of eruptive history, and Creation of Eruption Event Tree based on Investigation of Eruption Sequence”; C-3: “Development of an Eruption Hazard Forecasting Method through Simulation”. (Fig. 1).

Outline of Each Subtheme

C-1: “Development of a Method for Forecasting of Branching in Eruption Event Tree through Analysis of Volcanic Pyroclasts”

In this subtheme, we will focus on major active volcanos in Japan, and regarding eruptions for which the eruption process is recorded, we will analyze volcanic product to elucidate: the current state of magma accumulation encompassing depth (pressure) / temperature / water content; the time scale from magma mixing ahead of eruption until eruption; and time scale from when magma began rising until eruption starting. Concurrently, we will conduct comparisons of the actual eruptive phenomena. In addition to the data newly obtained through this research, we will refer accordingly to existing research

results to deliberate standards for conducting eruption event divergence forecasting from volcanic product. As well as conducting research on 11 volcanos within the planned period, in linkage with C-2 we will analyze some samples collected in its eruption history survey. Furthermore, in order to usefully apply the large body of amassed eruption product data into forecast of branching in eruption event divergence forecasting, we will consolidate a platform for analysis, and prepare a utilization environment that is available to a wide range of volcano researchers and students.

C-2: “Medium-to-long term Forecasting of Volcanic Eruptions through Investigation of Eruptive History, and Creation of Eruption Event Tree based on Investigation of Eruption Sequence”

In this subtheme, we will focus on active volcanoes in Japan centered on 26 key volcanos that have a major societal impact when erupting, and based primarily on geological and materials science methods, elucidate their long-term eruption history, while as far as possible carrying out detailed analysis of the type of eruption style and its sequence for each individual eruption. For the first 5 years, we will select 5 very important volcanoes (Mashu, Chokai, Asama, Aso, Kikai (Satsuma Iojima), and carry out intensive boring and trench surveys, to elucidate a more highly precise eruptive history. Furthermore, we will create high precise “time – eruption volume diagrams (step diagrams)” for each of these volcanoes, while also clarifying magma process based on materials science analysis of eruption product corresponding to eruptive history, with the aim of creating the eruption event tree that encompass medium-to-long-term forecasting of eruption and branch probabilities.

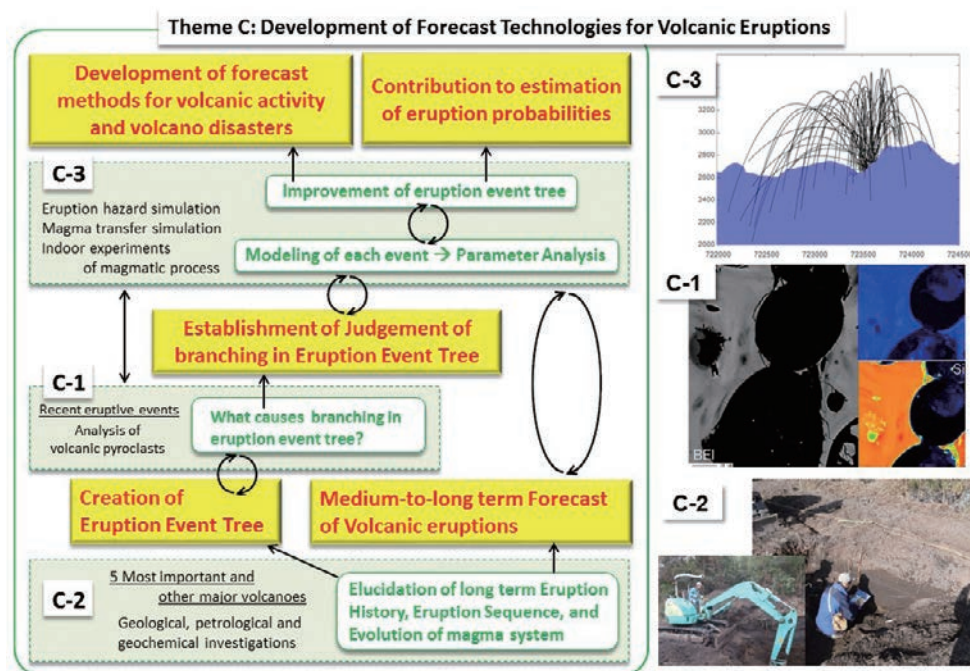


Fig. 1: Image of intertwining of implementation contents in Theme C.

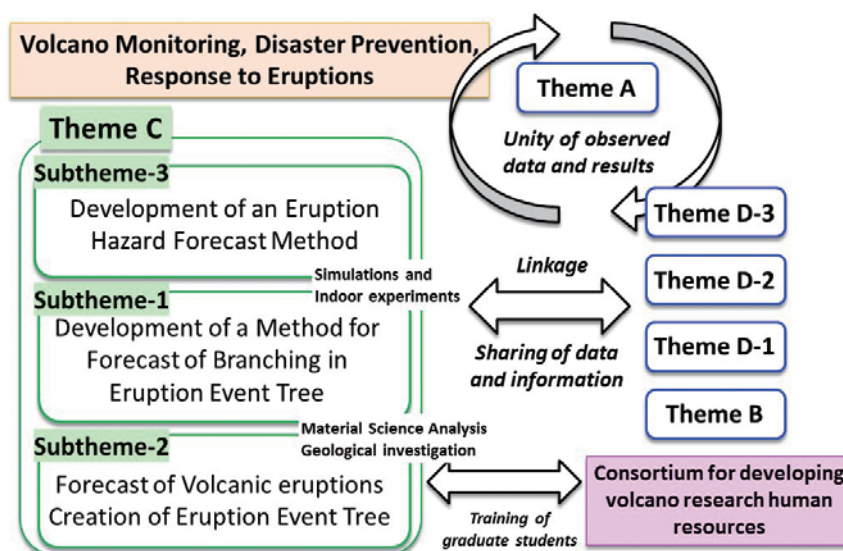


Fig. 2: Relation between Theme C and other themes including construct consortium for developing volcano research human resources.

C-3: “Development of an Eruption Hazard Forecasting Method through Simulation”.

In this subtheme, we will develop an eruption event tree through numerical simulation. By the 7th year of this project, we will develop models and numerical simulation technology for each individual phenomenon (for example, transfer of magma underground). In doing so, we will bring to light parameters that govern each respective phenomenon, and also conduct sensitivity analysis. We will concurrently develop physicality models through experimental methods, feed the results of this into numerical simulations, and enhance functionality. During the 8–10th year of this project, we will develop a volcano hazard evaluation system reflecting the occurrence/divergence conditions for each event, and a magma transfer process evaluation system. We will also conduct multi-pattern numerical simulations, and based on these, aim to present event divergence probability.

Linkage with other themes and other domains

Theme C will be implemented in close linkage with not only C-1 to C-3, but also interlinked with other themes, external research institutions, and the consortium to develop human resources (Fig. 2). Within Theme C, we will employ data pertaining to eruption transitions and eruption scales of past events for each volcano provided from C-2 to examine the divergence conditions for creating the eruption event trees in C-1. On the other hand, the most recent volcano deep portion information provided by C-1 will be utilized to develop eruption forecasting methods to be conducted under C-2. Similarly, information provided under C-1 – magma accumulation depth and magma ascent rate, and geological data provided under C-2 such as eruption volume, eruption rate and vent location – will be utilized in simulations implemented under C-3.

The large amount of data made usable by Theme A, and observation results/observation parameters from Theme B will be used for simulation under this theme. For Theme D, there will be overlaps with D-1 regarding observation information required for real-time hazard forecasting, and linkages with D-2 regarding volcanic ash forecasting technology on the mesoscale, and tie-ups with D-3 regarding the handling of methods for expressing hazard information and eruption occurrence probability.

C-3 will have a particular emphasis on linkages/integration with other fields. For example, when it comes to developing numerical simulations and hazard evaluation systems, we will introduce expertise on the latest algorithms from the computational science field. Similarly, we will adopt the expertise from materials science/engineering and condensed matter physics for constructing physicality models and for the destruction process for dyke intrusion. For C-2 and C-3, we will implement research under linkages and information exchange with overseas research institutions. In particular, we intend to link the database of compositional analysis obtained in C-1 with major overseas websites for publicizing analytical data.

The research findings of this theme will be utilized in lectures and exercises held under the Project to Construct a Consortium to Develop Volcano Researchers. This theme will also be used as a forum for cultivating human resources. The geological surveys and materials science analysis conducted under C-1 and C-2 in particular will be suitable research themes for graduate students in these domains. We also envisage that each participating institution will intake graduate students and conduct training for geological surveys and chemical analysis. In that sense, the major part of education/training in the fields of geology and materials science for the “human resource development project” will be likely borne by this theme.

Societal Significance

The aim of this project which is eruption forecast technology is required for volcano monitoring, disaster preparedness countermeasures, and response to eruptions. As such we hope that it will be applied broadly throughout society. The major results of this project – namely “medium-to-long term eruption forecasting” and “eruption event trees” – will surely provide foundational resources that are indispensable for the JMA and The Volcano Disaster Prevention Council in deliberating eruption scenarios and formulating disaster countermeasures including evacuation plans. We also plan to hold a series of lectures every year from 2018 aimed at residents living near each volcano in order to promulgate the research findings and medium-to-long term eruption forecasts, and in doing so will enhance the level of awareness among residents regarding volcano research and volcano disaster preparedness. We hope that the volcano hazard evaluation system will not only be utilized for response during times of eruption, but also utilized in volcano disaster preparedness countermeasures.

Development of a Method for Forecasting of Branching in Eruption Event Tree through Analysis of Volcanic Pyroclasts

Leader: Atsushi Yasuda, Earthquake Research Institute, The University of Tokyo

In this theme, we will conduct analysis of volcanic pyroclasts in the aim of developing a method for forecasting what sort of transition an eruption event will follow. When some kind of abnormality is observed beneath a volcanic body, will this lead to an actual volcanic eruption, or in fact will no eruption occur? Or, after an actual eruption commences, will it be a gentle stream of lava, or an explosive eruption that scatters pyroclastic material over a wide area? Will the eruption be over in a short time, or continue for a protracted period? Carrying out such judgements is the essence of “forecasting of branching in eruption event”. The overarching objective of this theme is to gather materials science data and to organize the information so that it can be used at any time. This enables us to swiftly carry out various judgements regarding likely style and transition of the eruption whenever we will observe events preceding an imminent eruption.

A great variety of data can be obtained by analyzing volcanic pyroclasts. It is still not sufficiently clear, however, what sort of data would be useful for the forecasting of branching in eruption event. So, regarding relatively recent eruptions for which we can understand the eruptive style and transition from observations and historical records, we have planned to investigate how the state and movement of magma is recorded within each volcanic pyroclasts. In particular, we will focus on: 1) composition and modal abundance of phenocrysts, 2) melt composition (+ water content), 3) texture and composition of groundmass, and 4) zonal structure of phenocrysts. From (1)-(2), we can understand the state of magma prior to eruption, in other words, the temperature and pressure of magma chamber, and the viscosity of magma. We consider these to be extremely important indices for the explosivity and the persistence of volcanic eruption. These can also be utilized for initial values and physical property values for the simulation to be conducted in C-3.

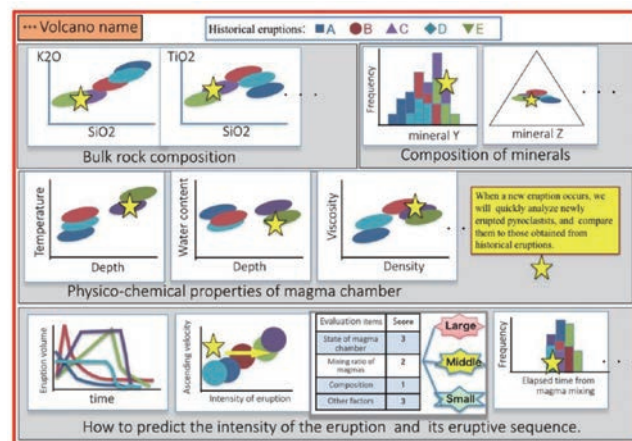


Fig. 2: Catalogue compiling analytical results of pyroclasts from recent volcanic eruptions (tentative).

We believe that (3) records the ascending speed of magma, and if for past eruptions we can identify a good correspondence between the speed of magma ascending and the eruptive style, we may be able to forecast the eruptive style for the next eruptions by applying the magma movement speed obtained from physical observations etc. to this correspondence. For (4), assuming a case where magma injection is the trigger for an eruption, we will try to estimate the time from magma injection until eruption, from the diffusion profile of elements within phenocryst. If we can obtain a characteristic time for a given volcano, it may be useful in future for responding to eruptions and strengthening volcano monitoring; when magma injection is estimated from physical observation, a severe eruption warning can be issued within a prescribed time period, and if nothing transpires during this period the warning can be lifted.

Within the project time period, we will gather the above-mentioned data for 11 volcanos, and examine whether analysis of volcanic pyroclasts is useful for the forecasting of branching in eruption event. In order to do so, it will be necessary to efficiently and precisely analyze an extremely large amount of volcanic pyroclasts. To this end, we are building an environment conducive to the highly efficient and highly precise analysis of volcanic pyroclasts (analytical platform) (Fig. 1). Data obtained is planned to be organized as an online web catalogue (Fig 2) where it is possible to gasp at a glance the characteristics of volcanic pyroclasts and eruptions for each volcano.

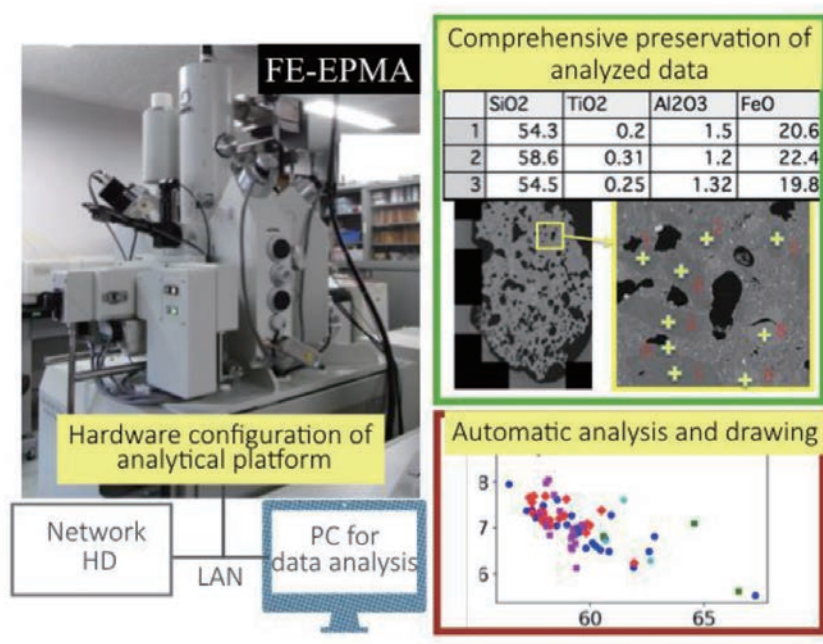


Fig. 1: Overview of analytical platform.

Medium-to-long Term Forecasting of Volcanic Eruptions through Investigation of Eruptive History, and Creation of Eruption Event Trees Based on Investigation of Eruption Sequence

Leader: Mitsuhiro Nakagawa, Graduate School of Science, Hokkaido University

In order to expedite “Development of Forecasting Technology for Volcanic Eruptions”, it is essential to obtain all kinds of monitoring data spanning the preparatory process of the eruption to the start and finish of the eruption, as well as materials science information which has recorded the process beneath volcanoes. Obtaining such data may allow us to elucidate the eruption preparatory process, the change and cause of eruptive style, and the conditions that led to the eruption ending. By accumulating a large number of such case studies, we hope to establish volcano eruption forecasting technology.

This subtheme will look at multiple active volcanoes and based principally on geological and materials science methods, elucidate highly precise eruption histories for each individual volcano, while re-establishing the eruption sequence for each individual eruption. Then, based on these results, we will create high precise “time – eruption volume step diagrams”. We will also carry out materials science analysis of volcanic product corresponding to eruption history in order to clarify the magma process. Based on the information from step diagrams in particular as well as the long-term evolution in magma process, we will develop medium-to-long term eruption forecasting methods, and conduct the medium-to-long term forecasting for each individual volcano. Furthermore, by accumulating as much information as possible about each individual eruption sequence, we will aim to create eruption event trees which include branch probabilities. Clarifying the characteristics of eruption events and similarities for each volcano, we will provide the necessary parameters for modeling eruption events – e.g. eruption volume, eruption sequence, magma physicality (composition, crys-

tal content, temperature etc.) - to themes C-1 and C-3 in particular. (Fig. 1)

For this subtheme, we have identified 26 key volcanoes to be the subject of our investigation, all of which are active and would have a major impact on society if they were to erupt. We have also selected the following 5 top-priority volcanoes for which boring and trench surveys will be intensively implemented: Mashu, Chokai, Asama, Aso, Kikai (Satsuma Iojima). As this subtheme will pivot on geological surveys and materials science analysis of volcanic product which will take a lot of time and labor, we have gathered together experts from many institutions. We have established a “Magma Evolution Process Analysis Center” within Hokkaido University to provide high-precision materials science analysis, which will be available to researchers and graduate students in participating organization in order to accumulate multifaceted and high-precision data.

Ultimately, for each volcano in the scope of this research, we will create time – eruption volume step diagrams for the past tens of thousands of years or an even longer time axis, and provide complete information for magma evolution corresponding to these. Based on this information we will develop a medium-to-long term eruption forecasting method, and as well as creating and publicizing medium-to-long term forecasts for eruptive activities, consolidate eruption event trees based on eruption history. Ultimately, our aim is that these are widely promulgated among local governments/municipalities, the Volcano Disaster Prevention Council, and among citizens, and are utilized in long-term infrastructure planning, volcano disaster preparedness and for educating citizens.

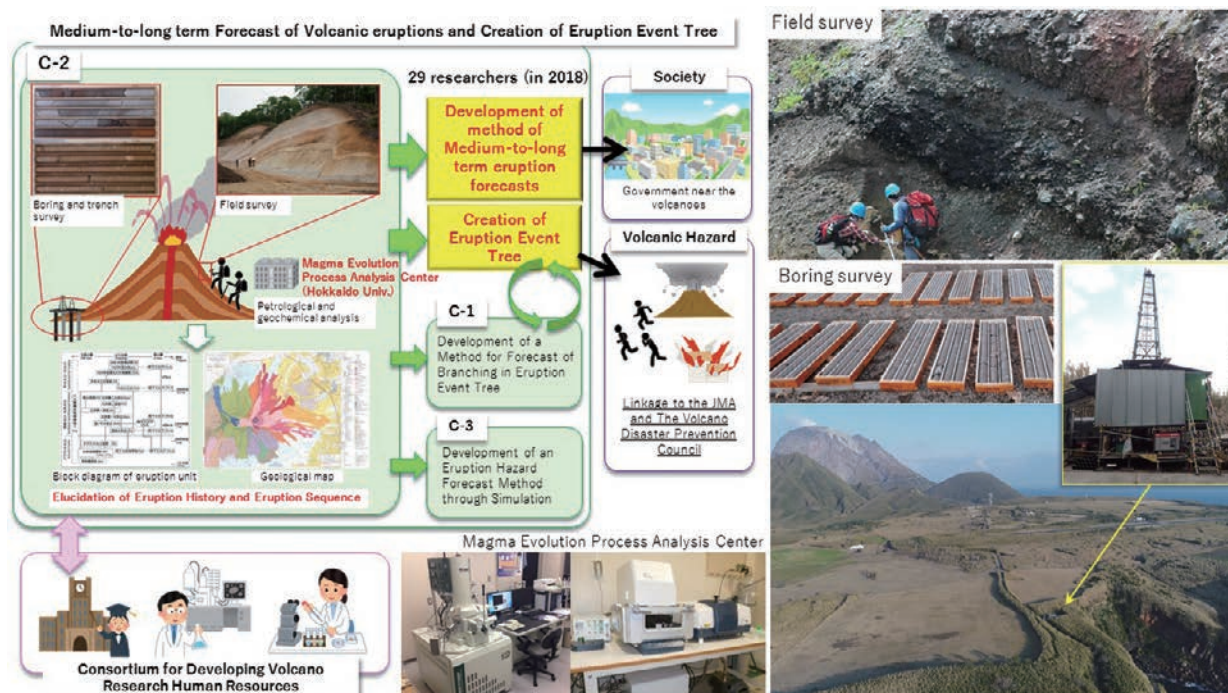


Fig. 1: Research methods and expected results for C-2, as well as intertwining with related themes/Consortium to develop volcano human resources.

Development of a Hazard Forecasting Method using Simulation

Leader: Eisuke Fujita, Center for Integrated Volcano Research, National Research Institute of Earth Science and Disaster Resilience

This subtheme will create “eruption event tree” for evaluating forecasting of volcanic activity and volcano disasters. These are tree diagrams that show the manifold possibilities that can occur in the entire process of volcanic activity - from stable times, to when abnormal activity is acknowledged, all the way to eruption - and encompassing the imminence, eruptive style, classification of potential hazards, and level of danger posed for our lifestyles and societal activities. While there are multiple possibilities for the transition that activity could follow, if we can determine which of these branches it will take and grasp the state of the volcano, we can enact countermeasures.

Volcanic eruptions and their accompanying volcano disasters occur due to a complex combination of physical and chemical elements, and result in a wide range of phenomena including lava flow, pyroclastic flow, eruption column, volcanic ash, and ballistic projectiles. To deal with volcanic eruptions, it is also important to grasp the movement of magma beneath the ground's surface. In order to elucidate the mechanisms of such complex phenomena and to forecast the occurrence of volcano disasters, based upon information/logic obtained from volcanic observation data and experimental data, we will create highly accurate models, carry out numerical simulations and then link them into forecasting.

In this subtheme, we will develop and enhance the functionality of: 1) Simulation of magma transfer underground conducive to anticipation of volcanic eruption/forecasting of transition, and 2) Eruption hazard simulation for volcano disaster mitigation. Regarding 1), we will aim to interpret the transfer process of magma underground (Fig. 1), and the flow pattern and eruptive style as gas-liquid two-phase flow, in order to systematically arrange determination criteria for event branching leading up to eruption. Furthermore, we will conduct indoor experiments, construct models regarding the physical properties that impact upon the volcanic fluid movement process, and enhance the functionality of numerical models for simulations. For 2), we

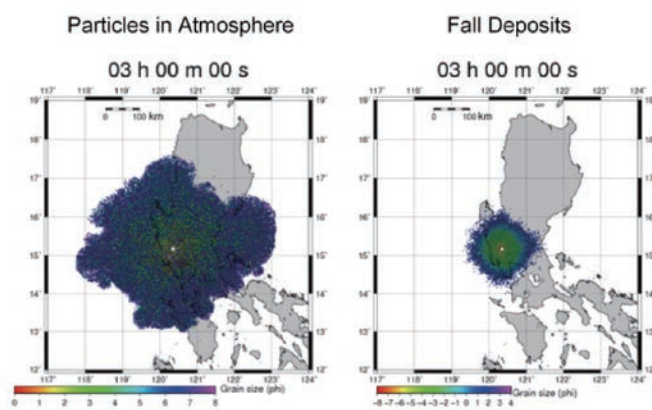


Fig. 2: Example of eruption column/volcanic ash large scale simulation using SK-3D modelling. Reproduction of calculations of eruption of Mt. Pinatubo in 1991.

will create a system for collectively evaluating the diverse volcanic phenomena that occur during eruptions such as lava flow, ash, smoke, pyroclastic flow, and ejection of materials, conducive to the highly-precise evaluation of volcanic hazards. Based on these findings, we aim to assign parameters for evaluating the branches of event trees, spanning volcanic activity to the occurrence of a volcanic disaster.

As an example of developing a smoke column dynamics model for conducting damage forecasting from numerical simulation, we are providing the case of an eruption column/volcanic ash large-scale numerical simulation through SK-3D model (Fig. 2). Numerical simulations can display the situation as it changes from minute to minute, and can provide information regarding damaged buildings and routes used for evacuation. There is great potential for these numerical simulations to be applied in disaster preparedness countermeasures commensurate to the transition of the volcanic activity.

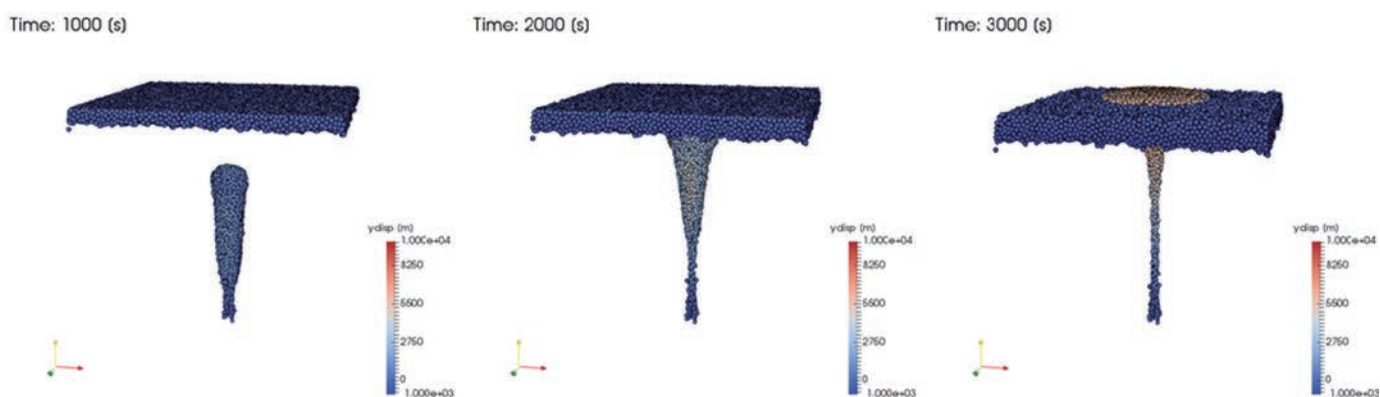


Fig. 1: An example of dyke intrusion simulation. An area $10 \times 10 \times 10$ km is expressed as 10 million particles with a diameter of approx. 100 m. In the middle of the crust, the tip of the dike is set 5 km underground, and in the case of excess pressure $32 \times$ that of lithostatic pressure, the conditions leading up to eruption can be seen. It was ascertained that initial excess pressure 10 times that of lithostatic pressure is the threshold for eruption or non-eruption.

Development of Volcano Disaster Countermeasure Technology

Manager: Setsuya Nakata, Center for Integrated Volcano Research, National Research Institute for Earth Science and Disaster Resilience.

In order to better respond to volcano disasters, this research theme will develop a series of technologies spanning from grasping the situation in real time, through promptly analyzing the data, forecasting the eruption sequences and evaluating disaster risk crisis, to all the way to providing countermeasure information (Fig. 1).

When a volcanic eruption occurs, in order to promptly evaluate the volcanic activity and to carry out the appropriate disaster response countermeasures, it is essential to gain detailed information regarding the conditions around the crater and the distribution of ejecta as quickly as possible. However, due to various restrictions including safety issue, it may well be the case that it is not possible to approach the area around the crater. Under the Comprehensive Observation Squad of the Coordinating Committee for the Prediction of Volcanic Eruptions, in order to comprehensively evaluate the state of the eruption, volcano researchers are able to enter the restricted areas during times of eruption, while securing their safety, for the purpose of observation and investigation. However, as it takes time to set up this squad, in the past it was often impossible to make a swift determination, due to observation points being destroyed by the eruption and not being recoverable, and also because of a lack of initial information about the eruption including ascertaining the state of the crater and ejecta. To compensate for this situa-

tion, this project will prepare a system for swiftly implementing emergency observation of volcanic eruptions for cases where precursory phenomena of a volcanic eruption are detected or when an eruption has actually initiated. Concurrent to these issues, theme D-1 will develop techniques for obtaining real-time information regarding the topography around the crater and regarding ejecta from around the time of eruption occurring, using unmanned vehicles including drones, and will also make provisions for sharing the information analysis results obtained.

Furthermore, irrespective of the scale of the eruption, the dispersal and falling of volcanic ash is a disaster among all volcanic disaster phenomena, which can have the greatest impact over a wide area. The effects of falling volcanic ash caused by the next eruption of Mt. Fuji will cause major issues for the Tokyo Metropolitan Area. Given this, real-time falling volcanic ash prediction information based on observation prior to eruption using models and simulation (regarding dispersing and falling volcanic ash) is considered to be highly important. Using Sakurajima Volcano as a case study, Theme D-2 is promoting research to utilize observational and meteorological data from before eruption to anticipate ahead of time the risk of moving/dispersing/falling of volcanic ash that would accompany the expected eruption, and to utilize this in disaster countermeasures. With regard to dispersing ash, preparations are in progress to

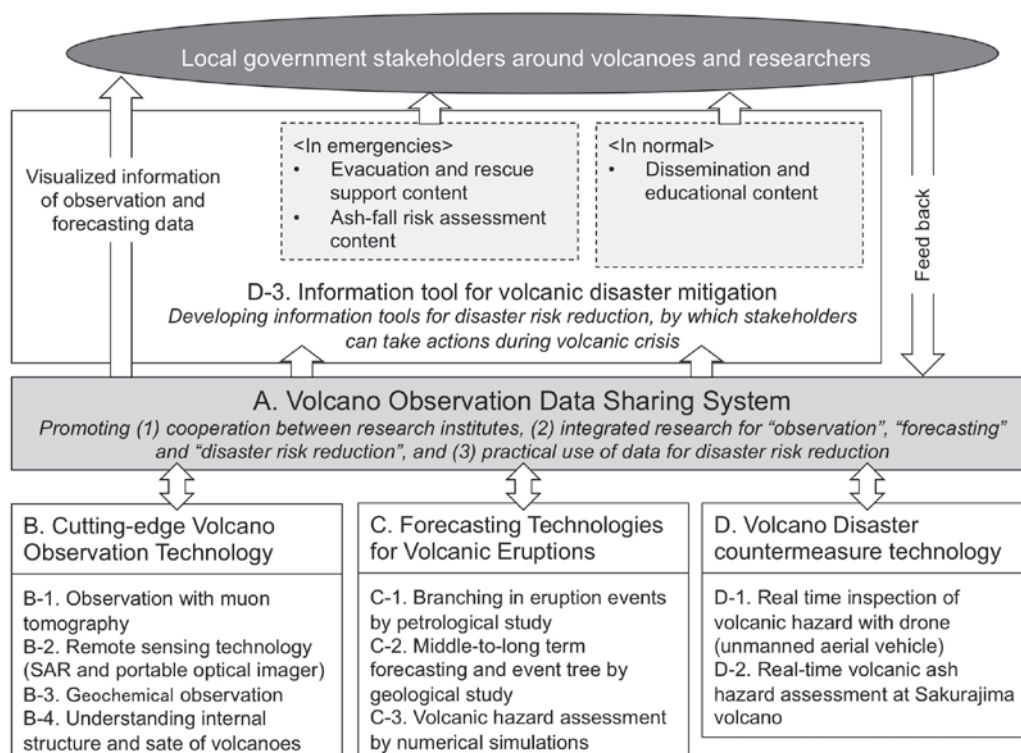


Fig.1: Diagram showing relationship between subthemes in Theme D, and for the overall project.

utilize the latest technologies including MP radar and GNSS to provide real time forecasting information that can capture the behavior of volcanic ash and reflect this into falling ash models.

In addition to these kinds of observation and forecasting information, we will employ the platform to be consolidated under Theme A, and under subtheme D-3 create tools for providing information and knowledge required by disaster preparedness stakeholders (local governments and experts involved in volcano disaster prevention council) .

Currently, the forecast for volcanic phenomena is handled by the JMA, and the Meteorological Service Law prevents any entity other than the JMFA from conducting forecast work. Even with such restrictions in the background, researchers involved in volcanic eruptions including universities and national research institutions are promoting research aimed at more highly precise volcano eruption forecasting technology to mitigate volcanic disasters, and are proactively involved in the Coordinating Committee for the Prediction of Volcanic Eruption while also making important contributions to enhancing the eruption forecasting technology that is used for the forecasting business by the JMA. Following the experience of the volcanic disaster at Mount Ontake in 2014, observation points were established around the craters of active volcanos. There is no doubt that having observation posts around volcano craters allows us to capture various abnormalities. However, being able to capture previously undetectable abnormalities does not translate into an ability to predict eruptions. With the Ontake eruption also, abnormalities were detected a fortnight before the eruption, and we are now only just beginning to decipher the meaning of this.

On the other hand, Japan has not experienced a large-scale eruption since volcanic observation research begun. Furthermore, it has never issued a warning for such a major eruption. In contrast, The Republic of Indonesia - which is still a developing country compared to Japan in terms of observation technology and research - has for several major eruptions the likes of which have not been observed in Japan in recent history, raised and lowered eruption warnings in a timely manner, keeping the

impact of disasters to a minimum. If we consider a comparison with the track record of Indonesia, it suggests that the consolidation of an observation network and the effective issuance of a volcano alert are not necessarily directly linked. Not limited to Indonesia, if we compare the volcano disaster organ-structure of Japan with other countries having active volcanos, it would seem that outside Japan, research institutions and organs in charge of volcano disaster preparedness are unified. With regard to the speed from observation through information transmission to decision-making, Japan is very much lagging behind. For Japan therefore, as per the aims of this research, as well as unifying observation data, it will be essential to foster smooth cooperation that involves promptly understanding and evaluating phenomena and disasters by using observation data, and to provide straightforward information to disaster preparedness organs and related experts, who can feed this into disaster preparedness countermeasures. Therefore, under the restrictions of the Meteorological Service Law, while making every effort to transmit observation data with uncomplicated commentary in real-time, it becomes important to develop tools for providing information regarding where the current situation fits within the eruption event tree of each target volcano, and what sort of disaster risks are possible. While this part is the objective of Theme D-3, it also constitutes an extremely important output for the project overall.

For the Project to Promote the Next Generation of Volcano Research, while the unification of observation data is a major theme, the objective is not merely to “unify” observation data. The overarching and essential aim of this project involves utilizing unified data to further the research of the entire volcano community throughout Japan, so that in times of emergency, the required and relevant information can be promptly provided in a straightforward matter to municipalities and experts participating in the volcano disaster prevention council, enabling effective rescue and evacuation countermeasures to be implemented.

Development of Technique for Grasping Volcano Disasters in Real Time Using Drones

Leader: Tatsuro Chiba, Asia Air Survey Co., Ltd.

When a volcano eruption starts, in order to exercise appropriate judgement for disaster response, it is important to get quickly a handle on the situation inside and around of the crater by obtaining visible images and topographical data, in addition to existing observation equipment such as seismometers.

However, at present, the method for knowing the state of the crater and ejecta is to inspecting the crater area from a long distance under a limited weather condition after the eruption onset. There, they have empirically estimated the situation using the aircraft footage taken by experts and media.

The purpose of this subtheme is to develop a system which can get high-resolution optical images of the crater nimbly with unmanned areal vehicles (UAV), analyze them, and perceive changes of the situation automatically, in a manner that is conducive to safe and rapid disaster response activities (Fig. 1).

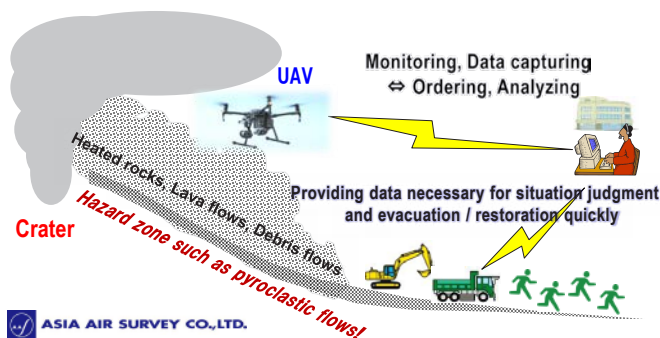


Fig. 1: Developing technology to swiftly catch the state of danger sites.

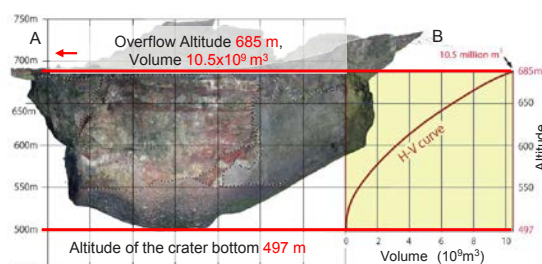
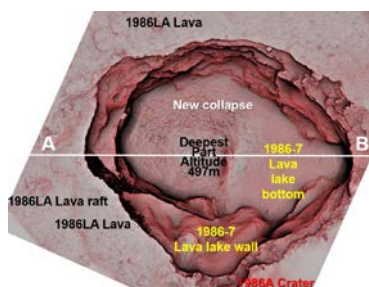


Fig. 2: Measurement of the Miharayama crater size at Izu Oshima with drone (left: 3-D model, right: graduated cylinder representation of the crater).

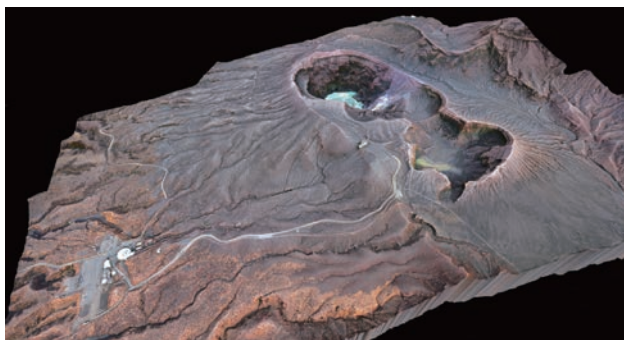


Fig 3: 3D image of the crater area of Mount Aso, created by emergency drone-photographing after the eruption in October 2016.

Task 1: Speeding up the obtaining of detailed information following eruption.

Due to safety issues, it takes time to grasp the details of the area around the crater and to obtain topographical information immediately after an eruption. Therefore, the task one is to develop techniques of images capturing speedy using UAVs like drones to provide the characteristics of ejecta and lava flows for the forecasting simulations and disaster response activities (Photo 1).

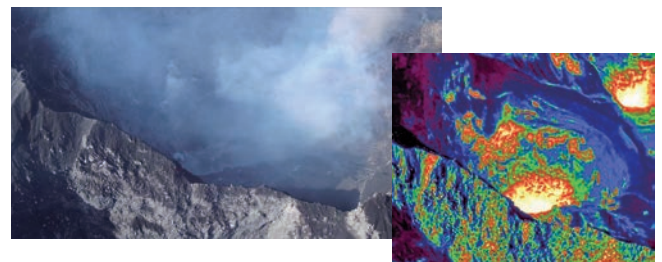


Photo 1: Minamidake B crater of Sakurajima, captured by drone (left: image captured by visible light. right: Image captured by far-infrared rays).

Task 2 : Enhancing the functionality of image analysis techniques

Although higher resolution images/footage provide more highly accurate on-site information, acquiring them is time-consuming. The task two is to develop techniques that can provide information with the required level of precision for the required situations in line with the time variation during times of disaster (Fig. 2).

If an eruption were to occur during this research project, we are ready to acquire images from airspace and map geographical data by building on the contents currently under consideration, and to swiftly provide this information (Photo 2; Fig. 3).

Development of Real-time Volcanic Ash Hazard Forecast Method

Leader: Masato Iguchi, Kyoto University Disaster Prevention Research Institute



Photo 1: Plume rising from Sakurajima's Showa Crater



Photo 2: Radar to detect volcanic ash from Sakurajima

Volcanic ash ejected by volcanic eruptions causes impact to farming, fisheries, industry and human health, and paralyzes the transportation network. Even after eruptive activity has calmed down, rainfall triggers debris flow and mud flow as secondary disasters.

At Sakurajima volcano, vulcanian eruption at Minamidake and Showa craters has caused increasingly severe damage from ash fall since 1955, and a major eruption (VEI 4 or 5) near future will not only wreak grave damage to the area around the volcano, but will also have implications up to East Japan. To decrease impact from volcanic ash, we need to grasp the state of transport and deposit of volcanic ash in real-time, and to forecast them immediately and accurately. In this sub-theme, Kyoto University, Kagoshima University, Tsukuba University, Kobe University, Tohoku University, Tokyo University, The National Institute for Environmental Studies, and the Japan Weather Association will develop the technologies outlined below, aiming to achieve ~50% ~ 200% forecasting accuracy for ash-fall deposit by collating existing volcano observation techniques with meteorology and fluid mechanics ;

1) Integrated monitoring of volcanic ash using X-band radar, Li-

dar and GNSS for transport of volcanic ash, and disdrometer for ash-fall deposit,

2) Reduction of time for forecasting transport and deposit of volcanic ash by estimating effusion rate of ash from the volcanic tremor and ground deformation accompanying with a volcanic eruption,

3) High-precision forecasting transport and deposit of volcanic ash with high-precision wind field taken into consideration of complex geometry of volcanic body, and the grain-size and falling velocity of ash-fall,

4) Technical development of online system for continuous forecasting volcanic ash for prolonged eruptions by data assimilation, 5) Stochastic forecasting of ash fall by statistical processing of precursory ground deformation prior to volcanic eruptions.

As well as the ability to provide information on the volume of volcanic ash in real-time, this forecasting method can contribute to the ash fall forecast by the JMA and to local disaster preparedness plans. Furthermore, there are high hopes that forecasting data will be utilized in the disaster countermeasures of municipalities as well for operations of transportation facilities.

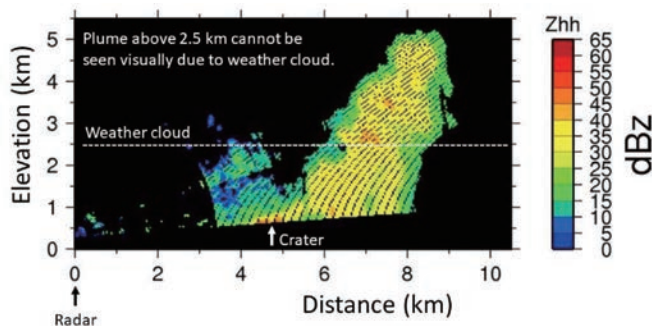


Fig. 1: Plume captured by a radar. The eruption occurred at Kuchinoerabujima volcano on December 18, 2018

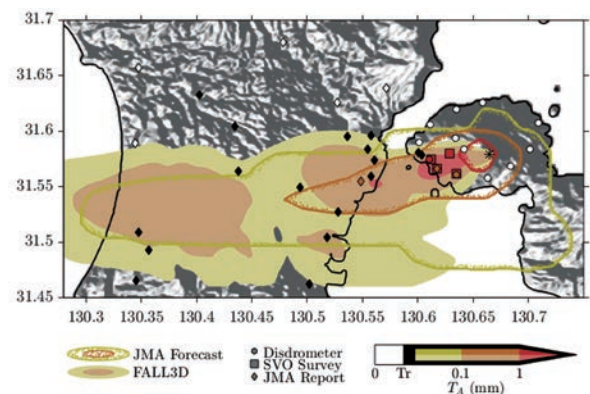


Fig. 2: The forecast of thickness of ash-fall deposit by an eruption on June 16, 2016 at Sakurajima volcano. Accuracy of the forecast is improved through high-resolution wind and accurate eruption rate.

Developing Information Tools for Volcano Disaster Countermeasures

Leader: Yousuke Miyagi, Center for Integrated Volcano Research, National Research Institute for Earth Science and Disaster Resilience

Observation, Prediction, and Countermeasures

Up until now, volcano research in Japan has revolved around research for observing volcanic activity and predicting eruptions. It is hoped that forecasting eruptions will allow us to reduce the damage caused by volcano disasters. However, unlike meteorological disasters, volcano disasters happen very infrequently, and while on one hand disaster prevention officers in municipalities do not have much experience in responding to volcano disasters, volcanic eruptions are accompanied by a diverse range of disasters and as such, the expertise of various domains is required to sufficiently anticipate the damage and to respond appropriately.

By contrast, while local disaster prevention plans for volcanoes up until now had mainly focused on countermeasures for local residents, the 2014 eruption at Mt. Ontake made clear the importance for countermeasures for tourists and mountain climbers.

Meanwhile, one type of volcanic disasters is that caused by volcanic ash. As well as obscuring visibility, even a small thin layer of fallen ash can have a major impact on local infrastructure including paralyzing transport networks. In particular, urban areas in Japan have not experienced falling volcanic ash, and moving forward there are many issues which require careful deliberation (Photo 1).

Furthermore, by concretely envisaging the conditions of a volcano disaster during normal times, it is possible to empower disaster prevention officers in municipalities to act swiftly and appropriately from the outset when a disaster strike. This subtheme, therefore, will link together “observation/forecasting” with “countermeasures”, and will develop information tools that can be utilized appropriately in disaster response.

Information Tools for Volcano Disaster Countermeasures

The information tools to be developed under this subtheme will comprise 3 contents (Fig. 1).

(1) Promoting the development of contents that will be effective for the evacuation and rescue of hikers and tourists when an eruption occurs. Following on from the same initiative in 2017, in 2018 a demonstration experiment was conducted called “Mt. Fuji Challenge 2018”, aiming to create a system to ensure the safety of people climbing Mt. Fuji. Dynamic data of climbers obtained for understanding the trends of mountaineers will be utilized to develop the contents.



Photo 1: Volcanic ash covers the outdoor cooling units in the eruption at Mt. Aso in October 2016.

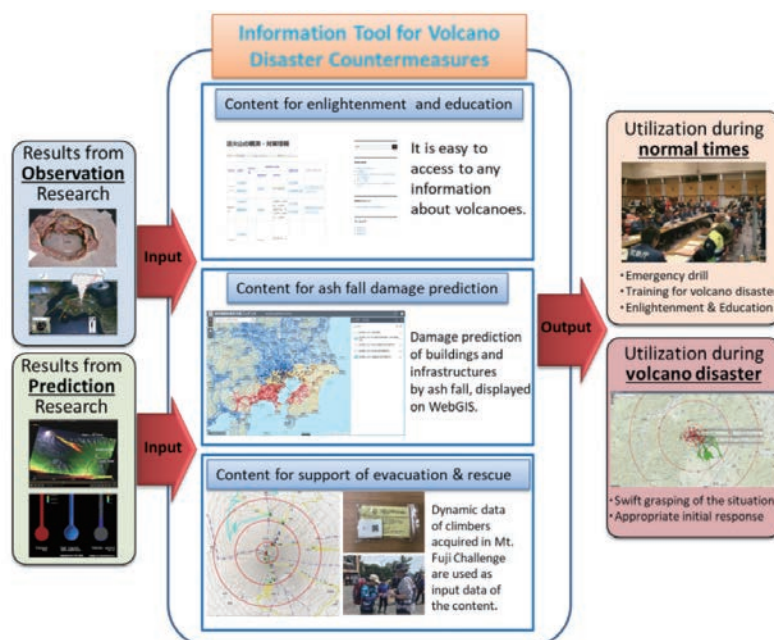


Fig. 1: Schematic diagram of information tools.

(2) Promoting the development of ash fall damage prediction contents for grasping the impact that fallen ash in urban areas will have on key facilities such as hospitals, which will be critical sites for disaster response. Through linkages with The Architectural Institute of Japan, we will aim to quantify the impact on buildings and structures by conducting ash fall experiments.

(3) Promoting the development of contents for raising awareness/education, to deepen knowledge of volcano disasters, and to support preparations and concrete “image training” of disasters in normal times. Based on needs obtained from surveys and hearing sessions with disaster prevention officers in municipalities throughout Japan, we are currently developing a comprehensive portal site that provides easy access to textbooks and educational resources regarding volcano disasters and volcano disaster prevention.

There is a strong need to combine these three contents into tools that can be easily utilized by volcano experts and disaster prevention officers during both normal times and during disasters. To this end, when it comes to developing the tools, we will closely cooperate with disaster prevention officers in municipalities where volcanoes are located, as well as with volcano experts, and draw upon the know-how and experiences of volcanologists and disaster prevention officers in order to develop the tools from the user’s point of view, and which bridge any existing communication gaps.

Finally, the information tools will not be restricted to the contents developed under this subtheme, but will also function towards promoting research for observation/forecasting/countermeasures in a unified manner. Incorporating the grasping of observation information and results of forecasting research, we aim to create tools that allow disaster prevention officers and experts in the Volcano Disaster Prevention Council etc. to gain a common awareness of the situation during a disaster, including being able to browse WebGIS at any time to gain a handle on the constantly evolving situation during volcano disasters.

Project to Form a Consortium for Volcano Research and Human Resource Development

Director: Takeshi Nishimura, Implementing Office of Institution Representing Consortium,
Graduate School of Science and Faculty of Science, Tohoku University

1. Outline

“The Project to Form a Consortium for Volcano Research and Human Resource Development” is an initiative to construct a consortium made up of universities and research institutes implementing cutting-edge volcano research, national organs and municipalities overseeing volcano disaster preparedness, as well as private companies that support each of these entities. By providing an environment for the systematic study of volcanology in a multidisciplinary manner, the project nurtures the next generation of volcano researchers.

2. Aims Behind Forming a Consortium

Up until now, students carrying out research into volcanoes have based their study around the specialties of the universities they belong to. However, as the number of volcano researchers at universities is limited, the content available to students at universities they belong to is also limited by the same token. However, in recent years, the enhancement of observation and survey technology has paved the way for constructing theoretical models for magma dynamics, and in research fields regarding the understanding of volcanic phenomenon and forecasting volcanic activity, there is a fusion underway of the 3 main fields of volcanology, namely geophysics, geology/petrology, and geochemistry. There are also high hopes from society for mitigation of eruption disasters, meaning that volcanology is established as a domain of disaster science in its own right.

Given this, the Consortium will implement the “Program for Next Generation Volcano Research and Human Resource Development”, transcending the bounds of universities and research institutions to provide a new option that is research with an increasingly interdisciplinary nature. This will deepen understanding of various volcano phenomena and advance cutting-edge volcano research that enjoys deeper international linkages, and in the process aim to foster the next generation of volcano researchers capable of playing a role in mitigating volcano disasters in highly networked information societies.

3. Consortium Participating Institutions/Cooperating Organizations and Bodies (as of December 2018)

@ Participating Institutions

Tohoku University (representative organization), University of Hokkaido, Yamagata University, The University of Tokyo, Tokyo Institute of Technology, Nagoya University, Kyoto University, Kyushu University, Kagoshima University, Kobe University

@ Cooperating Institutions

National Research Institute for Earth Science and Disaster

Resilience (NIED), National Institute of Advanced Industrial Science and Technology (AIST), Japan Meteorological Agency (JMA), Geospatial Information Authority of Japan, Shinshu University, Akita University, Hiroshima University, Ibaraki University, Tokyo Metropolitan University, Waseda University.

Table 1: Consortium Organizations and Roles.

Participating organizations	Main roles
Universities	<ul style="list-style-type: none"> - Giving volcanological lecture and practice - Instruction of subjected research - Field training in Japan and overseas - Providing texts
National research institutes and government organizations	<ul style="list-style-type: none"> - Research instruction and cooperative research - Data sharing and facility utilization - Internship on volcano disaster mitigation and research development - Seminar on research and business results - Providing texts
Local government organizations	<ul style="list-style-type: none"> - Internship on emergency and disaster prevention works - Seminar on business examples
Private institutions	<ul style="list-style-type: none"> - Internship - Seminar on measures technology, disaster prevention and development of related issues
Academic societies, etc.	<ul style="list-style-type: none"> - Field training and excursion - Cutting-edge seminar on volcanology and social science

@ Cooperating Bodies

The Volcanological Society of Japan, Japan Society for Disaster Information Studies, Italy's Interuniversity Center for Research in Volcanology (CIRVULC), Hokkaido, Miyagi Prefecture, Kanagawa Prefecture, Nagano Prefecture, Gifu Prefecture, Nagasaki Prefecture, Kagoshima Prefecture.

@ Private institution

Asia Air Survey Co., Ltd.

4. Contents of Program to Develop Next Generation of Volcano Researchers

4-1. Eligibility

Principally Graduate Students in master and doctor courses Recruitment is scheduled to take place in November every year.

@ Foundation Course (equivalent to one-year MA degree): 14 students/per year

@ Applied Course (equivalent to two-year MA degree): 14 students/per year

@ Advanced Course (equivalent to Doctor degree): 6 students/per year

4-2. Main Curriculum Offered

A. Curriculum offered at universities participating in Consortium

@ All classes available to students of Master's Courses at Grad-



Photo 1: A volcanology seminar in progress at Mt.Unzen.
(November 2018)

uate Schools related to geophysics, geology/petrology, geochemistry, Disaster Prevention Science, and Natural Disaster Science.

Students will be able to take diverse classes in various fields that are not provided from a single university. The consortium will use Web conference system to allow students to take classes remotely.

B. Classes/curriculum to be convened by the Consortium

@ Volcanology field study

- Field Works at Active Volcanoes

Observation of active volcanos in Japan, and in-the-field survey techniques will be taught over 5 days. Furthermore, for those aiming to enter doctoral course, a practical study of domestic volcanos together with major volcanos overseas will be implemented through cooperation with renowned overseas researchers, with the aim of developing young scholars capable of implementing research pursuant to mitigating volcano disasters both in Japan and overseas.

- Observation/Surveys implemented by Project to Promote Next-generation of Volcano Researchers

Students will participate in observation surveys carried out under research projects, and learn cutting-edge observation research techniques.

@ Volcanology Seminar

- The latest volcanology research

- *Volcano measurement in engineering/agriculture, fields related to disaster preparedness*

- *Fields related to natural disasters including humanities/social sciences*

As well as the latest findings in volcanology, the program will also convene special classes and seminars in fields related to engineering, social sciences and volcano disaster preparedness with the aim of cultivating the next generation of volcano researchers capable of contributing to mitigating volcano disasters.

@ Internships

Internships will be available in organizations participating in the consortium, where students will learn the importance of carrying out research that is mindful of a touchpoint with society.

These classes will be denominated as units, and students can complete the foundation course and applied course by fulfilling the necessary requirements for acquiring units.

4-3. Advisory Board

To provide students with advice regarding their research trajectory, career path, job-seeking etc., a support system will be provided, consisting of officers from organizations and bodies participating in the consortium.

4-4. Career Development Support

@ To increase awareness regarding career paths, briefing sessions will be held by consortium participating/cooperating organizations.

@ Encouragement to present research at academic conferences etc.

4-5. Creating Textbooks

Create textbooks regarding volcanology and volcano disaster preparedness, as well as volcano fieldwork textbooks. As well as deepening expertise, textbooks will be designed in order that students from other fields can do review/revision or independent study.

4-6. Special Students

We will design a curriculum not just regular university students,



Photo 2: Volcanology field study in progress at Stromboli (Italy).
(June 2018)



Photo 3: Volcanology field study in progress at Mount Sinabung (Indonesia). (July 2018)

Table 2: Classes available under the Program to Develop Next-generation Volcano Researchers.

Qualities required for volcano researcher	Fundamental course	Application course	Advanced course
	First year Master's	Second year Master's	Doctoral course
Learning basic and specialized knowledge	Class subjects at universities (Three main fields)		
Broad knowledge and technical skills	Individual research		RA for research Pj
Learning observation and survey methods	Volcanology seminars (e.g., advanced research)		
Conducting research	Field study in Japan		
Skills to give back research finding to society		Overseas field study	Special training for volcanology research
Knowledge of disaster mitigation in society		Conference presentation	Special seminar for disaster mitigation
	Volcanology seminars (social sciences, engineering, and disaster mitigation)		
	Award of completion certificate		

Class subjects are counted in terms of units, and certificates of completion are awarded for fundamental, application, and advanced courses.

but also whereby employees of national organs and local governments can take classes under this program. We will provide opportunities to learn about the diversity of volcano phenomena and regarding the current state of techniques for gauging volcanic activity, with the aim that each body of knowledge can be applied in volcano disaster prevention and monitoring of volcanic activity.

4-7. Linkages with overseas organizations

Through linkages with the Asian Consortium of Volcanology, Italy's Interuniversity Center for Research in Volcanology (CIR-VULC) and others, we will deliver an educational program in tandem with post-graduate students who aim to carry out volcano research in other countries and researchers in organizations involved in actual monitoring of volcanos.

4-8. Implementation Structure for Project

A human resources development steering committee made up of implementation officers from organizations participating in the consortium shall deliberate the implementation method for this program.

Furthermore, working in tandem with the "Project to Promote Next-generation Volcano Research" which implements research and development, we will provide opportunities for students to access cutting-edge research.



Photo 4: Social Science Seminar in progress. (Tohoku University, June 2018)

The secretariat shall be established in Tohoku University (the representative organization) to ensure the smooth implementation of the project. The contents/current status of the program, and syllabus for each class being offered will be accessible on a website in order that persons with an interest in volcanology other than students (special students) can understand the program.

Homepage for Project to Form a Consortium for Human Resource Development in Volcanology

<http://www.kazan-edu.jp/index-en.php>

5. Evolvability of this Project

The project will contribute to strengthening the future framework of the nation's volcano disaster preparedness:

- @ Dispatch experts possessing basic knowledge regarding volcanology and disaster preparedness to the Volcano Disaster Prevention Council
- @ Government/local government employees can obtain basic knowledge of volcano disasters as well as developing a future vision regarding disaster preparedness.
- @ Enable government/local government employees to share issues regarding disaster countermeasures with volcano researchers, forming human assets capable of carrying out effective disaster preparedness response measures.
- @ Through linkages with organizations in other countries, provide two-way flow of human resources/knowledge for disaster preparedness frameworks.

6. Encourage the development of young researchers

- @ Elevate the appeal of volcano research
- @ Grow body of researchers capable of approaching complex and multifarious volcano phenomena from multifaceted viewpoints.
- △ New research results regarding volcanic activity and eruptions
- △ New developments in technological development regarding prediction of volcano eruptions.
- △ The development of research fields related to disaster preparedness countermeasures.

Participating organizations

Next Generation Volcano Research

Akita University / Asia Air Survey Co., Ltd. / Hakusan Corporation / Hokkaido University / Hot Spring Research Institute of Kanagawa Prefecture / Ibaraki University / Kagoshima University / Kobe University / Kumamoto University / Kyoto University / Kyushu University / Mount Fuji Research Institute, Yamanashi Prefectural Government / Nagoya University / National Institute of Advanced Industrial Science and Technology (AIST) / National Research Institute for Earth Science and Disaster Resilience (NIED) / Nihon University / Obayashi Corporation Technical Research Institute / Shizuoka University / The University of Tokyo / Tohoku University / Tokai University / Tokoha University / Tokyo Institute of Technology / Waseda University / Yamagata University

Consortium for Human Resource Development in Volcanology

Tohoku University (representative institution) / Hokkaido University / Yamagata University / The University of Tokyo / Tokyo Institute of Technology / Nagoya University / Kyoto University / Kyushu University / Kagoshima University / Kobe University / Shinshu University / Akita University / Ibaraki University / Hiroshima University / Tokyo Metropolitan University / Waseda University / National Institute of Advanced Industrial Science and Technology (AIST) / National Research Institute for Earth Science and Disaster Resilience (NIED) / Japan Meteorological Agency (JMA) / Geospatial Information Authority of Japan (GSI) / Miyagi Prefecture / Nagano Prefecture / Nagasaki Prefecture / Kanagawa Prefecture / Gifu Prefecture / Hokkaido Prefecture / Kagoshima Prefecture / The Volcanological Society of Japan / Interuniversity Center for Research in Volcanology (CIRVULC) / Japan Society of Disaster Information Studies / Asia Air Survey Co., Ltd.

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