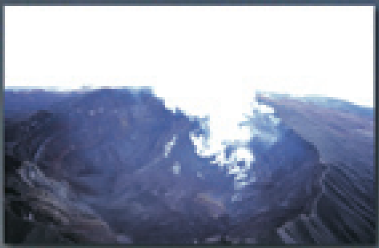
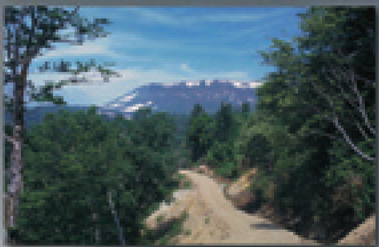
Volcanic Eruptions and the Blessings of Volcanoes






The Front Line of Volcanic Research by AIST

Volcanic Eruptions and the Blessings

Volcanic Research to Reduce Disasters and Make the Most of the Blessings of Volcanoes

Research Coordinator (Geology & Marine Science) **Eikichi TSUKUDA**
Director of Geological Museum **Masahiro AOKI**

A Nation of Volcanoes

There are many volcanoes on the Japanese archipelago, where approximately 10% of the world's on-land volcanoes are said to exist. The crust of the earth is covered with more than 10 gigantic rock plates. Slight movements of these plates are thought to cause a variety of disasters, including earthquakes and volcanic activities.

The subduction of the Pacific plate to the east or the Philippine Sea plate to the south under the Eurasian plate on the west side (the continent side) is the basic cause of active volcanic activities around the Japanese archipelago.

Volcanic Research by AIST

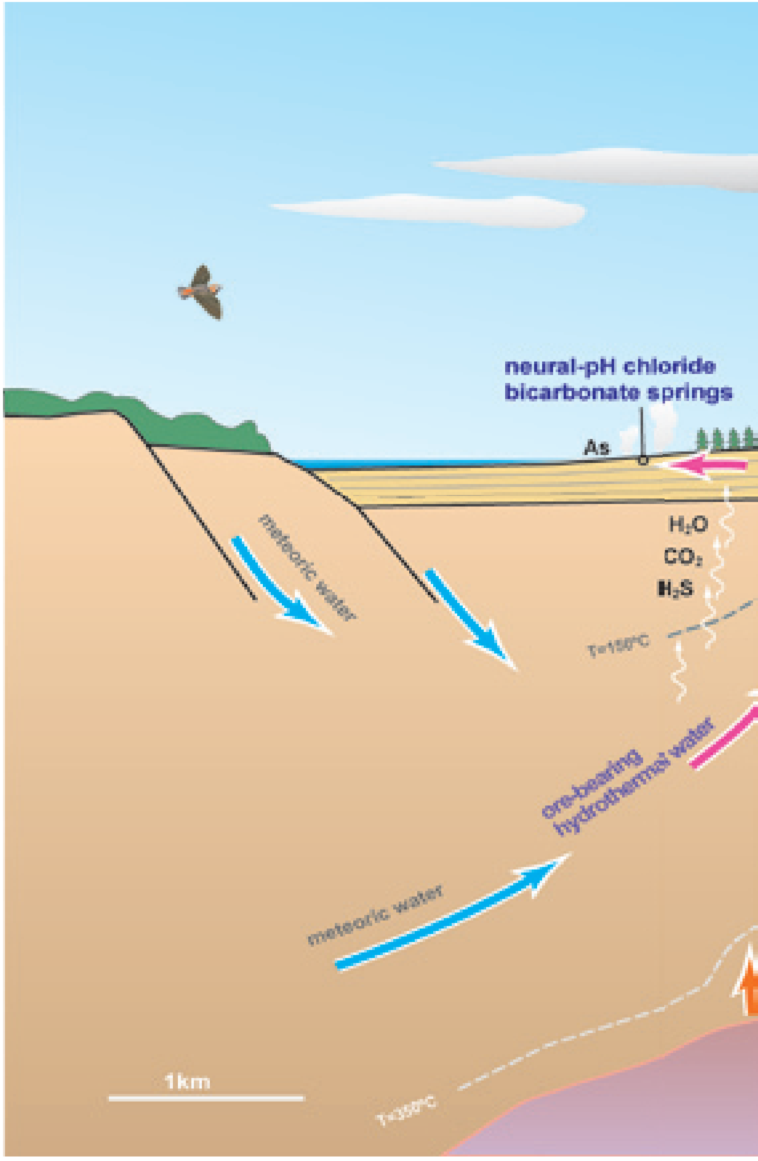
AIST's Geo Information Research branch, Institute of Geology and Geoinformation and Institute for Geo-Resorces and Environment, and Research Center for Deep Geological Environments are using their own approaches to independently conduct broad volcanic research ranging from research aimed at reducing disasters due to volcanic eruptions to research of geothermal heat resources and mineral resources that are the blessings of volcanic activities. Most of the research is aimed at seeking profound scientific understanding and is based on years of consistent surveys and observational studies. We are expected to offer scientific information necessary for disaster prevention measures and exploitation of volcanoes. In this Leaflet, we will introduce you to the front line of volcanic research by AIST.

Disaster Prevention Measures Start From Understanding Volcanoes

In Japan, serious disasters sometimes occur due to powerful volcanic activities. Eruptions of Mt. Usu in Hokkaido and of the volcano on the Izu Island of Miyake in 2000 are still fresh in our memory. It is necessary to always understand the way nature works to protect our lives and properties from the threat of nature and to prevent disasters.

Although volcanic activities themselves are natural phenomena, they cause disasters and damage both human life and industrial activities. The first step in developing disaster prevention measures starts from fully understanding volcanoes. It is then necessary for individuals, communities, governing bodies, and nations to take measures from each respective standpoint.

We are conducting research activities to provide the most basic information with the aim of improving reliability.



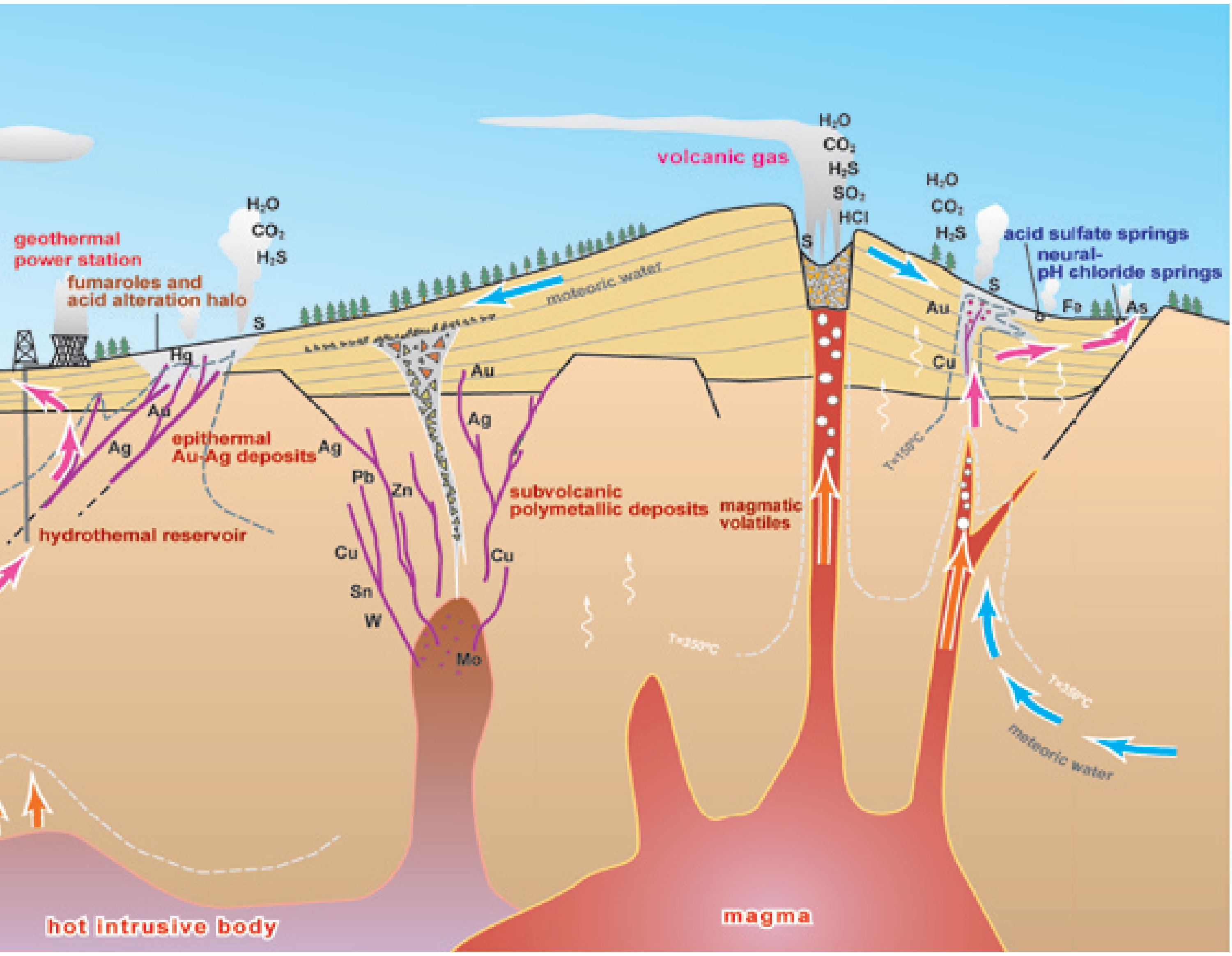
Understand Volcanoes Better

Many people live around volcanoes in Japan and also visit volcanoes for their beautiful natural environment, hot springs, and sightseeing. However, these people do not necessarily understand volcanoes well. We sincerely hope that people will deepen their understanding toward the actual conditions of volcanoes, take measures to minimize damage, and live a rich and peaceful life while enjoying the daily blessings of volcanoes. We are hoping to contribute toward that end through our research.

The AIST series Challenge Volcanic Eruptions (edited by the Geological Survey of Japan) focusing on research to reduce damage from volcanic eruptions is published by Maruzen. It may help you

from the Earth

The Mt.Asama eruption (2004)
Image by Dr. Kohei Kazahaya, GSJ



deepen your understanding.

At the Geological Museum in the AIST Tsukuba center, the state of the earth and the mechanisms of its change are introduced in a simple way using plenty of geological specimens, three-dimensional models, and images. Above all, we are trying to introduce a variety of geological phenomena from many viewpoints, such as volcanic eruptions and hot spring phenomena caused by magma rising to the earth's surface. Volcanoes let us feel the “living earth” and they greatly excite our curiosity. While volcanoes bring life threatening eruptions and landslide disasters, they can also enrich our lives with hot springs and geothermal and mineral resources. Coexistence with volcanoes may be an eternal theme for those who live on the Japanese archipelago. Many interesting questions about volcanoes arise, including: Where do active volcanoes exist and what kind of eruptions did they cause in the past, for instance what damage could occur if Mt. Fuji erupts? How are volcanoes and hot springs associated? How can we extract the energy from the geothermal fluid existing under volcanic regions? In what kind of places are clay deposits and metal veins such as gold, silver, copper, and zinc formed? How can we find a vein?

Why not visit the Geological Museum and discover the answers to these fundamental questions?

Pursuing the Eruption: Emergency Survey on Miyake-jima

Institute of Geology and Geoinformation
Hiroshi SHINOHARA

Collection of Detailed Data in order to Learn about Volcanic Activities

There are 108 active volcanoes in Japan, which repeat eruptions. Even large-scale volcanic activities which require the evacuation of local residents occur every five years on average. Modern volcanic observation network has allowed us to almost certainly catch the signs of a large-scale eruption beforehand. However, currently it is difficult to predict the style and the duration of an eruption as well as the shift of volcanic activities beforehand.

Accurately grasping the state of volcanic activities and having a clear picture of the shift in activities is necessary in order to reduce the damage of an eruption. Therefore, the Coordinating Committee for Prediction of Volcanic Eruptions will collect detailed observational data and analyze volcanic activities at the brink of an eruption. AIST is conducting surveys on eruption products, volcanic gases and of ground deformation in cooperation with the Japan Meteorological Agency, Universities, and related research institutes. Cooperation from many researchers in various fields is necessary in order to conduct urgent and concentrated surveys and research when an eruption occurs. Thus, emergency observation task force team may be created temporarily, for example AIST set up the Emergency Countermeasure Headquarters, in which our vice chairman was assigned as the chief, and nearly 40 staff cooperated when the eruption occurred on Miyake-jima.

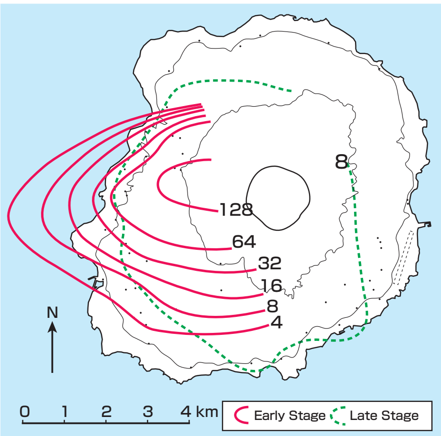


Figure 1 The distribution of volcanic ash released from the Miyake-jima volcano on August 18, 2000 (numbers refer to thickness in mm)

Indispensable Local Surveys

Volcanic activities on Miyake-jima which began in June, 2000 were large-scale ones said to have happened for the first time in 3000 years. All residents were forced to evacuate from the island due to possible eruptions followed by the release of a large amount of volcanic gases.

When an eruption occurs, the most important thing is to determine the characteristics of the eruption based on a local survey and predict subsequent volcanic activities. On Miyake-jima, a collapsed crater of 1.6 kilometers in diameter was formed on the summit of the volcano in July and August with repeated eruptions. During the eruptions, AIST researchers conducted surveys in the island covered with volcanic ash and studied the distribution and the amount as well as

Table Latest major volcanic eruptions and damage

2000 -	Miyake-jima	Collaped crater formation. Large amount of gas emission. Evacuation of all residents.
2000	Mt. Usu	The lava dome.
1990 - 1995	Mt. Unzen	Pyroclastic flows and debris-avalanches 43 death.
1986	Izu-Oshima	Lava flows. Evacuation of all residents.
1983	Miyake-jima	Lava flows. Villages were buried.

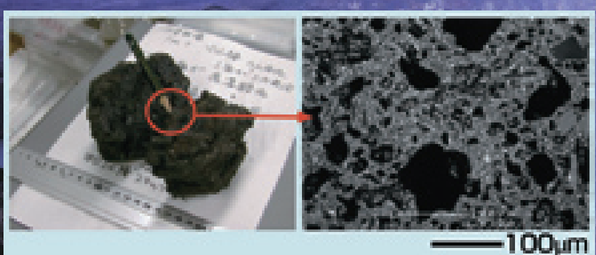


Figure 2 Volcanic bombs ejected from the Miyake-jima volcano on August 18, 2000 and their microscopic images

Photo 1 The collapsed crater formed on the summit of the Miyake-jima volcano and volcanic gases being actively released

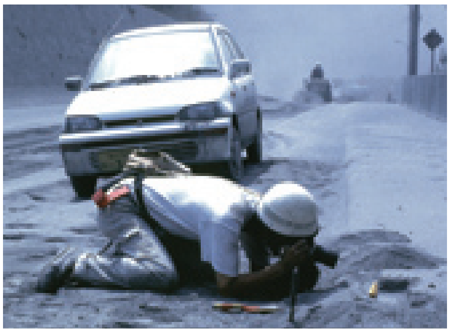


Photo 2 The survey of eruption products on Miyake-jima: taking pictures of the layers of accumulated volcanic ash

the form and the composition of eruption products (volcanic ash and volcanic bombs) to determine the characteristics of the magma which caused the eruptions.

On Miyake-jima, large amounts of volcanic gases were continuously released after the formation of the collaped crater, a rare phenomenon globally. Residents of Miyake-jima are still in evacuation because these poisonous volcanic gases continue reach to residential areas.

AIST is continuously monitoring the emission and the composition of volcanic gases as well as other activities in cooperation with the Japan Metrological Agency and Universities, since precise understanding of volcanic activities is the key to judge the risk of an eruption and volcanic gases. An urgent and detailed survey of an eruption is not only necessary to directly reduce damage, but also important as the basic research in volcanology. An eruption is a precious opportunity for research.

Mankind has not experienced many eruptions since the development of modern observation methods. Therefore, volcanic researchers who have experienced actual eruptions are like doctors treating patients with rare diseases and are invaluable within their fields. Researchers at AIST are conducting front-line surveys and research on eruptions, aiming to reduce damage and hazards by developing a better understanding of volcanic processes.

Monitoring of Volcanic Activities Using Satellites

Institute of Geology and Geoinformation
Minoru URAI

The use of satellites enables us to monitor volcanic activities safely, extensively, periodically, and consistently. Satellites are especially effective at volcanoes where observations from the ground are difficult. For example, Mt. Chachadake on Kunashiri Island, one of the most active volcanoes, has a severe natural environment in addition to some political issues, making it the most difficult volcano for ground observation.

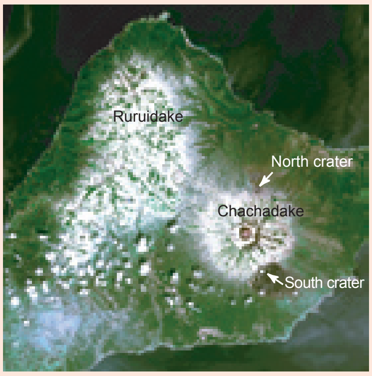


Figure 1 Mt. Chachadake observed by ASTER on May 8, 2002 The range of all images is 30 km × 30 km

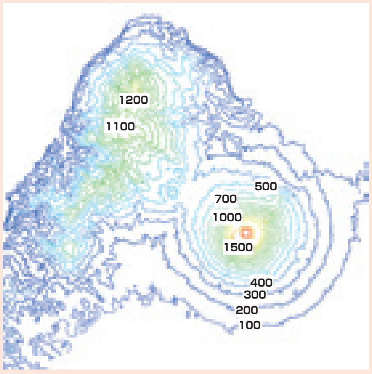


Figure 2 A topographical map of Mt. Chachadake created from the stereo image pairs of ASTER

Figure 1 is an image of Mt. Chachadake observed by the ASTER sensor developed by the Ministry of Economy, Trade and Industry. We can observe that vegetation near the south and north caters is not recovered yet which was dameged by 1973 Eruption.

Figure 2 is a topographical map created by using the stereo-image function of the ASTER sensor. The topographical map of this region had not been updated since it was issued by the Geographical Survey Institute in 1922. The new topographical map shows the detailed topography of the south crater and the north crater.

Figure 3 shows the distribution of surface temperatures on Mt. Chachadake observed at night; the brighter parts indicate high temperature, and the darker parts indicate low temperature. Even though the surface temperature lowers as the height above sea level increases, brighter points can be found on the summit of Mt. Chachadake. This indicates higher surface temperatures on the summit than in the surrounding areas due to volcanic activities. Meanwhile, no heat abnormalities are found in the south or north crater. The temperature of the sea on the north side of the island is low because of drift ice alongside the coast, while the temperature of the sea on the south-side of the island is higher than the land temperature.

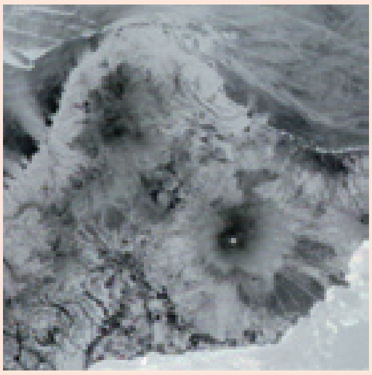


Figure 3 The distribution of surface temperatures on Mt. Chachadake observed by ASTER on March 13, 2001

Mechanism of the Ascent of Magma to an Eruption

Institute of Geology and Geoinformation
Akira TAKADA

Understanding the mechanism from the ascent of magma to an eruption is indispensable when developing theories based on various observational and surveyed data for predicting a volcano eruption (Figure 1). It is also important when making a program of numerical calculations. The keys to the mechanism are magma movements due to cracking and the vesiculation during the ascent of magma, both of which are dynamic physics and are difficult to analyze theoretically. Although typhoons can be monitored by using satellites, magma cannot be observed directly. There are technologies for observing magma such as geophysical surveys and drillings, equivalent to X-rays and endoscopes; however there are still limits on observational accuracy, depth, temperature conditions, and budget. Thus, we utilize the magic of innovation; we analyze the mechanism by reproducing the magma plumbing system in a laboratory.

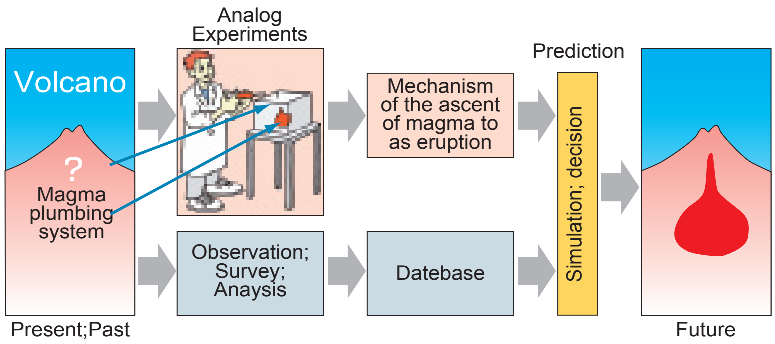


Figure 1 The purpose and positioning of analog experiments

Vesiculation During the Ascent of Magma

This is an approach that reproduces a magma plumbing system and artificial magma in a laboratory by generating high-temperature and high-pressure conditions equivalent to the earth's interior. The size and amount of bubbles in pumice are indicators representing vesiculating process that controls explosivity of volcanic eruptions. In order to observe the process in our laboratory, we have developed a pressure vessel for gas pressure with decompression speed controller that can reproduce the ascending process of magma for observation[1] (Figure 2 on the left). Magma, produced by re-melting of actually-erupted rocks at 100 MPa (1000 bar) and 900ºC, was enclosed in the vessel and underwent bubble formation. We measured the vesiculating texture of the artificial pumice formed in the experiment. The results showed that the vesiculating process was greatly affected by the ascending speed of magma[2] (Figure 2 on the right).

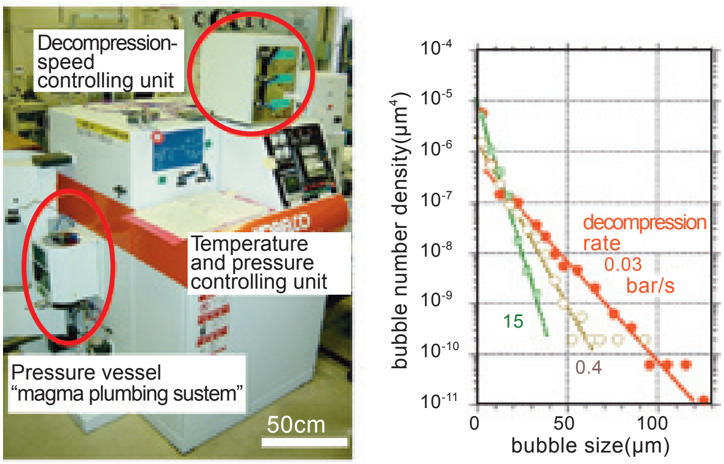


Figure 2 The equipment used for the decompression experiment (left)[1] and the size distribution of the resulting bubbles (Right)[2]

Magma Movements due to Cracking

This is an approach that reproduces an artificial magma plumbing system in a laboratory by using an analog material and reducing the scale. Oil, designed to function as magma, is injected into transparent gelatin as a brittle elastic body that represents the earth, to form a crack. Then its movement is observed. In this system, the physical properties and stresses of gelatin as well as the physical properties and injection rate of oil can be controlled, depending on purpose. Though the theoretical analysis is limited to two dimensions, this experiment enables us to observe the basic shape of a three-dimensional fluid-filled crack and its movements under various stresses. As

Reference
- [1] A. Tomiya & I. Miyagi: Program and abstracts, Volc. Soc. Japan, 2001 Fall meeting, No.2, 177 (2001)
- [2] A. Tomiya: Eos. Trans. AGU, 84(46), Fall Meet. Suppl., Abstract V51L-01 (2003)
- [3] A. Takada: J. Volcanol. Geotherm. Res.93,93-110 (1999)
- [4] A. Takada: Cities on Volcanoes, Abstracts,127 (2003)
- [5] A. Takada: Chisitsu News, GSJ, 591, 24-27 (2003)

a result, new ideas such as mechanical interaction between cracks have emerged[3) (Figure [3)]. Recently we have reproduced the analog of a fissure eruption under stress. [4)] A model of a magma plumbing system due to cracking was created, and it was a common concept to consider that magma moves due to the formation of cracks even at the time of Unzen, Usu, and Miyake-jima eruptions. This concept is applied to explain the difference between a polygenetic volcano and a monogenetic volcano. This experiment is widely used in promotional activities for public and science education.[5)]

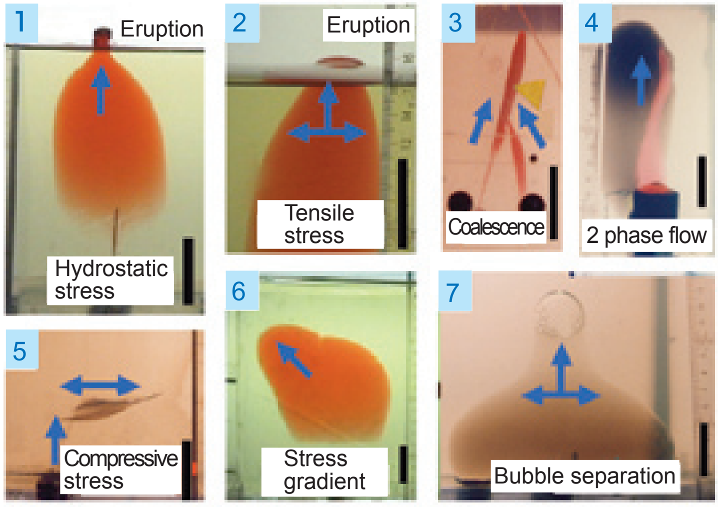


Figure 3 Examples of the analog experiment of cracks. 3 and 5 are the sides of the cracks. The rest are the front of the cracks. The arrow is the flow of the liquid. The black scale is 3 cm.

Scientific Drilling Reached the Magma Path of 1990-95 Eruption of Unzen Volcano

Institute of Geology and Geoinformation
Kozo UTO

Unzen Scientific Drilling Project (USDP) is a six-year term international project started in April 1999, co-sponsored by the Japanese Government (MEXT) and International Continental Scientific Drilling Program (ICDP). More than 20 institutes nationwide and abroad are participating the project, and AIST is serving as one of the principle research centers. The highlight of this project, to penetrate the magma path (conduit) of the Heisei eruption in the middle of the mountain, was successfully completed after reaching the conduit of the Heisei magma in July 2004.

At Unzen volcano, pyroclastic flows caused by the collapse of lava domes occurred frequently during the Heisei eruption between 1991 and 1995, causing serious damage and 44 casualties. The surveys on these eruptions produced much observational data on such as earthquakes, uplifts, and deformations of mountains, which provided us with a detailed model of the ascent and eruption process of magma.

USDP is aiming to understand the growth history, subsurface structure and magma ascending mechanism of Unzen Volcano not only by scientific drillings but also by related geological, geophysical and geochemical studies. In the project, we planned to drill a hole to reach the conduit of the Heisei eruption in order to clarify the ascending and degassing process of magma and understand the mechanism of an eruption. The driling work began in February 2003 from the site on the northside slope of Unzen volcano at the altitude of 850 meters. Work was suspended several times, but we were able to reach the Heisei conduit by making some revisions after drilling approximately 1.3 kilometers horizontally and approximately 900 meters perpendicularly, the total drilling distance was 2000 meters.

There was a conduit zone near the area right under Mt. Fugen at around the sea level, where old and new conduits including the Heisei conduit were concentrated within approximately 500 meters. The temperature in the conduit zone is approximately 200°C, lower than expected before the drilling, which is assumed to have resulted from quick cooling due to hydrothermal activities.

Future extensive research is expected to provide the details of the ascending process of magma.

Photo Unzen Scientific Drilling site on the north-side slope of Unzen
Fifty meter-high rig were set up in an area of approximately 2000 m2, and a road was constructed in the national forest. (Pictures provided by Professor Setsuya Nakada, Univ. Tokyo)

Geological Map of Volcanoes: Research of Recent Eruption History

Institute of Geology and Geoinformation
Hideo HOSHIZUMI
Shun NAKANO

Japanese Volcanic Islands

The Japanese Islands are a region where volcanoes cluster. As seen in Figure 1, active volcanoes, however, do not exist all over Japan but their distribution is partial. The edge of the distribution on the Pacific side is called volcanic front that runs almost parallel to the Kurile, Japan and Izu-Ogasawara Trench, along which the Pacific plate is subducting beneath the continental plate.

There are many volcanoes along the volcanic front, a few of them appear in the west (Japan Sea) side, but none is seen in the east of the trench. Deep earthquake plane occurs at approximately 110 kilometers directly beneath the volcanic front, which indicates that the formation of the volcanoes is closely associated with the subduction of the Pacific plate.

In western Japan, there is a volcanic front that runs from the San-in region through Kyushu and then spreads toward the Tokara Islands. This volcanic front is formed as result of subduction of the Philippine Sea plate.

Active Volcanoes and Volcanic Disasters

Volcanoes which erupted in the past 10,000 years are defined as active volcanoes, and they have the potential to erupt again in the future. There are 108 of such active volcanoes are recognized by the Japan Meteorological Agency (Figure 1). Regardless of their scenic beauty and neighboring hot springs that attract sightseers and climbers, however, most of the recognized volcanoes, once reactivated, may cause serious destruction to themselves and surrounding areas.

Quaternary Volcanoes in Japan Database

http://www.aist.go.jp/RIODB/strata/VOL_JP/

Quaternary volcanoes are referred to those active within the last 1.8 (or 1.7) million years, naturally, including the active volcanoes. In this particular time span, the general distribution trend and range of volcanoes are similar to those of the active volcanoes shown in Figure 1. There are more than 300 Quaternary volcanoes recognized in Japan. For example, Gassan in the Tohoku region, Nantaisan in Nikko, and Daisen in the San-in region are famous volcanic mountain though not active. Should a volcano that erupted within the last 10,000 years reactivate we will label it as an active volcano.

Within AIST's research database (RIO-DB), data on Quaternary volcanoes are open to the public. The data cover all the volcanoes that were active during the Quaternary. Data include volcano type (stratovolcano or lava dome), rock type (basalt, andesite, etc.), activity period, names of topographic maps showing locations of volcanoes (longitude and latitude) and related literature. The data also contain eruption records and pictures of the active volcano. Geological maps issued by AIST are to be added to the database in addition to a plenty of pictures for each volcano. At the present, the database is available in Japanese, but in the near future, English version will be published. In general, it is planned to be developed to a more detailed and socially useful database.

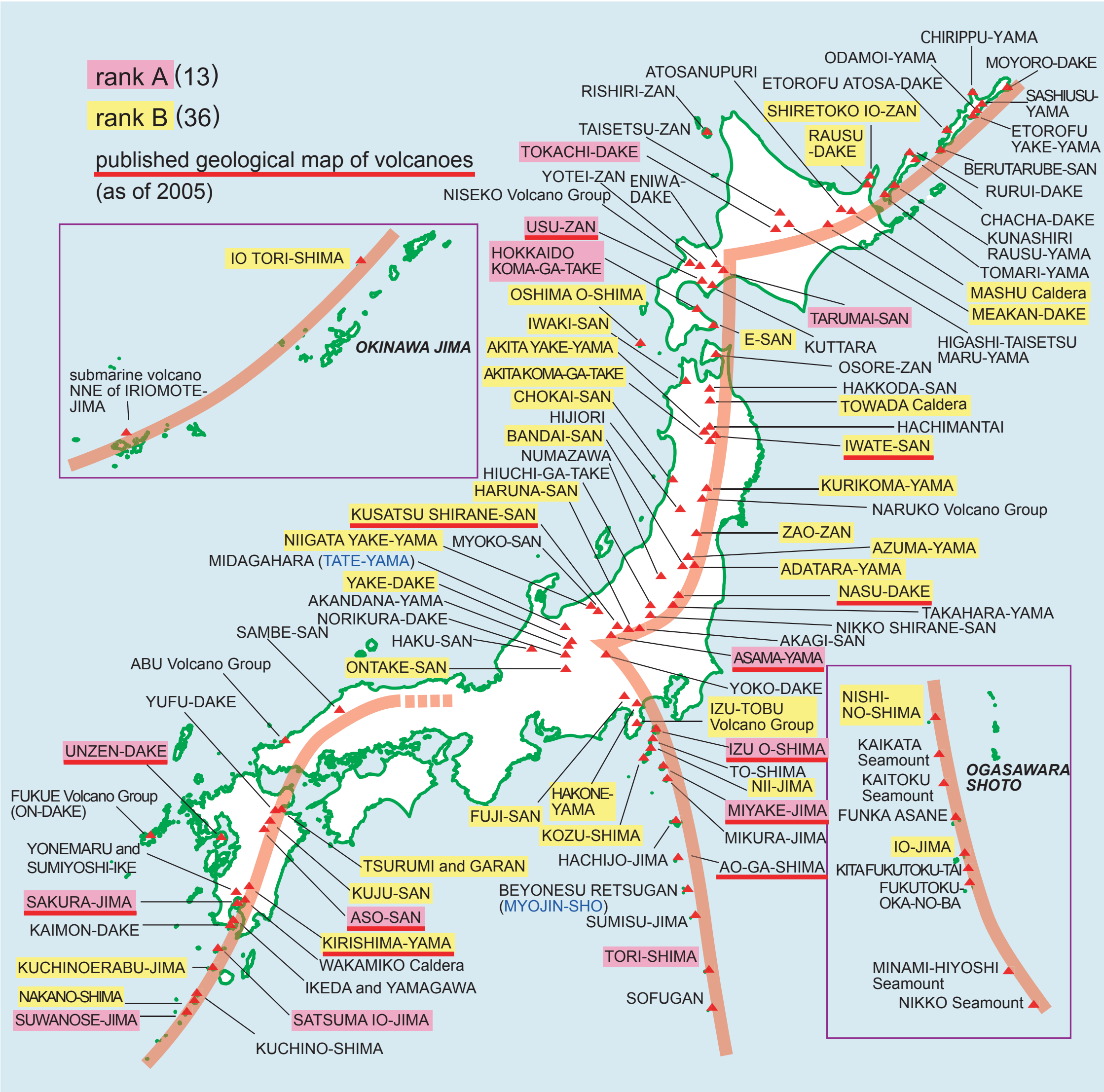
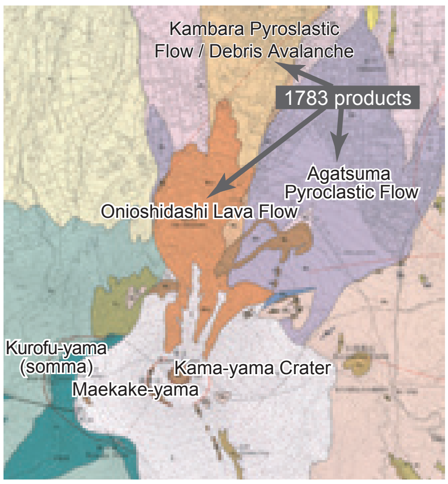


Figure 1 Distribution of active volcanoes in Japan. Active volcanoes are classified into three ranks from A to C with decreasing scale of activity: A- most active includes 13 volcanoes, B- includes 36 and C- includes 36 volcanoes. Submarine volcanoes and those in the Southern Kurile Islands (Kunashiri and Etorofu) are excluded from this classification. Future survey may add more active volcanoes. Thick orange lines are volcanic fronts.

Figure 2 Part of the geological map of Asama volcano (1993 issue). Erupted products are color-coded according to time and type. Active part is in the Kama-yama crater inside the Maekake-yama cone. The latter is surrounded by somma of Kurofu-yama that was formed by a gigantic collapse of the mountain body. For this particular structure Asama volcano is often referred as a triple volcano. In 1783 eruption the volcano released a large amount of pumice fall, followed by pyroclastic flows and ended by the Onioshidashi Lava Flow.

AIST has been making geological maps of past eruptions of active volcanoes since the time of our antecedent, the Geological Survey of Japan, and has been providing them as geological maps of volcanoes. Questions such as when, where and how a volcano erupted and affected can be determined based on our intensive study of past distribution of erupted products, eruption time and characteristics using field surveys and laboratory experiments.

Each volcano has its own varying characteristics, patterns, frequencies, and scales of eruption. The geological map of a volcano can be referred to as a resumé of the volcano since the time it was formed by clarifying such differences mentioned above. The geological map of a volcano will help with prediction of shift in the activity when an eruption is imminent or actually begins. The data on patterns and scales of past eruption are used as basic material to establish hazard map (a chart of expected damage due to an eruption) by local administration.



The Blessings of Volcanoes : The Front Line of the Utilization of Geothermal Heat

Institute for Geo-Resources and Environment
Hirofumi MURAOKA

High-Temperature Hydrothermal Convection Systems Generated by Volcanoes

Many volcanoes in the Japanese archipelago are considered to have been formed by lava and pyroclastic flows spewed out repeatedly from magma chambers in the shallow part of the crust formed by the magma rising from the upper mantle and the bottom crust. The calc-alkaline series magma is believed to form a magma chamber in the shallow part, a few kilometers underground, due to its high buoyancy. Many hot springs with a temperature of 90°C or higher, near boiling point, are found around volcanoes originated from calc-alkaline rocks because the magma chamber in the shallow part heats up groundwater and forms a high-temperature hydrothermal convection system.

Advantages of Geothermal Power Generation

When drilling is conducted on a hydrothermal convection system around a volcano, even hot reservoir water will vaporize and become steam with a temperature of 160-330°C due to reduced pressure during the ascent in a well and will flush out to the surface by itself. It is possible to generate electricity without consuming fossil fuels if this steam is used to rotate a turbine. This is the mechanism of geothermal power generation.

Geothermal power production is advantageous not only in terms of energy security because it is a purely domestic energy, but also as a countermeasure against global warming because it is a clean energy that generates only a very small amount of carbon dioxide. However the capacity of the geothermal power generation facilities in Japan is approximately 550,000 kW, which places Japan only sixth in the world.

Recently, even nations with few volcanoes are working toward the development of geothermal power production by drilling to great depths and utilizing non-volcanic crustal heat flow. Needless to say, a volcanic nation like Japan has advantages regarding geothermal power production, thus Japan is aiming to improve its systems for more extensive use.

Approach to High-Temperature Magma

Japan is leading the world in the development of geothermal technology. We have already mentioned imagining actually observing a magma chamber in the shallow part of the crust forming a high-temperature hydrothermal convection system. This image was in fact physically proved for the first time in the world by the Deep Geothermal Resources Survey in Kakkonda, Shizukuishi-cho, Iwate Prefecture in Japan. In the survey, the 3729 meter-deep well, called WD-1a was drilled in 1995. As shown in Figure 1, the well passes through the hydrothermal convection system and also the Kakkonda Granite, a solidified magma chamber, the heat source of a hydrothermal convection system. The complex can be referred to as a newly-solidified magma chamber because the temperature at the boundary of granitic rock was 370°C and the temperature at the bottom of the well dug to the depth of 3729 meters was more than 500°C, as shown in Figure 2. These records lead the world in terms of scientific achievement in geothermal drillings and thus have caught the world's attention.

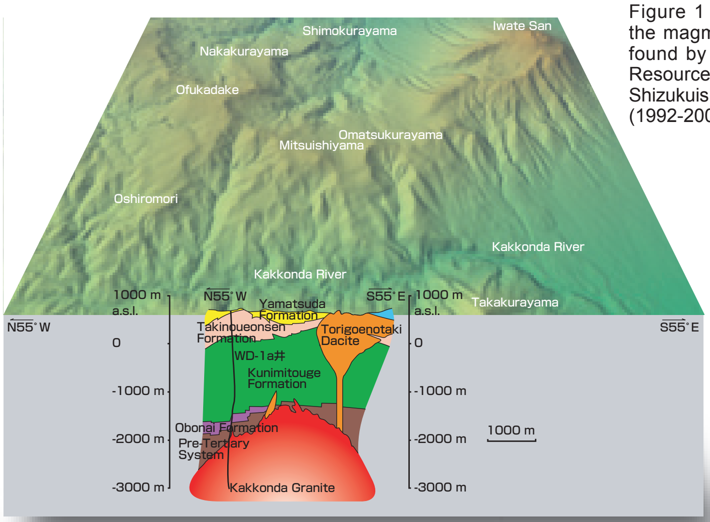


Figure 1 A sectional image of the magma chamber (solidified) found by the Deep Geothermal Resources Survey in Kakkonda, Shizukuishi-cho, Iwate Prefecture (1992-2000)

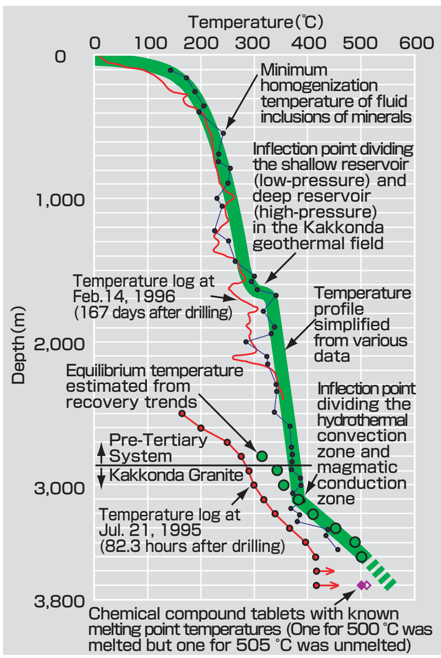


Figure 2 The distribution of the temperatures around Kakkonda granitic rock and explanations

Volcanoes as Tourism Resources : Marvelous Views and Hot Springs

Institute for Geo-Resources and Environment
Keiichi SAKAGUCHI

Pleasures Provided by Volcanoes

Volcanoes provide us various pleasures (see Figure). First of all, they provide us amazing landscapes with high-rise peaks such as Mt. Fuji and crater lakes filled with blue water such as Lake Towada. The attraction of volcanoes can be appreciated from the fact that they exist in 18 of Japan's 28 national parks.

Volcanoes also provide us pleasures of climbing and skiing. Quaternary volcanoes account for nearly half of Hisaya Fukada's 100 Well-Known Mountains in Japan. Many popular ski parks including Zao and Myoko utilize the slopes of volcanoes. Furthermore, volcanoes provide us plenty of spring water at the foot of mountains. Much of the spring water found around volcanoes such as Mt. Yotei, Mt. Fuji, and Mt. Aso is included in the Selected 100 Exquisite and Wall-conserved Waters.

Hot Springs in Volcanic Regions

The greatest blessing of volcanoes for the Japanese people is the hot springs they provide. There are 3,100 hot springs in Japan, where annually 140 million people in total visit and stay (from data presented by the Ministry of Environment in fiscal 2002). Recently, hot spring development in non-volcanic regions such as in plains is very popular. Although hot springs in volcanic regions do not account for a very high proportion in terms of their numbers, there are many attractive hot springs in volcanic regions including many high-temperature hot springs and those with wide-ranging chemical characteristics. In volcanic regions, interactions between water and rocks under high temperature as well as a mixing of gases and fluids from magma and groundwater occur because of a hot magma chamber existing underground. Hot water produced by such processes is spread by a hydrothermal convection current to the outskirts to form hot springs with various characteristics.

Can Electricity be Generated from Hot Springs?

Bad Brumau in Austria is a spa resort known for its unique buildings. It is also known as an eco-resort. A hotel there conducts geothermal power generation using hot spring water of 110°C and recycles the hot water used in the power generation for hot-water supply systems by heat exchange (see photo). Even though hot water of 110°C is not suited for conventional geothermal power generation, they have adapted a binary cycle power generation technique that vaporizes the low-boiling point medium by heat exchange to rotate a turbine with the steam generated.

Austria has no volcanoes. Bad Brumau is a hot spring found during a prospective survey for oil conducted in the 1970s, and obtains hot water from a bored well 2000 meters deep. High-temperature hot water can be obtained more easily at hot springs in volcanic regions.

Many foreign countries have already adapted binary cycle power generation facilities of various scales. A survey on potential binary cycle power generation using hot springs has just started in Japan. Future development is anticipated.

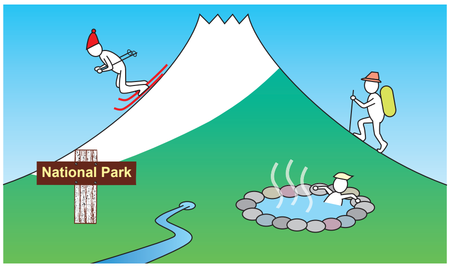


Figure Pleasures provided by volcanoes

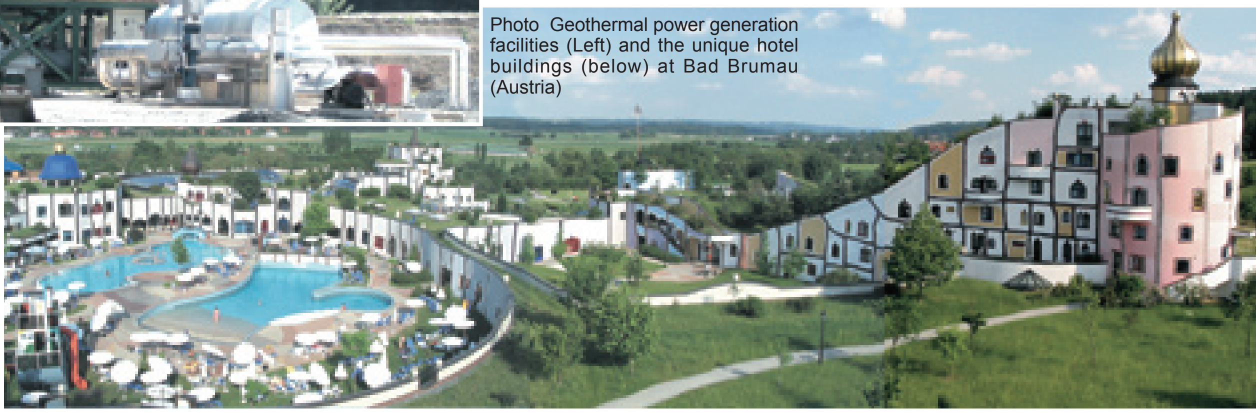


Photo Geothermal power generation facilities (Left) and the unique hotel buildings (below) at Bad Brumau (Austria)

Mineral Resources Produced by Volcanic Activities

Institute for Geo-Resources and Environment
Yasushi WATANABE

Solving the Puzzle of the Formation of Metal Deposits

Volcanic activities and the accumulation and deposition of metal elements are closely related as seen in the gold deposition on the summit of Osorezan in Aomori Prefecture because the magma that forms a volcano contains metal elements. However, surprisingly little is known about the processes required for the metal elements in magma to form a deposit. Deposits are not often found near volcanoes remaining in the original form because the metal deposits are formed at depths of hundreds to thousands of meters beneath the surface. Instead, many deposits have been exploited near volcanoes which have lost their original form due to erosion. Not all volcanoes have metal deposits; in fact volcanoes with a deposit are extremely rare.

Mt. Muine, the highest peak in Sapporo city in Hokkaido, (see Photo) was formed by the eruption of andesite lavas approximately three million years ago. Silver, indium, zinc, lead, and copper are being mined at the Toyoha deposit in the north. Even now, the temperature of the host rocks of the underground tunnels at the Toyoha deposit is as high as 100°C or higher, which indicates that not much time has passed since the metalliterous veins were formed. Therefore, this is a good example to study how metalliterous veins are formed.

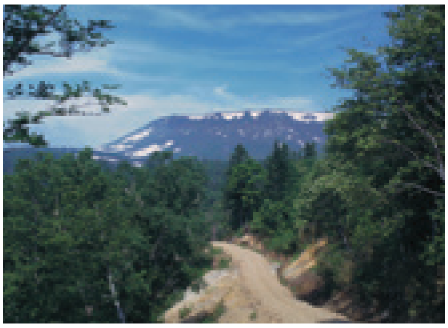


Photo Overlooking Mt. Muine from the east

Our Model of the Magma-Hydrothermal System

We designed a model of the magma-hydrothermal system as mentioned below based on the surveys and investigations on ground surfaces and the undergroud (see Figure). After the eruption of lavas at Mt. Muine volcano, magma and hydrothermal fluid accumulated at a greater depth, two kilometers below the mountaintop. The hydrothermal fluid separated into hot volcanic gases and brine. Volcanic gases abundant in SO_2 ascended and reacted with the andesite around the volcanic craters to form advanced argillic rocks made of alunite and cristabalite.

Meanwhile, the brine, dissolving large amounts of base metal elements including silver, zinc, and lead, flowed toward the outside, separately from the volcanic gases due to its high density. The brine ascended the fault belt and mixed with meteric water that penetrated from the surface after flowing approximately three kilometers northward. It then precipitated into quartz and metal-sulfide minerals such as pyrite and sphalerite as veins. At the same time, it caused propylitic and sericitic alteration around the veins, turning them mostly into chlorite and illite. Then, after forming the veins, the remaining hot water ascended the faults and formed an argillic alteration zone mainly consisting of kaolinite. The zone is in Yunosawa, to the east of the deposit.

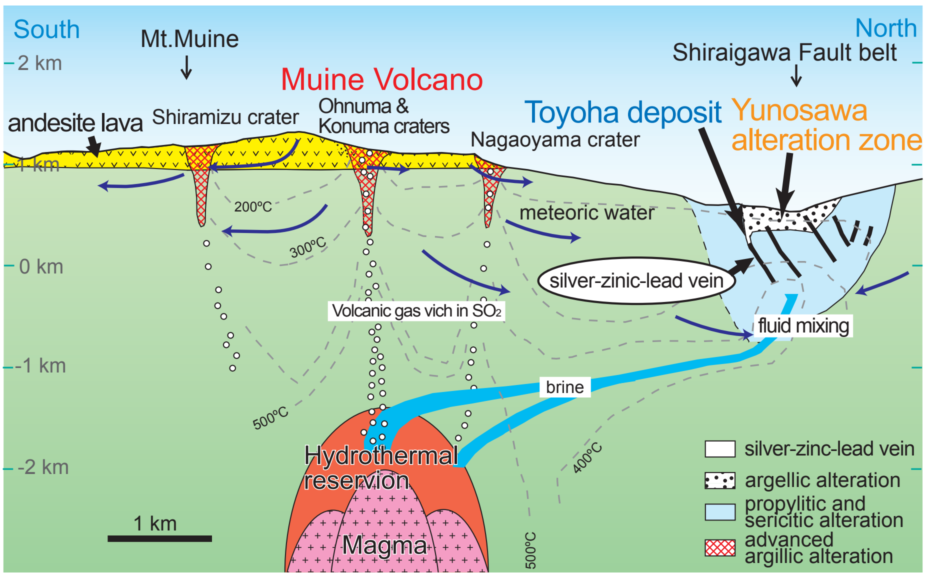


Figure Section images of the Muine-Toyoha magmatic hydrothermal system

These results provide us with indicators in our search for metal veins around volcanoes. Massive intrusion of magma immediately after the formation of a volcano is necessary for the formation of a metal deposit, and whether hydrothermal alteration zoes are developed or not is the key to the distinction. Furthermore, it is important to understand which part of a hydrothermal system developed by the magmatic intrusion you are observing by examining the combination and chemical composition of minerals in hydrothermally altered rocks in detail, and in which part you can expect the accumulation of metal elements by analyzing the geological structures.

Seafloor Hydrothermal Systems

Institute of Geology and Geoinformation
Kokichi IIZASA

Sulfide Deposits Formed by Seafloor Volcanic Activities

Seafloor hydrothermal activities, in which hot water vigorously spouts out from chimney-like holes (chimneys) formed in the ocean bed, are one of the most active geological phenomena on the earth. Shifts within the earth are observed through the movements of heat and substances such as heavy metals caused by seabed volcanic activities followed by hot fluid circulation (see Photo). This hot fluid circulation supplies copper, lead, zinc, iron, gold, and silver as sulfides to the surface of the seabed. Also, an ecosystem peculiar to hydrothermal fields is formed there.

AIST is conducting basic surveys and research on seabed hydrothermal systems in active ocean areas including ones around Japan and ones in the central oceanic ridge. We are collecting data using manned submersibles, unmanned vehicle, and benthic multi coring system and are working to determine the mechanism of the movements and accumulations of substances and to produce a model of the deposit formation mechanism.

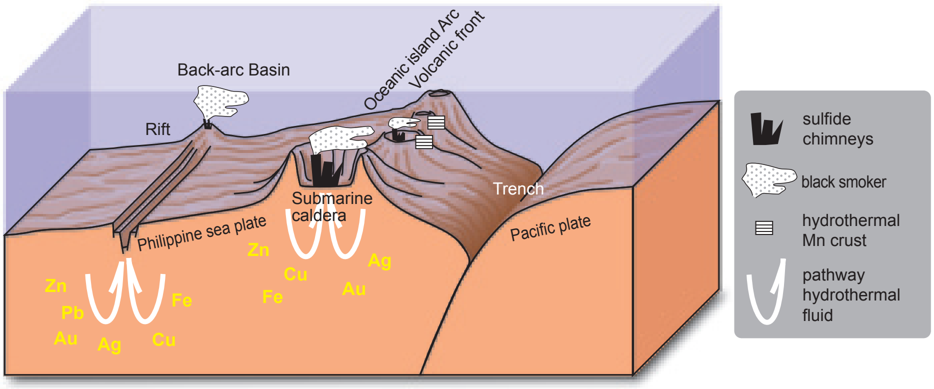


Figure 1 Distribution of potential sulfide deposits in sea areas around Japan, and schematic illustration of mineval formation processes

The Izu and Ogasawara Arc, equal to the Honshu Arc in size, is located in the area of sea south of Tokyo. In this seabed, there are many active seabed volcanoes on the west side of the Trench as well as islands in the southern and northern directions. The line of volcanoes along the trench is called a volcanic front. On the west side of this volcanic front, long and narrow depression, called a back-arc rift, lies from the north to the south. Many submarine calderas existing in the volcanic front and back-arc rift have concave topography where active hydrothermal activities are taking place. At submarine calderas with active hydrothermal activities, sea water sinks into the depth through cracks. Then the penetrated water is heated by the heat of the magma chamber and rises again to the surface of the seafloor as a hot fluid solution containing heavy metals and produces a potential sulfide deposit abundant in heavy metals, called a kuroko-type deposit (Figure 1). The same phenomenon as seen in the Izu and Ogasawara Arc is also taking place in the Ryukyu Arc.

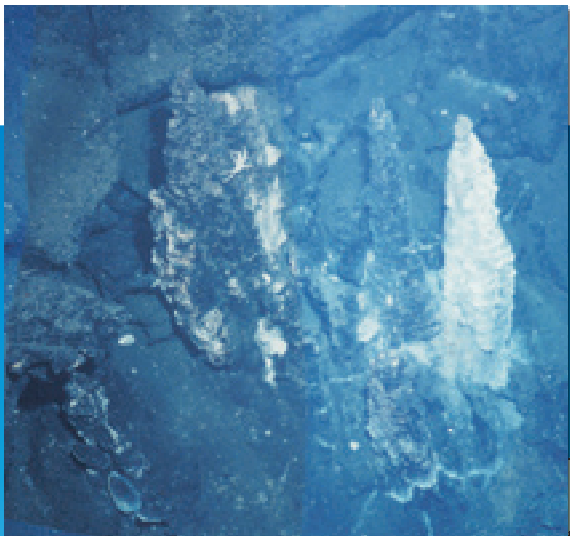


Photo Approximately 1 meter-high sulfide chimneys and sulfide debris (The Sunrise deposit on the Myojin knoll) (Photographed by Iizasa by JAMSTEC Shinkai 2000)

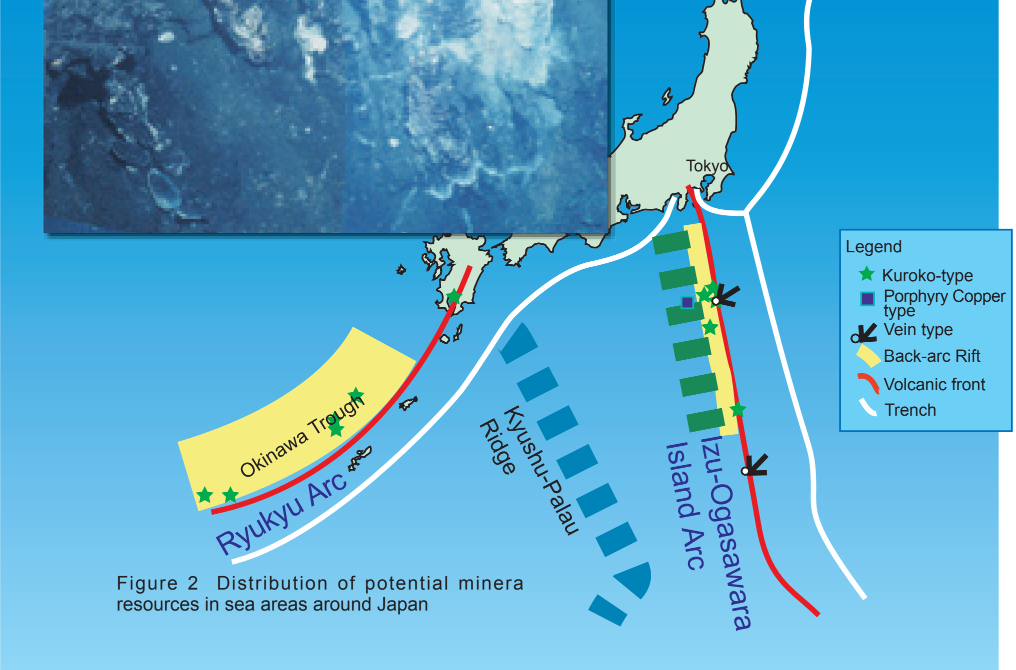


Figure 2 Distribution of potential minera resources in sea areas around Japan

The Distribution of Metal Deposits in Seas around Japanese Islands

In the exclusive economic zones around Japan, many potential metal deposits formed by the processes mentioned above (marked ? in Figure 2) containing an abundance of gold, silver, copper, lead, and zinc, exist in volcanic fronts and back-arc rifts.

The Roles of Geological Survey of Japan, AIST

The Geological Survey of Japan is an organization that conducts the geological surveys that need to be carried out on behalf of the nation. Geological information, indispensable in various spheres of life, is considered basic information of national land. In order to establish geological information, we have been conducting geological surveys consistently and responsibly since the 1882 establishment of our predecessor (the former Geological Survey of Japan). AIST's Geoinformation Center, four Geological Survey branches, and Geological Museum are working to establish and promote geological information, and the groups from these units engaging in geological surveys are generally referred to as the Geological Survey of Japan.

Actively conducting research to achieve its own goals, each unit engaging in geological surveys has its own missions. In addition, the research coordinator take the initiative in organizing Geological Survey of Japan, and all units, from the actual research sites to our office, will help him by internally and externally promoting systematic cooperation. We believe that it will allow us to communicate the achievements of our research to the general public more effectively.

Research Coordinator (Geology & Marine Science)
Eikichi TSUKUDA

There has long been great social demand for geological information in the search for mineral resources, coal, and petroleum. After the oil shock, however, such information has become more significant and in increased demand due to the search for natural gas and geothermal energy as alternative energies to petroleum and as a countermeasure to worsening global warming. Recently, there is greater demand for application of geological information to reduce damage from earthquakes and eruptions and to secure safe water.

The rise in social demand for geological information as human activities continue to expand is a sign that people have recognized the limitations of traditional but chaotic development and exploitation that consume the earth and have begun taking action to care for and coexist with the limited earth from a global viewpoint.

An important task now is how to sustain social development within the tolerance level of the limited earth. In order to establish a sustainable society, it is important to accurately evaluate the impact of human activities and natural phenomena on the earth and to predict the earth's future. We are required not only to understand the current state of the earth, but also to trace the origins of the earth as a system. Such understanding allows us to accurately predict its future. It is also necessary to acknowledge that global and regional issues are closely related.

The Geological Survey of Japan, AIST will broadly contribute to the well-being and safety of people by offering more accurate predictions through technical development and the establishment of information. Under our motto "Understand and Coexist with the Earth," we aim to realize a sustainable society.

Geological Museum

In the four exhibition rooms and the center hall, themes including the history of the earth, its shape, transformation mechanisms, and association with humans are introduced in a simple manner along with a systematic exhibition of geological samples.

Closed on: Mondays (Tuesday when a national holiday falls on Monday) and Dec. 28 to Jan. 4

Business hours: 9:30 to 16:30
(takes about one hour to observe)

Admission fee: Free

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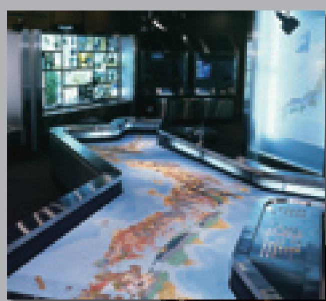

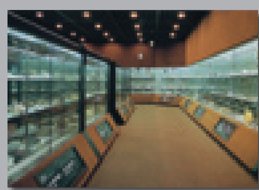

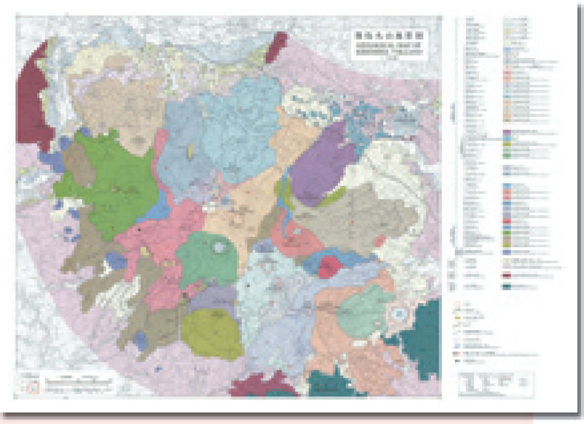

Geological map of volcanoes issued by Geological Survey of Japan

( ) is the year issued.

No. 1 Sakurajima Volcano (1981)	¥1,260
No. 2 Usu Volcano (1981)	¥1,155
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No. 4 Aso Volcano (1985)	¥1,155
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http://www.gsj.jp/Map/

Contact the Geoinformation Management office at the Geological Survey of Japan for purchasing and other information.
Tel : 029-861-3601 Fax : 029-861-3602

Geology-Related Publications by AIST

AIST series (published by Maruzen Price: 1,575 yen (net price 1,500 yen))
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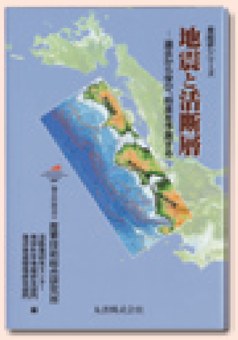
Volcanoes Challenge the Eruption

Introduces volcanic research by AIST including the findings produced from the surveys on the Usu, Miyake-jima, and Unzen eruption activities, the past and current state of Mt. Fuji, and the efforts for future predictions.

Earthquakes and Active Faults Learn from the Past to Predict the Future

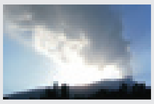
Helps understanding of the scientific basics of earthquakes and active faults and introduces earthquake research in progress aimed at future predictions based on geological surveys that characterize AIST.



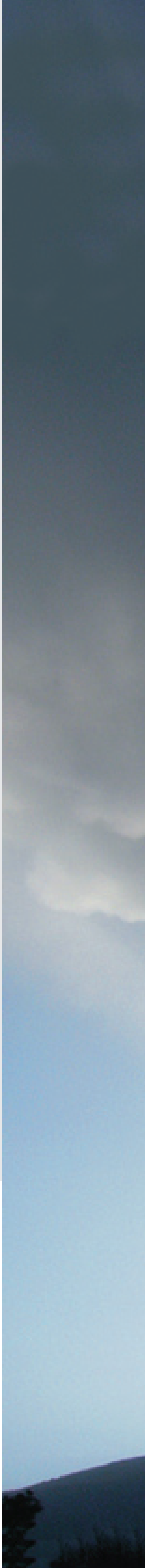
For further information on geological research by AIST, visit the website of the Geological Survey of Japan.
http://www.gsj.jp/

Volcanic Eruptions and the Blessings from the Earth
The Front Line of Volcanic Research by AIST

Cover Photo



The Mt.Asama eruption (2004)
Image by Dr. Kohei Kazahaya, GSJ



AIST NATIONAL INSTITUTE OF ADVANCED INDUSTRIAL SCIENCE AND TECHNOLOGY (AIST)

Publication Office, Public Relations Department, AIST
AIST Tsukuba Central 2, 1-1-1 Umezono, Tsukuba, Ibaraki, 305-8568, JAPAN
Tel:+81-29-862-6217 Fax:+81-29-862-6212 E-mail:prpub@m.aist.go.jp http://www.aist.go.jp/

Geological Survey of Japan, AIST
AIST Tsukuba Central 7, 1-1-1 Higashi, Tsukuba, Ibaraki, 305-8567, JAPAN
Tel:+81-29-861-9122 Fax:+81-29-861-3672 E-mail:secr@gsj.jp http://www.gsj.jp/

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