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Study on the Evaluation Method of Volcanic Activity and the Improvement of Volcanic Information: Preliminary Report

Kazuhiro ISHIHARA, Masato IGUCHI, Daisuke MIKI, Keigo YAMAMOTO, Wataru KANDA, Takeshi TAMEGURI, Daisuke FUKUSHIMA*, Takehiko MORI*, Hiromitsu OSHIMA**, Jun-ichi HIRABAYASHI***, Kenji NOGAMI*** and Yasuaki SUDO****

* COE Researcher, DPRI, Kyoto University
** Graduate School of Science, Hokkaido University, Japan
***Volcanic Fluid Research Center, Tokyo Institute of Technology, Japan
**** Graduate School of Science, Kyoto University, Japan

Synopsis

This paper is a preliminary report that describes the outline of targets and present results of our research project. Problems on volcanic information and education for mitigation of volcanic hazards fairly became clear by a workshop and educational activity. Present results on new tools applied for volcano monitoring at active volcanoes in southern Kyushu are described; geomagnetic observation, remote sensing for volcanic gases, and so on. Basic concept of a system of information processing on seismic data is described.

Keywords: Volcanic information; Volcano monitoring; Information processing

1. Introduction

There are 108 active volcanoes in Japan, and 5 volcanoes have erupted on average, and several volcanoes indicate abnormal activity each year. Among them, 3 to 4 volcanoes have induced severe hazards or threatened people every decade, e.g. eruptions at Unzen volcano (1991-1994), Usu volcano (2000) and Miyakejima volcano (2000-) and volcano-seismic crisis at Iwate volcano (1998). Since eruption ejects huge amount of volcanic materials and completely destroys everything around a volcano, people must evacuate from hazardous zone to safety area before eruption. Therefore, forecasting of volcanic eruptions, volcanic hazard maps, and plan for volcanic disaster prevention are essential tools for mitigation of volcanic disasters.

In Japan, the Japan Meteorological Agency (JMA) has responsibility for volcano monitoring and has issued volcanic information to publics in volcano crises. To cover insufficient ability of JMA in volcano monitoring and evaluation of volcanic activity, the Coordinating Committee for Prediction of Volcanic Eruptions (CCPVE) was organized in 1974. Universities, Coast Guard, and other institutions are the members, and CCPVE has evaluated significant volcanic activity and given statements which have been announced as volcanic information of JMA. This system has worked effectively in case of the 2000 eruptions at Usu and Miyakejima volcanoes, where volcanic alerts were issued just after detection of significant earthquake swarms, and people evacuated in safety area before the onset of eruptions.

Miyakejima and Usu volcanoes are rather exceptional, because most of Japanese volcanoes indicate no significant seismic precursors just before eruptions, and it is difficult to evaluate volcanic activity only by seismic data and to issue clear statement on the possibility of eruptions. At present, local governments and people at most volcanoes are urged to respond volcanic crises, accepting incomplete and ambiguous volcanic information.

In this study, we will treat two topics. The first one is related to volcanic information and public education for mitigation of volcanic disaster. The second one is improvement in quality and ability of prediction of volcanic eruptions, e.g. new methods of volcano monitoring and evaluation method of volcanic activity, including quick information system on volcanic activity. In this paper, we will report the outline of research activity during past 2 years.

2. Volcano information and public education

2.1 Workshop on volcanic information

On March 11, 2003, 'Sakurajima Workshop on Information for Mitigation of Volcanic Hazards' supported by 21stCentury COE program for DPRI, Kyoto University, was held at Sakurajima, Kagoshima (Ishihara ed., 2003). The main purposes of the workshop are to exchange knowledge and experiences in recent volcano crises at Usu, Iwate, Miyakejima, and Suwanosejima volcanoes, and to clarify problems related to volcanic information and research topics in near future. 65 participants came from JMA, local governments, universities, Japan Coast Guard, Ministry of Land and Transportation, mass media and institutions. Totally 14 papers were presented.

[1] Revised definition and classification of active volcanoes in Japan, based on their past activity (Uhira, JMA-Headquarter)

[2] Volcano information and effective communication among disaster prevention organizations in the 2000 eruption of Usu volcano (Miyamura, JMA-Sapporo)

[3] Volcanic disaster of the 2000 Usu eruption and response of autonomy (Tanabe, Sobetsu Town Office)

[4] The point of hazard mitigation at Usu volcano: Support for communities through communication (Okada, Hokkaido Univ.)

[5] Volcano information and countermeasure for the volcanic unrest at Iwate volcano since 1998 (Yoshikawa, JMA-Sendai)

[6] Mitigation of volcanic hazards and response done by universities (Hamaguchi, Tohoku Univ.)

[7] Volcano information and monitoring of Miyakejima volcano (Usui, JMA-Tokyo)

[8] Response of Tokyo Metropolitan Government and relationship with volcanologists for the 2000 Miyakejima eruption (Sasai and Miyazaki, Tokyo Metropolitan Gov.)

[9] Volcanic activity and volcanic information at Suwanosejima volcano in 2002 (Hiramatsu, JMA-Fukuoka)

[10] Volcano information and alert level of Sakurajima volcano (Daiku et al., JMA-Kagoshima)

[11] Volcanic processes of large eruptions and information at Sakurajima (Ishihara, Kyoto Univ.)

[12] Investigation on alert level of active volcanoes in Japan –Present and future view- (Yamasato, JMA-Headquarter)

[13] User requirements on volcanic information (Hayashi et al., JMA-Headquarter)

[14] Requests on volcanic information from local governments (Higashi, Kagoshima Prefecture Gov.)

Summary of active discussion are as follows:

(1) Contents and essential parts of 'Volcanic information' are not easy to understand for staff of local governments and people. Who are the users of volcanic information? And to whom issue of volcanic information is oriented? Detail explanation should be done by JMA, and lesson on volcanological terms is expected to staff of local governments and residents at active volcanoes.

(2) Local governments expect to get 'additional information and advice' from volcanologists of universities. They need the other line of information in addition to volcanic information from JMA.

(3) 'Alert level of volcanic activity' which will be soon applied by JMA to 5 volcanoes was appreciated by most of participants. Application to other volcanoes and is expected, after negotiation on the criteria of alert level with related autonomy is done.

(4) Communication systems among residents, local government, scientists and so on at volcanoes are important for mitigation of volcanic hazards.

2.2 Practical Public Education

Daisuke Fukushima, a COE researcher, has continued practical activity to get procedures on how to stimulate interest of residents toward Sakurajima volcano and how to transfer knowledge for mitigation of volcanic hazards, based on 'Ecomuseum' concept (Fukushima and Ishihara, 2004). His activity includes lectures for students and adults, lecture and field tours for member of Sakurajima Friend Association organized by him. He collected questionnaire from attendants and analyzed it. He temporarily got some conclusions. Lecture and education directly oriented to hazard mitigation are not necessarily effective. Combined program of lectures with field tours are more effective for education on disaster, and the contents of the program should include culture and nature of Sakurajima.

3. Development of evaluation method of volcanic activity

Southern Kyushu is the most active volcanic zone in Japan (Fig.1). Both Sakurajima and Suwanosejima volcanoes have intermittently erupted for about half a century. Satsuma-Iwojima has emitted continuously huge amount of volcanic gases over one thousand years, started emission of volcanic ash in 1997. Kuchinoerabujima volcano, which repeated strong phreatic explosions, indicated gradual increase in volcanic activity. Thus, southern Kyushu is the best test field to develop monitoring and evaluation methods on volcanic activity. In addition, Kagoshima prefecture government published volcanic hazard maps and made plan for mitigation of volcanic hazards for these volcanoes (Table 1).

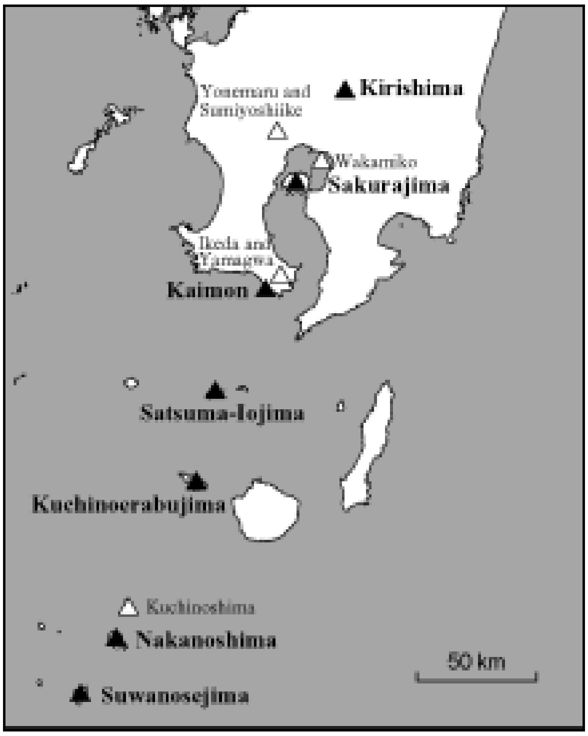

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Fig.1 Active volcanoes in southern Kyushu. Open triangles are those added as active volcanoes by revised definition of active volcanoes in 2003.

Table 1 Monitoring and hazard maps at volcanoes in Kagoshima prefecture

Volcano	Monitoring	Hazard map	Last eruption
Kirishima	JMA, Univ.	Published	1991
Sakurajima	JMA, Univ.	Published	1955〜
Kaimon	Univ.	ー	885
Satsuma-Ionia	JMA, Univ.	Published	1998〜
Kuchinoerabujima	Univ.	Published	1980
Nakanoshima	Univ.	Published	1949
Suwanosejima	JMA, Univ.	Published	1949〜

2.1 Research on the evaluation of eruption potential at Kuchinoerabujima volcano.

Kuchinoerabujima volcano originated strong phreatic explosions in 1841, 1931, 1933 and 1966. Many residents were killed and some communities were destroyed completely by eruptions and mud flows. The 1966 eruption was followed several minor eruptions until 1980. Sakurajima Volcano Research Center started seismic observation in 1992 using an interactive personal computer system (Iguchi, 1991), as eruption potential is expected to increase in a decade. Volcanic earthquakes have actually increased since July 1999 (Fig.2).

Joint Observation by universities was carried out in 2000-2001 to get baseline data on seismic, geodetic, geomagnetic, geothermal and geochemical observation (Sakurajima Volcano Research Center, 2002). Most of observation data and results of research suggested consistently that the storage of eruption energy might be located 0.5-1 km under the summit crater, e.g. location of micro-earthquakes was concentrated at a zone shallower than 1 km under the crater and no earthquakes deeper part. It was also recognized that seismic and geodetic data are not enough to evaluate eruption potential for phreatic explosions, and geomagnetic and geochemical observation are required to be continued to detect geothermal state under the volcano.

Continuous observation of geomagnetic force around the summit crater was initiated using satellite telecommunication in late of 2000 (Kanda et al., 2001) and the method of data processing is developed (Kanda and Fujii, 2003). Geomagnetic changes at a rate of a few nT/y started in the mid of 2001, which suggested demagnetization of volcanic body at a depth shallower than 1km due to temperature increase, probably, up to 400 ℃ or more. The rate of geomagnetic changes at stations around the crater has been accelerated up to 10 nT/y since January 2003. Then new fumaroles appeared on the wall of the summit crater in February, and CO was detected in volcanic gases, which suggested temperature in the subsurface of the summit area increased significantly. Volcanic processes of the volcano are summarized as follows:

1) 1991-June, 1999: Normal state
2) Mid of 1999- mid of 2001: Temporal increase in internal pressure at shallow part indicated by seismic and GPS data
3) Mid of 2001-December 2002: Temperature gradually increased under the crater suggested by geomagnetic changes and gradual increase in seismicity.
4) January 2003-: Hydrothermal system under the crater has been activated indicated by new fumaroles and temperature increase on the crater wall, acceleration of geomagnetic change and change in chemical components of volcanic gases.

Thus it was revealed that geomagnetic observation is powerful tool to evaluate geothermal state at shallow part of active volcanoes. However, it is still unsolved problem how to evaluate quantitatively heat energy accumulated under the crater from the data of geomagnetic changes, and whether phreatic explosions is triggered mainly by the heat energy accumulation or excited by additional intrusion of magma.

Residents reported that they recognized volcanic rumblings or weak earthquakes immediately before some of former explosions. To forecast eruptions, we need both quick information processing of seismic data and information on abnormal phenomena from residents.

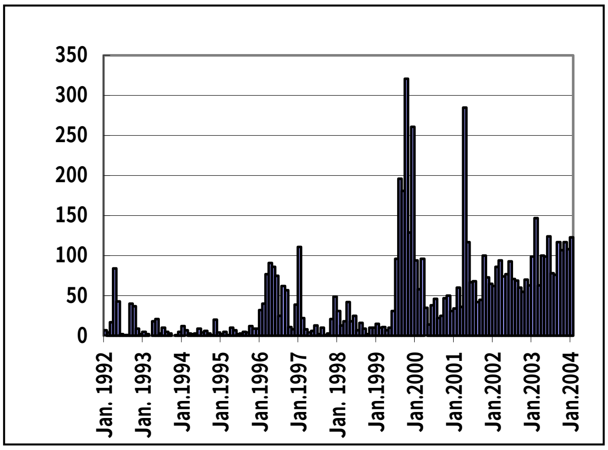

Fig.2 Monthly number of volcanic earthquakes at Kuchinoerabujima volcano

2.2 Geochemical tools for monitoring of volcanic gases and volatiles in magma

Monitoring of gas flux and gas components from active volcanoes and evaluation of volatiles in magma are considered as the most important tools for evaluation of volcanic activity and forecasting volcanic eruptions for geochemists, since most of eruptions are excited by gases dissolved from magma.

Recently, a new portable instrument for measurement of SO2 emission is produced; differential optical absorption spectrometer (DOAS). The size, weight and consumed electric power of DOAS are much smaller than the former type, that is, COSPEC (Correlation spectrometer), as brought and operated by a single person at volcanoes. Takeshi Mori, a COE researcher, made experimental observation at Sakurajima and Suwanosejima to check its performance of instrument and reliability of obtained data with colleagues (Mori et al, 2004). There are no significant difference in data between DOAS and COSPEC and also no discrepancy in data among three sets of DOAS. It is also verified by continuous monitoring for several hours performed at the summit of Suwanosejima that DOAS is useful for observation of temporal changes in SO2 emission rate.

Volatile components trapped into volcanic ash particles were analyzed, using ash samples of Sakurajima collected by SVRC during the past 30 years, and compared with eruption styles. Volcanic ash emitted during swarms of B-type earthquake contained higher amount of chlorine than that emitted by explosive eruptions. This supports the hypothesis derived from geophysical observation that swarms of B-type earthquakes might be originated by extrusion of fresh magma (Ishihara and Iguchi, 1989).

2.3 Development of an automated information system on volcanic earthquakes and activity

It is well known that volcanic earthquakes and tremors observed at active volcanoes are classified into several types, and predominant types of seismic events change with the progress of volcanic activity, including amplitude and number of volcano-seismic events. Classification of volcano-seismic events and statistical evaluation of the data is useful for forecasting volcanic eruptions (e.g. Nishi, 1984; Hidayati et al, 1998). Nishi (1988) proposed and developed a prototype of automated data processing system for volcanic earthquakes. It is composed of two parts: the one is classification of seismic events using several parameters and the other one is statistical evaluation of volcanic activity. The main parameters using classification are

[1] Arrival times of triggered events
[2] Maximum amplitudes
[3] Spectra of seismic waves
[4] Duration
[5] Amplitude of air shocks, and combined parameters among seismic stations.

Using these parameters, each event was classified into 'A-type earthquakes', 'B-type earthquake', 'Explosion', 'Eruption', 'Volcanic tremor', 'C-type tremor', 'Debris flow' and 'Not volcanic'. He tried to evaluate statistically the possibility of explosions in next 24 hours, using the data of B-type earthquakes. The results were partly satisfactory for a short time, but not necessarily acceptable throughout a long time, because the quantitative relationship between B-type earthquakes and explosions changes with stage of activity. Later, more reliable forecasting system, 'Automated Warning System for Summit Explosions' was developed using deformation data (Kamo and Ishihara, 1989), and the system has been used by Kagoshima Meteorological Observatory.

Volcano monitoring system at Sakurajima Volcano Research Center (SVRC) has expanded to island volcanoes in Kyushu (Fig. 1). New seismic data processing system is now being developing, based on Nishi's trial. The concepts and purpose are, however, different from his idea. The purpose is not 'forecasting eruptions' but 'informing levels of volcanic activity' to researchers working at volcanoes, volcano experts, autonomies and others. The outline of the concept is illustrated in Fig. 3.

(1) Classification of seismic events at each volcano is done in a similar way as Nishi did, though types of seismic events at each volcano are differ from those at other volcanoes.

(2) Short daily reports are regularly transmitted to

researchers and others by hand-phones or e-mails. Detail data are accessible through internets. When earthquake swarm or large earthquakes are detected, rapid reports are transmitted.

(3) Information of three levels is in consideration: for volcano experts [level A], for governmental use [level B], and for residents [level C].

Now, this system is in test operation at SVRC. We have several problems to be solved on practical use of this system, e.g. check of result of classification of volcanic earthquakes, criteria for evaluation of eruption potential and some technical problems.

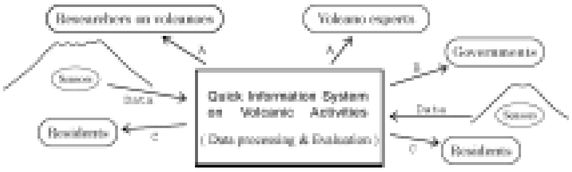

Fig.3 Concept of information system on volcanic activity

4. Concluding Remarks

It became fairly clear through the workshop and practical activity on public education; what people expect for volcanic information and how we should transfer knowledge on mitigation of volcanic hazards. Some tools were newly put into volcano monitoring and a system of information processing on volcanic data was introduced. It is our task in this project to improve the evaluation methods of volcanic activity from volcanological point of views, and to develop the information system useful for mitigation of volcanic hazards.

Acknowledgments

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要　旨

ワークショップの開催，実践的な教育・普及活動に取り組み，火山防災情報の質の向上にかかわる問題点の整理がかなり進んだ．また，火山活動の評価手法を目指して，薩南諸島の火山において地磁気の連続観測，近年開発されたDOASによる二酸化硫黄の放出率の測定等を行い，また，過去30年間の桜島の火山灰中の揮発成分の分析を行い，他の観測調査データ等と比較することによって，これらの観測・分析手法が火山活動評価や噴火機構研究の有効なツールとなりうることを確認した．さらに，複数の火山の火山性地震を自動分類し，その結果を必要に応じて携帯電話やE-mailで関係者に通報するシステムを開発し，試験運用を開始した．

キーワード：火山防災情報，火山観測手法，自動データ処理，情報伝達

火山活動の評価手法の開発と火山防災情報に関する研究（序報）

○　石原和弘

１．はじめに

わが国には，108 の活火山があり，毎年平均５火山で噴火が発生し，ほぼ同数の火山で異常現象が発現している．また，顕著な災害を引き起こす火山活動は，十年間に３～４火山で発生している．約 30 火山では，ハザードマップなどが作成・公表され，火山災害に対する対応を地域防災計画で定めている．特定の火山では，噴火の直前予知と対応には実績があるものの，数多くの火山ではいまだその段階には達しておらず，噴火様式の予測などについては，未だ困難である．わが国では，気象庁が火山活動の監視と火山情報の発表の責務を負い，自治体が住民の安全確保の責任を負っている．本研究では，火山活動の評価手法の開発と，情報伝達にかかわる諸課題の解決に向けた取り組みに焦点をあてた．

２．火山防災情報に関する研究

（１）火山防災情報ワークショップ in 桜島

2003 年 3 月，全国の大学，気象庁，自治体，防災関係者が集合し，火山活動のレベル化，活火山の見直しなどの新たな動き，有珠や三宅島などの危機時の火山情報と自治体等の対応について議論し，平常時・危機時の火山防災の取り組みと火山情報のあり方について討議した．

（２）火山防災のための教育・普及活動

COE 研究員福島大輔（COE12 参照）は，火山防災の意識を住民・行政に根付かせるにはどのような取り組みが必要か探るため，講演，出前授業，野外研修などさまざまな活動を行い，教育普及活動のあり方を模索している．

３．火山活動評価手法の開発

（１）水蒸気爆発の発生過程

長い休止期間の後の大規模噴火は，水蒸気爆発から始まる例が多く，その発生過程・機構の理解は火山噴火予知の重要課題のひとつである．20 世紀に顕著な水蒸気爆発を繰り返し，近い将来において噴火発生の可能性の高い口永良部島を対象に，水蒸気爆発の発生過程の解明を目的として，各種の調査・観測を行ってきた．その結果，山頂火口の地下浅部で，エネルギーの蓄積が緩やかではあるが着実に進んでいることが，地震，地殻変動，地磁気，地温，火山ガスなどの観測によって捉えられた．

（２）火山ガス，マグマ中の揮発成分

近年開発された二酸化硫黄濃度の小型軽量な遠（DOAS）を用いた火山ガス中の二酸化硫黄放出率の試験観測を，COE 研究員森健彦らが諏訪之瀬島，桜島等で実施した．従来の装置（COSPEC）と整合する測定値が得られるこ，また，活動中の諏訪之瀬島で連続観測を実施し，噴火機構解明に有益な顕著な二酸化硫黄の濃度の時間変化のデータを得た．野上他は，桜島の火山灰中の塩素濃度が噴火様式の間で変化することを見出した．

（３）火山活動度の自動評価システムの開発

火山活動研究センターでは，南九州の５火山の火山性地震・微動の自動分類装置の開発に着手した．活火山を調査する観測者・研究者や住民の安全確保を図るため，分類結果をもとに火山活動を評価して，異常を検知したとき，携帯電話やインターネットを介して，防災関係者に通報するシステムへと発展させたいと考えている．