Long-term forecast of eruptions from Mono-Inyo volcanic chain, CA, USA

Marcus Bursik[1], Galina Rogova[1], Solene Pouget[1], Shannon Kobs-Nawotniak[2]

[1]Department of Geology, Center for Geohazards Studies, University of Buffalo, USA, [2]Department of Geosciences, Idaho State University, USA

E-mail: mib@buffalo.edu

In collecting data for long-term forecasting in a volcanic region, one of our main goals is to correlate scattered outcrops of deposits to one another, to a particular vent, and ultimately to an eruptive sequence. In this way, we reconstruct the eruptive history and are enabled to forecast future events. It becomes increasingly difficult to correlate layers one to another as the layers are more deeply buried, hence less easily or frequently exposed near the surface, or as they are thinner and less extensive. It becomes increasingly difficult to correlate layers to vents or to eruptive sequences as the number of vents increases or as the eruptive history becomes longer.

We have explored the use of clustering and multiple artificial neural networks combined within the framework of the Transferable Belief Model and Extreme Value Theory to construct a hybrid information processing system as an aid in the correlation of Mono-Inyo pyroclastic layers and eruption forecasting. The idea is that the hybrid system could prove useful in discerning eruptive patterns that would otherwise be difficult to sort and categorize.

Development of the information processing system has proceeded along with improvements in chronometric, geochemical and lithostratigraphic datasets. Our results to date include a systematization of the analysis framework from inception of a forecasting project. We have found that clustering and neural networks can yield a confidenc interval to proposed tephra correlations, but are still limited by analytical uncertainties in the underlying data. Return period forecasts are tempered by the uncertainties in both the data and the mathematical characteristics of the forecast model.

A multi-scale risk assessment for tephra fallout and airborne concentration from multiple Icelandic volcanoes - Part I: hazard assessment

Sebastien Biass[1], Chiara Scaini[2], Costanza Bonadonna[1], Kate Smith[3], Arnau Folch[2], Armann Höskuldsson[4], Adriana Galderisi[5]

[1]Section of Earth and Environmental Sciences, University of Geneva, Switzerland, [2]CASE Department, Barcelona Supercomputing Center (BSC-CNS), Spain, [3]University of Exeter, UK, [4]Nordic Volcanological Center, University of Iceland, Iceland, [5]Universita Federico II di Napoli, Italy

E-mail: sebastien.biasse@unige.ch

In order to assist the elaboration of proactive measures for the management of future volcanic eruptions in Iceland, we developed a new approach to assess the medium- to long-term hazard related to tephra fallout at various scales and for multiple sources. We coupled field studies with numerical modelling to compile a local ground deposition assessment using the advection-diffusion model TEPHRA2 and a regional atmospheric ash concentration assessment using the numerical model FALL3D.

This study focuses on four volcanoes – Hekla, Katla, Askja and Eyjafjallajökull – selected for their high probability of eruption in a near future or their high potential impacts. Due to their different eruptive behaviours and different degrees of knowledge of past eruptions, separate schemes for the quantification of the hazard were developed. All scenarios are a combination of 1000 runs of each model, varying Eruption Source Parameters (EPS) and/or meteorological conditions (in 10 years of Reanalysis data). EPS (plume height, erupted mass, eruption duration) were defined for each scenario based on field and literature studies.

Two scenarios were considered for Hekla volcano (based on the 1947 and on the 2000 eruptions as references) using the Eruption Range Scenarios approach (ERS), where wind conditions and EPS are stochastically sampled. Eruptions at Katla are numerous and heterogeneous in eruptive styles, including basaltic, silicic and long-lasting eruptions. One ERS was produced for the VEI 2-3 classes to account for the basaltic activity. At Askja, two One Eruption Scenarios were considered to account for both the phreatomagmatic and the magmatic phase of the 1875 eruption, with varying wind conditions and EPS fixed deterministically. We also produced an ERS for VEI 5, based on field evidences of deposits larger than the 1875 eruption. At Eyjafjallajökull, we modelled possible patterns of tephra dispersal associated with a long-lasting eruption similar to 2010. Outputs are produced in a variety of shapes such as probability maps of ground tephra accumulation and airborne concentration, isomass maps for a given probability, hazard curves and atmospheric travel and residence times. At a local scale, results show a strong prevailing pattern of tephra deposition and transportation towards the E and NE part of the island, leaving a very low probability of Reykjavik to be impacted. At regional scale, there is a low to medium probability of having critical ash concentration in Northern Europe and UK airspaces.

This method combines field and numerical approaches and provides a multi-scale hazard assessment to describe both the local hazard associated with ground deposition of tephra and the hazard at a regional scale associated with the long residence time of volcanic particles in the atmosphere, which is the first step to the compilation of comprehensive risk assessments. The vulnerability and impact are presented in Part II.

A multi-scale risk assessment for tephra fallout and airborne concentration from multiple Icelandic volcanoes - Part II: vulnerability and impact assessment

Chiara Scaini[1], Sebastien Biass[2], Adriana Galderisi[3], Costanza Bonadonna[2], Kate Smith[4], Arnau Folch[1], Ármann Höskuldsson[5]

[1]CASE Department, Barcelona Supercomputing Center (BSC-CNS), Spain, [2]Section of Earth and Environmental Sciences, University of Geneva, Switzerland, [3]Università Federico II di Napoli, Italy, [4]University of Exeter, United Kingdom, [5]Nordic Volcanological Center, University of Iceland, Iceland

E-mail: chiara.scaini@bsc.es

The aim of this project is to perform a multi-scale risk assessment of tephra dispersal and fallout from explosive activity in Iceland. The vulnerability and impact assessment presented here, together with the probabilistic hazard assessment presented in Part I, provide the necessary information for long-term risk management of explosive eruptions at local and European scales.

Results of part I show that explosive activity at Iceland may produce consequences at local and regional scale, and a vulnerability assessment for both tephra dispersal and deposition is necessary. A multi-scale vulnerability assessment is presented for both for Iceland and for the European cities, airports and airspace, with a special focus on systemic and socio-economic vulnerability.

The analysis of socio-economic background of Iceland at local scale allows to identify the most of the relevant vulnerability themes. The themes considered for the estimation of systemic vulnerability are: presence of primary road network, redundancy of road network, presence of critical facilities and accessibility from main cities to critical facilities. From the socio-economic point of view, we take into account the presence of agricultural activities, and the productivity of milk and wool, which are relevant for the economy of aisled towns and rural areas. Thematic vulnerability indicators are defined and estimated for each municipality with a common vulnerability rating system in order to produce thematic maps. A cumulative vulnerability map is produced by combining all thematic maps, with the assumption that vulnerability themes have all same weight. Expected impacts are estimated for selected eruptive scenarios, identifying critical areas for intervention.

European air traffic network is highly vulnerable to the failure of main transportation hubs, and this analysis allows for the identification of the critical airports and routes that might be the most affected by an Icelandic eruption. The socio-economic vulnerability is estimated for Nuts-2 regions, depending on the population and the multi-modal accessibility of the region. Expected impacts on European air traffic system are estimated for selected eruptive scenarios.

Results are vulnerability maps for Iceland and European air traffic, and expected impact maps for selected eruptive scenarios. This is the first attempt of performing a multi-scale vulnerability assessment for both tephra dispersal and sedimentation. The concepts of systemic and socio-economic vulnerability are applied here to local and regional domain, to produce a comprehensive multi-scale vulnerability assessment. The presented methodology could significantly improve current risk-management practices both at local and regional scale. Moreover, results are useful for risk mitigation at local scale and long-term planning at regional scale.

MODELING FOR THE DISTRIBUTION OF PYROCLASTIC FLOW MERAPI VOLCANO USING TITAN2D AND LIDAR DIGITAL ELEVATION MODEL

Nurnaning Aisyah[1], Christina Widiwijayanti[2], Subandriyo Subandriyo[1], Dewi Sri Sayudi[1], Noer Cholik[1], Kazuhiro Ishihara[3], Masato Iguchi[3]

[1]Geologycal Agency - Ministry of Energy and Mineral Resources, Indonesia, [2]Earth Observatory Of Singapore - Nanyang Technological University, Singapore, [3]Sakurajima Observatory - Kyoto University, Japan

E-mail: nurnaning2012@gmail.com

Characteristics of Merapi volcano eruption marked by growing lava dome, when collapse so formed pyroclastic. Pyroclastic flows be primary hazard Merapi eruption that causes victims with many materials losses. Pyroclastic are a mixture of gas and rocks (From fine grains to large of stone) which has a very high temperature (> 600oC) and flows to a lower place are controlled by gravity and topographic. In 2010, outside the general pattern, pyroclastic eruptions Merapi are formed by the combination of the lava dome collapse and explosion. Almost of spreading the pyroclastic flow to all valleys and main rivers, and dominant to the south with the largest volume (> 30
Models validation use data from Merapi eruption in the past and in 2010.

The VORISA project: A novel approach to assessing long-term volcanic hazard in the Kingdom of Saudi Arabia

Mohammed R Moufti[1], Jan M Lindsay[2]

[1]Geologic Hazards Research Unit, King Abdulaziz University, Jeddah, Saudi Arabia, [2]School of Environment, The University of Auckland, Auckland, New Zealand

E-mail: j.lindsay@auckland.ac.nz

The Kingdom of Saudi Arabia has numerous large monogenetic volcanic fields, known locally as 'Harrat'. The northern part of Saudi Arabia's largest such field, the 20,000 km2 Harrat Rahat, extends for 300 km south of the Islamic holy city of Madinah and is called Harrat Al-Madinah. Although basaltic cones and associated lava flow fields dominate, small shield volcanoes and trachytic domes and maars are also present in Harrat Al-Madinah. The most recent eruption took place in 1256 AD through a c. 2 km-long fissure, resulting in the formation of 7 cones, as well as lava flows that travelled within 20 km of Madinah. With over 500 visible vents and periodic seismic swarms indicating stalled eruptions, an understanding of the likelihood, magnitude and style of future eruptions in Harrat Al Madinah is vital.

In order to systematically address the need for long term volcanic hazard assessment in this important region, we developed the VORiSA Project, a 3-year, multi-disciplinary research collaboration between King Abdulaziz University in Jeddah, Saudi Arabia, and the University of Auckland, New Zealand. The project is divided into two scientific themes, a 'Geoscientific' theme and a 'Probabilistic volcanic and volcano-seismic hazard' theme. Both geological and geophysical studies are integrated into the Geoscientific theme. Detailed mapping and geochemical studies will be integrated with new and existing age determinations to determine the style and sequence of events during past basaltic and trachytic eruptions, thus providing insight into possible future scenarios. In order to geophysically characterise the structure and nature of the crust beneath the Harrat, and thus constrain possible physical controls on magma propagation, results from gravity and magnetotelluric (MT) surveys will be combined with microearthquake data from an 8-station borehole seismic research array. Data from the seismic research array will also be used to calculate a new seismic velocity model for this area. In the 'Probabilistic volcanic and volcano-seismic hazard' theme, data such as vent locations; volumes and spatial distributions of past eruptive products; aeromagnetic and seismic interpretations of sub-surface structure; regional tectonic models and geochemistry of erupted products are all being integrated to determine possible relationships between data sets. Thus both existing and new geoscientific data are being synthesised to determine patterns in eruption frequency, magnitude, and style of past activity, as well as the probable location of a future event.

Despite the challenges of working in this isolated and remote area, joint Saudi/NZ geological/geophysical field campaigns and workshops have resulted in a very successful research collaboration that will, in time, lead to a much greater understanding of long term volcanic hazard in Saudi Arabia.

Re-evaluation for the Impact of a Gigantic Eruption from Ilopango Caldera, El Salvador, Central America, in the 3rd to 6th Centuries

SHIGERU KITAMURA

Faculty of Social Welfare, Hirosaki Gakuin University, JAPAN

E-mail: kitamura@hirogaku-u.ac.jp

The information on the impact of past eruption to human societies is important for the assessment of volcanic hazards. On the other hand, we must note that the influence of a gigantic caldera eruption in the age without historical documentation tends to be overestimated because of the scale of volcanic phenomena beyond our imagination. For appropriate assessment to the impact of caldera eruption in the past, multidisciplinary approach is valuable, of course, and re-examination under the academic progress in individual subject is also necessary. This presentation will summarize the latest pyroclastic eruption of Ilopango Caldera, El Salvador, Central America, in the 3rd to 6th centuries, and re-evaluate its impact to human societies in comparison with previous studies.

Ilopango Caldera (size; 8 x 11 km) is located in the neighbor area of San Salvador, the capital of El Salvador, Central America. In the latest gigantic eruption of the caldera, which occurred in the 3rd to 6th centuries, produced voluminous pumice flow and broadly dispersed air-fall ash. Mesoamerican archaeologists traditionally considered that the pyroclastic deposit called the "TBJ" should be the boundary between the Preclassic and the Classic horizon, and that destructive impacts of the eruption on the Prehispanic societies of Maya should caused remarkable cultural change (e.g., Sharer, 1978). This idea was supported by radiocarbon dates scattered around the end of the 3rd century (Sheets, 1983) and geological data suggesting thickly deposited volcanic ash such as a thickness of 50 cm at a distance of 70 km from the origin (Hart & Steen-McIntyre, 1983).

Recent tephrochronological work illustrated that the TBJ air-fall ash is not so thick as described in previous studies, only 20 to 30 cm thick outside the area 40 km from the caldera, where the the TBJ pumice flow was emplaced. It suggests that the area within 40 km of the caldera must be destroyed severely by the TBJ pumice flow, while it was possible to keep agriculture for life in the outside because the maize, one of principal foods in the area, can reach out its root over 30 cm deep to buried organic horizon under the ground (Kitamura, 2010). AMS radiocarbon dating added dates suggesting that the eruptive date should be postponed to the 5th or the 6th century (Dull, et al., 2001; Dull, et al., 2010). Some archaeologists also consider that the latest Ilopango eruption occurred in the Classic Period and the Classic culture was not interrupted by the eruption, on the basis of additional data obtained by stratigraphic excavation and precise positioning method in the ruin and broad correlation in the region (Shibata, et al., 2009).

TOPAZ: Long-term volcanic risk forecasting for deep geological repositories for radioactive waste

Ellie Scourse[1], Chuck Connor[2], Olivier Jaquet[3], Steve Sparks[4], Willy Aspinall[4], Neil Chapman[1], Mick Apted[5], Junichi Goto[6], Hideki Kawamura[7]

[1]MCM Consulting, Switzerland, [2]University of South Florida, USA, [3]In2Earth, Switzerland, [4]University of Bristol, UK, [5]Intera, USA, [6]NUMO, Japan, [7]Obayashi Corporation, Japan

E-mail: ellie.scourse@mcm-international.ch

The TOPAZ Project is an unusual application of volcanic event forecasting as it endeavours to look forward thousands of years into the future. The 2011 Tohoku earthquake highlighted the susceptibility of Japan to major disruptive tectonic events, but also the need to adopt risk-based approaches to quantifying specific hazards, in particular the location-specific likelihood of events exceeding given hazard levels. Japan intends to manage its higher activity radioactive wastes from nuclear power generation in deep geological repositories. Geological repositories might be susceptible to disruption by direct hit or closely adjacent events such as volcanic intrusion or major fault shear, as well as by slower processes, such as exhumation by uplift and erosion. The likelihood of specific impacts needs to be quantified for different timeframes, so that any consequent radiological risks can be estimated. For tectonic events, a risk-based approach combining specific event likelihood with consequences can be used to help decide on site suitability, the treatment of hazards from future volcanic events is more challenging. Since 2002, the Nuclear Waste Management Organisation of Japan has been developing methodologies for quantifying a range of tectonic hazards at potential sites. The avoidance of disruption over the first few thousands of years is of paramount importance in a safety case for waste disposal, as the intrinsic hazard potential of these wastes is high during this period. Although hazard potential decreases considerably after a few thousand years, regulatory requirements might entail estimating impact scenarios out to 1 Ma. One development of the project extends the 100 ka methodology for forecasting over longer periods by using expert elicitation to capture expert judgments on alternative modes of evolution of the tectonic system and associated volcanic events, and to characterize the related process uncertainties. This technique rationalizes the full range of expert knowledge and converts it into relative scenario weights to support probabilistic assessment for both tectonic and volcanic futures. For the latter, the approach developed by NUMO produces quantified hazard maps of impacts for use in site selection. These have been developed to show the probability of any event within 25 km2 blocks and the probability of explosive volcanic events of a specified magnitude (M5) or greater on the VOGRIPA scale. The maps provide information for quantitative radiological risk assessments and quantify project risk by identifying locations where uncertainties/risks are either acceptable or a credible safety case would be difficult to sustain. This paper briefly outlines the approach, provides examples of the hazard maps produced for different regions of Japan and discusses the uncertainties involved in this novel application of volcanic risk evaluation. Additional current work is extending the scope to include caldera-scale event likelihood.

Quantitative modelling of disaster risk at La Soufriere, Guadeloupe

Susanna Jenkins[1], Peter Baxter[2], Robin Spence[3], Jean-Christophe Komorowski[4], Sara Barsotti[5], Tomaso Esposti-Ongaro[5], Augusto Neri[5]

[1]University of Bristol, UK, [2]University of Cambridge, UK, [3]Cambridge Architectural Research, UK, [4]Institut de Physique du Globe de Paris, France, [5]Istituto Nazionale di Geofisica e Vulcanologia, Italy

E-mail: susanna.jenkins@bristol.ac.uk

As part of the CASAVA project, potential consequences of an eruption at La Soufriere volcano, Guadeloupe, have been quantified for the local population and infrastructure through development of an impact model. For a given eruption scenario, and on a 250m grid, the model incorporates hazard information about areas potentially affected by ash fall (vertical loading) and/or pyroclastic density currents (peak dynamic pressure, temperature and duration) sourced from numerical modelling able to describe the transient and 3D features of the phenomena. This is combined with vulnerability information derived from engineering and medical analyses of the exposure and response of humans and buildings to these hazards. Model outputs include maps of the numbers and severity of human casualties and building damage for each given scenario. The impact model is further coupled with a dynamic casualty management model that then tracks the rescue, transport and treatment of casualties to estimate the impact of the eruption on the emergency services and on casualty numbers with time following the eruption. This allows dynamic mapping of human survival in space and time following the eruption scenario and can be combined in GIS with emergency management data to support public officials responsible for planning for a crisis. To identify suitable actions that could be taken to reduce the loss of lives and infrastructure, the consequences from different disaster risk scenarios are tested by varying the crisis conditions for each model run. For example, by incorporating short- and long-term mitigation activities (e.g. partial evacuation, construction of additional road capacity), differing emergency management (e.g. the location of triage centres) or simulating alternative disaster conditions (e.g. reduced rescuing capacity because of ashy conditions). The models are deliberately generic in nature and could be applied to any volcano, providing input hazard scenarios and appropriate exposure and vulnerability data are available.

Towards a global volcanic hazards index

Melanie R Auker[1], Steve Sparks[1], Susanna Jenkins[1], Chris Newhall[2], Gill Jolly[3], Ed Venzke[4]

[1]University of Bristol, United Kingdom, [2]Earth Observatory of Singapore, Singapore, [3]GNS, New Zealand, [4]The Smithsonian Institution, United States

E-mail: ma6549@bristol.ac.uk

Globally, many people live in areas that have the potential to be affected by volcanic hazards; this number is growing. The need for judgements regarding the extent of these potential hazards is therefore more pressing than ever. When properly understood and communicated effectively, hazard assessments can be hugely beneficial in land use planning during times of quiescence, and in emergency planning during times of unrest.

Focus in this work is on hazard assessment methods applicable at the global scale, to identify volcanoes likely to pose greatest hazard during timescales relevant for risk applications, i.e. one generation (approximately 30 years). These must be computationally simple to ensure worldwide application is feasible, yet capture the complexities of volcanic hazard as fully as possible. A handful of attempts at creating such methods exist, most commonly using an indices structure in which quantitative variables are used to represent different aspects of volcanic hazards. One of the best-regarded of these is the USA National Volcano Early Warning System (NVEWS) of Ewert (2007); more recently, Aspinall et al. (2011) created a new method that addresses some of the shortcomings of the NVEWS method, and was applied to sixteen developing countries.

We continue this iterative procedure of improvements to create a new globally-applicable, indices-based volcanic hazard assessment method. This new method first divides volcanoes into eruption frequency classes, based on the number of eruptions in the volcano's record, the date of the most recent eruption, and unrest since. A score is assigned to each frequency class. Separately, each volcano is scored based on factors reflective of eruption magnitude. These include VEI, and the incidence of pyroclastic flows, lahars, and lava flows. The frequency and magnitude scores are then combined multiplicatively to give the volcano an overall hazard score. We use the Holocene volcano database available from the Smithsonian Institution for consistency and simplicity.

Preliminary testing using well known volcanoes shows promising results, with relative hazard scores in line with expectations. We have used data on the numbers of fatalities caused by pyroclastic flows, lahars, and lava flows (Auker et al., 2013) to inform the weightings of the hazard factors that form the magnitude score.

Our next step is to set a minimum number of eruptions in a volcano's eruptive history below which the amount of data is deemed insufficient for the method to be applied effectively. In cases of insufficient data, a hazard potential score based on the hazard score of "similar" volcanoes will be calculated. The volcano's hazard potential score will then be added to its hazard score to provide an overall hazard summary. This work is currently in progress.

The completed method will be used as part of the UNISDR Global Assessment of Risk Report 2015.

Long–term eruption forecasting at Ischia volcano

Laura Sandri[1], Lucia Zaccarelli[1], Sandro de Vita[2], Mauro Antonio Di Vito[2], Fabio Sansivero[2]

[1]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Bologna, Bologna, Italy, [2]Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Vesuviano, Napoli, Italy

E-mail: laura.sandri@bo.ingv.it

The island of Ischia, located in the Eastern side of the Gulf of Naples in Southern Italy, is a densely inhabited and highly touristic active volcano, characterized by effusive and explosive eruptions alternating with quiescent periods. The island undergoes a mechanism of caldera resurgence, and recent volcanic activity has been clearly influenced by the resurgence mechanism, although there is not a clear pattern in terms of eruption type or size.

In this study, we consider geological knowledge, represented by the volcano's past activity and observed deposits, to set up a Bayesian Event Tree for a long–term eruption forecasting. We try to (i) constrain the probability of next eruption in a given time interval, (ii) set up a spatial probability map for vent opening, and (iii) propose a classification of the possible eruptive types, quantifying their relative probabilities. In particular, for points (i) and (iii) we rely on the eruptive catalog available, and for point (iii) we also consider a more general frequency–size relationship.

For point (ii) we base our evaluation both on structural/morphological evidence, mostly related to the resurgence mechanism already proposed in the literature, and on the location of past eruptive vents. For all the above points, we pay a particular attention in keeping account of the uncertainty associated to our estimates, both of aleatory and epistemic types. Being a small island, a substantial source of epistemic uncertainty arises from the impossibility of constraining vent location and erupted volume from distal deposits (which are under the sea), while proximal ones are often buried by more recent lava flows, tephra layers or landslide deposits. In this respect, we take into account the different uncertainty on the inferred vent locations and erupted volumes of the different eruptions.

The resulting long–term eruption forecasting represents a quantitative probabilistic basis for a full Probabilistic Volcanic Hazard Assessment, that must necessarily account for the uncertainty in eruption occurrence, vent location and eruptive type and size.

Tephrostratigraphy Concerning Resedimentation of Tephras

Tomohiro Tsuji[1], Michiharu Ikeda[1], Akira Furusawa[2], Kiyoshi Ichikawa[3], Makoto Yanagida[3], Naoki Nishizaka[4], Yuki Ohno[4]

[1]Shikoku Research Institute Inc., Japan, [2]Furusawa Geological Survey Co. Ltd., Japan, [3]Hanshin Consultants Co. Ltd., Japan, [4]Shikoku Electric Power Co. Inc., Japan

E-mail: t-tsuji@ssken.co.jp

The identification and establishment of widespread tephra is very important not only in understanding volcanic processes but in its application to related fields of geology. Tephrostratigraphies are usually established based on focusing mainly on marine and/or lacustrine deposits which are good for preserving tephras, whereas resedimented tephras are also easily preserved. So the identification of the resedimentation of tephra has to be done carefully but has not been examined in detail. Then we described and analyzed tephras in a 120 m long core drilled at Uwa basin (UWA core) in western Shikoku Island to establish tephrostratigraphy taking in to the consideration of resedimentation of tephra.

Kyushu Island has six famous calderas which have produced many wide spread tephras and continue to be active now. Shikoku Island, being directly east of Kyushu, is a potentially favorable location for studying the volcanic history of Kyushu, because tephras are typically carried northeastward or eastward from Kyushu by the prevailing westerly winds. The Uwa basin, an inland basin formed in the upper region of the Hijikawa River in western Shikoku, provides an excellent research opportunity in that preserves continuous lacustrine deposits as well as many tephras.

We found some tephras that resembled the petrological characteristics in some horizons in the UWA core, so we tried to identify whether they are resedimented or not based on their sedimentary structure and contamination of exotic materials.

In each tephra sample, bulk grain composition, heavy mineral composition, morphology type of volcanic glass shards, refractive indices of volcanic glass shards and heavy mineral phenocrysts as well as chemical composition of volcanic glass shards were examined. Grain-size analyses in some tephras were also conducted to check the contamination of exotic material. Fission Track dating of zircon of three tephras were measured by Kyoto Fission-Track Co. Ltd.

Based on Fission Track dating, the sediments have been deposited successively since about 800 ka. We recognized 76 tephras including tephric sediments and identified 20 of them as original deposit layers. The thickest tephra is the Aira-Tn (AT) tephra which is 180 cm thick; however, most of it was resedimented. Thus, the thickness can be modified a few times thicker or thinner from the original. These results suggest that the estimation of accurate thickness and number of tephras must be considered to evaluate past volcanic activities.

We successfully correlated 14 tephras with previously identified widespread tephras mainly derived from Kyushu such as AT, Aso-4, K-tz, Ata, Aso-ABCD, Aso-3, Aso-2, Ata-Th, Aso-1, Ng-1, Kakuto (Kkt), Oda, Shimokado and Shoubu. In addition, some unknown local tephras which have never fallen in the Osaka and Boso region could be included in the UWA core. This high-resolution tephrostratigraphy is an essential key to clarify the eruptive history of the Kyushu volcanic region.

The development of structures and morphology in analog debris avalanches: Implications for natural examples

Engielle Mae R Paguican[1], Benjamin van Wyk de Vries[2], Pablo Grosse[3], Alfredo Mahar Francisco Lagmay[1]

[1]National Institute of Geological Sciences, University of the Philippines, PHILIPPINES, [2]Universite Blaise Pascal, Laboratoire Magmas et Volcans, FRANCE, [3]CONICET (Concejo Nacional de Investigaciones Cientificas y Tecnicas) and Fundacion Miguel Lillo, ARGENTINA

E-mail: engiellepaguican@gmail.com

Exposure of a volcanic flank to one or a combination of tectonic activity, magmatic intrusion, and weakening of the edifice by hydrothermal alteration and gravitational spreading can cause flank destabilisation. One or a combination of earthquake, magmatic intrusion or meteoric event can trigger the collapse of a destabilised flank generating a large landslide or a debris avalanche. The emplaced debris avalanche deposit (DAD) has internal structures also well observed on the surface as faults and folds. These structures can determine the kinematics and dynamics of avalanche emplacement. The identification and characterization of the surface features of DADs by remote sensing is an important component for studying possible scenarios for debris avalanche causes, and their triggering and emplacement mechanisms. We present sets of analog debris avalanche experiments on curved and straight inclined ramps to study the development and formation of the different surface structures and morphology from slide initiation to final stop. In curved ramp experiments, materials accelerate until reaching a gently sloped depositional surface where deposit thickens. The thickened mass then further remobilizes and advances by secondary collapse of the thickened mass. Such a stop-start process may be important in many mountainous avalanches where there are rapid changes in slope. We observed that frontal accumulation is produced during flow as materials at the front move slower relative to those in the medial and proximal zones and helps maintain a thicker mass that flows further. When the front destabilizes, secondary collapse happens. On a constantly inclined straight ramp, analog slides are longer than on curved ramp and show continued extension by horst and graben structures forming a rib-and-ridge morphology and transtensional grabens. Strike-slip shearing at the levees and sets of compression and extension structures in the middle are observed in both set-ups. Here we present mapping and identification of these features by visual interpretation of optical satellite imageries and aerial photographs, field observations, and using available geophysical data in natural DAD including the 2006 Guinsaugon rockslide-debris avalanche (Philippines), Mt Meager rockslide debris avalanches (Canada), and Storegga Slide (Norwegian margin) and previously unmapped DAD in Tacna (Peru).

Estimate of mass flow in gas plumes from the 2010-2012 eruptions of Gorely Volcano, Kamchatka

Evgeny I Gordeev, Valery V Droznin, Irina K Dubrovskaya

Institute of Volcanology and Seismology, Russia

E-mail: gordeev@kscnet.ru

Since early June 2010 to present days Gorely has been erupting gas emissions.

Previous eruptions of Gorely in 1961-1964, 1981-1982 and 1984-1986 were phreato-magmatic.

Thermal infrared studies were performed by AGA-Thermovision 680 in 1981, 1982 and 1986 and in 1993 by TIMS (NASA, USA) and since 2008 we have been used high-resolution thermovision ThermaCam P 640.

Thermal anomalies called "hot ground" and "steaming ground" are mainly located on inner slopes of the central crater. The hot-ground thermal anomalies are observed on the outer part of the edifice.

The 2010 eruption occurred from the vent with a diameter of 25 m located at the bottom of the crater. The eruption produced a jet of hot steam at more than 870 degree converting to a steam plume at the altitude.

The steam and gas plume is considered to be a mixture of produced water steam and air. We suggest that the plume contains saturated steam therefore one can analytically reveal physical properties in the plume through the temperature. The temperature was measured by the thermovision and the velocity in the plume was determined by the video record.

The paper presents examples of determination of mass flux at Gorely volcano using ThermaCam P640 data and meteorological observations.

Geochemical precursors for eruption repose length

Rebecca M Green[1], Mark S Bebbington[2], Shane J Cronin[2], Geoff Jones[1]

[1]Institute of Fundamental Sciences, Massey University, Palmerston North, New Zealand, [2]Volcanic Risk Solutions, Massey University, Palmerston North, New Zealand

E-mail: r.green@massey.ac.nz

Volcanic eruptions are inevitable but the ability to accurately forecast their occurrence can lead to considerable reductions in risk through incorporation in land-use planning and emergency management scenarios. Volcanic hazard forecasting is based around the idea that a volcano's future activity is best predicted by its prior history. Thus, models are usually assembled using point processes techniques and renewal theory. A point process assumes that events occur in a period of time $(t+\Delta)$ with probability $\lambda(t)\Delta t$. One special case is the Poisson point process which assumes that events occur at a constant average rate $\lambda(t)=\lambda$, exhibiting no trend over time. This is extended to form a renewal process by allowing the elapsed time since the previous eruption to solely control the timing of the next eruption. Most of these models are purely temporal in the sense that they only consider the distribution of onset times as predictors of future volcanic activity. It has been hypothesized, however, that there are underlying cycles in geochemistry data that could be linked to the eruption rate.

We illustrate through the use of a high-resolution Holocene eruption record from Mt Taranaki (New Zealand) that by incorporating geochemical data using a proportional hazards type approach the current renewal-type models can be improved on. The use of a proportional hazards model incorporates geochemical influences into the eruption process by attaching a vector of covariates to the inter-onset hazard. These covariates act multiplicatively on the hazard and as a result the timing of the next eruption becomes dependent on both the magnetite geochemistry of the previous eruption and the time since the last event.

Mt Taranaki is an andesitic stratovolcano that has an activity record that includes long periods of quiescence and subsequent re-awakening. Thus the distribution of inter-onset times is bimodal, with the possibility of anomalously long reposes. Using magnetite major-element chemistry as a proxy for the state of the magmatic system, the concentrations of TiO_2 and Al_2O_3 (or MgO) are useful predictors of repose length. In particular, they provide a better explanation than a bimodal renewal distribution, with the important feature that this predictive information is available at the beginning of the repose to be forecast.

Eruption history, conduit migration, and steady discharge of magma for the past 50,000 yr at Esan Volcanic Complex, northern Japan

Daisuke MIURA[1], Ken-ichi ARAI[2], Kiyoshi TOSHIDA[1], Tatsuya OCHIAI[2], Michi-hisa TANAKA[2], Takahiro IIDA[3]

[1]Central Research Institute of Electric Power Industry (CRIEPI), JAPAN, [2]Asia Air Survey, Co. Ltd., JAPAN, [3]CERES, Inc., JAPAN

E-mail: dmiura@criepi.denken.or.jp

We have undertaken a detailed field, petrological, geochronological, and modeling study of Esan Volcanic Complex (EVC), northern Japan, in order to establish its eruptive history over the past 50,000 yr. The EVC includes seven lava domes, which are endogenous domes developed without basal edifices. Each dome was produced by intermediate to silicic magmas with 57-67 wt% SiO_2 that were erupted in magnitude 4-5 eruptions. Five explosively erupted pyroclastic units cover the aprons of these lava domes. The spatial and temporal relationships of the domes and the pyroclastic units have been determined in order to constrain the eruptive sequence of the EVC.

A simple elastic model, assuming a hydraulic connection state, was utilized to study variations in long-term magma discharge at the EVC, which have been attributed to changes in magma storage conditions. The stepwise change in magma discharge with time, which is 4.2 to 5.3 x 10^4 m^3/yr, is interpreted to reflect a change between magma chamber radius (R_c) and magma depth (H_c) caused by an upward migration of magma. Assuming a continuous input of magma from a deep source at a constant supply rate, the magma storage system that existed during the early stage of the EVC has been renewed, which will result in a shorter recurrence interval between eruptions rather than a long period of dormancy (22,400 yr). Given this finding, and the fact that the most recent eruption occurred at 9,000 yr ago, there is currently a risk of a large eruption at the EVC.

Modeling of a non-eruptive volcanic deflation with strong earthquake swarm by integrated observation data in Meakan-dake, Hokkaido, Japan

Hiroaki Takahashi[1], Tomo Shibara[2], Hiroshi Aoyama[1], Teruhiro Yamaguchi[1], Masayoshi Ichiyanagi[1], Noritoshi Okazaki[2], Jun'ichi Miyamura[3]

[1]Hokkaido University, Japan, [2]Geological Survey of Hokkaido, Japan, [3]Japan Meteorological Agency, Japan

E-mail: hiroaki@mail.sci.hokudai.ac.jp

Strong volcanic earthquake swarms were frequent observed in not only eruptive stage but also non-eruptive era. Increasing of seismic activity might be precursor of eruption but not all time. Total understanding of origin source of swarm triggering and individual earthquake/tremor will give clues for activity forecasting.

We have installed integrated volcano monitoring system on active Meakan-dake volcano in Hokkaido of southwestern Kuril subduction zone. This volcano is characterized as one of high seismicity volcano in Japan. No magmatic eruptions were recorded at least in recent two centuries but several phreatic eruptions were observed. Alert to public associated with frequent earthquake swarm based on quantitative understanding is requested from resident.

Broad time constants of volcanic phenomena require proper observation equipments which can capture full range of signals. Short-period and broadband seismographs, bubble-type tiltmeter, GPS, and volumetric strain meter by water level sensor, and ground temperature sensor on active crater have been in operation. This network successfully recorded a successive earthquake swarm event on end of September 2008. Firstly, regional volcano deflation was detected by strain sensors and it had been continued during two days. Earthquake swarm also started almost same moment of strain signal. No GPS signal was recorded. Two days after, a shallowest volcanic tremor with 1-min ramp-function signals in strain, tilt and broadband seismograph were observed. This rapid inflation signal might indicate phase change from liquid to gas beneath active crater. Increased ground temperature on active vent was recorded after a few hours of tremor but no explosive events were recognized by visual observation. Swarm activity was rapidly calmed down after the tremor.

These multidisciplinary signals suggested successive activity was triggered by volatile migration from deeper to shallower. Instability of system due to volatile injection might induce seismicity and drive migration of liquid packet to surface. Deflation volume of deeper source, which is countable from regional strain changes, might indicate heat flux to shallower, and be quantitative indicator of forecasting phreatic eruption.

Seismic anomaly as a medium-term precursor of new (2012-2013) fissure eruption of Plosky Tolbachik volcano, Kamchatka

Yulia Kugaenko, Vadim Saltykov, Petr Voropaev

Geophysical Survey of Russian Academy of Sciences, Kamchatkan Branch, Russia

E-mail: ku@emsd.ru

New fissure eruption of Tolbachik volcano has begun on November 27, 2012. The radial fissure with length near 5 km directed to SSW has appeared on the south slope of the Plosky Tolbachik Volcano (PTV). Power lava fountain, intensive lava flow and moderate ash ejection were observed from several eruptive centers along fissure. The PTV and area of scoria cones were in the stage of rest from 1976 after completion of the Large Tolbachik Fissure Eruption (LTFE) 1975-1976. In contrast of the LTFE the eruption 2012-2013 was not forestalled by intensive seismic preparation. We analyzed seismicity of PTV retrospectively using regional catalogue 1999-2012. Anomalies of low-energy (M>1.5) seismicity parameters (increase of sesmicity rate and seismic energy) were discovered. The duration of these anomalies is 3-4 months. This is evidence of seismic activation. The whole PTV including area of new fissure break was covered by this activation. The significance of this anomaly was estimated by distribution function of emitted seismic energy in 1999-2012. Statistically significant transfer of seimicity from background level to high level and extremely high level was revealed. It corresponds to multiple increase of earthquake number and seismic energy in 2012, July-November. The transition from background level to high level was happen in August 2012. During last three weeks before fissure eruption seismicity of analyzed seismoactive volume was on extremely high level. There is no similar anomaly during 1999-2012 in the area of Plosky Tolbachik Volcano.

Assessing volcano state from multi-parameter monitoring data streams and other evidence using Bayesian belief networks

Henry Odbert, Willy Aspinall, Steve Sparks, Tom Sheldrake

University of Bristol, UK

E-mail: h.odbert@bristol.ac.uk

Changes in the eruptive state of a volcano affect the potential for hazardous activity. When volcanoes exhibit unrest, risk-managing authorities often seek science-based decision support. Evidence available to scientists about a volcano's internal state is typically indirect, secondary or very nebulous. Approaches to volcano monitoring have advanced substantially in recent decades, increasing the variety and resolution of multi-parameter timeseries data recorded at volcanoes. Interpreting these multiple strands of parallel, partial evidence has thus become increasingly complex. In practice, interpreting timeseries typically requires familiarity with idiosyncrasies of the volcano, monitoring techniques, configuration of recording instruments, observations from other datasets, and so on. Assimilation of this knowledge is necessary in order to select and apply the appropriate statistical techniques needed to extract the required information.

Bayesian Belief Networks (BBNs) use probability theory to treat and evaluate uncertainties in a rational and auditable scientific manner, but only to the extent warranted by the strength of the available evidence. The concept is a suitable framework for marshalling multiple observations, model results and interpretations - and associated uncertainties - in a methodical manner. The formulation is usually implemented in graphical form and could be developed as a tool for near real-time, ongoing use in a volcano observatory, for example. We explore the application of BBNs in analysing volcanic data, the uncertainties of inferences, and how they can be updated dynamically. Such approaches provide an attractive route to developing an analytical interface between volcano monitoring analyses and probabilistic hazard analysis. We discuss the use of BBNs in hazard analysis as a tractable and traceable tool for fast, rational assimilation of complex, multi-parameter data sets in the context of volcanic crisis decision support.

Quick analysis method for estimating debris flow prone area causedby rainfall in the volcanically disturbed watersheds

Takao Yamakoshi[1], Hiroshi Kisa[1], Takeshi Shimizu[1], Tadanori Ishizuka[1], Akihiro Maeda[2], Shigetaka Takiguchi[3]

[1]Public Works Research Institute, Japan, [2]Kyushu Regional Bureau, Ministry of Land, Infrastructure, Transport and Tourism, Japan, [3]Fujitsu, Co. Ltd., Japan

E-mail: yamak226@pwri.go.jp

A volcanic eruption disturbs watersheds and, if it is large enough, results in a drastic increase in the number of lahars, such as cases observed in the rivers around Sakurajima Volcano which continuously erupts and provides tephra deposit around the mountain edifice. It is known that tephra thickness is positively correlated to the risk of lahar occurrence. Therefore, it is necessary to know the distribution of tephra thickness to evaluate level of lahar risk and to show debris flow prone area at the time of rainfall.

The authors recently developed the quick analysis method to estimate debris flow disaster prone area caused by rainfall in the volcanically disturbed watersheds. This method is designed with a concept of " Most quickly as far as certain level of accuracy is ensured". In general, the 2D numerical simulation of debris flow requires a lot of parameters, so that the authors reduced the number of indispensable parameters from the point of view of sensitivity to the simulation result and the feasibility of information acquisition. Furthermore, the authors composed a simplified numerical simulation system called QUAD-V (QUick Analysis system for Debris flow caused by Volcanic eruption). Our quick analysis system was actually applied to show the area for evacuation against debris flow caused by volcanic eruption at the time of the 2011 Eruption of Kirishima Volcano. It succeeded in providing 35 hazard maps for debris flow within one week.

Ellipse-approximated isopach maps for estimating ashfall volume at Sakurajima volcano

Yasuhisa Tajima[1], Takao Yamakoshi[2], Akira Tsune[3], Keiji Tamura[4], Shinjiro Tsurumoto[5], Eiichi Takahashi[6]

[1]Nippon Koei Co., Ltd., Japan, [2]Public Works Research Institute, Japan, [3]Deep Ocean Resources Development Company, Ltd., Japan, [4]Sabo and Landslide Technical Center, Japan, [5]Miyazaki Office of River and National Highway (MLIT), Japan, [6]Osumi Office of River and National Highway (MLIT), Japan

E-mail: tajima-ys@n-koei.jp

In studies of volcanic tephra, it is usual that the overall volume of tephra is estimated ashfall volumes based on representative locations within the ashfall area. The precision of the volume estimation largely depends on the number of the locations. However, in the case of ongoing eruptions in island volcanoes, such as Sakurajima volcano, the observation locations are usually limited. We therefore have developed a practical method for estimating ashfall volume and distribution in such case. The method approximates the distribution of ashfall as ellipses, with the distribution area (A) and thickness or weight of deposit (T) determined by $A=\alpha T^{-1}$. The ellipse-approximated isopachs (EAI) can be determined by using the direction of the ellipse axis and ashfall data at two points. In determing the ellipse axis exactly, we usually need additional ashfall amounts from the other locations. We set 37 samplers around Sakurajima volcano, and retrieved the samplers 15 times, from April to December, 2008.

The EAI provided a swift geometric method for assessing ashfall eruptions. In many cases, the distributions calculated using the EAI method correlated well with the observed data for the Usu and Asama volcanoes, in which small eruptions recently produced low columns. Under these conditions, we could approximate the ashfall distribution as a single exponential function. The EAI method is useful for small, continuous eruptions and for small island volcanoes where terrestrial ashfall is naturally limited to the area of the island. When using the EAI method, it is important to determine the correct EAI calculation axis and to confirm the fit between several observation points and the calculated distribution. This method will be useful for spatial ashfall monitoring for lahar risk assessment, analysis of rate of current eruptions and volume estimation of historical ashfall records.

The next-generation real-time volcanic hazard assessment system in G-EVER

Shinji Takarada

G-EVER Promotion Team, Geological Survey of Japan, AIST, Japan

E-mail: s-takarada@aist.go.jp

The Asia-Pacific Region Global Earthquake and Volcanic Eruption Risk Management (G-EVER) Consortium among the Asia-Pacific geohazard research institutes was established in 2012. There are currently 4 working groups that were proposed in the G-EVER Consortium. The next-generation volcano hazard assessment WG is planning to provide a useful system for volcanic eruption prediction, risk assessment, and evacuation schemes at various eruption stages. The assessment system is planned to be developed based on volcanic eruption scenario datasets, volcanic eruption database and numerical simulations. Defining volcanic eruption scenarios based on precursor phenomena leading up to major eruptions of active volcanoes is quite important for the prediction of future eruptions. A high quality volcanic eruption database, which contains compilations of eruption dates, volumes and styles is important for the next-generation volcano hazard assessment system. Formulating international standards on how to estimate the volume of volcanic products (eg. tephra and pyroclastic flow deposits) is needed in making high quality volcanic eruption database. Spatial distribution database of volcanic products (eg. tephra and debris avalanche distributions) that are encoded on Geographic Information System (GIS) is necessarily for more precise area and volume estimation and risk assessments. For example, tephra fall distribution database of major eruptions in the world with estimated total volume, column height and flux are important for the future tephra fall risk assessment during volcanic eruptions. The volcanic eruption database is developed based on past eruption results, which only represent a subset of future scenarios. Therefore, numerical simulations with controlled parameters are needed for more precise volcanic eruption predictions. The "best-fit" parameters of the past major large-scale eruptions in the world have to be estimated and the simulation results database should be made. Using these best-fit parameters is quite useful for emergency situation especially when similar-style eruptions happened before. The use of the next-generation system should enable the visualization of past volcanic eruptions datasets such as distributions, eruption volumes and eruption rates, on maps and diagrams using timeline and GIS technology. Similar volcanic eruptions scenarios should be easily searchable from the eruption database. Using the volcano hazard assessment system, prediction of the time and area that would be affected by volcanic eruptions at any locations near the volcano would be possible, using numerical simulations. The system should estimate volcanic hazard risks by overlaying the distributions of volcanic deposits on major roads, houses and evacuation areas using a GIS enabled system. The next-generation real-time hazard assessment system would be implemented with user-friendly interface, making the risk assessment system easily usable and accessible online.

Assessing long term hazards for la Soufriere of Guadeloupe volcano: insights from a new eruptive chronology, credible scenario definition, and integrated impact modelling

Jean-Christophe Komorowski[1], Yoann Legendre[2], Sara Barsotti[3], Tomaso Esposti-Ongaro[3], Susanna Jenkins[4], Peter Baxter[5], Georges Boudon[1], Frederic Leone[6], Augusto Neri[3], Robin Spence[7], William Aspinall[4], Delphine Grancher[8], Marie Redon[9], Caroline Chopineau[10], Jean-Bernard de Chabalier[11]

[1]Institut de Physique du Globe de Paris, UMR CNRS 7154, 1, rue Jussieu, Paris 75238, France, [2]Bureau de Recherches Geologiques et Minieres, Le Houelmont, Gourbeyre, Guadeloupe, France, [3]Instituto Nazionale di Geofisica e Vulcanologia (INGV), sezione di Pisa, Italy, Italy, [4]University of Bristol, Wills Memorial Building, Queen's Road, Bristol, BS8 1RJ, UK, [5]Institute of Public Health, University of Cambridge, Cambridge, CB2 2SR, UK, [6]GRED, Univ Paul Valery Montpellier 3 & IRD, UK, [7]Cambridge Architectural Research Ltd, 25 Gwydir Street 6, Cambridge, CB1 2LG, UK, [8]Univ Paris 1 Pantheon Sorbonne, CNRS UMR 8591, France, [9]PRODIG, Paris, et Univ Paris 13-Nord, Paris, France, [10]MASA Group, Paris, France, [11]OVSG, IPGP, Le Houelmont, Gourbeyre, Guadeloupe, France

E-mail: komorow@ipgp.fr

Mild but persistant seismic and fumarolic unrest since 1992 at La Soufriere volcano prompted renewed interest in geologic studies, monitoring, hazard, risk modeling, and crisis response planning. We present results of our new detailed chronology for the last 12000 years of La Soufriere eruptive activity based on the stratigraphy of more than 250 outcrops and 181 new radiocarbon age dates. The magmatic activity of La Soufriere (frequency and magnitude) is significantly higher than previously interpreted with 16 eruptions in the last 9150 years. Activity over the last 12000 years consists of at least 10 major explosive eruptive phases with a large range in magnitude (erupted volume: 0.01 to 1 km3), and at least 9 dome forming eruptive phases of large magnitude (0.1 km3) characterized by an important explosivity including vulcanian pumice producing phases and the generation of at least 6 to 7 high energy pyroclastic density currents. At least 8 flank collapse events are associated with these eruptive events. La Soufriere activity is dominated by multistage eruptive events (flank collapse, dome growth, explosive open conduit activity) that occur over a short yet unknown span of time. Hence, base rate eruption probabilities for Soufriere of Guadeloupe can be updated now with this new chronology of activity. Moreover, eruptive recurrence, magnitude and intensity place quantitative constraints on the event tree of La Soufriere to elaborate credible scenarios in case the current unrest, with evidence of the involvement of magmatic fluids, leads to a renewal of activity at La Soufriere. Thus, the most probable scenario would involve a major dome forming phase that is likely to be associated with partial flank instability of the dome and a major explosive subplinian phase that could share some analogy to the 1530 AD event. However, the detailed reconstruction of the eruptive past also highlights the occurrence of smaller vulcanian explosive eruptions as well as less frequent Plinian eruptions of higher magnitude that could have much more widespread impact. As an example of what is being considered for each major eruptive scenario, we present preliminary results of computational deterministic as well as probabilistic simulations of subplinian tephra dispersal and fountain collapse PDCs. This serves as a basis for elaborating a quantitative framework for the assessment of their impact on vulnerable infrastructures, networks, and population including preliminary results on the influence of sociocultural risk perception and governance issues on disaster preparedness. This work has implications for volcano monitoring, risk informed decision making for crisis response and long term strategies of volcanic risk mitigation for Lesser Antilles volcanoes. Other authors: Denain, JC, Gherardi, M, Lesales, T, Bonnel, C, Heymann, A, Mas, M, Chenet, M, Magnier, A, Lemaitre, E, Baillard, M.D, Villemant, B and the CASAVA Consortium

Multi source- ash fallout hazard map in western Caldas department (Colombia)

Carlos Borrero[1], Ana M. Garcia[2], Hugo F. Murcia[3], Carlos M. Jaramillo[4]

[1]Dept. of Geological Sciences, Caldas University, Manizales, Colombia, [2]Consultant Geologist, Manizales, Colombia, [3]The University of Auckland, School of Environment, Auckland, New Zealand, [4]Consultant Geologist, Manizales, Colombia

E-mail: borrero_c@yahoo.com

In order to prepare the emergency plans for management of volcanic risks for the western sector of Caldas department (Colombia), a regional scale evaluation of the ash fallout hazard was intended for Corpocaldas (department environmental agency). The regional and local stakeholders were interested in a unique scenario related to the co-existence of three different sources of ash, from north to south: Cerro Bravo, Nevado del Ruiz and Santa Isabel volcanoes, which are located at the Central Cordillera in middle Colombia, and they are part of the most northern volcanic complex of the Northern Volcanic Zone in South America.

The background definition of the ash fallout hazard is quite variable for the different sources, the Cerro Bravo and Nevado del Ruiz volcanoes have geology-based hazard maps with variable age constraining of their events; and Santa Isabel volcano has only an UNDRO indicative hazard map without any age data. Actually, the Nevado del Ruiz Volcano is the only active of these three volcanoes since 1984.

The recent 2012 activity of Nevado del Ruiz volcano showed a different dispersion of the ash fall from its former hazard map, due to the changes of wind direction by the restricted plume heights during the VEI 1 to 2 activities in 2012 the dispersion changed dramatically to N-NW and W directions affecting mainly the western zone of the Caldas department.

The methodology employed to evaluate the ash fall hazard was based on Bonasia et al., 2011 at the Colima volcano, where they run Hazmap creating a statistical analysis with different wind profiles obtaining as a result ash concentration maps for each month during a year.

Hazmap simulations were run for the Cerro Bravo volcano, we used the averaged mass reported from the main eruptions: 2.8 * 1011 kg and a average column height of 25 km that represent a VEI 4 eruption, with particles density of 900 kg/m3 (pumice) and 1000 kg/m3 (lithics). For the Nevado del Ruiz and Santa Isabel volcanoes we use a mass of 2*109kg and a column height of 6,300 m.a.s.l. for VEI 1 eruptions and 2*1011kg and 13,300 m.a.s.l. for VEI 2 eruptions, with particles density of 2750 kg/m3 (lithic) and 900 - 1726 kg/m3 (pumice) in both cases. The wind profiles necessary to set the speed and direction of wind dispersal, were extracted from the NOAA home page, taking a wind profile per month for a year.

We obtained for Cerro Bravo volcano a SW trend for most of the months, NW in February, SE in June, July and August and NE in November. In comparison, the isopach lines obtained by Lescinsky, 1990 show over-estimated thicknesses, and only W-SW trend dispersion axes.

In a similar way, Hazmap was run for the Nevado del Ruiz and Santa Isabel volcanoes related to VEI 1 to 2 eruptions, with E-W and NW-SE trends in the dispersion of ash respectively. Finally, a Multi-Ash Fallout Hazard map for the surveyed area was built using ArcGIS, combining the dispersion axes from each one of the volcanoes.

Exploring the interface of probabilistic hazard analysis and risk assessment using BET_VH, Okataina Volcanic Centre, New Zealand

Mary Anne Thompson[1], Jan Lindsay[1], Laura Sandri[2], Gill Jolly[3]

[1]School of Environment, The University of Auckland, Auckland, New Zealand, [2]Istituto Nazionale di Geofisica e Vulcanologia (INGV), Sezione di Bologna, Italy, [3]GNS Science, Wairakei Research Centre, Taupo, New Zealand

E-mail: m.thompson@auckland.ac.nz

Volcanoes are characterized by complex long-term hazardscapes. Uncertainties in future eruption style and sequence make it difficult to define the magnitude, time scale and intensity at which different dangerous phenomena will manifest. Long-term hazard analysis tool BET_VH (*Bayesian Event Tree for Volcanic Hazards*) introduces a way to account for this inherent uncertainty in hazard modeling by integrating such variables together into one inclusive event-tree framework, allowing for a probabilistic evaluation of many different eruption types, vent locations, and hazard outcome scenarios and their associated uncertainties.

BET_VH's capacity to integrate multiple sources of information, expand upon existing hazard data, and generate detailed spatial information about the likelihood of a wide spectrum of hazard scenarios could play an important role in constructing effective and relevant long-term evaluations of risk. The custom and versatile nature of the BET_VH analyses supports hazard mapping tailored to both large- and small-scale long-term risk assessment interests. This study uses BET_VH to analyze Okataina Volcanic Centre tephra fall hazard at accumulation thresholds considered damaging to agriculture, a primary and sustaining industry of New Zealand. We investigate how the robust probabilistic hazard data generated can contribute to and enhance existing risk assessments by providing quantitative values for use in land-use planning, agricultural management practices and other risk reduction strategies in the region.

The study provides insight into the advantages of using a streamlined probabilistic framework for long-term hazards analysis in complex volcanic environments, and discusses the strengths and limitations of integrating quantitative hazard data into risk assessment and management.

Modeling volcanic hazards of Jan Mayen

Eirik Gjerlow[1], Armann Hoskuldsson[1], Costanza Bonadonna[3], Pedersen Birger Rolf[2]

[1]Nordic Volcanological Centre, Institute of Earth Sciences, University of Iceland, Iceland, [2]Centre of Geobiology, Department of Earth Sciences, University of Bergen, Norway, [3]Earth and Environmental Sciences Section, University of Geneva, Switzerland

E-mail: eirik@hi.is

The Island of Jan Mayen is situated at 71 degrees N and 8.3 degrees W in the north Atlantic. It is a volcanic island extending for about 53 km from SW towards NE. The island can be divided into two major volcanic centers, South Jan and North Jan. Known eruptions on the island have occurred in 1732, 1818, 1851, 1970 and 1985. The four last eruptions were mainly effusive and bound to the northern most part of the island. However the 1732 was a phreatomagmatic explosive eruption that covered most of the island. The eruption in 1970 started with an explosive phase producing a steam and ash cloud 10 km high. The plume was observed to extend towards east then fanning out ESE from the island. Latter the eruption became effusive and confined to the northern foothills of Beerenberg. Reports from UK mentioned prolonged twilights and red sunset during the eruption indicating sulfuric contamination in the atmosphere due to the eruption. North Jan is characterized by Beerenberg, a major volcano reaching an altitude of some 2277 m. It has a breached summit crater, about 1,5 km in diameter. The edifice shows a petrological evolution from porphyritic ankaramites in the distal peripheral craters to more plg porphyritic trachybasaltic composition higher up and a summit region composed mainly of tristanite. No major explosive eruption has yet been tied to the volcano. South Jan on the other hand is characterized by small fissures, lava flows and domes. Its petrology indicates evolved trachybasalts to trachytes. One major explosive tephra sequence is identified within the South Jan complex, the Borga formation, its age is unknown but the volume of deposits indicate that it could be related to a caldera formation.

Volcanic hazard on Jan Mayen has only been briefly been analyzed by Sylvester(1976), in light of increasing Norwegian and Icelandic activity on the Jan Mayen ridge and in light of recent events in Iceland a new and more comprehensive analysis needs to be carried out. In this presentation we will present data from modeling of the 1732 phreatomagmatic eruption and potential effusive eruptive scenarios in order to estimate near and far field hazard for the island of Jan Mayen.

Risk analysis of Colima volcano, Mexico

Carlos Suarez-Plascencia[1], Miguel A Camarena-Garcia[1], Francisco J Nunez-Cornu[2]

[1]CUCSH/Univ. of Guadalajara, Department of Geography, Guadalajara, Jalisco, Mexico, [2]CUC/Univ. of Guadalajara, SisVOc, Puerto Vallarta, Jalisco, Mexico

E-mail: csuarez@cencar.udg.mx

Colima volcano, also known as Volcan de Fuego (19 30.696 N, 103 37.026 W), is located on the border between the states of Jalisco and Colima and is the most active volcano in Mexico. Began its current eruptive process in February 1991, in February 10, 1999 the biggest explosion since 1913 occurred at the summit dome. The activity during the 2001-2005 period was the most intense, but did not exceed VEI 3. The activity resulted in the formation of domes and their destruction after explosive events. The explosions originated eruptive columns, reaching attitudes between 4,500 and 9,000 masl, further pyroclastic flows reaching distances up to 3.5 km from the crater. During the explosive events ash emissions were generated in all directions reaching distances up to 100 km, slightly affected nearby villages as Tuxpan, Tonila, Zapotlan, Cuauhtemoc, Comala, Zapotitlan de Vadillo and Toliman.

During the 2005 and January 2013 this volcano has had an intense effusive-explosive activity, similar to the one that took place during the period of 1890 through 1900. Intense pre-plinian eruption in January 20, 1913, generated little economic losses in the lower parts of the volcano due to low population density and low socio-economic activities at the time.

Shows the updating of the volcanic hazard maps published in 2001, where we identify whit SPOT satellite imagery, helicopter flights and Google Earth, change in the land use on the slope of volcano, the expansion of the agricultural frontier on the east and southeast sides of the Colima volcano, the population inhabiting the area is approximately 533,000 people, and growing at an annual rate of 1.6 percent, of the total population, 60 percent live in towns with less than 250 inhabitants, also the region that has shown an increased in the vulnerability for the development of economic activities, supported by the construction of highways, natural gas pipelines and electrical infrastructure that connect to the Port of Manzanillo to Guadalajara city.

The update the hazard maps are: a) Exclusion areas and moderate hazard for explosive events (rockfall) and pyroclastic flows, b) Hazard map of lahars and debris flow, and c) Hazard map of ash-fall.

The cartographic and database information obtained will be the basis for updating the Operational Plan of the Colima Volcano by the State Civil and Fire Protection Unit of Jalisco, Mexico, and the urban development plans of surrounding municipalities, in order to reduce their vulnerability to the hazards of the volcanic activity.

Re-interpretation of the Mugogo 1957 eruption in the framework of the volcano-tectonic structure of the Virunga Volcanic Province, D.R.Congo and Rwanda

Sam Poppe[1], Benoit Smets[2], Fabien Albino[3], François Kervyn[3], Matthieu Kervyn[1]

[1]Department of Geography, Earth System Sciences, Vrije Universiteit Brussel (VUB), Belgium, [2]European Center for Geodynamics and Seismology (ECGS), Grand-Duchy of Luxembourg, [3]Geology Department, Royal Museum for Central Africa, Tervuren, Belgium

E-mail: sam.poppe@vub.ac.be

The Virunga Volcanic Province (VVP) is situated within the Western branch of the East African Rift system at the boundary of D.R.Congo, Rwanda and Uganda. The Western VVP comprises two active volcanoes. Nyamulagira is recently the most active volcano on the African continent, with 30 eruptions since 1900, while Nyiragongo hosts a semi-permanent lava lake in its crater and fed a catastrophic lava flow in 2002. The six volcanoes in the Central and Eastern VVP are supposedly historically inactive to the exception of an eruption that occurred in 1957, 11 km North of Visoke volcano. This so-called 'Mugogo' eruption constructed a scoria cone and a ∼1.5 km long lava flow issued from an East-West oriented fissure. While the eruption was automatically attributed to Visoke Volcano due to its relative proximity, the magmatic source and the implications for the volcanic hazard in the area are poorly constrained. We re–assess the Mugogo 1957 eruption characteristics using the colonial time eruption report, the geochemistry of eruptions samples and a new volcano–tectonic map of the VVP. Geochemical sample analyses are compared to a new geochemistry database for the VVP volcanic products, compiled from the literature and colonial time reports, to constrain the magmatic source of the eruption. The boundaries of the lava flow and pyroclastic cone were traced from the interpretation of topographic and multispectral remote sensing data, as part of a new volcano–tectonic mapping effort for the whole VVP. The location and fissure orientation of the Mugogo cone relative to the surrounding volcanoes and scattered volcanic vents in the VVP is analysed. The Mugogo 1957 eruption illustrates the importance of the analysis of historic volcanic activity in the Central and Eastern region of the VVP for an assessment of potential Holocene activity in the Central and Eastern VVP. The event represents the first case study for the assessment of the potential volcanic risk in that region. The volcano–structural map and the geochemistry database assist the evaluation of the potential future eruption scenarios and the derivation of the spatial distribution of eruption probability for the entire VVP.

Potentially hazardous volcanic systems in southern Ethiopia

Vladislav Rapprich[1], Yewubinesh Bekele[2], Daniel Kassaye[2], Jiri Sebesta[1], Leta Alemayehu[2]

[1]Czech Geological Survey, KlÃąrov 3, 118 21 Praha, Czech Republic, [2]Geological Survey of Ethiopia, P.O.Box 2302, Addis Ababa, Ethiopia

E-mail: vladislav.rapprich@geology.cz

Quaternary volcanoes of the Ethiopian Rift in southern Ethiopia are studied much less intensively compared to the Central Ethiopia and Afar Region. Our research covers the area of about 35000 km² extending between towns of Ziway N08° and Arba Minch N06° comprising several active and dormant volcanic systems. Historical and geochronological data are scarce or absent in this area. Alutu Volcano represents one of the large volcanic complexes with numerous vents. Voluminous obsidian lavas and pumice layers were produced during numerous eruptions. Hydrothermal activity is prominent till nowadays. O´a Caldera was formed in Pleistocene. After caldera formation, several monogenetic cones, tuff rings and lava domes were formed inside the caldera. Fumarolic and hot spring activity is described from all around. The southernmost Corbetti Caldera seems to be the most hazardous volcano in Southern Ethiopia. Inside the caldera, two new volcanoes emerged. Chabbi Volcano to the east is a shield volcano consisting of widely spread obsidian lavas. The Urji Volcano to the west is dominantly explosive with observed fumarolic activity in its crater. This volcano produced widespread young pumice fall deposit covering the area between Shashemane and Aje. This pumice layer covers also scoria cones south of Lake Shalla. East Ziway Volcanic Field consists of approximately 55 scoria cones aligned in N-S direction. Prominent soil layer has evolved on all of these cones and even the best preserved cones are overlain by the pumice from Alutu Volcano. Awassa Volcanic Field is a group of 7 basaltic scoria cones, tuff cones and tuff rings inside the extinct Awassa Caldera. All these small monogenetic volcanoes are significantly weathered. South Shalla Volcanic Field is group of about 10 basaltic scoria and spatter cones and 2 maars. The scoria cones have basaltic composition and some of them display fumarolic activity. Bilate River Volcanic Field comprises three maars arranged N-S on the eastern bank of the Bilate River. These three maars are associated with 11 scoria, spatter and tuff cones, some of them with small lava flows. North Chamo Volcanic Field comprises 7 scoria cones with intermediate composition. Deposits of initial phreatomagmatic phase can be seen at the base of most of these cones. Humbo Volcanic Field with about 50 scoria cones has not been reported before. Among many scoria cones, a Korke Seluwa obsidian dome-complex rises. More than 80 scoria cones are arranged NNE-SSW in the 70 km long row of the Butajira-Silti Volcanic Field. According to the satellite data, Debes Qoto scoria cone is the youngest cone of this volcanic field. The Debes Qoto Volcano emitted a 6 km long lava flow, filling up the canyon. The research is supported by the Czech Development Agency and the Ethiopian Ministry of Finances and Economic Development.

The Tolbachik Fissure Basalt Eruption, Kamchatka (2012-2013)

Evegeny I Gordeev, Valery A Droznin, Anna O Volynets, Yaroslav D Muravyev

Institute of Volcanology and Seismology, Russia

E-mail: gordeev@kscnet.ru

There is a large volcanic center in the south part of the Klyuchevskaya group of volcanoes, for which fissure eruptions of mafic lavas are typical in historic times. The latest large effusion of lavas in this zone occurred over the period 1975-1976 and was called the Great Tolbachik fissure eruption (GTFE).

After 37 years of rest, in the evening of November 27, 2012 liquid basalts started to effuse extensively to the south of Plosky Tolbachik Volcano. One day prior to the eruption, a swarm of earthquakes was recorded beneath the volcano. Seismic data showed that the fissure opened at 17h45m local time at an altitude of about 2.5 km on the southern flank of Plosky Tolbachik. The fissure stretched 6 km from north to south. Local residents reported three areas of eruptions late at night. The eruption was obviously explosive in the upper part of the fissure. At this stage the fissure produced the most powerful ash emissions resulting in ash deposits as far as several tens of kilometers from the volcano. In its lower part the fissure started to produce extremely fluid basaltic lava. A small lava flow from the central area of eruption traveled to the west and descended 9 km along the valley of Vodopadny creek to a height of 650 m a.s.l. and destroyed Vodopadnaya base camp, which had been built during the 1975-1976 Great Tolbachik fissure eruption. By November 30, the movement of Vodopadny lava flow had ceased.

The main lava flow resulted from the central part of the fissure. Gradually, the main eruptive center with up to three vents was formed above the upper fissure. The vents activity varies in time. By mid January 2013 a crater with a lava lake had been formed above the upper fissure. The crater is continuously fountaining hot material. Over the period of two months the erupted lava had covered an area of 30 km2. New portions of lava are coming to the surface along the lava channels increasing the thickness of the lava field. Sometimes lava bursts out of the field in forms of sporadic narrow 2-3 km long flows. The total volume of the eruptive material is estimated to be 0.3-0.4 km3.

Short seismic swarm and high-aluminous composition of effusing basalts provides evidence that magma comes to the surface from an intermediate chamber, the roof of which is located beneath the caldera of Plosky Tolbachik at a depth of about 4 km.

Geology and eruptive history of the Asama-Maekake volcano, central Japan, as a clue to the long-term prediction of volcanic hazards.

Masaki TAKAHASHI, Maya YASUI, Hiroyuki TAKEMOTO, Tatsuo KANAMARU

College of Humanities and Sciences, Nihon University, Japan

E-mail: takama@chs.nihon-u.ac.jp

The Asama-Maekake volcano is the youngest active volcano in the Eboshi-Asama volcano group, aligning in EW direction for a distance of about 23km. The construction of the Maekake volcano began in 13cal.ka (11ka) just after cessation of the activity of the Hotokeiwa volcano. The eruptive history of the Maekake volcano consists of the two contrasting stages: active and dormant. The active stage comprises both Plinian (including sub-Plinian) and Vulcanian (including Stronbolian) eruptions; the former is large-scale and the latter is intermediate to small-scale. The first dormant stage with a time span from 13 to 9.2 cal.ka continued about 3,800 years, accompanying several large Vulcanian eruptions. The first active stage with duration of about 600 years comprises the two Plinian eruption: Fujioka pumice fall deposit in 9.2cal.ka (ca.0.19km^{3}DRE) and Kumakawa pumice fall deposit in 8.6cal.ka (ca.0.07km^3). The second dormant stage commenced in 8.6cal.ka and continued to 6.3cal.ka with duration of about 2,300 years, during which the two large Vulcanian eruptions were occurred. The second active stage with duration of about 1,100 years consists of four Plinian eruptions, which gave rise to the Kuni pumice fall deposit in 6.3cal.ka (ca.0.29km^3), the Miyota pumice fall deposit in 6.1cal.ka (ca.0.13km^3), the Sengataki pumicd fall deposit in 5.7cal.ka (ca.0.04km^3) and the D pumice fall deposit in 5.2cal.ka (ca.0.13km^3). The third dormant stage with a time span from 5.2cal.ka to fourth century continued about 3,600 years, during which three ash fall deposits were produced by large Vulcanian eruptions. The third active stage with duration of at least about 1,650 years includes the historical eruptions; they are the Plinian eruptions in fourth century (ca.0.54km^3), 1108A.D. (ca.0.95km^3), 1128A.D. (As-B') (ca.0.02km^3) and 1783A.D. (ca.0.57km^3). The eruptive volume of the large-scale eruption in the third active stage is larger than those of the previous stages. The periods in the active stage between the Plinian eruptions further consist of the two sub-stage: continuously eruptive and relatively quiescent stages. Vulcanian eruptions frequently repeated in the continuously eruptive stage. The Maekake volcano is not a typical stratovolcano composed of lavas and pyroclastic rocks but a densely welded pyroclastic cone. The Plinian eruption is not a typical one cycle eruption in which the pyroclastic fall, pyroclastic flow and lava flow ejected in this order, but the eruptions of pyroclastic fall, pyroclastic flow and clastogenic lava were overlapped.The volcanic cone of the Maekake volcano has grown through every Plinian eruption, especially the historical large-scale eruptions contributed to the construction of the essential portion of present volcanic edifece. The Vulcanian eruptions do not play an important role for the formation of volcanic cone.

Relationship between volcanic activity and chemical and isotopic compositions of thermal waters in Tokachidake volcano, Japan

Ryo Takahashi[1], Tomo Shibata[1], Yasuji Murayama[1], Tagiru Ogino[1], Noritoshi Okazaki[2]

[1]Geological Survey of Hokkaido, Hokkaido Research Organization, Japan, [2]Hokkaido Research Organization, Japan

E-mail: takahashi-ryo@hro.or.jp

Tokachidake volcano is one of the most active volcanoes in Japan, and three magmatic eruptions (AD 1926, 1962 and 1988-89) occurred in the 20th century. We have investigated chemical and isotopic compositions of thermal waters in Tokachidake volcano. Recently, as the volcano tends to be active, we discuss the relationship between the volcanic activity and these compositions of thermal waters.

Bengara hot spring (BHS), Hakuginso hot spring (HHS), Fukiage hot spring (FHS) and Okina hot spring (OHS) are located at the western flank of the volcano, about 3 km from the summit craters. The chemical compositions of BHS, FHS and OHS and those of HHS have been continually measured since AD 1986 and 1992, respectively. The temperature of thermal waters of BHS, HHS and FHS ranges from 48 to 56 ℃, whereas that of OHS is about 25 ℃. These thermal waters are acidic with the pH ranging from 2.5 to 3.0.

These thermal waters have various dissolved species. Here we show the Cl/SO_4 ratio. The ratio of these thermal waters was about 0.2 in AD 1986. Since then the ratio had abruptly increased, and the ratio of BHS and FHS was about 2.9 and 3.9, respectively, at the time of the AD 1988-89 eruption. The increase of the ratio had continued until AD 1992, whereas then the ratio had gradually decreased to 0.6 until AD 2010. Temporal change of the chemical compositions of HHS shows similar to that of BHS and FHS, and the ratio had decreased until AD 2010. However, temporal change of the ratio of these three thermal waters has changed to nearly constant or weak increase since AD 2010. In addition, these thermal waters have shown obvious increase of the ratio since June 2012, and the ratio reached about 1.0. In all thermal waters, there is no remarkable temporal variation of SO_4^{2-} concentration, and hence we can consider that temporal change of the Cl/SO_4 ratio has been caused by change of Cl^- concentration.

In addition to the chemical compositions, the oxygen and hydrogen isotopic compositions of these thermal waters have been investigated since AD 2011. All samples collected before July 2012 show nearly the same isotopic compositions as meteoric waters, ranging from $d^{18}O$=-13.6 to -12.1 per mil. In contrast, thermal waters of BHS and HHS, which were collected after October 2012, show heavy oxygen isotopic composition compared with meteoric waters, ranging from $d^{18}O$=-10.9 to -9.8 per mil.

The increase of the Cl/SO_4 ratio and shift of the oxygen isotopic composition toward heavier value could indicate that volcanic gas is supplied into thermal waters more than before. Observations of chemical and isotopic compositions of thermal waters are important for evaluating the future volcanic activity.

Volcano-tectonic interactions during rapid plate-boundary evolution in the Kyushu region, SW Japan.

Sue H Mahony[1], Laura M Wallace[2], Masaya Miyoshi[3], Pilar Villamor[4], R. Steve J Sparks[1], Toshiaki Hasenaka[5]

[1]University of Bristol, UK, [2]University of Texas at Austin, U.S.A., [3]University of Fukui, Japan, [4]GNS Science, New Zealand, [5]Kumamoto University, Japan

E-mail: Sue.Mahony@bristol.ac.uk

Evolution of the local plate tectonic and volcanic system relationship at Kyushu Island is defined by major changes in tectonics and volcanic style at approximately 15, 10, 6, and 2 Ma.

Plate reconstructions suggest that prior to 15 Ma, the Pacific plate subduction dominated Kyushu tectonics. From 15 to 6 Ma, the evolving relative plate motions shifted the triple junction between the Pacific plate, Philippine Sea plate, and southwest Japan northwards, so that the Philippine Sea plate was subducted beneath Kyushu. From 17 to 10 Ma felsic plutons were formed and high magnesian andesites erupted. This was followed from 10 to 6 Ma by dominantly effusive volcanism and a hiatus in subduction related volcanism. We suggest that this change in volcanic style from 10 to 6 Ma is due to shallow subduction of the young Shikoku Basin lithosphere.

By 6 to 5 Ma, changes in the Philippine Sea plate motion led to more rapid, nearly trench-normal, subduction of the Eocene west Philippine Basin crust beneath Kyushu. This model is supported by an increase in arc-like geochemistry of lavas since approximately 6.5 Ma. Subduction of fluid-rich features such as the Kyushu-Palau ridge introduced large volumes of fluids into the Kyushu arc system, leading to voluminous volcanism across Kyushu, focused particularly in areas where the ridge subduction occurs in tandem with local extensional tectonics, such as the Beppu-Shimabara graben and the Kagoshima graben. These grabens have been the location of 9 caldera forming volcanoes in the last one million years.

Key issues, such as the timing of Izu arc collision with central Japan and the history of motion of the Philippine Sea plate, have been reassessed, resulting in a model that favours Izu arc-central Japan collision at ca. 8 to 6 Ma, rather than the more widely accepted date of ca. 15 Ma.

Only by understanding the long-term interactions between these physical processes can we begin to forecast locations of future volcanic and tectonic activity on a shorter time scale. The ability to forecast on timescales of up to 1 million years is necessary, for example when dealing with the disposal of nuclear waste.

Dry and wet debris avalanche deposits at Mt Meru volcano, Tanzania.

Audray Delcamp[1], Ben van Wyk de Vries[2], Matthieu Kervyn[1]

[1]Vrije Universiteit Brussel, Belgium, [2]Laboratoire Magmas et Volcans, France

E-mail: delcampa@tcd.ie

Mt Meru volcano is located in the Northern Tanzanian Divergence Zone where the East African rift splits into several branches. This 4565 m-high stratovolcano overlooks the highly populated city of Arusha. The edifice is breached on the east side by a 4x5 km horse-shoe shaped valley that was attributed to landslides associated with lahars deposits (Wilkinson et al., 1986; Dawson, 2008) and a major collapse dated at 7800BP (Wilkinson et al., 1986; Roberts, 2002; Dawson, 2008). An ash cone has grown up within the collapse scar, with its last eruption occurring in 1910.

Although Meru major scar has been identified, boundary and characteristics of the deposit remain poorly known as most studies have been based on remote sensing mapping and limited field observation. In this study we combine remote sensing with detailed field mapping. We identify a dry and a wet debris avalanche units originating from the large east scar and from a buried NE scar respectively. The wet debris avalanche travelled first as a dry avalanche that turn into a debris flow while entering in a river. As a consequence, its inertia increased and the debris flow was able to climb or even splash over topographic highs such as cinder cones. The dry avalanche -i.e. debris avalanche s.s.- might have a lower inertia compared to the debris flow, but its energy was enough to travel far away from the source. The debris avalanche has been deviated to the south by Kilimanjaro and Ngordoto volcanoes.

Building a flood hydrograph caused by the volcanic eruption of Baekdusan in Cheon-ji caldera lake

Khil-Ha Lee[1], Sung-Wook Kim[2], Sang-Hyun Kim[3], Sung-Hyo Yun[4]

[1]Daegu Univ(DU), S Korea, [2]GI Co Ltd., S Korea, [3]Pusan National Univ, S Korea, [4]Pusan National Univ, S Korea

E-mail: khil_ha@yahoo.com

Recent reports pointed out the Baekdusan volcano that is located between the border of China and North Korea as a potential active volcano. Since Millennium Eruption around 1000 AD, smaller eruptions have occurred at roughly 100-year intervals, with the last one in 1903. The volcano is showing signs of waking from a century-long slumber recently and the volcanic ash may spread up to the northeastern of Japan. The development of various forecasting techniques to prevent and minimize economic and social damage is in urgent need. Floods from lake-filled calderas may be particularly large and high. Volcanic flood may cause significant hydrologic hazards for this reason. This study focuses on constructing a hygrograph triggered by the breach failures of the caldera lake and/or uplift of lake bottom in the Baekdusan volcano. A physically-based break and uplift model was developed to compute the amount of water and time to peak flow. The ordinary differential equation was numerically solved using the finite difference method and Newton-Raphson iteration method was used to solve nonlinear equation. The final goal of the study stresses the potential flood hazard represented by the huge volume of water in the caldera lake, the unique geography, and the limited control capability. Only a flood hydrograph is built as an upper boundary condition and channel routing downstream is not considered in this study. The study will contribute to build a geohazard map for the decision-makers and practitioners.

Keywords: Volcanic flood, Volcano, Caldera lake, Dam break, Hazard

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Eruption History and Future Scenario of Sinabung volcano, North Sumatra, Indonesia

Mitsuhiro Yoshimoto[1], Setsuya Nakada[2], Natsumi Hokanishi[2], Masato Iguchi[3], Takahiro Ohkura[4], Muhamad Hendrasto[5], Akhmad Zaennudin[5], Agus Budianto[5], Oktory Prambada[5]

[1]Faculty of Science, Hokkaido University, Japan, [2]Earthquake Research Institute, University of Tokyo, Japan, [3]Sakurajima Volcano Research Center, Disaster Prevention Research Institute, Kyoto University, Japan, [4]Institute for Geothermal Sciences, Graduate School of Science, Kyoto University, Japan, [5]Center for Volcanology and Geological Hazard Mitigation, Indonesia

E-mail: m-yoshi@mail.sci.hokudai.ac.jp

Sinabung volcano is an andesitic stratovolcano located 40 km northwest of Lake Toba, North Sumatra. It is characterized by multiple thick lava flows/domes, and their collapsed materials (block-and-ash flow and associated surge deposits). The latest lava spine is located at the southern end of one of the summit craters which trend in N-S. Historical eruptions have not been reported prior to the phreatic eruptions of August-September 2010. The latest eruption caused panic among the people living around the volcano. We conducted geological survey, geochemical analyses and dating of charcoal samples to establish the future eruption scenario based on the eruption history.

The activity of Sinabung volcano began after the last caldera-forming eruption of Toba Lake (ca. 74ka). The volcanic history of Sinabung volcano can be divided into two stages (old and young stages), based on the topographical and geochemical features. The old stage is the activity of lava flows of porphyritic, two-pyroxenes andesite with/without hornblende, which are exposed in the dissected western area. The young stage is the activity of lava flows and pyroclastic deposits of porphyritic, two-pyroxene basaltic-andesite to hornblende two-pyroxenes andesite, which are distributed in the eastern part of edifice including summit domes. The youngest block-and-ash flow and associated surge deposits on the southeastern flank were emplaced at ca. 1.1 ka, based on the radiocarbon ages of charcoals (1145±20 and 1155±20 years BP). Mafic enclaves are commonly found in lavas, suggesting common magma mixing or mingling before eruption in this volcano. Pyroclastic fall deposits of plinian- to subplinian eruptions were not found, implying no occurrence of large explosive explosions in this volcano throughout its history.

One of the plausible scenarios for future eruption is a dome-forming eruption or lava flowing from near the summit. During dome growth, partial collapse of the lava dome will generate block-and-ash flows and surges. If a large lava dome grows at the summit crater, the most serious scenario is a failure of the old and weak volcanic edifice due to the load of the dome or deformation by lava intrusion. Relatively large-scale collapse of the volcanic edifice may generate a lateral blast preceding the pyroclastic avalanche, as observed in the 1997 event at Soufrière Hills volcano, Montserrat, where the crater wall overridden by the growing lava dome collapsed together with a part of the overlying dome.

If magma is less viscous due to low SiO_2 content or higher temperature driven by a high effusion rate, lava will flow down on the flank from the summit crater, being associated with minor pyroclastic flows from the flow front.

Evolution of scenarios may be forecastable by continuous monitoring of volcanic earthquakes and ground deformation.

Late Holocene stratigraphic record of Gunung Agung (Bali, Indonesia): an explosve basaltic andesite volcano

Karen Fontijn[1], Igan Sutawidjaja[2], Chris Newhall[1]

[1]Earth Observatory of Singapore, Singapore, [2]Centre for Volcanology and Geological Hazard Mitigation, Indonesia

E-mail: karenf@earth.ox.ac.uk

Gunung Agung is a large stratovolcano that is a sacred mountain of great importance to the Balinese people. Four historic eruptions have been reported since 1808. The most recent one, in 1963 - 1964, was one of the largest explosive eruptions to occur in Indonesia in the 20th century. It extruded ca. 110 x 10^6 m^3 of lava, followed by two large explosive eruptions with devastating pyroclastic flows and lahars that claimed almost 2000 lives. Since 1964, Agung has been largely quiet. Reports have been made of probable inflation at Agung between mid-2007 and early 2009. Because of this reported inflation, we reconstructed the Holocene explosive eruptive history of Agung, enabling an assessment of the eruptive frequency and range of magnitudes and styles of eruptions. Field stratigraphic logging was complemented with ^{14}C dating on charcoal and palaeosols, and with petrological and whole-rock geochemical data to fingerprint specific deposits and to distinguish deposits from neighbouring Gunung Batur. The stratigraphy is dominated by scoria fall and valley-filling pyroclastic flow deposits of basaltic to andesitic composition. Intercalated (trachy)andesitic-to-dacitic pumice fall deposits are interpreted to originate from Batur. For Agung, we find evidence for at least 25 eruptions within the last ca. 4.5 ka. Using deposit thickness and maximum grain size of fall deposits as a first-order approximation of eruption intensity (most tephra falls are deposited on Agung's NW flank), about 1 out of 3 of eruptions is of similar and 1 out of 5 of higher intensity than the 1963 event.

Late Quaternary tephrostratigraphic record of Siete Lagos region, South-Central Chile

Karen Fontijn[1], Harriet Rawson[1], David M Pyle[1], Tamsin A Mather[1], Maarten Van Daele[2], Jasper Moernaut[3], Ana M AbarzÃža[4], Marc De Batist[2], Hugo Moreno[5], Jose Antonio Naranjo[5]

[1]University of Oxford, United Kingdom, [2]Ghent University, Belgium, [3]ETH Zurich, Switzerland, [4]Universidad Austral de Chile, Chile, [5]SERNAGEOMIN, Chile

E-mail: karenf@earth.ox.ac.uk

The volcanoes of the Siete Lagos region in South-Central Chile form part of the Southern Volcanic Zone of the Andes and include some of the most active volcanoes in South America, i.e. Villarrica and Llaima. The Late Quaternary (ca. last 15 ka) regional tephrostratigraphic record for this region is however still poorly developed. We combine detailed stratigraphic logging of terrestrial sections in the vicinity of Llaima, Sollipulli, Villarrica, Quetrupillan and Mocho-Choshuenco volcanoes with petrological, whole-rock and glass geochemical data and correlate the on-land sequences with existing ^{14}C-dated lacustrine records of Laguna Las Ranas and Lagos Villarrica, Calafquen and Rinihue. The combined record includes previously described major eruptions, e.g. Llaima Pumice (Llaima) and Alpehue Pumice (Sollipulli), which help to constrain the relative timing of events. For Llaima Pumice, we present newly updated dispersal maps and magnitude estimates. The record also includes at least 8 newly described pumice-producing events for Quetrupillan. The new stratigraphy contributes to the regional stratigraphy of major explosive eruptions in the Southern Volcanic Zone, and will shed light on the relation between deglaciation and eruptive frequency in this continental arc segment.

Volcanic hazard estimation using tephra GIS and geo-spatial information

Mamoru KOARAI[1], Takehiko SUZUKI[2]

[1]Geospatioal Information Authority of Japan, Japan, [2]Tokyo Merlopolitan University, Japan

E-mail: koarai@gsi.go.jp

There are many data of tephra in Japan such as 'The tephra atlas (Machida and Arai, 2003),' however, less database of tephra in Japan, compared with Quaternary volcanoes, active faults and land slides and so on. As the database of tephra is produced with location information in GIS, it is possible to identify each tephra easily in field works, for the researchers of Quaternary field such as geomorphology, geology, volcanology and archeology. In addition, it is expected the governmental utilization for disaster prevention such as the production of hazard maps and the estimation of environmental impact, because it is easy to analysis the distribution data of tephra combined with other spatial data such as DEM, NSDI and land condition map of volcano.

In this research, the authors have developed the tephra GIS data about the tephras originated from Tohoku District, North East Japan, and middle and upper Pleistocene wide area tephras. In this presentation, the authors introduce the results of case study for hazard map use in Kitakami Plain, Tohoku District, Japan.

The authors digitized the tephra distribution data about Iwate Volcano and Akita-Komagatake Volcano on the Tephra Atlas and so on, and overlay thepra distribution and transportation network data of Spatial Data Infrastructure 25000 on GIS. As the results of overlay analysis, highway and national road where located on the east foot of Iwate Volcano was covered by volcanic ashes of Iwate Volcano several times in ten thousands years, and volcanic ashes of Akita-Komagatake Volcano when the caldera of Akita-Komagatake Volcano was formed gave large influence on the wide area near Morioka City.

Next, the authors introduce the way to open the tephra GIS database using Web-GIS. Outcrop information and tephra distribution information on the 1/25,000 topographical maps are distributed by Cyber Japan Web System. The authors developed the trial Web GIS system about Bandai Volcano and Akita-Komagatake Volcano. At first, the location information of outcrops is described on topographical maps. When the users click the location of outcrops, various data about outcrops is described such as photo of outcrop, column section, sketch of the outcrop, mineral composition, petrologic characteristics, index of each minerals, chemical composition and so on. Input information about Bandai volcano is based on Suzuki et al. (1995), Koarai et al. (1995), Koarai and Soda (1995) and so on such as the tephras originated Bandai Volcano and wide spread tephras. Input information about Akita-Komagatake Volcano is the isopack maps of each tephras and outcrop information based on Wachi et al. (1997) and chemical composition of each tephras based on Fujinawa et al. (2004). In additionally, the assumption of volcanic hazard areas on hazard map, polygon data of landform classification, the results of automated landform classification using 50m DEM and 10m DEM are input in this database.

Gravity change and crustal deformation in active Tokachi-dake volcano, Hokkaido, Japan

Noritoshi Okazaki[1], Wataru Hirose[1], Ryo Takahashi[1], Hiroaki Takahashi[2], Masayoshi Ichiyanagi[2], Ryo Honda[3]

[1]Geological Survey of Hokkaido, Japan, [2]Hokkaido University, Japan, [3]Tono Research Institute for Earthquake Science, Japan

E-mail: okazaki-noritoshi@hro.or.jp

Magmatic mass monitoring is one of fundamental parameter for activity forecasting. Recent development in portable gravity meter and high precision GPS positioning techniques have allowed us to make gravity observation on active volcano repeatedly. Simultaneous observation of gravity and ground deformation at same point will provide valuable information for deformation source material, e.g. magma or water.

Tokachi-dake is active basaltic-andesite volcano in southwestern Kuril subduction zone. Three magmatic eruptions had been recorded in a recent hundred years. To investigate magma storage system, relative microgravity measurement along a loop-profile with 27 benchmarks has been carried out since 1998. Scintrex CG-3M and CG-5 gravity-meters, and dual-frequency GPS receiver for three dimensional positioning has been simultaneously in operation at benchmarks.

Broad gravity increasing and ground subsidence was detected during 1998 to 2011. Total 0.12mGal gravity increase and 15cm subsidence in maximum were observed. Free-air calibrated gravity data well agreed with that estimated from ground subsidence. These facts implied deflation of volcano edifice during totally 13 years induced gravity buildup.

Active geothermal activity with ground temperature increasing was observed during 1995 to 2000. Lowering in ground temperature, however, had recorded in 2003. Weak geothermal activity has been kept in a recent decade. Possible volcano deflation due to weakening of geothermal activity could explain gravity increase and ground subsidence. Localized inflation near active crater since 2007 might induce lesser deformation than that of 1995 to 2000. These observations implied complex geothermal system has been in progress during rest stage of this volcano.

Tiltmeter observation in Klyuchevskaya volcano, Kamchatka, Russia

Hiroaki Takahashi[1], Hiroki Miyamachi[2], Takeshi Matsushima[3], Hiroshi Aoyama[1], Akio Goto[4], Evgeny Gordeev[5], Yarosrav Muravyev[5], Sergey Serovetnikov[6], Mitsuhiro Nakagawa[1]

[1]Hokkaido University, Japan, [2]Kagoshima University, Japan, [3]Kyushu University, Japan, [4]Tohoku University, Japan, [5]Institute of Volcanology and Seismology, Russia, [6]Kamchatka Branch of Geophysical Survey, Russia

E-mail: takeshi_matsushima@kyudai.jp

Klyuchevskaya is one of most active volcano in the world. Medium and big eruptions have occurred in every year and quarter of century, respectively. Clear magma plumping system from upper mantle to surface was imaged by seismic tomography. Diverse eruption styles has been observed, e.g. strombolian at central corn crater, lava flow from central corn crater, fissure eruption at mountain slope and mountain base, parasitic cones generation, etc.
Aim of this research is to clarify branch condition of eruption style. A hypothesis that magma discharge rate from shallowest chamber and buoyant equilibration of magma density might be controlling factor will be tested. To monitor crustal deformation associated with magma intrusion, four bubble-type tiltmeter has been operated around volcano. Low power consumption, huge flash memory, and air battery allowed us to operate one year without maintenance. Tiltmeter have broad dynamic range from dozens of seconds to DC. High sampling rate of 100Hz give opportunity to analyze not only DC component but also transient signals with duration more than high frequency cutoff period. Signals of the 2011 Tohoku earthquake (Mw9.0) seismic waves suggested that this system can record long-period signals well. Theoretical modeling and sensor sensitivity indicated that this tiltmeter network might detect magma migration with volume less than $10^7 m^3$.
Klyuchevskaya has been in quiet period since 2011. This might suggest that magma plumping system in the shallowest part was possibly initialized. This condition might be ideal because our network will capture entire process of future magma intrusion from initial stage to eruption.

Near real-time hazard assessment during the 2011-2012 eruption of Puyehue-Cordon Caulle volcano, Southern Chile.

Alvaro Amigo[1,2], Luis E Lara[1], Daniel Bertin[1], Gabriel Orozco[1], Carolina Silva[1]

[1]Geological Survey of Chile (SERNAGEOMIN), Chile, [2]CEGA (Andean Geothermal Centre of Excellence), Fondap 15090013, Chile

E-mail: alvaro.amigo@sernageomin.cl

The Puyehue-Cordon Caulle complex (40.6^{0}S, 72.1^{0}W) is one of the most active volcanic complexes in the southern Andes, where both explosive and effusive eruptions have occurred during historical times. During late May - early June 2011, the Chilean monitoring network detected increasing precursory seismicity, which resulted in a new eruption on June 4, 2011. The initial phase of the eruption was characterized by a Plinian-like eruptive column that lasted for more than 24 hours, resulting in widespread tephra deposits in Chile and Argentina with an estimated volume of ca. 0.5 km^3 of magma (DRE). On the other hand, fine ash disrupted air navigation across the Southern Hemisphere for several days. From mid-April 2011 to March 2012, the eruption was characterized by the emission of blocky lava of similar volume to historical lava flows (< 1 km^3). Additionally, simultaneous fine ash emission derived from weak plumes caused several flight suspensions in Chile and Argentina. The Volcano Hazards Program at SERNAGEOMIN developed a dynamic approach in order to generate hazard maps using numerical models, taken into consideration the evolution of the eruption. During the explosive phase, sub-daily reports of potential tephra accumulation on the surface were done using an advection-diffusion model (ASHFALL) and forecast wind fields. In addition, all through the eruption areas susceptible to be inundated by lahars were delineate using the LAHARZ model, whereas areas susceptible to be impacted by pyroclastic density currents where estimated according to the energy cone method. Based on field and seismic observations as well as available satellite imagery, inputs for the models were calibrated and therefore hazard maps were updated, allowing timely information for civic officials.

Oblique photogrammetry system for real-time monitoring of volcanic activity

Hisashi Sasaki, Kenichi Arai, Shigenori Fujimaki, Yumiko Yamaguchi, Manabu Maya

Asia Air Survey Co., Ltd., Japan

E-mail: hss.sasaki@ajiko.co.jp

Volcanic eruptions often cause topographic changes, such as the destruction of an edifice due to an explosive eruption. For volcanic hazard mitigation, it is important to quickly measure these topographic changes. When a volcano erupts explosively, an airplane cannot fly directly over a crater to carry out aerial photography and LiDAR measurements. In order to obtain information regarding topographic changes, we can take many oblique aerial photos from an airplane and a helicopter, but it is difficult to obtain spatial information such as the spread area of pyroclastic flow deposits from oblique aerial photos. Therefore, we have developed an oblique photogrammetry system for real-time monitoring of volcanic activity. This system is capable of analyzing a single oblique aerial or terrestrial photo image using digital elevation model (DEM). There are three characteristics to this system: 1) making an orthophoto image from an oblique aerial or terrestrial photo; 2) measurement of position, distance, and square; and 3) generation of GIS data such as shape format. This system is also able to link to a video camera monitoring volcanic eruptions. Analysis of the monitoring video camera images enables prompt measurement of the distance ejecta travel from the crater. In addition, this system can generate a three-dimensional model from many oblique photos. The three-dimensional models are generated by an image correlation method. From this data, we can estimate the volume of ejecta and analyze topographic changes. We analyzed a lava dome from the 2011 eruption of Shinmoedake volcano, Kirishima volcanic group, Japan. We measured the elevation of the summit of the lava dome and the distance of the lava spread area, and estimated lava thickness from cross sections generated from the three-dimensional data. Our measurements were consistent with results of airborne synthetic aperture radar (SAR) and photographic surveying using oblique aerial photographs. The accuracy of this system is sufficient for real-time volcano monitoring. This system is also less expensive than airborne SAR and LiDAR. The oblique photogrammetry system enables a quantitative measure of the change in topography. For example, this system can be used to conduct a time series analysis of the formation and movement of craters or growth of lava dome.