Shimabara 2007
CITIES ON VOLCANOES 5

ABSTRACTS VOLUME

CITIES ON VOLCANOES 5 CONFERENCE

Shimabara, Japan
November 19-23, 2007

Miyakejima Eruption in 2000

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CONFERENCE

Shimabara, Japan

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Conference Lectures

CL 1

The 1990-1995 Eruption of Unzen Volcano –Spectacle of Lava Dome Growth and Menace of Pyroclastic Flows and Lahar–

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Mt. Fugen had erupted after the 198 years dormancy and formed lava dome at interval of bout 5000 years from previous document. We could observe the formation process in detail for forty-five months by air observations. When magma supply was active more than 5 - 10 m^3/day, fluidal lava were extruded and formed lobes. Lava effused showing the form like a flower with several petals. They grew into mounds on the top of the dome, and on the other hand, they grew into tongue shape on the slope, showing bisecting-crease-structure initially. Some lobes of them were buried by the following ones, and most of them were destroyed by pushing of following lava and generated pyroclastic flows. Lava extrusion site was changed 13 times inside the 300 m in diameter through the whole lava extrusion period, and lava was piled up to a big lava dome. The 11th-B lobe is remained only on the eastern slope. Formation type of lava dome like these corresponded to the squeeze-type offered by Yokoyama (2006). When magma supply was decreased less than 5 - 10 m^3/day, solidified or semi-solidified lava were uplifted just above the conduit and formed fragmented lava cone with spines. We can see them now at the top of lava dome. Formation type of lava dome like these corresponded to the spine-type offered by Yokoyama (2006). Falling sediments from the lava dome flowed down as lahars and promoted the development of fan deposits at the foot in coast area.

CL 2

Last 30 Years of Volcanic Hazard Mitigation in Japan

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In the last 30 years, Japan has witnessed an average of 3 volcanic eruptions as well as many more volcanic crises each year. Out of 50 deaths occurred during this period, 44 were caused by the pyroclastic flows of Unzen volcano in 1991. Except this Unzen case, the low death rate and the large number of evacuated residents during the crises (ca. 40,000 people in 7 events) may indicate effectiveness of recent preventive measures. In a few cases, including the 2000 eruption of Usu, forecasting was so successful that large number of residents had been evacuated before the eruption actually started. The most regrettable was the loss of 43 people in the peripheral part of pyroclastic surge during the 1991 June 3 eruption of Unzen, The victims were not sufficiently warned of the danger, which in the hindsight, could have been done by the volcanologists, including myself, and the authority. Thanks to this event, no question was asked when 16,000 people followed the evacuation advisory in fear of the pyroclastic flow during the 2000 Usu eruption. During the last 30 years, hazard maps were prepared for more than 30 volcanoes covering most of those on the black list. The swarms of long-period earthquakes beneath Fuji volcano in 2000-2001 gave a finishing touch. The impact of possible major eruption like the one occurred in 1707 gave good enough incentive to the national government which launched a comprehensive investigation. The time is now ripe to take further steps to elaborate well coordinated disaster mitigation plans involving many government agencies and citizens-communities. The most needed agenda for Japan is not to implement more hardwares but to strongly enhance software expertise in science, technology, and administration.

Session 1-1

11-O-01

Recent Developments In Volcano Research: Diversity In Volcanism

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We have yet to explain all aspects of diversity in volcanology which limits our ability to forecast the path of future eruptions. Reducing eruption impacts critically needs better knowledge of what controls the style and intensity of eruptions. Sudden shifts in the style or intensity of eruption are particularly difficult to deal with in the environment of an escalating volcanic crisis. Recent history suggests that variations in eruptive intensity during a single eruption may be as large as 7 orders of magnitude. Shifts in eruptive style can be equally abrupt, e.g. stable Plinian plumes may give way abruptly to dome growth, or paroxysmal pyroclastic density currents, or phreatomagmatic explosions, or an abrupt cessation of activity. Eruption intensity, duration and style are determined either during magma storage, which provides the overpressure driving an eruption, or in the volcanic conduit, where magma decompresses, loses volatiles, and sometimes partially crystallizes. These environments cannot be observed directly and must be inferred from geophysical data, theoretical models, analog experiments, and the textures preserved in the eruptive products. Recent models have sought to explain gradual and abrupt shifts in eruptive style/intensity in volcanic systems in terms of changing conduit/vent dimensions, unsteady non-linear behavior during conduit flow and in eruption plumes, shifts in mass flux, onset of permeability and outgassing of ascending magma, or pressure shifts in shallow magma chambers causing transitions from steady to unsteady conduit flow. Much of our current understanding of the dynamics of ascent and eruption of magma has come from the studies of Mount St Helens, Unzen and Soufrière Hills for silicic volcanoes and Etna, Stromboli and Kilauea for basaltic systems. For these recent eruptions the disciplines above have combined to offer models based on very broad data sets. The remaining challenge is to bring these linkages between geology, hydrology, geochemistry, geophysics, analog experimentation and numerical modeling together to offer reliable forecasts on reasonable time scales.

11-O-02

Seismic Imaging of Magma Chambers Under Active Arc Volcanoes and Hotspots

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We have used multi-scale seismic tomography methods to image the detailed three-dimensional velocity structures of the crust and mantle beneath active arc volcanoes in Japan, intraplate volcanoes in the continents, and hotspot volcanoes in the oceanic regions. Applications of local and teleseismic tomography methods to high-quality data recorded by the dense seismic networks on the Japan Islands have resulted in clear images of the subducting Pacific and Philippine Sea slabs and magma chambers in the crust and upper mantle wedge beneath active arc volcanoes, indicating that geodynamic systems associated with arc magmatism and back-arc spreading are related to deep processes, such as convective circulation in the mantle wedge and dehydration reactions of the subducting slab (Zhao, 2001). Evidence also shows that arc magma and slab dehydration may also contribute to the generation of various types of earthquakes in subduction zones (Zhao et al., 2002, 2007). The active intraplate volcanoes in NE China (e.g., Changbai, Wudalianchi) are not hotspots like Hawaii, but a kind of back-arc volcanoes related to the deep dehydration process of the stagnant Pacific slab in the mantle transition zone under East Asia and the corner flow in the big mantle wedge above the stagnant slab (Zhao, 2004, 2007). The active Tengchong volcano in SW China is associated with the subduction of the Burma microplate under Asia (Huang and Zhao, 2006; Zhao, 2007). Our recent global tomography (Zhao, 2004, 2007) has detected deep mantle plumes originating from the core-mantle boundary under a dozen of hotspot volcanoes such as those in Hawaii, Iceland, Kerguelen, South Pacific and East Africa. The deep mantle plumes usually do not show a simple vertical pillar shape, but exhibit winding images, suggesting that the plumes are deflected by the mantle flow. Upper-mantle plumes are detected under some hotspot volcanoes, such as Easter, Azores, Erebus, and Baikal (Zhao et al., 2006; Zhao, 2007).

11-O-03

Temporal Change of Spectra of Volcanic Earthquakes at Kuchinoerabujima Volcano, Japan

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Kuchinoerabujima volcano is located at south off Kyushu, Japan. Phreatic or phreato-magmatic eruptions occurred at active crater-Shindake in 1841, 1914, 1931-1934, 1945, 1966 and 1980. Seismicity of volcanic earthquakes increased and have kept the high level since 1999. In this study, focusing on seismograms since January 2006, volcanic earthquakes at Kuchinoerabujima are divided into three types; high-frequency (HF), low-frequency (LF) and monochromatic events. Seismicity increased significantly in August, when 115 monochromatic events recorded, then followed by occurrence of 55 LF events in October, and HF events reached 450 events in November.

HF events are dominated by high-frequency component in range of 6-25 Hz. LF events have lower-frequency content of 1-5 Hz. Monochromatic events have an unique waveform, especially at coda part which shows a slowly decaying amplitude of coda part. Based on their frequency content, monochromatic events are sub-divided into two types, low-frequency monochromatic (LFMC) and high-frequency monochromatic (HFMC) events. LFMC events have dominant frequency of 1-5 Hz and show some peaks of subdominant frequencies. HFMC events show higher dominant frequency at 6-15 Hz and some peaks of subdominant frequencies also appeared. Subdominant peaks have varied frequency content from low-frequency, less than 5 Hz, to higher-frequency more than 5 to 30 Hz.

Associated with increase of monochromatic events, inflation of ground around the crater was observed by GPS observation and it was followed by increase in fumarolic activity. Monochromatic events at Papandayan volcano recorded in June-July 1998, which was related to the increase in seismicity and the anomalous gas emission from the active crater. Monochromatic events may be related with accumulation of gas and its vibration.

11-O-04

Subvolcanic Plumbing Systems beneath Caldera Volcanoes: Relevance to Prediction of Eruptions

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A study is currently underway to understand the physical and chemical processes that occur beneath Okataina caldera complex (OCC), Taupo Volcanic Zone (TVZ), New Zealand. This includes a compilation of existing geochemical data from eruptives of OCC, and additional new data from early caldera-forming events, in particular those associated with the c.280ka Matahina ignimbrite. Plutonic lithic blocks, brought up by several eruptive units, including the c.60ka Rotoiti ignimbrite and 1314AD Kaharoa eruption from Tarawera volcano, are being used to identify petrographic and compositional ranges within the high-level sub-volcanic magma chambers beneath OCC.Older exposed high-level granite bodies are regarded as potential analogues of these magma chambers, and those from the Coastal Maine Magmatic Province (USA), the southern Nevada/northwestern Arizona (USA) plutons and the Bungaree Intrusives of Stewart Island, New Zealand, are compared to the data from OCC in order to build up a 3-D picture of the subsurface magma system there. All of the data collected so far suggests that intrusion of mafic magmas into the high level (c.5-8 km depth) silicic magma chambers is a very important process beneath OCC. These mafic magmas rise through dikes parallel to the regional faults in the TVZ, and intrude into the 'active' part of the silicic magma chambers as sill-like bodies, in places breaking up into 'pillow-like' forms. Some mixing and mingling occurs. The increased heat input from the mafic intrusions may well be an important factor in triggering eruptions.

11-O-05

A Numerical Model for the Development of Magma Permeability During an Eruption

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Magma permeability and eruption rate are closely coupled. Permeable networks of bubbles may develop as magma rises and bubbles grow and impinge on one another. The rate of release of overpressure as gas escapes through these networks influences the rate of bubble growth, hence, the rate and style of eruption. Conversely, the eruption rate influences the changing pressure enviroment experienced by a rising packet of magma. This, in turn, controls the morphology and permeability of the bubble networks.

I present a numerical model for the development of the permeability of a packet of magma as it rises through the volcanic conduit. The model, which resolves individual bubbles, allows the morphology and permeability of the magma to be determined as a function of position in the conduit.

In the modelled system, anisotropic expansion of the magma confined within a conduit results in anisotropic permeability: percolation occurs first across the conduit and permeability is enhanced across the conduit. This implies that lateral degassing predominates.

11-O-06

Fluid Dynamics of Volcanic Blasts: Application to the Soufriere Hills Volcano, Montserrat (W.I.)

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Directed volcanic blasts are powerful explosions with a significant laterally-directed component, which can generate devastating, high-energy pyroclastic density currents. Such blasts are an important class of eruptive phenomena, but quantified understanding of their dynamics and effects is still incomplete. Here we use 2D and 3D multiparticle thermofluid dynamic flow codes to examine a powerful volcanic blast that occurred at Soufriere Hills volcano on Montserrat in December 1997 as well as similar scenarios for hazard assessment. We investigate the burst phase of the explosion, the gravitational collapse phase resulting in an asymmetric, collapsing stream of mixed ash, blocks, and gas, and the subsequent pyroclastic density current (PDC) phase with movement over a complex topography. We vary key parameters to understand their influence on simulations and thus demonstrate the important influence of total gas mass and energy on the initial burst phase (first ~5s) and of total solid mass on PDC dynamic pressure and runout distance. The simulations illustrate the interplay between various phases of a volcanic blast and realistic 3D topography. We compare the simulations with independent field observations of damage and deposits. We also examine damage associated with volcanic blasts to assess the relative role of flow dynamic pressure and shock waves in causing observed devastation, and conclude that the damage sustained at villages on Montserrat can be reasonably explained by high dynamic pressures and clast impact loading in a stratified PDC.

11-O-07

Insights into Magmatic Processes at Nevado de Toluca, Mexico

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Nevado de Toluca is a large stratovolcano in the Mexican Volcanic Belt, 80 km southwest of Mexico City. The dacitic 10.5 ka Upper Toluca Pumice eruption is one of the largest recorded in central Mexico during the Quaternary. During the event more than 8 km^3 of magma was erupted explosively which generated widespread pyroclastic flows and >40 km-high plinian columns. The surrounding area is now densely populated; an eruption from Nevado de Toluca today could affect the lives of more than 19 million people.

Major and trace element profiles across the dominant plagioclase phenocrysts and trace element abundances of the melt inclusions, trapped at various stages of the crystallisation, provide a detailed record of magmatic processes. Here we present this temporal record and explain the processes that led to the accumulation and eruption of the large volume dacitic magma.

The plagioclase phenocrysts show multiple, and often prominent (up to ~300 μm), resorption zones. Profiles across many crystals show considerable fluctuations in An (An25-An55) and MgO (20-450 ppm). MgO- and An-rich plagioclase infill the resorbed zones, and the highest An and MgO contents are observed at the crystal rim. Using partition coefficients we established that variations reflect those of changing melt composition. Melt inclusions also show significant compositional variation that cannot be explained by fractional crystallisation modelling of typical phases. These records suggest that the dacitic magma system that fed the Upper Toluca Pumice eruption was open and intermittently fed by more mafic batches that subsequently crystallised to form dacitic magma.

The An- and MgO-rich plagioclase rims and the presence of some more more mafic matrix glass (54.0-66.7 wt.% SiO_2; dominant melt 71.5-75.5 wt.% SiO_2) suggests that there was a more mafic input immediately prior to eruption. It is likely that this intrusion triggered the Upper Toluca Pumice event.

11-O-08

Brittle-ductile Deformation of Silicic Lava: Implications for Lava Dome Emplacement and Seismicity

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A major challenge in volcanology is to understand and predict the behaviour of silicic lava domes, and much progress has been recently made through studies of dome growth at volcanoes such as Unzen, Soufriere Hills and Mount St Helens. It has been established that the brittle-ductile rheology of dome lava is key to dome emplacement, and is strongly influenced by shallow degassing and crystallisation of magma.

There is increasing evidence that patterns of dome growth and seismicity are controlled by fracture and faulting in highly viscous lava within the dome and upper conduit. This evidence includes the realisation that brittle-ductile fault zones are commonplace in dome lava, high-temperature deformation experiments which have demonstrated that fracture of hot lava can trigger volcanic earthquakes, and successful modelling of frictional processes in conduits and domes.

We are thus approaching a radically new way of understanding lava dome emplacement, where the fracture mechanics of high-temperature lava may provide the link between geophysical signals such as volcanic earthquakes and the state of magma in the dome. Laboratory investigations of lava deformation at simulated volcanic conditions will provide a framework for modelling the brittle-ductile deformation of dome lava, and measurement of acoustic emissions prior to failure of samples will give us new insights into which patterns of seismicity may indicate imminent dome collapse.

Despite the great potential of current research, we must, however, remain cautious about our ability to reliably predict dome behaviour, since lava domes are extremely complex systems. Even if the characteristics of seismicity could be used to gauge the stability of the system, other external factors such as precipitation are also capable of triggering dome collapse. It is therefore essential that communication about current understanding of lava dome eruptions acknowledges the uncertainty inherent in any predictive models of dome behaviour and associated hazards.

11-O-09

Observations of Volcanic Degassing Processes and Their Implications for Hazard Assessment

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It is of interest to study volcanic degassing processes in order to: quantify Earth degassing and volatiles in the mantle; understand how degassing determines magma rheology; quantify the emission of climate-sensitive gases into the atmosphere; assess volcanic hazards and forecast eruptions. Magmatic volatiles and volcanic degassing are of great importance in the assessment of volcanic hazards as they are a primary control on eruptive style. The ability of magma to degas efficiently or not will determine whether an eruption proceeds effusively or explosively.The geochemistry of volcanic degassing processes can be studied using a variety of approaches. Volcanic gases can now be quantified with unprecedented detail using spectroscopic techniques which allow remote and accurate measurements of gas flux and composition. Methods to monitor and measure volcanic gases include using fixed UV scanning spectrometers, which allow real-time and automated measurement of SO_2 flux throughout daylight hours downwind of a volcano. Continuous SO_2 flux monitoring at White Island and Soufriere Hills allows insight into magma supply and interaction with the hydrothermal system. Fourier Transform infra red spectrometers allow the quantification of gas composition, including the proportion of water and carbon dioxide, remotely and accurately, using hot vents or lava flows as IR sources. The composition of volcanic gases emitted from Kilauea volcano varies in space and time. This variability can be explained, in part, by dynamic shallow degassing processes such as the separation and ascent of gas slugs and large bubbles. Volatiles exsolve from melts throughout magma evolution and crystallization, leaving evidence of their past abundance in melt inclusions trapped in crystals. A combined study of volatile concentrations in glasses and volcanic gases elucidates degassing processes in a range of volcanic settings. Examples are given from Soufriere Hills and Kilauea volcanoes, both associated with volcanic hazards arising from degassing processes.

11-O-10

Degassing of Convecting Magma Column: Interplay with Eruptive Activities

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Non-erupting continuous degassing, called as persistent degassing, such as at Etna, Stromboli, Masaya, Sakurajima, Miyakejima etc, discharges huge amount of volcanic gases, whose global sum is more than half of the global volcanic gases discharged from subaerial volcanoes. The large volcanic gas discharge rate implies degassing of a large volume magma; e.g., 2000 t/d SO_2 discharge requires degassing of 0.1 km^3/y of basaltic magma or 0.5 km^3/y of andesitic magma, that corresponds to VEI=4 eruption once a year. Persistent degassing has common features of large gas discharge rate (>100 t/d SO_2), long-term and stable activity, and magma head at near surface. The persistent degassing is considered to be caused by convection of a magma column in a volcanic conduit. The magma convection in a conduit is driven by degassing, because the degassed magma has larger density than undegassed magma. The degassed magma will sink through the less-dense undegassed magma back to the deep magma chamber, and the convection can continuously supply the undegassed magma as long as the magma column is stable and the magma chamber will not be completely degassed. Vulcanian and strombolian eruptions are commonly associated with the persistent degassing activity, and the amounts of gases discharged by these eruptions are small compared with the rate of persistent degassing. Therefore, these eruptions should be regarded as the processes occurring during the continuous magma convection, and observations or eruption mechanisms of these eruptions need to be interpreted considering the dynamic convecting magma column as the background condition rather than a static magma column, as commonly assumed. Although earthquakes and crustal deformation are the common indication of magma movement in the shallow crust, the

continuous degassing associated with the rapid magma movement in the volcanic conduit does not causes significant volcano tectonic earthquakes and deformation with shallow sources.

11-O-11

Experimental Volcanology on Eruptive Products of Unzen Volcano: 1990 - 1995 Eruption

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Protracted dome-building eruptions may be profitably investigated by a wide range of techniques, including laboratory-based experiments. Here we present a comprehensive review of experimental work on the products of the 1990-1995 eruption of Unzen Volcano, Japan, and their application to the eruption dynamics of Unzen: Rapid decompression experiments focused on several aspects of the degassing (permeability) and the fragmentation behavior (threshold, speed, and efficiency). Those investigations have been flanked by analyses of flexural strength, fracture toughness, seismic velocities, to provide new insights into processes as for instance dome failure. Density distribution studies of the pyroclastic flow deposits of the 1990-1995 eruption allow us to apply the results of experimental investigations on Unzen dacite to the interpretation of the last its eruption.

Thus implications for an overall view of a volcanic system are provided in this study. We evaluated a dependence of elastic wave velocities on temperature changes; this accounts for the host rock as well as the conduit margin and bears vital constraints for the interpretation and modeling of volcano seismic data. The results of the fragmentation experiments are applicable for dome rocks, the vesicular interior of a conduit, and rocks from the conduit margin and contain important implications for the modeling of volcanic processes. Combining the results of the performed experiments is likely to contribute effectively to a refined understanding of pre- and syn-eruptive processes. This may allow an improved analysis of precursor phenomena in volcanic areas and consequently provide important constraints to the hazard and risk management.

11-O-12

Scientific Results of Conduit Drilling at Mount Unzen

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Directional drilling into the conduit of the last eruption was carried out on the northern slope of Mount Unzen during 2003-2004, to understand the structure of the conduit and magma's degassing mechanism within the conduit. The target was set at the hypocenter region of isolated volcanic tremors that occurred in the initial stage of the eruption. The conduit was encountered successfully in the deepest level (about 1.5 km below the summit) of the "conduit zone" (300 m wide). The conduit zone consists of multiple parallel dykes (young and old conduits) and tuffisite veins in volcanic breccias. The conduit of the last eruption, which was confirmed by chemical identification with the dome lava, had been cooled as low as 180 °C. It is a composite dyke as thick as 40 m thick, consisting of several sub-dykes with different textures, up to 7 m each. Conduit lava recovered was devitrified and hydrothermally altered such that the original texture disappeared. The permeability of the wall rock around the conduit was extremely low, so that it is unlikely that degassing of magma occurred laterally into the country rock in the drilled depth.

Unzen is the extreme example of effusive eruption of dacite magma, where the lava extrusion at surface was preceded by 5 months of intermittent small phreatic explosions. SO_2 emission can be disregarded prior to the lava extrusion, and, then, it harmonized with the lava effusion rate. These and the drilling results suggests degassing into the edifice at the level <<1.5 km under the ground, at least, before the lava extrusion and degassing mainly using the conduit itself thereafter. These facts give the important constrain on modeling of degassing mechanism within the conduit. Some of volcanic tremor events should have been associated with the formation of tuffisite veins.

11-O-13

The CALIPSO Project on Soufriere Hills Volcano, Montserrat, BWI: Status and Sciencetific Results From 2003 to 2007

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The “Caribbean Andesite Lava Island Precision Seismo-geodetic Observatory,” (i.e. CALIPSO) has greatly enhanced the geophysical infrastructure at the Soufriere Hills Volcano (SHV), Montserrat with installation of an integrated array of borehole and surface instrumentation at four sites. This project is a multi-institutional and multi-national collaboration, funded by the US NSF and the UK NERC, with a total investment of >$2.5M US. Each site has a Sacks-Evertson dilatometer, sensitive to nanostrain, a three-component seismometer (~Hz to 1 kHz), a Pinnacle Technologies tiltmeter, and Trimble NetRS CGPS receiver with choke ring antenna, similar to volcano sites in western North America as part of EarthScope.

CALIPSO sensors recorded the collapse of the SHV lava dome on Montserrat in July 2003, the largest such event worldwide in the historical record (Mattioli et al., 2004). Dilatometer data show remarkable and unprecedented rapid (~600s) pressurisation of a deep source. Voight et al. (2006) inferred an oblate spheriodal source with average radius ~1 km centered at 5.5 to 6 km depth for this event. An overpressure of ~1 MPa, was attributed to growth of 1-3% of gas bubbles in supersaturated magma, triggered by the dynamics of dome unloading. Explosions associated with the dome collapse resulted in ionospheric waves recorded by integrated electron content measurements from GPS (Dautermann et al., 2007).

Pyroclastic flows entering the sea may cause tsunami generation at coastal volcanoes worldwide, but geophysically monitored field occurrences are very rare. Mattioli et al. (2007) reconstructed the process of tsunami generation and propagation during the collapse of 2003. Mattioli (2005) further reported that periods of surface uplift recorded by GPS at SHV correspond to an inflating, and subsidence, to a deflating Mogi source. Inverted depths are between 6 and 13 km, with the recent observations favoring a deeper source, supporting a temporal evolution of the mid-crustal pre-eruption storage zone from 1995 to 2005. Long term trends in surface deformation data have been be used to predict expected surface lava flux in the near term.

11-O-14

Probing the Emergent Structures and Mechanics of Pyroclastic Flows: Integrating the Dynamics and Deposits of Volcanic Eruptions

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The inherent difficulty of observing volcanic events as well as the scarcity of on-going eruptions has resulted in a continuing debate about the internal particle concentration of pyroclastic flows from dilute to dense end-members. In order to probe the internal structure of these flows an Eulerian-Eulerian-Lagrangian (EEL) computational approach coupled with an examination of the deposits of Kos Plateau Tuff (KPT) was used. In particular, the KPT eruption provides a unique opportunity to compare flows that may have traversed a body of water (and thereby filtering out their bed-load) versus flow that have traveled over-land. In the EEL computational approach, separate particle sizes are treated as distinct phases that can move relative to each other. This coupled deposit-driven and numerical investigation reveals that energy-dissipation at the basal boundary is one of the primary factors determining the run-out distance of pyroclastic flows. A significant portion of the momentum of over-land flows is transported in a bed-load region dominated by numerous particle-particle and particle-boundary interactions. Particle size sorting in the KPT deposits corresponds well to the simulated deposits and provides a mechanism to link the dynamics of a flow to its depositional record. Further, this investigation demonstrates that neglecting fluid entrainment and particle-bed interaction may underestimate run-out distance by over 100%.

We have identified four aspects of over-water transport that can differ from over-land transport: 1) Drag at the water-air interface, 2) hydrous phase change, 3) a mass sink as a result of particle loss, 4) entrainment of water. Provisional results suggest that the flow structure is not significantly altered by the incorporation of an air-water drag boundary condition as opposed to a no-slip boundary: in both cases lithic material is concentrated at the front and base of the simulated pyroclastic flows.

11-O-15

Contrasting Depositional Features and Emplacement Mechanism of the 1991-95 Block-and-ash Flows and 1792 Mayuyama Debris Avalanche at Unzen Volcano, Japan

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More than 9400 block-and-ash flows (BAFs) were generated by lava dome-collapse during the 1991-1995 eruptions of Unzen Volcano in western Japan. The 1792 Unzen Mayuyama debris avalanche occurred as a result of the collapse of the eastern sector of Mayuyama lava dome. Both events occurred as a result of dacite lava dome collapse. The major differences between these gravity currents are temperature and debris volume.

BAF flow unit contains, reversely graded, subangular to subrounded blocks. The layer 2a unit generally occurs at the base of the flow unit. The large reversely graded, subangular to subrounded blocks and basal layer 2a suggest that interactions between blocks occurred during the deposition stage. Large blocks accumulate at the bottom of turbulent flow due to variations in slope angle and channel width. Slow-speed, lobate and high-density grain flows are developed at the base of a relatively high-speed turbulent BAF.

Debris-avalanche blocks from the 1792 debris avalanche, deposited around 3-10 km from the source, are homogeneous and vary in the degree of fragmentation. Due to the weight of the overlying mass and underlying topographical variations, initiation of sliding occurred unequally throughout the mass, resulting in shear stress-induced jigsaw cracks. The sliding mass progressed as a laminar plug flow during the main stage of transport, preserving the jigsaw cracks and angularity. Debris-avalanche matrix formed during initial failure and continued to form during transport from shear stress and entrainment of basement. A dramatic decrease in slope angle caused the sliding mass to disaggregate laterally.

In BAF events, disaggregation of the collapsed lava dome occurred during the initial stage due to the fragile high-temperature lava. In contrast, the disaggregation of the debris avalanche occurred during the transport and depositional stage due to the large volume and low temperature of the debris.

11-O-16

Large Scale Experiments on the Mechanics of Pyroclastic Flows

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A new open-space facility for the experimental study of pyroclastic flows is here presented. The design consists of a cylindrical conduit that is filled with up to 190 kg of pyroclastic material. The base plate of the conduit holds injectors that convey the flow from a charge of 14 litres of compressed gas. The charge is released by the opening of solenoid valves and the impulsive coupling of the gas pressure to the pyroclastic material provokes the propulsion of particles out of the conduit. Depending on the balance between gas overpressure and load of pyroclastic material, expressed as the specific work (SW) of the system, various processes are observed. When SW is higher than 2.6 kJ/kg, a dilute plume develops and particles are deposited simply by fallout. When SW is lower than 1.5 kJ/kg, a high concentration gas-particle column, shortly after exiting the conduit, collapses under its own weight and develops a shear current similar to a pyroclastic flow. The Reynolds number of the shear currents is in excess of 10^6 implying that all the scales of turbulence present in natural pyroclastic flows are replicated by the experiments. The shear currents have velocities proportional to the impact mass flow rate (IFR), which is the ratio between mixture density and impact velocity.Analysis of sensors and video data combined with the grain-size of the particles deposited by the currents suggests that the scale of the experiment is large enough for reproducing the transportation dynamics of natural pyroclastic flows. Two sets of experiments were carried out using a flat and a cone-shaped topography, in order to investigate the effect of landscape morphology on dynamics of PDCs.

11-O-17

TITAN2D Modelling of Block-and-ash flows at Merapi Volcano, Java, Indonesia: Implications for Hazard Assessment

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The May-June 2006 eruption of Merapi Volcano consisted of three eruption phases that produced a complex sequence of dome-collapse pyroclastic flows directed mainly toward the south-western and southern flanks of the volcano. Among these events, the pyroclastic flows are most interesting because their generation mechanisms changed with time. On 14 June, the largest block-and-ash flows reached distances of ~7 km from the summit in the Gendol River valley (southern flank), causing two fatalities and the partial burial of the village of Kaliadem. The block-and-ash flows generated during the peak of activity on 14 June are interpreted as unsteady, rapidly agitated, inertial granular flows with flow regimes where the collisional and inertial forces are higher than the frictional forces. They were generated by sustained, multiple-pulse dome-collapse events over a period of a few hours. The block-and-ash flows generated after 14 June are short- to medium-runout, quasi-steady granular pyroclastic density currents with flow regimes where gravitational and frictional forces are balanced. They correspond to flows generated by short, single collapses of parts of the 2006 lava-dome. Numerical simulations using the TITAN2D geophysical mass-flow model developed at the University of Buffalo, USA (e.g., Patra et al., 2005, J. Volcanol. Geotherm. Res., 139, 1-21), allow reconstruction of the different paths, velocities and extents of these two types of flows and a better characterization of the key parameters that control their flow behaviour. The “TITAN_Thin_Layer” code (Dalbey, pers. comm., 2007) is capable of simulating the large block-and-ash flows of Merapi that occurred on 14 June. The model results provide the basis for estimating the areas and levels of hazards associated with both types of pyroclastic flows and guidance for improving disaster mitigation plans at Merapi.

11-O-18

Motion of Volcanic Fragments in Pyroclastic Density Currents and Volcanic Debris Avalanches as Indicated by Thermo-Remanent Magnetiztion Vectors

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Thermo-remanent magnetization (TRM) vectors of volcanic fragments potentially record the mechanism supporting the fragments in pyroclastic density currents and volcanic debris avalanches, as shown in the 1984 debris avalanche of Ontake volcano, central Japan where lava blocks rotated mainly about a vertical axis. When pyroclastic currents are rapidly cooled down and hot fragments gain TRM immediately before or after their landing on the substrates, the motion of the fragments could be inferred from the TRM vectors. TRM vectors rotate in response to the motion of fragments, and their stereographic projection delineates a circle whose center coincides with a point of the rotation, or does an arc where the rotation is restricted. The latter examples from Japan include the scoria flow of Cape Shiosenomisaki, Oga Peninsula, and the submarine scoria flow of Kasaura, Shimane Peninsula. The sites of their emplacement are likely to have been proximal to the sources and/or watery. Rotation axes for the constituent fragments are inferred from the TRM vectors to be normal to the flow directions, suggesting that sliding, rolling or saltatiing fragments settled on the substrates to incline in response to the local undulation or rugged surface. Single large blocks in block and ash flows of Senyama pyroclastic cone, Oe Takayama volcano in SW Japan record complicated TRM vectors, perhaps reflecting multidirectional rotation in a longer cooling time or by recycling in repeated eruptions.

11-O-19

Recent Developments in Modeling of Tephra Dispersal

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Tephra is one of the main products of explosive eruptions

and can be transported in the atmosphere for long time and distance causing respiratory problems to human and animals, serious damage to buildings and also affecting several economical sectors such as aviation, agriculture and tourism. As a result, the study of tephra dispersal has followed two main directions: (i) the detailed investigation of the dynamics of tephra fallout and (ii) the mitigation of tephra hazards. In particular, the first approach tries to capture the complex processes of particle transport in volcanic plumes and in the atmosphere, whereas the second approach focuses on the analyses of all the possible effects of tephra dispersal on people (e.g. infrastructures, health) and on various economical sectors (e.g. aviation, agriculture). The first approach has produced highly sophisticated models that, due to their complexity, are often difficult to validate with field data and cannot be used for hazard assessments. In contrast, given that probabilistic analyses are typically computationally very expensive, models derived from the second approach often had to compromise the sophistication of the physical formulation for computation speed. Recent advances in computer technologies have helped reduce the gap between the two modeling approaches allowing for more flexibility in the physical models, more reliability and resolutions of probability maps and more rigorous validations with field data. As a result, even though specific processes of particle sedimentation still require an accurate parameterization (e.g. particle aggregation, effects of particle shape on their settling velocity), models for tephra dispersal can now be used to investigate the dynamics of fallout and derive crucial eruption parameters as well as compiling reliable hazard maps and forecast the trajectory of volcanic clouds.

11-O-20

Numerical Investigations of Tsunamis Generated by Pyroclastic Flows from the Kikai Caldera, Japan

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Tsunamis generated by volcanic eruptions in shallow seas can seriously damage coastal areas. In such events, a sudden entrance of pyroclastic flows into the sea is one possible generation mechanisms for tsunamis due to the a rapid transfer of flow momentum into seawater, which transmits the damaging effects of an eruption over large distances, as seen in 1883 Krakatau eruption and 3.6 ka Santorini eruption. The 7.3 ka eruption of Kikai caldera, the largest and notable caldera-forming eruption in Japan during the Holocene, occurred in a shallow sea and was of larger scale than the Santorini or Krakatau eruptions. Recently, the relationship between tsunamis generated by caldera collapse and the respective eruption scale was investigated using simple plunger models with shallow water wave equations and a hypothetical caldera collapse scale was established (Maeno et al., 2006). However, the conditions of voluminous pyroclastic flow entering sea and their impacts are still to be studied in detail. In this presentation, tsunamis generated by a voluminous pyroclastic flow entering sea during the Kikai eruption were investigated numerically, using a two-layer shallow water model, in order to limit them to the source conditions and impacts on coastal areas. Results of numerical computations showed that the maximum height of tsunami was largest when the volume flux was a maximum. The approximate source conditions of the tsunami, which can stir sediment particles on the sea floor, were also investigated, using the Shields-Bagnold non-dimensional boundary shear stress. Results from our simulation showed that threshold shear stress to initiate movement of sediment particles could not be easily achieved in areas where tsunami evidences exists. A caldera collapse is more likely to have generated the huge tsunami rather than a pyroclastic flow.

11-O-21

A non-Newtonian Rheological Law for Highly Crystalline Dome Lavas

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Volcanic eruption models are still hampered by the lack of multiphase magmatic rheology laws. Most rheological models describe lavas as Newtonian suspensions using the Einstein-Roscoe equation or a modification of it. Yet crystal-rich dome lavas are expected to be non-Newtonian, possessing strain-rate dependent viscosities. Experimental investigation of non-Newtonian flow of lava is dearth. Here, experiments using a high-load, high-temperature uniaxial apparatus were carried out to simulate multi-phase lava deformation under various stresses (1-60 MPa) and strain rates (10^{-6} to 10^{-3}) in order to correct this situation. Samples from Unzen, Colima, Anak Krakatau and Bezymianny (containing ~50, 55, 70 and 80 % crystals, and 6, 8, 23 and 9 % vesicles respectively) were chosen for this study. The results obtained reveal that multi-phase lavas do indeed behave non-Newtonianly. They may be described as pseudo-plastic fluids exhibiting an important component of shear thinning. The viscosity of all lavas investigated here decreases exponentially by ca. 1.5 log unit between the strain rates of 10^{-6} and $10^{-2.5}$ s^{-1}. Beyond $10^{-2.5}$ s^{-1} viscous heating and micro-cracking are detected. The effects of varying the crystallinity from 50 and 80 vol% as well as that of varying the interstitial melt's viscosity, were insignificant (+/-0.2 order of magnitude of viscosity). The strong exponential dependence of the viscosity on strain rate (ă) yields a general non-Newtonian rheology law valid for eruption model considering lavas with less than 25% vesicles at 850-1010 ^{o}C and at strain rates between 10^{-6} and $10^{-2.5}$ s^{-1}. These results appear to invalidate the adequacy of Einstein-Roscoe-based formulations for suspension rheology applied to dome lavas. We anticipate that unresolved questions of dome deformation and eruptivity will be better served via this flow law.

11-O-22

18 March 2007 Ruapehu Crater Lake Break-out Lahar: Preliminary Results

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On 18 March 2007, the refilling summit Crater Lake of Mt. Ruapehu, New Zealand, breached a fragile barrier of tephra emplaced during the 1995-96 eruptions, releasing 1.3 million m^3 of water. The flood rapidly bulked by entraining debris along the steep gorge of the upper Whangaehu valley, forming a non-cohesive debris flow within 7 km before debouching onto the Whangaehu Fan where it braided into multiple distributary channels. The lahar collected into a single channel again to continue downstream, reaching the coast 155 km away at c. 3 am the following morning as a sediment-laden flood. No lives were lost and property damage was minimised, largely due to a comprehensive interagency response plan developed over the previous decade.

In the lead-up to the lahar, a comprehensive research plan was developed to to capture maximum scientific benefit from this highly opportunistic event. Key components were: (1) capturing geomorphic changes resulting from the lahar using pre- and post-event high resolution topographic surveys (airborne and terrestrial LiDAR and differential GPS) and vertical aerial and oblique imagery of the flow path; (2) instrumenting the Whangaehu River valley, from the Crater Lake to the coast to collect multi-parameter time-series data; (3) mobilization of observer teams to collect real-time data; (4) stratigraphic logging and granulometric analyses of the lahar deposits; and (5) testing and Calibration of numerical lahar models using the newly acquired data.

By the time the lahar occurred, more than 50 sensors had been installed along the river at over a dozen locations: in combination with multiple observer teams these captured a dataset of unprecedented quality and volume for a single lahar event. This information, once analysed, will inform future models of lahar behaviour that will feed into better hazard prediction and mitigation planning both in New Zealand and globally.

11-O-23

Modeling Lahar Evolution and Runout Behavior

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Lahars represent far-reaching hazards at many volcanoes, able to propagate rapidly to distances >100 km from source. Their danger is exacerbated by their typical sudden onset, which may lack precursory eruptions or other phenomena. Mitigation of the hazards posed by lahars requires an understanding of the factors influencing initiation and downstream evolution of flow properties. Modeling lahar behavior has therefore become the focus of much attention in recent years. A variety of approaches seek to understand the fundamental physics of lahars and the consequences for runout distance and areal inundation. Our work has focused on modeling lahar evolution due to incorporation or loss of additional materials (sediment, water, debris) as the flow propagates downslope. Using a formulation similar to the St. Venant equations, we model the processes of bulking, debulking, and dilution with the inclusion of terms in the conservation equations describing additions or losses of material to or from the flow. In order to calibrate and validate the model, however, comparison with field data is essential. The March 18 2007 Crater Lake lahar at Mt. Ruapehu provided an unprecedented opportunity for model calibration. This event unleashed 1.3 x 10^6 m^3 of water onto the flanks of the volcano, the fate of which was captured by a suite of instrumentation and post-event fieldwork, yielding a data set of unparalleled quality. From these data we derive model boundary conditions, as well as a suite of flow parameters (e.g., velocity, stage height, discharge) for comparison with model output. We will present simulation results for the 2007 event. Once validation is complete, the model will be applied in a predictive capacity for lahars at Ruapehu and elsewhere to derive quantities such as inundation limits, travel times, impact forces and eroded/deposited volumes, which are of key relevance for hazard assessment and mitigation purposes.

11-O-24

Lava Flow Hazard Maps Through Numerical Simulations

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Assessment of hazard by lava flow invasion, through numerical simulations, is presented for the cases of Mt. Etna volcano (Italy) and Nyiragongo volcano (Democratic Republic of Congo). Mt. Etna is a basaltic volcano located on the east coast of the island of Sicily, Italy. Its effusive activity is frequent, occurring from both summit and flank vents. In the last 400 years, about 20% of the total area of the volcano has been covered by lava flows. Similarly, in the last decades, effusive activity was vigorous producing frequent eruptions in the summit craters and no less than 15 flank eruptions. Due to the frequent eruptions and the significant hazard associated to them, Mt. Etna is the natural laboratory to test our approach. Mount Nyiragongo, on the other hand, erupted on January 2002 producing the most relevant case of lava flow impact with a large town ever. Lava flows entered the town of Goma and devastated a significant portion of it, leaving more than 50,000 homeless and forcing the spontaneous exodus of nearly all of the population mainly into neighbouring Rwanda. The produced lava flow invasion probability maps are based on the probability distribution of the future vents and the probability distribution of the length of future lava flows. For both volcanoes, more then 50,000 simulations were performed using a simulation code that is based on the steepest descent path assumption, with spreading of lava flow front and obstacle overcoming accounted for through stochastic variations of the topography. The simulated paths very well reproduced the real lava flow paths for both volcanoes, despite the very different DEM used, with resolutions ranging from 2 to 90 m.

11-O-25

Building a Numerical Volcano: Modeling the Evolution of Effusive Silicic Eruptions

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In this work we develop a numerical model of an effusive silicic volcanic eruption involving time-dependent magma chamber evacuation, conduit flow, and deformation of the surrounding elastic rock. This approach allows us to use multiple datasets (here, both geodetic and dome-growth data) to better constrain magma physics in the chamber and conduit, and also to move beyond the simplistic geodetic source models typically used for the inversion of data. By modeling the changing pressure in the magma chamber over the course of an evolving eruption, we are able to calculate how dome volume and surface deformation (including effects due to the conduit, topography, and material heterogeneity) evolve with time. We fit the model to the full temporal evolution of GPS timeseries and extrusion data using a nonlinear inverse procedure. Applying the model to the ongoing eruption at Mount St. Helens, Washington, allows us to estimate key eruption parameters including magma chamber shape and volume, initial magma chamber overpressure, rate of chamber recharge, magma compressibility, and conduit properties. Further work will allow us to integrate additional datasets into the model, and enhance the model predictive capabilities.

11-P-01

Emplacement Temperatures Determined by Progressive Thermal Demagnetization of Six Volcanic Deposits from the 1990-1995 Eruption of Unzen-Fugendake, Southwestern Japan

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Thermo remanent magnetization (TRM) of lava blocks in volcanic deposits from the 1990-1995 eruption of Unzen-Fugendake, southwestern Japan, is investigated to obtain quantitative data in the form of emplacement temperature to differentiate between pyroclastic- and debris-flow deposits. Progressive thermal demagnetization (PThD) performed in order to remove low temperature components shows that four deposits were emplaced at temperatures varying between 200 and >590 ^{o}C indicating deposition by pyroclastic flow, one deposit was emplaced at ambient temperature indicating deposition by debris flow and one deposit was emplaced at approximately 150 ^{o}C suggesting deposition by a high temperature debris flow. Emplacement temperature is higher in deposits emplaced during periods of higher effusion and dome growth rate.

The relationship between magnetic mineralogy and magnetic remanence is briefly explored with the help of intensity decay curves. Magnetic remanence in unoxidised lava decays uniformly during thermal demagnetization indicating that it is carried by titanomagnetite with ranging TiO_2 content. Remanence in oxidized lava remains stable up to temperatures above 400°C indicating that this is carried by purer magnetite (with low-TiO_2), which also gives rise to a stronger natural remanent magnetization (JNRM) in this type of sample.

11-P-02

Character and Origin of Lithofacies in the Conduit of Unzen Volcano, Japan

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Unzen, western Kyusyu, Japan, is an andesitic to dacitic, polygenetic volcano that reaches an elevation of 1486 m above sea level. A 1996-m-long hole has been drilled on a slanted trajectory passing beneath the volcano, penetrating the conduit zone of the volcano at 30-150 m below sea level. Spot drill cores, totalling 75 m in length, were recovered between lengths 1582 to 1996 m of the hole. The principal lithofacies of the cores are polymict volcanic breccia (74 vol.% of total drill cores), coherent dacite (13 vol.%), coherent andesite (6 vol.%), partly brecciated coherent dacite (5 vol.%), and volcaniclastic vein (2 vol.%). The polymict volcanic breccia is poorly sorted, non-graded and made up of various clasts of andesite/dacite composition, 1-120 cm across, in a matrix of andesite/dacite fragments, up to 5 mm across. The clasts are subangular to subrounded, non-vesicular to vesicular, and contain 62-66 wt.% SiO_2. This facies is interpreted to form the subvertical body of a diatreme, and to have been produced by fragmentation of vent-conduit wall rocks by explosive eruptions and associated gravitational failure. The coherent dacite (SiO_2 = 66-67 wt.%) is uniform to flow-banded and commonly has chilled margins. The dacite is porphyritic containing phenocrysts of plagioclase, hornblende, biotite and minor quartz in a non-vesicular groundmass. This facies is interpreted to represent dykes that have intruded into the polymict volcanic breccia. The coherent andesite (SiO_2 = 59 wt.%) and partly brecciated coherent dacite (SiO_2 = 69 wt.%) are massive to fractured, vesicular and porphyritic. These facies are interpreted to be lavas extruded during the old stage (500-300 ka) of the Unzen volcano. The volcaniclastic veins occur within all the lithofacies described and range from 0.1 to 250 mm wide. The veins consist of volcanic lithic and mineral fragments up to several millimetres across, and are inferred to have formed by injection of high-temperature fluid and entrained particles into temporarily opened fractures. Below 30-150 m sea level the conduit zone is at least 350 m wide in the north-south direction, and consists of polymict volcanic breccia and east-west-striking subvertical dykes. Both single dykes, 4-8 m wide, and composite dykes, 26->44 m wide, are present. Numerous volcaniclastic veins intrude both the breccia and dykes.

11-P-03

Petrochemistry of Juvenile Micro-pumice Detected From Early Tephra Before Lava Dome Appearance in Unzen Volcano 1990-1995 Eruption

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Fugen-dake, the main peak of Unzen Volcano, initiated to erupt on November 17, 1990 after 198 years of dormancy. Following a period of intense precursory activity, a new lava dome appeared on May 20, 1991. Non-hydrated and vesiculated micro-pumice was detected in steam-dominated tephra eruptions after February 12, 1991 and even in phreatic eruption at November 17, 1990. The micro-pumice was considered to be juvenile material from ascending magma. We reexamined these two kinds of clear vesiculated glass shards (micro-pumice). One kind is the colorless micro-pumice which we had found before appearance of the dome. The other kind is brown-colored micro-pumice. Both micro-pumices are non-hydrated and are readily distinguished from pre-existing glassy rocks. In the early tephra of November 1990, silica content of brown glass is about 68% and that of colorless glass is about 77%. Both of these compositions increased about 2% probably due to crystallization during 6 months. We examined the temporal change of the abundance of brown and colorless micro-pumice. Brown micro-pumice content decreases during successive precursory eruptions, and disappears in the dome lava. Although in the dome lava we can find a lot of dark inclusion, the composition of inclusion can be distinguished from the brown micro-pumice in the early tephra. The abundance of colorless micro-pumice increases quickly during precursory eruptions. From these facts, the magmatic process was discussed.

11-P-04

History of Mayuyama, Unzen Volcano, Japan: Inferred from Stratigraphy and Petrological Feature of Borehole Cores

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The Mayuyama volcano is located at the easternmost part of the Unzen volcano. It comprises two lava domes of the Shichimenzan and the Tenguyama. The borehole cores have been obtained from the northeastern flank of the Mayuyama volcano. We have made a detailed growth history and stratigraphy of the Mayuyama volcano by lithofacies and bulk rock chemistry analysis of cores. The borehole cores are subdivided into five geologic units from bottom to top as follows. (1) Pre-Mayuyama volcanic rocks, (2) Mayuyama forming products (early pyroclastic flows), (3) Mayuyama forming products (block and ash flow deposits), (4) Mayuyama erosion deposits and (5) 1792 debris avalanche deposit. Small and sparse biotite with pyroxene phenocrysts are specific to the pre-Mayuyama volcanic rocks. In contrast, large biotite phenocrysts are specific to the essential fragments of Mayuyama forming products, Mayuyama erosion deposits and 1792 Tenguyama debris avalanche deposit. The whole rock SiO_2 contents of pre-Mayuyama volcanic rocks range from 59.8 to 65.7 wt.%. On the other hand, those from essential fragments of Mayuyama forming products, Mayuyama erosion deposits and 1792 Tenguyama debris avalanche deposit range from 65.1 to 66.5 wt.%, which overlap with outcrop samples of the Mayuyama volcano. Early pyroclastic flows are monomictic and contain vesicular blocks and their ash. They are distributed around eastern flank of the Shichimenzan, although they are fully buried beneath the following block and ash flow deposits and erosion deposits. However, no Mayuyama forming products are observed around eastern flank of the Tenguyama. This can be explained by (a) no supply of Mayuyama forming products, or (b) 1792 Tenguyama debris avalanche eroded Mayuyama forming products, or (c) Mayuyama forming products lie deeper in this area.

11-P-05

Geochemical Evolution of Unzen Volcano: Analysis of Drilling Cores from USDP-3

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Unzen volcano is an active volcano in SW Japan. Its eruptive products are composed of hornblende andesite to dacite lava domes, lava flows and pyroclastics. Unzen volcano reopened the eruption in 1990 and the extrusion of dacite lava continued from 1991 until 1995. The Unzen Scientific Drilling Project (USDP) started in 1999. After two drillings at the flanks of Unzen volcano (USDP-1 and -2), and one pilot drilling (USDP-3), the conduit surveying well was drilled on the northern slope of the Unzen volcano (USDP-4). In this study, we made systematic analysis of major and trace elements compositions for USDP-3 borehole (352 m in total length) samples in the purpose to investigate the geochemical evolution of the Unzen volcano. USDP-3 samples have radiometric ages in the range 100-210 ka (Matsumoto et al., 2005), correspond to those of Middle (150-300 ka) to Younger (0-150 ka) Unzen volcano. The whole rock SiO_2 contents of USDP-3 samples range from 59 to 65 wt.%, which overlap with outcrop samples of the same ages such as Nodake volcanic rocks. In the SiO_2 contents of samples versus drilled depths diagram, several steps are evidently observed chemically, where SiO_2 content increased with time. At the depths of 100 m and 169 m below the surface, SiO_2 contents decrease suddenly, suggesting each chemical steps started at these depths with the input of high temperature magma into a magma chamber. On the other hand, another SiO_2 change observed at a depth of 322 m below the surface. This is explained as due to a concealed fault inferred from radiometric ages of core samples (Matsumoto et al., 2005). Thus, at least three chemical steps can be recognized in the USDP-3.

11-P-06

The Movie Record of the Growth of Lava Dome for 5 years

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The first appearance of Lava Dome was 7 a.m., May 19th, 1991. 30 hours later, the lava lobe grew 30m high. The rate of the growth was about 1m/h. Since then, 13 lava lobes had grown one after another with pyroclastic flow. The growth of the lava lobe was so slow (20m/day) that we could not recognize the movement of the change. To keep a record of the growth of the lava lobe, I took more than 13,000 pictures at the 4 fixed places, located in the eastern part of Mt. Fugen. One of the four places was Shimabara Upper Secondary High School and I took pictures almost every day except for the days when I could not watch the lava lobe. I used 400mm telephoto lens. I had much difficulty in taking clear pictures because that place is 8.5km distant from the lava dome. Even when it was fine, the dome was covered with ashy air. All the pictures were digitized and the images processed by PC, so that we can see cleared pictures with presentation software. Moving pictures quickly, we can watch the animated pictures of the growing lava dome. This is the first movie of 'The Growth of Lava Dome' in the world recorded from the birth to the end.

11-P-07

Magma Chamber Model of Unzen Volcano Causing 1990-1995 Eruption Inferred from Seismic and Ground Deformation Data Using FEM

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Based on previous studies, the eruption of Unzen Volcano in 1990 was caused by ascended magma from deep part of Chijiwa bay toward the crater (Ohta 1972; Umakoshi *et al.*, 1994 and Kohno *et al.*, 2005).

The hypocenter of the earthquakes swarm, which occurred around Unzen area during 1989, 1990 and migrated to eastward from beneath Chijiwa Bay, is described clearly by Umakoshi *et al.* (1994). Furthermore Umakoshi *et al.* (2001) made clearly the result by applied mechanism solution around Unzen volcano.

In previous study (Kohno *et al.*, 2005) by used three types of ground deformation data: leveling, GPS and tidal data, we conclude there are four point magma sources beneath this area. The magma sources were arranged as ascending start from under Chijiwa Bay to eastward the crater, with the deepest source around 15 km.

The result showed there is similarity with previous study (Umakoshi *et al.*, 1996), however there are some inconsistent points in Umakoshi *et al.* (2001). In our study we used assumption sphere shape for the point sources; nevertheless in Umakoshi *et al.* (2001) some seismic mechanisms cannot explain the consistency of the spherical magma reservoir shape, inferred from geodetic data.

To solve this inconsistency, we apply Finite Element Method (FEM) to consider the shape of magma sources for Unzen volcano based on ground deformation and earthquake mechanism data. Concerning ground deformation data, we use leveling data (1986-2004), GPS data (1996-2004), and tidal data (1996-2004) around Shimabara peninsula for this study. For seismic data around Unzen Volcano, we refer to Umakoshi *et al.* (2001) result. The purpose of this study is to get realistic model during eruption (1990-1995) until now and understand the system of magma supply of Unzen Volcano.

11-P-08

Silicified Rock at the Unzen-Jigoku Steaming Ground, Nagasaki, Japan

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The Unzen-jigoku is located at the central part of Shimabara Peninsula, about 3.5 km to the southwest of Mt. Fugen-dake. Advanced argililic alteration zones are dominant in and around the jigoku due to the present acid-sulfate steam-heated waters. Among the jigoku, silicified rock mainly composed of quartz is distributed at the Old-Hachiman-jigoku. Fluid inclusions from quartz veins in the rock suggest that the rock was formed in two phase fluids under 170 to 220 °C at a depth of about 100m. Moreover, dickite occurs from a kaolin zone surrounding the silicified rock at the southwest of the rock. Some of sulfur isotope data of alunite minerals occurred near the silicified rock indicate a hypogene origin, although many of alunite minerals were formed under steam-heated water. Such alteration features introduce to a conclusion that the silicified rock at the Old-Hachiman-jigoku was formed under a volcanic acid fluid environment above 200°C, which was eroded out at least 100m and located at the present surface. The degree of the erosion seems to be largeer than that of nomal weathering condition.

11-P-09

The 1792 Mt. Mayuyama Debris Avalanche, Unzen Volcano, Japan: Implications from Field Characteristics, Granulometry, and Clast-shape Analysis for Transport and Emplacement Mechanisms

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The 1792 collapse of the eastern flank of Mt. Mayuyama, Japan, a hornblende-dacite lava dome associated with Unzen volcano, generated a destructive debris avalanche that entered the Ariake Sea, resulting in >15,000 fatalities. The transport and emplacement mechanisms of the resultant debris-avalanche deposit have not been extensively studied.

Block-facies deposits, the most common deposit type, are often observed in sharp contact along irregular boundaries and typically consist of poorly sorted, structureless, jigsaw-fractured, portions of the original edifice varying in the degree of fragmentation. Matrix-facies deposits are infrequent and comprise poorly sorted, structureless mixtures of the overlying block facies

and foreign material, often displaying ductile-deformation structures.

As the median-grain diameter decreases, the degree of sorting worsens among block- and matrix-facies deposits. Block-facies deposits display an overall decrease in the gravel content, increase in sand, and essentially no change in mud with distance. In general, granulometry data from the Mt. Mayuyama deposit compare well with data from relatively coarse-grained debris-avalanche deposits that do not have an accompanying explosive component. Clast-shape analysis involving five parameters shows differences between the shapes of particles from block- and matrix-facies deposits; however, neither facies type demonstrates appreciable changes in clast shape with distance.

Block facies were transported in a laminar-plug flow gliding on a thin layer of matrix facies in the avalanche base and along the margins where most of the shear strain was concentrated. Matrix facies formed during the initial failure stage from grinding between the overlying sliding mass and the substratum, assuming a temporary turbulent behavior. Irregularities in the subterrain caused disaggregation, dilation, and slight deformation of heavily fractured blocks during transport. Deceleration due to a dramatic lessening of the slope resulted in a graduated cessation of movement from the base to the upper portions of the deposit, resulting in lateral disaggregation that formed hummocks.

11-P-10

Utility of Aeromagnetic Studies for Imaging of Subsurface Structures in Two Active Volcanoes: Unzen and Sakurajima Volcanoes, Kyushu, Japan.

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Aeromagnetic analyses have been conducted in Unzen and Sakurajima volcanoes, Kyushu, Japan, in order to reveal the subsurface structure.

In Unzen volcano, the characteristics of the magnetic structure are summarized as follows; (1) it turns out that the Unzen graben has the features of a half-graben, with the northern fault (the Chijiwa fault) down in the western Unzen region and the southern fault (the Futsu and Fukae fault) down in the eastern Unzen region. Moreover, it clarified that the layers of low magnetization extend to the near surface beneath Shimo-Dake, Kami-Dake, and the Unzen hot spring. (2) Local magnetization lows on Heisei-Shinzan suggest that the Heisei lava produced by the 1991-1995 eruption has not yet been cooled enough. (3) Magnetization lows lie outside of the Unzen graben, corresponding to debris flow deposits and pyroclastic-flow deposits of the Older Unzen (500-150 ka). Magnetization lows, corresponding to fan deposits of the Older Unzen (500-300 ka), are distributed along the Chijiwa fault. In contrast, magnetization highs are distributed in the northern part region of Azuma-Dake and Hachimaki-Yama and around Takaiwa-Yama, where the lava of the Older Unzen (500-300 ka) is exposed.

In Sakurajima volcano, the obtained magnetization intensity map was discussed with surface geology, rock magnetizations for the selected volcanic units, and geothermal activity. Magnetization highs distribute over several lava flows and a weak but significant correlation with intensities of NRM and total magnetization for corresponding lavas were found. In contrast, magnetization lows are locally distributed around the Showa crater and north of active craters of Minamia-Dake, probably reflecting the recent geothermal activity.

11-P-11

Hydrothermal System Inside Unzen Volcanic Terrain by Alteration Analysis of Conduit Drilling, USDP-4

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The conduit drilling USDP-4, International Cooperative Research with Scientific Drilling for Understanding Eruption Mechanisms and Magmatic Activity, begun at the site of about 840m above sea level on the northern side of the Mt. Hesei-shinzan in 2003. In July 2004, the drilling head reached the conduit corresponding to the 1990 eruption and all of the drilling operation was over. The length of the all USDP-4 drilling hole is 1995.75m. Cuttings were sampled at every 2m point of the drilled hole and sixteen cores were sampled at the points deeper than 1582m. The drilled cores consist of hornblende-bearing andesite to dacite lavas or pyroclastic rocks. Alteration minerals in the cores show lower formation temperature than general geothermal fields at surface. In addition, surveyed temperature in the drilled hole showed lower than 200°C even around the conduit. Most of the alteration minerals such as smectite, chlorite and pyrite in the core occur generally good correlation with the depth. On the other hand, some minerals such as kaolinite occur along fractures. Therefore, it is considered that the relative high temperature solution rose along the fractures or faults which could provide good pathways for volcanic related fluids. In addition, it is considered that tuffisite veins have also become good pathways during the hydrothermal period. Calcites occur as veinlets at the depth shallower than 1900m. Stable isotope ratios, carbon and oxygen, were measured for the calcites in the cores and cuttings. The carbon isotope values are almost same, being independent of the depth. The oxygen isotope values show a tendency to be lower at the deeper positions. These alteration minerals and the isotope compositions indicate that the hydrothermal system circulates with a large scale inside the Unzen volcanic terrain and becomes higher temperature withe the depth.

11-P-12

Eruptive Conditions of the Last Three Historical Eruptions at Unzen Volcano, Japan, Identified by Magnetic Petrological Analyses

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Unzen volcano in southwest Japan is one of the most active volcanoes in Japan. The most recent activity was the 1991-1995 eruption, which led to the emplacement of lava domes and the generation of numerous block-and-ash flows following dome collapse. Recent studies revealed a lava dome eruption is a familiar mode of eruption for Unzen volcano. However, two historical eruptions before 1991 produced lava flows in 1663 and 1792. In order to clarify the eruptive conditions of the last three eruptions at Unzen volcano, we carried out magnetic petrological analyses on the 1663, 1792 and 1991-1995 lava samples.

Our results indicate that three kinds of lava samples show distinct magnetic behavior and iron-titanium oxide mineral assemblages. All samples contain two kinds of titanomagnetite with different Ti content. Ti-poor titanomagnetite whose Tc is about 450 degrees C is commonly found in three lava samples. However, each lava shows another Ti-rich titanomagnetite with distinct Ti content. Ti-rich titanomagnetite in the 1991-1995 lava shows the highest Tc of about 350-400 degrees C. The 1792 lava shows lower Tc of about 300 degrees C and the 1663 lava shows the lowest Tc of about 200 degrees C. This indicates that Unzen samples are derived from two magmas with different temperature and temperatures of the high-T magma differ among three lavas. The amount of low Tc titanomagnetite increased from 1663 lava to 1991-1995 lava. This suggests that the relative amount of high-T magma differs among the three lavas. This difference of magma temperature and relative amount of high-T magma probably causes the different mode of eruption and the different fluidity of three lavas.

11-P-13

Geochemical and Hydrological Studies on Groundwaters around Unzen Volcano: With Reference to Dispersion of Magmatic Volatiles through Groundwater Flow System

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Unzen volcano (1486 m in elevation) is developed on the western part of Beppu -Shimabara graben (20 km NS wide and 200 km EW long) located at Kyushu Island, SW Japan. We have been studied groundwater system of the volcano using geochemical and hydrological techniques in order to estimate flux of magmatic volatiles through the groundwater. The results of water chemistry and stable isotopes in over 400 water samples including springs, rivers, and wells are as follows. The groundwater have elevated HCO_3^- concentrations in the Unzen graben, especially on the E-W faults in the Shimabara area, being inconsistent with the uniform hydrogen and oxygen isotopic ratios observed there for the groundwaters. Even shallow groundwaters contain large amount of magmatic helium with high $^3He/^4He$ ratio, about 7 times higher than the atmospheric value in the eastern part of the Unzen graben. This value is almost identical as those in thermal water of this region (Shimabara Spa). The $^3He/^4He$ ratios of hot springs around Unzen volcano show an increase from west to east in the Unzen graben (Obama < Unzen < Shimabara) which is consistent with previously determined by Kita et al. (1993) and Notsu et al. (2001). Non-uniform HCO_3^- distribution and high $^3He/^4He$ ratio with high concentration in the eastern side of the graben may result from the addition of magmatic gases ascending along the faults. The difference in $^3He/^4He$ ratios among the hot springs around Unzen volcano would reflect the difference in residence time in thermal water reservoir and/or difference in the fluxes of magmatic gas components in each region.

11-P-14

Seismic Reflection Survey of the Crustal Structure beneath Unzen Volcano, Kyushu, Japan

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Unzen volcano is located in the western part of Kyushu, Japan. We carried out a seismic reflection survey to elucidate the structure of the volcano and the mechanism of eruption which occurred during the period 1990-1995. We performed the survey experiment in the volcanic area under the ill-conditions due to erosion, exploitation, artificial noises, and complex structures consisting of lava and deposits. Using vibrator sources and large number of stacking signals, we resolved the detail structure beneath the profile. Processed depth sections confirmed that Unzen volcano grew in a graben structure, as suggested in other geological studies. We imaged many subsurface normal faults shallower than 1 km that were not only identified at the surface but were also covered with volcanic lava and deposits. Strong reflectors were found at a depth of 3 km. Its horizontal location corresponded to just above the pressure source of the last eruption inferred from geodetic data.

11-P-15

Resistivity Structure of Unzen Volcano Derived from Time Domain Electromagnetic (TDEM) Survey

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TDEM surveys in Unzen region have revealed the large scale resistivity structure of the Shimabara Peninsula. In the shallow part of the of the peninsula, a conductive layer is found and distributed widely around Shimabara Peninsula at depth ranging for about 100 m to 2.5 km

below sea level indicating the existence of a water-saturated and altered layers in the area. High conductivity due to the supply of volcanic gases into the water saturated layer, represented as high conductance zones is found between inside the Unzen Graben. A high conductance zone trending W-E direction in the shallow part is also found at around the western part of the peninsula toward the summit. This zone is correlated strongly with the pattern of the frequent swarm earthquakes that started relatively long before the 1991-1995 eruption indicating the repeating emission of volcanic gases into the shallow water layer through the fault system in the western part of Unzen, which affects the degassing efficiency during the magma migration of the latest eruption. Another zone, the highest conductance zone, is located around the northern part of Mayu-Yama. This zone is correlated with the high spatial distribution of volcanic gases as inferred from geochemical studies that traced the escape of volcanic gas from a deeper magmatic source, and might indicate the presence of magma beneath Mayu-yama.

11-P-16

Determination of Surface Area of Silicic Magma

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Measurement of the surface area of volcanic products is still quite rare in the field of volcanology and mostly restricted to ash samples. The surface area of rock samples is supposed to react much more sensitive to cracks and fractures, as for instance the porosity, especially in the case of moderate to highly porous samples. Thus the surface area may allow shedding light on late-stage processes during emplacement and cooling of silicate melts. In this context, it has to be distinguished between the primary surface of a rock and secondary processes affecting this value. Thermal cracking, fragmentation, and secondary mineralization lead to increased values of the surface area. This yields important information on the strength as well as alteration of the natural material and its behavior in a stress field.

Based on gas sorption theory, we analyzed the surface area of volcanic products from Unzen Volcano and Montserrat. Entire rock cylinders as well as pyroclasts generated during rapid decompression experiments and natural ash samples were measured following the multipoint method of Brunauer-Emmett-Teller (BET). With the estimated surface area increase and the fracture-surface energy of silicic rocks from literature we are able to quantify the amount of energy consumed to create new surface during a fragmentation event to be in the order of a few percent.

11-P-17

Diffusive Degassing of Magmatic CO_2 around Unzen Volcano, SW Japan

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Spatial distribution of diffusive CO_2 flux from ground surface around Unzen volcano, SW Japan, was obtained in order to assess the significance on magmatic CO_2 degassing processes. The field campaigns were carried out during the quiescent period, from 2001 to 2004. We observed CO_2 flux, soil air CO_2 concentration and carbon isotopic composition at 219 observation sites in the Shimabara peninsula. The magmatic CO_2 contribution in CO_2 flux was estimated by the carbon isotopic mass balance using soil air CO_2 concentration and carbon isotopes, both $^{14}C/^{12}C$ and $^{13}C/^{12}C$. As carbon isotopic composition in soil air CO_2 is higher than that of CO_2 released from soil surface caused by molecular diffusion, $\delta^{13}C$ and $\delta^{14}C$ values of soil air CO_2 were corrected for almost sampling locations, excepted as those in fumarolic areas where degassing process is not controlled by molecular diffusion.

The most of the observation sites detected magmatic CO_2 is located inside Unzen graben. The degassing style is found to be different between east and west areas where areal and pin-point degassing occur, respectively. Magmatic CO_2 emission is spread even outside the graben in the eastern area. The contrast of magmatic CO_2 flux between east and west areas is likely related with some geological features: location of volcanic peaks, fault activities and age of sediments. The fault system seems to have two roles: a barrier for magmatic CO_2 transportation beyond the fault zone, and an ascending path of magmatic CO_2 along the fault. An integration of isogram of magmatic CO_2 flux using interpolation algorism provided the total flux around Unzen volcano, showing much larger value than that from the summit degassing during the quiescent period. The above-mentioned feature found in spatial distribution of magmatic CO_2 flux may indicate that CO_2 directly ascends from deep magmatic sources inside the graben.

11-P-18

Groundmass Crystallization Process in the Dacite Dikes of Unzen Scientific Drilling Project 4 (USDP−4)

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The groundmass textures and compositions of the dacite dikes of the Unzen Scientific Drilling Project 4 (USDP−4) were analyzed for understanding the groundmass crystallization and degassing processes during magma ascent or the emplacement history beneath the Unzen volcano. In the drilling depth range of 1582.2−1995.75 m ("conduit zone"), drilled samples can be classified into four apparent dacite dikes (1607−1615 m dike, 1634−1638 m dike, 1763−1789 m dike, and 1954−1995.75 m dike). The typical groundmass textures of these dikes reveal an annealing-like texture ranging from cryptocrystalline to microcrystalline with an equigranular mosaic of plagioclase, alkali feldspar, quartz, and pyrite (<10 μm) with a small abundance of coarser-grained plagioclase microlites ranging from 10 μm to 0.3 mm in

size. The ternary diagram of the Qz'－Ab'－Or' system in the finer grains (<10 μm) of the groundmass composition exhibits a ternary minimum at a lower pressure (<50 MPa), suggesting that the crystallization of plagioclase, alkali feldspar, and quartz occurs simultaneously. A comparison of the compositions of the coarser grains of plagioclase microlites and groundmass, the plagioclase microlite textures, and the mineral assemblage between most of the dacite dikes and the historical eruption at the Unzen volcano revealed characteristics that were quite different. This implied that the dacite dikes experience different pressure－temperature conditions and residence times in the conduit, similar to the magmas that previously erupted at Unzen and extruded to the surface. Despite these general features, only the C14－1－1 (1977.4 m in drilling depth) sample showed compositional and textural features similar to those of the last eruption products. This implied that the C14－1－1 sample may be a feeder dike that was connected to the surface in the 1990－1995 eruption. The vesicularity of the C14－1－1 sample is low (～10 vol.%) and its vesicle texture is characterized by small isolated spherical bubbles that form a network around microlites and phenocrysts, suggesting that the escape of gas may have occurred below/at this depth (40 MPa).

11-P-19

Characteristics of the June 3, 1991 Pyroclastic Surge at Unzen Volcano, Kyushu Island, Japan, and Implications for Disaster Mitigation

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The dome building eruption of Unzen Volcano (1990-1995) displayed destructive aspects of block-and-ash flows in Shimabara City. 16 years passed from the June 3, 1991 eruption resulted in the deaths of 43 people by pyroclastic surge. After that surges are causing deaths at Merapi (1994) and Soufriere Hills (1997), it's a most important program to predict the risk from surges for hazard assessment. This study focuses on the generation of surges in special relation to topographic control. On June 3, 1991, a major block-and-ash flow descended the eastern slope to cascade down a steep cliff in Mizunashi River. Surge was spread over the hill 3 km from the cliff. It traveled with great speed and force, and intence heat to kill 43 people in Kita-Kamikoba. The deposit consists of well-sorted coarse ash, few centimeter thick. In axial zone many buildings and trees above basement levels were removed or burned. While in peripheral area buildings remained standing with damages, but almost buildings were secondary burned during few hours. In the depositional area only 2 millimeter thick, All people were dead in and out the buildings with heavy damages. Flow directions of the surge based on damaged trees show a radial pattern from the bottom of the cliff n Mizunashi River. Closer to the cliff the deposits are thicker and coarser. These suggest that the surge was generated at the bottom of the cliff. Similar surge deposits were recognized on June 8,1991, September 15, 1991, and June 23,1993. These case studies have a similarity that surges were triggered by cascading down topographic gaps of a large volume block-and-ash flows, involving spontaneous fragmentation of large hot blocks and violent expansion of released gasses initially at high pore pressure. The disaster potential for such violent surges has a clear implication for volcanic hazard assessment.

11-P-20

Crustal Velocity Structure beneath Unzen volcano

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Tomography structure of Unzen volcano was clearly imaged in this present study. The results are described a velocity pattern with high resolution, particularly 20 km beneath sea level. It is revealed that: High velocity anomaly was found in the shallower part (1 km below sea level) beneath the Unzen volcano. Further more low velocity anomaly was found beneath Chijiwa bay western part of Unzen volcano with the deep around 15 km, and the anomaly extend to region around 5 km toward beneath the Unzen volcano. The low velocity seems to correspond with seismicity and pressure sources inferred from crustal deformation survey. The hypocenter distribution are located on the edge of the low velocity area, moreover the pressure sources are placed at the low velocity area, this indicates that the region with low velocity anormaly possibly the path of magma. Detail structure of the low velocity anomaly will present in this discussion.

11-P-21

Scatterer Distribution beneath Unzen Volcano

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While the volcanoes give us many benefits such as hot springs and geothermal heat, it may bring serious disaster when the volcanoes erupt. In order to proceed understanding volcanic eruption, it is important to know the structure of volcanic body where the phenomena occur. Especially, the location of the vent and magma reservoirs is important to understand shallow magma process and to design observation network to catch precursory phenomena.

We found scatterers beneath Unzen volcano by seismic array analysis using the seismograms recorded in the stations of SEVO, Kyushu Univ. during the seismic reflection survey was carried out in 2001. The stations are far from the survey profile. In the result of array analysis, we found scatterers at almost same position of pressure sources inferred from geodesical data. They are located on the path where hypocenters migrated from Chijiwa bay to the summit just before the eruption. Ohta (1973) suggested a magma ascent model estimated from chemical study on hot springs. In that mode, the magma ascends from deep magma reservoir under Chijiwa bay to the summit. Therefore it is inferred that they are magma reservoirs.

11-P-22

Numerical and Geosciences Investigations of Obama Geothermal Field, Western Flank of Unzen Volcano

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The Obama geothermal field is located in the western side of Kyushu Island, southwestern Japan. For the detailed understanding of the Obama geothermal field, a numerical simulation technique has been carried out at the Obama geothermal field after combining gravity and hydrogeochemical results. The reservoir occurs in the Obama area at around 1000 m depth. The reservoir consists of Pliocene-to-Quaternary volcanics. The Obama geothermal field is located within the volcano-tectonic depression zone. The superficial part of the reservoir has a direct connection with the cold sea water interface. Many surface manifestations can be seen at the surface (geyser, hot springs). The groundwater is in most cases of meteoric origin. However, in this area of Obama it is partially marine. The heat source is considered to be magmatic. The temperature of the geothermal reservoir is around 200-250 ^{o}C. A conceptual model of the Obama geothermal field has been presented based on current knowledge of the geology, hydrology, and chemistry of the system. The model shows that in the transient state the central part of the field is subject to a hot upflow (enthalpy of 400 kJ/kg and mass flow of 30 kg/s) of geothermal fluid at depth connected with the faults of the Obama geothermal field, and a much larger cross-downflow of meteoric and cold groundwater, which enter from the east at different levels. From the simulation results, a high enthalpy lateral inflow is observed, which enters the modeled area from the east. This superheated steam flow is characterized by a high enthalpy of 3200 kJ/kg and a mass flow of 300 kg/s, which is supposed to be related with a shallower magma. The estimated heat flux from the two heat sources is around 1010 MW. The Obama geothermal field can be used much more for various kinds of geothermal energy utilization.

11-P-23

Year-to-year Change in Self-potential on Unzen Volcano

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Many previous studies have reported positive self-potential anomalies around geothermal areas or active craters of volcanoes. Several mechanisms have been proposed for such self-potential anomalies. Among them, the streaming potential due to subsurface fluid flow is widely believed to play a major role in generating the self-potential. Thus, some self-potential change associated with an eruption is expected. The author is monitoring the self-potential on Unzen volcano by repeat surveys since 1991. In Unzen self-potential has shown dramatic increase in association with the lava dome extrusion in 1991 (Hashimoto and Tanaka, 1995; Hashimoto, 1997). Mapping just after the eruption has revealed that the new dome (Heisei dome) is about 1 volt positive to the peak of Fugendake, the previous summit, and that areas of lower elevation in the horseshoe-shaped caldera (Myoken caldera) are also positive. This feature is probably produced by the developing hydrothermal system due to the eruption and probably by the anomalous conductivity around the new vent as well. It has been basically maintained through the eruptive period to the present. The author's repeat surveys have revealed that the self-potential continued to change markedly for several years even after the eruption ceased, but turned into overall decrease since 1997. This declining trend, however, has almost stopped in most area after 2000, except for the NW part of the Heisei new dome. It is inferred that the self-potential in the western part of the new dome, under which the latest vent is probably located, had considerably elevated just before the eruption and that the positive anomaly is now recovering to the initial state.

11-P-24

U-series Disequilibrium Dating applied to Zircons from Unzen volcano

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Uranium disequilibrium dating was applied to zircons separated from the Unzen volcanic rocks to estimate zircon crystallization ages, which are further considered to understand magma chamber behaviour. U^{238} and Th^{230} concentrations were estimated using the LA-ICP-MS system at Kanazawaza University with NIST610 glass as an external standard and Si^{29} as an internal standard. Initial incorporation of Th^{230} into a crystal was estimated based on the U^{238} concentration of the dated zircon and Th^{232}/U^{238} ratios of zircon and volcanic glass. After testing the several laser ablation settings to obtain significant Th^{230} signal intensities, crystallization ages were calculated. The 1990-1995 eruption contains zircons as old as >10 ka (10-400 ka), suggesting that the latest volcanic activity was the result of magmatic activity which lasted since ~400 ka.

11-P-25

Phreatomagmatic Explosions and Block-and-ash Flow by Activity of the Dacite Lava Dome: the Okanotake Lava Dome of the Futago Volcano Group, SW Japan

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The Okanotake lava dome (biotite-hornblende dacite) is composed of the early Pleistocene Futago Volcano Group distributed in the Kunisaki Peninsula, SW Japan. We investigated the volcanic products by activity of the Okanotake lava dome. In the early stage of activity, the lapilli tuff layer of 70-m thick deposited to northwestward of the Okanotake. The lapilli tuff layer consist of about 30

flow units, the lower part include many basement rocks, the upper part is dominated by the lapilli of biotite-hornblende dacite. Impact structure and cross-lamination of the feature in the pyroclastic surge deposits are observed in some layers. These scarcely contain the volcanic glass. It implies that the dacite lava of high temperature contacted the water and exploded. It is considered that such explosions are the phreatomagmatic explosions in wide sense. Such activity by the dacite lava dome has not been reported so much. Then, the Okanotake lava dome had been grown. Consequently, a lava dome collapse type block-and-ash flow occurred and deposited 5m thick on the lapilli tuff layer. Finally, several dikes (biotite-hornblende dacite) intruded in the lapilli tuff layer.

11-P-26

Progradation Structure of Pyroclastic-Flow Deposits Revealed by GPR at Merapi Volcano, Indonesia

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Pyroclastic-flow deposits'structures have been poorly studied onsite, and most of the times are relying on outcrops visuals or outcrops comparison with geophysical surveys. In order to assess these internal structures where no visual is available, we conducted a GPR – Ground Penetrating Radar - survey on a pyroclastic-flow deposit on the Southern flank of Merapi volcano in Indonesia during its last eruption in 2006. The field study was carried out with 50Mhz, 100Mhz, and 500MHz antennas, and the data treatment done under Reflex® software. Results are highlighting the deposit' structure, which is composed by progressive progradation, each layer overlapping each other. The GPR profile is also showing a previous pyroclastic deposit, covered by the latest event, and eroded by this one. Then, we could calculate the pyroclastic-flow deposit volume quite accurately, since the GPR profile provided us the exact base of the deposit, taking into account the previous erosion processes that could have occurred before the deposition process. Thus, GPR surveys can be a precious help to understand pyroclastic-flow deposits' structure and volume when no visuals are available, and also a way to measure the erosion potential if a pre-event fine topography and GPR survey is conducted.

11-P-27

Simulation Modell of Pyroclastic Flow Considering 3-dimensional Topography

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Flows consisting of solid particles mixed in gas, referred to as gas-solid two-phase flows, can be observed in a wide variety of phenomena in nature. One of such phenomena is a pyroclastic flow, which is a fluid of pyroclastic materials (e.g., volcanic ash and lapilli) mixed in air that flows down the slope of a volcano after eruption into the air by volcanic activity. Japan has many active volcanoes and thus many regions that are vulnerable to disasters caused by pyroclastic flows. Mt.Fugen volcano in Nagasaki Prefecture erupted in 1990 releasing several pyroclastic flows. Of particular note was the disastrous flow of June 1991, which took 43 lives, including those of journalists. To mitigate such disasters, it is essential to develop models for analyzing the motion of pyroclastic flows, to predict the characteristics of motion by numerical modeling, and to use the findings to create hazard maps and design disaster mitigation facilities. In this study, a set of fundamental equations based on hydrodynamic principles is developed into a model for pyroclastic flows. In addition to predicting the main parameters such as flow velocity, a 3-dimensional topography data mesh is employed as one of the input parameter sets, allowing analysis of the likely path and width of pyroclastic flows from any selected flow origin on the topography. And proposed numerical model is applied to real field in Mt.Fugen volcano in Nagasake Prefecture.

11-P-28

Characteristics of Merapi-type Pyroclastic Flow Deposits Observed on the 2006 Mayon Lava Flow

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Merapi- type pyroclastic flows generally form by non-explosive disintegration and collapse of flanks of domes and unstable lava flows. In the case of pyroclastic flows generated from lava collapse, the resultant pyroclastic flow deposits commonly form near the fronts and sides of lava flow. At Mayon Volcano, we have recognized the deposits of merapi-type pyroclastic flows occurring on top of the 2006 lava flow.

The merapi-type pyroclastic flow deposits occur as large blocks or short pinnacles, about 2 m high, scattered above the 2006 lava flow. Except for the indurated nature of these deposits, they show similar characteristics to typical merapi-type pyroclastic flow deposits such as poor sorting, absence of stratification and limited aerial distribution. The deposits can be distinguished from the autobrecciated portions of the lava flow by their characteristics, which consists of rounded to subrounded dense, highly oxidized juvenile lapilli to boulder lapilli set in coarse ash matrix.

Grain size analyses of representative samples show a uniform distribution of coarse (> 0 φ) and fine (< 0 φ) size fractions with a peak on the biggest size fraction (-4 φ) indicating block-and-ash pyroclastic flow deposits.

Video footages and photos of the 2006 eruption show that pyroclastic flows were generated when portions of cascading lava near the vent detached and fragmented forming Merapi-type flows. Some of the deposits must have been emplaced on top the still moving lava flows; some were carried as far as the lava front, more than 7 kilometers away from the crater.

11-P-29

Block-and-Ash Flow Deposits of the 2006 Eruption of Merapi Volcano, Java, Indonesia

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A series of pristine block-and-ash flow deposits from the May-June 2006 eruption of Merapi constitute an exceptional record of small-volume pyroclastic flows generated over a period of approximately two months. Associated deposits form at least ten overlapping lobes reaching ~7km from the summit in the Gendol River valley on the volcano's southern flank. These represent a record of successive flows generated during and after the major dome-collapse event on June 14. Both, single pulse (post-June 14 events) and multiple-pulse pyroclastic flows generated by sustained dome collapses on June 14 are recognised and three types of deposits are distinguished: (1) valley-confined basal avalanche deposits in the main Gendol river valley, (2) 'overbank' deposits, where parts of the basal avalanche spread laterally onto interfluves and were subsequently channelled into the surrounding river valleys and (3) dilute ash cloud surge deposits along valley margins. Surface particle assemblage analyses of different lobe deposits reveal variations in the abundance of the main lithological components from proximal to distal reaches. Moreover, the variations in distribution, surface morphology and lithology of the deposits are strongly related to varying modes of transport and deposition of the different flows. The minimum temperatures of the largest block-and-ash flows generated on June 14 range between ~400 C for the basal avalanche and ~165 C for the overlying ash-cloud. Inferred flow velocities vary from 44-14m/s for the basal avalanche and from 63-24m/s for the ash-cloud surge. Due to the ability of being rechannelized into adjacent river valleys and of flowing at high angles to the main basal avalanche flow direction, the 'overbank' flows are considered the most hazardous part of the block-and-ash flow system. The conditions that lead to their development during flow transport and deposition must be taken into account when assessing future pyroclastic flow hazards at Merapi.

11-P-30

Particle Array and Flow Direction of the Sanbe Pyroclastic Flow, Western Japan

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Direction of the lineation of elongated fragments and anisotropy of magnetic susceptibility (AMS) of the crystals and lithic fragments were measured for the Sanbe pyroclastic-flow deposit that had erupted about 30,000 years ago accompanied with caldera formation. The measured lineation of elongated fragments more than 1mm in length indicated a preferred orientation of flow in the localities of about 60 percent, and was corresponding to the flow direction of Sanbe pyroclastic flow estimated from the distribution of the deposit. Imbrication was confirmed by X-ray CT image in a vertical section parallel to the direction of preferred orientation. On the other hand, the flow direction that had been measured from AMS was different from the flow lineation in the thin section. A three-dimensional X rays CT image of the AMS sample showed that the direction of the elongated crystals was corresponding to the direction obtained from AMS. The direction of grains less than 1 mm in length by AMS indicates a different direction from the preferred orientation of elongated grain larger than 1 mm and from the imbrication in spite of measuring on the same horizontal plain. The difference of these array directions suggests that the mechanism, which controls the emplacement, is different by grain size.

11-P-31

Objective Rapid Delineation of Areas at Risk from Inundation by Block-and-ash Pyroclastic Flows

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Assessments of pyroclastic flow (PF) hazards are often based on mapping of PF and surge deposits and estimation of inundation limits, and/or computer models of varying degrees of sophistication. These methods are often limited, due to poor exposures and large uncertainties on dynamic parameters. In volcanic crises a hazard map is sorely needed, but limited time, exposures, or safety aspects may preclude field work, and insufficient time or baseline data are available for reliable dynamic simulations. We have developed a statistically constrained simulation model for PFs calibrated with data from many volcanoes to estimate potential areas of inundation from PFs, following Iverson, Schilling and Vallance (1998). The predictive equations for block-and-ash PF inundation are given by $A = (0.05\text{-}0.1)V^{2/3}$, $B = (35\text{-}40)V^{2/3}$, where A is cross-sectional area of inundation and B is planimetric area. The proportionality coefficients were obtained from statistical analysis, and comparison of simulations to mapped deposits. The method embeds predictive equations in a GIS program coupled with DEM topography, using the LAHARZ program of Schilling (1998). Although the method is objective and reproducible, any PF hazard zone so computed should be considered as an approximate guide only, due to uncertainties on average coefficients with respect to individual PFs, DEM details, and release volumes. The gradational nested hazard maps reflect in a sense these types of uncertainty. The model does not explicitly consider dynamics aspects, which can be important. Surge impacts must be extended beyond PF hazard zones and we have explored several approaches to do this. The method has been used to quickly supply PF hazard maps in two crises, Merapi 2006, Montserrat 2006-2007. We have also compared our *PFz maps* (using the term coined by C. Newhall) to actual recent PF deposits, and to maps generated by several other model techniques. NSF support.
Keywords: pyroclastic flows, simulation, LAHARZ, inundation area

11-P-32

Estimation of the Emplacement Temperature of Habushiura Pyroclastic Flow Deposit of Mukaiyama, Niijima Using Remanent Magnetization

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There have been few reports, which argue the emplacement temperature of pyroclastic flow or pyroclastic surge accompanied with phereatomagmatic eruption. AD 886 eruption of Mukaiyama volcano began at the offshore of Niijima Island. In the early stage of this eruption, phreatomagmatic eruptions occurred and formed Habushiura pyroclastic flow deposit at the southern part of the island. Existence of antidune structure at the distal area suggests that the pyroclastic flow had high velocity. Remanent magnetization is measured in order to estimate the emplacement temperature of Habushiura pyroclastic deposit. Pumice fragments sampled from nine flow units and lithic fragments sampled from five flow units were measured. Progressive thermal demagnetization was carried out for every specimen. Neither pumice fragments nor lithic fragments exhibit the single-component remanence parallel to geomagnetic field. This indicates that the pyroclastic flow was not hot above the maximum blocking temperature, while lithic fragments indicate that the emplacement temperature was 200-350°C. No pumice fragments denote stable remanence. It would appear that Habushiura pyloclastic deposit cooled off during the flowage, because the direction of their remanent vectors change each demagnetization step. Lithic fragments exhibit two-component remanence. The lower partial thermal remanent magnetization components that range from the ambient temperature to 200-350°C are grouped in orientation parallel to geomagnetic field. This indicates that the basement rock locating around the eruptive vent was heated by the essential material through the vent and retained temperature ranging from 200°C to 350°C.

11-P-33

Origin of Agglutinates at Ohachi Volcano, Kirishima Volcano Group, Southern Kyushu, Japan.

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Ohachi Volcano is a small, active stratovolcano situated at the southeastern part of the Kirishima Volcano Group, occupying an area about 600 km^2. It has a considerably large crater compared to the size of its volcanic edifice, and consists mainly of succession of thick tephra layers, some of them graded to thick agglutinates, especially on the walls of the crater. At least 15 tephra deposits were recognized around the volcano.

Correlation of the proximal deposits to the distal tephra revealed that the volcanic edifice had grown mainly during two sub-plinian eruptions. This suggests that the volcanic edifice of Ohachi had grown mainly during comparatively large-scale sub-plinian eruptions (order of 10^7m^3 to10^6m^3) and strombolian, vulcanian, small-scale sub-plinian eruptions hardly contributed to the growth of the edifice.

Field evidence and grain size analyses show that the thick agglutinates are composed mainly of small scale pyroclastic flow deposits which were generated during marginal collapse of the eruption column or boiling over directly from the vent. This also indicates that the agglutinates are the proximal facies of pyroclastic flow deposits. Near-vent pyroclastic flow deposits are likely to be welded because they do not lose much heat during transportation. Hence, the most important process in generating agglutinates is rapid accumulation of tephra as pyroclastic flows during large-scale sub-plinian eruptions. This suggests that agglutinates are always accompanied with the emplacement of sub-plinian tephra and pyroclastic flow deposits around the volcano.

11-P-34

Modelling Dome-collapse Pyroclastic Flows for Crisis Assessments on Montserrat with TITAN2D

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Pyroclastic flows caused tens of thousands of deaths in the 20th century, partly due to lack of hazard maps. Toward resolution of this issue we have tested the model code TITAN2D (Patra et al. 2004), compared output to a unique database from Soufriere Hills Volcano, Montserrat, and used it for crisis assessments. TITAN-2D is a map plane (depth averaged) simulator of granular flow and yields mass distributions over a DEM. Two Coulomb frictional parameters control behaviour and Montserrat calibrations on small volume flows suggests basal friction between 7^o and 17^o. Many tens of simulations were run, using combinations of flow volume (2 to 40 Mm^3), basal friction (5-12^o), apparent internal friction (15-25^o). An advantage is that the flow kinematics are captured, so that the dynamics of flow can be examined spatially from frame to frame, or as a movie. The full story is not merely in the final deposit map, and a hazard map should include not only final deposit, but also areas inundated by moving debris prior to deposition. Simulations from TITAN2D were important for analysis of the Jan-Mar 2007 crisis because they showed that any large mass released on the NW slope would be strongly partitioned, because of local topography. The simulations made it doubtful that a Belham River flow of large size (>20 Mm^3) could be generated, because of partitioning of much of the collapsed mass to the north and east. This limited runout. Further, the runs suggested that much of the surge generated by the partitioned mass would likely be released early and move NE-NNW, rather than down the populated Belham. These effects were interpreted to greatly reduce the down-valley surge risk. This research is fostering improved understanding and computer code enhancements that should make the method more effective for hazards applications. NSF research support.

11-P-35

Dispersal of Ash From Weak Columns and PDC Ash Couds: An Underestimated Hazard for Central and Southern Italy

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Volcanic ash is the result of intense magmatic or phreatomagmatic fragmentation during explosive eruptions. After injection into the atmosphere, the ash is dispersed as convective columns and umbrella clouds, which are subjected to the combined effects of gravity and wind speed, or are transported close to the ground as pyroclastic density currents. The long time of residence in the atmosphere allows also low-altitude winds to have an important role in the dispersal behaviour of fine ash. The accumulation of ash can induce roof collapses, interruption of lifelines, closure of airports and noise to communication or electric lines. The injection of ash into the atmosphere can cause damage to aircraft or can impact public health causing respiratory problems. Ash deposition decreases soil permeability, increases surface runoff, and promotes floods. Ash leachates can result in pollution of water resources, damage to agriculture and forest, impact pasture and livestock health, impinge on aquatic ecosystems and alter the geochemical environment of the seafloor. Despite some recent advances in understanding the impact of fine ash on environment and infrastructure, the dynamic of dispersal of fine ash remains poorly understood, and consideration of the associated hazards have not yet been fully addressed and included in the mitigation plans. This is particularly true for the active volcanoes of southern Italy, whose deposits of past explosive eruptions were dispersed in large parts of central and southern Italy. In many cases these ash were generated during subplinian eruptions or final vulcanian phases of Plinian eruptions, and this oblige to face with ash dispersal over large areas from moderate-size eruptions. As an example we present and discuss the data of ash dispersal from the Avellino and AP3 eruptions from Somma-Vesuvius, which dispersed centimetric thick ash blankets far beyond 300 km south and 600 km north from the source.

11-P-36

Volcanic Gravity Flow Simulation on GEO Grid System: Introducing Next Generation Hazard Map

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GEO (Global Earth Observation) Grid is an E-Infrastructure to accelerate GEO sciences based on the concept that whole data related to earth observation are virtually integrated with a certain access management. The GEO Grid is easy to handle by the endusers those are enabled by a set of Grid and Web service technologies. The core contents of the system are the observation data from ASTER onboard Terra satellite and geoscientific information, such as geological and environment technology data in AIST. Numerical simulation of pyroclastic flows on volcanoes using ASTER digital elevation model (15 m mesh) is one of the major applications of the GEO Grid project.

Volcanic disaster mitigation maps (Volcanic hazard maps) are available for most major active volcanoes in Japan. A web-based GIS system combining various types of information with real time numerical simulations are necessarily for the next generation of volcanic hazard maps.

Pyroclastic flow simulations using the energy cone model were made on the GEO Grid system. An interactive user interface is available on the GEO Grid website. Column collapse height and the equivalent coefficient of friction are necessarily to evaluate the potential area affected by pyroclastic flows. In this stage, pyroclastic flow simulations are available for 14 volcanoes, such as Merapi (Indonesia), Fuji, Unzen, Sakurajima, Usu, and Bandai Volcanoes. It is possible to update the DEM data during the eruptions by taking new ASTER satellite data. Runtime for each simulation is only 10 seconds to 3 minutes due to grid computing technology. The energy cone simulation on the GEO Grid system is applicable to other disasters such as debris avalanches and landslides. The pyroclastic flow simulation is open to all scientists and local government officials at http://www.geogrid.org/gridsphere. Numbers of applicable volcanoes are increasing. Future numerical lava-flow and grain-flow simulations have been planned.

11-P-37

Eruption-Triggered Pleistocene Giant Landslide at an Ocean-Island Volcano: Evidence From a Newly Discovered Onshore Debris-Avalanche Deposit, Tenerife

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A large debris-avalanche deposit has been discovered covering >70 km^2 of the flank of Las Cañadas volcano, Tenerife. The onshore run-out exceeded 15 km, thought to be a small part of a more widespread offshore emplacement. It is the only well exposed onshore debris-avalanche deposit at Las Cañadas, it uniquely records an eruption trigger. A single soil-bounded eruption-unit records initial phonolitic pyroclastic density currents immediately followed by sector collapse, generating the 50-m thick debris-avalanche deposit with hummocky topography, immediately followed by emplacement of further phonolitic ignimbrites into intra-hummock basins. Post-eruption sediments record ephemeral, perched hummock-dammed lakes. The landslide deposit comprises (1) block facies of sheared, pervasively shattered yet coherent rock masses of diverse lithology, a few cm to >20 m in size, elongated in the flow direction and decreasing with proximity to source; and (2) mixed facies of heterolithic, extremely poorly sorted breccia, present at most levels of the deposit and commonly surrounding the block facies. The field evidence indicates dry emplacement predominantly by

sliding and ductile shear of relatively coherent masses with limited granular mixing, abrasion and no erosion, with local transformations into wet debris flow. The giant landslide can be dated precisely as it contains sanidine-bearing phonolite juvenile blocks that were evidently hot at the time of emplacement; they preserve fluidal textures, post-emplacement chilled prismatic-jointed rims, locally baked matrix and an absence of jigsaw-fit fracturing. Within-error Ar/Ar dates of ca. 731 ± 6 ka have been obtained from these blocks, and from identical juvenile blocks in the upper and lower enclosing ignimbrites of the same composition. TRM studies to constrain emplacement temperatures of the blocks are in progress. The magmatic trigger seems to have been broadly analogous to the far smaller 1997 Boxing Day collapse at Montserrat.

11-P-38

Small Debris-avalanche Deposit Discovered at an Archaeological Site in Aso Volcano, Japan

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A small debris-avalanche deposit, Nigorikawa debris-avalanche deposit, was discovered during excavation at an archaeological site on the western part of post-caldera central cones of Aso Volcano, southwestern Japan. The deposit forms a terrace along the left bank of the Nigorigawa River and the maximum thickness is 3 m. It contains numerous plastically deformed debris-avalanche blocks (<3.7 m) of volcanic ash and soil layers in a poorly-sorted silty to clay matrix. Captured lithic clasts (<1.6 m) were concentrated around 0.5 m above the base of the deposit. Dominant orientation of long axis of the clasts within the deposit coincides with the interpreted flow direction. Furthermore, a coarse-depleted part (0.3-0.5 m thick) occurred at the base of the deposit. The coarse-depleted basal part contains soil blocks and wood fragments captured during flowage. These depositional features suggest that the plug flow model is consistent with the transportation and depositional mechanisms of the debris avalanche. We obtained a ^{14}C age of 2,230±30 years BP from a wood fragment in the deposit, which corresponds to 400-100 cal BC (2 σ). The date is consistent with the age of cultural remains (the Yayoi period: 300 BC-300 AD) underlying the debris-avalanche deposit. The debris avalanche deposit overlying the archaeological site preserves a record of a protohistoric volcanic disaster and this discovery provides important information about volcanic hazards in the western part of post-caldera central cones of Aso Volcano.

11-P-39

Large-volume Volcanic Edifice Failures in Central America and Associated Hazards

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Edifice-collapse phenomena have to date received relatively little attention in Central America, although about 40 major collapse events (larger than 0.1 cu. km) from about two dozen volcanoes are known or inferred in this volcanic arc. Volcanoes subjected to gravitational failure are concentrated at its western and eastern ends. Failures correlate positively with volcano elevation, substrate elevation, edifice height, volcano volume and crustal thickness, and inversely with slab descent angle. Collapse orientations are strongly influenced by the direction of slope of the underlying basement, and hence are predominately perpendicular to the arc (preferentially to the south) at its extremities and display more variable failure directions in the center of the arc. The frequency of collapse events in Central America is poorly constrained because of the lack of precise dating of deposits, but a collapse interval of about 1000-2000 years has been estimated during the Holocene. These high impact events fortunately occur at low frequency, but the proximity of many Central American volcanoes to highly populated regions, including some of the region's largest cities, requires evaluation of their hazards. The primary risks are from extremely mobile debris avalanches and associated lahars, which in Central America have impacted now-populated areas to about 50 km from a source volcano. Lower-probability risks associated with volcanic edifice collapse derive from laterally directed explosions and tsunamis. The principal hazards of the latter here result from potential impact of debris avalanches into natural or man-made lakes. Much work remains on identifying and describing debris-avalanche deposits in Central America, and the identification of potential collapse sites and assessing and monitoring the stability of intact volcanoes is a major challenge for the next decade.

11-P-40

Perrier Deposits (French Massif Central): a Good Example of How to Distinguish Lahar and Volcanic Debris Avalanche Deposits

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Lahar and debris avalanche deposit distinction (DADs) is critical for hazard assessment because these do not have the same origin, frequency, and environmental impact. Several features allow this distinction to be made, e.g. hummocky topography, jigsaw cracks for DADs; flat surface, absence of debris avalanche blocks for lahar deposits. Nevertheless many instances are still controversial due to exposure quality or deposit complexity.

At Perrier, four units, separated by fluvial layers, have been interpreted either as lahar deposits, or as DADs corresponding to Mont Dore volcano collapse about 2 Ma ago. They all exhibit a sandy-silty matrix supported facies

with small air cavities and an almost flat roof that can be a characteristic of lahar deposits. Unit 1 and 4 also show DAD features such as jigsaw crack blocks, matrix injections and stretched sediments. Even so, Unit 1 presents an absence of large megablocks (> 10 m^3), a homogenous matrix and an upwards increase of air cavity content and size. In contrast, Unit 4 has large megablocks (up to 20,000 m^3) near the base, inducing significant substratum erosion, sharp contact between different colour matrices, and jigsaw fit (open jigsaw cracks filled by matrix) near block boundaries. We conclude that Unit 1 was a cohesive lahar possibly spawned from a DAD upstream. There are two small similar deposits (2, 3) that have clear lahar affinities and a fourth that is a distal DAD facies. Thus, Mont Dore first produced fluvial deposits and lahars with a possible sector collapse source, then had a large debris avalanche about 2 Ma ago.

We show that it is possible to differentiate the origin of enigmatic volcanic breccias with detailed structural, lithologic and sedimentologic analysis and assign a DA or lahar, or mixed ancestry.

11-P-41

Mathematical Simulation of Magma-hydrothermal System at Iwodake Volcano, Satsuma-Iwojima, Japan

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The thermal activity of Iwodake volcano, Satsuma-Iwojima, south of Kyusyu, Japan, is characterized by the predominant volcanic gas ejection at the summit crater and the heat discharge from high ground temperature area, which is distributed widely from the summit crater to hillside of the mountain. The volcanic gas at the summit crater is of magmatic origin and its temperature is observed to be 880°C in maximum. The total amount of the volcanic gas discharged from the summit area is estimated to be 200kg/sec from the SO_2 measurement and the chemical composition of the volcanic gas. The heat discharge rate from the high ground temperature area at the hillside is estimated to be 30MW from the surface temperature measurement. These thermal activities of Iwodake volcano are thought to be continued for more than 800 years. The continuous active degassing causes the hydrothermal system within the volcano because the volcanic gas, ascending the conduit, is diffused to the surrounding formation. The development of such hydrothermal system is studied using the mathematical simulation. The simulator accounts for mass and heat convection of liquid water and/or vapor within a porous media. In this calculation, the degassing is considered as the source at the top of the columnar magma with constant high temperature. The results show that the overall thermal activity of Iwodake volcano such as the volcanic gas ejection at the summit crater, widely distributed ground temperature anomaly at hillside can be caused by the volcanic gas flow which is diffused from the vent. The important factors in order to induce the wide-ranging hydrothermal system are permeability of the volcanic edifice and the depth of the degassing. The simulation indicates that the permeability of 0.1 darcy and the degassing above sea level are necessary condition for the Iwodake thermal activity.

11-P-42

High Emissions of Sulphur Dioxide fom Vanuatu Volcanoes

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Vanuatu archipelago horsts 6 aerial active volcanoes with different manifestations, including strombolian type, Lava Lake, fumaroles, and regular eruptive manifestations. One of its volcano also horsts the largest acid Crater Lake worldwide. These volcanic edifices continuously release high amount of volatiles into the atmosphere. Due to difficulties in having access to these volcanoes, their degassing have never been measured in the past. Our recent measurements using the mini-DOAS, combining with the OMI observation, have highlighted the extraordinary rate of SO_2 release from these volcanoes. A conservative emission rate from these volcanoes surpasses the 60 kg/s, which represents some 11 to 20 % of the global SO_2 release into the atmosphere from volcanoes. Ignoring the emissions of Vanuatu volcanoes into the atmosphere is a major source of error in an estimation of the global SO_2 budget.

11-P-43

Volatile Content of Olivine-Hosted Melt Inclusions of Miyakejima Volcano, Japan: Implication for Magma Degassing and Evolution of High-Alumina Basalt

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Chemical analyses of melt inclusions in Mg-rich (Mg#78-84) and Mg-poor (Mg#68-72) olivines from a bomb and lapilli from the 18 August 2000 eruption of Miyakejima volcano, Japan, were carried out in order to investigate degassing and evolution process of the magma. Analyses of major elements, sulfur and chlorine of the melt inclusions were made by EPMA, and H_2O and CO_2 by FTIR and SIMS (Miyagi et al., 1995; Hauri et al., 2002). Major element composition of Mg-poor olivine-hosted melt inclusions is similar to that of groundmass in the bomb of the eruption. These inclusions have volatile contents of 1.4-2.9 wt.% H_2O, 0.003-0.018 wt.% CO_2 and 0.07-0.12 wt.% S, and 0.064-0.095 wt.% Cl, that are roughly similar to those of plagioclase-hosted inclusions (Saito et al., 2005). Gas saturation pressure of the magma is calculated to be 60-100 MPa on the basis of the H_2O and CO_2 contents. A ratio of H_2O and S contents of the inclusions is similar to that of volcanic gas emitted from the summit, while a ratio of CO_2 and H_2O contents is lower than that of volcanic gas. These results suggest that degassing and crystallization of the magma at shallow depth (<4 km). On the other hand, the Mg-rich olivine-hosted melt inclusions have SiO_2 and K_2O-poor but Al_2O_3-rich composition than

the whole rock composition of the bomb. Preliminary results indicate that they have higher H_2O, CO_2 and S contents and lower Cl content than those of Mg-poor olivine-hosted inclusions; 3.4-3.8 wt.% H_2O, 0.016-0.026 wt.% CO_2, 0.13-0.20 wt.% S, and 0.039-0.065 wt.% Cl. Existence of the Al_2O_3-rich less-evolved melt with high H_2O content is consistent with the petrological and experimental studies that low-MgO high-alumina basalt is derived from primary magma with high H_2O content (Uto, 1986; Sisson and Grove, 1993).

11-P-44

Hydrothermal Fluid Sediment Interaction in the Wakamiko Submarine Crater, South Kyushu, Japan

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The Wakamiko submarine crater is a small depression (4km × 2km) located in the Kagoshima Bay in Japan. Warm fluid shimmering from a sediment mound associated with fumarolic gas emissions had been located at the seafloor at 200m water depth. During NT05-13 dive program conducted in August in 2005 using ROV Hyper-Dolphine (JAMSTEC), another active shimmering site was located (and named as the North Site) at 0.8km apart from the previously discovered site (named as the Center Site). To study geochemical signature of hydrothermal alteration related with submarine volcanic activity, six core samples were collected from the surface sediment (up to 30cm) within these active sites. The pore fluids from the active sites can be explained as mixing of ascending hydrothermal component and the seawater. Bulk chemical composition of the sediment from the Center Site showed depletion in potassium and occurrence of montmorillonite other than plagioclase and quartz. However, montmorillonite is not stable with the chemical composition of the pore fluid at the temperature of 117 °C which was measured at 40cm below the surface. This disagreement implies that the pore fluid chemistry has recently changed due to involvement of the fumarolic gas emitting near the hydrothermal mound. On the other hand, small amount of illite / smectite interstratified minerals were identified as alteration minerals in the North Site sediment, which is accordance with the fluid-sediment interaction at temperature around 150 °C estimated on the assumption that the pore fluid consist of the hydrothermal component and seawater at mixing ratio about 2:1. While the fluid-sediment interaction is likely to be equilibrium in the North Site, involvement of gas component would induce instability of the fluid-sediment interactions at the Center Site.

11-P-45

A Model for Episodic Degassing of an Andesitic Magma Intrusion and Application to La Soufriere de Guadeloupe Volcano (Lesser Antilles) since its Last Eruptive Crisis in 1975-77

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Episodic magmatic degassing has been observed at numerous volcanoes, especially those of intermediate composition. It can span timescales from years to decades. We propose here a physical model for the degassing of a shallow magma intrusion to explain this phenomenon. The magma cools by convection, which leads to melt crystallization, volatile exsolution and magma overpressure. When the pressure reaches a critical value, wall rocks fracture and the exsolved gas escapes. The intrusion then returns to the initial lithostatic pressure and a new cooling-crystallization-degassing cycle occurs. A series of such cycles leads to an episodic degassing. The trend and time scale of the degassing process are mainly governed by magma cooling. Two degassing regimes, with a high gas pulse frequency for the first and a lower for the second, are exhibited. The transition between these two regimes is caused by the strong viscosity increase when the magma crystallinity exceeds the crystal percolation threshold. We find that the time to this transition is dependent on magma volume, to a first approximation.

This model is applied to interpret chemical analyses of spring waters sampled on La Soufriere de Guadeloupe volcano over the past 30 yr, since its last eruptive crisis. This study enables to give a global interpretation for the evolution of the spring water composition and the fumarolic and seismic activities since 1975-77. Moreover, it provides constraints on key aspects of the sub-surface magmatic system, including estimation of stored magma volume and host rock tensile strength. This model therefore represents a relevant tool for volcanic surveillance and hazard assessment.

11-P-46

Sulfur Isotope Ratio of Volcanic Gas from Miyakejima and Implications to the Condition of Magma Degassing

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Miyakejima is an insular volcano located in Pacific sea. After the eruption in 2000, the volcano has emitted a large amount of SO_2 gas. We have installed chemical traps composed with aqueous KOH solution to sample volcanic gas on the flank. The sulfur component in volcanic gas was absorbed into KOH solution. The $\delta^{34}S_{CDT}$ of sulfur trapped by KOH solution revealed that the $\delta^{34}S_{CDT}$ of sulfur in magma of Miyakejima volcano is +4.4 to +5.7 ‰, being consist to the characteristic value for Quaternary volcanoes in Japan.

The observed $\delta^{34}S$ showed a gradual increase. The increase could be explained by an open system degassing of magma chamber. The consistent isotope effect at the degassing of sulfur (= 1000 $\ln\alpha_{gas\text{-}magma}$) was estimated to be -1.0 to -0.3. The oxygen fugacity producing the above isotope effect was estimated to be

+0.6 to +1.2 log unit higher than NNO buffer. Yasuda et al. (2001) petrologically estimated the oxygen fugacity, +0.2 to +0.5 higher than NNO, for the lava ejected at the eruption in 2000. A discrepancy in redox potential was found between volcanic gas and lava which has been expected theoretically by Burgisser and Scaillet (2007).

11-P-47

Computed Tomography (CT) Reconstruction of SO_2 Concentration Distributions in the Volcanic Plume from Miyakejima Volcano

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The measurement of SO_2 concentration distributions in a volcanic plume is very important from point of view of Volcanology and disaster prevention. In previous studies, ladder traverses were made across a plume by an aircraft with a SO_2 analyzer to obtain the SO_2 distributions. Since ladder traverse takes dozens of minutes, significant changes in the shape or orientation of the concentration distribution would occur during the flight. Furthermore, flying through the volcanic plumes is dangerous. Recently, several groups applied computed tomography (CT) reconstruction to obtain SO_2 concentration distributions instead of the ladder traverse technique.

We mounted three compact UV spectrometer systems (COMPUSS) aiming at three different elevation angles (π/4, π/2 and 3π/4 respectively) on a helicopter and flew under the plume about 10 km downwind from Miyakejima volcano. Four traverses were made at a speed of 110-150 km/h, at an average altitude of 130 m. Each traverse took less than two minutes.We calculated CT reconstructions of SO_2 concentration distributions using SO_2 path integral concentration data of the three COMPUSSes. CT reconstructions were performed using the smooth basis function minimization (SBFM) technique. The plume profile of reconstructed SO_2 concentration distribution showed horizontally and thinly spread feature, and maximum SO_2 concentration was a few ppm.

11-P-48

Quantification of Volcanic Water Vapor Using the Atmospheric Infrared Sounder (AIRS)

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Increases in stratospheric water vapor can increase surface temperatures, cool the atmosphere, and expedite chemical reactions. Volcanic eruption columns are an important mechanism for transporting not only magmatic, but also atmospheric water vapor entrained in the column, to the relatively dry stratosphere. Due to the natural abundance of water vapor in the lower atmosphere, the retrieval of this pervasive volcanic gas has largely been ignored. NASA's Atmospheric Infrared Sounder (AIRS) provides us with the potential to retrieve volcanogenic water. Model spectra for recent stratospheric eruptions including Manam (October 2004), Sierra Negra (October 2005), Augustine (January 2006) Rabaul (September/October 2006), and Shiveluch (March/April 2007) have been created using a radiative transfer forward model for varying atmospheric conditions and compiled into a data library. The new retrieval algorithm compares AIRS radiance data to the model spectra using a fitting algorithm, where the differences in spectra in fitting windows are used to quantify the amount of water vapor in the volcanic plume.

11-P-49

Observation Records of Hydrothermal Activity and Iron Sedimentation in Nagahama Bay, Satsuma Iwo-jima, Kagoshima

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Satsuma Iwo-jima has hydrothermal activity around the bottom of the active volcano "Iwo-dake". The water along the island seems ivory-red as the effects of aluminum and iron. We focus on the Nagahama-bay, which preserves reddish brown color with the precipitation of iron, to understand the sedimentation of the ferric deposition. Following points we studied in this bay; a) detail topographic map, b) observation of the sediment by underwater camera c) sampling by gravity coring, d) sediment trap, e) observation and geochemical measurement of the water condition there for 2 weeks. As a result, clay size iron deposited 20-150cm in thickness on the sedimentation velocity of 0.12-0.18g/cm^2/day. We also found crust mound with the highest 53.7℃ in temperature. One example of hot spring flowing out along the bay side, the water consisted pH5, 35°C, ～0% in salinity, Fe ion dissolving which turn to deposition just after mixed to the sea water. In the Nagahama-bay, there occurred the sedimentation of ferruginous deposit and iron crusts as a consequence of the neutralized the acid hot water including ferrous ion. We suggest that this small bay is proper to understand the iron sedimentation.

11-P-50

SO_2 Emission Imaging with the SO_2 Camera at Stromboli Volcano, Italy

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Recent development of the SO_2 camera enabled us to obtain images of SO_2 column amount distributions in volcanic plumes. With the time-series images of SO_2 distributions, we can not only derive the SO_2 behaviours in the plume but also have high time-frequency SO_2 flux

information. The SO_2 images are very beneficial for better understanding of the degassing mechanism from volcanoes and for hazard protections. In October 2006, we carried SO_2 imaging measurements at Stromboli volcano, Italy, one of the most active volcanoes in the world. We placed the SO_2 camera on the flank of the volcano about 2.2 km north-east from the summit craters. Here, more than 400 images of SO_2 plume were retrieved with time interval of ~ 5 s between 8:55 and 9:35 (GMT) on October 3. Temporal variations of SO_2 flux was calculated from the images with ~5 s time resolution, and major increases observed were related to uprising plume of Strombolian eruptions according to the movie of SO_2 images.

We also took the SO_2 camera to the summit of the volcano to quantify the amount of SO_2 emission related to respective Strombolian eruptions. The SO_2 camera was set on the location about 400 m from craters where the blue sky comes behind the plumes from the observation point. The SO_2 camera with a single UV band-path filter (Center wavelength: 310 nm, HWHM 10nm) was used in the measurements. We obtained about 600 images of the plume with time interval of ~2 s. Using the SO_2 images, we estimated the amount of SO_2 emitted for respective strombolian eruptions during the observation period. In the presentation, we are going to show movies of SO_2 plume and the results of observed SO_2 emissions.

11-P-51

A study on Magma Degassing from the Millennium Explosive eruption of Tianchi Volcano (China/North Korea) Track From Melt Inclusion

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Tianchi volcano, which is located on the border area of northeast of China and North Korea, has a long eruption history over 2 Ma. As far as we know, there are at least three eruption periods occurred in Holocene, i.e. the one about 5000 ~ 4000 years ago (Eruption Period I, this paper), another 1000 years ago (Eruption Period II, i. e. the millennium large eruption) and about 300 ~ 100 years ago (Eruption Period III). The Eruption Period II is believed to be one of the largest plinian eruptions within 2 000 years in the world . The products of that large eruption, comenditic pumice and pyroclastic flow, once covered 5 000 km^2 of Changbai Mountains area and even reached north Japan.

Two populations of melt inclusions, nominated as 'C' and 'Y' group and hosted in alkali feldspars from comenditic and trachy-pumice from the millennium large eruption of Tianchi volcano, have quite different properties. These inclusions imply the existence of two compositional melts prior to the millennium eruption. EMPA and FTIR of these melt inclusions show the preeruptive magmas contain high H_2O and Cl contents. Generally, heated melt inclusions would easily lose most of H_2O and Cl contents comparing to the unheated ones according to our data. As for S degassing, it was rather complicated and could be a continuous degassing process because of its limited dissolubility in melt. We haven't found relation with S and other elements or oxides. However, petrologic estimates appear to underestimate the amounts of Cl and S emissions. Accordingly, the mass of degassed magma is much more than that of the magma emitted or involved during the millennium large eruption of Tianchi volcano.

The magma depressurizes during ascending in their conduits. Volatile exsolves from magma melt and gathers at the top, resulting in the gradient of concentration and density, which greatly affects the eruption dynamics of magma chamber. The high volatile contents, especially the high water and chlorine contents in the magma, cumulated and exsolved while ascenting and made the magma chamber overpressurized, finally led to the millennium explosive eruption of Tianchi volcano.

11-P-52

Magmatic Volatile Flux Through the Groundwater Flow System at Iwate Volcano, Japan

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Volcanic body acts as a good reservoir for groundwater because of its high permeability and porosity. Since magmatic volatiles first encounter groundwater during ascent, groundwater flow system may play as one of the dispersion pathway of volatiles. Quantitative estimation of magmatic volatile flux is important for monitoring of volcanic activity and evaluating the affected area. In this study, we investigate the magmatic volatile distribution in groundwater flow system, and estimate the flux of magmatic volatiles.

Remarkable feature from chemical and isotopic compositions of water is observed at two regions; large shallow groundwater flow system at north to east flanks and an active faults zone at southwest flanks. Two big shallow groundwater flow system of which recharged area cover the summit fumarolic area are existed in the north and east flanks. The groundwaters have magmatic signature such as high $^3He/^4He$ ratios, whereas the deep groundwater have lower $^3He/^4He$ ratio. This suggests that deep aquifers are isolated from the shallow groundwater flow system. In the active faults zone, both shallow and deep groundwaters have magmatic contribution, suggesting that the magmatic volatiles are likely upwelling via active faults.

Estimated magmatic ^3He fluxes based on the residence time and magmatic ^3He concentration show the remarkable differences by changes in discharged area and geological age of aquifers. The ^3He flux of big springs including shallow aquifer inside the present Iwate volcanic body is high, whereas that of deep aquifers in Tertiary volcanics and pre-Tertiary sediments are low in the north and east flanks. In the active faults zone at southwest flank, ^3He flux is large regardless of geology and aquifer. These results suggest that the major dispersion pathway of magmatic volatiles are concluded to be the shallow groundwater flow and to the fault groundwater systems, and are significantly restricted by the subsurface geological structure.

11-P-53

Measurement of H_2O in Volcanic Plumes with a

Portable Raman lidar

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Measurement of H_2O concentration and flux emitted from volcanoes is important in two ways. Firstly, latent heat transported by water vapor is a major source of energy discharge from volcanoes, especially in a pre-eruptive stage. Secondly, H_2O plays a fundamental role in determining explosibility of magma. Measurement of the total H_2O in a plume is essentially important as the first step for a precise estimation of the magmatic H_2O. However, no previous remote sensing techniques has not yet succeeded in profiling the H_2O in fumaroles because of the difficulty to distinguish volcanic water vapor from ambient atmosphere. A lidar (laser radar) is capable of measuring atmospheric quantities as a function of line-of-site distance (range), and therefore could be used to measure H_2O distribution inside and outside a plume. A transportable Raman lidar with a pulsed Nd: YAG laser (532 nm, 0.6 W) and a telescope with a 35.5 cm diameter has been built in order to monitor water vapor profiles in the atmospheric boundary layer in RISH, Kyoto University. We have applied this lidar to measuring water vapor distribution in volcanic plumes. The first experiment was carried out at Nakadake of Mt. Aso, in Kyushu, Japan in November 2005. We conducted alternating observations of horizontal distribution of water vapor in the directions towards the plume and the ambient. This lidar on board a vehicle enabled us to profile the water vapor at a distance of 500 m with a half maximum width of 200 m. We further customized the instrument to the field-use by using more sensitive PMTs (photomultiplier tubes), a smaller telescope with a diameter of 20.3 cm, and a mounting tripod, which yielded higher portability without degrading the sensitivity. The second and third experiments using the new system was carried out in January and June 2007 at the same site, which demonstrated the effectiveness of our new system.

11-P-54

Evolution and Preservation of Degassing Pathways Within Silicic Conduits Assessed Using X-Ray Computed Micro-Tomography

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To understand the evolution of porosity and permeability within silicic conduit systems as a function of time and emplacement depth, we have synthesized a unique data set from four volcanic systems: Unzen, Kyushu, Japan; Bezymianny, Kamchatka, Russia; Mount St Helens, Washington, USA; and Inyo Domes, California, USA. Using 3D X-ray computed micro-tomography (CT) we will compare the small-scale (< 1 cm) porosity and permeability preserved in samples from eruptive deposits as well as subsurface samples from drill cores from the volcanic systems listed above. X-ray CT allows us to qualitatively and quantitatively explore variability in the shape, size, and distribution of voids larger than ~10 μm in their smallest dimension. The comparison of spine and conduit samples retrieved from Unzen revealed extensive post-emplacement degassing and alteration of the magma at 1.5 km beneath the summit dome. However, voids were not completely eradicated and spatial variability across the conduit persists (0.01 – 0.59 vol%). Additionally, we found the dome lavas exhibit evidence for both brittle failure and ductile deformation on the micro scale while the preserved porosity (4.47 vol%) is an order of magnitude greater than that of the magma emplaced at depth. By conducting similar measurements on samples retrieved via scientific drilling at Inyo Domes and shallowly emplaced cryptodome blast materials from the 1956 and 1980 cataclysmic eruptions of Bezymianny and Mount St Helens, respectively, we expand this study to form a broader view of preserved porosity, alteration and degassing within silicic conduits.

11-P-55

Holocene and Late Quaternary Tephra Supply from Active Nemrut Volcano into Lake Van (Eastern Anatolia)

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The active Nemrut Volcano (Eastern Anatolia) has supplied Late Quaternary and Holocene tephra layers as fallout and possibly rhyolitic syn-ignimbrite turbidites into adjacent huge alkaline Lake Van. Tephra layers in the cores drilled during the exploratory phase (2004) in preparation for a major ICDP drilling project planned for 2009 are being analyzed texturally and compositionally and are compared with pyroclastic and phreatomagmatic onland deposits presently studied. A major rhyolitic hydroclastic surge and fallout deposit mantling the caldera rim is interpreted as resulting from a subplinian eruption through the caldera lake. First results from the ongoing project will be presented.

11-P-56

Structural Changes of Volcanic Ash Surface due to Variable Explosion Conditions During Emplacement of A Rhyodacitic Dome, Dikkartin Dag (Mt. Erciyes Stratovolcano, Central Anatolia, Turkey): Inferences From Sequential Fragmentation/Transport Theory (SFT)

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We studied the evolution of a rhyodacitic dome, Dikkartin Dag on flank of Mt. Erciyes stratovolcano (Central Anatolia, Turkey) where the eruption begins as purely magmatic and continues as phreatomagmatic with

interlayered phretoplinian fall and surge deposits related to the amount of water interacted with vesiculating magma. The phreatomagmatism forms an explosion crater and a tuff ring. The eruptive style changes from explosive to effusive so a rhyodacitic dome emplaces and it buries the previous explosion crater.SFT (Sequential Fragmentation/Transport) theory has been applied to Dikkartin tephra. Four distinct subpopulations were determined in all samples in varying degrees of prominence. Coarser modes subpopulation A and B can be separated from those of fine subpopulations C and D. Subpopulations A and B are dominantly formed by magmatic fragmentation and subpopulations C and D are formed by phreatomagmatic fragmentation. In order to find how the water/magma mass ratio (R) varied during the course of the Dikkartin eruption, we assumed that the fraction of phreatomagmatic constituents is a measure of water abundance and that for magmatic constituents is a measure of magma abundance. We normalized their ratio to 1 where all fragmentation is phreatomagmatic. The vesicularity indexes (V%) for each sample were calculated. The particles are generally vesicular, indicating that magmatic gases had a role in disruption. However, the vesicularity values do not show correlation with eruption types and bed-forms indicating that magma/water interaction occurred at a later stage, after vesiculation. Quantitative surface descriptors were calculated on SEM micrographs of volcanic ash particles (250-500μm). We calculated several roughness parameters, quadtree decomposition parameters and generated polar plots describing gradient frequencies on ash surfaces. Roughness parameters, quadtree decomposition parameters and shape descriptors on polar plots seem to be suitable for quantifying the structural changes of the ash surface due to variable explosion conditions.

11-P-57

Controlled Serial Grinding for High Resolution Three-Dimensional Reconstruction of Volcanic Ash Surface

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Not only the volcanic ash particles, but also many natural particles have been widely described and quantified by their outlines. In addition to their outlines, the volcanic ash surfaces also need to be expressed in quantitative ways. Although much information about alteration intensity, fine particle abundance, vesicle shapes can be gained by microscopy and image analysis on surfaces, these approaches have the limitation of being based on 2D. A complete analysis can thus be obtained through 3D characterizing. Many techniques such as microtoming, serial grinding and polishing, X-ray microtomography, focused ion beam (FIB), micromiller have been used for acquiring 3D datasets for reconstruction. However, artefacts resulting from microtoming, limited resolution of techniques, laborious procedures and problems of registration and estimation of thickness of abraded cross-sections made some techniques inappropriate for high-resolution 3D reconstruction. Despite reported disadvantages of serial grinding and polishing such as its being destructive, labour-intensive and difficulty in producing cross-sections of constant thickness, previous studies on paper surfaces claimed that its combination with SEM imaging offers a unique way of acquiring images from microstructures. Volcanic ash particles were placed on a double sided carbon adhesive disk and a cylindrical aluminum stub. The epoxy resin was mixed with polymer spheres which were used as landmarks for registration purposes and for determining the thickness of the abraded sections. The stub was embedded in epoxy resin and polymer mixture and allowed to cure for 24 h at room temperature. The images of volcanic ash particles were acquired consecutively after serial grinding and polishing. SEM in low vacuum mode was used to avoid coating samples with carbon, thus reducing the time required for preparation and image acquisition. Filtering, registration and volume rendering was performed in a public domain software. The method seems to be applicable for obtaining datasets for high-resolution 3D reconstruction.

11-P-58

Structural Changes of Volcanic Ash Surfaces Due to Groundmass Crystallization and Tachylite Formation: A Case Study, 2000 Eruption of Miyakejima volcano (Japan)

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We made qualitative and quantitative analysis on SEM micrographs of volcanic ash particles (500-1000 im) from summit subsidence (8 July-9 August) and explosion stage (10 August-29 August) of the 2000 eruption of Miyakejima volcano (Japan). We concluded that activities produced 3 end-members of juvenile ash: (1) glassy (2) tachylite and (3) transition type between types 1 and 2. We labeled surfaces of ash particles on SEM micrographs according to their surface smoothness, alteration, vesicularity, bubble shapes, pockets abundance and types (glass, transition, tachylite). We calculated roughness descriptors, quadtree parameters on ash surfaces. Polar plots were generated based on frequency of gradients. Different shape descriptors were calculated on polar plots. We also labeled general views of ash particles including their outlines according to their angularities, phenocryst or mold of phenocryst content and types (glass, transition, tachylite). We calculated shape descriptors and fractal dimension on their outlines. Quantitative and qualitative variables were subjected to correlation analysis and ANOVA (analysis of variance) for determining the correlation between variables and verifying their suitability for differentiating among the samples. Roughness descriptors Ra, Rq, Rp, shape descriptors of polar plots, nQT are suitable to describe the alteration intensity on ash surfaces. Rsk and Rku have strongest correlations with bubble shapes on surfaces. Roughness descriptors, quadtree parameters and form factor of polar plots seem to be suitable for quantifying the structural changes of the

ash surfaces due to variable crystallinity of groundmass (tachylite-glass) and microlite-controlled vesicle shapes. The outline parameters do not have correlation with groundmass crystallinity, however form factor of outlines describes the angularity of the particles. Surface parameters; Rq, Ra, Rsk, Rv, Rp, Rt, shape descriptors, quadtree parameters and outline descriptors; form factor and fractal dimension are suitable for differentiating between samples, having p-values well below 0,05 with a 95% confidence interval (CI).

11-P-59

Holocene Volcanic History Based on Tephrochronology in Hokkaido, Northern Japan

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1. Holocene tephras in Hokkaido

The Holocene sedimentary record of Hokkaido, northern Japan, is dominated by tephras. Most of the Holocene tephras in Hokkaido can be easily identified based on the refractive index of dehydrated glass in addition to some other petrographic properties. On the basis of identifications of 32 tephras, an eruptive history of Holocene volcanoes in Hokkaido, i.e. Komagatake, Usu, Tarumae, Mashu, etc., is arranged. Every tephra reported here is favorable not only for establishing the magnitude and type of eruptions but also for studies in interdisciplinary sciences including the chronology of paleo-disasters such as tsunamis and earthquakes.

2. Case study on Usu volcano

The AD1663 ejecta of Usu volcano have a thickness of approximately 2 m and are divisible into seven units (Unit-A to -G) on the eastern foot of Usu volcano. Most of these units were produced by phreatomagmatic activities, whereas Unit-B is typical in many respects of the product as plinian activity. Unit-D is typical of phreatic deposits. According to historical records, the first eruption (Unit-A) occurred on August 16, 1663, followed by the climactic eruption (Unit-B) on August 17. The explosive eruptions lasted approximately 20 days.

3. Case study in Shiretoko peninsula

Cores were drilled in 2005 in an attempt to obtain detailed records of Holocene tephras in peat bogs adjacent to Rausu volcano, Shiretoko peninsula, using a peat sampler and geoslicer. In addition to pyroclastic layers from Rausu and Tenchosan volcanoes, tephras from Komagatake and Tarumae volcanoes occur in the study cores, providing valuable time markers for establishing Holocene chronology.

11-P-60

TEM+EDX Study of Weathered Layers on the Surface of Volcanic Glass

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Analyses by TEM +EDX reveal the surface characters and thickness of the weathered layers of the volcanic glass in the pumice. The result shows that the average thickness of the weathered layers on the volcanic glass for the eruption (1000 B.P.) is 0.98 mm. For the eruption (5000 B.P.) the average thickness of the weathered layers on the volcanic glass is 3.74mm. These features indicate that the thickness of the weathered layers on the volcanic glass from the Tianchi volcano are related with the ages of volcanic eruptions. Therefore, they can be used as indicators for determination of a sequence of volcanic eruptions. The EDX analysis also shows that the weathered layers on the volcanic glass contain increased Al and reduced Si in chemical composition with respect to the volcanic glass itself. It is inferred that such a change should have occurred in a low-temperature setting and a nearly neutral to weak acid solution. Hence it is possible to identify the dates and sequences of volcanic eruptions as well as their environments based on a systematic study of micro characteristics of eruptive materials in the Tianchi caldera.

11-P-61

Reevaluation of the Influence of a Gigantic Eruption from the Ilopango Caldera to Ancient Mesoamerican Societies

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In the period from 3rd to 5th century, a gigantic eruption occurred at Ilopango Caldera (size: 8 x 11 km), which is located in the center of El Salvador, Central America. In this eruption, voluminous pumice flow was deposited around the caldera and fine ash named "TBJ tephra" was dispersed broadly. In many archaeological studies, destructive influences of the eruption to ancient Mesoamerican societies, such as abandonment of populated cities or mass migration to other area, have been presumed.

Although the distribution of the TBJ tephra had been illustrated previously in Hart and Steen-McIntyre(1983), it was investigated more detailed and more broadly in this study. As a result, overestimation and correlation error were found out in some cases in the paper, especially in Chalchuapa and the surrounding area, ca.70 km from the caldera to the northwest (i.e., downward of local wind). Although the TBJ tephra is described to be ca. 50 cm thick in Chalchuapa in the previous paper, it was observed to be only 16 to 18 cm thick in this study. Accordingly the thickness of TBJ teprha in the area described in the previous paper should be reduced, and the scale of the eruption should be also revised. In order to estimate the scale of the eruption precisely and evaluate the influence to the ancient society exactly, further investigation of the distribution of the TBJ tephra is necessary.

11-P-62

Tephra Hazard Analyses Incorporating Potential Multi-stage Volcanic Events

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While volcanic events are commonly characterised by multiple eruptive stages, most previous probabilistic tephra hazard analyses have only considered the major (paroxysmal) stage for each simulated event. To test the validity of this approach, we simulate events in the traditional manner (single-stage analysis) and then also incorporate probable smaller-magnitude explosive stages (multi-stage analysis). This builds upon the results of a global statistical study of multi-stage explosive events and uses the Okataina Volcanic Centre in New Zealand as a case study. The two sets of resultant hazard - in the form of spatial tephra thickness, the associated cumulative duration of explosive behaviour and the duration of the entire eruptive sequence - are compared to assess the difference in approaches. The multi-stage analysis shows an increased hazard when compared with the single-stage analysis and we found the greatest difference in duration and tephra thickness to lie at middling distances from the vent. In some places, tephra thickness increased by one order of magnitude and up to 25% more of New Zealand's North Island was impacted, while the probability of an event lasting longer than 1 month increased sevenfold. The more traditional single-stage approach is recommended where little previous eruptive history has been established, so that the modelling does not become too dependant upon global analogies. Given an eruptive history as in-depth as that at Okataina Volcanic Centre we recommend the second multi-stage approach, which leads to more realistic event simulation and thus a better understanding of the probable hazard.

11-P-63

Validation of an Ash Distribution Model using the 1974 Eruption of Fuego (Guatemala)

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ASHFALL is an advection/diffusion model for calculating the distribution of ash fallout on the ground from volcanic eruptions. It is a simple model for rapid computation, and makes certain assumptions, including a narrow vertical eruption plume, and zero vertical diffusion. Previous tests of this model have given a good agreement for total ash thickness, but data for each ash size from the 1974 eruption of Fuego (courtesy of William I Rose, MTU) has provided a fuller test of this program.

The actual total ash thickness is in good agreement with the model, except for a slight change in the direction of maximum thickness. This difference in direction is probably due to meteorological factors, in other words a difference between the wind direction at the climate station and at the volcano, which is not the fault of the model. Similarly, the pattern of ash thickness for each size of ash shows a good general agreement with the predicted thickness distribution.

This model is aimed at providing an estimate of ash thicknesses for hypothetical or actual eruptions. There are at least three ways of calculating the errors in such a model, either by using the ratio or absolute difference of actual/predicted thickness (for all ash or ash of a particular range of sizes) or a comparison of the horizontal distance between the location with a certain actual thickness, and the nearest point where that thickness was predicted. Part of the validation process is looking at which method is most useful for looking at the important thicker part of the ash deposit.

11-P-64

The 1971 Lahar Dynamics, North East Flank of the Villarrica Volcano, Chile

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The lahar that flowed down the northeast flank of the Villarrica volcano in 1971 was one of the most devastating lahars associated with this volcano in the 20th century. It destroyed the easternmost part of the city of Pucón. Since then this city has considerably grown and the occurrence of such a lahar in the future could considerably threaten the eastern part of the city.

The aim of this study is to analyse the 1971 lahar dynamics in order to determine the characteristics of the flow, the volume and trajectory of the transported blocks, the flow velocities as well as the transport/entrainment capacity. These different parameters have been determined from field data.

Approximately 40 sections have been studied along the Pedregoso-Turbio river. Dimensions of transported blocks located either on the top of or within the lahar deposit have been measured. The largest floating block (F-type) has a volume of 90 m^3 whereas the volume of the largest internal (I-type) block is 2.8 m^3.

The flow regime has been determined from the deposit internal structures. The 1971 lahar deposit exhibits normal and inverse grain size distribution, cross bedding, parallel and crossed lamination among other structures which are typical of a hyper concentrated fluid.

The city of Pucón is located at 20 km from the source of the lahar. Based on the maximum size of the blocks (O'Connor, 1993), the maximum velocity reached by the flow can be estimated to 50 km/h with a mean value of 20 km/h. Consequently, a similar lahar could reach the outskirts of the city of Pucón in app. 30 minutes.

The real extension limits of the 1971 lahar are hidden by recent vegetation and urbanisation. However the maximal extension of the 1971 lahar, as well as potential similar lahar, can be estimated with numerical simulation.

11-P-65

Lahar-Streamflow Interactions, New Data from the 18 March 2007 Lahar at Ruapehu, New Zealand

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Ruapehu lahars are typically derived from eruptions or outbursts from the hydrothermally heated Crater Lake. Hence the chemical contrast of this pulse of acidic brine

into normal streamflow can be used, alongside sediment concentration and flow stage/discharge to understand the interaction of lahars and river water in their path. Observations of eruption-triggered lahars in the Whangaehu River in 1995 led to the following model: 1) a head of normal stream water, with low sediment and salt concentrations persisting up to the peak stage; 2) a mixing zone between stream water and incoming brine, accompanied by a rise in sediment concentration to a peak that lagged peak stage by 15-45 minutes; 3) highly sediment-charged flow with decreasing stage and increasing salt concentrations that reach a maximum up to 15-30 minutes after the sediment concentration peak; followed by 4) a long tail where the flow slowly returns to normal streamflow conditions. For the 18 March 2007 lake-breakout lahar from Ruapehu, we were able to mobilise several observer teams to collect a far more detailed set of time-series data at sites along the Whangaehu River. This data was also expanded upon by the use of a broad-band seismometer to allow determination of the content and energy of coarse sediment within and at the base the flow, and highly detailed sampling of sediments deposited during passage. These new data sets confirm and expand on previous observations from the Ruapehu lahars. In all cases suspended sediment, bedload sediment and salt concentration peaks lag the maximum stage and discharge. The observations from dip samples are expanded upon by the seismic signals, where a peak in overall vibration energy lags the stage/discharge maxima. Depositional records also record three distinct units corresponding to stages 2, 3 and 4. The new data implies that the head of the lahar wave appears to be made up of normal stream water, apparently displaced by the incoming pulse of Crater Lake water and suspended sediment.

11-P-66

Age, Origin, and Depositional Process of Hongo Lahar Deposits in the Takaragawa-Jhinzugawa River, Central Japan: Enormous Volume Lahar Deposit From Yakedake Volcano Group

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The Hongo Lahar, the largest Pleistocene lahar in the Hida Mountain Range at the central high land area of Japan, formed on the Yakedake Volcano Group, which is the most active volcano in this area, descended the Takara and Jinzu river system to 90+km. In the Hongo-Inotani area, 30-60km along the Takara-Jinzu River downstream from the volcano, this lahar deposit makes remarkable terraces. This lahar deposit is ~100m thick, and its cover area is >18km^2 in Hongo-Inotani area. The overall volume of this lahar deposit is estimated to be >0.7km^3.Based on the examination of previous tephrochronological study and the K-Ar age from the daicite clast of this lahar, the age of Hongo Lahar shows 140-100ka.

The clasts (long axis over 64mm) of this lahar mainly are biotite-hornblende dacite or andesite (>70 %). From the petrographic viewpoints, origin of dacitic and andesitic clasts in the lahar is considered to be the Odana Volcano (ca. 120 ka) of older Yakedake Volcano Group. Thus, the depositional age of this lahar is 120-100ka, probably in MIS 5e.

The Hongo lahar succession shows two distinct sedimentary facies, interpreted as debris-flow deposits and hyperconcentrated flow deposits. The lower part of Hongo Lahar deposit mainly is composed of debris-flow deposits, but the upper part of lahar deposit is composed of hyperconcentrated flow deposits which is >50m thick sometimes. This lahar deposit is characterized by thick hyperconcentrated flow deposits.

The distribution, sedimentary facies, and volume of Hongo Lahar suggest that the abundant water more than the present Takara-Jinzu River is necessary for the occurrence of Hongo Lahar. We propose that this enormous volume lahar occurred due to the breaking of dammed lake, which the paleo-Takara River was dammed up by the Odana volcano of older Yakedake Volcano Group.

11-P-67

Geophysical Insights into the Properties of a Moving Lahar, 18/03/2007, Ruapehu, New Zealand

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Hazards to infrastructure and life from lahars are difficult to prepare for, in part because lahar wave dynamics and evolution are so poorly understood. Specifically, there is a lack of quantitative information about flow characteristics at different points along a lahar's flow path. The anticipated Mt Ruapehu Crater Lake outbreak provided a unique opportunity to gather such information. On 18th March 2007, the long-awaited dam-collapse occurred, releasing an estimated 1.3x106 m^3 of water from the lake. A variety of geophysical equipment had been installed at a series of sites along the Whangaehu Channel and teams of scientific observers were on-call, in order to capture the lahar as it flowed past, making this the most comprehensively studied flow to date.

Pre-, during-, and post-event geophysical data were used to evaluate the changing properties of the channel, site-specific characteristics, and the interactions between streamflow and lahar. Flows were captured by stage height, pore pressure and seismological methods. These were complemented in part by observations and dip samples from the moving flow various sites throughout the event. Post-event GPS surveys were also used to establish tideline heights, channel cross-sections and estimates of superelevation that could be used to constrain peak flow velocity.

Combining these data, it is possible to calculate approximate maximum flow velocities, which together with time-series stage records, can be used to evaluate discharges and total flow volumes at 7 sites along the channel from 5 km to 173 km from source. This process highlighted that standard hydrological methods for discharge estimation in pure water flows (such as slope-area calculations) are inadequate for use in sediment-rich lahar flows which display varied stage-discharge relationships. The broadband seismological records served as an excellent proxy for measuring movements of particles within flow and bulk flow excitation. The combination of data from these

multiple instrumental and observational records, show that this lahar behaved very differently from known past flows at Ruapehu. It had a very complex pattern of repeated sediment entrainment and loss, thus rapidly changing its stage height, sediment concentrations, erosion potential and bed-load movement. Further constraint of these properties will be essential for testing and evaluating a new generation of mass-flow modeling and hazard forecasting techniques.

11-P-68

Intracaldera Lake Break-outs in the Western Pacific: Case Studies from New Zealand and Japan

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Volcano-hydrologic hazards display a wide variety of causative mechanisms, including those directly related to volcanic activity such as explosive ejection of a crater lake, and indirectly-related phenomena such as rain-triggered lahars and break-out floods from temporary lake impoundments. Globally, such events rank as the third most lethal hazard from volcanic activity, being responsible for more than 30,000 deaths since 1783 AD. Population growth has meanwhile increased societal vulnerability as people have colonised the flat lahar terraces that fringe the river systems that drain many dormant and active volcanoes, areas often excluded from volcanic hazard assessments.

Geomorphic and sedimentary studies have identified intracaldera lake break-out events in a number of volcanic arcs: paleohydraulic reconstructions indicate that some are amongst the largest post-glacial floods on Earth. Intensive work in New Zealand's Taupo Volcanic Zone has discovered evidence of multiple floods from a number of volcanic centres. Two floods have been identified from Lake Taupo, the largest body of freshwater in Australasia, with events at 26 and 1.8 ka releasing 60 and 20 km^3 of water respectively. Recurrent floods have also been identified from the Okataina Volcanic Centre, where growth of intracaldera lava domes has repeatedly dammed the outlet channel, and Lake Rotorua, which has a complex history multiple highstands and potential outlets.

Geological similarities between Japan and New Zealand suggest that the Japanese volcanic arc should also have experienced break-out floods from intracaldera lakes. Reconnaissance-level studies have identified a post-13.5 ka break-out of c. 5.5 km^3 of water from Towada caldera in northern Honshu, while the Aso caldera in Kyushu has experienced three phases of lake development since 90 ka in what is now a dry basin, raising the possibility of a break-out event. Other candidates exist amongst the caldera lakes of Hokkaido.

11-P-69

Integrating Seismic and Acoustic Source Models for Long Period Events

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The long period (LP) event is commonly attributed to fluid oscillations in active volcanoes and is one of the most important signals for seismic monitoring owing to its utility in short term eruption forecasting and its close relation to certain types of tremor. At Mount St. Helens, data from an array of broadband infrasound sensors collocated with a broadband seismometer at 13 km range indicate that the process that generates LP seismic events intermittently generates infrasonic pressure signals that radiate away from the volcano through the atmosphere. Whenever present, the infrasonic LP events are shorter in duration and more impulsive than the seismic LP events and lack a prominent long period coda.

We summarize the observations and then present preliminary numerical investigations of the coupling mechanism between seismic and acoustic LP events using a 2.5D finite difference representation of the elastodynamic and acoustic wave equations, including the effects of topography and wind. We also consider the infrasonic wavefield generated by a pressure transient in a subsurface resonant steam-filled crack.

11-P-70

Volcano-tectonic Earthquakes at Guntur Volcano, West Java, Indonesia

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Guntur volcano is an andesitic volcano-complex located in West Java, Indonesia. Volcanoes are aligned from youngest crater Guntur (SE) to Masigit (NW) and, Gandapura and Kamojang calderas are located northwest and west, respectively. For almost 160 years since 1847, it has been in a quiet state. Number of VT earthquakes increased in 1997, 1999 and 2002. Seismic energy release rate increase in 2000 and 2002, caused by frequent occurrence of VT events at Gandapura. The hypocenters that are aligned along Guntur-Masigit volcano zone located at depths of <2km. The hypocenters in Gandapura are distributed deeper at 2-4 km and >4km in Kamojang. No seismicity found at SE flank of Guntur crater. Magnitude of events around Guntur-Masigit is <M1.5, while from Gandapura and Kamojang >M1.5. Focal mechanisms were determined using polarity and amplitude of P-wave first motions, assuming double couple mechanism and homogeneous half space. The fault plane solutions in Guntur-Masigit were indicated by normal and reverse fault mechanisms. The nodal line striking in the direction of NW-SE, the direction of the strike seems to be connected to the volcano alignment. The focal mechanisms of VT events are similar to those near active crater, such as Sakurajima, Unzen and Merapi volcanoes. In Gandapura, mechanisms are normal faults with strike NW-SE direction. In Kamojang, the mechanism is strike-slip faults with the nodal lines

oriented in NE-SW and NW-SE (N-S extension). The faults around Guntur volcano mainly strike SW-NE. The VT events at Kamojang are affected by tectonic stress, as shown in VT events far from active craters at Sakurajima and Unzen volcanoes.

11-P-71

Geophysical Explorations in Japanese Volcanology

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The joint project for the exploration of volcano structure by explosion experiments was established since 1994. Enhanced geophysical explorations, seismic explorations have been applied in 11 volcanoes in Japan during these 13 years. Results and yields of these explorations will be presented.

Researches of volcanic structure are one of the most important subjects in volcanology. Volcanic structure plays important roles in understanding various volcanic phenomena precisely from two points of view. The one is the background property of the volcanic phenomenon. Another is dynamic response on the travel path convolved in observed data.

The purpose of the project is detecting magma reservoir since 1994, as a part of the national project for prediction of volcanic eruption. These 11 volcanoes, Kirishima (1994 and 1996), Unzen (1995), Bandai (1997), Aso (1998), Izu-Oshima (1999), Iwate (2000), Usu (2001), Hokkaido-Komagatake (2002), Fuji (2003), Kuchino-Erabu (2004), were selected as annual targets. Such annual execution is a uniqe Japanese style.

In the early years of the project, only seismic explorations were carried intensively. Tomographic velocity inversions using the first arrivals have been applied. Reflection analysis becomes to apply recently. The project has been enhanced with including natural earthquake observations and geomagneto-electric surveys for the purpose of total understanding of volcanic structures.

Tomographic inversion reveals "high velocity core" in volcanic edifice (Kirishima, Unzen, Bandai, Aso, Iwate, Usu, Fuji, Kuchino-Erabu). And yielded precise 3D velocity field improves resolution of volcanic seismicity (Iwate, Bandai, Usu). It is significant that magma movement was successfully constrained with precise location of volcanic earthquakes in Usu volcano during its 2000's activity.

Reflection analysis reveal reflectivity features beneath active volcanoes, such as reflection structure correlated with magma chamber (Kirishima), reflection structure beneath the central cones of caldera volcano, reflection structure of strato-volcano and contrast with its background. These reflection analysises suggest it is a useful tool to approach deeper structure of volcanoes and constrains sizes of horizontal extension within several kilometers. A new method, Pseudo Reflection profiling as a sort of the autocorrelation seismology, is developed to improve applicability of seismic reflection method in volcanic areas.

11-P-72

Seismic Reflectors in the Pressure Source Region of Ground Deformation in Asama Volcano

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Some clear seismic reflecters in the source region of ground deformation in Asama volcano is discussed, which revealed by dense array observation of explosion experiment in 2006.

A temporal dense seismic network was deployed around Kurumazaka pass at the west of Asama volcano with north-south strike over 8.5km for observation of seismic explosions for volcanological exploration.208 temporal stations were spread with about 50m interval.

4.5Hz type sensors and the 24bit digital recorders, model LS8200SD, are installed at a station. Continuous recording were programmed in order to capture all the shots. Positioning of the stations was made by the rapid-static method with using GPS receivers installed on the vehicles of each party and operated while their installation operations. A reference station for GPS operation is placed in the center of the array. Whole array was split into three sections and three pairs were deploying instruments for three days.

206 stations were successfully completed their data acquisition. Data editing has already completed and are now under processing.

Important description of the obtained data are as follows; Complicated later phases with high apparent velocity appear at the northern part while rather simple appearance of later phases in the southern part. Single fold profiling and pseudo-reflection profiling were applied to the data. The single-fold profile is overlapped with a swelling high velocity portion in the velocity profile by Aoki et al.(2007). Apperance of misceraneous reflectors are different beteen south and north sides. Some clear reflecters appear at c.a. 4km depth in the nortern part of the high velocity swell. These clear reflectors must be intruded magma of Asama volcano.

11-P-73

Volcano Deformation Modeling by using FEM Simulation Database

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In the recent years, the high-precise observation of crustal deformation on a summit area of volcano became possible by a dense GPS network and differential interferometric SAR. Until now, the analytic solution of crustal deformation on a uniform semi-infinite elastic body such as the Mogi model and the Okada model has been used in the analysis of these data. We tackle the research that used the three-dimensional finite element method (FEM) including topography and heterogeneity structure for the fine modeling of volcano deformation. This analysis needs FEM software, high-performance computer, and much time. This analysis is not possible

doing "by everybody, at everywhere, and immediately." The analysis method for a modeling of volcano deformation by using a FEM simulation database (FEM-DB) was developed to solve this difficulty. It is constituted of the following steps. 1) Surface displacements on a volcano are calculated for various pressure sources (position and shape of source) by using FEM (FEM-DB). 2) The best source model is chosen from FEM-DB by the comparison between observed and simulated data. The intensity of source is calculated from the ratio of observed and simulated displacements. 3) The more precise model is interpolated from this source and the surrounding sources. This procedure was build into the MaGCAP-V that is the Windows PC software to evaluate the magma activities from volcano deformation and geomagnetic changes observed at volcano. Using this software, an equivalent result analyzed with FEM is obtained by an ordinary Windows PC.

11-P-74

Calculations of Fundamental Pressure Source Models by FEM

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Numerical calculation is needed for getting detailed crustal deformation around volcanoes, where volcanic edifice and inhomogeneous structure exist. We analyzed relatively simple-shaped models using finite element method (FEM) and obtained basic information on volcanic crustal deformation and technique of calculation as follows:
1) As the FE model becomes larger, the precision of calculation becomes higher. However, a large model necessarily produces a large number of nodes which leads to an accelerative increase in calculation time. So we recommend model region of 15D-20D (D: depth of the pressure source).
2) We compared the analytical solution by Yamakawa (1955) and that by McTigue (1987) with the result of spherical pressure source model. When a/D (a: radius of the pressure sphere) increases, the values of a/D that agree with the result of FE analysis within 1% are 0.22 for the Yamakawa's solution and 0.45 for the McTigue's solution.
3) When low-velocity surface layer exists, surface displacement increases, especially in horizontal displacement.
4) We analyzed many cone-shaped volcano models changing the shape of summit crater. As the capacity of the summit crater becomes larger, the horizontal displacement at the crater rim becomes larger.
5) An expression which agrees with displacement by ellipsoidal pressure source model was found by modification of the analytical solution by Davis et al. (1974). This expression can also represent the displacement by columnar pressure source by adjusting parameters.

11-P-75

Repeated Subsurface Dike Intrusions beneath Izu-Oshima Volcano during Recent 50 Years

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A subsurface dike which had been placed in past magmatic event and are currently shrinking due to cooling contraction can cause a local subsidence of the ground surface. We found such subsidence in the repeated precise leveling data around Izu Oshima volcano Japan which erupted in 1986. The following pieces of evidences strongly suggest that the found subsidence is caused by cooling contraction of subsurface dike placed in past volcanic event (some of them were during 1986 event, and others are older) 1) The way of decay of subsidence rate is in good agreement with model prediction, 2) The subsidence rate (typically 10mm/a at the epoch 10 years after the event) itself is explainable by the contraction of a dike of 5m thickness, 10 km width (vertical) which cooled by about 100 degrees in a few years, 3) The spatial distribution of such suggested dikes is in good agreement with configuration of the vents of the past fissure eruptions derived from geological studies (e.g. Tsukui et al. 2006).

11-P-76

The Research of Volcanic Landforms using Airborne Laser Scanner (LiDAR).

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Airborne laser scanner (equals LiDAR which stands for light detection and ranging), like radar, is an active remote sensing technique. High-resolution digital spatial data generated from airborne laser scanner is very useful in understanding the various volcanic landform and geomorphological analyses for active volcanoes. For interpretation of volcanic landform, we devised a new mapping technique using the slope gradation map which is superimposed with the elevation graduated coloring map, and named it ELSAMAP (Elevation and Slope Angle Map). ELSAMAP, which is generated from digital elevation model using airborne laser scanner, is effective in visualizing topographical features, especially to interpret slight change of altitude on the ground, such as lava flow, pyroclastic flow, other volcanic landform, broad deformation of the ground, and microtopography in the low land, etc. We presented the example of the lava flow which erupted from the Sakurajima volcano, southern Japan in 1914, and the example of the lava flows of the Rausudake volcano, northern Japan. The spatial data of airborne laser scanner is also useful for a study of the quantitative evaluation of the crater shape and the estimation of the volume of losses by erosion. We researched the changes in shape of Minamidake crater of the Sakurajima volcano which has been continuously active since 1955. The change in shape of the crater from 1981 to 2001 was examined by using digital elevation model. The floor of the crater decreased by about 200 m

or more during investigated 20 years. The lost volume was calculated to be about 0.037 km^3.

11-P-77

Deep Electromagnetic Imaging of Asama Volcano

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Asama volcano in Central Japan is an active volcano with historical records of Vulcanian eruptions. Most recent eruption took place on September 1st, 2004 after the 22 years of dormancy. From the regional GPS monitoring and the volcano seismicity during this eruption, Takeo et al.(2006) inferred the eastward migration of a dike toward the vent. To image the underlying dike, we carried out magnetotelluric measurements at 14 stations along a profile crossing the suspected dyke locations, which is 3km west of the vent. First, we confirmed that the observed impedance data support that the underlying structure is two-dimensional with a strike of N60^{o}W. This direction is consistent with the suspected dike direction. Shallow part of the resistivity structure is characterized by a 2-3km thick conductive layer covered with surface resistive layers of pyroclastics. The conductor probably implies Miocene volcano-sedimentary formations. The deeper structure is generally resistive, but at depth around 10km, a vertical conductor is imaged under the suspected dike location. This conductor may imply the magmatic dike, however, such low resistivity as few ohmm may be difficult to explain solely by magmatic melt and may require contribution from saline fluids.

11-P-78

Acoustic and Seismic Signals Observed during the 2004 Mt. Asama volcanic activity

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On September 1, 2004, Mt. Asama erupted for the first time in 21 years. All the five eruptions were moderate scale and were of the vulcanian type. Each event was accompanied by clear seismic and acoustic signals. Results of the waveform inversions of the seismic signals show that the vertical single force component is dominant for all the events, indicating that the dominant source processes are essentially the same for all the events. Although all the eruptions are of the vulcanian type, and dominant vertical single force components are common for all the events, waveforms of the seismic and acoustic signals differ from event to event. Although the seismic waveforms can be classified into two groups, the classification for seismic waveforms cannot be applied to the acoustic waveforms. Events whose seismic waveforms are similar, are not necessarily be accompanied by the similar acoustic waveforms. The differences in the seismic waveforms reflect the difference in the way the pressure is released from the top of the volcanic conduit. Seismic waveforms also reflect the physical process following the pressure release stage. On the other hand, the differences in the acoustic waveforms reflect the variation in the injection rates of the hot material into the atmosphere during eruptions. The observed differences in the waveforms of seismic and acoustic signals indicate that the physical processes are significantly different from eruption to eruption, and the way they are combined are also different. From the seismic and acoustic waveforms, we infer the force system exerted on the conduit wall and the material injection rate from the conduit to the atmosphere, respectively. Combination of these two different types of information makes it possible to understand the physical processes during the eruptions in more detail than using only one of them.

11-P-79

Analysis of Water Level Change of Hot Crater Lake: Application to the 1st Crater at Nakadake, Aso Volcano, Japan

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We have developed a model of water temperature-level change of crater lakes on volcanoes. Our model suggests that the crater topography is an important role in the process of the lake formation. If the area of lake surface is significantly changed due to the heavy rain or some eruptions, the sense of the water level variation may change even if the heat input from the crater bottom does not change. Applying the model to the 1st crater at Nakadake, Aso volcano, we built the detail digital surface model "DSM" using the data of airbone laser scanner. Combining the DSM and the water level data obtained by our automatic image recording systems, we estimate the variations of water level, area and volume. In August 2006, water level was almost constant with water surface temperature in 60 degrees, and little rain was observed. If the mass of seepage from the crater bottom is 1000 ton/day, our model shows that inputted mass and its enthalpy were about 50 kg/s and 1900 kJ/kg, respectively. This result indicates that the hot water and vapor were emitted from the lake bottom.

11-P-80

Seismic Activity around and beneath Krakatau Volcano, Sunda Strait, Indonesia

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The Krakatau volcano is located in Sunda Strait between Sumatra and Java Island. The Volcano belongs to the volcanic chain of the Sunda Arcs. A zone around the volcanic is formed by interaction between the subducting oceanic Indo-Australian plate and continental Eurasian plate. Convergence between two plates occurs in the NNE-SSW direction at a rate of 7 cm/yr. The Sunda Arc changes direction of convergence substantially between Sumatra and Java; the direction is nearly orthogonal off java and oblique off Sumatra. We present seismological verification to supporting the latter concept. A characteristic seismicity prototype around and beneath Krakatau volcano was recognized by seismological data. A line similar like groups of events probably related with the dynamic activity of Krakatau volcano is clearly different and separated from the events in subduction zone. The accuracy of hypocentral determinations for the cluster does not differ from that for inters and intra plate earthquakes of to the subducting slab. The depths of the cluster events vary from very shallow to about 100 km without any apparent discontinuity. On the contrary, there is an evident aseismic gap in the slab zone just beneath the volcano at depths 100-165 km. We used seismic reflection and refraction data to investigate the crustal structure and evolution of the Sunda Strait, which is linked to the obliquely convergent geodynamic setting of the Sumatran trench. The transtensional character of the study area is manifested in faulted blocks of arc basement and active normal faults detected on both sides of a large graben at the western entrance to the Sunda Strait. The combined interpretation of reflection and wide-angle data reveals over 6 km of sediment graben fill associated with substantial crustal thinning. The southern part of the study region is only 50 km from the trench and the Moho of the down going plate is found at a depth of 28 km.Base on that data, we found that Krakatau cluster assign aseismic gap to the volcano at the surface. The specific stress and tectonic circumstance are explained by the earthquakes clusters rather than by magma ascent process. We consider the seismotectonic behavior of the continental wedge beneath Krakatau correlated with the bending of Sunda Arc in Sunda Strait area.
Keywords: Krakatau, Sunda Strait seismicity.

11-P-81

High Density Helicopter-borne Aeromagnetic Survey in Aso Volcano

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To obtain the detailed information about the spatial distribution of volcano-magnetic change, we tried to use the aeromagnetic survey. The main problem of aeromagnetic repeated observation is the difficulty of the observation point control. In the two flights, it will be impossible to flight exactly same position. So that, it is very difficult to separate observed field changes to temporal variation due to the volcanic activities and the spatial variation due to the difference of the observation points. If the detailed distribution of geomagnetic field is obtained on quiet period of the volcano, and the field intensity on the arbitrary point around the active area is estimated interpolating the observed data, we can correct the spatial variation of the repeated aeromagnetic survey data caused by the difference of flight position, and it may be possible to detect the field changes associated with the volcanic activities. For this purpose, we made very high density and low altitude helicopter-borne aeromagnetic survey on Aso Volcano, central Kyushu Island of Japan, in July 2002.

11-P-82

Source Process of Eruption Earthquake at Suwanosejima Volcano, Japan

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Suwanosejima is an andesitic volcano, located at southern Japan and currently repeats small-scale explosive eruptions at the summit crater. In this study, we reported characteristics of waveform and hypocenter of eruption earthquakes. And moment tensors of the initial part of the eruption earthquakes were estimated using waveform inversion. The first motion of eruption earthquake was dilatational (down and toward the crater in the vertical and radial components, respectively). Compressional wave dominated by the vertical component in this first dilatational motion appeared 0.2-0.3 s after the arrival of the first motion. These characteristics were common at all stations. Particle motion of the first dilatational motion was linearized in the direction to the crater. The compressional motion came from beneath the station. The hypocenters of the dilatational and compressional motions were located at depths from 200 to 300m around the summit crater and located at depths from 400 to 600m beneath the summit crater, respectively. To obtain source mechanism of the dilatational and compressional motions, we determined the moment tensor solutions using a method of waveform inversion. Three diagonal components of the estimated moment tensor of the dilatational motion were negative and had similar values. Non-diagonal components were less than 10% of the diagonal components. Moment tensor of compressional motion was dominated by positive vertical dipole. Other components of the moment tensor were less than 10% of the vertical dipole. These results of source mechanism showed that the eruption earthquake was initiated by an isotropic contraction at depths from 200 to 300m around the summit crater, and then an expansion dominated by vertical dipole was generated 0.3s after the isotropic contraction at depths from 400 to 600m beneath the summit crater.

11-P-83

Distribution of the Ejecta from 2004 Sept 1st. Vulcanian Eruption of the Asama Volcano - An Evaluation by Field Survey of the Results by IKONOS High-resolution Satellite Imagery –

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Vulcanian eruption has frequently repeated from the beginning of the 20century in Asama volcano. In such a

case, it is very difficult to identify the date of the eruption for each of the products. Sasaki and Mukoyama(2006) made an impact crater distribution map of the September 1st. 2004 eruption of Asama Volcano using IKONOS high-resolution satellite imagery, and it is useful to determine the distribution of the ejecta by this eruption. However, this determination was difficult in a deep forest, and the rock type of the ejecta could not determine by this imagery, therefore, we carried out a field survey. As a result of the visits to the 130 plots among those found by Sasaki and Mukoyama(2006), we confirmed that more than 80% of them really consisted of impact craters with various size accompanied by destruction of plants, caused by massive and/or alterated blocks. Therefore, the information of the small deformation of topography and vegetation provided by the satellite image is important. Among another 20% of the plots, we found ten breadcrust bombs identified as a juvenile material of the eruption on September 1st. And we also found two of them were not plotted in the imagery map. A few ejecta and impact craters in a forest or scorched evidence lower than 30cm that the satellite image could not detect were also found by field survey.

11-P-84

Search for Magma Body below Mt. Fuji, Japan

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We seek new methods to delineate and quantify the geometry and relative amount of partial melt below Mt. Fuji, Japan. Tomographic inversion for velocity structure beneath Mt. Fuji, Japan, suggests the presence of a large, localized structure of low velocity indicating magma accumulation. To constrain the relative amount of melt or partial melt we are pursuing a broad program to extract an array of seismic parameters that will further illuminate structure and geologic detail in the magma storage system and conduit geometry. The first step involves an extensive investigation of seismic amplitude, spectral content and attenuation of energy below the Mt. Fuji edifice. Using 41,572 local and regional events detected by 23 stations (NIED) surrounding Mt. Fuji from 1995 to 2006 we extracted 80, 425 pairs of stations that align along nearly linear directions from their respective sources. The spectral amplitude is modeled by $A(f)=S(f)P(f)I(f)C(f)B(f)G$ where S(f) is the source spectrum, P(f) is path effects, I(f) is instrument response, C(f) is site response, B(f) is attenuation effects, and G describes geometric spreading and the focal mechanism. S(f),P(f), and G can be eliminating by taking the spectral ratio of each pair that share the same event source. Initial results suggest that waves that traverse beneath the Volcano edifice suffer considerable spectral fall off and suggest the presence of considerable partial melt. The large data-set provides a basis for a simple two-dimensional tomographic inversion for crustal Q in the vicinity of the active volcano. This independent result seems to corroborate results of the velocity inversion and analyses of anomalous b-value studies below Mt. Fuji.

11-P-85

Modeling of Large Scale Crustal Deformation at Iwo-jima Caldera

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Iwo-jima is a caldera volcano with a quite high uplift rate for the last several hundred years, about 0.2 m/a. We have conducted geodetic surveys, continuous GPS observation, micro-gravity survey and InSAR research for monitoring the crustal deformation of the island. The crustal deformation pattern is characterized by two modes, a steady mode with contraction at the caldera center and uplift in the surrounding area, and an episodic mode with large uplift spreading over the whole island occurring with several to ten year interval. The crustal deformation is explained by a model with the contraction source at a depth of about 1 km beneath the central part of the caldera, and with magma intrusion underneath the contraction source. This model can explain the distribution of phreatic explosions and may be useful for risk evaluation of Iwo-jima.

11-P-86

The Role of an Aquifer in Generating Continuous Tremor at the Shallow Part of Nakadake, Aso Volcano.

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In five years from 1999 to 2003, four experiments of volcanic tremor observations using one or two dense seismic arrays consisting of short-period seismometers were performed near the active crater at the Aso volcano by the joint team of Tokyo University, Kyoto University, and Tokyo Institute of Technology. The main purpose of the observations is to reveal the mechanism of generation of short period continuous tremor at the volcano. In all of the four experiments, a seismic array was deployed at the same place 700 m west of the active crater, allowing us to investigate secular changes in the tremor activity during the five years. Despite of the significant secular changes in the spectral features and arrival azimuth of the continuous tremor, the slowness observed at the west arrays are remarkably stable (about 0.6 s/km) for the frequencies around 4.7 Hz throughout the 1999 to 2003 experiments. The small slowness for the frequency band relative to the adjacent frequencies suggests the dominance of body wave arrivals over the seismic wave field. The stability of the slowness also implies that the source depths of the continuous tremor do not change so much throughout the experiments. The estimated tremor source depth based on the slowness values is shallower than about 300 m beneath the active crater, which broadly corresponds to the depth range of high electric conductivity layer found by Hase et al. (2005). This coincidence suggests that the ascending fluids meet an aquifer which extends horizontally beneath the active

crater at the depth, and that the continuous tremor is generated by the contact of gas and water there.

11-P-87

Magma Intrusion Process Based on Ground Deformation using with GPS Observation and Precise Leveling in Ontake Volcano, Central Japan in 2007

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First historical eruption was recorded at Ontake volcano, central Japan on October 1979. After the phreatic eruption, volcano activity was decreasing and volcano steaming was also disappeared until 2000.

In end of December 2006, earthquakes were observed just beneath the 1979 eruption fissure and steaming occurred again on March 16, 2007. GPS measurements of GSI, JMA and TRIES detected few to 10 mm horizontal displacements around the volcano since middle of December 2006 to June 2007. Very long-period events were observed and largest VLPEs was observed at seismic stations over 100 km from the volcano on January 25.

We had precise leveling in the eastern mountainside of the volcano in April, and 8 mm uplift was detected in the northeastern mountainside in the period of April 2006 to April 2007.

We discuss a magma intrusion model based on the ground deformation by GPS measurements and leveling. It is suggested one dike intrusion striking northwest-southeast at a 3 km depth of the volcano summit. Totally, intrusion volume of the dike is estimated to be 10 x $10^6$$m^3$. From the precise GPS processing also makes clear the significant ground deformation was detected before the occurrence of earthquake swarm beneath the summit.

11-P-88

Imaging Rabaul Caldera, Papua New Guinea

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We did P-wave traveltime tomography using Fast Marching Method to map low velocity anomalies beneath Rabaul Caldera, Papua New Guinea. We used local and regional earthquake data recorded by the Rabaul Harbour Network and RELACS stations. For model parameterisation we used different horizontal cell sizes from (1 km x 1km) to (3 km x 3 km) to gauge how the results varied. The recovered velocity anomalies show two low anomalies directly beneath Rabaul Caldera at depths 3-5 km and 11-14 km. We also picked up another low velocity anomaly northeast of Rabaul Caldera. Results of checkerboard tests suggests the two anomalies beneath Rabaul Caldera are quite reliable, but the northeast anomaly may be less reliable since it is located on the fringes of good model recovery. Our results are consistent with Finalyson et al (2003) and Bai and Greenhalgh (2005) for the shallow anomaly beneath Rabaul Caldera and to some degree with Bai and Greenhalgh (2005) for the northeast anomaly. The anomalies beneath Rabaul Caldera can be comfortably interpreted as magma reservoirs since they are located directly beneath the active caldera system which has a very record of active volcanism.

11-P-89

Crustal Deformation for 2006 Volcanic Activity of Iwo-jima Volcano Detected by PALSAR/InSAR

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Vertical movement at a GPS site located in the Motoyama district of Iwo-jima volcano changed from continuous subsidence since 2003 to uplift in mid-August of 2006. Increased seismicity was also observed. We apply InSAR technique using PALSAR abroad the ALOS satellite, and detect crustal deformation associated with the increase in volcanic activity. Just before the increase of volcanic activity, a slant-range change representing a subsidence of several centimeters was detected throughout the Motoyama district, but it seemed to differ from the contraction pattern that had been dominant in the area. The contraction in Motoyama may have slowed down just before the increase in volcanic activity. Three months after the increase in volcanic activity, a slant-range change suggesting that the whole island had uplifted was detected. It suggests that crustal deformation induced by a relatively deep source was prominent in this period. When the volcanic activity was highest, the uplift accelerated and seismicity increased further. PALSAR observations were conducted from ascending and descending orbits in this period, and a two-dimensional displacement field could be obtained from these data. The obtained result is characterized by an uplift pattern suggesting inclination of the whole island with uplifts in the south end of the island of 8cm and uplifts in the north end of 40cm. In the north-south fault zone in the west coast area, crustal deformation with an expansion and an east-up pattern was detected. Additionally, a steep gradient of vertical movement detected along the fault zone located in the south end of Motoyama district extended to the east and west. This crustal deformation pattern suggests a blockwise uplift of Motoyama district. Since the wavelengths of these deformation patterns were relatively short, crustal deformation induced by a relatively shallow source must have dominated in this period.

11-P-90

The Relationship between Resistivity Structures and Geothermal Fluids in the Shallow Part of a Volcano

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The resistivity of rock can become extremely low depending on the fluids contained in the rock and the clay minerals produced through alteration. Through surveys on resistivity structures, it is known that there are low resistivity zones in the shallow part of volcanoes, although their entities have not been clarified yet. In this research, considering that aquifer structures within the volcanic edifice, which is one of the factors causing diversity of eruptions, can be detected through measuring resistivity, we conducted a survey on shallow-depth resistivity structures at the northeastern foot of Unzen volcano, where the existence of geothermal fluids and their flow have been indicated by thermal profiles of borehole data. After comparing the detected resistivity structures with the permeability and temperature profile of the drilled wells and samples, we found a correspondent relationship where resistivity lowers with rise in temperature, hitting the lowest at the hottest area. In addition, the drilled samples from a low resistivity structure showed higher permeability while those from even deeper layers contained clayey materials that could be considered to be impermeable layers. Therefore, our results have shown that the low resistivity structure corresponds with layers of abundant geothermal fluids while clay layers at the lower depth are relatively high in their resistivity at the northeastern part of Mt. Unzen.

11-P-91

Estimation of Fault Parameters using SAR Interferograms Observed from Two Orbits; Applications to Volcanic Earthquakes in the Izu Peninsula and Mt. Iwate

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Space-borne SAR interferometry (InSAR) is an innovative technique to visualize the special distribution of surface deformation in and around active volcanoes. It dose not need any terrestrial observation instruments and L-band InSAR, especially, performs well against some decorrelation factors such as vegetation and mountain slope. It provides a lot of 2-dimensional information of line-of-sight (LOS) displacements due to crustal deformation with very high special resolution. In this study, we estimated fault mechanism of some volcanic earthquakes by using pairs of interferograms observed from two cross-track directions of both ascending and descending satellite orbits. (I) Dyke intrusions associated with earthquake swarms in the east Izu Peninsula of central Japan, where is the monogenic volcano area, in March 1997 and April-May 1998 were detected by JERS-1 InSAR. Patterns of crustal movements were explained by one major tensile fault and one left lateral fault induced by tectonic earthquake (M=4-5), which was consistent with a model from other terrestrial observations (GPS, EDM, leveling survey and relative & absolute gravity change). (II) Volcano inflation followed by the shallow earthquake in the geothermal field near Mt. Iwate Volcano in the Tohoku region of Japan during April -October, 1998 was detected by JERS-1 InSAR. Two dimensional vectors of surface displacement were calculated using two LOS displacements from the ascending and descending orbits and time sequence of crustal deformations can be shown as series of differential interferograms. On 3 September, the Iwate-ken Nairiku Hokubu earthquake (M=6.1) was caused by two reverse faults, whose fault parameters were well estimated from remarkable patterns of the differential interferograms observed from two orbits. Visible fringes with good coherence were obtained over steep slopes around the focal region under longer baseline conditions (Bp=1240m, 132 days and Bp=1900m, 44 days interval) using L-band SAR data.

11-P-92

Imaging of Volcanic Deformations by using of Space-borne Interferometric Synthetic Aperture Radar (InSAR)

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Potential of space-borne interferomteric synthetic aperture radar (InSAR) technique to detect crustal movements induced by earthquake, volcano deformation and ground subsidence etc. were investigated. Especially, L-band SAR on board JERS-1 and ALOS is robust against the decorrelation due to steepness and vegetation in mountainous area in Japan. In this study, we summarize results of InSAR (L-band SAR; JERS-1 in 1992-1998 and ALOS in 2006-, C-band; Radarsat and ENVISAT) applied to active volcanoes in Japan as follows; (1) Mt. Unzen in central Kyushu, which erupted during 1990 to 1995 and deflation around the summit was measured, (2) Mt. Sakurajima in southern Kyushu, where volcanis inflation has been observed, (3) Mt. Kuju in central Kyushu, which erupted in 1995 and significant deflation has been continued, (4) East Izu Peninsula, in central Honshu, where volcanic earthquake swarm intermittently activated in 1980' to 1990', and dyke intrusion occurred in 1997 and 1998 were detected by InSAR, (5) Mt. Iwate in northeastern Honshu, where volcanic inflation followed by the shallow earthquake (M=6.1) in 1998, and its fault model parameters were well estimated by the results of InSAR observed from both directions of the ascending and descending orbits, (6) Mt. Usu in Hokkaido, where significant subsidence around the summit has been well imaged which may be caused by cooling and deflation of crypto-lava dome made at the previous eruption in 1977. On the other hand, details of data analysis processes are opened and some important techniques for precise imaging, baseline estimation method and remove residual phase (flat earth fringe and topographic phase) method etc. will be discussed.

11-P-93

Volcanological Influence on Borobudur's Basin and lacustrine Development These Last 350.000 years: Preliminary Results

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Located on Java Island, Indonesia, Borobudur's basin is surrounded by four active volcanoes: Merapi, Merbabu, Sumbing and Sindoro. If it is not for Merapi's last 10.000 years, knowledge is extremely limited concerning these volcanoes. Even historical phenomenology remains unveil as yet. Therefore we drilled the basin's floor in two locations using a rotative corer, in order to have an overview of past activities of these volcanoes and especially Merapi. The two bores are located to the South of the basin at the Elo and Progo rivers confluence and near the Sileng River. They are respectively 70 m and 111 m deep. Both bores are bottomed by deep lava-rocks that are K/Ar BP158.000 and K/Ar BP362.000. Informations registered in these logs are concerning major events. Pyroclastic-flow deposits are to be found in both bores, but were principally recorded in the bore located near the Sileng while the units located in the other bore seem to have been washed away by erosion. Dated pyroclastic-flow deposits are K/Ar BP113.000 and K/Ar BP75.000. These pyroclastic-flow deposits would coincide with Merapi's major eruptions. Bores also recorded lacustrine formations. The most important lacustrine deposit seems to have occurred around 14C BP27.000. We did not find any trace of a more recent lake, but a 14 C BP20.000 years hiatus in the Elo's bore from 14C BP27.000 partly blinds us for the most recent period, and further researches have to be carried on.

11-P-94

Formation Process of the Summit Caldera on the Stratovolcano - A Case Study of the West-Iwate Caldera, Iwate Volcano, NE Japan -

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Iwate Volcano that lies about 20km northwest of Morioka City, having a population of 300,000, in northeastern Honshu, Japan, is an active strato-volcano, comprising basaltic to basalt-andesitic rocks. Based on topographical features, the volcano is divided into two volcanic bodies, i.e., East-Iwate and West-Iwate. East-Iwate Volcano is a strato-cone, which buries several sector-collapsed walls; whereas West-Iwate Volcano has a caldera (2.5km by 1.5 km-wide; ca. 1.5 km^3) was formed on the its summit. The volcanic activities are divided into 7 stages based on correlation between eruptives that constitute volcanic edifices and air-fall tephra layers. It is assumed that the caldera was formed in West-Iwate Omisaka stage of about 90 ka to 45 ka. During this stage, several lateral cones erupted and a number of dykes intruded around the caldera rim. The cones were formed by magmatic to phreato-magmatic activities, and a small-scaled (<0.002 km^3, DRE) pyroclastic flow was generated by a lava or welded-cone collapsed. Formation of the lateral cones continued after the start of the caldera depression. The frequency of explosion of air-fall tephra was accelerated from ca. 72 ka to 45 ka, resulted in the formation of a tephra group with intercalations of thin soil layers. This tephra group is composed mainly of scoria and volcanic-sand layers, and a few intercalated pumice layers, although erupted volume for the most voluminous pumice layer is also exceeded 0.078 km^3, DRE. Total magmatic volume of the tephra group is 0.9 km^3, DRE. On the basis of the boring core samples, it is speculated that part of mountain body lost by a caldera collapse may occur by the end of this stage. Considering the geological information, West-Iwate Caldera was not formed by a single and catastrophic event, but constructed by the depression activity which gradually progressed.

11-P-95

An Account of the Eruptions of Jorullo Volcano: A Nested Monogenetic Volcano or "New" Active Volcano in Mexico?

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Jorullo volcano was born in 1759 in the Michoacán-Guanajuato Volcanic Field (MGVF) in western Mexico During the birth of the volcano several lava flows were emitted as well as Jorullo, Norte, Unnamed, Enmedio, and Sur cones were constructed, all N-S aligned. Jorullo is made up of tephra and lava flows erupted from the crater. Enmedio erupted highly vesiculated tephras including granitic xenoliths. Sur is made of spatter and bombs. Both cones collapsed towards the west and their deposits show a hummocky morphology. After the collapses, phreatomagmatic activity from Unnamed cone blanketed Enmedio, Sur and Jorullo cones with sticky surge deposits. These events occurred after formation of the 3 southern cones. Besides the lavas erupted in1759-1774, other lava flows with different composition were erupted in a previous, unknown date. These lava flows were mapped as poured out from the same source from which Jorullo products were emitted. This may mean that the fracture system that allowed the birth of Jorullo has been active for long time and, therefore, it may allow an eruption in the future. So, considering Jorullo a monogenetic or polygenetic volcano is a crucial matter because it implies an attitude from the population and authorities to face future eruptions. The 1759-1774 activity of Jorullo volcano affected the region strongly, although the damage was minor and people got back later. Population of the region has increased enormously over the last few hundred years, and thus, hazard assessment becomes crucial, particularly because the eruptive magnitudes and effects of such small cones have often been underestimated. Studying the history of volcanic activity aids our understanding of eruptive hazards and evaluates the likeliness of future eruptions. These processes at Jorullo volcano (cone collapse, phreatomagmatic activity) have not been previously described and are of great importance because of their implications for hazards assessment.

11-P-96

Re-examination of Eruptive History of the Post-caldera Stage at Towada Volcano, Northeast Japan Arc

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We re-examined the eruptive history of the post-caldera stage (15 ka to present) at Towada volcano, Northeast Japan arc, on the basis of the results of detailed geological survey of Ogurayama Lava Dome and minor tephra layers (eruptive episode D' and D), and AMS radiocarbon dating of soil samples directly below tephra layers (eruptive episode B, D', D and G). Stratigraphic relations show that the Ogurayama Lava Dome was formed between 9.4 and 6.1 ka (in calendar age). The D' is stratified ash fall deposits derived from intermittent phreatomagmatic eruptions. Similar ash fall deposits were newly identified directly above the pumice fall deposits of the eruptive episode D. On the basis of radiocarbon dates, the eruptive ages of eruptive episode B, D', D and G are estimated to be 2.8, 7.6, 8.3 and 10.6 ka, respectively. In the beginning of the post-caldera stage, intermittent eruptions of Goshiki-iwa Lava Flows and Ninokura Scoria occurred during 15 to 11 ka and formed a central cone. Subsequently, five explosive eruptions that erupted 0.1-0.6 km^3 magma in each occurred between 11 and 7.5 ka at intervals of 500-1100 years. The Ogurayama Lava Dome was formed in those years. Subsequently, the eruptive episode C, B and A occurred in 6.2 ka, 2.8 ka and AD 915, and erupted 2.7, 0.5 and 2.3 km^3 magma, respectively. These three eruptions occurred at relatively longer intervals of 1700-3400 years. Source vents of these eruptions are estimated to be a central crater on the central cone. Nakanoumi Caldera (2.5 km in diameter) was possibly formed in the AD 915 eruption. Eruption sequences of each eruption in the Towada post-caldera stage are characterized by an initial Plinian phase and a subsequent intermittent phreatomagmatic phase. Such eruptions have occurred six times of eight eruptions after 11 ka.

11-P-97

Hazard Assessment of Gede Volcano, West Java - Indonesia

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Gede volcano is one of the Indonesian active volcanoes in West Java, located some 70 km to the west of Bandung and 80 km to the south of Jakarta. It is a big strato volcano as high as 2958 m (a.s.l.); composed of alternating layers of lava flows, pyroclastic falls, and pyroclastic flows. Before 1957 it was a very active volcano where the interval of eruptions ranges between 1 - 37 years, but since then this volcano does show any eruption anymore except phreatic eruption.

The youngest big deposit of Gede volcano is pyroclastic flows those are widely distributed to the north - northeastern and which covers wide area up to 12 km from the source. It contains at least two layers of pyroclastic flow deposits which were dated about 850 + 120 years BP. The bottom layer of this deposit composed of big blocky fragments of andesite within gray ash matrix. Once this deposits covered thick forest with big trees. The upper part of the pyroclastic flow is mostly composed of pumiceous fragments with ash matrix.

At present time, the Gede volcanic complex is surrounded by several developing small towns such as Cipanas, Cianjur, Sukabumi, Bogor and Ciawi which are densely populated.

Based on the geological records and historical eruptions of Gede volcano, it is not impossible the same event may occur in the near future like it used to be. Within five decades this volcano is in quiescence status, occasionally it shows increase seismicities but then disappeared and visually it doesn't show significant change.

Due to its quite long rest, careful and intensive monitoring should be carried out to avoid the future eruption that may cause loss of life and property.

11-P-98

Revision of "Geological Map of Usu Volcano"

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[Usu Volcano and Its Geological Map]

Usu volcano is one of the most active volcanoes in Japan. It has erupted repeatedly at intervals of 30-50 years, causing many casualties. During the last eruption in 2000 A.D., many explosion craters opened just close to densely inhabited area. Such a history and distribution of eruptive products have been compiled in "Geological Map of Usu Volcano 1:25,000" (Soya, Katsui, Niida and Sakai, 1981) published by Geological Survey of Japan. Since this map was equivalent to a disaster map of the volcano, it offered basic data for a hazard map of Usu volcano. Now, we have revised the map after a lapse of 25 years.

[The Point of the Revision]

In the 2nd Edition of the Geological Map of Usu Volcano (Soya, Katsui, Niida, Sakai and Tomiya, 2007), the main revised point is an addition of the information on the 2000 eruption. We drew distribution of craters and eruptive products of the eruption on the map, and summarized the sequence of the eruption. We also replaced some old-fashioned terms and data into up-to-date ones. In regard to various findings during the past quarter century, however, the revision was restricted to a minimum. We hope that the new edition of the Geological Map of Usu Volcano will be fully used in various purposes, such as disaster prevention and volcanological research.

11-P-99

The 1814 Plinian Eruption of Mayon Volcano, Philippines: A Brief but Catastrophic Event

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The February 1, 1814 eruption is the only Plinian eruption of Mayon Volcano in recorded history. Although it lasted just six hours, it was the most catastrophic and devastated five towns, killing at least 1,200 people. This study reconstructs the eruptive sequence through field mapping, use of historical accounts and laboratory analyses.

During the six hour period this eruption generated: two Plinian basaltic andesite fallout deposits, pyroclastic flow and surge deposits, and syn-eruption hot lahars emplaced mostly at the southern sectors of the volcano. The lower fallout unit is 40cm-thick in the medial outcrop is well sorted, loose, and consists predominantly of scoria lapilli and bomb with minor dense lithics. It was emplaced at high temperature as evidenced by the presence of abundant charred wood in the deposit. This lower fallout unit grades laterally into pyroclastic flow and surge deposits. Rain-triggered lahars probably reworked the upper portions of the unit, generating hot lahar deposits. The upper fallout deposit is 30cm-thick in the medial outcrop and consists predominantly of scoria but incorporates more altered lapilli than the lower fallout unit. The abundance of altered lapilli indicates vent erosion and widening in the final phase of the eruption. Major syn-eruption hot lahars occurred.

Most damage and casualties were probably caused by direct impact and incineration from the fallout. Some areas were also affected by the impacts of pyroclastic flows and surges and lahars.

A similar Plinian eruption today would be far more deadly, as the population around the volcano has increased significantly since 1814.

11-P-100

Re-examination of The Prehistoric Activity of Hokkaido-Komagatake Volcano, Northern Japan

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Hokkaido-Komagatake volcano, northern Japan, is one of the most active andesitic volcanoes in Japan. Major historic eruptions have occurred four times since the 17th century after 5000 years of dormancy. In contrast, in previous studies, four units of plinian eruption deposits have been recognized prior to the first and the largest historical eruption in 1640 AD (Ko-f: 5.5 ka; Ko-g: 6 ka; Ko-h: 17 ka; Ko-i: 32 ka). A new prehistoric eruptive history of the volcano has been proposed by new findings at ejecta of the last 32,000 years. The findings have been obtained from descriptions of eruptive units, radiocarbon dating of charcoal woods, and whole-rock chemistry of juvenile materials. Our study revealed the seven new eruptive units below the 1640 AD products in the northern flank area of the volcano. Eruptive ages of the new events were estimated as follows: P1 (5.5-5.7 ka); P2 (5.5-5.7 ka); P4 (11 ka); P5 (12.5-13 ka); P6 (14.3-14.5 ka); P7 (14.5-14.7 ka); and P8 (15-16 ka). By the long-term dormancy, the eruptive history of the volcano can be divided into four eruptive stages, i.e., before 32 ka, 17 ka to 11 ka, 6 ka to 5.5 ka, and after 1640 AD. Each stage has distinct whole-rock chemistry of each juvenile material. An eruption sequence of first larger and subsequent middle and small scales characterizes the style of last three stages. The result of our study could provide a basis for long- or mid-term prediction of the future activity of the volcano.

11-P-101

Stratovolcano in Nyiragongo

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Nyiragongo, located in the Western branch of the Rift Valley near Lake Kivu and the Congolese-Rwandese border, is one of the world's most active volcanoes. It is notorious for its lava lake and producing lateral eruptions with extremely fluid, fast-moving lava flows that repeatedly devastated areas around the volcano, such as the Goma desaster on January 2002, when a lava flow destroyed much of the city's commercial center and promted 200,000 people to flee. The large lava lake contained in its deep summit crater, now active again, became famous in the 1960's and 70's when volcanologists such as the Kraffts and Tazieff studied it. It had been active for half a century before it drained in one of the volcano's recent most catastrophic eruptions in 1977: through openings in its outer flanks in 1977, a huge lava flow poured out and killed hundreds of people. A similar event happened again in January 2002, when lava flows from flank vents drained the lake and cut through Goma, reaching Lake Kivu.In contrast to its neighbor volcano, Nyamuragira,- a typical, and very active shield volcano comparable with Mauna Loa,- the 3470-m-high Nyiragongo displays the steep slopes of a stratovolcano. Terraces inside the steep-walled, 1.2-km-wide summit crater mark levels of former lava lakes, which have been observed since the late-19th century. Two older volcanoes, Baruta and Shaheru, are partially overlapped by Nyiragongo on the north and south and look like lateral cones. About 100 parasitic cones are located primarily along radial fissures south of Shaheru, east of the summit, and along a NE-SW zone extending as far as Lake Kivu. Many cones are buried by voluminous lava flows that extend long distances down the flanks of the volcano.

11-P-102

Stratigraphy and Ages of Quaternary basaltic Lavas from Choogaryong Volcano, Center of the Korean Peninsula

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There was no data about eruptive history of Choogaryong

Volcano located on the border between South and North Koreas. Around the Chongok-ni Paleolithic site near DMZ, one of the oldest and the most famous archeological sites in South Korea, the stratigraphy and chronology of Quaternary basaltic lavas from Choogaryong Volcano are based on the field survey, XRF, EPMA, and K-Ar and fission track dating, The basalts are subdivided into two stratigraphic units: the Chongok basalt and the Chatan basalt. The former is older than the latter. There is distinct uncomformity such as erosive valley and soil between the Chongok and the Chatan basalts. They are typical alkali olivine basalts and their phenocrysts compositions and grandmas are almost same. They can be distinguished only by whole-rock major and trace element composition, but the differences are very slight. For example, wt% of SiO_2 in the Chatan basalt is just 1 % higher than that of the Chongok basalt. The results of plagioclase K-Ar dating of 18 samples from both basalts and fission track dating of 4-burnt soil show that the Chongok basalt is 0.5 Ma old and the Chatan basalt is 0.15 Ma old. We recognize two eruptions at Choogaryong Volcano.

11-P-103

Hotspot Volcanism vs. Erosion: High-resolution Morphometry of the Canary Islands

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Hotspot-induced lineaments of islands represent an opportunity to study long-term evolution of volcanic landforms, following volcanic and morphological stages mostly defined in Hawaii and Society Islands. This work focus on the volcanic construction and destruction rates of hotspot-induced islands. The Canary Islands were selected because the slow-moving African plate and a composite mantle plume extend the duration of volcanism (20-25 Ma), providing a broad variety of chronological and morphological markers. We built a high-resolution topographic database of the seven islands with ArcGIS (vector and raster DEM, shaded relief after TIN, slope maps and aspect ratio with a 5-20 m pixel resolution). This data were used to create the morphometric database combining the digitalized geology, the ages of the volcanic formations and the geomorphology. We specially focused our study on 170 valleys (transects and longitudinal profiles, length, width, depth, age of the topmost eroded lavaflow). During the first stages (shield stage), the destruction is mostly represented by massive and instantaneous failures, involving about tens of km^3. These events have immediate consequences (scarps, debris avalanches, tsunamis), but they also influence the further volcanic and morphological evolution of the islands. The long-term erosion rates (eg. vertical incision rates of the valleys, so-called barrancos) are low during the hiatus stage (scarce or absent volcanism), whereas they are high during the postshield and rejuvenated stages and mainly depend on the dynamics, spatial distribution and rates of volcanic construction. We could quantify these rates and their relationships (eg. volcanic construction vs. erosion rates, slope distribution vs. hotspot stage of evolution). The methodology developed in the Canary Islands, could be enlarged to others hotspot archipelagos.

11-P-104

Temporal Change in the Volcanic Field of Early to Middle Pleistocene Central Japan: Volcanic History of Yatsugatake Area and the Special and Temporal Change

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The Area where the volcanism continues long term is leaving the evidence of the several volcanisms in the past. To research volcanism of the past is connected with foreknowledge of an eruption understands. However, it was difficult to clarify in-depth volcanic history, because the volcanoes in these areas are lacking geological and chronological data.

Central Japan was subducted of Philippine Sea plate and Pacific plate, volcanic front of the Yatsugatake area is located on the side of back arc compared with Northeast Japan and Izu-Mariana arc. As for this area, the two volcanoes exist and differ from activity period and the arrangement of these volcanic centers (Yabashira Volcanoes: about 1.2-0.8 Ma, Yatsugatake Volcanoes: about 0.5-0 Ma; Nishiki et al., 2007). Based on the result of field works, I examined the characteristics of two volcanoes from eruptive style, chemical composition and total volume. As a result, it was clarified that these two volcanoes have the different characteristic. Consequently, it was clarified that spatial and temporal change of the in-depth long-term volcanism in the Yatsugatake area since Early Pleistocene. Additionally, because the volcanic field of Yabashira Volcanoes spreading in the NW-SE direction, on the other hand, the volcanic field of Yatsugatake Volcanoes spreading in the N-S direction, I consider change of volcanic field and crustral stress field as well in consideration of volcanism in surrounding area.

11-P-105

Mechanically Disrupted And Chemically Weakened Zones In Segmented Kimberlite Dyke Systems Cause Vent Localisation

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Deformation and alteration zones along kimberlite dykes hold clues as to how point-source vents can localise along sheet-like intrusions. Brittle deformation zones occur in host rock adjacent to kimberlite intrusions of the Swartruggens Kimberlite Dyke Swarm, South Africa. Deformationincludes local fracturing and brecciation and is associated with relay zones between offset dyke segments. Breccia zones indicate dilation andhydraulic fracturing and some were also affected by chemical corrosion, forming joint-bounded spheroidal structures surrounded by onion-skinconcentric foliations of altered rock. The alteration was caused by volatiles released in advance by the magma which then moved ahead in thefracture. Consideration of the time-scales needed for chemical corrosion of the host rock require intrusions to stall at depth prior to transportto higher crustal levels. Highly disrupted offsets could be preferred locations for explosive activity and initial kimberlite pipe formationas

dykes approach the surface. The pipe forms after breakthrough of magma to the surface and the altered zones are reamed out and thechemically altered spheroidal clasts are incorporated into the pipe fill along with more angular country rock material, as observed in layeredvolcanic breccias in kimberlite pipes at Venetia mine, South Africa. This model has wider implications for the localisation of conduits atother types of volcanoes. Dyke segmentation provides weak zones where hydrothermal fluids and magmatic volatiles can be preferentiallychannelled. Chemical corrosion can further weaken these zones which may then become the locus for initial phreatic and phreatomagmaticexplosions creating shallow vents that can then channel magma to the surface.

11-P-106

Growth and Eruption History of Unzen Volcano, Japan

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Unzen volcano is an active volcano composed of lava domes, thick lava flows and pyroclastic deposits of hornblende andesite to dacite. Tectonically active Unzen graben dissects volcanic edifices of the volcano. During the Unzen Scientific Drilling Project (USDP), two drillings were conducted at the northeastern (752 m depth) and eastern (1463 m depth) flanks of the volcano, respectively, to fully recover accumulated deposits of the volcano hidden beneath the younger eruptives. Extensive K-Ar and $^{40}Ar/^{39}Ar$ age determinations have also been conducted on both surface rocks and drilling cores. Unzen volcano starts to grow at 0.5 Ma above the Pre-Unzen pyroxene andesite. Unzen volcano has been divided into three volcanic stages, the Older Unzen, the Middle Unzen and the Younger Unzen. The Older Unzen (0.3-0.5 Ma) products consist of pumice-rich pyroclastic flows, block-and-ash flows, associated volcaniclastic debris flows and thick lava flows. The north- and south-dipping fans spreading outside the graben are sharply cut by the faults. Unzen volcano grew rapidly in the first 200,000 years of its history and formed a conical volcanic edifice. The Middle Unzen (0.15-0.3 Ma) products mainly fill in the graben. In the western half of the deposits of this stage, thick lava flows cover widely inside the Unzen graben. On the other hand, thick alternated piles of pyroclastic deposits were recovered both from USDP-1 and -2 cores. In the USDP-2 core, phreatomagmatic deposits about 250 m thick with essentially abundant glass materials of ca. 0.3 Ma. These findings suggest that rapid subsidence of the Unzen graben at around 0.3-0.2 Ma led strong interaction between the magma and groundwater. Younger Unzen volcano (0-0.15Ma) is composed of four edifices, all locate in the eastern half of Unzen volcano. Block-and-ash flow deposits or related debris flow deposits were continuously supplied to the eastern flank of the volcano.

11-P-107

Shallow Dike Emplacement, Geometric Stabilization And Drainage Revealed From Thermal Surveys During The 2002-03 Etna Southern Eruption (Italy)

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The 26 October 2002 - 28 January 2003 eruption of Mt. Etna volcano was characterized by lava effusion and by an uncommon explosivity along a 1 km-long-eruptive fissure. The intense activity promoted the rapid growth of cinder cones and several effusive vents. Analysis of thermal images, recorded throughout the eruption, allowed the investigation of the distribution of vents along the eruptive fissure, and of the nature of explosive activity. The spatial and temporal distribution of active vents revealed the phases of the dike intrusion, expansion, geometric stabilization and drainage. These phases were characterized by different kind of explosive activity, with gradual transition from fire fountaining to mild strombolian activity, through transitional phases and ending with non-explosive lava effusion. Here we interpret the mechanisms of the 2002-03 Etna southern dike emplacement and the eruptive dynamics, according to changes in the eruptive style, vent morphology and apparent temperature variations at vents, detected through thermal imaging. This is the first time that dike emplacement and eruptive activity have been tracked using a handheld thermal camera and we believe that its use was crucial to gain remarkable evidences for a detailed understanding of the eruptive event.

11-P-108

A Cellular Automata Model for the Formation of Lava Tubes

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Lava flows represent a problem particularly challenging for physically based modeling because the mechanical and thermal features of lava change over time. In order to generate complex trajectories due to the interactions between lava flows and the underlying topography, we need to model the main mechanical features of lava and the way they evolve over time depending on temperature. We developed a model for lava flow simulations based on Cellular Automata, called MAGFLOW. An algorithm based on Monte Carlo approach to solve the anisotropic problem was included. A steady state solution of Navier Stokes equation, in the case of laminar pressure-driven Binghamian fluid, was taken into account as evolution function of CA. The model takes into account a vertical thermal structure in the flow. To this aim two layers are considered: a lower layer, where the temperature is homogeneous and an upper layer across which heat is transferred by conduction. At free surface of the flow, we

have heat radiation to the atmosphere. The upper layer is taken to coincide with the plug, defined as the region where no shear deformation takes place in a Bingham flow. The cooling mechanism is controlled by the increase of yield stress, which produces a thicker plug and makes the heat loss slower. As result of heat loss into the atmosphere, a crust, defined as the layer which is above the isothermal surface at the solidus temperature, is gradually formed on the upper surface of the flow. We assume that a lava tube is formed when such a crust is sufficiently thick to resist the drag the underlying flow and sustain itself under its own weight. The achievements related to simulate the path of lava flow outpoured during some eruption of Etna volcano are shown.

11-P-109

Cellular Automata Flow Simulations Using Thermal Satellite Data at Mt Etna

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The ultimate goal of lava-flow-hazard mitigation is prediction of the direction and advance rate of lava flows. That challenge has inspired the development of computer code to simulate lava flows. Much of the physical parameterization of lava flows in terms of viscosity, yield strength, and density has improved computer simulations. In the past decade, great advances have been made in our understanding of the physical processes that control basalt-flow emplacement, resulting in improvement of our tools for the mitigation of lava-flow hazards. We developed the MAGFLOW Cellular Automata model which involves a steady state solution of the Navier-Stokes equations coupled to heat transfer and solidification effects modelled via a temperature dependent viscosity. MAGFLOW model requires as input data a digital representation of the topography over which the lava is to be emplaced, the location of the eruptive vent, knowledge of the relationships of viscosity and yield strength with temperature, and an estimate of the lava effusion rate. The principal factor controlling final flow dimensions is the effusion rate. MAGFLOW model can take into account the way in which effusion rate changes during an eruption and how this influences the spread of lava as a function of time. Indeed, lava effusion rates can vary by orders of magnitude over a matter of hours, and are difficult to determine in-situ. We developed an automatic system that uses near-real-time thermal infrared satellite data acquired by MODIS and AVHRR sensors (low spatial/high temporal resolution) to drive numerical simulations of lava flow paths. We validated this system reproducing the effusion rates of 2004 Etna eruption, and comparing these results by a topographic approach evaluation of total lava volumes outpoured during the eruption. We describe and show the operation of this system by using an analysis of the lava flow-forming during 2006 Etna eruption.

11-P-110

Rhyolitic Magmatism of the Takahara Volcano, Japan, Inferred From Various Petrographic Features of the Obsidian

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The Takahara volcano is a Quaternary volcano in northern Kanto, central Japan, and is located on the active volcanic front of northeast Honshu arc. The Takahara volcano is regarded to have been archaeologically as one of the supplier for the obsidian. However, there were no descriptions about the obsidian from the Takahara volcano by geological or petrological researches on Takahara volcano. In Japan, there are many archaeological studies of occurrence and identification for obsidian. On the other hand, geological studies for obsidian are poor. Therefore process of a magma producing obsidian was not sufficiently elucidated.

The purpose of our present study is to clarify the emplacing process of the magma producing the Takahara obsidian. As the result of the field survey, it has became clear that the primary mode of occurrence of the Takahara obsidian had been lost by erosion or later volcanic activities, and there are two separated occurrences of obsidian layers, such as the Kengamine ridge and the neighboring area and the Amayuzawa valley area. Both obsidians have the very similar field-occurrences of volcanoclastic layers and gravel beds, and these obsidian show the very various texture, fabrics and banded structure in size of microscopic to hand specimen. The obsidian includes commonly spherulites and vesiculations of the various degrees of the contents and the size and most obsidian are observed to have devitrificated features.

The micorophenocrystic minerals of the various obsidians are plagioclases, orthopyroxene, and iron-ore minerals. The bulk chemical compositions determined from the glasses of the various obsidian specimens are the similar with few variations（SiO_2 = 76.5-77.6wt%）suggest that the Takahara obsidians are derive from a single magma through a simple magmatic process and they erupted by the activity of rhyolitic magma formed lava flow or lava dome in the Takahara volcano.

11-P-111

Topographic Controls on Pahoehoe Lava Flow Inflation

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Inflation is a well-documented process within lava flows; however, topographic controls on lava flow inflation are poorly constrained. This study examines the relationship between initial topography and lava inflation within pahoehoe flows of differing discharge rate. Quantitative correlations between inflation, initial surface relief and slope are based on Differential Global Positioning System (DGPS) measurements that were obtained at two localities on the Island of Hawai'i. First, topographic

surfaces were mapped before and after the emplacement of a low discharge rate (0.01-0.05 m^3s) lava lobe from the current Pu'u'O'o-Kupa'ianaha eruption. Second, profiles were obtained for the higher discharge rate (<5-10 m^3/s) lava flows from the 1974 Mauna Ulu eruption and adjacent pre-Mauna Ulu terrain. Regions of maximum lava inflation correspond to regions of low slope and paleo-topographic lows. We infer that as slope decreases the flow must attain a greater thickness before the shear stress in basal viscoelastic layer exceeds its yield strength and begins to deform down slope. Consequently, surfaces with low slopes will favor upward inflation because lateral spreading rates cannot fully accommodate the lava influx. This process is enhanced within paleo-topographic depressions and can lead to topographic inversion of the local landscape. Furthermore, small discharge flows were found to stagnate within less than 24 hours and reached a maximum length of 30-50 m. Although low discharge lava flows may appear too short lived to affect the overall advance of the flow field, localized inflation on shallow slopes may form topographic barriers that affect the development of preferred pathways (e.g., lava tubes) in subsequent flows. It is therefore important to consider both low discharge breakouts and higher discharge flows when attempting to model the evolution of active lava flow fields.

11-P-112

Lava Flow Invasion Susceptibility Map for Etnian East Flank: A Methodology by Cellular Automata

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Modeling complex behavior of lava flows represents an ambitious goal in the field of hazard mitigation. Nevertheless, the use of numerical methods for solving the partial differential equations that govern them turn to display extremely a heavy computational burden, necessitating of large computational resources, thus resulting a "nowcasting" of the event out of reach. Among simplified approaches, Cellular Automata (CA) based methods proved powerful in modeling natural phenomena and in simulating lava flows, flowtype landslides and pyroclastic flows in particular. The objective of this work is the application of a new technique for the definition of lava flows hazard maps to a vast area on the Eastern flank of Mt Etna (Italy). The method relies on a "virtual laboratory", namely the lava flows simulation CA model SCIARA which allows to forecast the paths of new hypothetical events on present morphological data. Specifically, the area was subdivided in different sub-areas, each one characterized by a different probability of activation of eruptive vents and their union "covered" by a regular grid of vents. From each vent, different simulations were executed, each one with a particular effusion rate and duration, based on historical geological data. By considering the extent of the considered flank of Mt Etna, the density of the grid and the number of simulations executed for each vent, a total of 40000 simulations were carried out. A "weight" was assigned to each single simulation, which was set greater for those simulations having the source point located in areas characterized by a high probability of vents activation, and a highly probable emission rate. The final map was therefore compiled by considering each cell of the Etnean flank DEM and, for each of them, by adding the weights of all the simulations that interested it.

11-P-113

Lava Flow Simulation Based on Shallow-Layer Equations

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For assessing the risks and damages associated with lava flows propagationwe need a quantitative description of lava emplacement.However, because of the complexity of the phenomenon, numericalsolution of the full 3-D conservation equations for lava flows ispractically impossible. To overcome the main computational difficulties,simplified models are usually adopted, such as 1-D and 2-D models,isothermal models, cellular automata, neural networks, etc.In this work we present a simplified 2-D model basedon the conservation of mass, momentum and energy in terms ofdepth-averaged variables: thickness, velocity and temperature.This results in first order partial differentialequations which are able to capture the basic physics of theseprocesses, valid when the undisturbed fluid heightis smaller than the characteristic waves length in the flow direction(the so-called " shallow-layer" limit).This represents a good compromise between the full3-D description and the need to decrease the computational time.The model was satisfactorily applied to simulate an episode of the1991-1993 lava flow at Etna. Here we show results obtained by using animproved version of the code, applied to the 2001 Etna eruption.

11-P-114

Viscosity of Magmatic Liquids: an Empirical Model.

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Viscosity is perhaps the single most important physical property governing the production, transport and eruption of magmas. Thus, the accurate prediction of silicate melt viscosity as a function of temperature and composition is of paramount importance for understanding and modelling magmatic and volcanic processes. The task of creating such models has been hampered, to date, by the complexity of including these volatile effects, together with multicomponent melt compositional effects, in the framework of a non-Arrhenian model. Here, we present an empirical model for predicting the viscosity of natural volatile-bearing silicate melts transforming a quarter-century of experimental study of melt viscosities, into a parameterisation which can adequately and comprehensively support numerical modelling of magmatic and volcanic phenomena. A comprehensive viscosity model for magmatic liquids has long been a goal

of earth scientists. Our model, based on >1500 viscosity data, and continuous in composition- and temperature-space, predicts the viscosity of natural volatile-bearing silicate melts (SiO_2, Al_2O_3, TiO_2, FeOtot, CaO, MgO, MnO, Na_2O, K_2O, P_2O_5, H_2O, F_2O-1) over fifteen log units of viscosity (10^{-1}-10^{14} Pa s). This model transforms a quarter-century of experimental study of melt viscosities, into a parameterisation which can adequately and comprehensively support numerical modelling of magmatic and volcanic phenomena.

11-P-115

Garnet-Clinopyroxene Fractionation from Arc Basalts beneath Northern Honshu, Japan

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Garnet-clinopyroxene fractionation is suggested for Quaternary basalts from northern Honshu, by reassessing previously reported major and trace element analyses from ten volcanoes. Ratios of Rb / Y significantly increase with differentiation in all of the volcanoes. The variation cannot be accounted for by removal of phenocryst minerals, but by fractionation of one or more yttrium-compatible minerals. Garnet and amphibole are yttrium-compatible minerals that can account for the variations, but the stability temperature of amphibole is lower than those of the basalt magmas. At pressures higher than 13 kbar, garnet can be stable at the magma temperature. Phenocryst removal is also unaccountable for major element variations. Clinopyroxene fractionation is suggested by the decrease in CaO / Al_2O_3 with differentiation (decreasing MgO). As a result, garnet and clinopyroxene, which are the ubiquitous high-pressure minerals in basaltic rocks (eclogite), are the most plausible fractionating phases from arc basalt magmas beneath northern Honshu. The assemblage garnet-clinopyroxene is stable at pressures higher than 13 kbar according to previous basalt melting experiments and to MELTS modelling. Therefore, basalt magma chambers are deduced to be located at levels deeper than 50 km, which is deeper than Mohorovicic discontinuity but within the low-velocity zone in the middle of the mantle wedge. We also estimated primary magma compositions by assuming garnet-clinopyroxene fractionation model. The estimated compositions imply that mantle melting also occurs in the low velocity zone in the mantle wedge. The result elucidated that crystallisation differentiation occurs just above the mantle melting region in the middle of mantle wedge.

11-P-116

Relationships Between Pre-KPTand KPT Volcanic Rocks on Kos Island (Dodecanese, Greece): Crescendo to the Largest Eruption of the Modern Aegean Arc

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In addition to geophysical methods (such as ground deformation, seismology) and surveys of volcanic degassing, petrology can be an important mean to understand how large silicic systems evolve and predict their behaviour. This study focuses on rhyolitic deposits from the Kefalos Peninsula (Kos Island, Dodecanese, Greece, erupted between ~3 and 0.5 Ma), in order to better define the conditions that led to the paroxysmal caldera-forming eruption of the modern Aegean Arc, the Kos Plateau Tuff (KPT), which occurred ~160,000 years ago Kefalos and KPT rhyolites are both typical high-SiO_2 arc magmas, almost identical in whole-rock composition (75-77 wt% SiO_2), temperature (780 ± 10 C) and fO_2 (NNO+1.5-1.7). . However, compared to the KPT, Kefalos units have (1) much smaller eruptive volumes, (2) lower crystallinities (<5 vol% instead of >30 % in most of the KPT), and (3) nearly the same mineral assemblage (plagioclase, quartz, biotite, Fe-Ti oxides, apatite, zircon, monazite) but lack sanidine, ubiquitous in the KPT.

The presence of sanidine in the KPT but not in Kefalos rhyolites translate into some changes in the thermodynamical conditions. As composition, temperature and fO_2 are similar for the two magmas, the appearance of sanidine in the KPT must be related to changes in pressure and/or H_2O content of the melt. As sanidine stability will be enhanced at lower pressure and lower H_2O content, a possible model could involve the shallowing of the magma chamber as the system grows to the large KPT reservoir.

11-P-117

Origin of the Mafic and Ultramafic Xenolith-bearing Dacites from Southwest Japan Arc

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Pliocene fractionated alkali basalts, sub-alkaline andesites and dacites are distributed in the Kanmuri-kogen Plateau area, SW Japan arc. These rocks, especially basalts and dacites, contain megacrysts, mafic and ultramafic xenoliths. Megacrysts are olivine, clinopyroxene and orthopyroxene. Ultramafic and mafic xenoliths consist of olivine websterite, hornblendite, clinopyroxene-hornblendite, hornblende-pyroxenite, pyroxenite. The green-core clino- and ortho-pyroxenes occur only in Kanmuri-kogen Plateau dacites (KPDs). The KPDs are black and compact, and show flow structure. Groundmass (95-90 volume %) shows hyalopilitic texture and is composed of plagioclase, sporadic orthopyroxene and opaque mineral scattered in brown glass. The phenocrysts are clinopyroxene, orthopyroxen and plagioclase. Ultramafic xenoliths are generally carried by alkali basalt, carbonatite and kimberlite magmas. Katsui et al. (1979) exceptionally found mantle xenoliths in calc-alkali andesites from NE Japan arc. Then Takahashi and Koyaguchi (1984) interpreted that the upper-mantle peridotite-bearing andesite may not be derived from the upper mantle and its peridotite xenoliths may have been carried by the primitive basaltic magma. The andesite is a mixing product between mantle-xenolith bearing primitive basalt and dacite magmas. In our case, the above petrographic observations indicate that the KPDs may not

be produced by a mixing between the alkali basalt and the felsic magmas. Fractional crystallization of the alkali basalt magma could not also produce the KPDs. This suggests that mafic and ultramafic xenoliths may have been derived from the upper mantle and/or lower crust by the KPDs or their parental magmas. Some possible mechanisms for generation of rhyolite, dacitie and andesite magmas in the upper mantle are (1) melting of subducting lithosphere (adakite), (2) melting of subducted sediments (rhyolite) and (3) melting of subducting sediments with interaction with mantle wedge (high-magnesian andesite). However, chemical characteristics of the KPDs are different from those of the above mantle derived rocks. Further geochemical work is necessary to understand the origin of the KPDs magma.

11-P-118

Shear-induced Magma Fragmentation in Volcanic Conduits: Evidence from the Kos Plateau Tuff, Aegean Volcanic Arc

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Large silicic explosive eruptions are the most catastrophic events of volcanic activity. Yet, the intratelluric mechanisms underlying are not fully understood. Here we report a field and laboratory study of the 161 ka Kos Plateau Tuff (KPT, Aegean Volcanic Arc), which provides an excellent geological example of conduit processes that control magma vesiculation and fragmentation during large caldera-forming eruptions. A prominent feature of the KPT is the occurrence of quite unusual plate pumice lapilli and blocks (max/min axis up to 10) from the early eruptive phases including sustained column and pyroclastic current activities. In particular, in massive to stratified pyroclastic current deposits, plate pumice clasts may even prevail over 'conventional', lensoid ones to form clast-supported, imbricated layers. SEM analysis shows that elongate, flat surfaces are parallel to tube vesicles, which commonly exhibit elliptical sections, while transverse faces mostly occur at ca. 45° to vesicle elongation. We show how the peculiar KPT pumice texture closely records high shear stresses acting during magma ascent in a central conduit prior to caldera collapse. Strong velocity gradients radially to conduit walls induced magma vesiculation and fragmentation in the peripheral conduit portions. Pressure release along shear planes caused bubble nucleation and vesicle stretching parallel to flow laminae, favouring magma rupture along shear planes and leading to a sort of feedback through which volatile exsolution was further enhanced. Plate magma fragments were quenched and preserved during eruption and emplacement. Conduit enlargement with ongoing eruption would have resulted into a decreasing proportion of plate vs. lensoid pumice clasts derived from inner conduit portions. The major change from central to multiple or fissure vent system at the onset of caldera collapse led to the disappearance of plate pumice clasts in the main pyroclastic currents and lithic-rich breccias produced at the eruption climax.

11-P-119

Effect of Magma Pocket on the Mixing Process of Two Magmas of Contrasting Viscosity and Density: Analogue Experimental Approach

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We carried out analogue experiments to examine the effect of magma pocket on the magma mixing processes at low Reynolds number. The apparatus was made of acrylic plate and pipe. In the experiments, upper vessel is connected downward to the pipe, box-shaped pocket, and subsequently another pipe. At first, we placed less dense and low-viscosity fluid-1 (red colored) over dense and high-viscosity fluid-2 (clear and colorless) in the upper vessel. The lower pipes and pocket were initially filled with fluid-2. The two fluids fell down by gravity. In the experiments, two types of flow behaviors were observed in the pocket (Type-1; Oblate disk shape, Type-2; Flotation shape). In the type-1, the two fluids entering into the pocket expanded and formed oblate disk shape in the pocket, and subsequently were sucked into the lower pipe. In the type-2, the fluid-1 stagnated around the inlet of the pocket. The fluid-1 subsequently spread laterally in the upper part of the pocket and head of the fluid-1 floated the roof of the pocket. The fluid-2 newly entering the pocket intermittently fell down as a droplet, where the drops stretch and downwarp the fluid-1. The phenomena were repeated and stripe layers of the fluid-1 and fluid-2 were formed. Theses two types can be classified by dimensionless parameter I ($I=\mu_1 U/g\Delta\rho R^2$, Koyaguchi and Blake, 1989), which represents the ratio of viscous to buoyancy forces. When $I < 0.1$, the fluid-1 floated in the pocket. When $I > 0.1$, the fluid-1 could not float and the type-1 occurred. These results are independent of Reynolds number ($Re=\rho_1 U D_1/\mu_1$), and the fluid-1 can float at low Reynolds number. Presence of magma pocket increases the effect of buoyancy, and may be one of the important factors that promote mixing of magmas.

11-P-120

A New 3D Method of Measuring Bubble Size Distributions from Bubble Fragments in Volcanic Ashes

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We have developed a new pioneering method of measuring bubble size distributions from bubble fragments in volcanic ashes. During fragmentation of an energetically erupting magma, the bubbly magma converts to gassy spray that leads to ash particles derived from the bubble walls and plateau borders formerly between bubbles. The shape of the ash fragments retains a record of bubble size in the curvature of the convex surfaces within the ash fragments. Measurement of the

curvature within the ash fragments is based on stereo imaging of ash particles obtained by tilting Scattered Electron Microscope (SEM). Stereo images are used to reconstruct the microscopic surface topography of fine ash particles that contain bubble fragments, resulting in Digital Elevation Model (DEM) datasets. These datasets are in turn used to identify and measure vertical cross-sectional profiles of the bubble fragment 'craters'. Function fit analysis for circular or elliptical functions are applied to each bubble cross section profile in two orthogonal directions to reconstruct sizes of the original, complete bubbles. The method allows measurement of submicron bubbles in ash particles as small as few microns across. The bubble size distributions so obtained can provide valuable insights regarding magma dynamics and vesiculation that lead to explosive eruptions. There are no previous systematic information/databases of vesiculation metrics for explosive silicic eruptions, but this new method can be used to produce these and thus provide better insights into prehistoric eruption styles in volcanic hazard assessment tasks, of particular interest in highly populated areas around active or potentially active volcanoes.

11-P-121

Isotope Study of Olivin-hosted Fluid Inclusions From Northeast Japan Volcanoes

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In this paper, we present the nitrogen(N) and helium(He), argon(Ar) isotope ratio from quaternary volcanoes, Northeastern Japan (Iwaki, Hakkouda, Hachimantai, Choukai, Takamatsu, Kurikoma, Zao, Nasu). We estimate effect of subducted compornents in island arc magmatism.Knowledge of the pre-eruptive volatile content of magma is of fundamental importance for understanding of various magmatic processes, eruption dynamics and one formation. Since volatiles in magma are largely degassed during subaerial eruption, it makes difficult to estimate their pre-eruptive concentrations from volcanic rock analyses. Fluid inclusions trapped in phenocrysts may retain dissolved volatiles in magmas, providing us information on pre-eruptive volatile concentration, because the host mineral surrounding the inclusion acts like a tiny pressure vessel.

11-P-122

Geochemistry of Thermal Fluids from Deception Island, Antarctica

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Deception Island in Bransfield Strait (Antarctica) is a most-westward subaerial Quaternary active volcano among a series of submarine volcanoes situated between Antarctic Peninsula and South Shetland Islands. Bransfield Strait is an immature back-arc basin. This basaltic-andesitic island experienced frequent volcanic eruptions since 19th Century with the recent ones in 1967 and 1969 that heavily damaged the scientific stations there. Thermal manifestation is characterized by low-T fumarolic activity and hot springs. Strong CO_2 bubbling is seen along the Port Foster beach. This poster gives the first results on geochemistry of thermal fluids from the island including noble gas analysis.

The relative abundance of N_2, He and Ar of the gases indicates that the gases were derived from mantle. The gases were carried out to the surface of the Earth by CO_2 that degassed from magma. This view was confirmed by magmatic $f^{13}C$ of CO_2 (-5~-6 permil) and high He isotopic ratios. On the $^3He/^4He$-$^4He/^{20}Ne$ space, they lie on a mixing curve between two end members; a magmatic component (having a high $^3He/^4He$ of ~9.8E-6 and $^4He/^{20}Ne$ ratio higher than 1000) and an atmospheric component having the $^3He/^4He$ ratio of 1.4E-6 and $^4He/^{20}Ne$ ratio of 0.32. The $^3He/^4He$ ratio of 9.8E-6 is slightly lower than those of MORB glasses. The gases are likely to have been derived from magma generated either in mantle wedge that was influenced by subducted components from the former Phoenix Plate that ceased subduction <4Ma ago or in the MORB source mantle that was contaminated by a small scale U-Th bearing mantle plume, as suggested by geochemical data on volcanic rocks from Bransfield back arc.

11-P-123

Magmatic Process in Asama Volcano, Central Japan during September 2004 Eruptions

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Asama volcano, central Japan was active during September to December, 2004. Among its several eruptions, vulcanian eruptions of Sept 1st. and Sept 23rd. were relatively intensive. We describe the ascent and crystallization process of the magma during these three weeks as follows. Before Sept. 1st, a column of new magma had risen into the pre existing andesite body beneath the crater floor. On Sept.1st, the built up gas pressure surpassed the tensile strength of the andesite body to result in a vulcanian eruption. This eruption provided fragments of the pre-Sept.1st andesite, along with smaller amounts of the essential breadcrust pumices, the glass of which contain 0.4-0.8wt.% of water based on the infrared absorption spectra measurement. Because the cap rock had disappeared, the magma could uplift, upper portion of which effused and made a dome inside the crater. It in turn became a cap rock for the succeeding magma. On Sept. 23rd, next vulcanian eruption took place, the ejecta of this eruption consisting of the lithic fragments and the essential scoria with 0.1wt% water. The textural and chemical analyses of the essential materials; pumice of Sept.1st and scoria of Sept 23rd, reveal the crystallization process in a chamber—vent system. Following the crystallization of phenocrysts in a deeper magma chamber, two crystallization stages are preserved in crystal size distribution of microlites both in

the pumice and scoria. First stage: Magma left the chamber and rose through complex path-steps with ever increasing nucleation. Second stage: In a shallower part in the vent, numerous microlites precipitated rapidly under a high undercooling condition. The similarity between the both CSD patterns implies that their magma had a common ascent history, although groundmass in the scoria has lower crystallinity than that in the pumice, suggesting that the scoria magma stood lower in the magma column.

11-P-124

Difficulty in the Numerical Analysis of Magma Convection by SIMPLER Algorithm

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Magma convection, which leads to substantial and heat transfer, is important in considering the magma reservoir evolution. We had been suffering from instability in the numerical analysis of this problem (e.g. Matsumoto et al., JPGU meeting 2007, V238-P008). Very short time step was necessary in order to avoid the instability, victimizing long calculation time of a few or several days. The same problem of long calculation time was reported by Kuritani (private remark) about his study (Kuritani, 2004). We have found that such a difficulty in the magma convection analysis originally comes from the characteristics of this problem. We will show how the difficulty appears, using SIMPLER algorithm, which is one of typical numerical methods for fluid flow analysis.

A dimensionless parameter gL^3/κ^2 (g: gravity acceleration, L: magma reservoir dimension, κ: thermal diffusivity) can be found in the gravity term of the governing equations. This parameter excesses 10^{22} in the case of a magma reservoir whose size is a few km. Setting up lithostatic pressure, the pressure terms are equivalently large. The other variables and constants are then relatively and extremely small. SIMPLER algorithm contains a calculation of temporary pressure field. If the pressure terms are extremely large, the residual between temporary and real pressure fatally affects the stability of the numerical calculation. Finally we cannot help using very short time step in order to decrease the residual.

11-P-125

Time-Dependent Model for Volume Changes in Pressure Sources of Volcanic Swarm Activity off the East Coast of Izu Peninsula, Central Japan using Geodetic Data during 1973-1998

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A time-dependent model for volume changes in pressure sources of the volcanic swarm activities off the east coast of Izu peninsula is developed from the observations of precise leveling, EDM, GPS, and tidal data during 1973-1998. Although the sill-like opening crack beneath the east area of Izu peninsula had been proposed by Murakami (2006) based only on the leveling data, we re-estimated the optimal source parameters of opening crack from both of leveling data and GPS data observed just before the occurrence of the swarm using a genetic algorithm (GA). The estimated opening crack had the length of 12 km at the depth of 13 km beneath the east area of Izu peninsula. We consider this crack with a dip angle of 40 degrees as a deep one. Combining this deep crack with the previous shallow crack that was detected by using the hypocenter distribution (Hayahsi and Morita, 2003), we calculate the temporal changes in the volumes of two cracks using the Akaike's Bayesian Information Criterion (ABIC) for the period from 1973 to 1998. The results show that (1) a large inflation started in the deep crack from 1974 to 1990, (2) the opening of deep crack was stagnant between 1990 and 1995, and (3) a deflation started from 1995 to 1998. It is worthy to note that the large inflation took place 4 years before the swarm activity started in 1978 as well as the deflation occurred 3 years before the quiescence in 1998. These features strongly show that the estimation of temporal change in the volume of the deep crack provides useful information with long-range prediction of volcanic swarm off the east coast of Izu peninsula.

11-P-126

Long to Middle Term Temporal Variation of Magma Feeding System: An Example of Recent Magma Chamber Beneath Zao Volcano

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Activities of the youngest stage (30 ka to present) of the Zao volcano can be divided into three periods. The Goshikidake pyroclastic cone was formed during the last period (ca 2.0 to present), which is composed of piles of pyroclastic rocks. Magmatic products of this period can be divided into unit 1 to 4, and the unit 4 (0.8 to 0.2 ka) is further divided into unit 4-1 to 4-5.

Rocks erupted in the last period are olivine-bearing pyroxene basaltic andesite, and these were formed by mixing of two end-member magmas, judged from the petrologic features. Most of plagioclase and some of pyroxene phenocrysts show patchy or oscillatory zoning, while clear type plagioclase phenocrysts are rarely found. Anorthite contents or Mg# of patchy ones keep lower values of An_{63-67}, Mg#(opx)=65-68, Mg#(cpx) =66-70. An-poor or Mg-poor zones of zoned phenocrysts have similar compositions as the patchy ones, while An-rich or Mg-rich zones show An_{71-85}, and Mg#(opx)=69-75, Mg#(cpx)=68-72, which is similar to or higher than the Mg# of Mg-poor olivine (Mg#=ca 68) but is lower than that of Mg-rich olivine (Mg#=ca 80). The clear type plagioclases have higher An contents (ca 90). These data are suggesting that the phenocrysts with patchy zoning would be derived from the reactivated felsic magma body. Oscillatory zoning would be formed in the hybrid layer emerged when the mafic magmas, with An-rich plagioclase and Mg-rich olivine, injected to the felsic body.

Looking at the chemical compositions of rocks in the past ca.0.8-ky eruptions closely, gradual decrease in Zr

(and increase in Cr) contents toward upper part can be seen at least three times, which may correspond to the progressive injection of the basaltic magma to the shallower andesitic magma chamber, and it is estimated that the duration of each injection is less than 0.2 ky.

11-P-127

Magma-Carbonate Interaction: An Experimental Study on Ultrapotassic Rocks

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The Alban Hills ultrapotassic volcanic district emplaced during Quaternary time along the Italian Tyrrhenian margin. Volcanics are made up of clinopyroxenes and leucites and their chemical composition is mostly K-foiditic. Differentiated products (Mg#=32) are characterized by low SiO_2 content (<50 wt%); geochemical features indicate that this unique differentiation trend is driven by crystal fractionation plus carbonate crust interaction.

In order to constrain the magmatic differentiation, we performed experiments on Alban Hills parental composition (phono-tephrite) under anhydrous, hydrous, and hydrous-carbonated conditions. Experiments were carried out at 1 atm, 0.5 and 1 GPa, temperatures ranging from 1050 to 1300°C, and H_2O and $CaCO_3$ in the starting material up to 2 and 7 wt%, respectively. Our experiments demonstrated that the occurrence of $CaCO_3$ strongly affects phase relations and, consequently, also the residual melts composition.

In particular, in the $CaCO_3$-free experiments magnetite and phlogopite crystallize at relatively high temperature driving the glass composition towards a silica increases. This results in a differentiation trend moving from phono-tephrite to phonolite. This trend is in contrast with the absence of magnetite and phlogopite phenocrystals in Alban Hills volcanics and with the composition of natural rocks. On the contrary, in the $CaCO_3$-bearing experiments (i.e., simulating a magma-carbonate interaction), magnetite and phlogopite stability fields are strongly reduced. By consequence melt differentiation is mainly controlled by the cotectic crystallization of clinopyroxene and leucite, resulting in a decrease of silica in the residual melts. These experimental results agree with petrological features of Alban Hills rocks and with the differentiation model inferred by mass balance calculations.

Noteworthy, by comparing different plumbing systems emplaced in carbonate country rocks it is apparent that carbonate contamination not always leads to SiO_2-poor residual melts. We believe that an important factor controlling the efficacy of carbonate contamination is the dynamics of the plumbing system.

11-P-128

Shear Deformation Experiments on Vesiculated Rhyolitic Melts: Evolution of Bubble Connectivity

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Degassing of magma ascending in a volcanic conduit controls flow dynamics and eruption behavior. Because shear deformation seems to enhance coalescence of bubbles in magma, it works permeable degassing via the formation of interconnected bubble network. This study aims to investigate the evolution of bubble network in sheared magma. For that purpose, we have performed shear deformation experiments and taken the 3-D images of bubble micro-structure in experimental samples by using X-ray computed tomography (CT). The deformation experiments were performed by using a piston-cylinder type apparatus with a rotational piston. Rhyolitic obsidian was used as a starting material. Before deformation experiments, the cylindrical obsidian was heated at 975°C to vesiculate the sample. The vesiculated sample was twisted by rotating the lower piston at rotational rates of 0.3 to 0.5 rpm from 0.5 to 10 rotations. The bubble number, size and shape in experimental samples were obtained from 3-D images taken by X-ray CT at BL20B2 of SPring-8.

The vesicularity of samples ranges from 20 to 45 vol%. The bubble size distributions in samples with similar vesicularity but different rotational degree show that the number of medium size bubbles decreased and a large bubble was formed with increasing rotational degree. Bubble connectivity defined by the ratio of volume of maximum bubble to total bubble volume starts to increase at vesicularity of 20 to 30 vol%. For the 0.5 rpm experiments, the connectivity becomes 0.8 at about 40 vol% vesicularity and the rotation number of 10. Because the shear stain rate of this study (maximum strain rate of 0.03 s^{-1}) is possibly yielded in ascending magma near the conduit wall, interconnected bubble network can be formed there. The formation of bubble network followed by magma degassing might control flow dynamics of magma in volcanic conduits.

11-P-129

The Origin of "Hyper-calcic" Silicate Melts and Their Role as Crustal Contaminant

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Magmatic differentiation of ultrapotassic magmas from the Roman and Campanian Provinces (Central Italy) generally starts from a parental trachybasaltic composition and, through crystal fractionation of spinel+olivine+clinopyroxene±leucite±phlogopite, moves towards higher silica content compositions, eventually ending with phonolitic products. Alban Hills behaves quite differently. Most of the products are K-foiditic in composition and even the differentiated products are

characterised by low silica content (down to 40 wt%) and high CaO and K_2O contents. Assuming also at Alban Hills a trachybasaltic parental magma, it is impossible to obtain differentiated K-foiditic products following a differentiation process similar to that inferred for the other Roman and Campanian districts. Mass balance calculations and geochemical and experimental data indicate that the Alban Hills magmatic system must have experienced a strong interaction with carbonate rocks enhanced by a favourable tectonic setting. At Alban Hills carbonate assimilation processes occur mainly by direct ingestion of carbonate wall-rocks in magmas, as testified by relicts of sedimentary carbonates in the volcanic products, either at macro- or micro-scale. Additional evidences of carbonate assimilation are represented by spinel-bearing olivine-clinopyrossenites originated in the carbonate/magma interface zone. These hypoabyssal rocks, characterised by $ä^{18}O_{Ol}$ and $ä^{18}O_{Cpx}$ ranging from magmatic (6.6 ‰SMOW) to sedimentary (11.1 ‰SMOW), are interpreted as originated from solid-solid and solid-liquid reactions involving carbonates and magmas. These reactions, in turn, lead to the formation of Al-rich spinel, Ca-rich forsterite, Ca-Tschermak-rich clinopyroxene, phlogopite, and 'hyper-calcic' silicate glasses (CaO=21 wt% and SiO_2=38 wt%). The latter are also characterised by extremely fractionated REE and are enriched in fluid-mobile trace elements. These 'hyper-calcic' silicate glasses are particularly interesting because they can represent the source of the anomalous trace elements (e.g. U and Th) enrichment observed in some Alban Hills differentiated volcanic rocks.

11-P-130

Magma-Feeding System Beneath Usu Volcano, Japan: Replacement or Continuous Existence?

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[Usu Volcano and Its Magma-Feeding System]

Usu volcano is suitable for studying evolution of a silicic magma-feeding system because the volcano has erupted dacite and rhyolite at intervals of 30-50 years since 1663 A.D.

Tomiya and Takahashi (2005:J.Pet.) demonstrated "continuous existence" of the magma-feeding system since 1663 on the basis of detailed petrographical observations, such as: all eruptive products since 1663 contain phenocrysts with the same characteristics (type-A); texture of the phenocrysts systematically changes with eruption age by growth, diffusion and dissolution. On the other hand, Matsumoto and Nakagawa (2006:Chikyu Monthly) argued, using variation of the bulk rock compositions, that there were three independent groups of magmas, and that "replacement" of magmas occurred two times since 1663. These two data appear to contradict each other, however, I can interpret them concordantly as follows.

[The Magma Mixing Processes Revealed by "Phenocryst Tracer Method"]

The essential difference between the two arguments is "the mixing ratio of old magma" (zero or not) at the appearance of new magma. Hence I have estimated the ratio. The ratio of old magma can be estimated using abundance of type-A phenocrysts because the phenocrysts are tracers of the old magma that existed at 1663. The abundance was obtained by means of textural analysis (e.g., CSD). As a result, the ratio of old magma at 1977, when a new magma appeared, is about 10 % (thus 90 % of new magma). Therefore, whether the 10 % was considered or not is the difference between the two arguments, that is, "continuous existence" or "replacement". Further research should be done to clarify other detailed differences, however.

11-P-131

Dispersal Characteristics Of Wet and Dry Phases of the Askja 1875 Eruption, Iceland.

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The 1875 eruption of Askja volcano in Iceland is the youngest 'type' example of Phreatoplinian volcanism and the only one documented by detailed historical reports. The main phase of the eruption began with a dry subplinian phase (unit B), followed by a phreatoplinian (unit C) and finally a Plinian (unit D) phase, lasting a total of 6.5 hours. Each phase produced a continuous tephra sheet over eastern Iceland, with the phreatoplinian and Plinian deposits forming a 1.5 cm thick deposit in Scandinavia, 1500 km to the east. Bt values calculated for the three principal phases are 1.0 km (B), 4.8 km (C) and 1.7 (medial) / 9.0 (distal) km (D) respectively. Pylograms of the three phases each show a minimum of 3 segments, with the proximal segment indicating significant overthickening of the proximal deposits irrespective of style or intensity. This overthickening must be due to instabilities from the jet and lower convective plume margins, resulting in enhanced sedimentation from these regions. In detail, there are differences in these proximal sedimentation regimes between wet and dry fall units. The proximal deposits of the wet phase are overthickened at an extended distance from vent (11 km) as compared to the Plinian phase (5.5 km). This overthickening must be related to the high density of the wet plume, leading to instabilities, generating dilute weak surge deposits and/or premature sedimentation of particles.More than 60 active volcanoes have water- or glacier-filled summit craters or calderas. Any eruption from these volcanoes will have some component of phreatomagmatic activity. Higher intensity phreatomagmatic eruptions have the potential to disperse wet ash over large distances and our Askja study would suggest greater accumulations closer to vent than would be predicted for dry plumes. Tephra dispersal models of dry plumes have been well developed in recent years, however dispersal models of wet plumes need to be better quantified.

11-P-132

Geochemical Variation of Volcanic Rocks within the Taiwan-Shinzi Folded Zone in Southwest Japan

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The Taiwan-Shinzi Folded Zone (TSFZ) was occurred from spreading along the arc system in back-arc side from South West Japan to Taiwam. Geochemistry of the volcanic rocks from the Hirado, Azuchi-Oshima and Chikuzen-Oshima islands believed to relate to the back-arc opening along the Japan Sea and East China Seas shows a change in source composition. Volcanism of syn-opening or post-opening 13Ma subalkalic volcanic rocks from basalt to dacite was tholeiitic character, whereas post-opening volcanism of ca.8Ma produced alkali basalts characterized by within-plate type chemical feature. This shows that the mantle of this area drastically changed after about 8 Ma.

11-P-133

Vesiculation and Crystallization under Constant Amount of Decompression: Numerical Study and its Comparison with Laboratory Experiments

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The vesiculation (bubble formation) and crystallization (microlite formation) in ascending magmas are key processes controlling the eruption behavior, and they interplay each other through the water exsolution process. We carry out the numerical study in order to understand vesiculation and crystallization processes in natural eruptions (decompression history is unknown) and in laboratory experiments (the amount of decompression is constant with time). The numerical results that takes into account homogeneous or heterogeneous nucleation, and growth and expansion of bubbles with diffusivity of water, viscosity, the amount of decompression, provide the quantitative understanding for the control on the bubble formation and the water exsolution in the constant amount of decompression. The water exsolution rate which is controlled by Peclet number in the viscosity control regime and by bubble number density in the diffusion control regime, plays a role of the effective cooling rate in crystallization process, which determines the microlite number density. The comparison with laboratory experiments suggests that the water exsolution proceeds by the diffusion control growth of bubble in the higher amount of decompression and by the viscosity control growth of bubble in the lower amount of decompression under the disequilibrium vesiculation regardless of the bubble nucleation style. The application to the textural analysis for bubbles and microlite in natural pyroclasts from sub-plinian eruptions of basaltic andesite shows that the water exsolution proceeds under the disequilibrium condition in the explosive eruptions.

11-P-134

Chemical Characteristics of Cross-cutting Dissolution Surfaces in Magmatic Plagioclases.

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Various textures formed by dissolution of crystals, which are called as dissolution textures, are frequently observed in magmatic plagioclases. It has been considered that the dissolution texture is key to understand the magmatic processes. The variation of the texture is classified according to the two main types of dissolutive events of crystal, which are, simple and partial dissolution events (Tsuchiyama, 1985). The partial dissolution results in the formation of dusty textures, whereas the crystals get smaller and get rounded by the simple dissolution. By the crystal growth after the simple dissolution, a dissolution surface is formed in the crystal. The dissolution surface is generally parallel to the facet crystal surface or neighbor zones, and dissolution surfaces cross-cutting to the neighbor zones is rarely observed. Although Pearce and Kolisnik (1990) and Pearce (1994) reported the cross-cutting dissolution surface, the origin of the formation does not remain to be clear.

Recently, Tsune (2006; oral presentation) reports that a dissolution surface is cross-cut by some crystal faces, he considers that the features are formed by dissolution of the crystal-settling occurred during magma mixing. In the present paper the cross-cutting dissolution surfaces in magmatic plagioclases are investigated by BSE images and chemical data.

The sampled plagioclase is from the tholeiitic dacite of the Shirahama Group, Japan (Tamura, 1995). The dacite rock contains the poor plagioclase crystals (6 vol.%) and rarely pyroxenes and magnetites. The core compositions of plagioclases 50 to 53 An mol%. Although the rim compositions range from 53 to 56, chemical compositions at the cross-cutting dissolution surface are up to 64 mol%. This suggests that the dissolution surface is formed during magma mixing and that the dissolution event occurs before the complete compositional homogenization of the mixed magma.

11-P-135

Numerical Simulations of Magma Chamber Dynamics and Associated gravity, Deformation, and Seismic Signals

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Forecasting the occurrence of a volcanic eruption is a complex task which requires both inverse and forward modeling in order to correctly interpret the signals observed through volcano monitoring networks. We have developed a finite element code which solves the fundamental time-dependent mass, momentum and energy transport equations for a homogeneous multiphase, multicomponent mixture from incompressible to compressible flow conditions, and have validated it through comparison with a number of classical test cases from the literature over a wide spectrum of flow regimes. The code is implemented with fully non-ideal P-T-composition-dependent H_2O + CO_2 saturation modeling calibrated over > 1000 experimental data from literature, and with P-T-composition-dependent models for the relevant multiphase magma properties density and viscosity. The resulting model has been applied to simulate the dynamics of magma convection and mixing associated with the arrival of new volatile-rich trachytic magma into a shallow phonolitic magma chamber at

Campi Flegrei, as well as the dynamics of volatile-rich magma rise preceding paroxismal eruptions at Stromboli. In both cases the simulation conditions were defined within the frame of dedicated projects which included experts from a variety of fields in volcano science, and who spent a significant part of their career working on the above two volcanic areas. The numerical results show a variety of processes the dynamics of which were not known before, as for the case of magma mixing and re-circulation of denser magmatic components inside the dyke feeding a magma chamber, or the complex pressure patterns associated with rise and expansion of deep volatile-rich magma inside a chamber or a volcanic conduit. Processing of the results from the numerical simulations allows the determination of the free air corrected gravity anomaly, as well as the first-order determination of the time-space patterns of ground deformation and of seismic signals associated with the simulated dynamics. This allows the definition of a reference frame for the expected geophysical signals that should be observed in association with the considered processes, contributing to the definition of the criticality levels at potentially erupting, hazardous volcanoes.

11-P-136

Along-arc Variation of Boron Data: The Influence of Philippine Sea Plate on the Composition of Mantle Beneath Kyushu, SW Japan Arc

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Volcanism in Kyushu island is associated with subduction of Philippine Sea Plate (PSP) under Eurasian plate. Kyusyu-Palau Ridge subducts nearly at right angles to central part of Kyushu, marking the boundary between young (15-26 Ma) PSP in the north and old (37-115 Ma) PSP in the south. Thus volcanic rocks from Kyushu are good samples to test the compositional difference resulting from the subduction of oceanic plates with different ages.We studied the difference in subduction component using boron element. The release of the fluid phase from the oceanic plate is believed to occur in two manners. One is by aqueous fluid at high temperature, and the other is by the dehydration process, i.e. the breakdown of hydrous phases at high pressures.

The across-arc variation as observed by B/Nb ratios in volcanic rock is almost absent in the northern Kyushu (NK), whereas it shows a gradual decrease in B/Nb from the volcanic front to the back-arc side in southern Kyushu (SK). In addition, the B/Nb ratio of rocks from the volcanoes at the volcanic front is relatively high in the SK (~8.3), whereas it is relatively low in the NK (~3.5).

The lack of lateral variation in subduction component in volcanic rocks from the NK indicates a possibility that the release of fluid phase is completed before the oceanic plate reaches the volcanic front. The relatively low number in B/Nb ratio also supports this hypothesis. The young age of oceanic plate suggests a high temperature gradient in the depth profile of the subducting plate. In contrast, the volcanic rocks from the SK show a normal across-arc variation of subduction component typically related with the subduction of relatively old and cold oceanic plate.

11-P-137

Azores Mantelic Plume and Volcanic Implications

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The Azores archipelago is located close to the triple junction defined by the North American, Euroasian and African-Nubia Plates. The radiogenic ages of the islands generally increase inversely with distance to the Middle Atlantic Ridge (MAR), a slow spreading center. The islands are located on the Azores Platform, a bathymetric, gravimetric and magnetic anomalous feature compatible with the interaction between a mantle plume and MAR. Azores volcanism is within-plate, alkaline ranging from basalts to trachytes, with relatively rare intermediate samples. The volcanological history of different islands points to very dangerous volcanic episodes, some of them in pre- and historic times, and all related to important caldera-forming composite volcanoes. The Azores have nine islands, however only six of them have evolved rocks and all are associated with caldera formation related to more or less 4km deep magma chambers. Primitive mantle-normalized REE plots indicate the importance of fractionation from the most primitive rocks to the trachyandesites and trachytes. The REE patterns suggest a continuous fractionation from a common melt with low degrees of partial melting. To help determine volcanic hazards connected with magma evolution within these volcanoes, recent studies of ^{226}Ra-^{230}Th-^{238}U disequilibria on volcanic glass constrain the rates and duration of magmatic differentiation processes. Inter-elemental ratios and Sr, Nd, U, Pb, Os, Ne and He isotope studies support the existence of a complex Azores plume, involving mixing between enriched mantle, depleted MORB mantle, and ancient recycled oceanic and/or subcontinental lithospheric mantle. Some inter- and intra-island compositonal variations are also due to differences in degree of partial melting of the mantle source. The existence of potentially active volcanoes in Azores with recurrence time rates exceeded constitute an attractive subject to proceed our research.

11-P-138

The Evolving Fluid Flux from the Subducting Plate Beneath Aso Area: Evidence From Boron in Volcanic Products

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Aso volcano is located in a complex area where old (40-115 Ma) and young (15-26 Ma) segments of Philippine Sea plate (PSP) and Eurasian plate meet. To investigate the temporal changes of subduction signatures, we analyzed boron (B) and other major and trace element compositions in volcanic products which erupted since 4 Ma. Since B is distinctly concentrated into slab-derived fluids among the earth's materials, we can estimate the slab contribution to the subarc mantle composition based on the B data in volcanic products.

We grouped volcanic activities of Aso area into four stages based on geochemical types of magmas. I) 4-3 Ma: High-magnesian andesites (HMA); II) 2-0.4 Ma: Adakitic andesites, arc-type andesites and high-alumina basalts (HAB); III) 0.3-0.09 Ma (caldera forming stage): Arc-type andesites and HAB with large volume of dacites and rhyolites; IV) 0.09-0 Ma (post-caldera stage): Arc-type andesites and HAB with small volume of dacites and rhyolites.

The ratios of B/Sm (0.4-1.0) and B/Zr (0.03-0.05) in the HMAs are lower than those of the HABs (1.3-5.0 and 0.06-0.17, respectively). B/Nb ratios in the HMAs (0.3-0.5) are similar to those of the mantle values (0.05-0.5). On the other hand, B/Nb ratios (1.4-4.0) in the HABs overlap with those of basalts from cool subduction zones (Kurile and NE-Japan) where fluid-induced melting of the mantle wedge dominantly occurs.

These observations suggest that the released phase has slab component beneath Aso area changed from melt derived from dehydrated slab to hydrous fluid between stage I and II. The fluid flux added to the mantle beneath Aso area probably increased with time. This may have resulted from the lowering of geotherm beneath Aso area caused by the change of subducted plate from young segment of PSP to the old one at 4-2 Ma.

11-P-139

Viscosity Measurement of Crystal Bearing Magma

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Rheological properties of magmas are important to understand volcanic processes such as lava flow velocity, shape of lava body, and mode of eruptions. Viscosity is especially a key parameter. Because most of erupted magmas contain some amounts of crystals, the effect of suspended crystals on viscosity should be evaluated. Many researchers utilize Einstein-Roscoe equation, which however does not take the effects of crystal shape and crystal size distribution into consideration. Our goal is to construct the method to quantitatively describe the effect of suspended crystals on viscosity of magma of arbitrary textures. For this purpose, we have performed laboratory high-temperature measurements of viscosity and textural analyses of magmas of various chemical compositions. In this presentation, the method of viscosity measurement will be shown with some knowledge obtained from our experimental results. Our results constrain applicable limitation about length/width ratio of suspended crystals on the Einstein-Roscoe equation, which describes well the relative viscosity-crystal fraction relation for isometric spherical crystals. When crystal fraction is below 0.35, the Einstein-Roscoe equation can predict the relative viscosity, which is the ratio of viscosity of magma to that of silicate melt, at least up to length/width ratio of 5. The equation, however, cannot be applied when length/width ratio of crystals is at least above 8. Our results also suggest that shear-thinning behavior becomes remarkable as crystals become anisotropic. Shear-thinning behavior is obvious for plagioclase-bearing magma when crystal fraction is at least above 0.15. The critical crystal fraction is much smaller than that for spherical suspension (ca. 0.4). We will explain these phenomena being related to the textures observed in the experimental samples.

11-P-140

Kusasenrigahama Pumice Cone from Aso Volcano, Kyushu, Japan: Petrological Characteristics of Pumice and Coeval Volcanic Products Representing One of the Largest Eruption after Caldera-formation

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Kusasenrigahama pumice cone, one of the Aso post-caldera central cones, has a flat crater with 1 km diameter. The pumice eruptions from Kusasenrigahama cone produced 2.39km^3 tephra at 30 ka (Miyabuchi et al., 2003), one of the largest after the 90 ka caldera forming eruption. Petrological study of Kusasenrigahama pumice and coeval volcanic products revealed the followings. 1) Almost all the Kusasenrigahama pumice clasts are extremely altered. Compositional trends show a mixing line between fresh pumice and allophane, an alteration mineral typically found in volcanic ash. Most altered pumice contains 40% SiO_2, 30% Al_2O_3, whereas fresh one contains 67% SiO_2 and 18% Al_2O_3. 2) Fresh pumice (SiO_2=67 wt.%) and welded pyroclastic rock (SiO_2=68 wt.%) from the crater rim are similar in composition. 3) Analyzed plagioclase and pyroxene crystals from the uppermost and lowermost position of the pumice layer show similar composition and estimated pyroxene temperature agree well in a range between 900 and 1000 degrees C. 4) Central cone lava, representing the latest activity, show undifferentiated composition (63% SiO_2), suggesting an input of undifferentiated magma. 5) Kusasenrigahama pumice and Sawatsuno lavas both show the same mineral assemblage, similar bulk chemical composition and similar mineral composition. Thus these two are probably derived by the common source magma.

11-P-141

Magma-water Interaction in CO_2-rich Enviroments: a Study Case from Albano Maar, Colli Albani (Central Italy)

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Understanding the factors controlling the most recent (<100 ka) hydromagmatic activity at the Colli Albani Volcanic District is crucial for the assessment of volcanic hazard in the densely populated area of Rome. The Albano multiple maar activity (70-36 ka) shows evidence of complex interactions between K-foiditic magma and fluid-saturated country rocks. Geochemical data indicate that hydrothermal fluids trapped in the Colli Albani reservoir are characterised by high CO_2-pressure associated with CO_2 degassing processes. We develop a thermodynamic model based on the mass and energy balance equations for the system K-foiditic magma + fluids saturated sediments in order to estimate the effects of CO_2 versus H_2O mass ratios (R_{CW}) on the efficiency of hydromagmatic eruptions. Depending on the efficiency of heat transfer from juvenile pyroclasts to gases during expansion to atmospheric pressure, two possible end members are considered: i) the adiabatic case in which heat transfer does not take place between pyroclasts and fluids and ii) the isothermal case in which pyroclasts and fluids maintain thermal equilibrium during expansion. Results suggest that a decrease of R_{CW} enhances the stability of saturated mixtures and increases the amount of available $H_2O_{(liq)}$ for reaction with $CO_{2(gas)}$ to give carbonic acid. In saturated conditions, where $CO_{2(gas)}$ and $H_2O_{(liq)}$ behave as a reacting mixture, the enthalpy of reaction (i.e.,~ -4.7 kJ/kg) changes the internal energy budget of the system and affects the efficiency of explosive interaction. In summary, our calculations demonstrate that an increase in R_{CW} significantly decreases the efficiency of explosive magma-fluid interaction. Therefore carbon dioxide may represent a major factor in reducing the explosivity of K-foiditic magmas in hydromagmatic eruptions..

11-P-142

Tidal Triggering of Lava Fountain Activity at Mount Etna, (Italy)

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In the last few years the influence of Earth tides on various geological phenomena, such as volcanic eruptions and earthquakes is widely discussed in the scientific community. Here we present integrated data sources and methodologies in the field of volcanology, geophysics and geo-engineery aiming at quantitatively correlate eruptive phenomena and flank instability to Earth tides at Mount Etna. The observed relationships between the occurrence times of lava fountain events during 1989, 2000 and 2001 South East Crater (SEC) activities and tidal signals are tested statistically. Moreover, the stress and strain release induced by tidal forces on feeder magma system is numerically modelled by means of 2D finite difference method (i.e., FLAC code) applied to a geological section along the south-eastern Mount Etna volcano flank. Stress and strain numerical analysis takes into account the actual geological and structural framework of the volcano edifice (i.e., rock geometries and properties, feeder conduit and vent systems, volcanic landforms) and magma properties (i.e., Bulk modulus, volatile content) and shows that quasi-diurnal, (i.e., ~24 h), semi-diurnal (~12 h) and ter-diurnal (~8 h) tidal constituents may have induced decompressions up to some kPa in the shallow (i.e., ~1500 m) magma reservoir below the SEC. In conclusion, we show that Earth tides may control the timing of lava fountain activity at Mount Etna. The implications of our analysis may help understand the disequilibrium state of the volcano edifice related to interacting magmatic and tidal phenomena and may provide an additional tool to refine statistically based forecast of explosive events.

11-P-143

Modeling of Several Recent Mt. Etna Eruptions by Using Ground Deformation to Image Different Sources and Mechanisms

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We present main results of source modelling of several eruptions occurred at Mt. Etna in the last years. These eruptions (2001, 2002-03, 2004, 2006) showed different mechanisms which were inferred by modelling the ground deformation data recorded by different techniques as periodical and continuous GPS measurements, eleptro-optical distance measurements (EDM), continuous tilt, satellite radar interferometry (SAR). Different models and inversion techniques were used and applied for the different eruptions cases. After a long recharge phase (1993-2001) dominated by a marked inflation, the effusive-explosive 2001 eruption was characterized by a violent final vertical intrusion modelled by deformation recorded by GPS and tilt permanent networks. The following violent 2002-03 eruption showed a double vertical (same path of 2001) and horizontal intrusion modelled through the static and permanent deformation recorded before and after the dikes propagation, and then refined by using a dynamic model implemented to invert all continuous tilt data recorded during the dikes propagation. After 2002 intrusion, the sliding of the eastern flank started to speed-up towards east, as clearly showed by GPS measurements, and a new mechanism, never observed before, characterized the 2004-05 eruption. In fact, this exceptional sliding provoked a maximum tension in the upper eastern flank causing the silent opening of the fracture from which the magma poured out passively, i.e. without associated volcanic and/or seismic and/or geochemical variations. In all these cases, the ground deformation modelling represented a primary key for inferring the eruptive mechanism and understanding the state and evolution of the volcanic activity.

11-P-144

Remobilization of Highly Crystalline Felsic Magma by Injection of Mafic Magma: Constraints from the Middle 6th Century Eruption at Haruna Volcano

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The latest eruption of Haruna volcano (Honshu, Japan) at Futatsudake took place in the middle of the 6th century, starting with Plinian fall, and followed by pyroclastic flow, and ending with lava dome formation. Gray pumices found in the first Plinian phase (lower fall) and the dome lavas are the products of mixing between felsic (andesitic) magma having 50 vol % phenocrysts and mafic magma. The mafic magma was aphyric in the initial phase, whereas it was relatively phyric during the final phase. The aphyric magma is chemically equivalent to the melt part of the phyric mafic magma, which probably resulted from the separation of phenocrysts at their storage depth of ~15 km. The major part of the felsic magma erupted as white pumice without mixing and heating just before the eruption, after the mixed magma (gray pumice) and heated felsic magma (white pumice) of the lower fall deposit. Although the mafic magmas was injected into the felsic magma reservoir (7 km depth), part of the product (lower fall ejecta) had preceded the felsic reservoir magma, due to upward dragging by the convecting reservoir of felsic magma. The mafic magma injection made the nearly rigid felsic magma erupt, letting low-viscosity mixed and heated magmas open the conduit and vent. Indeed, the lower fall white pumices preserve a record of syneruptive slow ascent to 2 km, probably being associated with the conduit formation.

(Reference)
Y. Suzuki and S. Nakada (2007) Remobilization of Highly Crystalline Felsic Magma by Injection of Mafic Magma: Constraints from the Middle 6th Century Eruption at Haruna Volcano, Honshu, Japan. *J. Petrol.*

11-P-145

Repetition of Fragmentation and Welding inside the Conduit: Evidences from Nakaoku Tuffite Dikes, Central Kii Peninsula, SW Japan.

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We report the field evidences for a repeated fragmentation and welding in a conduit, at the middle Miocene Nakaoku tuffite dikes (NTDs), Kii peninsula, SW Japan. NTDs are probable arcuate conduits (15km×20km) for caldera-forming eruption. The dike width is commonly 20-40m.

The wider dike exposes lapilli tuff (LTB), lapilli tuff (LTC) and tuff facies from its central to marginal sections. The dike is mainly composed of LTB and LTC facies, though the marginal tuff is rare. The LTB facies contains clast with lapilli- to block-sized and amoeboid-shaped juvenile fiamme (LTA), in the matrix of rhyolitic glassy welded tuff. In LTC facies, there is not only fiamme-bearing lapilli tuff clast similar to LTA facies, but also granule- to boulder-sized accidental block into matrix of glassy welded tuff. While the internal LTA clast of LTB facies keeps its shapes, at the contact with LTC, the LTB matrix is gradually resolved into ash-sized particles in the LTC. Thus the rhyolitic fragments in LTC can be interpreted as those of LTA origin derived from the LTB facies.

Based on these observations and interpretations, we can propose following three stages of NTDs' fragmentation and welding processes: (1) formation of LTA facies due to magma fragmentation and welding at the deeper level of conduit; (2) subsequent fragmentation and welding of LTA facies to form LTB facies, and contemporaneous mixing of the LTA and LTB facies; and (3) formation of the LTC following mixing with host rock materials and final welding at the shallower level.

These geological findings and interpretations strongly suggest that at 1-2km depths, an abrupt change of physical process in conduit could take place, and it might control facies variation of magmatic products. Repeated cooling and heating process considerably plays an important role to change conduit process in ash-flow eruption.

11-P-146

Thermal-mechanical Modeling of Ground Deformation and Stress Field in a Viscoelastic Medium

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Time dependent ground deformation and stress changes due to volcanic pressure sources embedded in a viscoelastic medium are evaluated using Finite Element Method. Especially in volcanic areas, the presence of inhomogeneous materials and high temperatures produce a lower effective viscosity of the Earth's crust that calls for considering the thermal regime of crustal volume surrounding the magmatic sources. In order to evaluate the temperature dependency of the viscoelastic solution we carry out a coupled thermo-mechanical numerical model. Both temperature distributions and ground deformation are firstly evaluated by solving an axi-symmetric problem to estimate the effects of thermo-viscoelastic response of the medium. The coupled thermo-mechanical model evidences that viscoelastic relaxation is responsible for significant time-dependent changes in long-term deformation and quasi-static stress field around the magmatic sources. These effects may be relevant for the interpretation and quantitative assessments of the spatio-temporal evolution of the seismicity associated with magmatic pressurization. With this in mind, we reviewed the expected ground deformation accompanying the 1993-1997 inflation phase on Mt Etna by setting up a fully 3D finite element model in which we used the real topography, to include the geometry, and seismic tomography, to infer the crustal heterogeneities.

11-P-147

Eruptive History for the Last 40,000 Years of Esan Volcano, Northern Japan

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Esan volcano is one of active volcanoes in Hokkaido, located at the NE Japan volcanic front, and is composed of a group of lava domes in felsic to intermediate magmas. Each lava dome directly lies on a marine terrace or a Tertiary basement rock without a massive stratocone. The dome migrates in each major eruption. The volcano exposes large number of block-and-ash flow and debris avalanche deposits, but does not expose plinian fall or associated pyroclastic-flow deposits. An average recurrence interval between major dome-building eruptions is a ten thousand year, and the age of last major eruption (MP) is ca. 8,000 yBP. Our recent investigation has revealed four or more eruptive units accompanying with lava dome growth in the last forty thousand years. Well-exposed four units are named as MP, HD1, HD2 and HD3 in descending order. An important finding is that HD1 is dated as ca. 29,000 cal yBP. This age is older than previous ^{14}C age, and thus the recurrence interval between the last (MP) and the 2nd last (HD1) events became ca. 20,000 years.

While the plinian eruption at Esan volcano is unknown, the migration character of dome is the hazardous potential for the nearest social facility where the magma can approach. Our new data for the eruptive age may reduce the hazardous potential than previous alert. Nevertheless, the long-term dormancy over ten thousand years and the lack of plinian eruption suggest the following important questions: (a) The longer storage of viscous magma, though the relatively high magma supply rate expected from upper mantle (no stratocone growth); (b) The smaller amount of dissolved gas, though the longer magma storage (no plinian phase).

11-P-148

Material Scientific Study on Vulcanian Eruptions of Sakurajima Volcano, Japan

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The present study reports textual parameters of volcanic ash to compare with geophysical parameters observed in vulcanian eruptions of Sakurajima volcano, Japan and gives constraints on factors controlling air shock intensity. Samples are volcanic ash from 17 vulcanian eruptions (1974 to 1987). Using the stereoscopic microscope, we classified volcanic ash particles into two type volcanic glass and free-crystals, and then divided volcanic glass into two sub-classes (smooth surface particles and non-smooth surface particles) from the view point of the surface state of particle. Further, smooth surface particles were classified into N-particle (particles not including vesicles) and V-particle (particles including vesicles) by the polarized microscopic observation. Statistical examination based on classification of volcanic ash shows that 1) for explosions without pre-explosion BL-type earthquake swarms (PBES), the ratio of the number of N-particle to V-particle (N/V number ratio) has positive correlation with air shock intensity, 2) for explosions with PBES, N/V number ratio has negative correlation with air shock intensity and 3) for explosions with PBES, the N/V number ratio has negative correlation with the duration time of PBES. Plagioclase microlite textural analysis was carried out for N-particles with smooth surfaces of five explosions without PBES. The result shows that plagioclase microlite number density (MND) and L/W ratio have the positive correlation with air shock intensity. MND is proportional to the power 3/2 of water exsolution rate from melt. The positive correlation between plagioclase MND and air shock intensity indicate that when water exolution rate (3.8×10^{-5}-1.2×10^{-4} wt.%/s) of magma is high, air shock intensity (54-360Pa: observed at station HAR) by explosion becomes high. On the basis of the textural results, we propose the possible model for magma supply and subsequent pressurization processes in vulcanian eruptions of Sakurajima volcano.

11-P-149

Experiments on the Gas Dynamics of the Mt. St. Helens 1980 Lateral Blast

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Field evidence suggests that the lateral blast in the 1980 Mt. St. Helens eruption behaved like an underexpanded jet flow. We conduct two experiments to investigate this hypothesis. In our first experiment, we use the compressible flow--shallow-water analogy to measure the geometry of the shock structure around the underexpanded jet, which is comparable with the position of the interface between the direct and channelized blast zones described by Kieffer (1981). Also, Kieffer and Sturtevant (1988) identified furrows created by the blast which were possibly formed by scouring due to Goertler vortices induced by curvature in the terrain. In our second experiment, carried out in a compressible flow laboratory, we investigate an additional Goertler vortex generation mechanism due to the curvature of the shear layer adjacent to the intercepting shocks in the underexpanded jet. These experiments allow for a more-detailed scrutiny of the underexpanded jet--lateral blast analogy proposed by Kieffer (1981).

11-P-150

Formation of Scoria Cone in 1986 Eruption of Izu-Oshima

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Scoria cones have been regarded to be formed by accumulation of ballistic bombs ejected by mild eruptions. However, more recent geological investigations show that some scoria cones could be formed during explosive eruptions. Here, we demonstrate how the scoria cone of the 1986 Izu-Oshima eruption was formed during the explosive eruption. We measured particle fractionation of the cone and propose a theoretical model to explain the observation. The model considers lateral transport of particles by turbulent eddies; particles that reached

characteristic column radius, L, are laterally transported to ωL where they starts to free-fall. We obtained ω = 1 and 2 for larger and smaller particles, respectively, which is consistent to the observation. In the model, extensive fallout takes place at the base of the column where it expands rapidly. We suggest that lateral particle projection and the rapid column expansion are the key processes to form the cones.

11-P-151

Mafic Triggering of the Mangaone Subgroup Eruptions, Okataina Volcanic Centre, New Zealand: Implications for Eruption Precursors

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Okataina Volcanic Centre is one of the most productive individual volcanoes in the world, with an eruption rate of 3.5 km^3/kyr. At least 14 eruptions from ~40-30 cal ka represent the Mangaone Subgroup. The deposits of many of the eruptions are widespread, with volumes ranging from 0.02-12 km^3. The Mangaone Subgroup deposits are dacite-rhyolites (65-78 wt.% SiO_2) and display a wide range of eruption temperatures (700-1050°C) and oxidation values (fO_2=NNO+0.55-1.63). They have a wide range in chemistry. Plagioclase composition ranges from An_{37-86}; orthopyroxene and clinopyroxene has a compositional range of En_{60-70} and En_{39-48} respectively. Hornblendes are calcic and atomic substitutions are temperature controlled. Small blebs of basalt and basaltic-andesite glass are mingled in with rhyolite glass in some pumices. A number of intermediate-composition glass shards represent hybrid-mixing between rhyolite and basaltic magmas in many of the units. This, combined with Mg-rich clinopyroxene, calcic plagioclase and olivine phenocrysts in some pumices provides evidence for mafic intrusions triggering some of the eruptions. The heterogeneous nature of many of the pumice clasts indicates brief mingling between magma batches prior to eruption, either at shallow levels in the crust, or within the eruption conduits. This is shown by multiple glass compositions within single clasts, normal and reversely zoned pyroxene phenocrysts, variation in eruption temperatures within clasts and between clasts. Two or more magmas have been tapped by some eruptions (e.g. 36.8 cal ka Maketu, 36.7 cal ka Te Mahoe and 36.1 cal ka Hauparu) while other eruptions involve only a mafic magma and one rhyolitic magma (33 cal ka Mangaone and 32.5 cal ka Omataroa). It is likely that many of the eruptions of the Mangaone Subgroup were triggered by the intrusion of basaltic magma into the base of cooling silicic magma bodies within the crust, priming the magmas for eruption.

11-P-152

Ascent Process of Magma during Recent Successive Eruptions at Suwanosejima Volcano, SW Japan

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Two types of eruptions occurred from December 2000 to November 2003 at Suwanosejima volcano, southwest Japan: short-lived, small vulcanian-like ash eruptions with some shock explosions, and continuous ash emission sometimes accompanied by strombolian eruptions. All the products consist of ash particles with two types of groundmass texture. C type particles have a clear glassy groundmass consisting of 20-50 wt.% plagioclase and pyroxene microlites, and 50-80 wt.% glass with SiO_2 <65 wt.%. D type particles have a dusty crystalline groundmass consisting of >50 wt.% plagioclase, pyroxene, and oxide microlites, and <50 wt.% glass with SiO_2 = 65-80 wt.%. Strombolian and continuous ash eruptions produce C type ash, and small vulcanian eruptions produce D type ash. The groundmass mineral assemblage and the variation trends of glass composition are in good correlation indicating that the glass of D type groundmass was generated by microlite crystallization of plagioclase, pyroxene, and oxide minerals in order of appearance from melt identical to the groundmass glass of C type particles;. Simulation of crystallization using the MELTS program shows that the trends in glass composition of the 2000-2003 products favor crystallization at shallow depths of magma with low H_2O content. The depth is consistent with the location of a shallow aquifer and with the pressure source of explosions revealed by recent geophysical observations. Component analysis of ash particles shows that high eruption columns (>800 m) have a higher proportion of hotter and less degassed C particles, interpreted as faster magma ascent of the central part of a thermally zoned conduit. The temperature heterogeneity of erupted materials is important for interpreting the ash cloud dynamics of small intermittent explosive eruptions.

11-P-153

Quantifying Motion of the Effusing Mount St. Helens Lava Dome Using Oblique Terrestrial Photography

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Traditional methods of monitoring the state of an eruption, such as seismic analysis, tracking ground deformation, and measuring gas geochemistry, have inherent limitations related to the nature and level of activity, personal safety, and an ability to deploy equipment in appropriate locations. Here we discuss another method, oblique terrestrial photogrammetry, which we have used successfully to estimate semicontinuous long-term rates of motion during a dome-building eruption of Mount St. Helens that began in 2004. Terrestrial photographic monitoring of the volcano began with a single camera deployed at the mouth of the volcano's crater during the first year of activity. Analysis of those images (subject to measurement errors of about ±2 m/d) indicates that the average lineal extrusion rate decayed approximately logarithmically from about 10 m/d to about 2 m/d from November 2004 through December 2005. It also indicates that the extrusion rate pulsated on time scales of days to

weeks. From May 2006 to May 2007, imagery from multiple cameras deployed around the volcano permits a more refined analysis that allows us to determine 3D motion of the dome complex. Software analysis of that imagery shows spatially differential, but remarkably steady to gradually slowing, motion, from about 1-2 m/d from May through August 2006, to about 0.5-1.0 m/d from September 2006 to May 2007. In contrast to its demonstrably pulsating behavior during the first year of extrusion, dome motion from May 2006 to May 2007 was monotonic (within errors of ±0.10 m/d) on time scales of days to weeks. The ability to measure spatial and temporal rates of motion of the effusing lava dome from oblique terrestrial photographs provides a significant, and sometimes the sole, means of identifying and quantifying motion dynamics of the dome during the ongoing eruption at Mount St. Helens and demonstrates the utility of using continuous oblique terrestrial photography to study and monitor volcanic eruptions.

11-P-154

Expansion Process of Lava Plug Associated with Vulcanian Eruption of Sakurajima Volcano

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At the onset of explosion at Sakurajima volcano, expansion process of a pressurized gas pocket formed at the top of a conduit is detected by broadband seismometers. This expansion is thought to be related to radiation of a shock wave because of a linear relation of amplitudes of seismic moment and infrasonic wave (Tameguri et al., 2002). In order to make clearer the seismic-infrasonic relation from the view of the origin time, we analyzed infrasonic records (5.6 km apart from the crater) and video images of Vulcanian eruptions in 2006-2007. Weak and slow increasing (<3 Pa and 0.1-0.4 s) air pressure preceded the impulsive compression (<80 Pa) and longer rarefaction phases of infrasonic waves at the eruptions. Travel speed of the preceding weak signal is regarded to be almost same as the sound velocity because of its no impulsiveness as observed in the following compression phase. In contrast, speed of the compression phase until 1 km above the crater bottom were higher (400 m/s) than the sound velocity. This caused lag of the origin times by 0.5 to 0.8 s between the preceding and the compression phases. This time of 0.5-0.8 s corresponds to the duration of increasing of seismic moment rate of the isotropic expansion process of the gas pocket. It suggested that volumetric increase would be generated by swelling up of the ground surface of the crater bottom before the collapse. And then, the strong impulsive main compression phase with high speed was radiated by sudden releases of pressurized gases, which caused decrease in seismic moment rate of the expansion of the gas pocket. Volumetric changes for the preceding signal was estimated as <300 m^3 from the waveforms based on a classical method of Lighthill (1978).

11-P-155

Facies Reconstructions of Submarine Felsic Volcanic Products as a Tool for Modern Volcanic Hazard Mitigation

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Submarine felsic explosive volcanic eruptions are a significant hazard to people and infrastructure in active island arc environments. Above 1000 m water depth, both magmatic and phreatomagmatic eruptions can occur, and the resultant steam and tephra plumes and jets and tsunamis can represent a serious threat to oceangoing vessels (e.g., Myojinsho, 1952) and nearby civilizations (e.g., Krakatau, 1883). Moreover, submarine eruptions are difficult to observe and predict, as early warning signs are concealed by the overlying water column, and sudden violent explosive eruptions allow for little response time.

Depositional products of modern submarine eruptions on the seafloor are largely inaccessible for detailed study; therefore, uplifted ancient submarine successions represent ideal targets for thorough facies architecture studies. Units such as the Pliocene Sarakiniko Formation on Milos Island, Greece provide indirect information on the behaviour of submarine explosive eruptions, and are invaluable in deducing the hazards they represent.

The Sarakiniko Formation is a 40-m-thick succession of felsic pumice that was emplaced in deep water. It comprises reversely graded, relatively well-sorted, tabular, coarse and medium lapilli beds with basal low-angle truncations and scattered jointed pumice blocks between thin intervals of planar stratified fine lapilli and coarse ash. Rare lithic clasts are significantly finer-grained, and are absent from the basal portion of the succession.

We interpret the Sarakiniko Formation to be the medial facies from a submarine explosive eruption that involved pulsatory collapse of the margin of a sustained eruption plume that originated from a deep-water vent. Low-angle-truncated bed bases, reverse grading, and sorting suggest that final deposition was by dilute, water-supported gravity flows. Lithic clasts and thicker beds in the upper part of the formation indicate an overall increase in discharge rate and vent widening. This interpreted eruption style represents a ubiquitous hazard in the Mediterranean and in other similar arc environments worldwide.

11-P-156

Magnetic petrology and its implications for eruption process of the 1884-1885 andesite lava of Suwanosejima volcano, Japan

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Suwanosejima volcano in Tokara Islands, southwest Japan, is one of the most active volcanoes in Japan. Strombolian eruptions have repeatedly occurred. During the last fatal eruption in 1884-1885, andesite lava flows were effused from the summit crater and covered the eastern flank of the volcano. The lava flow deposits show smooth and ropy surface, like Pahoehoe lava. Lava tubes are also observed in some places. These occurrences

indicate that the viscosity of the erupted andesite lava was as low as basaltic lava. In order to clarify the eruption process of the 1884-1885 activity, we carried out magnetic petrological analyses on the 1884-1885 lava samples.

As a result, we found interesting magnetic petrologic characteristics that seemed to be derived from the eruption process of 1884-1885 eruption. Petrological analyses revealed that the lava is two-pyroxene andesite (SiO_2 56.9-57.2 wt.%), containing phenocrysts of plagioclase, clinopyroxene and orthopyroxene. Fe-Ti oxide phenocrysts are absent. Small microphenocrysts of Fe-Ti oxides are crystallized in the samples from the central part of the flow units. This feature was consistent with magnetic results. Samples from the flow surface showed very high MDF of 100mT, though samples from the inner part showed moderate MDF below 25mT. It suggests that magnetic minerals in the samples from flow surface are very fine titanomagnetites and the samples from inner part contain larger titanomagnetite. Crystallization conditions were estimated by using MELTS program (Ghiorso and Sack, 1995; ver 5.0.0). As a result, an initial water content below 0.5wt.% and high eruption temperature about 1100 degrees C were estimated. It suggests that such dry magma, which lacks Fe-Ti oxide phenocrysts, effused at high temperature about 1100 degrees C and the lava showed high fluidity, resulting in the textures like Pahoehoe lava flow.

11-P-157

Phreatomagmatic Eruption Occurred in Felsic Lava Flows Emplacing the Wet Environment: Example of Hime-shima Volcanic Group, North Kyusyu, Japan

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In Hime-shima volcanic group, located in north Kyusyu, Japan and erupted in the Quaternary, there are some felsic lava flows presumed to emplace the wet environment, which are directly covered with some pyroclastic cones generally produced by phreatomagmatic eruption (Ito, 1989). It is important in understanding the volcanism on the wet environment to reveal such an alternation of eruption style and the contact mode of magma and external water. In this paper, we describe the occurrence of volcanic products in Hime-shima volcanic group and try to reconstruct the development of volcanic activities.

The basal part of felsic thick lava flows in Hime-shima volcanic area is charactaristically glassy and brecciated. Furthermore, many water-quenched cracks and pyroclastic dikes (spiracles) are observed on the basal part of lava flows, which reflects the direct contact and the interaction between hot lava and surface water. Pyroclastic cone deposits covering lava flows are composed of poorly vesiculated lava fragments, obsidian fragments which have water-quenched surface, and rounded andesitic gravels derived from basement rocks of Hime-shima volcanic group. These geological observation suggests that phreatomagmatic eruption occurred as a result of the explosive interaction between the basal part of lava flows and surface water. Thus, although in general the effusion of lava is non-explosive volcanism, explosive eruptions can occur due to the mutual effect between lava and water when lava flows into the water area. These phenomenon may cause the volcanic disaster.

11-P-158

New Insights in the Dynamic of the Volcanic Processes at Piton de la Fournaise Volcano (Reunion Island) Using ENVISAT-ASAR Data

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Piton de la Fournaise (La Réunion Island, Indian Ocean) is one of the most active volcanoes in the world. Indeed, since August 2003, 14 distinct eruptions occurred : the last one during April 2007 with the major and unusual collapse (approx. 30.10^6 m^3) of the summit crater Dolomieu. This exceptional activity also coincides with the beginning of a systematic ENVISAT-ASAR data acquisition. Thanks to our large database (220 ASAR images, 1500 interferograms with 65 spanning one of the 14 eruptions), we have performed, in quasi operational conditions, a continuous monitoring of the volcanic activity, during both the eruption episodes and the rest periods (4 to 7 months). Several high SNR interferograms (perpendicular baseline < 700 to 1500 m depending on the swath geometry) are available on each different activity episode, providing us a better constraint on the edifice 3D displacements.A three dimensional Mixed Boundary Element Method is combined with a Neighbourhood Algorithm inversion to search for dike models that best explain the observed interferograms. Most of the estimated dikes dip 50° to 75° eastward and originate 1000 to 1500m asl. The dykes sometimes split in en-echelon structures towards the surface. However for 3 eruptions (Jan 04, Feb 05 and Dec 05), the co-eruptive displacements are slightly different and should not be explained with a single dyke injection. The larger wavelength displacements observed during the rest periods should be related to the activity of a deeper structure (1500 to 3000 m below summit) such as an intermediate magma chamber. We thank the ESA for providing ASAR data through the AO-746 project.

Session 1-2

12-O-01

Volcano Observatories and Volcano Hazards Mitigation in the Information Age

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The collection of geophysical data on volcanoes has changed over the years from being the exclusive realm of a volcano observatory, with a network of ground-based sensors and observers, to one which is decidedly multidisciplinary, often interagency, and with geographically separated observers. An important reason for this shift is that new tools and techniques developed for other applications (e.g., climate or weather) sometimes aid in tracking volcanic unrest or providing eruption alerts, but data from these ancillary systems are almost never adequate in and of themselves to accurately portray the status of an active volcano. Examples of sensor systems that produce data potentially valuable to volcano observatories include: ground-based weather radar, high-resolution commercial satellite imagery (e.g., IKONOS and QuickBird), the Ozone Mapping Instrument (OMI), and multiple orbital systems operating at a variety of wavelengths, (e.g., ASTER, MODIS, Landsat, Envisat, ALOS, etc.). Also, other groups install instruments such as seismometers and GPS receivers on or near volcanoes for their own use (e.g. tsunami warning) that are also useful for volcano monitoring. There are many data available, and most can be downloaded in one form or another via the Internet. The challenge is to convert these abundant data into useful volcano hazards information, and this is the legitimate role of a volcano observatory. Thus, the challenge facing observatories in the 21st century is to assimilate all available data as quickly and efficiently as possible and to provide a cogent hazard synthesis in the form of timely forecasts, predictions, or alerts that are useful to communities on the ground and to aviation. Access to the ancillary data streams requiring increasing Internet connectivity and bandwidth, in-house or readily accessible archives, good communications with the sensor-subject-matter experts, and/or broad in-house technical expertise are some of the new requirements of 21st century observatories.

12-O-02

Instrumentation Requirements for Improving Monitoring Capabilities at U.S. Volcanoes

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In 2006 a panel of U.S. academic and government scientists was assembled to determine instrumentation requirements for U.S. volcanoes under the U.S. Geological Survey's National Volcano Early Warning System, or NVEWS, initiative. The primary tasks of this panel included: 1) defining thresholds for seismic monitoring capabilities; 2) defining depth-change, volume-change, and other thresholds for ground-based geodetic instrumentation; 3) defining criteria for deployment of lahar detection/warning systems; 4) defining the entire range of instrument mixes to be employed in ground-based networks and remote/aerial-based monitoring of deformation, geochemistry, hydrology, seismicity, thermal emissivity, and other phenomena; 5) developing a remote sensing requirement for volcano monitoring; and 6) developing requirements for mobile response instrumentation. We also defined four different levels of monitoring capabilities so that the size and configuration of monitoring networks could be matched with the threat posed by individual volcanoes, with threat levels defined by Ewert and others (2005).

One of the primary issues that arose in our discussions was how to establish an upper limit for the "best" networks. While recognizing the role of discovery and basic research in improving the ability of observatories to detect and correctly interpret early unrest, we ultimately adopted a standard that emphasized those capabilities that have been found at one or more volcanoes to be important for identifying precursory activity and/or for improving accuracy of forecasts of impending or ongoing eruptive activity. Even with such a standard, resultant networks for the most threatening U.S. volcanoes will be significantly improved under NVEWS over their present-day configurations. In this talk we will present summaries of, and scientific rationales for, our recommendations.

Ewert, J.W., Guffanti, M., and Murray, T.L., 2005, An assessment of volcanic threat and monitoring capabilities in the United States: Framework for a National Volcano Early Warning System: U.S. Geological Survey Open-File Report 2005-1164, 62 pp.

12-O-03

Local Stress Field Reorientations Preceding Volcanic Activity: A Synthesis of Case Studies from Alaska and Montserrat

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Systematic changes in the orientation of local crustal stresses have been observed prior to and during several recent episodes of volcanic activity. Thus, the use of volcanic stress field analysis to identify characteristic stress field reorientations may provide a basis for intermediate-term assessments of eruption likelihood. Fault-plane solutions for volcanotectonic earthquakes recorded during recent eruptions at the Soufriere Hills Volcano, Montserrat, and Crater Peak, Alaska, and during dike intrusion at Iliamna Volcano, Alaska, demonstrate characteristic stress field responses to magmatic activity that may be explained in terms of different mechanisms of magma-host rock interaction. At the studied volcanoes, the orientation of the local stress field is homogeneous and identical to the orientation of the regional stress field during periods of volcanic quiescence. Prior to and during periods of eruption at Soufriere Hills and Crater Peak, the local stress field is heterogeneous and characterized by a local axis of maximum compression oriented ~90° to regional maximum compression. During an intrusion at Iliamna Volcano and during an inter-eruptive period at Crater Peak the local stress field is heterogeneous and characterized by two oblique fault-plane solution p-axis trends characteristic of slip on two sets of conjugate faults. A likely explanation for slip on conjugate fault sets during periods of low-level volcanic activity is that elevated pore pressures in the rock surrounding the conduit allows slip

on faults poorly oriented with respect to ambient (regional) stress. The ~90° change in local maximum compression is modeled as the result of stresses transmitted into the host rock during dike inflation in the direction of regional minimum compression (in a weakly deviatoric regional stress field). This model is further supported by studies of shear wave splitting in the vicinity of active magmatic conduits, which confirm the presence of a locally-reoriented crustal stress field consistent with dike inflation.

12-O-04

Precursory Data of the 2006 Eruption of Mt. Merapi

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The 2006 Merapi eruption was preceded by quite clear precursory signals from seismic, deformation and geochemistry data. Alert level was step by step increased based on the increasing activity of the volcano. The onset of the eruption, which is the time when magma reached surface, is about in April 26th, 2007. About 5 weeks before, in March15, 2006 the alert level was declared to increase from NORMAL (level 1) to WASPADA (level 2). This decision was based on the increasing volcanic earthquakes and on the summit deformation.

In the beginning of April 2006, the average number of MP (summit quakes) events increase to ab out 160 events/days, from about 35 events per day in the time when Level-2 was declared. However, number of lava rockfalls was does not change significantly.

Increasing of VTB quakes (depth < 2 km from summit) indicates that magma approaches to summit zone. Summit deformation measured with GPS, EDM, was also detected. The strongest deformation was reported occurring at the south summit slope of Merapi volcano. Shortening of EDM distance was about 3 (three) meters compared with the data of January 2006.

According to the acceleration of deformation data, Merapi activity was raised from WASPADA (level-2) to SIAGA level (level 3).in April 12, 2006. In thet moment, the rate of seismic MP events is about 150 time/days. Lava rockfalls from the summit started to appear. On April 26, 2006, a new dome was visible from Kaliurang observatory. This is the start of eruption phase.

When the first pyroclastic flow appears, the alert lavel was raised to Awas (level 4) in May 13, 2006. This is the highest alert level on Merapi with a meaning that people should be evacuated from the danger area. The first big pyroclastic flow occurres in May 15 2006, two days after the evacuation. Most pyroclastic flows went to the southwest direction, filling the upstream of Krasak river.

A strong tectonic earthquake occurred in May 27, 2006. The source is located at about 45 km to the south-southeast of Merapi volcano. After the earthquake, some small pyroclastic flows went to the south-east direction, to the upper Gendol river. The unusual change of pyroclastic flow had maken a breach on the southeast part of the summit, the Gendol breach. A part of Merapi's southeast rim collapsed in June 4, 2006.

In June 9, 2006, a series of big pyroclastic occurred travelling 5 km away to Gendol river. A small crater was formed at center part of new dome with an opening facing to southeast.

At that moment the Merapi eruption seems has achieved its peak eruption. The activity then decreased suddenly. Based on this decreasing activity, alert level is lowered to SIAGA (level-3). However, in June 14, 2006, one day after, Merapi showed a strong increasing activity. Thus, the time is become limited. At about 11.00 a.m., June 14, 2006, a pyroclastic flow went to Gendol. From its deposit, we recognized that it is originated from older materials which could means that there is a collapse of summit part. At about 12.00, sirens alarm at Kaliadem, 6 km from the summit, locates near Gendol river, was switch "on". The sound was quite strong for people, about 50 persons, to quit Kaliadem. The second sirens was activated at about 14.00 p.m. to strongly ask people to leave Kaliadem. According to the emergency procedure, the alert was raised again to AWAS (level-4). At 16.00 pm, about 4 hour after the first siren, the biggest pyroclastic flow hit Kaliadem. Two persons killed at Kaliadem.
The Kaliadem event had provided a lesson about the important role of pre-installed sirens as the emergency tool to evacuate people. This is very useful when monitoring data is not sufficient to explain the real condition of the volcano especially when the situation change suddenly.

Instead of going to the usual west-soutwest flank, the Merapi eruption in 2006 has been directed to the southeast flank, an unusual direction which has been long time was not touched by pyroclastic flow. This was more difficult because the southeast flank is more densely populated than the southwest.

12-O-05

Towards Mid-Term Eruption Prediction: A Conceptual Model and Some Evidence from the Results of Integrated Monitoring of Izu-Oshima Volcano, Japan

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In order to make successful mid-term or long-term eruption predictions, we need to detect particular processes operating in magma-plumbing system quantitatively. By integrating the precursors to the 1986 eruption of Izu-Oshima volcano, we proposed that the accumulation of magma had continued for more than 10 years until 1980, and then basalt magma started to rise up through the well-developed conduit. In order to observe the whole process of magma accumulation and migration leading to the next eruption, we have constructed a dense seismic and geodetic observation network covering the whole volcano, and electromagnetic and microgravity observation system around the summit crater. Since 1989, we have detected the secular re-inflation of the volcano and further revealed the repeated inflation-deflation cycles, resulting a net inflation of the volcano. We naturally suppose that the volcano inflation is caused by the supply of magma from depth. What is the origin of the deflation? There are two possible processes causing the deflation; magma drain back and the contraction of magma due to degassing. If the latter is the case, the inflation-deflation cycle indicates the accumulation and relaxation of magma beneath the volcano and closely relates to the way of magma achievement of the conditions to start its rising up toward the eruption. To monitor the degassing of basaltic magma

accumulating beneath the volcano, CO_2 is most helpful because CO_2 separates from melt at the earliest stage of accumulation. In September 2005, we started continuous monitoring of soil CO_2 concentration at the eastern part of the summit of Izu-Oshima volcano. We observed correlated increase of the soil CO_2 concentration and seismic activity around Izu-Oshima volcano. We will discuss the magma accumulation and degassing processes beneath Izu-Oshima volcano based on ground deformation, seismic activity, and changes in magnetization, electrical resistivity and CO_2 concentration beneath the summit.

12-O-06

Monitoring Volcanic Activity by Real-time Observations of Lightning and Electrical Activity

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We have detected lightning and smaller electrical discharges in the eruption of Mount Augustine, Alaska. If the prolific discharges produced by the Augustine eruption are common to most eruptions this technique could serve as a method to independently monitor volcanic activity. The technique is unaffected by clouds or bad weather. We observe the lightning in thunderstorms or volcanic eruptions by determining the time of arrival of impulsive radio emissions from electrical discharges at several stations. We use a radio band near 60 MHz. At this frequency we can observe the many small discharges that make up both in-cloud and cloud-to-ground lightning. During the explosive phase of the eruption of Augustine volcano we saw thousands of small discharges each second close to the summit. We also saw these small discharges in 2 of the 3 smaller eruptions that followed on the same day. We expect that these small discharges will be a common feature in many volcanic eruptions. The lightning in photographs of Sakurajima eruptions is close to the eruption column and may be the same phenomena. We are currently operating several real-time lightning mapping systems for monitoring and studying thunderstorms.

12-O-07

Infrasound Detection During 2007 Mild Explosive Activity At Tungurahua Volcano, Ecuador

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Since the onset of the present eruptive period (1999) of Tungurahua volcano (5023 m asl located in the Central Andes of Ecuador), the occurrence of weak to powerful ash and gas emissions has been a very common condition. Eruption plumes range in height from few hundredths meters up to 16 km above the crater level. Depending on prevailing winds, Tungurahua's ash emissions endanger inhabited areas and airplane navigation. Ash emissions at Tungurahua are accompanied by all kinds of sound and infrasound. Scientists at the Tungurahua Volcano Observatory (OVT) and local observers living in the volcano vicinity report audible signals from explosions and degassing events. Infrasound detected by the RIOE array, some 40 km SW from the volcano, is analyzed by the Infrasound Laboratory, University of Hawaii at Manoa, in the framework of the ASHE project (Garces et al, this volume). Acoustic signals from explosions converted to P waves are recorded by the Seismic Network operated by Instituto Geofísico (IG) as part of the volcano monitoring system. 857 explosions were detected by RIOE between March 1 and April 30 2007, during a renewed period of activity at Tungurahua after the climatic eruptions of July and August 2006. The IG seismic network detected only 251 of those explosions and OVT scientists reported just 102. RIOE infrasound station shows a better performance at detecting acoustic and subacoustic signals from Tungurahua; however, a number of seismic detections in the IG seismic network, as well as ash columns observed by or reported to OVT scientist were not clearly identified by the RIOE station. At this stage of research it seems evident that cooperative efforts between local observatories and remotely controlled infrasound arrays such as the ASHE prototype is needed in order to improve the present detection level and reliability.

12-O-08

Infrasonic Observation near Active Volcanoes and its Results in Japan

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Infrasonic observation is one of the most important method in volcano monitoring. Japan Meteorological Agency (JMA), which has the responsibility to survey volcanic activity and to release Volcano Information for disaster mitigation, had been monitoring infrasonic signals using micro-barometers and other instruments. Since 1980's, JMA has installed infrasonic microphones near active volcanoes and is monitoring infrasonic signals at 25 active volcanoes in present. For Sakurajima and Suwanose-jima volcanoes, where explosive eruptions have been frequently occurring, infrasonic microphones detect explosive infrasonic signal for each explosion. During the phreatomagmatic eruptions at Miyake volcano in 2000, continuous infrasonic signals with large amplitude were observed and we could know the sequence of the eruptive activity. At Vulcanian explosive eruptions of Asama volcano on 1 September 2004, infrasonic signals were observed also at infrasonic microphones more than 1000 km distant from the volcano (Fujiwara et al., 2004). Using infrasonic microphone network we could determine source locations at some volcanoes. The source location determination of infrasonic signals was carried out at Unzen volcano for the first time. Yamasato et al. (1993) analyzed infrasonic signals from pyroclastic flows and estimated their speed and direction. Yamasato et al. (2002) applied this technique to the activity of Usu volcano in 2000 and identified at which of three craters eruption occurred. We are investigating the effect of meteorological conditions to

infrasonic signals aimed at more precise source determination (Fujiwara et al., 2007).

Infrasonic observation produces important information on the mechanism of volcanic eruption and other phenomena. We have found out small signals preceding explosive pulses from explosive eruptions at some volcanoes (e.g., Sakai et al., 2001), harmonic infrasonic waves associated with harmonic volcanic tremors (e.g., Sakai et al., 1996), and dilatational infrasonic pulses from low frequency earthquakes (Fujiwara et al., 2006) and others.

12-O-09

WOVOdat: The World Organization of Volcano Observatories Database of Volcanic Unrest

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The World Organization of Volcano Observatories (WOVO) is developing a global database of volcanic eruptions and unrest (WOVOdat), based on monitoring data of its about 70 member observatories and partner institutions. WOVOdat is an interdisciplinary project created for the purpose of storing data on worldwide volcanic unrest and making it internet accessible. It will serve as an important reference tool for interpreting volcanic unrest and forecasting eruptions. This volcanic “epidemiological” tool will greatly expand ways that data can be used and exchanged between observatories and institutional data sources.

Planning workshops in 2000 and 2002 resulted in an initial draft database schema. In November 2006, an internationally staffed steering committee was formed to provide scientific oversight. A technical workshop in February 2007 established a small technical advisory group for defining the technical framework and procedures.

As one of its results, INGV (Italy) and NIED (Japan) are now leading a pilot study with a limited dataset and functionality, based on an existing WOVOdat database schema (WOVOdat 1.0, Venezky & Newhall, 2007) that was revised after feedback at the workshop. The server location is in Japan, using open-source MySQL, and will host data from NIED, INGV, and other contributors. Initial API programming and visualization/query tools have been delegated within the group. The system architecture features a central WOVOdat server with contributing partners (observatories, institutions). Client applications will be modular to provide additional tools and visualization solutions from individually funded projects at Universities, observatories, and institutions. Data entry will be both based on web forms and on a staging tables (metafiles) using both a server-side script accessible to WOVOdat administrators only, and also custom scripts for contributors for creating such transitional metafiles from local databases. A database editorial board is also being formed.

http://www.atmos.colostate.edu/chemistry/wovo/logon.html

http://www.wovo.org

Venezky, Newhall 2007: “WOVOdat 1.0”, USGS Open-File-Report 2007-1117 (http://pubs.usgs.gov/of/2007/1117)

12-O-10

Integrating Eruption Forecasting and Cost/Benefit Analysis for Decision Making During an Emergency: the Case of BET_EF Applied to Vesuvius in the MESIMEX Experiment.

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We have integrated a probabilistic eruption forecast tool with a cost/benefit analysis in order to show how a reliable eruption forecasting can help Authorities and decision makers to make the "right" choice during a volcanic emergency. Eruption forecasting is based on a Bayesian method called BET_EF (Bayesian Event Tree for Eruption Forecasting), useful for computing and visualizing volcanic hazard and probabilities of occurrence. The code has been implemented for Vesuvius, accounting for physical and volcanological models, past data from Vesuvius and "analog" volcanoes eruptive history, and monitoring measures commonly taken at Vesuvius. BET_EF computes the different probabilities of interest in a possible volcanic crisis, like the probability of unrest, of magmatic unrest, of eruption, of the size of the impending eruption, and the spatial probability of vent opening given there is an eruption. BET_EF provides also the uncertainty associated to the probability estimates. Cost/benefit analysis is an essential step to move from probability of occurrence towards practical actions, like, for instance, the call for an evacuation. In particular, we have applied the method in real time during the MESIMEX (Major Emergency Simulation Exercise) exercise, held in Naples during 18-23 Oct. 2006, whose aim was to simulate a realistic pre-eruptive scenario at Vesuvius; the goal of our application is to show in practice how sounding and straightforward procedures for cost/benefit analysis linked to a probabilistic eruption forecasting may significantly help Civil Protection Authorities in managing a real volcanic crisis.

12-O-11

The 2007 Stromboli Eruption

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On 27 February 2007, a new eruption of Stromboli began with the emission of a lava flow from a fracture on the NE

crater, which rapidly reached the sea. The eruption was heralded by an increase in the amplitude of tremor and flank movement. Short-term precursors were an increase in the rate of occurrence of small landslide on the Northern flank of the volcano: the “Sciara del Fuoco”. A few hours later a new vent opened on the Sciara del Fuoco at 400m asl causing the sudden termination of the summit lava flow. Lava effusion ended on 2 April, 2007. The eruption was characterized by a rapid decrease in the eruption rate after the first days. On 15 March, the increase in lava outpouring, observed by a thermal camera, heralded by 11 minutes the occurrence of a violent explosion with the emission of small pumices mingled with black scoriae. The pumice had a composition similar to that of the lava and black scoriae, but with a much lower content of micro-crystals in the groundmass. A similar feature has been repeatedly observed during the major explosive paroxysms of Stromboli. Monitoring activity was made by a joint team of researchers from the INGV sections of Catania, Napoli, Palermo, and Roma together with researchers from the University of Florence, Pisa, Roma Tre, and Palermo. This activity was coordinated within a Synthesis Group appointed by the Italian Civil Protection (DPC). Several prevention measures were adopted by DPC, the main of which were the evacuation of the coast zone when strong acceleration of the Sciara del Fuoco slope motion (occurred twice) could led to a dangerous tsunami by flank collapse and two days before the 15 March paroxysm when access was prohibited to the part of the volcano above 200m asl.

12-O-12

Comparison Between the 2002-03 and 2007 Flank Eruptions at Stromboli Volcano: Basis for Predicting Future Volcanic Events

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Predicting volcanic events is a difficult task, and our ability in this field depends on the knowledge of the volcanic system and its intrinsic variability. If a volcano is characterized by a steady behaviour such as Stromboli, then predicting its future activity should, in principle, be a fairly easy task. Stromboli volcano shows a persistent state of activity with a remarkable steady state that has continued for at least the past two millennia. The 2007 eruption started on 27 February and finished on 2 April, and had many similar features to the 2002-03 event. Although lava output was roughly an order of magnitude greater, the total volume of emitted lava was similar. The greater effusion rate resulted in a much shorter duration, and this suggests a constant volume for the upper conduit and a steady supply from below. In addition, a similar sequence of events occurred during the last two eruptions: (1) breaching of the NE crater, (2) opening of multiple effusive vents along the Sciara del Fuoco depression, and, (3) a paroxysmal explosive event while lava was still pouring out from a lower vent on the Sciara del Fuoco. The same sequence of events suggests a similar threshold for triggering major explosive events. We suggest here that the emptying of the upper conduit might be sufficient to depressurize the shallow reservoir and spill undegassed magma from the source region. In absence of an effusive eruption, a steady supply reaches the threshold volume after about 6 months, and this explains the recurrence of major explosions twice a year during the steady, mild explosive activity that characterizes this volcano. Considering a steady supply for this volcano and a steady volume for the shallow reservoir, it is possible to infer when we can expect a major explosion.

12-O-13

Topographic Monitoring of The 2007 Stromboli Eruption

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The Stromboli 2007 eruption started on 27th February opening a vent at 650 m a.s.l. on the North-East flank of the NE Crater. Lava accumulated on the Pianoro at the base of the Bastimento crest, the northern wall of Sciara del Fuoco scar. Two distinct flow branches propagated on the Sciara steep slope reaching the sea in a few minutes. A few hours later the Pianoro sector, downhill the eruption-feeding dike intrusion, underwent a large gravitational movement leaving an uphill scar and bulging the Sciara downhill to ca 400 m. On the front of the movement, a little landslide preceded the main eruptive vent opening (400 m a.s.l.) and ended the lava emission from above. After a short stopping of the main vent, a new small vent (500 m a.s.l.) opened on 9th March feeding the forth lava flow for two days. Lava from the main vent produced, until 2nd April, a compound fan-shaped flow field, discharging most of the lava into the sea. It built a 600 m wide and 100 m long lava delta on the shoreline. A so large delta had not been seen at Stromboli since 1955.

Three photogrammetric surveys were carried out during and soon after the end of the eruption (4 and 15-16 March, 12 April) providing Digital Elevation Models and orthophotos. The orthophoto allowed to delimit the four lava flows, carry out a morphologic analysis and identify possible instability phenomena. The volumes of the lava flows and of the Sciara instable areas were calculated by comparing the three DEMs with a pre-eruption surface (LIDAR survey of July 2006).

The 2007 eruption involved the same area of the 2002-03 one, whose evolution was studied by a similar approach. A comparison between the two eruptions was carried out to evidence analogies and differences.

12-O-14

Volcanic Ash and Aviation safety: Challenges To Delivering Timely Eruption Information.

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The International Airways Volcano Watch is a worldwide warning system for volcanic ash clouds. The system is based around relationships between volcano observatories, local meteorological offices, aviation offices, and nine centres of expertise, the Volcanic Ash Advisory Centres (VAACs). VAACs combine remote sensing techniques with the stream of information, if any, from volcanological or aviation sources to detect eruption clouds and produce advisory information for aircraft.

Aviation operators would prefer to be notified as soon as eruption occurs and to then take diversionary action, but instant notification is not practical either from the ground or using remote sensing. Meteorological remote sensing gives relatively frequent images (up to half-hourly) and is an extremely valuable information source, but still takes time to analyse and can be limited by overlying cloud or by ice-rich eruption clouds. Successful operation of the warning system relies upon receiving the best possible forecast of an eruption and working closely with the aviation industry to encourage them to manage their risk. This approach has proven very successful during some eruptions, such as the major eruptions of Manam (Papua New Guinea) in 2004/05. However, the great resource disparities between nations, communications issues, language issues, different safety policies between airlines, different behaviour of volcanoes and varying understanding of that behaviour all pose threats to this approach.

As part of the holistic improvement of the International Airways Volcano Watch, it will be very important to develop protocols for sharing information and dividing labour. For example, VAACs will be increasingly using near-real time SO_2 images to identify and track volcanic clouds, and can give expert interpretations to volcanic observatories of cloud features in these and other remote sensing images. Similarly, observatories can give definitive advice on what remote sensing or pilot observations mean in the context of the eruption itself.

12-O-15

Role of Volcano Observatories in the US National Plan for Providing Ash-Hazard Warnings to Aviation

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Volcanic activity is known to be a serious hazard to aviation, and aircraft must be warned away from all volcanic ash clouds. To strengthen the warning process in its airspace, the United States has prepared a National Volcanic-Ash Operations Plan for Aviation, as part of a coordinated inter-agency program to detect and track volcanic-ash clouds. The plan documents the roles, communication protocols, and prescribed warning messages of the Federal Aviation Administration (FAA), National Oceanic and Atmospheric Administration (NOAA), Air Force Weather Agency (AFWA), and US Geological Survey (USGS) within the context of operational procedures established by the International Civil Aviation Organization (ICAO). As recommended by ICAO, US Volcano Observatories assign color-coded alert levels to volcanic activity that are specifically intended for aviation hazards and are evaluating a proposed, specialized message format for observatory notices aimed at aviation users. When an ash-producing eruption occurs, the plan also directs US Volcano Observatories to telephone the appropriate regional units in the civil aviation authority (the FAA) and civilian and military aviation-weather offices (in NOAA and AFWA) as rapidly as possible. The plan comprises an operational reference guide that can be used by new personnel who may be unfamiliar with the ash hazard to aviation. Because the plan mirrors global ICAO guidelines, it provides an example that could be adapted by other countries. Recognizing the additional burden that disseminating aviation-hazard information can impose on Observatories worldwide, ICAO provides a mechanism for selected (non-US) Volcano Observatories to recoup communication costs related to contacting aviation users.

12-O-16

Semi-automated SAR Processing System and Applications of InSAR to Monitoring Volcanoes in the Aleutian Arc, Alaska

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Precise mapping of surface deformation is a critical element in the assessment and mitigation of volcano hazards. Utilizing two or more radar images of the same area acquired at different times, interferometric synthetic aperture radar (InSAR) is capable of mapping deformation at an unprecedented level of spatial detail. With its global coverage and all-weather imaging capability, InSAR is being used to map deformation from a variety of causes, including volcanic activity. However, current InSAR data processing procedures are tedious and time-consuming, and therefore only suitable for analyzing a small number of SAR scenes at a time. Before InSAR-derived deformation maps and models can be used as an operational volcano monitoring tool, an automated data processing system is required. This presentation describes an automated SAR Processing System (SPS) being developed by the U.S. Geological Survey (USGS), and some applications of InSAR to Aleutian volcanoes. The SPS utilizes a state-of-the-art database approach for SAR and InSAR processing, which is a significant improvement over existing methods that employ a variety of programs and scripts running on UNIX/Linix computers. InSAR processing and deformation map generation are accomplished through a few simple steps using a platform-independent, web-based graphical user interface (GUI). SPS can semi-automatically process large amounts of SAR data for deformation map production and also catalog, archive, and retrieve processed images and deformation maps, thus providing a foundation for real-time InSAR monitoring of volcanoes. Our investigations of Aleutian volcanoes demonstrate that InSAR is an excellent tool for detecting ground deformation at restless volcanoes, in some cases long before other precursors such as anomalous seismicity or volcanic gas emissions are detected. InSAR-derived deformation patterns in the

Aleutians are diverse, providing an opportunity for better understanding of magmatic plumbing systems and differing eruption cycles in the Aleutians and elsewhere.

12-O-17

Ground-based Thermal and Topographic Remote Sensing of Volcanic Terrain Using The AVTIS Millimetre Wave Instrument

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Direct observations of active volcanoes are often severely restricted by environmental conditions, preventing the acquisition of essential data both during and leading up to hazardous activity such as the collapse of lava domes. AVTIS (All-weather Volcano Topography Imaging Sensor) is a state-of-the-art millimetre wave (MMW) remote sensing instrument designed for portable ground-based deployment around volcanic lava domes. AVTIS uses a combination of low power radar and passive radiometry to record thermal and topographic data with a single 0.35 m antenna at ranges of up to approximately 7 km under almost any viewing conditions. AVTIS has been proven in the field at the Soufrière Hills Volcano, Montserrat, between 2004 and 2006 where it recorded topographic change of the lava dome alongside thermal imagery in cloudy conditions as well as monitoring displacement of lava flows on Arenal, Costa Rica in the spring of 2005. From the topographic change measurements valuable information on extrusion rate and hazard can be derived. I will present the measurement capabilities of AVTIS against the context of MMW instrumentation developed for alternative remote sensing applications as well as summarising results gathered in the field alongside a discussion of the practical strengths and weaknesses of the system. I will also discuss future plans for the development of AVTIS as a tool for round-the-clock, autonomous remote monitoring of environments under difficult viewing conditions.

12-O-18

Measuring Volcanic Emissions with the Ozone Monitoring Instrument (OMI)

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The UV Ozone Monitoring Instrument (OMI), launched on NASA's EOS/Aura satellite in July 2004, is providing a unique set of observations of sulfur dioxide (SO_2) emissions from volcanoes worldwide. OMI couples high SO_2 sensitivity with a small footprint, permitting measurement of SO_2 in lower tropospheric volcanic plumes and small eruption clouds. The measurements present an opportunity to address important questions, including the magnitude of global volcanic SO_2 production and the partitioning of gases between eruptive and passive emissions at individual volcanoes. In September 2007, OMI will have been operational for 3 years, during which time the SO_2 data have contributed significantly to the monitoring of unrest or detection of eruptions at numerous volcanoes, including Fourpeaked (Alaska), Anatahan (CNMI), Nevado del Huila (Colombia), Aoba (Vanuatu), Home Reef (Tonga) and Ubinas (Peru). OMI has also tracked stratospheric volcanic clouds from Soufriere Hills (Montserrat) and Rabaul (Papua New Guinea) as they traveled many thousands of kilometers from their source. We review some of these cases and provide an update on the status of the OMI SO_2 retrieval algorithm and its sensitivity to pre-eruptive degassing. We also speculate how OMI images of SO_2 plumes can be used to infer the mode of gas release from volcanoes (e.g., puffing vs. continuous emission). Efforts to distribute near real-time and operational OMI data products to end-users (e.g., volcano observatories and VAACs) via the Internet will also be discussed.

12-O-19

Disaster Management Support using Daichi (ALOS)

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JAXA contributes to disaster management including Volcanic activity monitoring at international and regional level using the Advanced Land Observation Satellite (ALOS), also called "Daichi". ALOS was launched January 24, 2006. JAXA has been the member of "International Charter Space and Major Disasters" since 2005. The International Charter is an international cooperative framework participated mainly by the space agencies across the world. At the occasion of a large-scale disaster, it aims to contribute to the understanding of its cause, the restoration of affected areas and follow-up management by providing the earth observation satellite-acquired data. JAXA has also been promoting the "Disaster Management Support System in the Asia-Pacific Region (DMSS)" in the "Sentinel Asia" project since 2004. The Sentinel Asia is a voluntary and best-efforts-basis initiative to use Remote Sensing information and Web-GIS data-delivery technologies in support of disaster management in the Asia-Pacific region. Domestically, JAXA is conducting the ALOS "Daichi" application experiment since 2006 for disaster prevention to promote satellite applications in ministries and agencies not only when disaster occurs, but also in usual disaster prevention operations. There are 6 working groups for the experiment such as Volcanic activity monitoring WG, Satellite image map WG and so on. In Volcanic activity monitoring WG, it aims to investigate of satellite data applicability on valcano surveillance, through ALOS observation of Japanese major volcanoes, and Include of satellite data as one of the standard measures of regular volcano surveillance.

12-O-20

Observation on Relationships Between Merapi Volcano Eruptions March-July 2006 and Yogyakarta Earthquake 27 May 2006 (Central Java, Indonesia)

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During the 2006 Merapi volcano's eruption cycle, a strong (Mw 6.4) and shallow (10km bsl) earthquake hit the nearby Yogyakarta region on 27 May 2006. We evaluate seismic, volcanological observatory, and satellite thermal data from March to July 2006 to observe relationships between these two events. Volcanic cycle started by volcanotectonic events since March and growing of new lava dome since April 2006. Pyroclastic flow events appeared since the second week of May whose direction was dominated toward the SW (i.e. typical direction of Merapi eruptions). After the 27 May earthquake, following changes were observed. First, frequency of eruptions increased significantly on 27 May-5 June, decreased on 5-13 June, increased again on 14-30 June, and decreased rapidly since the end of June. The second major change was the direction of eruption changed from SW into SSE. We suggest that the tectonic earthquake affected the dome stability and/or created new fractures that resulted in increasing rate of magma outflow. As the outflow rate increased, the shallow magma chamber might have dried up quickly and volcanic activities decreased. Soon later the empty magma chamber was refilled from the lower magma, and another period of intensive eruptions occurred until the end of June. After that volcanic activities decreased rapidly probably because whole magma has been erupted. The tectonic event therefore caused a more violent but shorter eruption cycle of Merapi 2006. However, the impact of tectonic event on the change of eruption direction is yet to resolve as volcanological observation data show that since April 2006 (i.e. before the quake) the volcano deformation was already dominated by surface expansion towards the south; this was already a major anomaly for Merapi. Inter-relationship between volcanism and tectonism is therefore still open for further research.

12-O-21

The Eastern Ruapehu Lahar Alarm Warning System In Tongariro National Park, New Zealand, And Its Successful Response To The 18 March 2007 Lahar

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The Eastern Ruapehu Lahar Alarm Warning System (ERLAWS) is comprised of a network of sensors, acoustic flow monitors (AFMs), telemetry to a base station and near real-time interfaces to pagers, telephones and the internet. Operated by the Department of Conservation, it is designed to give sufficient early warning of lahars down the main lahar path off Ruapehu Volcano, including a well predicted dam-break lahar. One AFM site was chosen to detect the lahar initiation at the Crater Lake dam site itself and two others down the upper Whangaehu Valley to detect the lahar passing. Integration with Genesis Energy, a locally-based electricity-generation company which hosts the base station, has offered many synergies. Automated paging and telephoning of alerts from the base station to responding agencies provides further integration and timely receipt of alerts but necessitates ongoing vigilance by the system operator, training, and commitment by the agencies.

The dam-break lahar on 18 March provided the first full test of the system and the suitability of the key sensor locations. It provided excellent examples of sensor response to lahar initiation by dam break, and lahar passage past geophones that are located up to 80 m vertically and 100m horizontally from the lahar path. Sensor data and supporting observations from 2002 have been interpreted for events including rain and snow storms, gales, snow pack evolution and melting, volcanic and regional earthquakes, a small eruption, wave action, and human activity, as well as the 18 March dam break and lahar. With the AFM default settings about one non-lahar alert per month occurred in the 2002-2007 period. Lake level sensors proved unreliable for alerting but very useful for monitoring.

12-P-01

Swarms of Repeating Events at Shishaldin Volcano, Alaska

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During 2001-2004, a series of four periods of elevated long-period seismic activity, each lasting about 1-2 months, occurred at Shishaldin Volcano, Aleutian Islands, Alaska. The time periods are termed "swarms of repeating events", reflecting an abundance of earthquakes with highly similar waveforms that indicate stable, non-destructive sources. These "swarms" are characterized by increased earthquake amplitudes, although the seismicity rate of one event every 0.5-5 minutes has remained more or less constant since Shishaldin last erupted in 1999. A method based on waveform cross-correlation is used to identify highly repetitive events, suggestive of spatially distinct source locations. The waveform analysis shows that several different families of similar events co-exist during a given swarm day, but generally only one large family dominates. A network of hydrothermal fractures may explain the events that do not belong to a dominant repeating event group, i.e. multiple sources at different locations exist next to a dominant source. The dominant waveforms exhibit systematic changes throughout each swarm, but some of these waveforms do reappear over the course of 4 years indicating repeatedly activated source locations. The choked flow model provides a plausible trigger mechanism for the repeating events observed at Shishaldin, explaining the gradual changes in waveforms over time by changes in pressure gradient across a constriction within the uppermost part of the conduit. The sustained generation of Shishaldin's long-period events may be attributed to complex dynamics of a multi-fractured hydrothermal system: the pressure gradient within the main conduit may be regulated by temporarily sealing and reopening of parallel flow pathways, by the amount of debris within the main conduit and/or by changing gas influx into the hydrothermal system. The observations suggest that Shishaldin's swarms of repeating events represent time periods during which a dominant source is activated.

12-P-02

Extremely Long-period Tremors at the Tatun Volcano Group, Northern Taiwan

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The Tatun Volcano Group lies at the northern tip of Taiwan only 15 km north of the Taipei, the capital of Taiwan that has more than seven million inhabitants. The Tatun volcanoes have been considered to be extinct because of no previous historical eruptions. However, some recent geochemical studies suggest that the possibility of future volcanic activity may not be completely excluded. Thus, the assessment for any potential volcanic activity in the Tatun area is not only a scientifically interesting topic, but will also have a great impact on the safety of the whole of the northern Taiwan area. Since 2003, a seismic array consisting of 8 stations equipped with both broadband and short-period sensors has been installed to monitor the seismic activity of the area. In addition to recording a variety of events including volcano-tectonic earthquakes and volcanoseismic signals like tornillos, monochromatic events and spasmodic bursts, an extremely long-period (~30 sec) volcanic tremor has been observed. Based on both of particle motions and travel-times recorded at broadband seismic stations, the source of the extremely long-period tremor has been estimated at shallow depth (1-2 km) beneath the Chihshinshan, which is the highest summit in the volcan group. These observations put into doubt the long-standing suggestion that the Tatun volcanoes are extinct and prompt for a thorough assessment of the volcanic hazard for this area.

12-P-03

Harmonic Events in Changhaishan-Tianchi Volcano

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By analyzing seismic data recorded in the Changbaishan-Tianchi Volcanic (CTV) region, we find one type of events whose waveform records appear to be harmonic. The station-averaged spectrum of each event consists of a series of evenly-spaced narrow peaks of a fundamental frequency and its overtones. In the Summers of 2002, 2003 and 2005, 38 such harmonic events were detected. They are most likely associated with fluid-controlled sources. Possible mechanisms include excitation of fluid-filled cracks and nonlinear pressure oscillation produced by flows in magmatic or hydrothermal channels. Therefore, the occurrences of harmonic events are evidence of existence of magma chambers beneath the CTV. Combining recent observations of rapid ground deformation and abnormal changes of hydrogeochemical parameters in recent years, we suggest that the apparent increasing of seismicity and the emergence of harmonic events in the CTV region are associated with deep magmatic intrusion activities.

12-P-04

Recent Seismic Unrest at Chanbaishan Tianchi Volcano

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Changbaishan Tianchi volcano is located in the Changbaishan Mountain on the border between China and North Korea. In the past 5000 years the volcano erupted several times and formed a 4 km long by 3 km wide lake near the top of the mountain. The eruption that occurred around 1200A.D. is considered an unusually large eruption globally in the past 2000 years. Since then, three small-to-middle size eruptions occurred in 1668, 1702 and 1903, according to the historic records. The seismic monitoring in the Changbaishan Tianchi volcanic area began in 1985. In June 2002, the seismicity in the Changbaishan Tianchi volcanic area increased abruptly. A multitude of small events and a series of earthquake swarms have been observed between 2002 and 2005 at the permanent seismic station and a temporary seismic network. Except a few LP events and several tens of harmonic-spectral earthquakes observed in 2005, almost all earthquakes are volcano-tectonic earthquake. Earthquake location result shows that these events mainly occurred near the Tianchi caldera. The focal depths are shallow, and usually less than 5km from surface. Earthquake swarms were concentrated at southwest of the caldera. Relative location shows that the hypocenters migrated from deep to shallow during the July 13, 2003 earthquake swarm and deeper events had upward first motion directions almost at all stations, showing obvious expansion component in source mechanism. Taking into account of significant surface deformation in Changbaishan Tianchi volcano since 2002, geochemical anomalies and harmonic-spectral earthquakes, we believe that the high seismicity was caused by magmatic and hydrothermal activity near the depth of 5km.

12-P-05

Seismic Events Observed Prior to and During the 1990-1995 Eruption of Unzen Volcano, Japan

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Seismic events recorded prior to and during the 1990-1995 eruption of Unzen Volcano in southwest Japan are discussed and correlated with observed volcanic activity. The main peak, Fugendake, began erupting on November 17, 1990, and the growth of an associated dacite lava dome proceeded from May 20, 1991 to February 1995. Seismic signals recorded at the volcano are classified into volcano-tectonic earthquakes, summit earthquakes (shallow volcanic earthquakes in the crater area), volcanic tremors, explosion earthquakes, pyroclastic flows, and debris flows. The seismic activity changed significantly throughout the eruption, correlating with changes in the magma supply rate, the style of dome

growth, and other features. The volcano-tectonic seismicity, active mainly on the western flank of the volcano starting one year prior to the 1990 eruption, declined sharply around the time of dome emergence, while summit earthquakes intensified immediately prior to dome emergence. The high level of summit seismicity continued until the final stage of eruption, indicated by gradual upheaval of a lava spine. Volcanic tremors were observed from four months before the 1990 eruption, and are identified as one of the most remarkable precursors of the eruption. An explosion earthquake was clearly recorded in association with a vulcanian eruption on June 11, 1991. Seismic signals due to pyroclastic flows caused mainly by partial collapse of the dome were frequent during dome growth, and seismic signals due to debris flow were observed during heavy rain. Seismic observation thus played an important role in eruption forecasting and monitoring of volcanic activity, and hence disaster mitigation.

12-P-06

Seismic Activity in the Early Stage of Dome Growth at Unzen Volcano, Japan (May - June 1991)

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During the 1990-1995 eruption of Unzen Volcano, SW Japan, seismicity in the crater area intensified during the growth of a dacite lava dome. In this study, we investigated the characteristics of seismic activity from May to June 1991, the early stage of dome growth. Major surface phenomena observed in this period included emergence of lava dome on May 20, large pyroclastic flows on June 3 and 8, and a vulcanian eruption on June 11. From May 12, about one week before the dome emergence, the number of HF events had started to increase gradually and NW-trending parallel cracks formed around Jigokuato Crater. Furthermore, inflation on the upper southern flank of volcanic edifice was detected by EDM (Saito et al., 1993). These phenomena were considered to be a sign of lava extrusion. Although the seismicity decreased slightly after the dome emergence, it had sometimes increased temporarily. On June 2, the number of small LF events increased markedly, which may have related to the occurrence of the large pyroclastic flow on June 3. Notable changes in seismicity level and/or dominant waveform type associated with the large pyroclastic flow on June 8 and the vulcanian eruption on June 11 were also recognized. We defined an earthquake group as a time series of earthquakes whose waveforms are similar or vary only slightly over time, and identified a number of groups in the study period. We discuss the characteristics of some typical earthquake groups and the correlation between the appearances of earthquake groups and the observed volcanic activity.

12-P-07

Seismic Monitoring of Stromboli Volcanic Activity: the February 2007 Effusive Eruption

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Stromboli is a volcanic island close to the North coast of Sicily (Italy). It is characterized by almost persistent explosive activity. On February 27, 2007 Stromboli volcano started an effusive eruption with a small lava flow on the NE flank. The effusive phase stopped on April 2, 2007. The permanent broadband seismic network operated by INGV on the volcano allowed to evidence anomalies in the seismicity before the effusive eruption and permitted to follow the phenomena over time, obtaining meaningful information about the eruptive dynamics. The period before the effusive phase was characterized by a progressive increment of VLP hourly frequency and by a moderate increment of the VLP amplitude. Also the microtremor amplitude gradually increased starting from January 2007. Four hours before the beginning of the effusive phase several landslide seismic signals appeared, forming sometimes a continuous signal superimposed to the volcanic microtremor. During the effusive phase a major explosion occurred on Marc 15. Two strainmeters, deployed on the volcano in the last year, recorded a pressure increment before the blast. After this explosion, that further destabilized the upper part of the edifice, swarms of LP and Hybrid events where recorded. The characteristics and the locations of these events suggest that they can be associated with the fracturing processes affecting the summit area of the cone.

12-P-08

Seismic Signals Associated to Phreatic Eruptions of the Nevado del Huila Volcano (Colombia). February and April 2007

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Nevado del Huila Volcano (5,364 m.a.s.l.), located in southwestern Colombia, 90 Km NE of Popayán city, had been presenting seismic levels of two to three events per day since beginning of surveillance. The more relevant activity was presented in 1997, 2000, 2001 and 2003 with small swarms of volcano-tectonic (VT) events mainly located in the southwest and northeast of the volcano.

On the beginning of this year, the seismic activity showed changes represented by swarms of VT events, now located in the subsurface of the Central Peak, presenting at the same time events associated with fluid motion inside the structure. This behavior was previous to the eruption that took place on February 18th, at 13:53 UT, to which both, a small ash emission and a small lahar flowing down the Paez River were associated.

During the following days the seismic activity returned to the low levels with few and small ash emissions that continued until April 17th when a new VT swarm was

registered. This last one showed a higher amount of fluid motion events preceding a new phreatic eruption that produced an ash emission and a larger lahar than the previous one which destroyed some road infrastructure on the influence zone of Paez River. Nevertheless, due to the opportune communication and quick evacuation of the people that lives in the most vulnerable zones there were no injuries nor lost of human lives registered.

This report was written with the purpose of showing the seismic behavior before, during and after Nevado del Huila eruptions that occurred on February and April of the present year, and its contribution to the volcanic crisis handling processes.

12-P-09

1994 and 2007 Debris Flows on the Paez River Valley (Colombia): Calibrating to the Plot of the LAHAR-Z Method.

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In the recent years two large scale debris flows have occurred through the Paez River Valley, which is the main drainage of the Nevado del Huila volcano, in Cauca State (Colombia). The 1994 flow was seismogenic and feed by more than 3000 landslides. The flow of April 2007 was volcanogenic and was feed by a water expulsion of the volcano and the lose materials in the volcano slopes and in the river bed. The results of the simulations made through the LAHAR-Z method of several debris flows volumes through the Paez river valley, overestimate the heights, the inundation section and volumes comparing with the occurred in the Paez basin during the 1994 and 2007. On the other hand, when calculating the lahar volume from measured heights for the April flow, the volume was drastically underestimated. Therefore, we decided to calibrate the method using the 1994 and 2007 flows information. The calculations at several points of the transverse inundated areas, their heights and also the volumes involved in the 1994 and 2007 debris flows were done in order to obtain the lahar information for the Paez basin. Finally after statistical and mathematical analyses carried out, the equation that better represents the measurements for these two flows is $A=0.0059\ V^{2/3}$. After measurements were made for several places located in the upper, middle and lower parts of the valley we realized that the calibration represents better agreement between the calculated and the measured, in places where the valley is approximately 'V' in shape. This situation occurs through the upper and middle Paez river valley. For a particular cross-section, the maximum difference in elevation calculated with the calibrated equation and the measured at the field is about 5 m, this is for the upper and middle parts of the Paez river valley.

12-P-10

Precise Hypocenter Distribution and Very-Long-Period Events of Ontake Volcano, Central Japan

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A dense seismic network has been operated around Ontake volcano, central Japan, by the Nagoya University, Nagano Prefecture, Gifu Prefecture, and the Japan Metrological Agency. Intense seismic activity just beneath the summit of the volcano started since the end of December 2006 and continued until now (May 2007). Volcano tectonic (VT) earthquake intensively occurred during the beginning to the middle of January 2007. Low-frequency earthquakes occurred and the daily number of VT earthquakes gradually decreased since the middle of January 2007. Volcanic tremors had been observed since the end of January 2007. The time history of the seismic activity consists with the generic volcanic earthquake swarm model [McNutt, 1996].We applied the DD method [Waldhauser and Ellsworth, 2000] to obtain the detailed hypocenter distribution beneath the summit of Ontake volcano. The hypocenters distribute at the depths of -1 to 3 km just beneath the fumarole area (Jigokudani) near the summit of Ontake volcano. Several of the volcanic tremors associated with very long-period events (VLPEs). Waveforms of VLPEs consist of very long-period (20 s) signals. Seismic signals of the VLPE on January 25, 2007 observed at broad band stations of the Nagoya University and the F-net, some of which are 140 km far from the volcano. Particle motions of the broad band stations near the volcano consistent with the vertical crack source mechanism whose strike directs NS.

12-P-11

Nature of N-type Earthquakes Observed at Asama Volcano: Time Variation of Wave Parameters and Hypocenter Distribution

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Long period (LP) events called N-type earthquakes are typical phenomena observed at many active volcanoes, such as Kusatsu-Shirane, Asama and Tokachi-dake volcanoes, which is probably related to activities of magma, ground water or volcanic gas and many source mechanisms such as resonance of fluid cracks or spheres and so on are proposed. In this study, we analyze the data of LP events observed at Asama volcano in Dec. 1-10, 1996 and show the features of the LP events revealing their source process by using the high quality data obtained by the seismic network close to the summit crater of the volcano. During the period, 112 N-type earthquakes were observed. The waveforms of these events seem to be a quasi-monochromatic oscillation whose amplitude is gradually decreasing. The spectrum has a dominant peak at 1.6-7Hz. Most of the events make a group in which the dominant peaks changes from 2.0 Hz to 1.6 Hz gradually. This means that the scale or the physical properties of the LP source

changes gradually if we accept the resonance model. Attenuation factors have a positive correlation with dominant peaks, but the coefficient of correlation was small. Hypocenters of the events determined by the travel time of the first motion are concentrated into a shallow range within the depth of 300 m underneath the summit crater and are distributed in the upper part of the region B-type earthquakes occur.

12-P-12

Temporal Changes in S-wave Splitting Associated with 2001 Hakone Sarthquake Swarm.

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Kanagawa Hot Springs Res. Ins. (HSRI) has developed 14 seismic observation stations around Hakone volcano. A temporal change of parameter of S wave splitting (LSPD: Leading Shear-wave Polarization Direction) observed at staions installed in Hakone volcano (e.g, Owakudani or Komagatake stations) during the greatest swarm earthquakes occurred in 2001. The change is dominant at Owakudani and Komagatake stations. During the swarm earthquakes, LSPDs observed at Owakudani and Komagatake agree with a direction of open crack, which estimated by tilt data, or alignment of small earthquakes.

This fact means that S-wave splitting can be a tool for monitoring volcanic activities.

12-P-13

The 2001 Swarm Activity in the Hakone Volcano

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The Hot Springs Research Institute of Kanagawa Prefecture (HSRI) operated uniquely by prefectural government has encompassed observation and research on earthquake and their application services for agencies and people in Kanagawa Prefecture. The HSRI established in 1961, and started seismic observation in 1968 in Hakone volcano. After 1989, we strengthened the seismic and crustal deformation observation network by using seismograph and boreholed tiltmeter, EDM, GPS. The hypocenter determined by using first arrival time of our 16 stations, each of which is equipped with three component velocity type seismometers adjusted to natural frequencies of 1 Hz and a damping coefficient 0.7.Remarkable seismicity from 1989 to 2006 is swarm activity in 2001. This swarm activity in Hakone volcano continued to for about four months from the 12th June to the first ten days of October. The number of total earthquakes counted by the HSRI was 15000 or more including the one that the hypocenter was not able to be decided. The maximum earthquake was M2.9 (July 21), but most earthquakes magnitude was one or less. The hypocenter distribution showed alignment from south to north under central cone. The hypocenter depth under the center part of this alignment was very shallow. In both ends of alignment, the depth of the hypocenter was distributed from 3 to 6km. Many focal mechanism show strike and normal fault types. The feature of this activity was to have observed crustal deformation that the upheaval and the expansion of the mountain are shown with GPS observation net (GEONET) of the Geographical Survey Institute, strainmeter of the Japan Meteorological Agency, and the EDM net of the our institute. It is the first time that such crustal deformation was caught in Hakone Volcano. The disaster map of Hakone Volcano was made with this seismic activity.

12-P-14

Analysis of Long Period Seismic Signals Observed before the Caldera Formation during the 2000 Miyake-jima Volcanic Activity

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We analyzed unusual long period (LP) seismic signals with dominant frequency of 0.2 or 0.4 for several days before the caldera formation that happened during the 2000 Miyake-jima volcanic activity. Each waveform of the LP events consists of the two parts; initial impulsive signal with a period of about 2 s and the later oscillatory wave. In this study, their source locations and mechanisms were determined in a waveform inversion method for each part. According to the analysis, the initial impulsive pulse and the later oscillatory wave are well explained by a nearly horizontal single force and a moment solution, respectively. The single force for the initial pulse works northwardly at the depth of about 2 km beneath the summit. The moment source is located at the depth of about 5 km below a southern part of the island. We found a clear positive correlation of the amplitudes between the initial pulses and the later waves, suggesting that the shallow sources trigger the deeper moment sources in spite of several km distances between the two sources. The source time functions of the six moment tensor components do not always oscillate in phase. To extract the geometrical features from the moment solution, we developed a new method in which source time functions are analyzed in the frequency domain. According to the result, the oscillation is axially symmetrical. One of the possible systems that meet the requirements for the moment solution may consist of two perpendicular cracks. We interpreted that the single forces that triggered LP seismic events were generated when some magma mixed with rock blocks suddenly happened to move in a chocked subsurface magma path below the summit, and the resulting pressure waves propagated and excited a resonance oscillation of the two cracks in the south region.

12-P-15

Volcanic activity and Tremor at Aso Nakadake after 1930

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The Aso Nakadake is one of most active volcanoes in Japanese Island. Based on analyses of volcanic tremors and eruptions after 1930, the activities are divided into the following four types. (A) An amplitude of volcanic tremor shows less than 1mm before eruption, and it increased more than 10mm with phreatic eruption, and then is increasing and shifted to continuous tremors with Strombolian eruption. (B) An amplitude of volcanic tremor is less than 1mm before eruption, and it increased less than 3mm with phreatic eruption, and then returned to less than 1mm with termination of eruption. (C) The volcanic tremors corresponding to the eruption show the following records; firstly an amplitude was increasing and shifted to continuous tremors with increasing of eruption of sediments and cinders. Finally the tremors reached maximum with Strombolian eruption. (D) An amplitude of the volcanic tremor is gradually increasing with proceeding of phreatic eruption at hot crater lake, and eruption of sediments from bottom of pond and cinders, then became to nearly zero at rest of eruption. After then an amplitude is increasing more than 3mm with development of Strombolian eruption.

Based on geological and petrochemical features of volcanic products, the eruptions after 1930 show the following history; phreatic eruption with sediments with gypsum and S=12.6-1.3wt% at the bottom of the lake, volcanic ash with scoria and Strombolian eruption of scoria with time. Essential fragments from 1930, 1933 and 1989 eruptions are basaltic andesite with 52.9-53.5wt% of SiO_2 content. FeO*/MgO (1.95 to 2.56) - element variation diagrams show similar trend in the fragments from each stage, indicating that fractionation of olivine, clinopyroxene and plagioclase took place in the similar magma in each stage.

12-P-16

Similar Earthquakes Observed at Kusatsu-Shirane Volcano

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Introduction: Kusatsu-Shirane volcano is an active volcano situated in the central part of Japan. Recent notable activity shows three phreatic explosions in 1976, 1982 and 1983. We have monitored the seismic activity with 6 stations installed around crater lakes (Yugama, Mizugama and Karagama), where most of the earthquakes are concentrated. Densely installed seismic stations including 3 bore-hole ones enable us to locate very small earthquakes (M=-1). It is well known that there are cases where multiple earthquakes are observerd as similar waveforms (similar earthquakes). If such earthquakes occur repeatedly, they can be an important tool to detect temporal changes in the crustal structure. In this presentation, we report activity of similar earthquakes found around the Kusatsu-Shirane volcano.

Data and Analysis: We use about 1600 earthquakes observed between July 2003 and May 2007. First we extract 2-second waveforms starting at the P-wave onsets. Then we apply a band-pass filter of 4 to 8 Hz to the waveforms and calculate cross-correlation coefficients for each stations. The maximum of the coefficients are saved. We consider an event pair as a similar pair if the cross-correlation coefficients at the bore-hole stations are greater than or equal to 0.8. From such similar pairs are formed similar groups when similar pairs share same events. Our analysis revealed that there are three large similar groups which occur repeatedly in the whole data period. These groups have more than 100 member earthquakes and about half of earthquakes used in our analysis belong to one of the three major groups. Two of the major groups occur in the north and northeastern part of Yugama at the depth 0.5-1 km below the surface. Other group occur about 1 km south of Yugama at the depth of 1 km.

12-P-17

Deformation Measurements at Machin Volcano, Colombia: An Approach to a New Volcanic Activity

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Machin volcano is located in the province of Tolima, in the central part of Colombia – South America. The active cone is situated 7.5 km NE of Cajamarca town (22,800 inhabitants) and 17 km NW of the city of Ibague (421,690 inhabitants). The volcano edifice is built over the basement rocks by many pyroclastic rings of 80-100 m hight. In the interior of the volcanic rings there are plainer areas where existed a small lagoon some years ago. The pyroclastic rings are broken in the SW. In the center of the volcanic complex there are 3 lava domes with a maximun hight of 2750 m.o.s.l. There are not records of eruptive activity duting historic times. The volcanic deformation measurements are considered as one of the most useful techniques for monitoring active volcanoes. The deformation networks are used to detect elevation changes of the surface due to overpressure in the magma system. Dry tilting and leveling measurements at Machin volcano have been carried out since 1987. Dry tilt and short-line leveling stations were built over the pyroclastic rings and on the volcanic domes. The stations are observed permanentelly. The results of the analysis of the data show at first, a pattern of surface displacement associated to big changes in ground tilt caused by a possible volcanic land slide in the SW flank where the pyroclastic rings are broken. In the future this deformation could unstabilize the system and generate an eruption. Other stations are showing a possible magma upwelling to a shallow reservoir centered at less than 3 km beneath the main crater. The amount of vertical migration of magma was estimated using the Mogi model and the relative tilt changes recorded in 8 stations located at different horizontal distance places from the center of the volcano.

Keywords: Machin volcano, deformation, leveling, volcanic land slide.

12-P-18

GPS Monitoring of the Lava Dome Deformation of Heisei Shinzan, Unzen Volcano

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An eruption started at the east side of Mt. Fugen, the main peak of Unzen volcano, in Kyushu, Japan in November 1990. Mt. Fugen extrudes high-viscosity lava from a creator and a dacite lava dome began to grow in May 1991, and continued until January 1995, finally reaching a volume of $1x10^8m^3$ and a height of 250m. The pyroclastic flows generated by the collapse of the lava dome ceased after spring of 1995, and the lava dome was named Heisei Shinzan. The dome is in the shape of a plateau and the crushed lava covers the dome.

We install GPS observation points on the dome. The point is the 5/8-inch bolt made from stainless steel embedded on a stable rock on the dome, and the GPS antenna was directly fixed on the bolt when observation made once or twice a year. The GPS survey showed that the displacement vector of the dome spreads out radially from the center of the lava dome, as a rate of about 10cm/y, and subsidence of about 30cm/y, which indicated that the temperature inside the dome was still very high and that deformation of the dome was viscous. However, after 2000, the subsidence rate ceased to 15cm/y and a little horizontal displacement is observed. This result means that the lava dome is now cool enough that consolidation is a major process of the deformation. The 11th lobe, the east half of the dome, is on the east slope of old volcano body. One GPS point near the lobe showed horizontal displacement of 3m to the direction of the steepest slope and subsidence of 4.8m within 10 years. This movement speculated as a landslide, we should continue the monitoring to avoid next disaster.

12-P-19

Crustal Deformation Derived from Continuous GPS Observation in Nothern Part of Kinko Bay, Kagoshima, Japan

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Continuous GPS observation by Kagoshima University started around Kinko Bay, Kagoshima in 1993. In Northern part of Kinko Bay there is one of the most active volcano Sakurajima and Aira caldera. Eto et al. (1999) reported that there is a pressure source beneath the Aira caldera according to leveling and EDM observations. Iguchi (2006) analyzed continuous GPS data in and around Sakruajima and found that episodic inflation occurred in the inflation source in the Aira caldera. This paper reported crustal deformation derived from continuous GPS observation by Kagoshima University and GEONET operated by GSI, JAPAN.

There are four sites named NOEV, TAKT, USKI and KD2H around Sakurajima Volcano. Observation at KD2H starts in April, 2002. Daily coordinates of the sites are calculated with GEONET sites by Bernese GPS Software Ver. 5.0 from April, 1996 to March, 2007. Troposphere parameters are estimated every 1 hour and tropospheric gradient parameters are also estimated every day. We adopt "minimum constraint solution" method for the datum definition (ITRF2000) of our network. This type of definition is based on Helmert constraints on coordinates of sites (TSKB, PETP, GUAM and LHAS) with respect to a reference frame.

Velocity of sites which is located near the Aira caldera is from 3.4 to 4.6 cm/yr with southeastward direction. Strain changes are calculated in three GPS triangles. Expansion occurs at almost constant velocity in two triangles which are composed of GPS sites exterior to Sakurajima. However, expansion was accelerated in 1999 and 2001 in the GPS triangle of Sakurajima. It seemed that observed expansion is caused by inflation of the point source beneath Sakurajima and Aira caldera and that inflation beneath Sakurajima occurred episodically.

12-P-20

Real-time Eruption Magnitude Estimation from Far-field Geodetic Data: A Proposal for Volcano Early Warning

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Quasi real-time magnitude estimations of earthquakes have been routinely processed, but there have been little trials for volcanic eruptions. Eruption phenomena include complex kinetic and thermal energy, therefore, eruption magnitude estimation has been not easy work. Newhall and Self (1982) proposed a volcanic explosively index (VEI) mainly using volume of ejecta and/or column height. This method has been widely used, but can not be applicable to predictive and real-time operation. From the viewpoint of disaster reduction, predictive and real-time quantitative magnitude estimation only gives effective and valuable information for resident evacuation. In simple terms, volcanic eruption is magma transportation from reservoir to the ground surface. This idealized model implies that total depression volume in magma reservoir may reflect maximum magnitude of ongoing eruption. Though seismographs have been basic and principle data to monitor volcanic activities, it has been difficult to estimate magnitudes of eruptions because pendulum periods are essentially shorter than volcanic eruptions. Meanwhile, geodetic data, e.g. GPS, tiltmeter and strainmeter, have flat response to the long-term deformation than seismometer, and directly reflect volumetric change of magma chamber and/or intruding dike to shallower part. Recent studies have clearly shown technical development of real-time telemetry and processing of these geodetic data had been in practical use. In this paper we show simple and robust examinations of predictive to real-time volume estimation of magma and/or gas migration using deflation signals observed at relatively far-field high-precision geodetic stations. Trial predictive and real-time magnitude estimations give close agreement with post-eruption total magma volume estimated by geodetic data and/or ejecta. Our result indicates the possibilities of predictive and real-time eruption magnitude alert, so-called, volcano early warning, based on quantitative volume estimation by geodetic data, which may be effective for resident evacuation.

12-P-21

Estimation of Magma Supply System of Izu-Oshima Volcano Using by High Density GPS and EDM Network

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Izu-Oshima volcano, located on the northernmost end in the Izu - Bonin Islands, is one of the most active volcanoes in Japan. This volcano is basaltic and has erupted periodically. The latest eruption occurred in 1986. After this eruption, the island has been continuing inflation caused by the magma supply to the shallow reservoir under the vent even in a dormant stage (Murakami, 2002). The area around the volcano, on the northern edge of the Philippine Sea Plate, is subject to the tectonically compressed field, which makes the principal pressure axis orient to NNW - SSE. Actually the old craters and cones in the Izu-Oshima Island are distributed in the NNW - SSE direction, which is consistent with the regional tectonic stress. Besides this regional tectonic environment, the deformation due to local stress field is recognized near the central crater and in the south-southeast region of the island. Thus the crustal deformation of the volcano and its outskirts will represent a combination of stress fields of different scales. We are trying to clarify dynamic magma supply/discharge process of Izu-Oshima, based on the observation of volcanic deformation by a dense GPS and EDM network.

12-P-22

Tilt Change Preceding to a Small Phreatic Explosion of Meakan-dake Volcano

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We found a strange very long period signal (duration ~60 seconds) in seismic record of a precursory swarm of small phreatic ex-plosion at Meakan-dake volcano, Hokkaido, Japan, in 2006. The long period signal was very small, but considerable one-sided os-cillation was contained in the velocity trace. Since such one-sided oscillation results from tilt change of seismometer, we interpreted the observed trace as a combination of rotational (tilt change) and translational motion (displacement change). Apparent displacement offset towards WNW direction indicates subsidence of ESE, which corresponds to azimuthal direction of summit crater of Meakan-dake volcano. We considered simple dual source model composed of deflating spherical source (Mogi's source model) and expanding vertical elongated crack. Although this model may be too much simplified, waveform features in the observed seismic trace are well explained. This research may serve as a reference for the physical monitoring of small phreatic explosions and the inter-pretation of broadband seismic trace.

12-P-23

GPS Observation of Crustal Movements in Aso Caldera

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In Aso volcano, leveling surveys have been repeatedly conducted since 1937 by Kyoto University. As the result, secular subsidence is observed in an area about 3km west of the Nakadake active crater (Kusasenri area). And it is revealed that the source of this subsidence was located at about 3km west of the crater with a depth of 5 km (Sudo et al. 2006). The location of this deflation source coincides with the low P- and S- wave velocity body revealed by a seismic tomography study (Sudo and Kong, 2001). Therefore, this low velocity body is considered to correspond to a magma reservoir. However, the magma supply system into this reservoir is not clear. On the other hand, Murakami (2004), with analyzing GEONET data, suggested that another dilatation source was located beneath the Nakadake active crater with a depth of 15 km and that caused crustal deformation in the middle of 2003. Therefore, in order to detect crustal movement associated with the accumulation process of the magma, we established a dense GPS network in the end of 2003. The observation in seven stations was started from December 2003. And four stations were added in 2004. The many of baseline length are 10 km or less. Continuous observation with a sampling interval of 30 seconds is performed at all stations. Observation data was analyzed using Bernese 4.2, and changes in each baseline length were obtained. As a result, it is found that some of the baselines showed slight expansion of a volcanic body from October 2004 to April 2005. Also, we found that these changes can be modeled by the inflation at the both of the sources, located beneath the Kusasenri area with a depth of 5km and beneath the Nakadake active crater with a depth about 15 km.

12-P-24

A Study of Risk Through a Geodesic Network in the Metropolitan Area of Guadalajara

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The geodesic measurements with Global Positioning System (GPS) have been used intensely in recent years, mainly in the fields of the Earth Science, specifically in geophysical research. The private enterprise is widely demanding this technology, to refer surveys, cadastral and photogrametric mapping, in the definition of political-administrative limits, in space analysis with thematic cartography, in GIS, in land-use planning to make it bounded to the satisfaction of social, economic, political necessities, as well as for the conservation of the environment. The city of Guadalajara and the surrounding urban area has expanded greatly in the last three decades as a result of industrial, commercial and housing

activity changing substantially its urban morphology. During this time, the metropoli has grown more than ever in its history. The urban process has been diagnosed as fast, disarticulated, unbalanced and deprived of a suitable planning. All of which makes her unsuitable to function as the most important in the western part of this country. The new developments around the former city of Guadalajara are in seismic and volcanic risk. The Geodesic Network must provide information in case of an emergency. It helps to measure non-perceivable cortical deformation by means of seismographs. We have made a study on the 89 geodetic sites located in the metropolitan zone of Guadalajara, aiming to contribute to the urban development and city planning regulation, including land use and urban and rural cadastre In this work we examined and evaluated the quality of the sites, as well as its correct distribution, following the growing patterns of urban expansion, the vulnerability of the urban zones and diverse risks that may threaten the region.

12-P-25

Long Term Prediction of the Activity of Mt. Usu with the Leveling Survey

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Mt. Usu is one of the most active volcanoes in Japan, and is located at the southwestern Hokkaido. The activity of Mt. Usu is characterized by the huge ground deformation and quite large number of felt earthquakes. The viscous dacite magma of Mt. Usu cannot drain back easily, and stay at the shallow position after the activity; therefore a new mountain is born in each activity. The volcano and its surrounding area are always subsiding in the quiescence. So, we couldn't find the precursory volcanic inflation near Mt. Usu. This study is the first attempt of inspecting the potential of the wide area leveling data for the long term prediction of the activity of Mt. Usu. To exclude the effect of the subsidence near Mt. Usu, the utilized data are limited to those which are obtained at distances more than 10km from the center of the volcano. The first leveling survey around Mt. Usu was made in 1905. As the second period from 1953 to 1968 and the fourth period from 1985 to 1992 of the leveling survey are quiescence, those data can be used for investigating the precursory deformation. The linear areal trend is assumed. After removing this regional trend in 1953-1968, the concentric contours of uplifts surrounding Mt. Usu appeared. This simple pattern indicates that the source can be assumed as an isotropic pressure source. As the result of the grid search, the source is located beneath the point, which is located at 1.5km south and 1.5km east from the center of Mt. Usu. The source depth is estimated at about 10km. The source location in 1983-1994 is estimated at the same position. The expansion rate of the source in 1983-1994 is several times larger than that in 1953-1968. This difference can be related with shortening the quiescence.

12-P-26

Deformation of Bromo Volcano Prior to 2004's Phreatic Eruption

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GPS deformation data of 2001 – 2004 period was used to know the geometric change of Bromo volcano at Tengger caldera before and after 2004 eruption. Prior to 8 Juni 2004 phreatic eruption of Bromo volcano, no increasing of seismicity clearly. Volcanic earthquakes was not increase in number. However several days before the eruption, volcanic tremor was recorded intensely with more than 1 cm amplitude. Base on horizontal displacement, strain analysis, and point source analysis inflation and deflation process were occurred in Tengger Caldera with the point source was located in depth of 1 kilometer beneath Bromo summit. Inflation was detected during 2001 – 2003 period and after June 2004 eruption deflation was occurred in Tengger caldera. Deflation was followed by volcanic earthquake swarm.
Keyword: Volcanic eruption, Deformation, GPS, Horisontal Displacement, Strain Analysis, Point Source

12-P-27

Hydrothermal System beneath Usu Volcano Inferred from Self-potential Survey

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We conducted self-potential (SP) surveys on Usu volcano since July to December 2006. The compiled SP map reveals positive anomalies around Ko-Usu lava dome and at the foot of the volcano, and a negative anomaly on the top of O-Usu lava dome. The SP profile on the summit caldera shows the same pattern of 1985's. However, the peak-to-peak amplitude of the SP value is different: the 1985's of that shows 1000 mV while the 2006's shows 1400 mV. Topographic effect is clearly shown along the southwestern foot of the volcano, in which coefficient is about -2.5 mV/m. The SP profile corrected of the topographic effect reveals a large and extensive positive anomaly over +600mV and several local positive anomalies over +1000 mV on the summit caldera. The corrected SP also reveals that a positive anomaly at the south part of Ko-Usu lava dome and a negative anomaly at the O-Usu lava dome do not exist. The revealed positive SP anomalies are likely to be affected by an extensive altered layer, located beneath the summit caldera. The largest positive anomaly is shown on the ridge of Usu-Shinzan cryptodome after topographic correction. This anomaly is not regarded to be formed by hydrothermal upwelling, because any indications of fumarolic and geothermal activities have not been observed on the ridge of the volcano. The SP anomaly may be affected by intruded material into the volcano. The SP amplitude in the northwestern part of Nishiyama is very small in spite of rugged topography. An extensive low resistivity layer (< 10 ohm-m) located in the shallow part in the northwestern of Nishiyama probably shields the SP variation.

12-P-28

Gravity Changes Observed during the 1990-1995 Eruption of Unzen Volcano, Japan

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We present gravity changes observed during the 1991-1995 eruption of Unzen volcano, Japan. Gravity data were obtained by the measurements repeated 17 times in the period from 1990 to 2002 at 32 gravity stations on Unzen volcano and in a wide surrounding area. Precise measurements by 3-8 spring gravimeters (L&R G-Meter and CG-3M) revealed gravity increases over 100 microgal at the summit area during the dome forming period 1991-1993. We decompose the gravity changes into those caused by topography changes (e.g. dome formation and deposition of pyroclastics), associated with ground deformations and caused by mass accumulation under the ground. The effects of topography changes are evaluated to be -30 microgal or more at the summit region and -15 microgal on the flank. The gravity changes associated with ground deformations are evaluated to be about +20 microgal at the summit area. We estimate the gravity changes caused by mass accumulation under the ground to be 50-60 microgal around the summit and we interpret these changes might be caused by a mass of about 10^9 kg accumulated at a very shallow part in the summit area. On the other hand, the pattern of short-term variations in gravity looks similar to that in ground water level. This suggests that a part of the mass can be ground water accumulated at the summit region associated with the volcanic activity, for example a water table deformed by magma intrusion.

12-P-29

Magnetic and Gravity Observations at Stromboli Volcano

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The 2002-03 eruptive activity of Stromboli highlighted a lack of the knowledge of the gravimetric and geomagnetic field changes produced by volcanic activity at this volocano and suggested testing some significant variations within the traditional geophysical monitoring, as regards both the tipology of intervention and geometry of the measurements device arrays. During 2003, taking advantage of the experiences gathered at Mt Etna, our Laboratories of Gravimetry and Geomagnetism designed and set up, a small permanent magnetic network, for a high resolution measurement of the total field, and a continuously running gravity station. At present the magnetic network is made up of 3 continuously recording stations equipped with Overhauser effect magnetic gradiometers (resolution 0.01 nT) which record the Earth's magnetic field every 5 s. The gravity station, instead, is equipped with the LaCoste and Romberg D-157 gravimeter, and acquire (1 datum/min sampling rate) gravity and other parameters (temperature, pressure, humidity, X and Y levels) which are used to reduce the gravity signal for instrumental effects in order to assess the volcano-related signal. The aim is to achieve substantial improvement of geophysical knowledge on the dynamics of the shallow plumbing system of Stromboli volcano by the study of the gravity variations coupled to possible phenomena of mass redistribution and magnetic transients associated with the modifications within the volcanic edifice of the stress field or of the thermodynamic state. Gravity and magnetic time series spanning five years recorded on the volcano are jointly analyzed. In particular, we investigated the possible correlations between potential field signals and seismic and volcanic activities.

12-P-30

A Review Of Magnetic Field Monitoring at Mt Etna (Italy)

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During the last two decades we have been intensively monitoring the magnetic field on Etna. The first observation goes back to the 1981 lateral eruption, when a large anomaly was considered to be the joint effect of piezomagnetism and thermal demagnetization engendered by an intrusive dike. A convincing case of thermomagnetic effect observation relates to the 1989 fissure eruption, when repeated measurements for two years revealed the slow buildup of a 130 nT anomaly. The nature and structure of the anomaly constrained the location and time of cooling of a shallow dike. Later, in 1995 a close array of five proton magnetometers recorded changes associated with the unrest of the NE crater. The center of the magnetic anomaly source, which was thought to be the region heated by high-temperature fluids, was estimated by the spatial distribution of the variation rate. The 2001 lateral eruption provided the first opportunity to verify the ability of present network equipped with Overhauser effect magnetometers. Significant variations ranging between 3 and 7 nT were detected during main volcanic events. These changes were mostly generated by stress redistribution due to magmatic intrusions at different depth and by the thermic demagnetization at a rather shallow depth. Remarkable changes were also observed at the onset of the 2002 flank eruption. Rapid variations of about 4-5 nT were associated with the seismic swarm recorded beneath the summit craters, and step-like variations of 9-10 nT were coincident with eruptive fissures opening up. The rate of growth of the anomalies leaded to the interpretation that the magmatic intrusion velocity was approximately 14 m/min. Finally, the 2006 lateral eruption was accompanied by a slow and continuous decrease in the

total intensity greater than 5 nT. Magnetic data indicate that changes are caused by thermomagnetic effects located in the southeastern flank.

12-P-31

Electromagnetic and Geochemical Monitoring of Taal Volcano, the Philippines: 2005 - 2007

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Taal volcano, the Philippines, is a very active volcano which had repeated phreato-magmatic eruptions in the central VOLCANO island in the Taal caldera lake. Since 1990's, however, the seismic crisis and anomalous humarole activity took place frequaently but they seased without eruption. We started electromagnetic (EM), geochemical and geothermal studies of this volcano under the cooperative project of PHIVOLCS and IUGG-EMSEV (Electromagnetic Study of Earthquakes and Volcanoes) group. Our observations are repeat TMF (total magnetic field) and SP (self potential) surveys and area survey of TMF, SP, soil CO_2 gas concentration, ground temperature and lake water temperature with satellite telemetry. We detected remarkable TMF and SP changes preceding and associated with the anomalous fumarole and geyser activities occurred in the Main Crater Lake in Feb.-Mar. 2005 and Nov.-Dec. 2006. These observations tell us that EM data can provide us with some short-term precursory information on the coming geothermal activity and even phreatic explosions. This is important because so many tourists visit the potentially dangerous geothermal areas in Taal volcano. In order to attain such purposes, we began the continuous measurements of SP and ground temperature on the northern flank of VOLCANO island.

12-P-32

Reexamination on the Geomagnetic Changes in Association with Lava Domes Extrusion of the Unzen Volcano in 1991

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Remarkable geomagnetic total force changes were observed associated with lava dome extrusions at the Unzen volcano in 1991. These geomagnetic changes were explained mainly by thermal demagnetization effects of rocks around a vent (Tanaka, 1995). We made a geomagnetic total force observation by installing continuous proton magnetometers on a south slope of Mt. Fugen in an early stage of the eruption in 1991. Rapid geomagnetic changes were observed associated with the extrusion of the first lava dome on May 20, 1991. Successively, similar geomagnetic changes were observed at the third, the fourth and the fifth extrusions of the lava domes. There is a possibility that a part of these rapid geomagnetic changes were caused by piezomagnetic effects due to stress changes of the volcano.

On the other hand, point pressure (the Mogi model) sources for the lava dome extrusions were estimated from a crustal deformation observation. We computed piezomagnetic fields generated by the pressure source models and re-examined the geomagnetic total force changes at the time of the lava dome extrusions by comparing with the piezomagnetic field models.

12-P-33

Hydrothermal System in Izu-Oshima Volcano as inferred from Self-potential Measurements

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Izu-Oshima is one of the most active volcanoes in Japan. In the past eruptions, various signals were observed as associating with magma ascend and descend. These phenomena suggested interactions between magma and groundwater, and a development of a hydro-thermal system. In order to enhance forecasting the eruptive activities and to understand mass and energy balances, it is important to clarify magma-hydrothermal system beneath the volcano. We conducted self-potential and AMT measurements in order to reveal groundwater flows beneath Izu-Oshima volcano. Self-potential survey was conducted around a caldera region to reveal groundwater flows in a dormant period. The difference of the potential within the caldera reaches up to 700 mV. In the southern part of the caldera, where a central cone Mt. Mihara rests, the self-potential is generally higher. Especially, local high potentials are detected at locations where geothermal anomalies such as high ground temperatures and fumalores are observed. This suggests a hydrothermal upwelling beneath Mt. Mihara. An apparent electrical resistivity model revealed by AMT measurement shows a conductive layer, which lies below sea level within the island, gets shallower beneath Mt. Mihara. Probably this also affects the high self-potential at Mt. Mihara. On the other hand, low electrical potential was observed in the northern part of the caldera. This low potential area coincides with a region where lava flows pile thicker than surroundings. This suggests differences of lithology affects behavior of groundwater flows. In the presentation, we discuss hydro-thermal system of Izu-Oshima volcano as inferred from the self-potential measurements.

12-P-34

Hydrogeochemical Monitoring of Popocatepetl and Citlaltepetl Volcanoes.

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Hydrogeochemistry has been used to monitor volcanic activity in Mexico for more than 20 years. Springs and shallow wells around Colima, Popocatepetl and Tacana volcanoes have shown anomalies preceding eruptions by weeks to months. More recently, Citlaltepetl and Ceboruco volcanoes have also been included in this monitoring program. Shortly after the onset of the current activity episode at Popocatepetl in 1994, a joint hydrogeochemical monitoring program of the National Disaster Prevention Center (CENAPRED) and the National Autonomous University of Mexico (UNAM) was started on water springs around the volcano. Most samples resulted dilute and immature cold waters. Chemical characteristics indicate water-rock interaction mainly with plagioclases, evaporites, ferromagnesian minerals and limestones. Volcanic activity has influenced CO_2, boron, chloride and sulfate concentrations through water interaction with volcanic gases, diffused or flowing through fractures. A slight increase of magnesium and silica was produced by water interaction with volcanic CO_2, and silicate minerals since 1995. The calculated percentage of residual acidity (PRA) defined by Varekamp (2000) showed the highest value, and boron was also detected for the first time in March 1996, at the time of the first dome emplacement. In the year 2000, along with the most intense eruptive activity, a PRA increase was also observed in three of the sampled springs. Citlaltepetl or Pico de Orizaba is the highest Mexican peak; snow and ice cover its uppermost parts. Although it has been quiescent since the 19th Century, it poses a hazard to nearly 750,000 people. Sampling campaigns have been carried out yearly since 2002, in low conductivity mixed bicarbonate, and high conductivity calcic bicarbonate springs, located at different heights. No geochemical anomalies have been observed in this period.

12-P-35

Diffuse CO_2 Emission At Izu-Oshima Volcano, Japan

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Izu-Oshima is a 15×9 km active volcanic island located around 100 km SSW of Tokyo. The centre of the island is occupied by a caldera complex with a diameter of 3 km. A large post-caldera cone know as Mt. Mihara is located at the southwestern quadrant of the caldera. Almost 30 parasitic cones and craters can be found at the island, located mainly along the three rift zones, being probably formed by the upward pressure of rising magma. Oshima has erupted 74 times, consisting mainly in fissure eruptions, both inside and outside of the caldera. The last eruption of Oshima occurred in 1986. In March 2007, a quantitative study of the diffuse CO_2 degassing at Izu-Oshima was carried out to quantify the diffuse CO_2 emission from the entire island and from the central crater and to identify the structures controlling the degassing process. The survey of diffuse CO_2 emission covered an area of 91 Km^2 and was carried out following the accumulation chamber method. Background mean value of CO_2 efflux for the measuring sites located inside the caldera was about 0.9 g m^{-2} d^{-1}, whereas the background mean value for the rest of the island was 7.3 g m^{-2} d^{-1}, suggesting a strong biogenic contribution at this area. The total amount of volcanic-hydrothermal CO_2 discharged through diffuse degassing was computed through a sequential Gaussian simulation (sGs) approach based on 240 measurements, being comparable to those released by other volcanic degassing areas of the world. The location of the CO_2 anomalies showed a close relationship with the structural characteristics of the volcano, with most of the gas discharged from the rim of the summit crater and the fissures of the 1986 eruption out of the caldera. These results suggest that crater morphology has strong control on CO_2 degassing.

12-P-36

Observed Changes on Diffuse Carbon Dioxide Emission Rate from Fogo Volcano, Cape Verde

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Monitoring diffuse CO_2 emission rate is becoming a potential geochemical tool for volcanic surveillance; therefore, one of the major goals of our recent gas geochemical research at Fogo volcano (2.829 m above sea level, Cape Verde) was to compare actual diffuse CO_2 emission rate values with the observed 1999 data (Zarát e et al., 1999). The 1999 survey showed that Fogo volcano (476 km^2) release to the atmosphere about 3.319 t d^{-1} of CO_2 in a diffuse form. A significative fraction of the total diffuse CO_2 was released through Fogo's summit crater (0,12 km^2), 919 ± 409 t d^{-1}, where high soil CO_2 flux values, ~ 130 kg m^{-2} d^{-1}, were observed. The 1995 fissural eruption study site (0,13 km^2) was an additional location to observe relative high diffuse CO_2 emission rates (2,3 ± 1,2 t d^{-1}) during the 1999 survey. A new diffuse CO_2 emission survey was performed at Fogo volcano from March 29 to April 3, 2007, and the observed value from Fogo's summit crater (55,6 ± 14,7 t d^{-1}) was much lower than the observed in 1999. This decreasing tendency was even stronger at the 1995 fissural eruption study site, where actual diffuse CO_2 emission rate is about 0,07 ± 0,01 t d-1. The observed changes on diffuse CO_2 emission rates at Fogo volcano seems to be clearly related to the eruptive cycle of Fogo volcano. The 1999 survey was just performed 4 years after the most recent eruption at Fogo volcano (April 1995), and this period of 4 years could be considered within the post-eruptive phase of Fogo volcano. Additional observations of diffuse H_2S emission were performed during the 2007 survey, and the total output of diffuse H_2S emission rate from the summit crater was 24 ± 11 Kg d^{-1}. Monitoring this geochemical parameter will be tremendously beneficial for Fogo volcanic surveillance program. References: *Zarát e et al., 1999, EOS.*

12-P-37

Diffuse Carbon Dioxide Emissions From Hengill Volcanic System, Iceland

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It is well documented that even during repose periods, volcanoes can release large amounts of CO_2 as diffuse emissions, and in the same order of magnitude than those from visible emanations. With the aim to identify the structures controlling the diffuse degassing process and to quantify the total diffuse CO_2 output emitted from Hengill volcanic system, Iceland, in August 2006 a study of diffuse CO_2 degassing was carried out at the entire volcanic edifice. The Hengill system consists of a central volcano, Mt. Hengill, which is transected by a 60 km long SW-NE striking rift zone. It is located in the Eastern part of the Reykjanes peninsula, at an unstable ridge-ridge-transform triple junction where Reykjanes Volcanic Zone, West Volcanic Zone and South Iceland Seismic Zone converge. The central volcano is marked by high volcanic production, occurrences of acid rocks and a high temperature geothermal field. Rifting events within the Hengill system are considered to be mainly associated with crustal dike propagation as dikes have only breached the surface in an eruption four times during the Holocene. Beyond it is one of Iceland 痴 largest high-temperature geothermal areas with two active geothermal power plants, Nesjavellir and Hellisheidi. The survey of diffuse CO_2 emission was carried out following the accumulation chamber method. The total diffuse CO_2 emission discharged was computed through a sequential Gaussian simulation approach based on 745 measurements, yielding 13,322 t d^{-1} with a standard deviation of 1,533 t d^{-1}. Spatial distribution of diffuse CO_2 anomalies showed a positive correlation with the areas of thermal activity, suggesting that part of the energy coming from the heat source beneath Hengill is used to heat up the local meteoric water penetrated through fissures. Operation of the power plants might affect to the degassing phenomena enhancing the release of gases to the surface environment.

12-P-38

Hydrogeochemical Monitoring for Volcanic Surveillance at Tenerife, Canary Islands

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On April 2004, an anomalous seismic activity was detected at Tenerife Island, Canary Islands, suggesting the initial stage of a period of volcanic unrest. Following this activity, a systematic program of water sampling and analysis was initiated by ITER (Instituto Tecnologico y de Energias Renovables). The purpose of this monitoring program was to evaluate temporal variations of physical-chemical parameters in the island groundwater system and its relationship to the seismicity and possible volcanic unrest. Physical and chemical characteristics of groundwaters have been investigated at a borehole located in Las Cañadas caldera and several galleries or groundwater drains that intercept the aquifer of this caldera or nearby aquifers along the volcanic ridges. From these galleries monitored, Hoya de la Leña gallerie show the most evidence physical-chemical groundwater variations related to the recent seismic-volcanic unrest. This gallerie shows a sharp increase in sulphate-chloride mass ratio in groundwater few days before the seismic activity unrest. Also a considerable increase in the partial pressure of CO_2 (pCO_2) in the groundwater system prior the recent period of volcanic unrest (2001-2004) has been detected comparing with the previous and later periods. Finally, an increase in water temperature at the 505m deep borehole in Las Cañadas has been observed since the end of 2001, and reaching a relative maximum on February, 2004. All these processes are likely to be related to an increase in the fluxes of deep volcanic gases and heat transfer from the volcanic-hydrothermal system, which could be produced by magma movement at deep.

12-P-39

Diffuse CO_2 Emission from Volcanic Lakes in Nicaragua, Central America

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Several volcanoees along the Central America volcanic arc contain caldera or crater lakes. The potential for violent mixing of water with magma presents a special hazard at these volcanoes which are commonly surrounding by a significant population. Diffuse CO_2 degassing rate is a useful geochemical tool for volcano monitoring not only at the air-soil interphase of volcanic systems but also at theair-water boundary in lake-filled calderas and crater lakes. The aim of this study is to evaluate diffuse CO_2 emission rate from the Nicaraguan volcanic lakes Apoyo, Jiloa and Tiscapa. Apoyo (78 m.a.s.l.) is located just 5 Km from Granada city and is the biggest lake-filled caldera in Nicaragua with 4 Km of diameter and 200 m of depth. Jiloa volcanic lake (47 m.a.s.l.) is located 18 Km distance from the capital, Managua, and has a 2 Km of diameter and 88,5 m of depth. Tiscapa volcanic lake (59 m.a.s.l.) is located inside the Managua city and has 0,5 Km of diameter and 40,6 m of depth. CO_2 efflux measurements at these volcanic lakes was performed by means of an accumulation chamber using a floating device. CO_2 efflux measurements from the lake-filled Apoyo caldera ranged from negligible values to 42 g m^{-2} d^{-1}. For Jiloa volcanic lake these values ranged from 6,2 to 395,3 g m^{-2} d^{-1}. The values for Tiscapa volcanic lake ranged from 0,9 to 58,7 g m^{-2} d^{-1}. The total output of diffuse CO_2 emission rate of these volcanic lakes were 539 $\pm$6 t d^{-1} from Apoyo, 734 $\pm$ 14 t d^{-1} from Jiloa, and 4 $\pm$ 0,2 t d^{-1} from Tiscapa. The Apoyo and Tiscapa volcanic lakes showed similar diffuse

CO_2 emission output per unit of area (42 and 59 t d^{-1} / Km^2) respectively, while Jiloa showed the biggest value, 196 t d^{-1}/ Km^2.

12-P-40

Temporal Variations of Diffuse CO_2 Emission from the Summit Crater of Teide Volcano, Tenerife, Canary Islands, Spain

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Teide (3,717 m a.s.l.) is a stratovolcano located in the central part of Tenerife (Canary Islands, Spain), where occurs the intersection of three major volcanic rift-zones. Low temperature fumaroles (81-85°C) occur in the summit cone, with chemical and isotopic compositions indicating a mixing of CO_2-rich deep-seated gas and atmospheric air. Diffuse CO_2 emission surveys at the Teide's summit cone are yearly performed since 1997, but in order to improve the geochemical monitoring for Teide's volcanic surveillance program diffuse CO_2 emission surveys are monthly performed at the summit crater since August 2005. Diffuse CO_2 emission measurements have been performed by means of a portable NDIR sensor according to the accumulation chamber method. Approximately 40 observations sites have been selected for the monthly surveys covering an area of 0.0078 km^2. Contour maps of diffuse CO_2 emission have been constructed by using Stochastic Gaussian Simulation (SGS) algorithms provided by GSLIB software (Deutsch and Journel 1998). Spatial distributions of diffuse CO_2 emission at the summit crater showed that the higher values of CO_2 efflux are located mainly at the NE and E inner flanks of the crater, close to the areas where fumarolic activity occurs. Estimations of the total diffuse CO_2 output from the summit crater ranged from 5.2 to 28.1 t•d^{-1} with an average of 17.1 t•d^{-1}. This value represent a small fraction, about 11%, of the total diffuse CO_2 emitted from the summit cone of Teide (0.5 km^2 and 150 t•d^{-1}). During this research period, relatively high total diffuse CO_2 emission had been observed to occur during September 2005 and 2006 suggesting a seasonal control on these emissions. No correlations have been observed with soil temperature gradient, wind speed and barometric pressure. A longer research period of the monthly diffuse CO_2 emission is needed to understand the observed temporal variations.

12-P-41

H_2O, CO_2, SO_2 and H_2S Emission from Sierra Negra Volcano, Galapagos

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Sierra Negra (1.124 m above sea level) is one of the most active volcanoes in Galapagos, and its most recent eruption occurred in 2005. Visible and diffuse gas emission studies were recently performed at the summit of Sierra Negra volcano with the aim to evaluate degassing rate values from this volcanic system. Ground-based SO_2 emission rate measurements were performed by using a miniDOAS in June 2007, and the observed average value was 11 ± 2,3 t•d^{-1}. Molar ratios of major volcanic gas components were also in-situ measured by a portable multisensor after following Shinohara's method (Shinohara, 2005). Multiplying the observed SO_2 emission rate times the observed $(gas)_i/SO_2$ mass ratios allowed us to estimate other volatiles emission rates. The results showed that H_2O, CO_2 and H_2S emission rates from Sierra Negra volcano are 2.685, 394, and 3 t•d^{-1}, respectively. A diffuse CO_2 emission survey was also performed in 2007. The observed soil CO_2 flux measurements ranged from neglible values to 22.368 g•m^{-2}•d^{-1}, and the mean value of the background population was 4,4 g•m^{-2}•d^{-1}. An anomalous or peak population (2.8% of the total data) was observed, and the peak mean value was 6.679 g•m^{-2}•d^{-1}. Most of the study area showed soil CO_2 flux background values, and the peak values are mainly concentrated at the Azufres area as well as at the site of the 2005 eruption. The total output of diffuse CO_2 emission from the summit of Sierra Negra volcano was 6.242 ± 652 t•d^{-1}. Therefore, diffuse CO_2 emission rate from Sierra Negra is one order of magnitude higher than the CO_2 emission from visible volcanic gas emanations, and the plume/diffuse CO_2 emission ratio is about 0,063. Monitoring these geochemical parameters will be tremendously beneficial to understand the degassing dynamics of Sierra Negra volcano. References: *Shinohara, 2005, JVGR*.

12-P-42

H_2O, CO_2, SO_2, H_2S and HCl Emission from Masaya Volcano, Nicaragua

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Masaya (635 m a.s.l.) is a large basaltic shield volcano located about 20 Km south of Managua, Nicaragua. It contains a large caldera (6 x 11.5 km) with 13 vents. Most activity at these vents has consisted of effusion of basaltic lava. Pyroclastic eruptions have constructed three main cones: Masaya, Nindiri, and Santiago. Masaya has displayed cycles of voluminous degassing, the most recent one which began in 1993, and is characterized by continuous degassing from the main crater, emitting large amounts of sulfur dioxide (SO_2). With the aim to investigate the composition of volcanic gas based on plume measurements, from December 6 to 10, 2006, a miniDOAS and a portable Multi-Sensor System (following Shinohara, 2005) were used to evaluate the SO_2

emission rates and the molar ratios of major volcanic gas components, respectively. Measurements were carried out at the rim of the summit crater. Observed average SO_2 estimates yielded 1,165 ± 255.7 t•d-1. Multiplying the observed SO_2 emission rate times the observed (gas)i/SO_2 mass ratios (H_2O/SO_2 = 16.76 ± 5.12; CO_2/SO_2 = 2.32 ± 0.98; H_2S/SO_2 = 0.046 ± 0.013; HCl/SO_2 = 0.29 ± 0.13) allowed us to estimate other volatiles emission rates. These ratios are similar to values reported for Masaya by Horrocks between 1998 and 1999, and Hayley J. Duffell on 2001. The results showed that H_2O, CO_2, H_2S and HCl emission rates from Masaya volcano are 19,521 ± 1,673; 2,698 ± 787; 28 ± 7.6 and 338 ± 82 t d-1, respectively, and in the same order of magnitude than gases emitted during continuous passive degassing of subduction related basaltic volcanoes such as Miyakejima and Villarica. The observed gas emission rates suggest that the volcanic gas from Masaya volcano is supplied as dissolved volatiles from a magma reservoir at low pressure located at shallow depth.

12-P-43

Sulfur Dioxide (SO_2) Emmission Rates from Mayon Volcano, Philippines During the 2006 Eruptions

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The Sulfur Dioxide (SO_2) emission rates from Mayon Volcano, Philippines were monitored during its 2006 activities. Since February 22, 2006, more than 80 measurements were conducted using a correlation spectrometer (COSPEC) mounted on a ground-based vehicle. Noticeable increase in SO_2 emission rate started on July 20, 2006 which coincided with the onset of lava flows at the southeast section of the volcano. Abrupt increase in SO_2 emission rate (12,500 tonnes per day) was observed on July 30, 2006, twenty-five times higher than the rate during Mayon's normal condition. The rate dropped to 1,900 t/d on August 5, 2006, two days prior to the series of ash explosions. Gradual decrease in SO_2 emission rate started on September 2, 2006, which was one of the bases in lowering of Alert status (Alert Level 4 to Alert Level 3) of Mayon Volcano on September 11, 2006. The decline in SO_2 emission rates persisted after that period. The SO_2 flux also coincided with the decline in other parameters like seismicity and ground deformation of the volcano. On October 3, 2006, the Alert Status of the volcano was lowered to Alert Level 2. The trend in SO_2 emission rates during Mayon's 2006 eruptions was helpful in the evaluation of the volcano's eruptive activity.

12-P-44

GIS : A Tool for Volcanic Gases' Survey : A Case Study at Vulcano Island, Southern Italy

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Temperature of the fumaroles is one parameter (with chemical composition of the gases) which could indicate a future eruption. In this purpose, the variations of the temperature have to be particularly studied. That is why we created: i) a web site collecting the temperatures' measurements of the fumaroles' vents of La Fossa crater, Vulcano (*http://ereiter.free.fr/Vulcano*) and ii) an add-on for Google Earth showing the location of the fumaroles' vents (*http://ereiter.free.fr/html/download.htm*). The purpose of the project is to create an internet resource which saves time to all researchers as it will publish available and future temperature measurements of fumaroles from La Fossa crater, Vulcano Island.

The base of the system consists of interactive digital maps and photos of the interested area. Each map is a layer of the system. Each layer represents data for a date of temperature measurements. The user can select in a menu one or more layers to be seen in the software. The background of all layers is the geological map of Vulcano Island or an aerial photo of La Fossa crater. Clicking on the location of a fumaroles' vent, a new web page appears, summarizing the temperature's evolution versus time appears, the gases' composition and photos of the fumaroles' vent.

During the same project, we develop an add-on for Google Earth allowing a nicer interface to locate the fumaroles' vents. Http links between the add-on and the web site exist to view the temperature's evolution of each fumarole.

This program can be adapted for all volcanoes and a lot of kind of data (isotopic compositions, deformation, epicenters' location, data from reduction capacity sensor or economic, population data around the volcano). It will run on and off-line. So you can have it on CD-Rom with your own data to study them.

An internet GIS can also be a source of information for the educated tourists and a base to train local guides.

12-P-45

Behaviour and Fate of Organic Gas Compounds in Volcanic Fluids: A New Geochemical Monitoring Tool For Volcanic Surveillance

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Thermodynamic modelling and multivariate statistical approach have recently been applied to investigate the complex relations between the evolution of volcanic activity and the compositional parameters of fluid discharges. These techniques have successfully allowed to use the main inorganic constituents of volcanic-hydrothermal fluids, such as CO_2, sulphur species, halogen acids, CO and H_2, as geoindicators. Differently, organic compounds, whose presence in volcanic exhalations mainly consist of methane and minor amounts of C_2-C_{15} species (i.e. alkanes, alkenes, aromatics and O-, S- and N- substituted hydrocarbons), have been only sporadically utilized for the geochemical monitoring of active volcanoes. However, the behaviour of these species in a volcanic environment is dictated by thermogenic processes, i.e. catalytic breakdown of decaying organic matter at medium-to-high temperature, and is strongly controlled by thermodynamic conditions acting in the fluid reservoirs. Accordingly, similar

hydrocarbon patterns have recurrently been observed in similar gas exhalations from active volcanic systems. In this work, the compositional data of the organic fraction composition of more than 500 fumarolic gases discharging from volcanoes mainly located in Italy and in Central and South America (e.g. Mexico, Costa Rica, Nicaragua, Chile, Argentina), have statistically and geochemically been investigated in order to evaluate the possible use of organic gas species as indicators of both temperature and redox conditions of the fluid source. Geothermometric applications based on the chemical reactions involving light alkenes/alkanes pairs have provided convincing results. Moreover, S- and O-substituted aromatics and heavy alkanes (>C_5) have resulted to be particularly sensitive to changes affecting the hydrothermal/magmatic systems feeding the gas discharges. These results suggest that organic geochemistry can likely be able to represent a useful source of information of the evolutionary trends in active volcanic systems, and, consequently, can play an important role for innovative studies aimed to the mitigation of the volcanic hazard.

12-P-46

Chemical Evolution of Fumarolic Fluids, Seismic Activity and Visual Changes at Turrialba Volcano (Costa Rica): Evidences For a Resuming of the Volcanic Activity?

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Turrialba volcano is a 3,349 m high stratovolcano (10°02N, 83°45W) whose last volcanic activity dates back 1864-1866 and that represents the southeast-most of Costa Rica's Holocene volcanic systems. The volcanic edifice is characterized by a broad summit depression consisting of three well-defined craters and that is breached to the northeast. Presently, the central and western summit craters are in a fumarolic stage. In the framework of a collaboration between the Volcanological and Seismological Observatory of Heredia (OVSICORI) and the Department of Earth Sciences of Florence (Italy), a geochemical, geophysical and visual monitoring of volcano has been carried out since 1998. Although the outlet temperatures of the fumarolic vents have maintained quite constant (up to 92 C), since September 2001 important compositional changes of the H_2O (CO_2)-dominated fluids have been detected. Basically, HCl, HF, CO and H_2 contents have progressively increased up to one order of magnitude and, in November 2001, SO_2 concentrations up to 70 mmol/mol were recorded. In the same period new fumarolic vents have appeared from newly formed fractures and a general increase in the gas discharge rate was observed. The disturbance of the Turrialba volcanic system has also been recorded in terms of seismic activity, likely related to hydrofracturaction phenomena. In 2007, newly formed fumaroles were recognized at the base of the volcanic edifice along the WSW-ENE-trending Ariete fault. In several areas of the southern flank heat destroyed vegetation. According to the chemical and geophysical modifications recorded, it is clear that the volcanic system is presently suffering pressurization in response to fluid vaporization induced by increased heat input. Standing this situation, two scenarios may be hypothesized: i) enhancing of the fracturing system may result in a release of the accumulated energy and ii) the overpressure may trigger small-to-medium size eruptions, similar to those occurred in 1864-1866.

12-P-47

H_2O, CO_2, SO_2, H_2S and HCl Emission from Fogo Volcano, Cape Verde

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Fogo (Cape Verde; 2.829 m above sea level) is one of the most active oceanic island volcanoes, and its most recent eruptive event - stromboliam type - occurred at the base of the volcano in 1995. Fumarole activity just occurred inside Fogo's summit crater, where relative high temperatures, up to 170°C, have been recently measured. Very few gas geochemical studies has been performed on this volcano (Zárate et al., 1999; Mota Gomes et al., 1999); therefore, new geochemical observations are needed to have a better knowledge of this volcanic system. Ground-based SO_2 emission rate measurements have been recently performed by using a miniDOAS from March 30 to April 2, 2007, and the observed average value was 6,4 ±1,6 $t \cdot d^{-1}$. Molar ratios of major volcanic gas components were also in-situ measured by a portable multisensor instrument. Multiplying the observed SO_2 emission rate times the observed (gas)i/SO_2 mass ratios allowed us to estimate other volatiles emission rates. The results showed that H_2O, CO_2, H_2S and HCl emission rates from Fogo volcano are 4.841 ±2.507, 4.914 ±2.736, 16 ±8, and 116 ±51 $t \cdot d^{-1}$, respectively. Monitoring these geochemical parameters will be tremendously beneficial for Fogo volcanic surveillance program since the levels of seismic activity can remain extremely low up to the onset of eruptions, virtually without felt events, according to the evidences from the last 100 years. In fact, the initial explosions of the 1951 and 1995 eruptions caught the population livng around the volcano by surprise (Fonseca et al., 2003).

12-P-48

Development of Volcanic SO_2 Imaging System with Small Machine-vision CCD Cameras

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Volcanic SO_2 flux is one of the most important observation parameters to monitor the volcanic activity. Relations between volcanic activity and temporal

variation of SO_2 flux have been reported at many volcanoes. Recently, a novel method using CCD camera sensitive to UV region was newly developed to visualize the distribution of SO_2 in volcanic plumes. There are several advantages in this SO_2 imaging method compared to traditional SO_2 flux monitoring methods using COSPEC or UV spectrometer systems. Since the SO_2 camera can visualize the distribution of SO_2 in the plume, we can obtain detailed behaviors of SO_2 plume with high time resolution SO_2 flux of second-scale by using time-series images. In this study, we developed a observation system using much compact and cheaper machine-vision CCD cameras. In the previous SO_2 visualizing method, two images with different UV wavelength were used to construct a SO_2 distribution image. However, this method could not give us correct images in the condition with clouds and aerosols. Thus, we developed a new method utilizing 3 wavelength images to minimize effect of clouds. In the presentation, we will introduce the new system together with recent observation results at some volcanos.

12-P-49

Over Two Decades of CO_2 and Conductivity Profiles Change at Lakes Monoun and Nyos (Cameroon)

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Passive CO_2-degassing appears to be an ubiquitous feature of Cameroon Volcanic Line (CVL) which hosts several crater lakes. Among them Lakes Nyos and Monoun are infamously known as “Killer lakes” over past two decades. Outburst of magmatic-CO_2 that accumulated in their bottom waters killed close to 1800 people and made thousands of refugees in mid-1980s. High CO_2-buildup rate observed after the gas-outbursts alarmed that the lakes were steadily returning to pre-eruption status. This situation urged scientists to warn the recurrence of another catastrophe and they strongly recommended artificial degassing of the lakes. Geochemical monitoring of the lakes over 20 years indicates that greatest changes in temperature, electric conductivity and CO_2 concentration occurred in the first 10 years at Lake Monoun and the first 2 years at Lake Nyos. Then the changes progressively slowed over time during the pre-degassing period. Under the Nyos and Monoun Degassing Project (NMDP), hazard-mitigation efforts started at Nyos and Monoun in 2001 and 2003 respectively using one degassing-pipe at each lake. In 2006, two more pipes were added at Lake Monoun. After degassing operations started, noticeable changes to water column were observed. January-2007 measurement indicates that the CO_2-content at Lake Monoun was reduced to nearly 40 % of the maximum level attained in 2003. At Lake Nyos the CO_2-content was reduced below the post 1986-events level. However the lake still contains 80 % of the CO_2 content observed soon before launching of degassing operation. Therefore, additional pipes are needed at Lake Nyos in order to alleviate potential for another hazardous gas-release given that displaced persons started to resettle on their ancestral lands. For Lake Monoun, time has come to consider the way to continuously vent out the natural CO_2 recharge and to remove the CO_2 remaining in the bottom-most layers (4-6m).

12-P-50

Measurement of SO_2 Emission Rate at Kuchinoerabujima Volcano

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The SO_2 emission rate is measured in active volcanoes around the world because the SO_2 emission rate becomes a important indicator of magmatic activity but measurements at volcanoes with few volcanic gas emission are difficult. Kuchinoerabujima volcano which located at southern Kyushu of Japan has repeated phreatic explosions at intervals of several decades. However, SO_2 emission rates have been not measured because it is difficult to measure at Kuchinoerabujima volcano and there are not many total amounts of volcanic gas emissions except for the period when the phreatic explosion had occurred. In the past several years, volcanic tremors, the dilatation in the shallow region, and an increase of the fumarolic activity are observed in Kuchinoerabujima volcano. These datas had suggested an increase of the volcanic activity. Moreover, SO_2 was contained in the volcanic gas sampled at the west and the south area of Shindake crater on February, 2005 and was contained at all areas on September, 2006. These facts suggest an increase of the magma activity. In recent years, the measurement instrument of SO_2 emission rates was miniaturized and the flexibility of an instrument has improved. A new measurement instrument (e.g. COMPUSS in Japan) enabled SO_2 emission rate measurement in Kuchinoerabujima volcano. In December 2006, we began to measure the SO_2 emission rate, and SO_2 emission rates recorded about 40 ton/day. After 1st measurement, we are measuring at intervals of about three months. We will present the result of SO_2 emission rates, which measured at Kuchinoerabujima volcano, and discuss about the measurement problem of the SO_2 emission rate which became known by these measurements.

12-P-51

Monitoring of the Spring Waters and Geochemistry of Ashes Leachates During the Eruptive Crisis (2006) of the Ubinas Volcano, Peru.

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Ubinas (16° 22 ' S; 70° 54 ' W, 5672 m.a.s.l.) is the most historically active volcano in southern Peru. Because of its high VEI and to the occurrence of a 6 km-distant 5000 inhabitants village, Ubinas is considered as the highest priority for volcano monitoring in southern Peru.We initiated in 1999 a geochemical monitoring program, with regular sampling and chemical analysis of two 6 km-distant thermal waters located along a N40-50W trending regional fault. Time-series show chemical changes of rising temperature, pH, SO_4^{2+}, Cl^-, HCO_3^- and SO_4/Cl ratios with 3 main trends: 1) a general decrease of the S/Cl ratio prior the magmatic unrest, 2) an increase of this ratio during the crisis indicating that new undegassed magma has been injected, and 3) some limited changes in Fria spring following the Mw=8.4, 2001, 23 June earthquake, probably resulting from permeability increase due to ground shaking of the N40-50W fault that temporarily enhanced fluid migration.Leaching of four ash samples allows to investigate S, halogens and trace metal composition of plume gases. We assume here that ash particles scavenge volatile elements from the plume and therefore may be used as a proxy for plume composition. HPLC and ICP-MS allowed to measure anions (SO_4^{2+}, Cl^- and F^-) and 53 metallic trace elements, respectively, and typical Cl/S and Cl/F ratios and enrichment factors (EF) were calculated. Results indicate considerable temporal changes of both the Cl/S and Cl/F ratios and the EF with time. The too low number of samples to not allow to track chemical changes of the plume in time and to deconvoluate potential processes (magmatic feeding, changing contribution of sedimentary sulfates, interaction in plume, meteorological factors). These results evidence that springwaters and ash leachates are usable for monitoring of degassing at Ubinas if high frequency sampling is performed.

12-P-52

Why Monitor Water Wells and Springs on Volcanoes?

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Groundwater level and spring discharge of a volcano can rise and/or drop when magma intrusions occur. Levels rise with compressional strain and drop with dilatation. The strain field is controlled by the size, depth, and shape of magma intrusions and, because of depth dependence, the local field can reverse as magma ascends. The magnitude of groundwater change is controlled by the strain change AND permeability of the aquifer. The greatest responses to compression are in wells that tap confined aquifers. Springs can still show some changes if compression is fast enough to pressurize an unconfined aquifer despite some pressure loss from outflow. The rate of water expulsion from a volcano can be greatly increased if there is high fracture permeability of either volcanic or tectonic origin.

In deep wells near Krafla (1977) and Usu (2000), water level rose as much as 100 m as magma intruded nearby. Anecdotal cases of water level drop include Mayon (up to 5 m) and Vesuvius. These changes were largely or fully recovered as elevated pore pressures dissipated and/or the strain field reversed. Unusually strong spring outflows occurred at Montagne Pelee (1902) and Huila (2007), forming dangerous lahars. Strong outflow at Unzen (1792) preceded sector collapse. Sometimes, as at Pelee, Raoul Is. (1964), Tokachi (1962) and Pinatubo (1991), outflow is hot and acidic, though generally it is not. These and many other reported groundwater changes occur within hours-weeks, not years, and are thus mechanically rather than thermally induced.

Water well and spring monitoring is an inexpensive proxy for high precision volumetric strain monitoring where the latter is not yet possible, and it is a good way to engage residents in monitoring of their own volcano.

12-P-53

Monitoring of Sulfur Dioxide Flux from Asama Volcano, Japan

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Asama volcano is characterized as a continuous degassing volcano, which emits SO_2 varying 100-1000 t/d (as of 2003) since emission rate has started to be observed in 1972. Asama volcano has erupted in 1973 and 1983 before the latest activity started in September 2004. During the previous eruptive period, SO_2 emission rate has grown up to 1000 t/d, while the emission has been kept lower in the dormant period between the eruptive activities. The average rate of the SO_2 emission during the dormant period is 200 t/d. The flux measurements have been done using COMPact Ultraviolet Spectrometer System (COMPUSS) since 2003. The degassing activity started in 2004 is the highest in terms of SO_2 flux, which is rated up to 3000 t/d. Repeated monitoring showed that short-term fluctuation in SO_2 flux seems to occur relating to the eruptive activity changes. Long-term emission rate declined to 100-200 t/d indicating activity is classified as dormant as of 2007. If gas emission occur by magma convection in conduits, the flux change occurs either by changes in diameter of conduit, density difference between upwelling and subsiding magmas or magma supply rate from a deep magma chamber, according to the equation of magma convection. Change in conduit width in such a short period is unlikely, therefore change in gas content or supply rate of magmas might be the cause of flux fluctuation. Strong relation between seismic activity (B-type quake) and flux change being found during 2006-2007 may indicate changes in supply rate or intermittent supply of magma is the main cause of flux fluctuation.

12-P-54

Chemical Features of the Lake Water and Floating Sulfur from Yudamari Crater Lake, Aso Volcano,

Japan

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Naka-dake is the only active central cone in Aso volcano, Japan. The crater has been filled with light-green-colored hot water after 1993's strombolian eruption, called Yudamari. Although formations of crater lakes are not so unusual, Yudamari shows remarkable characters of high temperature (over 50 degrees C) and strong acidity (below pH 1) without accompanying magma ascent. Aso's case is outstanding among the most active volcanoes in the world. It is suggested that high flux of volcanic gas continuously input to the crater lake.

To understand the formation and the maintenance mechanism of the crater lake at Naka-dake and to watch the change of volcanic activity, we sampled the lake water on this March. This is the fifth time of sampling after an absence of 4 years since August 2003. The water showed strong acidity of pH 0.3; the value is slightly higher than that in 2003. Temperature of the lake water was directly measured by using a maximum thermometer. As a result, the temperature of 56 degrees C was obtained. This value is about ten degrees C higher than the value (45 degrees C) from a radiation thermometer. Geochemical analyses revealed that the concentrations of constituents become lower than those in 2003. In the summer of 2005, water was decreased greatly and a part of the crater bottom was appeared. That event may reset the system of the crater lake.

Two kinds of floating sulfur were sampled accidentally. In addition to fine sulfur powder, many spherical sulfur crystals were identified. This crystal contains a small amount of iron, indicating it crystallized from the molten sulfur under the water. This suggests that molten sulfur pool exists into the crater lake, like Poas volcano, Costa Rica.

12-P-55

Surveys of Volcanic Activity in the Waters around Japan by the Japan Coast Guard

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Activities of many volcanoes in the waters (submarine volcanoes and volcanic islands) surrounding the Japanese archipelago include explosive eruption, collapse of a volcanic edifice and tsunami, which cause serious damages to vessels in passage and residents living along the coasts nearby. To minimize disasters from such volcanic activities, the Japan Coast Guard has conducted surveys of volcanic activities around the South Islands (Izu Islands and others) and the Southwest Islands (Ryukyu Islands and others) and emergency inspection of on-going eruption on marine volcanoes. The latter is often risky such that, during an eruption at the Myojin Reef in 1952, a research vessel and the crew of 31 were sacrificed by phreatomagmatic explosion. Learning a lesson from this accident, the Japan Coast Guard has made efforts to ensure safety during survey, also considering development of unmanned survey boats.

Recently, we engage in topographic, seismic profiling, gravity and magnetic surveys together with dredging volcanic products using survey vessels, visual and thermal imaging of surface temperature using airplanes, and direct research on active submarine volcanoes using unmanned boats. Collected and analyzed data are regularly reported to the National Coordinating Committee for Prediction of Volcanic Eruption, and opened in the website;
http://www1.kaiho.mlit.go.jp/GIJUTSUKOKUSAI/kaiikiDB/list-2.htm.

12-P-56

Development of an Automatic Forecasting Tool for Volcanic Activity. An Application to Teide Volcano

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In order to attend the Tenerife's sismo-volcanic crisis automatic software has been developed for volcanic activity forecasting. This tool is based on the Method of Material Failure FFM of the seismic signals in real time. This methodology can solve the problem of the subjectivity in the establishment of the forecastings. The method application has show the forecasting possibility of some seismic events occurred in Tenerife.

In the first stage of unrest, the energy related to the volcanic activity is in the same magnitude order or inferior than the atrophic and meteorological seismic noise. Different techniques of temporal series analysis have been applied to improve the signal/noise relation and to detect any change in the activity of the volcano. Determinist methods are being applied for this proposal, like some based on the nonlinear dynamic systems theory, and others based on the stochastic modelization. The first applied results to Tenerife show that tecto-volcanic events can cause significant transitions in the system dynamics. This, and having into account that the information contained in the tremor can be used for date occurrence events forecasting, indicates a bidirectional relation between tecto-volcanic tremor and events. In Tenerife, it is possible to see that the seismic signal variogram indicates that the system disposal a mid term memory of approximately 3 days.

The analysis of the seismic signals of Teide and other active volcanoes has shown that the minimum spectral value of the volcano is a good activity indicator. This analysis has been implemented in a continuous way for Teide (http://www.am.ub.es/~teide). This seismic signal spectral analysis has detected an increase of the minimum spectral amplitude and a variation of the predominant frequencies, previous to the occurrence of a seismic event in the volcanic zone, with an advance of days.

12-P-57

Monitoring and Surveillance of Current Ubinas Volcano Eruption

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The most active volcano of Peru, Ubinas volcano (16.355ºS, 70.903ºW, 5672m) started to erupt at the end of March 2006. The Geophysical Institute of Peru (IGP) is carrying out the monitoring of the seismic activity associated to the eruption by using a network of 4 short period stations, the data are telemetered to Cayma Volcanological Observatory (Arequipa), and 2 digital broadband portable seismic stations. We present in this work the main characteristics of the temporal evolution of the seismicity during this eruptive process. Phenomenological observations were used to support our interpretations. Five stages can be distinguished: (1)Setting up of the intrusive system (March 25th-June 24th): After a period of phreatic explosive activity which probably cleaned and/or opened conduits, the magma reached the surface. The activity was characterized by few tremors, but the number of events and their amplitude increased with time. Strong explosions occurred during this period, they were preceded by LP events and followed by tremor (2)Open system behaviour, weak flow (June 24th-July 16th): The second identified period is characterised by weak tremor and numerous (until 3 by day) but low energetic explosions. These events were not preceded by LP events. (3)Increase of eruptive flow (July 16th-October 28th): The number of tremors and their energy increased strongly. The highest daily energy level was reached on August 18th and 20th. After that date, the energy gradually decayed. Explosions were newly preceded by LP events. (4)Magma volume depletion (October 28th-March 29th 2007): During these period which lasted four months, the daily energy decreased significantly, tremor and explosive activity decreased gradually until reaching an almost rest state.(5)New eruptive flow (March 29th to June 2007): Explosion activity started up again and harmonic tremor appeared for the first time. The LP events preceding the explosions, were analyzed and used for emitting explosion warnings.

12-P-58

Monitoring a Waxing and Waning Volcanic Activity: the July 14th and August 16th 2006 Eruptions of Tungurahua Volcano (Ecuador)

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Tungurahua volcano (5023 m asl), located in central Ecuador, is one of the most active volcanoes of the Northern Andes. During historical times, Tungurahua experienced important (VEI 3-4) pyroclastic flow-forming eruptions in 1640, 1773, 1886 and 1916-1918. Periods of low-to-moderate explosive activity -November-December 1999, August 2001, September 2002 and October -November 2003 punctuated the current ongoing eruptive period, initiated in mid 1999. These periods were characterized by strombolian fountaining, canon-like explosions and light regional ash fallout. Periods of quiescence have also been observed, being the most notable since February to December 2005. At the beginning of April 2006, IG scientists detected some DLP seismic events (5-15 km depth) that preceded a change in the degassing pattern of the volcano (beginning of May), which was followed by an important deformation in the upper part of the cone (end of May). Since the beginning of July, seismic activity ramped up dramatically and culminated with the 14th July (VEI 2) and 16th August 2006 (VEI 3) eruptions. For the first time since the beginning of this eruptive cycle, Tungurahua volcano produced explosive, pyroclastic flow-forming events, which swept the western half of the cone, as well as formed 16+ km height eruption columns. The estimated juvenile material deposited during the two eruptions were around 2 millions and 20-30 millions cubic meter respectively. This important volume of erupted magma is consistent with a high magma ascent rate during these eruptions. This parameter could be considered as the key factor controlling the transition from low (1999-2005) to high (May-August 2006) explosive activity, by allowing or avoiding, respectively, the onset of an efficient gas segregation mechanism. To explain, in turn, such a change in the magma ascent rate, data suggest the occurrence of a deep magmatic intrusion as the driving force of the 2006 Tungurahua eruptions.

12-P-59

A Seismic Activity Index Related to the Eruption Process at Tungurahua Volcano

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During volcanic unrest there is an always-rising demand from public officials and the media for more specific and accurate information about the present and future level of activity of an erupting volcano. The Geophysical Institute has developed a seismic activity index (SAI) for Tungurahua Volcano that quantifies the mean seismic energy released day by day and reflects its level of activity. Our working hypothesis states that any significant change of internal physical processes of the magmatic system will be noticeable in our seismic records; so will be the superficial consequences of those internal changes. Seismic signals detected at a reference station due to volcanic activity -long period, hybrid and volcano釦ectonic events, tremors, explosions, exhalations- have different physical interpretations and release energy at different orders of magnitude. The SAI takes into account those differences so that integration and comparison of the energy of all the events is done using normalized and weighted values. The central limit theorem, widely employed in statistics, is utilized to determine the significant variations of the daily mean seismic energy, which we suppose is related to changes inside the volcano. In using the SAI at Tungurahua, we have observed an acceptable correlation with the principal events of the 1999 – 2005 eruption period. The index daily values and its first and second order derivatives

showed significant changes few days before July 14, 2006 and August 16, 2006, dates of the two biggest eruptions since 1999, and peaked when pyroclastic flows where generated for the first time since 1999. For this reason we believe that the SAI may be used as a valuable tool for more precise public communication of the state of activity of Tungurahua volcano and has interesting perspectives for its usage in andesitic open system volcanoes elsewhere.

12-P-60

Activity Levels at Galeras Volcano and Its Implications

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Galeras volcano in the SW of Colombia is characterized by permanent periods of activity and the location of around 460.000 inhabitants, 8000 of them living in the most high risk area, at distances less than 6 km, where the volcano had produced pyroclastic flows among other phenomena. According with historical records (last 500 yeras), this volcano produces eruptions each seven to ten years (in average) and bigger eruptions roughly each 70 to 100 years. One of the concerns of INGEOMINAS is how to transmit the levels of volcanic activity to the authorities in order to make easier for them the related decisions. In agreement with the authorities of the Regional Committee of Disasters Prevention and Attention, weekly reports were adopted and extraordinary communicates in cases of relevant changes in the volcanic behavior, explaining technical parameters of the activity ending with a paragraph about a possible(s) scenario(s). This form of communication produces interpretations from the authorities, deviating them from their focus. Due to this INGEOMINAS proposed at the end of 2004 a volcanic scale with 4 levels which was accepted on March, 2005. For the last two year of Galeras activity INGEOMINAS has emitted at least 7 extraordinary reports, some of them just to explain the eruptive phenomena, two were produced hours to months before explosive eruptions, two were emitted for the occurrence of seismic swarms and two for changes in the activity which did not end with explosive eruptions. For Galeras case, the management of activity levels represents a hard task due to short term changes in the activity, variation in the precursor signals and the difficulty to define the right moment to increase or decrease the level according with the activity development. Local authorities have decided that evacuation order will be given at Level II and the community can return to their places at level III.

12-P-61

Eruptive Activity at Galeras Volcano from June, 2004 up to June, 2007

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Galeras, located SW of Colombia, is considered one of the most active volcanoes in this country. The most recent period of activity was detected at the end of June, 2004 which remains in evolution. In this time interval, it has been presented different episodes like conduit cleaning revealed by a period of ash emissions from July to August, with a deposited volume of around $4{,}8 \times 10^5$ m^3 and three Vulcanian eruptions on August 11, 12 and November 21, 2004 which produced shock waves, gas and ash emissions, eruptive columns (9 to 11 Km height) and ballistic rocks (founding blocks of 40 to 60 cm in diameter up to 2 Km from the vent). This process has been associated with changes in seismicity, deformation, temperature variations, etc. Other important process was from August 19 to 22, 2005 with the record of a swarm of around 40 Volcano-Tectonic events, epicentrally located between 3 and 4 Km NW from the active cone and depths between 6 and 8 Km; 9 of them had local magnitudes from 3 to 4.7 (felt in the region) in addition, deformation process were observed. A swarm of around 700 Long Period events was recorded in 5 hours on February 12, 2007 and another significant activity of Volcano-Tectonic events on February 26, 2007 with around 50 events, one of them with 4.8 in local magnitude. This activity was related with the extrusion and emplacement of an andesitic lava dome observed in the crater on January 13, 2006, with a total volume of 3×10^6 m^3. Afterwords an explosive eruptive episode took place on July 12, 2006 affecting a minor part of the dome. Since November, 2006 up to March, 2007 the volcano registered Tornillos which showed a special patterns in its characteristics similar to those observed before some of the Galeras explosive eruptions.

12-P-62

Improving the Time-Window for Forecasting Volcanic Eruptions; Case Study for Rabaul Caldera, Papua New Guinea.

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Two post-caldera volcanoes, Tavurvur and Vulcan, in Rabaul, Papua New Guinea erupted simultaneously on 19 September 1994. The eruptions occurred approximately nine years after the 1983-1985 Rabaul seismo-deformational crisis. The crisis period was marked by numerous instense seismic swarms and about 1.5 m of vertical uplift at the central part of the submerged caldera. An eruption was seen to be eminent then, however it did not occur. After the main phase of the eruption ended in April 1995, Tavurvur resumed eruptions again in November 1995. Sporadic eruptions have since continued until present time. During this period some interesting observations have emerged between a certain group of earthquakes and the eruptive activity. We have abbreviated these earthquakes as NE earthquakes due to their spacial direction from Rabaul Caldera. In summary, the occurrence of the NE earthquakes have always preceded higher levels of eruptive activity or renewed eruptions from Tavurvur. We speculate these correlations

have magmatic and/or stress implications. Based on these observations, we are inclined to conclude that the 1992 NE earthquakes (the only occurrences before the eruption) are part of this mechanism and therefore could be considered as the actual pace-setter or precursor for the 1994 eruptions. Therefore it is quite appropriate to conclude that future eruptions at Rabaul Caldera may be forecasted with a confidence level of >50% using the NE earthquakes as the prime precursor.

12-P-63

Automatic Detection System for Anomalous Volcanic Crustal Deformation Using Real Time Observation Data

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For prediction of volcanic eruption, we need to estimate a state of underground magma beneath the volcano by using observation data. However, the quantitative estimations are usually not in time for eruptions of a volcano where time to eruption is relatively short since the sign of eruption appears. We developed a system that automatically detects anomalous crustal deformation and estimates an appropriate source model for the real-time observation data of NIED. NIED has conducted continuous observations of volcanic activities at 5 volcanoes in real-time (Mt. Fuji, Izu-Oshima, Miyakejima, East-Izu, and Mt. Nasu). The automated system can provide practical information for short-term prediction of volcanic eruption. For the detection of anomalous crustal deformation, we use 1-hour sampled borehole tiltmeter data with high accuracy and high temporal resolution. For the estimation of deformation source model, we use the tiltmeter, GPS and hypocenter data. We tested a performance of the system by using a test data set that is based on a volcanic process of the 1707 eruption of Mt. Fuji estimated by the Mt. Fuji Working Group of CCPVE (Report of CCPVE, 2003). In the estimated process, a dike ascended from a magma chamber 15 km deep beneath the summit about 2 months before the eruption on Dec. 16, and then the chamber contracted during the eruption of about 0.7km^3 for a half-month. The result shows that the system has a capability to detect automatically a small tilt change before an eruption and estimate a location and amount of intruded magma in real-time for eruption sizes such as the test case.

12-P-64

Volcano Alert Systems: Is There A Generic Global One ?

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Globally over 60 volcano observatories exist to monitor and assess volcanic activity. Individual volcano observatories can be responsible for anywhere from one to over 40 volcanoes. They are typically set up to provide advice and warnings to National, Regional or Local governments, emergency responding agencies, industry and the public. This advice is usually communicated by 'volcano alert levels' and 'volcano status bulletins'.

A wide variety of needs have to be catered for in these systems. Globally there is acceptance of the concept of volcano alert levels and systems. The question is can we produce a generic or global system? In some locations volcanic activity is almost a daily occurrence, while others have not experienced an eruption for decades to centuries. Hence the expectations and needs are quiet different. Two basic styles of volcano alert/warning systems have developed which relate to the status of a volcano, that is: is it frequently in eruption or is it reawakening?

Systems dealing with frequently active volcanoes have steps in them that are typically linked to the 'current' status of the volcanic activity, especially ongoing eruptive activity. They may carry an element of prediction, forecasting or warning and some indication of the degree of risk that the public are placed in while undertaking normal (non-restricted) activity on or about the volcano. In contrast, systems based on expected activity (reawakening) are based on the next expected level of unrest, some include time-windows to the next level or the commencement of eruptive activity.

The structure and responses to the alert systems vary between volcanoes and countries, resulting in a lack of international uniformity in our alert-warning systems. Does this undermine the important function they achieve and could we have a global system?

12-P-65

Active Volcano Monitoring and Research in China

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There was no much work done dealing with active volcanoes before 1990's in China because no many scientists believed that there are any volcanoes with eruption potential which could bring up large hazard in that period. In 1993, with administrative and financial support from the central government, Active Volcano Research Center of China Earthquake Administration (AVRCCEA) was established, which marked beginning of comprehensive studies of potential active volcanoes of China. Since then, a great deal of progress has been made in terms of both volcano monitoring and research in China. With the efforts from the scientists in the field of volcanic geology, geophysics and geochemistry for over 23 years, we found that there are at least six volcanoes with eruption potential in China. These active volcanoes include Tianchi volcano, Longgang volcano, Wudalianchi volcano, Jingbohu volcano, Tengchong volcano, and Qiongbei volcano. In order to deduce the potential threat of volcanic hazard, six volcano observatories were established in recent ten year. The major monitoring methods that have been applied so far are seismology, ground deformation and gas geochemistry. We have accumulated about 6-year continuous observation data. In 2007, the National Volcano Data Center (NVDC) was established. As the headcounter of the active volcano monitoring and research of China, the major tasks of NVDC are: data management and analyzing for all six volcano observatories; annual situation report on volcano activity to the administration; and volcano knowledge education and outreach to the public.

12-P-66

The Transition of Magma Supply System Between 100 and 29 ka at Aira Caldera in Southern Kyushu

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Aira pyroclastic eruption, one of the largest caldera-forming event in Japan, produced more than 300km^3 of tephra at 29 ka. This eruption is unique because the volcano had been active prior to this event (100-30 ka), and produced tephra which recorded the transition of magma supply system. We made XRF analyses for the volcanic products from 9 units representing pre- and syn-caldera-forming stages.

Our result showed the existence of four magma types, i.e. A, B, C and D. Two types of magmas (Type A; 67-70 wt. % SiO_2 and Type B; 56 wt. % SiO_2) had been active for the period of 100-60 ka. Magmas representing a wide compositional variation occurred at 60 ka (Type C; 58-71 wt. % SiO_2 and D; 73-78 wt. % SiO_2). This corresponds to Iwato tephra formation. It contains scoria, banded pumice and white pumice, whose compositions make a straight line in Harker diagrams, suggesting a magma mixing event. However, after 60 ka, only felsic end member (Type D) has been active until the Aira pyroclastic eruption. This implies that magma composition similar to that of Aira pyroclastic materials appeared as early as 60 ka, and existed in magma reservoir until 29 ka. Earlier studies of Sr-Nd isotopic analyses suggest a magma supply model that the dacitic and basaltic magmas mixed beneath the Aira caldera between 1 and 0.5 Ma before the long dormant period. Two types of magma activities between 100 and 60 ka is consistent with this model. A period prior to Aira pyroclastic eruption marks a transition from independent two magma supply systems to a homogeneous silisic magma system for Aira pyroclastic eruption at 29 ka.

12-P-67

APOLLO: an Automatic Procedure to Forecast Transport and Deposition of Tephra

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Volcanic ash fallout represents a serious threat to communities around active volcanoes. Reliable short term predictions constitute a valuable support for to mitigate the effects of tephra fallout on the surrounding area during an episode of crisis. We present a platform-independent automatic procedure aimed to periodic (daily) forecast volcanic ash dispersal. The procedure builds on a series of programs and interfaces that allow an automatic data/results flow. Firstly the procedure downloads mesoscale meteorological forecasts for the region and period of interest, filters and converts data from its native format (typically GRIB format files), and sets up the CALMET diagnostic meteorological model to obtain hourly wind field and micro-meteorological variables on a local finer mesh. Secondly a 1-D version of the buoyant plume equations assesses the distribution of mass along the eruptive column depending on the obtained wind field and on the conditions at the vent (granulometry, mass flow rate, etc.). All these data are used as input for the ash dispersion model(s). Any model able to face physical complexity and coupling processes with adequate solving times can be plugged into the system by means of an interface. Currently, the procedure contains two the semi-analytical models HAZMAP and TEPHRA able to simulate tephra deposits, and the 3-D model FALL3D, in both serial and parallel versions, able to simulate both tephra deposits and airborne ash concentration. The last step is to post-processes the model(s) outcomes to end up with homogeneous maps written on portable format files. Maps plot relevant quantities such as predicted ground loads, expected deposit thicknesses or visual and flight safety concentration thresholds. Several examples of an application to recent volcanic eruptions such as Etna 2001, Vesuvius 1944 and Mt Spurr 1992 are presented.

12-P-68

The Research Method of Volcanic Eruption Using High-resolution Satellite Images and Digital Orthophoto

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High-resolution satellite imageries and digital orthophotos generated from aerial photographs are very useful in understanding the outline of the eruption phenomena safely and quickly. Asama volcano, central Japan, erupted on September 1, 2004, and volcanic bombs, lapilli, and volcanic ash were ejected. We investigated the distribution of the volcanic bombs by using IKONOS satellite imagery. IKONOS imagery with one-meter ground resolution enabled us to identify the distribution of the impact craters greater than three meters in diameter. Many impact craters are distributed northwestward from the central crater, according to the distribution density chart of the impact craters. Shape of the central crater was analyzed by using DEM created from airborne laser scanner data, and the result shows that there is no barrier in the crater area to prevent volcanic bombs to be projected at an angle of 63 degree that gives the maximum attainment distance. The overview of the eruption can be understood based on the distribution pattern of the impact craters larger than three meters in diameter, which can be interpreted from IKONOS imagery. Meakandake volcano, north Japan, erupted on March 21, 2006, from the summit crater and newly opened fumaloles on the slope. Mudflow descended on the northwestern slope of the crater and stopped in the vicinity of the forest limit. Because accurate positions of new fumaloes were not able to be specified in the early stage of eruption, we generated the digital orthophoto from vertical aerial photographs taken on March 22. Digital orthophoto imagery was useful in determining not only the locality of new fumaroles but also the distribution of mudflow and ashfall. In the future, taking pictures by Digital Matrix Camera (DMC) will be expected to advance,

and quickly created digital orthophotos will be useful for the appreciation of the situation when a volcano erupts.

12-P-69

CNMI Emergency Management Office Volcano Monitoring System and Anatahan Volcano Eruption

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Volcanic Hazards of the Northern Mariana Islands. Camacho, J (jtcamacho@cnmiemo.gov.mp); Emergency Management Office of the Commonwealth of Northern Mariana Islands, P.O. Box 10007, Saipan, MP 96950, U.S.A.The primary goal of the Emergency Management Office of the Commonwealth of Northern Mariana Islands is to provide scientific information that can be used to reduce risks due to volcanic activity. On the basis of seismic telemetry and infrastructure/data, we have begun to build the capabilities of the CNMI to respond to volcanic crises in the northern islands.Within the Commonwealth of the Northern Mariana Islands (CNMI), nine active volcanoes pose a significant hazard to air traffic and to planned settlement and economic development of many of the islands. A volcano monitoring system is required to provide early warning of future eruptions, and is required for each of the islands slated for resettlement and economic development. The Commonwealth of the Northern Mariana Islands Emergency Management Office (EMO) and the U.S. Geological Survey (USGS) are working together to assess the volcanic hazards. In addition, we plan to install and operate a volcano-monitoring network across the active volcanoes in the CNMI.Why is it important to monitor these volcanoes? Ash produced by Mariana volcanoes poses a significant hazard to airborne travelers. Airborne volcanic ash is known to cause total loss of power in all four engines of a jet aircraft. The volcanoes within the CNMI pose a significant hazard to air traffic and, thus, to the economy of CNMI. Within the immediate airspace surrounding the CNMI, there are approximately 25,000 large commercial passenger flights per year and more than 1,000,000 flights of large commercial aircraft that transit from Asia to Australia and New Zealand. On average, more than 1,200 passengers and 86,000 pounds of cargo fly in and out of Saipan each day.

12-P-70

The 2006 Merapi Eruption Observed by Earth Observing Satellites

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Merapi volcano, which is located in Central Java, Indonesia, was active in 2006. Lava dome, thermal anomaly, volcanic plume and pyroclastic flow were observed by Earth observing satellites. IKONOS and ALOS PRISM images, which are high special resolution images, showed detail structure of the active lava dome. The extension of new lava dome was 200 m by 150m from the IKONOS observation on May 11, 2006. ASTER thermal IR images showed thermal anomalies related to the active lava dome and fresh pyroclastic flow traces. The maximum temperatures of the lava dome observed by ASTER were less than 20 °C from October 2002 to March 2006, in which the volcanic activities were relatively low. The lava dome temperature was sharply increased up to 29 °C on May 5, 2006, ten days before the pyroclastic flow activity on May 14. Maximum temperature of 94 °C was observed on June 6, in which the Alert Level was 4. Pyroclastic flow traces were clearly seen in the ASTER thermal image on and after May 14. Satellite remote sensing is a powerful tool for monitoring active volcano especially for ones in remote area.

12-P-71

Recent Volcanic Activity of Cerro Machin Volcno, Colombia. 1988-2007, and Implications of Volcanic Hazard Assessment

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Cerro Machin Volcano (CMV), is an active volcano located in the central part of Colombia. The hazard assessment map shows CMV to be a very dangerous volcano. It is an explosive volcano, with several ultraplinian eruptions during the last 10000 years. Pyroclastic flows and lahars are the most important threats. Lahar deposits from CMV cover a vast area. Flooding caused by CMV lahar dams on the Rio Magdalena cover a large portion of the central part of Colombia.

The activity of CMV is characterized by frequent earthquake swarms. During recent years the interval between the earthquake swarms has decreased to less than one month between swarms. The swarms follow a general pattern that starts with a tectonic earthquake of local magnitude greater than M3 located at a depth of 9 to 15Km beneath or around the CMV. After a lapse of no more than 15 days a volcanic earthquake swarm occurs at shallow depths (3-5Km) beneath the volcano. This behavior could be associated with the intrusion of material into a deep large magma chamber, later affecting the upper part of the volcano and implying an ascend rate of magma of less than 500 m/day up to a shallow small magma chamber, which is not yet totally filled. Temporal changes of seismic attenuation have been observed suggesting changes in thermodynamic conditions, perhaps an increase in gas content with time.

Temporal variations have been detected in temperature and in some cation levels in some of the hot springs during recent years. Radon gas measurements have also changed through time. In addition, ground deformation measurements have shown important changes during last years, up to 400 uradians of cumulative deformation near the main dome.

Based on these facts, we believe that CMV is currently in a pre-crisis period, gradually increasing in activity and danger.

12-P-72

Volcanic Hazard in Copahue Volcano, Andes of

Argentina and Chile.

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This contribution intends to put into consideration to the volcanological community Copahue volcano hazards in order to start a scanned monitoring program. Caviahue and Copahue villages have increasing population (over 100%) and tourists who ignore the volcanic hazard. This is the most vulnerable region (demographically mattered) in Argentina territory, in the case of a volcanic eruption. The hazards exposed are in increasing order: 1) Volcanic earthquakes. Earthquakes are monitored by European experts. 2) Volcanic gases. Continuous emission of SO_2 and HCl occur in Caviahue and Copahue villages. CO_2, CO, H_2O, HF and S, become highly concentrated in periods of low winds. Fog (or VOG, volcanic fog) covers the caldera. This also affects severely every metallic machine, engines and turbines, in Caviahue lake pH is too low to allow fish life. 3) Lava flows. This phenomenon is not hazardous at present. 4) Lava domes. The last lava dome was dated in 0,9 Ma. High silica content of Copahue volcano rocks indicates probable develop of a new lava dome. Continuous control of slope and crater deformation should be considered. 5) Pyroclastic flows (nueè ardent). Ashes, gases and rock fragments (over 500 °C) generate pyroclastic flows. The collapse of a previous breccia flow and a sector of the crater wall built over unconsolidated volcanic blocks can shoot a pyroclastic flow descending the crater. 6) Ash clouds and pyroclastic fall. During the last eruption (2000) pyroclastic bombs and large fragments blowed up to 3 Km from the crater rim in the eastern slope, ashes and lapilli reached over 60 Km. Copahue volcano one of the Andean hazardous volcanoes, furthermore aircraft routes and flight frequency is increasing in the last years. Permanent information and a network program is one of The Volcanic Advisory Ash Center (VAAC) in Buenos Aires hardest tasks. 7) Mud and debris flows (lahars). Glacier melting, snow and heavy rains in concordance with geysers and hot springs summed to occasional crater explosions, have periodically provoke lahars. Data from years 2000, 1992-1993, 250 BC and 6820 BC, eruptions reported lahars. In July 1st 2000 , a lahar that reached the Dulce valley have had a speed between 50 and 20 Km/h, a flow of 60.000 m^3/sec., forming a delta fan under the Caviahue (El Agrio) lake. 8) Debris avalanches. Unstable slopes (more than 30°) are common in El Agrio caldera. In the northern caldera rim, debris avalanches expose a hummocky morphology.

12-P-73

Developing the Monitoring Strategy at Volcan de Colima, Mexico: integrating thermal and infrasound data

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Activity at Volcán de Colima has recently increased and since 2001, the volcano has been in almost constant eruption with daily explosive activity and three significant effusive periods occurring since 1998. It is clear that small variations in certain factors, such as the magma ascent rate, temperature or volatile-contents can promote a change in eruption style. During 2005, various rapid switches were observed, with at times simultaneous occurrence of explosions and dome growth at different vents within the crater. The sequence of explosions included the largest observed since the last Plinian event in 1913.

The monitoring strategy at a potentially dangerous volcano should be based on models of its internal processes. Volcán de Colima offers a great opportunity for study, given its frequent transitions between eruption style and its relative accessibility. It is critical to establish the critical parameters of a monitoring network and relevant threshold levels to efficiently manage a potential crisis. Traditional systems are being supplemented with thermal and infrasound monitoring, which are greatly increasing the data available to study the evolution of activity and facilitate hazard assessment.

Vulcanian explosions have been characterized by variable ash-content, column ascent velocity and gas emission, the larger events producing pyroclastic flows. Rapid sealing of the system has been often followed by brittle fracturing within the conduit. During subsequent pressurization, seismic swarms were detected as precursory signals to the following event. Monitoring of fumarole temperatures remotely using a thermal camera has been highly successful with increased temperatures observed during periods of magma ascent and large transients before some larger magnitude explosions. It is clear that seismicity alone does not reflect the magnitude of the explosions. Infrasound sensors installed close to the volcano are permitting an improved characterization and understanding of the partitioning of acoustic and seismic energy.

12-P-74

Investigation of Effect of Meteorological Factors to the Volcano Thermal Observation Data Using infrared Thermal Camera

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The Japan Meteorological Agency carries out thermal observation using infrared thermal camera. Thermal observation in volcano area is very important to evaluate volcano activity. Many kind of thermal abnormalities have been reported, such as rise of temperature or remarkable fumarolic activity in crater bottom for precursor of eruption. To evaluate volcano thermal activity, we need to measure temperature and thermal abnormal area much properly. However, infrared thermal camera measures thermal radiation value and converts it to temperature, therefore, the temperature of ground surface measured by infrared thermal camera is greatly affected by meteorological factors such as wind speed, air temperature and humidity.

Accordingly we need to understand quantitative effect of meteorological factors to the observation data.

We started "Investigation of effect of meteorological factors to the volcano thermal observation data using infrared thermal camera" in Izu-Oshima volcano. We report this summary in the poster.

12-P-75

Continuous Thermal Monitoring of Fumaroles at Active Volcanoes in Nicaragua and Ecuador

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Fumarole temperatures can indicate changes in a volcanic system preceding eruptive activity, since the fumaroles respond to changes in mass flow within the system. We aim to isolate volcanic effects on fumarole temperatures by continuously measuring these temperatures and comparing them to the behavior of the volcano. We installed Campbell Scientific dataloggers and chromo-alumel thermocouples near fumaroles on the flanks of Masaya, Telica and Cerro Negro volcanoes in Nicaragua and at Cotopaxi volcano in Ecuador. We compared these fumarole temperatures to atmospheric pressure and temperature, and to seismicity and rainfall where available, to better understand the effects of these variables on temperature and to determine when changes in fumarole temperature were directly due to volcanic activity.

Data from Masaya Volcano in Nicaragua suggest that ground temperatures sampled every five minutes in a fumarole can indicate changes in the volcanic system even before changes are observed within the crater. For example, elevated temperatures were recorded during a period of increased degassing in June 2006 and beginning three days prior to a lava extrusion in October 2006. The temperature signal had a distinct, repetitive structure during these episodes, with a sudden temperature spike followed by exponential decay and then a sudden drop to background level. We attribute this to a combination of the effects of rainfall and increased gas flow.

Atmospheric pressure did not have an effect at any of the monitored volcanoes beyond diurnal variations. A correlation between rainfall and spikes in temperature was frequently observed at Masaya volcano, attributed to cold water percolating down to hotter levels and flashing to steam. At Telica and Cotopaxi volcanoes we observed long period cycles in temperature, which may reflect the current low-level activity at these volcanoes. Temperature signals and atmospheric variables recorded at all four of these volcanoes allow us to better constrain the driving mechanisms for temperature changes at fumaroles, and move us closer to using fumarole temperatures as a monitoring tool.

12-P-76

Lava Dome Deformation at Unzen Volcano as Viewed from ALOS PALSAR Interferometry

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At the Unzen Volcano, after the small eruption from summit in September 1990, the lava dome was appeared and pyroclastic flows occurred frequently resulting from collapse of the dome since February 1995. The dimension of the lava dome (called Heisei-Shinzan) was 1000m X 500m and the thickness was 230m approximately. The extrusion of lava was almost terminated by the beginning of 1995 and contraction and sinking were observed after that. This study shows that ALOS PALSAR interferometry detected the deformation of the lava dome. ALOS (Daichi), launched in February 2006, has L-band SAR (PALSAR) and the sensor has many advantages to analyze the crustal deformation around volcano areas using InSAR. In this study, we use one pair of images captured at August 26 and October 11, 2006 (interval 46days), took from westward, and the perpendicular baseline was 620m. The SAR data were processed using the JAXA/SIGMA-SAR software [M.Shimada,1999]. The coherence of two images were very good and nice interferometry image was created. The turbulence caused by water vapor was observed, but it could be removed by subtraction the valuecalculated from terrain height. Interferometry image shows that the deformation of the lava dome was several centimeters in the direction that went away from the satellite. MRI observed the deformation of lava dome using GPS receivers with Fukuoka district Meteorological observatory and (former) Unzen weather station. The result of observations shows several tens centimeters per year. This result is consistentwith InSAR observation.

12-P-77

Realtime Monitoring of Active Volcanoes in East Asia Using Satellite Visible and Infrared Images

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We have been operating a real-time monitoring system for active volcanoes in East Asia since 2001. The new system developed recently uses visible and infrared images from the MODIS and MTSAT sensors onboarded the Terra/Aqua series of polar orbiting satellites and the MTSAT series geostationary satellites, respectively and are targeting 147 volcanoes. MODIS data being down-linked to Institute of Industrial Science, University of Tokyo and also downloaded from NASA are used in this system. Those of MTSAT are down-linked to Earthquake Research Institute, University of Tokyo. The results and analyses of the MODIS infrared observations, essentially thermal images and time-series radiance trends of each volcano targeted, are automatically uploaded on the WWW. As to MTSAT, both visible and infrared images are renewed every 60 minutes on the WWW immediately after reception, which is useful for early detecting volcanic

eruptions or change in activity style. In this way it is planned that volcanologists and other interested parties might use the MODIS and MTSAT data as a broad check on the surface thermal state of the volcanoes they are studying and may apply their own interpretations to any identified heating or cooling trend. In the 2004-2005 eruptions of Asama, we found increase of thermal activity preceding to the eruptions from the time-series variation of MODIS nightime infrared data. This kind of thermal precursors will be useful for perdition of volcanic eruption by satellites. We also found a close relationship between thermal anomaly and magma supply — a thermally active period, with or without eruptions, occurred a few weeks after a deep dyke intrusion event detected by crustal deformation measurements. The web site for the MODIS and MTSAT based system is accessible at the URL: http://vrsserv.eri.u-tokyo.ac.jp/REALVOLC/.

12-P-78

Volcanic Processes, and Possible Precursors of Eruptions at Etna and Stromboli Volcanoes Revealed by Thermal Surveys

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Thermal imaging has been introduced in volcanology to analyze a number of different volcanic processes. This system allows us to detect magma movements within the summit conduits of volcanoes, and to reveal volcanic activity within the craters even through the curtain of gases usually released by active volcanoes. Thermal mapping is essential during effusive eruptions, since it distinguishes lava flows of different age and concealed lava tubes' path, improving hazard evaluation. Recently, thermal imaging has also been applied to reveal failure planes and instability on the flanks of active volcanoes. Excellent results have been obtained in terms of volcanic prediction during the eruptions of Mt Etna and Stromboli occurred in 2002-2003. On Etna, thermal images monthly recorded on the summit of the volcano revealed the opening of fissure systems several months in advance. At Stromboli, helicopter-borne thermal surveys allowed us to recognize the opening of fractures one hour before the large failure that caused severe destruction on the island on 30 December 2002. The INGV - Sezione di Catania started in 2001 to monitor active volcanoes using a hand-held thermal camera. This instrument was used in field and from helicopter to detect any thermal anomaly recorded on the surface of active volcanoes, and has since been applied to a number of eruptions and eruptive processes. After the two major eruptions at Etna and Stromboli, fixed thermal cameras have been installed on Stromboli, Etna and Vulcano, allowing us to keep under control the eruptive activity, flank stability and ash emission. On Etna, we have monitored the 2002-03, 2004-05, July 2006 and August-December 2006 eruptions. On Stromboli, thermal surveys allowed us to follow the propagation of ephemeral vents and thus the path of hidden lava tubes, as well as the stages of inflation and deflation of the upper lava flow field.

12-P-79

Network Camera Monitoring of the Mayon 2006 Eruption and Insular Volcanoes in Southwest Japan

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Long-term automatic observation of Mayon volcano in the Philippines commenced in June 2003, utilising digital still and video cameras. Imagery was obtained at an observatory 11 km SSE of the summit crater. Visible and near-infrared (NIR) network cameras with a NAS facility were installed in February 2004, and connected with the internet in April 2004. From June to November 2005, a lava dome inside the summit crater grew and its glow after dark was often observed. In July 2006, a considerable amount of lava was emitted from the summit crater, and resulting lava flows descended to 450m elevation southeast of the volcano. Numerous night-time images of hot lava flows were subsequently obtained by both the NIR camera and the video camera using night-shot mode, until the end of August.

Long-time automatic observation of eruption clouds in remote islands in southwest Japan is also discussed. Interval recordings at Satsuma-Iojima volcano by digital still and video cameras started in July 1998. A network camera with a server computer was installed at a building in Nakanoshima island 25 km northeast of Suwanosejima volcano in August 2002, and was replaced by a NIR type in February 2004 so as to obtain clearer images in misty conditions. A web-camera system connected with the internet, was also installed in Satsuma-Iojima in February 2003 and changed to a NIR type in December 2003. The advantages of a NIR camera include the detection of faint aerosols, and identification of hot anomalies.

12-P-80

Seismoacoustic Tremor Recordings At The P'u' 'O'o Crater Complex, Kilauea Volcano, Hawaii

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Synchronizing seismic and acoustic recordings of volcanoes can help constrain eruption dynamics. The continuous effusion from the Pu‘u ‘O‘o crater complex, the active vent of Kilauea Volcano, Hawaii, produces nearly continuous tremor. To study this tremor, two infrasonic arrays were deployed, one at 2.5 km and one at 12.5 km from the Pu‘u ‘O‘o summit crater, with a broadband seismometer collocated at the closer array.

Infrasonic recordings of the tremor exhibit significant temporal changes. A sharp, complex spectral peak of ~0.6 Hz is present in the entire dataset, and tends to bifurcate and shift frequency over time. Although the

seismic wavefield at Kilauea is complex and path effects appear to play a significant role, this spectral peak is also weakly manifested in the seismic recordings. Array processing of the infrasonic data reveals an abundance of broadband signal as well. Most of the signal appears to originate from the main crater region. However, the 2.5 km array detected the presence of a skylight with growing hornitos ~400 m south of Pu'u 'O'o on the active lava tube system. Infrared data from the main vents and skylight are also used to help understand and verify the seismic and acoustic recordings.

Data from this experiment shows that significant infrasonic and seismic tremor is present at Kilauea. We hypothesize that changes in this seismoacoustic tremor signal may be indicative of changes in the ongoing eruptive activity.

12-P-81

Tuning Infrasound Arrays for Automated Remote Sensing of Hazardous Eruptions

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The Acoustic Surveillance for Hazardous Eruptions (ASHE) project aims to develop and evaluate the capability to use low frequency sound to provide robust, low-latency (5-20 minute) notifications of volcanic eruptions at regional distances. Infrasound monitoring complements both seismic observation and satellite remote sensing to improve continuous monitoring of wide regions of potential eruption hazard at modest cost. The ASHE stations use very sensitive microphone arrays and broadband sensors deployed sufficiently far from volcanic devastation zones to promote ease of maintenance, survivability, and observational continuity during destructive eruptive episodes. We describe current field deployments of several small, autonomous seismoacoustic stations in Washington State and Ecuador. The arrays in Washington have detected diverse eruption signals from Mount St. Helens, and the arrays in Ecuador have captured eruptions from Tungurahua and Sangay Volcanoes, as well as from Galeras Volcano in Colombia. We also present preliminary results from research infrasound array deployments at Kilauea Volcano, Hawaii, ~2.5 km and 12.5 km from the Pu'u 'O'o summit crater, with a broadband seismometer collocated at the closer array. The monitoring stations send continuous real time data to a central facility where automatic analysis techniques for eruption detection are being prototyped. For the ASHE stations automated notification products are sent on a test basis to a participating ICAO-designated Volcanic Ash Advisory Center for comparison and possible integration with their existing warning systems. Coupled with this operational mission, we have a parallel and complementary interdisciplinary project that seeks to study the conditions that trigger and sustain volcanic eruptions. This research project, sponsored by the National Science Foundation, integrates the seismoacoustic data collected at the aforementioned volcanoes with other data sources. This set of volcanoes covers basaltic, dacitic, and andesitic compositions and has already provided a unique sound library of eruptive activity ranging from Hawaiian to Vulcanian.

12-P-82

Volcanic Unrest at Ngauruhoe, New Zealand?

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Ngauruhoe is an andesite cone-volcano in New Zealand's North Island that last erupted in 1975. As part of the Tongariro Crossing it is one of New Zealand's most popular natural tourist destinations. In June 2006, volcanic earthquake activity increased prompting GNS Science to raise the Scientific Alert Level from 0 (no activity) to 1 (signs of unrest). In response to the increased seismicity, three portable seismographs were installed to supplement an existing permanent monitoring network and the existing program of volcanic gas and temperature monitoring was intensified.

Since the unrest began more than 5000 small volcanic earthquakes (magnitudes 0-1.4) have been recorded (average 13/day). These are typical of volcanic earthquakes, having emergent onsets, dominantly low-frequency waveforms, and an absence of obvious S-wave energy. It was only possible to locate the largest earthquakes with the addition of data from the portable seismographs as even these events are clearly recorded at only two permanent seismographs. The earthquakes do not appear to be located beneath the crater of Ngauruhoe, but at the edge of cone and about 1 km below the surface. The earthquake waveforms have remained very similar throughout the activity, indicating that the source is fixed in one location, it is repetitive and non-destructive. There appears to be an upper-limit to the size of the largest earthquakes indicating a scale limited process. The absence of S-wave energy and the repetitive, size-limited source is consistent with a source mechanism involving fluids (magma, gas, or water) rather than repeated slip on a fault. We will present initial results from finite-difference modelling of the volcanic earthquake source to test the validity of this model.

One year after the apparent unrest began the elevated seismicity continues, but fumarole compositions and temperatures remain unchanged, and there has been no eruptive activity. Do the earthquakes really represent volcanic unrest or are they perhaps some kind of non-volcanic perturbation in the shallow hydrothermal system?

12-P-83

Barrier and Water Control Simulation for Lava-flow

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We evaluated the quantitative effects of artificial barriers and water-cooling on lava flow using the lava simulation program LavaSIM. Lava flow is basically subject to the topography around the path, effusive rate, viscosity, and surrounding conditions such as water and the atmosphere. To prevent damage due to lava flow, we conducted experiments in controlling the flow direction, velocity and temperature. The simulation demonstrated that a barrier can successfully bend the direction of a lava flow and that a barrier is more effective when placed almost along the flow direction at a point where the topography is not very steep, while a barrier placed perpendicular to the flow direction can only stop the flux temporarily, ultimately allowing the solidified crust to accumulate and causing the following mass to go over the barrier. The water-cooling trial was also effective in controlling the direction and temperature.

12-P-84

Cryptodome Formation Process by Precise DEM Analysis - Mt. Usu (1977-82) and Mount St. Helens (1980)

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A new cryptodome "Usu-Shinzan" (maximum apparent height change: + 273 m by DEM) was born in 1977-82 at Mt. Usu, which is an active dacite volcano in Japan. The doming deformation was investigated by Digital Elevation Model (DEM). Precise DEM (mostly 1 m grid) were newly developed from large-scale topographic maps (1:2,500 and 1:5,000) for several periods. The analysis of differential DEM before and after the 1977-82 intrusive episodes revealed remarkable thrusting up of Usu-Shinzan block which was delineated by U-shaped fault. On the other hand, it also revealed significant local subsidence which was taken place at pre-existent old lava domes, Ko-Usu, Oo-Usu, and Ogariyama. Lava domes subsided in the graben significantly (-10 m to -70 m) accompanying with shallow seismic swarms. Similar doming deformation has been reported at Mount St. Helens in 1980 (Moore and Albee, 1981) and Bezymianny in 1956 (Gorshkov, 1959). For conducting comparative study between Mt. Usu in 1977-82 and Mount St. Helens in 1980, DEM was also created for Mount St. Helens. The remarkable bulging of northern flank, significant subsidence of the summit lava dome were extremely similar deformation characteristics between Mt. Usu in 1977-82 and Mount St. Helens on March-May in 1980. The common physical process of dacitic magma intrusion exists between them, that is a rapid dike intrusion (1-3×10^6 m^3/day) in the early doming stage and the lateral growth of cryptodome (totally 1-2×10^8 m^3). No sector collapse occurred at Mt. Usu in 1977-82 because the summit had been already truncated by the sector collapse several thousand years ago. However, the magmatic intrusion process was quite similar each other. Our results also imply subsurface structures such as the root of old lava dome play an important role in deformation pattern (including absolute subsidence) and the occurrence of shallow seismic swarms

12-P-85

Monitoring of Magma Re-accumulation Process After the 1990-1995 Eruption of Unzen Volcano

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Unzen Volcano started eruption in 1990 after 198 years dormancy and formed a lava-dome complex at the shoulder of summit. The amount of lava effusion in the eruption reached about 0.2 cubic kilometers. We had successfully detected precursory activity of earthquakes and tremor before the eruption. The intensive observations were carried out during the eruption, and various observations such as seismic, geodetic, geomagnetic, fumarole and groundwater observations have been still continued after the eruption in order to reveal the magma supplying system and to monitor the magma re-accumulation process.

The activity of volcano-tectonic earthquakes declined rapidly after the appearance of lava dome, and keeps low level until 2007. The seismicity of shallow volcanic earthquakes occurring beneath the summit is also low after the eruption. The observation of the magnetic total force shows that the gradual demagnetization had continued until 1999, but stopped in 2000. The temperature of fumarole at the lava dome, which was higher than 700°C in 1995, decreased monotonously and was about 200°C in May 2007. The geodetic measurements revealed that the pressure of shallow magma reservoirs also decreased after the eruption. These suggest that a sequence of the last eruption has been completed and the new magma has not been supplied at the shallow part of the volcanic edifice. However, the geodetic measurements show the possibility that the magma began to accumulate again at the deeper magma reservoirs. The preparation process for the next eruption has probably started beneath Unzen Volcano.

12-P-86

Development and a Maneuver of "Mobile Observatory for Volcanic Explosion (MOVE)"

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To understand the properties of dangerous volcanic explosion for hazard mitigation, it is important to observe the volcanic explosion from near field and collect fresh samples. For these purposes we have started to develop an unmanned new observational instrument, "Mobile Observatory of Volcanic Explosion (MOVE)", in 2002.

MOVE is remodeled from unmanned carriershovel MPX10 of Hitachi Construction Machinery. To operate from remote, the radio control system is enhanced, four cameras are added, and a heat insulation box containing electric instruments is installed on the base machine. MOVE is designed to send sound, visible and infrared images on real time to the operation site, record temperature and pressure of volcanic blast and/or surge into the multi channel data logger, in addition to installation and collection of observation instruments and volcanic samples, respectively.

After its completion, we ran MOVE at Mihara-yama volcano on Izu-Oshima island in June, 2006, to confirm its utility on real volcanic observation. On the most difficult and farthest (>2km from the operation site) one among the three routes, those were selected through the preliminary inspection, we simulated the operation to observe the former 1986 eruption. Although wireless communications were sometimes hindered by topographic shades between the operation site and MOVE, we succeeded in completing each missions, such as sample collection and visible image transmission, from remote on the way of round trip between the flank of the volcano and the crater rim, without any support from the test site.

Thus far the system for running MOVE is still weak because of its poor manpower. The next step is to organize the comprehensive system to keep MOVE in good working order, in addition to ensure the stable wireless connection between MOVE and the operation site.

12-P-87

Feedback of Results of Japan-Indonesia Collaboration on Indonesian Volcanoes toward Japanese Prediction of Volcanic Eruption

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Disaster Prevention Research Institute (DPRI) of Kyoto University and Directorate General of Geology and Mineral Resources (DGGMR) started collaboration study on "Eruption mechanisms of volcanoes and Tectonics in Java, Indonesia" in 1993 and the arrangement were succeeded to DPRI and Geological Agency (GA) in 2006. Under the collaboration, Sakurajima Volcano Research Center of DPRI and Volcanological Survey of Indonesia (VSI, currently Center for Volcanology and Geological Hazard Mitigation; CVGHM) of GA conducted collaboration study on Guntur, Merapi and Semeru volcanoes. Repetition of increase in seismicity and change of distributed pattern of hypocenters and focal mechanism of VT events at Guntur volcano, which has 160 years dormant period, could provide data for long-term prediction at volcanoes with long dormant period. Migration of pressure source to shallower part detected by tiltmeters at Merapi volcano in the activity in 1995 suggests process of ascent of magma. Observation at Semeru volcano, where small vulcanian eruptions occur with time intervals of 5 min. to 1 hour, reveals mechanism of volcanic eruption. Minor deflation is detected 4-5 s prior to occurrence of the eruption. The minor contraction is followed by expansion and lead to the eruption. Inflation stage is interpreted as accumulation of volcanic gas at the top of the conduit, because SO^2 gas emission rate decreased about 3 min. before the eruption. Contraction may be caused by leakage of the gas and induces sudden bubbling of over-pressurized magma at deeper part.

12-P-88

The Unusual Lava Lake Activity and Its Influence on the 2002 Eruption at Nyiragongo Volcano in Democratic Repblic of Congo (DRC)

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Nyiragongo volcano is located at about 10km north of Goma city in DRC. The nearby habitants (ca 500,000) have been always exposed to the high volcanic risk produced by rapid lava flow drained from the persistent lave lake in the summit. In 1994, we have constructed the Goma Volcano Observatory (GVO) of CRSN in case of the refugee crisis and since then have continued the monitorings of seismicity around the volcano and of long-term variations of lava lake activity by EDM, camera and eye-witness systematically. In this paper, based on these data sets, we aimed to interpret the mechanism of 2002 eruption, which was preceded by unusual precursory events such as abnormal high seismicity, rumbling, many antelope death by Mazuke (poisonous gases), small ash fall at Kibati ca 6 hour before the main eruption and was followed by the post-collapse of lava lake lid and occurrence of many felt shocks around Goma. These features were not observed at the preceding eruption in 1977, which was explained by the magma hydro-fracturing at the higher slope level. The distinct difference of lava lake conditions just before the eruptions in 2002 and in 1977 was simply whether the pit crater in the lava lake was closed off or opened, suggesting that this feature was a critical factor for gas escape from the conduit. We proposed the pressure-cooker model for the lava lake activity with thick lid in 2002 and that advective overpressure associated with bubble ascent in the molten lava lake is the key to understand the various features observed before and after the 2002 eruption. The long fissuring starting at the foot of Shahele cone was supposed to be initiated by a burst increase of overpressure in the lava lake triggered by small fissuring at the higher slope.

12-P-89

Global Warming and Climate Change: Challenges for

Bangladesh

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Global Warming and Climate Change: Challenges for Bangladesh: Greenhouse gas emissions are expected to lead to climatic changes in the 21st century and beyond. These changes will potentially have diverse effects on the natural environment as well as on human societies and economies. Scientists have made estimates of the potential direct impacts on various socio-economic sectors, but in reality the full consequences would be more complicated because impacts on one sector can also affect other sectors indirectly. Climate models calculate that the global mean surface temperature could rise by about 1 to 4.5 centigrade by 2100. It is also suggested that increase in climate variability or extremes has taken place in recent decades. To assess potential impacts, it is necessary to estimate the extent and magnitude of climate change, especially at the national and local levels. Although much progress has been made in understanding the climate system and climate change, projections of climate change and its impacts still contain many uncertainties, particularly at the regional and local levels. Bangladesh, a developing country, is under severe threats of global warming and climate changes and the projection and warning systems are very weak in terms of capacity and technology. However, this papers is an attempt to focus on the impacts of global warming and climate change to Bangladesh and how an early warning and projection system could be effective to mitigate challenges emanating from global warming and climate change. : Keywords: Global warming, climate change, early warning, projection and Bangladesh.: : Md. Mansorul Haque(Bangladesh): Note: I am working on “Global Warming and Climate Change: Challenges for Bangladesh” The named conference ‘Cities on Volcanoes 5’ would help me on my research.:

Session 1-3

13-O-01

Emergency Planning and Mitigation at Vesuvius, Italy: A Human Risk-based Approach

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Vesuvius is one of the most dangerous volcanoes in the world and an Italian National Emergency Plan exists which is based on the hazard presented by a maximum foreseeable event on the scale of the 1631 eruption, the largest of the last millennium. The EU EXPLORIS project advances emergency planning and mitigation using an event tree approach which incorporates expert judgement and the assignment of probabilities to define a range of different eruptive events (in particular, Plinian, sub-Plinian and violent Strombolian eruptions) and related emergency scenarios. As one representative eruption does not dominate the risk profile, a risk assessment approach was adopted and a proportionate response incorporated into emergency planning for the first time. The risk assessment is based on human vulnerability to the main injury agents in explosive eruptions, such as heat, inhaled particles and hot gases, missiles and fires (pyroclastic density currents), and trauma from roof collapse, inhaled ash and clasts (tephra fallout). The impacts of these eruptive phenomena on the urban built environment in the densely populated circum-Vesuvian area were also studied using new modeling tools to evaluate human risk and devise mitigation measures. This probabilistic, evidence-based approach to risk assessment can be applied during the state of unrest to support decision making, such as for evacuating populations, in an eruptive crisis. The presentation will outline the EXPLORIS methods and the range of human impacts that can occur and which need to be incorporated in disaster management at explosive eruptions around the world.

13-O-02

Relief Activities for Victims of a Pyroclastic Surge During the Unzen Crisis

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The eruptions of Unzen volcano frequently generated pyroclastic flows during 1991 and 1995 to cover Shimabara City with gray volcanic ash. When a relatively large flow occurred on the 3rd of June 1991, the civil defense officials announced that some people were injured. Soon after that, seventeen people with severe burn injuries were brought to Nagasaki prefectural Shimabara hospital one after another. Relief activities for the victims were conducted with appropriate triage decisions under the strong leadership of the leader and vice leader of the relief activity team. Although some victims managed to walk from ambulances to the treatment room, all parts of their body had swelled up from the burns. Without quick treatment, we could not secure the airways and blood vessels. All the patients except three were transferred to some hospitals with sufficient capacity after receiving first-aid. Twelve patients with airway burns died. Ten of the twelve had over 90% of their total body surface area burnt and the other two had 40-60%. Two crucial factors allowed us to efficiently conduct the relief activities. One was that we had prepared a special emergency room for such a disaster in advance. The other was that the crisis happened at four o'clock in the afternoon when many of the hospital staff could easily join the relief activity team. From this experience, I learned that the establishment of a specialist team during non-crisis times is essential to manage an efficient emergency response.

13-O-03

Occupational Safety and Health Measures for Personnel Engaged in Disaster Countermeasures against Volcanic Eruptions at Mt. Unzen Fugendake

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June 3, 1991 at Shimabara City Hall, Nagasaki Prefecture: An emergency situation occurred a little past four o'clock in the afternoon when pyroclastic flows hit the city. Male city workers, who were called in on very short notice and quickly allocated to their emergency tasks, disappeared, scattering into the darkness of the stuffy night with the burning smell of volcanic ash to assume each individual responsibility. It was the beginning of all the following disaster countermeasures taken against Mt. Unzen (Fugendake) eruptions that lasted over five years, which none of the workers at Shimabara City Hall had ever experienced before. From the day 43 people died in the disaster, all city workers had to run about in confusion day after day, involved in preparing evacuation sites for as many as four thousand residents who were forced to evacuate suddenly, receiving and distributing enormous volumes of aid supplies arriving every day and so forth. In the meantime, staff at the headquarters had to be on night duty, monitoring pyroclastic flows on screen in the disaster countermeasures office over four years. During that time, various measures for occupational safety and health were taken at disaster sites, including measures for overwork and health damage prevention among personnel engaged in disaster measure operations, safety measures for jobs in dangerous areas within the reach of pyroclastic flows and others. Nowadays, the above-mentioned can be recognized as the key factors in risk management at the time of the disasters caused by eruptions from Mt. Unzen (Fugendake). We will consider appropriate measures for occupational safety and health management in times of disaster by referring to the health survey results and various approaches practiced for city workers at Shimabara City Hall, who experienced an unprecedented, long-term volcanic disaster.

13-O-04

Psychiatric Problems Among Citizens During the Unzen Eruption

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I will talk about the psychiatric problems examined and treated at Takagi hospital mainly in Shimabara city during the eruption of Unzen volcano. Unzen volcano became active on November 17th 1990. The volcanic activity affected the area in which many people had lived in Shimabara city and Fukae town and the citizens had to live with enormous fear and insecurity. Many people had to quickly evacuate their homes. Some people lost their homes to fire, farmers lost rice and vegetable fields and tea plantations. Under these circumstances I examined and treated 27 people with psychiatric problems. Thirteen of these people suffered from a marked increase in dementia. Three people had phobic anxiety disorders and two of these three died. Three people had generalized anxiety disorder and four people with delusional disorder and four people with depressive episode.

Notable features are:1).Fifty-nine percent of the 27 people were over 70 years old. 2).All the thirteen people who suffered from dementia had strong symptoms appear after evacuation while being housed at the emergency evacuation sites. 3).Seventy percent of the people with dementia were women. 4).The dementia was so strong that it was difficult to treat them outside of the hospital. 5).Four people suffered from suicidal thoughts and one of these four attempted suicide. 6).People who had physical or mental disease and were fragile prior to disaster were affected strongly by it, i.e., the elderly, people living alone, people with a prior history of apoplexy, with dementia, with diabetes and, neurotic people were particularly at risk.

13-O-05

Health Hazard From Endogenous Gas Emissions In Alban Hills (Rome, Italy)

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The quiescent volcano of Alban Hills, near Rome, is characterized by strong emission of endogenous gas (mostly CO_2 with minor H_2S) from zones (e.g. Cava dei Selci and Solforata) where excavation removed the superficial impervious cover. These gases - denser than air- accumulate in morphological depressions and many lethal accidents to animals and also to one person have occurred in the last years. Another hazard is related to gas blowouts from boreholes reaching gas pressurized shallow aquifers. In order to evaluate the gas health hazard of the area, several geochemical surveys were performed measuring the CO_2 and H_2S soil release and air concentrations. In the urbanized area of Vigna Fiorita, dangerous indoor conditions were found with [CO_2] up to 10 % and [H_2S] up to 30 ppm. Lethal indoor [CO_2] (up to 22%) persisted within a non-ventilated house. Results will help in suggesting appropriate prevention measures to be adopted by residents. An important discovery was found measuring CO_2 and H_2S air concentration (by TDL at 30 cm from the ground). In periods of very low or no wind (generally in night-time) lethal concentrations were reached by H_2S both at Cava dei Selci (up to 400 ppm average concentration on a 40m long profile) and at Solforata (up to 350 ppm average concentration on a 118m long profile). These data indicate that the many animal deaths occurred in these years and previously attributed to CO_2 were instead caused by H_2S as indicated by the first results of a specific study on the health effects of this gas on man and animals. Alban Hills test site provides useful methodological indications on how to assess the insidious hazard associated to soil gas release in inhabited zones of quiescent or recent volcanoes.

13-O-06

The Health Impacts of Persistent Degassing at Nyiragongo Volcano (DR Congo)

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Volcanic plumes generated by persistent passive degassing are a potentially significant but poorly understood health hazard. Nyiragongo volcano (DR Congo), located 18 km north of the city of Goma (pop. 500,000), has hosted an active lava lake in its summit crater intermittently for decades. The lava lake is an often-prodigious source of volcanic gas emissions, which are a potential health hazard to surrounding communities. Following an effusive eruption in January 2002, emissions of sulfur dioxide (SO_2) from Nyiragongo were measured remotely for the first time using ultraviolet (UV) satellite data from the Earth Probe Total Ozone Mapping Spectrometer (TOMS). Beginning in September 2004, the UV Ozone Monitoring Instrument (OMI) on NASA's EOS/Aura satellite is now providing a unique set of daily observations of passive SO_2 degassing from volcanoes worldwide, including Nyiragongo. Since mid-2005 we have also conducted annual ground-based measurements of H_2O, CO_2, SO_2, CO, HCl, HF and OCS in the Nyiragongo volcanic plume using Fourier-transform Infrared (FTIR) spectroscopy, which indicate a stable gas composition in 2005-2006. These remote sensing datasets offer new opportunities to evaluate the health impacts of Nyiragongo's persistent gas plume. Using the daily OMI SO_2 measurements, we can derive average SO_2 concentration maps on various timescales, which show the strong seasonal dependence of plume dispersion from Nyiragongo. The satellite data are being ingested into a GIS to delineate regions polluted by the volcanic plume. Health data collected from communities inside and outside these regions will then be compared, to evaluate if any health impacts related to the volcanic emissions can be detected. This presentation will report the initial results from this effort, the first attempt at using daily satellite measurements of SO_2 emissions to investigate the health impacts of a tropospheric volcanic plume.

13-O-07

High Sulphur-Dioxide Concentration Events at the Surface of Miyakejima and Sakurajima Volcanoes

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At the foot of Sakurajima volcano, four stations monitor the surface concentration of sulphur-dioxide (SO_2) and suspended particulate matter (SPM), and have provided continuous records with one-hour resolution since the 1980s. Comparison of data with the record of volcanic clouds and wind data indicates that SO_2 concentrations accumulate at the foot of the volcano only when the winds around the summit are strong enough to transport gas plumes down to a measuring station, forming a lee wave.

The same mechanism was confirmed to work at the foot of Miyakejima volcano. Poisonous gas emissions of enormous proportions have been continuous there since mid-August 2000, forcing all of the inhabitants to evacuate the island from September 2000 to January 2005. The number of gas monitoring stations at the foot of the volcano increased from three in December 2000 to fourteen in April 2004. Since February 2005, when the inhabitants returned, the monitoring at each station provides the basis of the island's gas warning system. The SO_2 concentrations at the flank of the Miyakejima volcano were also measured occasionally, and are consistent with the meteorological conditions to transport gas in a limited leeward direction. The main features of the gas flow can be detected in satellite images of the vegetation index, as confirmed by ground observation using near-infrared cameras.

13-O-08

2000 Miyakejima Eruption - Changing Countermeasures for Volcanic Gases -

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Miyakejima volcano has been emitting volcanic gases including sulfur dioxide since the eruptions in June 2000. The periods can be divided into four from the viewpoint of the safety measures against the volcanic gases taken by the civil defense and other authorities.
The four periods are:
1) Period of physical avoidance, September 2000 - September 2001. Since the emission of the volcanic gas was so vigorous that the on-site disaster measures headquarters had to be on an offshore ship, and later on Kouzushima Island 30 km west of Miyakejima Island.
2) Period of chemical avoidance, September 2001 - December 2003. Chemical desulphurization equipment was installed in most of the public and semi-public buildings, to which residents evacuated in an emergency. The buildings were called "clean houses".
3) Period of forecasting avoidance, December 2003 - October 2004. Indices of sulfur dioxide concentration were defined on the basis of short and long-term influence on human health. High risk areas were specified with the long-term indices. Except for the high-risk areas, the residents were allowed to stay overnight at their houses if they had at least one room with desulphurization equipment to use during the short-term high concentration of sulfur dioxide.
4) Period of institutional avoidance, November 2004 - January 2005. With the increase of observation sites and warning systems, and the establishment of a new evacuation act (provision of clean houses, etc), residents were allowed to stay overnight in their houses without desulphurization equipment except for two areas where the sulfur dioxide concentration remained extremely high.

13-O-09

Fatal Accidents by Volcanic Gas and their Prevention

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In 1997 in less than 5 months, there were three episodes of volcanic gas accidents claiming altogether nine lives.

On 12 July, three SDF soldiers performing a night ranger training in Mt. Hakkoda were killed and 15 more were carried into hospitals after falling into a hole with low

oxygen and high carbon dioxide concentrations. Precautious measures for the training in old volcano areas should have been taken. Barriers for the holes or filling them may be considered to prevent a future accident.

On 15 September, three women in a group of 14 middle aged hikers going down from the summit of Mt. Adatara were instantaneously fainted by hydrogen sulfide in a basin. Another was also immobilized after trying to rescue them. All the rest could nothing but just observe the four to die. There seemed to be little to prevent similar accidents but general precautionsfor the danger of hydrogen sulfide for hikers and spa lovers, especially in low spot on windless days. I assume that there may be many more hydrogen sulfide accidents which had not been recognized as volcanic gas accidents but reported as a personal ailment.

On 23 November, in the summit of Mt. Aso, when about a thousand tourists were observing the crater, concentration of sulfur dioxide had sharply increased to 8ppm and during the evacuation, two of them with asthmatics died after severe coughing. Because 8 ppm of sulfur dioxide is not a lethal concentration for healthy people, we need to consider more effective warning to prevent those with higher susceptibility but going to the summit.

The three episodes described above were in different volcanic areas by different gases and possible preventive measures may also be different. Taking these examples, a multi-causality (host-agent-environment) approach to develop preventive measures for volcanic gas accidents will be proposed.

13-O-10

Factors Contributing to Volcanic Gas Accidents in Japan

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Volcanoes showing signs of volcanic unrest issue continuous smoke. Even in a dormant state, they also degas continuously. Volcanic gases are responsible for death and hazard because noxious gases such as sulfur dioxide, hydrogen sulfide and carbon dioxide are the common constituents of volcanic gases.

In Japan, hydrogen sulfide was the common cause of volcanic gas accidents. Since 1951, 30 volcanic gas accidents killed 52 people. Condensation of volcanic gases through interaction with meteoric water and/or aquifer in subsurface zones can produce highly concentrated hydrogen sulfide and carbon dioxide. These gases diffused in the atmosphere are invisible and powerless, which increases risk of volcanic gas accident. Further, hydrogen sulfide and carbon dioxide are denser than air and flow downward as a density current. Then, they accumulate in depressions and caves, especially in calm wind conditions. In 1971, on the flank of Kusatsu-Shirane volcano, central Honshu, Japan, six skiers were killed just after passing through the area filled with hydrogen sulfide. In rare cases, the gas incidents occurred in snow holes, tents and bathhouses.

Hot springs and volcanoes in Japan are very popular tourist spots. Visitors might be vulnerable to toxic gas accidents unless countermeasures are taken. At Kusatsu-Shirane Volcano, automatic warning system equipped with hydrogen sulfide gas sensor was installed in 1977. Since then, no gas-related accidents have occurred there. Yet, Kusatsu-Shirane volcanic gas hazard map showing alert level has been also published since the middle of 1990s, which certainly contributes to mitigation of volcanic gas hazard.

13-O-11

Enhanced Atmospheric Radon Concentration Due to Volcanic Activity

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. Tarumizu city, Kagoshima is located at about 10km south-southeast of Mt. Sakurajima which has been activated since 1950s. Tarumizu had the largest volume of volcanic ash fall during 1970s to 1980s. According to our preliminary analysis, the lung cancer mortality among women living in Tarumizu was significantly higher than that in surrounding control cites, though there were no significant differences in mortality from smoking-related cancers other than lung cancer between Tarumizu and the control cities. These results suggest that volcanic ejecta might be a stronger risk factor of lung cancer than smoking in Tarumizu. Radon, radioactive noble gas, and its decay products are emitted from craters, fumaroles and volcanic edifices with other volatiles. It is therefore the elevated mortality from lung cancer in Tarumizu might be explained by the exposures to those radioactive nuclides in last several decades. In order to evaluate possible associations between volcanic activity and radon, measurements of radon have been carried out at a fixed point in Tarumizu since 2003. Some findings on associations between volcanic activity and outdoor radon concentrations will be reported in this presentation. There has been no evidence so far that radon due to the volcanic activity of Sakurajima has an impact on lung cancer risk among inhabitants in Tarumizu.

13-O-12

Effect of Acidic River Water Neutralization on Mobility of Arsenic in Kusatsu-Shirane Volcano Area, Gunma, Japan

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Mt. Kusatsu-Shirane, an active volcano, is located in the central Japanese Island of Honshu, and there are many volcanic hot springs around it. Since those hot springs are all acidic, rivers in this area are also acidic. In 1964, the local government has started the operation of the acidic river water neutralization system using lime waters as a neutralizer in the Kusatsu hot spring area, which is located at the eastern foot of Mt. Kusatsu-Shirane. The suspended matters as neutralization products flow into a lake formed by a dam in this area and accumulate there. Those neutralization products are mainly amorphous iron

oxyhydroxide, and work as a scavenger for several dissolved components.

A drastic increase in the concentration of arsenic had been observed in the Bandaiko hot spring, which has the largest flow rate in this area, between 1980s and 1990s. Nowadays, its annual supply of arsenic is around 50 tons. It flows into the rivers that the neutralization system is operated on. Arsenic flowing into the rivers is almost completely scavenged by neutralization products. Based on our mass balance calculations, 25 tons of arsenic is accumulated in the dam every year, and 3 tons of arsenic is annually transported to the downstream over the dam. Thus, the neutralization system also works to prevent diffusion of arsenic to the outside of this volcanic area. In addition, our calculations suggest that near 20 tons of arsenic originated from the Bandaiko hot spring is penetrating into the ground in this area.We should keep paying attention to the mobilization of arsenic in this area.

13-O-13

Cristobalite Formation in the Soufrière Hills Volcano Lava Dome: Implications for Health Hazard Assessment

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Cristobalite is found in abundance in volcanic ash from the Soufrière Hills Volcano, Montserrat. The concentration and grain size of the cristobalite in the ash has led to concern over its potential respiratory health effects. However, toxicological studies indicate that the ash may not be as toxic as would be predicted from its cristobalite content. In order to understand this, we have carried out detailed studies on the form and composition of the cristobalite. The characterisation of cristobalite in the ash is confounded by its fine grain size so analysis was carried out on Soufrière Hills dome rock. XRD results show that up to 29 % of the bulk rock composition is cristobalite. The cristobalite in the dome is present in two forms – as euhedral and platey crystals, both of which are interpreted to have crystallised by vapour-phase deposition within the dome. The crystals are found within amygdales, often completely filling the vesicles in the dome rock, thereby significantly decreasing its porosity. We found little evidence of cristobalite formed by devitrification of volcanic glass, although we did observe quartz as a devitrification product in ancient samples. Electron microprobe analysis shows that the cristobalite is impure, with substitution of SiO_2 with Al_2O_3 (0.5-2.8 wt.%), charge balanced with Na_2O (0.3-1.2 wt.%). Raman spectrometry within an SEM allowed confirmation of the polymorphic variety of individual crystals. The results have bearing for the discussion on the potential toxicity of ash. The impure nature of the cristobalite may act to inhibit its respiratory pathogenicity as Al is known to ameliorate toxicity. The crystals have undergone phase transition from beta to alpha cristobalite. The resulting volume change cracks may act as fracture points during fragmentation of the dome rock within pyroclastic flows, thereby providing a mechanism for the formation of respirable particles.

13-O-14

Quantitative Assessments of Health Hazards from Volcanic Ash at Mt. Etna (Italy)

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We report results from new empirical measurements and from advanced numerical modelling for characterizing the dispersion of volcanic ash from a range of eruptive scenarios of Mt Etna and potential impacts on human health and infrastructures. PM10 measurements from DustTrak instruments provide a detailed dataset of the airborne concentration of ash particles potentially harmful to health. These data together with information from other available sources are used to constrain VOL-CALPUFF models when exploring the parameter domain for simulating long-lasting weak plume eruptions. Monte Carlo techniques are used to capture the effects on ash concentration estimates due to volcanological uncertainties and meteorological variability. Our numerical simulations indicate the likelihoods of experiencing significant PM10 concentrations at various populated locations around the volcano, including the city of Catania (population ca. 300,000), and at key facilities, such as airports and main roads. Ash deposit thicknesses and ambient air concentrations of PM10 are predicted at different times of the day taking into account weather conditions and the influence of traffic movements. Our findings can be used to inform civil protection mitigation measures against tephra fallout to protect human health and road transport and aviation safety.

13-O-15

Management of Health Hazards and Societal Impact of Recent Volcanoes Eruptions in Papua New Guinea

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Nonga Base Hospital, Rabaul, Papua New Guinea is located on the North and South Bismarck Microplate, in the direct ash fallout of Tavurvur Volcano (also called Matupi). The continuing constant local ash exposure over the hospital exacerbates the symptoms of hospitalized patients increasing the already strained resources and workload.In addition the physicians of Nonga Base Hospital respond to other eruptions in this island region.

Evacuations, treatment of health related problems, and helping the displaced populations to adapt the eruptions is a constant challenge. Ingenuity and adaptability mark the response of physicians and health

care personnel in this resource-challenged country.

Disaster preparedness is the subject of much discussion, however the reality in the remote communities is that health care during volcanic crises is largely provided by local health centers and village aid posts. A few physicians with a high degree of professional and personal commitment to this region respond as conditions and transportation allow.

Analysis is ongoing of the medical response to recent eruptions and the variety health hazards presenting in this area of active volcanoes. Improving response and prevention of potential health hazards is vital to this region.

13-P-01

Environmental Exposure To Volcanic Fluoride And Health Risk Evaluation

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Excessive exposure to fluoride (F) by ingestion is associated with a myriad of health effects in humans and livestock. Natural fluoride in drinking water creates an endemic health problem in many parts of the world. Volcanoes are inarguably a prominent natural producer of fluoride, constituting a steady or intermittent source of F emission and deposition into the environment. Furthermore, volcanic F has been (or remains) a documented hazard in Iceland, Vanuatu, New Zealand, and other volcanic settings. Direct links between volcanic fluoride in the environment and health are provided by consumption of water and food, inhalation of gas and particulates, and incidental ingestion of soil and ash. However, the health risk posed by volcanic F is typically evaluated in reference to contaminated drinking water only, with little consideration for other exposure routes. Yet, we assert that these may well be important in the volcanic context. Further, neither the fate of volcanic fluoride nor factors affecting biological absorption are well-constrained.

Our evaluation consists of three steps in a cross-disciplinary approach to dispel the uncertainty in F exposure risk and facilitate improved hazard forecasting in diverse volcanic scenarios. First, we execute a detailed chemical and mineralogical characterization of F in different F-bearing materials, i.e. aerosol, ash, soil, water, and food samples. These data provide insights into the levels of volcanogenic F at exposure point and the geochemistry of volcanogenic F in the different exposure media. Subsequently, we perform experimental determination of the fate of F during synthesized human digestion of F-contaminated ash, soil, water, and food samples. These data permit improved evaluation of the relationship between exposure dose and absorbed dose (the absorption factor) of volcanogenic F, and are interpreted in light of the pre-determined geochemistry. The final step consists of definition and quantitative modeling of scenario-specific human exposure to volcanic fluoride.

13-P-02

A deadly Erruption of Tseax volcano, Canada: Flash Flood or Gas?

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Tseax Volcano is a small alkali olivine basaltic volcano in northern British Columbia, Canada. An eruption in 1775 destroyed a Nisga'a first nation's village, killing an estimated 2000 people. Early evidence and analysis of the oral history associated with the eruption suggested that the people met death as a result of CO_2 poisoning. "There were fumes spreading ahead, and those who smelled them were smothered. They died and their body stiffened like rock…" Determining the viscosity of the lava flows and gases released by the eruption is the focus of one branch of research on the eruption products; the other has been detailed mapping of the flows. The flows extends to a distance of over 40 km with depths of as much as 10 meters. The villagers described the flows as flames coming towards them in "huge swift currents". Mapping of the flows reveal "mega" pillow structures (tubes), with marginal gas explosion vents, pillows and extensive areas where the flow surface has glassy margins. Where the flows first interacted with the Nass River, and just upstream from the destroyed village shows extensive water interaction features. According to oral history, the villagers evacuated their homes via canoes. At the time of the eruption, there was a significant widening of the Nass River at this location and it is described as a lake. "The fire then rolled down like a river, filled the lake and for a time the water was a bed of flames." It is speculated that the flows entered the water at a very fast rate and created a temporary dam. The dam may then have failed catastrophically, dooming those paddling to safety across the lake. Results of the chemistry will help constrain the results suggested by the mapping.

13-P-03

Volcanic Air Pollution: A Widespread Volcanic Hazard in Hawai`i

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Kilauea's current east rift zone eruption, running 24 years to date and still going strong, continues to be the emblematic "living laboratory" for studying volcanic and tectonic processes, and their associated hazards. Volcanic air pollution, commonly called vog - a term coined in Hawai`i - is a low-key but widespread hazard that has become a part of everyday life on the island of Hawai`i, and at times can affect the entire island chain. Although lava flows and lahars produce devastating results when communities are overrun, the reach and range of these hazards is constrained by topography, whereas volcanic emissions, which are dispersed by the

wind, can affect distant locations and populations. On the island of Hawai`i, studies investigating the hazards of volcanic emissions incorporate exposure and health data, as well as meteorology and volcanic plume composition and chemical conversion data. Strong community participation in the research process has contributed to the success of these multi-disciplinary studies. An ongoing 5-year study is examining respiratory health in a generation of school age children that has had frequent exposure to the eruptive plume. Preliminary results show that exposure of 1842 children, ages 10 to 12, to increasing ambient acid sulfate particle load (0.5-5.5 ug/cubic meter) is correlated with an increase in chronic cough. The correlation was even stronger with a subset of 300 respondents who had previously-diagnosed asthma. Communities on the Island of Hawai`i have adopted strategies for living and working in an environment with volcanic pollution. For example, local Civil Defense officials, in cooperation with State Departments of Health and Education cancel outdoor sports activities in affected areas when air quality deteriorates. Community groups hold vog information seminars to inform residents on how to co-exist with the volcanic emissions. The U.S. Geological Survey's Hawaiian Volcano Observatory and the National Park Service have developed a color-coded, real-time SO_2 advisory system that alerts and advises park visitors and employees when measured sulfur dioxide gas concentrations exceed predetermined levels.

13-P-04

Developing a Rapid and Reliable Method of Quantifying the Amount of Crystalline Silica in Volcanic Ash Using X-ray Diffraction

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The development of a relatively rapid and dependable technique for quantitatively identifying crystalline silica in volcanic ash and rock samples is an important step in assessing the severity of the health hazard to exposed populations during and after a volcanic eruption. It is recognized that the inhalation of crystalline silica particles such as quartz, cristobalite and tridymite, can be detrimental to human health and has been associated with diseases such as pulmonary fibrosis. Recent studies, using X-ray diffraction and RAMAN spectroscopy, have shown that crystalline silica is present in the ash and rocks deposited after the eruption of dome building volcanoes, such as the Soufriere Hills volcano, Montserrat, West Indies. However, a reliable method of silica phase quantification in volcanic samples has not been established. Once a method has been refined, it could be utilised in characterising many other crystalline silica-containing multiphase samples humans are potentially exposed to, such as ashes produced after biomass burning and industrial processes.

The diffraction data was collected using a curved position sensitive detector (PSD) giving a detection range of 120°. Samples of volcanic rock, from the Soufriere Hills volcano, Montserrat were powdered (average grain size ~ 5-20 μ m) and loaded into a rotating circular well mount fixed at 12° to the incident beam. The PSD allows repeatable, high precision, high resolution diffraction patterns to be acquired. Data for each sample was, therefore, need only be collected for 10 minutes. Two methods of quantitative analysis were tested; 1) Using an internal standard, a known weight of Z_nO mixed into the sample, and 2) Whole pattern stripping method first devised by Cressey and Schofield (1996). The results from these methods are compared.

G. Cressey and P.F Schofield. 1996. Rapid whole-pattern profile stripping method for the quantification of multiphase samples. Powder Diffraction, 11 (1), 35-39.

13-P-05

'A Constellation of Disease' European Health Crises and the Laki Fissure Eruption

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The eruption of the Laki Fissure in 1783, a Europe-wide sulphurous fog and coincident mortality crises, have been noted by several researchers who have investigated monthly mortality totals recorded in English and French parish registers; an entirely convincing explanation for these deaths, however, has yet to be advanced (Grattan et al., 2003, 2005; Witham and Oppenheimer 2004). This paper researches this phenomenon from a different viewpoint, that of contemporary and near contemporary health professionals and other professional observers.

In 1795, Dr. J. Barker a medical doctor living in the English midlands published his book "Epidemicks", which focussed particularly on the state of the air and appearance of various diseases; he devoted an entire chapter to 1783. In common with other observers he noted the foul sulphurous air and the extraordinary heat; but he also records the widespread appearance of burning fevers which "were accompanied with uncommon symptoms, horrid terrors and a considerable degree of fatality". Amongst these uncommon symptoms "ulcerated mouths, and also pains in the face, became epidemical. Burning fevers accompanied with pleurisy and inflammation of the lungs were very common." As if this were not enough he recorded "great numbers of people were taken ill of these lingering fevers and attended with great weakness and a variety of complaints ... the burning fever with Diarrhoea and Dysentery". It seems likely that the environmental influence of the Laki Fissure gases and derived aerosols exacerbated and intensified illnesses already endemic in the population and reduced the ability of weakened individuals to resist their afflictions and the crude attentions of their physicians.

13-P-06

Gas Incident Induced by Heavy Snow at Doroyu Hot Spa, Northeast Honshu, Japan

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Volcanic gases are responsible for death and hazard because noxious gases such as sulfur dioxide, hydrogen sulfide and carbon dioxide are common constituents of volcanic gases. In Japan, hydrogen sulfide was the common cause of volcanic gas accidents. Condensation of volcanic gases through interaction with meteoric water and/or aquifer in subsurface zones can produce highly concentrated hydrogen sulfide and carbon dioxide. These gases released in the atmosphere are invisible, which increases risk of volcanic gas accident. On December 29, 2005, hydrogen sulfide gas incident occurred at Doroyu Spa, Akita, northeast Honshu, Japan. The depth of snowfall was higher than 2 m then. A family (two children and their parents) from Tokyo fell into a snow hole and all of them were killed. Investigations in wintertime clarified that a chain of snow holes were formed along the hot spring pipeline and that the snow hole was filled with hydrogen sulfide. However, low temperature fumaroles issuing hydrogen sulfide gas were not found in and around the snow hole. Carpet surveillance across Doroyu Spa was performed in summertime using hydrogen sulfide gas sensor. Powerless fumaroles were found on the slope near the accident site. Hydrogen sulfide concentration in the powerless gas was ca. 10%. The fumarolic area on the slope was also covered with heavy snow at the incident. The heavy snow blanket prevented hydrogen sulfide from diffusing into the air and led the toxic gas to the snow holes. Hydrogen sulfide could accumulate in the poorly ventilated chambers. Since 2006, the local government has prohibited people to accessing to the snow hole area in wintertime, which certainly contributes to mitigation of volcanic gas hazard.

13-P-07

Reinvestigation of the Volcanic Gas Disaster and the Reaction of the Municipal Office in Japan

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Reinvestigation of the volcanic gas disaster was carried out by sending out questionnaires to each prefecture and city offices concerning about the disaster prevention in Japan after the repeated accident in 1997. Volcanic gas activity was recognized at 640 localities in 57 volcano and gas fields in Japan. The gas accident has been occurred at 14 fields. The number of death by volcanic gas is 53 since 1950, but the number is not precise enough because of the lack of the accident report. Total number of victims by the direct volcano eruption was 108 in the same period, so the poisonous gas is a very important factor as the volcano disaster in Japan. Among the victims, 42 are by H_2S, 7 are by SO_2, and 4 are by CO_2. And 21 victims were recognized as younger than 20 years old. The accident occurred during the climbing or hiking (19), sightseeing (11), skiing (7), taking baths (7), construction works (5), and military works (3). Total number of the municipal corporation for the survey was 87 among about 3000 in Japan at that time. The type of the reaction for the volcanic gas disaster for each municipality is different from office to office, and was divided into following four groups; 1) having no information about the presence of the volcanic gas field in their district, 2) having the information about the presence of the volcanic gas field but not aware the dangerous condition, 3) having the knowledge about the volcanic gas disaster in their district but keeping the information inside their office, 4) having the knowledge about the volcanic gas disaster in their district and keeping the public relation with the residents and the sightseers.

13-P-08

Measures Taken by the Local Officials Against the Sulfur Dioxide Emission From Miyakajima Volcano

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Measures taken by the local officials against the sulfur dioxide emission from Miyakajima volcano will be presented. All of the contents are based on the information provided by the Miyakejima village officials. Miyakejima volcano has been emitting sulfur dioxide gas from the summit caldera since the eruptions in 2000. This volcanic activity forced all the residents of the Miyakejima Island to leave their home during September 2000 and February 2005. Even now, the concentration of the sulfur dioxide sometimes exceeds 5ppm in the residential area. This makes impossible for the Miyakejima residents to live on the island without any restriction. The Miyakejima village officials introduced some mitigation measures to allow the residents to return their home except for the area with the extremely high concentration of sulfur dioxide. The main measures taken by the village officials are: 1. Observation of the concentration of sulfur dioxide. The village officials measure the sulfur dioxide concentration at the 14 points on the island to provide real-time information. 2. Issue of warnings. The warnings of four levels are distributed around the clock through the 44 outdoor loudspeakers, 14 warning lights, home receivers, and mobile receivers for the people sensitive to sulfur dioxide. 3. Advise for evacuation. The village officials provide the residents with the evacuation facilities and guide the residents when a warning is issued. Buses may be used when needed. 4. Spread the information of the risk of sulfur dioxide. The village officials explain the potential effects of sulfur dioxide and the possible countermeasures. "Miyakejima's guidelines on the disaster mitigation" was prepared for that. The Miyakejima residents combine the information from Meteorological Agency with the countermeasures by the village officials. No significant health hazard has been reported by May 2007.

13-P-09

The Evacuation at Takagi Psychiatric Hospital During the Unzen Eruptions in the 1990s

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I will talk about the evacuation at Takagi hospital, which I ran, during the eruptions of Unzen volcano from 1990 to 1995. Takagi hospital is a private psychiatric hospital in Shimabara city. It was located about 6km from the main peak of Unzen volcano, Fugendake, at the time of the eruptions. Since Nakano River was beside the hospital and had a risk of being covered with debris flows and

pyroclastic flows, I had to make the decision on the evacuation of the hospital to ensure the safety of all 170 patients. The evacuations were conducted 23 times, mainly because of heavy rainfall that might cause debris flows. As a temporary evacuation site, we used a sports hall about 20 minutes by car from the hospital. In order to transport all the patients in the quickest possible time, eight mini-buses were used. This process was especially problematic as the hospital was not located on a main road, and therefore access was difficult. When there was a likelihood of heavy rainfall at night, the evacuation was completed before nightfall. Medical supplies and the patients' medical records were also transferred in order to ensure that the patients could be properly treated in the temporary evacuation site. The hospital kitchens prepared food and drink, and then transported it to the temporary evacuation site, when possible. Otherwise, we hired a catering company to serve food and drink. Since some patients refused to leave the hospital, I spent much time persuading them. Sometimes, we had to remove them from the hospital by force. The employees were also under great stress because many of them lived in the local area, and therefore, the eruption and subsequent effects endangered their and property and loved ones. Unfortunately, we received no help from the emergency services or from the Self Defense Force.

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21a-O-01

Case Studies of Iwate Volcanic Crisis in 1998

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In 1998 earthquake activity increased drastically at Iwate Volcano, and a possibility of eruption was elevated. However, with its long cycle of eruptions, both people and authorities concerned with disaster prevention did not seriously consider Iwate Volcano to be an active volcano, and no countermeasures against possible volcanic hazards existed. The Iwate Network System (INS) Conference for Volcanic Disaster Prevention at Mt. Iwate was launched with the participation of scientists, those concerned with disaster prevention and the press, based on the active background of industry-academia-government collaboration in Iwate. It played the role of an engine for establishing quick construction of official disaster prevention measures including improvement of volcano monitoring systems, setting of hazardously potential area, and planning of and training for urgent countermeasures. Through exposure of information, efforts were made to build confidence among scientists, officials, residents and concerned bodies. Additionally, roles and responsibilities of scientists, the governor and mayors were clarified so that scientific judgements based on volcanic observation reports could be converted to actual disaster prevention practice including issuance of an evacuation order and so forth. Fortunately, volcanic activity of Iwate declined, and a possibility of eruption became remote. In the meantime, the tetragon system established in Iwate for disaster mitigation, linking scientists, administrative bodies, the press and residents is considered to be an effective model of volcanic disaster prevention for ensuring community safety.

21a-O-02

Understanding Disaster Response

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Disasters come with little or no warning. In Oklahoma City, officials never believed America's heartland could be a target for terrorists. Prior to 9-11, New York City fire and police personnel never imagined an incident that was beyond their ability to handle. Residents in the remote areas of west Texas never expected a Space Shuttle to fall on them. Gulf Coast officials never believed something called Katrina would destroy every part of an infrastructure that took 200 years to build. And finally, there were no plans in place for a 9.1 earthquake generating a massive tsunami that killed thousands, destroyed cities and impacted multiple countries. The reality of disaster is that local responders and organizations will be overwhelmed and will be victims of the event. Loss of personnel, equipment and infrastructure will inhibit information gathering and decision making. Disasters and the initial response are a local responsibility. Local government must anticipate plan for and prepare to receive and use help that is coming. Without leadership, guidance, mission tasking and information from the local responsible agencies, outside help will be squandered through misuse, duplication of effort, waste and delay. Local leaders must make hard decisions with limited and confusing information. People will misunderstand and disagree with decisions made during critical moments in time. The public reality is that people are not listening, are not prepared, and do not accept responsibility for their own safety – they expect government to provide for their every need immediately. In turn, government has made promises they cannot keep in response to criticism of past shortfalls. In summary, disasters happen and they happen to anyone, anytime, and anywhere – when it's least expected. Without training and a plan that is practiced and learned recovery will be harder. It's time we quit learning the same lessons.

21a-O-03

From MESIMEX Exercise to the Stromboli Emergency: the Italian Civil Protection Organization for the Volcanic Risk

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In October 2006 Italy realized an exercise at European level on volcanic risk in the Vesuvius area. The main objectives of the exercise (MESIMEX) were: to test and improve emergency procedures, from the early warning phase up to the evacuation of the population from the red area (18 municipalities, 550.000 persons, piroclastic flow

hazard), before the beginning of a volcanic eruption; to control the communication procedures among the various decisional and operative levels involved; to check the use of the principal emergency escape ways established by the Emergency Plan, the activation of the intervention model for the cultural heritage protection;the joint effort coordinated by the Italian Regions twinned with the 18 Municipalities of the red area. In this framework for the first time, was tested the Member States effectiveness in responding to major emergencies by testing models of intervention of VETs (Volcano Experts Team) and FASTs (Foreigners Assistance Support Teams). France, Spain, Portugal and Sweden took active part with experts from the VET and FAST teams. The exercise provided the opportunity to verify the Civil Protection and scientists (Synthesis Group) reaction to a precursor scenario proposed by an independent group of scientists. The exercise involved a real time evaluation and analysis of effective data collected during the operations as well as discussion and interpretation of the precursors provided each day by the scenario, in the context of the volcanic emergency. During the last Stromboli emergency (February 2007) the same dynamic strategy was proposed. All monitoring and assessment activities was reported to a Synthesis Group, composed by volcanic experts and monitoring managers, that constantly evaluated the hazard state of the volcano providing the basis for all emergency procedures. According to the fast evolution of volcanic dynamics and the consequent variation of the hazard evaluation, the population was precautionary moved out, from the dangerous areas of the coastline several times. Moreover the safeguard altitude limits for hikers, accompanied by volcanic official guides were also modified.

21a-O-04

Simultaneous Hazardous Events: The 2006 Eruption of Merapi Volcano and The M6.4 Yogyakarta Earthquake, Indonesia

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Merapi Volcano is one of the most active volcanoes in Indonesia. Its activity consists primarily of lava-dome growth and collapse, resulting in extremely hazardous pyroclastic flows and surges that threaten populations living on the volcano. Merapi's most recent eruptive activity in 2006 was preceded by significant precursors with a new lava dome emerging in late April 2006 and dome-collapse pyroclastic flows beginning in early May. During the eruption (April-August 2006), the direction of the pyroclastic flows changed from dominantly southwest in May to south and southeast in June and July. The change in flow direction and an increase in lava extrusion rate appear to roughly correspond to the M6.4, 27 May 2006 earthquake that struck 20 km SSE of Yogyakarta, a city of 3 million people located 30 km south of Merapi Volcano.

The 2006 eruption was challenging for crisis management for several reasons. First, in previous decades, pyroclastic flows went primarily to the west and southwest; thus the change in pyroclastic flow direction affected populations that had not experience these destructive flows for some time. Fluctuations in volcanic activity and the length of the eruption made determining alert levels, used by civil authorities for evacuations, difficult. And, finding the right public information balance took time. Too little information resulted in the public not understanding the dangers. In contrast, too much information, but insufficient understanding of the information received, led to unnecessary evacuations. The earthquake added to these challenges. Not only did it change the direction of the pyroclastic flows into previously unaffected areas, but it also affected those who had been evacuated from the Merapi area to Yogyakarta, who now also faced the risks from a damaging earthquake. These events underscore the difficulties of managing natural hazard crises in geologically complex areas.

21a-O-05

Volcanoes and Aviation: Lessons Learned in the 25 Years since the 'Jakarta Incident', and Lessons We Have Yet to Learn

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Since the near-disastrous all-engine failure during a British Airways flight in 1982, there have been further volcanic ash and aviation incidents, many of them life threatening. Fortunately, through a combination of luck and effective warnings, none have actually have been fatal. The International Airways Volcano Watch (IAVW) has been developed through co-operation between two UN specialist agencies: the International Civil Aviation Organization (ICAO) and the World Meteorological Organization (WMO), in collaboration with the more informally organised volcanological community. The 'luck' aspect includes instances of critical information not being transmitted through lack of ground-based resources in the volcanological community, not being properly acted on because of resource and training factors in the meteorological community, and not being heeded through ignorance in the aviation community. Examples of these will be given in the presentation.

Through a slow, formal, but consensus-driven process, the IAVW has been evolving towards a robust and procedurally driven global warning system for volcanic clouds. Specific initiatives include: a) the development of a standard form for the provision of eruption information to aviation from observatories, b) arrangements to allow the reimbursement of volcanic communications costs to selected observatories from the aviation sector, c) regular tests of the transmission of warnings for aircraft, and d) internationally standardised, fully consistent text and graphical warning formats. Some other issues that have not yet been addressed are the development of all IAVW partners as robust 24/7 operations, a mismatch of the time-scales that volcanologists and the aviation industry work to, and an over-dependence on personal networks and ad-hoc arrangements rather than organisational procedures for information sharing.

Future development of the IAVW should also incorporate a checklist/flow-chart driven decision support structure that gives consistent, reproducible results, and formal inter-agency post-analysis of major events.

21a-O-06

Increase of Eruptive Activity and the Role of Journalists at Volcan de Colima, Mexico: The Need to Understand People's Perception of Risk

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Volcán de Colima has increased its activity considerably since 1998 with four periods of effusion and since 2003, daily Vulcanian explosions. During 2005 the magnitude of the explosivity increased and produced various pyroclastic flows, two of which reached over 5 km from the volcano, making them the largest events since the last Plinian eruption in 1913. A significant risk is also presented in the region by the lahar hazard, with various examples of damage to infrastructure during the last few years and at least 23 people killed in 1955. Surrounding a part of the volcano are several small settlements with nearly 5000 living within 15 km. Since 1997 six studies have been carried out in the region in an attempt to define the relationship that exists between the population and their neighbour. The results of the studies highlight the role of the increasing activity on risk perception. Despite the volcano making its presence felt, in most cases it is the combination of various socio-cultural, historical and political factors that define the perception volcanic risk within these villages. Limitations exist which prevent journalists from accurately portraying the situation in a more realistic manner. Experiences in other regions should be considered.

21a-O-07

TV News on Recent Volcano Crises in Japan

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When a volcano erupts or a possibility of eruption is indicated by researchers, the main focus of a TV news report will be on the "current state of the volcano," "predictions of its activities," and "how community residents should respond." When it comes to actual reporting, the "current state of the volcano" includes airing live images via TV cameras and the introduction of observational data provided by the Meteorological Agency and others. "Predictions" incorporate press conferences and interviews with the Meteorological Agency and volcanic researchers, while "residents' responses" are conveyed by covering related local autonomies' measures based on scientific knowledge. Regarding "residents' responses," they will be "already prepared responses" when the situation changes in accordance with researchers' predictions based on a hazard map. When an unexpected incident takes place, the focus of the news report immediately shifts to the "risk managing emergency response." Such an abrupt turn will severely impact residents' lives and may include evacuation, and it becomes mandatory to provide people with enough information to allow them to grasp the situation. In order to discuss how volcanic researchers, local autonomies and the press should work together and play individual roles, we will quote cases of three volcanic disasters including Mt. Unzen Fugen, Mt. Usu and Miyake Island in terms of how release of information and news reports changed to "protect people's lives" at the times of eruption disasters.

21a-O-08

The 2000 Eruption of Miyake-jima Volcano: From Total Evacuation (September, 2000) till Return Home (February, 2005)

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Total of 3800 inhabitants had to evacuate from a volcano island Miyake-jima in September, 2000, owing to large eruptions associated with the caldera formation. Their return was prevented by harmful SO_2 gas emission for 4.5 years until February, 2005. Tokyo Metropolitan Government supported the refugees' life in a various way, for example by supplying public housing free of charge. One of the reasons for such a long-term evacuation was that the SO_2 gas emmission rate remained almost on the same level as high as several to ten thousands tons/day since the middle of 2002. The medical scientists committee proposed the safety criteria against SO_2 gas poisoning, while Miyake Village provided various countermeasures including several SO_2-protected public fascilities, public alert system against the gas, medical diagnosis and health care education for refugees. Although some areas in the island were frequently assaulted by high concentration gas even in 2004, the Village mayor made a decision that they would come home under sufficient countermeasures against SO_2 gas, which was supported by the Japanese and Tokyo Metropolitan Governments. The gas emmission rate decreased down to a few thousands tons/day after their return. However, two areas in the island are still assigned as habitation restricted, and the refuge order is sometimes issued against high concentration gas. Fortunately, no one was harmed by the gas after their return home. It is evaluated that the countermeasure against SO_2 gas by Miyake Village is a good success.

21a-O-09

Crisis Management in the Eruption of Usu Volcano in 2000

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On March 31, 2000, Mt. Usu started eruption after 23

years of quiescence. For the eruption, the government took disaster prevention measures by adopting legal systems and organization control that were established based on harsh lessons from the Great Hanshin-Awaji (Kobe) Earthquake. As the beginning of eruption had been predicted due to elevated volcanic seismicity, measures against it could be set in motion prior to the eruption. This is because appropriate measures beforehand for the impending eruption had been tried through collaboration between communities and volcanic researchers under normal circumstances. Fortunately, there was no direct human damage in the last eruption, although as many as 16,000 people had to evacuate at one time.

The measures taken for this eruption marked a major epoch in the history of Japanese disaster prevention. That is to say, the government's new system was tested in actual practice at Usu, achieving some positive results. Especially, the disaster headquarters on site set up by the government for the first time played an important role in this process, through effective cooperation with the local authorities. In addition, it was characterized by incorporation of a variety of information equipment and systems for disaster prevention, heralding the start of new disaster management in an information age, as well as categorization of areas in accordance with degree of danger/safety, depending on the eruptive activity, allowing agile and flexible judgments on evacuation or temporary entry, so as to achieve a good balance between evacuation and people's everyday lives.

21a-O-10

Volcanic Disaster Prevention Countermeasures in Terms of Evacuation Systems at Eruptions and Related Phenomena

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Since November 2006, through the "Panel to Discuss Volcanic Disaster Prevention Countermeasures Corresponding to Volcanic Information," the Cabinet Office, Japan Meteorological Agency and other related bodies have been discussing desirable volcanic information and evacuation systems toward establishing more effective systems to prevent volcanic disasters.
Based on these discussions, a framework of "Desirable Volcanic Disaster Prevention Measures Regarding Evacuation Systems at the Time of Eruptions and Related Phenomena (provisional title)" was put together in March 2007. Within this framework, the necessity of constructing linkage between councils consisting of organizations concerned as well as related municipal and prefectural and joint headquarters has been indicated in addition to enhancing volcanic information through the introduction of eruption alert levels. Also recommended have been drawing-up of evacuation plans corresponding to volcanic phenomena even during ordinary times and educational activities at schools and in communities. In formulating evacuation plans, it is necessary to prepare hazard maps, assume eruption scenarios and discuss target areas, timing of evacuation and shelters in detail as well as their connection with eruption alert levels. In the current year 2007, we will continue detailed discussion on the above mentioned and complete "Desirable Volcanic Disaster Prevention Countermeasures in Terms of Evacuation Systems at the Time of Eruptions and Related Phenomena (provisional title)" to form more effective volcanic disaster prevention countermeasures in each volcanic area.

21a-O-11

The 2006 Supertyphoon Reming Lahars of Mayon Volcano, Philippines

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The passage of *Supertyphoon Reming ("Durian")* over Mayon Volcano on November 30, 2006 brought 466 mm rainfall over a 12-hour period, generating destructive lahars and floods in rivers on the southern flanks. Witness accounts indicate that muddy streamflows first entered downstream communities at 1400h, followed 10-20 minutes later by lahars that persisted until 1700h. The lahars were characterized as occurring in 2-3 pulses, dark, slurry-like, boulder-laden and accompanied by rumbling and sulfurous stench, consistent with debris flows. Some 29 barangays in five towns were consequently devastated by burial, impacting boulders, associated flooding and washout to sea, resulting in at least 1,200 casualties, 1,400 injuries and displacement of hundreds of families.

Preliminary field evidence show that the lahars were generated by rain-induced failure of steep gully walls near the apices of pyroclastic aprons and mobilization by incipient lahars of old fan deposits at midslopes. Passage of erosive debris flows and hyperconcentrated streamflows is indicated respectively by extreme 10-20 meters incision and 60 meters lateral scouring at the middle channel reaches. In one case (Buyuan-Padang fan), stream piracy led to disastrous lahar avulsion on a populous portion of the lahar fan. In contrast, more erodible 2000-2001 pyroclastic flows on the southeastern slopes were sealed off by a 6.4 km-long lava flow in 2006, limiting lahar generation in this sector.

The lahar deposits fan out at 100-200 meters elevation, and are as much as 4 meters thick and a kilometer wide downstream. These consist predominantly of massive debris flow deposits with abundant boulder floats (up to 2 meters in diameter) and tree debris and associated hyperconcentrated streamflow units. Preliminary deposit stratigraphy is consistent with witness accounts of at least three lahar episodes.

We are currently conducting additional studies on the Reming lahars, consequent changes in channel-fan geomorphology, and future implications on lahar and volcanic hazards in Mayon.

21a-O-12

Civil Defense Disaster Preparedness and Response to Mayon Lahar from Typhoon Reming

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The Province of Albay had suffered four typhoons and one volcanic eruption in year 2006. The worst was Typhoon Reming with 604 people confirmed dead, 419 missing and 1,465 individuals injured due to mud and debris flows from Mayon Volcano. Lifelines such as power, water and infrastructures suffered seriously.

More than 24,000 vulnerable families were pre-identified, early warning and evacuation advisories were issued but the emergency response was minimal. Evacuation failure was due to: Power supply problem to support early warning and evacuation advisories using local broadcast radio. Victims were never affected by the previous typhoons. Most evacuation centers were destroyed. Warning issued was limited to wind strength. No warning was issued on rainfall volume. The communication system between the province and the municipality was good but between the municipality and barangay and between the barangay and individuals was poor.

The rainfall volume was so high therefore people from vulnerable areas of landslides, storm surges, flood, except those from lahar were early evacuated hence, no casualties in coastal and other areas affected by other effects.

The immediate coordination was done due to the institutionalized Provincial Disaster Management Office. Emergency support services from the government, private sectors and the International NGOs were so fast. No duplication and overlapping of activities were reported due to well organized disaster response where there was only one institution in charge of the emergency information management.

The ultimate recommendation is to institutionalize a community based early warning system supported with communication system and protocol as well as early evacuation system and procedures.

21a-O-13

Organisational Response to the March 18, 2007 Mount Ruapehu Crater Lake Dam-burst Lahar: Expectations Before the Event and Implications for Response

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In 1995-96 Mount Ruapehu in New Zealand underwent a series of eruptions which resulted in the emptying of its Crater Lake and the deposition of a tephra barrier at the edge of the lake. During the eleven years subsequent to the eruptions, the Crater Lake refilled to above its natural level, with the tephra barrier acting as a dam to the water. It was anticipated that the barrier would fail at some stage, allowing a lahar to flow down the Whangaehu River valley, posing a threat to lives and infrastructure further downstream.

As the probability of a significant lahar occurring was well recognised, planning was undertaken with the aim of reducing the risks from the lahar to lives and infrastructure. The Eastern Ruapehu Lahar Alarm Warning System (ERLAWS) was installed to detect the triggering of the lahar and planning was undertaken so that agencies could respond effectively to the alarm and the event itself. The planning involved a number of key stakeholders and the Northern and Southern Ruapehu Lahar Response Plans were formulated to define agencies' roles and responsibilities during the response. The written plans were supplemented by annual exercises undertaken by organisations to practice responding to the lahar event.

As the risk of a significant lahar event was high, semi-structured interviews were conducted with representatives of response agencies one year before the event itself, to articulate their expectations for the planned response. The lahar event occurred on 18 March 2007. One month following the lahar, the same individuals were interviewed and their organisational performance during the actual response was assessed. This allowed a systematic analysis of agency and inter-agency management of volcanic hazard events to be conducted. By comparing pre- and post-lahar interview data, this paper identifies the factors (e.g., information management, decision making, inter-agency collaboration) that comprise an effective agency response to volcanic hazard events. Drawing upon this analysis, the training and organisational implications for developing capability to manage complex volcanic hazard events is discussed.

21a-O-14

12 Years of Eruptive Activity at The Soufriere Hills Volcano, Montserrat and 12 Years of Monitoring: A Challenge in Understanding Volcanic Processes and Achieving Meaningful Communication of Hazard

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The eruption of the Soufrière Hills Volcano over the last 12 years is one of the best studied in the world. The repeated cycle of growth and collapse of andesite lava domes has included three clearly defined phases of active lava extrusion separated by residual activity. Each phase has had its own distinct characteristics, thus past activity is not necessarily a guide to future. The role of the Montserrat Volcano Observatory remains to provide impartial advice to the Civil Authorities on the level volcanic activity and the associated hazards and the risks. Monitoring is now state of the art, with a seismic network linked to a 24/7 automated alarm system. Yet there is much we do not understand about the volcanic processes, and much uncertainty remains. At the end of May 2007 the lava dome stood at 208 Mm^3, making it the second largest of the eruption. Lava extrusion ceased in early April and subsequently measurable activity remained low. This resulted in a perception that the risks were much reduced, and the main communication issue has been to ensure that it is understood that the hazard remains. Whilst the dome may not be actively growing, it reamians as a large mass of partially molten lava capable of collapsing or exploding. Concern also remains that the dome may be pressurising thus a lateral blast is a real possibility. Whilst the island's Governor has overall is responsible for safety of the island, pressure from the

community is exploited by local politicians and ultimately the focus becomes the scientists. The Montserrat public are, after 12 years self-appointed "experts" on the volcano. Since the worst case hasn't happened and memories are short, managing the crisis becomes ever more difficult and trust in scientific advice is at an all time low.

21a-O-15

How To Deal With Unpredictable Volcanoes In A Developing Country?

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Although being closely monitored, on 7th October 2006 Tavurvur volcano unexpectedly went sub-plinian. This was the largest eruption from Tavurvur in historic times. The eruption column reached 18 km in height; the 1 cm ash isopach extended for 50 km to the south and southwest. About 25% of the cone was destroyed by collapse, causing localised tsunamis and then, before visibility returned, was substantially rebuilt by massive lava flows and scoria/pumice falls. In total about >0.2 km^3 of material was erupted in less than 6 hours. A sulphur dioxide plume was tracked as far east as South America. Like the 1994 eruption there was no unambiguous medium to short-term precursors. The only indication that there was a build up to a major eruption, amongst the on going sub-continuos small vulcanian events, was an inflation that started Jan. 2005 and amounted to about 14 cm of uplift in the centre of the caldera. At the time of the eruption the volcano locally provided its own alert, shock waves breaking plate glass windows >7 km away. The population of Matupit, less than 1.5 km from the centre of the vent, began to evacuate immediately and the other effected areas also spontaneously started to leave; the local business community and Provincial Disaster Office facilitating these voluntary evacuations. RVO via situation reports immediately provided alerts and updates to the aviation sector, provincial, national and international organisations. In light of the lack of monitoring, or difficulty in recognising short-term precursors at some PNG volcanoes RVO's public and institutional awareness programmes and strategies are already weighted to providing local communities with information enabling them to respond proactively to rapid onset emergencies.

21a-O-16

Emergency Response To The 2005 Volcanic Eruption At Garbuna, Papua New Guinea

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Garbuna volcano in West New Britain Province, Papua New Guinea, erupted in October 2005 after about 1800 years of dormancy. Officials from the West New Britain Provincial Disaster Office (WNBPDO) coordinated the emergency response to the event in conjunction with scientists from RVO who were later join by a team from the Volcano Disaster Assistance Program (VDAP) of the United States Geological Survey (USGS) to assist with monitoring the eruption. The eruption was short lasting only a few days. During the onset of the eruption, the WNBPDO coordinated an evacuation exercise together with private businesses that provided transportation. People were evacuated to two areas outside a 10 km radius from the volcano, a similar arrangement as had been done during the Pago eruption in 2002, also in West New Britain. Technical advice was provided initially by RVO and then assisted by scientists from the USGS VDAP Team that included current status at Garbuna, alert levels, and possible scenarios of what may occur during the next few months/years. This information was made available to the WNBPO, the business community, and Non Government Organizations such as churches and the Red Cross for planning purposes. During the same time scientists assisted by Provincial Disaster officials carried out a public awareness and education program and broadcast on the local radio station as well. The awareness program included types of volcanic hazards, hazard maps of Garbuna, and the evacuation plan. The response to the Garbuna eruption was a low-tech success story that reflected a coordinated effort between the Provincial Disaster Officials, local government authorities, the business sector, and NGO's. Its success was attributed to the experience gained from the 2002 Pago eruption.

21a-P-01

Preventive Evacuation, a Difficult Reality Due to Galeras Volcano Activity

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Without doubt, Galeras volcano is considered as one of the most active volcanoes in Colombia and also declared as a decade volcano by IAVCEI during the 90's. Galeras has been apparently in calm for the last 10 years, but at the end of June 2004, the volcano showed renewed activity. The population that inhabits the high volcanic hazard zone, has had to take care of permanent evacuation orders given by the Mayor of Pasto city, due to the probability of pyroclastic flows on this area. Around 60% of this population (about 3.200 people) has decided to evacuate to temporally shelters. The rest of the inhabitants stays incredulous or concern to leave everything what means their project of life, their yearnings and illusions.The municipal system for prevention and attention of disasters preceded by Mayor, has made many efforts concerted with those communities in order to satisfy their necessities during their stay in temporary shelters; nevertheless, for many it is not the same to sleep in their own houses, surrounded by the privacy that means its land parcel, that although small, is own. In their thoughts Galeras is their best friend, the one that does not make damage, the guardian of people, but the reality is quite different, at least from the authorities point of view. The authorities are conscientious of the responsibility that implies to maintain out of the danger area 5.400 people. For that reason the main goal is concentrated in the design of a resettlement project and to obtain funds for it,

as a real solution to the problem. In the meantime the authorities made an effort to convince up to the most reluctant, on the necessity to evacuate before the eruption occur, because, being in the wrong place at the wrong time may cause death.

21a-P-02

Management of the Disaster Situation due to a Possible Volcanic Eruption of the Galeras Volcano Situated on Nariño Department Colombia.

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The Galeras Volcano in Nariño is beeing considered the most active in Colombia. For the last 17 years of constant vigilance, the occurrence of eruptions by Galeras Volcano between 2004 and 2006 have been mostly catalogued as small ones, but also because of the increasing down settlement of lots of people, approaching continously year after year the high risk areas of Galeras volcano. This fact increases vulnerability and consequently intensificates the high risk level, particularly due to the high occurrence probability of extrem dangerous phenomena like pyroclastic flows, also the switching process between activity level III into level II “probably eruption in the course of days or weeks of volcan Galeras. Immediately after this the mayors of Pasto, Nariño and la Florida did release a decree for evacuation of all those settlers living at high risk zones, this meant a total of 7935 persons to evacuate. For all of them the government disposed of huge economical resources for the evacuation proceedure, lasting 7 months. The volcanic eruption took finally place the 12th of july, without causing any personal nor material damage. The long-term management of evacuations, like those perpetuated at the high risk zones of Galeras volcano. The government difficulties are had to maintain a total evacuation, Situation is it worries since to the authorities if an eruption will be presented in hours of the day, the measures of the contingency plan would not be enough to save the lives of people. For the first time in Colombian history, a disaster situation has been declared before real happening. The 15th November of 2005, with help of Decree 4106, the National Government declared the existence of an disaster situation within the counties of Pasto, Nariño and La Florida, all making part of the Nariño Department.

21a-P-03

Huila Lahars Caused by Rapid, Voluminous Water Expulsion

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Small (VEI 1-2) phreatic eruptions of Huila Volcano, Colombia, occurred on February 19 and April 18, 2007. The February 19 eruption generated a small lahar under 3 m in depth that extended tens of kilometers down the Río Páez, Several homes were destroyed along with livestock and agricultural lands. The April 18 eruption generated much larger, 10m-deep lahars simultaneously in the Río Páez and Símbola drainages that flowed more than 100 kilometers down the Río Páez. No lives were lost in the April lahar due at least in part to recognition of seismic precursors by INGEOMINAS, immediate communication of that information to local emergency managers and a rapid, successful evacuation of thousands of people.

Evidence strongly suggests the lahars were caused by large volumes of water expelled from the volcano at the moment of the phreatic eruptions. Both lahars were observed 20-25 kilometers downstream within minutes of the phreatic explosions. Observed and hypothetical velocities for each lahar are consistent with initiation at the time of the eruption. Subsequent aerial inspections of Huila revealed no hot pyroclastic deposits that might have melted snow or ice, but each eruption caused a separate crack in the edifice 1-2 km in length, with evidence of water flowage from each of the cracks. The volcano’s steep sides and absence of a crater appear to preclude the possibility that the water was stored in a topographic bowl or subglacial basin before being released.

The generation of large, dangerous lahars by water expulsion during relatively small eruptions with limited precursors is an unusual but significant volcano hazard with little or no historical precedent. Changes in groundwater levels and spring discharges are commonly seen at volcanoes and are associated with magmatic intrusion. The events at Huila appear to be much larger in scale than these typical hydrologic reactions. We are working to understand the mechanism behind these voluminous water expulsions and the meaning of this phenomenon.

21a-P-04

Volcano Emergency Management at Nevado del Huila, Colombia

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After more than 500 years of quiescence, Nevado del Huila volcano located at south western part of the country, had two small eruptions one of then generated a 75 x10 6 cubic meters lahar that went down the Paez and Simbola rivers, travelling more than 120 km down to Magdalena river. Nevertheless, this lahar produced none deaths, none injures and none disappeared people.

INGEOMINAS, the Colombian Geological and Mining Survey is the scientific institution responsible for the volcanic monitoring, as well as, the volcanic hazard evaluation. The National System for Prevention and Attention of Disasters-SNPAD was present early in the crisis; with all the institutions that made up the System and INGEOMINAS is part of it. After two months of work preparing the emergency plan among institutions, authorities, indigenous organizations and community, the situation was far from perfect but when it was necessary to respond facing a new eruption, the results were outstanding. The first communication was issued at 6:10 pm, a second at about 10:00 pm and the third at the moment of the eruption at 2:58 am, nine hours after the first announcement.

The success of the managing Huila crisis might be

based on the facts that: 1 INGEOMINAS issues for the two eruptions, proper and timing alerts to the System and from this to the community. 2 There was a cross checking during the 'call chain'. 3 The community has good perception of the lahar or so called 'avalanche', because most of the towns in the Paez basin were affected for the 1994 lahar. 4 After 1994 lahars, people in the country side and in small villages were relocated at higher places lowering their vulnerability and consequently the risk.

However, the road and bridges infrastructure was severely damaged, 3 bridges and 19 pedestrian crossings were destroyed.

21a-P-05

Tungurahua Volcano's 2006 Eruptions, Monitoring and Alert Notifications

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Tungurahua volcano experienced two pyroclastic flow (PF) generating eruptions on July 14 (VEI=2) and August 16 (VEI=3) 2006, after seven years of mild but threatening eruptive activity. The deployment of a monitoring system by the Instituto Geofísico (IG) since 1988 and the installation of the Tungurahua Volcano Observatory in 1999 on a location close to the volcano, allowed IG scientists to communicate to the authorities the course of volcanic events during the seven years process, and finally to successfully issue early warnings to national and local authorities and to the people before the July and August catastrophic eruptions. Starting the last day of 2005, after a full year of minimal activity, the monitored parameters at Tungurahua increased remarkably suggesting that a new magma injection was possible. On May 12, 2006, the IG released a special report to authorities stating that escalating activity at Tungurahua could lead to several situations, being the worst-case scenario the generation of pyroclastic flows impacting the inhabited areas close to the volcano. By early July Tungurahua was generating several hundreds of loud and "dry" explosions per day, inflation on the upper north flank was evident and daily SO^2 emission was in the order of 2000 tons per day. After four days of relative calm, and three hours of dramatic ramping up of tremoric activity, Tungurahua produced its first PFs of the present eruptive period. A similar but less evident seismic pattern led to the August PFs eruptions. In both cases the IG issued early warnings, three and ten hours before the climatic eruptions respectively, based specially in the information of BB seismic stations recently deployed in conjunction with the Japanese Cooperation Agency. Although close to 3000 families lost their possessions, the August PFs killed only six people, when they did not heed official orders to evacuate.

21a-P-06

Tungurahua Volcano 2006 Eruptions, Experiences from Scientists responsible for Early Warnings

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Tungurahua volcano experienced two climatic eruptions in 2006: July 14 (VEI=2) and August 16 (VEI=3). The Instituto Geofísico's monitoring system and Tungurahua Volcano Observatory, allowed IG scientists to detect the onset of the new eruptive period in 1998 after 80 years of dormancy, to communicate to the authorities the levels of activity during the steady state eruption that endured for six years (2000 to 2005) and to successfully issue early warnings before the paroxysms of 2006. During the July eruption 21 pyroclastic flows were detected descending through 8 different channels on the N, NW and W flanks. At 17:33 (local time) the paroxysmal stage started; IG scientists issued early warnings to authorities, at 17:45; people living in the N and W flanks were quickly evacuated; the largest flows of this eruptive episode took place at around 19:32. No person was killed during these events. The greater August eruption witnessed tens of pyroclastic flows descending through 17 different channels on the N, NW, W, and SW sides. IG scientists issued early warnings to authorities at 09:30; people living in the NW and W flanks were evacuated around midday, and those on the SW flanks during the evening, but people living to the North, in the touristic town of Baños refused to leave or were not acquaint of the warnings. The initial, small PFs began around 17:00; the largest flows occurred around midnight; a total of 31 PFs were recorded by seismic instrumentation. On the SW foot of the cone, incandescent flows claimed the lives of six people, when they did not heed official recommendations to evacuate. How and when IG scientists decided to issue the early warnings, how the official authorities were communicated, how authorities and people responded to the warnings and other related experiences are recounted in this paper.

21a-P-07

Volcanic Crisis in Ecuador 1998-2007: Unprepared Public Versus Unprepared Authorities - Some Lessons Learned

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Ecuador as part of the Northern Andean Volcanic Zone exposes some 17 volcanoes in its continental territory, which are considered to be active. Since 1998 various of these volcanoes entered in eruptive phases of different scales leading subsequently into substantial economic damage to infrastructure, socio-economic activities and unfortunately also to few fatalities. Crisis management in Ecuador was an unknown subject until recent years. Therefore, mismanagement of the governmental side, lack of geoscientific data or any data base due to a lack of experience in volcanic surveillance, leaded to the loss of trust of the unprepared public to their authorities, huge economic losses, lack of investment and partial migration away from the supposed extended but not really defined risk area of several volcanoes. As result of this past

failures, and prior to new upcoming even more severe volcanic activities, the newly elected government decided to reduce Ecuador's volcanic vulnerability in several ways. The national civil defense will be enforced with their own, centralized volcanic monitoring as they obtained data and their interpretation of second hand and usually to late. A second step includes the installation of human decision-independent, early alert systems for lahars and the construction of economically useful mitigation structures (sabo dams etc.) close to active volcanoes. Another important step is dedicated to the permanent education of the public and especially of the children and last but not least the most difficult step, the re-location of public of high-risk areas. The last step incorporates micro-credits for the investment of a new house and/or farm for the re-located families as part of the re-compensation of their economic losses. How past mistakes leaded to the new policy of Ecuador's volcanic disaster management and how scientists of the CGVG-USFQ together with the authorities progress in this program will be demonstrated.

21a-P-08

Explosive Activity at Ubinas Volcano (Peru) During March 2006 to April 2007

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Ubinas is considered the most active volcano in southern Peru during historical times, with 24 episodes of high fumarolic activity since the 16th century. Approximately 5000 people live in 6 towns located near the volcano. The onset of explosive activity in March 2006 was preceded by ~8 months of increased fumarolic activity. On 27 March 2006 a mild explosion caused ash fall in Querapi village (4 km SE of the volcano). On 14 April the first notable explosion produced a gray, ash-laden eruptive column to 800 m above the volcano's summit. On the 19th, a 60-m-diameter incandescent lava body was observed in the summit crater, and at 10:50 on 20 April an explosion propelled a column of gas and ash to 3 km above the crater rim. Products emitted from 14 to 23 April 2006 consisted of hydrothermally altered blocks up to 70 cm in diameter within the caldera rim, and significant ash. From May through July 2006, activity consisted of persistent degassing with 2-3 major explosions per month. Explosions emitted ash to heights of 3 to 4 km and distances up to 40 km. There was one major explosion in both August and September, with slightly shorter column height and ash fallout distances. From November 2006 until the middle of March 2007, Ubinas showed decreasing activity characterized by gas emission to ~500 m above the crater rim. Activity picked up from 29 March though April 2007 with ash emissions to 2 km.

The ash emitted over the course of the eruption is fine, gray, and forms layers that are up to ~10 cm thick within the caldera, and ~2 cm thick at a distance of 6 km. This ash has and continues to affect residents, livestock, water supplies and crop cultivation within an area ~100 km^2 of the volcano.

21a-P-09

Scientific and Social Response to 2006-07 Activity at Ubinas Volcano, Southern Peru

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Ubinas is a stratovolcano in the regional district of Moquegua, southern Peru (16º 22' S, 70º 54' O; 5672 masl). Explosive activity began at Ubinas on 27 March 2006, following approximately 8 months of heightened gas emissions. Activity continues to present day as continuous degassing with intermittent Vulcanian explosions that have ejected blocks up to 40 cm to distances of 2 km from the vent. Ash columns rise to 4 km above the crater rim and disperse to distances of 80 km.

Initial explosions spread ashfall within 7 km of the volcano, and in April led the Comitè Regional de Defensa Civil de Moquegua (CRDMC) to order the evacuation of >150 people living in the village of Querapi (~4 km from the volcano) to Anascapa (Refugio I, ~8 km from the volcano). Due to substantial increases in volcanic activity through April and May, an integrated scientific committee (with members from Instituto Geologico Minero y Metalurgico [INGEMMET], Instituto Geofisico del Peru [IGP], and the Universidad Nacional San Agustín de Arequipa [IG-UNSA]) recommended that CRDMC increase the level of alert and implement a previously established evacuation plan for five villages in a valley within ~12 km of Ubinas. CRDMC issued the evacuation order, and between June 9-11 approximately 1000 people relocated to a shelter in Chacchagen (Refugio II, ~20 km from the volcano). Though volcanic activity persisted, after ~8 months in Chacchagen, over 85% of evacuees had returned to their places of origin, citing difficult living conditions and lack of productive capacity as their reasons for returning. This presentation will sequentially detail highlights of volcanic activity alongside the key scientific and social responses.

21a-P-10

Volcanic Hazard In Mexico City

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Popocatepetl Volcano, 60 km to the east of Mexico City, which is the political and economic center of the country where over 20 million people live, has been erupting since December 1994. Some of these small eruptions have produced ash fall in the city and caused the airport to be shut once for hours and the second time for several minutes. Ash fall from the June 30, 1997 and July 19, 2003 eruptions, which had plumes 8 and 5 km high above the volcano (13,500 and 10,500 masl), caused traffic congestion, problems with communications and increased pollution. Grain-size analyses shows ash was fine-grained, and although respiratory effects were noted,

due to the sporadic nature and small volume, effects were reversible. Volcanic aerosols in the atmosphere (Aerosol Optical Depth) of the city were also detected with the sun photometer at UNAM. The ash plume of the largest recent eruption on January 22, 2001 (18 km high) was directed to the east so Mexico City was not affected on that occasion. Plinian eruptions from Popocatepetl occur on the order of every 1000-3000 years. If this type of eruption was to occur, more than 10 cm of pumice could cover the entire city. Another volcanic hazard is related to monogenic volcanoes. At least 2 volcanoes erupted in the last 2000 years near Mexico City, both produced extense basaltic Pahoehoe and Aa lava flows that damned rivers and covered constructions of the people living the area. New activity in this field would also be accompanied by increased local seismicity and ash fall.

21a-P-11

Develop of a Software Tool for Evacuation Management in Volcanic Crises and Application to Evacuation of the Icod Valley, Threatened by Teide Volcano, Tenerife, Canary Island, Spain

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The unrest of Tenerife Volcanic system in 2004 made necessary the increased of monitoring network and definition of the Event Tree and expected eruption impact scenarios. Its last effusive eruption was in 1909 and it last explosive one, 2000 years ago, but in the last 20 years, populations and infrastructures have expanded, increasing the risk level in the area. Monitoring data showed a probably subplinian eruption (VEI 4) in Teide-Pico Viejo volcano complex, where Icod Valley, situated in the north flank of the volcano with a disperse population of 35000 inhabitants, would be seriously affected.Given the characteristics of the volcanic dynamics, if we want to take to end a correct management of the volcanic phenomena, there will be necessary the application of a preventive evacuation of the whole valley. So we are developing a tool that simulates this process, allowing evaluating the times and the most suitable routes. This tool will be integrated in a Geographical Information System (GIS) that contains the data bases of population, infrastructures, road network, digital elevation model and volcanic scenarios of the awaited eruption. This tool is added to which at the moment (o now days) they are used to evaluate the hazard and the risk. The affected area presents marked slopes, disperses population and a complex road network, without definite main lines. For that reason, the use of the simulator can improve the final management of the evacuation process.The simulator considers the characteristics and guidelines of population behavior, and includes the vulnerabilities of the routes, by earthquakes, ash fall, lahars and meteorological phenomena, in addition to the characteristics of available means. The output of the simulator allows considering the times of evacuation, the tactically important points of the road network and the zones where it is left population in difficulties.

21a-P-12

Displaced Residents of Pagan Island: Perceptions of Natural Hazards 25 Years After Evacuation

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The May 15, 1981 eruption of Mt. Pagan volcano in the Commonwealth of the Northern Mariana Islands prompted the evacuation of all 54 residents of Pagan Island. Residents of the 48 square-kilometer island were the only witnesses to increasing volcanic activity in the months before the eruption. Two days after the onset of the plinian eruption, residents were carried 320 kilometers south to Saipan aboard a passing Japanese freight boat. Nearly 25 years after the evacuation of Pagan Island, the former residents have not been granted clearance by the government to return.

The volcanically active island has erupted numerous times since 1981, most recently in 1993 before low level eruptive activity in December of 2006. Volcanic threats on the sparsely populated northern islands are primarily to air traffic. Commercial flights between Hawai'i and the Philippines and Hong Kong, and between Japan, Saipan, Guam, Australia, and New Zealand, pass over volcanoes of the Northern Mariana Islands. The Northern Mariana Islands government is attempting to resettle the northern islands and a pozzolan mining operation on Pagan is currently being debated.

A survey of 64 people was conducted in June, 2006 in Saipan. Former residents of Pagan who were present for the 1981 eruption completed a survey with questions regarding their evacuation, resettlement and their perceptions of natural hazards. Residents of Saipan, who were not on Pagan Island during the eruption, completed a survey regarding their experience with the refugees and their own perceptions of natural hazards. Survey data is being analyzed and will be presented at the Cities on Volcanoes 5 conference in 2007.

21a-P-13

Lessons Learned from Office of U.S. Foreign Disaster Assistance (OFDA) and Volcano Disaster Assistance Program (VDAP) Volcano-Related Responses Worldwide During 2004 to 2007

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USAID assists foreign countries in recovering from disasters and their Office of Foreign Disaster Assistance (OFDA) provides humanitarian assistance shortly after disasters. In 1986 OFDA began funding USGS for the Volcano Disaster Assistance Program (VDAP). VDAP compliments OFDA's humanitarian assistance by providing crisis response, capacity-building, technical training, and hazard assessments to developing countries. Over 20 years, VDAP responded to 24 major crises, built capacity in 12 countries, and helped save tens of thousands of lives and hundreds of millions in property. VDAP responses evolved as host country capabilities

grew, but the pace of work has not diminished: in the last four years, VDAP conducted 44 capacity-building projects and responded to 12 crises.

During 2004-2007, OFDA responded to both isolated eruptions and more complex events with multiple hazards. For example, activity at Dubbahu in Ethiopia (10/2005) displaced thousands; OFDA provided emergency health interventions. Simultaneous disasters in El Salvador (10/2005)- flooding from Tropical Storm Stan and a Santa Ana eruption - affected millions; VDAP assisted SNET with advice and monitoring equipment. Merapi's eruption in Indonesia (5-7/2006) was complicated by an M 6.3 earthquake, which impacted >1 million people; OFDA provided emergency relief supplies, and deployed VDAP and disaster teams. Indonesia's CVGHM forecast eruptive events, saving lives. An eruption at Tungurahua in Ecuador (8/2006) impacted thousands; VDAP provided monitoring equipment and modeling results to assist Instituto Geofisico (IG) with their response. IG accurately forecast the eruption, saving thousands. Finally, activity began at Huila in Colombia (3-5/2007) after hundreds of years of quiescence; VDAP assisted INGEOMINAS with accurately forecasting lahars… again saving thousands.

Lessons include the value of preparedness in decreasing response levels and the importance of technical advice for saving lives. Recent eruption forecasting successes reflect the bolstered capability of observatories in developing countries and the long-term benefits of investments in technical assistance.

21a-P-14

Staying Focused: Preparing for Low-Probability, High-Hazard Volcanic Events

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Preparation is critical for a successful volcano response. This requires scientists knowing and working with the public officials and organizations responsible for disaster response prior to the start of a volcanic event. For low-probability events with potentially hazardous consequences, an important issue is how to keep preparedness in place during long periods of volcanic quiescence.

In the U.S. portion of the volcanic Cascades Range, from Mount Baker to Lassen Peak, there are on average 2-4 eruptions per 100 years, with many more periods of volcanic unrest that require some scientific scrutiny before a dangerous eruption can be declared unlikely. Response officials must balance use of scarce personnel and financial resources for these low-probability volcanic events against demands of many natural and man-made disasters that happen far more frequently. Thus, scientists must compete to get the attention of the responders by showing that the potential consequences of these low-probability events are high, which requires a thorough understanding of a volcano's eruptive history and hazards. Scientists must also be able to articulate actions that the emergency responders can take to mitigate the hazard, as well as the degree of certainty for various outcomes.

In an effort to maintain preparedness, scientists at the USGS' Cascades Volcano Observatory have worked with Federal, State, Tribal and local responders to develop interagency plans that coordinate activities in the event of volcanic activity at nine of the major centers. Key elements of the plans include (1) defining agency responsibilities, (2) establishing communication protocols, (3) holding at least one yearly face-to-face meeting, and (4) periodically exercising the plan. However, even the modest goal of meeting annually has not been met for several of the plans. This has generally happened where there was not a strong local governmental partner and, or, where there was little community involvement.

21a-P-15

Comparative Assessment of Disaster Management Conditions at Lamington Volcano, Papua New Guinea, in 1951 and 2007: Case Study of a 'Score Card' Methodology

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Disinterring and assessing historical information on how volcanic disasters were managed in the past, is useful for comparing and assessing the progress of disaster-management strategies used today. Largely unpublished sources have been accessed for the disaster at Lamington volcano on 21 January 1951 when almost 3000 people, mainly from the Higaturu and Sangara settlements and nearby villages, were killed by pyroclastic surges. A good deal is known about the science of the eruption itself from the well-known volcanological account given by G.A.M. Taylor and published in 1958 as BMR Bulletin 38, but much less has been available up until now on the disaster-management controversies that were prevalent in 1951. For example, people in the area were unaware that Lamington was even a volcano, although there was 'buried' information to the contrary, and early-warning signs of danger were dismissed by the authorities. Strategies for disaster mitigation (M) and preparedness (P) at the volcano were non-existent in 1951, but the response to the disaster by Australian colonial authorities during the relief (R) phase was speedy and effective. The recovery phase (R), too, was generally well planned and executed. The four phases of the disaster-management spectrum (MPRR) have also been assessed for the situation at Lamington volcano today using a simple score-card approach which is here proposed as a useful method for comparative assessment in other volcanic areas. Most people in the Lamington area today are too young to remember the 1951 eruption, and population pressures have led to encroachments of settlements onto the higher-risk parts of the volcano which has not been active since 1951. However, awareness-raising activities have been undertaken recently in some parts of the Lamington area, and signals from a seismometer and tiltmeter on the mountain are relayed directly by HF-radio to the Volcanological Observatory at Rabaul, 700 kilometres away.

21a-P-16

A Small Town of Kakaskasen, Tomohon City, on The

Eastern Foot of Lokon Volcano, North Sulawesi, Indonesia

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A small town of Kakaskasen, Tomohon City just located of about 4 - 5 km eastern part of the Lokon active crater. Lokon is one of the most active volcanoes in Indonesia, located at 1.21ºN and 124.47ºE in Tomohon City, Minahasa Regency, North Sulawesi, Indonesia. Lokon complex was formed in Plio-Plistosen orogenic. The beginning activities formed Old Empung. The activities moved to southern part and formed Lokon about 700 year ago. Lava plug was formed on the summit at the end of activities. In 1750 Young Empung was formed. Series of activities continued until the end of 1800. Flank eruption was occurred in 1829 on saddle between Lokon and Empung formed current active crater. The historical interval periods of activities typically have periods 1 - 4 years with dormant intervals of 8 – 64 years. The activity of Lokon Volcano was initiated by ash/gas explosion and followed by magmatic eruptions. Sometimes the activities were accompanied by pyroclastic flows. The recent eruptions were occurred in Februari–April 2001 and February-April 2003. Ash rose 400 - 1500 m above the volcano and fell over a wide region around the volcano on several villages 3-4 km from the crater. In normal condition, the Lokon activity is solfatara/fumarole stage. The maksimum height of the white cloud was about 150 m above crater rim of Tompaluan.Monitoring of Lokon Volcano and volcanic hazard preparedness of the people around the volcano are very important.

21a-P-17

Effective Warning Systems: A Model Developed in Preparation for the 18th March, 2007, Crater Lake Barrier-collapse Lahar, Ruapehu Volcano, New Zealand

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Intense public interest has focussed on a potential lahar following the 1995-96 eruptions of Ruapehu. That lahar occurred at about 11:21am, March 18th, 2007. A similar 1953 lahar produced New Zealand's worst volcanic disaster. Both lahars were the result of tephra building up at the outlet of Crater Lake. As the refilling lake reached a critical elevation behind the tephra barrier, it collapsed.

The Eastern Ruapehu Lahar Alarm Warning System was implemented leading up to the 2007 event. It comprises three geophones close to the barrier, and two more each at two sites down the channel, on the upper mountain flank. While the barrier existed, it also contained a tripwire. Automated telemetry activates pagers in an event, initiating an emergency response plan. The system effectiveness hinges on the actions of people receiving the information, and on their combining it with technical data to produce appropriate responses. Therefore, complementary social research focussed on detailed multi-agency planning and response competencies required to effectively respond. Our team recommended the documentation of reliable planning (with ongoing review) of all warning system steps, including decision-making, response roles, message content, message dissemination lists, and intra- and inter-agency communication protocols.

An 'effective warning system' model has evolved from integration of this work with other studies, calling for (1) early warning hardware and public notification, (2) effective system planning, (3) discussion, communication and participation, (4) education and engagement, and (5) regular exercises and blind tests. System effectiveness must be regularly quantitatively evaluated, with the five steps underpinned by regularly updated natural process science, and by technical warning system science. This model was in place for the 2007 lahar, and warning system response was widely considered effective, with no casualties despite a lahar larger than in 1953, and increased local population. This model also provides a template for multi-agency response management planning for other complex volcanic crises.

21a-P-18

Community Emergency Management During the 2005 Ambae Eruption, Vanuatu, SW Pacific

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Community-based emergency management and self-reliance is an objective pursued globally. It is particularly important in the context of volcanic islands, where external help is not rapidly available. We present a case-study where village-level and island-level community plans developed during 2002-04 through a participatory approach were tested by a recent eruption on Ambae Island, Vanuatu. A series of surtseyan explosions through the summit caldera-hosted crater lake (at c. 1400 m asl.) started at the end of November 2005 and broke a c. 90 year silence from the island volcano. Fears of deadly lahars were driven by oral traditions of past eruption events and led to the spontaneous formation of an island-level disaster committee. Following an official change in volcanic alert level, two days after the onset of activity, an evacuation of people from potential lahar paths was ordered and managed for over four weeks by this committee. Use of almost entirely local resources (transport, food, shelter, and staff) during the highly efficient operation meant that its costs were very low and only minimal external assistance was necessary. Coordination between the island-level committee and individual villages/tribal groups was generally very positive, marred only in cases where existing political disputes existed. In hindsight, lahar hazards from the eruption were low; however, fears of past events, along with the long interval since the last significant events from

this volcano sparked the “premature” evacuation. The local management would have been vulnerable had activity escalated, because no planning had been made for hand-over of control to the national level. In addition, the effectiveness of local management was compromised by only partial support from national authorities and overseas aid donors. Interference by an ad-hoc volunteer group of government servants with parochial Ambae interests also at times disrupted due process and sensationalist local and international media coverage also placed further pressure on island-level organisation.

21a-P-19

Monitoring of Volcanic Activity and Advisory Information in Volcano Crises - Case Histories of Usu and Miyake in 2000 -

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In volcano crisis it is very important to monitor the volcanic activity and to offer the relevant information. I will report the outline of countermeasure taken by Japan Meteorological Agency (JMA) in the crisises at Usu and Miyake volcanoes.

Regarding Usu volcano, in volcanic earthquake swarm JMA issued Volcanic Alert and prompted evacuation directives by the local governments before the first eruption. After then, the Coordinating Committee for Prediction of Volcanic Eruption (CCPVE) evaluated the volcanic activity everyday and the dangerous area was classified into three zones and various operations such as temporal returning home of the people were done. The zoning was determined based on the energy cone model of pyroclastic flow (Yamamoto, 2001). During the operations, volcanologists who boarded a helicopter of the Self Defense Forces continuously watched the volcano, JMA watched the data of seismographs, infrasonic microphones and other instruments, and the wireless communication system was prepared for abnormal circumstances.

Regarding Miyake volcano, one hour after the start of volcanic earthquake swarm, JMA issued Volcanic Alert and prompted evacuation. Fissure eruption did not occur and the evacuation directive was released 3 days after the alert. However, volcanic earthquake swarm started again beneath the summit and JMA issued Volcanic Observation Report, then the village prohibited the entry to the summit area before the first summit eruption. The eruption became very large and low temperature pyroclastic flows occurred. The CCPVE commented the possibility of higher temperature pyroclastic flow and evacuation of all people in Miyakejima Island was decided. After then, the island was classified into three zones for public workers for maintenance of infrastructures and/or volcanological research. As well as the case of Usu, the operations were carried out under the volcano watch of JMA, which set alert thresholds determined from the data during the large eruptions.

21a-P-20

The New Volcanic Alert Level

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For mitigating volcanic disasters, the Japan Meteorological Agency (JMA) watches active volcanoes on 24/7 basis, and issues text information on present volcanic activity when needed. To make it easy for users to realize the present volcanic activity, JMA had issued the volcanic alert level since November 2003. It had described present volcanic activities with the number of 0-5. The level had been applied to 12 volcanoes. However, it was on the basis of magnitude of eruption and hard to realize "what should we do?" such as (preparation for) evacuation, restriction of approaching volcanoes and so on. For the convenience of users, the JMA modifies the volcanic alert level and starts to apply for each volcano.

The new alert level has the features as follows:
- They are divided on the basis of disaster measures, not on the basis of magnitude of eruption.
- The old level 0 and level 1 are united into the new level 1. They will be the same from the viewpoint of practical action. The new level consists of 5 levels (1-5).
- Each new level is related to keyword which corresponds to actions to be taken. For example, 'the new level 3' means "Caution: No need to prepare for evacuation for the time being, but approaching the volcano is restricted".

Before applying the new alert level to each volcano, it is important to have discussions with local municipalities and establish practical action plans for every alert level. We have a plan to apply this new alert level for about 30 volcanoes. The new level is for people near volcanoes, not for aviation. (For example, Lava flows will influence to people on the ground but not to airplanes.) We will apply another volcanic alert level (known as 'the Aviation Color Code') for the safety of aviation.

21a-P-21

Advanced Evacuation Framework Based on Eruption Scenario and Volcano Information of Hokkaido-Komagatake Volcano

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Hokkaido-Komagatake, located in Hokkaido northern Japan, is prominently active volcano. With 1640 eruption the tidal wave occurred in Funka bay due to debris avalanche and caused a little more than 700 sacrifices. In 1694, 1856 and 1929, plinian eruptions occurred and fell the abundant pumice and the volcanic ash around, accompanied also the pyroclastic flows.

Sapporo VOIC, responsible for volcanic activities watch and the disaster prevention information regarding the volcanoes in Hokkaido, strengthens the observation system for Hokkaido-Komagatake volcano since its activities are high and the case where it erupts influence to be large. In addition, its grace from when precursor observed until large eruption occurred is so brief that inhabitant evacuation must execute rapidly. So, Sapporo VOIC drew up an Eruption Scenario on the basis of past volcanic activities records obtaining the cooperation of the well-informed person, and then the Council of Volcanic

Disaster Prevention for Komagatake (Secretariat is Mori Town) provides Disaster Prevention Plan based on the Eruption Scenario, which provides detailed disaster prevention process triggered by Volcano Information of Sapporo VOIC.

Furthermore JMA is advancing preparation of new volcanic activity level based on necessity of disaster prevention instead of on eruption scale. Since an affinity between the new level's concept and the Disaster Prevention Plan for Hokkaido-Komagatake is high, so Sapporo VOIC can offer more useful disaster prevention information within this year.

21a-P-22

Comparison for Interorganizational Relation of Volcanic Eruption Disaster-mitigation for Residents

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We researched social disaster responses in 8 volcanic eruption disaster in Japan from 1977 to 2007. From these investigation, we obtained 14 issue of each volcanic disaster-mitigation from the perspective of disaster preparedness and response. We report here the result that reinvested disaster preparedness and responses about these issues, and ideas of volcanic disaster-mitigation from the perspective of inhabitants. The eruption disaster that I intended for is as follows; (1) 1977 usu eruption, (2) 1983 miyake eruption, (3) 1986-87 Izu-oshima eruption, (4) 1990-96 unzen-fugendake eruption, (5) 1997-2002 Iwate eruption-crisis, (6) 2000 Usu eruption, (7) 2000-05 Miyake eruption, (8) 2004 Asama eruption. We used multiplex perspective as the analytical method. This method analyzes as for three respects; rationality of organization and individual, organization behavior, individual behaviors. As a result, we extracted 14 following issues. (A) Concentration of scientific information (B) Conversion to information about disaster-mitigation (C) Build-up of observation system (D) discriminate between judgment and information, (E) Existence of a disaster-mitigation coordinator, (F) Translation function of scientific information for society (G) Explanation to inhabitants (H) Intervention and behavior of prefectural governments (I) publicity activities (J) Transformation of an administration system (K) Relations among the subject; media and administrator, scientist, inhabitant (L) evocation of society (M) connection between the alarm system and the operation system, (N) inhabitant action for mitigation. Each disaster-mitigation response of 8 eruption is characterized by 14 issues, which can be interpreted as quite satisfactory.

Session 2-1b

21b-O-01

Challenges of Long-Term Volcanic Hazard Assessment

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Increasingly, volcanologists are called upon to make hazard assessments for critical facilities, such as nuclear power plants, high-level radioactive waste repositories, dam projects, and other such projects that depend on immense societal investment, and hence require siting in regions of very low geological risk. For many nuclear facilities, acceptable hazard levels are considered to be 1 x 10^{-8} to 1 x 10^{-6} per annum. Evaluation of such low hazard rates places a high burden on volcanological interpretations and on probabilistic volcanic hazard assessments. The stakes are high. Many nuclear facilities are in operation, and some closed, that were constructed in volcanically active regions without adequate characterization of volcanic hazard or risk. These include: the closed nuclear power plant at Bataan, the Philippines, cited by the Union of Concerned Scientists as being at particular risk from volcanic activity; the Armenia nuclear power plant, constructed within a Quaternary basaltic volcanic field; and the Mulheim-Karlach plant, Germany, which was never operated because of potential geologic hazards within the Eifel volcanic field. Volcanic hazards are currently being investigated for their potential impact on proposed facilities, such as Yucca Mountain, USA, and the Muria site, Indonesia. As construction of these types of facilities is occurring globally, and failure of such facilities may have regional, or perhaps global affects, it is entirely appropriate for the international volcanology community to develop guidelines and vet scientific methods used in such hazard assessments. Several challenges in long-term volcanic hazard assessments include: the need to develop consistent methods to estimate the probability of eruptions at long-dormant volcanoes; the need for quantification of uncertainty in the application of spatial and temporal probability models to regions of comparatively low rates of volcanic activity; and the strong requirements placed on model validation and verification when numerical simulations are used to characterize extremely rare or energetic events.

21b-O-02

A Quantitative Estimate of the Volcanic Hazard Based on Eruption Energy Release Trends

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Volcanic hazard is defined as the probability of occurrence of potentially destructive eruptions. This probability may be estimated in a volcano analyzing the sequence of past eruptions, and assuming that the effects of eruptions are proportional to the energy (magnitude), and the rate of energy release (intensity). The VEI (Newhall and Self, 1982) qualify eruptions using both parameters. We introduce here an extension of the definition of volcanic hazard in terms of the expected annual release of energy by eruptions in each VEI category. This concept is based on the averaging property of a large set of volcanoes to release the same amount of energy in each VEI category over a sufficiently

large time interval, i.e., a set of volcanoes produce eruptions in such a way that the many smaller ones release about the same energy than the few larger ones (De la Cruz-Reyna, 1991). The annual rate at which energy is released by eruptions is described by $log(EmKm)=bM+a$, where Em is the energy released by eruptions in the VEI magnitude class M, and Km is the occurrence rate of such eruptions. The parameters a and b depend on the eruptive history of individual volcanoes. The slope b determines the preferred mode of the volcano to release energy: through smaller (negative slope) or through larger (positive slope) eruptions. The parameter a determines the volcano energy potential. The method is applied to three Mexican volcanoes: Colima, Citlaltepetl and Popocatepetl, calculating the parameters from the historical and geological eruption data. Although Colima has the largest energy potential, its b-value has a small negative trend suggesting that the volcano tends to release more energy by frequent, smaller eruptions. Popocatépetl and Citlatepetl show smaller energy potentials than Colima, but almost flat slopes indicating a uniform tendency to release energy by eruptions of any size.

21b-O-03

Methodology of the Evaluation of Regions of Future Volcanism Based on Spatio-Temporal Patterns in Volcanism Combined with the Related Phenomena

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The basic policy for evaluating volcanism for selecting sites for HLW geological disposal is excluding regions of future volcanism to avoid direct damage to the repository due to magmatic intrusion or volcanic eruption. For this purpose, two kinds of scale of evaluation should be recognized in the context of deterministic or empirical approach. One is the evaluation on a scale of individual volcano from the viewpoint of the migration of magma to the repository from each existing volcano as a magma plumbing system during its lifetime. The other is the evaluation on a scale of volcanic cluster from the viewpoint of the generation of new volcano around the target area in the future. In order to accomplish these evaluations, it is important to understand geologic processes causing the phenomena concerned and to establish plausible geological models using various data such as spatio-temporal patterns in volcanism combining with the related topographical, geological and geophysical data.

For establishing geological models for evaluating regions of future volcanism, recent research revealed a lot of useful information about uneven and concentrated distribution of volcanism and the related geologic processes responsible for the repeated formation of new volcano within particular regions in the form of volcanic cluster for the last millions of years in subduction zone of the Japanese Islands. In our Tohoku case study, for example, the following key phenomena were combined: spatio-temporal patterns in the past volcanism, crustal movement indicating concentration of volcanism, and the continuity of uneven distribution of hot regions within the Mantle wedge.

In this presentation, current information on characteristics of uneven distribution of volcanism in time-space in the Japanese Islands and the related key phenomena for the evaluation of volcanism will be described, and the methodology of the evaluation for selecting sites for HLW geological disposal will be introduced.

21b-O-04

A Stochastic Model for Estimation of Long-Term Volcanic Hazard

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Long-term volcanic hazard is gaining relevance due to increasing societal demands on timescales of hundreds to hundreds of thousands of years as regards to the siting of critical facilities. As input for risk assessments, long-term volcanic hazard constitutes the dominant source of uncertainty. Uncertainty is mainly related to imperfect knowledge of non-linear volcanic processes, to space-time variability of distribution and intensity for volcanic events and to a limited amount of information. For these reasons, the estimation of volcanic hazard is based on a probabilistic formalism. Recent efforts to develop a geologic repository in Japan have stimulated the development of a specific stochastic model for improving uncertainty characterization. The theoretical basis and concepts of this model are given and then a methodological illustration is provided using a subset of the Database of Quaternary Volcanoes of Japan, in this case the Quaternary Tohoku volcanic arc in northern Honshu.

21b-O-05

Assessing Long-term Volcanic Hazards Using Volcano Distribution Databases

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There is an increasing need to forecast volcanism far into the future to protect society from rare, large magnitude eruptions and to allow critical facilities, such as nuclear installations, to be located where probability of volcanism is low. We develop methods for long-term forecasting of risk of future volcanism and attendant hazards based on the analysis of volcano databases, which contain information on past volcanic activity in space and time. There are three problems apparent with the analysis of volcano databases to forecast future volcanism and risk. First we cannot be sure that all volcanoes are included in the database. Second, there is no standardised definition of a 'volcano', thus leading to alternative groupings of features that collectively are deemed to be a single volcano. Finally there is the issue of finding criteria and evidence to assess when volcanoes become extinct and when they begin.

In this study, 31 datasets formed from alternative volcano definitions, are used to create 2d probability

surfaces over the Tohoku region of Honshu, Japan. It is then possible to forward model for each dataset (data from the Catalog of Quaternary Volcanoes in Japan (Committee, 1999)) to observe and compare their forecasting ability. 'Test sites' were selected throughout Tohoku to observe how alternate datasets affect the probability of a new volcano forming within the next 1 Ma. Site 3 shows the greatest probability variation, a range of 0.025 to 0.22. The probability surfaces created vary with each alternative dataset. Sites near volcano clusters tended to have higher probabilities of future volcanism, but exceptions occurred including when volcanoes were grouped by volume and by distance to neighbour. Certain groupings of volcanoes showed a strong tendency to cluster and so can be forecast with greater confidence. Forward modelling showed that formation of extrusive volcanoes can be well forecast.

21b-O-06

Volcanic Hazard Assessment for the Bataan Nuclear Power Plant, Luzon Peninsula, Philippines

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Nuclear facilities built in active volcanic areas require special hazard assessments in order to prevent major disasters. As an example, we present here a comprehensive volcanic hazard assessment for the Bataan Nuclear Power Plant (BNPP; Luzon Peninsula, Philippines), which is built 14 km west from Mount Natib and about 50 km south of Mount Pinatubo. The nuclear facility was covered by about 10-15 cm of volcanic ash from the 1991 Plinian eruption of the nearby Mount Pinatubo and could be affected by the rejuvenation of Mount Natib, an Holocene to upper Pleistocene mainly andesitic stratovolcano. As a result we have compiled a volcanic hazard assessment for potential pyroclastic density currents, debris avalanches and tephra accumulation. The hazard assessment for pyroclastic density currents and debris avalanches, from nearby Mount Natib, is based on the energy cone model that estimates the potential runout of these flows along the line of transport, based on the potential energy of the flows at their origin. Potential tephra accumulation at the BNPP is based on a probabilistic analysis of tephra dispersal and sedimentation from both Mount Pinatubo and Mount Natib, using the diffusion-advection numerical model TEPHRA. Explosive eruption scenario for Mount Pinatubo corresponds to the climactic 1991 Plinian eruption (VEI 6). For Mount Natib, we randomly sample eruptions in a range of column height from 14 km to 40 km, corresponding roughly to the upper limit of a VEI 3 to a VEI 7, with eruption duration from one hour to six hours, leading to total erupted mass from 1.5×10^{10} to 6×10^{12} kg. Wind data are randomly sampled from NOAA reanalysis data for 2006 and for a worst case scenario, we set the wind blowing directly toward the nuclear facility.

21b-O-07

Supporting International Development in the Asia-Pacific Region through Probabilistic Volcanic Eruption Assessment

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About 200 million people in the Asia-Pacific region live within 50 kilometres of a Holocene volcano. Furthermore, one third of the largest volcanic eruptions worldwide since 1800 have taken place in this region, and in Indonesia alone about 130,000 lives have been lost to volcanic disasters during the last 200 years. The importance of disaster-risk reduction in ensuring long-term sustainability of development and economic growth has gained increased awareness within the Australian Agency for International Development (AusAID) prompting an assessment of natural hazards in the Asia Pacific. An important part of this project is aimed at helping AusAID understand the potential consequences of large volcanic eruptions in the region and thus improve disaster mitigation, preparedness, and emergency response. Part of this process involves identification of areas with the highest hazard from large eruptions — that is, eruptions having a Volcanic Explosivity Index (VEI) of 4 or more. The approach we took involved calculating the frequency of large eruptions, and accepting that the shorter the return period of large eruptions the greater the hazard. Return periods were calculated from 'frequency-magnitude' plots using eruption data provided by the Smithsonian Institution's Global Volcanism Program. These return periods represent absolute *maximum* values. Furthermore, roughly half of the volcanoes in the region have no eruption chronologies, the eruption record for the most part extends back only 400 years, and good records exists for only the last 180 years. Nevertheless, the *relative* hazard can be determined as eruption-record incompleteness is similar across the region. Perhaps not surprisingly, Indonesia has the most frequent large eruptions, followed by Papua New Guinea, Vanuatu, and Philippines. Furthermore, several provinces are highlighted as high hazard zones, including East Java, North Sulawesi, and the Madang and West New Britain provinces of Papua New Guinea. The relative hazard in several key areas, including Sumatra, Central Philippines, and the Solomon Islands unfortunately could not be determined owing to limited data.

21b-O-08

Assessing Volcanic Hazards at the Restless Campi Flegrei Caldera, Italy

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Volcanic hazards assessment for the restless Campi Flegrei caldera has been performed using stratigraphical, volcanological, structural and petrological data, and statistical analyses. Although only 4 out of 70 eruptions of

the past 15 ka were effusive, it cannot be excluded that the next eruption will be effusive. The past explosive eruptions are grouped in low-, medium-, and high-magnitude events. A future explosive eruption could likely occur in the north-eastern sector of the caldera floor that is under a tensile stress regime, when the ongoing deformation will generate mechanical failure of the rocks. A vent could open also in the western sector, at the intersection of two fault systems, as in the 1538 AD last eruption. The eruption will probably alternate between magmatic and phreatomagmatic phases with the generation of tephra fallout, and dilute and turbulent pyroclastic currents. In order to perform a zoning of the territory in relation to the expected volcanic hazards, we have constructed hazards maps in which the areas at variable probability of opening of a new vent, those which could be affected by variable load of fallout deposits, and those over which pyroclastic currents could flow, are delimited. The areas in which a vent could open have been defined on the basis of the dynamics of the caldera's ongoing deformation, and of a statistical analysis of critical elements. To construct the fallout hazard map we have used the frequency of deposition of fallout beds, the frequency of load on the ground by tephra fallout and the direction of dispersal axes of the deposits of the last 5 ka, and the limit load of collapse for the variable types of roof construction. The pyroclastic -current hazard map has been based on the areal distribution and frequency of the pyroclastic-current deposits of the last 5 ka.

21b-O-09

Recurrence Rates of Large Explosive Volcanic Eruptions

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A global database of large magnitude explosive volcanic eruptions has been compiled for the Holocene and analysed using extreme value statistics to estimate magnitude-frequency relationships. The database consists of explosive eruptions with Magnitude greater than or equal to 4, where the magnitude defined as Log10M – 7 and M is the erupted mass in kg. The data are characterised by under-recording of events and a censoring method has been applied to estimate the degree of under-recording. Under-reporting increases back to 2000 years BP and the remains constant between 2000 and 10000 years BP. There is only an approximately 20% probability that an explosive eruption larger than magnitude 6 will have been recorded. Analysis of the dataset in the restricted time periods 1750 to the present and 1900 to present minimises the effects of under-recording, but indicates that that these periods are too short to give reliable estimates of return periods of explosive eruptions with M> 6. Analysis of the Holocene dataset with corrections for under-recording bias provide robust magnitude-frequency relationships up to M = 7. The results depend on the threshold magnitude used in the analysis. As the threshold increases the results for the larger magnitude events improves but the uncertainties also increase. A threshold of M = 5.5 is chosen on the basis of the optimum trade off between these two opposed effects. Extrapolation of the model fits to these large magnitudes (> 8) fails to give results consistent with geological data. The model predicts upper limits of less than M = 8 even taking model uncertainties into account. The upper limit of explosive eruptions is at least M = 9.2 and the return period of M>8.1 is estimated to be at least 1 in 800,000 years (Mason et al., Bull. Volcanol. 66, 735-748, 2004). We interpret this result as the consequence of different mechanisms operating for explosive eruptions with M > 7. Explosive eruptions at approximately M = 7 and above form calderas. A possible physical explanation of the magnitude-frequency relationship above M = 7 is that they relate to the formation of magma chambers which exceed a size threshold for frequent eruption (Jellinek and de Paolo, Bull. Volcanol., 65, 363-381. 2003).

21b-O-10

First step to Understand a Preparing Process of Caldera Forming Eruption

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It is a big problem for all citizens, administrative officials and volcanologists how we overcome a huge volcanic eruption after long term resting phase. Caldera forming eruption is a typical case. This talk considers this problem from researcher's standpoint. We can know what happened in the past by investigating the eruptive history, and we can imagine what kind of impacts we will receive if the similar eruption occur in the future. But we have a high hurdle to overcome this large eruption. Because we have to keep watching for a long term ranging ranging thousands of years from hundreds of years, although we can detect significant precursor just before the eruption by sufficient observations. From this reason, caldera forming eruption has been removed from the object of the prediction program in Japan. The authors paid attention to the facts that magma stops rising in many volcanoes which have attempted eruptions. After repeated examinations, we set up the following hypothesis; magma has been stored after repeated intrusive events under a certain favorite condition, and reaching newly supplied basic magma to stored magma cause a huge eruption. This hypothesis leads that significant amount of magma will be detected beneath volcano which has caldera forming eruption in the future. It is also important to know where magma stops rising and why. The first step to understand a preparing process of caldera forming eruption is to clear those questions.

21b-O-11

Challenges in Caldera-related Hazard and Risk Assessment in Developing Countries

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Metro Manila, with a population of 12 Million, lies on top of

a thick volcaniclastic deposit derived mainly from the eruptions of two calderas, Laguna and Taal, situated 20 km and 60 km, respectively, from the metropolis. Pyroclastic-flow sheets and their epiclastic facies from these calderas serve as foundation for almost all buildings and infrastructures in Metro Manila, particularly in the cities of Manila, Pasig, Mandaluyong, Makati and Quezon. The young and virtually undeformed deposits are non- welded to incipiently welded, and have andesitic-dacitic compositions (54-62% SiO_2). The Teresa scoria flow (<27 ka) and the Binangonan pumice flow (27-29 ka) constitute the youngest eruptive units of Laguna caldera.

Intermittent seismic swarms recorded around the caldera and at volcano island during the last decade has placed Taal on the list of active calderas in the world. The youngest caldera eruption was marked by the emplacement of the Sambong scoria flow between 5-6 ka. Fallout ashes from some of the larger historic eruptions of the active Taal volcano island were observed to have been deposited in the metropolis and therefore pose a serious threat to Metro Manila from more explosive eruptions.

Hazard and risk assessment for megacities lying on a caldera remains a challenge. First, very little is known about the eruptive activity of Laguna and Taal calderas and a comprehensive assessment on the potential impact of large-scale eruption has yet to be carried out. Secondly, precursors to a calderagenic eruption have not yet been clearly established. Thirdly, undertaking a research program to conduct a high-resolution age determination and geochemical fingerprinting is costly. Soliciting funds to support such studies has proven difficult to justify because of the general perception that very little can be done to reduce the impact of such eruptions.

21b-O-12

Rhyolite Eruptions Tapping Multiple Magma Bodies: Implications for Monitoring of Calderas and Hazards

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The Taupo Volcanic Zone is the most frequently active silicic area on Earth, erupting at a millennial scale frequency. Many rhyolite eruptions from the Taupo Volcanic Zone tap multiple, compositionally distinct magma bodies. Recent studies at North America calderas also suggest some eruptions tap numerous, chemically distinct magma bodies (e.g., Streck & Grunder, 1997; Heumann et al., 2002; & Simon et al., 2007). Originally, compositional heterogeneity in the silicic deposits was associated with tapping large magma chambers that had become zoned during their prolonged residence in the crust. This advance in linking the compositional diversity to separate homogeneous batches has been made possible by detailed understanding of physical volcanology and recent analytical advances. Micro-analytical techniques have provided a unique insight into the history of the magmas.

These multiple magma bodies can be erupted out of the same vent (e.g., Rotorua eruption; Smith et al., 2004), along vent zones up to 20 km long (e.g., Rotoma & Whakatane eruptions; Smith et al., 2006), or from adjacent (30 km apart) calderas (Ohakuri & Mamaku ignimbrites, Gravley et al., 2007). This has serious consequences for hazards and monitoring. It appears that once one of the batches erupts it leads to changes in stress and pressure regime within the crust and can cause faulting and eruption of other batches that would not have necessarily erupted.

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21b-O-13

Assessing Long-term Volcanic Hazard and Risk in Auckland, New Zealand

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New Zealand's largest city, Auckland (pop. 1.3 million), lies directly on a small-volume intraplate basaltic field. Activity in the field has occurred from about 50 scattered vents during the past 250,000 years, the most recent eruption producing the small shield volcano of Rangitoto 800-600 years ago. Past volcanism suggests a reawakening will generate a new volcano. Whilst a future eruption is expected to be relatively small, the associated risk is very high given the high physical and economic vulnerability of Auckland City. Auckland is also susceptible to volcanic ash fall from the large andesite-rhyolite volcanic centres in the central North Island; in fact over the last 50,000 years distal eruptions have impacted Auckland at least four times more often than local eruptions.

Paleolake tephra records reveal significant ash fall from a local eruption on average at least once every 2,500 years over the last 50,000 years. There is, however, growing evidence that activity in the Field is not regular, rather that clusters of volcanoes have erupted in time, followed by long quiet periods. In addition, some volcanoes show complex episodes of activity (separated by time breaks) rather than single (monogenetic) events. Although the likely eruptive style is well known, the youngest volcano, Rangitoto, displays anomalous petrology, eruptive style and size, indicating a possible change in evolution of the Field. Future magma ascent rates are expected to be fast, corresponding to a short period of precursory seismic activity (hours to days).

Assessing long-term hazard is therefore challenging. Despite this, Auckland has a Contingency Plan for a local eruption, due to be tested and revised during a national simulation exercise in 2008. The monitoring network is being expanded to include downhole seismometers, and good communication and collaboration between all agencies ensures Auckland is well-placed to respond to any future activity.

21b-O-14

A Reappraisal of Volcan Jorullo (Mexico) Almost 250

Years After its Birth in a Sugar Cane Field

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Jorullo volcano, a group of scoria cones and lava flows, was born on September 29, 1759 on the premise of a sugar-cane hacienda located in the State of Michoacán in the western Trans Mexican Volcanic Belt (TMVB). The eruption ended in 1774 leaving a wasteland of >50 km^2 covered mostly by lava flows and fallout tephra. The upcoming year of 2009 will be the 250th birthday of this volcano, the first of two historic monogenetic eruptions in Mexico. In this context, it is worth mentioning that the TMVB comprises >3,000 Quaternary monogenetic scoria cones and their lava flows, which is unique in the world. A repeat of a monogenetic eruption on Mexican territory in the future is thus almost certain. This compelling fact, emphasizes the need of knowing more about the initiation and style of monogenetic eruptions in Mexico. Jorullo's anniversary represents a unique opportunity to conduct a modern scientific study of this eruption, its fatal consequences for nearby populations, its impact on the environment, and especially to reach out to the general public in order to raise awareness. During the year of 2009, Jorullo might be declared a "Geopark" under the umbrella of UNESCO's program aimed at preserving natural landscapes of major historic and societal interest. As part of the celebrations, a scientific meeting and accompanying cultural events would serve as a vehicle to enlighten and inform a broader public on the nature, hazards, and risks of explosive volcanism. To this end, we have initiated a detailed volcanological study of the Jorullo eruption. First results will be presented and include a geologic map, stratigraphy and its correlation with eyewitness accounts found in historic documents, ca. 50 chemical analyses (including major, minor, Sr, Nd, Pb, Re, and Os isotopes), and determination of erupted lava and tephra volumes.

21b-O-15

Volcanic Risk Assessment In Areas without Historical Volcanism. The Case of Olot, Catalan Volcanic Zone (Girona, NE Spain)

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We want to address your attention to the problem that arises when we try to assess volcanic risk in regions from which the lack of data and of recent (historical) eruptions could let to assume that volcanic hazard and, consequently, risk do not exist. We examine the case of Olot a Quaternary basaltic volcanic field included in the Catalan Volcanic Zone (CVZ). The CVZ, located at the NE of Spain, has been active during the last 12 Ma and is related to the European Rifts System. Despite the fact that this volcanism is significant in extension and volume, and that several eruptions occurred in Holocene times, it is mostly unknown compared to the contemporaneous alkaline volcanism in other parts of Western and Central Europe. The Olot volcanic field comprises more than 50 monogenetic cones including cinder and scoria cones, lava flows, tuff rings, tuff cones and maars. Magmatic eruptions range from small to violent strombolian. Phreatomagmatic activity occasionally generated extensive pyroclastic surges and explosion breccias, and in many occasions appears associated with strombolian activity. The age of this volcanism is poorly constrained but stratigraphic relations and the existence of a few radiometric dates suggest a time period covering the last 300 ka, having the last eruptions occurred a few thousand years ago. The important socio-economic development of the Olot region and its surroundings and the high number of infrastructures, including airports, that could be affected by an eruption of the same type than the last ones occurred in the area, recommends to accept that volcanic threat could constitute a potential problem. In fact, if we apply the same protocol used by the USGS to evaluate volcanic threat in the USA to Olot we identify volcanic risk as moderate. Based on a spatial probability analysis of vent opening and hazard assessment of the area we develop an eruption scenario to illustrate the short and long term consequences of an eruption there and we discuss the implications of conducting risk assessment on those volcanic zones in which the probability of new eruptions could assumed as very low or even zero.

21b-P-01

The Lifetime of Volcanoes on the Japanese Islands for Reasonable Evaluation of Potentiality of Volcanoes

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In case of planning or construction of artificial facilities with long use time (several tens or a hundred years) having potential risk, evaluation of affection by natural phenomena including volcanic activity should be evaluated. Japan Meteorological Agency detected 108 active volcanoes and has been continued observation and research for prevention of volcanic disasters.The criteria of active volcano are 1) volcano erupted after 10ka or 2) with active fumaroles' activity now.By a point of view of reasonable evaluation of potentiality of volcanoes for artificial facilities, the authors studied the lifetime of volcanoes on the Japanese Islands.The study is mainly based on existing database, 1) Catalog of Quaternary volcanoes in Japan (Committee for Catalog of Quaternary Volcanoes in Japan, 1999) 2) Quaternary Volcanoes in Japan Ver.0.9E (Geological Survey Japan AIST, 2006).According this database of volcanoes, the followings are resulted. 1) There are 348 volcano groups and 722 volcanoes. There are 306 volcano groups and

577 volcanoes with data of eruption ages. 2) The activity beginning age of 282 volcano groups (92% of all volcano groups) are in Pleistocene. 3) Average of lifetime of volcano groups is less than0.4 million years. 4) Average of interval of activity of volcano groups is less than 0.2 million years. 5) Average of lifetime of volcano groups as less than 0.4 million years is significantly less than length of Quaternary 2 million years. The authors conclude that almost volcanoes on the Japanese Islands began their activity in Pleistocene and have their lifetime less than 0.4 million years and interval of activity less than 0.2 million years. So in case of reasonable evaluation of potential volcanoes for artificial facilities in the Japanese Islands, the scope should be the quaternary volcanoes. This study was supported with 9 Japanese Electric Companies, JAPC and EPDC.

21b-P-02

Correlation between Changes in Long Term Eruption Rate and Edifice Collapse, Magma Temperature, and Magma Geochemistry.

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Crater migration is important factor in volcanic hazard evaluation. Lateral migration of magma as dikes is the cause of vent migration. Assessment of lateral magma migration, which results in crater migration, is critically important to the long term safety evaluation of HLW geological disposal site. Previous assessment studies in HLW have been based on crater distribution by itself, but lateral migration of magma is affected by various changes in the volcanic activity. We need to understand and evaluate magma migration with its relation to changes in volcanic activities.

The study is focused on simultaneous changes between long term eruption rate and other changes in volcanic activity. Long-term eruption rate is related to crater stability. Volcano with central conduit has high eruption rate, and volcano without central conduit such as monogenetic volcano field has low eruption rate.

Edifice collapse events are found in volcanoes with high or increasing eruption rate, such as Vesuvius, Etna, and Hokkaido Komagatake.

Dacite magma temperature increase events are simultaneous to eruption rate increase in Mount St. Helens and Rishiri.

The start of silicic magma activity at predominantly mafic volcano is correlated to increase in eruption rate, which is found in Clear Lake and Higashi Izu. The change in geochemistry from silicic to mafic magma is correlated to decrease in eruption rate, which is found in Spirit Lake period of Mount St. Helens, and the younger stage of Ontake. The activity of mafic magma at predominantly silicic volcano is correlated to decrease in eruption rate, which include intracaldera activities of caldera volcanoes such as Kuttara.The evaluation method for lateral magma migration that incorporates these correlations, as well as stress field and geological structures, is proposed.

21b-P-03

GIS Database of Monogenetic Volcanoes in Kyushu & Yamaguchi, SW Japan

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The grasp for past volcanic activities, spheres and magma supply systems (magma moving range) is important issue concerned with long-term stability assessment for deep geological disposal.Previous database is mainly focused on the Quaternary volcanoes and is not enough for assessment of monogenetic volcanic group which have been active from Quaternary or before. Characteristics of monogenetic volcanic groups distributed in back-arc side of southwest Japan are summarized as follows, (1) Vents migrate for every eruption; (2) Each monogenetic volcano is distributed within a certain definite area. We constructed the GIS database focused on the monogenetic volcano in Kyushu and Yamaguchi district where many monogenetic volcanoes with variety of activities are distributed. The database is composed of information about monogenetic volcanoes i.e., location, age, geochemistry, previous literature etc. and basement geology, geophysical data and geodetic data. The inspection soft ware is ArcGIS and ArcReader of ESRI. Further data accumulation is useful for the study of space-time distribution of monogenetic volcanic groups. And that is effective for evaluate the prospective durability and spread of one.

21b-P-04

A Study Of Population Exposure To Tephra Fall In The Asia-Pacific Region

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As the global population increases, so does exposure to volcanic perils. In investigating the Asia-Pacific region, this study employs probabilistic methods to calculate and rank exposure of the population to tephra fall. A tephra advection-diffusion model, ASHFALL, simulates tephra footprints from each volcano in the region for a range of possible future eruption scenarios. Unpublished historical records from the Smithsonian Institution are employed to develop likely eruption scenarios and likely profiles of windspeed and direction with height are determined from NCEP/NCAR Global Reanalysis Project data. Exposure is inferred from population density and the impact of tephra fall from both local and distal volcanoes. The impact of the tephra fall is estimated from quantitative variables such as tephra thickness and the likely fatalities, injuries and evacuations. In contrast to previous studies, this work uses a broad range of probable eruption scenarios and, by incorporating the spatial variation of the tephra impact, calculates the threat *from* a volcano, as well as *to* a city from potentially multiple volcanic sources. Urban areas and volcanoes are ranked independently to evaluate the sensitivity of the results to different methods of determining exposure.

21b-P-05

Assessing the Tephra Fallout Hazard at Concepcion Volcano, Nicaragua: Numerical Modeling Using TEPHRA2

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Concepción has been the second most active volcano in Nicaragua in the last 120 years. It forms the NW side of the Ometepe Island in the Lake Nicaragua, where population is over 40,000 inhabitants nowadays. A number of VEI 2 eruptions have occurred in the last 50 years, requiring the eventual evacuation of two villages affected by the volcanic tephra. Major towns lie around this volcano in a radius no greater than 14 Km, which have been repeatedly affected by volcanic ash fallout and in a minor degree by volcanic gases. A vast number of people in the island rely almost entirely on farming activities, and consequently a major volcanic eruption involving a sustained ash emission may cause the economy of the island to collapse. Using the TEPHRA2 code we have modeled some scenarios, concerning VEI 3 and 4, for volcanic tephra fallout from Concepción volcano that are expected to take place in the near future. TEPHRA2 is an advection-diffusion model that describes diffusion, transport and sedimentation of volcanic particles for a stratified atmosphere (wind interpolation between atmospheric levels), particle diffusion time in the rising plume and settling velocities including the Reynold's Number variations along the particle fall. This model also accounts for topography. Local authorities in the island and civil defense, involved in the prevention and mitigation program of natural disasters in Nicaragua, will be provided with the modeled scenarios. This modeling effort will reinforce the decision making process during a potential volcanic crisis of Concepción volcano.

21b-P-06

A Statistical Method for Volcanic Hazard Assessment: Applications to Three High-Risk Volcanoes of Mexico

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The statistical analysis of volcanic eruption time series is an important step in the precise assessment of volcanic risk. The study of low-magnitude eruption sequences, containing larger data populations can usually be done using conventional methods and statistics, namely the Binomial or Poisson distributions. Unfortunately these series are usually confined to historical data, since the smaller eruptions do not leave long-lasting deposits. On the other hand, major-eruption geological records are usually incomplete and their occurrence dates and magnitudes may be uncertain. Additionally, the eruption occurrence rates may vary with time, i.e. may be non-stationary. Therefore time-dependent processes, or sequences including rare or extreme events involving very few data, require special and specific methods of analysis, such as the non-homogeneous Poisson process analysis or the extreme-value theory. A general methodology for analyzing these types of processes is proposed in this work with the purpose of calculating more precise values of the volcanic eruption hazard linking the historical and geological data series. This is done in four steps: First, an exploratory analysis of the repose-periods and eruptive magnitudes series is done complementing the historical eruptive time series with geological eruption data and thus expanding the data population. Secondly, a Weibull analysis is performed on the repose-time between successive eruptions distribution. Thirdly, the eruption occurrence data are analyzed using a non-homogeneous Poisson process with a generalized Pareto distribution as is intensity function. Finally, these results are compared with fittings obtained from conventional Poisson and Binomial distributions. The hazard or eruption probabilities of three active polygenetic Mexican volcanoes: Colima, Popocatépetl and Citlaltépetl are then calculated with this method and compared with the results obtained with other methods.

21b-P-07

Assessing Volcanic Debris Avalanche Hazards With a Simple Statistical Method

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From the 17th century volcanic sector collapses (SC) and debris avalanches (DA) have killed directly or indirectly about 20 000 people worldwide. We propose a rapid estimation of DA hazard frequency and affected area for little studied volcanoes with a simple model based on few data, such as volcano height above base, average volcano slope and surrounding topography. We analyse literature data, and then apply results to case studies.

SC average recurrence time is clearly linked with their construction and expressed by their shape. We observe that high-slope volcanoes (> 30°), edifices with Somma-like scars or those built on clear geomorphological boundaries may have a SC every several 100 y to few ky. In contrast, low-slope volcanoes (< 20°) or edifices built on a flat substratum are likely to experience a SC every several ky to few 10 ky.

The SC initial volume (Vi) correlates with the volcano height above base (Hc) and as Vi is about 80% of the deposit volume (Vd), we find $Hc/Vd^{1/3} \sim 1.3$. The surface DA (A) is linked to Vd and surrounding topography. For an almost flat, open topography $A/Vd^{2/3}$ ratio is about 60 and extends from 20 for confined to 200 for steep surrounding topography (> 5%). From the Vd, it is also possible to estimate L/H ratio (runout distance/height of fall) with L/H < 7.5 for Vd < 1 km^3 and L/H > 15 for Vd > 10 km^3. Knowing Hc and rough topography, it is possible to estimate the surface affected by a medium-sized SC.

This basic model can be simply applied to large regions and can be improved with additional information, such as magmatic discharge rate, volcano history, and tectonic setting. It provides a useful first step and a framework for building up a more robust hazard assessment.

21b-P-08

Linkage of Eruptions and Earthquakes in the 9th Century along Boundary Between East-West Japan

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In Japan, historic documents including disasters for some 1500 years have contributed to the understanding of historic eruptions and earthquakes. We are now reviewing these records combined with geological data and reports of excavation of remains aiming to reconstruct the history of eruptions and seismic activity for a long-term prediction. As a result, we recognized linkage of big eruptions and seismic activities in the 9th century over 800km long crossing Japan Arc. In the 9th century there were big eruptions at Mt. Fuji, Izu-Oshima, Miyakejima, Niijima, Kozushima, Niigata-Yakeyama, and Mt. Chokai. These volcanoes sit on a North-South trending zone. Besides these magmatic eruptions, at Yatsugatake volcano, debris avalanche occurred probably invoked by a strong shock in 887AD, and it successively changed to a flood, which flowed down along the Chikuma River.In addition, we confirmed that seismic activities ranging from Magnitude 7 to 8 were very likely to have taken place along the Itoigawa-Shizuoka active fault system (in 841 or 762AD), Nagano fault system (887AD), Echigo Plains (863 AD), Shonai Plains (850 AD), Akita Plains (830AD) and Nankai trough (887AD) .Geologically this seems to be a surface expression of East-West compression along eastern margin of the Amurian Plate (eastern margin of Japan Sea - Echigo Plains - Shinano River - western margin of the Fossa Magna - Nankai trough) over 800km and Mt. Fuji - volcanoes on Izu arc. We can point out similarities of volcanic and seismic activities occurred during the last 50 years with those in the 9th century in their source areas and manners.

21b-P-09

Geological and Petrological Approach for Long-term Eruption Prediction: Case Studies of Tarumai and Hokkaido-Komagatake Volcanoes in Southwestern Hokkaido

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Long-term eruption prediction for two active volcanoes in SW Hokkaido, Tarumai and Hokkaido-Komagatake, is discussed on the basis of detail eruptive history and temporal evolution of magma plumbing system. These volcanoes have repeated eruption since 17th century. Geological research reveals age, eruptive volume and style of each eruption for long duration of these volcanoes to revise magma-discharge stepdiagrams, which show relationships between time and cumulative eruptive volume. In each volcano, active and dormant periods can be recognized. Active periods has continued for several hundreds years after several thousands? years dormancy. Initial largest eruption was followed by several medium and small eruptions in each active period. In addition, it seems that total eruptive volume of the active period is similar in each volcano. This suggests that magma supply rates are nearly constant, and that magma had accumulated to form magma chambers during the dormant period. According to the stepdaigrams, it can be estimated that enough volume of magma has already discharged in these volcanoes. Detail petrological analysis clarifies structure of magma plumbing system and its temporal evolution. The initial eruptions of the volcanoes were triggered by injection of mafic magma into voluminous felsic magma chambers. After the injections, compositionally zoned magma chambers were formed to produce following medium-small eruptions. Due to these repeated eruptions, major magma type, felsic one, has been exhausted in Tarumai volcano and cooled to contain nearly 50% crystals in Hokkaido-Komagatake volcanoes. These geological and petrological analysis suggest that the present states of the volcanoes must be in the latest stage of the historic active period. We may predict that considerable scale of magmatic eruption could not occur in near future, and that dormant period would start soon to accumulate felsic magma for next active period.

21b-P-10

Volcanism-induced Tsunamis and Tsunamiites

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As can be deduced from the 2004 Indian Ocean disaster, tsunamis can cause large amounts of casualties. For the assessment of future risk posed by tsunamis, it is necessary to have sufficient information for understanding past tsunami events. Recent work on tsunami deposits has provided new information on paleotsunami events, for instance about their recurrence interval and the size of the tsunamis. Tsunamis are caused not only by earthquakes but also by volcanic eruptions. The 1793 Mayuyama tsunami is one of the cases. Because volcanogenic tsunamis occur less frequently than earthquake-related tsunamis, it is even more important to find and study geological evidence for past eruption-related tsunami events. In this study, eight recent case studies on volcanism-induced tsunami deposits are reviewed. These regard the tsunamis related to the Managua, Santorini, Aniakchak, Komagatake, Kurakatau, Vulcan, Karymskoye and Tavurvur eruptions. The most distinct feature of these tsunami deposits is a "pumiceous sand" layer. This is a mixture of pumice and beach sand; both are transported and deposited inland by a tsunami. The possible origin of the pumice in the layer is drift pumice, reworked pumice, and primary pumice fall-out during the tsunami run-up. This unique sediment layer is often observed in near-source tsunami deposits of volcanic origin. Chronological correlation of tephra and tsunami deposits provides a rare opportunity to study the tsunami-generating process during the eruption. Volcanism-induced tsunami deposits are informative, especially for studies of eruption-related tsunamis that occurred in the prehistory and useful to evaluate future risks due to tsunamis of volcanic origin.

21b-P-11

CO_2/H_2O Ratio of Magmatic Gas Estimated from the Analysis of Fumarolic Gas; Implication to Tatun Volcano, Taiwan.

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On dormant volcanoes without historical eruption, the forecast of eruption is important for mitigation of volcanic disaster. The H_2O and CO_2 are dominant gas species dissolved in magma. Their contents in magma are important factors of magmatic eruption. Because the solubility of CO_2 is much less than that of H_2O, CO_2 is selectively released from magma relative to H_2O. The CO_2/H_2O ratio emitted from degassing magma is expected to link with the eruptive potential of dormant volcanoes. For example, a high CO_2/H_2O ratio suggests the early stage of magma degassing or a continuous supply of CO_2 rich magma to chamber brought by a deeper magma source. In this study, $^{36}Ar/H_2O$ ratio of fumarolic gas is correlated with $\delta^{18}O$ of H_2O. Comparing the correlation with the correlation between CO_2/H_2O ratio and $\delta^{18}O$, the CO_2/H_2O ratio is evaluated. Applying this method to Tatun volcanoes in Taiwan, the CO_2/H_2O ratio was estimated to be 0.03. A similar application to Kusatsu-Shirane and Hakone volcanoes in Japan gave us 0.006 for CO_2/H_2O ratio. The high ratio of Tatun volcanoes suggests the magma is enriched in CO_2 relative to the magmas underlying Kusatsu-Shirane and Hakone volcanoes.

21b-P-12

The Most Recent Eruption of the Tatun Volcanic Group Near Metropolitan Taipei, Taiwan: Inferred From Juvenile Volcanic Ashes in the Taipei Basin Deposits

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Over two and half million peoples in the metropolitan Taipei are living with the Tatun volcanic Group (TVG) in northern of Taiwan. Moreover, one fifth of them lived at the foot of the TVG hill. The volcanic pyroclastic flow and/or lahar could rush down the slop, if the TGV is reactive. The serious hazard not only of human lives but of regional economies in these densely populated areas shall occur. An effective and reliable volcanic hazard mitigation is absolutely mandatory. However, volcanoes are pretty complex system, hazard mitigation can be achieved by applying numerous techniques, based on reliable data base. How to understand the most recent eruption of the TVG will be much important hint for prediction the future activity of eruption. Over 5000 mm heavy rain per year in the TVG area could result the highly erosion and weathering on the surface. They caused the original eruptions records were incompletely preserved. The Center Geological Survey of Ministry of Economic Affair handled to drill more than 20 wells in the Taipei basin to investigate the subsurface geology of basin in last ten years. These continuous core samples offered the best materials to investigate if any volcanic ashes deposited in the basin in the last 100 kyrs. The samples in every 20 cm from the core top of the Kuantu well (KT-1) and the Shihlin well (SL-1) were collected for above purposes. Total more than 350 samples have been tested. The juvenile volcanic ashes with the identical chemical compositions and pumice morphology were firstly identified in the late Pleistocene Sunshan formation in SL-1 and KT-1 cores, respectively. According to the radiocarbon (C-14) ages of core samples, the time of the tephra layers in both cores was extrapolated around 18.6 kyrs C-14 B.P. This new founding of eruption event is much younger than that of previous understanding as around 200 ka. This air-fall ash deposits found in the core directly demonstrated that there had been re-active in the TVG in the last 20 kyrs. This new founding well coincides with three historical records of submarine eruptions in the northeastern offshore of Taiwan. Then, we strongly suggest that a program of the volcanic hazard reduction should be considered around the metropolitan Taipei and northern Taiwan.

21b-P-13

Long-Term Seismic Monitoring of the Tatun Volcano Group, Northern Taiwan

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The Tatun Volcano Group (TVG) is located at the northern tip of Taiwan, near the capital Taipei and close to two nuclear power plants. Because of lack of any activity in historical times it has been classified as an extinct volcano, even though more recent studies suggest that TVG might have been active during the last 20 ka. In May 2003 a seismic monitoring project at the TVG area was initiated by deploying eight three-component seismic stations some of them equipped with both short-period and broadband sensors. During the three years observation period local seismicity mainly consisted of high frequency earthquakes either occurring as isolated events, or as a continuous sequence in the form of spasmodic bursts with local magnitudes typically smaller than 2. Mixed frequency events were also present during the same period, even though they occurred only rarely. Low frequency events in the form of tornilos and monochromatic signals were recorded by a number of stations and after an analysis of their attenuation characteristics it was concluded that they represented oscillations of a crack filled with ash laden gas. Additionally, tilt episodes were recorded by the broadband sensors probably indicating deformation of the Chihsinshan edifice (the highest peak in the TVG area). Unusual seismic activity was also recorded during April 24, 2006 when an earthquake of magnitude (ML) 3.5 occurred and was followed by a number of aftershocks. A long-term monitoring effort that combines geophysical, geodetic and geochemical techniques is currently under way and will hopefully allow a more thorough evaluation of the magmatic system status of TVG.

21b-P-14

Phreato-Magmatic Eruption as Future Hazard in Densely Populated Area Around Ceremai Volcano, West Java

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Ceremai volcano (3.078 m a.s.l) is located about some 25 km southwest of Cirebon the nearest big city in the area. This is an A-type active strato volcano in West Java, Indonesia. This volcano is surrounded by three major densely populated towns namely Kuningan, Cirebon and Majalengka and hundreds of villages around its flanks. The latest activity during the 20th century which is claimed as phreatic eruption took place in 1938. The previous eruption products show that they are resulted from the magmatic and phreato-magmatic eruptions originating from both central crater and flank eruption vents. The central crater produces pyroclastic flows, pyroclastic falls and ejected rocks, lava flows and lahars as the secondary process, whereas the flank eruption vents produce lava flows, pyroclastic cone (tuff rings) and maars. Most of the flank eruption vents produce lava flows, but farther to the gentler and flat plain areas the eruptions tend to form maars associated with pyroclastic cone. As the evidence, this kind of maar with pyroclastic cone has occurred in densely populated area during the 19th century called Setu Patok, about 7.5 km south of Cirebon.The geologic structures in the area is probably the most responsible media related to the presence of several flank eruptions produce pyroclastic cones/tuff rings, lava flows and maars around Ceremai as the nearest active volcano. The activation of Baribis Fault that passes through this region may trigger the eruption of Ceremai volcano, result in the formation of parasitic cones, maars and or tuff rings in the future at several the adjacent towns and villages those are now very densely populated.

21b-P-15

Exposure Risks to Local Populations from Volcanic Gas and Ash Emissions at Consistently Degassing Volcanoes in Vanuatu

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Extensive measurements of volcanic sulfur dioxide (SO_2) have been made at Ambrym and Yasur volcanoes (Vanuatu) since 2005 utilizing the miniature ultraviolet correlation spectrometer 'FLYSPEC.' These measurements are being used to further understand the exposure risk of volcanic airborne emissions presented by Vanuatu's multiple and consistently degassing volcanoes to its local inhabitants. Volcanic SO_2 emission data, in addition to weather and geographic data, are analyzed and compiled in a geographic information system (GIS) as a volcanic gas and ash hazards map. These analyses are part of the development of tools for use by the Vanuatu Department of Geology, Mines, and Water Resources (DGMWR) in their volcanic hazard mitigation efforts.

21b-P-16

Phreato-plinian Activity, a Previously Unrecognized Hazard at Jocotitlan Volcano, Central Mexico.

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Jocotitlan strato-volcano, located in the central Trans-Mexican Volcanic Belt is largely composed of a succession of lava flows and domes, in addition to pumice fallout and interbedded pyroclastic flow deposits that reach far into the lacustrine plains of the northern Toluca valley. Previous studies at Jocotitlan revealed the existence of a debris avalanche deposit dated at 9690±85 y. BP (Siebe et al., 1992). This volcano is still considered extinct by the local population, although its last minor eruption occurred only. 680±90 y. BP. Accordingly, this volcano should be considered dormant, and presently in a state of repose. Such types of volcanoes, when reactivated, are particularly hazardous. For this reason, stratigraphic studies of this volcano were reinitiated. Our investigations focused on a Late Pleistocene (radiocarbon results are pending), up to 7 m-thick phreato-plinian sequence that is best exposed ca. 5 km to the SW, NW, and NE from the summit. There, dry and wet surge deposits are intercalated with plinian pumice fallout. A map showing the distribution of these deposits, as well as a detailed stratigraphic characterization and its implications will be presented. A repeat of such a high-magnitude eruption in this densely populated area would have catastrophic effects. Phreatomagmatic surges could directly impact more than 133,000 inhabitants in the towns of Atlacomulco, Jocotitlan, Acutzilapan, etc. in the immediate surroundings of the volcano. Further away, unfavourable wind directions could produce ash fallout in larger cities, such as Mexico-City (80 km distance) or Toluca (45 km distance), where it would affect important infrastructure and millions of people. A first step toward the reduction of potential hazards should consist in raising the awareness of the local inhabitants, many of which do not recognize Jocotitlan as a volcano but just as a "mountain". A next step should include production of a hazards map.

21b-P-17

The 1913 Plinian Eruptive at Volcan de Colima, Mexico

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Volcán de Colima is located in the western portion of the

Trans-Mexican Volcanic Belt (MVB). It represents the youngest active volcano of the N-S aligned Colima Volcanic Complex (CVC). The most recent explosive eruption of Volcán de Colima occurred on January 20, 1913, producing a Plinian column. A new study of the 1913 deposits indicates that the eruption began with vulcanian explosions that generated Merapi type pyroclastic flows (4 km long) toward the S-SW ravines. The eruption continued with more frequent explosions that produced Soufrière type pyroclastic flows (9.5 km long). During the most explosive phase of the eruption several pyroclastic flows (ash, pumice and scoriae) and accompanied pyroclastic surges developed. The pyroclastic flows reached as far as 13-15 km around the volcano. During this phase a 25 km high Plinian column established during several hours. The material was transport to the NE up to a distance of more than 720 km and covering an area of 165,000.00 km^2. The re-estimated volume of the 1913 eruption is ca. 1.9 km^3 (0.7 km^3 DRE). A future eruption of Volcán de Colima will pose in danger more than 250,000 people that live in ranches, villages, and cities within a radius of 30 km of the volcano.

21b-P-18

The Bayesian Event Tree for short- and long-term Eruption Forecasting (BET_EF) at Campi Flegrei, Italy

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We present the implementation at the Campi Flegrei caldera of the Bayesian Event Tree method for short- to long-term Eruption Forecasting (BET_EF). The analysis has been carried out in the framework of the DPC_V3_2 Campi Flegrei project, funded by Italian Civil Protection. Past data, physics and volcanological models, expert opinions and monitoring information are the input of a single tool that merges them to estimate short-term (useful for managing volcanic crises) and long-term (useful for land-use planning) probabilities of all possible events in which we may be interested in. The code also explicitly evaluates both aleatory and epistemic uncertainties. In particular, we show the long-term volcanic hazard assessment due to ash fall at Campi Flegrei, accounting for possible different sizes of eruption and vent locations, and how this estimation changes in time depending on the monitoring measures and the state of the volcano.

21b-P-19

Quaternary Calderas in Java Island and its Proximity, Sunda Arc, Indonesia

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Volcanic hazards are major threat for the densely populated Java island of Indonesia. Among fifty Quaternary volcanoes here, some are known for causing among the deadliest volcanic hazards in human history. Caldera-forming super eruption is the most devastating one, and therefore studying calderas gives significant contributions for long-term volcanic hazard mitigation. Our study reveals that several Holocene calderas are present, i.e. the Krakatau, Sandsea, Ngebel Lake, Raung and Kawah Ijen calderas, and possibly the Panaitan caldera just off west Java. Moreover, Pleistocene calderas are also present, i.e. the Danau, Sunda, Pangkalan, Geger Halang, Dieng, Ngadisari, Tengger, and Ijen calderas. Caldera-forming eruptions occur in all sections of Java volcanic arc, despite crustal compositions vary from continental in the west to oceanic in the east. The Krakatau and Panaitan are exceptionally located within an active crustal extensional regime, while other calderas are located within regional compressive structures. The Dieng caldera was formed during a period of transition from the backarc-ward migration trend of volcanic arcs since the Tertiary into a trench-ward migration during the Quaternary. Caldera's primary magmas show a more evolved composition than primitive basalt and they experience advanced fractional crystallization that elevate silica contents up to 72% (only 63% SiO_2 for normal volcanoes). The Ngebel Lake and Tengger calderas in east Java have high Sr/Y signature that may represent a basaltic parent rather than mantle as their source of silicic magmas. Quaternary calderas have low $^{87}Sr/^{86}Sr$ values, suggesting that crustal influence is not significant. Evidence from Krakatau, Dieng, Tengger, and Ijen suggests that once a super eruption occurs within a volcano, the next super eruption is likely to occur again. Implications of these findings on long-term volcanic hazard mitigation are discussed.

21b-P-20

Huge Caldera-forming Eruptions and Associated Disasters

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About 30 caldera volcanoes of Quaternary age are known in Japanese Islands. Twenty percent of them include active volcanoes within the caldera. Huge volcanic eruptions that form caldera gush $10^6 km^3$ or more of magma. Such eruptions occurred about once per 10,000 year in Japanese Islands during the late Quaternary period. Many of the eruptions were chiefly originated from a source in Kyushu and influenced throughout the Islands. One of the eruption occurred at the offshore of the south Kyushu 7300 years ago, which spouted the Plinian eruption column at first, then the large-scale pyroclastic flow called Koya was generated afterwards. The Koya pyroclastic flow traversed the sea, landed into Kyushu mainland, and swept away people's livings in the Jomon period that prospered in the Southern Kyushu region at that time. Large-scale pyroclastic flow is a catastrophe as the civilization is destroyed. The similar eruption occurred in the Aira caldera at the northern part of Kagoshima Bay 28,000 years ago and in Aso caldera at the central part of Kyushu. The volcanic gas discharged along with such large-scale eruption brings abnormal weather of global scale, and causes the temperature decrease in the

troposphere and surface of the earth. The huge eruption brings disasters not only to the region where the pyroclastic flow reaches but also to the entire earth.

21b-P-21

Origin of Volatile Components in the Aira Pyroclastics, SW Japan: Why and How did Catastrophic Pyroclastic Eruption Take Place?

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The Aira pyroclastic eruptions are typical examples of the Late Pleistocene catastrophic eruptions. Inclusions within phenocrysts from the Aira pyroclastics and the basement sedimentary rocks were investigate.

The phenocrysts contain inclusions of glass, F-apatite, corundum, Fe-S and carbonaceous materials. Some carbonaceous inclusions contain high concentrations of boron. δ ^{13}C values range from -26 to -31‰. These features are characteristics of marine sediments, suggesting that the felsic magma supplying the Aira pyroclastics interacted strongly with surrounding Shimanto belt sedimentary rocks during magma stoping and subsequent storage in the magma reservoir. Concentrations of carbon and sulfur in Shimanto Belt pelites show the following tendency with increasing thermal metamorphism: Carbon concentrations change little from low grade metamorphic rocks to cordierite hornfels (about 0.55 to 0.50 wt%), but decrease dramatically in migmatites (0.10 wt%). In contrast, sulfur concentrations decrease sharply from the lower grade rocks through cordierite hornfels to migmatite (from ～ 0.48 wt%, to 0.17 wt%, to 0.02 wt%). Maximum concentrations of fluorine and sulfur in glass inclusions in Osumi pyroclastic deposit phenocrysts are F=0.10 wt% and SO_3=0.04 wt% in the lower part, F=0.16wt% and SO_3=0.04 wt% in the middle part, and F=0.22wt% and SO_3=0.20wt% in the upper part. Although concentrations of volatile components in glass inclusions in the upper part are greater than those in the lower part, some glass inclusions in the lower part are vesiculated. This suggests that the lower part of the magma reservoir was oversaturated with respect to volatiles. We infer that most of the volatiles (C, F, Cl, S) were supplied from surrounding Shimanto Belt sedimentary rocks. The magma are oversaturated in volatiles in both the upper and lower parts of the magma reservoir. Magma bumping and catastrophic eruptions then took place. This phenomena is analogous to that of the 1986 gas eruption in Lake Nyos.

21b-P-22

Preliminary Study on Active States of Volcano and Classification of Volcanoes in China

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Based on the examples of active volcano, the active states of volcano in different stages are summarized, and the conceivable mechanism are discussed in this paper. The physical situations of volcano active, from magma supply to eruption, can be divided into 3 phases (stages), magma supply, formation of conduit, instability and eruption.

The volcano threat in China can be sort into 7 levels: they are safety, attention, stand by, alarm, threat, hazard, disaster, accordingly the active states, the inferred major mechanism and their primary physics are discussed in this paper.

Basic on the dangerous levels of volcanoes, the activity of volcanoes in Chinese continent can be classified into 4 kinds: (1) in active phase, such as Changbaishan Volcano, which is in process of active, (2) evidence in potential active stage, such as Tengchong volcano, stay in the late-dormancy stage, although has potential threat of eruption, (3) in some possibility of potential eruption, includes Wudalianchi, Jingpohu, Haikou Volcano, geophysical and geochemical signals are in the background category, (4) the situation are not clear up to now, they are Aer Shan, ErKe Shan, Xiao Gulihe, Wulanhada, Keluo, Turphan, west Tianshan, Ashi, and Kekexili.

21b-P-23

Possible Volcanic Hazard in Active Collapse-calderas of The Mexican Volcanic Belt

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Several collapse calderas are reported in the Mexican Volcanic Belt (MVB), these range in age from Late Miocene (ca. 7 Ma) to Quaternary (ca. 0.1 Ma), and have sizes from ca. 30 km to less than 5 km. The largest (10-30 km) are semi-circular depressions produced mostly by collapse that were associated with large-volume ignimbrites, and the smaller (<5km) are summit structures formed by explosion and sector collapse of stratovolcanoes that produced small-volume ignimbrites. From the literature, it is well known that the active life of a large (>10 km in diameter) collapse caldera could be in the order of 1 Ma. For instance, Yellowstone caldera had the last collapse eruption about 600 Ka, but is considered still active posing a serious volcanic risk. On this basis, three Quaternary calderas of the Mexican Volcanic Belt should be considered still active, since their caldera collapses and corresponding ignimbrites occurred within 500 Ka; these are, La Primavera with 100 Ka Tala tuff, Los Azufres with no reported major ignimbrite but associated to 300-140 Ka dome-related pyroclastic flows, and Los Humeros-El Potrero nested caldera complex with 460 Ka Xaltipan and 100 Ka Zaragoza tuffs. La Primavera caldera had the last dome activity just 30 Ka ago, Los Azufres erupted the last pyroclastic products also at 30 Ka, and Los Humeros-Los Potreros complex last activity was at 20 Ka. All these centers are close or within heavily populated areas, in particular La Primavera, which lies next to Guadalajara City with a population of about 3 million. However, these calderas have not shown evidence of unrest, but they still show intense fumarolic activity and high heat flow, in such proportions that have been utilized as active or potential geothermal power plants. These calderas should be considered as a

potential volcanic hazard in the long term.

21b-P-24

Urbanization and Volcanic Hazard: Case Guadalajara City, Mexico

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Guadalajara is the second largest and important city in Mexico, with intense industrial, economic, cultural and tourist activities; located in the Atemajac Valley 1,567 meters above sea level (masl), the Guadalajara Metropolitan Zone has a 4 millions population and 1,412 km. Very near to this city is La Primavera Caldera Complex of Pleistocene age, 11-13 km diameter, and represents a source of geological hazard to people living more and more closer to the Caldera. Located western of Trans-Mexican Volcanic Belt (TMVB), have been extensively studied mainly by geothermal power purposes. Extensive geological, geochemical and geophysical studies of this caldera have been carried out to understand their volcanic and magmatic evolution, subsurface structure and underlying magma chamber.

Constituted by comenditic domes annular distribution with elevations of 1,550 to 2,200 masl, pyroclastic flows and ignimbrites with intercalations of lacustrine and fluvial sediments that overlays a Tertiary volcanic sequence constituted by andesites, lithic tuffs and ryolites. The local basement is a granodioritic intrusive probably of Miocene age. The Guadalajara city is settled in a volcanic plain with pyroclastics and plain relief with some hills of gentle slopes.

The possibility of re-starting volcanic activity is not far and the effects on the people, the industrial and economic activities would be catastrophic. For this reason is necessary the volcanic and seismic monitoring of the caldera and an appropriate information to the people now living in this area. The Federal Commission of Electricity made volcanologic studies and actually passive seismic monitoring to elaborate hazard maps of volcanic eruptions and municipalities territorial arrangement of the zone.

21b-P-25

Extension of The Unknown Alkaline Volcanism in The Southeastern Colombia

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In the Andean Northern Volcanic Zone (NVZ) it has been recently established an extended alkaline back-arc, located east of the main arc, from 2° N to 1° S Latitude, covering parts of Colombia and Ecuador. In southern Colombia, the Neogene volcanism outcrops in the Upper Magdalena Valley in the Huila department and the Northwest of Putumayo department and it is defined by monogenetic pyroclastic cones and rings associated to lava flows and pyroclastic fall deposits, and a couple of small compound volcanoes. This volcanism is possibly the result of the collision against the Colombian Trench of the Carnegie Ridge coupled with the Malpelo Rift beginning 8 Ma ago (Borrero and Castillo, 2006). This collision permitted the formation of slab window into the subducted Nazca plate (Borrero, 2006). The back-arc volcanism located to the east from the main Colombian Quaternary arc (Northern Volcanic Zone) occupies an area of about 3,200 km^2 with ancient eroded cones and recent well-conserved cones especially around the San Agustin and Pitalito towns. In this area of Colombia there is a long term risk of formation of new volcanic vents that would affect the population of the area, about 300,000 inhabitants, and the petroleum industry. Although the volcanic activity of this area is under-estimated in comparison with that of the big stratovolcanoes of the main arc, the activity still continues, and a good example is that this volcanism could be in relation with the “climatic change” proposed by the anthropologists like the main factor for the complete disappearance of the Agustinian culture in the XIII-XIV? Centuries placed in different settlements around the San Agustin area, this culture is worldwide recognized by the big statuary built with volcanic products.

Session 2-2

22-O-01

The Heisei-eruption of Mt. Unzen and Measures against Volcanic Disasters

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The Heisei-eruption of Mt. Unzen had started on November 17 in 1990. Dangerous volcanic phenomena such as pyroclastic flows and debris flows had occurred intermittently, and brought about 44 people casualties and 2,511 destroyed houses. Though no one had experienced and estimated the occurrences of such events, soon the central government of Japan and the Nagasaki prefecture government started to ensure the appropriate measures for reducing expanding disaster. The first approaches were preparation of Hazard-map for evacuation and execution of temporary works .To enhance effects of measures, they had developed many new methods such as unmanned construction and executed the measures to mitigate or prevent debris flows and pyroclastic flows disaster. The measures against the volcanic disaster were executed by considering three viewpoints as follows; (1) The measures must be able to cope with various phenomena. (2) The measures should be executed in short term. (3) The safety of workers had to be ensured. Also inhabitants, academic persons and administrators were in corporate and coped with the Mt. Unzen volcanic disaster. As a result of the execution of the measures, the safety zone of life in Shimabara city was restored and communities were reconstructed. Therefore the preventive measures in Mt. Unzen were evaluated successfully. Recently we see and hear the destruction of social infrastructures by volcanic disaster in many cities in the world. I will introduce the actual

prevention works, especially the Volcanic Sabo works executed by the central and local governments in Mt. Unzen as a model case of the mitigation or prevention measures against the volcanic disaster. As the useful information on the measures, I hope the knowledge of my presentation will be applied in various parts in the world in future.

22-O-02

Erosion and Sediment Discharge of Tephra-covered Dillslopes

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Volcanic eruptions create a radical alteration of the hydrologic and erosion regime of the surrounding areas. The hydrologic and erosion phenomena caused by volcanic eruptions have been investigated at many volcanoes, including Usu volcano, Sakurajima volcano, Mount St. Helens, Merapi volcano and Unzen volcano. Sediment yield and sediment discharge have been found to decrease with time except for volcanoes with continued volcanic activity, such as Sakurajima volcano. Sakurajima, which is an active volcano, has been continuously in action with frequent and lively small scale ash eruptions since 1972. Through this long period of volcanic activity, the flanks of Sakurajima volcano became thickly covered with volcanic ash. Moreover, the flanks have experienced accelerated erosion, and consequently debris flows have often occurred in the rivers located around them. From 1991 to 1995, the Unzen volcano had many pyroclastic flows; the flow deposits widely and thickly covered the flank of the volcano and created a radical alteration of the hydrologic and erosion regime of the areas. As a result, debris flows have frequently occurred in the rivers on the flank of the volcano and the topography of the basins has much changed. In this paper, the hydrologic and geomorphological characteristics associated with volcanic eruptions were examined mainly on the basis of field observations and measurements at the three volcanoes, Sakurajima and Unzen volcano in Japan and also Merapi volcano in Indonesia.

22-O-03

Lahars and Rain-Triggered Floods at Tapachula, Chiapas, Mexico derived from the Tacana Volcanic Complex

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The Tacana Volcanic Complex (TVC) is located at the international border between Mexico and Guatemala. The complex is surrounded by numerous towns including the City of Tapachula in the Mexican side and the City of Tacana in the Guatemalan side. The TVC has been built during the past 200,000 years with the formation of the Chichuj, Tacana, Las Ardillas and San Antonio volcanoes. Tacana and San Antonio, have produced several explosive eruptions during the past 40,000 years. Most pyroclastic material of these eruptions has been remobilized along the Coatan river to the west, and the Suchiate river to the east, of the complex. Both rivers debouched into the Pacific Ocean. Volcaniclastic sedimentation along the Coatan River has formed a 13-km long alluvial fan, on top of which, was founded the City of Tapachula (180,000 inhabitants). Extraordinary rains produced by Hurricane Stan in October 2005, produced several landslides that increased the sediment load of the Coatan river flow and its erosion capabilities. The flood caused the worst natural disaster in Tapachula's history destroying four bridges, the railway tracks, 10 neighborhoods, 2,000 houses, and affecting 100,000 people. The flood also eroded parts of the alluvial fan exposing its stratigraphic record that consists of at least ten lahar deposits emplaced during the past 25,000 years as supported by C-14 dates. The upper part of this sequence consists of at least ten sediment-laden streamflow deposits emplaced during the past 680 ± 45 yr BP. Strikingly, seven of these deposits have occurred during the past 100 years, including the 2005 event. As attested by eyewitness accounts, some of these events were larger than the 2005 Stan flood, however, they did not caused any damage to Tapachula whose urban growth toward the Coatan river started three decades ago.

22-O-04

Optimized Countermeasures for Debris Flow and Landslide Mitigation in Mayon Volcano, Philippines

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The Philippines as part of the Pacific Ring of Fire and Asia-Pacific Typhoon Belt is highly prone to sediment-related disasters because it has abundant rain during the rainy season, it is also prone to earthquakes with numerous fault lines, it has 220 volcanoes, 22 of which are active while major parts of the country are mountainous. Human lives and properties are put at risk because settlements are located on unstable slopes, at the foot of the mountains or alluvial fans, floodplains and deltas for easy accessibility and economic reasons. The most recent destructive debris flows and landslides which destroyed properties and caused loss of close to 1,000 lives happened around Mayon Volcano when Typhoon Durian made landfall over Eastern Philippines in November 2006.

The Government of the Philippines has developed a two-pronged approach to disaster mitigation, that is, the Structural and Non-Structural Mitigation. The Philippine government has institutionalized its disaster preparedness and mitigation program through the establishment of the National Disaster Coordinating Council (NDCC) under the Office of the Civil Defense (OCD) of the Department of National Defense (DND). Structural Mitigation includes employing proven engineering interventions such as dikes, levees, retention ponds, sedimentation basins, sabo facilities, channeling, river walls and revetments and floodways which are the most conventional approaches made to counteract the negative effects of disasters. Adequate non-structural support as a comprehensive approach to flood and sediment disaster mitigation necessitates the establishment of an effective forecasting, monitoring, and warning systems. Capacity building workshops for

disaster response teams as well as providing them with the necessary equipment to effectively respond to disaster emergencies greatly minimizes threats to both lives and properties.

The increasing occurrences of water and sediment related disasters make the government recognize the urgency and importance of countermeasures to mitigate the impacts of debris flow and mudflow disasters.

22-O-05

Countermeasures of Mt. Merapi Volcanic Disaster Mitigation; Strategy Development Planning to Prevent Infrastructure

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Merapi activities today is long period activities than previous activities. More than one year Merapi has erupted. The bigger eruption at June 8 and June 14-15, 2006 gave impact to infrastructures surround Merapi mainly at Gendol River. Pyroclastics attacked South Merapi area with range 8 kilometers from vulcano and rainfall lahar flood 18 kilometers. Water resources, public recreation area and some facilities are victim of Merapi activities. The volcanic material prediction at South Merapi is more than 7 million metric cubic with potential flow to Gendol River 3 million metric cubic, Woro River 2 million metric cubic and Krasak River and Boyong river 1.5 million metric cubic. Several SABO Dams have overload capacity and will give additional problem with flood velocity. Some action now is progressing to reduction risk, hazard and disaster with build new SABO Dam and Dam and River normalization. Observation and analysis on potential hazard area will give picture of frequencies and consequences of possibility risk and hazard. Satellite imagery and weather satellite data are very useful to predict pyroclastic cloud, ash and lahar direction and affected area, and implementing on Potential Risk, Hazard and Disaster Mapping as one of main action to predict and prevent people and infrastructure from possibility of destruction based on field observation and analysis. The results of mapping, observation and analysis will developed into strategy development planning. Two ways radio communication is one important supporting system to inform situation and condition to public. This communication is a part of early warning system to inform mitigation and response plan include coordinating evacuation when disaster come. All information is distributed to government, community and public as risk reduction programs. The government, community and public will make initiative and strategy to protect their infrastructures and properties.

22-O-06

Ruapehu Lahar 18 March 2007 - Lessons for Hazard Assessment and Risk Mitigation from 1995-2007

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The moderately large lahar caused by a collapse of a tephra dam occurred 11 years and 4 months after the situation that led to it was first recognized. This allowed sufficient time for emergency managers, other agencies and the Government to learn about the hazard and risks, plan and prepare for them, and practice an integrated emergency response plan. Scientific understanding developed progressively and significantly, and early involvement of a wide range of agencies and the media was encouraged with frequent meetings, for most of the period. This encouraged transfer and updating of knowledge, developed interagency relationships, helped educate the emergency response community (and others), and provided a forum for a mitigation strategy to evolve in the face of difficult, sometimes controversial mitigation options.

Decisions about mitigation options were based primarily on maximizing public safety and long-term utility in a valley subject to frequent, sometimes large, past and future lahars. These decisions, which had a significant political component also considered option suitability in a national park-world heritage setting, and practicality. They were made in a logical sequence as the time before the lahar would occur was poorly constrained, and drew on formal and informal risk assessments.

A best-practice alarm system based on acoustic flow monitors was installed with expert input from the US Geological Survey. Following modeling to predict the worst case lahar, a sabo structure was built to protect a highway and other vulnerable infrastructure and a river system near-by, and a key highway bridge was raised and strengthened. Response agencies each prepared their own emergency plans which were then integrated and practiced over 3-4 years. Successful execution of the plan needed commitment and preplanned backups. Response on 18 March proceeded smoothly.

22-O-07

Potential Impact of Post-Eruption River Channel Aggradation on Infrastructure

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Both eruptive and non-eruptive processes can deposit large volumes of erodible volcaniclastic sediment on the outer flanks of stratovolcanoes and on surrounding terrain. Pyroclastic flows, debris avalanches, and lahars are particularly efficient in concentrating sediment at the heads of rivers draining such volcanoes. If the volume of sediment mobilized by rainfall and snowmelt runoff exceeds the transport capacity of the rivers, channels will respond by widening, aggrading, shifting laterally, and periodically avulsing for tens to hundreds of kilometers downstream. Such effects may not show up in downstream reaches for several years after an eruption, but they can persist for decades. Channel responses to sediment loading by a late 18th century dome-building eruption at Mount Hood (USA) and by the 1991 explosive eruption at Mount Pinatubo (Philippines) provide direct evidence of the potential magnitude and timing of river sedimentation responses. Nearly 20 m of vertical channel aggradation occurred within a decade 61-87 km downstream of Mount Hood by purely fluvial deposition, and it took nearly a century for the river to incise to its

pre-eruption level. In rivers draining Mount Pinatubo, where much larger sediment volumes were imposed on the landscape, hundreds of small lahars augmented normal fluvial deposition and accelerated aggradation. Vertical aggradation as great as 40 m and lateral bank-erosion rates as high as 3 m/min occurred along rivers 10 to 40 km downstream from the volcano within two years of the eruption. Downstream impacts were huge-entire towns were buried and destroyed; major bridges were washed away; blocked tributaries periodically released natural dambreak floods; hundreds of square kilometers of agricultural land were backflooded due to disruption of lowland drainage networks; and regional road systems became impassable. While primary volcanic hazards are generally well anticipated in mitigation plans and warnings to at-risk populations, the more delayed and persistent distal effects of post-eruption (or post-debris avalanche) channel aggradation are commonly overlooked.

22-O-08

Variations in Community Vulnerability to Lahar Hazards of Mount Rainier, Washington (USA)

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As the 1980 Mount St. Helens eruption showed, volcanoes pose significant threats to U.S. Pacific Northwest communities. Although past eruptions of Mount Rainier have been less frequent and explosive than those of Mount St. Helens, increasing urbanization on lahar deposits in the South Puget Sound lowlands makes Mount Rainier a significant regional threat to life and property. Lahar hazards downstream of Mount Rainier have been identified and publicized by the USGS for more than a decade. How communities have chosen to develop and function in lahar-hazard zones downstream of Mount Rainier varies considerably, and these variations determine their vulnerability, defined here as the exposure, sensitivity, and resilience of social, economic and infrastructure systems. Identifying, understanding and communicating variations in community vulnerability are critical if emergency-management and land-use practitioners and policymakers are to effectively manage, and hopefully reduce, local risks.

To demonstrate how community vulnerability assessments can complement hazard assessments, warning systems and outreach efforts, a case study is presented on the variations in vulnerability of incorporated cities within Pierce County, Washington, to Mount Rainier lahar hazards. Geographic information system (GIS) tools are used to integrate hazard scenarios and socioeconomic characteristics of the region, including information on land use, land cover, population and demography, cultural assets, economic assets and critical infrastructure. Statistical analyses are used to identify regional trends and outliers of community vulnerability. Results indicate that community exposure and sensitivity to lahar hazards varies considerably for the eighteen cities in Pierce County that occupy lahar-prone land downstream of Mount Rainier.

22-O-09

Mapping Lava Flow Hazards at Mt Etna Using Numerical Simulations

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The lava flow hazard on Mt Etna by means of the MAGFLOW cellular automata model was evaluated. This model was developed for simulating lava flow paths and the temporal evolution of lava emplacement. The effects of rheology and cooling are included in the model. MAGFLOW represents the central part of an extensive methodology for the compilation of hazard maps related to lava invasion at Mt Etna. Hazard map was realized by simulating a number of lava flows from a set of initial data (a record of past eruptions) and with different parameters of the volcanic system in a meaningful range of variation. We assumed a preliminary zonation for identifying possible emission regions with the highest probability of opening. After that, a set of reference values for the parameters of the simulation model based on the knowledge of past eruptions was estimated. So, MAGFLOW was used to determine for each emission region the area that can be invaded by lava flows originated from sample points located in that region. Last step was to assign the probability of lava invasions to interested region, calculated on the basis of the simulated lava flows. Resulting hazard map shows areas that likely would be affected by future volcanic activity and is extremely useful to people living nearby to judge for themselves the relation between potentially dangerous areas and their daily lives. The assessments are also critical for planning (1) long-term land-use; and (2) effective emergency-response measures, especially when a volcano begins to show signs of unrest.

22-O-10

Increasing Preparedness Through Volcanic Vulnerability and Risk Mapping

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Volcanic disasters are increasing in frequency despite improvements in hazard assessment and monitoring. More people and infrastructure are exposed to volcanic hazards and the populations affected and economic losses are also rising. Hazard assessment of active volcanoes in populated areas has only limited value without accompanying vulnerability and risk analysis, which takes into account the circumstances of those citizens threatened by a future eruption. Here we present the results of preliminary fieldwork in two islands of the Eastern Caribbean (St. Vincent and Dominica), designed to develop a method for producing vulnerability and risk maps that are created using currently available data sets and based on stakeholder needs. Key to this is

stakeholder engagement via semi-structured interviews and questionnaires with a number of different end-users – emergency managers, planners, aid agencies – to understand how they define risk and vulnerability and ascertain what factors they would like included in the vulnerability and risk maps. Another focus is to establish which data sets can be used as a proxy for the vulnerability factors chosen, and to develop a method of quantifying these factors through the creation of a vulnerability index that may be mapped and combined with hazard data. Potential sources include local census data for socio-economic and demographic factors, in addition to remote sensing data for land use characteristics. All the data will be incorporated into a GIS to assist stakeholders in rapidly mapping and analysing volcanic vulnerability and risk, and providing users with a tool to make informed decisions both before the onset of volcanic unrest and during volcanic crises.

22-O-11

An assessment of Japanese Mitigation Systems on Volcanic Disasters by Reviewing Hazard Maps, Mitigation Plans, and Risk Analyses

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More than 60 volcanic hazard maps have been published for 33 active volcanoes among the 108 active volcanoes in Japan. There are two maps of Komagatake (1983) and Tokachidake (1986) in Hokkaido published before 1990, nine maps after the 1991 eruptions of Unzen, and 22 maps after the 2000 eruptions of Usu and Miyakejima. Apparently large eruptions greatly increase the concern for volcanic hazards. Earlier maps were academically rigid, however recent maps have been designed to be understandable with plain explanations of volcanic terms. This is especially so with revised maps. According to the Disaster Countermeasures Basic Act, 1961, the Basic Disaster Management Plan is promoted by the national government, and a Disaster Management Local Plan is to be promoted by each local government. However, only five local governments of 25 prefectures neighboring active volcanoes have established specific volcano disaster countermeasures. Others mention volcanic disasters within storm and flood countermeasures or general disaster countermeasures, and another six have no special countermeasures for volcanic disasters. This contrasting unconcern is somewhat related to budget-making policies. Real-time hazard maps with probability tree algorithms for forecasting volcanic events are needed for effective volcanic disaster management. For this purpose, volcanic hazard maps, volcano disaster countermeasures, and assessments of volcanic threat analyses have to be completed. However, no assessments of volcanic risk analyses have yet been carried out by any local government in Japan. Although the reasons are comprehensively complicated, local governments with the cooperation of volcanologists and the support of the local residents are urged to take action before the next eruption occurs.

22-O-12

Damage Impact Scenarios and Mitigation Measures in the Vesuvian Villages

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The paper reports part of the work developed within the activities of EXPLORIS (Explosive Eruption Risk and Decision Support) an international project supported by European Union to 9 Research Units of 5 different Countries. One of the main goals of the project was to develop tools capable to evaluate a reasonable estimation of the cumulative damage impact scenario consequent to a volcanic eruption of assigned intensity. A first attempt to the problem is here presented focusing its complexity and a possible path to model the numerous aspects concurring to the final result. A volcanic eruption is here assumed as a sequence of several events of different hazardous phenomena having characteristics connected to each other and distributed in time and space. The model here presented has been so far calibrated on a specific level of eruptive intensity: the Sub-Plinian I like. It has been chosen since this eruptive scenario intensity is the reference for the Italian Department of the Civil Protection to prepare the Civil Protection Plan for the vesuvian villages involved in a potential eruption of the Mount Vesuvius in Campania (IT). The model, integrated in a Geographic Information System of the territory impacted by a potential vesuvian eruption, taking advantage by specific a Event Three and Vulnerability Functions of cumulative damages on the buildings, develops a tool able to control the progressive impact on the Humans and on the Structures up to the final impact scenario. The results can be useful either in the preparation of the Civil Protection Plan or during the Emergency Phase.The research investigates possible mitigation measures to be adopted; in the presentation, by using the model, the sensitivity of some mitigation measures on the reduction of the impact is shown.

22-O-13

Vulnerability Analysis of the Power-Distribution Infrastructure in Western North Island of New Zealand to Ashfall from Mt Taranaki/Egmont

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The Taranaki Region is unique in New Zealand, because it is the only location where hydrocarbons (oil, condensate, natural gas, and related products) are produced at commercial levels. Continued production in these areas is dependent on local power generation and transmission. The region is also the location of major hydrocarbon-fuelled electricity generation resources and hosts major power transmission lines and substations that impact on the supply of electricity to the industrial areas further north. Also located on the west coast of the North Island is the 2518m andesitic stratovolcano of Mount

Taranaki/Egmont. Through analysis of tephra layers in lakes and swamps an extensive history of volcanic eruptions has been constructed to derive a probabilistic-based ash fall forecast for Taranaki. Given the historical evidence (including in NZ) of ash fall impacts on electricity transmission, the new volcanic hazard information allows the first probabilistic risk assessment critical electrical infrastructure elements to ashfall. This was carried out using current wind patterns and focusing on critical sites, including: grid exit points, gas production facilities, substations, generation facilities and other major industrial sites. Critical ashfall thickness for the 33kV distribution network are estimated to be 1mm wet and 2mm dry fall to generate "creepage" and "tracking" over the insulator, leading to flashovers and possible local or national blackouts. All of the critical points identified have probabilities of >10% for impact of 1 mm ash over the next 50 years (16% average over 50 years, or, 0.42% average annual probability), although power generation and substation resources east of the mountain have the highest probablilities of impact (25% for 1 mm over 50 years, or, 0.6% average annual probability).

22-O-14

Potential Impacts of Volcanic Ash on Wastewater Systems and Telecommunications Infrastructure in New Zealand

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Serious volcanic ash impacts on wastewater systems are rare. This is because few eruptions have deposited large amounts of volcanic ash (>5mm) in urban areas. Urban wastewater/stormwater systems have therefore not often been tested in terms of large quantities of volcanic ash entering the systems. One notable occasion where a significant amount of ash has entered the wastewater system was at Yakima during the 1980 Mount St Helens eruption. At the processing plant, grit removal screens began to suffer vibrations, pipes became blocked and pumps began to struggle and fail to move the huge amount of solid matter (15 times the usual amount). But would this type of effect be shared by other systems? Auckland, New Zealand's largest city, is subject to being affected by ashfall from numerous sources, and has a shared stormwater/waste water system. Any ashfall on Auckland therefore has a huge likelihood of entering the wastewater system, potentially damaging or blocking pumping stations, and causing further damage at the processing plant. This presentation illustrates recent experimental work that aims to determine the potential for damage of this type in New Zealand. Another lifeline addressed in this presentation is telecommunications infrastructure. In addition to ashfall downing telephone lines, it has the ability to affect exchanges – whether indirectly (e.g. through power cuts), or directly through impacting exchange buildings, smaller exchange boxes or cell-phone exchanges. Exchanges tend to be well sealed, except for the air-conditioning intakes. This study looks at air-conditioning unit performance in ashfall conditions, and the potential consequences of inhalation of ash by these units during ashfall.

22-O-15

Evaluation of the Design Target for the Volcanic Sabo Planning Based on the Cumulative Frequency of Eruptive Magnitude

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In ordinary public works projects, it is essential that the target of the project is set by decision makers in order to clarify the plan as public interests. While ordinary disaster prevention projects, such as flood control or erosion control, have stochastic methods to configure the design targets, volcanic hazard mitigation projects is hardly applicable such methods, because most volcanic activity recurs less frequently than rainfall. When we get enough data of historical eruptions with actual events and estimated volumes of volcanic products, a stochastic method is available as well as ordinary public works. The authors attempted to evaluate the target phenomena in the volcanic Sabo (erosion control) planning based on the cumulative frequency of eruptive magnitude. Mt. Fuji had erupted 110 times in 3,200 years in which we had data of vents, phenomena and scales of every eruption. The target events of the Sabo project are lava flows, snow-melt lahars, and ash-fall induced debris flows, each considered for engineering control to reduce hazardous impact. The authors designed the target scale of the project will be accurate for 70 percent of expected eruptions. The estimations are; $18\times10^6m^3$DRI as lava flows, $10\times10^6m^3$DRI as ash fall eruptions that will cause generation of rainfall induced debris flow. Debris flows will frequently occur in mountainous areas where more than 10 cm ash accumulates, as shown by historical studies of 1707 eruption.

We studied alternative structural measures against target events and eruption magnitude. Snow-melting lahars and rainfall induced debris flows could be controlled by arrangements of series of check dams, sand pockets and training levees, but it will be hard to control the target volume of lava flows.

22-P-01

Lahar and Streamflow Hazards Associated with Heavy Rainstorms on the Southern Flank of Pico de Orizaba (Citlaltepetl) volcano, Mexico.

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Pico de Orizaba or Citlaltépetl (5675 m a.s.l.) is an active volcano located in the eastern part of Mexico. It has a well defined conical form and the summit is permanently covered by snow. Pico de Orizaba (PO) is the southern end of an N-S oriented volcanic chain that divide the Mexican Altiplano from the Coastal Plains of the Gulf of Mexico. This orographic barrier, capture the wet wind currents from the ocean, producing high intensity

rainstorms during the rain season. The volcano is dissected by a heavy hydrologic net, especially on the southern and eastern flanks where the slope is higher. Along the gullies, prehistoric and historic lahar and streamflow deposits can be found. The most recent event occurred on June 5th of 2003. After heavy rainstorms, water and sediments stream flows descended along the rivers. The damages caused by the stream flow were of high consequences, especially at the low lands, where floods cover partially the cities of Nogales and Mendoza. The major damages occurred after the rupture of a gas pipe line impacted by the water with catastrophic consequences. The PO pyroclastic deposits on the higher flanks constitute an important potential source for the generation of debris flows and lahars. The granulometric characteristics of the deposits change along the course of the rivers. The fine fraction (<0 phi) was separated from the coarser one (>0 phi) and produced non cohesive deposits over the flood plains on the urban zones. An estimated population of 500,000 is living on the Orizaba-Nogales-Ciudad Mendoza area. Also is occupied by a complex infrastructure consisting of oil and gas pipe lines, high voltage electricity lines, highways and railroad ways. For these reasons is very important to make hazards and risk studies in order to mitigate the consequences of future events.

22-P-02

Utilization of Landform Classification and Topographical Information for Volcanic Hazard Mapping

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A hazard map in micro scale is needed for the mitigation of disasters. In order to produce it, an effective use of “land condition map” and “land classification map” are required. These maps clarify natural conditions of the land by landform classification in large scales using aerial photo interpretation method. To grasp the meaning of landform evolution point of view, it is useful for understanding the disaster characteristics of that land. In this presentation, the author explains the relationship between the damaged areas by volcanic activity described in hazard maps and the landform classification described in “Volcanic Land Condition Maps”. As these “Volcanic Land Condition Maps” are recently produced vector data format, then it is easy to analyses combing variable national land data using GIS. In this study, the author analysis the relationship between landform classification and disaster damages to combine the vector data of “Volcanic Land Condition Maps” and information of the estimated volcanic disaster area in hazard maps using GIS, especially case of Bandai Volcano and Adatara Volcano.In additionally, topographical information is important for estimation of volcanic hazard. In this study, the author analysis the relationship between the results of topographical analysis using various grid size DEM and landform classification, and between same analysis results and estimated volcanic hazard.

22-P-03

Impacts of the 2006 eruption of Merapi Volcano on Agriculture and Infrastructure in the Yogyakarta Region, Indonesia

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This poster presents first-hand observations of the impacts of the 2006 eruptions of Merapi volcano, in central Java, on agriculture and infrastructure of the Yogyakarta region. A field team visited the region during the period 22 June - 5 July 2006, representing the University of Canterbury’s Natural Hazards Research Centre, GNS Science, the New Zealand Earthquake Commission and the New Zealand Ministry of Civil Defence and Emergency Management. In addition to coverage of agricultural and infrastructural impacts, this poster also includes a description of the volcanology of the 2006 eruptions, and a discussion of the Indonesian response to the volcanic crisis including evacuation and crisis management. Agriculture received the most damage of any economic sector, mostly due to the close proximity of a significant number of farms to Merapi volcano. Impacts on crops varied with tephra thickness, as well as by crop type and plant maturity. Up to 100% of crops were lost in some locations. Significant weight loss in cows was observed, due to animals eating tephra covered fodder. Overall, impacts to infrastructure were slight. Lifeline utilities and other infrastructure exhibited a higher degree of resilience than expected, probably due to the absence of rain as the eruption occurred during the dry season. Deposits left from the eruption on the upper, south-facing slopes of Merapi still pose a severe lahar threat to the floodplains below in times of heavy rain. Despite their relatively small size, the 2006 eruptions of Merapi caused two deaths, the destruction of most of the village of Bebeng/Kaliadem, the displacement of tens of thousands of people, and significant impacts on the agriculture of the region. We conclude by attempting to draw lessons for New Zealand from our findings.

22-P-04

Agricultural Fragility Estimates for Volcanic Ash Fall Hazards in New Zealand: Towards Better Damage Ratios for the Riskscape Program

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This poster presents estimates of expected damage ratios (fragility functions) for the agricultural sectors of pastoral farming, horticulture, and production forestry in New Zealand when they are subjected to volcanic ash fall hazards of varying intensities. The fragility functions are derived from a combination of 1) literature review of existing fragility estimates, 2) development of new functions based on consultation with agriculture and volcanic hazards experts in New Zealand, and 3) field observations of impacts to agriculture from the 2006 eruption of Merapi volcano in Indonesia (Kaye et al., this

conference). Different functions are given for production loss (loss of valuable commodity produced by the farm, e.g. milk) and asset loss (non-saleable assets on the farm, e.g. milking sheds). This differentiation recognises the different resilience levels of the many different components of agricultural production on New Zealand farms. Changing vulnerability of agricultural sectors with seasonality is identified as an important component in determining fragility of agricultural commodities to an ashfall, and the functions provided here are thusly weighted according to the seasonality of each sector. A theoretical example of a scenario ashfall event at Mt. Taranaki/Egmont Volcano is given to illustrate the application of the provided fragility functions.

22-P-05

Lahar Hazard Zonation on the Western Flank of Villarrica Volcano Using LAHARZ

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Villarrica volcano is a stratovolcano located in the Southern Volcanic Zone of the Andes of Chile and is one of the most active volcanoes in South-America during historical times. One of the main hazards related to the volcano is the generation of lahars triggered by sudden ice/snow melting during eruptive events. therefore, the determination of lahar hazards zones is crucial for emergency and land-use planning. LAHARZ is a software developed by the USGS that predicts the inundation zones by lahars in a semi-empirical way, using the data of 27 lahars at 9 volcanoes. Some of the drawbacks of the model are the use of a limited number of volcanoes and the mixture of different types of flows (very different order of magnitude, and cohesive versus non-cohesive lahars) in the calibration, thus the model may not be accurate for other volcanoes, together with some simplifications such as the assumption of the occurrence of just 1 pulse for during a lahar event. The lahar deposits of the 1971 eruption on the western flank of the volcano are non-cohesive with an estimated volume in the order of 5-10 x 10^6 m^3. The data of the section areas of lahars with this characteristics and the section of the deposits studied, are very much smaller than the predicted by LAHARZ, therefore a new coefficient for the cross section area was chosen to test the model. The results show a better fit of the model with the field data and also a better sensibility to the DEM resolution, that also will allow to better simulate the response to a lahar event to topographic changes due to the deposition of various pulses within the same event.

22-P-06

Mudflow Prediction Model Regarding Spatial Distribution and Physical Properties of Tephra

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In order to reduce loss of human lives and many kinds of economical losses resulting from a secondary mudflow caused by a post-eruption rainstorm, it is critical to evaluate risk of mudflow occurrence from volcanically disturbed watersheds immediately after an eruption. The immediate and accurate evaluation leads to optimum choice of countermeasures, appropriate early warning and precise hazard map, all of which could minimize the additional damages to cities on erupted volcanoes. Previous reports have already shown that in general the thicker tephra deposition is likely to generate mudflows by rainstorms after volcanic eruptions. In this study, the authors have developed the physical and spatially-distributed prediction model of water and sediment discharge which takes into account the spatial distribution and the geotechnical properties of tephra. This numerical model was applied to the Miyakejima volcano, which erupted with emissions of fine-grained tephra and suffered from mudflow disasters. There, water and sediment discharge from slopes and torrents were measured after the eruption and geotechnical properties were examined. The developed model allows us to determine all the parameters from topographic surveys and existing geotechnical tests. This means that it is fully-deterministic model with no need to calibrate because it had been designed to intend to predict the risk of mudflow before the first attacks. The authors have shown that water and sediment discharge from volcanically-disturbed watersheds could be simulated by this model if the spatial distribution of soil properties of deposited tephra were given appropriately according to the field measurements and the geotechnical tests using the material which was sampled at the site. On the other hand, it is the way to obtain appropriate spatial distribution and geotechnical parameters easily and promptly that is necessary to be developed.

22-P-07

A Study of the Trial Production of Synthetic Volcanic Hazard Map Using GIS

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Disaster mitigation must be complicated because of the complexity of volcanic disaster. To do effectively the disaster mitigation is to maintain the information related to volcanic disaster. However there are a lot of purposes which presented volcanic hazard map is made, it is not integrated. Paper based volcanic hazard map has limitation of information. This paper shows the possibility the integrated volcanic hazard map using GIS.GIS allows to data mining effective geographic information. The integrated volcanic hazard map using GIS helps to make a disaster prevention plan. It is easy to maintain and to disclose the volcanic formation

22-P-08

The Downstream Flowing Conditions of 1926 Volcanic Mudflow of Mt. Tokachi, Hokkaido

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The downstream flowing conditions of 1926 volcanic mudflow of Mt. Tokachi volcano, located in central Hokkaido, were clarified based on interviewing survived eyewitnesses and examining remnant of the mudflow deposits. Tokachi volcano is one of the most active volcano in Japan and large-scale mudflow with 144 deaths occurred as an aftermath of the eruption on May 1926.

As a result of our researches, we have conjectured that the hydrograph of the mudflow had one peak and the main flow kept on flowing for from 20 to 30 minutes, and the flowing mudflow was hot and its density was from 1.6 to 1.7 g/cm^3. The flow in the upper stream area with the velocity from 11 to 17 m/s, the depth from 4 to 6m was capable of serious destruction of houses at the foundation. After that, the mudflow separated to two directions in the lower stream area, the flow to the east area was capable of destroying houses and faster than the flow to the west area. These results suggest that the 1926 mudflow flowed down in various behavior in the downstream flooding area.

22-P-09

Heat Transfer into Shelter buried by Pyroclastic Flow and Insulation Methods

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Insulated shelter structures can effectively protect humans from pyroclastic flows. In this study, heat transfer was simulated between a pyroclastic flow and a shelter amended with different types of thermal insulation. Temperature conditions were evaluated inside the Kaliadem village shelter, which was buried by the main body of pyroclastic flow from the Mount Merapi eruption on June 14, 2006. Numerical analysis of one-dimensional steady state, two-dimensional steady-state, and non-steady-state heat transfer into the shelter was performed to determine the effectiveness of insulation materials lining shelter doors, the changes in doors' thermal conductivity, and the effects of door thickness on temperature reduction. Results show that average temperatures inside the shelter greatly exceed human body temperature in every scenario except when doors are lined with cellulose insulation. When the shelter is buried by a pyroclastic flow with a maximum temperature of 800 °C, the average temperature inside the shelter can be reduced below human body temperature if double doors are lined with at least 80 cm of cellulose, or triple doors are lined with at least 50 cm of cellulose.

22-P-10

Hydrographic Changes in Mudflows Caused by the March 18,2007 Crater Lake Rupture on Mount Ruapehu

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Quantifying hydrographic changes in mud flow as a function of travel distance is essential for better understanding of mud flow behavior and mechanisms. In this study, we created mud flow hydrographs based on particle imaging velocimetry-analysis of Mount Ruapehu mud flow images that included serial static pictures from automated cameras and video footage collected by New Zealand authorities and local television companies. We then analyzed changes in the mud flow hydrographs with travel distance. We characterized hydrographic changes based on the relationship between flow depth and velocity, Manning roughness coefficient, coefficient of velocity and topographic factors such as river gradient and river width.

22-P-11

Hyperbase of Volcanic Hazard Maps in Japan

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. "The Database of the Volcanic Hazard Maps of Japan" was published with DVDs in 2006 which was prepared by the collaborative efforts of members of the National Research Institute for Earth Science and Disaster Prevention（NIED) and members of Commission on Mitigation of Volcanic Disasters (established in 2004 after completing Hazard Map WG), The Volcanological Society of Japan, with the intent that the hazard maps will be utilized by administrative officials in charge of volcanic disaster prevention and researchers on volcanic disasters for the mitigation of damages. And now "the Hyperbase of Volcanic Hazard Maps in Japan" was released on the web to cover a wider range of concerned parties (http://www.bosai.go.jp/libray/v-hazard/index.html). The Hyperbase covers all the volcanic hazard maps of Japan and reference materials which are made to distribute to residents by municipalities, issued from 1983 to the present, including all editions. The number of digital images of 116 maps and 74 reference materials are available now. Each map and material includes two different sizes of image files; one is a small file for inspection on display and the other is high resolution images for print out in the original size. The former one is available for free download, but the latter one for free download requires simple registration. There have been 12,000 traffics to the Hyperbase for one year since May 2007, during which only low resolution images are available. High resolution images will be released soon. The Hyperbase is growing both in quality and in quantity with increasing number of maps and materials and successive improvements taking advantage of Web's characteristics from here on; for example, linking various related information such as disaster prevention plan made by municipalities.

22-P-12

Effects of Grid Interval Difference of Digital Map on Numerical Simulation Result of Lava Flow

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In order to carry out a numerical simulation of lava flow, a digitized landform or a digital map is needed. When a simulation is carried out, the grid interval of the digital map is determined empirically in many cases. Essentially, if the calculating area is simple geometric landform, such as a flat slope and a plane, the difference in a grid interval has an insignificant effect on the calculation result. However, in examination of the lava flow hazard map (Report of Hazard Map of Mt. Fuji Examination Committee, 2004), it was pointed out that the deposit area by the lava flow simulation is difference if the grid interval of digital map changes. In this study, for the purpose of understanding the effects of the grid interval difference of the digital map on the simulation results of lava flow, the some cases of lava flow simulation which the grid interval and the amount of lava flow were changed were carried out using the digital map of Mt. Fuji. And the correlation of the scale of the characteristic of landform, the grid interval, and the amount of lava flow was considered quantitatively. The results showed that the grid interval of digital map is larger, the deposit range of lava flow shortens, and flowing width widens. Moreover, it became clear that this tendency appears more notably, if the width of the macroscopic valley landform which is the main stream of lava flow is narrower on the original counter map.

22-P-13

Lava Dome Measuring System to Secure the Safety of Sabo Works

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It has passed 17 years since Mt. Unzen began to erupt in Nov. 17th 1990 and now the rehabilitation works have been progressing steadily. Although the dormancy of volcanic activity was declared in Jun. 1996, approximately one hundred million cubic meters of lava domes still exist unstably around top of the mountain.At present, structural measures have been executing from the lower reaches and the construction site will come up close to the lava dome. Therefore the collapse of lava dome or rock falls would be considered to make the workplace hazard. In order to intensify the security measures against such hazard, Unzen restoration work office has been observing the displacement of lava domes by electro-optical distance measuring system and rock falls by seismometer.The electro-optical distance measuring system, which has 8 reflection prisms are set on the lava dome, are observing from 2 observation points. The measuring distance between the reflection prisms and the observation points is about 2,500-3,800m. The electro-optical distance measuring instruments are TSP1201 (Produced by Leica), of which accuracy is measure distance times 3ppm.According to the observed data, the lava domes tend to shorten approximately 10cm average per year. From this tendency, the lava domes are considered to move downward and the lower part of them are pressured in terms of compressive force. So the lower part of the lava domes is presumed to become unstably, even the collapse of domes or rockfalls. By the result of an experiment test, we confirmed that seismometer can detect within the range of nearly 1 kilometer when the 8.6 tons weight of rock falls from the height of 1.5m.In order to ensure the safety of rehabilitation work, continuous observation by the above mentioned measuring system is considered to be indispensable.

22-P-14

Riskscape: A New Tool for Volcanic Hazard Risk Assessment in New Zealand

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We present the prototype volcanic hazard risk assessment component of the new Riskscape software, a HAZUS-like program being developed by GNS Science and the National Institute of Water and Atmospheric Research to assess risk from natural hazards in New Zealand. Usage of Riskscape is illustrated by applying the model to compute the risks posed by volcanic hazards to the Rotorua District in New Zealand and Mammoth Lakes, California in the USA. Riskscape facilitates quantitative estimation of the damage inflicted upon an inventory database by a suite of natural hazards present during a set of pre-defined or user-generated scenario events. Hazard models are chosen by the user to determine the hazard intensities of damaging volcanic phenomena at specified locations. As one example, tephra thickness is modelled by the user with the ASHFALL program (Hurst and Smith, 2004) within the Riskscape software. As another example, lahar inundation zones are pre-computed outside of Riskscape via a set of flow volumes with the LAHARZ software (Iverson and Schilling, 1998) and the resultant inundation zone polygons are available to the user within Riskscape. Once hazard intensities have been specified by hazard models, fragility functions specific to each hazard and inventory class are then applied to the selected inventory items (e.g. buildings, bridges, electrical transmission lines) to compute damage ratios. Probabilistic determination of the likely return period of each of the set of hazard intensities in each model allows quantification of relative risk in a probabilistic framework. Riskscape outputs tables and maps via a GIS-like interface to provide the end user with a more thorough, map-based understanding of the risks from volcanic hazards in their community. This allows better land-use planning practices, such as preventing the construction of new critical infrastructure items such as hospitals in high volcanic risk areas.

22-P-15

Ashfall and Tephra Problems on Volcanic Islands

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It is known that volcanic eruptions can produce a wide variety of hazards which can kill people and destroy property. In historical times, thick and widespread of ashfalls had been associated with many eruptions, for example, those occurring on volcanic islands such as Tambora (Indonesia) in 1815, Krakatau (Indonesia) in 1883 and Hekla (Iceland) in 1947-48 and 1970. The proportional impact on small volcanic islands is greater. Ashfalls are the most common of all eruptive phenomena. Ashfalls vary widely in their effects, depending mainly on the volume of material from the eruption and the duration or intensity of the eruption. Any one of these impacts causes difficulties and inconvenience during or after a volcanic eruption, but when eruptive activity occurs on a small volcanic island problems increase. Therefore, it is necessary to develop prevention and public awareness on volcanic islands with new technological tools. In the past years, GIS and numerical modeling of pyroclastic dispersal have become useful tools for risk assessment in volcanic areas. Geographic Information System (GIS) technology offers the opportunity for many interdisciplinary projects. It is useful to establish GIS-type mapping of hazards on islands with active volcanoes. This system permits efficient hazard mapping and display potential impact from general standard geological, geographical and meteorological data (topography, land cover and prevailing winds) and help in contingency and islands planning. The numerical modeling will help to display possible transport and deposition of tephra using the transport equation (advection-dispersion equation) to model the wind profile, atmospheric turbulent diffusion and particles sedimentation. The application of mathematical modeling to already available scientific data from several fields – together with GIS mapping - can lead to very useful expert advice to civil authorities and population living on volcanic islands. With GIS mapping, and modeling of ash fall coverage, we can determine which areas will be affected by future volcanic events. By superimposing volcanic hazard areas on volcanic island ashfalls dispersion, and other critical natural and infrastructure elements, in a spatially correlated project, GIS in association with mathematical modeling can provide an incomparable dataset to make decisions for the development, preparation, and emergency planning necessary for safe and sage cohabitation for active volcanoes. An integrated programme that combines mathematical modeling, GIS and scientific data will provide information from expert mode to civil authorities. This general approach is a key point for risk mitigation and will help the civil authorities to evaluate early warning, emergency management and land use planning for islands.

22-P-16

Follow Up on Vegetation Impact Over 2 Years of Rapid Degassing: Turrialba Volcano, Costa Rica.

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Turrialba Volcano (3340 m) is located at the southern end of the Mesoamerican Volcanic Arc. The summit area has three craters aligned NE-SW: Since the middle of 2005 one of the greater degassing events took place provoking serious effects on vegetation namely bushes and dwarf coverage around the W crater.On august 2006 a report was given to the national and international community due to the rapid burning and death of major tree species. Most of dwarf vegetation and small vegetation coverage rapidly disappeared thus affecting directly a fragile balance between flora and fauna. By February 2007 a growth in the area affected by gases was observed during a flight and documented as seriously affected. Photographs will depict differential effects on native and exotic species. Behavioral disorders in a community of coyotes were reported as well, related to acute impact of volcanic activity on their habitat. More changes in other species that inhabit the summit areas are have been observed. Moreover, pressure and impact from these coyotes on settlers, living in the low lands around the volcano, is also expected. A poster will illustrate areas of gas expansion and physical instability. It will also show areas where major impact on vegetation and fauna is taking place. At least one specific study is undergoing to determine the role played by dry and wet acid deposition in the low cultivated areas. Potato fields and grassland is qualitatively affected. Greater impact on these items may impact the local economy that depends heavily on their dairy industry and agriculture.At least one advance on the results from this study will also be presented.

22-P-17

Atmospheric Corrosion Due to Volcanic Emmisions from Poas Volcano, Costa Rica: Potential to Economically Impact Infrastructure

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Corrosion due to rapid environmental acidification derived from Poas volcano was qualitatively and quantitatively studied for 18 months. Metallic materials were exposed and documented on a routine basis. Damage to the physical properties of material due to rapid corrosion indicate an acid media that may be extrapolated to residential areas along the path of gases, in the direction of prevailing winds.It has been determined that in countries where corrosion is studied and their population is trained to mitigate this problem, economic losses could be reduced by up to 20 % of the estimated economic losses. Economic losses could be between 1.5-3.5 % of the national gross product. Volcanic emissions are rich in SO_2, HCl, HF, etc., which are corrosive chemicals. Minimal information is available about studies of corrosion velocity in volcanic zones and even less common are corrosion velocity studies in the vicinity of active vents. Atmospheric conditions depend on the values of oxygen, atmospheric humidity and atmospheric contaminants (SO_2, NaCl, NOx, etc.) Atmospheric corrosion is controlled by an electrochemical mechanism. Under dry atmospheric conditions metallic corrosion is negligible, in contrast, when metallic surfaces are humidified, corrosion becomes important. The electrochemical mechanism is possible through an extremely thin layer of humidity (a few nanolayers) where metal does not look wet; or alternatively through an aqueous film a few micrometers

thick, where metal looks wet. Depending on the type of metallic material, corrosion occurs after 60-80% relative humidity values, increasing corrosion velocity when the atmosphere is polluted. Our work presents qualitative and quantitative results from a corrosion velocity study developed near the crater rim of Poás volcano during 2001 and part of 2002. In addition, we will present the methodology that will be followed to obtain quantitative results in a corrosion velocity study for the following metallic materials: low carbon steel, stainless steel 316, cooper, aluminum and galvanized steel. A photographic follow up will be presented as well for illustrative purposes.

22-P-18

Gas Hazard Assessment in the Roman Province by TDL and Accumulation Chamber

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The city of Rome lies between the two Quaternary volcanic complexes of Mts. Sabatini, to the North, and of Alban Hills to the South. Both these volcanic areas are characterized by zones with a huge endogenous degassing and several accidents have occurred to people and animals in the last 20 years. CO_2 is the main component (up to 98 vol.%) of the gas emissions followed by H_2S (1-2 vol.%), and N_2. The Caldara di Manziana depression hosts the main gas manifestation of Mts. Sabatini. Here a total (diffusive and viscous) CO_2 release of ca. 160 tons/day from 0.15 Km_2 has been measured. The Colli Albani edifice extends to the south-eastern periphery of Rome. Its main gas emission zones are Cava dei Selci and Solforata di Pomezia. Cava dei Selci is an area located in the suburb of the homonymous village. CO_2 diffusive flux from the soil (from 6000 m_2) ranged between 25 and 5 tons/day in the last 7 years. The continuous monitoring of CO_2 and H_2S in air (1m) in the confining village has shown the frequent overcome of the (TWA and STEL) threshold limits for both gases. At Solforata di Pomezia a 44 tons/day CO_2 diffusive flux has been estimated from 1.9 hectares, with 0.5 tons/day of H_2S. On 2007, two multi-technique surveys have been carried out to estimate the total gas output of these three degassing sites, by measuring CO_2 and H_2S fluxes from the soil (by accumulation chambers) and the gas flux from bubbling pools. Moreover the CO_2 and H_2S concentration in air were measured by several TDL profiles. Results confirm the high gas hazard of these areas. Particularly in late afternoon and night, when wind strongly lowers, lethal concentrations are frequently reached by H_2S, whereas CO_2 remains at high but tolerable values.

22-P-19

Vulnerability of Populations Around New Zealand's Volcanic Centres

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Data on a range of variables that contribute to the vulnerability of an individual or community were collected for increasing radii from 5 major volcanic centres; White Island, Okataina, Taupo, Ruapehu and Taranaki, for a 15 year period. The aim of the study is to examine any changes in vulnerability with time and identify the greatest contributing factors. Are the residents who live around New Zealand's volcanoes become more or less vulnerable, and is this due to general population change or specific factors? The vulnerability variables investigated include usual population, children under 15 and adults over 65, ethnic minorities, educational, number of dwellings and gainful employment. The data from four censuses were analysed in a GIS to produce a series of maps showing the percentage change in each variable between each census year (1986, 1991, 1996, 2001) at varying distances from each volcanic centre (10, 25, 50, 100 and 200km). Findings from this analysis can assist local authorities and emergency management with public education, welfare and recovery planning.

22-P-20

Vulnerability of Rural Water Supplies to Volcanic Ash in New Zealand

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Volcanic ash is the most widely-distributed product of explosive volcanic eruptions, with even relatively small explosive eruptions distributing ashfall hundreds of kilometres from the volcano. It is well established that even small quantities of volcanic ash fall can disrupt water supplies. However, most studies in this area have focused on the urban environment, often on comparatively large-scale water supply, sewerage and storm water systems. In general, little attention has been paid to the impact of volcanic ash on rural water supplies.

Water demands of modern farms are wide-ranging, and include stock watering, irrigation and cleaning, as well as household supply; many aspects are vulnerable to volcanic hazards.

This poster presents the findings from our recent study of the vulnerability of New Zealand's rural water supplies to volcanic ashfall. The study considered dairy farms, sheep and beef farms, vineyards and orchards in Hawkes Bay, Taupo, the Waikato and Taranaki regions. Specific areas of interest were:

•An assessment of water sources in the different regions (relative proportions of surface water and groundwater) and critical demand periods;
•Vulnerable points in water supply, storage and distribution systems (such as intake structures, open ponds and stock watering troughs);
•Vulnerability of farm equipment such as effluent pumps to ash contamination using artificial mixtures of water and

ash;
•Critical water demand periods for different farm types and regions (seasonal vulnerability);
•Using New Zealand and international water quality guidelines for primary production to identify the water quality characteristics (eg pH and turbidity) at risk from ashfall contamination;
•Applying a simple model to predict impacts of ashfall on water quality;

Our findings will be used to develop mitigation measures before, during and after an ashfall.

22-P-21

Impact of Ruapehu Crater Lake Break-out Lahar at 18 March 2007 on River Channel Settings

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Impact of lahar (volcanic mudflow) induced by Crater Lake break-out of Mt. Ruapehu at 18th March, 2007, was investigated. Magnitude of the lahar flow was estimated at 1.2 million cubic meters. After flushing over the alluvial fan located in the eastern foot slope, the lahar flew into the Whangaehu River along the state highway 1 and crossed the state highway 49 at the Tangiwai Bridge located in 39km from the summit. At last the lahar has passed through the gorge channel toward the Tasman Sea. Water level gauge and automatic water sampler set up at Colliers Bridge located in approximately 70km from the summit have successfully monitored the lahar flow regime. Cross section and disturbance of the lateral bank along channel reach has observed immediately after the event. Water level of the lahar flow has attained to 4m high half an hour later than the lahar forefront passing. The lahar flow was a kind of hyper concentrated flow and it was composed by middle and small fragment at 60% in the upper reach of alluvial fan, small fragment and coarse sand at 80% under the Tnagiwai Bridge, and fine and coarse sand at 80% under the Colliers Bridge. The results suggest that the lahar flow has not only decreased the water level but also gradually changed in particle size containing from mountain to sea. Damaged vegetation of the lateral river bank and changes in channel morphology are reported based on the urgent field survey.

22-P-22

Tephra Fall Hazards in Chile Related to Fine Ash Transport and Sedimentation: Insights from Numerical Modeling

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According to the tectonic segmentation model of the Andean margin, discrete zones with widespread Holocene volcanism have been identified. In the particular case of the Chilean Andes, the volcanic zones present are Central (18-27°S), Southern (33-46°S) and Austral (49-56°S), where there have been registered 13, 27 and 4 volcanoes with historic activity (roughly from 18th, or even 19th century) for each zone respectively. It is relevant to note that around 90% of the Chilean population is concentrated between 33°S and 42°S. Explosive volcanic activity has occurred in all these segments; however tephra fall hazard studies are limited. Atmospheric circulation varies strongly with both latitude (18-56°S; more than 4000 km) and altitude, resulting in non-uniform patterns of tephra dispersion, transport and sedimentation. In this contribution, we investigate the potential consequences of Plinian-like eruptions in order to assess both which eruptive and which atmospheric circulation conditions will result in hazardous distal tephra fall accumulations in Chilean cities, as well as those Argentinian and Bolivian cities close to the Chilean border. We have used analysed meteorological data in an advection-diffusion model (TEPHRA) and particle trajectory calculations to simulate fine ash transport and surface mass accumulation. The eruptive parameters have been chosen according to records available from each region. Both inter-seasonal and inter-annual variability have been investigated.

22-P-23

A Cautionary Tale in Use of Sabo Check Dams from Gunung Merapi, Indonesia

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Sabo dams (or check dams) are frequently constructed within valleys to protect human lives and property from destruction by volcanic and non-volcanic geophysical mass flows. They typically give stability to a valley at a specific location and provide some storage potential for laharic debris behind them. They are also often used to support other infrastructure, including water reticulation systems and roads. They also can provide a local economic benefit through mining of the sediment trapped behind them for construction aggregate. Possible negative implications of these structures include their changes to a channel profile, particularly forcing channels into narrow “bottlenecks” and raising bed levels by up to 10 m (or more in some cases) at the point of the dam structure. Both effects reduce channel capacity – especially for high-energy flows with strong potential for superelevation. We present a case study from Kali Gendol on the southern flanks of Merapi volcano, Indonesia where a recently constructed Sabo dam had locally raised the channel bed by >10 m. This had also reduced the local valley slope through aggradation of sediment behind the dam and for several hundred metres upstream. Multiple partial dome-collapses at 12.00 hrs and 14.45 hrs on 14 June 07 fed two main series of pyroclastic flows. The first flow terminated just at the Sabo dam (4.5 km), while the second flow deposited up to 30 m of breccia within the main valley up to 7.5 km from source. At two main sites the largest flow(s) overtopped channel banks to spread large volumes of breccia up to 300 m laterally from the channel. The first spillover was located at a sharp channel bend as the flow initially entered a well-defined deep valley at an uninhabited area, c. 3 km from source. The second and most destructive

was directly at and 100 m upstream of the Sabo structure (c. 4.5 km from source). Here the pyroclastic flows spilled over into the Kaliadem area, causing the loss of two lives and destroying an observatory, and several houses and tourist facilities. From the Sabo site at Kaliadem the largest volume and extent of overbank deposition occurred, apparently due to channel fill behind the Sabo dam from earlier flows and pre-eruption sedimentation. We present the sedimentological properties of these pyroclastic flow deposits in relation to the flow axis and local topography and describe the geometry of conditions that most readily allow pyroclastic flows of this type to escape valley systems. This example throws a shadow onto the usefulness of Sabo dams in protecting lives at all places along a river system. Here the local impacts were highly influenced by rapid deposition and channel changes caused by the Sabo structure.

22-P-24

Volcanic Ash Fall Preparedness and Response at Seattle-Tacoma and Anchorage International Airports

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Airports are critical infrastructure elements that are particularly vulnerable to volcanic ash fall. Even minor ash fall events can completely curtail operations, damage aircraft on the ground, and cause maintenance problems for ventilation, water, electrical, and other systems. Clean-up is costly and requires specific techniques that do not exacerbate the abrasive and mobile nature of dry, fine ash. Ted Stevens International Airport (TSIA) in Anchorage, Alaska and Seattle-Tacoma (SEATAC) International Airport in Washington are two U.S. airports at risk of ash fall from multiple volcanoes. Most recently, TSIA faced the possibility of fallout from eruptions of Augustine Volcano in 2006. In 1992, an eruption from Mount Spurr closed the Anchorage airport for 20 hours during the busy summer-travel period. SEATAC has remained in a heightened state of readiness for possible ash fall during the current activity at Mount St. Helens.

Both facilities have developed emergency operations plans that detail pre-event planning, resource requirements, emergency response, and clean-up. Key concerns in these plans are the staging of adequate protective and cleaning equipment; handling and disposal of volcanic ash; employee safety and scheduling; and aircraft cleaning. Each airport has a clear understanding of how they will be notified by state or other government authorities in the event of a volcanic eruption and potential ash fall. Communication protocols with Air Traffic Control to minimize disruption to air traffic and to help anticipate required mitigation actions are in place. Ash fall events have been rare in the U.S. and most employees have no direct experience with the phenomena. As such, frequent review of the plan and reinforcement of essential hazard guidance, with the input of volcanologic authorities, is advised. Ash fall preparedness planning can also reinforce emergency planning and readiness for other natural and human-caused events such as earthquakes and chemical spills.

22-P-25

Volcanic Risk Assessments: Integrating Hazard and Social Vulnerability Analysis

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Despite advances in technology and the scientific understanding of environmental phenomena, losses from natural hazards appear to have increased. Evidence suggests this is not due to a significant increase in the number of severe natural events, but increasing human vulnerability. That is more people being placed at risk from environmental extremes due to population growth, poverty and other sociological pressures. Many current mitigation strategies tend to focus on the physical processes that underlie volcanic hazards but fail to fully consider the anthropogenic components of risk or their implications for framing mitigation and emergency response plans. An important component of most management strategies is the use of risk maps that provide information regarding the potential spatial distribution of a particular hazard from a given magnitude event. However, minimal demographic information and almost no socio-economic information is included within these maps, and the use of Geographical Information Systems (GIS) and remote sensing remains limited. A conceptually novel approach to volcanic risk management is required that integrates an assessment of both the geophysical hazards and socio-economic vulnerability. This research aims to develop such an interdisciplinary approach to volcanic risk mapping, using GIS, for two volcanoes; Mount Rainier, USA and Volcan Tungurahua, Ecuador. This will be achieved by exploring the geophysical characteristics of the two case-study volcanoes, using existing literature and current volcanic hazard maps. The social, cultural and behavioural factors that shape human vulnerability in the two socio-economically contrasting regions will be explored, using questionnaires and semi-structured interviews with key stakeholders. This methodological approach has been applied to fieldwork already conducted in the area surrounding Tungurahua. In addition, issues of whether such integrated hazard mitigation and emergency preparedness measures can be applied to the management of other natural and man-made hazards will also be considered.

22-P-26

Making Time-sequence Hazard Maps Based on Eruption Scenarios in Sakurajima

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When we establish a hazard mitigation plan according to multiple eruption phases of variable style in historical

evidence, it is quite difficult to forecast exact process of future eruptions or to estimate their magnitudes. Consequently, measures against them may tend to the largest eruption scenario to be on the safe side. One of the methods to settle this issue is construction of time-sequence hazard maps based on eruption scenarios. The authors tried to apply this method in Sakurajima Volcano which has two types of volcanisms; one is large scale plinian eruption with pyroclastic flows and lava flows that will occur after several centuries' quiescence; another is outbreaks of vulcanian and phreatic explosions that will continue for several decades long. Based on the studies of the historical events and geological characteristics, the authors classified thirteen eruption time-lines which include sequential occurrence of events and their scales, wherever possible. One of the typical scenarios is as follows; (1) detection of precursory activities; (2) consequent unrest and beginning of explosive eruption with ballistic projectiles and ash emission several months after; (3) approximately three hours after pyroclastic flow production, lava flows will start from diagonally flank vents continuing for two to three months before the eruption ceases. We estimated hazardous areas of every event along the time-line then made time-sequence hazard maps. The ongoing volcanic hazard prevention plan for Sakurajima established by local government was based on the largest eruption scenario. Because of this, local government will be reacting to unexpected and unanticipated volcanic activity of a different nature. To establish comprehensive mitigation measures against volcanic hazards, whole organizations should prepare each program in shared rule and common eruption scenarios.

22-P-27

On Impacts to the Local Communities by Future Eruption of Mt. Fuji and the Volcanic Sabo Project

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To estimate various impacts to the local communities from the future eruption of Mt. Fuji, the authors evaluated eruption scales of each volcanic event that were focused by geological inspections. The method is based on numerical simulations reflected by kinetic characteristics of lava flows or debris flows that are enable to indicate prone areas of inundations, estimating damages by overlaying property data on them. The amounts of direct damages were estimated from several hundreds billion to two trillion yen according to flow directions when the largest scale of lava flow occurs as seven hundred million cubic meter DRE. Furthermore, indirect influences are figured out as one hundred billion yen from disruptions of the highway and railway systems, more than six hundred thousand residents will be disturbed their livings and large numbers of factories and tourism industries will be severely interfered their yields. These damage estimations clarified the necessity of measures against volcanic hazards. Mount Fuji Sabo Office has been studying to establish the volcanic Sabo plan to attempt mitigating estimated damages from several cases of eruptions. The fundamental strategies of the project are as follows; (a) installation of structural measures such as sand pockets and check dams that will capture a part of lava flows, sediment of lahars and debris flows to decrease their volume or training dykes that will change flow directions, (b) narrowing inundation areas on the volcano foot to reduce direct damage to infrastructures, (c) assuring evacuation duration of local people by reducing arrival time of lava flows. Although it will not be easy to accomplish the project, the Sabo project around Mt. Fuji will perform mitigating various volcanic and sediment related hazards.

Session 2-3

23-O-01

A History of Lava Flow Hazard Mitigation Efforts in Hawai`i

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Since the Hawaiian Volcano Observatory was founded in 1912 by Thomas Jaggar, there have been many attempts to mitigate the lava flow hazards in Hawai`i. Jaggar himself was a strong proponent of diversion and building barriers to shield cities. The idea was considered strongly into the 1980s as a possibility for protecting Hilo, the largest town and port on the island, but is not now considered a viable strategy by Hawai`i Civil Defense In the 1970s and 1980s, qualitative hazard zones for lava flows were defined for the islands of Hawai`i and Maui—nine zones for Hawai`i and five for Maui—as a way to identify areas of relative hazard. The maps were intended to guide future development away from the most hazardous areas. The zones were based on the rate at which areas were covered by lava flows in the past. The maps were virtually ignored by planners but an updated Hawai`i map released in 1992 was widely used by insurance and mortgage companies to dictate rates and policies for home owners. We are currently working on a probabilistic lava flow hazard map for Hawai`i island using the latest flow-by-flow geologic map coupled with new dating. The algorithm attempts to correct for progressively poorer representation of older flows. Preliminary results are promising. Probability estimates will allow direct comparison of lava flow hazards with other hazards in a multihazard environment.

23-O-02

Land Use and Emergency Response Planning: Lessons from Mount St. Helens

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The onset of renewed volcanic activity at Mount St. Helens in October 2004 ended an 18-year period of quiescence and provided the first real test of emergency response plans that were established following the catastrophic May 18, 1980 eruption. The rapid pace of 24-hour live news coverage and thousands of visitors

who gathered at monument visitor centers and viewpoints posed a significant challenge to federal, state, and local officials. Close collaboration between scientists, land managers, and law enforcement officials and implementation of an Incident Command System under a multi-agency unified command were key ingredients in the success of emergency response efforts.

The timely evacuation of volcano visitors and implementation of 5, 8 and 11-km radius contingency closure zones around the volcano in 2004 was greatly facilitated by federal acquisition of private and leased lands around Mount St. Helens following the 1980 eruption. Volcanic hazard maps were incorporated into planning for the Mount St. Helens National Volcanic Monument and roads and facilities were placed outside of immediate hazard zones and on ridge tops above the level of valleys draining the volcano. Visitor Center roofs were designed to support the combined weight of projected volcanic ash fall and precipitation. Land use and facility planning greatly reduced the potential hazard to life and property and simplified the situation faced by emergency managers during the rapidly evolving volcanic events and public and media response of 2004. Mount St. Helens provides a compelling example of the successful application multi-agency response planning and the application of volcanic hazard maps to the appropriate placement of public infrastructure and tourism development near a volcano.

23-O-03

Reducing Volcanic Risk Through Land-use Planning: Is It An Option?

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Land-use planning is frequently discussed but seldom implemented around many of the world's most dangerous volcanoes. Apart from the evacuation of people and removal of transportable assets (if possible), there are few or no mitigation options available to pre-existing facilities to counteract many of the destructive volcanic hazards that exist. Limiting the building of permanent structures in high risk volcanic areas however, is a low cost and effective mitigation measure. The limited use of land-use planning for volcanic hazard risk reduction will be discussed in the context of three case studies; 1) volcanic hazards in New Zealand; 2) the growing residential populations around Mt Rainier, USA and 3) communities around Cotopaxi volcano in Ecuador. The growing volcanic risk can be attributed to a range of complex interrelated social, political and economic drivers such as poverty, growing population pressures, short-term economic development needs, local, and central politics and lack of risk understanding by communities. Overcoming these barriers is an ongoing challenge, as land-use planning is a major aide in lessening the risk to growing communities.

23-O-04

Probabilistic Tephra Fall Hazard and Consequences for Greater Tokyo

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A repeat of the 1707 Hoei eruption of Mount Fuji would have severe economic consequences for the Greater Tokyo area, causing flow-on effects to Japanese and global economies. But what is the probability of such an event? Should Tokyo prepare for more likely scenarios? We present the early stages in developing a stochastic volcanic hazard and loss model for Greater Tokyo.

The model combines probabilistic tephra dispersal simulations and vulnerability studies and allows the input of exposure information at various spatial resolutions. For each model run, tens of thousands of scenarios are generated with corresponding probabilities and loss statistics.

The tephra-fall hazard has been simulated for Mount Fuji and Hakone volcanoes using parallel computing techniques. Detailed model calibration has been carried out using geological data from several well studied events, including the Hoei eruption. Meteorological parameters were then sampled randomly and volcanological parameters varied to describe the range of previous activity, current eruption trends and to account for the volcanoes inherent future unpredictability.

We have considered the impacts of previous volcanic events, including the 1991 Unzen eruption and the on-going tephra falls from Sakurajima Volcano effecting Kagoshima and Tarumizu cities. An extensive survey of buildings in Greater Tokyo has been conducted, with characteristics including building condition, roof construction and the height of openings above ground level collected. Geographical areas could then be classified by their vulnerability to tephra falls and mudflows.

23-O-05

Land Use Plan after 2000 Eruptiion of Usu Volcano

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Records show that Mt. Usu has erupted nine times since 1663, and as many as four times in the twentieth century. When it erupted in 2000, the scale of its volcanic activity was extremely small. The damage, however, was quite extensive owing to the fact that the volcano and residential areas are closely situated, and public facilities including disaster prevention bases (fire headquarters) were also damaged.

In the areas surrounding Mt. Usu where eruptions repeat in every 20-50 years, it is important to prepare the

communities for upcoming eruptions. According to the "Plans for Disaster Reconstruction of the Areas Affected by Volcanic Activity" formulated by Hokkaido Prefecture and the surrounding cities/towns in 2001, land use plans have been made based on a hazard map, while those facilities at issue since the 1977 eruption, including primary schools and hospitals, have been relocated to safer areas.

In this session, community development coexisting with a volcano that is being implemented in the surrounding areas of Mt. Usu will be introduced.

23-O-06

Eruption Hazards and Reconstruction of Communities by Raising the Land

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Communities on Annaka triangle in Shimabara, Nagasaki Prefecture were destroyed mostly by repeated debris flows associated with the eruptions of Mt. Unzen (Fugendake). This made it impossible for residents to reconstruct their communities on an individual level, which led to a decision on a total bank raising in consideration of the permanent safety and environment of the area. Since this reconstruction, however, could not be carried out within the range of ordinary public works, an unprecedented project method was adopted. As a result, communities were rebuilt in line with residents' desires. The method and lessons learned through this project will be introduced here.

23-O-07

Current Situation of Disaster Victim Assistance in Japan

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In Japan, reconstruction and rehabilitation following natural disasters have long been discussed in terms of cities, while in principle disaster victims have been expected to help themselves. In particular, residences have typically been seen as private property and not suitable for public assistance. People have therefore been encouraged to purchase disaster insurance. However, with the disastrous eruption of Mt. Unzen-Fugen, followed by the Great Hanshin Awaji Earthquake, the difficulty of reconstruction in an aging society became apparent. The elderly, unable to rebuild their homes on their own, were forced to live in provisional housing or reconstructed public housing far from the city center and cut off from communities. As a result, cases of solitary death, dementia and alcoholism increased, becoming social issues. People in disaster areas began to claim that community reconstruction could not proceed without reconstructing houses, which moved affected autonomies and civic organizations, leading to the passing of the Natural Disaster Victims Relief Law in 1988. In 2004, this law came into force with the addition of a "system to assist residential stability." Yet while certain results have been achieved, there remains an urgent need to construct the framework of a system to assist disaster victims, as this law does not apply to the main body of houses and measures for vocational assistance are insufficient.

23-P-01

Land Use and Planning on Heimaey, Vestmannaeyjar Arcipelago, S-Iceland

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In January 1973 an eruption started on the island Heimaey, which is the largest and only inhabited island of the Vestmannaeyjar archipelago of the south coast of Iceland. The eruption started about third of the prosperous fishing village of thriving on Heimaey island. A catastrophe of this amplitude had not been seen in modern Iceland and revealed that a nation living on a volcanic island should be more aware of its nature. The eruption that lasted for about 6 months flowed over most of the eastern half of the island and added to it some 2 square kilometres. First after the eruption the new land was used for heat excavation, by spraying the new lava with seawater and harnessing the steam thus generated. This activity ended some 20 years ago and since the new land and the lava used with little respect. For about 20 years there was no formal planning for the area covered by the new lava and the islanders used it for waste disposal and gravel mining. During the last couple of years a new planning has been accepted for the area. With in these plans the new lava has been divided up into several recreation areas, industrial area and gravel mining areas. The value of new land created in the eruption has thus increased in the mind of the islanders, while the years following the eruption where characterised by little respect to the new land. A thorough hazard analysis of the island is yet to be created.

23-P-02

Issues and Opportunities for land-use Planning for Volcanic Hazards: A Case Study from New Zealand

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A significant number of active volcanoes exist in New Zealand, including the basaltic volcanic field beneath Auckland city, the largely andesitic cone volcanoes of the North Island and the highly destructive rhyolitic calderas located in the central North Island. As a result, New Zealand is subject to a variety of volcanic hazards including pyroclastic flows and surges, lahars, debris avalanches, lava flows and ash falls. Mapping of areas around the North Island has served to identify the hazards posed by many of the volcanic centres and these have been expressed in the form of hazard maps (e.g. Okataina Volcanic Centre; Mount Ruapehu; Mount Taranaki, etc).

A number of cities and towns are located either alongside or near to these identified areas of volcanic hazard. Some urban areas could quite successfully employ land-use planning techniques to mitigate the effects of a volcanic eruption (e.g. mitigate against ash falls or lahars). Others may be subject to destructive hazards (e.g. pyroclastic flows) and will find it more difficult to plan for such events, but some success could still be achieved through use of land-use techniques.

In New Zealand, therefore, there still lies an opportunity to employ land-use planning initiatives to mitigate volcanic hazards. Where volcanic hazard areas have been identified (e.g. through mapping) land-use mitigation methods could include:

--Avoiding new development in hazardous areas altogether;
-Employing low density development to minimise the number of people living in a volcanic hazard area;
-Restricting or minimising further subdivision in areas already developed;
-Siting key facilities out of hazardous areas;
-Making use of good urban design to minimise the effects of ash falls;
-Planning for the disposal of volcanic debris after an eruption;
-Planning for other land-use recovery aspects; and
-Linking land-use planning in with emergency management provisions to allow the mitigation of residual risk (e.g. through warnings, evacuation, etc).

This paper will discuss New Zealand's volcanic landscape and the hazards and risk posed by the volcanoes there. Based on several case studies, it will then go on to discuss land-use mitigation options that could be employed for volcanic hazards in such an environment. Finally it will discuss the issues associated with land-use planning for volcanic hazards including considering the concept of acceptable risk; prioritising planning for volcanic issues when compared with other natural hazards; and considering what barriers may need to be surmounted to achieve acceptable outcomes with respect to planning for volcanic hazards.

23-P-03

An Investigation on Construction of Urban Infrastructure Leaned by Prolonged and Enlarged Volcanic Activities of Mt. Unzen

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The long-term and enlarged volcanic activities of the Mt. Unzen Volcano rendered severe bad effects on the local economy in commerce, industry and agriculture. It is very important to accommodate urban infrastructure to long-term volcanic activity in Shimabara district. Disaster prevention officials of road, railway, electric power supply, water supply system, telecommunication and gas recognized the danger of the mountain eruptions and considered a counterplan to protect their facilities. They also considered emergency and permanent restoration plans after debris flows and pyroclastic flows attacked their facilities. In this paper, emergency counterplan, damage and both temporary and permanent restoration plans of urban infrastructure systems to volcanic disaster of Mt. Unzen and social affects are reported and discussed. A survey is also undertaken to know need about the countermeasure for improvement of urban infrastructure. Problems now to be solved as well as some lessons to be learned are also explained. To defend urban facilities from the eruption disaster as a result of the investigation, it was shown that it was important to maintain arrangement of urban facilities and a necessary function before the disaster in the volcanic zone region.

23-P-04

Relations Between the Change of Topography and the Change of NDVI After Recent Unzen Uruption

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This study aimed to clarify the relation between the topographical subsurface change and the vegetational change around Unzen volcano caused by recent eruption. The analytic works were studied for this purpose: 1) classification by aerial photo interpretation on the affected area by the eruption, 2) analysis of ground elevation changes on topographic maps, 3) analysis of normalized difference vegetation index (NDVI) changes on LANDSAT data from 1988 to 2001 were studied. Relationship between damages by the eruption and the vegetational changes was discussed. In this time, we would like to show poster presentation about them.

Area of over 20 km^2 was affected by the eruption. It's classified into 8 areas, pyroclastic flow thick covered area, pyroclastic flow thin covered are, burned area, withered forest area, debris flow area, gully, ash fall area, and lava dome. Ground elevation became higher depending upon development of lava dome, and deposition of pyroclastic flow originated from the lava dome or debris flow originated from the pyroclastic flow and ashes. In a few parts, where erosion increases, ground elevation decreased. The affected area was classified into 3 areas on NDVI change of decreasing from 1988 to 1996 and the change of increasing from 1996 to 2001 by Jenks' natural breaks classification. Furthermore, the two maps on NDVI change from 1988 to 2001 were overlaid and the affected area was classified into 9 areas. The distribution of 9 areas is resembled to it of 8 areas on the eruption, and it seems that the distribution is related with the slope direction or the ground elevation change. We think that the relations between the change of topography and the change of NDVI give us good suggestions to landuse planning for long term in each drainage area.

23-P-05

Debris Flow Disaster "Yukishiro" of Mt.Fuji

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Debris flow is one of the natural hazard phenomenon that frequently occurs in Mount Fuji area. Typically, this type of debris flow is called "Yukishiro" in Japanese. This slope deformation can be classified to a rapid mass movement in which loose mass (scoria) combine with air, and water

to form slurry that then flows down slope, usually associated with steep slope. Recently, Yukishiro widely attracted public attention because its disaster affected a quite large area near to Five Step, an entrance place to climb Mount Fuji from Yamanashi Prefecture side. Large Yukishiro disastersw occurred on 5th December 2004 and 25th March 2007. The area affected by the Yukishiro is mostly underlain by scoria on the top surface. This scoria is grouped into "Younger Fuji Tephra" which composed of scores of dark brownish scoriaceous tephras, reaching several meters in thickness in the Fuji area. Outcrops around the debris area expose mostly a thick and thin pile of layers scoria and air-fall ash. In order to characterize the shear behaviour of scoria within low stress level condition, drained triaxial compression tests were performed on dry scoria under low confining pressures (10-80 kPa) which are assumed representative of the field surface stress conditions. Different from the normal sand, scoria is quite difficult to perform in triaxial test under saturated condition, because of its physical properties. Therefore, in the present study, the tests were held under dry condition with refers to drained triaxial compression tests. The effects of grain size and confining pressure upon stress-strain behaviour to angle of internal friction and dilatancy are investigated.

Session 3-1

31-O-01

Volcano Risk Mitigation Strategy Based on a Cooperative Linkage among Officials, Scientists, People and Media --- Decades-long Efforts and State-of-the-Art at Mt. Usu, Japan

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During the 1977-1978 crises at Mt. Usu, insufficient linkage between local officials and scientists resulted in major difficulties. Since then, symbolic status was a volcano hazard map; an evidence from refusal to practical use. Turning-over point was the 1985 Ruiz and 1988 Tokachi crises for scientists, and for the community it was Mt. Unzen's terror pyroclastic flow in 1991. Tourist business people started to visit Volcano Observatory, and ask the effectiveness of the map and lead-time of the coming eruption. Reality of actual risk elsewhere, even non-volcanic event like the Okushiri's Tsunami in 1993, encouraged hesitating Abuta Mayor to accept the hazard map. The map was finally circulated all homes in 1995. At the occasion, "The '95 International Workshop on Volcanoes Commemorating the 50th Anniversary of Formation of Showa-Shinzan Lava Dome" was organized by small town Sobetsu. It was the Pre-COV type conference following the 1988 International Kagoshima Conference. It was fortune those 5 years-long time allowance was still available toward the 2000 eruption. The social linkage was actually tested at the 2000 eruption and resulted in general success. Later, the efforts also extended over evacuation cancellation, and new policies in recovering stage. Sobetsu Town participated in the main position in this safety preparedness. Basic researches since Omori and Minakami era, gave a basic guideline. Members of Hokkaido University and Mimatsu Museum were among the main supporters to the town. Cultural activities including Kids Program, repeated field tours, lectures and workshops over past 30 years surely contributed to upgrading a proper man power in Sobetsu. Special thanks were due to many oversea scientists who visited UVO, especially Dr. Harry Glicken for his participation in the 1987 Kids Program, and Dr. Donald Peterson for the table of contrasting arguments between volcanologists and journalists.

31-O-02

Volcanic Risk Perception in Campi Flegrei Area (Southern Italy)

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The Campi Flegrei, which includes part of the city of Naples, last erupted in 1538 AD; however, two seismic crises associated to strong uplift occurred from 1969-72 and again from 1982-84, forcing an evacuation of the town of Pozzuoli. Since 1984 development of a volcanic emergency plan has been underway, and in 2000 civil protection officials designated a Red Zone from which residents would need to be evacuated before an eruption. The first study to evaluate the volcanic risk perceptions of the people living within the Campi Flegrei area was completed in summer 2006. A 46 item questionnaire was filled by a sample of 1161 students, parents, and adult members of the general population. Results indicated that most residents of Campi Flegrei, while aware of the volcanic threat posed by Vesuvius, are not familiar with more local volcanic hazards in their area. Respondents also indicated that earthquakes and ground deformations are more serious threats than eruptive phenomena. Of significant importance is that only 17% of the sample were aware of the Emergency Plan and 65% said that they have not received enough information about the possible effects of an eruption. Additionally, residents with a stronger Sense of Community expressed greater confidence in scientists' and government officials' ability to deal with a potential eruption. The study is seen as a useful tool to improve risk mitigation strategies planning and actions carried out in strong collaboration among local authorities, the scientific community and citizens.

31-O-03

Colombia Experiences of Managing Volcanic Crisis, Galeras and Nevado del Huila Eruptions

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In the last three years, Colombia has been confronted with eruptions in two volcanoes. Galeras had eruptions in August and November 2004, November 2005 and July 2006 and Nevado del Huila had eruptions in February and

April 2007. In both volcanic crisis the National System for Prevention and Attention of Disasters have been in front of the situation of managing the crisis. This system is planned to be an inter-institutional team that work coordinated to cover all the different aspects during the re-activation of a volcano. The objective of this presentation is to share the experiences of INGEOMINAS Volcano Observatories, as the institution with the responsibility of the monitoring and hazard evaluation in the volcanoes during those periods of crisis and pre-crisis.

At Galeras volcano, in three occasions evacuation of about 8000 people was ordered, but the response of most of the people have been very limited. In two of those evacuations, there were eruptions without serious consequences. The Nevado del Huila activity caused twice the evacuation of about 2000 people. In both occasions eruptions took place and produced lahars along the Paez and Simbola rivers. The February eruption produced a small lahar that affected only the upper most part of the basin, but the second eruption in April destroyed 19 pedestrian crossings and 3 bridges, travelled about 120 km down to the main Colombian river, but there were not fatalities or injuries.

Although, the hazard and the activity of the volcanoes are different, the reactions of the people were quite different in both cases. It was different the response to the evacuation and also to the idea to be relocated in other place too. The perception of the hazard and risk among the community is one of the main aspects that facilitates or not the work in managing volcanic crisis, as well as the social organization and political views.

31-O-04

How the Word 'Pyroclastic Flow' Became Accepted among the Japanese Citizens

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The death of 43 people during the pyroclastic flow eruption of Unzen volcano, on 3 June, 1991, led to a sudden and nation-wide recognition of the term 'pyroclastic flow' and the phenomena related to it. However, before the disaster, there had been 20 years of turmoil in which volcanologists struggled to outspeak the danger of the pyroclastic flows who met strong refusal of not let them speak in fear of the possible confusion and panic set off by the disclosure of such a bizarre and horrible notion. During which time, volcanologists, including myself, were torn between the vocation of speaking the truce and saving the people and the fear of triggering unnecessary panic caused by misunderstanding public who will not listen properly and be misled by those irresponsible mass media. In Unzen case, there was also hot arguments whether the phenomena should be first publicly announced as “pyroclastic flow” or not. When asked, I made a small mistake of offering a small compromise to call it “small scale pyroclastic flow” which was scientifically correct, in order to appease the opponents. My terminology was made public. Then the disaster struck and a deluge of prosecution, heart-searching, diagnosis, etc. followed. Among those, there was criticism of letting the public, mostly media reporters, underestimate the danger because of the term “small scale”. The lessons learnt are not straight forward because of the difficulty of evaluating correct wording especially addressed to the media. On the contrary, I was deeply impressed by the influence of the media especially television. The correct explanation of the phenomenon “pyroclastic flow” was promptly televised nationwide after the official announcement assisted by briefings made by the volcanologists. Next morning, every citizen knew what the pyroclastic flow was thanks to the vivid video images taken by helicopters flying so close to the pyroclastic flows.

31-O-05

The Alaska Volcano Observatory's Information Management Systems during the 2006 Eruption of Augustine Volcano, Cook Inlet, Alaska

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The Alaska Volcano Observatory (AVO) is a partnership of the U.S. Geological Survey, University of Alaska Fairbanks Geophysical Institute, and the Alaska Division of Geological and Geophysical Surveys. Information flow between the AVO partners and with public and emergency responders during the eruption of Augustine was accomplished through the AVO website, e-mail, fax, meetings, and phone. The internal AVO website provided reliable, rapid access to much of the monitoring information at all AVO offices in Anchorage and Fairbanks. Selected real-time data sets and hourly updates on the public AVO website allowed many emergency responders, private citizens, and aviation and meteorology professionals to follow the eruption in near real-time from their home or office. AVO's Operations Center (Ops) provided a central location to both receive and disseminate information and conduct media interviews. Ops became the hub of Augustine monitoring activity from January 10 through May 19, 2006. Twenty-three AVO staff and twelve additional scientists from other USGS volcano observatories staffed Ops. In order to provide a comprehensive, uniform, and timely response to callers ande-mails at all three of its cooperative organizations, AVO staff compiled binders of vetted resources that were placed by each Ops room phone and available through the internal AVO website. An observation log on the internal AVO website allowed users to enter information about anything from satellite passes to seismic activity into a searchable database. Additionally, the individual(s) on duty in Ops used forms on the internal website to post timely summaries of activity directly to the web, ensuring that the site was always up to date. The web site and Ops were the backbone of AVO's information management systems and provided quick, easy access to the latest information within the observatory, to emergency managers, and to the public during the 2006 Augustine eruption.

31-O-06

Cooperation with the Press in Dealing with the Mt. Iwate Volcanic Crisis

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When Mt. Iwate faced the possibility of eruption by elevated seismicity in 1998, a system to ensure community safety through cooperation among scientists, administrative bodies, the press and residents, a so-called "tetragon for disaster mitigation," was pursued and put in practice. Through this crisis, the importance of building relations of trust between scientists plus officials who issue information and the press who transfers such information to communities was recognized. In Iwate, efforts to raise press awareness of volcanic and disaster prevention were repeated by individual briefings for reporters, internal training in newspaper and TV reporters, open official meetings and detailed lectures for reporters. In addition, relations of trust between scientists and people concerned with disaster prevention were built through thorough disclosure of volcanic observation reports at the Iwate Network System (INS) Conference for Volcanic Disaster Prevention at Mt. Iwate, where scientists and those concerned with disaster prevention met at personal levels, following suggestions made by the press. They shared a common understanding that the standard of information evaluation should be based on whether it is useful for community safety or not, making it possible to send out accurate and quick information on volcanic activities and disaster prevention measures within the communities.

The issue now is how to maintain this awareness level of protecting community safety among administrative officials and the press who cannot avoid short-term personnel changes.

31-O-07

New Zealand's All-Hazard Civil Defence Emergency Management Structure: Cooperation and Mutual Support For Volcanic Crisis Management

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New Zealand volcanic emergencies are managed under the Civil Defence Emergency Management Act 2002. The Act and associated National Civil Defence Emergency Management Plan dictate the actions of the Ministry of Civil Defence & Emergency Management (MCDEM), the wider "all-of-government" response and regional Civil Defence Emergency Management (CDEM) Groups. Hazards are managed under the headings of Reduction, Readiness, Response and Recovery and New Zealand has purposefully taken a predominantly "functional" all-hazards approach to planning for hazard management. This means, for example, transferable warning and evacuation response procedures across those hazards that can be warned and evacuated for (e.g. volcanoes, tsunami, wildfire, terrorism). Details that are unique to a hazard may be covered under hazard-specific headings within the functional plans, and in some cases hazard-specific contingency plans are developed.

Hazard events are detected by a range of national and international agencies. Volcanic hazard monitoring falls under the jurisdiction of the GeoNet project, which is run by GNS Science and core-funded by the Earthquake Commission. Volcanic warnings pass from GeoNet to MCDEM, who then feed them through National Warning System to regional CDEM Groups. CDEM Groups are comprised of regional, district and city councils, emergency services including Police, Fire and Health, and Lifeline Utility operators. It is the job of MCDEM to provide guidance and resources for CDEM Groups to manage hazards.

At all levels (national, regional and local) cooperation in planning and exercising crisis responses between CDEM authorities, scientific agencies, media and public groups is essential to achieving effective management of an event. For example, recent (2006) national cooperation agreements with television and radio networks complement arrangements at a regional and local level. While planning for agencies that have to act during a crisis primarily falls under "readiness and response" activities, having these agencies engaged in the reduction and recovery planning process through the CDEM structure has produced a much more robust all-around risk reduction strategy for the country.

31-O-08

Transforming Geoscience Knowledge into Disaster Prevention Action in the Andes: The MAP:GAC Experience

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One of the challenges faced by geoscience institutions and, particularly, volcano observatories is the transformation of the knowledge they produce into disaster prevention actions. Past experiences, such as the 1985 tragic eruption of Volcan Nevado del Ruiz, Colombia, have shown that relying solely on standard means of data dissemination have had limited success in preventing disasters. In addition, scientists and scientific institutions are frequently separated (often intentionally) from the politically loaded atmosphere that characterizes decision-making processes. The failure to engage has kept them from participating in the crucial phases of “transforming science into action” and showing the social relevance of geoscience knowledge.The Multinational Andean Project: Geosciences for Andean Communities (MAP: GAC), is an initiative proposed and funded by the Canadian International Development Agency in coordination with the national geoscience agencies of Argentina, Bolivia, Canada, Chile, Colombia, Ecuador, Peru and Venezuela. The MAP: GAC has been providing the opportunity for the geoscience institutions to learn and better understand the resource constraints and processes necessary for the appropriation and application of scientific knowledge for disaster prevention and

emergency management. Communities living near active volcanoes in Chile and Peru are interacting (communicating), sharing resources with their respective geological surveys, authorities, and other private and government organizations to generate, transfer, appropriate and, to apply volcanological, human and social knowledge for disaster prevention. As a result, in both countries, community organizations have been strengthened; emergency plans have been proposed and implemented and, long-term educational strategies are now in place.

31-O-09

The miyakejima 2000 Eruption and Web Journalism

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In the bulletin board system of internet people, can be to written freely. Because the immediate exchange of the information is possible, that it is useful to prevent volcanic disasters. Unlike repeated fissure eruption, the 2000 eruption of Miyakejima forming the caldera that 2km diameter and 450m depth in the central part of the island. The fine grained volcanic ash accumulated in island at every phreatic eruption. And many debris flows occurred at every rain. As eruption becomes extreme, entry of BBS increased. The BBS took notice not only volcanologist but also the citizen of entire country and became the big social phenomenon. In August 29th, entry of BBS was 250, access reached to approximately 100,000. Some information from the islander include more details then the mass media. Argument on the bulletin board was extreme ones. Because there was danger of large eruption, the agreement that was achieved "you should evacuate from the island". The photograph was published to the BBS only 2 hours after the pyroclastic flow occurred in August 29th. This photograph became one of the materials to decide evacuation from the island. Although extreme feeling expression and false rumors were written in the bulletin board, the manager maintained BBS with performance with resolute deletion. The bulletin board was obtained the appraisal that it was useful to prevent volcanic disasters, as journalism.

31-O-10

Combining Scientific and Social Components to Achieve Sustainable Risk Mitigation at Tungurahua Volcano, Ecuador

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The eruption of Tungurahua is now in its 8th year and the around-the-clock monitoring of the volcano by the IGEPN has never ceased, neither has the full-time presence of IG scientists in the zone. While the labor of scientists is usually regarded as limited to monitoring and technical assistance to the authorities, over the course of the years a different relationship between scientists and the community has developed. The DIPECHO-CRS-CAFOD project "Communities affected by Tungurahua: Mitigating the risks of living near an active volcano" sought to develop sund community-based risk mitigation practices that would be exercised by the local people. Through the process, rural communities at risk came to know the effects of a volcanic eruption, hazard zones, security areas and auto protection measures. Members of the Instituto Geofisico, based at the local volcano observatory- Guadalupe, became important actors in the process, conveying and sharing with the local people information about the volcano as well as listening to the insights of the rural population. The process became dynamic between the population and the scientists through the sharing of perceptions about Tungurahua and its risks. The IGEPN earned much credibility with the community by involvement in numerous informal evening meetings, in which most community members came to participate. The experience helped the population to realize the need to have an Early Warning System and therefore to perceive scientific information as quite valuable. Their perception stood the test in July and August, 2006, previous to the VEI 2 and 3 eruptions, when the local authorities and the population heeded the advice given by scientists about the threat of the volcano, and effectively evacuated the high hazard zones, preventing loss of life. The success was possible because scientists worked with the community and not for the community. The concept of working closely scientist and community, the continual presence of volcano scientists in the area and their integration into the community, plus the integration of county authorities, has generated a new model of risk management in Ecuador.

31-O-11

Collaborative Communication Efforts Key to Reducing Volcanic Risk in Pierce County, Washington, USA

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The famous movie quote says it all, "What we have here is a failure to communicate." It's a lesson that is learned again and again. The problem is often "turf." It can be very difficult for multiple agencies to break down silos to work in a collaborative manner. More than 10 years ago in Pierce County, a work group was formed to bring together a variety of agencies, jurisdictions, scientists and local citizens to cooperatively address volcanic risks from Mount Rainier. As the work group lead, Pierce County Emergency Management has implemented a variety of projects that rely on cooperation, mutual support and communication for effective response in volcanic crises, as well as other hazards. One of these efforts, named PCWARN, is an alert and warning mechanism that utilizes pagers, cellular telephones and e-mail to spread information to a large audience in a matter of seconds. Another is a more technical application called the ACU 1000 which allows radios (regardless of frequency), telephones and cell phones work together seamlessly. Most recently, we employed a tremendously effective system called Intellicast that calls every home and business within a pre-identified geographical area. Tens

of thousands of calls can be generated in just minutes. The system has proved effective during recent events and the response from citizens has been overwhelmingly positive. The final piece of the collaborative puzzle is a crisis communications web site that allows us to immediately communicate with local media, even if telephones aren't available. These efforts compliment the more traditional alert and warning tools as well as the ongoing community education so critical for a truly successful program. Pierce County is considered a leader in collaboration with local agencies and together we have made great strides in protecting the citizens of our county.

31-P-01

Volcanic Environments - Destinations With a Risk Factor

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Volcanic Environments - Tourism Destinations with a Risk Factor? Volcano Tourism has been widespread in European countries for centuries, with a long history of being included in the "Grand Tour" dating back to the 18th century. Observation of volcanoes was not only fashionable, but was considered educational and inspirational. Today travel and recreation are often closely linked to volcano national parks, which offer unusual landscapes, including geothermal phenomena like hot springs or geysers. Many volcanic environments worldwide can be classed as extreme environments and are major draw cards, contributing significantly to the revenue from tourism. Tour operators offer tours with various levels of difficulty and risk factors. The most sought after attractions are glowing lava flows, strombolian eruptions and fissure eruptions. Volcanic environments are frequently located within protected areas and some of them have been World Heritage listed. The group of 'decade volcanoes' is especially popular, as the prospect of heightened activity appears to draw larger numbers of tourists to eruption centres. The task of hazard and risk management in volcanic environments is extremely challenging due the varying degrees of potential danger from active volcanoes which can generate different types of hazards. Remoteness, difficult terrain and adverse climate conditions often present additional complications in an emergency. The valid question is whether visitors of volcanic environments are seeking enough information about individual destinations from available sources like Internet and guidebooks. Guidelines and instructions for emergencies may not be available everywhere. What can be done to raise more awareness about the potential danger of volcanic environments? The volcano tourist needs to know beforehand how to prevent accidents and who is in charge and/or responsible. Communication can be a problem in remote areas with dire consequences. This poster presents examples of popular volcanoes and the local tourist activities.

31-P-02

Public Awareness - A Preliminary Element of Risk Reduction for Cities

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Public awareness and the creation of widespread understanding about disaster reduction must be a key element in risk management strategies. Public awareness conveys knowledge about hazards and existing solutions that can reduce vulnerability to volcanic hazards. For risk reduction measures, particularly for cities, it is essential for all stakeholders to be aware of the hazards they are likely to face. National, regional and cities authorities have a basic responsability to inform the people about potential hazards. However, in order to sustain public awareness, many other sectors of the society must be involved in disseminating information. For cities, risk information and education as professional training are crucial. Therefore, a successful programme must include professional and civic organization and national and local authorities. However, the aim of public awareness programmes should not limited to conveying and understanding about volcanic hazards and risks to the public, also it should motivate people living in the city to become involved in activities that can reduce the potential risks to which they are exposed. Media also has an important role to play when a volcanic crisis occurs, because it is recognized from experience that current tools and guidelines are not enough, in part due to the limited exchange of information about global acomplishments.

31-P-03

Human Suffering from Pyroclastic Flows at Mt. Unzen (Fugendake) on June 3, 1991

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The small-scale phreatic explosions that occurred near the top of Mt. Unzen (Fugendake) on November 17, 1990 marked the beginning of eruptive activities that lasted over four years. These eruptive activities were characterized by the continuous growth of a lava dome accompanied by pyroclastic flows caused by partial collapse of the lava dome. The pyroclastic flow that occurred at 4:08 in the afternoon on June 3, 1991 deprived 43 people of their precious lives including firefighters, local residents, volcanologists and the press. It turned out to be the worst volcanic disaster in modern Japan and contributed to public notoriety regarding pyroclastic flows.

Pyroclastic flows and debris flows ran down mainly the eastern slope of the volcano, destroying many buildings. The eruptive activities caused severe damage among the residents at the foot of the volcano as well as the surrounding areas. The amount of damage totaled as much as 230 billion yen. Warning zones were designated to protect people's lives from pyroclastic flows and debris flows, evacuating up to 11,000 people from their homes in both Shimabara and Fukae areas.

In this session, our focus will be on a report on human damage caused by the pyroclastic flows on June 3, 1991 as well as consideration of the conditions and evacuation behavior that determined life or death, based on the evidence of the survivors from the pyroclastic flows, drawing out useful lessons on volcanic disaster

prevention for future hazard mitigation.

31-P-04

Volcanic Risk Perception in the Vesuvius Population

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Following an earlier study of citizens' perceptions of risk regarding volcanic hazards near Vesuvius in 2003, the present study involved a larger, more diverse sample of students, parents and members of the general population in metropolitan Naples during May - July, 2006. Surveys were distributed in schools and public venues in the 18 towns of the Red Zone, the area closest to the volcano that is exposed to pyroclastic flow hazards and whose 550,000 residents will have to be evacuated in case of an eruption crisis. Surveys were also distributed in three additional towns and neighborhoods of Naples within the Yellow Zone, an area exposed to potential pyroclastic fallout hazards. A total of 2,655 completed surveys were returned, representing a 74% response rate. Results indicated that people have realistic views of their risk: they think an eruption is likely, that it will have serious consequences for their towns and for themselves personally and they are worried about the threat. However, other social, economic, and security-related issues were seen as more salient problems than Vesuvius. The study also demonstrated a widespread lack of knowledge about the evacuation plan, and a lack of confidence in the plan's success and in public officials' ability to handle such a crisis. Respondents also demonstrated low levels of self-efficacy regarding their ability to protect themselves from the volcanic threat. It is clear from the results that a more integrated approach to public education that involves more cooperation among scientists, government officials and citizens is needed to improve the public's knowledge, confidence and self-efficacy, thereby improving collective and individual preparedness for a future volcanic emergency. Discussion of the implications of this study will also include results of a civil protection exercise which took place at Vesuvius in October 2006.

31-P-05

A Lesson of Eruption Disaster Reporting of Mt.Fugen in Unzen. A Viewpoint as a Media Representative

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As one of the features of the eruption disaster of Mt. Fugen in Unzen, having taken out victims from the side of the mass communications, which covered itself, is enumerated. Among 43 people who passed away by pyroclastic flow on June 3rd, 1991, if the taxi driver who picked up the coverage staff also is included in a media representative, half of the victims, about 20 people were Media resentatives. Have mass communications fully recognized the danger of a pyroclastic flow, and have they informed people of that? From the position that I myself was in charge of coverage on the spot those days, I verify how mass communications recognized and covered the intention of researchers who warned the danger of a pyroclastic flow and correspondence of administration. Moreover, with this disaster, the morals of the coverage were also rigidly asked against the background of the overheating report (scoop battle). Concerning the death of a fire brigade member, the view that mass communications had a big responsibility is still there firmly. As one of the members of mass communications who were engaged in the coverage, I consider how researchers, the administration, the mass communications, and the residents should cooperate at the time of disaster.

31-P-06

GeoNet: A Robust Volcano Monitoring System for New Zealand

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GeoNet provides real-time monitoring and data collection for rapid response and research into earthquake, volcano, landslide and tsunami hazards In New Zealand. It is a collaboration between the Earthquake Commission and GNS Science.

In March 2001 the Earthquake Commission announced it would provide NZ$5 million a year for 10 years, sufficient to launch the GeoNet project and meet 60% of the required long term funding. The major focus of the first three years was upgrading of the national earthquake monitoring system for strong and weak-motion recording, the addition of data communication links, the modernising of data management practices, the upgreading of volcano-seismic networks and the introduction of new initiatives for volcano surveillance, landslide response and earth deformation monitoring.

An international strategic review of GeoNet completed in October 2004 concluded that the project meets the best international standards and is making a valuable contribution to public good. The review recommended additional investment and on June 2, 2005 the Commission announced it would increase its funding to NZ$8 million a year to ensure GeoNet is built and operated to the recommended specification. The extra funding will improve further New Zealand's readiness and ability to respond to an emergency.

Volcano monitoring has become much more robust and complete with the advent of the GeoNet project. Monitoring now includes volcano-seismic networks on all active volcanoes, using 3-D sensors and digital communications, microphones, continuous GPS sites, mini DOAS gas monitoring, airborne gas monitoring with COSPEC, Lycor and Intrascan equipment; near real-time data processing and web page display. This enhanced and robust data collection is interfaced with the National Civil Defence Plan to bring volcanic alerts and warnings.

31-P-07

Crisis GIS: Preparing for and Responding to Volcanic Eruptions in the United States

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The Volcano Hazards Program (VHP) of the U.S. Geological Survey (USGS) is charged with monitoring the nation's high-risk volcanoes and issuing timely warnings of potential volcanic hazards to responsible public officials and to the affected population. Geographic Information Systems (GIS) technology is a key component of VHP's monitoring and response capabilities. GIS is used to produce electronic and paper maps illustrating volcano hazards and potentially threatened areas, to visualize and analyze changes in the surface and volume of volcanic features, to aid in geologic mapping, and to catalog the locations, types, and specifications of monitoring instruments. A well-designed and constructed GIS of U.S. volcano information is therefore invaluable during a crisis when timely analysis and communication of volcanic hazards are most critical. VHP GIS specialists have developed a "Crisis GIS" plan to ensure rapid, reliable delivery of spatial information for data analysis and visualization for any required location during a volcanic crisis within the United States. The plan primarily involves the construction of a GIS database that stores large datasets, handles large tables of attribute data, accepts the addition of new datasets in an efficient and straightforward manner, allows datasets to be easily updated, is easy to organize, manage, and maintain, and is readily accessible for crisis response by VHP GIS specialists stationed at disparate locations around the U.S. Crisis GIS is currently being implemented in preparation for future events at U.S. volcanoes and in response to continuing eruptions at Mount St. Helens, Washington; Kilauea Volcano, Hawaii; Augustine Volcano, Alaska; and Anatahan Volcano, Commonwealth of the Northern Mariana Islands (U.S. commonwealth). As a response tool, Crisis GIS enhances VHP's ability to visualize and analyze volcano hazards and to quickly communicate threats posed by volcano hazards to public officials, the media, and the public.

31-P-08

Developing an Alternative Conceptual and Methodological Approach to Interpreting and Utilizing Volcanic Forecasting within Early Warning Systems

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Despite advances in scientific understanding and technology for forecasting volcanic hazards, a number of recent disasters have highlighted early warning system (EWS) weaknesses or failures that led to loss of life, including Nevado del Ruiz, Columbia, (1985), and Soufrière Hills, Montserrat (1995 continuing). The effectiveness of volcanic forecasts and warning systems continues to be hindered by institutional weaknesses; in procedures and infrastructures; poor integration and sharing of knowledge between scientists and community; and effective communication. We do not, however, fully understand the relative impacts of these various dynamics on the ability to manage volcanic risks through effective EWS. Conventional volcanic disaster management systems adopt linear procedural models for information processing and dissemination. However, given the diversity of volcanic hazards and socio-economic variables involved this may not be the most effective methodology to utilize.

This research adopts an alternative conceptual and methodological approach, viewing volcanic forecasting and EWS as a series of dialogues and negotiations. Analysing the interactions between the diverse user groups within the early warning / disaster management system as a whole will aid the understanding of how these groups' knowledge cultures are shaped and transmitted, and the processes of dialogue or negotiation between them. The research aim is, through comparative research, to investigate the interaction of volcanic forecasting and EWS development in the context of the risks associated with volcanic hazard types and local population vulnerability. Within this process, variations in scientific and disaster management organisational structures and cultures, and local political and socio-economic contexts will be examined for their influence and effectiveness. It is expected that the results will enable exploration of volcanic forecasting and EWS processes, allowing modifications that will support more efficient and effective communications amongst all stake holders, and help to reduce loss of life and socio-economic damage during future volcanic crises.

31-P-09

Science, Risk and Policymaking in Volcanic Hazard Zones

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Avoiding volcanic catastrophes involves good science and sound public policy. The population living in volcanic hazard zones is growing, making risk reduction an increasingly important goal of public policy. The scientific community is providing greater and greater detail and specificity about volcanic hazards to policy makers and emergency managers; but are they listening and acting to reduce community risk? This paper explores the intersection of volcanic science and public policy by studying how scientists, policy makers, and non-governmental organizations in the vicinity of the Tungurahua volcano understand and prepare for a possible volcanic eruption. We test hypotheses derived from the literature on policy and scientific networks and develop a framework for thinking about how to successfully manage volcanic events. Our approach uses field interviews and secondary data analysis and the results can be generalized to other volcanic hazard zones.

31-P-10

Development of Crisis Management Scenario Simulations for Volcanic Eruption

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The authors have developed crisis management scenario simulations of volcanic eruptions. They offer an opportunity for administrative officers and volcanologists to learn disaster responses. One of the simulations we report here is a table top exercise for the players to provide a common ground for discussion on different aspects of crisis management in general and preparation for an eruption of Fuji Volcano in particular. The scenario used is based on, at the moment, a fictitious but possible eruption of Fuji Volcano. The procedure of the simulation is as follows. (1) The players are divided into groups of five to seven persons. Each group is asked to act as a crisis manager of a local government situated near Fuji Volcano. (2) All groups receive the same information as to the progress of the eruption. (3)After several situation reports or messages, each group is asked to prepare advice based on the questions presented to them. Roughly 20 minutes are available for each such group discussion. (4) After each of the discussions, two or three groups are asked to make brief presentations of their advice. The other groups have an opportunity to comment on the contents of the presentations. The authors had the experience of running the above-mentioned scenario simulation three times: The first one was for 107 administrative officers of local governments; The second one was for 25 people including volcanologists, the mass media, and the administrative officers; The third one was for 15 administrative officers of the central government. The evaluations of the players were generally positive, which can be interpreted as quite satisfactory.

31-P-11

Scientific and Inhabitants Interaction: Tungurahua (Ecuador) and Aoba (Vanuatu) Crises.

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Communication between scientists and local population have often been difficult and obviously increase in state of emergency. Indeed managing stressed young researchers during crises, and sharing information with the media can make the observation even more difficult than usual. This is why I aim to study the day-to-day life in laboratories as well as the interactions between the scientists and all the Actors in the volcano Network, using an ethnographic method. This will bring out new responses to the lack of communication.In Ecuador, several volcanoes are potentially active, which means that a true policy is needed for the protection of the inhabitants, as well as for the collaboration between researchers, Civil Defence, volunteers, the Church, the army, government, journalists, etc. Tungurahua volcano crises gave us an interesting case of study in sumer 2006 but alerts are permanent, and the potential danger for thousands of individuals living in town or villages is still an issue today. I believe that with an anthropological approach of the actors of volcano Network, we would be able to find the answer for a better communication between the human beings who live near volcanoes.

31-P-12

Volcanic Disaster Prevention Summit in Hokkaido

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About one-fifth of Japanese active volcanoes are located in Hokkaido. Since the pioneering Volcano Hazard Map of Hokkaido-Komagatake in 1981, long-lasting efforts have been made also for other active volcanoes. It is very important to share various necessary information including the difficulties, on volcanic hazards and crisis managements among the different communities, those have to co-exist with their active volcanoes. Multi-lateral relationship among the scientists, mass media personnel, administrators and local people should be well established, favorably in face-to-face basis, while the volcanic is still in a dormant stage.

For solving those problems, "Hokkaido Volcanic Disaster Reduction Summit" has been held since the 2005 Sapporo Summit. The 2006 Iburi Summit was held at Tomakomai City, four active volcanoes including Mt.Tarumai and Mt.Usu is located in Iburi area, in Hokkaido.

In the Summit, our efforts were especially focused on the support of local people. Toward the future safer community, the coming generations, kids/young people in the area will surely participate great roll during future possible volcanic hazards. So, their understanding and contribution will be the vital key toward safer community. The summit program offer the field experiences and laboratory experiments for kids/young people, those programs contributed to their fresh touch and memory of the breath of active volcanoes. At the end of the summit, 13 mayors of Iburi area declared start of co-operative mitigation efforts, with the short musical performed by local high school students.

31-P-13

Researchers, Administrators and People at Risk: Knowing Each Other for Cooperation and Mutual Support.

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Every time we gather for a scientific meeting, at least one participant talks about the necessity of knowing more about the results of the research in our own field, and in other fields of study related to volcanic hazards. For one thing each conference results in a huge production of new

knowledge, hundreds of academic and professional works, all of which we could hardly be expected to read. For another thing, it means that we cannot force ourselves to absorb knowledge or understand or even get acquainted with so many contributions to the prevention and mitigation of volcanic disasters.To organize this great collection of works, I have reviewed the works of the last three CVOs, which took place in New Zealand (2001), in Hawaii (2003) and in Quito (2006).I classified each of them according to which discipline the participant belongs to, his professional background, his country of origin, and the subject presented at the Congress. With this first approach I studied in particular those contributions that deal with any of the Social Sciences. This second part goes further in classifying the contents of each presentation, trying to find an alternative for a transdisciplinary production out of the interdisciplinary work. This new epistemological level has been claimed by most scientists who think that communication between volcanologists, authorities (federal, state, municipal or local), emergency managers, sociologists and people living near volcanoes is important for a well-informed and well-prepared scientific and public community.Here, I am presenting the outlines of the contributions focused on anthropology, education, communication, sociology, social psychology, social work, history, economics and political science. Such a presentation will show the path for an easier encounter among all of us, so that our findings may be shared and used for the sake of the communities at risk.

31-P-14

Tsuchida Diagram and Mimatsu Diagram of Mt. Usu, Japan -Voluntary Scientific Contributions, and Their Significances in Hazard Mitigation Culture

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The 4 dome-building activities of Mt. Usu were well studied in the 20th century. Local people including teachers and officials had also contributed to volcano observation as well as construction of hazard mitigation culture. The famous "Mimatsu Diagram" presented to the 1948 IAVCEI Oslo Assembly illustrates successive growth of Showa-Shinzan lava dome in 1944-1945. The diagram was one of the great contributions by the local postmaster Mr. Masao Mimatsu, who had experienced volunteer guide for visiting scientists during the 1910 eruption, and learned basic knowledge of volcanology. Prof. Takaharu Fukutomi of Hokkaido University provided Mr. Mimatsu a theodolite and valuable advises, so it became the first complete scientific record of dome growth in the world. Many valuable materials including his original sketches and diaries are exhibited at Mimatsu Masao Memorial Museum in Sobetsu Town. The museum had contributed significantly to form a better linkage among people, officials, scientists, and journalists during the repose period toward the 2000 eruption. Similar diagrams were made during the 1977-1982 dome-building activity such as "Tsuchida-Matsushita Diagram" by teachers of Date High School, "Kikuchi Diagram", and "Kiyokawa sketches". Mr. Yoshiki Tsuchida conducted frequent angle measurements using theodolite and made 196 sequential sketches from the school about 8 km SSE direction. The recent detailed digital elevation map (DEM) analysis (Okada, 2007) revealed the upheaval of Usu-Shinzan cryptodome (ca. +270 m in relative height change), and the subsidence of Kousu and Ousu lava domes (both ca. -70 m), and are also well consistent with the result of the diagram. Those materials have been and will be effectively utilized in the local community such as field visits, hazard mitigation lectures, kids schools. Similar efforts were also known for the 1990-1995 dome-building activity of Mt. Unzen, such as still-photo movie by Kunihisa Terai, a Shimabara High School teacher.

31-P-15

A Case Study of Cooperation: The New Zealand 'Auckland It's Our Volcano' initiative

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Auckland is New Zealand's largest and fastest-growing urban area, and has been developed over a potentially active basaltic volcanic field. "Auckland: It's Our Volcano" (AIOV) is an initiative that was set up in 2006 by scientists from the University of Auckland and GNS Science to facilitate collaboration between all groups and organisations with interests in the Auckland Volcanic Field (AVF). Interests include research, emergency management, and land-use planning. The AIOV vision is to pool interested people to identify research gaps and develop a strong foundation from which projects can be launched and funded, and which can also act as a conduit for information exchange for everyone interested in the AVF.

The inaugural meeting was held on the 9th of October, 2006, with representatives from 19 emergency management, local government, central government, and research agencies related to Auckland. The group is open to involvement from any interested parties, and intends to actively share information with the wider Auckland community. Building and maintaining public awareness of the risk to Auckland as a city on a volcano is difficult as there has been no historical eruptive activity. However, European colonial history is extremely short, less than 200 years, and the last eruption (about 700 years ago) was probably near the very beginning of Maori colonial history.

Research projects currently sharing information through the group focus on: maar volcano drilling; magma system characterisation; geophysical characterisation; seismic properties of the crust and mantle; modelling of vent alignments; structural controls on volcanism; eruption precursors; Auckland Volcano-Seismic Network;

the Down-hole Seismograph Experiment; understanding the potential impact and consequences of AVF eruptions; probabilistic tephra dispersal and loss modelling; community resilience and preparedness; eruption response planning; warning systems and public notification arrangements; understanding and planning around volcanic landscapes; greater protection for Auckland's volcanic heritage; and The Volcanic Impacts Study Group of the Auckland Engineering Lifelines Group.

31-P-16

Creating Emergency Management Structures with Local Communities on Tarumae Volcano

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Tarumae is one of the most active volcanoes in Japan. Tarumae Volcano is located in Hokkaido's economic and transportation center. A dome-growth volcanic eruption occurred in 1909. Since then, none of major eruption has been occurred. Around 100,000 local residents will need to be evacuated if the worst case and rare scenario happens and Hokkaido's economic will be damaged. To discuss these problems, we have brought together all these agencies, so they can sit down together and examine how they should coordinate eruption response efforts. The first formal eruption response coordination meeting was held in 2005. Current state and problem of the plan for the disaster prevention of each agency were shared, and eruption scenario that became basic of the correspondence plan examination at the volcanic activity was decided. We will be working together to create an eruption response manual for each organization involved.

Session 3-2

32-O-01

Volcano Education and Risk Communication. Some Comments From a Scientist Perspective

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Volcano education and risk communication are often mentioned when considering strategies for reducing risk. The way scientists understand and develop these topics reflect their worldview. A worldview where communication and education are frequently seen as unidirectional "devices" that are brought to "fix" risk management problems.

When the "expert" knowledge is brought to fix problems via communication strategies (for example, "erroneous" perceptions of risk), risk communication becomes synonymous with risk education. Experts launch communication and educational campaigns to reduce the "knowledge deficit" on the part of the receivers. There is a striking similarity between the communication campaigns or strategies that rely solely on divulgation and dissemination and the education campaigns frequently found in volcanic risk management procedures. In both cases there seem to be the underlying assumption that the person or organization with "knowledge deficit" once exposed to the divulgation and dissemination process or education strategy will change and improve their behavior toward volcanic hazards and the vulnerability associated with those hazards.

Unfortunately this is not always the case. In many occasions, educational booklets or communication campaigns have not stopped the population of high-risk volcanic areas. There are important communication mediated agents and processes between the knowledge generated (in this case, by scientists and experts) and the behavioral change or action is intended with the generated knowledge. To identify these agents and processes it is necessary to understand communication not only as a tool for informing or disseminating information, but also as a mean for transforming the surrounding reality. In the same fashion, education needs to be seen not only as a long-term formative process, but also as a transformative process with immediate results. In both cases, based on knowledge and resources available, communication and educational processes are proposed and implemented with the participation of experts, practitioners, and the community in general.

32-O-02

Effective Communication Through Message Based Interpretation

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Volcanic hazards communication and outreach can be enhanced through the use of message-based interpretation (MBI). Volcano visitors process information and relate to new ideas in different ways. Some people come to a volcanic park or museum to learn, so we must appeal to their intellect. Others come to a park to feel the power of an active volcano, so we must appeal to their emotions. Effective communication involves the constructive use of a tool kit that contains a variety of interpretive techniques including analogies, humorous or thought provoking props, and personal stories. An effective MBI interpreter needs to be able to reach into the tool kit, select the appropriate technique, and use it to make a specific intellectual or emotional connection with their audience.

Making complex scientific concepts meaningful to diverse audiences is challenging! Message based interpretation (MBI) involves translating technical information into meaningful stories and concepts that connect with the hearts and minds of audiences while appealing to their diverse experiences and learning styles. The three founding principles of MBI are clarity of purpose, effective organization, and delivery of a compelling message. Use of a clearly defined message provides a framework for creatively selecting and distilling volumes of scientific information into an enjoyable, thought-provoking program. An effective, MBI presentation is well-organized and incorporates an introduction, body of content linked by transitions, and conclusion that gathers together and revisits content in support of a single, unifying message. By forging an

emotional or intellectual connection with audiences, MBI interpretation not only provides for effective communication, it is as fun for MBI interpreters as it is for volcano visitors!

32-O-03

Lost in Translation: Communicating Volcanic Risk in the Eastern Caribbean

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The communication of information regarding risks related to volcanoes has been an on-going process in the Caribbean through a number of sources including the government, the local scientific team at the Seismic Research Unit (SRU), and the Red Cross. However, the overall effectiveness of communication efforts has never been evaluated to establish whether messages are being understood as intended. This paper discusses work conducted in the region using the 'mental models' approach as a guiding methodology, in an attempt to gauge people's understanding of volcanic hazards, and how information may need to be tailored according to differences in these models.

Two contrasting islands have been chosen – one with recent experience of a volcanic eruption (St Vincent) and one without any (Dominica). An initial field season involved interviews with the key communicators mentioned above, and local residents in high risk volcanic zones. Data analysis showed that, despite high levels of public trust in both scientists and local authorities, a number of misconceptions exist that could lead to problematic behavioural responses in an emergency. These include beliefs that ash is an eruption precursor; that warning periods will be weeks-months; that only 'hot water' rather than pyroclastic flows travel down river valleys; and that the sea water could become hot or rough and so be dangerous during an eruption – potentially a major issue as some evacuation by sea will be essential.

The prevalence of key different mental models has been estimated during a second field season using quantitative questionnaires. Focus groups were also conducted to discuss the merits and drawbacks of existing outreach materials in circulation. Results from this research will be presented at this conference, and also fed back to the SRU and local disaster preparedness authorities to enable the improvement of future outreach efforts.

32-O-04

Merapi Case Study: Applicable Integrated Management Technology as Volcanic Disaster Prevention System on Community Basis at Balerante Main Observatory Post

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Yogyakarta has affected by 2 potential disasters (hazard) such as Geologic Hazard – volcanic disaster, earthquake and tsunami, and Climatic Hazard – Cyclone, Storm and weather change. Pre disaster actions use applicable technology such as satellite imagery, weather satellite data, seismograph interpreter, internet, rainfall measurement, high zoom binocular, digital camera and two ways communication as peripherals to observe and analysis of potential risk, hazard and disaster. This peripheral is operating by Balerante main Observatory Post (independent observatory that developed by community has established one year ago). This post is monitor and observed Merapi 24 hours a day. Based on 24 hours monitoring and observation, we calculated correlation between Merapi activities -earthquake activities, and Merapi activities-weather activities and other correlation. All correlation has counted and processed with Risk Management Analysis as a tool to measure potential risk, hazard and disaster. Example, when Merapi eruption, all independent post around Merapi will report via two communications about the weather condition and cross check with real time weather monitoring by satellite for general condition, direction of wind, temperature and pressure. Early information will distribute to all independent post as prevention for people around Merapi. Measure of response time between earthquake and Merapi activities to calculated possibility of eruption. Weather activities will monitor 24 hours a day to find possibility of rainfall around Merapi that potential causing rainfall lahar. Potential hazard map has a one important program to give early information and to prepare action and response planning to people around Merapi. The contribution and involvement of community has express use two ways communication equipment that active to inform and make report to Balerante. Use this communication the education about Merapi, weather and earthquake has informed and distributed, at other side the community understood how to manage and to response when disaster come (pre disaster action).

32-O-05

Tourism Around Active Volcanoes in Costa Rica. Opportunities to Raise Awareness and Reduce Hazards.

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Costa Rica has received an average of 1.6m tourists every year in the last 4 years. Out of this figure, 60% of visitors declared to have visited at least one of the volcanoes. This number remains above those mentioning a visit to beaches or mountains as preferred destination.From NW to SW the 5 active volcanoes visited are; Rincon de la Vieja, Arenal, Poas, Irazu and Turrialba.Although all these active volcanoes (monitored by OVSICORI-UNA) are visited, some receive more tourists than others e.g. Arenal and Poas. Several reasons explain this differential in visitation, namely accessibility, vicinity and level of volcanic activity. Arenal lies some 3 hours drive from the Central Valley. Despite its rural location and weather limitations it is one of the

most visited offering a wide variety of activities around it. Some of the most salient topics in recent years is the growth of visitors, many of them undertaking illegal tours offered by unconscious tour guides. Despite this fact, and after several fatal and non fatal incidents, most of visitors play an important role in sensitizing local settlers and tourist entrepreneurs. Their solely presence and the investment they make to visit and admire such natural element is enough for nationals to take measures to protect it and respect it. Such awareness along with new communication technologies provide volcano researchers with a wide variety of ready informants around the volcano. Ongoing activity and description of past events are recorded and transmitted informally by these settlers, visitors and tour guides to the Observatory.As settlers and tourism businessmen receive profit from this active volcano, tour guides are more conscious about the information they pass to their clients, this transpires to the general public provoking more and better informed setlers around the volcano. Poas volcano, on the other hand, receives a similar average number of visitors than Arenal. Nonetheless the acute informant effect does not take place due to the distant areas where communities are located and to the lack of sight to the summit. In this case OVSICORI relies on information coming from Park Rangers, tourists and tour guides. These two cases will be revised in this presentation along with comparative examples from other active volcanoes mentioned above.It is believed that a comprehensive effort in the near future, among Park Rangers, locals, tourists and Civil Defense staff will bear better informal observation and information skills, useful for more formal volcano monitoring duties.

32-O-06

The Role of the Museum in Volcano Education

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We are given many blessing and disasters from the volcanoes. And volcanic activity in cycles; some volcanoes active every few years, some every few decades, others after being dormant for hundreds of years. These intervals are sometimes very long in human history, so it is very difficult to raise an awareness of volcanoes in each generation. Children don't have enough information about volcanoes. Even in their school education, there is not enough time to integrate their study of nature and cultures. It is therefore very important that museums take the main role in volcano education.To understand volcanoes is to understand the working of nature and cultures. The same understanding also reduces the impact of disaster from volcanoes. In also Volcano Museum, we have been doing fieldwork studies for many years, as well as online education for students. Recently we have been inviting 38 junior high schools in Kumamoto city to study at our museum. In my speech, I'll tell you about our museum activity and about the importance of the role of the museum.

32-O-07

Efforts to Learn About Volcanoes at Mt. Unzen Disaster Memorial Hall

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Purposes of establishing the Mt. Unzen Disaster Memorial Hall include conveying the danger and lessons of hazards caused by eruptions at Unzen (Fugendake), inheriting awareness of preventing natural disasters, and playing the role of providing comprehensive learning functions as the core facility of the Heisei Shinzan (new lava dome) Field Museum.

This hall has been actively involved in hosting various activities, including workshops called the "Heisei Shinzan Family Class to Cope with Volcanoes." Parents and children are encouraged to learn about volcanoes and disaster prevention through volcanic experiments in the kitchen and actual mountain climbing so that children can easily learn about volcanoes and natural phenomena, become aware of disaster prevention and acquire necessary wisdom to co-exist with the volcano.

As children who participate in these events have not actually experienced the disaster caused by eruption at Mt. Unzen sixteen years ago, they become quite interested in pyroclastic flows and debris flows. Parents participating together with their children also comment that it is a good opportunity to remind themselves of the disaster and reconsider the volcano and disaster prevention.

We hope to continue hosting events and workshops for the purpose of providing information on volcanoes and natural disasters as well as handing down awareness of the eruption disaster. We would like to remain active as the core facility of an information and volcanic education center by providing accurate information on volcanoes and raising public awareness of disaster prevention.

32-O-08

Educational Activity At Ingv Centres To Mitigate Risk Of Vulcano And Stromboli Active Volcanoes (Aeolian Islands, Italy)

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Vulcano and Stromboli are the most active volcanoes of the Aeolian Islands. Vulcano is in a quiescent stage since the eruption of 1888-90, but in the last decades it underwent several crises with huge increase in the gas output and temperature of crater fumaroles, and in the magmatic gas components. Stromboli is characterized by a permanent mild explosive activity, episodically interrupted by major explosions, lava effusions, or paroxystic explosive events (October 2001: a tourist killed; December 2002: lava effusion, tsunami generated by flank collapse; April 2003: explosive paroxysm, block fallout on Ginostra village; February-March 2007: lava effusion and paroxysm). Both island are renowned tourist sites and during summer risk increases as there are 10,000-15,000 persons per island (only a few hundreds in winter). In order to reduce the risk by educational activity, a Volcanological Information Centre has been established on each island (since 1990 at Vulcano and 1997 at Stromboli), by Istituto Nazionale di Geofisica e Vulcanologia (INGV) in cooperation with National Civil

Protection and local authorities. Visitors receive informations on volcanic hazards, volcano monitoring systems and preparedness plans. Past and current volcanic activity is illustrated in the exhibition rooms, where real-time images of the active craters of Stromboli, Vulcano and Etna can be observed, together with seismic and geochemical signals, on dedicated monitors. A special attention is given to provide instructions minimizing the risk for those willing to climb the summit crater area. Booklets and posters are distributed freely. During summer, volcanology students of several Italian universities, coordinated by senior researchers, are involved in the tourist educational/information activity in the visitor centres.

32-O-09

Volcano Education and Ecomuseums

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Natural disasters vary depending on the region, and it is important to take measures in accordance with individual regional risks. The concept of an ecomuseum is that an entire area is seen as a museum where conservation, exhibition and explanation using actual things are carried out on the spots. Such a concept enables it to play an extremely significant role in disaster prevention as it can convey the characteristics of local nature and hazards. At Sakurajima Museum, an eco-tour has been organized where explanations are given while looking at real things, assuming the whole of Sakurajima to be a museum. Lecture sessions and support for school education are also provided. Lecture sessions are generally considered not so interesting and less attended, yet their educational effects on motivated participants are significant. On the contrary, experience-based events such as eco-tours attract many participants who are often repeaters as well. There is a tendency for people to respond well to phrases like "this time only" or "special," and the rate of participation drastically changes depending on how the events are announced. In addition, it is more effective to convey indirectly how volcanoes are related to people's familiar themes than directly explaining volcanoes. For adults, explanation-based programs addressing their intellectual curiosity work better, but are not appropriate for children. For children, experience-based programs incorporating actions "making," "touching" and "searching" are extremely popular and effective.

32-O-10

The Teaching of Volcano at School

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In elementary school, pupils (=students) study 'The change of landform by volcanic activities and earthquakes.' They choose between 'volcano' and 'earthquake' on the basis of interest and curiosity. In lower secondary school, students study active volcanoes; Unzen Volcano, Sakurajima Volcano, and Izu-Osima Volcano. The type of volcano is caused by the viscosity of lava flow, but teachers need not explain temperature and chemical elements about lava. In a textbook, we can learn about six igneous rocks; rhyolite, andesite, basalt, granite, diorite, and gabbro. In a class, in fact, students usually study only two rocks. One is volcanic rock and the other plutonic rock. Almost all the textbooks deal with andesite and granite. And also, students study rock forming minerals like quartz, feldspar, biotite, hornblende, pyroxene, and olevine. 20% of the upper secondary schools of the whole country have earth-science class. On National Center University Entrance Examinations, only 25,000 (4%) students (out of 550,000 examinees) take the earth-science examination. This is why we cannot expect the diffusion of the earth-science literacy on the teaching of upper secondary school. It is not too much to say that, in Japan, students come to establish volcanic common sense by the end of lower secondary school. So, in a class for social education, I usually try to explain the basic knowledge of rhyolite, andesite, and basalt so that the participants can understand dacite. In addition, I try to prepare substances in order that they can understand volcano more easily.

32-O-11

Virtual Volcano Field Trips in New Zealand: Enthusing School Children in the Science behind Volcanoes

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Traditionally, volcano-related outreach activities engaging school children have involved printed material, school visits/talks by scientists, videos, and, rarely, visits to observatories and volcanoes. While there is no substitute for first-hand learning experiences on a volcano or personal interactions with volcanologists, often this is not possible due to costs, logistics, or heightened volcanic activity. Research on community resilience in Auckland has shown that traditional outreach methods (e.g. pamphlets) have had limited success, and more innovative strategies to engage and motivate the community are needed. Increasingly, the internet is being used as a tool to reach school children in educational activities. We suggest that adapting or piggy-backing on established internet educational programmes may provide a useful, low-cost outreach strategy with the potential to engage and motivate large numbers (thousands) of young people at once.

LEARNZ, a government-supported online educational programme, has been running virtual field trips for school children to New Zealand volcanoes for over 10 years. Linkage to the curriculum and low enrolment costs ensure a high level of uptake; typically 50-120 classes participate in each trip. Trips involve a combination of background reading, live audioconferencing between students and 'experts' (e.g. volcanologists), daily video clips, competitions, web-board discussions, classroom activities and teacher and student feedback, all facilitated by the 'LEARNZ teacher'.

Whilst the LEARNZ field trips are not currently part of any official outreach activities specifically aimed at increasing awareness and preparedness, there is huge potential for future campaigns to be incorporated into the existing (or similar) programme(s). Secondary school

children in New Zealand are often difficult to interest in volcanoes and volcanic hazards, having been overexposed in kindergarten and primary school. LEARNZ has had great success in enthusing children of all ages by focussing on the science of volcanoes and by utilizing technology that students are familiar with and enjoy.

32-O-12

A Multidisciplynary and Multi-hazard Educational Path: The Italian EDURISK Project

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The natural risks assessment and its further step in researching how to mitigate these risks, gives to education and outreach activities an important and peculiar role. Volcanoes are one of the people favourite scientific issue, and the request of information about them, is particularly frequent and pressing in active volcanic areas, where information and education should walk together. EDURISK is an educational project financed by Italian Civil Protection Department and National Institute of Geophysics and Volcanology (INGV), involving 63 primary to high Italian schools, in developing and testing a multidisciplinary approach to hazard learning and the management of psychological aspects related to risk. Teachers formation activities, WEB designing for e-learning and teachers support, and educational material production, are the different phases of EDURISK educational programme, that was also drawn on peculiar regional environmental characteristics. Particularly interesting has been the multi-hazard approach dealing with earthquakes and volcanoes, tested on a primary school located in Ercolano, the famous roman town destroyed during the 79 AC eruption. Vesuvian area peculiar natural features, the related hazards and psychological aspects linked to seismic and volcanic risks, have been the main themes developed in the EDURISK educational path proposed to the Ercolano school teachers. Students from 6 to 11 years have been stimulated to work on their fear of earthquakes or a Vesuvian eruption, but also to retrieve memories from their parents, their territory and their town past. The last Edurisk experience has been the developing of an innovative educational exhibition “All Fall Down”, set up at Ercolano school in May 2007. The exhibition consists essentially in several “game-machines” and experiments that allow kids to learn in a funny way more about earthquakes and volcanoes.

32-O-13

The Tastiest Book on Volcano, in the World as an Teaching Material in Japanese Public School to Reduce Volcanic Hazard

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The author published "The Tastiest Book on Volcano, in the World" on December 2006th, to spread knowledge about volcanoes among the junior high school students in Japan and to decrease human damage by volcanic hazard. The book is a handbook on volcano written in Japanese. This book contains plain explanation of volcano, and manual of ten volcano experiments using kitchen material. About 40,000 books were sold until May, 2007. The purpose of this book is to spread knowledge of volcanoes to Japanese Junior high school students and to reduce risk of eruption.

The base of this book is the author's experience of lecture in public Junior high school. The author has taught as much as 70 classrooms (about 2,000 students) within these five years. Customer research in these classrooms was useful when writing this book. Largeness of gigantic eruption is explained by comparison with turtle like monstrous beast "Gamera" (classic and well known to Japanese), origin of caldera is explained by a simulation experiment using cocoa powder and condensed milk. The author will present some of the tips for teaching in classrooms and for writing book to Junior high school students.

32-P-01

The Effectiveness of Volcanic Hazard Communication in the Caribbean: A Case Study of St. Vincent

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Despite improvements in the monitoring of volcanoes, eruptions continue to have a major impact on lives and property. As a result, the effective communication of the nature of volcanic hazards is imperative in increasing awareness of the threat from an eruption. Maps are frequently adopted to communicate volcanic hazards but the effectiveness of that medium of disseminating the risk from volcanic hazards has rarely been considered. Furthermore, little attention has been given to discovering from which resources people actually receive information about hazards and, indeed whether current methods of disseminating this information are the optimum channels through which the relevant stakeholders would prefer to receive this information.

Information regarding the nature of volcanic hazards in the Caribbean can be found mainly in scattered journals and scientific papers, mostly in a form inaccessible to vulnerable communities most in need of this information. The Volcanic Hazard Atlas was produced as a means of assimilating this information and transferring it into a more accessible resource to be used as a tool in disaster preparedness, development planning, volcanic hazard mitigation and public education. This research uses quantitative and qualitative methods to examine the effectiveness of the Atlas in communicating volcanic hazard information in St Vincent. The rationale for this research is to obtain an insight into improvements for future projects that seek to ensure that volcanic hazard communication tools are tuned to the needs of the users.

32-P-02

Community Understanding of the Lahar Risk Around Mount Rainier, USA

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Mt. Rainier is a large, active volcano in Washington State, United States. While a variety of volcanic hazards at Mt Rainier threaten the region, there is more summit snow and ice cover on Mt. Rainier than all other Cascade volcanoes combined, exacerbating the lahar hazard. A number of actions have been taken to mitigate the lahar hazard and its effects on downstream communities. One such mitigation measure includes the installation of an automated lahar detection system which triggers alerts when lahars are generated. In addition, the USGS, local educators, and emergency managers have been involved in a public education program with the intention of informing residents and visitors about volcano hazards, evacuation routes, and other appropriate response measures. This poster presents a summary of the results from the 2006 community awareness survey undertaken in several at-risk communities. The vast majority (82%) of respondents know that their community has a warning system in place. Regarding evacuation, 56% of respondents stated that the official evacuation routes in their community do not provide an adequate means of escape in the event that a warning is issued. Furthermore, 45% said that they have considered using an evacuation route different from the one outlined in the official plan. By far the most common reason for considering alternate routes is fear of traffic jams, panic and congestion when trying to use official evacuation routes. Of those residents who have children in school, 27% said that they did not know if their child's school has an evacuation plan, and of those who were aware of such a plan, only 35% express trust this plan. An important finding is that approximately 40% of these individuals said they would not allow their children to stay at school and would come to get their child in the event that a lahar warning was issued. The results of this study identify a number of key issues that need to addressed in future emergency management planning, warnings system testing and exercises and public education initiatives.

32-P-03

Comparison of practical ways of volcano disaster prevention knowledge corresponding to local characteristics.

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Appropriate disaster prevention activities for residents and visitors in volcanic areas are essential for hazard mitigation. To live in coexistence with volcanoes, residents shall do the following three things: (1) To be aware that they are living at the foot of an active volcano. (2) To understand that their coexistence with the volcano while it is resting may be disrupted by a serious volcanic disaster. (3) To understand the possible kinds of hazards, the potential vulnerability and intensity on their lifestyle, and know how to cope with a volcanic hazards. The authors studied practical ways to inform all local residents with little or no knowledge of these issues by making of the teaching tools, and a local briefing session in each area. Studies were carried out in areas surrounding Chokaisan, Tsurumidake and Asamayama volcanoes; each having its own unique local and geographic features. In a questionnaire of 356 residents around the Chokaisan volcano, 77 percent of respondents answered that the volcanic hazard map was effective. Sustained action such as the publication of volcanic hazard maps is necessary but funding and staffing problems need to be addressed. In our presentation, we will introduce some of the communication items and activities we have developed and discuss their future implementation.

32-P-04

Cultural Responses to Geophysical Hazards in Indonesia.

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Recent natural disasters in Indonesia have highlighted the need for improved, proactive, and culturally sensitive emergency management. The 2006 volcanic crisis of Mt Merapi, Java, initiated this investigation into the role of culture in the perception and management of volcanic hazards. The aims of this project are to build indigenous hazard knowledge into improved disaster management scenarios and to provide community based risk awareness amongst at-risk populations. Data collection methodology includes adapting participatory social science research methods such as community based hazard mapping and focus groups. This provides a bottom-up research approach fostering an educative change without eroding the cultural values of the community at risk. The community based hazard maps will be integrated with more conventional remotely sensed and field-based geo-hazard maps. The resulting resources will form the basis of more readily-understood hazard maps and the development of a culturally acceptable and more effective emergency management for ethnically diverse volcanic regions. The data will also provide a foundation for the design of an educational outreach programme for Indonesian volcanoes which is both successful without altering the indigenous beliefs of the local at risk populations. The two field areas, Mt Merapi, Java and Mt Agung, Bali, were chosen as they are both volcanically active having erupted within living memory and culturally diverse. In addition the residents living on the flanks of the volcanoes have recently refused to evacuate in times of heightened volcanic activity due to their indigenous beliefs. The religious, cultural and geophysical differences of these field sites epitomize

Indonesia and the need to investigate the indigenous beliefs controlling people's reactions to volcanic hazards and other geophysical hazards.

32-P-05

Promotion Methods for Cooperation on Volcano Disaster Prevention and Mitigation

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Local governments play very important roles in disaster response to volcanic eruption. However, since volcanic eruption is an extremely rare type of nature phenomenon, experience accumulation becomes difficult. Moreover, because of the change in personnel per 2-3 years, it becomes more difficult for Local Governments to response quickly and properly.

In order to resolve this problem, a kind of exercise becomes to be necessary, in which situation after volcanic eruption is simulated and response action could be discussed during the exercise. On the other hands, as a complement to local govenment's capacity, exercises that could promote citizens' self-reliance and mutual aid are the same important. These exercises are usually called Disaster Response Exercises, which prove to be effective tool to improve response capabilities to disasters. However, because of the lack of know-how in exercise methods and disaster imagination, this kind of Disaster response exercises are difficult to be conducted by local governments at present. In order to spread the implement of Disaster Response Exercise, cooperation between citizens and experts on exercises and volcanic disaster, and etc. is thought to be indispensable.

This paper introduces a process from the plan to the implementation of a volcanic Disaster response exercises on the basis of cooperation between citizens and experts on exercises and volcanic disaster, and etc. And then, its effective is verified from the viewpoint of participators from local governments and citizens. Finally, consideration is conducted on promotion methods for this kind of volcanic Disaster response exercises.

32-P-06

Kazan Friendship Network as an Online Community to Familiarize with Volcanoes

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The Kazan Friendship Network (hereafter KFN), was born in the internet in 2001 and has formed an online community to familiarize with volcanoes. The KFN consists of ordinary people, including volcanologists, and everyone who has interests in volcanoes can join it. All the members are linked by a mailing list and can communicate at any time and place. In the mailing list, the members exchange a lot of topics about not only hazards, but also blessings from volcanoes every day; flash reports of recent activities of active volcanoes around the world, interpretation of brand-new volcanological studies, travel reports of volcanoes, information on events (symposiums, lectures and field excursions) and entertainments (TV programs and movies) related to volcanoes. A WEB site (*http://kazan-net.jp/*) has been constructed to spread interests and fascinations of volcanoes to the public and increase new volcano fan. The KFN also have organized field excursions and events as opportunities for direct interaction among the members.

An important role played by the KFN is to form a community to share interests in volcanoes among ordinary people, who are hard to join scientific professional community. Another role is to enable us to contact information on volcanoes every day through the mailling list. The daily communication can change unfamiliar existence of volcanoes to familiar one in ordinary people's awareness, and correct understanding for volcano's behavior and volcanic hazards is expected to be facilitated.

32-P-07

An Ash Fall Atlas Postesr for Volcano Hazard Education in the U.S.

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Ash fall is the most aerially extensive primary volcano hazard during explosive volcanic events. However, the consequences of ash fall are difficult for people to imagine without direct experience with an eruption or with ash as a physical substance (which bears no resemblance to the more commonly known fireplace ash). As a result, some people may over-react to warnings of ash fall. Others may dismiss the hazard and fail to take adequate precautions. To help address this, we are preparing a pictoral ash fall atlas that presents images of ash fall ranging from the lightest of dustings to severe and damaging inundation. We are generally following the model of the Beaufort wind force and sea state scale which are frequently depicted by increasingly severe photographs of sea surface conditions as wind force and wave action escalate. Included will be imagery of scenes during and after ash falls to illustrate changes in sky conditions and visibility, as well as impacts on structures and other familiar elements in typical communities. In addition, we are developing more precise language and mitigation guidance to improve the text of formal volcano ash fall warnings that are issued by the National Weather Service, the U.S. Geological Survey, and other authorities in the United States. This atlas will reference the excellent existing guidance available on the Internet such as
http://volcanoes.usgs.gov/ash
and
http://www/ivhhn.org
and other resources available in the western U.S.

32-P-08

Navigating the Journey from Science to Education: Challenges and Solutions

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The Seismic Research Unit of the University of the West Indies monitors earthquake and volcanic activity in the English-speaking islands of the Eastern Caribbean. Since its inception in 1952, the Unit's focus has primarily been to provide contributing island governments with sound scientific advice on the geo-hazards to which they may be vulnerable. Although scientists have long recognized the important role of communications and public education in conducting the Unit's core mandate, it was not until 2001 that a formal education and outreach strategy was adopted by the Unit. As the Unit seeks to define its role in the area of geo-hazards education in the region there have been several challenges including limited human and financial resources, redundancy of efforts among other regional hazard awareness agencies and paucity of information regarding which communication tools are most effective in the region. This poster discusses the challenges faced by the Unit in forging its new role in the area of geo-hazards education and the strategies used to overcome some of these challenges.

32-P-09

Thirty-years-long Cultural Activities for Safer Community Including Kids Programs Around Usu Volcano, Japan

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The risky 1977 eruption experience encouraged the local community, especially Sobetsu town gradually to take long-range precautionary countermeasures. Various community-based cultural activities started since then, and contributed to establishing gradually mutual collaboration between local officials, people, media and scientists. A starting point was "Sobetsu Town Collage Program" in 1982-83. Then, Sobetsu Kids Program began in 1983 by Sobetsu Educational Office. The Kids Program was consisted of 3-6 weekend programs to study local history which includes two fields visits to (1) Showa-Shinzan, and (2) the summit of Mt. Usu, with collaboration of Mimatsu Masao Memorial Museum and Usu Volcano Observatory. They enjoyed and never forgot those experiences. Nearly 800 schoolchildren already took the program in a small town Sobetsu only ca. 3500 population. They had grown up and some were acted as a hazard management official at the eruption. The main turning point was the 50th Showa-Shinzan Anniversary Program. The '95 International Workshop was the one of the early pre-COV-type events and attracted 834 participants (36 overseas). Two days Kids program was also held with 165 attendants, including the invited children from Mt. Unzen, Izu-Oshima and Mt. Tokachi areas. After acceptation of a volcano hazard map in 1995, preparedness also started in Abuta; Mt. Usu map for school children, musical based on the children's compositions "the night of falling-stones", school operation manuals. Those efforts were actually tested by the 2000 eruption. Special thanks should be due to the media as well as oversea scientists including Dr. Harry Glicken, a young USGS volcanologist who was later killed at Mt. Unzen. Because of great social recognition, the area gained much supports after the 2000 eruption; Kids Video, Kids Booklets, Sobetsu Kids Programs, Field Kids Schools, School Lectures and Forest Revegetation Field Programs.

32-P-10

Public Outreach and Education by the Hawaiian Volcano Observatory

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Hawai`i residents have become accustomed to living with Kilauea's long-lived eruption (since 1983), and may forget about the hazards posed by this volcano and its potentially more destructive neighbor, Mauna Loa. The Hawaiian Volcano Observatory (HVO) is challenged with keeping the public informed about seismic and volcanic hazards.

To promote hazards awareness, HVO disseminates information through community presentations, the Internet, the National Park Service, Hawai`i County Civil Defense, and the news media. HVO's Web site (http://hvo.wr.usgs.gov) provides daily updates and current maps of volcanic and seismic activity, hazards, and Webcam views of Pu`u `O`o and Mauna Loa summit. Automatically generated maps show earthquake locations and magnitudes within minutes. HVO staff also write a weekly "Volcano Watch" column for local newspapers.
One of HVO's partners in public education is the Center for the Study of Active Volcanoes (CSAV) at the University of Hawaii-Hilo. Since 1990, CSAV has produced seminars, teacher training workshops, and video programs that explain natural hazards in Hawai`i. A cooperative grant established in 1997 funds a Natural Hazards Outreach Coordinator, who organizes visits to schools and community associations.

The October 15, 2006, earthquakes (M6.7 and 6.0) that shook the State of Hawai`i provided an excellent opportunity for HVO and CSAV to enhance public awareness of hazards. Because the quakes were located in north Hawai`i, many residents feared that an eruption of Mauna Loa or Hualalai was imminent. Web sites were immediately updated, and press releases and interviews were made available to the media. HVO and CSAV fielded questions from the public; documented the damage to homes, institutions, and businesses using videotape and photography; and distributed copies of the earthquake seismograms islandwide. Additional visits to schools and communities to talk about the cause of the earthquake and strategies for preparedness proved especially successful where damage was greatest.

32-P-11

Various Public Relations for Community Awareness about Risk and Beneficence of the Tokachi-dake Volcano, in northern Japan

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Mt. Tokachi-dake is one of the most active volcanoes in Japan. The volcanic lahar killed 144 people in 1926. It is important to improve community awareness on mitigation of volcanic disasters in this region, because 18 years have already passed since the last one in 1988-1989. Hokkaido Regional Development Bureau of MLIT, Japanese Government is developing effective public relations together with the various related organization in addition to provide better Sabo facilities and improved monitoring systems. In this presentation, we report our activities which include new field guide map and the special outreach programs for the elementary and junior high school students. Those programs has a specific purpose to hand the past disaster experience by the residents down to the coming generation, especially in the field. Besides, it is also important to inform the tourists about the active volcanism and the disaster mitigation efforts in the area. For these purposes, we set a special field course which includes visiting several volcanic landforms, inspecting animals and plants in the volcano flanks, and studying regional eco-systems, visiting historical traces and the monuments of the 1926 disastrous lahar, the Sabo facilities and the monitoring systems. We are attempting to upgrade the contents step by step based on the actual field excursions with the local government, school children and teachers. The kids/young people program is composed of the short lecture by the volcanologist and the audio-visual studies including volcanic eruption CG in 3D images. The contents include risk of the eruptions, favorite nature of a volcano, and the principles and effectiveness of the Sabo facilities. According to the questionnaire survey of the students who attended the special lesson, their recognition of eruptive phenomena and unfamiliar Sabo facilities became to be improved. Therefore, we believe it is important to continue such public outreach programs.

32-P-12

Collaborated Work for Disaster Reducing and Outreach with Citizen, Administrators and Scientists, at Kamifurano Town, Tokachi-dake Volcano.

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'Knowing the volcano' is the one of effective methods for reducing from volcanic disasters. Tokachi-dake volcano, located in the central Hokkaido, northern parts of Japan, has three major eruptions in the twenty century, especially, 1926 events gives extremely serious damage due to snowmelt lahar triggered by the phreatic explosion, killed 144 resistant. This tragedy became a novel.The 1988-89 eruption, several countermeasures were carried out before the disaster occurred. Hazard map prepared before the eruption starts in 1987, and structural countermeasure and lahar warning systems installed and evacuation training for residents carried out during eruptions. Hazard map also remake in 1990 and 2006. The latest hazard map utilize the latest simulation technology to hazard estimation. Education for disaster mitigation is also performing at elementary school in every year indicate as follows; Excursion to disaster prevention facilities for families; Administrators of countermeasures invite one day tour with families, elementary school kids and their teachers to check dam sites with a explanations and short games, to have understanding more deeper. The civil authorities also holds mitigation meeting for citizen with scientist lecture. In this presentation, we will introduce the status of disaster mitigating education at around Tokachi-dake volcano.

32-P-13

Public Awareness and Education at Tongariro Volcanic Complex, New Zealand: Social Science Guiding Risk Management for a Transient Dispersed Population

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Tongariro Volcanic Complex (TVC) hosts one of New Zealand's most popular day hikes, the Tongariro Crossing. The most recently active TVC vent is Ngauruhoe volcano which last erupted in 1975 producing ash fall, pyroclastic flows, and blocky lava flows. Quiet since 1975, it was previously the most frequently historically active volcanic vent in New Zealand. Te Mari Craters have also been active in the short European history (less than 200 years).

Sitting in Tongariro National Park, there are no permanent settlements on TVC's flanks. However, managing volcanic risk is complicated by the highly transient at risk population of tourists. The Crossing takes tourists directly past the steep flanks of Ngauruhoe and other Holocene vents. People may not camp on the active cones, but there are three accommodation huts on the lower TVC flanks. Although TVC is intensively monitored, officially notifying hikers of an impending eruption is nearly impossible along the 17 km track. 'Blue-sky' eruptions can also occur.

Public volcanic hazard maps have been developed to highlight natural warning signs and self-action. A baseline pubic awareness survey found that most walkers: (1) had confidence in 'authorities' to warn them should a volcanic event be imminent, but thought they would need to be self reliant if an eruption occurred; and (2) wanted hazard information to be visual (not text) and available both on track and in tourist facilities. Also, in contrast to a similar study at Montserrat (K. Haynes pers. comm., 2004) the majority (60%) of respondents found map-view easier to interpret than annotated oblique aerial photos. Visitors have mostly seen map-views of the track on signs and brochures, and are generally predisposed to reading 'maps'. Without this research we would have relied on the Montserrat findings, highlighting the need for social

science to guide risk management strategies. Further surveys will gauge changes in public awareness of the maps.

32-P-14

Libra: A Board Game for Teaching Uncertainty of Volcanic Disaster

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A common situation of volcanic crises is that scientists know that an eruption is likely but do not know what size and kind of eruption will occur. Volcano education needs to discuss the uncertainty of volcanic forecasts (Newhall, 2000). The author has developed "Libra", a board game for teaching uncertainty of volcanic disaster. "Libra" is a board game for learning uncertainty of volcanic hazard, and is based on the probability tree, which was prepared on May 17, 1991 about one month before catastrophic eruption of Mt. Pinatubo. "Libra" game set includes a playing board, twelve playing pieces, five activity level cards, a dice, money cards and some items to understand the situation of the virtual volcano named "Tokotan". Playing board is designed like a simplified hazard map. Playing pieces symbolize inhabitants around volcano. If the player wants to put inhabitant pieces to the distant and safe place, he must pay some costs for evacuation. State of volcanic activity changes from turn to turn by card and dice. By playing this game, players can experience many virtual eruptions and will aware of benefits and costs of precaution evacuation.

32-P-15

The "Kids in Aso as Volcanologists" Project - Building Children's Volcanological Skills

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The Aso Volcano of the Kumamoto prefecture in Kyushu, Japan which is famous for its caldera has given us a lot of resources such as rocks, water and sightseeing, and also has been an area for natural disaster. People living in the Aso volcanic area need volcanological skills. The "Kids in Aso as Volcanologists" project has been aimed to build children's volcanological skills with elementary school students to research about the resources from the Aso Volcano. We are in a partnership with elementary schools (Tateno Elementary School, Miyaji Elementary School and Hekisui Elementary School) in the Aso area, and experts such as volcanologists in the Aso area and the Kumamoto prefecture.

Students in each school have original research themes. The research themes have close links with the resources at the area where Elementary Schools are located. For example, the theme of Tateno Elementary School is "the Mystery of Tateno Valley". The school sits on an area of which a large portion of the western part of the caldera rim has been broken away. The students research why this phenomenon has occurred. Then, Miyaji Elementary School's theme is "Natural Springs and Life in Aso" and Hekisui Elementary School's theme is "Detecting the Origin of Odoriyama Spring and where it went".

These unsolved studies are very interesting. They study for half a year with the support of us, volcanologists, folklorists and hydrologists in Aso and Kumamoto then they will present these studies at a symposium organized by Aso Volcano Museum in this October. By having worked on these studies, the students show much curiosity and great interests about the Aso Volcano and build volcanological skills. We will have a presentation on the projects contents and it's research and educational effects on the students in the symposium.

32-P-16

Alaska's Volcano Teaching Kit: Building Awareness of Volcanic Hazards through State-wide Science Education

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As part of its efforts to reduce the risk to communities from volcanic activity, the Alaska Volcano Observatory (AVO) works with science educators to teach students about Alaska's volcanoes. As part of this effort, AVO offered the course, "Building a Volcano Science Kit", held at the Alaska Pacific University in the fall of 2006 through the USGS Alaska Science Center. The thirty-hour, ten-week course was offered to secondary level science teachers for two career advancing, professional development credits. Participants began the development of sustainable, place-based, Alaska Science Standards-referenced lessons for a secondary level volcano teaching kit. Lessons presented in the kit will include: Plate Tectonics; Alaska's Volcanic Landscape; Volcanoes and the Atmosphere; Anatomy of an Alaskan Volcano; Alaska's Volcanoes Rock!; Alaska's Volcanoes and You; and Careers and Monitoring Alaska's Dynamic Volcanoes. The kits will be available beginning in the 2007- 2008 school year. They will be housed at several facilities and clearinghouses throughout the state for check-out by educators for classroom use.

32-P-17

School Education for Volcanic Disaster Mitigation using 3D Satellite Image Presentation System SiPSE

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A system to provide data sets for the 3D presentation of Landsat images with their viewer was uploaded as the SiPSE homepage in the Internet in September 2000, initially covering Kyushu, Japan. Since 2001, coverage includes the whole of Japan. The digital elevation model data with 50 m resolution are embedded in the data sets. The SiPSE data viewer is able to drive a satellite 3D image in real time motion as a flight simulator in a

personal computer. A satellite image for 3D presentation may be selected from true or natural color, and single band modes. In particular, a monochromatic view of TM band-4 proved very useful in recognizing water and land areas, vegetation coverage and mountainous topography, and to compare with aerial and ground photographs with near-infrared mode. Topography and vegetation of active and dormant volcanoes can be vividly understood by the SiPSE system and its image outputs. The operation of the system was successfully tested by high-school students in the education for volcanic disaster mitigation at Sakurajima Volcano, and proved to be very useful in understanding the geographic situation around the volcano. The SiPSE web-site in Japanese is
http://sipse.edu.kagoshima-u.ac.jp/sipse/,
and an outline is described in English at
http://sipse.edu.kagoshima-u.ac.jp/sipse/sipse-e/index-e.html

32-P-18

Teacher Guide for Education in Volcanic Risk. Civil Defence Spain.

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The Spanish Proteccion Civil (Civil Defence) edited a Teacher Guide for Education in Volcanic Risk for primary and secondary schools. This teaching packet reflects the goals of the International Decade for Natural Disaster Reduction (IDNDR) in the management of volcanic crisis and the last European Research Projects in Volcano Risk. The contends include a illustrated background information over the nature of volcanoes and volcanic eruptions, volcanic risk, Civil Defence actuation and warning systems in volcano emergencies, autoprotection measures, psychological support in Volcano Crisis and the pedagogic guide for primary and secondary schools. Include a teacher's material for the classroom; poster, CD, toys and reproducible activity sheets for the students.

32-P-19

Supplementary Readers on Tarumae Volcano

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Tarumae is one of the most active volcanoes in Japan. Major industrial city and an international airport locate at the foot of the volcano. Major highways and a railway which cover the principal physical distributions in Hokkaido Island also pass through the south foot of the volcano. A dome-growth volcanic eruption occurred in 1909. Since then, none of major eruption has been occurred. Local residents and local government officials do not have proper images on hazardous volcanic activity. The first volcanic hazard map was published and distributed in 1994, but none of enlightenment program was done in this region.

A series of enlightenment programs has started since 2004. One of such program is to publish supplementary readers on the volcano for school children. Editorial board was established under financial support from Hokkaido Development Bureau, Ministry of Land, Infrastructure and Transportation. The board member including representative of school teachers around the volcano started editorial works in 2005. A block copy of the supplementary reader for junior high school level has completed in March 2007. The copy is A4 size and 90 pages consisting of 5 chapters and supplementary field trip guide. Titles of each chapter are: formation of Hokkaido Island; growth history of Tarumae volcano; natural environment; volcanic eruption and disaster; and information. A model curriculum using the reader is now planning and also elementary school level reader is now editing.

32-P-20

Nine years of Schoolchildren's Summer Course in Seismology and Volcanology

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The Seismological Society of Japan and the Volcanological Society of Japan have been hosting a "Schoolchildren's Summer Course in Seismology and Volcanology" in various locations related to earthquakes and volcanoes throughout Japan almost every year since 1999, which so far has been attended by a total of 355 children from ages 10 to 18. It is designed for experts on the frontlines of research and practice to have opportunities to communicate directly with children regarding the mechanisms and true nature of earthquakes and volcanoes together with the blessings of nature that are inseparably related to disasters. The course consists of games, experiments and communication that arouse children's curiosity.

Mr. Shimizu and I, both brought up at the foot of a volcano, have been active in this course and have learned about the parts that cannot be seen of Mt. Usu and Mt. Izu- Oshima Island, which have been familiar to our eyes since childhood. Through our experience, we have been able to expand our ways of thinking and understand how volcanoes are formed and even loved by people. We have been encouraged to face volcanoes in life rather than preventing disaster simply by evacuating from eruptions. This has had a major impact on our thoughts about our future.

Based on our involvement as staff in the course, we will report on seismology and volcanology education as an attempt to nurture a next generation who are aware of the affluence and scientific interest brought by volcanoes and earthquakes as well as their terrifying aspects.

32-P-21

Living with a Volcano in Your Backyard: an Education Program to Better Acquaint Students and Teachers with Mount Rainier, Washington

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The year 2007 marks more than a decade of education program collaboration between the U.S. Geological Survey (USGS) and the National Park Service (NPS). This partnership was conceived to provide resource materials, education, and field experiences for teachers and students concerning the history and hazards of Mount Rainier. The program's three components include teacher workshops, educational curriculum, and an education center for school group programming. Teacher workshops have been organized and conducted annually by USGS and NPS staff, and with assistance from trained teachers. A four-day workshop about Mount Rainier's volcanic history and hazards is funded by the hosting agencies and is free to participants. Teachers receive continuing education credits for participation and will be able to receive graduate credits in the future. The workshop has attracted approximately 15 to 20 teachers annually, with waiting lists some years. An inquiry-based curriculum entitled "Living with a Volcano in Your Backyard" was developed by scientists, teachers, and park educators for middle-school students. It addresses the cause, nature, benefits and hazards of Cascade volcanism. The curriculum challenges students to apply their knowledge of volcano hazards by increasing family and community preparedness. In July, 2006, Mount Rainier National Park opened its new Education Center. Park staff designed and built the center to be a showcase for sustainability and green construction. The Park Education Center features two classrooms and other amenities. The park recently received a grant to fund a volcano teaching mural for one of the classrooms. Visiting students and teachers can learn about the volcano, its products and hazards, and ecology. Results from multiple assessments suggest that there is increased community awareness about Mount Rainier's volcano hazards. Educating current and future generations is crucial to understanding and being ready for future eruptive activity of this beautiful, powerful volcano.

32-P-22

Educational Program on Regeneration of Woodlands After Usu Volcano Eruption

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After the eruption of Usu Volcano in 2000, we have endeavored to teach about the volcano's past experience, incorporating disaster mitigation. Primary schools and junior high schools have the lessons to teach this subject based on the published subtext in this area.

Though, teachers do have to be careful in the lessons because some of the children lived where houses and schools were destroyed and were directly effected by the volcano. Also, in their lessons, it was expected that teachers would refer to the research on regeneration of the woodlands that had been devastated by the volcano. The theme of regeneration has been central in encouraging the students about rebuilding after disaster. The regeneration research has also been utilized in engineering technology to regenerate natural, diverse and native woodlands.

The lessons on this concept were initiated in 2004 by Toyako Spa Primary school, which had to relocate to a safer site after the eruption. Disaster mitigation and environmental conservation are incorporated into the ongoing education program.

In addition, the seedlings of trees grown through the lessons are utilized for regeneration of woodlands in the huge sediment retarding basin constructed in the area devastated by the mudflow.

32-P-23

Potential of Unzenn Volcano as Teaching Material – Its Application to the Periods for Integrated-Study at Junior High School –

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In this study, I considered Unzen volcano to be one teaching materials and performed teaching materials study for volcano learning and local learning. In addition, I performed development / choice of learning contents to be able to inflect in period for integrated study in a junior high school. And I considered them in a class how it was good to perform positioning, any kind of learning guidance. In addition, I performed it after having taken the actual situation of a junior high student into account based on a questionnaire result by a class about a volcano in the periods for Integrated-Study when the writer performed it in a junior high school attached to Nagasaki University when I considered it.

32-P-24

Mt.Fuji and Sakawa-river—How Do We Hand Down the Ancesters' Fighting to the Descendants?

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1. Mt. Fuji is located on the island of Honshu and it is in the center of Japan. Here, the Eurasian, Philippine Sea and North American plates meet. Therefore, we have had seismic activities and orogenic movements caused by mantle-convection in the Mt. Fuji area. Mt.Fuji was formed about 10000 years ago by huge quantities of lava from an old volcano. It has had repeated eruptions, but during the last 2200 years we haven't seen eruption from the top crater. Eruptions have occurred only from the side crater.
2. Mt. Fuji erupted on Dec. 16, 1707 and belched out huge quantities of volcanic ash and dust for two weeks. The westerly winds carried the ash and dust to the east far away as 100km. People in the Ashigara-Kami area was affected for a long period of time by deep ash and dust. Examples:
(1) Sky (*Ten*)-Ground (*Chi*)-turnover (*Ten-Chi-Gaeshi*):

People turned the ground soil over the ash, and raised crop. It was terribly hard work done only by hand. Every time it rained heavily, great deal mud from the ash and dust flowed down from mountainous regions and raised the riverbed. This caused recent riverbank renovations to be ruined.

(2) In 1711, a big flood drastically changed the course of the river and flooded six villages. Some people from the six villages were forced to evacuate to the neighboring hills. People say it took 150 years before most of the people returned to their former villages.

(3) Kyugu Tanaka, appointed by famous commissioner Echizenn Ooka, renovated the two main riverbanks (The east and west Bunmei banks). He dedicated shrines at the two banks to the god of flood control, whose name was “U”, another name was “Bunmei”, the king of “Ka Kingdom” in 2000 BC, China. He wrote three items on each of the stone monuments:

a. People should plant peaches, plums, Japanese pears and Japanese chestnuts along the riverbanks.

b. Everyone should hold the festival, and visit the shrine once a year, bringing a stone, which can be used to protect from a flood in case of an emergency.

c. The Fund of 120 *Ryo* (a million dollars) for these events was presented by the Government. We write these items to hand down to generations for the next 1000 years on this stone monument.

3. This year, on the 300th anniversary of the Mt. Fuji-Hoei eruption, we the ARC members, are carrying out the following three programs:

(1) To pupils and teachers:

a. Making and distributing a supplementary-reader “Mt. Fuji and The Sakawa River” (100 pages).

b. Opening a “Summer Vacation Consulting Room” (for one week).

c. Distributing the supplementary-reader to the pubric libraries.

(2) To parents and people in the area:

Lectures at the various meetings, a club for elderly people, neighborhood association, etc.

(3) For everyone:

Dramatization by a famous acting troupe (under way).

32-P-25

Learning the Mysteries of Abu Volcano Group on Hagi City with Citizens and Schoolchildren

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Abu Volcano Group, one of 108 active volcanoes in Japan, are distributed on Hagi City and adjacent area, Southwest Japan. We have continued an education and outreach activity that attracts citizens' and children's interests on Abu volcanoe. In 2002, one of the authors (Nagao) held the special exhibition "Volcanoes on Yamaguchi Prefecture" in collaboration with the Yamaguchi Museum. Nagao also published the booklet and opened the home page on Abu Volcanoes. Moreover, Nagao and Fukuda designed permanent exhibition "Hagi as portrayed by rocks and stones” of Hagi Museum opened in 2004. Then we held the school children's summer course "Mysteries of the Abu Volcanoes” in 2005 and 2006 supported by Japan Science and Technology Agency (JST). The program consists of field excursions, easy experiments, and lectures on the volcanoes. We have also taught Abu volcanoes and their related subjects at elementary and junior high schools and provided the digital curriculum on Abu Volcanoes. Moreover, Nagao, Yamashita and Fujita proposed the volcano program which can be used from elementary schools to junior high schools in Hagi City. It is also important for an education and outreach activity on volcano to preserve the important outcrops. Recently, we found the large and beautiful deposits of the tephra from a scoria cone, which we have never seen in Abu Volcano Group, in the site of construction by Yamaguchi Prefecture. We are consulting with a department of Yamaguchi Prefecture to preserve the outcrops.

32-P-26

Mitigating Risk Through Student Education

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When volcanic disasters happen, the majority of citizens are not prepared. Orting is a small town in the valley located just north of Mount Rainier, in Wasington State, USA. It is the first town to be overcome when a lahar flows down the northwest flank of Mount Rainier. The evacuation time is a mere 40 minutes for thousands of people who make Orting their home. Orting and the valley are experiencing extensive housing growth. Emergency coordinators inform citizens of the hazards they will likely face in their community. Through the education programs at Orting High School, students learn about tectonic processes as well as the hazards they pose. Incorporating emergency preparedness training into the curriculum benefits both students and their parents. Quite often students do not understand the benefit of learning. They question, ”Why do I need to know this?” In this program, students learn about various hazards and then focus on Mount Rainier as this is the greatest hazard specific to the Orting/Puyallup Valley. They are expected to learn volcano processes, understand how they need to prepare, and then work on the actual preparation. They obtain information by accessing emergency preparedness websites, both non-profit and government. The students work with their parents to create a family emergency plan that is consistent with the school, city, and county plan. This activity has been well received. Many families are now working together to become prepared for an event from Mount Rainier as well as other natural disasters. One major benefit of the Orting tectonics curriculum is that it helps students become responsible and informed adults. More importantly, students at an early age learn the importance of understanding the geosciences and preplanning for disasters, thus mitigating the risk before the disaster.

32-P-27

Volcanological Education Program "Six Ways to Enjoy Volcanic Rocks in Sakurajima"

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At 18 Feb. 2007, volcanological education program "Six ways to enjoy volcanic rocks in Sakurajima" has been performed in order to create an opportunity for local residents to learn science literacy about volcanic rocks and the surrounding environment in Sakurajima. This program is carried out in the walking trail " Yougan nagisa yuuhodou". Availability of the educational field trip of the lava coast is reported.

Sakurajima is located in Kagoshima City, Kyushu, and is one of the world's most active volcanoes. Despite the increasing importance of economical development by the tourism industry as well as natural education activities in the area, there are few volcanological education programs to take advantage of the area.

Walking trail called " Yougan nagisa yuuhodou" (that means trail enjoying lava and coast), which is located on Taisyou lava outflowed in the west part of Sakurajima. This trail runs 2 km along the coast and there are abundant hints that learn the volcanic rock. For example, (1) cooling joints in the lava can be readily observed here. We can find interesting radial pattern of the joint and can touch the spiky surface of the lava. (2) Abundant pumice, which is rounded off, is cast ashore. Banded patterns can be found in parts of the pumice. (3) We can observe crystals included in broken lava blocks. (4) Stone monuments made by the lava let us to learn the usage of the lava.

We have led the walking tour with the local residents along the lava trail in order to monitor the educational value of the lava trail. The questionnaire data shows that the trail is sufficiently available for the education program.

32-P-28

Lesson from Mt. Usu Eruptions - Fruit of Volcanic Disaster Prevenntion Activities during the Dormant Period

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The population around Mt.Usu have experienced 9 times of eruptions, every 30-50 years, since1663. But our contemporaries are rather ignorant of the hazardous eruption involveing pyroclastic flow, which the Edo period witnessed 4 times. Two cases in the first half of the 20th century were minor as the eruption took place at the mountain foot and that underpopulated area. The 1910 eruption yielded hot springs; the one in 1944 gave birth to a new volcano; both of which proved to be resources for tourism, along with postwar restoration and economic growth.

August 7, 1977, in utter lack of public knoeledge of volcanic hazards, the Usu started to erupt at its summit, on a medium scale, whithin 32 hours after the advanced earthquakes, a column of smoke rising high into the stratosphere; 142 year record. Although the local people badly suffered socially and economically, they took steps in 47 days to cancel evcuation order and return to tourst business defying warning and advice; three persons falling a victim to lahar. Nevertheless, in the public mind, "human power has overcome that of volcano".

Later Sobetsu Town carried a through analysis which showed disaster was avoided by series of luck. People living close by the Usu should know disadvantage as well as advantage of their environment and prepare themselves against mishaps. No disaster is avoidable but casualties can be lessened with proper preventive measures. Which the Town had been promoting? Then, in 2000 the Usu erupted again. How did it go?

32-P-29

Project Exhibition about Mt. Usu Eruption in 2000

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Mt. Usu started eruption on March 31, 2000. Nobody was hurt or killed, because researchers, mass media, administration, and inhabitants cooperated well in advance and inhabitants could evacuate before the start of the eruption.

A Project Exhibition entitled "Mt. Usu Eruption in 2000. Living with the active volcano -" was held at Hokkaido University Museum in summer 2006. The exhibition was planned and executed by students of the Graduate School of Letters at Hokkaido University. They exhibited people's response, life, and the thoughts and feelings along the chronological development of the hazard. Visitor's special attention was focused to the real-size reproduction set of a temporary refugee room. Many visitors took off their shoes and went on the tatami mat floor, and they took pictures and looked at the imitated samples of the provided meals. Visitors were surprised that local residents expressed their friendship to Mt. Usu, and they believe Mt. Usu is a safe volcano, which was shown in one of the corners of the exhibition.
The characteristics of the exhibition were the following:
- the students who specialized in cultural anthropology and sociology rather than in science planned the exhibition, - the main subject of the exhibition showed the effects and the influences of the eruption on the livelihood of "the people" living at the foot of the volcano,
- the exhibition showed the present efforts such as an ecomuseum the use of a volcano.

Such characteristics attracted favorable comments from volcanologists, expert officials of disaster prevention, and others. The exhibition will travel throughout Japan for about 1 year starting in spring 2008.

32-P-30

Mount Rainier-Fuji Sister Mountain Curriculum Project and Teacher Exchange Program

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There is a long history of connections between Mount Rainier and Mount Fuji volcanoes as Sister Mountains. Mount Rainier National Park (MRNP) has relationships with the Fujisan Club, Waseda University, and Japanese

Volunteers-In-Parks Association.

In 1999, MRNP and The Mountain Institute's Sacred Mountains Program (TMI) began collaborating on joint education, outreach, and interpretation projects that include an exhibit, bookmark, consultation on the sister mountain relationship, planning for a future Mount Rainier Institute, a pilot seminar, staff trainings, and a teacher workshop. In 2002, TMI received a National Park Service Pacific West Region Partnership Achievement Award for its work with the park.

In 2005, the park received a National Parks As Classrooms grant for MRNP and TMI staff to conduct a Mountain Geography and Cultures teacher workshop and hosted a Japanese graduate student as a summer Education Intern. Teachers learned about the natural and cultural resources of Mount Rainier and Mount Fuji volcanoes, MRNP and TMI research and education programs, and Sacred Mountains of the World.

The Mount Rainier-Fuji Sister Mountain Curriculum Project and Teacher Exchange Program will build on these existing relationships and materials. The project includes developing comprehensive, interdisciplinary curriculum materials for US and Japanese teachers to introduce their students to the natural and cultural values of both volcanoes and use Fuji and Rainier as lenses to learn about the history, culture, geography, and environmental issues of each other's countries. Using the curriculum, we will conduct teacher exchange workshops at both Mount Rainier and Mount Fuji, with an equal number of spaces in each workshop for US and Japanese teachers.

We hope this will become a National Park Service Centennial Signature Project.

*MRNP and TMI are collaboratively applying for a US-Japan Foundation Grant to start in Fall, 2007 and will know the status of this grant by COV5.

32-P-31

Practice of Field Museum Activities on nature and culture of Mt. Aso

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Aso Museum Nonprofit Organization was established in 2004 aiming to be a base for research and practice of museum activities for 21st century in Aso. Aso Volcano Museum as one of strongholds, our main activities are educational promotion, collecting and dispatching information, research on disaster protection and the risk management, and the promotion of Aso tourism as well as the basic research on nature and culture of Aso.In addition to the traditional museum activities such as investigation and research, collection of material, exhibition and preservation, we need to add a field museum activity and nature school activity to observe the surrounding nature utilizing museum facilities and material. We should be ready to have a multi-valued and varied time in the coming future. We will think of the above as a new way of revitalizing the area and develop the Aso Volcano Tourism, eco-tourism of Aso Volcano as a new strategy of tourism. With this new concept we would like to contribute to high quality and good tourist site development. We will introduce some researches, programme-making, and substantial examples of human resource development.

32-P-32

The Education Program for Understanding Volcanic Hazards in The Kirishima Volcano, Japan

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Since 2005, the Miyazaki Office of River and National Highway, of the Ministry of Land, Infrastructure and Transport has been offering open lectures on sabo works in the Kirishima Volcano. Conducted along with a field excursion to the Kirishima volcanic region, the course is for the public to heighten understanding of the relationship between our lives and sabo work through the study of the volcano from various views including benefits and sediment-related disasters. It has been held twice a year, in spring at the flowering time of *Rhododendron kiusianum* and in autumn during the season of beautiful changing leaves. Participation is free of charge; approximately 20 people from elementary school children to adults have attended each time.

During the field excursion, volcanologists explain the eruptive history of the Kirishima Volcano and its mechanism of eruption, showing land features and outcroppings, while biologists describe the ecosystem formed by the animals and plants there. Participants come to understand through the program that the natural surroundings of the Kirishima Volcano exist as the result of the destruction by eruptions and subsequent regeneration; they also learn about the fragility of human life and the importance of sabo work to minimize destruction caused by eruptions. The lecture includes a study of volcanology, not only from aspects of earth science, but also as a part of the observation of nature as a whole, and comprehension of the volcano by participants becomes quite high. The course has enjoyed popularity each time, and many participants have come repeatedly. It is necessary to continue to offer similar lectures.

Session 3-3

33-O-01

Historical Volcanic Eruptions and Coexistence of Human Communities with Volcanoes

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In Japan, we have 108 active volcanoes. Some of them have erupted in historic times, causing a serious influence to nearby communities. In these cases, various types of volcanic disasters have been caused. It also posed a major problem of how to live with volcanoes in eruption-prone areas. In case of Mt. Fuji eruption in 1707, a large amount of scoria buried villages. After that, inhabitants faced starvation since the crops could not be

reaped. Furthermore, volcanic deposits frequently caused flood damage for a long time. In case of Mt. Asama eruption in 1783, pyroclastic flow and debris avalanche buried one village, also causing a big flood that destroyed many villages along the river. At the eruption of Mt. Bandai in 1888, mountain body collapsed by phreatic explosion and debris avalanche rushed down to bury villages killing 477 people. Such disasters by large-scale eruptions had serious impacts on communities at that time. As a result, the way for rehabilitation of devastated area was very severe and needed long time. In Japan, use of land around volcanoes, especially development for tourism, has been actively promoted. Therefore, how to coexist with volcanoes is a big problem for these areas. It is very important how to advance community vitalization utilizing volcano as a useful resource. and the "creation of a volcanic disaster resistant community" as the preparedness for future eruption. By learning what kind of disasters have been caused in case of historical eruptions, "hazard maps" for disaster prevention have been prepared and published for main active volcanoes. But, how to utilize them for actual disaster prevention is largely dependant on the awareness of local government and local people living in those volcanic areas. To know the past is the first step to prepare for future.

33-O-02

Folktales, Legends, and Myths about Volcanoes

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There are numerous old stories related to volcanic activities in the world. For ancient people, disastrous volcanic eruptions were supernatural, bizarre, and monstrous phenomena. They anthropomorphized volcanic eruptions as gods, goddesses, dragons, and giants. In Japan, many folktales, legends, and myths seemingly originated from volcanic eruptions. Daidara-Botchi is a wide spread legend about a giant, which probably originates anthropomorphized volcanic plumes. There are many stories of raging dragons with quintuplet, octuplet, or nontuplet heads, including the famous myth of Yamatano-Orochi. Many of these dragon stories, especially from the areas near volcanoes, seem like depictions of volcanic eruptions. The dragon legend of Hachiro-Taro is doubtlessly a volcano-related story. The story well describes the eruptive sequence of an eruption of Towada volcano in the 10th century, commencing with a plinian eruption, followed by a pyroclastic flow, and a lahar. The story describes the plinian eruption as the battle of the dragon Hachiro-Taro and the priest Nansobo, the pyroclastic flow as running away of Hachiro-Taro, and the lahar as being expelled by divine mice from a lake where he temporarily settled in. During the millennium, the volcanic disaster was told from mouth to mouth as the legend of the god dragon's act. However, a number of tales that seemingly describe volcanic eruptions are not related to volcanic activities in fact. The story of growth competition of Kometsuka and Nukatsuka mountains in Yamagata prefecture sounds like description of growth and collapse of cinder cones, but neither of these mountains is not a volcano. Spatially prevailed knowledge of an eruption at some place may have been analogized to the local mountains.

33-O-03

Pitfalls of Interpretation of Volcanic Eruptions on the Basis of Oral Traditions: the AD 1452-53 "Great Kuwae Event" (Vanuatu)

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A circular argument was developed through a series of studies that link a major climate-modifying eruption in the mid-15th century with Kuwae caldera inferred to be the fourth largest eruption in the past 10 ka. Oral traditions report that Tongoa, Epi, and Tongariki once formed "Kuwae" landmass, which was disrupted by a catastrophic eruption, causing many fatalities and flight of inhabitants from the area. Linguistic evidence, lineages, and legends support a cataclysmic eruption in the mid-15th century, however, no clear geological evidence has yet been identified to support a high intensity, large magnitude event. A large submarine caldera (12x6 km) between Epi and Tongoa is an obvious location for the Kuwae eruption, however, oral traditions locate it elsewhere. Extensive targeted archaeological studies were carried in the 1960s and 1970s to identify habitation sites preserved by this catastrophe in a similar vein to Pompeii. However, all sites in proximal areas show little or no volcanic effect on human settlement horizons. In addition, current archaeological work in key habitation sites 70 km southward on Efate Island have not yet identified evidence of distal Kuwae tephra. The obvious pumices deposits found over human occupation sites initially attributed to the "great" Kuwae event are actually reworked deposits from local early Quaternary or Pliocene-aged sequences. On Tongoa the largest island near the Kuwae caldera rim, pumice deposits clearly show lithic clast concentrations increasing toward the rim. Lithic-rich lag-breccias can also been traced in the southern lowlands of Epi to the north of the caldera. Previously reported widely distributed welded ignimbrites are inferred to be welded pyroclastic deposits formed due to various localised welding processes including dyke and sill intrusions and coincident basaltic lava fountaining. The characteristics and dispersal of the preserved subaerial deposits imply several eruptions occurred, rather than one giant event, and these appear to have been of low to moderate magnitude and intensity. The inconsistency between conclusions reached from oral traditions and geological data highlights the fact that good critical analysis of all types of evidence is needed before conclusions can be reached about past cultural "catastrophes" or also possible global influence on climate.

33-O-04

The Impact of Haruna Volcano on Human Life in the 5-6th Centuries A.D.

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Explosive activities of Haruna volcano occurred three

times in the 5-6th centuries A.D. in central Japan. Their impacts were so strong as to cause extensive damage in the area, which was reconstructed using an approach combining volcanology and archeology. The first eruption of Arima ash (Hr-AA) produced small amounts of pumice and ash in the 5th century A.D. It is believed that ancient people in this area began to worship Haruna volcano after this eruption.

The last two eruptions are ranked as VEI 4 and VEI 5 in order. The second eruption took place in the beginning of the 6th century A.D. and was characterized by phreatomagmatic eruptions forming fine ash fall as well as block and ash flow deposits. These deposits are collectively named the Shibukawa Tephra Formation (Hr-S). Observation at archeological sites suggests that three types of volcanic activity had an impact on human life and the environment: fallout of phreatomagmatic ash devastated farming fields, pyroclastic surges originated in block and ash flows that burned houses and blew down trees, and lahar finally buried the farm land.

This study has demonstrated that not only thick tephra fallout but even a thin pyroclastic surge could have a great impact on human lives, and thus, human society. Secondary disasters caused by lahar were also extensive in scal and lasted for a long period.On the other hand, the study has proven the strong will of ancient people to fight against the volcanic disaster. Some farms buried with Hr-S lahar deposit were rebuilt just after the cessation of Hr-S deposition. The quick recovery was identified from the newly reconstructed paddy field layout which precisely followed the previous one just below Hr-S. In addition, forests devastated by Hr-S pyroclastic surges were subsequently used for arable and pasture.

33-O-05

The Eruption of Oaefajokull 1362 and Destruction of the District Herad, SE- Iceland.

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The Oraefahjokull eruption in 1362 AD, is the largest explosive eruption in historic time in Iceland. It was a plinian rhyolitic eruption, with a bulk volume of some 10 km^3. The tephra from the eruption was deposited towards the SE of Iceland, thus covering only about forth of Iceland. Most of the tephra was deposited on sea and it is estimated that it covered several tens of thousand square kilometers, being observed in peat sections in Europe. Proximal studies of the deposits show that in the beginning of the eruption several pyroclastic flows and surges where generated as the plume was evolving above the eruptive vent. The Oreafajokull volcano is covered with a glacier through which the emerging volcaniclastic material had to go. As a result several jökulhlaups where generated, which flowing down the slopes of the volcano and onto prosperous planes around it. The eruption started early June 1362 AD, after a period of dormancy that had lasted for centuries. Prior to the eruption the district Herad in SE Iceland was a prosperous one, with a population of some 400 people. Anals from the time of the eruption mention that not a single person within the area survived. Excavations of farms destroyed in the eruption show that prior to the eruption earthquakes had struck the area, as stone in the walls had collapsed prior to the deposition of the tephra. The two farms so far excavated, show that all houses where stripped of usable material after the eruption. This has given ideas that some people might have escaped the destruction, however the pyroclastic flow and surge deposits indicate that this is an unlikely scenario and that the farms where stripped of usable goods in the aftermath of the eruption.

33-O-06

Restoration of Cultural and Natural Environment of the Area Covered by Volcanic Eruptions

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Our main aim in this study is the reconstruction of past natural and cultural environments of the areas damaged and ruined by volcanic eruptions.The areas were damaged and buried completely, but on the other hand, they keep good conditions in the sense of natural and cultural environments just before these eruptions, because they were covered very rapidly and completely with some pyroclactic deposits.And moreover, in that particular condition many other information of natural and cultural changes in these areas after the eruptions are accumulated under the ground, so we can say that they would give us many useful information for achieving our study, applying multi-disciplinal approaches in which human sciences and natural sciences are combined.We have selected Vesuvius in southern part of Italy, Kaimon-dake in Kagoshima pref. Japan and Haruna-san and Asama-yama in Gunma pref. Japan as some model cases, and now we continue the studies on some local archeological sites historically damaged by eruptions of these volcanoes.Until now many useful information have been gathered and analyzed in various study fields concerning of these sites.For the purpose of the reconstruction of natural and cultural environments of the areas damaged by eruptions, those results of studies in various fields will be integrated and finally amalgamated to make a new multidisciplinal study field, and we hope that we can present some general reconstruction models for the future damage suffered from some volcanic eruptions.

33-O-07

Four Major Late Holocene Explosive Eruptions That Affected The Larger Managua Area (Nicaragua)

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Four closely spaced major late Holocene explosive eruptions affected the present area of Managua: (1) A footprint surface in pits in the suburb of Acahualinca, the base of a phreatomagmatic eruption, is correlated with the Masaya Triple Layer (2.1 ka BP, basaltic-andesitic, 4.2 km^3 DRE). A swath of bipedal footprints up to 5.7 m wide made by 15-16 people comprises a central group with most tracks of children and 2 marginal groups (teenagers, women and men: different lengths of tracks and strides). The footprint surface was muddy. The people walked briskly towards the nearby shore of Lago Managua, possibly for protection and/or boats for escape from the powerful eruption of Masaya volcano 10 km south. (2) Overlying ol-bearing pumice lapilli and hyaloclastite are correlated with the Chiltepe eruption (1.9 ka BP, dacite, 14.4 km^3 DRE) whose deposits covered an area of today's most important lifelines of Nicaragua. (3) Masaya Tuff (c.1.5-1.8 ka BP, basaltic andesite, 6.6 km^3 DRE) in the pit is massive debrite. Powerful base surges affected the entire region. Such an eruption today would devastate this region including much of Managua. (4) Deposits of recently discovered Nejapa maar eruption (c. 1–1.5 ka BP, ol-rich basalt, >1 km^3), possibly not represented in the pit, covered western Managua. Late mafic tephra in marine cores, possibly Nejapa, suggests a much larger DRE. The dominantly juvenile, well-bedded dense lapilli and ash are >10m thick proximally. Underlying pottery (*Usulután technique*) maybe related to the Mesoamerican indigenous *Cultura Charotega-Nicarao*, ceramics above the deposit to the Ometepe people.

33-O-08

The Damage of the Mt.Tokachi Eruption in 1926 and the Recovery Process of Kamifurano

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The eruption of Mt. Tokachi in 1926 brought Kamifurano, Biei and Nakafurano serious damage by mud flow. In this disaster 144 persons died or became missing and 19 persons got injured. Women and children occupied more than 60 percent of the victims. Especially in Kamifurano, fields, buildings, roads and bridges were destroyed and the railroad and communication service was suspended. Since this village suffered the most serious damage in the disaster area, at the beginning it was thought that recovery is almost impossible.However in Kamifurano, immediately after the disaster the people in the village engaged in relief and associations of young people and local branches of ex-soldiers of the neighboring towns and villages helped to restore roads and to remove driftwoods as volunteers. In the process of the restoration, priority was given to repair the railroad and to recover the communication system which temporarily confused the relief activities.

At the time of the Mt. Tokachi eruption, the government was concerned about the fact that the increasing Japanese population in future could led into a scarcity of food and expected that the number of migrants to Hokkaido would increase and the agriculture there would be developed. Therefore, the government considered that the recovery of Kamifurano was indispensable in order to make the development of Hokkaido successful and accepted the budget of the Hokkaido government (Hokkaido-cho) and determined the budget of the recovery project. But among the people in the village Kamifurano there were also some people who were dissatisfied about having to pay the expenses for the recovery project as a whole village and they were opposed to each other.

33-O-09

Role of Those Living at the Foot of Volcano - Handling down the Wisedom to the Next Generation

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At the end of December 1943 frequent quakes shook the whole area around the Mt. Usu. Mimatsu Masao, postmaster of Sobetsu, remote village at the eastern foot of the Usu, knew what it meant and what he was supposed to do. He had assisted Oomori Fusakichi, noted professor of the Tokyo University, with his field survey, first ever in the history, on the volcano in activity when the Usu erupted in 1910. And he kept in his mind the professor's remark; you are only 22 years old. You might have chances to meet several eruptions of the Usu. Eruption is a disaster for the population in the area but a windfall for volcanologists. The one who happens to be on the scene should learn his lesson thereby and make beat use of it to reduce future damages which have no way to avoid. With the old year out, the Usu become more active. But it was a wartime. The military authorities put the matter in strict secrecy; no circumstances allowed volcanologists to come. Mimatsu Masao said to himself not to miss this chance. He made an objective record on his own, which eventually depicted the dramatic process of wheat fields turning into a volcano.

Analysis of his works surely help to forecast the development of future volcanic activities. On top of it his very challenge to volcanic hazard has led residentsto mind the prevention of it, I believe.

33-O-10

Socio Economic Impact of Volcanic Eruptions:

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In many cases, areas with volcanoes live off tourists, offering hot springs, mountaineering and marine sports, and the tourist industry is their main income source. Therefore, it often takes a long time for their local industries to recover after returning home from evacuation at the time of a disaster caused by volcanic eruption. In the tourist industry especially, economic damage can be considerable in neighboring areas where no volcanic disaster has occurred owing to so-called "harmful rumors." For people based and living in such communities, mental pain and anxieties sometimes surpass physical pain when they cannot make a living

through their regular business. In addition, this can also present a serious bottleneck for communities trying to rebuild themselves. In this report, we will first generally summarize the socio-economic impact by exploring the psychological and social factors of economic impact after a volcanic eruption. Secondly, we will consider the relationship between the medium- and long-term socio-economic impacts of volcanic eruptions and anti-disaster measures, focusing especially on ash falls, based on surveys conducted on the manufacturing and tourist industries in preparing a Mt. Fuji hazard map.

33-O-11

Socio-psychological Issues in Relation to Eruption Hazards

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In this presentation, the following issues will be discussed:
1.Evacuation
In hazardous situations, delay in evacuation may occur when experts' understanding of crisis cannot be shared by governments and residents, where a psychological effect called "normalcy bias" works.
2. Hazard
MapWe will consider what is required in a hazard map for appropriate evacuation.
3. Volcanic Information and Evacuation
PlansIntroduced here are efforts to make evacuation plans linked with volcanic information, focusing on a case of Mt. Fuji.
4.Panic and Rumors
There are very few panic cases before hazards. People, however, tend to become psychologically more sensitive, which could lead to occurrence of rumors and occasional evacuation dramas.
5. Life as Evacuees
Various problems with people's lives as evacuees will be examined.

33-P-01

The Archeology of Mind" in Pompeii Studies

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In a certain method and perspective of historical research, particularly relevant is the case of Pompeii because of its superb and significant conditions of conservation. Standing on the site where ancient people lived their daily lives, we could have the feel of their breath. The task of the present study is to probe into the mentality of the ancient people and make a systematic analysis of it, making full use of the historical documents and materials. It is surprising to find, in any small house, a large space provided for worshiping, where they pray for gods and goddesses, especially the genius of family (Lares). Cicero endorsed the custom, saying, "We should not neglect our worship of Lares passed by our ancestors." (*Leg*., 2.27) Below is our quantitative survey of Lares in the urban district of Pompeii: Number of space of Lares (lararium) 408.

Number of house 413. Here in almost all houses and shops we can see remains of Lararium. Cicero said with Thales of Miletus, "We can have not only images of gods and goddesses in our minds, but also their figures with our eyes." He even went so far as to say that because "early man and woman were living most near to gods and goddesses," they would all the more eagerly worship their ancestral divinities. Here we can discern how close to gods and goddesses the ancient people were living their lives.

Based on the perspective of "Archeology of Mind," which will try to excavate the feeling and thought of the ancient people, their spiritual life can be brought to limelight in our analysis of their inner world.

33-P-02

An Archaeological Excavation of a Roman Site in the Southern Part of Italy

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The first investigation of the roman archaeological site situated on the northern foot of Mt. Vesuvius was undertaken in the 1930s. Despite limited area investigated then, the monumental character of the revealed building and its topographic location were deemed sufficient to identify it with the residence where the first Roman Emperor Augustus spent the last days of his life. The investigation was, however, definitively suspended for political reasons in the following years. About 70 years later, a new investigation, initiated in 2002, has been conducted by the multidisciplinary research team of the University of Tokyo. It aims to examine this valuable Roman archaeological site from diverse perspectives, and, as such, consists of not only archaeologists but also experts in volcanology, geology, history, geography, palaeobotany, information technology and so forth.According to the volcanologist's investigation in relation to the sequence of eruptive events of Mt Vesuvius. The predominance of the volcanic deposits which cover directly the architectures derive from the eruption dated to 472 AD. This suggests that the building was used for at least a few hundred years, before it was at last buried in the late Roman period. The data acquired to date neither prove nor disprove the traditional hypothesis of identification of this building as the "Villa of Augustus". Excavated structures seem, however, largely relevant to an entrance of a building of considerable size and prestige. It is certain, at least, that the building was constructed by a person of the highest rank in the Roman society. What has been already brought to light is only

part of a presumably huge architectural complex. In order to acquire brand new knowledge of the ancient Roman world, the investigation needs to continue.

33-P-03

3-D Modeling of Somma and Pompei Excavations Buried by Eruption of Mt. Vesuvio

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In this research, we present our activity of 3-D modeling and its utilization of Somma and Pompei excavation, which have been buried by an eruption of Mt.Vesuvio in AD79.

Due to the recent evolution of sensing technology and computing performance, and our data processing technique, it has been becoming quite easy to capture real scene and crate its virtual realty model by computer graphics -- "Modeling from Reality". It enables to archive precious cultural heritages with a crises of disappearance on a computer, publish them through the Internet, and moreover help artistic and archaeological study by changing viewpoint, position of objects, colors, etc., taking advantage of merits of computer graphics.

Somma excavation is still under unearthing by Aoyagi's group from Japan, where some male and female statues and parts of residence which seems to had been a villa of Augusto. Here we scanned these articles and the "growth" of whole the excavation every year, and utilized the models in several ways: virtually adhered parts of a statue which was found as separately, verified the restoring effect of broken structures, etc.

Pompei is well excavated and known as a large seeing spot, and there remains beautiful paintings on quite a few walls. We targeted two buildings for modeling, and compared horizontal cross section of the model data and literary drawing. Also we measured spectrum of paintings for photometric analysis, and digitally reproduced its original color and the view under various illumination conditions such as sunset and torchlight

33-P-04

Burial Process of the Roman Villa on the Northern Flank of Mt. Vesuvius

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An archaeological excavation site at Somma Vesuviana in Italy provided a 3-D outcrop with height of 10 m to study the volcanic succession at the northern foot of Mt. Vesuvius. Through the stratigraphical study of the sediments and the chemical analyses of the juvenile fragments, the timing and the sequence of the burial processes of the villa, which had been attributed to the Emperor Augustus, have been revealed. The sediments filled the villa can be divided into five groups by the presence of intercalated soil deposit. The bottom unit directly covering partly collapsed Roman building includes air-fall, surge and epiclastic flow deposits. Charcoals found in this group give the age of 1500 years BP, and the juvenile scoriae show compositions within the range of the AD472 eruption ejecta and are completely different from the AD79 eruption, which attacked Pompei. The uppermost group consists of alternation of scoria and ash-fall layers and the overlying ash-fall layer. The petrographical features and the composition of juvenile materials coincide with those of the AD1631 eruption. The other three groups in between include air-fall and epiclastic flow deposits. From these sedimentary features, the burial process of the Roman villa is described as follows. When the AD472 eruption started, the villa had been partly collapsed. This damaged building was mantled by air-fall deposit with thickness of several tens centimeters. The remaining building was soon attacked by several phases of lahars and was buried up to the height of 5 m. The villa experienced at least four more eruptions and their ejecta and subsequent lahars buried the building further. The last eruption which completely buried the villa up to the present ground level was the AD1631 eruption. This reconstructed scenario suggests lahars generated just after the eruptions were major agent to fill up the Roman villa.

33-P-05

Watershed Geomorphology and Sedimentology of Vesuvius Volcano (Italy) and Pinatubo Volcano (The Philippines)

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A single volcano usually has a radial drainage system, running in various directions from the central summit area to different parts of the piedmont. Therefore, watersheds surrounding a volcano face in different directions. The geomorphological and geological properties of such watersheds are not identical, and each watershed may have unique hydrological characteristics which affect water resource availability and the probability of flood/sediment hazard. Such differences may have influenced the distribution of human activities such as settlement, especially in the historical past when human power for controlling resources and hazard was limited. Therefore, analyses of watershed characteristics in terms of geomorphology, sedimentology and hydrology are relevant to archaeological studies in volcanic areas. As an example of such analyses, watersheds in Vesuvius Volcano, Italy, and Pinatubo Volcano, the Philippines, were investigated. Both volcanoes experienced large eruptions in the recent past, significantly affecting surface conditions of watersheds and causing hazard from sediment and debris flows. Major watersheds on these

volcanoes were delineated using digital elevation models (DEMs) and GIS. DEMs also permitted the derivation of geomorphometric properties of the watersheds such as the mean and frequency distribution of slope angle. Geologic maps of the volcanoes were also digitized. These data were analyzed to quantitatively compare the watershed characteristics, which provided some useful insights. For example, the currently excavated site of Somma Vesuviana, or so-called Augustus' Villa, is located in a watershed whose structure seems to favor water supply from the upstream area more than in other watersheds of Vesuvius Volcano. Field surveys were also conducted in some watersheds of the two volcanoes to understand the distribution and properties of fluvial deposits, which may facilitate the reconstruction of past water flow. The results suggest that water flow and sediment transport has been related to volcanic eruption, resultant vegetation destruction, and subsequent vegetation recovery.

33-P-06

Restoration of Cultural Landscape and Natural Environment at the Area Covered by Volcanic Eruptions

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The Site of our research is available for understanding the natural environment and the landscape at the time of volcanic suffering. Because the site was packed by volcanic ejecta. We can expect that the pollen and the carbonized seed of plants are excavated many in it. By these samples with excavation, we make the system of identification kind of kind clear, research the past natural environment. Our study attempts aiming also the fact that it contributes to the future regional plan and agricultural promotion of the locale. We found the carbonized woods and seeds (Pinus pinea, Castanea sativa, Abies alba, Quercus tipo sempreverde and Quercus tipo caducifoglie etc) in the site. Those were from 4 century to 5 centuries. With the many analysis of such excavation case, is connected to the restoration of the landscape which surrounds the site. In addition, when the sample where the extraction of DNA is possible is excavated, relation system of the plant of today, it becomes possible to attach.

33-P-07

Geophysical Survey of Archaeological Sites Suffered from Volcanic Eruption of Mt.Kaimondake in 874 AD, Kagoshima, Japan

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Mt. Kaimondake is an active volcano and is located in Ibusuki city, Kagoshima Prefecture, Japan. It was recorded in historical documents that the mountain had erupted violently on the 25th of March in 874 AD. A huge amount of volcanic product fell and covered over the whole area of Ibusuki city. Its deposition is called "Murasaki-Kora", whose meaning is "purple-colored turtle shell", because it is purple-colored and very hard like a turtle shell. Archaeological sites and remains covered by Murasaki-Kora are in good preservation conditions and they can provide many kinds of information: for examples, how ancient people lived, how and what they cultivated, and etc. Furthermore, by analyzing archaeological sites over Murasaki-Kora in time-space domain, we can get information about recovery process after volcanic disasters. Purposes of this research are to find archaeological sites under Murasaki-Kora by geophysical techniques and to examine volcanic disasters and their recovery processes. This paper reports about three archaeological sites surveyed until now; Shikiryou site, Kaimon junior high school site, and Keigo site. At Sikiryou site located in 12.5km to the northwest of Mt. Kaimondake, widely spread rice paddies were found by GPR survey. At Keigo site in only 4.5km to the east of the mountain, marks of cropping were discovered under a thick Murasaki-Kora layer, and this is the first discovery of cropping in such area close to Mt. Kaimondake. Kaimon junior high school site in 2km to the north of the mountain is assumed to be an original site of Hirakiki Shrine which suffered from the volcanic disaster in 874 and was moved. GPR and a resistivity surveys were applied. An anomaly seemed to be artificial was found and it may be interpreted as a stone wall. This research is supported by Grant-in-Aid for Scientific Research on Priority Areas No.16089206.

33-P-08

Investigation of the Remains Which Suffered from Eruption of the Ninth Century of Mt. Kaimondake

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We conducted selection and excavation of remains with cooperation of the Ibusuki municipal archaeology museum and Ibusuki-shi Board of Education, making a study team entitled "the reconstruction of life culture environment in volcanic eruption affliction place in Japan", who researches on the land Ibusuki-shi, which was represented by Takano.Before excavation, a radar inquiry was performed by a study squad of Professor Hiroyuki Kamei of Tokyo Institute of Technology. As a result, we found the ridge of a rice field about 1meter below the surface, it was covered by the volcanic ashes spout in the night of 25th in March, 874, which is commonly called as "Purple Colla" in this region, and the ridge was almost detected by form according to the result of the radar inquiry.A western furrow made 5.5m, East about 7m, a trapezoid of about 9m south side, and the area was about

56 square meters. The rice field was buried in water for a typhoon once, but many hollows of the trace stock sign became clear after water attracted, and there were 470 places when they were considered to be hollows clearly and we could stand and counted a bamboo skewer. By comparison with a rice field of the present age, there would be a crop from this rice field to about 15kg when I estimated a harvest of this rice field and understood that it was a rice field having quite high productivity.

33-P-09

A Large-scale Breakout Flood from an Ignimbrite-dammed River after the Numazawako Eruption (BC 3400), Northeast Japan: Geomorphic and Sedimentary Evidence and Lahar Hazards

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Syn- and post-eruptive hydrological processes (i.e., lahar) including catastrophic breakout floods from intracaldera lakes and other volcanically dammed impoundments can produce widespread impacts and cataclysmic hazards. The impact of lahar often surpasses the primary eruptive impacts, in terms of extent and persistence that ultimately result in severe hazards in downstream areas. Numazawa volcano, northeast Japan, erupted most recently at BC 3400 and emplaced a large volume of unwelded ignimbrite (Numazawako eruption). More than 4 km^3 of valley-ponded ignimbrite dammed the Tadami river gorge to a depth of > 100 m, temporarily impounding >1.6 km3 of water before catastrophic release of the lake. Post-eruptive resedimented pyroclastic material is widely distributed along the Tadami and Agano rivers where aggradational deposits are 10's of meters thick, and finally reached the coastal Niigata Plain more than 150 km downstream of the eruptive center. Geomorphic and sedimentary evidence for a single flood event found along the rivers includes: 1) fine-grained thinly laminated lacustrine deposits upstream of Numazawa volcano along the Tadami River; 2) 30 m thick, pumiceous debris flow and hyperconcentrated flow deposits showing continuous aggradation; 3) fine-grained slackwater deposits at tributary river mouths; 4) large flood boulders forming lags on stripped ignimbrite surfaces or outcropping within hyperconcentrated flow deposits and on younger terrace surfaces; and 5) high water marks along downstream reaches. Paleohydraulic reconstructions of the flood estimate a peak breach discharge of 20,000—30,000 cumecs. Burial of Neolithic Jomon archeological sites by flood deposits at distal locations indicates that catastrophic volcano-hydrologic hazards impacted contemporary human life. Most of the buried archeological sites were not directly affected by the actual ignimbrite eruption and/or pyroclastic fall. This demonstrates that secondary volcano-hydrologic hazards can have a wider and more sustained reach than the better-known primary impacts of volcanic eruptions.

33-P-10

Villages and Volcanic Eruptions at Izu Ilands, Japan, in YAYOI Period

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There have been many villages in the Izu volcanic islands since JOMON period. They are thought to be the residence for acquiring the abundant ocean resources and taking the obsidian of Kozushima Island. In this study, we point out that any sites do not disappear in the Izu Islands in the middle of YAYOI period. We estimate that inhabitants of the villages (Ozato Higashi site and Bouda site) in Miyakejima Island of YAYOI period took the obsidian of Kouzushima Island that engaged to the principal occupation circulation to Kanto and Tokai district. But in the middle of YAYOI period, these sites disappeared and it decreased the circulation quantity of the obsidian. The change of the residence environment with volcanic eruption is expected as the primary factor which brought Bouda Higashi site disappeared. As a result of the geological survey at Izu-misaki in Miyakejima Island, a little rhyolite tephra (small pieces of pumice-type glass and obsidian) was detected directly under the Tairayama scoria layer. The Tairayama scoria covered the Bouda site which participate in the circulation of the obsidian. In other words, eruptions happened continually in the middle part of Izu volcanic islands in short time. The people in Miyakejima Island left because of the change of natural environment around the area including Miyakejima Island. And it is thought that circulation of the obsidian decreased as a result.

33-P-11

The Burial Processes of Remnants from the Era of Yayoi in Miyakejima Volcano, Japan

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Ancient remnants give us considerable information about not only the eruptive processes but also the effect of eruptions, mud flows, and the social environments in ancient age. Based on this concept, we, a volcanology-archaeology joint team, investigated the archaeological site ”Kokomanokoshi” of the Yayoi-era in Miyakejima Volcano. This site includes many kinds of remnants which are composed of shards of typical Yayoi ware, bones of swine and fish, and obsidians' ware. We never found human bones. This site had been attacked by the caldera-forming eruption occurred in ca. 2200yBP reported by the method of 14-carbon ages. The depositional sequence in this site is a scoria-fall deposit, an ash-fall deposit including the accretionary lapilli, mud flow deposits, and explosion breccia deposit onward. We revealed that the remnants were interbedded only among

the mud flow deposits. Therefore, the settlement of Yayoi-era had located inland from Kokomanokoshi site. We also present the occurrence and processes of the mud flows.

33-P-12

Reexamination of the Eruptive Activity of Kirishima Volcano Recorded in the Heike Monogatari (The Tale of the Heike)

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"The Tale of the Heike" is one of the most famous pieces of Japanese classical literature. More than ten versions of it exist. In one of them, which is called *"Nagato-hon"* a description is assumed to be about the eruption of Kirishima volcano. This report presents results from a volcanological investigation in the description; nevertheless, it is common knowledge among historians and scholars of literature that some descriptions in *"The Tale of the Heike"* cannot be taken as historical fact.

The description of the eruption in *"Nagato-hon"* has been interpreted as indicating the eruption of the volcano in A.D. 945. However, detailed investigation of the contents of *"Nagato-hon"* have revealed that the description of the eruption includes no basis for its date. On the other hand, the description on the eruption is highly credible; for that reason, it can be interpreted that the author of *"Nagato-hon"* had witnessed an eruption and included the description of the eruption of Kirishima volcano with an effusion of lava, associating it with some historical material. Considering geological evidence, this statement in the *"Nagato-hon"* version is likely to describe the eruption of the Ohachi volcano in the mid-13th century, which implies a limited range for the date when *"The Tale of the Heike"* was written, which has not been settled thus far.

33-P-13

Digital Archive System for Historical Picture Materials on Volcano Disasters

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Mt. Asama, one of the most active volcanoes in Japan, erupted in 1783 and it is documented in many picture materials. In this research, we analyze these materials on Mt. Asama eruption in order to clarify: 1) the expanding process of the hazard and 2) recovery process of the damaged local communities.

Former studies mostly focused on the investigation of natural disasters themselves, however, we try to reconstruct the images for disasters held by those directly afflicted, those who were informed of the disaster, and those who obtained the information years after the disasters.

Utilizing "Integrated Cultural Resource Digital Archive", this study proposes to holistically grasp the digital data of historical picture materials collected from various areas. Our digital archive system holds the image data of historical picture materials on Mt. Asama eruption from various organizations including Earthquake Research Institute of the University of Tokyo, and Historiographical Institute in the University of Tokyo, Mitsui Bunko, Gunma Prefectural Museum of History, and Gunma Prefectural Archive.

Our digital archive system supports the reconstruction of geographical, mental and chorographical mapping of natural disasters, which in turn enables the systematic understanding of mass production of the seemingly incorrect images for disasters created and held by people.

33-P-14

Hazard Perceptions Observed in Stone Structures Built After Eruptions of Mt. Asama in the 3rd Year of the Tenmei Era, 1783

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Eruptions of Mt. Asama in the third year of the Tenmei Era (1783) devastated a vast area. Especially along the Agatsuma River, a large number of people, horses and houses were carried away by mudflows, leaving the communities and agricultural fields completely buried under debries.

Many stone works relating to this eruption hazard were constructed, counting over 120 proven to exist through literature research and field surveys. More than 60% of them are located in cities, towns and villages along the Agatsuma River. Thirty percent of stone works (inscriptions) show their construction to have been in either the 3rd or 4th year of the Tenmei Era, with many in the latter anniversary year. The inscriptions tell what the stone works were built for, including as tombstones and monuments for fallen people and horses, to pass on the facts of the incidents to future generations, and to honor and award saviors. Some of them have been designated as cultural assets of the prefecture and their city/ward/town/village. Notice boards explaining their historic significance have also been put up by local boards of education.

Currently, seven sites have been recognized for annual memorial services attended by community residents. In these locations, without exception, new stone monuments have been erected since the bicentennial anniversary in 1982, which can be interpreted as efforts to carry forward the damages of volcanic eruption in the past as their "community's history" to the future.

33-P-15

Benenfits of Improved Communicaiton Between Volcanologists and Rehabilitation Teams in case of Volcanic Eruption? The case of Agricultural Land

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Volcanic soils have long been known for their high level of

fertility and, in consequence, a significant number of active volcanoes are surrounded by agricultural land. But as the products of volcanic activity can strongly modify the physical and chemical properties of the soil, they can also negatively affect the livelihood of local farmers significantly when a new eruption occurs. The assessment of necessary rehabilitation work tend to take place some time after the activity has ceased, as a distinct step after the emergency management and follow-up of volcanic activity. Volcanologists and other scientists monitoring the activity of the volcano are generally in possession of a vast amount of data in respect of the products emitted by the volcano, including their composition and their pattern of dispersion, as well as models for the prediction of secondary dispersion (e.g. lahars). Case studies show, however, that this data is sometimes not used directly by those involved in rehabilitation work and, where investigation is carried out, it is based on a whole new set of data collected for the purpose. Improved communication leading to the use of the information collected by scientists monitoring the eruption could lead to reduced costs and to a much more time-efficient assessment of the work required for the land to be brought back into agricultural use. Furthermore, this would help securing funding for the rehabilitation faster, as requests would be made in a timeframe much closer to the volcanic eruption and the disaster it may have caused. In addition, farmers are generally left with very little resources whilst their land remain unusable, or become dependant on emergency food aid; an integrated approach could thus also reduce the funds required for emergency management as time-lags between disaster and recovery would be reduced.

33-P-16

Erupting Conversations: Social Volcanology in Ecuador

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*Erupting Conversations*is a post-disciplinary research project, based in Ecuador and led by Lancaster University, which will combine social science methodologies with volcanological studies in order to develop research in the new field of “social volcanology”.

Active volcanoes such as Tungurahua in Ecuador provide the setting for a collision between unpredictable natural forces and resilient communities with diverse belief and knowledge systems about nature, time and place, scientists attempting to forecast dangerous eruptive activity and, increasingly, economic pressures to market and exploit potentially dangerous places as attractive destinations for western adventure tourists. This combination of factors produces an environment in which social relations within communities and traditional connections with nature are being severely tested *(Lane et al. 2004).*

In parallel, free market forces are accelerating natural resource extraction in remote areas, thereby provoking fundamental changes in local people's livelihoods, which more often than not trigger deep internal divisions in communities already stressed by an encroaching world of economic and socio-political complexity, which demands their dependency while denying meaningful participation. The transformation of traditional ways of life and cultural practices goes hand in hand with the loss of knowledge embedded in and passed on through such practices.

On volcanoes, such knowledge is not only about the varying signs that may announce an imminent eruption, but also, and particularly interestingly given the contemporary predicament of rapid climate change, about how to perceive, cope with, and live life at constant risk of environmental catastrophe. In Ecuador, these areas of inquiry converge with current volcanological research at the erupting Tungurahua volcano. Erupting Conversations will bring together researchers, civil society actors and indigenous peoples’ representatives to explore and establish future research questions and topics.

Lane LR, Tobin GA, Whiteford LM (2004) Volcanic hazard or economic destitution: hard choices in Banos, Ecuador. Global Environmental Change B,5:23-34

33-P-17

Commemorating The 40th Anniversary of Arenal Volcano Eruptions.

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Next July 2008 commemoration of Arenal reawakening will take place. On july 29, 1968 Arenal volcano, Costa Rica erupted violently after sleeping for near 500 years. Some 90 human lives were taken along with important patches of grass and agriculture land. Livestock, houses and roads were swepted in a matter of few minutes.Since its reactivation this volcano has presented different eruptive modalities; explosive, effusive, gaseous as well as other secondary activities. Although in 1968 population around the volcano was scarce, these days the area has experienced a surprising rapid growth. A singular community of tourism entrepreneurs, conformed by locals and outsiders, bring and keep thousands of tourists daily at the base of the volcano. Moreover some hotels and spas offer their services and infrastructure to poorly informed tourists. Three original towns are also included in the area.40 years seem too far in the past to remember. Nonetheless staff from our Observatory wishes to set up a platform to remember those victims of Arenal reawakening. COV5 could be a great meeting to start looking for international partners willing to exchange their similar experiences in their own volcanoes. Friends of Arenal volcano will be invited to contribute in different ways to this commemorative act. Individual and organizations will be sensitize in order to receive feedback and potential contributions for a well deserved commemoration.A national and international effort can visualize academic and financial resources that eventually may contribute to our organization.Activities will be planned well in advance to assure that no one in the area forgets Arenal`s fury and energy. Almost 40 years of non stop activity has given researcher a considerable amount of findings, documents and

opportunities to share with the community and other interested ones.Tourists, locals and bystanders will be asked to participate and become involved in all sort of activities to take place in the most developed community around Arenal; Fortuna.A comprehensive campaign should include among others; social and cultural activities, official acts, scientific exhibits, meetings from different audiences, etc.OVSICORI-UNA along with governmental institutions, private businesses and locals will receive suggestions from all those participating at cities on volcanoes 2007 of how to better recall a gray passage in the recent Costa Rica`s history to transform it in a fruitful lessons for the new generations.One specific poster combining Arenal most salient events within the last 40 years of activity, along with details about the organization for its commemoration, will be presented.

33-P-18

Overcoming volcanic cataclysms: The Aetas of the Philippines in the face of the 1991 Mt Pinatubo eruption

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In 1991, Mt Pinatubo violently came to life after five centuries of slumber in what is considered as the second most powerful volcanic eruption of the 20th century. At the time of the eruption, the slopes of the volcano had been inhabited for centuries by the Aetas, an indigenous group of short height, very dark complexion, and curly hair who depended for their livelihood on cultivating root crops and other vegetables, hunting and fishing, and also on gathering plants and wild fruits that abound in their surroundings. This poster explores the way the Aetas overcame the Mt Pinatubo eruption through the lens of the concept of resilience. Resilient societies are those able to overcome the damages brought by the occurrence of volcanic eruptions, either through maintaining their pre-disaster social fabric, or through accepting marginal or larger change in order to survive. This study particularly focuses on the communities located within the Pasig and Sacobia River Basins on the eastern flank of Mt. Pinatubo, in the vicinity of the former Clark American facilities. It relies on extensive field work conducted between July 1999 and June 2000 and completed by additional field explorations between June and September 2001. The study suggests that the capacity of resilience of the Mt Pinatubo Aetas rely on four factors, namely: the nature of the hazard, the pre-disaster socio-cultural context and capacity of resilience of the community, the geographical setting, and the rehabilitation policy set up by the authorities. These factors however, significantly vary in time and space, from one disaster to another. It is important to perceive their local variations to better anticipate the capability of traditional societies to overcome the damage brought by the occurrence of volcanic eruptions.

33-P-19

Agricultural Recovery from an Explosive Volcanic Eruption

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Volcanic ash is the most widely distributed product of explosive volcanic eruptions, with even relatively small explosive eruptions distributing ash hundreds of kilometres from the volcano and commonly impact agricultural land. It is well-established that volcanic ashfall can disrupt agriculture, even in small amounts, as happened after the 1995/96 eruption of Ruapehu volcano, New Zealand. The total impact of volcanic hazards to agriculture is however not well established and there is often significant uncertainty as to what information emergency management or agricultural authorities should distribute during a volcanic crisis.

This study assesses the likely impacts of a medium-sized explosive eruption to the agriculture sector in New Zealand, including impacts to pastures, soils, water supplies and farm management practices. It includes:

- Preliminary results from greenhouse and field trials, including the damage caused by varying thicknesses of ash fall to pastures and soils and the effectiveness of different rehabilitation techniques (focus on temperate agriculture).
- A comparison will be made of the effects from the 2006 eruption of Merapi to tropical agriculture.
- Findings from a study of the vulnerability of New Zealand's rural water supplies to volcanic hazards.
- Analysis of farm vulnerability (i.e. seasonal influences on vulnerability).
- Results of a study modelling a simulated evacuation of stock during a simulated volcanic crisis.
- Rural community resilience, including an analysis of community needs and how assistance can best be given.
- Information access, and how to best get information where it is needed rapidly and efficiently.

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