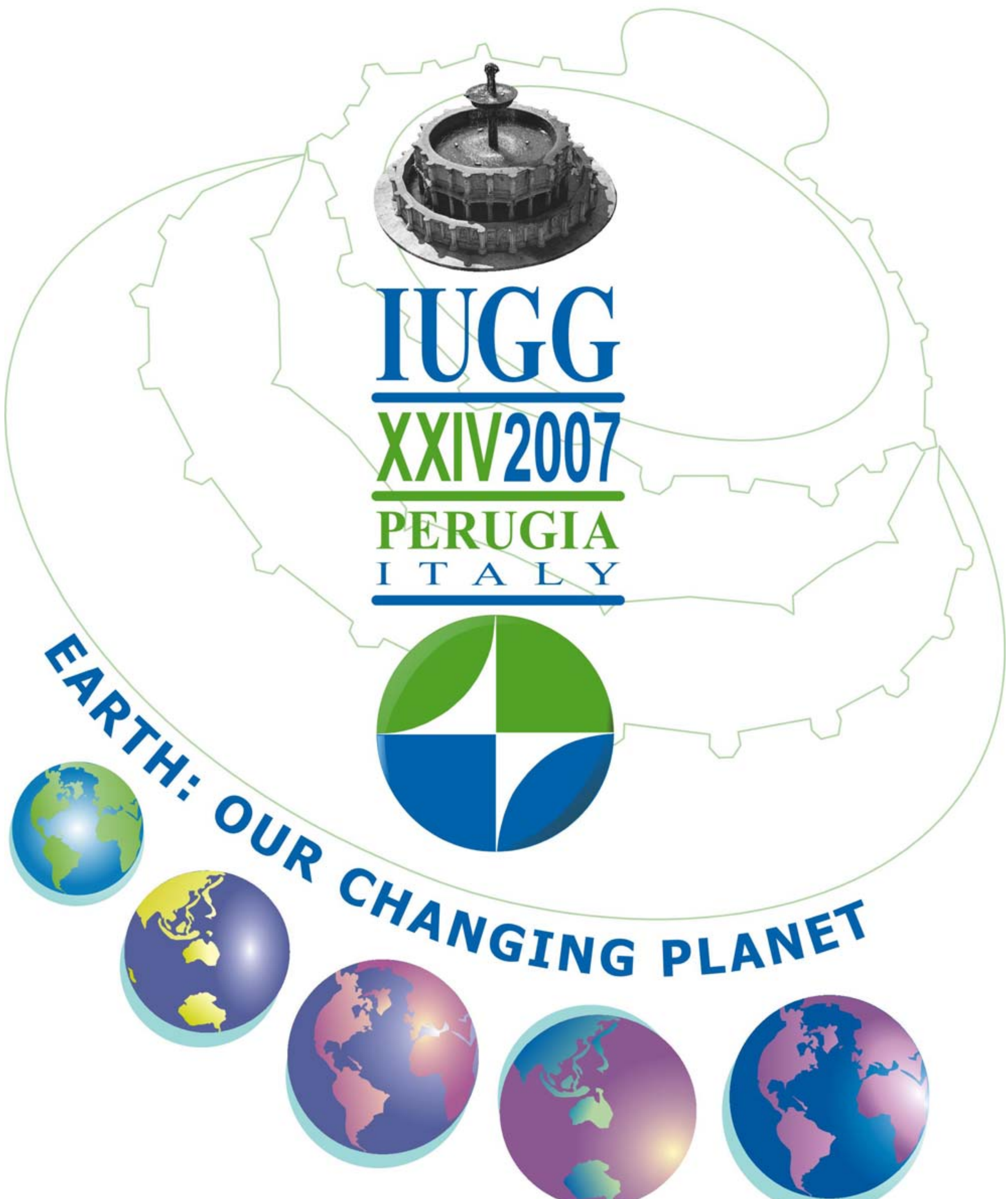
Perugia, Italy July 2-13, 2007



IAVCEI

INTERNATIONAL ASSOCIATION OF VOLCANOLOGY AND CHEMISTRY OF THE EARTH'S INTERIOR

ASSOCIATION SYMPOSIA AND WORKSHOPS

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Compiled by Lucio Ubertini, Piergiorgio Manciola, Stefano Casadei, Salvatore Grimaldi

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Perugia, Italy **July 2-13, 2007**

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ITALY

EARTH: OUR CHANGING PLANET

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Abbreviations

IAG	International Association of Geodesy
IAGA	International Association of Geomagnetism and Aeronomy
IAHS	International Association of Hydrological Sciences
IAMAS	International Association of Meteorology and Atmospheric Sciences
IAPSO	International Association for the Physical Sciences of the Oceans
IASPEI	International Association of Seismology and Physics of the Earth's Interior
IAVCEI	International Association of Volcanology and Chemistry of the Earth's Interior
CliC	Climate and Cryosphere
Ev-K2-CNR	Everest-K2 CNR Committee
GEWEX	Global Energy and Water Experiment
HKH-FRIEND	Hindu Kush-Himalayan Flow Regimes from International Experimental and Network Data
IABO	International Association for Biological Oceanography
IACS	International Association of Cryospheric Sciences
ICACGP	International Commission on Atmospheric Chemistry and Global Pollution
ICASVR	International Commission on Atmosphere-Soil-Vegetation Relations
ICCE	International Commission on Continental Erosion
ICCL	International Commission on Climate
ICCLAS	International Commission on the Coupled Land-Atmosphere System
ICCP	International Commission on Clouds and Precipitation
ICDM	International Commission on Dynamic Meteorology
ICGW	International Commission on Groundwater
ICIMOD	International Center for Integrated Mountain Development
ICMA	International Commission on the Middle Atmosphere
ICRS	International Celestial Reference System
ICSIH	International Commission on Snow and Ice Hydrology
ICSW	International Commission on Surface Water
ICT	International Commission on Trac
ICWQ	International Commission on Water Quality
ICWRS	International Commission on Water Resources Systems
IGAC	International Global Atmospheric Chemistry
IGS	International Glaciological Society
ILP	International Lithosphere Program
INQUA	International Union for Quaternary Research
ION	International Ocean Network

IRC	International Radiation Commission
PUB	Prediction in Ungauged Basins
SCAR	Scientific Committee on Antartic Research
SEDI	Study of the Earth's Deep Interior
SPARC	Stratospheric Processes and their Role in Climate
UCCS	Union Commission for the Cryospheric Sciences
UNESCO	United Nation Educational, Scienti. c and Cultural Organization
UNITAR	United Nations Institute for Training and Research
WMO	World Meteorological Organization

Session code naming

The first letter of the session codes indicates whether the session is a Union, a Joint Interassociation or a single Association sponsored event, the second letter indicates the type of event: Symposium (S) or Workshop (W). For Joint events, the second letter indicates the Lead Association (with the abbreviations listed below) and the third indicates whether a session is a Symposium (S) or a Workshop (W). In some cases (namely IAGA, IAHS) Association session codes have an extra codi. cation referring to a speci. c Theme or Division.

U	UNION
J	JOINT
G	IAG
A	IAGA
H	IAHS
M	IAMAS
P	IAPSO
S	IASPEI
V	IAVCEI

Some examples:

US002

is a **U**nion **S**ymposium; **JGW**001 is a **J**oint IA**G** **W**orkshop with IAG as the Lead Association;

MS003

is an Association (IA**M**AS) **S**ymposium. **AS III** 020 is an Association (IAG**A**) **S**ymposium sponsored by its **III** Division.

VS001 **Symposium** **(6625 - 6632)**

Convener : Dr. Maria Teresa Pareschi, Dr. Giovanni Zanchetta, Dr. Kevin Scott

Sediment-laden gravity flows in volcanic settings: generation, sedimentation, prediction and hazard assessment

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VS002 **Symposium** **(6633 - 6643)**

Convener : Dr. Sharon Allen

Submarine volcanism: eruption processes, transport mechanisms and links with hydrothermal systems

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VS003 **Symposium** **(6644 - 6680)**

Convener : Dr. Shinji Takarada, Prof. Tim Druitt

Volcanic Flows: Observation, Experiment, and Theory

VS004 **Symposium** **(6681 - 6696)**

Convener : Dr. Guido Giordano, Prof. Ray Cas

Intraplate monogenetic basaltic and kimberlite volcanic provinces and processes

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VS005 **Symposium** **(6697 - 6729)**

Convener : Dr. Giuseppe Puglisi, Prof. Renato Cristofolini, Dr. Patrick Allard

The Magma Feeding System of Persistently Active Basaltic Volcanoes: Mount Etna and Others

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VS006 **Symposium** **(6730 - 6754)**

Convener : Prof. Giovanni Orsi, Dr. Sandro De Vita

Calderas I - Calderas and resurgent calderas

VS007 **Symposium** **(6755 - 6771)**

Convener : Dr. Gianfilippo De Astis, Prof. Roberto Scandone, Dr. Guido Ventura

Calderas II: Calderas and caldera forming eruptions

VS008 **Symposium** **(6772 - 6796)**

Convener : Dr. Roberto Carniel, Dr. Susanna Falsaperla

Volcanic hazard evaluation: methodologies and applications

VS009 **Symposium** **(6797 - 6824)**

Convener : Dr. Jacopo Taddeucci, Dr. Greg Valentine

Models and products of mafic explosive activity

VS010 **Symposium** **(6825 - 6851)**

Convener : Prof. Benedetto De Vivo, Prof. Angelo Peccerillo

Modeling the plumbing system of active volcanoes by integrated petrological, geophysical and fluid inclusion studies

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VS011 **Symposium** **(6852 - 6862)**

Convener : Prof. Salvatore Di Gregorio

Modeling and simulation of volcanic related phenomena for hazard mitigation

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VS012 **Symposium** **(6863 - 6884)**

Convener : Prof. Giovanni Orsi, Dr. Jan Lindsay
Co-Convener : Dr. Claire Horwell, Dr. Peter Baxter

Cities on Volcanoes: looking at the links between volcanology and communities issues around volcanoes (merged with VS020)

VS013 **Symposium** **(6885 - 6892)**

Convener : Dr. Peter Baxter
Co-Convener : Prof. Augusto Neri

Quantifying and expressing volcanic risk: a challenge for the Millennium

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VS015 **Symposium** **(6893 - 6918)**

Convener : Prof. Ken Dean
Co-Convener : Dr. David Rothery

New Techniques using Remote Sensing Data for Volcano Monitoring and Analysis: Observations, Integration, Hazard Assessments and Modeling

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VS016 **Symposium** **(6919 - 6935)**

Convener : Prof. Giampiero Poli, Prof. Bernard Bonin

Volcanic-plutonic provinces: a tool to understand magma genesis and geodynamics

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VS017 **Symposium** **(6936 - 6942)**

Convener : Dr. Ulrike Martin

Pedagogical and didactical methods in earth science education and geopark concepts in demonstrating volcanic processes

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VS018 **Symposium** **(6943 - 6955)**

Convener : Dr. Karoly Nemeth

New advances in understanding phreatomagmatism: from experiments to volcanic facies analyses

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VS019 **Symposium** **(6956 - 6962)**

Convener : Dr. Richard Ernst

Large Igneous Provinces

VS021 **Symposium** **(6963 - 6974)**

Convener : Prof. Roberto Scandone

Eruptions of Stromboli Volcano, Italy, March 2007

VS022 **Symposium** **(6975 - 6980)**

Convener : Dr. Karoly Nemeth

Mt Ruapehu (NZ) breakout lahar, 18 March 2007

(V) - IAVCEI - *International Association of Volcanology and Chemistry*

VS001 **6625 - 6632**

Symposium
Sediment-laden gravity flows in volcanic settings: generation, sedimentation, prediction and hazard assessment

Convener : Dr. Maria Teresa Pareschi, Dr. Giovanni Zanchetta, Dr. Kevin Scott

This session will focus on state of the art and new views and concepts concerning the triggering, transport and sedimentation mechanisms that characterize sediment-laden gravity flows in volcanic settings. Methods for prediction and hazard assessment. Sediment-laden gravity flows are common occurrences in volcanic settings, where they present widespread and continuing risk to human settlements and life. Sediment-laden gravity flows are initiated by various mechanisms, among which the most common are intense and/or prolonged precipitation, breakouts of crater lakes, melting of snow or glacial ice during an eruption, or seismic triggering of landslides that evolve to debris flows. Volcaniclastic mass flows can be generated both during or shortly after an eruption or some years to centuries later. A common source area is the terrain mantled by tephra deposits downwind from a volcano. Geological history, morphological constrains and modeling can yield important constrains for hazard assessment. It is very important to understand the mechanisms promoting the generation of sediment-laden flows in volcanic terrains, with particular attention to erosion processes in loose volcaniclastic material. Because rainfall is the most common triggering factor in slope stability, analysis of rainfall intensity and frequency is the most frequently adopted approach to forecasting the debris flows initiated in this way. Rainfall thresholds are also commonly adopted for civil protection purposes and to establish alarm networks in endangered areas. Therefore, improvements in our knowledge of hydrologic behavior, including modeling, in volcaniclastic terrains are key elements of hazard assessment. Once flows are triggered, other processes can greatly influence the transport and sedimentation of sediment-laden flows, and thus affect the size of areas potentially subject to inundation. Those factors include the processes of bulking and debulking--the addition and loss of sediment and water to the original flow volume, respectively, and the effects of longitudinal change in slope profile.

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VS001 **Oral Presentation** **6625**

The effect of Initial conditions on flow dynamics and deposition patterns

Mr. Gustavo Cordoba
Department of Earth Scences Student IAVCEI

Heidy Mader, Steve Sparks

Dilute particle-laden currents can be an important hazard to the structures and lives. The extend of the afected area by pyroclastic surges or sub-marine turbidity currents are usualy gr eather tha n t he recorded deposit. We here p resent numeric al work in progress aimed a t giving a better idea of the emplacement mechanism, d eposit, structu re, and dynamical parameters of pyroclastic flows and turbidity currents. Modeling is now an attractive to ol for hazard assessment which can provide a better understanding of the phe nomenon to the d ecision ma kers. At least thre e major approaches of dilut e flow modeling are in researc h: 1) quasi-empirical mo dels, which try to use the knowledge of past flows to arrive a simple and general laws (i.e. Energy Lines); 2) quasi- analytical models , which adopt analytical so lutions by simplify the pro blem, and 3) the co ntinuum approach, which ass ume that t he flow can be d escribed by pure fluid dynam ics equati ons. In modelling dilute flows, a fluid dynamical approach is possible and we use the Navier -Stokes equations, coupled with one Convection-Diffusion-Sedimentation equation for each particle size to describe the flow. The ass umption of the same velocity for particles and fluid allow u s to use only one set of Navier-Stokes equations which r educes the CPU cost. The equation system is solved by the Finite El ement Method. In order to provide confidence in the model, several tests hav e been performed. The resu lting velocity and concentration fields have been tested against several laboratory experim ents, which acco unt fo r run- out distance, co ncentration profiles, and deposit shapes. Also, the change in time of the concentration and velocity has been tested. The modeled amount of deposited material is tested for mono and polidisper se flows. For the fr ont advance i n time, the model shows no statistical difference between the numerical appr oach and t he experiments. Good agreement is shown between the modeled concentration and deposited material and the experiments. A pr oblem of interest in understanding turbidity currents co ncern th e initial aspect ratio at the time that sedimentation begins. Any given turbidity current can be considered to have three stages: an ini tiation stage (the source), an eros ional stage and a de positional stag e. During the erosional stage the current sp reads and it can be expected that deposition therefore initiates for a wide range of aspect ratios. A study of how the aspect ratio and gro und bondary conditions might affect the characteristics of the deposition and runout are shown.

Keywords: turbidity currents, numerical modelling, deposit pattern

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VS001 **Oral Presentation** **6626**

Recent lahars at Volcan de Colima (Mexico): origin and hazard evaluation.

Dr. Lucia Capra
Centro de Geociencia UNAM Mexico IAVCEI

Norma Davila, Gianluca Norini, Juan Carlos Gavilanes, Nick Varley

Volcan de Colima is the most active volcano in Mexico, and poses significant risk to more than 500,000 people. In 1998 the volcano renewed its activity, with the extrusion of a lava dome and subsequent lava and block and ash flows. During the recent period of activity pyroclastic products did not directly affect villages around the volcano, however, several lahars did. During heavy rains, which usually occur from June through to October at this latitude, water easily removes deposited material and bulks to debris flows able to transport metre-sized clasts over long distances, inundating and provoking damage to infrastructure such as bridges as happened during 1999 and 2005 events. Generally the lahar deposit shows a clast supported base topped by a more dilute layer, sometimes normally graded. Finally they dilute to stream flow further from the source. We used LIDAR topographic coverage, ASTER and LANDSAT images for the recognition of morphological changes in the drainage system and lahar detection. For lahar delineation we applied principal components analysis and canonical classification (Tasseled Cap) in order to perform a supervised image classification using the maximum likelihood rule algorithm. LAHARZ (objective delineation of distal debris flow hazard zones) has been used and tested using two topographic datasets with different resolutions, which provided evidence of the importance of high resolution topographic coverage in hazard assessment. Finally a hazard map for lahars is presented, showing that morphological changes induced by products of the intense explosive activity deviated the drainage system. As a result, certain populated areas previously affected by lahars now are located outside of the high risk zone.

Keywords: mexico, lahar, remote sensing

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VS001 **Oral Presentation** **6627**

Learning from LAHARS: characterising the predicted Ruapehu Crater Lake break-out flood

Dr. Vern Manville
CVS member IAVCEI

Shane J. Cronin, Jon N. Procter, Suzy E. Cole, Hilary K. Mcmillan

The predicted break-out lahar from the summit Crater Lake of Mt. Ruapehu offers an unparalleled opportunity to capture maximum scientific benefit from a single, discrete lahar event. The challenge is to capture as much data as possible from an event which is largely unpredictable in timing, too energetic for traditional river gauging methods, and stretched over 155 km of river channel with 2530 m of relief. Our proposed scientific response to the predicted lahar is made up of a number of complementary components: 1. Instrumentation of the lahar path as if it were the bed of a giant laboratory flume. Using a diverse range of sensors including radar stage gauges, acoustic flow monitors, conductivity probes, load-cells, pressure transducers, and broadband seismometers we hope to capture time-series data on such key flow parameters as depth, velocity, sediment concentration and profile, bed aggradation/erosion, and degree of mixing with ambient river water. By measuring these parameters at a number of key locations we will be able to track the downstream evolution of the lahar from an initial clear-water flow, to its maximum discharge as a debris flow, and then its subsequent attenuation and debulking through downstream propagation. 2. Fixed digital still and video cameras will supplement the planned sensor arrays, capturing rare footage of a dambreak and lahar event. 3. Collection of time-series lahar samples and visual records by observers stationed at key sites. 4. Determination of changes in the bed of the Whangaehu River through capture of pre-and post-event, high-resolution topographic and ortho-image data. A pre-event survey has already been undertaken using LiDAR technology (airborne laser scanning). This has yielded a sub-metre resolution DEM of the first 58 km of flow path and an 18 cm pixel-size set of vertical digital air photos. A repeat survey after an event will enable changes in channel cross-section and profile to be mapped and identification of critical areas of sediment erosion and deposition. These remote sensing surveys will be supplemented by differential RTK-GPS ground surveys in key locations. 5. Post-event ground surveys of the lahar deposits will allow reconstruction of flow parameters at non-instrumented sites and cross-referencing with hydraulic data at locations with sensor arrays. 6. State-of-the-art numerical models of lahar flow at Ruapehu will be calibrated against the real-world data captured from the predicted break-out event. The newly refined models will be run over the precise DEMs obtained from the LiDAR surveys to improve future risk assessments and mitigation plans at Ruapehu and other cone volcanoes. Using a combination of resources and skills between a number of agencies we have the opportunity to collect globally unique data on break-out lahar motion, erosion and deposition. This will in turn help improve mitigation and planning approaches for protection of communities from both volcanic and non-volcanic debris flows.

Keywords: lahar, ruapehu, mass flow

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VS001 **Oral Presentation** **6628**

Debris flows in volcanic terrains and their relation to pyroclastic fall deposits: the Campania Region (southern Italy) case study

Dr. Marina Bisson
Sezione Pisa Istituto Nazionale di Geofisica e Vulcanologia

Pareschi Maria Teresa, Zanchetta Giovanni, Sulpizio Roberto, Santacroce Roberto

Debris flows are one of the most recurrent and dangerous natural hazards in volcanic terrains (Newhall and Punongbayan 1996; Scott et al. 2001, Macas et al . 2004). They occur not only du ring and s hortly after an eruptive event but also during a volcanic quiescence when storms or earthqua kes take place in areas where the pyroclastic fall deposits have an appreciable thickness. One of the most st riking examples of debris flows ori ginated in volcanic te rrains is in the Campania region (S outhern Italy). Historical investigation allowed the identification of more than 500 events during the last four centuries; in particular, more than half of these events occurred in the last 100 years causing hundreds of deaths. For instance, five events (1823, 1841, 1910, 1954 a nd 1998) killed more than 100 people (e.g. Migale and Milone 1998); between 1996 and 199 9 more than 170 pe ople were killed by volcaniclastic deb ris flows in the ar eas bordering mountain slopes (Cal caterra et al. 2003; C alcaterra and Santo 2004). In order to identify debris flow proneness and to quantify hazard we analyse and compare several elements such as the distribut ion of historica l volcaniclastic debris flows from AD 1500 t o the present, the dispersion of pyroclastic f all deposits pr oduced by the eruptions of Vesuvius and Phlegrean Fiel ds volcanoes during the last 1 8 ka a nd the slope factor. Re sults show tha t the areas c haracterized by a cumulative thic kness of pyroclastic fall deposits less than of a few decimeters have low probability of generating volcaniclastic debris flows. Flow occurrence is not only a function of the cumulative thickness of deposits but also depends on the age of empl acement. Deposits you nger than 1 0 ka (Holocene eruptions) apparently increas e the risk of d ebris flows, while those older than 10 ka (Late Pleistocene eruptions) seem to play a les s prominent role. Based on these results and by considering that the areas with slopes greater than 25 have the highest probability of triggering debris flows, we proposed a large-scale debris flow hazard map of Campania region in which five main hazard zones are identified: very low, low, moderate, high and very high.

Keywords: debris flows, volcanic eruptions, hazard mapping

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VS001 **Oral Presentation** **6629**

Burial process of Roman villa at Somma Vesuviana, northern foot of Mt. Vesuvius

Dr. Kenji Niihori
Earthquake Research Institute Tokyo University

Masashi Nagai, Takayuki Kaneko, Toshitsugu Fujii, Setsuya Nakada, Mitsuhiro Yoshimoto, Atsushi Yasuda, Masanori Aoyagi

We investigated the volcanic succession at the excavation site of the luxurious Roman villa buried by the volcanic activities of Mt. Vesuvius at Somma Vesuviana in Italy, for revealing transport and deposition of eruptive and epiclastic flow deposits buried this building, as a member of a Japanese-Italian joint archeological team consisting of various research groups. These deposits buried the villa are divided into five groups, that is, Group1, Group2, Group3A, Group3B, and Group3C, by the presence of interbedding soil deposits. This stratigraphic notation is adopted by Kaneko et al. (2005) which first described the stratigraphy of the deposits at the excavation site and stated that this villa was buried by the AD 472 eruption. The relationships between these deposits and the Roman buildings allow us to reconstruct the burial process of the villa and the emplacement mechanisms of the deposits by detailed geological observation under contemporary excavation. The burial process of the villa is followed: (1) the first eruptive stage (Group1) started from the AD 472 eruption and the Roman villa which had already collapsed was covered by scoria- and ash-fall deposits and pyroclastic surge deposit. (2) Following this eruption, epiclastic flows (four mud flows and two fluvial flows) have attacked the villa and their deposits buriedmore than half of the villa up to 5 m in height. (3) After the series of the AD 472 activities, soil was developed up to 5 cm. (4) The next eruptive stage (Group2) started from ash-fall event, which resulted in the deposit containing accretionary lapilli. After the deposition, epiclastic flow deposits occurred with interbedding three fall deposits without soil. (5) During the stage (Group3A ~ Group3C), three eruptions occurred and they covered the villa as two scoria-fall deposits and one alternation of scoria- and ash-fall deposits interbedding soil deposits. In the result, this Roman villa was perfectly buried by volcanic and epiclastic flow deposits. We made chemical analysis of considerable amounts of the juvenile materials from this site. Compared juvenile materials in this site with those of the historical eruptions collected from type localities, it was concluded that the scoria of Group3C was supplied by the AD 1631 eruption. Our data set shows that scoria of the AD 472 and AD 1631 Subplinian eruptions have more compositional variations than those of reported data. Kaneko et al. (2005) Geochem. J., 39, 573-578.

Keywords: vesuvius, the roman villa, burial process

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VS001 **Oral Presentation** **6630**

Difference scale migration manifestations of mud volcanic activity the dynamics in processes of main earthquakes preparation with magnitude 5.0 9.0

Dr. Oktay Babazade
Seismology Centre of Seismology and Earth's Physics

Nigyar Babazade, Boris Romanov

Some remarkable migration of mud volcanic eruptions prior to the main earthquakes are described based on the systematic analysis of the National Catalogue of the active mud volcanoes in the period of 1810-2004 in and around the south Caspian depression including the region ofeast Central Iran. The discovery of pattern of migration of the mud volcanic activity before the main earthquake can be considered as new precursory phenomena. There was used a methodology of finding of two types of migrations of mud volcanic eruptions by reconstruction of the earthquake preparing pattern. There are provided the detailed results of revealing the ordered migration of the mud volcanic eruption by reconstructions of the preparatory phase of earthquakes of November 25, 2000 (M=5.8; 6.3) and December 6, 2000 (M=7.3), having respectively, arisen in a few kilometers to the southwest and northwest of Baku in Caspian Sea and to the West Turkmenistan. These Absheron mud volcanic eruptions were triggered by M9.0 great earthquake preparation patterns that occurred on December 26, 2004 of the west coast of northern Sumatra. The relationship between Caspian Sea level oscillations and the seismic dynamics the largest magnitude 6.0 to 8.0 and greater, earthquakes worldwide in the Sumatra-Andaman main event preparation regions during the last 200 years is revealed. The found earlier unknown migration phenomena of mud volcanoes eruptions towards the future seismic focal zone with far from distance more than the focal zone dimensions and in before and simultaneously in the moment of the main earthquake are related with model of distribution of tension waves along the sub-vertical and sub-horizontal zones and systems of faults of the Earth crust sedimentary part. The conception of the sedimentary-stage geodynamics of blocks and mechanism of joint action of the vertical and horizontal creep and seismic movements, providing these manifestations is proposed. These found phenomena may give an important clue to the understanding of processes in this region and may be used for constructing the earthquake preparing pattern and also as short and medium term precursors of their (earthquakes) prediction.

Keywords: mud

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VS001 **Oral Presentation** **6631**

Post eruption dome collapses a potentially unexpected hazard source

Mr. Thomas Platz
Volcanic Risk Solutions Massey University IAVCEI

Shane Cronin, Jonathan Procter, Bob Stewart

Lava dome-forming eruptions can last from a few days up to several decades. In most cases, the impacts of these, typically small volcanic eruptions are already forgotten within years to decades after the event. This leads to development of complacency within the surrounding population and a consequent underestimation of volcano-derived hazards and perhaps earlier resettlement or redevelopment of eruption-affected areas. This is particularly the case where population pressures are high and the level of government regulation low. A lava dome extruded and remaining intact in a summit crater is only in a metastable state. Its collapse can be triggered at any time. We present a case study of such an event from Mt. Taranaki, . In this case, at least 19 years after lava dome emplacement, at least half of the structure collapsed triggering a rock avalanche as large as many of the earlier block-and-ash flows known from this volcano. Studies on the remnant summit dome of Mt. Taranaki revealed details of the reconstruction of the lava dome geometry, growth mechanisms, the identification of collapse sectors and mechanisms. The dome geometry, reconstructed using elliptical paraboloids showed a maximum tholoid volume of 5.9106 m3 was originally emplaced. Magma extrusion rates of 3.6-22.4 m3s-1 are calculated, which would correspond to eruption duration of between 3 and 19 days. Random magnetic alignment of clasts within the rock avalanche deposit indicates a deposition temperature below 350 C. Using estimates of conductive and rainfall induced cooling, it would have taken about 19 years to cool the original dome to below this temperature. The collapse of a cool dome can be distinct from hot domes since many areas of rock of contrasting appearance can develop in different parts of the dome due to localised variations in hydrothermal alteration, cooling and degassing. Hence the rock avalanche appears polylithologic compared to common monolithologic block-and-ash flows that originated at the same summit crater but during active eruptive periods. The post-eruption dome collapse could have simply been triggered by the interplay of small earthquakes and/or heavy rain storms. We present how a historic lava dome-forming eruption can be reconstructed, what conditions led to the post-eruptive collapse of lava domes, and how the potential deposition areas for dome-collapse derived mass flows (i.e. rock avalanche and block-and-ash flows) can be identified. Rock avalanches may be as far reaching as block-and-ash flows but since they may be triggered with little or no warning decades after an eruption they may be very deadly.

Keywords: post eruptive, block and ash flow, rock avalanche

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VS001 **Oral Presentation** **6632**

Understanding hazards induced by catastrophic mass wasting processes on New Zealand volcanoes

Dr. Jerome Lecointre
Soil & Earth Sciences Massey University IAVCEI

Rapid mobilisation and recurrent redistribution of loosely consolidated material are key processes contributing to the morphological evolution of andesitic stratovolcanoes and surrounding lowlands. Ring plain associations are represented in New Zealand by volcaniclastic sequences that include deposits from debris avalanches, lahars, and fluvially reworked volcanogenic sediments, interbedded with tephra layers and paleosols. At Tongariro, internal conditions (e.g. overpressure in hydrothermal system; tectonic activity; magma intrusion and/or eruption) are thought to have initiated c.60,000 yr ago, the sudden destabilisation of a saturated upper portion of the proto-edifice. A flank or sector-collapse resulted in the catastrophic emplacement of a volcanic debris avalanche that rapidly transformed into a clay-rich or cohesive debris flow. By contrast, non-cohesive lahars dominate the post-Taupo volcaniclastic landscape at Ruapehu. Here, debris flows and hyperconcentrated flows were and are still generated by (1) expulsion of acidic waters from the c.10 Mm3 Crater Lake, (2) melting of the snow-and-ice cap by hot pyroclastic material, and (3) heavy rain on tephra-covered slopes (1995-96 eruptions). Key lithological sections from volcaniclastic units only preserved in medial/distal reaches of the ring plain suggest however, that large volume, repeated prehistoric collapse events occurred early in the evolution of the volcanic edifice. We illustrate this point with the presentation of results from recent studies conducted around volcanoes of the Tongariro National Park, and in particular Mt Ruapehu, where flank collapses and lahar activity have coexisted for more than 150,000 yr. In addition to field-based studies, we have developed a range of partially-scaled, analog experiments in order to better understand the physical properties and flow behaviour changes that characterise the emplacement of clay-rich debris flows. Saturated clay+sand+ gravel mixtures, with a bentonite content varying between 2.5-15%vol, were used on a 3m long experimental set-up for that purpose. Experimental challenges and preliminary results are discussed. The objective of this dual approach is two fold: (1) increase our understanding of the processes that lead to discrete but recurrent flank destabilisation events on andesitic stratovolcanoes, and (2) refine our current practice used to determine volcaniclastic mass flow hazard in New Zealand (delineation of inundated areas; calculation of volumes and frequencies; identification of potential damages and mitigation measures). This paper is a contributionto the New Zealand Foundation for Research, Science, and Technology-funded project MAUX 0401.

Keywords: debris avalanche, cohesive debris flow, analog modelling

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VS002 **6633 - 6643**

Symposium
Submarine volcanism: eruption processes, transport mechanisms and links with hydrothermal systems

Convener : Dr. Sharon Allen

Recent detailed volcanological, geophysical, hydrological and geochemical studies of modern volcanoes on the seafloor have provided us with new insights into the mechanisms and products of submarine eruptions. It is also clear that there are close links between seafloor volcanoes and ore-forming hydrothermal activity. Complementary studies on ancient, submarine successions provide a 3-dimensional analysis of the facies architecture and transport and depositional processes involved during sedimentation. We invite contributions that focus on : (1) observations of the volcanology and sedimentology of modern seafloor volcanoes; (2) models for both explosive and effusive seafloor eruptions; (3) transportand depositional mechanisms of the products of submarine eruptions; (3) character, setting, and temporal and spatial variability in seafloor and sub-seafloor hydrothermal systems; and (4) links between magma reservoirs, magma migration, eruptive processes, and hydrothermal activity.

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VS002 **Oral Presentation** **6633**

Submarine Volcanic Landforms of the Marsili Seamount, Tyrrhenian Sea

Dr. Michael Marani
Istituto di Scienza Marine Geologia Marina di Bologna

Fabiano Gamberi

Marsili volcano rises 3500 metres from the basement level of Marsili basin to a minimum depth of 489 metres. It is elongated 60 km NNE-SSW with mean width of 16 km. A narrow >1 km wide linear region of lower gradient, approximately bounded by the 1000 metre isobath, marks the summit rift zone that stretches 20 km along the main axis of the volcano. The northern and southern tip regions are also characterised by linear volcanic constructs outlining the continuation of the rift zone up to the volcano base. The summit of Marsili volcano is marked by a large circular cone topped by two vents and is the site of an extensive hydrothermal field. On the lower flanks of the volcano a range of seamount morphologies develop, including flat top and conical volcanoes, deeply cratered cones, lava ridges and volcanic terraces. Based on its geodynamic setting, the volcano began construction at about 0.7 Ma ago and is considered to represent the super-inflated spreading ridge of the Marsili backarc basin. New insights of the processes at the origin of the variety of edifice styles shown by Marsili volcano are provided by the data from recent surveys involving swath bathymetry, deep towed sidescan sonar, seafloor visual observations and sampling.

Keywords: edifice styles, backark, tyrrhenian

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VS002 **Oral Presentation** **6634**

A multiparticle mass conservation based Box Model

Mr. Gustavo Cordoba
Department of Earth Scences Student IAVCEI

Heidy Mader, Steve Sparks

The modeling of dilute fl ows like volcanic pyroclastic surges or sub-marine turbidity currents are mostly based either on the continuum mechanics a pproach or simple models based on quasi-empirical/quasi-analytical appr oaches. Mo delling o f po lydisperse-compressible flo w usin g the co ntinuum assumptio n needs numerical solvers and strong computational resources. The inherent numerical stability and convergence techniques us ually include ad ditional parameters which need to be adjusted according to the model, domain configuration and even initial conditions. Si mple approaches need strong assumptions to reduce a complex fluid dynamics pr oblem to a simple one. Howeve r, as a simple problem they need less parameters to be adjusted and can result in useful approaches according to the needs of the researchers. Box Models have been prov en to produce acceptable results in the prediction of the flow front advance and have been useful to st udy the dynamics of past flows. They assume that a gravity curre nt is incompressible, inviscid, two dimensional and typica lly they ass umes that the dilute flows are very well mixed d ue to turbulence. An addi tional assumption of constant density in time allowed to introduce an e qual areas law. Up to no w it is been applied to a flat topographies. The proposed Box Model, extends the use of the equal areas law to a mass and energy balance laws. As the mass within the box is reduced by deposition, th e mass balance is conserved by accounting the m ass within the vol ume and the mass in the d eposit. Us ing the energy ba lance law, the model allows t o account for the slope changes. The model can be used as a hazard a ssessment tool as it provid e information abo ut runo ut distances, fro nt velo city, density and front dynamical over-pr essure. Simple implicit numerical solution to the equation system is performed. Excellent agreement with multi-particle laboratory exp eriments are shown. The deposit of a sub-marine turbidity current originated from a Montserrat volcano pyroclastic flow are reproduced using a distribution of 16 particle sizes.

Keywords: boxmodel, multiparticle, massbalance

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VS002 **Oral Presentation** **6635**

Submarine equivalents of spatter in the early to middle Miocene Josoji formation, Shimane peninsula, SW Japan

Dr. Kazuhiko Kano
Institute of Geology and Geoinformation Geological Survey of Japan IAVCEI

Shun Nakano, Yoshihiro Ishizuka

An accumulation of water-chilled bombs and their fragments of poorly vesicular silicic, alkali-poor andesite occurs in the early to middle Miocene shallow to deep marine succession of the Josoji Formation, along the coast from Sakaura to Akaura Inlets for a distance of 0.8 km. Bombs are flattened and variably warped or twisted into spindle, ribbon, and other fluidal shapes. Sparse vesicles 5 to 10 mm long lie immediately below their surfaces, and cracks extend from their surfaces to the interiors to form a latticework-like pattern with an aperture of 0.5 to 30 mm but with no extrusion of the interiors through the cracks. Many bombs are broken in part or entirely into fine lapilli to coarse ash grains, which are surrounded by curvi-planar surfaces and locally rotated to intermingle with the matrix composed of the fragments of similar appearance and size. The succession of these deposits has a maximum total thickness over 80 m at the eastern sea cliff of Akaura Inlet and thins to the west and east. As typically observed at the western sea cliff of Sakaura Inlet, the lower two-third of the succession is dominated by bombs 0.2 to 1 m long and the upper one-third of the succession is dominated by fine lapilli and coarse ash. The lower coarse succession contains 2-to-3-m-thick fines-dominated beds at the base and middle horizons but has neither stratification nor preferred orientation of bombs. The upper succession contains swarms of small bombs and their fragments but shows neither stratifications nor grading clearly defined. Rootless dikes and veins cut across the succession, even the solidified matrix with a thickness of tens of centimeters thick. They are filled with coarse ash and/or fine lapilli of the same composition and fragments of the host rock. Platy-jointed, locally pillowed, 2-to-4-m-thick lava sheets occur in the pyroclastic succession at the eastern and western sea cliffs of Akaura Inlet. Constituent bombs likely represent submarine explosive magmatic eruptions but the cracks developed on their surfaces demonstrate quenching in direct contact with water. Abundant blocky lapilli and ash grains in the upper succession, however, may demonstrate intermittent explosions that break up the lid of solidifying lava. Injection of clastic dikes and veins can be attributed to the rapid fallout and accumulation of hot fragments, that likely heated the interstitial water to steam, and partialiy welded themselves, and built an excess pressure to induce liquefied flows, succeedingly. Accumulation of fluidal lava fragments form spatter on land but could be more or less fragmental in water as rapidly cooled. We envisage the accumulation of water-chilled bombs and their fragments at Sakaura is submarine equivalents of spatter though the source vent remains unknown.

Keywords: water chilled bomb, spatter, submarine explosive eruption

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VS002 **Oral Presentation** **6636**

Multiple reversely graded beds of submarine pumice breccia on Milos, Greece: implications for submarine explosive eruptions

Dr. Sarah Gordee
Earth Sciences and CODES University of Tasmania IAVCEI

Sharon Allen, Jocelyn Mcphie

Submarine pumiceous units such as the Pliocene Sarakiniko Formation on Milos provide indirect information on the behaviour of submarine explosive eruptions. Submarine eruption plumes differ markedly from subaerial plumes. The resulting deposits reflect these differences. The confining pressure exerted by the water column inhibits gas expansion, thereby reducing plume height, and the interstitial fluid in the plume undergoes a phase change from gas to liquid, accompanied by a dramatic reduction in volume and increase in plume density that leads to collapse. Ingestion of water by pumice clasts is controlled by cooling rates related to pumice clast size. Small hot pumice clasts are quenched and waterlogged more rapidly than larger hot (or cold) pumice clasts, and preferentially enter gravity flows. Very coarse (metres across) pumice clasts and ash can be separated from the plume because of their buoyancy. Deposition of these grain sizes may occur far away from and much later than any genetically related gravity flow facies. The Sarakiniko Formation is a 40-m-thick succession of rhyolitic pumice emplaced in deep water. The succession comprises weakly reversely graded, tabular, coarser (medium lapilli) beds between thin intervals of finer grained, diffusely planar stratified ash and fine lapilli. Some stratified intervals are truncated at low angles at the bases of overlying medium to very thick beds. Lapilli beds include scattered pumice blocks and only minor matrix. Lithic clasts are significantly finer than pumice clasts. The lower part of the formation is composed exclusively of highly vesicular, subangular pumice clasts and dominated by thick beds, whereas the upper part also includes rare lithic clasts and very thick beds are common. We interpret the Sarakiniko Formation to be the medial facies from a submarine explosive eruption that involved pulsatory collapse of a sustained eruption plume. The presence of subrounded pumice clasts, low-angle truncations at bed bases and grading suggest that the final deposition was by means of water-supported gravity flows. The highly vesicular pumice lapilli must have been waterlogged rapidly, probably because they were hot and delivered directly into water. The presence of multiple beds with similar dimensions and lithofacies characteristics implies that gravity flows were generated repeatedly from a sustained eruption plume. We speculate that the multiple collapses preferentially sampled the outer parts of the plume where seawater was entrained and where cooling triggered the gas-liquid phase change. Reverse grading of pumice lapilli could reflect sorting in the gravity flows that was inherited from the cooling and waterlogging process so that leading parts of the gravity flows were richer in finer pumice lapilli compared with the trailing parts. The conspicuous though very small volume of lithic clasts and thicker beds in the upper part of the formation could indicate an overall increase in discharge rate and vent widening.

Keywords: submarine, explosive, pumice

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VS002 **Oral Presentation** **6637**

Transport and deposition of submarine pyroclastic flows; Soufrire Hills volcano, Montserrat, West Indies

Dr. Jess Trofimovs
Department of Earth Sciences University of Bristol IAVCEI

R.S.J. Sparks, P.J. Talling

What happens when pyroclastic flows enter the ocean? To date, the subject of submarine pyroclastic flow behaviour has been controversial. Ambiguity results from inconclusive evidence of a subaqueous depositional environment in ancient successions, to difficulty in sampling the in situ products of modern eruptions. A research voyage of the RRS James Clark Ross (9-18 May 2005) sampled 52 sites offshore from the volcanic island of Montserrat. The Soufrire Hills volcano, Montserrat, has been active since 1995 with eruptive behaviour dominated by andesite lava dome growth and collapse. Over 90% of the pyroclastic material produced has been deposited into the ocean, largely by the direct entrance of pyroclastic flows. In July 2003 the Soufrire Hills volcano produced the largest historically documented dome collapse event. 210 10^6 m^3 of pyroclastic material avalanched down the Tar River Valley, southeast Montserrat, to be deposited into the ocean. A sophisticated monitoring network recorded in detail the subaerial expression of the dome collapse. However, little was known about the flow behaviour or deposits after the pyroclastic flow entered the submarine environment. Bathymetric imaging and coring of offshore pyroclastic deposits, with a specific focus on the July 2003 units, reveals that the pyroclastic flows mix rapidly and violently with the water as they enter the ocean. Mixing takes place between the shore and 500 m depth where the deposition of the basal coarse-grained part of the flow initiates on slopes of 15 or less. The coarse components are deposited proximally from dense basal slurries to form steep sided, near linear ridges that amalgamate to form a kilometre-scale submarine fan. These proximal deposits contain <1% of ash-grade material. The finer components (dominantly ash-grade and fine sand) are elutriated into the overlying water column to form turbidity currents that flow distances >40 km from source. The total volume of pyroclastic material off the east coast of Montserrat exceeds 280 10^6 m^3, with 60% deposited in proximal lobes and 40% deposited as distal turbidites. This broadly correlates with the block and ash components respectively, of the source subaerial pyroclastic flows. However, the efficient sorting and physical differentiation of the submarine flows, in comparison to original mixture of their subaerial counterparts, suggests that the pyroclastic flows mix thoroughly with seawater and generate sediment gravity currents, which are stratified in grain size and concentration.

Keywords: submarine, pyroclastic, montserrat

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VS002 **Oral Presentation** **6638**

The Volcanic History of a Recent Effusive Sea Floor Eruption: Timing, Distribution and Composition of Lavas from the 2005-2006 Eruption of the East Pacific Rise, 9 46-56N

Prof. Ken Rubin
Geology and Geophysics SOESTUniversity of Hawaii IAVCEI

S. Adam Soule, Mike Perfit, Daniel Fornari, W. Ian Ridley

We report here observations of a prolonged effusi ve volcanic event that occurred in 20 05 and 2006 on the East Pacific Rise (EPR) near 9 5 0N, a site th at also experienced a well-documented eruption i n 1991-92. The area is an i ntegrated-study site of the US Ridge2000 progr am for interdisciplinary ocean ridge research. The latest er uption was initially de tected by the non-recovery of some ocean bottom seismometers (OBS) in the area and c haracterized in d etail by a broad range of o bservations and sampling carried ou t on exp editions in th e follo wing mo nths, with an overall goal of u nderstanding eruption co nditions and imp acts o n hydro thermalism an d eco logy at the site. The fo cus o f this presentation is on geological, petrological a nd ge ochronological observation s of th e newly emplaced lava field, focusing on the timing of eruptive activity using radiometric methods, the distribution of lava flows along ~1 8 km of the EPR axis betwe en 9 46-56N , compositional variations withi n the flow fiel d and their co llective implications fo r conditions of magma accumulation and eruption at a magmatically robust, fast spreading ocean ridge volcano. Lava samples collected primarily using the submersible Alvin are being dated by the 210Po-210Pb method to produc e 1-2-month resolution ages. T he method uses time series 210Po activity measurements in volcanic glass after initially being degassed during eruption. Major and tra ce element compositions of these sa me s amples plus a dditional Alvin and remotely collected specimens collectively demonstrate systematic variations in space and time of what and where eruptive activity occurred over nearly a year, during which time significant microseismicity was detected by the few rec overed OBS. Together with v isual obse rvations of subtle s ediment cover variations and young-on-young flow contacts within the flo w field, the data indicate an extended eruption duration (8 4 mos.), similar to the 1991-2 eruption. Detailed maps of the lava distribution and surfa ce morphology were produced using digital seafloor imagery collected on 37 camera tows and direct observations made on10 Alvin dives over the 14.6 km2 flow field . The eruptions were sourced from fissures within the EPR axial summit tr ough as well as fissures located on an off-axis fissure mound ~600 m ea st of the EPR axis between 9 52-56N. The eruptions were highly dest ructive to establis hed biological communities in the summit trough and signifi cantly reorganized hydr othermal flow to chimneys in the area. The 2005-2006 lava is d ominantly infla ted lobate lava with ca 1m flow fronts of lobate and pillow forms, and contains numerous lava channels ~10-50 m wide by 1-5 m deep that trend approximately E-W. Portions of the lava flow reached as far as ~2 km east of the EPR axis near 9 51.2N, much farther than flows of the 1991-92 eruption.

Keywords: eruption, basalt, submarine

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VS002 **Oral Presentation** **6639**

Interdisciplinary survey on Petitspot - a new type intra-plate volcanism in the NW Pacific-

Dr. Natsue Abe
IFREE JAMSTEC IAVCEI

Naoto Hirano, Kiyoshi Baba, Toshiya Fujiwara, Hiroko Sugioka, Kr03-07, Kr04-08, Yk05-06 And Kr05-10 Onboard Scientists

Petitspot is a newly found s ubmarine volc ano on the abyssal plane (~ 6000 m water depth) in th e northwestern Pacific (Hirano et al., 2006). It is composed of numerous small knolls and looks similar to an alkaline mono-volcanic field on land. The volcanoes were discovered on the Early Cretaceous (~135 Ma) NW Pacific Plate. They are very small knolls and erupted strong to moderate alkaline basalt, generally including deep-seated xenoliths. This volcanic field is far from spreading centers and is also out of any subduction systems, therefore these are cla ssified as a kind of intra-oceanic plate volcanism. In this area, however, there are neither any hotspo ts no r large igneo us pro vince prev ious repo rted. Therefore, this volcanic activi ty is not adequate fo r any existence volcanic models on t he earth. The n, we named this special volcanism petitspot. According to Hirano et al. (2006, Science), they interpret the volcanism occurs along small fractures in the old cold Pacific plate r espond to the flexure befor e subduction. To understand m ore detail of the mechan ism for this petitspot eruption, weve been taking interdisciplinary surveys. The ma in res ults of these s urveys using JAMSTEC four cruises (KR03-07, KR04-08, YK0 5-06 and KR05-10) and shore-based research are listed below. 1) Sea beam mapping shows there are a lot of small knolls assumed young volcanoes. The arr angement and the size of the knolls imply that this volcanic field is a mo nogenic vo lcanic cluster, which are o ften o bserved in the intra-continental plate.2) Volcanic rocks were sampled from more tha n four knolls by dredges and submersible dives. They are highly vesicular, and ge nerally include peridotite xenol iths and peridotitic xenocrysts..3) Single Channel Seismic (SCS) Reflection sur vey profiles suggest that main body of the young volcano exists betwee n pelagic sediment an d oceanic basement .4) Magnetotelluric soundings (MT) experiment using ocean bottom electromagne tometers (OBEM) implies the maximum electric conductivity observed around 180 km depth. In addition to these results, some seismic activities (M3 5) were observed in this area by world network of seismic stations for this quarter century. As a whole, petitspot volcanism is quite unique and highly remarkable phenomenon.

Keywords: petitspot, xenoliths, flexure

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VS002 **Oral Presentation** **6640**

Off-axis volcanic ridges on the flanks of the Pacific-Antarctic Ridge

Dr. Anne Briais
Terrestrial and Planetary Dynamics Laboratory CNRS IAG

Hlne Ondras, Frauke Klingelhoefer, Laure Dosso, Cdric Hamelin, Herv Guillou

We analyze large off-axis volcanic structures mapped and dredged on the western flank of the Pacific-Antarctic ridge between 40S and 55S. Two of them form ridges on either side of the Menard transform fault (TF) near 50S, and other ridges are oriented nearly E-W at 42S. South of the Menard TF, 9 large off-axis volcanoes, 12 km di ameter on a verage an d 50 0 m to 2000 m high, show two types of morphology. O ne type exhibi ts conical shapes with a su mmit caldera, and low backs cattering in th e EM12 imagery, probably due to the presence of sedi ments. They are loca ted on 25 My-old lithosphere. The other typ e is represent ed by N70 or EW-elong ated structures, a nd associated to narrow, EW-trending volcanic ridges, some of them showing strong backscattering o n the EM1 2 echo sounder imagery. They are located on 03 My-old lithosphe re. K/Ar dating of samples dredged on these structures reveal a co ntrast of up to 3 m. y between the vo lcanoes and the underlying crust. North of the Menard TF, the volcanoes have a n average diameter of 6 km, and hei ghts of 100 to 1600 m. They are elongated and linked by N100 to EW-trending narrow ridges. All volcanoes show calderas opened to the east. They are located on lithosphere aged 15 Ma. The volcanoes closest t o the axis show the strongest EM12 backscattering. Two EW-trending ridges have been surveyed near 42S. One ridge, from 11140W to 11230W at 4155S, appears to be very linear and narrow, and probably did not form by the coalescence of individual volcanoes. Near 4115S , a ridge extends between 11210W an d 11355W. It is composed of elongated volcanoes linked by volcanic ridges. Both ridges are also located on 1 to 5 My-old lithosphere. The volcanic activity, as suggested by the young K/Ar ages of some samples and by the strong backscatter in sonar images, appears to be limited to areas of seafloor younger than about 3 Ma. The major volcanic structures on the flanks of the Pacific-Antarctic ridge might result from intrapla te deformation near the axis, following recent kinematic changes.

Keywords: off axis, mid ocean ridge, pacific

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VS002 **Oral Presentation** **6641**

Summit Construction, Caldera Formation, Cone Growth, Hydrothermal Processes, and Sulfide Deposition on Submarine Volcanoes of the Southern Kermadec Arc

Prof. Alexander Malahoff
Office of the CEO GNS Science IAVCEI

Six active Ker madec arc submarine volcanoes located between 34S and 3630 S were mapped an d sampled between April and July 2005 using submersibles Pisces V and Pisces IV aboard the mother ship the R/V Kaimik ai-o-Kanaloa. The purpose wa s to stud y the relationship between hydrothermal activity, formation o f hydro thermal mineral depo sits, and the biodiversity of life associ ated with the hydrothermal vents. Of the volcanoes examined, all sh owed evidence of hydrothermal activity, including metal-rich plumes and helium anomalies. Only two of the volcanoes, namely Brothers and Clark, showed chimneys and surficial poly metallic sulfid e deposition. Hydrothermal venting at a water depth of approximately 1,650 meters near the base of the northwest caldera wall of Brothers volcano has produced a field o f chimneys, up to seven mete rs high and dischar ging black smoker venting. Temperatures up to 300C were measured from the active vents. Clark volc ano has a double cone summit at a water depth of 875 meters. The shallowest cone has a near-summit hydrothermal vent field with five-meter tall venting ch imneys with s maller structures around the periphery. Water temperatures of 200C were recorded for these chimneys. Geoche mical and petrological analysis of the massive polymetallic su lfide samples collected previo usly fr om Broth ers an d Clark sh ow a ran ge in min eralogy. This range is clearly a f unction of hydrothermal fluid temperatures. Chimneys fro m Brothers are mai nly sphalerite dominant with lesser amounts of chalcopyrite. Sulphides from Clark volcano tend to be barite-rich with lesser sphalerite and pyrite/marcasite. Sulphides from Broth ers volcan o range in gold concentration between 0.2 and 1.9 ppm with silv er concentrations u p to 4,390 ppm . A mineral formation mod el for the volcanoes sugges ts hydrotherm al fluid boiling within the volcanic edifice. Surficial deposits for these shallow volcanoes include native sulphur and lower temperature oxides. Only the deeper vent sites at Brothers volcano shows ma ssive sulfide deposi tion along the marginal fa ults near the cald era floor. Volcanoes show evidence o f su mmit edifice construction thro ugh summi t volcanism followed by summi t collapse and summit reconstruction through cone volcanism and gro wth. Young co ne gro wth in the calderas is ubiq uitous and de monstrates th e recurring th eme o f summi t collapse and summit regrow th through cone formatio n. Talus, rather than co ntinuous lava flo ws, dominates the upper slopes of the volcanoes. A model suggests periodic catastrophic rather than steady summit collapse for caldera formation and volcanic ed ifice growth. Sulfide chim ney deposits are strung along the basal caldera wall fa ults. Fragmented and disseminated sulfides in a talus matrix are probably located below the contact between the caldera wall and floor.

Keywords: kermadec, volcanoes, minerals

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VS002 **Poster presentation** **6642**

A report on findings of pumices from the Central Indian Ocean basin

Dr. Niyati Kalangutkar
Geological Oceanography Division National Institute of Oceanography

Dr Sridhar D. Iyer, Dr V.M. Matta

A number of pumice clasts along with p olymetallic nodu les were collected from the Central Indian Ocean Basin (CIOB), which extends fro m 0o to 25oS and 70oE to 90oE. Based on the dr edge and grab samples, an ar ea of about 600,000 sq km covered with pumice has been identified. This is the largest pumice field identified in the world ocean. The water depth of sample collection is greater than 5000 m. Pumices, characteristic products of explosive eruptions and with a very low specific gravity, are believed to form at water depths less than 500 m. The CIOB pumices has been suggested to be drifted after the 1883 Krakatau eruption. But there are also reports that the Krakatoan prod ucts do not occur in significant amo unts to the ea st of 80o E longitude. Yet, another report suggests that the seamounts along 90o E ridge as a source of pumice. About 400 sa mples were classified based on shape and size. A majority of samples range between <1 cm up to 36 cm and plot in the equant and oblate fields in the Zinggs shape diagram. The Corey Shape Factor (CSF) for most of the sa mples is close to 0.7, which is common for volcaniclastic m aterial. Th e eq uant clasts with CSF value s ~1 will have settling velocit ies close to that of a sphere and will float for a longer time; whereas the non-equant ones settle relatively faster. The nature of the ve sicles may als o play an important role in deciding the s ettling velocity . Microscopy of the pu mices reveals vitroph yric textu re with phenocrysts of feldspars an d clinopyroxene while elongated vesicles to be predominant over spherical ones. Deep s ubmarine pumi ces have bee n reported from >3500 m water depth from the world oceans. The Afanasy-Nikitin seamount (04o S, 83 o E) is capped b y trachyandesites, flanks and slopes by mod erately alkaline ba salts while N-MORB occur at the base. Some amount of tuffs has also been recovered, which attest to an explosiv e eruption. In the central, pa rt of the basin N-MORB and its varian ts have been recovered. The association of this suite of rocks and pumice s may be the result of e xtreme fractionation of tholeiitic basalts. Experimentally it has been proved that hot pumices sink faster than cold pumices. Hence, the possibility of in situ formation of pumices in the CIOB can not be ruled out as substantiated by occurrence of pumices neare r to the seam ounts. The pumices are either fresh or pa rtially to fully coated by FeMn oxides (upto a few cm). It is believed that under normal hydrogenous precipitation accretion of 1 mm of FeMn oxide takes about 1x106 year. There fore, this suggests that either the coated pumices are olde r than the 1883 Krakatau eruption or else the rate of oxide accretion is much faster probably as a result of hydrothermal inputs.

Keywords: pumice, submarine volcanic eruption, ciob

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VS002 **Poster presentation** **6643**

Giant pumice: unique highly vesicular coarse clasts erupted from submerged silicic domes

Dr. Sharon Allen
School of Earth Sciences University of Tasmania IAVCEI

Richard Fiske, Yoshiko Tamura

New exploration on the seafloor of in the western Pacific has discovered swarms of giant (1-10 m across) pumice clasts on the slopes and summits of three compositionally identical silicic dome volcanoes. These volcanoes lie on the western margin of the Sumisu volcanic complex and erupted pumice at different water depths (1100 to 200 m). Giant pumice clasts are unique as they have properties of being both highly vesicular but are metre-sized. They are known to occur in uplifted ancient submarine and lacustrine successions, and on the modern seafloor, and have been witnessed temporarily floating during historical submarine eruptions. However, their eruptive origins have remained enigmatic. We use in situ observations and site-specific sampling, combined with vesicularity studies to understand the eruption and emplacement mechanisms for giant pumice clasts. The giant pumice clasts are polyhedral blocks having planar surfaces that either exhibit a cracked, wrinkled texture, formed where the outer surface of the frothy dome lava quenched in seawater, or a hackly texture from brittle breakage of the pumice along internal, closely-spaced curviplanar fractures. The giant pumice clasts occur together with domains of intact pumiceous carapace. The carapace is also indented by pits tens of metres across where the pumiceous carapace has been excavated by steam explosions. The giant pumice clasts and carapace are highly vesicular; all vesicles are elongate parallel to one of the quenched and cracked, wrinkled surfaces. These highly vesicular, giant pumice clasts are restricted to, and hence diagnostic of, relatively deep (~>100 m) subaqueous eruptions of water-rich silicic magma associated with dome volcanoes. The eruption style involves the complete vesiculation of water-rich silicic magma during ascent. Giant pumice clasts were liberated as seawater penetrated deep into the hot interior of the carapace via quench fractures and rapidly expanded. Subaqueous settings allow generation and preservation of large pumice clasts. The deep water reduces magmatic explosions allowing the formation of vesicular froth. The density of water-logged pumice causes slow settling and the surrounding water protects the clasts from abrasion.

Keywords: submarine, domes, pumice

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VS003 **6644 - 6680**

Symposium
Volcanic Flows: Observation, Experiment, and Theory

Convener : Dr. Shinji Takarada, Prof. Tim Druitt

This session will focus on the dynamics of volcanic flows, such as pyroclastic density currents, debris avalanches, lava flows, and lahars. Contributions concerning field observations of such flows, the characteristics of their deposits, laboratory experimentation using real or analog materials, and theoretical modeling are relevant to this session. Research linking models with quantitative field measurements of flows and flow deposits are particularly welcome.

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VS003 **Oral Presentation** **6644**

Littoral Blasts: Pumice-Water Heat Transfer and the Conditions for Steam Explosions When Pyroclastic Flows Enter the Ocean

Dr. Josef Dufek
Earth and Planetary Science University of California, Berkeley IAVCEI

Michael Manga, Marcel Staedter

Steam explosions, or littoral blasts, generated when pyroclastic flows interact with seawater may be a common, although rarely documented, phenomena. The development of steam explosions rather than passive steam production is related to the rate of thermal energy transfer from hot pyroclasts to water. We conduct a series of laboratory experiments to quantify the heat transfer and steam production rates when hot pyroclasts encounter water. Hot pumice (> 200 C) rapidly ingests water while remaining at the surface, producing measurable amounts of steam during the process. Approximately 10 % of the thermal energy of the pumice particles is partitioned into the production of steam, and smaller particles have greater steam production rates. The laboratory experiments are used to develop a subgrid model for steam production that can be incorporated into a multiphase numerical framework. We use this model to study the critical steam production rates required to initiate explosive events. For conditions typical of many pyroclastic flows, particles smaller than ~ 1 - 5 mm are required to initiate a littoral blast. A second set of 2-D numerical simulations is conducted to simulate the July 12-13 Soufrire Hills dome collapse event that reached the sea. The simulations predict that the focus of the blast is likely generated several hundred meters off-shore and although the landward directed base surge is primarily dry (< 15% water vapor), the area immediately above the blast is steam-rich and may be a likely site for the production of accretionary lapilli.

Keywords: pyroclastic flow, eruption dynamics, steam explosion

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Compaction and gas loss in welded pyroclastic deposits: porosity, permeability, and electrical conductivity measurements of the Shevlin Park Tuff

Dr. Heather Wright
Geological Sciences Monash University IAVCEI

Katharine V Cashman, Jeffery J Roberts

The dominant controls on welding in pyroclastic flows are poorly constrained. Due to the lack of historic observations of the welding behavior of pyroclastic flow deposits, emplacement conditions must be inferred from the textures of preserved pyroclastic deposits and by extrapolation from observations of pyroclastic eruptions that do not produce welded deposits. Cooling and compaction models rely on limited observations to simulate the behavior of these multicomponent depositional systems. Here, we examine compaction that accompanies welding in the Shevlin Park tuff, a variably welded, valley filling ignimbrite deposit. Petrographic characteristics of welding rank correlate well with physical properties of the Shevlin Park tuff, in a manner similar to measurements for other welded tuffs. In general, permeability decreases with decreasing porosity, although there is several orders of magnitude variation in permeability at any given porosity. Electrical tortuosity measurements of welded tuff samples suggest that pore pathways become increasingly dominated by crack-like geometries with increasing degree of welding. The aperture widths of these cracks are small, ranging from 0.5 to 13 µm, according to Kozeny-Carman predictions through slit-shaped pores, and are slightly higher (0.8 to 20.7 µm) for disk-shaped Kozeny-Carman approximations. These calculations show that cracks do not have to be large to maintain permeable pathways through the deposit. However, at low porosities, permeability of tuff samples drops rapidly, suggesting a percolation threshold at 8% porosity. We model the permeability-porosity trend using a power-law fit with a percolation threshold to fit the data. This general relationship can be used in models of compaction and cooling in pyroclastic flows and may help further constrain the role of volatile resorption on pore reduction in welding deposits and the timescales of gas loss during viscous deformation of glassy volcanic shards.

Keywords: welding, pyroclastic, flows

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The 2006 block-and-ash flow deposits of Merapi Volcano, Java, Indonesia: comparison of field observations and TITAN2D flow simulations

Mr. Sylvain Charbonnier
Earth Sciences and Geography Keele University IAVCEI

Ralf Gertisser

In May 2006, after five years of quiescence, volcanic activity at Merapi resumed with lava dome growth and the generation of block-and-ash flows directed mainly toward the south-western sector of the volcano. After the devastating Bantul earthquake on 27 May, the activity peaked in June 2006, when a shift in dome growth direction and breach of the eastern crater rim, allowed flows to travel down the volcano's southern and south-eastern flanks which weren't affected by pyroclastic flows for more than a century. On 14 June, the largest block-and-ash flows reached distances of ~7 km from the summit in the Gendol river valley, causing two fatalities and the total destruction of the village of Kaliadem. Associated deposits form about ten < 80 m wide overlapping lobes, which represent a record of successive flows generated during and after the major event on 14 June 2006. Both, single pulse (post-14 June events) and multiple-pulse pyroclastic flows generated by sustained dome collapses on 14 June 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 ridges and interfluves and were subsequently channelled into the surrounding river valleys and (3) overlying, dilute ash cloud surge deposits on valley margins. Surface particle assemblage analyses on different lobe deposits have revealed variations in the abundances of the main lithological components from proximal to distal reaches. The overbank deposits are enriched in scoriaceous clasts compared with the valley-confined deposits. Moreover, hydrothermally altered and oxidised clast contents within surface particle assemblages are generally higher in lobes or flows produced by multiple-collapse events of the unstable eastern crater rim. Friction or impact marks occur on all sides of large dense blocks within the deposits and significant erosional features were observed at valley margins at distances > 5 km from the summit. These indicate that the 2006 block-and-ash flows can be considered as unsteady, rapidly agitated granular flows with strong frictional contacts during transport. Numerical simulations of these flows using the TITAN2D model developed at the University of Buffalo, USA, stay within the extent of the mapped deposits. Insights gained from these preliminary results are considered invaluable in guiding future hazard assessment of pyroclastic flows at Merapi.

Keywords: merapi, block and ash flows, numerical modelling

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Large-scale density currents of Avellino eruption (Somma-Vesuvius, 3.8 KA): lateral facies variations, transport mechanisms and impact parameters

Dr. Rosanna Bonasia
Geomineralogico Universit di Bari

Dellino Pierfrancesco, La Volpe Luigi, Sulpizio Roberto

The Avellino Pumice eruption at Somma-Vesuvius (Italy), attributed to the Bronze Age (3.8 ka), represents one of the major events occurred in this period in the Mediterranean area. Three distinct units can be recognized in the deposits stratigraphy, which correlate with three phases of the eruption: an opening phase, a plinian phase and a final, phreatomagmatic phase. This work focuses on the final phreatomagmatic phase of the Avellino Pumice eruption, with the aim of evaluating the impact of its products on the surrounding areas and contributing to the volcanic hazard evaluation at Vesuvius. For this purpose, the study has been devoted to the physical characterization of the most powerful dilute pyroclastic density currents occurred during the final phase of the Avellino eruption. Eleven stratigraphic sections were studied and described on the slopes of the volcano and on the surroundings, up to a distance of more than 11 km. Based on lithostratigraphic correlation between various beds, a composite stratigraphic section was reconstructed. Lateral facies variations show the passage from a massive facies to plan- parallel laminated facies with increasing distance from the vent. Facies interpretation models are in accordance with the Turbulent boundary layer shear flow theory. A model for characterizing dilute pyroclastic density currents of Avellino eruption was developed and allowed the calculation of flow density and velocity by matching the structural and granulometric characteristics of the deposits particles. The model is based on the aerodynamic equivalence between dense juvenile fragments and pyroxene crystals. It allowed the evaluation of the fluid-dynamics parameters that characterized the shear current. Successively, by means of the stratified flow theory, the height of the flow, concentration and Rouse numbers of particles were calculated. By means of these parameters, it was possible to evaluate the density and velocity profiles of pyroclastic surges, at different distances from the vent. The dynamic pressure profiles were obtained by combining density end velocity profiles. Specific dynamic pressures values, of 10 m height of the flow, were calculated by integrating the dynamic pressure profile. The average values vary between about 20 kPa at a distance of about 2.8 km from the vent, and 2.2 kPa at 11.6 km from the vent.

Keywords: avellino eruption, dynamic pressure, pyroclastic surges

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A quantitative shape analysis for predicting the settling velocity of pyroclastic particles

Dr. Daniela Mele
Diprtimento Geomineralogico Universit degli Studi di Bari

Dellino Pierfrancesco, Braia Giuseppe, La Volpe Luigi, Sulpizio Roberto

The investigation of aerodynamic propert ies of juvenile particles is of great importance in the modelling of both sedimentation of particles from plumes and s ustained columns and transport and deposition processes in pyroclastic density currents. The settling velocity of a particle though a fluid is a function of particle size, density and shape features as well as properties of the fluid. In the past, for predicting the settling velocity of pyroclastic particles, re duced forms of the impact l aw were developed, assuming particles of spherical shape. This obviously can lead to serious errors. Previous attempts of defining the settling velocit y of the irregularly shaped volcanic particles were prop osed, but these forms have unknown quantities as the drag coefficient (Cd), th at is a fun ction of Reyn olds n umber. Here, we propose new experimental data to predict the settling velocity of juvenile particles by means of e asily measured part icle characteris tics, as: the d ensity, the true grain size and shape fact or of juvenile particles. We s how also a dataset of shape factor fo r a wi de range of pyroclastic parti cles of different eruptions and/or eruptive units. The resulting model allows predicting the settling velocity of pyroclastic particles with an average error of 12% , which compare favourably with previous models.

Keywords: settling velocity, shape factor, pyroclastic particles

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Thermal effects on magma flow dynamics

Dr. Antonio Costa
INGV INGV Sezione di Napoli

Oleg Melnik, Steve Sparks, Elena Vedeneeva

Viscosity of silicate melts is strongly affected by temperature variations. That implies that energy and momentum equations in magma flows are strongly coupled. In order to study effects of local viscosity stratification due to temperature gradients in magma flows, we solve numerically mass, momentum and energy equations for magma flow inside a cylindrical conduit and heat conduction equation in the surrounding host rocks imposing local far field conditions for rocks temperature. For sake of simplicity we neglected magma solidification and melting of host rocks. Simulation results show that both viscous dissipation and heat loss to the conduit walls have a pivotal role on magma dynamics allowing to distinguish three regimes: i) a conductive-heat-loss-dominated regime, ii) an intermediate regime, and iii) a viscous-heating-dominated regime. When viscous dissipation effects are negligible heat loss to conduit walls is responsible of a significant local increase in magma viscosity near the boundary and as a consequence of an increase in the conduit friction. In this case the flow is localized in the central part of the conduit. Maximum velocity is 5 to 6 times larger than average (for a Poiseuille parabolic velocity profile the ratio between the maximum and the average velocity is 2). When viscous dissipation effects are dominant, there is a local temperature increase near the walls with a consequent decrease of the viscosity which strongly affect both temperature and velocity profiles. Flow can evolve from a Poiseuille type, with a uniform temperature distribution at the inlet, to a plug type with a hotter layer near the walls. The maximum velocity is just slightly larger than the average in this case. Fully 2D computational results were used for better parameterising the friction factor that can be used in simplified 1D models. At the end-member cases some analytical parameterizations are proposed. Calculations have direct implications for interpretation of magmatic conduit flows. Observed phenomenon that can be linked to temperature variations include re-melting and erosion of wall rocks due to temperature increase and instabilities, textural differentiation due to strain localization, local crystal resorption and/or formation due to thermal layering. Finally a possible role of viscous dissipation effects is in leading to a transition between extrusive/effusive to explosive eruptive regime.

Keywords: magma, flows, thermodynamics

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VS003 **Oral Presentation** **6650**

Gas retention in pyroclastic flow materials at high temperature

Prof. Tim Druitt
Lab. Magmas et Volcans Universit Blaise Pascal & CNRS IAVCEI

Geoffroy Avard, G. Bruni, P. Lettieri

The ability of a dense pyroclastic flow to maintain high gas pore pressure, and hence low friction, during runout is dete rmined by (1) the strength s and lo ngevities o f gas so urces, and (2) th e ability o f th e material to ret ain residual gas once those sources becom e ineffective. The latter is termed the gas retention capacity. Gas retentio n capacity in a defl uidizing granular material is governed by thr ee timescales: one for the evac uation of bubbles (tbe; brief and no t considered further), one for hindered settling from the expanded state (tsett), and one for diffusive release of residual pore pressure from the non-expanded state (tdiff). T he relative magnitides of tse tt and tdiff depend on bed thickness, tset t dominating in thin systems and tdiff in thick ones. Three pyroclastic flow materials, two ignimbrites and a block- and-ash flow sample, were studied experime ntally to investigat e expansio n b ehaviour u nder vertical gas flow and to deter mine gas retention times . Effects of particle size were evaluated by using two size cuts (<4 mm and <250 micron) from each sample. Careful drying of the materials was necessary to a void effects o f humidity-related co hesion. Two sets of experimen ts were carried ou t: (1) expansion in the non-bubblin g regime at 5 0-200 C, (2) b ed collapse tests from the initially bubbling state at 50-55 0 C. Provided that gas channelling was avoided by gentle stirring, all the samples exhibited a regime o f uniform expansion prior to the o nset of bubbling. Fine particle siz e (in particular high fines co ntent), lo w particle density an d high temper ature all f avoured smo other fluidizatio n by increasing the maximum expansion possible in the non-bubbling state. An empirical equation describing the uniform expansion of the materials was determin ed. High temperature also favoured greater gas partitioning into the dense phase of the bub bling bed. Large values of tse tt and tdiff wer e favoured by fine particle size. Temperature had less influenc e, suggesting that experimental results at low temperatures (50-200 C) can be extrapolated to higher temperatures. Gas retention times provide insight into the ability of pyr oclastic flo ws in expand ed (t sett) or non-expanded (tdiff) flow states to retain gas onc e air ingestion or gas production have become ineffective. Finer-grained pyroclastic flows are expected t o retain gas l onger, and he nce ha ve hig her apparent m obilities, than coarser-grained ones of comparable volume, as has been observed on Montserrat.

Keywords: pyroclastic flows, fluidization, hindered settling

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VS003 **Oral Presentation** **6651**

Dynamics of Laboratory Ash Flows

Mrs. Girolami Laurence
Volcanology Laboratoire Magmas et Volcans IAVCEI

Tim Druitt, Olivier Roche

Pyroclastic flows are dense flows of hot particles and gas generated by explosive volcanic eruptions. Their fluidal behaviour is widely attributed to high interstitial gas pore pressures and associated fluidization. We carried out experiments on the dynamics of laboratory-scale flows of fluidized pumiceous ash in a 3.5-m-long linear lock-exchange flume at ~170C, which is hot enough to render negligible effects of humidity-derived cohesion. The ash was the sub-250 m fraction of a trachytic ignimbrite. The 1-D expansion and settling properties of the ash were first investigated in the flume reservoir with the gate shut. When fluidized, the ash expanded uniformly up to 42 vol % above loose packing prior to the onset of bubbling. Hindered settling velocities were determined by first expanding the material, then allowing it to re-sediment under gravity by abruptly cutting the gas flux (bed-collapse test). The flows were generated by first expanding the ash to a known amount (6-42 vol%) in the reservoir, then opening the lock gate. Each flow defluidized progressively as it travelled down the flume until motion ceased. Despite the polydisperse nature of the ash, no significant segregation took place during flow. Frontal velocities and runouts both increased with increasing initial bed expansion, the most expanded flows being ~5 cm thick with speeds of ~2 m.s-1 and runouts of ~2.8 m. Flow was laminar as revealed by tracer particles. Each flow exhibited three phases during transport: (1) a short initial phase of gravitational acceleration, (2) a dominant, approximately constant-velocity phase, and (3) a short stopping phase. Deposition took place by sediment aggradation at the flow base, the flow thinning progressively as it travelled down the flume until it ran out of mass. Within a given flow, the sediment aggradation rate was constant for most of the runout distance. Moreover, the rate of particle settling in a flow of given expansion was identical to that in a 1-D bed-collapse test at the same initial expansion. It appears that neither shear-dispersive stresses nor interparticle collisions within the flows were strong enough to affect particle-settling rates, despite high rates of shear (up to 80 s-1). Runout time trun scales as trun/tgrav = (tsett/tgrav) to the power 0.55, where tgrav is a characteristic time of gravitational acceleration and tsett is a characteristic time of particle settling. This function reflects the strong control of sedimentation on the flow dynamics.

Keywords: pyroclastic, sedimentation, experimental

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VS003 **Oral Presentation** **6652**

Double compositional zonation of an ignimbrite: case study from Los Humeros caldera

Dr. Gerardo Carrasco
Centro de Geociencias Universidad Nacional Autnoma de Mxico IAVCEI

Vertical compositional zoning is a relatively common feature in ignimbrites and typically records changing discharge with time. It shows an upward trend within the juvenile components from relatively evolved silicic pumice at the base of the ignimbrite to less-evolved, more mafic pumice at the top. This pattern is commonly inferred to record progressive eruptive withdrawal from the top of a density stratified magma-chamber, initially tapping less dense, more silicic uppermost parts of the magma chamber and then progressively deeper, denser, more mafic parts of the chamber with time. Although this pattern may be common in multiple flow units, there are just a few examples of individual flow units showing this feature. One is the Zaragoza ignimbrite, which was erupted from Los Potreros caldera in central Mexico approximately 60 100 kyr ago. The layer exhibits in a section of 1 6 m thick an interesting double (normal-to-reverse) pattern of chemical zoning, marked by differing compositions of both the juvenile and the accidental components. A basal rhyodacitic (67.6-69 wt.% SiO_2) zone grades up via a mixed zone into a central andesitic (58-62 wt. % SiO_2) zone, which, in turn, grades up into an upper rhyodacitic (67.6-69 % SiO_2) zone. Zoning is also defined by vertical variations in lithic clast populations. We infer that pyroclastic fountaining fed initially rhyodacite pumice clasts to a sustained granular fluid-based pyroclastic density current. The composition of the pumice clasts supplied to the current then gradually changed, first to andesite and then back to rhyodacite. Inverse grading at the base of the massive layer may reflect initial waxing flow competence. The pumice concentration at the top of the massive layer is entirely rhyodacitic and was probably deposited during waning stages of the current, when the supply of andesitic pumice clasts had ceased. The return to rhyodacitic composition may have been the result of eruption-conduit modification during collapse of Los Potreros caldera, marked in the ignimbrite by a widespread influx of hydrothermally altered lithic blocks, and/or a decrease in draw-up depth from a compositionally stratified magma chamber as the eruptive mass flux waned. The massive layer of ignimbrite thins locally to less than 2 m, yet it still shows the double zonation. Correlation of the zoning suggests that the thin massive layer is stratigraphically condensed, and aggraded relatively slowly during the same time-interval as did much thicker (≤50 m) massive layer.

Keywords: ignimbrite, zoning, flows

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VS003 **Oral Presentation** **6653**

En-masse versus aggrading deposition in small-scale pyroclastic and volcaniclastic flows: field evidences for a reconciliation

Dr. Roberto Sulpizio
Dipartimento Geomineralogico Universit di Bari IAVCEI

Pierfrancesco Dellino, Daniela Mele, Giovanni Zanchetta

The research on behaviour of pyroclastic and volcaniclastic flows is one of the main topic in present day volcanology, and involves disciplines that range from sedimentology to geophysics and from laboratory experiments to numerical simulations. The vast interest is justified by the complex nature of these currents and by their very dangerous nature that threaten million of people around the world. In recent years significant goals have been reached in understanding the physics of pyroclastic and volcaniclastic flows, the most important probably the description of different types of pyroclastic and volcaniclastic flows within a continuum spectrum of phenomena in which the dominance of fluid or solid particles on motion determines the wide range of observed deposits. Of primary importance is also the involvement of the granular flow theory in description of the particle-particle dominated (lower) part of pyroclastic and volcaniclastic flows. Since these flows are density stratified, particle-particle interaction play a role in all types of pyroclastic and volcaniclastic flows, with probably the exception of extremely diluted ones. The interpretation of some deposits in the light of granular flow theory opened some interesting perspectives for future research. The first is the unification of present day two major models of pyroclastic and volcaniclastic flow deposition, the progressive aggradation and the en-masse freezing. The second is that a pyroclastic or a volcaniclastic flow do not move as a single body but comprises different pulses that moves at different velocities downvalley. The reconciliation of progressive aggradation and en-masse freezing models is then proposed on the basis of a model that takes in account the stepwise aggradation of discrete pulses that develop within a single current and that stop en-masse when the resisting bulk forces exceed the driving ones.

Keywords: pyroclastic density currents, volcaniclastic flows, sedimentology

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VS003 **Oral Presentation** **6654**

Modelling the growth of a volcanic talus

Dr. Alina Hale
ESSCC The University of Queensland IAVCEI

Laurent Bourgouin

Part of the natural evolution of lava domes are collapse events, which may partly or completely remove the dome depending upon the severity of the collapse event and the physical properties of the dome. Of fundamental importance to volcanology is knowing what the required conditions are for a dome to collapse. Collapse events commonly result in the genera tion of pyroclastic flows, avalanches of hot rock and ash, which travel at hurricane speeds and can generate a tsunami when entering the sea. The most hazardous eve nts are those that remove sufficient do me material to all ow rapid vesic ulation (volati le loss) of magma either within active domes, or within magma stored at high levels in a volcanic edifice . Thermally, a lava dome can be divided in to two uni ts: a hot interi or (the core) and a cooler outer surface with temperatures generally less than 100 deg C. As material is extruded into the dome interior, the solidified surface is forced to break apart genera ting debris which is deposited at the flow front an d forms a talus that eventually enshrouds the lava dome. It has been identified that dome collapse events commonly follow a trend of initial ta lus collapse through to explosive acti vity when the core is exposed. This suggests t hat the tal us is critical to the cont ainment of the volatile-ric h lava and for stability. We computationally model the growth and e volution of a l ava dome incl uding the talus, a c ommonly neglected component of dome growth. We utilise the Finite Element Method (FEM) to model the growth of the lava do me. The talus is mode lled t o develo p fr om lava solidifi cation via vola tile l oss which promotes crystallization as observed in inter mediate composition lava flows. We model the dome core lava as a Newto nian fluid with a co nstant viscosity, appr opriate because the lava cor e will maintain higher temperatures due to the low thermal conductivity of the lava. The talus is modelled as a Drucker-Prager materia l with the interface between t he core and talus taken to be the solidus transition. The free-surface a nd core/talus interface are modelled using the level-set method, a te chnique to trace interfaces and flow fronts with out distort ing th e mesh . Ou r mode l is axi-symmetric and provides information on the extent and growth of the talus, and the volume of collapse required before the collapse scar will reach the dome core. The extrusion rate of the lava, solidus transition and the physical properties of the talus gover n the extent of the do me and talus/core interface. Model results show how talus is predominantly generated at the top of the lava dome and deposited at the toe of the flow.

Keywords: lava dome, talus, fem

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Flow and deposition of pyroclastic granular flows a combined field and experimental study

Dr. Gert Lube
Volcanic Risk Solutions - INR Massey University IAVCEI

Armin Freundt, Shane J. Cronin, Thomas Platz, R. Stephen J. Sparks, Herbert E. Huppert

Small-volume pyroclastic fl ows form frequently duri ng explosive erupti ons with lit tle warning and are thus one of the most hazardous volcanic phenomena. Assessing this hazard req uires physical understanding of their high mobility, tr ansport and sedimentation processes. Experimental and numerical mod els of ge ophysical mass flows need to be tested against natural flows a nd/or deposits, but suitable complete data sets are still scar ce. We therefore studied a series of pristine small-volume flow units from the 1975 eruption of Ngauruhoe volcano which are one the worlds best deposits of low-energy, coarse-grained pyroclastic flows, which were also witnessed during eruptio n. Through a hig h-resolution GPS survey of deposit morphology, excavations across the flow deposits along the entire flow length, and sedimentological analysis we acquired a unique data set. This includes the geomorpholog y, internal structure and texture with respect to laterally varying mode of deposition. The detailed data is used to elucidate transport, segregation and deposition mechanisms of low- energy pyroclastic granular flows as a fun ction of flow volume, travel distance, granulometry, generation mechanisms, degree of topographic confinement and local sl ope. Field data is shown together with results fr om analogue experiments on dry granular flows that elucidate the time-dependent motion of the lower flow boundary and the influence of topographic confinement on flow mobility. Deposition from these PD Cs began only on slopes at or around the materials angle of repose (c. 30o). In unconfined settings, the granular PDCs are interpreted to have been quasi-steady, forming sheets and lobes around the angle of repose. Where flows were confined, sheet-like proximal facies made up around 10% of the deposit volume at the angle of repose, but 90% of the material was deposited from apparently unsteady inertial granular PDCs as a distal leve-and-channel facies o n slopes well belo w the repose angle. Hence, confined PDCs were able to travel up to 50% farther than unco nfined flows. In the distal facies the deposit width is inversely correlated to the local slope, and t he heig ht of the leves (above the depo sit centreline) is po sitively correlated with slope. Internally the deposits comprise three parts, a coarse-grained fines-free sole layer that laterally c onnects to lev es (Zone I), an ashy matrix-supported central body (Zon e II) and an overlying coarse plaster of clasts (Zone III). Trends in grain-size data suggests these zones derive from a continuous un-mixing of c oarse particles from the in itial bulk material by gr anular segregation that preferentially drives large particles to the upper free surface of the flow where they are concentrated at the front of flow before being deposited and overr un. By co mparison to analo gue experiments, we suggest a model of flow and deposition where the temporally and spatially varying mode of deposition is determined by the flow velocity, the local sl ope, the vertical velocity gradient, the velocity gradient at the free surface and the vertical deposition rate. Using this model, estimated vertical deposition rates of c. 5 cm s-1 from the Ngauruhoe PDCs agree with those determined in laboratory experiments on inertial granular flows.

Keywords: pyroclastic flow, transport mechanisms, analogue experiments

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VS003 **Oral Presentation** **6656**

Comparison between the emplacement mechanism of the 1991-1995 block-and-ash flows and 1792 Mayuyama debris avalanche at Unzen Volcano, Japan

Dr. Shinji Takarada
Geological Survey of Japan Researcher IAVCEI

Christyanne Melendez

Block-and-ash flows (BAFs) are high-temperature (> 600 C) and high-speed gravity currents that are typically produced by a hot lava dome collapse event. Volcanic debris avalanches are large-scale, low-temperature, high-speed gravity currents that are typically result from the collapse of unstable portions of volcanoes. More than 9400 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 the 4ka Mayuyama lava dome. Both events occurred when dacite lava domes collapsed. The major differences between these gravity currents are temperature and debris volume (BAF: <0.001 km3, debris avalanche: 0.34 km3). BAF deposits comprise >10 flow units, with the thickness of each flow unit ranging from 0.20 m to 2.0 m. Each flow unit contains <2 m size, reversely graded, subangular to subrounded blocks. Lobes and levees are sometimes developed at the surface of the deposit. The layer 2a (<20 cm thick, <5 cm size clasts) 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. Video image shows large blocks rolling and saltating, indicating turbulent transport of BAFs. 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 km from the source, are homogeneous and vary in the degree of fragmentation. Less fragmented portions contain angular blocks with pervasive jigsaw cracks. Blocks in outcrops 1 km from the source display abundant jigsaw cracks. The northern margin of the amphitheater contains a debris- avalanche matrix outcrop. 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. Strong shear stress resulting from the friction between the sliding mass and underlying basement are concentrated along the margins and base, creating debris-avalanche matrix during the acceleration stage. Debris-avalanche matrix 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. After the cessation of movement, unstable sections of the mass collapsed forming hummocks. In BAF events, disaggregation of the collapsed lava dome mass occurred during the initial stage due to the fragile high-temperature lava. In contrast, the disaggregation of the collapse mass in debris avalanche events occurred during the final deposition stage due to large volume and low temperature of the debris.

Keywords: pyroclasticflow, debrisavalanche, unzen

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A comparison between water and initially gas-fluidised granular flows: implications for the dynamics of ash-rich pyroclastic flows

Dr. Olivier Roche
Laboratoire Magmas et Volcans Universit Blaise Pascal - IRD IAVCEI

Santiago Montserrat, Yarko Nino, Aldo Tamburrino

Experiments were carried out on water and granular flows generated in a 3- m long horizontal channel from the sudden release of a volume initially at re st in a reservoir (dam- break type). The gra nular material consists of small glass beads (~80 microns) and is initially fluidised in the reservoir by a vertical gas flux passi ng thro ugh a basal po rous plate. Water flo ws pro pagate o ut o f the channel whereas granular flows progressively defluidise during tr ansport until motion ceases. We studied the flo w kinematics as a function of the initial reser voir aspect ratio (a=height/le ngth), varying from 0.5 to 8. The flows prop agate in three distinct stage s, depending on a and on the characteristic time scale f or free fall tf=(h0 /g)1/2 of the i nitial column of height h0 in the reservoir. (1) Water and granular flows accelerate very rapidly and t hen propagate at constant velocity U until t/tf~1. 5, where the flo w height hf reaches a maximum value and hf/h0~0.2. The initial Froude number Fr 0=(U/gh0)1/2 is smaller than the theoretical value ~1.4 for an orifice fl ow, an d th e fl ow Fr oude n umber Fr=(U /ghf)1/2 steadily decreases to ~2 as hf increases. (2) Then the flow s accelerate abruptly, and at 1.5<t tf =""><4.5 they propagate at a second, higher constant velocity equal to that for an orifice flow for a<2-3 (Fr0~1.4), or is slightly smaller for a>2-3 (Fr0 decreases to ~1.2). At 1.5<t tf=""><2, during which the flow depth is nearly co nstant, Fr increases abruptly to ~3, whic h is ve ry close to the theoretical v alue for dam-breaking (Fr~2.8). Then the flow depth steadily decreases and in consequence Fr increases to ~3.6. (3) At t/tf>4.5, b oth types of flows enter a different regime. Water flows propagate at the orifice flow velocity whereas initially fluid ised granular flows stea dily decelerate until their motion ceases at t/tf~6 for a<2-3 or a t smaller t/tf down to ~4.5 at a>2- 3. These results show t hat initially flui dised granular flows and water flows have the same kinematics and flow resistance u ntil t/tf~4 .5, corresponding to about 3/4 of t he gran ular flo w duration. Granular flows behave as inviscid, Newtonian fluids, which suggests negli gible particle interactions (friction and colli sion) and neglig ible moment um exchange between the particles and the interstitial air corresponding to drag forces exerted by air passing through the grains as initial pore fluid pressure diffuses and/or particles settle. Departure from this behaviour a t t/tf>4.5 is inte rpreted as significant interparticle fr iction, as pore pressure has diffus ed out, and which slows down the flows until f inal deposition . It is in ferred that as h-rich pyroclastic flows behave as inviscid, Newtonian fluids for most of their emplacement.</t></t>

Keywords: pyroclastic flows, experiment, granular flows

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VS003 **Oral Presentation** **6658**

Rheology of crystal bearing magmas

Mr. Luca Caricchi
Earth Sciences ETH Zurich

Manuele Faccenda, Peter Ulmer, Luigi Burlini, Daniele Giordano, Claudia Romano

Magmas are suspension of gas and crystals in a silicic melt. Combining experiments and numerical simulations we focus on the physical effect of crystals on the rheological behavior of magmatic suspensions. While the experiments provide rheological data, the numerical simulations are aimed to understand the physical processes responsible for the complexity observed in the experiments.Crystal-bearing hydrous rhyolitic samples and natural rocks from the Monte Nuovo eruption (Phlegrean Fields, Italy) have been deformed in an internally heated Paterson pressure vessel, covering a wide range of crystallinity (50-80 vol. %) and strain rates. All experimentally deformed samples lack yield strength but they exhibit a tendency to non-Newtonian and Binghamian behavior at relatively high (>10-4 s-1) strain rates. The experiments have been performed under temperature and strain rate conditions at which the melt phase behaves Newtonian. Moreover, in the strain rate range applied, viscous heating is unable to account for the observed shear thinning effects (decrease of viscosity with increasing strain rate); consequently, the non-Newtonian effects must be due to the presence of crystals in the magma.The numerical simulations have been designed to reproduce numerically the experiments and consequently identical stress and strain rate conditions have been applied. Both, samples from experiments and numerical simulations, reveal the generation of melt-enriched bands oriented at around 30 with respect to the direction of flow. The melt enrichment induces localization of the strain in these regions and leads to a geometrical redistribution of melt and particles that could account for the rheological complexity observed.

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VS003 **Oral Presentation** **6659**

Submarine transformation processes of the 30/12/2002 Stromboli tsunamigenic landslide

Dr. Michael Marani
Istituto di Scienza Marine Geologia Marina di Bologna

Antonella Bertagnini, Alessio Di Roberto, Fabiano Gamberi, Mauro Rosi

On 28 decemb er 2003, lava emission on the Sciara del Fuoco slope of Stromboli Island preceded th e landslide that t ook place three days later, on 30 December 2002, involvi ng 25-30 x 106 m3 of volcanic material. The landslide gener ated the larges t tsunami waves do cumented in the pa st two centuries o n the island.Deposits of the landslide in both its distal and p roximal facies were investigated during two high resolution marine s urveys conducted of fshore the SdF in Se ptember 2004 a nd July 2005. Results indicate that the proximal, c oarse-grained landslide deposit extends over an NNW elongated area at water depths between 1600 and 2 000 m at a distance of 6 to 8 km from the shoreline. The depos it consists of several discrete, mainly chaotic assemblages of fresh cobble-sized scoriae and lav a flow clasts within a coarse sand matrix. Down-slope and laterally, the coarse-grained deposit grades to black volcaniclastic s and often arranged in ripple bed forms. The landslide material cont rasts with the surrounding seafloor in being completely devoid of a hemipelagic sedime nt cap. Initial interpretation of sediment textures indicate that the proxim al, coar ser de posits derive f rom low-coherence, granular debris flow processes. Distally, box coring performed about 24 km north from the shoreline of the Sciara del Fuoco, in a site located on the right side of the Stro mboli canyon, sampled a sedi ment sequence capped by a 2-3 cm-thick layer. In the s ame sa mpling site, the top most la yer was not present in September 20 02 when a previous gravity core was al so collected. Grain size and componentry of the layer indicate t hat it is a vo lcanoclastic sand turb idite with mineralogy and glass compo sitions matching the character of the material of the 2002 la ndslide. Sedimentological and compositional features of the layer are consi stent with an origin from a volcanicla stic t urbidity current cogenetic to the debris flow generated by the 2002 land slide. Our study stresse s th e potential of the marine e nvironment in recording landslide events b oth as the coa rser grai ned pr oducts of debris flows and a s the cogenetic turbidites that register the distal deposition of collapse-derived finer-grained products.

Keywords: stromboli, volcanic landslide, submarine debris flow

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VS003 **Oral Presentation** **6660**

Transport and deposition processes of volcaniclastic deposits inferred by multivariate statistic analyses and GIS applications. The case of Nevado de Toluca volcano (Mexico).

Mr. Fernando Bellotti
Dipartimento Scienze della Terra Universit degli Studi di Milano

Lucia Capra, Gianluca Groppelli, Fabio Galgano

Particle size analysis is widely used in sedimentology to determine the characteristics of different depositional environments and infer flow transport and depositional processes. However for volcaniclastic flows, this methodology has been applied mainly for a deive purpose or for typical generic consideration of down flow variation of statistical parameters. For this study we choose the case of Nevado de Toluca volcano (Mexico) due to the previous knowledge of its geological evolution, stratigraphic succession and spatial distribution of volcaniclastic units. Grain size analyses (by coupling photo-sieving, particle size and photosedimentographic analyses) and frequency distributions curves have been carried out to characterize block-and-ash flow and debris avalanche deposits. The multivariate statistic analysis (discrimination function) shows that sedimentological parameters are good discriminators between samples belonging to block and ash flow and debris avalanche deposit. In addition, the application of the same methodology within each single deposit (DAD and BAF) allows to identify the presence of sub populations and reveals differences among proximal, medial and distal facies. The resulting subpopulations have been plotted in a GIS environment to evidence these sedimentological variation respect to the deposit thickness and flow interaction with topography. By overlapping the flow thickness map with the subpopulation statistic analyses it is possible to define the relationships between facies and its position into the flow and to provide a model of transport and deposition mechanism of debris avalanche deposit and block and ash flow at Nevado de Toluca volcano.

Keywords: multivariate statistic, volcanoclastic deposits, flow and transport model

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VS003 **Oral Presentation** **6661**

Deep water gravity core from the Marsili Basin (Tyrrhenian Sea) records pleistocenic-holocenic explosive events and instability of Aeolian Archipelago (Italy).

Dr. Alessio Di Roberto
Dipartimento di Scienza della Terra Universit di Pisa

Mauro Rosi, Antonella Bertagnini, Alessia Del Principe, Michael Marani, Fabiano Gamberi

A 4.8 m long gravity core was recovered during cruise TIR2000 at about 3200 m of water depth, on a relative topographic high, in the northern part of the Marsili Basin (Tyrrhenian Sea). The core consists of a quasi-conformable succession of distal, fine-grained turbidity current layers alternating with hemipelagic mud beds and a few primary tephra layers. The most prominent bed of the core is a coarse-grained, granule - to pebble-size volcaniclastic turbidite with thickness of about 20 cm, that occurs at 3.86 m (after CGVT). The basal part of the bed is coarse-grained, (up to cm-size grains), normally graded and exhibits an unconformable erosional base. Thirty samples, taken from primary tephra beds and from the turbidite units were studied for grain- size, componentry and SEM analysis. Primary tephra respectively belonging to the eruptions of Lower Pollara (Salina, 243.6 ka), Gabellotto-Fimumebianco (Lipari, 8.5 - 11.5 ka) and Secche di Lazzaro (Stromboli, ~5 ka BP) were identified in the core at the expected relative stratigraphic high. Two more beds composed of monogenic glass shards were also identified and interpreted as quasi-contemporaneous remobilization of primary tephras of Vesuvius (3.5 ka -79 AD) and M. Pilato (Lipari, 749 or 580 AD) via turbidity currents.The CGVT strongly differs from the other volcanogenic deposits of the core. Its grain size parameters point to the large carrying capacity of the originating gravity flow, in conformity with the thickness of the deposit and the strongly erosive base. These characteristics imply that a large scale, impulsive event was the source of the turbidity current that generated the deposit. The turbidite is mainly constituted by pyroclastic and metamorphic fragments and by lavas with andesitic composition; in addition pumice clasts with composition ranging from basaltic andesites to rhyolites, strictly similar to those emitted by Lower Pollara eruption designate Salina Island and in particular Lower Pollara cone area as the source. We suggests that a major episode of flank failure would represent the necessary process for the triggering of the turbidity current at the origin of the CGVT .From our reconstruction, the failure and resulting landslide however, did not take place during or immediately after the eruptive event but after an interval in the order of some hundreds of years after the failure as testified by the interposition of 16 cm-thick hemipelagic mud between the tephra of Lower Pollara and the turbidite deposit.

Keywords: turbidite, collapse, salina

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VS003 **Oral Presentation** **6662**

A Lagrangian model for ballistics

Dr. Mattia De Michieli Vitturi
Sezione di Pisa INGV IAVCEI

Tomaso Esposti Ongaro, Augusto Neri

A Lagrangian 2D/3D model for the analysis of clasts of different sizes ejected from volcanoes is presented. The novelty feature of the model consists in the one-way coupling between the carrier flow field, given by an Eulerian code, and the particles trajectories. The model is based on a simplification of the Basset-Boussinesq-Oseen (BBO) equation, expressing the Lagrangian equation of a particle as the sum of the forces exerted on the particle along its trajectory. At present, no shape effects for the drag coefficient are considered and a constant value has been assumed. Furthermore, no effects of the high frequency turbulent fluctuations have been considered.The model has been applied to the well-documented sequence of Vulcanian explosions that occurred in 1997 at Soufriere Hills Volcano, Monserrat. The results are compared with ballistic crater fields mapped by helicopter following the August explosions. Compared to the previous models, in which it was assumed that clasts were ejected into a stationary atmosphere, values of the order of one or larger were obtained for the drag coefficient, that allowed to reproduce the greater distances of the largest blocks with respect to the smallest ones. Furthermore, our approach allowed us to describe the acceleration phase of the ballistics and to study their trajectory as a function of the initial position along the conduit.

Keywords: ballistic ejecta, lagrangian model, vulcanian eruptions

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VS003 **Oral Presentation** **6663**

Surface wave instabilities and pyroclastic flow emplacement

Dr. Eliza Calder
Dept. Geology UNiversity at Buffalo IAVCEI

Nigel Cassidy

We draw evidence from the 1993 pyrocla stic flow de posits at lascar volcano, Chile, for composite pyroclastic deposit fans having been emplaced by gr anular flows that ex hibited inertial instabilities on their flow sur faces. The instabilities play ed an integral role in flow emplacement, generating unsteadiness and the development of successive waves, which in the fina l stages o f runout, emplaced discrete onlapping units now identifiable within the deposit lobes. Visualization of these features is aided by the unique perspective provided by ground-penet rating radar (GPR), a tool that w e believe has remarkable potential in unraveling transport pro cesses of geophysical mass flows . Surface wave instabilities are already known from other t ypes of natural and experimental gran ular flows, and on a theoretical basi s are anticipat ed with in the context of vo lcanic granul ar a valanches. The ir existence is relevant to a series of on-going debates including the significance of flow units, interpretation of source- versus flow-derived current unsteadiness, and the nature of density profiles through pyroclastic density currents. This work will use the co nvincing evidence from Lascar to 1) present a case for considering the role surface wave instabilities may have played during deposition a t other sites , and 2) strongly advocate using geophysical tools, such as GPR, for advancing our understanding of deposit-wide as well as detailed field relationships.

Keywords: pyroclastic, flow, instabilities

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VS003 **Oral Presentation** **6664**

Effects of channel morphology on the behavior of simulated pyrocalstic flows using the TITAN THIN-layer code

Mr. Adam Stinton
Geology University at Buffalo IAVCEI

Michael Sheridan

Pyroclastic flows are gravity-driven highly mobile geophysical mass flows. Their behavior can be strongly influenced by the geometry of the topography over which they move. There are several cases of observed pyroclastic flows in which topography strongly effected the behavior of the flows. However, the link between channel morphology and flow behavior is not quantitatively understood. The purpose of this study is to investigate the effects of channel morphology on pyroclastic flow behavior through a series of computer simulations using the Titan2D thin-layer mass-flow model. A total of 100 simulations were run using five different synthetic DEMs, four volumes and five values for bed friction. The different DEMs represented: 1) a slope with out a channel, 2) a straight channel, 3) a constricted channel, 4) a channel with 45 bends, and 5) a channel with 90 bends. Data on flow velocity, flow thickness, travel time, runout distance and inundation area were studied, to discern effects of the different channel morphologies.Results of the simulations show that there are clear links between the channel morphology and flow behavior. Flows slowed and thickened when traveling across a change-in-slope (from steeper to gentler slopes), when entering a channel and when passing through a constriction. Flows in some simulations exhibited a sudden deceleration at the change-in-slope between 35 and 25 degrees. The loss of momentum associated with this abrupt change (~-8 m/s/s) could account for the accumulation of large boulders at the base of actual deposits near similar breaks in slope. Where flows passed through a constriction in the channel their thickness increased by a factor proportional to that of the reduction in channel width. Flows confined to the channel have longer runouts, maintain higher velocities for longer periods of time, and have shorter travel times. For flows confined to the constricted channel, runout is longer than for comparable flows confined to the non constricted channel. Flows in the channel with uniform width had longer runouts than the corresponding flows run over the slope without a channel. This suggests channelization of the flows preserved momentum by inhibiting spreading. Channel constrictions may also lead to the development of pulses as flows are impeded in an incremental fashion from front to rear. When running up the outside of channel bends, the flows slowed and thickened. Flows also over banked at the bends, resulting in lateral unconfined flow that slowed and thinned rapidly.

Keywords: titan2d, computer, simulations

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VS003 **Oral Presentation** **6665**

Rockfalls from lava domes

Dr. Eliza Calder
Dept. Geology UNiversity at Buffalo IAVCEI

Rockfalls, are anything but, the benign aspect of lava dome eruptions they are often given credit for being. Monitoring rockfall characteristics can potentially allow the detection of incipient lava dome collapse. Rockfalls are important as they represent an integral part of the collapse history of the dome. Probability density functions for natural hazards, need to consider the complete inventory not overlooking small-tail end- member events. This work illustrates the importance of considering the magnitude and timing of major collapses not in isolation of rockfalls. Rockfall frequency- magnitude relationships are best approximated by gamma distributions, a similar pattern, to that observed for other natural hazards. In this regard, there is scope for conceptualizing and very probably modelling, the mass wasting processes from growing lava domes as sandpile analogs. Theoretical sandpile models predict power-law frequency magnitude and frequency-repose relationships, although experimental and natural avalanches commonly show more complex behaviour. A critical factor is how, a process such as sandpile collapses, ordinarily governed by the statistics of self organized criticality (in terms of time , space and magnitude), behave when additionally forced by the non-stationarity of lava dome growth as well as other external and/or second order controls . Information on rockfall seismic signal duration, energy, max amplitude, and repose interval, has already been collated. Occurrence frequency is extrusion-rate dependant. Extrusion rate, becoming increasingly significant in determining rockfall frequencies when rates are relatively high, whereas other factors become increasingly significant when rates are low. In addition, it is seen that rockfall energy (J/Kg) increases exponentially in the 48-hour period before some major collapses (e.g . 20th May 2006 collapse). This may be a manifestation of a dome pressurization cycles, normally associated with hybrid earthquakes and crater rim inflation/deflation cycles. An interpretation that is also strongly supported by cycles in long period rockfall counts during the days prior to the 20 May 2006 collapse. Thus, increases in rockfalls, especially with a 4-12 hour periodicity might be the most sensitive and reliable means to identify these cycles. Alternatively, the processes leading to collapse may have already initiated and these rockfalls might be the result of carapace adjustment to deep-seated viscous creep before incipient brittle failure. Despite efforts towards understanding the physical mechanisms behind dome collapse at Soufriere Hills Volcano, Montserrat, and elsewhere, the propensity for lava domes to collapse with little or no apparent warning remains a serious issue that still jeopardizes lives. The challenge now, is to develop methodologies to observe and better understand the causative mechanisms and specifically temporal controls and precursors to lava dome collapses, and tackle the issue of forecasting. Monitoring rockfalls can play an instrumental role in this.

Keywords: rockfalls, dome, lava

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VS003 **Poster presentation** **6666**

Pyroclastic deposits of January 11, 2005 eruption of Bezymianny Volcano, Kamchatka, Russia

Dr. Olga Girina
VS003 Volcanic Flows: Observation, Experiment, and Membership number: 578 IAVCEI

On 11 January 2005, Bezymianny volcano erupted explosively sending an ash plume to 7-10 km (26,400 33,000 ft.) ASL, where it drifted to the west-southwe st. As result of this eruption ther e were formed pyroclastic deposits: ash fall, pyroclastic flows and surges. According to satellite images, the square of ash deposits was about 5,000 km2. Run out of the block-and-ash pyroclastic flow was a bout 7-8 km. Flow deposits accumulated in a valleys on the south-eastern flank of the volcano. Lava fragments of the flow constituted dense and porous bl ocks in size till 3-4 m. Porous blocks were half-round and had marks of deformations. Probably these blocks were very hot and plastic w hen they rolled down by the flow. Con tent of prevailin g fr action of pyro clastic flow de posits matrix (0.25-0.5 mm) was ~ 30 %. Pyroclastic surge deposits occurred in association with the block-and-ash flow deposits in the valley, and are also found separately on the south-western flank of the volcano. The run-out of surges deposits was about 10 km. The thickness of pyroclastic surge deposits at the south-western flank of the volcano was about 30-40 cm. Con tent of prevailing fraction of pyroclastic surges deposits matrix (0 .25-0.5 mm) was ~ 50 % at a top part of volcanic slopes an d ~ 20 % - in 5-7 km from the volcano. There was noted a gradual change of lava fragments content (a volume and a composition) into surge deposits from a top part of the volcanic edifice till th is front. Pyroclastic surges were transformed gradually to pyroclastic flow on the south-western flank of the volca no. The volume of eruptive p roducts of January 11, 2005, Bezymianny eruption was about 0.07 km3, and VEI ~2.

Keywords: explosiveeruption, pyroclasticflow, pyroclasticsurges

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VS003 **Poster presentation** **6667**

The Nyiragongo Volcano eruptions in the Virunga Region, Western Rift Valley, D.R. Congo

Mr. Wafula Mifundu Dieudonne
Department of Geophysics CRSN GOMA IAPSO

Celestin Mahinda Kasereka, Andr Ndontoni Zana, Hiroyuki Hamaguchi

Nyiragongo is a stratovolcano belong ing to the V irunga volcanic region located at the northern end of lake Kivu (1460m) in the Western Rift Valley of the East African Rift System. Nyiragongo is composed of a central co ne and two seco ndary co nes o n the so uth Shaheru and t he no rth-east flank B aruta. The Nyiragongo central crater is encircled with three plat forms called terraces. The first terrac e is located at 180m bellow the crater rim, the second 180m bellow the first and the third 60m bellow the second. The eruption activities of this v olcano is characterised by two types of eruptions: one is intra-crater eruption leading up to the formation of lava lake in the central crater and another flank fissure eruption. The lava lake was see n in the crater of Nyiragongo sinc e 1928 and its level was progressively increasing. On January 10, 1977, Nyiragongo erupted on its flanks when the lava lake level reached the first terrace. All lava in the crater about 22 x 106 m3 w as drai ned thr ough 4 fissures opened on t he fla nks of the volcano. After 5 years of q uiescence the la va lake in the summit crater suddenly re appeared on Jun e 21, 1982. During this eruption 70x106 m3 of lava was accumulated inside the crater a fter 3 months of lava outpouring. The new lav a lake was solidified at the level of th e third terrace. In June 23, 1994 th e lava lake re appeared again in its summit c rater after twelve years of q uiescence. During this eruptio n the lava lake was episodically seen in the summit crater. The most exciting episode wa s that observe d from March 15 to 16, 1995 characterise d by big fountain of lava and flow on the solidified lava. A small volcanic cone of 60m was built up during this episode in side the crater. The lava lake activities continued up to August, 1995. The upper p art of the lava lake was solidif ied between the first and th e second terrace. The content of fluid lava i n the crater cou ld be estimated to more tha n 100x106 m 3. The last flank f issure eruption of Nyiragongo occu rred on January 17, 2002, seven years after the lava lake activities ceased. Severa l fissures were associat ed to this eruption. All the content of the covere d lava lake flowe d out through the fissures. Some im portant precursors we re always poin ted out before the occurrence of all these er uptions mainly the for flank fissure events. After the eruption on January 2002, a very short period of quiescence was observed, no lava lake activity could be seen in the summit crater of the volcano. In Nov ember 2002, fresh lava appeared in the bottom of the crater and the lava lake activities continues up to now and the volume of lava still increasing. Now three terraces are visible in the crater; the first terrace still remains, the second 100m bellow the first and the third about 300m bellow the second.

Keywords: volcanic flows, observations, experiment and theory

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VS003 **Poster presentation** **6668**

Modelling of laboratory ash flows

Prof. Tim Druitt
Lab. Magmas et Volcans Universit Blaise Pascal & CNRS IAVCEI

Zina Khrabrykh, Laurence Girolami, Olivier Roche

In an accompa nying paper, G irolami et al. p resent the res ults of experim ents on the propagation and sedimentation behavio r o f la boratory-scale flows o f ho t pumiceo us ash in a horizontal lo ck-exchange flume. The ash was expanded by fluidization to 6 to 42 % above loose packing, then released down the flume as thin (<10 cm), but fast-moving (1.5-2.3 m/ s) shear flows. Since the floor of the flume was impermeable, the ash defluidi zed progressively until motion ceased. Flow was lami nar in all cases, with slip conditions at the flume walls. Despite th e polydisperse nature o f the a sh, no size segregatio n took place during fl ow. Deposition occurred by p rogressive sediment aggradat ion at the flow base. Particle hindered settling velocities in the flows were indistinguishable within err or from those measured in 1-D bed-collapse tests at given v alues of expansi on. We modeled the ash flows using 2-D depth-averaged equations of motion that included terms for deposition by hindered settling a nd a resistance stress due to material rheology. Wall and air drag were both inferred to be negligible. As a first approximation the rheology of the expanded ash-gas mixture was assumed to be Newtonian. This was justified by previous rheological s tudies of fluidized powder s, an d by the low Bagnold Numbers of ash flows. Dimensionalizing the equations revealed three charac teristic times: tgra v, the time for gravitational acceleration; tsett, the time f or hindered settling, an d tvisc, the time for deceleration b y macroviscous stresses. Thre e non-dimensional paramete rs governed the system: a, t he aspect rati o of the initially fluidized bed i n the reservoir, the ratio tsett/tgrav, and the r atio tgrav/tvisc. The equations were solved using a numer ical code capable of reproducing anal ytical dam-break solutions to a hi gh degree of accuracy. Hindered settling velocities were determined independently as a function of expansion from 1-D bed-collaps e tests in th e reservoir wi th the lock g ate shut. The only free variable was the macroviscosity of the fluidized ash. Distance-time curves for flows over the entire expansion range were fitted by a single value of kinematic viscosity (1.4 x 10-4 m2/s). This is equivalent to dynamic viscosities of 0. 09 0. 13 Pa s (values de creasing with increasing expa nsion), which lie in the range o f previo usly published v alues for fluidized powd ers. The study yielded simple scal ing laws for the runout distances and durations of 2-D flows of fluidized ash.

Keywords: pyroclastic flow, numerical modelling, hindered settling

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VS003 **Poster presentation** **6669**

High-Speed Video Analysis of Laboratory Ash Flows

Mrs. Girolami Laurence
Volcanology Laboratoire Magmas et Volcans IAVCEI

Thomas Corpetti, Olivier Roche, Tim Druitt

In an accompanying paper, Girolami et al. present the results of experiments on the propagation and sedimentation behavior of laboratory-scale flows of hot pumiceous ash in a horizontal lock-exchange flume. The ash was expanded by fluidization to 6 to 42 vol% above loose packing, then released down the flume as thin (<10 cm), but fast-moving (1.5-2.3 m/s) shear flows. Since the floor of the flume was impermeable, the ash defluidized progressively until motion ceased. A key feature of the flows was that deposition occurred by progressive sediment aggradation at the flow base. Particle hindered settling velocities in the flows were indistinguishable within error from those measured in 1-D bed-collapse tests at given values of expansion. In order to investigate the flow dynamics in more detail, we filmed a number of experiments using a high-speed (1000 frames per second) video camera. By repeating each experiment several times, we were able to observe the sedimentation behaviour both as function of time and with distance down the flume in the short-lived and highly unsteady flows. This was possible because the experiments were reproducible. Examples of the video footage will be presented here. Using specially designed image analysis software, we have been able to use the video footage to measure sedimentation aggradation rates and compare them with values determined in 1-D bed-collapse tests. Analysis of particle velocity fields in the moving flows also allows temporal and spatial evolution of velocity gradients.

Keywords: dynamics, pyroclastic, experimental

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VS003 **Poster presentation** **6670**

Petrogenetic Significance of the Igneous Intrusives from the Gondwana Coal fields of Damodar Basin, Eastern India.

Dr. Kaustav Nag
ONGC ONGC IAVCEI

Large scale intrusions of early Cretaceous lamproites and lamprophyre rocks are observed, particularly in the coal bearing measures of Gondwana sedimentary sequence of Damodar Basin in eastern India. The sedimentary sequence consists of alternating rock types of sandstone, shale along with coal bearing seams. The intrusives intrude mostly the Barakar Formation as sub-vertical dykes or sills trending E-W or ENE-WSW and at places display conspicuous thermal metamorphism by completely de-volatilising the coal seams. The petrography, mineral chemistry, major and trace element data, carried out on samples from Bokaro, Jharia and Raniganj coal fields demonstrate that the co-magmatic suite of lamproites, ultramafic lamprophyres and minettes have crystallized from magmas derived by partial melting of mica bearing harzburgite source rock of mantle origin as suggested by earlier workers. The essential characteristics of the lamproitic- lamprophyre clan of rocks which is indicated from the present study include i) silica undersaturation ii) ultra potassic i.e high K_2O content (Max- 7.5 %) iii) presence of phlogopite mica of possible mantle origin iv) high Mg # (MgO/ FeO + Fe_2O_3) v) presence of carbonates and hydrous minerals vi) absence of plagioclase feldspar vii) high TiO_2 content and high abundance of Ba,(12149ppm) Sr, Th and REE with pronounced fractionation trend. Experimental petrological studies were also conducted at upper mantle pressure conditions in presence of water to elucidate the genesis of these rocks. The studies establish that the genesis of these K rich rocks are essentially related to lamproitic assemblages by heteromorphic reactions in presence of water and volatiles under mantle conditions.

Keywords: lamprophyres, lamproites, harzburgite

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VS003 **Poster presentation** **6671**

Tracks of the middle triassic Pietra Verde calderas southern Alps/N Dinarides

Dr. Johannes Obenholzner
NHMVolcanology NHM IAVCEI

Diagenetically compacted subaqueous pyroclastic flows (spf) and ash turbidites up to 130 m thick are deposited in non-volcanic, basinal environments N of Tolmezzo, Italy. Two of the W sections comprise deposits of 2 major explosive events, an Anisian (A) and a Ladinan (L) event, which bracket the A/L boundary (determined within ranges of 400 k. a. (6) and 2 m.a.). The Carnic Alps (Austria) host ignimbrites several m thick. The Kammleiten ignimbrite (A) is characterized by bauxitic alteration on top indicating tropical climate during the Triassic (1, 2, 3). It is intercalated between conglomerates which are indicating a paleo-relief and erosion. Further to the E oxidized and densely welded ignimbrites are known (Julian Alps, Italy; Karavanke Mts., Slovenia). Lithics included in the deposits of the Pietra verde caldera are basalts and intermediate igneous rocks (slightly alkaline to calcalkaline) indicating volcanic activity before the caldera formation. Shallow marine carbonate clasts at the base of the flows, the missing of a central volcanic edifice in the stratigraphical record lead to the conclusion that the caldera event happened in a shallow marine environment fragmenting some earlier erupted, oxidized products of subaerial settings. Uncharacterized volcanics are known from drill sites in the river Po plain, Italy . The caldera eruptions happened at least partially subaerial as accretionary lapillis are known from ash beds. The thicknesses (20-30 m) of ash turbidites on top of the spfs might indicate heavy rain falls during the eruption. Co-ignimbrite ash falls seem to have remained partially in situ. The separated fine ash had been responsible for producing relative crystal-rich spfs. A retro- diagenetical decompaction of flattened pumices (chlorite-smectite patches) would increase the measurable thicknesses of individual units up to 3 to 4 times as a conservative estimate.A paleogeographical and structural reconstruction of this ca. 200 km long segment of the Southern Alps/N Dinarides is still missing. The various lithified, pyroclastic rocks indicate a rather huge caldera, which had been compared with the Campanian Ignimbrite (CI) caldera in the past (4) according to pyroclast morphology. The various sections are not dated yet as fossils are scare. New outcrops in the E (Luce, Slovenia) at unknown tectonic displacement relative to the Tolmezzo area suggest an even larger diameter than the CI caldera (ca. 20 km). It is remarkable that the non-compacted spfs of the Minoan eruption, Thera (5), are only ca. 80 m thick in proximal facies. The non-compacted CI deposited at the caldera rim is ca. 30 m thick, offshore Vesuvius ca. 100 m (7) without remarkable ash turbidites. The preserved 2 Triassic ignimbrites might represent one pulse within less than 2 m.a.. The A-L spans ca. 17 m.a. covering ca. 40 explosive events preserved as pyroclastic/volcaniclastic layers of minor thicknesses in the W Southern Alps (6).

Keywords: triassic, flow, subaqueous

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VS003 **Poster presentation** **6672**

Kinematic Features of Isolated Volcanic Clouds Revealed by Video-records

Dr. Akihiko Terada
Faculty of Science, Kyoto Univesity Aso Volcanological Laboratory IAVCEI

Yoshiaki Ida

Analyses of observed volcanic clouds using 1D models have given some useful information on the dynamics of eruptions and some properties of the erupted mass. It should be noted that the entrainment hypothesis assuming that the volume of the entraining air is proportional to the ascent velocity has played a central role in these analyses. In addition to the entrainment hypothesis, another relation that was obtained from a simple dimensional analysis by Scorer (1957) may be usefully applied to volcanic clouds. If this Scorer's relation is combined with the entrainment hypothesis and the mass conservation law, we can calculate the location, size and density of a volcanic cloud as a function of time in a simple way as far as the conversion of thermal to mechanical energy in it can be neglected. To apply the above simple models to real volcanic clouds, we must check the kinematic feature of the cloud, i.e., the relationships among the ascent velocities, radius and height of the clouds. In this study, we examined the applicability of the entrainment hypothesis and the Scorers relation to volcanic clouds in nature with their characteristic constants. We analyze sequential photographs of volcanic clouds obtained at Asama and Miyakejima volcanoes. In this analysis, each segment of the volcanic cloud is treated as an isolated thermal, i.e. a spherical body ascending independently by its buoyancy. Our kinematic analysis reveals simple relationships among the ascent velocity, radius and height of volcanic clouds. The empirical dimensionless constants characterizing the entrainment hypothesis k and the Scorers relation C are more or less scattered and their mean values are about 0.36 and 0. 6, respectively. The wide dispersions of the values of k obtained here are probably caused by more irregular conditions of the fluid ejection compared with those in laboratory. These empirical relations can be used to evaluate kinematic features of volcanic clouds approximately without thermodynamic consideration. Our results suggest, however, that C may change with the height, probably reflecting the effect the ambient density stratification in part. Furthermore, the values of C for the volcanic clouds tend to be less than those obtained by the laboratory experiments. So we have to examine the applicability of Scorers relation more carefully.

Keywords: thermal, entrainment

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VS003 **Poster presentation** **6673**

Fluidization of granular mixtures in a rotatory drum with implication on pyroclastic flows

Dr. Paola Petrosino
Scienze della Terra Universit di Napoli Federico II IAVCEI

Bareschino Piero, Lirer Lucio, Marzocchella Antonio, Salatino Piero

During the last decade we have witnessed significant progress toward mechanistic understanding of the establishment and flow of pyroclastic gravity currents. In particular, the recognition of the role played by fluidization in the emplacement of dense pyroclastic flows, hypothesized since the late sixties, has recently received additional support. Notwithstanding, quantitative assessment of fluidization in pyroclastic flows is still poor. The current lack of fundamental understanding, despite the extensive published literature on rapid granular flows, is largely due to the fact that investigations in this field mostly addressed steady flows of granular materials down inclines at velocities far smaller than those typical of pyroclastic density currents. Due to this limitation, most studies miss the complex dynamics of the frontal zone, which is likely to play an important role in the onset of fluidization. Moreover, the relative extent of frictional, collisional, streaming, elastic-inertial and turbulent stresses, which dictates the rheology of the flow, does not even approach conditions relevant to pyroclastic flows.The behaviour of granular currents moving over the ground has here been simulated in experiments carried out with a big rotary drum, 1800 mm inner diameter and 200 mm width. The cylinder is rotated around its horizontal axis by a controlled step motor at a constant angular velocity. The granular material used in the experiments was a narrow cut of FCC , 40m diameter, 1580kg/m3 particle density, belonging to the A-group of the Geldart classification of powders. Experiments were focused on the structure and the dynamics of the frontal zone of the current, and on its interaction with the surrounding medium (air). Factors that promote air entrainment in the moving bed and the establishment of fluidization were assessed.Experiments have been carried out in a range of angular velocities between 5 and 30rpm, corresponding to peripheral velocities in the range 0.47-2.9 m/s . A pronounced change of the phenomenology was observed across this range, with an almost abrupt change of the flow pattern from solid/plastic to free-flowing nearly inviscid at linear velocities between 1.5 and 2 (corresponding to canonical Froude number of about 2.5).The change of the flow regime is apparently related to the onset of avalanching, at rotational speed corresponding to Froude number of about 2.5, as a consequence of the inherent instability of the rapid granular flow. Avalanches eventually develop into plunging breakers whose collapse promote extensive air entrainment and fluidization of the current. The scenario is completed by the extremely slow deaeration of the powder which ensures that the fluidized state, once established, is preserved over time intervals comparable with the flow time scale. The combination of avalanching and slow deaeration rate is the key of the self-fluidization process and of the nearly inviscid rheological behaviour of the current at large propagation velocity.

Keywords: self fluidazion, rotary drum, pyroclastic flow

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VS003 **Poster presentation** **6674**

Compositional variations and groundmass crystallization of Miocene Lovejoy Basalts, Northern California.

Dr. Rachel Teasdale
Geological Sciences CSU Chico IAVCEI

Lovejoy Basalt lava flows of northern California erupted from vents located at Thompson Peak in Lassen County. Flows traveled nearly 250 km west, across the Sacramento Valley to Putnam Peak, near Vacaville, California. Isotopic ages of Lovejoy Basalt lavas are difficult because of low phenocryst content, but a whole rock age is reported as 15.68 My (Garrison, 2004). Paleomagnetic signatures indicate that the flows were erupted within a relatively short timeframe, a few hundred to a few thousand years (Coe, 2003). Lavas are tholeiitic and remarkably compositionally homogeneous, ranging from 50-52% SiO_2 but are also noteworthy in their high Ba content (up to 2400 ppm). In spite of high Ba and low Nb, Lovejoy Basalts have good isotopic and geochemical correlations with Columbia River Basalts which are contemporaneous. A sequence of eight lava flows were emplaced at Red Clover Creek (approximately 30 km from source) and have been sampled for crystallinity analyses. Flows are approximately 10-20 m thick and several have columnar jointing. Groundmass is dominated by plagioclase with lesser amounts of clinopyroxene, olivine, Ti oxides, and in some samples, acicular apatite. Groundmass plagioclase anorthite compositions range from 34-48%, some of which include post-emplacement cooling, which can be distinguished by crystal textures. Compositional variations between flows at this locality are minor, but highest groundmass plagioclase proportions are correlated with highest Al_2O_3 composition.

Keywords: basalt, lava

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VS003 **Poster presentation** **6675**

Vesicle growth during vulcanian explosions of Soufrire Hills Volcano, Montserrat, 1997.

Mr. Giachetti Thomas
Laboratoire Magmas et Volcans Universit Blaise Pascal IAVCEI

Timothy H. Druitt, Laurent Arbaret

In 1997 the Soufrire Hills Volcano on Montserrat had two periods of repetitive vulcanian activity, explosions occurring on average every 10 hours. The explosions generated pumiceous pyroclastic flows by fountain collapse; synchronous fallout also took place from associated buoyant plumes that ascended to heights of 315 km. Explosions are inferred to have been initiated when magma overpressure behind a highly viscous, degassed plug exceeded a critical threshold. An average explosion emptied the conduit to a depth of 1-2 km. High-resolution vesicle size distributions (VSDs) in pumices and breadcrust bombs from the explosions reveal histories of bubble nucleation and growth. The vesicular interiors of breadcrust bombs are dominated by a population of small vesicles that must post-date fragmentation, since the glassy rinds of the bombs are vesicle-free. These vesicles have diameters of 10-80m, with a mean of 30m, and ~60 % of them are non-connected. Two pumices, one from the fallout and the other from associated pyroclastic flows, each contain three almost identical vesicle populations: (1) a small, 10-80 m population very similar to that in the breadcrust bomb, (2) an intermediate, 100-300m population, and (3) a large, 500-3000m population. The large and intermediate populations, in which almost all vesicles are connected, probably formed by nucleation, growth and coalescence at depth in the conduit during slow magma ascent between explosions. By analogy with the breadcrust bombs, the small population is interpreted to be syn-eruptive. However, unlike in the breadcrust bombs, this population nucleated prior to magma fragmentation, since no vesicularity gradients are present in fallout pumices preserving tabular forms acquired at fragmentation. The origin of the small vesicle population is tentatively explained by the interplay between decompression and fragmentation waves in the conduit. Nucleation was triggered immediately after eruptive onset by the rapid propagation down the conduit of a decompression wave. Decompression at shallow levels in the conduit was immediately followed by fragmentation, so that vesicles in the breadcrust bombs grew entirely after fragmentation. At deeper levels, the time interval between arrivals of the decompression and fragmentation waves was long enough that syn-eruptive vesicle growth was well advanced prior to fragmentation. Hence the smallest vesicles in pumices are syn-eruptive, but pre-fragmentation. Syn-eruptive vesicle growth probably took place largely in the conduit prior to quenching in contact with air, since fallout and flow pumices experienced different thermal histories after leaving the vent, but have the same VSDs.

Keywords: vesicle size distribution, vulcanian eruptions, soufrire hills

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VS003 **Poster presentation** **6676**

P-T Dependance of viscosity of hydrous rhyolitic melt

Mrs. Paola Ardia
Departement of Earth Sciences Institute for Mineralogy and Petrology, ETH Zurich

Daniele Giordano, Max W. Schmidt

The rheological properties of silicate melts control transport dynamics, eruption style and rates of physicochemical processes in magmas. Magma viscosity varies up to 15 orders of magnitude due to composition, temperature, pressure, and volatile content (mainly H2O). The effect of water is dramatic, 1 wt% added to a rhyolitic melt at eruptive temperatures decreases viscosity by 6 orders of magnitude. Rhyolitic melts may contain up to 10 wt% of water at magma chamber pressures (up to 5 kbar). We employ the falling sphere technique (in static and centrifuging piston-cylinders) to investigate the Newtonian viscosity of a dry and hydrous (2.7, 3.7, 5.25 and 8.2 wt% H2O) haplogranitic melt (GG1) as a function of water content, temperature and pressure. The viscosity of a homogenous haplogranite was determined between 580 and 1350C (at 5 kbar), at accelerations of 1 to 1000 g, in order to decrease the settling time of the sphere. The resulting viscosities vary between 102.4 and 107 Pa s, and all the compositions exhibit Arrhenian behaviour. To constrain the effect of pressure on viscosity we performed experiments from 5 to 25 kbar. In all the experiments the viscosity increases in a similar fashion. The activation energy (EA) increases with pressure and with the decrease of the dissolved water. Extrapolation of anhydrous viscosity data measured by the concentric cylinder technique at high T (1500-1650C) indicates a higher EA, more than twice the one determined in H2O bearing melts. The results yield the expected strong decrease of viscosity with temperature and water content, but show variable pressure dependence. The EA increases with pressure and decreases with increasing water content in the melt. The values broadly agree with the viscosity prediction of (Giordano et al., GCA, 2004) but at low temperatures, measured viscosities are lower. The results are used to build a more general composition, T and P dependent viscosity model for silica-rich melt.

Keywords: viscosity, experiment, model

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VS003 **Poster presentation** **6677**

The evolution and geochemical aspects of megaporphyritic basic-intermediate lava in Azerbaijan, Iran

Dr. Reza Monsef
Geology Tarbiat Modares University

Mohammad Hashem Emami

The studied ar ea is in the northwest of khalkhal (, NW of Iran) and related to Alb orz st ructural zone. The oldest stra tigraphic units belong to pre-Cretac eous deposits and the youngest units are quaternar y alluvials deposits. The Eocene volc anic roc ks are composed of olivin e basalt, trachy basalt, trachy andesite and megaporphyritc basic- interm ediate lavas. The latter have few centimeter s phenocrysts of plagioclase and are extended in a large area from NW to SE of Iran volcanic belt (Urumieh-Dokhtar magmatic belt). They are good in dication for Upper Eocene volcanic activity in Iran . Geochemical and isotopic data f or megaphyritic lavas show that the basaltic r ocks have transi tional t rend with sodi c character and the intermediate terms belong to calcalkaline series with sodic or potassic affinities due to different rates of crustal contamination and fractional crystallization (AFC process). The basaltic lavas are not relatively rich in plagioclase phenocrysts an d have been ascended rapidly to the surface but the rich megaporphyritic intermediate lavas are the resu lt of basic magma storing in upper crust chambers, suffering fr actional crystallization and crustal co ntamination. These me gaporphyritic lavas are also interested for Cu,Pb,Zn mineralization .

Keywords: urumieh dokhtar, megaporphyritc, afcprocess

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VS003 **Poster presentation** **6678**

Archaeological, volcanological and rock-magnetic investigation on the impact of pyroclastic density currents on Bronze age settlements around Somma-Vesuvius, Italy

Dr. Mauro Antonio Di Vito
Istituto Nazionale di Geofisica e Vulcanologia Osservatorio Vesuviano IAVCEI

Zanella Elena, Gurioli Lucia, Lanza Roberto, Sulpizio Roberto, Tema Evdokia, Amato Lucio, Bishop Jim, Boenzi Giuliana, De Filippis Angela, Isaia Roberto, Laforgia Elena

Around 3800 yr BP a violent eruption, known as the Avellino eruption, impacted the plain to the northwest of the Somma-Vesuvius (Italy). During the eruption dilute, turbulent pyroclastic density currents (PDCs) extended 20 km to the NW from a vent located slightly to the west of the current Vesuvius cone. These currents impacted and buried several human settlements. Following the recent discovery of one such Bronze Age village close to the town of Afragola, 15 km from the inferred vent, an interdisciplinary study has been carried out to assess the impact of the eruption on that village. Archaeological excavations show that several PDCs impacted the village. The first PDC engulfed the village, entering the huts and leaving an ash layer up to 30 cm thick. Thousands of human footprints and animal hoofprints were discovered on the top of this deposit revealing that people survived this first event and were then able to walk on it bare footed. The pause before the arrival of the second PDC was therefore also long enough to allow (1) substantial cooling of the first deposit and (2) the passage of members of the local populations. The second PDC covered the footprints with a 6 cm thick deposit. This, in turn, was topped by a further 40-50 cm of deposits comprising the following PDCs. Later alluvial deposits then completely buried the remains of the village. Volcanological investigations show that the PDCs emplaced dune-bedded, thinly stratified, lithic rich, fine grained ash deposits. These attained a maximum thickness of 8 10 m at the inferred vent location, and thinned downcurrent across the Campanian plain. These deposits correspond to the onset of the phreatomagmatic phase of the eruption, during which efficient magma-water interaction triggered highly energetic PDCs. Field investigations integrated with a detailed facies analysis reveal that the presence of the village huts, made of wood, canes and thatch, locally affected the distribution and accumulation of these dilute PDCs. Magnetic fabric analysis show flow directions diverted by huts and fences, and the possible occurrence of small vortices down flow of obstacles (as revealed by upstream directions found at some sites). Measurements of the thermal remanence of lithic and pottery fragments embedded in the deposits show that the PDCs, even if dilute and distal, were still hot, with temperatures of at least 240 280 C. Our results show that in this distal location the horizontal component of the PDCs, coupled with their density, was not strong enough to destroy small wooden structures. Furthemore, these thin ash layers were able to cool rapidly, allowing people to walk on them. They remained in a plastic state, to allow the foot imprints to be impressed and preserved.

Keywords: pdcs, archaeology, vesuvius

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VS003 **Poster presentation** **6679**

Emplacement dynamics of felsic lava flows from Terceira Island, Azores: a morphological analysis

Mr. Adriano Pimentel
Centro de Vulcanologia e Av. de Riscos Geolgicos Universidade dos Aores IAVCEI

Steve Sparks, José Pacheco

A physical model was developed to analyze the empl acement dynamics of thick fels ic lava flows on Terceira Island (Azores). The model follows a simplified deterministic approach to describe, by a system of equations, the effects of the main governing factors during the lava emplacement.We considered that lava is fed from an overpressurized magma chamber through a cylindrical conduit, in a laminar regime. The initial effusion rate is g iven by the Poiseuille flow law for magma with Newtonian rheology. In this simplified case, lava dischar ge rate at the vent follows an exponenti al decrease with time.It was assumed that, during emplacement, the erupted volume of lava is related to flow parameters (such as flow width, length and thickness) by a shape factor. This assumption was also used to correlate the final volume of the lava flow with the actual lava dimensions, at presen t time. Based o n experimen tal studies, it was considered that the width of a lava flow is a function of the initial effusion rate and the underlying slo pe.The model also ta kes into account the effect of the complex rheology of lava, considering the apparent vis cosity of the lava, wh ich depends of the initial viscosity and follows a power-law to describe its va riation with time and distance.Finally, the Jefferys equation was used t o incorporate the influence of the speed of the flow-f ront in the mode l as function of the physical properties of the lava and the underlying slope.The phy sical approach presented here was used to model the emplacement of recent (< 20 ka) felsic la vas from Santa Brbar a and Pico Alto volcanoes on Terceira Island (Azores). Lava flows from both volcanoes are very similar in ter ms of chemic al composition (65 - 70 wt% SiO_2), average crystal cont ent (~ 12 vol%), and even in morphology. They reach a maximum of 2800 m in length, with widths ranging from 110 to 900 m and thickness of 15 to 70 m. The ca lculated volumes range from about $3x10^5$ to 10^8 m^3.M odel solutions show a good correlation with the length r ange observed on the fe lsic lava flows, demonstrating that the proposed physical model is able to reproduce the actual dimensions of these thick flows. Modeling the emplacement dynamics of felsic lavas from Terceira also allowed to obtain a better understanding of the dominant eru ptive co nditions thro ughout their ex trusion (e.g. init ial lava viscosit y and effusion rates).This generic model can also be applied to other volcanic areas or even to lava flows with different compositions.

Keywords: felsic, flows, azores

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VS003 **Poster presentation** **6680**

The july 17th 1999 block and ash flow and July 18th Lahar at Colima Volcano: a reological model.

Dr. Damiano Sarocchi
Instituto de geologa UASLP, Mexico IAVCEI IAVCEI

Macas Jos Lus

On July 17 1999, a strong explosion occurr ed at Coli ma volcano (Mexico) that produced a 10 km hig h eruptive column. The partial column collapse originated a block-and-ash flow (BAF), that moved toward the south, along San Antonio and Montegrande ravines, reaching 3.3 km from the volcano summit. The flow filled the preexisting ravines with a volume estimated in 7.9x105 m3. This material was removed by intense rain on July 18, originating a lahar that reached the plain at the north of Queseria village, where it deposited in a wide alluvial fan. The eros ion of these deposits occurred between 1999 and 200 2 providing excellent longitudinal outcrops that allo wed their detailed textural study. The study was carried out by means of textural analysis techniques. These techniques are: 1) intersections of Rosiwal, to carry out vertical granulometric profiles, 2) complete granulometric analysis, from -11 to +9 phi, and 3) Fourier and fractal analysi s to analyze the pa rticles shape. These m ethods provide sensitive and reliable data. Granulometric and morfometric paramete rs obtained with these methods, were used to identify vertical and longitudinal variation patterns in the BAF deposit and to recognize two depositional units justifiable by means of physical mechanisms an d a reologic model. This model considers that in steeper slope (up to 40) the pyrocl astic flow moved faster and the momentum transfer mechanism was based on collisions (colisional regime). After the break in slope (<29) the flow disacelerate suddenly and occurred a drastic change in rehology. Afterwards, the flow regime was characterized b y high frictions at the base that spread quickly toward the summit causing the freezing of the material in less than 1 km. After a day, this material was removed by rain originating a lahar with a sediment concentration in the debris flows range, which moved for about 10 km, ch anging its rehological regime in function of its solid load, confinement in the ravine and slope. The textural variations observed in the deposit reflected these rehologic changes. Finally, Fourier and fractal analysis applied to pa rticle shape an alysis allowed to discriminate among particles belonging to BAF depo sits and lahars, m ethod that could be use in the future to discriminate between these two types of deposits.

Keywords: block and ash flow, colima volcano, textural analysis

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VS004 **6681 - 6696**

Symposium
Intraplate monogenetic basaltic and kimberlite volcanic provinces and processes

Convener : Dr. Guido Giordano, Prof. Ray Cas

The session will focus on the effects of the interplay between regional stress, other regional factors and the magmatic source on the development of monogenetic intraplate basaltic and kimberlite volcanism. The session is aimed at giving researchers the opportunity to discuss the variety of eruptive styles and volcanic features that characterise plains basalt provinces and kimberlite provinces. Effusive, strombolian, violent strombolian and phreatomagmatic styles are generally all displayed in plains basalt provinces. In both systems regional distribution of volcanoes and volcano types reflects the interaction of the rising magma with the structural fabric of the crust, the orientation and intensity of the regional stress field and the presence or absence of ground or surface water. Studies on both modern and ancient systems are welcome, as well as those on exhumed intrusive plumbing systems of such volcanic provinces. Hazard-related studies are also welcome.

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VS004 **Oral Presentation** **6681**

Interpreting original textures in strongly altered kimberlites: examples from the Ekati Diamond Mine, NWT, Canada

Mrs. Lucy Porritt
School of Geosciences Monash University IAVCEI

Ray Cas

In volcanic rocks it is important to recognize primary textural features such as sorting and clast- or matrix-supported nature, as this will lead to an understanding of the mode of formation of the deposits. In particular, the efficiency of sorting processes during eruption, deposition, and possible syn- to post-depositional fluidization can be assessed. Kimberlites are highly reactive volcanic rocks which are commonly strongly altered to a combination of serpentines and clays. This alteration can be pervasive and often overprints the original textures making genetic interpretation somewhat difficult. In particular, where the kimberlite matrix appears to be principally serpentine, whether this is secondary pore-filling cement or a replacement of original fine-grained ash matrix is contentious. Where there are fine grained opaque minerals within the serpentine it is assumed that the original ash matrix has been replaced leaving behind only those minerals more resistant to serpentinization. However in cases of intense serpentinization the converse may not be true. The origin of very fine-grained diopside microlites is also subject to debate as to whether the crystal morphology is indicative of growth into open pore space or could also form as a subsequent replacement texture. In order to interpret the formation processes of these highly altered rocks, a combination of methods has been utilized to see through the alteration. The macro- and micro-textures of the primary pyroclastic deposits of two kimberlite bodies, the Fox and Koala pipes of the EKATITM Diamond Mine, NWT, Canada, have been studied. The studied facies in Fox is a massive to diffusely stratified, matrix supported, poorly sorted, fragmental mixture of country rock xenoliths, macrocrysts of serpentinized olivine and pelletal lapilli in a fine-grained matrix dominated by serpentine, which is termed a tuffisitic kimberlite (TK). In Koala the deposit is texturally similar to that at Fox, however it is lacking the pelletal lapilli and is relatively poor in country rock debris, and is classified as a pyroclastic kimberlite (PK). XRD and SEM derived identification of the alteration mineral assemblage gives a better understanding of the processes involved in the textural modification of these deposits. The effects of alteration on both the olivine crystals and the matrix components are presented, with high magnification SEM textural studies showing the presence of an original fine ash matrix. In addition the presence of widespread packstone textures indicate that an original matrix was present. Alteration is likely to have been multi-stage, with a progression from fresh olivine to serpentine then talc and clays being common. In single thin sections it is possible to see the presence of one or more styles of altered olivine components. These features have been used to show the differences in alteration and texture related to eruption style and deposit type between the two pipes.

Keywords: texture, alteration, kimberlite

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VS004 **Oral Presentation** **6682**

Experimental constraints on the role of fluidisation in kimberlite emplacement

Mr. Thomas Gernon
Department of Earth Sciences University of Bristol

Steve Sparks, Mark A. Gilbertson, Matthew Field

Gas-fluidisation is commonly invoked as an important process during the formation of vent-fill deposits in diverging kimberlite pipes. In this study, we performed a series of laboratory experiments to determine the gas-fluidisation behaviour of particles in both confined straight-sided and tapered containers, as an analogue to volcaniclastic materials infilling a kimberlite pipe, in the presence of a gas flow. We investigated the effects of taper angle, bed height and gas flow rate on fluidisation behaviour, focusing on mono- and poly-disperse mixtures of fine- and coarse-grained particles. We show that beds in straight- sided containers become homogeneously fluidised, whereas beds in tapered containers become heterogeneous, with fluidisation limited to a central, roughly hyperboloid-shaped region. Either side of the well-mixed fluidised core, marginal wedge-shaped regions remain unfluidised, and the width of unfluidised regions decreases with increasing gas flux. The unfluidised wedges are internally laminated and slip downwards when a critical proportion of the bed is fluidised (90%). This generates a conveyor-belt-type mechanism of particle transport. These experimental observations demonstrate how fluctuations in gas flux can produce steep internal boundaries between laminated and well-mixed regions. The observations also show how marginal inward dipping layered sequences could slip into deep parts of kimberlite pipes. Our results provide a first-order framework for interpreting the volcaniclastic lithofacies of kimberlite pipes.

Keywords: kimberlite, gas fluidisation, experiments

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VS004 **Oral Presentation** **6683**

Characteristics of a tectonically controlled basaltic volcanic field

Dr. Greg Valentine
Earth and Environmental Sciences Los Alamos National Laboratory IAVCEI

F.V. Perry

Identification of patterns in the timing and location of monogenetic volcanoes in basaltic fields provides information on the interplay between tectonics and magmatism as well as information that is needed for volcanic risk assessment. Basaltic volcanism in the Southwest Nevada Volcanic Field (central Basin and Range Province, U.S.A) occurred in six episodes of activity during the past 5 Myr. We show that the episodes followed time-predictable behavior since 3.8 Ma; the timing of each episode is a function of the cumulative volume prior to the episode and a steady eruptive magma flux of ~0.5 km3/Myr across the volcanic field. The onset of this flux rate and time-predictable behavior correspond to a decrease in the degree of partial melting as indicated by trace element compositions. Volcanic episodes < 3.8 Ma in the volcanic field reflect the melt-migration response of heterogeneous lithospheric mantle to low strain-rate extension. Larger volume volcanic episodes relieve relatively more tectonic strain because they have relatively thicker feeder dikes, consistent with the differences in lava effusion rates estimated for volcanoes of different size in the field. The behavior of this tectonically controlled basaltic field contrasts with magmatically controlled fields where the magma flux is sufficiently high (e.g., ~100-1000 km3/Myr) to equal or exceed tectonic strain and the systems are more likely to be volume-predictable (i.e., timing of an episode cannot be predicted, but eruptive volume is predictable based upon the repose time leading up to it). Eruptive fissures and vents in tectonically controlled fields are more likely to be strongly influenced by pre-existing structures that may not be orthogonal to the regional σ3, while fissures and vents in magmatically controlled fields are not strongly influenced by pre- existing structures. In a time-predictable volcanic field the timing of the next volcanic episode can be forecast empirically, an aspect that can supplement the development of probabilistic models for risk assessments.

Keywords: volcanic field, monogenetic, predictability

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VS004 **Oral Presentation** **6684**

The major problems with existing volcanological models and terminology associated with kimberlite pipes

Prof. Ray Cas
School of Geosciences Monash University IAVCEI

P. Hayman, A. Pittari, L. Porritt

Five significant problems hinder advances in understanding of the volcanology of kimberlites. They are: 1. Kimberlite geology is too model driven, 2. Many of the inferred processes and deposits are not based, on actualistic modern volcanological processes, 3. There is poor understanding of the significance of preserved textures. 4. The effects of alteration on preserved depositional textures have been grossly underestimated and have not been fully understood. 5. A highly genetic terminology drives deposit or facies interpretation. All need to be broken free if understanding of kimberlite volcanology is to truly advance. The traditional, steep sided southern African pipe model (Class I) consists of a steep tapering pipe with a deep root zone, a middle diatreme zone and an upper crater zone (if preserved). Each is thought to be dominated by distinctive facies: respectively, hypabyssal kimberlite (HK, deively called here massive coherent porphyritic kimberlite), tuffisitic kimberlite (TK, deively here called massive, poorly sorted lapilli tuff) and crater zone facies which include variably bedded pyroclastic kimberlite and resedimented volcaniclastic kimberlite (RVK) of various ilks. Hypabyssal kimberlite, (porphyritic coherent kimberlite), may however also be emplaced at different levels in the pipe, and although the model has it as the source for generating tuffisitic kimberlite through sub-terranean fluidisation fragmentation, it can also be a later intrusion. The (sub-terranean) fluidisation origin for tuffisitic kimberlite (lapilli tuff) has become accepted as a factual process, but is in fact unproven. It should be discarded and actualistic volcanological processes should be considered. So-called transitional facies is extremely poorly understood. Crater zone volcaniclastic facies can occur deep in some pipes, in the diatreme zone, indicating that the pipe was largely empty at the end of the eruption, and subsequently began to fill-in through largely resedimentation and sourcing of pyroclastic deposits from nearby vents. More recent Class II and III Canadian kimberlite models have a more factual and process basis, but over-emphasis on fitting different kimberlite bodies into the three model types is hindering progress with understanding kimberlite geology. Every kimberlite is altered, which cannot be avoided given the vent context, and few preserve original texture. The effects of syn- to post- emplacement alteration on original textures have not been adequately considered, and require considerable assessment to back-strip the alteration overprint and identify original textural elements and configurations. The presence of basic sedimentological textural configurations (grainstone, packstone, wackestone and mudstone) should be determined as a guide to emplacement processes. The traditional terminology has too many connotations about spatial position in pipe and of process. Perhaps the traditional terminology can be retained in the industrial situation as a general lithofacies-mining terminological scheme because it is so entrenched. However, for scientific purposes a more deive lithofacies terminology should be adopted to facilitate detailed understanding of deposit characteristics, important variations in these, and from that process origins. For example every deposit of TK is different in either componentry, texture or depositional structure and fabric. However, because so many deposits in many different pipes are called TK, there is a perception that they are all the same and that similar processes were involved, which is far from clear.

Keywords: kimberlites, volcanology, modeldriven

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Geometry, facies architecture and emplacement processes of kimberlite megaturbidite packages, Fort la Corne kimberlite field, Saskatchewan, Canada.

Dr. Adrian Pittari
School of Geosciences Monash University IAVCEI

Ray A. F. Cas, Stephan Kurszlaukis, Nathalie Lefebvre, Kimberley Webb

Upper and extra-vent kimberlite deposits are rarely preserved, and of those that do exist, very little has been revealed about their physical emplacement processes. The Fort la Corne kimberlite field, Saskatchewan, consists of at least 70 kimberlite bodies/clusters dominated by volcaniclastic deposits contained within a contemporaneous sedimentary basinal sequence. Recent diamond drilling across five kimberlite bodies (bodies 219 and 145 of the Orion Central cluster and bodies 118, 158 and 101) has enabled a three dimensional analysis of their geometry and facies architecture in light of the spatial variation in transportational and depositional processes. This presentation describes similarities in the geometry and facies architecture of the most voluminous volcaniclastic packages associated with five bodies, and highlights a significant, although not exclusive, upper and extra-vent emplacement process which has occurred at Fort la Corne. Each of the studied bodies is characterised by a >130 to 200 m deep broad, palaeolow or depression, circular to elongate in plan section with an area <0.3 km2, which cross-cuts the pre-existing siliciclastic basinal sequence which itself contains interbedded conformable volcaniclastic kimberlite beds or packages or beds . Palaeolows are discordantly infilled with thick continuous kimberlite volcaniclastic packages up to 175 to 250 m thick which rapidly thin to less than 16 to 47 m thick on the adjacent higher topographic margins, where they are concordant with host rock dark marine mudstones. In some bodies the upper surface of the palaeolow infill defines a low relief mound (e.g. >30 m in body 101). The infilling volcaniclastic packages consist of amalgamated multiple depositional units of massive to stratified , poorly sorted facies, which are matrix- to near-clast -supported, garnet-ilmenite-bearing, highly to extremely olivine-rich sand- to gritty pebble-sized facies with a subhorizontal to oblique grain alignment fabric. Thick deposits within the palaeolows are generally massive, relatively coarse-grained, with <5% pebble-sized or larger lithic clasts. Thinner deposits on the adjacent palaeolow margins are relatively finer-grained, lithic poor and consist of normal graded beds with massive coarse-grained basal zones and laminated to low angle cross -laminated fine-grained upper zones, consistent with the lower parts of Bouma turbidite beds. Localised facies characteristics provide evidence for soft sediment deformation (e.g. localised folded zones, deformed mudstone intraclasts, load casts) and erosional scouring (e.g. substrate rip-up clasts, angular basal contacts).The deposits infilling the palaeolows of the studied bodies are considered to have been emplaced rapidly within a marine environment by a sequence of megaturbidity currents sourced from a collapsing dense, crystal-rich eruption column. Palaeolows acted as microbasins capturing these high concentration, water-supported granular flows, which experienced marked variations in flow properties and processes, perhaps even flow splitting, over the high palaeorelief.

Keywords: kimberlite, megaturbidite, volcaniclastic

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The volcanological implications for Kimberlite emplacement based on the study of contrasting pipe margin contacts: a case study of the Muskox and Jericho pipes, Northern slave province, Nunavut, Canada

Mr. Patrick Hayman
School of Geosciences Monash University IAVCEI

Raymond Af Cas

We examine contrasting types of pipe margin contacts to better understand kimberlite emplacement as well as the physical and chemical effects imposed on the host rock during and after emplacement. The Muskox and Jericho kimberlites (~172 Ma) are emplaced in weakly foliated Archean granite to granodiorite and provide an excellent laboratory to examine pipe margin contacts as they have both been drilled extensively and, in the case of Jericho, can provide larger-scale observations as it is currently being mined. From studies of these deposits we recognise two broad types of pipe margin contacts, one between fragmental kimberlite and granite and the other between coherent kimberlite and granite. The pipe margin contact between fragmental kimberlite and granite is sharp, planar to undulose and has the appearance of being formed through abrasion during the waxing phase of the eruption. The country rock adjacent to fragmental kimberlite contains numerous contact parallel joints that are abundant near the pipe margin (~1 cm apart) and steadily increase in distance apart until ceasing to exist altogether ~2 m from the pipe margin. The same features are observed in a few drill core examples but more commonly alteration and jointing make core reconstruction impossible. Coherent kimberlite is found in contact with granite in two contrasting settings, one in the eastern portion of the Muskox pipe and the other as dykes (~<10 cm). The contacts are sharp but are only planar for the case of the dykes. Pipe filling coherent kimberlite appears to force its way into joints and fractures within the granite host producing a distinguishing contact in comparison to extrusive ones. Preliminary petrographic and compositional data (X-ray fluorescence) show that the host rocks adjacent to fragmental kimberlite are generally unaffected aside from the jointing. In contrast, granites next to pipe-filling coherent kimberlite contain abundant calcite and serpentine between feldspar crystals up to ~10 m from the pipe margin. The differences observed in the host rocks are largely controlled by the contrasting emplacement styles (intrusive versus extrusive) and the temperature differences associated with fragmental kimberlite (<600oC) and coherent kimberlite (~>1200oC). As contacts are often preferential pathways for fluids we also consider the effects of post-emplacement alteration.

Keywords: kimberlite, emplacement, pipe margins

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Welded/agglutinated intra-crater deposits: an example from the Victor Northwest kimberlite pipe, Northern Ontario, Canada

Mr. Bram van Straaten
Earth and Ocean Sciences University of British Columbia, Vancouver, Canada IAVCEI

Maya G. Kopylova, J.K. Russell, Kimberley J. Webb, Barbara H. Scott Smith

Welding of pyroclastic deposits involves the sintering of hot glassy particles and is greatly facilitated when emplacement temperatures exceed the glass transition temperature (Tg) of the juvenile volcanic material. Welding can occur on various scales as observed in large welded pyroclastic flows, in small-volume agglutinated spatter rims, or as in partly/completely coalesced clastogenic lava flows. The result of welding is to produce dense, massive, coherent pyroclastic deposits. In this abstract, we present evidence for welding of originally clastogenic rocks from the Victor Northwest kimberlite pipe, Canada. Interestingly, unequivocal welded kimberlite deposits have never been described before. The Victor Northwest pipe forms part of a volcanic complex comprising several adjacent and cross-cutting kimberlite pipes. These steeply dipping (~70) pipes occur in a ~275m thick Palaeozoic sedimentary succession, unconformably overlying granitoid basement. After kimberlite emplacement in the Middle-Late Jurassic, the upper portions of the pipes (~50-300m) have been eroded. The infill of the Victor Northwest kimberlite pipe is complex, and comprises: (i.) Sedimentary Country Rock Breccias (CRB), consisting of diverse country rock fragments and minor kimberlite; country rock fragments are mixed and out-of-place with respect to their original stratigraphic position. (ii.) Volcaniclastic Kimberlite (VK) is found throughout the pipe, is massive to thickly bedded, and contains variable proportions of juvenile pyroclasts (crystals rimmed by selvages of crystallized melt) and country rock fragments. (iii.) Apparent Coherent Kimberlite (aCK, the focus of this work) is generally dark-coloured, massive, competent and macroscopically featureless. This unit has two distinctive textures. Firstly, the unit features evenly distributed, well crystallised groundmass minerals (carbonate laths, spinel, perovskite, phlogopite). Secondly, a prominent feature in certain parts of this unit is the presence of olivine crystals with diffuse fine grained selvages that are gradational to the slightly coarser-grained surrounding matrix. The textural similarity between diffuse selvages in the aCK and juvenile pyroclasts in the VK, and the many gradational contacts from aCK to VK show that these diffuse selvages are relics of juvenile pyroclasts. This indicates that at least part of the aCK has a welded clastogenic origin. It might prove difficult to determine the origin of the coherent kimberlite with no diffuse selvages, as both densely welded pyroclastic deposits and kimberlite lavas are expected to have a similar appearance. Therefore, we conclude that the most important, as yet unresolved, issue is related to the scale of the eruption(s) forming the pipe-infill. More specifically, is this deposit a proximal record of a fall-back from a large, dense and hot eruption column, or did these rocks form by small-scale fire-fountaining, agglutination and/or effusive activity. This first account of a welded kimberlite deposit has important implications for other coherent-looking rocks in kimberlite pipes, as well as the dynamics and emplacement of kimberlite volcanoes.

Keywords: kimberlite, welding, agglutination

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VS004 **Oral Presentation** **6688**

Transition from monogenetic to polygenetic volcanism at Mt. Melbourne volcanic province, McMurdo Volcanic Group, North Victoria Land (Antarctica)

Dr. Guido Giordano
Scienze Geologiche Universisit Roma TRE IAVCEI

Fabrizio Balsamo, Federico Rossetti, Francesco Salvini, Fabrizio Storti

The Ross Sea Region, at the northeastern edge of the Antarctic Plate, is characterised by the widespread occurrence of Cenozoic post-rift alkaline volcanism. Volcanism is dominantly monogenetic and charcaterised by the scatter occurrence of small scoria cones and lava flows, at several places highly affected by interaction with melting ice-water. Monogenetic centres are generally associated with the major right-lateral strike-slip fault systems, which cut through the Transantarctic Mountains. Fault systems strike northwest-southeast and cut across North Victoria Land, connecting the passive margin of the Southern Ocean, to the north, with that of the western Ross Sea, to the south. The activity of these strike-slip fault systems started in Eocene times and caused the transition from orthogonal to oblique rifting in the Ross Sea. Faulted Late Cenozoic volcanic rocks of the Mt. Melbourne volcanic province indicate a recent tectonic activity of these crustal-scale shear zones. The kinematics of these fault systems changes to transtensional approaching the Ross Sea basin, where faults turn to N-S direction. Where fault systems change direction and kinematics, volcanism changes from small volume and monogenetic to produce shield volcanoes and stratovolcanoes. Mt. Melbourne is a quiescent, N-S trending stratovolcano, located between Campbell glacier and Tinker glacier, at the transition from the NNE-trending Southern Cross Mountains and the RossSea. Volcanological and structural data illustrate the focussing of volcanism at the bend of the NE-trending Campbell fault system, with a clear transition from Mio cene-Pliocene monogenetic effusive to strombolian volcanism, to Pliocene effusive shield volcanism, to Quaternary effusive to explosive polygenetic volcanism.

Keywords: volcanism, antarctica, tectonics

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VS004 **Oral Presentation** **6689**

The volcano-tectonic setting of the intraplate, Pliocene-Holocene, Newer Volcanic Province (SE Australia): factors influencing volcanism

Dr. Guido Giordano
Scienze Geologiche Universisit Roma TRE IAVCEI

Chiara Lesti, Francesco Salvini, Raymond A.F. Cas

The Cenozoic-Holocene Newer Volcanic Province in Victoria, SE Australia , is a wide volcanic field site of the most rec ent volcanic activity of the Austra lian continent. The i ntraplate sign ature and the localization on the no rthern side o f the So uthern Ocean have been used in the past to ascribe the volcanic activity either to the presence of a mantle hot spot or t o thermal anomalies inherited from the seafloor sprea ding that separated Australia from Antarctica, during th e Go ndwana break- up. The spacing and distribution of clusters of eruption points suggests the presence of a ca. 40 km deep mantle thermal anomaly. Alignments of eruption points indica te a strong t ectonic c ontrol on magma emplacement mainly along NW-SE Mesozoic-Cenozoic str uctures, an d alon g N-S P alaeozoic an d E-W Late Cretaceo us structures. T his vo lcano-tectonic se tting r elates tothe interference of t he left-lateral kinematics of the major N-S trending faults asso ciated with the Tasman Fracture Zone and the extensional structures o f the Otway basin. This interp retation is also coherent with stress in situ dat a and focal mechanisms of earthquakes (SHm ax oriented N1 50). This inter pretation enhances the role of the Tasman Fracture Zone, a major sinistral transform, on the reactivation of transtensi onal structures, and on triggering the magmatism of the Newer Volcanic Province.

Keywords: volcanism, australia, tectonics

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VS004 **Oral Presentation** **6690**

Structurally disrupted and chemically weakened zones in segmented kimberlite dyke systems cause vent localization

Mrs. Janine Kavanagh
Earth Sciences University of Bristol

Dr Richy J. Brown, Prof R. Stephen J. Sparks

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. Deformation includes local fracturing and brecciation and is associated with relay zones between offset dyke segments. Breccia zones indicate dilation and hydraulic fracturing and some were also affected by chemical corrosion, forming joint-bounded spheroidal structures surrounded by onion-skin concentric foliations of altered rock. The alteration was caused by volatiles released in advance by the magma which then moved ahead in the fracture. Consideration of the time-scales needed for chemical corrosion of the host rock require intrusions to stall at depth prior to transport to higher crustal levels. Highly disrupted offsets could be preferred locations for explosive activity and initial kimberlite pipe formation as dykes approach the surface. The pipe forms after breakthrough of magma to the surface and the altered zones are reamed out and the chemically altered spheroidal clasts are incorporated into the pipe fill along with more angular country rock material, as observed in layered volcanic breccias in kimberlite pipes at Venetia mine, South Africa. This model has wider implications for the localisation of conduits at other types of volcanoes. Dyke segmentation provides weak zones where hydrothermal fluids and magmatic volatiles can be preferentially channelled. Chemical corrosion can further weaken these zones which may then become the locus for initial phreatic and phreatomagmatic explosions creating shallow vents that can then channel magma to the surface.

Keywords: dyke, kimberlite, brecciation

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VS004 **Oral Presentation** **6691**

Clastogenic kimberlite rocks

Dr. Richard Brown
Earth Sciences University of Bristol IAVCEI

Ben Buse, Mark Tait, Steve Sparks, Matthew Field

We document in a number of kimberlite pipes in Southern Africa, a dense kimberlite rock type that typically exhibits all or most of the following features: (1) a dark blue-green or black appearance; (2) a hard, competent nature; (3) low abundances (<2-10 vol. %) of accidental lithic clasts, most of which are (4) highly altered and may have irregular fluidal outlines; (5) abundant in-tact pseudomorphed olivine macrocrysts and euhedral phenocrysts and microcrysts; (6) low abundances of broken crystals; (7) crystalline igneous textures with a groundmass composed of primary kimberlite minerals; and (8) irregular pools (segregations) of calcite and serpentine. This rock type is found at all levels within pipes and forms bodies with varying volumes and geometries. Contacts with adjacent clastic kimberlite rock types are typically gradational. Sub-horizontal clast fabrics in some pipes are suggestive of layer-by-layer deposition. The simplest explanation for this rock type is that it is a clastogenic deposit formed by the agglutination of hot pyroclasts on deposition. Clastogenic rocks have not been widely reported in kimberlite pipes and most bodies of coherent igneous-textured kimberlite have been interpreted as intrusions. However, we know of no theoretical arguments as to why clastogenic and welded kimberlite rocks should not form during a kimberlite eruption.

Keywords: kimberlite, clastogenic, welded

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VS004 **Oral Presentation** **6692**

Potrok Aike Maar soft-substrate maar volcano? Implications for vent geometry and the palaeo-environmental setting

Dr. Ulrike Martin
IAVCEI

Helga De Wall

The Initiation of the Potrok Aike Lake Sedim ent Archive Drilling Project (PASADO) within the framewor k of ICDP intend s to address s everal key iss ues one of which is related to the evolution of the maar crater. Laguna Potrok Aike belongs to the Pali Aike Volcanic Field in southern , which consists of several maar diatreme volcanoes,. Due to the close d vegetation cover, outcrops of teph ra ring sequ ences are rare, and only exist in the ste ep inner cliffs of so me larger maars. Small and broad, sha llow tuff rings are often covered with shallow lakes that ar e extremely similar to lakes developed on a deflation basin. Existence o f maar and tuff rings is co mmonly inte rpreted on ly on the bases of shallow geoph ysical methods and some morphological analyses of the la ndscape. However, clear identification and/or description of tephra units surrounding shallow (commonly lake filled) depressions that a re characteristic of phreatomag matic volcanic origin are rare. Therefore the planned drilling into the maar structure will definitely support the investigation of this maar diatrem volcano. First investigations of the tephra ring deposits confirm the phreatomagmatic or igin of the Potrok Aike setting. Chilled juvenile fragments (e.g. volcanic glass), accidental lithics and the common bed forms associated with base surge deposition are all indicating a typical phrea tomagmatic explosive event in generating t he Potrok Aike maar and its pyroclastic succession. The cra ter of Potrok Aike has a diametre of 2400 m and the whole maar-diatreme structure seems to have the champagne glass shape. This large diameter can be a result of repeated phreatomagmatic explosions with down ward m igrating locus of thermohydr aulic explosion or is a consequence of the s oft subtrate environmen t.Accidental lithics comprise many basaltic clasts apparently derived from older lava flows. Distinguishing accidental clasts from juvenile c lasst is crucial and needs car eful investigati ons especially when ag e determinations are based on volcanic clast from the deposits. So far, the age of the Potrok Aike M aar is no t well co nstrained. Ar/Ar-dating o f glass fragments (0.77 0.24 Ma) reflects the heterogeneity of volcanic fragments in the pyroclastic deposits.

Keywords: phratomagmatism, maar diatreme, intra plate volcanism

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VS004 **Poster presentation** **6693**

Dynamics of kimberlite pipe formation: insights from wall-rock structures and lithic distributions in volcaniclastic kimberlite

Mr. Ben Buse
Earth Sciences The University of Bristol

Prof. Stephen Sparks (Rsj Sparks), Mr Matthew Field

Field observations at the B/K9 kimberlite, Orapa, Botswana suggest (1) fluidisation influences the emplacement of coherent volcaniclastic kimberlite (CVK) and (2) initial pipe formation involves the formation of peperites. The B/K9 kimberlite consists of three coalesced pipes; the north, central and south lobes. The CVK of the north lobe was examined. The kimberlite was intruded into the Karoo Supergroup, which consists of mudstones (Tlapana & Tlhabala Formations), overlain by sandstones (Ntane Formation) and basalt (Stormberg Formation). Lithics within the CVK of the north lobe display diffuse variations in lithic clast size, abundance and type. The lithics have a fractal dimension of 2.5, suggesting they have undergone abrasion (Barnett 2004). At the margins of the CVK there are diffuse inward dipping layers defined by lithic abundance and clast orientations. The deposits characteristics are consistent with a fluidised regime within the conduit. Fluidisation allows the amalgamation and mixing of magmatic material with lithic clasts (supplied from the conduit wall); where this mixing is imperfect diffuse variations will be produced. Marginal inward dipping layers are observed in fluidisation experiments of divergent conduits (Gernon et al 2006). Within the Stormberg basalt wall-rock, there are peperite veins consisting of fine sandstone and rare kimberlite minerals. These veins are attributed to the kimberlite magma interacting with the water-saturated Ntane sandstone aquifer. Peperite veins also occur within A/K6, a kimberlite pipe within the region. Peperite formation may be a common process within the regions kimberlite pipes, as a consequence of the Ntane sandstone regional aquifer. Observations imply the B/K9 north pipe formed as follows. Kimberlite magma ascended towards the surface and interacted with the Ntane sandstone to produce peperite. The peperite explosively expanded, fracturing and injecting peperite into the overlying Stormberg basalt. Crater forming explosions followed, ejecting the peperite and the overlying basalt, preserving only the outermost fringes of peperite-veined basalt. Continued eruption and pipe wall collapse resulted in the pipe growing. This phase of pipe growth was not sufficiently prolonged to remove all the peperite veined basalt and was probably terminated by the eruption waning. Material would have begun accumulating within the pipe, forming an aggrading fluidised bed, which filled the pipe. Field observations suggest that the final basaltic wall-rock collapse occurred after fluidisation had ceased, resulting in the basalt breaking into blocks which rotated and slid into the pipe, deforming the adjacent kimberlite. It is clear from this sequence of events that peperite veins will only be preserved where the eruption is short-lived, with limited pipe growth. Peperite formation probably occurred in all the kimberlite pipes within the region, in response to the stratigraphy.

Keywords: kimberlite, fluidisation, peperite

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VS004 **Poster presentation** **6694**

Auckland volcanic field, New Zealand: geophysical characteristics and regional structure

Dr. Corinne Locke
School of Geography, Geology and Environmental Sci The University of Auckland IAVCEI

John Cassidy, K. Bernhard Sporli, Jennifer D. Eccles, Helen A. Williams

The late Quaternary monogenetic Auckland volcanic field (AVF) consists of 49 distinct basaltic eruption centres. Eruption styles range from phreatomagmatic, through Hawaiian/Strombolian cone building to effusion of lavas. The field is very young (probably less than 250,000 yr) and possibly still at a juvenile stage of development. It lies at the tip of a northward propagating lithospheric fracture along which volcanism has migrated for the last 2 Ma. (Briggs et al., 1994); magmas are probably sourced from the lithospheric mantle at depths of about 80 km (Horspool et al., 2006). The AVF is coincident with an area of crustal complexity within a linear Mesozoic terrane suture involving the Dun Mountain Ophiolite belt (part of the Maitai terrane). This suture zone, reactivated during the Cenozoic and now buried, is marked by a NW-SE linear magnetic anomaly, known as the Junction Magnetic Anomaly (JMA), which is a key tectonic marker and extends throughout the length of New Zealand. The regional aeromagnetic data show that in the Auckland region the JMA is subdivided into multiple parallel linear magnetic anomalies across the AVF which are interpreted as resulting from serpentinite shear zones in the Dun Mountain Ophiolite rocks. The AVF occurs in the region of a discontinuity in this suture zone, marked by an abrupt narrowing and subtle change in strike orientation of the JMA. Gravity studies show that the AVF is also located towards the southern end of a large (50km wide) gravity anomaly, interpreted as resulting from the largest block of dense material (most probably non-sheared ultramafics) known within the Maitai terrane. This large competent crustal body of ultramafics may have momentarily arrested the northward propagation of the lithospheric fracture along which volcanism has migrated, permitting the joint arrays in the complex stress field at the crack tip to extend into and decompress lithospheric mantle regions, allowing magma to be mobilised. The distribution of volcanoes in the AVF is complex, with no unequivocal alignment of vents, although some possible alignments parallel to regional Quaternary structural trends are apparent. Recent paleomagnetic data suggest that a number of volcanoes in the AVF may have been active at the same time but there appears to be no simple structural relationship between these volcanoes.

Keywords: gravity aeromagnetic, suture zone, auckland volcanic field

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VS004 **Poster presentation** **6695**

Recent Basaltic Vulcanism in the Sierra Chichinautzin near Mexico City Mexico.

Dr. Ana Lillian Martin Del Pozzo
Instituto de Geofisica Universidad Nacional Autonoma de Mexico IAVCEI

Ramon Espinaza Perea, Susanne Straub

Basaltic eruptions are part of the recent monogenetic volcanism of the Chichinautzin Sierra, to the south of Mexico City. Lavas originated from E-W trending scoria cones which are probably fault related. Lava volume is much larger than tephra volume. Chichinautzin and Xitle volcanoes erupted less than 2000Ka and although Suchiooc has not been dated, its cone morphology and visible flow ridges suggest it is also a Holocene volcano. These 3 basaltic volcanoes produced long fluid Pahoehoe and Aa lava flows fed by a complicated network of varying-sized lava tubes with lengths of up to 18 km, which reflect changing effusion rates. Volumes range from 1 to 3 km3 and we know from the archaeological sites that eruptions possibly lasted several years. Eruptions from the 3 volcanoes have impacted the local inhabitants since they are associated with these archaeological sites and findings. The origin of basaltic volcanism is still controversial since most of the field is andesitic and thought to be subduction-related, notwithstanding chemical differences berween closely spaced volcanoes suggest they are related to different parents associated with local mantle heterogeneities. Magmas from these 3 young basaltic volcanoes are subalkaline, have high Sr, Ni and MgO, as well high Ni in the olivines which is consistent with mantle melts mixing with cooler melts in the crust. The young age of this basaltic volcanism is especially important since the area is heavily populated.

Keywords: basaltic, monogenetic, lavatubes

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VS004 **Poster presentation** **6696**

Crater-infill at Diavik: facies architecture, textures, volcanic processes and implications

Mr. Stephen Moss
Earth and Ocean Sciences University of British Columbia, Vancouver IAVCEI

Processes responsible for crater-facies kimberlite deposits remain poorly understood because there are few well-preserved occurrences globally. New open-pit exposures of the A154N kimberlite pipe at Diavik in the Lac de Gras region of the Northwest Territories, reveal well-preserved crater-facies deposits. Here, we describe the geometries, structures and componentry of the deposits from the uppermost 150m of the A154N pipe. We then interpret the processes responsible for their emplacement on the basis of these properties. The base of the 150 m section features a poorly-sorted, magnetic, and primary massive volcaniclastic deposit (MVK) grading upward into a better-sorted pyroclastic kimberlite (PK2). The PK2 is overlain by ~65m of re-sedimented volcaniclastic kimberlite (RVK). The RVK is, itself, overlain by a moderate to well-sorted pyroclastic kimberlite (~40-50m) that is sourced from another kimberlite volcano (PK1). The PK2-RVK contact is sharp and marked by the onset of bedded grain flows, wedge-shaped volcanic debris, and large, anomalous blocks of mud-rich kimberlite. This interface represents the penultimate deposition of primary pyroclastic material at the end of the eruption, and marks a transition to episodic sedimentation from collapse of an unstable volcanic edifice into an open crater. Deposits from post-eruption, resedimentation of the volcanic crater (RVK) record vertical variations in component sizes and types and imply a gradual change in sedimentation style. Sediments grade upward from coarse, kimberlite-rich debris to fine-grained, mud-rich thinly-layered deposits. This variation is consistent with a change from large volume, high-energy, en-masse debris flows in a sub-aerial to shallow sub-aqueous environment to smaller, lower energy, grain flows and sedimentation from suspended fines in deeper water. Late H_2O-rich fluid causes a serpentinization reaction front which crosses the stratigraphic contact between PK2 & RVK. Pyroclastic kimberlite (PK1) marks the top of the A154N pipe. The PK1 shows a variety of textures on different scales which suggest a pyroclastic origin, including a grain and clast-supported fabric, vesiculated juvenile pyroclasts, and the absence of matrix mud. Grading over a 40-50m scale in the deposit, sharp contacts with underlying RVK deposits, and the absence of bedding suggests hydraulic sorting of an en-masse deposition of this pyroclastic kimberlite into a deep water column, contributed to the A154N pipe from one of the many adjacent pipes in the Diavik area. The deposit, therefore, represents cross-fertilization of A154N by an extra-crater kimberlite deposit from a later-erupting pipe in the cluster. These observations have implications on kimberlite volcanic processes and grade distribution.

Keywords: kimberlite, volcanology, pyroclastic

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VS005 **6697 - 6729**

Symposium
The Magma Feeding System of Persistently Active Basaltic Volcanoes: Mount Etna and Others

Convener : Dr. Giuseppe Puglisi, Prof. Renato Cristofolini, Dr. Patrick Allard

The eruptive behavior of persistently active basaltic volcanoes is closely dependent on the geometry and the dynamics of their magma feeding system. Therefore, quantitative imaging and modeling of magma feeding systems is essential to improve our eruption forecasting capabilities. This can be obtained from multidisciplinary investigations of the volcanic activity, of its solid and gaseou s products, of geoph ysical and geochemical signals, as well as of the regional and local structural fram ework. Since its inclusio n among the IAVCEI Decade volcanoes, Mount Etna - the largest active volcano in Europe - has been the target of growing studies and monitoring, which ha ve allowed substantial progress on these aspects. Nevertheless, there still remain a number o f question s, for instance abo ut the respecti ve triggering effects of magma replenishment and regional tectonic forces, that could only be resolved through closer combination of different methodologies. The same is tru e for oth er basaltic volcanoes elsewhere. This session is thus aimed at mak ing a standpoint of our current knowledge of the magma feeding system and eruptive dynamics of Mt. Etna and o ther persistently active basaltic volcanoes. We welcome either single or multi disciplinary contributions dealing with geop hysical, geoch emical, petr ological, structura l and remote se nsing approaches. Inter-comp arison between different ba saltic volcanoes is encouraged. One final objective should be to identify a number of priorities in future investigations of magma dynamics and feeding systems on basaltic volcanoes.

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VS005 **Oral Presentation** **6697**

Geophysical observations at Mt Etna during the December 2005 January 2006 anomalous non-eruptive period

Mr. Luciano Zuccarello

Daniele Carbone, Chris Bean, Gilberto Saccorotti, Domenico Patan

Between 16 December 2005 and 13 Janu ary 2006 a step rise in the amplitude of the volcanic tremor was observed at Etna. Both t he start and the end of this period were marked by energetic explosions from the summit craters zone. The most striking feature of the tremor during the high period is given by the occurrence of three-hour cycles modulating its amplitude. Neither the spectral features of the tremor, nor th e position of i ts source appear to change markedly thr oughout the entire ano malous period. It is also remarkable that no eruptive acti vity was observed during the aforementioned period. Through an automatic detection procedure, applied to the continuous data stream from Etna's broad-band seismic network, more than 10000 Ver y Long Period (VLP) events were recognize d between 01 October 2005 and 31 Januar y 2006. These events depict a dominant period of about 2 0 seconds, and rapidly attenuate moving awa y from the su mmit craters. Polarization ellipsoids generally depict a radial orientation to the direction pointing to the summit zone, and incidence angles clustering over the 55-60 interval. Some observations indicate that, b etween the en d of Decembe r 2005 a nd th e first days of January 2006, the overall phenomenon behind th e anomalous period underwent an important modification. In fact it was observed both an increase in the seismic energy released through the VLPs and a marked i ncrease in the incidence angles. In co njunction with these variations, a tight correlation was found between the signal from one of t he two summit gravity stations and the RMS of the volcanic tremor, over a six-h our window sliding along the two signals. This correlation fades away soon before the end of the high tremor period and in conjunction with a decrease i n the energy r eleased through the VLPs. Conversely, the incidence angles of VLPs do not return to the values they had before January 2006. The larg e amount of available observations a ssures that tight con strains can be set over the source mechanism which lead ed to the Dece mber 05-January 06 anomalous period. Nev ertheless, the cause/effect r elationships between the a bove obse rvations are difficult to clarify and thu s an y interpretation able to exp lain all the observ ed changes is still difficult to deliver. At the present stage, only some preliminary conclusions can be drawn. The cyclic feature of the volcanic tremor could indicate the establishment of a closed or quasi-closed system within which cyclic pressure changes occurred. In spite of the stability in time of (i) the spectral features of the tremor and (ii) the position of its source, it can be hypothesized that, since the start of January 06, the amount of mass associated to the tremor source became more important. In fact, the transi ent anti-correlation between RMS of t he tremor and gravity signal i ndicates that t he source modulating the amplitude of the tremor over time intervals of the order of a few hours becomes also able to indu ce measurable grav ity changes. T he same source could also be responsible for the increase in the en ergy released through the VLPs since the beginning of January 06. Whatever the case, this integrated study shows how the qualitative information supplied by the volcanic tremor, and li nked to the dynamics of the shallow plumbing system, can be comp leted, on the quantitative side, by t he study of other pa rameters through which the volumes/masses involved in the studied processes can be inferred, thus asse ssing how poten tially dangerous the future activity will be.

Keywords: vlp, tremor, microgravity

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VS005 **Oral Presentation** **6698**

Gravity steps at Etna and Merapi volcanoes. Instrumental effects or evidences of earthquake-triggered magma density changes?

Dr. Daniele Carbone

Philippe Jousset, Carla Musumeci

Continuous observations of the gravity field are a relatively new tool to monitor and study the internal dynamics of volcanoes. This technique is not widely used due to the high cost of spring gravimeters, which limits the number of instruments available at a single site, and due to the high instrumental sensitivity, required to assess the expected changes (within a few tens of microGal), but implying a high response to environmental perturbations (temperature, pressure, etc.). However, continuous gravity measurements are nowadays routinely accomplished at certain active volcanoes and long high- quality sequences have been acquired. In order to detect anomalies with the best chances of being volcano-related, sequences coming from different volcanoes must be compared with each-other. At Mt. Etna a mini-array of three continuously running spring gravimeters was installed during the nineties, to couple the network of benchmarks for discrete campaigns, and has worked intermittently since then. At Merapi volcano, a multiparameter station, including a spring gravity meter, recorded data for more than 8 years. Several meaningful variations were already detected at the two volcanoes and explained in light of the ensuing volcanic activity. We focus on steep variations observed in the signal from gravimeters installed at Etna and Merapi volcanoes. At Merapi volcano, gravity steps within 5- 15 microGal were observed on 14 and 17 January 1997. They occurred in correlation with intense earthquake swarms and nues ardentes corresponding to dome collapses and/or vulcanian explosions. On 24 December 1997 and 13 October 2006 changes within 15-20 microGal were observed at Mount Etna over periods of the order of a few minutes. In both cases, the steep changes were observed simultaneously at two summit gravity stations and when volcanic activity was in progress in the summit zone. Furthermore, in both cases, the gravity steps took place at the same time of small- magnitude tectonic earthquakes. To understand whether the steep gravity change observed at the two Etna stations on 13 October 2006 could be the instrumental response to the ensuing seismic perturbation, we calculated the displacement and acceleration produced at the seismic station closer to one of the gravity stations by all the earthquakes recorded between June and December 2006. The 13 October displacement/acceleration threshold is reached or crossed on some occasions without the occurrence of steep gravity changes. This would indicate that, rather than being instrumental, the anomaly is a real change of the gravity field. Further analyses are still to be accomplished to provide support to this preliminary result. An alternative geophysical explanation for the gravity steps must take into account that they occurred in correspondence with seismic events and when summit volcanic activity was in progress. Accordingly, they could be the direct or indirect effect of the pressure changes induced by the passing seismic waves on shallow magma bodies. If this hypothesis is proved to be true, it would demonstrate that the gravity steps are one of the few evidences of mutual triggering between volcanic and tectonic systems.

Keywords: volcano, microgravity, earthquakes

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VS005 **Oral Presentation** **6699**

Syn-eruptive style variations in basaltic volcanoes: the example of the Etna 2001 event

Dr. Carmelo Ferlito
Scienze Geologiche Universit di Catania IAVCEI

Marco Viccaro, Renato Cristofolini

Changes of eruptive behaviour during medium to long-lasting events have been broadly recognised and studied for andesitic volcanoes or for volcanoes with a generally acknowledged explosive behaviour. Lower attention is usually paid to prevailingly effusive basaltic systems. In particular, there is little awareness of the relevant effects that even slight changes of some chemical and physical magma parameters can exert on the eruptive style, as little study has been devoted to them. A model of how differentiation processes, within the feeding system, can affect the eruptive behaviour has been derived from the evolution of the 2001 event at Mt. Etna, Italy. Here, two different magmas have been taking part for 20 days to an adventive eruption from two distinct segments of a fracture system on its southern flank. Major and minor element chemistry of rocks and minerals show that a slightly fractionated magma mixed with a more primitive one, with a distinct isotopic signature, and that the mixed member was erupted only during the last phase of the event from the Laghetto vent. A crucial effect that mixing exerted on the dynamics of the eruption, was that it evolved to become much more explosive. VOLATILECALC calculations indicate that the primitive magma was close to volatile saturation conditions. Thermodynamic simulations of an isenthalpic mixing process, performed by MELTS, are in agreement with a fast liquidus drop in the primitive magma. This induced the nucleation and growth of anhydrous crystalline phases, such as Fe-oxides, which in turn triggered volatiles exsolution. These joined factors may also be viewed as paramount in controlling the rheology of the mixed magma. Specifically, the last effused lava was highly viscous and an autoclastic flow, at least 50 times more voluminous than the earlier flow units leaving a 30 m high plug inside the Laghetto crater. Regards the 2001 event, tectonics too certainly played a significant role on the transition from a quiet effusion to explosive style of activity as well as on the final plug-like extrusion. This implies that, due to the fast opening and widening of the feeding structure, gas exsolution had been very efficient, driving in this way the shift from low- to high-emission rate. The explosivity of an eruption and the rheology of lava flows are relevant factors in determining the volcanic hazard. The example here proposed provides new clues to consider more sources of risk also for basaltic volcanoes.

Keywords: hazard, gas exsolution, lava viscosity

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VS005 **Oral Presentation** **6700**

Integrated monitoring of magma accumulation and CO2 degassing at Izu-Oshima Volcano, Japan: towards mid-term prediction of future eruptions

Prof. Hidefumi Watanabe
Earthquake Research Institute University of Tokyo IAVCEI

In order to conduct mid-term prediction of eruptions, we need to clarify precursory processes: especially, magma accumulation and the way of magma achievement of the conditions to start rising up toward eruption. We have detected the secular re-inflation of Izu-Oshima volcano since 1989 after the last eruption in 1986-87, and further revealed that the volcano has repeated inflation-deflation cycles resulting a net inflation and the accelerated inflation has been accompanied by the elevation of shallow seismic activity in the caldera region. We naturally suppose that the volcano inflation is caused by the supply of magma from depth. However, what is the origin of the deflation? There are two possible processes causing the deflation; magma drain back and the contraction of accumulated 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. Consequently, the intensive observation of inflation-deflation cycles might give us an invaluable clue to understand the precursory processes. To monitor the degassing of basaltic magma accumulating beneath the volcano, CO_2 is most helpful because CO_2 has a low solubility in magma and separates from melt at the earliest stage of accumulation. On 28 September 2005, we started continuous monitoring of soil CO_2 concentration at the eastern part of the summit of the central cone Mt. Mihara of Izu- Oshima volcano. Measured data are stored every 5 minutes in a logger and accessed via radio LAN system. All the instruments are powered by solar battery. We further surveyed the distribution of soil CO_2 concentration around the summit area, and installed another continuous measurement system in December 2006 at the western part of the summit. The CO_2 concentration data showed temporal variations in the range of 0.1-2.8vol% and the following features. 1) Soil CO_2 concentration sometimes increased with duration of several hours to days. 2) Decrease of 1m-depth temperature followed that of soil CO_2 concentration with delay of several hours, suggesting that both the soil CO_2 and high temperature fumaroles are fed by volcanic gas emanating from depths. 3) There occurred several correlated increase of the soil CO_2 concentration and the seismic activity in the caldera. 4) There occurred peculiar seismic events (with a predominant frequency of about 1Hz) originating from very shallow depths beneath the summit in the period of elevated CO_2 concentration. These low frequency events might be generated by rapid flow of volcanic gas beneath the summit. We will further elucidate the magma accumulation and degassing processes beneath Izu-Oshima volcano by integrating ground deformation, seismic activity, and changes in magnetization, electrical resistivity and CO_2 concentration beneath the summit.

Keywords: eruption prediction, magma accumulation, co2 degassing

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VS005 **Oral Presentation** **6701**

The impact of the plumbing-system geometry on gas segregation and passive degassing in basaltic volcanoes

Dr. Thierry Menand
Earth Sciences Univeristy of Bristol IAVCEI

Jeremy C. Phillips

Like many other basaltic volcanoes, Mount Etna and Stromboli volcano in Italy emit substantial amounts of gas over long periods of time while erupting relatively little degassed lava, implying that gas segregation must have occurred in the magma feeding system. The geometry and degree of connectivity of this plumbing system control the movement of magma in that system and could therefore provide an important control on gas segregation in basaltic magmas. Gas segregation has been investigated using analogue experiments and analytical modelling in a simple geometry consisting of a vertical conduit connected to a horizontal intrusion. Our investigation shows that non-vertical elements of the plumbing systems act as strong gas segregators. The presence of exsolved bubbles induces a buoyancy-driven exchange flow between the conduit and the intrusion that leads to gas segregation. Bubbles segregate from the fluid by rising and accumulating as foam at the top of the intrusion, coupled with the accumulation of denser degassed fluid at the base of the intrusion. Steady-state influx of bubbly fluid from the conduit into the intrusion is balanced by outward flux of lighter foam and denser degassed fluid. The length and time scales of this gas segregation are controlled by the rise of bubbles in the horizontal intrusion. These gas segregation processes are shown to be effective in bubbly fluid containing up to 40% gas bubbles by volume. Comparison of the gas segregation time scale with that of the cooling and solidification of the intrusion suggests that gas segregation is more efficient in sills than in horizontally-propagating dykes, and that this process could be efficient in intermediate as well as basaltic magmas. Gas segregation also provides an important control on generation of gas-rich and gas-poor magmas at persistently active basaltic volcanoes. For low magma supply rates, very efficient gas segregation is expected, which induces episodic degassing activity that erupts relatively gas-poor magmas. For higher magma supply rates, gas segregation is expected to be less effective, which leads to stronger explosions that erupt gas-rich as well as gas-poor magmas. These general physical principles can be applied to persistently-active basaltic volcanoes, and in the case of Stromboli volcano are shown to be consistent with independent field data. Observations of gas segregation at Stromboli can be explained by the presence of a shallow reservoir of sill-like geometry at 3.5 km depth with exsolved gas bubbles 0.1-1 mm in diameter. Transition between eruptions of gas-poor, high crystallinity magmas and violent explosions that erupt gas-rich, low crystallinity magmas are calculated to occur at a critical magma supply rate of 0.1-1 m3 s-1.

Keywords: gas segregation, plumbing system, passive degassing

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VS005 **Oral Presentation** **6702**

The dykes swarm of MT. Calanna as an example of coherent intrusion complex within the alkaline sequence of MT. Etna Volcano (Italy)

Dr. Carmelo Ferlito
Scienze Geologiche Universit di Catania IAVCEI

Eugenio Nicotra

Dimensions and geometry of magma reservoirs for an open conduit basaltic volcano such as Mt. Etna still constitute unanswered questions. Connected to shallow resident reservoirs are the sub-volcanic bodies, whose presence and role in the Etnean area have been in the past overlooked. These bodies, commonly present in the deeply eroded roots of many volcanic edifices characterized by basic volcanism, can provide a substantial amount of information on the upper part of the feeding system of the volcano, as well as on the tensile regime in the volcanic region. A dykes swarm formed by a high number of concentrated, sub-parallel, intrusive planar bodies, defines a coherent intrusion complex (CIC). Such complexes represent the uppermost part of shallow magma chambers and, more in general, of the volcano feeding system. Data from seismological tomography as well as gravimetric and magnetic anomalies from the Etnean area, indicate the presence of a high velocity level interpreted as the remains of ancient magma bodies intruded at crustal levels beneath the south-eastern sector of Mt. Etna. A new geological survey in Val Calanna has brought to the definition of the stratigraphic sequence cropping out in the south-eastern sector of the Mt. Etna volcano. In particular, structural survey and petrochemical data from the rocks of Mt. Calanna, provide evidence that its main frame constitutes a coherent intrusion complex formed by at least two hundreds sub-volcanic planar intrusions that can be considered as a portion of a magmatic plexus that fed the eruptive activity of one (or more) ancient alkaline centers. The analyses performed on the orientation and dip of both dykes and tensile structures within the CIC, indicate the existence of three groups with different intrusion orientation. These changes can be caused by modifications of the local stress fields due either to slight rotation of the regional tectonic regime or, in alternative, by a response to the growth of the volcanic edifice. The implications of our findings are quite important in establishing the geometry of the Etnean plumbing system that, at least in the past, concentrated at relatively shallow depths a high number of feeding structures.

Keywords: dykes swarm, etna, structural survey

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VS005 **Oral Presentation** **6703**

Infrasonic Tremor Variability from Pu'u O'o, Hawaii

Dr. Milton Garces
Infrasound Laboratory University of Hawaii, Manoa IAVCEI

David Fee, Robin Matoza, Michael Hedlin

Infrasound signals from Kilauea volcano provide a unique opportunity to investigate volcanic acoustic source processes in an active basaltic volcano. The Pu'u O'o crater complex, the active section of Kilauea Volcano, Hawaii, has experienced continuous effusion and degassing since 1992. Although infrasonic emissions from Pu'u O'o were discovered only in 2002, it is very likely thatitsfeedingsystemhas been radiating subaudible sound for decades. Acoustic excitation of magma and gas-filled conduits and lava tubes are hypothesized to produce near continuous infrasonic tremor. To capture the sounds from the ongoing activity at Pu'u O'o, a 4-element infrasound array was deployed in October of 2006 within a dense tropical forest ~12.5 km away from the crater. Infrasonic and meteorological data is transmitted from the array in real-time, with results being displayed on a dedicated website.An abundance of acoustic tremor signals has thus far been recorded. Although the tremor is assumed to be constant at Pu'u O'o, recordings of the tremor exhibit significant temporal changes. Some of the variability appears to be due to acoustic propagation effects created by changing atmospheric conditions, particularly diurnal wind changes. Although local meteorological data is not representative of regional wind patterns, low frequency (<.3 Hz) infrasonic amplitudes can be used as a proxy. Harmonic and gliding tremor have also been observed. Changes in gas content, mass flux, and conduit geometry may be partly responsible for tremor variability. Gas pistoning events are also be potential sources of deep infrasound. To further examine the tremor signals at Pu'u O'o, we want to study the relationship between the infrasound and seismic, gas, deformation, and meteorological data. Preliminary comparisons with seismic data suggest that the infrasonic signals may have a different source process. An expedition to install an infrasound array closer to the vent and perpendicular to the lava tube system is planned for Spring of 2007. These new results may permit a better identification and characterization of the volcanic processes producing infrasound.

Keywords: infrasound, volcano, hawaii

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VS005 **Oral Presentation** **6704**

Extremely Long Period Oscillations Observed by Tiltmeters at Miyakejima Volcano, Japan

Dr. Hideki Ueda
Volcano Research Department NIED IAVCEI

Motoo Ukawa, Eisuke Fujita, Eiji Yamamoto

Extremely long period (ELP) oscillation had been observed during 2002-2005 by borehole tiltmeters at Miyakejima Island, which is a basaltic volcano located about 170 km to the south of Tokyo, Japan. Miyakejima has been continuously emitting a large amount of SO_2 gas from the summit crater with a rate of several thousand tons per day since 2000. The oscillation exhibits a sinusoidal wave train with an extremely long period of 20 -60 minutes and was observed at all five stations and fully synchronized each other. The amplitude of the oscillation (less than 5 nrad) is very stable, sustaining for several days. Their polarization directions and amplitudes variation indicate a periodic expansion and contraction of the island caused by a periodic pressure change of a magma chamber at the western part of the island 5-10 km deep , which was modeled from crustal deformation data by Ueda et al.(2004, AGU fall meeting). The commencements of ELP oscillation in the many cases had been coincident with the high activity of the shallow seismicity (<3km) inside of the summit caldera until an active period of July and August 2005. Although no significant change was observed in the earthquake activities, the ELP oscillation weakened in September and quieted down after November 2005. After 2006, the gas emission rate decreased to less than 3000 t/day. The oscillation that has an extremely long period and a single peak spectrum without overtones is reasonably explained by Helmholtz resonance of a magma system proposed by Ueda et al. (2005, the Meeting of Volcanological Society of Japan). The magma system is composed of the magma chamber and a conduit that connects the summit caldera to the magma chamber, causing a sinusoidal wave train with a single predominant period as observed. The load of magma in the conduit and the repulsion of magma oscillate the magma head and the pressure of the magma chamber, being similar to a simple mass-spring system. Since the ELP oscillation is very stable, a continuous bubble formation in the conduit probably continuously stimulates the oscillation of the magma head.

Keywords: miyakejima, long period oscillation, tiltmeter

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VS005 **Oral Presentation** **6705**

A fluid mechanical model of the evolution of sulphur, chlorine and fluorine ratios from passively degassing volcanoes.

Mr. Fred Witham
Earth Sciences University of Bristol IAVCEI

Jeremy C. Phillips, R. Steve J. Sparks

Many persistently degassing volcanoes require a constant source of magma to shallow levels in order to exsolve volatiles and maintain the flux of gasses observed at the surface. If no magma is erupted, the denser, degassed magma must be returned to a reservoir at depth. We have developed a fluid mechanical model of a negatively buoyant, turbulent plume of degassed material returning to a convecting magma chamber. End-member regimes of the model are: a) At high convective velocities, degassed material is uniformly mixed into the reservoir b) At low convective velocities, degassed material pools at the base, giving a reservoir that is zoned in volatile contents. Volatile (S, Cl, F) contents for degassed and primitive magmas are taken from the literature. From these, the evolution of S/Cl and Cl/F ratios can predicted for given conduit and reservoir convective velocities. We predict that S/Cl and Cl/F ratios decrease with time. Uniformly mixed reservoirs produce gas ratios that decrease at a decreasing rate with time, whereas zoned reservoirs produce gas ratios that decrease at an increasing rate, or decrease in a stepwise manner, with time. We compare the predictions of the model to field observations from Etna and other persistently degassing volcanoes. S/Cl and Cl/F ratios tend to decrease as a degassing event progresses. Observations from Etna, Stromboli and Montserrat best fit a zoned reservoir model with convective velocities of order 1 cm s-1 - in agreement with previous fluid dynamical scaling constraints on convective velocity scales. Whilst the published record of the time-evolution of gas ratios from persistently degassing volcanoes is improving rapidly, we highlight the need for observations with a finer temporal resolution than is often achieved at present. Detailed studies of degassing in its persistent state, as opposed to during or following an eruption, would enhance the comparison of field and modelled gas data.

Keywords: degassing, model, ratio

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VS005 **Oral Presentation** **6706**

Eruptions, Deformation, Seismicity and the Magma Feeding System of the Giant Basaltic Klyuchevskoy Volcano, Kamchatka

Prof. Sergei Fedotov
IAVCEI

N.A. Zharinov

The basaltic Klyuchevskoy volcano is the largest and the most productive volcano of the Kuril-Kamchatka volcanic belt. This stratovolcano is about 6000 years old 4750 m high and persistently active. 11 summit and more than 17 adventive eruptions were in 1932-2005. The average magma production rate equals 60*106 t of basalt per year. 1/3 - 1/2 of its products including 90% of pyroclastic material and volcanic gases are erupted from the changing 750 m wide summit crater. It was completely filled after moderate eruptions and was 500 m and more deep after paroxismal ones. 1/2 - 2/3 of volcano products appear from fissures and craters of its adventive lava eruptions. Results of 1986-2005 studies of eruptions, deformations, seismicity and properties of its magma feeding system are considered. The steady rise of adventive eruptions and radial fissures from the base of volcano at altitude 450 m to the summit crater at altitude 4750 m took place during 1932-1990. The upper part of the cone was not destroyed by continuous final eruptions in 1986-1990 but only summit crater eruptions and collapses were observed since that in 1991-2005. The magma feeding system of the Klyuchevskoy volcano is divided into 5 parts. The deep source of energy, fluids and melts is located near to upper boundary of subducting plate at depth about 160 km. Magma origin and rise in magma columns occur in asthenosphere at depths 160-40 km beneath volcano. Rising deep magmas are accumulated in intermediate magma chamber located in the crust-mantle layer at depths 40-20 km. Many small low-frequency earthquakes are observed here. The next part is a vertical continuous magma conduit in the crust at depths 20-5 km. Magma rises along it to the upper part of the feeding system located above the depth 5 km in sediment layers and the volcano basement. Here are many earthquakes and a source of numerous radial dikes, magmas and volcanic gases of adventive and summit eruptions.

Keywords: klyuchevskoy, feeding, system

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VS005 **Oral Presentation** **6707**

Dynamics of magma in the shallow plumbing system of MT. Etna Volcano: inferences from a decade of petrologic data

Dr. Rosa Anna Corsaro
ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA SEZIONE DI CATANIA IAVCEI

Lucia Miraglia

During the last decades, the understanding of Mount Etnas plumbing system has greatly benefited from geophysical, volcan ological, geochemical an d petrol ogic data. In par ticular, petrologic data have revealed that Etnean magmas differentiate for the in terplay of processes such as cr ystal fractionation, mixing, interaction with crustal and mantle-derived fluids occurring from the sedimentary basement up to the summit conduit region.Here, we investigate the dynamics and pr ocesses of magma residing in the shallow portion of the plumbing system, from 5 km b.s.l. up to the surface. To this end, we selected specific eruptions occurring fr om the end of th e 1992-93 eruption up to 2006. The selected events comprise a broad spectrum of volcanological features such as flank and/or summit eruptions, explosive and/or effusive activity, Strombolian explosions and/or sustained fire-fountaining episodes etc.Lava and tephra erupted during these eruptions have been st udied for their petrol ogic features. We reassessed data already published in lite rature and obtained ne w information on petrography, mineral chemistry, major, trace e lements, Sr/Nd isot opes of th e bulk rock and glass composition. The analysis of these data allowed identifying and q uantifying the main processes modifying ma gma composition. Furthermore, we modelled paths of crystallization of magmas in intra-telluric conditions by using MELTS numerical code and simulating different compositions, volatiles content and temperat ures of magma at various lithost atic pressures.Our re sults highlight that all magma residing and differ entiating in the shallow Etnean plumbing s ystem after the 1992-93 eruption to date, shar e a K-affinity, enrichment in Rb and Sr isotopic ratio with respect to magmas erupted pre-1970 at Etna. This uniform compositional imprint is inherited from processes occurring at gr eater depth. Notwi thstanding this homogeneity, w e observe a fairly scattered distributi on in modal mineralogy, major , trace elements, Sr-Nd isotopic ratios and glass composition of the analyzed rocks. Most of these petrologic features result from the complex interplay of the magmatic processes that we mode lled, which take place in the uppermost part th e shallow plumbing system, ins ide the volcanic pile or at the interface with the sedimentary basement. Here, there is a complex net work of d ikes and magma p ockets. They are often comp ositionally and thermally zoned and refilled by magmatic input fr om d epth, thereby making the central conduit plumbing system particularly hetero geneous. It is als o n oteworthy that the dynamics affecting the eastern flank of the volcano proved to ha ve an im portant role in triggering and controlling recent volcanic events.

Keywords: petrology, magma differentiation, plumbing system

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VS005 **Oral Presentation** **6708**

Insights into the shallow magma reservoir at Etna (Italy) from the 1989, 1995-1996, 1998-1999, 2000 and 2001 eruptions

Dr. Sylvie Vergniolle
Institut de Physique du Globe de Paris IPGP IAVCEI

The 2001 eruption of Etna volcano is marked by 16 eruptive episodes, lasting from 4 to 7 hours and separated by a few days. Each episode shows a series of Strombolian explosions, which may lead to a fire fountain at the vent. Insights into fire fountain formation is provided by a close comparison of the sound produced by an episode leading to a fire fountain (July 12) with one solely with a series of Strombolian explosions (July 4). The strong similarity between both episodes, both in the number of explosions and in the bubble characteristics, suggests that strombolian explosions and fire fountain have the same origin. Hence a fire fountain at Etna corresponds to an inner gas jet, formed in the reservoir by the coalescence of a foam layer trapped at the top of the reservoir. That foam has been accumulated over the few days separating each episode. Therefore, the increase in the number of explosions and in bubble length, observed on July 12, is the consequence of a more active foam coalescence than on July 4. A value of 1.2 is used for the dimensionless foam height, as being characteristic of the strombolian activity of July 4. When combining it with the gas flux, the bubble diameter at the top of the reservoir is found to be 0.71 mm. If we suppose that all the erupted gas volume results from the entire gas volume trapped in the foam at the top of the reservoir, its area is 0.06 km2. The gas volume fraction is estimated at 1.0 %, from its relationship with gas flux and bubble diameter. A gas flux, 1.6 times larger on July 12 than on July 4, is explained by an increase in the bubble diameter, at 0.90 mm. That leads to a dimensionless foam height of 2.0 on July 12, indeed the mark of a more active foam coalescence than on July 4. The recent series of eruptions, have shown a cyclicity between quasi-fire fountain episodes, such as during the 1989, 1995-1996, 1998-1999, 2000 and 2001 eruptions. Visual observations of the surface activity have been used to estimate the gas flux in the reservoir. While some eruptions show a decrease in time of the gas flux, other eruptions have a fairly constant gas flux. Surface activity combined with gas flux at depth gives constraints on the bubble diameter and gas volume fraction in the shallow reservoir for each eruption. If the duration of the eruption is related to a progressive depletion in the gas content trapped within the shallow magma reservoir, the height of the degassing reservoir can be estimated from the bubble diameter to be between 30 m (1989) and 120 m (2000).

Keywords: fire fountain, eruption mechanism, etna

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VS005 **Oral Presentation** **6709**

Tracking of degassing pathways in the COHS-silicate melt helps to understand phenomena leading towards either high- or low-energy eruptions at Mt. Etna

Dr. Roberto Moretti

Barbara Gambardella, Luigi Marini, Nicole Mtrich, Paolo Papale, Johannes C. Hunziker

At Mt. Etna, high-energy Plinian eruptions took place in the past (e.g., 122 BC), and still represent the major volcanic threat for the town of Catania and its surroundings. By investigating the H2O-CO2-SO2-H2S-silicate melt system, we could track the pathlines of magmatic degassing and give insights into the phenomena determining the evolution of volcanic activity towards either high- or low-energy eruptions. Thermodynamic modeling of liquid-gas properties allowed us to describe gas evolution up to surface under various conditions as long as information was provided in order to estimate a) the redox buffer holding over the PTX range of interest, b) the bulk composition, including total (dissolved+exsolved) volatile contents, c) indicators for closed vs. open system degassing. The results we present give further insights into the deep-roots features of the magmatic feeding system, and confirm the large amount of carbon dioxide that have been already found in the literature. We compared the information retrieved from melt inclusions of the 122 BC plinian event to those from more recent eruptions (e.g. February 1999). From a volatile point of view, the deeper part of the plumbing system shows almost unchanged chemical and thermobarometric features. However, the focus on the conjugated chemical and isotopic features of sulfur allowed us to investigate the differing sulfur degassing patterns drawn by these two eruptions. It seems that elucidating the processes controlling S chemistry during the evolution of Etna magmas, from classic Strombolian or fire-fountain based activity to plinian eruptions may provide useful indications to discriminate the evolution to either high or low-energy eruptions.

Keywords: volatiles, sulfur, redox

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VS005 **Oral Presentation** **6710**

Ground deformation preceding and following the 2004-2005 eruption at MT. Etna, from GPS and DINSAR data

Dr. Alessandro Bonforte
Sezione di Catania Istituto Nazionale di Geofisica e Vulcanologia IAVCEI

Alessandro Bonaccorso, Francesco Guglielmino, Mimmo Palano, Giuseppe Puglisi

GPS networks, surveyed in 2003 and in 2004, evidenced very intense ground deformation patterns after the 2002-03 eruption, especially on the eastern flank of the volcano, even in absence of any volcanic activity. A pressurizing point source was located at about 3 km b.s.l., beneath the summit craters area, by inverting GPS vectors measured from July 2003 to July 2004. Suddenly, an eruption started on September 7, 2004 on the upper south-eastern part of the volcano. The eruption onset was completely silent in the sense that there was no volcanic activity at the summit craters, no significant gas emission, no seismic tremor or seismicity both on the days before and during the fracture propagation and lastly, no appreciable tilt variations which are usually observed in intrusion processes. The appearance of the magma at the surface was due to its passive intrusion in the shallow part of the volcanic pile, induced from the exceptional extension on the summit area that GPS and DInSAR data revealed; this unusual deformation was caused by the high sliding rate of the eastern flank of the volcano induced by the big intrusion occurring in 2002 along the north-east rift zone. The eruption lasted until March 12, 2005. During the eruption, a marked deflation of Mt. Etna volcano was measured by GPS surveys. The modelling of GPS data encompassing the eruption (from the 2004 to the 2005 surveys) defines a sill-shaped source located at a depth of about 4 km b.s.l. beneath the upper south-eastern flank of the volcano. This result testifies that the emptying of the shallow magma reservoir, which fed the 2004-2005 vents (at least at the early stages of the eruption), caused also a drainage of a deeper magma reservoir. From the 2005 GPS survey to the 2006 one, the volcano restarted to inflate, showing an opposing ground deformation pattern to that detected during the 2004-2005 eruption. A vertically elongated pressurizing source was located by GPS data inversion at a depth of about 3 km b.s.l. The goodness of this model has been tested also by producing the corresponding synthetic interferogram which was compared with the real DInSAR data available for the same period. The inflation source is shallower than the deflation one (detected during the 2004-2005 eruption), being very close to the point pressure source detected from ground deformation data during the year preceding the 2004-05 eruption. The modelling of the inflation measured for the 2005-2006 time interval indicates a refilling of the plumbing system of the volcano by magma upraising from depth. In fact, the ellipsoidal pressurization source is vertically elongated and well reproduces a vertical conduit from the western side of the high Vp body detected by seismic tomography towards the upper part of the volcano.

Keywords: etna, ground deformation, modelling

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VS005 **Oral Presentation** **6711**

From the sound of erta Ale Lava Lake (Ethiopia) to eruption dynamics into a magma reservoir

Mrs. Emmanuella Bouche
Laboratoire de Dynamique des Fluides Gologiques Institut de Physique du Globe de Paris
IAVCEI

Sylvie Vergniolle

The basaltic volcano of Erta Ale, located on the East African Rift, has a permanent lava lake whose behaviour presents similarity with a shallow magma reservoir. In March 2003, continuous measurements of acoustic pressure, images from video, temperature, seismicity, and wind velocity, were perfomed to understand the eruptive behaviour of this volcano. The videos show that two types of gas bubbles break at the lave lake surface. Modelling acoustic pressure gives bubble overpressure and size. Bubbles are either large (radius 2 m) and overpressurised (40000 Pa) or of intermediate size (radius 1 m) and weakly overpressurised (450 Pa). The large bubbles come from the conduit at the base of the lava lake whereas bubbles of intermediate size are produced by the destabilisation of a foam accumulated below the crust overlying the lava lake. Hence, their overpressure is related to capillary pressure of the rising small bubbles, suggesting that their diameter is 3.6 mm. The formation of bubbles of intermediate size is related to the local foam coalescence because of foam sluggish drainage. However, overpressure shows sudden peaks every eighteen hours, up to 6000 Pa. Each peak is related to a massive coalescence of a foam having reached a critical thickness of 6 cm. This involves a much larger number of bubbles than foam drainage, hence a much larger overpressure. The rapid and massive coalescence leads to a sudden withdrawal of the foam. The disappearence of the foam suppress the buoyancy that sustained the cold and dense crust at the top of the lava lake, forcing the crust to sink. The average gas flux (6.10-3 m3s-1) is estimated over an eighteen-hour cycle from modelling the frequency of sound waves. Furthermore the diameter of the small bubbles deduced from the overpressure on synthetic waveforms can be combined with gas volume fraction observed on videos to estimate the gas flux between 3.5.10-3 m3s-1 and 7.10-3 m3s-1. The excellent agreement between these two independant methods reinforces the validity of our approach.

Keywords: erta ale, acoustic measurements, lava lake

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VS005 **Oral Presentation** **6712**

Why do deep magma reservoirs accommodate more magma than shallow magma chambers? Accommodation of magma by ductile flow of Icelands lower crust

Dr. Freysteinn Sigmundsson
Nordic Volcanological Centre University of Iceland IAVCEI

Basaltic volcanism in Iceland i s episodic. Rift-zone volcanoes in along the divergent boundary between the North- Amercian and Eu rasian plates may show pe rsistent magm atic activity over a dec ade, separated by dormancy periods over centuries. An example is the most recent major rifting episode in in 1975-1984, at the Krafla volcano in Northern Iceland. Continuous inflow of magma towards a s hallow magma chamber at 3 km depth occurred throughout th e rifting episode , punctuated by diking event s and eruptions that temporaril y lowered the pressure in the magma chamber and caused subsidence. The inflow to the shallow magma cham ber can be attr ibuted to flow from a deeper s ource of much larger volume, through a relatively narrow channel between the chambers. The deeper magma chamber appears to have been able do accommodate much larger volume than the shallow chamber prior to the rifting episode. So is the case for a number of other volcanic events in Iceland; deep magma reservoirs appear to be able to accommodate more magma tha n s hallow ones. It is suggested that rheological response of the magma chambers surroundings is influential. Deep magma chamber in the ductile lower crust below the uppermost elastic li thosphere can accommodate large volume of magma by ductile yielding of hos t rock, if excess pressure in these re servoirs is sustained over long periods. Upwell ing from the mantl e with certain excess pressure can only inflate a ma gma chamber to a certain extent, if elastic rheolog y dominates, as is the cas e fo r s hallow m agma ch ambers. For deep ones, ductile response of the host rock is inevitable. Ma gma upwelling from the mantle may s ustain about e ven excess pressure in a deep magma chamber as it yields in a viscoelastic manner. Assuming this case and the simplest Maxwell visco elastic material model (one dimensio nal), the ratio o f visco us versus immediate elastic strain will s cale by the ratio of elas tic rigidity and viscosity, multiplied by the duration of the assume d constant excess pressure (s ustained by m agma upwelling). Recent crustal defo rmation studies in Iceland suggest ri gidity of about 40 GP a, and viscosity of about 5x1018 Pa s. For these values, the simple model would predict s train due to vis cous flow of a bout equ al magn itude as th e elastic, if durat ion of excess pressure is ab out 10 ye ars. For lon ger du ration of overpr essure or lowe r viscosity, this r atio can be m uch larger. Strain in ho st rock due to viscous flow w ill ad d to the elasti c strain and create additional s pace for magma accumulation. Therefore deep magma chambers collect more magma than s hallow ones. Such rheological control of magma storage capacity is suggested for basaltic volcanic systems in general.

Keywords: magma chamber, viscoelastic rheology, magma flow

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VS005 **Oral Presentation** **6713**

The magma plumbing system of Mount Etna: update from a three decade perspective.

Dr. Patrick Allard
Earth Sciences CNRS IAVCEI

We propose an updated ass essment of Etna magm a plu mbing system, taking acco unt o f abundan t petrologic, geochemical and geophysical da ta that were gathered over the last thre e decades. The major event in this period was a mantle-derived pu lse of new, more alkaline volatile-rich basaltic magma that i nvaded the i ntermediate to shallow plumbi ng system (≤15 km depth below summit craters) at a mean rate ~3.7 m3 s-1, triggering enhanced eruptive activity and lava extrusion. This new magma differs from all trachy- basaltic prod ucts erup ted i n previo us cen turies by ha ving higher K2 O content, higher Rb/Th, K2O/Cl and S/Cl ra tios, an d more radiogen ic S r an d B is otope ratios. T hese features are recorded by melt inclusions entrapped at ≥400 MPa (≥12 km) in Mg-rich olivine crystals, so they canno t re sult fro m crustal co ntaminations in the sha llower sedimen tary basement ; instead, they track recent p artial melting of a geochemi cally dist inct po rtion of the mantle so urce. The new feeding magma could reach the s urface almost unmixed for the first time during a brief eccentric eruption in 1974, then du ring powerful summit lava f ountains (1998-2000) and, more vo luminously, during two highly explosive flank eruptions in 2 001 and 2002. It s dir ect extrusion was made pos sible either by lateral dyke intrusions that bypassed the central co nduit system and/o r by fast a scent across this system. Otherwise, the new magma grad ually mixed wi th and replaced t he alkali-poorer trachybasalts previously filling the plumbing system , as demonstrated by the spectacular evolution of alkalis/Th ratios versus Th in lavas erupted since the early se venties. From this mixing trend, the cumulati ve amounts of erupted lava, a nd SO2 constr aints on the de gassed/erupted magma ratio, we re-evaluate as ~3.5 km3 the overall magma storage capacity of the intermed iate to shallo w plu mbing system o fMount Etna . Molten magma wo uld thus o ccupy a tiny volumetric fraction (3) plutonic body that is e mplaced within the ~10 km thick sedimenta ry basement. Concordant info rmation fro m seismic to mography, gro und deformations and crystal melt inclusions suggest that two magma ponding zones exist at ~132 and ~53 km beneath the craters, in coincidence with two majo r lithologic discontinuities in the crustal basement. Continuous degassing but dis continuous extrusio n of the evolving magma mixture has been regulated by the shallowest ponding zone, where partial magm a dehydration and crystallisation due to deep CO2-flushing o ccurs. This po nding zo ne is also the ma in so urce o f pre- eruptive seismicity and gro und deformation. A t the interface between the volcanic pile and the sedim entary baseme nt (2-2.5 km depth), a network of sills and dykes, connec ted to central volcanic conduits ~25 m wide, may exert an important control on magma degassing and the genesis of seismic tremor. Over 30 years, only 25-30% of the cumulat ed supplied m agma were e ventually ext ruded. Most of the uner upted, d enser degas sed magma was likely drained back into sub-v olcano feed ers, co ntributing to solid accretio n and stress accumulation in the plutonic body, as well as to enhanced instability of the eastern volcano flank.

Keywords: magma, plumbing, system

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VS005 **Oral Presentation** **6714**

The magma feeding system of the persistent present-day activity of Stromboli Volcano, Italy: Inferences from micro-analytical Sr-Isotope and trace element data

Prof. Lorella Francalanci
Dipartimento di Scienze della Terra Universit degli Studi di Firenze IAVCEI

Isabella Nardini, Massimo Tiepolo, Riccardo Avanzinelli, Patrizia Landi, Mauro Rosi

The steady-state activity of Stromboli has been characterised by persistent mild explosive eruptions over the last several hundred years. Periodically, lava flows and paroxysms interrupt the normal activity, as it occurred during the 2002-2003 eruptive crisis which broke a phase of intense Strombolian activity. This consisted of a lava flow (from 28-December-2002 to 22-July-2003), a landslide into the sea causing a tsunami and a paroxysm (on 5-April-2003). The last effusive event, with lavas flowing down along the NE part of the Sciara del Fuoco into the sea, started on 27-February-2007 and it is presently going on. A degassed and highly porphyritic magma (crystal-rich magma), with a basaltic shoshonitic composition, is erupted by the normal activity and by the lava flows, whereas a slightly more mafic and volatile-rich magma with low phenocryst content (crystal-poor magma) and lower Sr isotope ratios is also erupted as pumices by paroxysms. Magmas with intermediate petrochemical and isotopic characteristics are sometimes erupted by more energetic Strombolian explosions, as it occurs on 9-January-2005.The different products (scoria and pumice bombs, lithics and lavas) erupted during the last few years have been analysed by the usual mineralogical and petrochemical methods. In addition, in-situ trace element and Sr isotope microanalyses on plagioclase, clinopyroxene and glassy groundmasses have been performed on a selected number of samples, including those of the 2002-2003 eruptive crisis.87Sr/86Sr values of 2002 lavas are mostly similar to those of 2001 scoria (ca. 0.70616), but in the groundmass of November-2002 scoriae 87Sr/86Sr values are slightly lower, leading to hypothesise a higher supply rate of the shallow magmatic system before the onset of the 2002 lava flow. Indeed, lower 87Sr/86Sr values (ca. 0.70611) still persist in the crystal-poor magma of 5-April paroxysm which is considered to represent the refreshing magma of the shallower crystal-poor magma reservoir. Mineral phasess show the largest Sr isotope variations (0.706401 0.705966), with the highest values usually found in the cores. 87Sr/86Sr of rims is often higher than the groundmass values, especially in lavas erupted after 5-April-2003 paroxysm.These results suggest that the shallow reservoir feeding the Strombolian activity and lava flows is still maintained in steady-state conditions. The fast system perturbations (paroxysms) caused by the refilling with fresh crystal-poor magmas are recovered quite quickly by efficient mixing processes, although magmas with intermediate compositions are sometimes erupted. The complex chemical and isotopic zoning of the phenocryst indicates processes of crystal recycling and variably efficient degassing, both correlated with new magma supply.

Keywords: stromboli, petrochemical data, sr isotopes

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VS005 **Oral Presentation** **6715**

Reconciling deformation and degassing at Mt. Etna

Dr. Michael Burton
UFVG INGV

Patrick Allard

In this work we attempt to reconcile ground deformation and magma degassing observations at Mt. Etna by posing the question: are the volumes of endogenously stored magma implied by SO2 flux measurements consistent with the depth and magnitude of ground deformation? The period between 1993- June 2001 was characterised by the absence of flank eruptions, and is therefore chosen as the test period. In the following we present both datasets for that time period, and then in our discussion examine if reasonable parameterisations of (i) compressibility of magma; (ii) the integrated bulk modulus of the medium between the deformation source and the surface; (iii) the geometry of the deformation source, can unify our observations in a single model. We then examine the implications of this analysis, with particular focus on the sources of deflation during eruptive episodes.

Keywords: etna, degassing, deformation

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VS005 **Oral Presentation** **6716**

Inflation of Mount Etna from 1993 to 2000: source inference based on 3D finite element modeling

Dr. Carlo Giunchi
Sismologia & Tettonofisica Istituto Nazionale di Geofisica e Vulcanologia

Elisa Trasatti, Spina Cianetti, Giuseppe Puglisi, Alessandro Bonaccorso

The study of the inflation process occurred in Mount Etna from1993 to 2000 is useful to understand both geometry and locationof the deep reservoir. Our aim is toconstrain the inflation source combining together geodetic data recorded with different techniques(GPS, EDM and I nSar) and performing inversions based on a nonlineardirect search of the parameters space.Displacements are computed by a 3D finite element techniquewhich provides equivalence betweena single element subject to prescribed traction on its faces and the deformation of a 3D ellipsoidal cavity dilating under constant internal pressure.The model allows to take into account heterogeneous rigidity inside Mount Etnaand the real topographic relief. The direct search is performed using the Neighborhood Algorithm followed by an appraisal of the sampled solutions. We compare sources inferred for different periods of almost pure inflation (like 1993-1997 and 1998-2000) and we discuss the role of simplified sliding mechanisms occurring in the SE flank.

Keywords: inflation, 3d finite element modeling, mount etna

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VS005 **Oral Presentation** **6717**

The shape and extension of Stromboli magma chamber in the light of fine thermobarometry

Dr. Corrado Cigolini
DSMP Univerity of Turin IAVCEI

Lavas and scorias erupted during the last effusive cycle of Stromboli exhibit nearly identical bulk, minerochemical and glass compositions. Golden pumices erupted during the explosive phase of April 5, 2003 show a lower degree of crystallinity (less than 10% modal) and a slightly more primitive compositions typical of a high-K basalt. Besides minor microphenocrysts of olivine, clinopyroxene and to a lesser extent of plagioclase, most of the crystals were inherited from interaction of this primitive component with the overlaying degassed crystal-rich magma (responsible for the origin of lavas and scorias). Thermobarometric estimates obtained by constructing a grid of selected reactions (involving crystal-melt-gas equilibria), indicate that Stromboli magma equilibrate at 290 -150 MPa and temperatures of 1200-1100 C. Then, it progressively undergoes decompression and degas before being erupted. In the light of these estimates, we evaluated the possible shapes and volumes of Stromboli magma chamber by considering a sphere, an ellipsoid (geometrically concordant with the regional stress distribution) as well as a feeder dike. The latter two models seems to be a better fit for the Stromboli upper reservoir.

Keywords: thermobarometry, magma chamber, degassing

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VS005 **Oral Presentation** **6718**

Magma intrusion and gravitational spreading of the Hawaiian volcanoes: New constraints from 9 years of InSAR data

Prof. Falk Amelung
Marine Geology and Geophysics University of Miami IAVCEI

The Hawaiian volcanoes are among the most active volcanoes in the world and actively deforming by a combination of magma intrusion and gravitational spreading. We present new constraints on why and how the volcanoes deform using geodetic data derived from satellite radar interferometry.For Mauna Loa it was not known how the spreading is accommodated in the lower part of the volcanic edifice. We present evidence from 2002-2005 InSAR data for secular inflation of a dike-like magma body at intermediate depth in the southwest rift zone. Magma accumulation occurs in a section of the rift zone which was unclamped by previous dikes and earthquakes suggesting that stress transfer plays an important role in controlling subsurface magma accumulation. For Kilauea volcano it is well known that the south flank is moving seaward what is commonly attributed to aseismic slip along a decollement fault on the paleo-seafloor. 1998-2007 InSAR data show that flank motion is associated with subsidence of > 6 cm/yr in the summit area and uplift along the southflank. We attribute this to aseismic motion along inward-dipping normal faults related to gravitational spreading.

Keywords: insar, hawaii, volcano

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VS005 **Oral Presentation** **6719**

In search of the missing magma source

Dr. Eleonora Rivalta
School of Earth and Environment University of Leeds

Paul Segall

Recent dike intrusions at Kilauea (Owen et al, 2000) and Afar (Wright et al, 2006) were accompanied by subsidence above reservoirs that apparently supplied melt to the intrusions. In both cases however, inversions of deformation data indicate a volume decrease that cannot account for the volume increase in the dike. For the 1997 intrusion at Kilauea the ratio r_V between the dike volume and the volume decrease at the magma chambers is about 3.8 and for the Afar 2005 intrusion r_V is about 5. While it is possible that magma was supplied from deeper sources that produce only weak deformation signatures, other explanations may be possible for this discrepancy. In particular, since mass, not volume, is conserved, changes in magma density may play a role in explaining the apparent missing source of magma. An exsolved volatile phase increases the magma compressibility, thereby diminishing the pressure drop as magma is withdrawn from the source reservoir (e.g., D. Johnson et al, 2000). Cracks (dikes and sills) are much more compliant than equi-dimensional magma bodies and magma compressibility may strongly affect volume changes. We explore this quantitatively considering a coupled magma chamber-sill/dike system with a multiphase magma, including the effects of gas exsolution on mass, volume and pressure balance. Mass is conserved between the chamber and the sill/dike, and we assume that the system is in hydrostatic equilibrium at the termination of the intrusion. Gas expansion is included using analytical and numerical models for exsolution. We investigate the change from an initial state, with only a magma chamber present, to a final state where the source is deflated and a magma-filled sill/dike has formed. For the simple case where no gas exsolution is allowed, the chamber and dike are at the same depth (and therefore pressure), and the change in magma chamber volume can be adequately described by a chamber compressibility b_c, mass conservation requires that the ratio r_V is equal to 1+ b_l/b_c, where b_l is the magma compressibility. This ratio can be significantly larger than one if b_l is a significant fraction of b_c. Gas exsolution increases magma compressibility and therefore the expected r_V. We find that for reasonable choices of parameters volume decrease in the source reservoir can be up to one or more order of magnitude less than the volume increase in the crack.

Keywords: intrusion, compressibility, deformation

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VS005 **Oral Presentation** **6720**

Degassing dynamics at basaltic volcano:insights from infrasonic activity

Dr. Emanuele Marchetti
Scienze della Terra Universit di Firenze

Giacomo Ulivieri

Degassing of persistently active basaltic v olcanoes is ge nerally underst ood as a quasi-steady "non-explosive" passive mechanism, when the slow exsolution process allows the continuous compensation of the gas pressure. H owever, infrasound at Stromboli consists on transients related to explosions and on small amplitude intermittent pulses associated with "active" degassing of the magma column, revealing that degassing can occur also in over-pressurized co ndition, associated to the bursting of small gas pockets at the magma free-surface. This intermittent release of gas induces in the atmosphere small (< 0.1 x105 Pa at the source) infrasonic pulses and occu rs almost regularly every ~1-2 s. This degassin g process represents the "over-pressurized" and "discrete" counterpart of the continuous degassing of the magma column, and its infr asonic features represent a unique opportunity to investigate the degassi ng dynamics of the magma feeding system. The permanen t small aperture 5- elements infrasonic array at Stromboli is monitoring in real-time both explosions and degassing providing position, over-pressure and occurrence of the source and revealing the complex and complete behavior of the magma column. Log-linear amplitude distribution of infrasonic data shows 2 different trends of decay suggesting tha t degassing and explosions are driven by a differe nt gas dyna mics. M oreover, infraso und lo cation indicates that over-pressurized degassing is active only in one vent at once. L ocation of the puffing is stable in a sin gle vent over hours-to-days periods, or it can shift from vent to vent with smooth or abrupt transitions. The stability in the position of the puffing within the cr ater terrace is suggesting that the over-pressurized gas b ubble flow is following only one preferential segment of the f eeding conduits at on ce. T he stable locati on of the bursting bubbles, however, may change from time to time and without any apparent evidence or tr igger mechanisms, leading to a shar p change in the rising path of gas bubbles. This gas bubble behavior seems to be consistent with experimental and nu merical studies on the flow of particles and drops at pipe bifurcations. In the experiments, gas bubbles and particles are rising in the p ipes following trajec tories c oinciding with the branch wit h the highest gas flux. Over-pressurized g as bursting coul d thus reflect higher ga s flux regimes in t he conduit and it will indicat e where the gas flux is more localized within the volcan ic system. Accordingly infrasonic monitoring on an active volcanic systems woul d not only help to detect this activity but also to track changes in gas flux regime.

Keywords: degassing, infrasound, stromboli

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VS005 **Poster presentation** **6721**

Dynamics of magma mixing at MT. Etna Volcano (Italy) as indicated by textural and compositional features of phenocrysts. part 1: chemical disequilibrium conditions

Dr. Marco Viccaro
Dept. Scienze Geologiche Universit di Catania IAVCEI

Renato Cristofolini

Repeated small-scale oscillatory zoning recorded by phenocrysts has been commonly ascribed to local kinetic effects at the crystal-melt interface, which might not necessarily imply significant varying chemical and physical conditions of the system. This can be viewed as the main process that rules the variability of phenocryst compositions of Etnean lavas emitted from vents in the summit area. Here, magma differentiation is mainly driven by polybaric crystallization in the open and repeatedly-filled conduit at steady degassing conditions, where fractionation effects are continuously compensated by magma inputs from depth. However, the careful examination of the mineral chemistry and geochemistry of products emitted from lateral eruption -not related to the open-conduit- reveals that other differentiation processes are commonly acting within the Etnean feeding system. Petrographic features and chemistry of the phenocrysts give evidence that plagioclase and clinopyroxene differing in their zoning patterns and olivine in its variable Fo contents generally coexist within the same sample, suggesting that mingling processes can frequently occur. Equilibrium conditions of the rims of plagioclase, clinopyroxene, and olivine crystals with the hosting lava were tested taking into account respectively the Ca/NaDplg/melt , Fe/MgDcpx/melt , Fe/MgDol/melt values in the least differentiated and porphyritic lavas in order to obtain data as close as possible to thermodynamic equilibrium conditions. In spite of the spread of the Dsol/melt values, results show that the phenocryst rims are far away from equilibrium conditions, especially when their compositions abruptly change towards increased An% for plagioclase, Mg# for clinopyroxene and Fo% for olivine. These large and abrupt changes, also recorded along the compositional profiles of the phenocrysts, can be accounted for as an evidence that at Mt. Etna residing and slightly more evolved magmas commonly go into contact and mix with inputs of less evolved, hotter and undegassed magmas during their stagnation within the shallow feeding system. Within such a frame, the composition of the end-members, their relative T and volatile contents play a main role in determining the extent of the compositional change.

Keywords: etna, mixing, chemical disequilibrium

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VS005 **Poster presentation** **6722**

Preliminary research of magma mixing and explosive mechanism of the millennium eruption of Tianchi Volcano,China

Prof. Qicheng Fan
Institute of Geology China Earthquake Administration IAVCEI

Jianli Sui, Ni Li, Qian Sun

In this paper we report new chronolog ical data and chemical analysis results on the Ti anchi Volcano, and provide further constrains on the eruptio n history and the changes o f magma types of the shield-forming stage and the cone- forming stage. At the beginning of the e arly Pleistocene (ca. 2Ma), the Tianchi Volcano started th e trachybasaltic activi ty of the shield-forming stage, and then the trachybasaltic magma changed to the trac hytic and trachyandesitic ma gmas at t he e nd of the earl y Pleistocene (ca. 1 Ma); the cone-forming st age of tr achyte mainly occur red in the mid dle Pleistocene, and the trac hyte magma changed to the pantelleritic m agma at the late Pleistocene (ca. 0.1 Ma). Studies on magma evolu tion an d on geoph ysical observation s in dicate th at th ere are two magma chambers ben eath Tianchi v olcano. Continuous basaltic magma influx fro m mantle chamber to crust chamber are essential to the keep Tianchi volcano active over a million years, and are also important to interpret the magma evolution of Tianchi volcano. In this paper, we prese nt evidence of magma influx and magma mixing from the gray pumice of the Mille nnium eruption of Tianchi volcano. The breccias in the gray pumice and the banded structures indicate the occurrence of magma mixin g. The petrological, mineralogical and chemical studies of these samples reveal the story of magma influx and mixing, which may trigger the Millennium eruption of Tianchi volcano.

Keywords: tianchi volcano, magma mixing, eruption history

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VS005 **Poster presentation** **6723**

Faulting on the western flank of Mt. Etna and magma intrusions in the shallow crust

Dr. Mario Mattia
geodesy agu

Domenico Patan, Marco Aloisi, Mauro Amore

Surface deformations on the western flank of Mt. Etna volcano, spanning from 1980 to 2004, have been analysed as they pertain to stress interactions between magma intrusions within the shallow crust along the S-SE Rift and fa ulting sensitivity. During this period, an accurate analysis of strain parameters , computed by inversion of SW EDM data, suggested that the observed strong displacements on this flank of the edifice can also be related to dextr al sh ear mo vements alo ng a ro ughly. NE-SW buried fault crossing the area covered by this network, as su pported by seismic observations of the April 20-24, 2001 swarm. Moreover, Coulomb stress ch ange model a nalysis confirms that the disp lacement along this fault, heralding the July-August 2001 er uption two months earlier, can be related to major stresses applied by a dike intrusion at depth along the S-SE Rift, a s testified by t he microseismi city oc curring between November 2000 and April 19, 2001

Keywords: edm, ground deformation, coulomb stress change

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VS005 **Poster presentation** **6724**

Dynamics of magma mixing at MT. Etna Volcano (Italy) as indicated by textural and compositional features of phenocrysts. part 2: kinetics of processes

Dr. Marco Viccaro
Dept. Scienze Geologiche Universit di Catania IAVCEI

When an input of basic magma into a more evolved chamber occurs , the potential transition from laminar to turbulent regime can be predicted from Reynolds number, calculated as: Re = ρ Q / η where ρ is the densi ty of the intru ding magma, Q th e bi-d imensional discharge rate for a fissure, η the viscosity of the intruding m agma. Assumi ng a quas i-Newtonian behav iour of the m agma, Q can be conservatively calculated assuming that the input through the fissure is primarily driven by buoyancy: Q = [(g Δρ)/(f ρ)]1/2 * d3/2 (1) where g is the acceleration due to gravity, Δρ is the diffe rence between the density of magma and of the intruded medium, f (~0.03) is a dimensionless friction coefficient [1] and d is the fissure width at the entrance of the magma chamber. At Mt. Etna, an averaged density for the substrate of the volcanic edifice can be cons idered as 2600 kg/m3 [2]. Density for the intruding basic magmas gives a value of 2500 kg/m3 (tested with MELTS), so that a Δρ ≈100 kg/m3 is obtained. The thickness of numerous ancient feeding dykes (1-5 m) indicates that 2 m could represent a reasonable val ue for d. Solving (1), a Re in the order of 103 is obtained, high enou gh to permit a turbulent flow regime to develop when m elts with similar viscosities are mixed. The length of the destabilization event may be estimated assuming that the envelope widths in plagioclase (with abrupt changes to high An%) represent th e interval of time of pla gioclase growth under chang ed equilibrium conditions. The averag ed wi dth fo r hig h-An% envelo pes generally are ~40 μm across. For basaltic systems, plagioclase growth rates in the range of 10-9 10-11 cm/s have been estimated on the basis of crystal size distribution. However, during the mixi ng proce ss between ev olved cooler and more basic hotter magmas, the latter ones may undergo some degree of undercooling, which in creases growth rates of some orders of magnitude (up to 10-6 10-8) . At Mt. Etna, basaltic lavas are at T ~1080C, with significant variations that can occur. As an exampl e, during the 2001 eruption, evidence of mixing between magmas with ΔT of ~150C hav e been provided [3]. Alth ough the actual growth rate is uncertain, if a minimum growth rate of 10-8 is assumed, a 40 μm-wide envelope can d evelop within about 2 weeks, whereas less than 12 hours are needed for the same envelope to grow by the highest growth rate (10-6) at higher undercooling, which anyway implies that mixing dynamics at Mt. Etna have fairly fast kinetics. [1] Huppert et al. (1984) Nature 309, 19-22. [2] Corsaro and Pompilio (2004) Terra Nova 16, 16-22. [3] Viccaro et al. (2006) J. Volcanol. Geotherm. Res. 149, 139-159.

Keywords: etna, mixing, kinetics

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VS005 **Poster presentation** **6725**

New insights on Mt.Etna's summit eruptive activity (2003-2007) from seismological and ground deformation data

Dr. Mario Mattia
geodesy agu

Domenico Patan, Giuseppe Di Grazia, Marco Aloisi, Valentina Bruno, Mimmo Palano

At Mt. Etna, summit eruptio ns are no t ge nerally preced ed by significant variations in V T seismicity and/or gro und defo rmation, whereas lateral eruptio ns are forerun by a few days of seismic cris is just before the eruptive fissures open. Since 200 3, the improvement of the seismic and ground deformation networks near the summit of the volcano all owed the availability of a better quality and quantity of data and the improvement on the investig ations on the shallow level magma migration processes. In this work we show an integrated approach to the modelization of geoph ysical data from perman ent monitoring networks on Etna collected between the end of the 2002-2003 eruption and the first months of 2007. The aim is to show how the pr ocesses of magma trans fer f rom the deep crustal levels t o shallower levels can also influence the sum mit eruptive activity, with a mechanism where the induced overpressure of uprising magma has a main role . Moreover, our findings indicate that t he presence of high-level mag ma storage, af fects the weak and fractured eastern flank of Etna, that s hows both an intense seismicity and an acceleration of gr ound deformation. In this framework, the opening of summit eruptive fissu res an d/or magma ou tpouring from su mmit craters is associated with weak geophysical signals recordable on ly from a proximal mon itoring network with stations very close to th e craters or to the opening fr actures. Furthermore, we sh ow that th e main engine of the recent volcanic activity is always the de ep recharge pr ocess. This mechanism is evident for all the pre-eruptive phases of the 2004 and 2006 summit activity.

Keywords: etna, ground deformations, gps

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VS005 **Poster presentation** **6726**

Ground deformation, gravity and magnetic variations at MT. Etna encompassing the 2006 eruptive activity

Dr. Alessandro Bonforte
Sezione di Catania Istituto Nazionale di Geofisica e Vulcanologia IAVCEI

Daniele Carbone, Davide Giudice, Filippo Greco, Francesco Guglielmino, Rosalba Napoli

Volcanic activity started at summit craters of Mt Etna during the night of July 14th 2006, when a fissure opened on the eastern flank of the SE crater. Three vents opened along the fissure field at about 3 000 m a.s.l., two of them emitting two lava flows propagating eastwards inside the Valle del Bove. The eruption onset was not accompanied by evident geophysical parameter changes accompanying the intrusion, but the eruption was characterized by strong degassing from the uppermost vent, with strong strombolian activity and, consequently, an increased tremor during the entire duration of the eruptive activity. This eruption ended on July 23rd 2006. The volcanic activity restarted at SE crater at the end of August 2006 and this phase lasted until mid September. A new eruptive fracture opened on October 13th from the E base of the SE crater, reaching the altitude of 2800 m; also this fracture opened with no geophysical parameter changes, as a new further fracture field formed on October 26th on the opposite side of the SE crater, involving also the southern flank of the BN crater at 3050 m of altitude. Only episodic increases in volcanic tremor accompanied the periods characterized by more intense degassing and strombolian activity at SE crater. We present and analyse ground deformation, gravity and magnetic data acquired at Mt. Etna during a time interval lasting about one year (eventualmente specificare le date) and encompassing the volcanic activity. Ground deformation data are computed by comparing the results of GPS surveys carried out in July 2006 on the whole monitoring network, in October 2006 mainly along a N-S profile (runs from North to South across the Summit Craters) and in January 2007 mainly along an E-W profile (on the southern flank of the volcano); both profiles are surveyed by the semi-kinematic technique. Furthermore, a DInSAR image is produced, by combining the September and October 2006 ENVISAT passes, in order to investigate the ground deformation with a higher spatial detail. The complete Etnas gravity network was surveyed in June. In addition, eight gravity surveys were carried out along the E-W profile between March December 2006, while the N-S profile was surveyed four times (June, July, September, October). The stations of the two gravity profiles are common to the GPS network. From the beginning of 2006 significant geomagnetic changes were recorded by the permanent magnetic network of Mt Etna. In particular, between January and July 2006, a slow and continuous decrease in the magnetic field total intensity greater than 5 nT was observed at almost all the sites of the southern flank of Mt Etna.

Keywords: etna, eruption, multidisciplinary monitoring

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VS005 **Poster presentation** **6727**

Modelling of ground deformation and gravity data from Mt. Etna using different inversion approaches

Dr. Alessandro Bonforte
Sezione di Catania Istituto Nazionale di Geofisica e Vulcanologia IAVCEI

Marco Aloisi, Antonio Camacho, Daniele Carbone, Maria Charco, Gilda Currenti, Ciro Del Negro, Jose Fernandez, Salvatore Gambino, Filippo Greco, Francesco Guglielmino, Mario Mattia, Mimmo Palano, Giuseppe Puglisi

In the framework of the Etna DPC-INGV Project, a cooperation between INGV and the University of Madrid (UCM) has been established in order to develop and implement new methodology, and the necessary software, for the joint interpretation of different terrestrial and spatial geodetic data and gravimetry, acquired in the same period of time. We selected two time windows to test different approaches in the data inversion.The 1996-1997 time interval was chosen to test the joint inversion of both GPS and Gravity data coming from surveys carried out on Mt. Etna; a tool based on the random search of simple point (mass and pressure) sources has been implemented to quickly invert geodetic (spatial and terrestrial) and gravity data. In addition, a free-geometry tool is being tested, that adjust the gravity changes as due to some anomalous mass bodies; this bodies are described as aggregation of cells filled with some prescribed density contrasts. The inversion approach is carried out in a step-by-step process. For each step a new cell is filled with anomalous density and then aggregated to the previous filled cells, to that the anomalous bodies are constructed in a growth process until to rearch the final size. The adjusted 3-D model can be described by means of horizontal and vertical cross-sections.We modelled also the temporal evolution of the continuously geodetic data recorded during the dike propagation on the southeast flank in July 2001, using a random search approach of a purely elastic earth model. The reproduction of the recorded signals allowed us to describe the geometry and characteristics of the intrusion in greater detail than the previous static inversion.

Keywords: modelling, etna, geodesy

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VS005 **Poster presentation** **6728**

The stability of lava lakes - insights into subsurface processes

Dr. Ed Llewellin
Department of Earth Sciences University of Durham IAVCEI

Fred Witham

A physical model of a generic lava lake system is developed. We derive the requisite conditions for the existence of an equilibrium lava lake in which magmastatic pressure at the base of the conduit balances the pressure in the underlying magmatic reservoir. The stability of this lava lake system is tested by investigating the response of the system to perturbation. We develop a graphical method, based on the system's pressuredepth profile, to predict the subsequent behaviour of the system. Despite the simplicity of the modelled system, we find a broad behavioural spectrum. Initially, the rise of bubbles through the magma is ignored. In this case, both stable, long-lived lava lakes, and unstable lakes that are prone to sudden draining, are predicted. The stability of the system is shown to be controlled by lake-conduit geometry, the solubility and gas expansion laws and the magma's volatile content. We show that an unstable lake must collapse to a new, stable equilibrium. Subsequent recharge of the system by, for example, conduit overturn, would promote a return to the original equilibrium, giving rise to cyclic behaviour. Such a mechanism is consistent with lava lake behaviour during the 19831984 Pu'u 'O'o eruption of Kilauea. When the rise of bubbles through the magma is considered, our model predicts that stable lakes must drain over time. We, therefore, deduce that persistently degassing, stable lava lakes, such as those observed at Mt. Erebus, Antarctica, and Mauna Ulu, Kilauea, Hawaii, must have an effective conduit convection mechanism or an exogenous supply of bubbles from depth.

Keywords: lava lake, stability, degassing

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VS005 **Poster presentation** **6729**

Ground deformations associated to the Nyiragongo 2002 and the Nyamulagira

Dr. D'Oreye Nicolas
Geophysiqueasctophysique National Museum of Nat. Hist. IAVCEI

F. Kervyn, V. Cayol, C. Wauthier

The Nyiragongo – Nyamuragira volcanoes are the only two active volcanoes of the Virunga Volcanic Chain that extends from North Kivu 60 km north-eastwards to Uganda, on western branch of the East African Rift. In 1977 and 2002, the permanent crater lava lake of the Nyiragongo suddenly drained out through lateral fissures in the direction of the nearby Goma city on the shore of Lake Kivu. In both cases, the live losses and damages were important, especially in 2002 when the hundreds thousands of people had to evacuate in a chaotic situation the partly destroyed city. The intense seismic activity, which started with the 2002 eruption of the Nyiragongo and which continues to day, underlined some close interaction with rifting tectonic events. Region-wide deformation patterns associated to that eruption were also observed on different independent InSAR pairs and are in agreement with the suggested major tectonic event. These interferograms are also showing a linear subsiding zone in the prolongation of the fissure open in the Nyiragongo southern flank, which confirms lake level variations observed during the eruption period. Six months later (July 2002), and again in 2004, it was the turn of the Nyamuragira to enter in eruption. Because the events occurred in highly vegetated areas, only part of the deformation patterns could have been observed by InSAR. However, none of these events produced any region-wide deformation as for the Nyiragongo event. This underlines the different behaviour of the two edifices. Last November/December, the Nyamulagira entered once again in eruption. This time we could benefit from the dense database and acquisition plan set up in the frame of the SAMAA V project (Study And the Monitoring of Active African Volcanoes by InSAR techniques). This large amount of data offered the possibility to find suitable pairs to observed signal in vegetated area that will soon become incoherent from the InSAR point of view. Following the eruption announcement, an emergency delivery request was sent to ESA, which allowed a fast FTP access. The scene was available 18 hours after its acquisition and less than 75 min later, the first interferogram revealed wide deformations along an axis that links the two volcanoes: an elongated inflation signal (at least 22cm in the line of sight of the satellite to the N and 17cm to the S) that follows an N-NW/S-SE axis that crosses the southern flank of the Nyamulagira volcano near the crater rim, up to the feet of the N-W flank of Nyiragongo, and an almost concentric deflation signal (>6cm in LOS) located at the East of the deformation axis. More processing as well as modelling are under way. Unfortunately Artemis failure currently prevent the use the richest and most convenient mode but the current results proved the efficiency to maintain a dense acquisition plan to compensate the rapid loss of coherence in dense vegetation environment.

Keywords: insar, ground deformation, nyiragongo nyamulagira

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VS006 **6730 - 6754**

Symposium
Calderas I - Calderas and resurgent calderas

Convener : Prof. Giovanni Orsi, Dr. Sandro De Vita

Caldera collapse and res urgence are common features in volcanic systems and have been classically interpreted in light of inflat ion and deflation pr ocesses of magma reservoirs. Their size can vary significantly as well as their dynamics. Such a variability can depend upon both the characteristics of the volcano, including its magmatic feeding system, and/ or of the cru st, and region al stress regime. P re-existing regional structures may influence stress propagation or may be r eactivated during collapse and resurgence. The regional stre ss field may di rectly influence the fo rmation of new structures, and the shape of calde ras and resurg ent blocks. Thi s Session is d evoted to the presentation, discussion and comparison of caldera colla pse and resur gence ca se hi stories. C ontributions based on geological , sedimentological, stru ctural, petrologi cal, g eophysical investigations, as well as on v ariable types of modelling, are solicited . Co ntributions on active calderas and resur gent calderas, with obvious implications on volcanic hazar ds assessment, are also welcome. Participants are encourag ed to register for Field T rip F7 on th e Neapolitan volca noes, during which the active Campi Flegrei and Ischia resurgent calderas will be illustrated.

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VS006 **Oral Presentation** **6730**

The enigmatic giant tuff cone and ignimbrites of Ambrym, Vanuatu: a more conventional story of mafic caldera formation

Dr. Karoly Nemeth
Volcanic Risk Solutions, INR Massey University IAVCEI

Shane J. Cronin

Ambrym is one of the most voluminous active volcanoes in the Vanuatu arc and it consists of a 35 by 50 km east-west elongated island, with a parallel active fissure zone. The northern part of the island is considered to be oldest and it is inferred to be part of a series of coalescing stratovolcanoes. In the central part of Ambrym ~800 m above sea level, a 12 km-wide caldera occurs, containing 2 active volcano, Marum and Benbow. Both volcanoes produce frequent (weekly-monthly) small-volume eruptions ranging from strombolian events through to phreatomagmatic explosions. On more rare occasions (c. 30 yrs) larger sub-Plinian and Vulcanian eruptions occur. These two frequently active volcanoes provide huge volumes of tephra to the caldera, creating an exceptionally large ash plain as well as sediment-choked fluvial systems leading out from the caldera. Although it has been proposed that ~2200 years ago a cataclysmic phreatomagmatic eruption led to the caldera formation and construction of a giant tuff cone. There is no supporting evidence of such an event based on new mapping. The giant tuff cone theory, however, is entirely built from constructing a layer-cake stratigraphy from a mosaic of sections located around the island. Current field studies show that this mosaic of sections cannot possibly be related to one-another, either genetically or chronologically. Instead, we show that the island is a composite structure, formed of many generations of coalescing monogenetic volcanic structures. The type localities of the giant tuff cone (dacitic) pyroclastic flow deposits in the northern shoreline of the island we interpret to be either (1) mafic, (hydrothermally altered), phreatomagmatic fall and surge sequences or (2) stacks of lahar and fluvial sediment derived from the caldera outflow and forming valley-fills. The sedimentary system of the present-day Ambrym appears to have existed for at least the last c. 2200 years, and the sediment produced is gradually infilling a deeply eroded older terrain. Apparent maturity of the volcanic system has resulted in the formation of the present caldera, and this structure is probably still evolving in response to mass loss through degassing and eruption from the central caldera vents. There is no evidence for a climactic (or for that matter dacitic) explosive caldera-forming event. Magma rise in the centre of the island from a long-term stable shallow magma storage system, followed by intense degassing and drainage of degassed magma along lateral dykes is inferred by us to be the major means by which the central 12-km wide caldera slowly formed. Hence we suggest that the theory of the giant tuff cone is not nessesary to explain the volcaniclastic facies associations of Ambrym, and the formation of its caldera. Furthermore, the volcano should not be used (as it has been) as a comparative example for large-scale explosive phreatomagmatism.

Keywords: caldera, phreatomagmatic, tuff cone

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VS006 **Oral Presentation** **6731**

From steep-slope volcano to flat caldera floor

Mrs. Stéphanie Barde-Cabusson
Volcanology Laboratoire Magmas et Volcans IAVCEI

Olivier Merle

Caldera formation is associated with eruption of volcanic products and is commonly attributed to the collapse of the roof of a reservoir resulting either from magma withdrawal during a single eruption or from recurrent eruptions leading to incremental collapse. However, the formation of some large caldera structures encountered in nature is difficult to explain in this way. In some cases, geophysical data together with field data show that there is not a magma reservoir large enough to permit such a collapse. For this reason, an alternative model of caldera formation triggered by the deformation of the hydrothermal system of a volcano has been proposed. Recent studies have shown that hydrothermal alteration of the core of a volcano may lead to sector collapse as hot fluid circulation of both groundwater and magmatic gas deeply alter volcanic rock. This can produce, in the whole edifice, volume loss together with clay-rich zones able to flow under their own weight. We show that the altered core of the volcano may become unstable if stress conditions change at the boundary of the hydrothermal system. This can be due to reduced lateral stresses or, with time, to the expansion of the hydrothermal zone. The ensuing collapse of the central part of the edifice may then create a caldera-like structure apparently similar to classical calderas but named "caldera-like" as the drained material is not magma but altered rock. In addition, most laboratory experiments of caldera collapse have dealt with reservoir emptying below a flat-lying overburden without an overlying analogue volcanic cone on top. The overload and the role of topography are then neglected so that the final flat floor within the caldera is directly linked to the initial one. New analogue experiments show that the deformation of a weak clay-rich core resulting from the hydrothermal alteration inside a volcanic cone can, in certain conditions, reproduce main geometric features of a caldera. In particular, this gives a good explanation to the formation of the flat floor of a caldera when resurfacing resulting from new eruptions or destructive processes seems unlikely. We investigate the slope modification inside a caldera structure forming from a steep-slope cone. The shape and the thickness of the ductile core as well as the cone-slope variation have been tested. Three successive stages of deflation, faulting and collapse are observed in the models, with time. Finally, the slope of the cone seems to be the major parameter influencing the deformation process.

Keywords: caldera, hydrothermal system, analogue modelling

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VS006 **Oral Presentation** **6732**

Las Caadas Caldera (Tenerife): multiple vertical caldera collapses and structural control

Mr. Nicolas Coppo
Institute of Geology and Hydrogeology University of Neuchtel - Switzerland IASPEI

Pierre-Andr Schnegg, Wiebke Heise, Roberto Costa, Pierik Falco

The Las Caad as caldera (LCC) of Tenerife is a well exp osed caldera depression fille d in by recent pyroclastic dep osits and lava flows of the active Te ide-Pico Viejo complex. It s formati on is currently admitted to follow from multiple phases of volcanic edifice construction and destruction by collapse. The caldera is one of the largest recharge zones of the island. Electrical properties of subsurface rocks play a significant role in groundwater behaviour. Beside th at, T enerife displays several giant lateral collapse structures. Their comm on origin wi th vertical collapses is controversial. One-D modelling of 200 audio-magnetotelluric (AMT) sites (tensor data) carried out in the period range 0.001 to 0.3 s provided a very detailed map of the top conductive layer underlying an infilling resistiv e one. This lo w resistivity is assumed to result from hydrothermal alteration an d weathering processes at shallow depth (30-800 m). In the eastern part of the caldera, the resistivity distrib ution of these layers clearly highlights tw o distinct areas t hought to be t he electrical pr ints of the Gu ajara and Dieg o Hernandez calderas at the origin of the current LCC. These structures are charac terized by a radially decreasing resistivity. This electrical pattern indicates multiple hydrothermal alteration intensities, stronger close to the caldera rim, and certainly constrained by the mo rpho-structural con text of the c ollapse. Toget her with the morphology of the top conductive layer, their shapes help understand caldera evolution processes, giant past structural events, and groundwater flows with in the resistive and permeable layer. Our results argue for a multiple vertical collapse orig in of the LCC a nd delimit very well the boundary between Guajara and D iego Hernandez calderas. Caldera ring fa ults appear also to be controlled by the three armed rifts thought to have built Tenerife. Interpreted in terms of rocks permeability, the top conductive layer is in ver y good agree ment with the distri bution of grou ndwater flowrates arou nd th e L CC. Electrical prints appear to be relevant indicato rs of pas t location, siz e, morphology and possibly evolution of the volcanic edifice. Strikes, calculated from t he phase anis otropy reveal a clearly radial influence of the Teide-Pico Viejo complex in most of the LCC, and the ascent of the top conductive layer close to the caldera wall.

Keywords: volcano electrical structure, audio magnetotellurics, hydrothermal alteration

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VS006 **Oral Presentation** **6733**

The interplay between volcanism and volcano-tectonism in resurgent calderas, and its implications on slope instability: the Ischia island (Italy) case history

Dr. Sandro De Vita
Istituto Nazionale di Geofisica e Vulcanologia Osservatorio Vesuviano IAVCEI

Giovanni Orsi, Enrica Marotta, Fabio Sansivero, Marta Della Seta, Paola Fredi

The island of Ischia is an active volcanic field in the Phlegraean Volcanic District. Volcanism started prior to 150 ka and continued, with periods of quiescence, until the last eruption occurred in 1302 A.D. It is dominated by the caldera-for ming eruption of Mt. Epomeo Green Tuff (5 5 ka), which was followed by block resurgence inside the caldera. In t he past 33 ka the resurgent block has been uplifted of about 900 m. Resurgence dynamics influenced the subsequent volcanic activity determining the conditions for magma ascent only within the eastern portion of th e resurgent block and along pre-existent regional faults. During the last period of activity, star ted 10 ka bp, volcanism was mainly concentrated at 5 an d in the past 2.9 ka, generating 35 effusive and explosive eruptions. Almost all the volcanic vents active in this period are located in the eastern part of the island. Over the pas t 5 ka, periods of quiescenc e alternate with periods of inte nse volcanism. As this volcanism was related to the resurgence dynamics, it has been speculated that resurgence was not continuous, but took place through intermittent uplifting and tectonic quietness phase s. In order to define th e resurgence kinem atics, the structural setting of the Mt. Epomeo block has been reconstructed. Th e re surgent area i s composed of differentially displaced blocks whose uplifting is maximum at th e Mt. E pomeo top and decreases south-eastward. It has a poligonal shape, result ing from reactivation of regional faults a nd activa tion of fau lts directly related to volc ano-tectonism. The western sector is bord ered by inward-dipping, hig h-angle reverse faults, testifying a compressional stress re gime acti ve in this area. These features a re cut by late outward-dipping normal fault s due to gravit ational readjus tment of the sl opes. The north-eastern and the south-west ern sides are bordered by vertical faults w ith right transtensive and left transpressive movements, r espectively. T he area locate d to the east of the m ost uplifted block is displaced b y outward-dipping normal faults and is chara cterized by a tensile stress regime. In the past 5 ka slope instability was induced by reactivation of vertical movements, which also generated faults and fractures that fed volcanism. The de posits related to surf ace gravitational movements, var ying from small landslides to h uge debris ava lanches, preceded and followed the emplacement of volcanic rocks. They were generated in four main phases, dated between 4.3 and 2.9 ka, around 2.9 ka, around 2.5 ka, and between 2.3 a nd 1.9 ka, res pectively. The same stru ctures that drove r esurgence and fed volcanism , also played an important role in the de finition of the geometry of the detachment areas of major debris avalanches. In conclusion it can be stated that there is an intimate interplay among resurgence dynamics, faults generation, seismicity, slope oversteepening and instability, and volcanism.

Keywords: resurgence, volcanism, landlides

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VS006 **Oral Presentation** **6734**

Discriminating the long distance dispersal of fine ash from sustained columns or near ground ash clouds: the example of the Avellino eruption (Somma-Vesuvius, Italy).

Dr. Roberto Sulpizio
Dipartimento Geomineralogico Universit di Bari IAVCEI

Rosanna Bonasia, Pierfrancesco Dellino, Mauro Antonio Di Vito, Luigi La Volpe, Daniela Mele, Giovanni Zanchetta, Laura Sadori

Volcanic ash (diameter <2 mm) 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. Irrespective of the eruptive mechanism or intensity, ash particles usually affect wide areas around volcanic centres, and have a greater mobility than the coarse-grained parental deposits. 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. Dispersal and deposition of ash has serious implications when dealing with volcanic hazard evaluation. The accumulation of ash can induce roof collapses, interruption of lifelines (roads, railways, etc.), 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 intermediate (subplinian) eruptions or final vulcanian phases of Plinian eruptions, and this oblige to face with ash dispersal over large areas not related with large ignimbritic eruptions. As an example we present and discuss the data of ash dispersal from the Avellino eruption from Somma-Vesuvius, which dispersed centimetric thick ash blankets far beyond 300 km south and 600 km north from the source.

Keywords: ash, volcanic hazard, somma vesuvius

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VS006 **Oral Presentation** **6735**

The magmatic system of Ischia island (Phlegrean Volcanic District, South Italy) in the past 10 ka: mineralogical, geochemical and isotopic constraints for the hazard evaluation.

Prof. Massimo D'Antonio
Dipartimento di Scienze della Terra Universit Federico II IAVCEI

Maria Chiara Andria, Ilenia Arienzo, Luigi Dallai, Sandro De Vita, Giovanni Orsi, Enrica Marotta, Fabio Sansivero, Sonia Tonarini, Alberto Trecalli

The island of Ischia is an active volcanic field belonging to the Phlegrean Volcanic District (South Italy), which includes also the Campi Flegrei caldera and the islet of Procida. The island is the emerged portion of a volcanic complex which rises more than 1 km above the seafloor at the north-western corner of the Gulf of Naples. Ischia is composed of volcanic rocks, landslide deposits and minor terrigenous sediments; its geological history has been characterized by a complex interplay among volcanism, tectonism, volcano-tectonism, erosion and sedimentation. Volcanism began prior to 150 ka B.P. and continued, with quiescence periods centuries to millennia long, until the last eruption occurred in 1302 A.D. Early volcanism was characterized by both effusive eruptions giving rise to small lava domes, and explosive eruptions culminating with the caldera-forming Mt. Epomeo Green Tuff eruption (55 ka). This tuff is made up of trachytic ignimbrites that partially filled a submerged depression, now constituting the central portion of the island. The caldera collapse was followed by block resurgence of the caldera floor, at least since 33 ka. Resurgence dynamics influenced the later volcanic activity determining the conditions for magma ascent mainly within the eastern portion of the island and along pre-existing, mostly NW-SE and NE-SW trending regional faults. During the last period of activity, started 10 ka B.P., volcanism was mainly concentrated at around 5.5 ka and in the past 2.9 ka. The volcanic system is still active, as testified by the intense volcanism in historical times, widespread fumaroles and thermal springs, and seismic activity. The past 10 ka volcanic activity at Ischia has been characterized by both explosive and effusive eruptions. The explosive eruptions, both magmatic and phreatomagmatic, generated tuff cones, tuff rings and pyroclastic-fall and -current deposits; the effusive activity generated lava domes and high aspect ratio lava flows. The volcanic rocks range in composition from shoshonite, through latite and trachyte, to phonolite, and have variable isotopic composition of Sr, Nd, Pb and B. These volcanics exhibit common textural and mineralogical evidence for disequilibrium: occurrence of banded pumice fragments, texturally different juvenile fragments in the same deposits, different populations of clinopyroxene, normal and reverse zoning of plagioclase and clinopyroxene, disequilibrium mineralogical associations, such as Mg-olivine and sanidine. All these features, along with geochemical and isotopic variations of whole-rocks and separated glass and mineral phases testify to these volcanics being the product of complex mixing and mingling processes among mafic and felsic magmas. The results of petrological investigations on selected volcanic rocks, integrated with volcanological and structural data, have allowed us to shed light on the behavior of the magmatic system of Ischia in the past 10 ka, and to get inferences for the hazard evaluation.

Keywords: magmatic system, geochemistry, isotope geochemistry

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Monitoring and modeling of high rate crustal deformation of Iwo-jima caldera, Japan

Dr. Motoo Ukawa
National Res. Inst. Earth Sc. and Disaster Prev. Volcano Research Department IAVCEI

Eisuke Fujita, Hideki Ueda, Taku Ozawa, Tetsuo Kobayashi

Iwo-jima is a caldera volcano belonging to the Izu-Bonin island arc. The main part of the island is located inside the caldera rim, exhibiting a high uplift rate for the last several hundred years, about 0.2 m/a. For the purpose of monitoring and investigation of the high rate crustal deformation, National Research Institute for Earth Science and Disaster Prevention has conducted geodetic survey every two years since 1976. On the basis of these long term geodetic data, we are able to categorize the temporal and spatial variation of deformation into two modes, a steady mode and an episodic mode. The steady mode is characterized by the contraction at the central area of the caldera with an average subsidence rate of about 0.15 m/a, and uplift surrounding the contraction area within the caldera rim with an average uplift rate exceeding 0.15 m/a. The episodic mode is characterized by the large uplifting spreading over the whole area within the caldera rim, lasting about one year or more. The remarkable uplift events with the maximum uplift exceeding 1 m were observed during the periods 1981-1984 and 2001-2002, accompanying high seismic activity and small phreatic eruptions. The contraction source with a sill-like shape is estimated to be at a depth of about 1 km beneath the central part of the caldera by using vertical and horizontal displacement data. Small horizontal displacements during the episodic uplift events contrast with those comparable to vertical displacements of the contraction deformation, suggesting the deeper source depth for episodic movements and the significant contribution of dislocation along the faults. We try to model the magmatic system responsible for the large crustal deformation, especially focusing on the recent uplift events during the periods 2001-2002 and 2006-2007 with the GPS, InSAR and microgravity data. The model consists of primary one magma reservoir with an episodic magma supply at the deeper part. The top of the magma reservoir suffers contracting deformation due to cooling and/or degassing. We discuss evolution of the deformation modes and the possibility of eruption, taking account of available geological, geo-morphological, and geophysical data.

Keywords: caldera, iwo jima, uplift

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VS006 **Oral Presentation** **6737**

Volcanic structures at Ischia Island (Italy) by seismic tomography and gravity inversion

Prof. Paolo Capuano
Dept. Science and Technology for the environment University of Molise IAVCEI

Raffaella De Matteis, Guido Russo

Ischia Island, whose last eruption occurred in 1301 A.D., belongs to the Campi Flegrei volcanic area located in the Campanian Plain (southern Italy). Campi Flegrei caldera, Somma-Vesuvius volcano and Ischia make the densely inhabited area, near the town of Naples, one of the most hazardous volcanic areas in the world.Eruption scenarios can be constructed on the base of a detailed knowledge of the volcanic structure, inferred from the elastic/attenuation, thermal, density and other geophysical parameter distribution. In fact, it may clarify the evolution and the associate eruptive dynamic. The objective of the research is the definition of a 3D crustal model of the Ischia volcanic region, by tomography analysis and gravity inversion, and the identification and detection of the possible crustal reservoir of magma feeding.Recently, an active seismic survey project (SERAPIS) was carried out in the Campi Flegrei caldera and surroundings using off-shore seismic energization and data acquisition on the sea-bottom and on land. An area centered onIschia Island has been selected and data recorded at eight seismic stations located on land and four located on sea-bottom have been analyzed. We performed a manual reading of about 8,000 first P wave arrival times on the waveforms band-pass filtered between 5 and 15 Hz. We have used the tomography code developed by Benz et al. based on a linearized iterative approach, already applied to several areas in the world. The method uses the finite differences technique to compute travel times by solving the Eikonal equation which provides a fast and accurate tool even in highly heterogeneous media. Different model parameterizations have been tested and resolution analysis has been performed.Gravity data collected, on land and on sea bottom, by several authors have been reprocessed, accurately checked for inconsistencies and finally validate. Faye and Bouguer anomaly have been computed using a reduction density of 2400 kg/m3. The anomalies have been modelled using a recent developed technique, based on the regularization inversion using block parameterization, to reconstruct a 3D image of Ischia volcanic area including studies on synthetic models calibrating the inversion procedure before applying to real data.We found that beneathIschia Island , a positive velocity perturbation is present between 1 and (about) 4 km depth and it seems to disappear at greater depths. The central area ofIschia is characterized by a slight positive velocity perturbation at shallower depths, while between 1 and 3-4 km the perturbation is negative. Preliminary gravity inversion shows density heterogeneity in the central part of the island that is in agreement (shallower part) with velocity model.

Keywords: ischia island, seismic tomography, gravity inversion

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VS006 **Oral Presentation** **6738**

A thermal conductive and convective model of the Campi Flegrei Magmatic system.

Dr. Valeria Di Renzo
Dipartimento di Scienze Fisiche Universit di Napoli Federico Ii

Salvatore De Lorenzo, Ken Wohletz, Lucia Civetta, Marilena Filippucci, Paolo Gasparini, Giovanni Orsi

A new conductive/convective thermal model has been developed with the aim of describing the thermal evolution and state of Campi Flegrei magmatic syst em. The proposed model has been computed on the basis of the present knowledge: (1) of the beginning of the activity of Campi Flegrei; (2) of its magmatic and volcanic history, as recorded by the er uption products and char acterised by the m ajor magmatic events, the 39 ka Campanian Ignimbrite and the 15 ka Neapolitan Yellow Tuff, that casused two large collapses of th e Campi Flegrei caldera; (3) o f physical properties of Campi Flegrei magmas and (4) the crustal structure below the volcano, as relieved by seismic reflection and tomographic data. The model will solve the heat co nduction equations following a 2D finite difference s cheme proposed to s olve the problem of the heat transfe r inside and a round a mag ma body. Moreover, the displacement of the boundary se parating the melt and t he solid magma, in the reservoir and the conduit, due to magm a crystallization, is computed with an ad hoc fixed grid scheme. It is also considered the thermal problem of the emptying of a large magma chamb er. For th e convective regime in the upper portion of the Campi Flegrei magmatic system an up-dated version of the HEAT code has been used, and it has bee n considered discontinuous rise of magma batches from deep reservoir (10-20 km depth) to shallow ones. The thermal modelling results will be significant for the definition of the thickness of the shallow layer capable to rep roduce earthquakes (or the depth of the ductile-fragile transition), t o understand the deformation processes of Ca mpi Flegrei, th e extent o f contamination of magma by surro unding rocks, previously evi denced by isotopic and geochemica l data, to define the temperature (hence t he degassing) of ground-waters at different depths and geometry, evolution and sta te of superficial hydrothermal system, hence for the Campi Flegrei case, its role in the bradyseismic crises.

Keywords: thermal modelling, conductive convective, magmatic system

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VS006 **Oral Presentation** **6739**

Water and carbon dioxide content in the Minopoli2 shoshonitic magma from melt inclusions and experimental studies

Dr. Annarita Mangiacapra
Volcanoly and Petrology Osservatorio Vesuviano-INGV IAVCEI

Malcom Rutherford, Lucia Civetta

Minopoli_2 eruption occurred in the first epoch of Campi Flegrei Caldera (Italy) activity (10.3-9.5 ka). The products of this eruption are shoshonite and represent the less evolved magma composition erupted in the caldera. New constraints on magma pre-eruption conditions and dynamics are provided by geochemical investigation on melt inclusions (MIs) and experimental studies. Measurements of dissolved H2O and CO2 in phenocrysts-hosted MIs were performed using FTIR spectroscopy. Water contents vary from 0.3 to 3.5 wt% and CO2 contents range from 40 to 910 ppm. Minimum pressures of entrapment calculated from MIs data ranges from 140 to 245 MPa, corresponding to depths of 5 9 Km. Low pressure trapping ranges from 37 to 50 MPa, corresponding to depths of 1.5 2 Km. Thus, the pre-eruption magma is interpreted to be water and CO2-rich and to have equilibrated in a shallow magma chamber prior to eruption. The sulphur speciation in glassy MIs is determined as ≥ 79% sulphate which is equivalent to a log fO2 ≥ NNO + 1.5. The low end of the fO2 range is interpreted to represent the pre-eruption magma at depth. Phase equilibrium experiments dry and with 3.5wt% H2 O have been done guided by the dissolved H2O in MIs. The phase equilibria of this shoshonite shows that the observed phenocryst assemblage (olivine, Ca-pyroxene, plagioclase and biotite) is stable at a temperature 102015 C over the pressures range of 40 to 150 MPa and to higher pressures. Based on the MIs data for volatiles and the experiments, it is concluded that the shoshonite cristallised the phenocryst assemblage (15 vol%) at a depth of 9 Km and 1025 C; only small degrees of additional crystallization occurred as the magma ascended to a depth of 2 Km with degassing of some MIs. These results can contribute to the understanding of magma chamber processes and conduit dynamics, relevant parameters for hazard assessment, especially in densely inhabited volcanic areas, as Campi Flegrei caldera, where the risk is very highand strong is the need todetermine the possible volcanic scenarios.

Keywords: volatiles, melt inclusions, hazard

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VS006 **Oral Presentation** **6740**

Source multiplicity during unrest at the Campi Flegrei Caldera (Italy)? insights from spatio-temporal variations in vertical gravity gradients

Dr. Joachim Gottsmann
Dep. of Earth Sciences University of Bristol IAVCEI

Antonio G. Camacho, Kristy F. Tiampo, Jose Fernandez

We present an evaluation of residual vertical gravity-height change gradients obtained from gravimetric and elevation data between 1982 and 2000 at the Campi Flegrei caldera (CFc) in Italy. Spatial and temporal variations in the gradients are indicative of multiple causative sources during unrest, in particular for ground subsidence from 1988 onwards. Supported by results obtained from time series inversion for the period 1988-2000 using a random search approach of a purely elastic Earth model and a genetic algorithm accounting for elastic-gravitational effects, we propose a centre of dilatation undergoing predominantly pressure changes yet negligible mass changes as the dominant cause for caldera deflation. Mass fluctuations along the periphery of the CFc can be best explained by dynamic changes along the caldera boundary (ring) faults. These changes do not seem to be accompanied by significant ground deformation and appear to occur randomly both spatially and temporally. Mass and density changes along ring faults are inferred to play a significant role during unrest at other calderas and we argue that such processes be also considered for hazard assessment at the CFc.

Keywords: gravity, unrest, ring faults

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VS006 **Oral Presentation** **6741**

History of the magmatic feeding system of the Campi Flegrei caldera.

Prof. Lucia Civetta
Department of Physics Universit Federico II, Napoli, Italy

Ilenia Arienzo, Massimo D'Antonio, Valeria Di Renzo, Mauro Antonio Di Vito, Giovanni Orsi

The definition of the magmatic feeding system of active volcanoes in terms of architecture, composition, crystallization time-scale, re lationships between composition of the erupted magmas and structura l position of th e vents, and magma processes, is of paramount importance for volcanic hazards evaluation. Investigations aimed at defining the Campi Flegeri magmatic system, include detailed mineralogical, geochemical and isot opic analyses (Sr, Nd, Pb, Th,U). Th e magmatic feeding system of the Campi Flegrei caldera is characterized by d eep a nd shallow magma reservoirs. In the deep reservoirs (20-10 km dept h) mantle-derived ma gmas differentiated and were c ontaminated by continental cr ust. In the shallow reservoirs is otopically distinct magmas, further differentiated, contaminated, and mixed and mingled before eruptions. These processes generated isotopically distinct components, variably interact ing wi th the d ifferent structural elemen ts of the Cam pi Flegrei caldera through timeThe relationships between the structural position of the eruption vents,duringthe last 15 ka of activity, and the isotopic composition of the magmas erupted at the Campi Flegrei caldera allow us to reconstruct the architecture of the magmatic feedin g system and to infer the chemical and isotopic composition of the magma feeding a future eruption, according to vent position.

Keywords: magmatic system, volcanic hazard, caldera

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VS006 **Oral Presentation** **6742**

Long-term ground deformation analysis of active calderas with the SBAS DInSAR approach: the Campi Flegrei (Italy) and Long Valley (east California) case studies

Dr. Pietro Tizzani
CNR IREA

We perform a ground deformation analysis relevant to the Campi Flegrei () and the Long Valley (east California) calderas that are localized in two different geodynamic contexts. In particular, we exploit the Differential Synthetic Aperture Radar Interferometry (DInSAR) technology that allows us to produce spatially dense deformation maps with centimeter to millimeter accuracy. More specifically we applied the Small BAseline Subset (SBAS) algorithm that allows us to generate mean deformation velocity maps and corresponding displacement time series from sequences of SAR images. We remark that the SBAS algorithm permits to process data relevant to extended areas (typically of about 100 x100 km), thus allowing to highlight the relationships between local deformation signals, i.e., displacements due to a volcanic source, and regional patterns associated to tectonic processes. For what concerns the Campi Flegrei caldera we used all the available ENVISAT ASAR data acquired on the swath I2 from ascending (track:129 frame: 809) and descending (track: 36 frame: 2781) orbits, in order to generate deformation time series extending from 2002 to date; moreover, we combined ascending and descending data to separate the vertical and horizontal components of the deformation velocity. The processed data revealed the start of a new uplift phase with the detected trend becoming very clear starting from June 2005. The area of maximum deformation is localized in the centre of the town of Pozzuoli, with the renewed activity showing a maximum velocity of about 2.8 mm/year. The shape of the deforming area seems to be modulate by main shallow structures zone. Moreover, we also show that with the respect the most recent unrest episode occurred in summer 2000, this phenomenon is lasting for a longer time, although with a significantly slower velocity. The analysis of the Long Valley area and surroundings has been performed by using ERS-1/2 data acquired from a single (descending) orbit; the dataset includes 21 acquisitions relevant to the 1992-2000 period. The computed mean deformation velocity map and deformation time series highlight three different deforming zones: a subsiding area localized in the volcanic Pahoa Island in Mono Lake; a deforming zone at southwest of the caldera, localized in the area of Hilton Creek Fault (Sierra Nevada); a very large deformation pattern affecting the overall caldera region. In this case the DInSAR results clearly show that the displacement phenomena affecting the caldera have a maximum in correspondence of the resurgent dome and are characterized by the sequence of three different effects: a 19921997 uplift background, a 19971998 unrest phenomenon and a 19982000 subsidence phase. Moreover, the analysis of the retrieved displacement time series allows us to map the extent of the zone with a temporal deformation behavior highly correlated with the detected three-phases deformation pattern: background uplift-unrest-subsidence. We also showed that the mapped area clearly extends outside the northern part of the caldera slopes. The final discussion has been dedicated to a comparative analysis between the long-term deformation patterns detected for the two investigated calderas; this allowed us to point out some peculiar differences on the detected dynamic of the two volcanic centers. In particular, it clearly emerges for Long Valley caldera the primary role played by the magmatic source on the deformation pattern geometry. Indeed, in the Campi Flegrei case study our analysis reveals the significant impact of the shallow block structures forming the caldera floor that introduce a modulation on the detected displacement pattern. References: Massonnet, D., Rossi, M., Carmona, C., Ardagna, F., Peltzer, G., Feigl, K., and Rabaute, T., (1993), The displacement field of the Landers earthquake mapped by radar interferometry, Nature, 364, 138-142. Berardino, P., Fornaro, G., Lanari, R., and Sansosti, E. (2002), A new Algorithm for Surface Deformation Monitoring based on Small Baseline Differential SAR Interferograms, IEEE Transactions on Geoscience and Remote Sensing, 40, 11, 2375-2383.

Keywords: ground deformation, dinsar interferometry, caldera

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VS006 **Oral Presentation** **6743**

Dacitic and silicic magma transport process - Twin pressure source model for Mt. Usu (1910 and 2000), Japan and Campi Flegrei (1982-85), Italy

Dr. Jun Okada
Institute of Seismology and Volcanology Faculty of Science, Hokkaido University, Japan
IAVCEI

Mt. Usu is an active dacite volcano in Japan. It is located at the southern rim of Toya caldera and had erupted 9 times since 1663. Ground deformation associated with the 2000 eruption was characterized by new cryptodome formation which resulted huge amount of local upheaval at the western flank, and edifice-scale deformation which was centered at the summit at the same time. Latter one was one order smaller (several m upheaval at the summit) but extended over several tens km from the center of deformation. Edifice-scale deformation excluding localized upheaval of new cryptodome at the western flank showed sharp decrease of displacement with distance (at around 4-6 km), uplift-to-subsidence reversal (at around 6 km), and a small subsidence and contraction at further distances (at 7-40 km). This concentric deformation pattern can be modeled by the simple combined Mogis pressure source model with shallow inflation (2 km) and deep deflation (10 km). Similar magmatic intrusion process can be applicable for the past eruptions of Mt. Usu such as 1910, 1943-45, and 1977-82. Each leveling data can be explained also by the application of the twin pressure source model. Nearly equivalent volumes were estimated at both deep and shallow depths for the models of 1910 and 2000. This model indicates magma transport from the depth to the shallow part under the summit (Okada, 2007). The depth of deeper source corresponds to that of magma chamber suggested by petrological study. Twin source model with shallow inflation and deep deflation was applied to the various types of volcanic deformations in the world. Deformation associated with the 1924 eruption of Kilauea showed all ground subsidence over wide area. This was well explained by single Mogis deflation source. On the contrary, deformation data obtained in the 1982-85 volcanic episode of Campi Flegrei Caldera showed all uplift. Vertical displacement data rapidly decreases with distance at 5-6 km. This is quite similar deformation pattern to that of Mt. Usu. It was well explained by the simple Mogis twin pressure source model; shallow inflation (3 km) and deep deflation (10 km) with equivalent volumes. Common physical process of dacitic or silicic post-caldera magma transport exists between Mt. Usu and Campi Flegrei. Both deformation activities were characterized by the 108 m3 orders of magma intrusion from the depth (around 10 km) and its significant part remains at shallow depth (2-3 km). Resurgent dome growth at Campi Flegrei (1982-85) was possibly induced by intrusion of additional new magma from the depth (e.g. Dvorak and Mastrolorenzo, 1991; Bellucci et al., 2006). Twin source model was also applied to the 1914 eruption of Sakurajima volcano (Aira caldera). From comparative deformation study, several important physical rules were obtained. There are three kinds of magmatic processes, which are magma transport from the depth, shallow doming activity, and outflow of the magma without shallow doming activity. The application of Mogis twin pressure source model with shallow inflation and deep deflation could successfully evaluate these different magma processes.

Keywords: usu, campi flegrei, ground deformation

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VS006 **Oral Presentation** **6744**

Magmatic processes and their timescale in the resurgent Campi Flegrei caldera: the Campanian Ignimbrite case history

Dr. Ilenia Arienzo
Scienze della Terra Universit di Napoli Federico II IAVCEI

Arnd Heumann, Lucia Civetta, Gerhard Wrner, Giovanni Orsi

The Campi Flegrei is an active volcanic area, whic h since more then 60 ka B P, has pro duced magmas with variable chemical and Sr isotopic compositions, with the highest ratios detected in the least-evolved shoshonitic products. The most striking structural element of the Campi Flegrei is represented by a wide caldera resulting from collapses following the Camp anian Ignimbrite (39.280.11ka) and the Neapolita n Yellow Tuff (N YT-14.90.4ka) eruptions. The Campan ian I gnimbrite dep osit (> 200k m3 DRE) is th e largest of the Mediterranean area in the last 200ka. Measurements of Sr and Nd isotope ratios and of U and Th isotope ratios and concentrations ha ve been performed on the Campanian Ignimbrite products aimed to investigate the mag matic processes that o ccurred in the Phlegr aean magmatic system before the Campanian Ignimbrite eruption and the t imescale of these processes. New S r and Nd isotope data on glasses, minerals and whole ro cks repr esentative of the least- , int ermediate and most-evolved erupted magmas, are combi ned to reconstruct the nature and origin of mixing endmembers of the trachytic to phonolit ic Campanian Ignimbrite ma gmatic system. The lea st-evolved endmember sho w equilibrium between host glas s and the mos t of phenoc rysts. This endmember is less radiogenic in Sr and Nd than the most- evolved magma. On the cont rary, only the Fe-r ich pyroxenes from the most - evolved samples are in equilibrium with t he matrix glass while all o ther minerals are in isotopic disequilibrium. On the basis of these geo chemical an d isotopic data and on the basis of model ling results, we hypothesed that the most-evolve d and more radiogenic pumices, and the least-evolved and less radiogenic pumices, represent isotopic ally and chem ically different magmas which mixed and mingled before and during the Campania n Ignimbrite eru ption. U -series data on w hole rocks sh ow relatively constant U/Th ratios and are c haracterized b y an excess 238U relative to 230Th. Th e 238U/234U isotopic ratios measured in wh ole rocks and selected minerals show that the U-serie s isotopes are not affected by chemical alteration. Internal mineral isochrons for thre e least-evolved samples yield ages of 433 ka, 463ka a nd 487ka, the weighted mean value bei ng 452ka. Th e 230Th/232Th initial ratios for these samples is sim ilar within the errors; the weighted mean value is 0.88 0.02. If our isochrones reflect the crystallizat ion age of the analy zed phenocrysts, then they indicate that (1) the CI least-evolved magma was er upted after a relati vely short resi dence times si nce the end of its crystallization, i.e. between 4 and 8ka prior t o eruption, (2) the mixing process between the two Campanian Ignimbrite endmembers occurred in this time interval, allowing to pr eserve the time information rec orded in the Campanian Igni mbrite analyzed samples and suggesting th at coalescence between magma batches could also happen just prior to large caldera-forming eruptions.

Keywords: mixing mingling, internal isochrons

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VS006 **Oral Presentation** **6745**

Evolution of the Fantale volcano (Ethiopia) and hazards implicationsEvolution of the Fantale volcano (Ethiopia) and hazards implications

Dr. Mauro Antonio Di Vito
Istituto Nazionale di Geofisica e Vulcanologia Osservatorio Vesuviano IAVCEI

Ayalew Dereje, Civetta Lucia, Dantonio Massimno, Dellerba Francesco, Giordano Felice, Orsi Giovanni, Yirgu Gezahegn

The Fantale volcano rises for 600 m above the plain of the Main Ethiopian Rift, in the Metahara region, next to its junction with Afar. The summit of the volcano is truncated by an elliptical caldera. Stratigraphical, structural and petrological investigations have permitted to define the volcanological and structural evolution of the volcano. The general stratigraphic sequence, from base upward, includes: Old Lavas, Main Cone Unit, Fantale Welded Tuff, and Products of the Post-caldera Activity. The erupted rocks show a typical mafic-felsic bimodal distribution with few intermediate terms. The Old Lavas are a succession of trachytic lava flows and domes, among the less evolved rocks of the entire sequence, erupted by variable vents. The Main Cone Unit includes rhyolitic lavas and obsidian flows intercalated to fallout pyroclastic deposits, mostly erupted in the upper part of the edifice. Its emplacement was likely followed by a period of quiescence culminated in the eruption of the voluminous Fantale Welded Tuff (168 ka), which was accompanied by the collapse of the summit caldera. This Tuff, is variably welded and includes many ash-flow units. The caldera, about 300 m deep, has a maximum elongation of about 3.5 along an E W oriented major axis. It is intersected by NNE and WNW trending fault systems which have strongly affected its evolution and present configuration. The Post-caldera Activity includes vents located both inside and outside the caldera. Trachytic lavas were erupted within the caldera and later intersected and tilted by EW trending faults. Eruption of pantelleritic pumice cones and lava domes occurred both inside the caldera and along the slopes of the edifice, along NNE and WNW directions. Basaltic eruptions produced lava flows and scoria cones. The last basaltic activity occurred in 1810 between Fantale and the Metahara town, along NNE trending fractures. Presently the caldera floor is characterized by widespread fumaroles and active faults. Historical eruptions and intense fumarolic activity are evidence of the persistent activity of the volcano. Therefore Fantale has to be considered a dangerous volcano. The Fantale area hosts a large population either in the town of Metahara, at the base of the volcano, or over and around the volcano. Other people live in two sugarcane and banana plantations, close to the volcano. Infrastructures which have a nationwide importance are exposed to the potential volcanic hazards. They include the mentioned plantations, which are a mean of subsistence for local population and for the entire country. The main road and the only railway connecting to the sea, at Djibuti, run through Methahara.

Keywords: main ethiopian rift, caldera, volcanic hazard

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VS006 **Oral Presentation** **6746**

The Campi Flegrei resurgent caldera: volcanism, deformation and hazards

Dr. Mauro Antonio Di Vito
Istituto Nazionale di Geofisica e Vulcanologia Osservatorio Vesuviano IAVCEI

Orsi Giovanni, Dellerba Francesco, Selva Jacopo, Sandri Laura, Marzocchi Warner, Quaglino Michaela

The Campi Flegrei caldera is a nested and resurgent structure generated by two major collapses. The whole structure is subsiding, while the central part of the younger caldera is affected by resurgence occurring through a simple-shearing mechanism. This long-term deformation has generated a maximum vertical uplift of about 90 m. After the last caldera collapse, volcanism was concentrated in three epochs of activity, alternating to periods of quiescence. The last eruption occurred in 1538 AD at the intersection of two fault systems delimiting the resurgent block. The areal distribution of the eruption vents in each epoch is a good tracer of the active structures which have favoured magma upraise to surface through time. The great majority of the recognised eruptions were explosive, almost all alternating phreatomagmatic and magmatic explosions. They were low- to medium-magnitude events, except two high-magnitude events, one in the I and another in the III epoch. During the quiescence between the II and III epochs, the stress regime still active in the caldera, began. The persistent activity of the system and its explosive character, accounts for the very high volcanic hazard. Due to such a high hazard and intense urbanisation the volcanic risk is also very high. The caldera has been affected by deformation over the past 2 ka. Two major and four minor unrest episodes have occurred since 1969. These short-term deformation events are interpreted as the result of the interplay of a ductile and a brittle component, both generated by pressure and temperature increase in the magma reservoir due to arrival from depth of small magma batches, less evolved and hotter than the resident magma. The striking similarity in shape between long- and short-term deformation suggests that the resurgence dynamics is not changed since the quiescence period between the II and III epoch. Furthermore the long-term results from the summation of many short-term deformation events. The collected data have permitted to perform a volcanic hazards assessment. The portion of the volcanic and deformation history of the caldera to be taken into consideration for such a purpose, has been hypothesised. Although it is impossible to define the time when an eruption will occur, according to the dynamics of the caldera deformation, the structural conditions which have to be acquired for magma to reach the surface, have been defined. According to the vents distribution in the past and the ongoing dynamics of the caldera, the areas within which a future vent could open have been located. The variable eruption scenarios have also been defined. The effects on the territory of such a scenarios have been represented in volcanic hazards maps.

Keywords: campi flegrei caldera, resurgence, hazard

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VS006 **Oral Presentation** **6747**

Evolution and volcanic hazards of the Pantelleria resurgent caldera

Prof. Giovanni Orsi
Osservatorio Vesuviano Istituto Nazionale di Geofisica e Vulcanologia IAVCEI

Dellerba Francesco

The results of stratigraphical, structural and volcanological investigations on the deposits of the recent activity of the Pantelleria resurgent caldera, have permitted to define in great detail the volcanic and deformation history of the system, the areal distribution of the volcanic deposits, and the location of the eruption vents. They have also permitted to group the volcanic edifices into four categories (one basaltic and three silicic), each typical of one type of long-lasting eruption. Furthermore they have been used to perform a first volcanic hazards assessment.Pantelleria, the type locality for pantellerites, has been the site of intense volcanism related to both regional tectonism and volcano-tectonism. The persistent state of activity of the system is testified by two submarine mafic eruptions occurred in 1831 and 1891 in the vicinity of the island, and by an intense fumaroles and hot-water springs activity.The last caldera-forming eruption occurred about 50 ka bp and generated the Green Tuff. The subsequent history has been subdivided into six silicic cycles, sometimes intercalated with basaltic eruptions. Areal distribution of the vents active during each cycle was related to distinct structural features.The structural setting of the island is defined by both tectonic and volcano-tectonic lineaments. A NE-SW faults system divides the island into two sectors and most likely represents a crustal discontinuity. The major volcano-tectonic features include caldera collapses and resurgence within the youngest caldera. Such a resurgence, begun after 33 ka bp, has generated uplifting and tilting of the Montagna Grande block, through a simple- shearing mechanism. The north-western side of the block is buried by rocks erupted in the last 10 ka trough NE-SW aligned vents. The distribution of these vents clearly indicate a genetic relationships between resurgence dynamics and volcanism. The selected volcanic edifices, assumed as typical of long-lasting eruptions, are the basaltic Mursia cinder cones and lava flows, and the pantelleritic Cuddia di Mida Tephra and pumice cone, Cuddia Randazzo partially collapsed edifice, and Cuddia Sciuvechi shield volcano.The results of the work carried out have permitted to make a first attempt of volcanic hazards assessment in case of renewal of volcanism in short-mid terms. In particular it is possible to define the portion of the known volcanic history to be taken as reference for volcanic hazards assessment. Furthermore it is possible to put forward some hypotheses on eruption scenarios, vent location, time, and characteristics of a future event. It is possible also to assume the characteristics of some of the past eruptions as reference for future single events of variable magnitude, and the evolution of some volcanoes as reference for future long-lasting activity.

Keywords: resurgent calderas, hazard

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VS006 **Poster presentation** **6748**

The submerged border of the Phlegrean fields caldera (Naples Bay, Southern Tyrrhenian sea, Italy): constraints from high resolution magnetic data and Multibeam bathymetry

Dr. Gemma Aiello
Istituto per l'Ambiente Marino Costiero (IAMC) Consiglio Nazionale delle Ricerche

Marsella Ennio, Ruggieri Stefano

The submerged border of the Phlegrean Fields caldera (Naples Bay, Southern Tyrrhenian sea, Italy) has been identified based on combined interpretation of high resolution magnetic anomaly map and Digital Terrain Model of the Naples Bay. High resolution magnetic and bathymetric data have been recorded during several oceanographic cruises carried out by the CNR-IAMC Institute of Naples, Italy onboard of the R/V Urania, National Research Council of Italy. A Total Magnetic Field (EMF) survey was recently carried out in the Naples Bay, having an advanced spatial coverage with respect to previous measurements, such as airborne magnetic survey recorded by AGIP in the 1981. Moreover, the data were acquired at a shorter distance from the source and at a lower velocity, giving more precise sampling and improved field restoration. The main magnetic anomaly fields recognised on the map have been constrained by geologic features based on geologic interpretation and correlation with lineaments identified based on the interpretation of Digital Terrain Model. Two main belts of sharp magnetic anomalies have been identified, the first one located offshore the Somma-Vesuvius volcanic complex and the second one offshore the Phlegrean Fields volcanic complex. The latter is here interpreted as the submerged border of the Phlegrean Fields resurgent caldera. The caldera border shows a NE-SW structural elongment, parallel to that of the Sarno-Sebeto-Dohrn canyon normal fault, controlling downthrowing in the Naples Bay half-graben. It is located in correspondance to the outer shelf of the Gulf of Pozzuoli and to the submerged volcanic banks of Nisida, Miseno and Pentapalummo. It represents a relatively complex magnetic anomaly area, characterized by several magnetic anomaly fields having different intensity. Two dipolar anomalies, indicating buried magnetised bodies and/or volcanic edifices, have been recognised. The first one, E-W oriented and located northwards is characterized by a minimum of - 200 nT, associated to a maximum of + 185 nT. Such a values should indicate small buried volcanic bodies. The second one, NW-SE oriented and located eastwards is characterized by a maximum -minimum couple having intensities similar to those of the previous field. Other non-dipolar anomalies, having weaker intensities, ranging between 40 and 135 nT are due to the occurrence of small volcanic centres. As revealed by the combined interpretation of DTM and magnetic anomaly map, the shape of magnetic anomalies is not directly related to the submarine topography of large volcanic banks, flat and terraced. It is probable that, after the formation of the banks, the intrusion of minor volcanic bodies occurred. The latter ones occur as lava domes cropping out at the sea bottom and elevated with respect to the flat top of the banks, terraced during the Late-Quaternary glacio-eustatic oscillations of sea level.

Keywords: caldera, magnetics, bathymetry

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VS006 **Poster presentation** **6749**

Three dimensional magneto-seismic reconstruction of the Torre del Greco submerged volcanic structure: evidences of the seaward elongment of the Somma-Vesuvius volcanic complex

Dr. Gemma Aiello
Istituto per l'Ambiente Marino Costiero (IAMC) Consiglio Nazionale delle Ricerche

Di Fiore Vincenzo, Marsella Ennio, Ruggieri Stefano

An integrated interpretation of high resolution seismic and magnetic profiles recently collected offshore the Mount Vesuvius volcano by the CNR-IAMC Institute of Naples, Italy has been carried out in order to attempt a three dimensional magneto-seismic reconstruction of a large volcanic structure (about 7.5 kilometres), located offshore the Torre del Greco town (Naples Bay, Southern Tyrrhenian sea, Italy) and representing the seaward prolongation of the Vesuvius volcano. Seismic stratigraphy of the volcanic structures show acoustically transparent seismic facies and high contrasts of acoustic impedance with respect to the overlying sediments. They show mounded external geometry and average dimensions in the order of kilometres. The base of the Torre del Greco structure is not acoustically evident, because it warps the volcanic seismic unit correlated to the "Campanian Ignimbrite" pyroclastic flow deposits. The top of the structure is irregular and eroded and show several culminations. The total magnetic field in correspondence to the Torre del Greco structure shows three main maximum values of the anomalies, dipolar in shape. Other volcanic mounded structures, identified by seismic interpretation and fossilised by sediments don't correspond to any magnetic anomaly field, also if they show an overall geometry similar to that of the Torre del Greco structure. Three dimensional reconstruction of the Torre del Greco structure has been carried out by using seismic constraints and correlation of volcanic structure to bathymetry. A kriking type interpolation has been applied both to magnetic and bathymetric data. The bathymetric dataset has been processed by the application of a median filter in order to remove the main sea bottom corrugations by smoothing the sea bottom topographic surface. In this reconstruction the sea bottom topography offshore the Somma-Vesuvius volcanic complex is compared to the top of the Torre del Greco volcanic structure represented by contour depth of corresponding seismic horizon. Proceeding from south-east to north-west it exists a good correspondance between the sea bottom topographic surface and the top of the volcanic structure, which doesn't crop out at the sea bottom. The uprising of the volcanic structure in proximity to the sea bottom corresponds to the occurrence of topographic undulations of the sea bottom in the order of ten meters. This is confirmed by the interpretation of seismic profiles, showing three main vertical culminations of the volcanic structure, where overlying sediment drape is significantly reduced. These culminations are linked to magnetic anomaly maxima, having values ranging between 250 and 350 nT. Further knowledge on the structure need detailed volcanological interpretation and age attribution of these bodies in the eruptive activity of the Somma-Vesuvius volcanic complex.

Keywords: vesuvius, seismics, magnetics

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VS006 **Poster presentation** **6750**

A quantitative study for the reconstruction of the Mercato eruption (8.000 yr B.P.) of somma-Vesuvius.

Dr. Daniela Mele
Diprtimento Geomineralogico Universit degli Studi di Bari

The reconstruction of eruptive and transportation processes of each eruption at Somma-Vesuvius are of primary importance in the continuous challenge of improving the volcanic hazard mitigation actions in the Neapolitan area. Here we report new volcanological studies which allowed the detailed stratigraphic reconstruction of the Mercato eruption (8000 yr B.P.) of Somma-Vesuvius. About 30 stratigraphic section were studied and described on the volcano slopes and its surroundings, up to a distance of more than 45 km. A composite stratigraphic section has been constructed, and four main eruptive phases individuated. The different phases were individuated on the basis of erosive surfaces and deposits of fine, massive ash. The occurrence of an erosive surface suggests that a major time break occurred at the end of the first phase, while the two massive, fine ash deposits of centimetric thickness mark the passage between the second-third, and between the third and the fourth phases. All the four phases were characterised by alternating fallout and pyroclastic density current deposits. Two main fallout deposits (L1a, L1b) occurred during the first phase, and dispersed fine pumice and accidental lithic lapilli towards NE. Two minor fallout deposits (L2a, L2b) occurred in the second phase, interbedded with a massive pyroclastic density current deposit. Three main fall beds (L3a, L3b, L3 c), occurred in the third phase, which was also characterised by the emplacement of three massive and at least four dilute pyroclastic density current deposits. The three fall beds blanketed a wide area in E direction. Three lithic-rich fallout deposits (L4a, L4b, L4c) occurred in the last phase, which were dispersed toward E. Two dilute and one massive pyroclastic density current deposits were recognised in this final phase. Column heights were between 18 and 22 km, corresponding to mass discharge rates (MDR) around 106 -107kg/s. Chemical analyses performed on samples from the whole stratigraphic succession yield a constant phonolitic composition. Stratigraphic data indicate a pulsating behaviour for the Mercato eruption, an eruptive style not yet described for the other Plinian eruptions of Somma-Vesuvius.

Keywords: plinian eruption, mercato eruption, somma vesuvius

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VS006 **Poster presentation** **6751**

A new giant caldera of Kamchatka, Russia: boundary, structure and pyroclastic volume

Dr. Leonov Vladimir
Russian Academy of Sciences Institute of Volcanology and Seismology IAVCEI

A new giant caldera recognized in Kamchatka, Russia. The caldera was formed within the Southern Kamchatka in Eo-pleistocene (1.2-1.5 Ma). We have reconstructed the boundary and size of the caldera approx. 15x25 km. In the northern-western part of the caldera there is an elevated block. The block is considered as a result of viscous rhyolite magma intrusion at later stage (approx. 0.5-0.8 Ma). In other words it is a resurgent dome. We have reconstructed the boundary of a large lake basin formed inside the caldera after the evolution of resurgent dome. The elongation of caldera and resurgences is controlled by perpendicular to the Quaternary East-Kamchatka volcanic zone (NNE-SSW) normal faults of Malko- Petropavlovskaya transverse zone (NW- SE). The estimated volume of rhyolitic to dacitic pyroclastics produced during the eruption caused the caldera formation - approx. 825 km3 (~2x1015 kg). It was the severest eruptions on the Kamchatka peninsula we known and one of the severest eruptions in the world. This work gives the data on the structural positions of modern hydrothermal systems and ore deposits, how they are connected with the caldera and its resurgent dome.

Keywords: caldera, resurgence, kamchatka

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VS006 **Poster presentation** **6752**

Ground deformation at Crater Rim of Vulcano (Aeolian Archipelago, Italy): gravity sliding or thermal expansion?

Dr. Alessandro Bonforte
Sezione di Catania Istituto Nazionale di Geofisica e Vulcanologia IAVCEI

Alessandro Bonaccorso, Salvatore Gambino, Carlo Giunchi, Francesco Guglielmino

Since 1990 a geodetic network was installed in the northern sector of the crater terrace of Vulcano islands and measured by EDM techniques, aimed at investigating the movement of the north upper slope of the cone, that was affected in the past by landslide phenomena. Five benchmarks of the network (F4-F8) are positioned above the depression, named La Forgia , characterised by intense fumarolic activity and slope instability. The other benchmarks are in relatively more stable bordering areas along the rim. Slope distance measurements departing from northern part of the island (Vulcanello) to the rim have been carried out frequently, especially during the first years. The measurements carried out during the period 1990 - 1994 showed a marked constant shortening of about 6-7 cm on the baselines from Vulcanello to F4-F8 benchmarks, which could be interpreted as a gravitational sliding. However, in the following years these baselines showed a slow extension (at a rate of about 1 cm/y) that gradually recovered most of the previous deformation. No particular variations were recorded on F1 to F3 and F9 to F12 benchmarks. We considered the relationship between the measured ground deformation and the crater fumaroles temperature variations recorded in the same period. In fact, between 1987 and 1997 these temperatures were characterized by the highest values since the 1920s. In particular, the temperature increased from about 300C in 1987 to 690C in May 1993 and then decreased to 400C in 1996-1997. We hypothesized that the shortening of the EDM baselines was related to the heating of the rock body lying beneath the area of F4-F8 benchmarks where fumaroles activity is well evident. We verified this hypothesis by calculating the expected dilatation of the body, as function of the volume of the rock and its thermal expansion coefficient, and comparing the expected deformation the observed one. Furthermore, finite element numerical modelling, considering real topography and contrast of rigidities, were implemented in order to provide a more accurate description of the phenomena.

Keywords: vulcano, geodetic monitoring, thermal expansion

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VS006 **Poster presentation** **6753**

Seismic images and rock properties of the very shallow structure of Campi Flegrei caldera (southern Italy)

Mr. Dello Iacono Dario
phisic science federico II - university of Napoli

Aldo Zollo, Maurizio Vassallo, Tiziana Vanorio, Sebastien Judenherc

The volcanic area of Campi Flegrei has been active in the recent past, as well illustrated by the historic eruption of Monte Nuovo in 1538, by the 1970-72 and 1982-84 bradiseismic rises , by the fumarolic activity, and by the hot springs. In September 2001, an extensive active-seismic investigation was carried out in the gulfs of Naples and Pozzuoli, with the aim of investigating and reconstructing the shallow crustal structure of the Campi Flegrei caldera, and possibly identifying its feeding system at depth (the Serapis Project). The present study provides a joint analysis of the seismic reflection data and tomographic images based on the Serapis dataset. This is achieved by reflection seismic sections obtained by the 3D data gathering and through. refined Pvelocity images of the shallowest layer of Pozzuoli Gulf (z<1000 m).From the refined Vp model, the overall picture of the Vp distribution shows the presence of a complex arc- shaped anomaly that borders the bay off shore. The deeper part of the anomaly (beneath 700 m, with Vp>3 500 m/s) correlates with units made up of agglomerate tuff and interlayered lava, which form the southern edge of the Flegrei caldera, which was itself probably formed following the two large ignimbritic eruptions that marked the evolutionary history of the area under study. The upper part of the anomaly that tends to split into two parallel arcs is correlated with dykes, volcanic mounds and hydrothermal alteration zones noted in previous shallow reflection seismic analyses. The depth of the transition between the upper and lower parts of the anomaly is characterized by an abrupt Vp increase on the one-dimensional (1D) profiles extracted from the 3D tomographic model and by the presence of a strong reflector located at about 0.6/0.7s Two Way Time (TWT) on Common Mid Point gathers. The move-out velocity analysis and stack of the P- P and P-S reflections at the layer bottom allowed to estimate relatively high Vp/Vs values (3.5 0.6) .This hypothesis has been tested by a theoretical rock physical modelling of the Vp/Vs ratio as a function of porosity suggesting that the shallow layer is likely formed by incoherent, water saturated, volcanic and marine sediments that filled Pozzuoli Bay during the post-caldera activity.

Keywords: phlegrean field caldera, shallow structure, seismic reflection

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VS006 **Poster presentation** **6754**

Analysis of PS-TO-PP amplitude ratios for seismic reflector characterisation in a volcanic region

Dr. Nils Maercklin
RISSC Lab Universita di Napoli IAVCEI

Aldo Zollo

Elastic parameters derived from seismic reflection data provide information on the lithological contrast at an interface and support the geological interpretation. Standard amplitude variation with offset methods analyse reflection coefficients and thus require the knowledge of source, receiver, and propagation effects. These effects are mostly reduced when looking at amplitude ratios of PP reflected and PS converted phases from the same interface. We present a technique to model and invert PS-to-PP amplitude ratios to estimate arbitrary strong elastic contrasts at a given interface in a layered medium. Our method is first applied to synthetic data to assess its possibilities and limitations. Second, we analyse amplitude ratios from real data acquired in the Campi Flegrei caldera (Phlegrean Fields, southern Italy), and we show first results for main discontinuities identified in this volcanic region.

Keywords: seismic, reflection, amplitude

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VS007 **6755 - 6771**

Symposium
Calderas II: Calderas and caldera forming eruptions

Convener : Dr. Gianfilippo De Astis, Prof. Roberto Scandone, Dr. Guido Ventura

Calderas involve the rapid eruption of magma from crustal reservoirs that vary in size and shape in different tectonic environments. Some caldera-forming eruptions have been far larger than any in the historical record and may have had large impacts on earth climate. In contrast, other large volcanoes have been active for hundred thousands of years without caldera- forming eruptions. Much recent volcanological research is aimed at understanding the conditions favoring the occurrence of large caldera-forming eruptions, how the magma reservoir develops in time, and how the resulting caldera is related to the style of the causative eruption. Lacking direct observation of unrest that preceded large caldera-forming events, we are dependent on the geologic record of precursory eruptive activity. Will we be able such data to forecast large caldera-forming eruptions in the future? This session focuses on the diverse methods, including field observations, petrologic and geochronologic studies, geophysical monitoring, and physical and numerical modeling, that can help understand the conditions leading to a caldera-forming eruption, its temporal evolution, and the form and shape of the resulting caldera and associated subvolcanic magma reservoir.

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VS007 **Oral Presentation** **6755**

CCDB: the worldwide collapse caldera database

Mrs. Adelina Geyer
Department of Geophysics and Geohazards Institute of Earth Sciences IAVCEI

Joan Marti

Field studies constitute the most important way to investigate and understand collapse caldera processes. The reconstruction of past collapse calderas and their comparison with present observed examples is a powerful tool to understand the mechanisms of collapse caldera formation. The objective of this work is the elaboration of a worldwide Collapse Caldera DataBase (CCDB). The CCDB should be a useful and accessible tool for studying and understanding caldera collapse processes. The databases records different types of information including: structural properties of the caldera, properties of the magma chamber and of the extruded deposits and magma, pre- and post-caldera volcanic activity and associated local, regional and plate tectonics. We have performed a comprehensive compilation of published field studies of collapse calderas. More than 200 references have been revised, and their information has been summarized in a database linked to a Geographical Information System (GIS) application. Thus, it is possible to visualize the selected calderas in a world map and to filter them according to different attributes (e.g. age, structure, etc.) recorded in the database. The final aim of the CCDB is to update the current field based knowledge on calderas, merging together the existing databases and complementing them with new examples found in the bibliography. Evidently, this database does not include all the calderas of the world, but it tries to be representative enough for further studies and analyses. Since communication and data exchange between scientific groups is still scarce and sometimes also unsatisfactory, the final and better use of this database is to convert it into an open and accessible tool for collapse calderas studies. A further purpose of this work is the elaboration of the CCDB web page. We are interested in the communication between research groups in order to streamline data and knowledge exchange. Consequently, in this web page users will be able to acquire (after registration and obtaining of a username and a password) the current database version, to propose corrections or updates and to exchange information with other registered members also involved in the study of caldera collapse processes. Additionally, the CCDB includes a formulary that will facilitate the incorporation of new calderas with their corresponding characteristics and attributes into the database.

Keywords: calderas, database

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VS007 **Oral Presentation** **6756**

The interplay between eruption dynamics and the mechanics of caldera formation

Prof. Roberto Scandone
Dipartimento di Fisica Universita' Roma Tre IAVCEI

Valerio Acocella

The formation of large calderas is a rare event and requires the eruption of enormous amount of magma in a matter of hours-days. The rarity of the events depends on the difficulty of developing the minimum conditions necessary to start first an explosive eruption and then a massive collapse of the magma chamber roof. Here we examine the required minimum conditions for caldera formation basing on new theoretical ideas regarding the development of large explosive eruptions (Scandone et al, 2006), and analogue models on the mechanics of caldera formation (Acocella, 2006). The sequential events leading to large caldera formation require: 1 - Presence of a large and shallow magma body; 2 - Development of a large explosive eruption through the formation of a continuous connected conduit between reservoir and surface; 3 - Large and fast depressurization of the reservoir because of magma drainage; 4 - Initial roof collapse with gaping faults connecting the reservoir with the surface and creation of a continuous ring conduit feeding annular vents; this condition is met only with aspect ratios (width/height) of the chamber roof A>0.64, when a single set of outward dipping reverse faults bordering the caldera forms. The first 3 points are necessary prerequisites for any caldera forming eruptions; however, they are not sufficient to start the catastrophic stage, unless the collapse of a piston block allows the formation of continuous conduit from the chamber to the surface (condition 4). This model is applied to several eruptions examples.

Keywords: caldera, collapse, depressurization

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VS007 **Oral Presentation** **6757**

Caldera types: how end-members relate to evolutionary stages of collapse

Dr. Valerio Acocella
Dip. Scienze Geologiche Roma Tre Universita Roma Tre IAVCEI

Currently proposed caldera types (downsag, piston, funnel, piecemeal, trapdoor) are mainly based on field evidence and are each viewed as end-members. An overview of recent experiments on caldera formation, under different conditions, shows remarkably consistent results and suggests four experimental stages characterized by progressive subsidence. Distinctive structural features of each stage are found in many calderas, highlighting an overall consistency. The evolutionary stages adequately explain the architecture and development of the established caldera end-members along a continuum, where one or more end-member may correspond to a specific stage. While such a continuum is controlled by progressive subsidence, specific collapse geometries will result from secondary factors, such as roof aspect ratio, collapse symmetry and pre-existing faults.

Keywords: caldera, analoguemodels

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VS007 **Oral Presentation** **6758**

Syntectonic multiple-vent eruption of a laterally extensive, pumice-free and crystal-rich ignimbrite (the Cretaceous Kusandong Tuff, Korea)

Prof. Young Kwan Sohn
Earth & Environmental Sciences Gyeongsang National University IAVCEI

Jong Ok Jeong, Yong Moon Jeon

The Cretaceous Kusandong Tuff, Korea, is a thin (1-5 m thick) but laterally extensive (~200 km), silicic (63-78 wt. % silica) ignimbrite emplaced upon a fluviolacustrine basin adjacent to a continental volcanic arc. The tuff has been used as an excellent key bed because of its great lateral continuity and unique lithology, characterized by the virtual absence of pumice and juvenile/cognate lithic clasts and an abundance of quartz and feldspar crystals (26-91 vol. %). Field and laboratory analyses show that the tuff can be divided into the Northern Kusandong Tuff (NKT) and the Southern Kusandong Tuff (SKT), which originated from the eruptions of compositionally different magmas from widely separated source vents. The NKT and the SKT show ten-fold difference in the content of accidental components (7.5 vol. % in the NKT and 0.8 vol. % in the SKT) and 10-20 vol. % difference in the content of crystals and lithics (34-74 vol. % in the NKT and 26-55 vol. % in the SKT) in the massive division. These contrasts are interpreted to have been caused by the fissure eruption of the NKT and cylindrical-conduit eruption of the SKT. The absence of pumice and juvenile/cognate lithic clasts is interpreted to be due to rapid ascent and shallow-level fragmentation of highly viscous silicic magmas, which was possible because of the fracturing of the rocks above the magma chambers by external tectonic forces. The apparently contemporaneous eruptions of the NKT and the SKT from widely separated vents also support the role of a regional extensional event in triggering the eruption of the tuff. It is thus inferred that the Kusandong Tuff is a product of syn-tectonic volcanism, and an ignimbrite with the characteristics of the tuff can be used not only as a key bed for stratal correlation but also as a key to interpretation of syn-tectonic volcanism and structural evolution of sedimentary basins.

Keywords: ignimbrite, syntectonic volcanism

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VS007 **Oral Presentation** **6759**

Implications for contemporaneous generation of proximal spatter and lithic-rich breccias in caldera forming eruptions as inferred from proximal breccias assoicated with the tufo rosso a scorie nere; the 151 Ka Sutri eruption, Vico Caldera, Italy

Mrs. Adele Bear
School of Geosciences Monash University IAVCEI

Raymond A. F. Cas, Guido Giordano

The 151 ka Sutri Formation, erupted from the Vico Volcano, Central Italy, represents a caldera forming association of pyroclastic fall out deposits and a variety of ignimbrite facies, including lithic and very coarse spatter breccias. This paper discusses the significance of the lithic breccias and spatter deposits to caldera collapse processes. The latter stages of the Sutri eruption, produced a southerly dispersed lithic-rich breccia (Sutri C) that grades vertically into a juvenile- rich deposit (Sutri D). A succeeding, more extensive and complex association of proximal lithic-rich and spatter- rich breccias that grade laterally into one another, are distributed radially around the present day caldera up to 7 km from vent (Sutri E4). Three subdivisions are recognised based on field analysis, grainsize studies and petrographic characteristics and all occur at the same stratigraphic level radially around the caldera: F1 - spatter-rich breccia (north - east); F2 - boulder size lithic clast-rich breccia with associated spatter component (southeast - south); F3 spatter-rich breccia with associated lithic clast component (southwest - west). The Sutri C lithic-rich breccia is interpreted to represent a co-ignimbrite lag flow breccia associated with an early vent-widening episode confined to the south. Lithic clasts are sourced from leucite lava flows and their hydrothermally altered equivalents, which are related to the earlier stratovolcano-building phase of activity as well as subordinate sedimentary xenoliths sourced from deeper parts of the volcanic conduit. The gradational vertical transition into a more juvenile clast dominant deposit (Sutri D) reflects changing source conditions at the vent, an increase in the output of juvenile material and a cessation of vent -widening activity. The radially dispersed spatter-rich and lithic-rich proximal breccias (Sutri E4) are associated with the second and final vent-widening episode of the Sutri eruption associated with final caldera collapse. This occurred contemporaneously with spatter-producing, fire-fountaining activity at the vent. F1 proximal breccia represents a dominance of fire - fountaining activity and production of spatter in the northeast. F2 proximal breccia features a high proportion of lithic clasts and comparatively less abundant spatter clasts suggesting vent widening (plinian activity) dominated over fire fountaining in the southeast-south. Lithic clasts were also derived from shallow leucite lava flows and the sedimentary subsurface, but also from deeper plutonic sources. F3 exhibits similar abundances of spatter and lithic clasts suggesting that vent widening processes and fire - fountaining were contributing relatively equally to providing source material for the proximal breccias in the southwest-west. Evacuation of the magma chamber and generation of a large volume, spatter-rich ignimbrite rapidly succeeded the emplacement of these proximal breccias and caldera collapse ensued shortly after. The contemporaneous occurrence of spatter juvenile clasts associated with shallow-level fragmentation with more deep-seated juvenile clasts is problematic.

Keywords: breccia

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VS007 **Oral Presentation** **6760**

Distribution of large silicic calderas in arc settings

Mrs. Gwyneth Hughes
Geological and Environmental Science Stanford University

Gail Mahood

Silicic calderas are of fundamental geological interest because they are the surface expressions of silicic magma chambers, the precursors of felsic plutons. Because the silicic nature of continental crust makes it resistant to subduction, the study of silicic magmatism in arc settings is key to understanding how continents form and persist. In addition, by determining the factors that control the occurrence of large silicic magma chambers in arcs, we hope to improve the interpretation of ancient arc settings. A global compilation of silicic calderas in arc settings was undertaken in order to analyze the occurrence of large-scale silicic magmatism within volcanic arcs. Approximately 100 arc-related silicic calderas younger than 2 Ma and larger than 5 km in diameter were identified for 14 arcs worldwide. The goal of this study was to analyze the intra- and inter- arc spatial distribution of silicic calderas, and determine whether the development of silicic volcanism in arc settings is related to any of a variety of factors including thickness and age of the crust underlying the arc, plate convergence rate, and subduction angle. The spatial distribution of silicic calderas was characterized by two methods: (1) measurement of the distance between each silicic caldera and the associated volcanic axis of the arc, defined by the stratovolcanoes of intermediate composition; and (2) calculation of a caldera density for each individual arc that quantifies the number of silicic calderas per kilometer of arc length. Caldera density positively correlates with plate-normal convergence rate, and the number of silicic calderas decreases with increasing distance from the volcanic axis. Both of these correlations are likely related to magmatic flux. Although calderas, in general, do not preferentially form at a specific distance behind the arc, in arcs on relatively mafic or young crust, calderas tend to occur along the arc axis; on older continental crust, calderas tend to occur behind the axis. Calderas located farther than 10 km behind the main axis of the arc are generally more silicic and larger than those closer to the axis.

Keywords: silicic, arc, calderas

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VS007 **Oral Presentation** **6761**

Volcanic evolution of the back-arc complex of Payun Matru (Argentina) and its geodynamic implications for caldera-forming eruption in a complex slab geometry setting.

Mrs. Aurelie Germa
Laboratoire de gochronologie, UMR IDES Universit Paris Sud (PARIS XI) IAVCEI

Quidelleur Xavier, Gillot Pierre-Yves, Tchilinguirian Pablo

About thirty volcanic formations of the back-arc Payun Matru Volcanic field (PMVF, Argentina, 36S, 69W) have been analyzed for geochronology and geochemistry, in order to reconstitute the eruptive history of the complex, particularly the collapse of Payun Matru volcano caldera, in the Andean geodynamic framework. K-Ar dating shows that the PMVF has been built since final Pleistocene until present (ages range from 28 0 5 ka to 7 1 ka). The geochemical data show that rocks belong to sodi-potassic calc-alkaline series, with characteristics of both arc and intra-plate magmas. By connecting these data to morphological study of the complex, three units can be distinguished. The shield volcano of Payun Matru s.s. is characterized by trachytic compositions and a large summit caldera (9 7 km). It was built on a basaltic field (Los Volcanes) which covers a large surface of the PMVF, with east-west trending structures. The earlier stages of the Payun Matru volcano are not dated, but we constrain the major explosive event, related to the eruption of a widespread ignimbrite and to the formation of the large caldera, between 168 4 ka (internal wall of caldera) and 82 1 ka (flow in the structure). Based on the geochemical similarity of the ignimbrite and the upper flow of the pre-caldera cone, we suggest that the age of this event is most probably located at the older end of this interval. The activity of Los Volcanes extends within the Holocene. Numerical modelling using GIS program allow us to propose a model of morphological evolution for Payun Matru volcano before and after the caldera collapse. South of the PMVF lies the stratovolcano of Payun, with intermediate geochemical compositions. Our ages show that it was built rapidly (1 km3/ kyr) at about 265 5 ka. Based on our geochemical data we show that Los Volcanes and Payun volcano lavas have been emitted from deep reservoir, whereas Payun Matru lavas evolved into a shallower magma chamber. The ignimbritic eruption associated with the Payun Matru caldera formation could be related to the regional tectonic environment, which is characterized by multiple quaternary extensional stages during the last 5 Ma (Ramos and Kay, 2006). Between 35S and 38S caldera dynamics have been linked to the activity of transtensional fault zones. Ages of collapse calderas and associated ignimbrite volcanism constrain the activity of these zones (Folguera et al., 2005) in the Neuqun Andes, the youngest and eastern most being the Payun Matru event. Finally, we aim to provide a time constrained geochemical dataset in order to extend our investigations to evolved rocks and to reconstruct the volcanic history of the PMVF in the framework of the regional geodynamic setting.

Keywords: payun matru, caldera, k ar geochronology

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VS007 **Oral Presentation** **6762**

The vent area of the Neapolitan Yellow Tuff (Campi Flegrei, ITaly): new insight from directional fabric through image analysis

Dr. Laura Valentini
Institute of Volcanology and Geochemistry University of Urbino

Bruno Capaccioni, Piermaria Luigi Rossi, Roberto Scandone, Damiano Sarocchi

The Neapolitan Yellow Tuff (NYT; 12 ka) is one of the more extensive pyroclastic deposits of the Campi Flegrei Volcanic District, in southern . This deposit has been investigated by several authors over the past two centuries; nevertheless, its source area is still uncertain. Two main contrasting hypotheses have been formulated: i) the NYT is the result of a single eruptive event from a sole vent; ii) the NYT originates from the piling up of different eruptive units, emitted from several centres. The NYT is composed of a variegated depositional sequence, with massive to finely stratified units, interpreted as the result of several flow pulses, with a wide spectrum of flow types, and minor fall episodes. The vertical and lateral variabilities in structural and textural characteristics point to the existence of variable emplacement mechanisms whose nature is still a matter of debate. To shed light on the NYTs source area and on its depositional mechanisms, we used computer-aided image analysis on rock slabs from 32 samples of the NYT in order to compile statistics on directional fabric. Two sets of samples were collected along vertical direction on selected exposures; other samples were taken from 15 outcrops widely distributed on the deposit. Fabric measurements within the investigated successions, revealed vertically homogeneous mean particle orientations, with considerable variability in the strength of iso-orientation among the different surfaces and/or samples. The well-developed degree of particle iso-orientation could be related to continuous sedimentation from a concentrated bedload region beneath suspension currents, producing massive or reversely graded beds by traction carpet sedimentation. The considerable vertical variability in the strength of iso-orientation may be the result of very unstable flow regimes, up to discrete depositional events, with a variable combination of traction carpet and/or direct suspension sedimentation. The vertical homogeneity in the mean orientation values, found in the investigated sections, may be derived from the sequential deposition of laminae or beds, whose relatively flat upper surfaces were unable to significantly deflect the depositional system of the following currents. The observed homogeneous mean particle orientation values along the investigated vertical sections allowed us to make inferences regarding the local paleo-flow direction, starting from only one sample. Hence, samples collected through areal distribution were considered representative of the paleo-flow direction of the deposit all along its thickness. The mean directions of the samples showed two different coherent patterns: the first, which includes all samples from the northern outcrops, appears to converge in a narrow area about 2 Km NE of the town of Pozzuoli; the second, which includes samples from Capo Miseno and Posillipo areas, points to the central part of the Pozzuoli Bay, about 4 Km offshore the town of Pozzuoli.

Keywords: neapolitanyellowtuff, imageanalysis, patternoffabric

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VS007 **Oral Presentation** **6763**

Magmatic control of the adjacent collapses resulting in the Las Caadas caldera of Tenerife

Dr. Tatiana Tentler
Institute of Earth Sciences Jaume Almera Consejo Superior de Investigaciones Cientificas

Carles Soriano

Magmatic accretion responsible for the formation of the island of Tenerife, >3.5 Ma ago developed in its central part an extensive plumbing system facilitating building of phonolithic Las Caadas complex comprising a number of eruptive centers. The presently exposed parts of their subvolcanic system include cone sheets, subvertical plugs, radial and ring dikes. The stratigraphy of the erupted units as well as distribution and structural characteristics of the intrusions change in the different sectors of the system suggesting that a number of adjacent, partially overlapping edifices were constructed in different times and subsequently collapsed. Such episodes of subsidence are inferred to be magmatically triggered, partitioned in space and time and resulting in the gradual increase of the Las Caadas caldera area, which, after the latest major episode of collapse 0.18 Ma ago, took shape of the present 16x9 km depression. Following eruptive activity build within the caldera a volcanic complex of Teide-Pico Viejo experiencing numerous central and flank eruptions. Magmatic fissures of the complex have a radial pattern that we suggest being characteristic for early stages of volcano evolution with magma chambers of limited lateral extend. Radial magma injection is also proposed to have occurred during early phases in the construction of former edifices of Las Caadas complex. However, it gave the way to later cone sheets when size of magma chambers increased and finally to ring intrusions related to subsidence. Vents of magma conduits feeding eruptions of various units of Las Caadas are exposed on the upper portions of the present caldera wall. Their location indicates that dimensions of the composite caldera resulting from the adjacent collapsed domains correspond to the extend of the shallow magmatic system of the central complex.

Keywords: caldera, dike, magma

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VS007 **Oral Presentation** **6764**

Active vs Passive collapse calderas

Prof. Joan Marti
Institute of Earth Sciences Spanish National Research Council, CSIC IAVCEI

Aguirre-Daz Gerardo, Geyer Adelina

The formation of collapse calderas require the combination of very specific thermo-dynamic, mechanical and tectonic condition, which are hardly achieved during the evolution of a volcanic system. Collapse calderas are usually assumed to form by gravitational collapse of the roof of a magma chamber during a volcanic eruption. However, in some cases calderas may develop during an intermediate stage in the evolution of a volcano-tectonic depression due to the interaction of the local tectonics with an underlying magma reservoir. Such a caldera behaviour is indicated by (1) the association of the basin with large volume eruptions, (2) the rapid subsidence of the basin during the main eruptive episodes, preventing erosion and significant sedimentation; (3) the existence of large fault-zone vents at the marginal zones of the basin; (4) the presence of co-ignimbrite lag deposits in some marginal zones; and, (5) the deposition of continuous successions of ignimbrites, sometimes several hundreds of meters thick, during single eruptions. Calderas of this types have been reported in several volcanic areas such as the Sierra Madre occidental in Mxico, Central Andes, or the Permian volcanism in the Pyrenees among other areas. We propose to name these volcano-tectonic depressions as "Passive Calderas" in contrast with the name "Active Calderas" that we reserve for the most common caldera structures. In passive calderas caldera-forming episodes are usually interbedded non-volcanic or epiclastic sediments, thus indicating that the subsidence dynamics of the basin pre-and post-dates caldera collapse. This fact indicates that the subsidence structures is created by local/regional tectonics and not as a direct response to the volcanic activity, as occur in active calderas. In passive calderas volcanism cause a high subsidence rate during the most important explosive periods by a mechanism similar to that of active collapse calderas but after the subsidence structure is already defined. For this reason, it seems reasonable to characterize this process and the resulting caldera-like structures as passive calderas, meaning that the caldera collapse is generated from a tectono-sedimentary subsidence structure. This is supported by the fact that the volcanic activity decreases progressively after the caldera episode and the basin returns to a normal rate of subsidence at the same time than non-volcanic sedimentation takes place again.

Keywords: calderas, tectonics, magmatism

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VS007 **Oral Presentation** **6765**

Hydro-magmatic caldera-forming eruptions in the Aeolian Volcanic District (Southern Tyrrhenian Sea, Italy) through multi-cyclic deposition of turbulent Pyroclastic Density Currents

Dr. Gianfilippo De Astis
Osservatorio Vesuviano Istituto Nazionale di Geofisica e Vulcanologia IAVCEI

Rosanna De Rosa, Federico Lucchi, Claudia Romagnoli, Claudio Antonio Tranne, Guido Ventura

Volcanological, geophysical and morpho-structural data, also supported by recent multi-narrow bathymetrical surveys, indicate that the Lipari-Vulcano volcanic complex is affected by a large, N-S elongated volcano-tectonic depression that includes minor caldera-like structures and submarine vents. Most of our data are from Vulcano Island where the sequential collapses of the Piano sectors due to NE-SW and N- S normal faulting tectonics associated to some eruptive events finally produced La Fossa Caldera structure. The reconstructed stratigraphy and data merging of the grain-size, compositional and SEM features obtained for the TGR Formation (emplaced between 21 and 7-8 ka) together with those coming from drilling stratigraphies, provide evidence that the La Fossa Caldera has been the source for the generation of these deposits. Moreover data on the plumbing system below that area suggest the presence of two main reservoir horizons in the last 30 ka, at ~5-6 km and ~1-2 km, whose relationships with tectonics allow to infer the proper conditions for collapse overlappings. Drilling data confirm differential subsidences of the caldera structure. Although the formation and geometry of subsidence of such multi-collapse topographic depression - now partially occupied by La Fossa Cone is not fully understood, it probably went through periods of shallow-water covering and multi-cyclic hydromagmatic eruptions, which were responsible for the deposition of turbulent Pyroclastic Density Currents (i.e. low-density ash-flow clouds), as the only products able to override the caldera walls whereas the coarse portions remained confined at depth, inside the caldera. Recent field studies on the Aeolian volcanoes have revealed that several ashy deposits older than 21.3 ka (with age up to 80 ka) are widespread on most of the islands (i.e. the Brown Tuffs) and even outcrop at Vulcano (Grotta dei Pisani Formation). They show a substantial uniformity of depositional, grain-size, structural and petrochemical features and are quite similar to the TGR Formation. The slight variations in colour and coherence that have been observed could be the result of the different depositional age and/or secondary processes. Therefore, the uniformity of features shown by the different BT Units and the TGR calls for a common eruptive and emplacement dynamics, recurrent during time. In this view, the volcano-tectonic depression evidenced by geophysical data, which includes north Vulcano and south Lipari could be loci for these hydromagmatic eruption and subsidence cycles, which contribute to their complex internal structures. Noteworthy, the time-interval of emplacement of the BT, which starts from ~80 ka, appears to match both the early phases (same age, ~80 ka) of collapse leading to La Fossa Caldera formation and the main collapse events in south Lipari (100-80 ka).

Keywords: vulcano caldera, multi cycle eruptions, piroclastic density currents

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VS007 **Oral Presentation** **6766**

The onset of decompression recorded in phenocrysts of the Bishop Tuff

Mr. Guilherme Gualda
Geophysical Sciences The University of Chicago IAVCEI

Ayla Pamukcu, Alfred T. Anderson Jr., Stephen R. Sutton

The Bishop Tuff is a large volume (~ 600 km3) pyroclastic deposit that formed 760 ka ago from the supereruption that created the Long Valley Caldera in California. The Bishop magma evolved during ca. 150 ka and erupted a significant fraction of its mass in a matter of days. We show here that the transition towards eruption is recorded in phenocrysts in Bishop pumice. Two independent lines of evidence show that a nucleation and growth event took place shortly before eruption. Significant growth is recorded in the crystallization of distinctive Ba-rich and Ti-rich rims on sanidine and Ti-rich rims on quartz, with rimmed and non-rimmed crystals coexisting in early-erupted pumice. Enhanced nucleation is revealed by the presence of a population of crystals < 50 m in diameter in studied late-erupted pumice. The sharpness of the contacts between rims and cores of crystals, as well as the time required to grow crystals 100 m in diameter constrain the timing of this event to be from months to at most ca. 30 years before eruption. Heating by intrusion of new magma and crystal sinking have been used to explain the crystallization of crystal rims. These processes, however, would not cause enhanced nucleation, and neither can account for the observed heterogeneity in crystal zoning. Decompression of the system can generate the supersaturation necessary to cause nucleation; it can also lead to biotite breakdown, which can cause mm to cm scale heterogeneity in Ba and Ti concentration in the melt. We interpret the initiation of this event to coincide with the onset of decompression of the Bishop magma, which eventually led to eruption. The transition from a slowly evolving system towards a supereruption such as the Bishop eruption is poorly constrained, and evidence for the timescales at which such transition takes place may have important consequences for magmatic evolution as well as for volcanic hazard mitigation. (We are indebted to Mark Rivers, Mathew Newville, Ian Steele, Andrew Campbell, and Laure Dussubieux for assistance with analytical work.)

Keywords: bishop tuff, supereruption, nucleation and growth

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VS007 **Oral Presentation** **6767**

15.4 MA Felsic ignimbrites caldera in Gutai MTS., eastern Carpathians, Romania

Dr. Alexandrina Fulop
Environmental Engineering North University Baia Mare, Romania IAVCEI

Complex volcanic processes developed in the Gutai Mts. (Eastern Carpathians) as in the entire Carpatho-Pannonian Region as a consequence of Miocene subduction processes involving the European Plate and the two microplates, Alcapa and Tisza- Dacia/ Tisia, developing the actual Intracarpathian area. Two types of volcanism have been identified : a felsic, mostly explosive, extensional-type volcanism and an intermediate, mostly effusive, arc-type volcanism. The Middle Miocene extensional volcanism developed in the Pannonian Basin, in Western and Eastern Carpathians, where extended and thick deposits of rhyolitic tuffs (eg. Lower, Middle and Upper Rhyolite Tuffs in the Pannonian Basin, Dej Tuff in Transylvanian Basin), mostly buried actually, were put in place . There are few attempts to reconstruct the sources: some of them have tentatively been outlined, others are still unknown. A caldera has been outlined in Gutai Mts., Eastern Carpathians, in Middle Miocene, related to the onset of the volcanism at 15.4 Ma. A back-arc extensional felsic volcanism, explosive and mostly terrestrial style, was responsible for the large sheets of rhyolitic ignimbrites and resedimented counterparts, underlain by the Paleogene flysch and mostly buried by a complex series of intermediate/andesitic volcanics dated between 13.4 to 7.0 Ma. Logging cores from 51 boreholes and a detaily study in outcrops enable the reconstruction of the geometry of ignimbrites, their relationships with the co-genetic reworked volcaniclastics, as well as their lithology and sedimentary structures. Lithology shows the physical constituents and the chemistry of the juvenile pyroclasts, pumice and crystals, emphasized the rhyolitic calc-alkaline character of the heterogeneous lapilli tuffs, overprinted by propylitic and adularia- sericite alterations (Flp , Kovacs, 2003). The fiame have been identified, suggesting the dense to moderate welding, as well as the explosive character of eruption. The alluvial character of the accidental lithic clasts suggests the transport on paleovalleys of the pyroclastic debris. Sedimentary structures reflect the rheology of the parental flows and the evolution of the explosive source. Multiple units with massive structure, normal coarse-tail grading of lithic clasts and reverse coarse- tail grading of pumice clasts are compatible with successive mass flows emplaced by progressive aggradation from a steady, maintained pyroclastic current. This is in accordance with the rheology of the basal layer belonging to a density-stratified suspension current, generated by magmatic explosions. The eutaxitic texture or welding texture, the cooling textures such as columnar jointings and gas escape pipes reflect a volatile retention regime and/or low cooling rates compatible with hot-state deposition. The ignimbrites are therefore emplaced as a single cooling unit, from the dense, basal layer of a maintained, stratified dilute pyroclastic current, in subcritical regime. This rheology, the temperature and volatiles regime is compatible with boiling-over eruptive style and caldera collapse. The source location is suggested in the southwestern part of the Gutai Mts. The geometry of deposits is a valuable element in reconstructing the source location and the subsequent evolution of the area. The 51 boreholes located on the south-western part of the area have been used to outline the spatial distribution of the ignimbrites, as well as their geometry. The ignimbrites have a wedge geometry with thickness decreasing from south-west towards east, from 350 m to 30 m. The constant 350 m thick and coarse westernmost deposits of ignimbrites extended to 10 km2 show dense welding and vapour-phase crystallization. They represent the proximal facies, the intracaldera ignimbrites which had been buried by 350 m thick complex succession of reworked pyroclastics interlayered with mudstones. This succession had been built up intracaldera, by mass flow reworking alternating with normal, deep water sedimentation. There is a steep slope between the intracaldera ignimbrites and the ignimbrite sheet defined as caldera outflow.

The outflow preserves the texture and the weldin g character in accordance with the hot state deposition. The set of data was useful in building up the genetical mod el of the ignimbrites, from th e dynamics of the eruption to the collapse of the caldera followed by intracaldera sedimentation entrained by subsidence. Cross se ctions through the area su ggest the orig inal morphology of the ignimbrit es which underwent subsequent tectonic processes combined with erosion. References Flp, A., Kovacs, M., 2003. Petrolog y of Badenian ignimbrites, Guti Mts. (Eastern Carpathians). Studia Univ ersitatis Babe? Bolyai, Geologie, 17-28

Keywords: ignimbrites, felsic, pyroclastic

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VS007 **Poster presentation** **6768**

Trachytic magmatic evolution of Talagapa Chico Caldera, Somun Cura Plateau, Patagonia, Argentina

Dr. Francisco Nullo
Ciencias Geologicas no IAVCEI

Corina Risso, Tomas Ganduglia

The Talagapa Chico Caldera (Upper Miocene) is a sequ ence of PDC and acid trachytic lavas located in the western Somun Cura Pla teau. The m agmatic proc esses comprise eight petrographic associations that respond directly to different explosive magmatic pulses. Over a basaltic flow (191 Ma) coming from the southeastern Talagapa C aldera, the vol canic sequ ence begins with basaltic brecci as, foll owed b y trachytic PDC and lavas that build the first caldera stage. Trachyte pyroclastic events continued with pyroclastic-flow deposits and porphyries necks, of the same composition, and ended with the collapse of the central caldera. The last magmatic activities re cognized are basaltic necks and lavas located around the caldera. This magmatic evolution is interpreted as fractional crystallization, parti al melting of underplated m afic magmas and mixing with the ac id cr ust in a shallower magmatic chamber. The described sequence that begins with basaltic lavas and breccias, followed by a trachytic association and ends with basaltic lavas, is seen repeatedly in different volcanic buildings in the Somun Cura Plateau from Lower Oligocene to Middle Miocene. The age of this trachytic volcanism in the Somun Cura Plateau decreases from southeast to northwest.

Keywords: trachytic, caldera, patagonia

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VS007 **Poster presentation** **6769**

Variations in eruption styles, transportation and depositional processes and deposit characteristics of the phonolitic, 151 ka Sutri member, caldera-forming eruption, VIco Caldera, Central Italy.

Mrs. Adele Bear
School of Geosciences Monash University IAVCEI

Raymond A. F Cas, Guido Giordano

Our current understanding of the often complex transport and depositional processes associated with pyroclastic flows produced during caldera-forming eruptions, and the deposits they produce, have focused traditionally on cases involving high viscosity-felsic compositions. Comparatively little is known about lower viscosity, more mafic composition examples such as phonolitic caldera - forming eruptions. They exhibit many similarities to their felsic counterparts as well as a number of key differences preserved in the deposits that reflect variations in eruption style and complex transport and emplacement processes occurring during caldera-collapse. The 151 ka Sutri eruption, Vico Caldera, Italy; a large volume phonolitic composition eruption that produced a 5.3 km3 ignimbrite sequence culminating in the formation of an 8 km diameter caldera will be used as a field example to understand the significant factors which influence explosive caldera-forming eruptions of this kind. The Sutri Member includes a plinian fall deposit; a small volume, variably welded ignimbrite; a complex association of proximal spatter and lithic rich breccias and a large volume spatter rich, zeolitised ignimbrite; all of which are indicative of a significant caldera forming, 'explosive' eruptive origin. A complex variation of eruption styles including Hawaiian-style fire fountaining and explosive Plinian style are represented. Transport processes vary from pyroclastic fall to pyroclastic flow as well as co-ignimbrite lag flow processes, all of which are greatly influenced by the nature of the two very different eruption styles that occur contemporaneously throughout multiple phases of the caldera-forming eruption. Detailed stratigraphic reconstruction of facies architecture and petrographic analysis are used to present a four-phase eruption model for the evolution of caldera collapse: Phase 1 - Initial Plinian eruption column formation characterised by pyroclastic fall processes; Phase 2 - Partial plinian eruption column collapse and generation of south-easterly directed small volume pyroclastic flow; Phase 3 - Contemporaneous (?) Spatter - fountaining/ Plinian column collapse and generation of northerly directly small volume, spatter rich pyroclastic flow - partial caldera collapse; Phase 4 - Contemporaneous Spatter - fountaining, vent widening episode producing spatter and lithic rich proximal breccias - Cessation of Plinian activity and generation of the large volume, radially directed pyroclastic flow - final caldera collapse.

Keywords: phonolitic

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VS007 **Poster presentation** **6770**

Evolution of a marine caldera-forming eruption, generating a low-aspect ratio pyroclastic flow, 7.3 ka, Kikai caldera, Japan: implication from near-vent eruptive deposits

Dr. Fukashi Maeno
Volcano Research Center Earthquake Research Institute IAVCEI

Hiromitsu Taniguchi

The VEI 7, 7.3 ka caldera-forming eruption of the Kikai caldera occurred in a shallow sea, and caused devastating damage to the prehistoric human settlements of southern Kyushu, Japan. This Holocene activity at this volcano records eruptions with compositional range of 56 to 74 wt% in SiO2 spanning with the climactic eruption. In this study, stratigraphy, component, and lithology of the pyroclastic deposits were analyzed at near-vent islands (Satsuma Iwo-jima and Take-shima) in order to reconstruct this eruption. Stratigraphical sections are characterized by plinian pumice-fall deposits (Unit A), intraplinian flow deposits (Unit B), voluminous ignimbrite (Unit C), and co-ignimbritge ash-fall deposits (Unit D). In total the estimated magma volume in the system was 70-80 km3 and the eruption therefore represents the evacuation of a major silicic magmatic system. The plinian stage (Phase 1) is subdivided into an initial small phase and a second large one. The column height in the second phase was estimated to be 40-43 km. The total tephra volume of this stage was estimated to be 40 km3. The magma discharge rate has been calculated from the column height data to be 2108 kg/s. The euption duration is also estimated to be a minimum of approximately 28 hours. Collapse of the column (Phase 2) produced Unit B, which consists of multiple thin lithic- rich or pumice-rich layers or pods, including welded pumice fall layers. The deposits are characterized by stratified or cross-stratified facies and display various degree of welding. These sedimentary characteristics indicate that, during the plinian column collapse, high temperature turbulent density currents were generated where dense pyroclasts were well segregated, resulting in the lithic-rich layers or pods. Phase 3 is characterized by Unit C, which is subdivided into three units (C1-C3). Unit C1 shows non-welded stratified facies, which consist of lithic and crystals, including quenched juvenile materials as a minor constituent. Unit C2 displays welded stratified facies, which consist of lithic-rich layers and pumice-rich layers. These two subunits occur only in topographic lows in Satsuma Iwo-jima, and can gradually change into Unit C3 with thickest and poorly-sorted non-welded massive facies. In proximal regions, Unit C3 includes fragments of welded tuff from underlying units. These facts indicate that the climactic pyroclastic density current was initially a high shear and high temperature body that produced Units C1 and C2 in the near-vent area. This was followed by the main sustained body producing Unit C3, a low-aspect ratio ignimbrite, distributed over a wide area of southern Kyushu across the sea. In addition, collapse of the caldera may have started before Unit C3 deposition, based on the evidence of a fault overlain by Unit C on the caldera rim. The source appears to have been biased toward the western side of the caldera, and was probably not a ring-fissure vent. The Holocene evolution of the Kikai volcano records the existence of a large silicic magma system at depths of about 7 km that coexisted with or was regularly recharged with mafic magma.

Keywords: caldera forming eruption, pyrocalstic density currents, kikai caldera

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VS007 **Poster presentation** **6771**

Gravity changes and ground deformation on the Island of Nisyros Volcano (Greece) for the period 2001-2006.

Mrs. Maria Di Nezza
Dipartimento di Scienze della Terra Universit di Roma La Sapienza

Michele Di Filippo, Beniamino Toro

A long-term gravity and elevation changes time seri es (2001-2006) at the restless caldera of Nisyros in Greece is here reported. After a period of intens e seism ic activity (19 95-1998), associated with an increase of fumarolic activit y and ground deformation of Nisyro s volcano which n o any eruption occurred, and then a gravity network was settled in June 2001 and re-occupied annually up to 2004 and in June 2006. Discrete gravity measurements have been carried out at located benchmarks surrounding Nisyros island in proximity to hydrotermal area wi thin the caldera floor and taking into account the effect of the vertical gro und movements in o rder to quantify gravity chan ges of the volcano. A general positive observed gravity change was determined at all stations of the network inside caldera rim. In the same time, a temporal and s patial evolution of the gravity changes was found between 2001 and 2004: it was observed a stead y-rise in gravity v ariations between 2001-200 3, obtaining maximum positive gravity variations up to +60 µGal confined in the caldera floor area at the base of the presently active crater, where the most fum arolic activity is concentr ated; in contrast a spatial distribution of gravit y changes is recorded during 2003-2004 and the maximum positive gravity variations are confined in the caldera rim near Nikia village. In this way residual gravity changes were obtained and applications of Gausss theorem to the study of the excess mass reco rded during 2001-2006 is explored. During recent unrest period magma replenishment genereted a great quantity of steam hot hydrothermal fluids which is released towards the surface underneat h the sout heastern part of t he caldera floor. The gravit y changes might be attributed to the migration of fluids probably occurring through pre-existing faults.

Keywords: caldera, geophysical monitoring, high precision gravity networ

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VS008 **6772 - 6796**

Symposium
Volcanic hazard evaluation: methodologies and applications

Convener : Dr. Roberto Carniel, Dr. Susanna Falsaperla

The aim of this session is to discuss quantitative tools to evaluate volcanic hazard, both from the theoretical point of view and from the point of view of the application to specific case studies. We welcome contributions that allow to characterize the entire processing line going from the monitoring data to the probability of a given eruptive scenario. In particular, the theory and application of methodologies that can be used to integrate different strands of evidence and that can handle new monitoring data as it comes in to evaluate updated probabilities are particularly welcome. These include for instance bayesian belief networks and event trees but also methodologies that can feed these tools with simpler input data, such as artificial neural networks, classification tools, data reduction tools, multivariate time series statistics, markovian models, logical models, expert elicitation techniques, etc.

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VS008 **Oral Presentation** **6772**

Algorithm of the eruption prediction of Bezymianny Volcano (Kamchatka)

Mr. Sergey Senyukov
Geophysical Survey Kamchatkan Branch of Geophysical Survey RAS IAVCEI

The Kamchatkan Branch of Geophysical Survey (KBGS) RAS began to monitor an activity of the Kamchatkan volcanoes in near real-time regime in 2000 (http://emsd.iks.ru/~ssl/monitoring/main.htm) using 3 remote methods: - seismic monitoring; - visual or video observation; - AVHRR sensor (NOAA satellite) remote sensing. 7 eruptions of Bezymianny volcano were registered and investigated from February 2000 to February 2004. As a result of this experience, on May 2004, an algorithm for eruption prediction was determined. Algorithm for eruption prediction: 1) The probability of an eruption is equal 0%, if: a) a seismic activity is normal, background (less 10 shallow earthquakes per day with local magnitude 0.75-1.25 and no shallow earthquakes with magnitude more than 1.25); and the maximum thermal anomaly temperature at the Bezymianny cone is not greater than maximum temperature of the thermal anomaly of the lava flow at the New Tolbachik Volcano (II) 1975. 2) The probability of an eruption is equal 50%, if seismic activity is above background. 3) The probability of an eruption is 90% for the next 30 days if seismic activity is above background during last 3 days and seismic activity increases with the growth of the maximum temperature of the thermal anomaly at the Bezymianny cone relative to the maximum temperature of the thermal anomaly of the lava flow at the New Tolbachik Volcano (II) 1975. 4) The probability of an eruption is 100 % for the next 7 days if seismic activity is above background, and rock avalanches (more than 5 per day) are detected by the KBGS seismic network. Inflation of the Bezymianny dome is the likely cause of an appearance of the rock avalanches. 5) The type and size of the future eruption can be estimated based on the intensity of the preceding seismicity. The intensity of the preceding seismicity is approximately proportional to the intensity of the eruption. 6) Recent seismic telemetric network allows us to carry out these investigations only if the amplitude of volcanic tremor at nearby Kluchevskoy volcano is less than 1 mpc at station CIR. All five last explosive eruptions of Bezymianny volcano (June 2004, January 2005, November 2005, May 2006 and December 2006) were predicted using this algorithm without false alarm. All five predictions were passed to participants of KVERT project. For the 2005-2006 events, predictions were passed to Kamchatkan Branch of Russian Advisory Council. This algorithm was tested by a joint, international, real-time experiment in November 2005 and included participants from the Kamchatkan Branch of Geophysical Survey, the Alaska Volcano Observatory, and the Institute of Volcanology and Seismology.

Keywords: eruption, prediction, algorithm

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VS008 **Oral Presentation** **6773**

Geochemical monitoring of active volcanoes: organic compounds in low-to-high temperature gas exhalations at Vulcano Island (Aeolian Islands; Italy)

Prof. Bruno Capaccioni
Earth and Environmental-Geological Sciences University of Bologna IAVCEI

Franco Tassi, Orlando Vaselli

The occurrence of a complex range of organic compounds in natural gas exhalations of many volcanic and geothermal systems has been recently recognized and quantified. Although their origin is still a matter of debate, many authors have suggested that the CH compounds (hydrocarbons) are mainly produced by thermal decomposition of complex organic matter at prevailing reducing conditions typical of hydrothermal environment. Then, they are likely transported within the production zone as water soluble organic species, such as carboxilic acids or alcohols. At Vulcano Island more than 20 different hydrocarbon species, pertaining to the classes of normal-, iso- and cyclo-alkanes, alkenes and aromatics (BTEX compounds), were recognized at both low- and high-temperature gas discharges, located at the foot (Baia di Levante beach) and at the summit crater of the active La Fossa cone, respectively. The mean value of the sum of the hydrocarbon contents, in the low-temperature gas exhalations (0.142 ppmvv), is significantly higher than that found in the high-temperature ones (0.0039 ppmvv). A further compositional difference between the two groups of gas emissions involves the methane/(ethane+propane) ratio, which in the Baia di Levante gas emissions is relatively high (>1000), suggesting that these gases are affected by variable inputs of methane produced by bacterial activity at relatively low temperature, while in the crater fumaroles this ratio is as low as <100, indicating the possible occurrence of a combination of hydrolitic disproportionation of n- alkanes and methane oxidation at medium-to-high temperature. Accordingly, the propene/propane ratio at the fumaroles of the beach area is generally low (<1), likely due to thermodynamic equilibrium established at relatively low temperature and reducing redox conditions, while the crater gas discharges, where the propene/propane ratio is >1, seem to be equilibrate at high temperature and oxidative redox conditions. BTEX contents are higher at the beach gases (up to 0.887 ppmvv) with respect to those of the crater (up to 0.137 ppmvv). The main component of this group of hydrocarbons is benzene (representing >90% of the BTEX contents), followed by minor amounts of toluene, ethyl-benzene, meta- and para-xylenes. The crater and the beach fumaroles show almost equal concentrations of sulphur-substituted heterocyclic compounds (thiophene and methyl-thiophene). Differently, furans and Di-methyl-sulphides (DMS), the latter being synthesized (by reduction) by various marine organisms (mainly phytoplankton), seem to be strongly enriched at the crater. The presence of marine-originated compounds in the high-temperature fumaroles of Volcano Island should be considered of particular interest for the geochemical monitoring of this volcanic system, since they could represent important tracers for lateral inputs of seawater-related hydrothermal waters into the ascending magmatic-related fluids. Similarly, the three hydrogenated halocarbons ($CHCl_3$, CH_3Cl and CH_3Br) detected in the fumarolic gases could be related to either abiotic synthesis or lateral input of hydrothermal waters, while $CFCl_3$ (CFC11) and CF_2Cl_2 (CFC12) are likely to be referred to the atmosheric component.

Keywords: hydrocarbons, geochemical monitoring, fumaroles

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VS008 **Oral Presentation** **6774**

Monitoring structural changes of volcanic tremor at Stromboli during April-May 2006

Dr. Francesca Fattori Speranza
Fisica Universit Roma Tre IAVCEI

Carniel Roberto

It is well known that the occurrence of a tectonic event sufficiently close to a volcano and/or sufficiently energetic can trigger a change in its eruptive activity. Examples include Ambrym (Vanuatu), where tectonic earthquakes have triggered a significant increase of the permanent lava lakes activity; Teide (Spain), where local tectonic events change the characteristics of the seismic noise during the current phase of possible unrest; Tungurahua (Ecuador) and Villarrica (Chile), where an increase of volcanic activity triggered by the occurrence of tectonic earthquakes. Of course this has serious implications in terms of hazard. However, no serious attempt has been carried out so far to formalize the identification of these structural changes with a statistical approach. In this work a statistical approach is then applied to test for structural changes in volcanic tremor recorded at Stromboli from April to July, 2006. We considered different fluctuation-type tests using the free source package strucchange in R language [Zeileis et al., J. Statist. Software, 2002]. Stromboli is a particularly interesting case of study, because previous works [Falsaperla et al., J. Volcanol. Geotherm. Res., 2003] had suggested that tectonic events have no influence on volcanic activity, while most recent results [Carniel and Tarraga, Geophys. Res. Lett., 2006] has suggested that they can have it. The aim of this work is to confirm by an objective method, the presence of any change in the recorded tremor related to the occurrence of volcano-tectonic events on Stromboli, as pointed out by Carniel and Tarraga [2006]. We found that there was at least one structural change associated to every earthquake, even in the cases for which the previous analysis could not see any variation [Carniel and Tarraga, 2006].

Keywords: structural changes, volcanic tremor, stromboli

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VS008 **Oral Presentation** **6775**

Classification of pre-eruption and non-pre-eruption epochs at Mount Etna volcano by means of artificial neural networks

Dr. Silvia Castellaro
Fisica, settore Geofisica Universit di Bologna

Francesco Mulargia

We apply artificial neural ne tworks to the classifi cation o f pre-eru ption time epoch s of M ount Etna volcano on th e basis of variables depen ding on tecton ics an d on th e volc ano 'recharging system'. We consider time-epochs from 7 to 30 days and train th e supervised nets, with th e aim of recognizing the time epochs preceding summit eruptions, lateral eruptions and not preceding any eruption. Tested on a number of independent datasets, these patterns ar e fou nd to be efficient (75 +-10 % success) in recognizing pre-summit eruption epochs, while distinguishing pre- lateral from non-pre-eruption epochs is impossible . We then apply non-supervised al gorithms to the w hole set of d ata obtaining a confirmation of the findings of supervised nets. This difficulty in recognizing patterns characteristic of pre-lateral eruption epochs is at odds with all prev ious work and seems t o depend on the small size of the eruptive series, which makes unstable the results of any multivariate analysis.

Keywords: artificial neural networks, eruptions, patter recognition

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VS008 **Oral Presentation** **6776**

Volcano-tectonic seismicity preceding the 1994 eruption of Popocatpetl Volcano, Mexico

Dr. Servando De La Cruz-Reyna
Instituto de Geofisica Universidad Nacional Autonoma de Mexico IAVCEI

Izumi Yokoyma, Alicia Martnez-Bringas, Esteban Ramos

Popocatpetl volcano has produced a wide range of eruptions, including Plinian events. This 5454 m high volcano, located in a densely populated area, reawakened in December 1994 after nearly seventy years of quiescence. The ongoing eruptive activity has been characterized by a succession of lava dome growth followed by dome destruction episodes. Similar events have apparently been typical for Popocatpetl in the last centuries, a period in which the volcano seems to be following a regime of well-defined episodes of effusive and moderately explosive activity alternating with long periods of almost total quietness. Here, we discuss the volcano-tectonic seismic activity detected before the onset of the current eruption, and interpret the observations in terms of particular internal processes related to stresses induced by magma and magma-related fluids developing under a volcano that has been quiescent for a long time. Yokoyama (1988) discussed an empirical relation for the threshold of cumulative seismic energy released before magmatic eruptions in polygenetic volcanoes after long repose times, and concluded that an eruption should occur when the seismic energy release reaches a cumulative level of 10**10 ~ 11 J. The calculated seismic energy release in the period 1990-1994, preceding the onset of the current eruption, falls within this range. The development of the precursory volcano-tectonic seismicity shows four distinct stages, that we interpret respectively as related to an initial intrusion of hot magma at depth in 1990, the slow opening of the pathways of magma and magma-related fluids towards the surface, the concentration of stress causing a protracted acceleration of this process, and a final relaxation or redistribution of the stress shortly before the initial eruption. A hindsight analysis of this activity shows that the acceleration of the seismicity in the third stage asymptotically pointed to the time of the eruption. The development of the seismicity suggests that the ascent of magma and related fluids may be inferred from the rate variations of seismic energy release, and that the magnitude (erupted mass) and intensity (eruption rate) of the incoming eruption may be directy related to the magnitudes of individual V-T earthquakes. Identifying these processes in active volcanoes that have been quiescent and closed for decades may help to forecast the time of the eruption and to set constrains on the magnitude and intensity of the upcoming eruption.

Keywords: popocatepetl, volcanotectonic, precursors

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VS008 **Oral Presentation** **6777**

Volcanotectonic architecture and history of the Rungwe Volcanic Province (SW Tanzania): Implications for hazard assessment

Mrs. Karen Fontijn
Geology and Soil Science Ghent University, Belgium IAVCEI

Damien Delvaux, Evelyne Mbede, Patric Jacobs, Gerald Ernst

80% of the worlds Holocene volcanoes that represent a potential threat for surrounding populations have never or hardly been studied within the scope of modern volcanology. Most of these volcanoes are located in developing countries and so does the Rungwe Volcanic Province (RVP). The RVP is a ~60 x 20 km NW SE trending volcanic area in SW Tanzania, which forms an accommodation zone in the East African Rift System. RVP volcanism is thought to have started 8 9 Ma ago, mainly producing lavas and tuffs of basaltic and phonolitic trachytic composition. Within the framework of volcanic hazard assessment in this region, attention is focused on the relationship of volcanism with tectonics and on the RVP eruptive history. During the Late Miocene-Pliocene, the RVP was developed on the triple junction (normal faulting under radial extensional stress) between the Malawi (S), Rukwa (NW, connected to the Tanganyika Rift) and Usangu (NE) Basins. During the Middle Pleistocene, the tectonic regime changed to strike-slip, with N-S to NNW-SSE horizontal extension, leading to the evolution of the RVP into a transform fault system between the Malawi and Tanganyika/Rukwa Rift basins. The present regime is dominated by strike-slip faults, which control the locations of recent volcanic eruption centers. The relationship between RVP volcanism and tectonics was investigated by combining Landsat TM imagery, SRTM DEM and aerial photographs integrated in a GIS. This allowed exploring the distribution and characteristics of recent (and older) volcanic centers in relationship to tectonic lineaments, together with the distribution of hot springs and CO2-vents mapped during field studies. An overall NW-SE trend is shown within the RVP, both in the locations of volcanic centers and hot springs, as well as in the general trend of large rivers. The exact location of several volcanic centers appears to correspond with intersections of these NW-SE trending features and older lineaments (NEE-SWW, NNE-SSW) visible in basement massifs, although this needs to be confirmed. Past field studies also provided a database of geochronological data of (however ill-known) eruptive events. Together with a record of dated volcanic ash layers found in RVP lakes, these geochronological data help building up an eruptive history of this densely populated area. It is clear that the local combination of tectonics and volcanism can be hazardous to the local population, and demands for detailed investigation towards valuable hazard assessment.

Keywords: rungwevolcanicprovince, hazardassessment, remoteimagery

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VS008 **Oral Presentation** **6778**

Probability map of vent opening at Campi Flegrei, Italy

Dr. Jacopo Selva
Sezione di Bologna Istituto Nazionale di Geofisica e Vulcanologia IAVCEI

Mauro Di Vito, Giovanni Orsi, Michaela Quaglino, Laura Sandri

We propose a spatial probability map of vent open ing at the Campi Flegrei caldera. In technical terms, we estimate the spatial conditional probabili ty for th e next vent o pening given an eruption occurs. We use a f ully Bayesian scheme, where prior information and past data are considered, and both aleatory and epistemic uncertainities are evaluated. This map may have an immediate use in evaluating the most dangerous areas of the caldera, but it is also an important factor to access the more general problem of quantitative volcanic hazard (VH) at Campi Flegrei. In fact, the proposed map is designed to represent a meaningfull estimation of the probability at one spec ific node of the Bayesi an Event Tree (BET) model, recently proposed by Marzocchi et al. (2004; 2006a,b), that allows to ev aluate VH in a fully structured, Bayesian fashion.

Keywords: vent opening probability, caldera, campi flegrei

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VS008 **Oral Presentation** **6779**

HIgh-precision eruption records for hazard assessment at reawakening volcanoes

Dr. Shane Cronin
Institute of Natural Resources Massey University, New Zealand IAVCEI

Michael B. Turner, Mark Bebbington, Ian E. M. Smith

The highest-precision records of volcanism at sporadically active volcanoes are often best achieved by collecting co res co ntaining ash depo sits within organic sediments of lakes and swamps. Using radiocarbon dating and developing an age-depth model, individual fa ll units can be tre ated as events, although this limits the resolu tion of the met hod to 1-10 ye ars (depending on sedimentation rates). On a series of re cords from Mt Taranaki,we demonstrate the following approaches to provide insights int o the volcanic system as well as develop ha zard fo recasts at such re-a wakening volcanoes:- Intervals between events as a re newal process distributions of inter-event times show several modes, hence a mixture (of Weibulls) model offers the best approxim ation. Time-varying forecasts (likelihood of an event) can be given over any future time fr ame, bu t depe nd strongly on the date of the last event, particularly relevant if there is so me uncertainty. - Using models of tephra fa ll attenuation, eruption volume can be hindcast fro m ash de posit reco rds at various sites. The resulting freque ncy-magnitude relationships can be used to provide time-varying ashfall exposure forecast s (likeliho od of ash fal l exceeding a certain thicknes s).- To obtain a complete rec ord of volcanis m from any o ne centre it is necessary to combine data from several sit es. Usin g the estimated age and uncertaint y of each event from spline-fit age models, te phra layers possibly resu lting from the same eruption can be identified in cores from different sites. In some cases t hese ca ndidates can be teste d by geo chemical matching. - Further info rmation o n erupt ion style and consequent h azard can also be derived fr om analysing geochemical and petrological characteristics through ash fall records, including glass characteristics and titanomagneitite-grain exsolution. This allows classificati on of er uptions into fast and slow rise-rate/eruption styles corresponding to sub- plinian and do me-effusion events, respectively.Once these steps have been taken, high-precision sequences of up to 10 000 years duration have the potential to constrain time-scales fo r underlying mo dels of magm atic systems at reawakening volcanoes examples presented will include nested sets of cycles that appear to represent rates of magma assembly in lower-crustal sills, and rates of mag ma-batch eruption and depletion. This knowledge can be used in- turn for the development of more detailed probabilis tic models, such as hidden Markov models, t o further refine probabilistic hazard forecasts for volcanoes under steady-state conditions.

Keywords: weibull, renewal process, markov model

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VS008 **Oral Presentation** **6780**

Inferences from spectral seismic energy measurement of a link between regional seismicity and volcanic activity at MT. Etna, Italy

Dr. Susanna Falsaperla
Sezione di Catania Istituto Nazionale di Geofisica e Vulcanologia IAVCEI

The existence of a relationship between regional seis micity and cha nges in volcanic activity has bee n the subject of several studies in the last years. Generally, activity in basalt ic volcanoes such as Villarica (Chile) and T ungurahua (Ecuador) sho ws very li ttle changes after the occurrence of regional earthquakes. In a few cas es volcanic activity has changed before the occurrence of regional earthquakes, such as observed at Teide, Tenerife, in 2004 and 2005 (Trraga et al., 2006). In this paper we explore the possible link between regional seismicity and changes in volcanic activity at Mt. Etna in 2006.On 24 November, 2006 at 4:37:40 GMT an earthqu ake of magnitude 4.7 stroke the eastern coast of Sicily. The e picenter was localized 50 km SE of the south coast of the island, and at about 160 km from the summit craters of Mt. Etna. TheSpectral Se ismic Energy Meas urement (SSEM) of the seismic signal at stations at 1 km and 6 km from the crater s highlights that fo ur hours before this earthquake the energy ass ociated with v olcanic tremor the pers istent background si gnal recorded on the volcano increased, reached a maximum, and finally became steady when the eart hquake occurred. Conversely, neither before nor after the earthquake, the SSEM of stations located between 80 km a nd 120 km from the epicenter and outside the volcan o edifice showed changes.A cha nge in volcanic activity with the onset of ash emission an d Strombolian explosi ons was observed a couple of h ours before th e occurrence of the regional earthquake. It can be inte rpreted as the magmatic response to a change of the distribution of tectonic stress in the edifice before the earthquake. In the light of this hypothesis, we surmise that the magmatic sy stem behaved similar to a dilatometer. Reference: M. Trraga , R. Carniel, R. Ortiz, J. M. Marrero, and A. Ga rca, 2006. On the pr edictability of volcano.tectonic events by low frequency seismic noise analysis at Teide-Pico Viej o volca nic complex, C anary Islands. Nat. Hazards Earth Syst. Sci., 6, 365-376.

Keywords: seismicity, eruptions, etna

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VS008 **Oral Presentation** **6781**

The 1631 Vesuvius subplinian event reviewed by iconographic analysis and mathematical approaches

Mrs. Julie Morin
Volcanologie, Institut de Physique du Globe Paris LSTUR, UMR CNRS-IPGP 7154 IAVCEI

Finizola Anthony, Ricciardi Giovanni, Tort Anthony, Lavigne Franck, Vilardo Giuseppe

Vesuvius is one of the most famous, studied and dangerous volcanoes in the world, mainly due to its 79 AD plinian eruption and its location near a densely populated area. Actual emergency plans are based on hazard maps created referring to 1631 subplinian eruption. This eruption is considered as the model eruption for next Vesuvius awakening, yet it is not completely well known. Some uncertainties indeed remain about its progress especially in connection with the elevation of cone decapitation which occurred during this explosive event. As mentioned by Nazzaro (1989), most of historical reports (Recupito, 1632; Carafa, 1632; Masculo, 1633) suggest a decapitation of the cone at an elevation about between 700 and 800 m above sea level, whereas another report (Braccini, 1932) propose a decapitation of the cone at an elevation of about 1020 m above sea level. In this survey, two innovating methods were used to better define the geomorphological evolution and structure of Vesuvius. On one hand the analysis of a rich iconographic database (743 oil paintings, engravings and Neapolitan gouache) allowed us to point up the evolution that occurred throughout the last open conduct interplinian cycle (which began in 1631 and ended in 1944, year of the last eruption of Vesuvius). Most of the artists were painting from the West part of Naples in an area located between Posillipo cape and San Vincenzo lighthouse, more precisely on Riviera di Chiaia and Mergellina promenades. This recurrent point of view permitted us to develop a geometrical approach to calculate the Vesuvius elevation for each dated picture. This allowed to propose a pre- and after- 1631 Vesuvius elevation and therefore an estimation of the height of its cone decapitation of about 170 m. On the other hand, the present day Vesuvius morphology has been investigated through a mathematical approach. The aim was to identify vertical morphological changes such as those possibly induced by a cone decapitation. For this purpose, the contour lines of a precise digital elevation model of Vesuvius cone were analysed by a systematic elliptic Fourier functions (EFF) performed on each contour line. This methodology, widespread in palaeontology and sedimentology, is quite new in volcanology (Tort and Finizola, 2005). Based on a hierarchical cluster analysis performed on the coefficients of the harmonic coming from EFF analysis, it was possible to identify two main groups of contour lines suggesting the boundary of the 1631 decapitation. The comparison between (1) this mathematical approach, based on the present day morphology analysis and (2) the historical iconographic analysis, based on external visual observations during the centuries, leads to a same vertical subdivision of the Vesuvius cone. The boundary is encountered at an elevation of about 970-980m above sea level. The results of this survey suggest that the 1631 subplinian eruption of Vesuvius volcano was probably not so destructive, in term of volcanic edifice decapitation, as some historical reports mentioned.

Keywords: 1631 vesuvius eruption, iconographical analysis, elliptic fourier function

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VS008 **Oral Presentation** **6782**

Incorporating crustal deformation results into time-dependent quantification of volcanic hazards along the divergent plate boundary in north Iceland: Role of magma availability

Dr. Freysteinn Sigmundsson
Nordic Volcanological Centre University of Iceland IAVCEI

Pall Einarsson, Erik Sturkell, Rikke Pedersen, Thora Arnadottir, Halldor Geirsson, Kristjan Saemundsson

Volcanic hazards can be quantified in differ ent ways. A study of the eruption history and past eve nts of a dormant volcano gives an e stimate of the long-term prob ability of renewed activity. S uch estimates are often hampered by limite d knowledge. Frequently, only few events are used to estimate statistical distribution of repose periods in a volcanic area. Such probabilistic estimates can be upgraded into time-dependent hazard estimates i f information is available about ongoing tectonic and magmatic activity in an area. A de tailed understa nding o f vo lcano dyna mics i s needed to f ully understa nd the ha zards involved. We explore how style of crustal deformation in a volcanic area inferred from repeated geodetic measurements can be incorporated into such hazard estimates. The role of geodetic measurements is at least two fold: (i) identification of areas of, and amount of, significant tec tonic strain acc umulation and (ii) identification of are as of magma movements and accumulation within the crust. G radual stretching across the divergent plate b oundary in Iceland ca uses strain accumulati on of 0.1 - 0.3 microstrain/yr. Associated tectonic stress build-up is on the order of 0.01 0.04 MPa/yr. When strain accumulation has reached a critical limit the plate bound ary fails and rifting occurs. The crit ical limit is highl y variable and depends strongly on av ailability of magma. If no magma is present at shallow depth along the plat e boundary, then normal faulting will relieve the stresses. In that case, the critical deviatoric stress is the one determinin g when normal faulting occurs. Initiation of slip of a normal fault at 5 km depth may require deviatoric stresses on th e order of 65 M Pa. If magma is in contact with stretch ed brittle crust, then diking events will re lieve the stress and accommodate spreading. The condition for rifting is then a deviatoric stres s that exceeds the tensile str ength of the c rust, inferred t o be about 6 MPa in , or an order of magnitude smaller t han if no magma is present. Inflow of ma gma towards shallow depths within the rift zone may therefore be a pre cursor to major rifting events along the plat e boundary. An order of magnitude longer time is needed to accumulate sufficient stress to cause large scale faulting in a magma st arved system. A major rifting episode with nine eruptio ns occurred in Icelands No rthern Volcanic Zone at the Krafla spreading segment in 1975-1989. It has been foll owed by no eruptive activity in the area. No known magm a accumulation is taking place at a s hallow depth in the crust, bu t magma accumulation near the crust-mantle boundary has been suggested (alternatively that signal may relate to pos t-rifting adjustment). Geode tic me asurements indicate a relatively uniform strain accumulation alon g th e le ngth of the plat e boundary an d suggest t hat segments adjacent to Krafla should be considered as likely locations of rene wed activity. However, fu ture location of magma accumulation at shallow depthmay de termine the site of t he next eruptive or intrusive activity in the Northern Volcanic Zone. Early detection of such re newed magma accumulation at shallow crustal depth, put in context with previous pattern of magma move ments in a volcanic area, is therefore a key in updating lo ng-term pro babilistic vo lcanic hazard estimates. Much longer time seri es of crustal deformation observatio ns are needed in No rthern Iceland to fully understand the haz ards thro ughout thecomplete plate boundary deformation cycle.

Keywords: volcanic hazards, plate spreading, magma accumulation

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VS008 **Oral Presentation** **6783**

Generalization capabilities of support vector machine for volcanic tremor classification at MT Etna, Italy

Dr. Susanna Falsaperla
Sezione di Catania Istituto Nazionale di Geofisica e Vulcanologia IAVCEI

Matteo Masotti, Horst Langer, Salvatore Spampinato, Renato Campanini

The automatic classification of volcanic tremor recorded on Mt Etna was carried out using a supervised classification strategy based on the Support Vector Machine (SVM) classifier. Spectrograms of the seismic signal were calculated and then separated in four classes, each assumed as representative of a different state of volcanic activity, i. e., pre- eruptive, eruptive, lava fountains, and post-eruptive. We verified the performance of the classifier using a data set recorded at a seismic station located at about 6 km from the summit craters of Mt Etna considering the eruptive episodes in July August 2001 and July 2006 (Masotti et al., 2006a, 2006b). Notwithstanding these eruptions differed considerably in terms of energy, the leave-one-out classification accuracy was over 90% for the whole data set. In this work, we investigated the generalization capabilities of the classification scheme. To this purpose, we trained the SVM classifier using the data of the 2001 and 2006 eruptions. Keeping its parameters fixed, we tested the classifiers performance on data recorded at the same seismic station during the Mt Etna eruption which took place between October 2002 and January 2003. We discuss the results of the classifier both in terms of its robustness as well as whether the data set used for training is representative of the 2002-2003 patterns. Masotti, M., S. Falsaperla, H. Langer, S. Spampinato, and R. Campanini (2006a), Application of Support Vector Machine to the classification of volcanic tremor at Etna, Italy, Geophys. Res. Lett., 33, L20304, doi:10.1029/2006GL027441. M. Masotti, S. Falsaperla, H. Langer, S. Spampinato, R. Campanini (2006b), Supervised and Unsupervised Automatic Classification Methods Applied to Volcanic Tremor Data at Mt Etna, Italy. Poster presentation at the AGU Fall Meeting, 11 15 December, 2006, San Francisco.

Keywords: volcanic tremor, support vector machine, etna

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VS008 **Oral Presentation** **6784**

Ischia, an active volcanic island in the Neapolitan Area (Italy)

Prof. Giovanni Orsi
Osservatorio Vesuviano Istituto Nazionale di Geofisica e Vulcanologia IAVCEI

De Vita Sandro, Enrica Marotta, Fabio Sansivero

The island of Ischiais one of the three active volcanoes of the Neapolitan area. It hosts a permanent population of about 50,000 people, which increases up to 200,000 in summer time. The volcanic hazard of the island is extremely high also because of its explosive character. The intense population, thriving farms and a complex trade -network with the city ofNaples, contribute to a high volcanic risk in the area. Volcanic hazards assessment is critically based on knowledge of the volcano past behavior and the definition of its present structural setting. Volcanism at Ischia began prior to 150 k a bp and continued until the 1302 A.D. last eruption. It is dominated by the Mt. Epomeo Green Tuff caldera-forming eruption (55 ka), followed by resurgence, which has caused a net uplift of the central part of the island of about 900 m over the past 33 ka. The most recent period of activity began at about 10 ka, with volcanism mainly concentrated around 5.5 ka and in the past 2.9 ka. During the past 5.5 ka, about 45 eruptions took place, with almost all the vents in the eastern portion of the island. The time-space vents distribution has been related to a simple-shearing block resurgence mechanism. Effusive eruptions emplaced lava domes and lava flows moving along valleys. Explosive eruptions generated tuff cones, tuff rings and variably dispersed pyroclastic-fall and -current deposits. Areal distribution maps of these deposits do not permit to estimate the magnitude of the explosive eruptions, as a large amount of tephra fell into the sea. Deposition frequency maps show the areas more frequently affected by tephra fallout and pyroclastic currents. Three classes of frequency have been defined. The fallout frequency map shows that almost all the eastern sector of the island has been covered by fallout deposits at least once in the past 10 ka. The pyroclastic-current frequency map shows that all the eastern sector of Ischia and a small area along the northern coast were invaded by pyroclastic currents originated by vents located east of the Mt. Epomeo resurgent block. As for fallout deposition, only one eruption emplaced pyroclastic-current deposits in the south-western part of the island. The results of stratigraphical, volcanological and structural investigations suggest that the possible eruption scenarios in case of renewal of volcanism in short-mid terms include either an effusive or an explosive eruption. The north-western part of the area active during the past 2.9 ka has the highest potential for opening of a new vent and invasion by lava flows and pyroclastic currents. All the eastern portion of the island could be affected by tephra fallout.

Keywords: caldera, hazard, eruption scenario

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VS008 **Oral Presentation** **6785**

Geostatistical estimation of volcanic hazards: from daily to millenary forecasts

Dr. Olivier Jaquet

Roberto Carniel, Christian Lantujoul

Geostatistics provides operational tools and probabilistic models for the characterisation and the estimation of volcanic hazards over the short as well as the long term. A methodology using geostatistical tools was developed that enables the analysis of multi-parametric data sampled over time at active volcanoes. Such a probabilistic approach provides valuable information to the identification of precursors potentially leading to the onset of eruptive activity. Regarding the long term, the methodology is extended to the space-time domain. A geostatistical model was developed for estimating volcanic hazards as needed by probabilistic risk assessments in relation to industrial activities. It requires as input the information from past volcanic activity, and the integration of geophysical data allows reducing uncertainty. Applications to the Etna volcano and the volcanic arc of Tohoku illustrate the proposed methodology.

Keywords: geostatistics, forecasting, hazard

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VS008 **Oral Presentation** **6786**

Methodological proposal to realise lava flow hazard map. The application to the Southern Rift Mount Etna (Italy)

Dr. Gianluca Groppelli
Istituto per la Dinamica dei Processi Ambientali Consiglio nazionale delle Ricerche IAVCEI

Barbara Aldighieri, Elisa Bertino, Federica Comoglio, Maria Luisa Damiani, Gianluca Norini, Claudio Silvestri

We present an integrated approach and a multidisciplinary methodology to compile volcanic hazard map for lava flow invasion. In addition we display an application of the proposed methodology to a sector of Mount Etna, the Southern Rift, one of the most active areas of the Volcano (Behncke & Neri, 2003).The basis and the starting point are a detailed geological and structural survey and a high- resolution stratigraphy (at 1:10,000 scale) that allow us to recognize and to map about 30 lava flows along the Southern Rift. The geological data (lava flow emission point location, relative or historical age, length and outcropping area) are organized in a geographic database. In addition GIS software analyses (Groppelli & Norini, 2005), statistical tests and probabilistic lava flow model (Damiani et al., 2006) are applied.Our methodology rests on six steps. 1) Detailed geological survey and historical descriptions (Branca & Del Carlo, 2004) to produce a geological map identifying eruptive fissures, recent lava flows and their distribution. 2) GIS analyses of geological data (e.g. lava flow length, eruptive fissure age, qualitative and quantitative spatial probability map that allows to recognize the areas where eruption probability is more relevant based on emission point density, etc.). 3) Statistical tests and analyses to evaluate the probability of eruption of each area previously recognized based on the historical and geological information. 4) Testing of a probabilistic lava flow simulation model (ELFM) based on a high resolution DEM to obtain the morphological constraint of the lava flow simulation (Damiani et al., 2006). 5) Preliminary lava flow hazard map computation based on the ELFM combined with the eruption probability of each pixel of the DEM. 6) Hazard map validation based on the geological map and its analyses.We applied the previous described methodology to the Southern Rift, from 2002-03 eruptive fissure (2900 m a.s.l.) to Monte S. Leo (1100 m a.s.l.) and we obtained the related hazard map for lava flow invasion, which can be useful for land use and urban planning.

Keywords: lava flow hazard map, mount etna, volcanic hazard assessment

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VS008 **Oral Presentation** **6787**

The Event Bush as a Potential Complex Methodology of Volcanic Hazard Assessment

Dr. Cyril Pshenichny
Levinson-Lessing Earthcrust Research Institute St. Petersburg State University IAVCEI

Cyril A. Pshenichny, Sergey I. Nikolenko, Roberto Carniel, Petr A. Vaganov, Zinaida V. Khrabrykh, Victor P. Moukhachov, Alexander A. Rezyapkin, Anton V. Yakovlev

The appearance of new method of assessment of volcanic hazard, the event bush, poses a question, whether it is competitive with, or complementary to, the existing approaches. We consider the interrelation of event bush with some of the most widely used techniques of quantitative hazard assessment including expert judgment elicitation and weighing by the examples of Elbrus (the Caucasus), Etna (Sicily), and Soufrierre Hills (Montserrat) volcanoes.The simplest, single-root event bushes can be compared with the event trees; however, the former require more abundant and better structured information with fixed vocabulary and, hence, produce a more correct and exact result, but at higher cost. Event bushes of any complexity can be transformed into Bayesian Belief Networks (BBNs) automatically. Principles of transformation, the algorithm, and resulting BBNs will be reported.Moreover, the structure of event bush allows to use it as an ontology of a domain of knowledge (e. g., the knowledge of dome-collapse eruptions, or eruptive seismic precursors, or earthcrust susceptibility for opening vents). Different terms used in the literature, references, comments, etc., as well as visual and numerical data, can be unlimitedly attached to the nodes of event bush, thus serving to clarify and reconcile the judgments and organize the body of knowledge.Given the sufficient vocabulary, an experts individual standpoint or reconcilable standpoints can be expressed by a single event bush. Competing views of different scientists can be expressed as a number of event bushes with similar vocabulary. Then their elicitation becomes a relatively routine procedure of comparing the edges of different bushes and asking additional questions to the experts when necessary. If some opinions appear irreconcilable, the corresponding bushes can be put in terms of predicate logic (Moukhachov and Pshenichny, see this volume). Further research must make it possible to compute and update the logical posterior probabilities of these bushes given the evidence from real eruptions.Natural variability of eruptive phenomena can be incorporated in the event bush by introducing fuzzy membership functions; if these functions are discrete, the bush will remain convertible into BBN, but with larger number of states of fuzzified variables that is expected to improve the quality of assessment.Attaching the values of time to its nodes, one can obtain temporal models of eruptive processes, including the processes with memory. In this case, nodes may define states for Markovian and alike models.Attributing co-ordinate values to the nodes of event bush enables an event bush-based spatial analysis (see Nikolenko et al., this volume) and a hazard assessment in GIS medium.The event bush is seen as a method that complements many existing approaches to hazard assessment and may unite many of them, including those which have not been co-employed. The research has been funded by Project V 4 of Instituto Nazionale di Geofisica i Vulcanologia, Italy, Development of quantitative tools to evaluate volcanic hazard, a Human Capital Foundation grant, Information Technologies cluster project, 2006, and NATO-Russia collaborative linkage grant.

Keywords: event bush, bayesian, logic

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VS008 **Oral Presentation** **6788**

First Results and Perspectives of Logical Modeling of Volcanic Eruptions

Dr. Cyril Pshenichny
Levinson-Lessing Earthcrust Research Institute St. Petersburg State University IAVCEI

Victor P. Moukhachov, Cyril A. Pshenichny

Logic, being a purely formal treatment of information, has found an application in the most perfect, strict, and well-crystallized domains of knowledge, mainly the mathematical theories. Application of logic may show, inter alia, whether a theory is self-consistent, complete and compact; contradictions obscured by natural language may be enlightened, gaps in inference detected, and different pathways to similar conclusion revealed. Logical inference can be automated, and thus long chains of inference involving many premises can be quickly computed. Obviously, these options could be useful in hazard assessment, including the creation of physical models, processing of expert judgments, composition of Bayesian Belief Networks and other frameworks for computation of hazards, and decision-making.Attempts of application of logic to the geosciences including volcanology have not led to expected results because of multi-disciplinary and highly intuitive character of knowledge in this field, largely based on description of individual cases and often subjective generalizations.Development of new knowledge engineering tools in volcanology, such as event bush, opens an opportunity of formalization and organization of deive knowledge of volcanic eruptions, strict enough to try the application of the logical notation used for mathematical theories, the predicate logic language (PLL). The architecture of event bush allows to introduce the elements of the PLL alphabet almost automatically, individual variables being provided by the subjects of some primary and environmental statements, predicate constants, by predicates of all the statements, logical connectives, by edges of different types, existential quantifiers, by one particular pattern of the bush structure, and universal quantifiers, by all the rest cases. The event bush describing the eruptive activity of Soufrierre Hills-type volcanoes was recorded in terms of PLL. This allowed to reduce the list of statements several times. PLL has vividly showed some general regularities in eruptive processes which are rarely put as such in the literature. Unfortunately, we could not avoid using second-order predicates that makes the whole logical system unlikely resolvable to the present day. However, we hope this can be avoided by appropriate substitution of variables. We studied the deducibility of various statements, some of them being apparently true, some, apparently false, from the knowledge stored in the event bush, by means of natural-sequent calculus. The results must allow us to conclude about the degree of maturity of the domain of knowledge describing the lava dome eruptions, optimize the formulation of volcanological knowledge, and improve the quality of eruption forecasting. This work is supported by Project V4 of Instituto Nazionale di Geofisica i Vulcanologia, Italy, Development of quantitative tools to evaluate volcanic hazard, a Human Capital Foundation grant, Information Technologies cluster project, 2006, and NATO-Russia collaborative linkage grant.

Keywords: logic, event bush, natural sequent calculus

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VS008 **Oral Presentation** **6789**

A study of Southeast Asia and Australasia's population exposure to volcanic perils

Mrs. Susanna Jenkins
Risk Frontiers (NHRC) Macquarie University IAVCEI

Russell Blong, John Mcaneney, Keping Chen

As the global population increases, so does its expo sure to volcanic peril s. Investigating the southeas t Asia and Australasian regions, this study calculates and ranks the exposure of the regions population to volcanic perils. The study framework is based upon a Bayesian belief network structure, with each node signifying major components and dy namics of the volc anic peril or the populati on. On a grid, at each point, for volc anoes within impact distance, parameters describing the spatial extent and imp act of different volcanic perils, the return period and likely magnitude of a future eruptio n will be used alo ng with the population density to infe r exposure. We weight the parameters subjectively using quantitative factors, such a s fatalities and damage. The result is an analysis of southeast Asia and Australasia s population exp osure to the volcanic perils produc ed by a future eruption from any of the active volcanoes in the vicinity. Urban areas are ranked to elucidate the most exposed areas.

Keywords: hazard and risk analyses, population exposure, explosive volcanic eruptions

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VS008 **Oral Presentation** **6790**

Deformation models and GPS time series analysis from Deception Volcano (South Shetland Islands, Antarctica)

Dr. Manuel Berrocoso
LABORATORIO DE ASTRONOMIA, GEODESIA Y CARTOGRAFIA RESEARCHERS IAG

Ramirez Eva, González-Fuentes María José, Fernández-Ros Alberto

Deception Island Volcano is one of the few active volcanoes in the Antarctica, with its last reported eruptions in 1967, 1969 and 1970. It is situated in the South Shetland archipielago, lying on the Bransfield Basin , wich constitutes an actively extending marginal basin separating the South Shetland Arc from Antartic Peninsula. In this area it also takes place the conjunction of four major tectonic plates, what makes this environment to be scientifically interesting from the tectonic and volcanic point of view. From 1989, GPS surveying campaings and seismic monitoring are planned every austral summer in order to control and monitor the volcanic status in the island. GPS data from the 12 stations that constitute the geodetic network are episodically processed with the BERNESSE v4. 2 GPS Scientific Software to obtain the displacements in the island along the years. In addition, GPS data were reprocesed by considering 30 min observation windows. Wavelets tools for the time-frecuency analysis of the data were applied to the obtained time series. In particular, this work deals with the filtering strategies and the detection of certain seasonal components that are not reflected by usual processing strategies, wich consider 24 hours observations windos, as well as time variation of the detected periodicities. A brief discussion about the noise property in the data is also included in this contribution.

Keywords: volcano geodesy, time series, wavelets analysis

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VS008 **Poster presentation** **6791**

Tremor Signals at Galeras Volcano, Colombia

Prof. Gerhard Jentzsch
Applied Geophysics Professor IAG

The Federal Institute for Geosciences and Natural Resources (BGR) runs in cooperation with the Colombian partner INGEOMINAS a multiparameter station of several geophysical and geochemical sensors at Galeras Volcano in southern Colombia since 1997. This multiparameter station aims for the monitoring of volcanic activity as well as for the research into fundamental processes of this volcanic activity. Three-component broadband seismometers are installed in close proximity of the crater area. Two different groups of seismic signals are recorded with these broadband seismometers at Galeras: Volcano-tectonic signals with their sources in rupture processes inside the solid material of the volcano and tremor signals emitted by the fluid system of the volcano. The terminus Tremor herein is used in its broadest sense referring to all seismically recordable forms of fluid flow induced noise, as it originates from non-stationary flow of the magma-gas fluid in the uppermost reservoirs of the volcanoes magmatic system. Tremor signals moved into the focus of scientific interest for their potential to give new insights into the flow regime. At Galeras we record three different types of Tremor signals: the distinct and singular signal types of the Tornillos, the longperiod (LP) events and the harmonic Tremor. Since their appearence in the vicinity of the 1993 eruption at Galeras volcano, Tornillo signals are intensely studied for their possible value as precursors in eruption forecasting. An extensive data set of tremor signals has been collected up to now since the installation of the multiparameter station at Galeras in 1997 especially during the periods of reactivation in winter 2000, autumn 2004 and 2005. In our work we do not focus on the analysis of the signature of only a few single events, but rather on the parametrization of a larger data set to use the distribution functions of these parameters as a base for physical modelling of possible oscillator and resonator sources. While the Tornillos are precisely determined by only a few parameters, it has been shown, that the LP-Signals extend over a wide range of kinematic and spectral parameters and parameter values. There are LP-Signals inhabiting the characteristics of Tornillos or Tremors and thereby causing great difficulty in the signal classification. One possible explanation for this heterogenity of the classified LP-signals is the assumption of a single source for the three signal classes, emitting in dependence of the stimulation mechanism the pure signal forms Tornillo/LP/Tremor or a continuum of transition forms. A general outline of the recorded tremor signals as well as first results of the parametrization will be presented.

Keywords: volcano seismology, tremor signals, tornillos

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VS008 **Poster presentation** **6792**

Utilization of photographic techniques to recognize zeolitized facies in the Orvieto ignimbrite, as potential pollutant for the underneath aquifer

Dr. Vittorio Zanon

Angelo Peccerillo, Pietro Conversini, José Pacheco, Adriano Pimentel

The weathering condition of a volcanic rock is of remarkable importance to the definition of its geotechnical characteristics, and in view of its possible future application to civil engineering. Zeolitization, caolinization oxidation, fumarolization, change partially, or even totally, the initial composition of a rock, modifying its original geochemical structure through the selective removal of some elements, the deposition of new minerals and the modification of its molecular structure. The most common of these processes is zeolitization of volcanic glasses, which leads to the total loss of the original textural characters of a rock. Such a process has great influence on the geotechnical characteristics of a deposit, causing it to become highly resistant to compression, so that the originally loose pyroclastic rocks acquire pseudolithoid behaviour. But the presence of zeolites inside a rock can also cause some problems of environmental pollution, due to their capability of bearing fluids in their crystalline structure. Therefore, the possibility of discriminating facies on the basis of their different zeolitic content, in the study of a remarkably extensive formation, is of great importance to present time investigations. In consideration of the typical reddish colour of zeolitized pyroclastic formations, the possibility and feasibility of applying photographic techniques to give evidence to the presence, extent and distribution of zeolitic facies was evaluated and applied. This methodology consists in sampling colour tones (in accordance to RGB values scale), and then measuring their intensity in each rock specimen through the utilization of Maxwell diagram. All the digital images were obtained under standardized capture conditions (digital filter sensitivity, lens angle, diaphragm, light intensity and temperature, light angle of incidence, focusing distance, etc.) and, afterwards, they were checked using equivalent values of colour intensity. This methodology, applied to samples from a pyroclastic flow of the Vulsini Volcanic District (Central Italy) showed a good correlation between the RED percentage values and the extent of zeolitization occurring in the different deposits, and thus allowed a fast discrimination of potentially hazardous facies within the deposit.

Keywords: zeolite, orvieto, photography

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VS008 **Poster presentation** **6793**

Time serial analysis of volcanomagnetic data in Tenerife Island

Dr. Nieves Sanchez
Volcanology Spanish Research Council IAVCEI

Alicia Garcia, Marta Tarraga

A magnetic network for the detection and analysis of volcanomagnetic signals associated to an eventual reactivation of the Teide volcanic system (Tenerife, Canary Islands, Spain) was designed and put into operation in June 2005. The network consists of three stations, one of them inside Las Caadas, one station on the southern slope of the edifice and the other on the northern part, in the Icod valley. Gmar Observatory (National Geographic Institute, IGN) is the reference point used in the process of data reduction. Comparison between these three stations and the reference base station, to study structural differences inside the volcanic edifice and site effects on every station, as well as their variation with time are investigated by means of time serial analysis. Recorded data span over almost two years which is a period of time long enough to characterize the activity of the volcano. The possible correlation between seismicity and changes of magnetic field is being investigated. At a first step it is necessary to discriminate seismic events in the environment of Las Caadas Caldera and the Teide-Pico Viejo Complex from those whose epicentre are located at a greater distance, in order to test if this influence in the magnetic field is due to tectonic or volcanic changes. In previous studies it has been shown that continuous seismic signal in Tenerife Island shows a kind of memory of the past. The memory expresses the persistence of behaviour, a necessary condition for any potential precursor. Variogram is used in this case as a geostatistical tool in order to quantify this memory. The same methodology has been applied to the volcanomagnetic signal recorded in the three network stations, allowing the correlation of both seismic and volcanomagnetic signals.

Keywords: tenerife, volcanomagnetism, time series

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VS008 **Poster presentation** **6794**

Spatial Volcanic Hazard Assessment by the Event Bush Method

Mr. Sergey Nikolenko
Laboratory of Mathematical Logic St. Petersburg Steklov Mathematical Institute IAVCEI

Pshenichny, Cyril Anatolievich, Sobissevich, Alexei Leonidovich, Yakovlev, Anton Viktorovich

The event bus h is a q ualitative tool designed to reason abou t a domain ofkn owledge. T ogether with algorithms originating from Bayesian belie fnetworks it forms a powerful instrument for geohazar d assessment.Spatial compone nt is essential in reas oning in earth sciences. Twoapproaches exist t o handling geographic/geodetic data in the event bushformalism.The most straightforward approach is to divide considered space domain(e.g., the mapped area) into small discrete intervals and produce a copy ofthe basic event bush for each qu antum, connecting the co pies together insome unified manner. We will describe this approach in detail. However,while for time intervals the discrete approach may work well, for large mapsthere will be way t oo much geographical quanta, a good deal of which mayappear not prone to t he hazard in q uestion e.g., s ummit zone cannot becovered by lahars, insusceptible area kilometers away from the foot of thevolcano must not be occupied by growing lava dome in reasonable time frames,and remote lo calities cannot be reache d by weak pyrocla stic fl ows. (Notethat Bayesian inference is NP-hard, that is, there are no effici ent scalablealgorithms ex cept for certain special cases.)Alternatively, one may note that eac h node denotes a process, which occursin s ome particular area(s). Thus every node ca n be regionalized, orco incided with some r eal contour on the map. We assume that the contours ofcause and effect mu st i ntersect in the regionalized event b ush; otherwisetransitional no de(s) sho uld be int roduced. In addition , each process can more or less self-propagate in a linear or radial mode affected bytopo graphy (e.g., lava flow flows, pyroclastic flow or lahar sweep acro ssthe gro und, a lava do me increase s its bott om surface, seismic disr uption ofrocks occurs in some localities, so does hydrothermal alteration of rocks,e tc.). Hence, the overall cont our related to each node should be the sum ofthe area of intersection with the cause(s) and the area of self-propagation.However, the definition of self-propagatio n areas fo r each node andintersection areas for each cause-effect pair, which can be based eith er on physical model s, or on observations, or on expert judgments, is acomplicated task, and upda ting c omputation o f areas o f so me no des given theothers may create comp utational problems.Pre senting the two approach es to s patial hazard assessment by event bush, wewill demons trate variou s mathematical techniques within both, d iscuss thecomputational complexity of thes e techniques and what is required to build anumerical mode l with each of them, using Elbrus a nd Shiveluch volcanoes (theCaucasus and Kamchatka, correspondingly) as examples.The study is being carried out under support of Project V4 of InstitutoNazionale di Geofisica i Vulcanologia, Italy, Development of quantitativetools to evaluate vo lcanic hazard, and a Human Capital Foundation grant,Information Technologies cluster project, 2006.

Keywords: hazard assessment, volcanic hazard, bayesian methods

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VS008 **Poster presentation** **6795**

Distal Tephra dispersion and related hazards in Chile: identification of latitudinal patterns

Mr. Alvaro Amigo
Earth Sciences Research student IAVCEI

Jorge Clavero, Matt Watson

The tectonic segmentation model of the Andean margin has identified discrete zones with widespread Holocene volcanism. In the particular case of the Chilean Andes, the following volcanic zones are present: Central (18-27oS), Southern (33-46oS) and Austral (49-56oS), where 13, 27 and 4 volcanoes with historic activity (roughly from 18th, or even 19th, century) have been recorded for each zone respectively. It is relevant to note that between 33oS and 42oS around 90% of the Chilean population is concentrated. Explosive activity has occurred in all of these segments, however tephra fall hazard studies are limited. Significant differences in atmospheric circulation occurs between 18- 56oS (more than 4000 km), resulting in non-uniform patterns of tephra dispersion and transport. In this contribution, we investigate the hypothetical consequences of future plinian-like eruptions in order to assess, as first approach, which eruptive and atmospheric conditions will result in hazardous distal tephra fall accumulations in the Chilean territory. We have used analysed meteorological data in advection-diffusion and particle trajectory models and have chosen eruption parameters to simulate fine tephra transport, according to records available from each region. Both interseasonal and interannual variability have been investigated.

Keywords: tephra, andes, circulation

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VS008 **Poster presentation** **6796**

Quick Extraction of Relevant Volcanological Information by Means of Semantic and Smysl Networks

Mrs. Victoria Shterkhun
Quaternary Deposits Department Karpinsky All-Russia Geological Research Institute IAVCEI

Pshenichny C. A

Modern methods of hazard assessment, such as Bayesian Belief Networks, may involve virtually any kind of information data, intuitive expert judgments, models, etc. that can give us a clue of future events in the hazard assessment procedure. However, this puts another task, to find, extract, and quickly organize this information in an appropriate order tractable by human mind and computer programs. Many tools of artificial intelligence and knowledge representation, such as semantic networks, conceptual graphs, classification procedures, have been used for this purpose. Nevertheless, their application in earth sciences remains limited. We suppose that the limit is put by the very nature of field geologic and volcanologic knowledge being largely descriptive, based on intuitively generalized particular cases, this knowledge would ruin any pre- existing framework. Only small pieces of it, after long multi-stage processing, can be brought to a formalized shape like event bush or predicate-logical record. Most of the information presented in published and unpublished sources, oral communications, and especially in the researchers mind, are like a streamflow that cannot be confined by solid embankments. This highly humanitarian character of knowledge urges us to turn to specific ways of reasoning existing in corresponding fields. One clue could be the similarity between the way of thinking described above and that presented in many classical Russian novels. A key concept of Russian humanitarian reasoning is smysl. This can be adequately translated into English as sense, with the crucial difference that the meaning of sense has nothing to do with thinking, while Russian root mysl literally means thought. In other words, smysl is something that cannot be defined but can be subject to operations of some kind of intelligent (though obviously non-logical) reasoning. We developed an approach that is based on recognition of smysls in texts and visual information. Mathematically, smysls can be managed as nodes in a polytree e.g., may be assumed to join a Bayesian Network and, correspondingly, assigned some states, or considered in a variety of other ways, depending on the formalism chosen. Each smysl can be attributed an unlimited number of names and properties. These may represent individual terms, or fragments of particular texts, drawings, photographs, etc. Names and properties may relate to more than one smysl. Edges connecting two smysls are discerned from those connecting smysls with names and properties. Both types of edges can be further specified. The resulting framework allows to add and search information not only by key words or key parameters but also by visualized feeling of smysl and thus facilitate the extraction of relevant information for needs of hazard assessment. Presented will be fragments of smysl and, for comparison, semantic networks built on published papers on the structure and activity of Etna Volcano (Sicily) and Shiveluch Volcano (Kamchatka). Financial support for this study has been provided by Project V4 of Instituto Nazionale di Geofisica i Vulcanologia, , Development of quantitative tools to evaluate volcanic hazard, and NATO-Russia collaborative linkage grant.

Keywords: semantic net, bayesian belief network, etna

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VS009 **6797 - 6824**

Symposium
Models and products of mafic explosive activity

Convener : Dr. Jacopo Taddeucci, Dr. Greg Valentine

This session will focus on the dynamics of explosively erupting mafic magmas from product analysis, multiparametric observations, and analytical, numerical, and experimental simulations. Mafic magmas can erupt explosively after a broad range of physical processes that, among those already identified, include: surface bursting of buoyant gas bubble slugs, multifarious interaction of magma with external water, overpressurization of cooled magma plugs, annular gas flow, and fast foaming of volatile-saturated melt. However different these processes may appear, they all reflect the fundamental properties specific of mafic magmas, mainly low viscosity and fast internal kinetics. A current challenge to volcanologists is to relate, possibly in a predictive manner, the above physical processes to the highly-variable eruptive styles observed and the products and hazards they emanate. The aim of this session is to bring together scientists with different approaches to the processes that underlie mafic explosive activity. In particular, three fields of research seems to increasingly converge on this topic: a renewed effort on the study of mafic pyroclasts and pyroclastic deposits; multiparametric geophysical, geochemical, and volcanological observation of ongoing activity; and analytical, numerical, and experimental simulation of eruptive processes. All the above (and other) specific aspects of mafic explosive activity will be welcome to this interdisciplinary session, and we specially encourage the submission of presentations showing integration of different approaches.

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VS009 **Oral Presentation** **6797**

Influence of decompression rate on the expansion velocity and expansion style of bubbly fluids

Dr. Atsuko Namiki
GSJ AIST IAVCEI

Michael Manga

The decompression rate of magma is correlated with explosivity of volcanic eruptions. We present a series of decompression experiments in a shock tube apparatus to investigate the effect of decompression rate on the expansion and eruption style of bubbly fluids. We also consider the effects of the pressure change DP and initial vesicularity phi. As an analogue for magma we use viscoelastic polymer solutions. For fast decompression, we observe fragmentation and rupture of bubble walls only for large DP and large phi. For slow decompression, however, bubbles maintain spherical shapes, and the bubbly fluid does not fragment, irrespective of DP and phi. We consider two theoretical estimates for the expansion of bubbles, which we refer to as equilibrium expansion, in which the pressures inside and outside the bubbles are assumed to be equal, and disequilibrium expansion, in which the enthalpy change caused by the pressure change is converted into kinetic energy. The observed expansion velocity is governed by the slower estimate. For slow decompression, where bubbles expand while maintaining their spherical shape, the measured expansion is well explained by equilibrium expansion. In contrast, for fast decompression, in which we observe the rupture of bubble walls and fragmentation, the expansion follows disequilibrium expansion. We conclude that the disequilibrium estimate is an upper limit velocity for the bubble expansion and fragmentation and the rupture of bubble walls require disequilibrium expansion. The calculated threshold decompression rate for disequilibrium expansion is consistent with the estimated decompression rate for the explosive/effusive transition in natural basaltic eruptions.

Keywords: bubble, expansion, fragmentation

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VS009 **Oral Presentation** **6798**

2006 summit eruptions of Mount Etna (Italy): hazardous mass-flow phenomena caused by interaction of basaltic magma with external water

Dr. Boris Behncke
Sezione di Catania Istituto Nazionale di Geofisica e Vulcanologia

Sonia Calvari, Marco Neri, Salvatore Giammanco

16 months after the end of its latest (200 4-2005) flank eruption, Etna entered into a new period of summit activity in mid-July 2006, which continued inter mittently fo r five months. A ll activity was concentrated at and near to the Southeast Crater (SEC), the yo ungest of Etnas fo ur summit craters, involving a number of vents in different location s at different times. The 2006 activity can be distinguished into two main phases. The first lasted from 14 to 24 July, when Strombolian and effusive activity occurred from a sh ort fissure on the lower ESE flank of th e SEC cone. This phase culminated with a burst of lava fountaining on 20 July. The second phase lasted from 31 August until 14 December and consisted of 20 eruptive episodes at or near the summit of the SEC cone, accomp anied, from 12 October onward, by periodic effusive activity from a number of vents located in various sites to the E-SE and W-SW of the cone. The most persistent effusi ve vents formed on 12 October at 2800 m a.s.l. on the upper W w all of the Valle del Bove, about 0.9 km SE of the SEC, and on 26 October at 3050 m a t the S base of the central s ummit cone, about 0.45 km from the SEC. While the former remained continuously active thro ugh early Decemb er, the latter tended to erupt mainly duri ng paro xysmal episodes at th e SEC and did not erupt aft er 24 Novemb er. Other effusive vents were intermittently active on the W, E, S and SE flanks of the SEC cone. After a final vigorous burst of activity from vents at the E side of the SEC and the fissure a t 2800 m el evation, the ac tivity stopped abruptly on 1 4 December. Maximum lava flow lengths during the 2006 eruptions were 3.9 km (July eruptive phase), 4.8 km (2800 m vent), and 3.5 km (3050 m vent). The t otal volume of lava emitted during the 200 6 activity is appr oximately 15-2 0 x 106 m3. The activi ty at the SEC itself was often accompanied by dramatic mass wasting processes such as collapse of parts of th e con e, h ighly unu sual flowage processes involving both old rocks and fresh magmatic material, and interaction of magma with external water. The most spectacular events of th is type occu rred on 16 November, wh en n umerous rockfalls and avalanches were generated during the opening of a large fracture on the SE flank of the SEC cone. The largest avalanches were clearly generated explosively - possibly by interaction of intruding magm a with water-s oaked rocks con stituting the c ones flan ks - and traveled up to 1 km from their source, representing a previously unrecognized hazard to visitors of the summit area.

Keywords: etna, basalt, magma water interaction

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VS009 **Oral Presentation** **6799**

The 24 November 2006 Paroxysm at South-east crater, MT. Etna

Dr. Daniele Andronico
Istituto Nazionale di Geofisica e Vulcanologia Sezione di Catania IAVCEI

Simona Scollo

The explosive event of 24th November 2006 at South-East Crater (SEC) of Etna may be considered the best documented among small paroxysms in the eruptive history of this volcano. From early morning of 24th November, a weak eruption column began rising above SEC. During the almost 10 hours of eruptive activity, the favourable weather conditions allowed us to follow the growth and evolution of the eruption cloud in real time, and to detail the associated tephra fallout in the distal areas. More than 30 ash samples were collected over a relatively small area away from SEC during the fallout and within a few hours after its end. Samples were subjected to grain- size, morphological, componentry and chemical investigations, both by dry sieving and binocular observations and by a new analytical procedure under Field Emission Scanning Electron Microscope. The study of the fallout deposit was completed by drawing the isomass map and estimating the erupted volume. During the eruption, the wind direction changed from the east to the south, resulting in the clockwise rotation of both the eruption cloud and ash fallout. As a consequence, a tephra amount ranging around 30-60 g/m2 covered the the city of Catania after the late morning and caused the closure of the International Fontanarossa Airport. The observation of the eruption cloud movement and timing of the fallout on the ground, on one hand, and the results from analytical studies of such high number of samples on the other, allowed reconstructing the dispersal process and inferring the eruptive mechanisms. Furthermore, the grain-size distributions of all the samples were used to evaluate the total grain-size of the deposit. By knowing the variation with time of both the column height and the wind speed and direction, we simulated the dispersal process and the deposit by using a tephra dispersal model and compared it with field data. The study of the 24th November episode at SEC well evidences that, on the whole, simulating weak and prolonged explosive events at Etna requires detailed knowledge of the wind dynamic and eruptive intensity with time with respect to shorter, higher energetic paroxysms, where the eruptive conditions can be supposed almost constant.

Keywords: eruption column, tephra fallout, dispersal processes

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VS009 **Oral Presentation** **6800**

Correlating vesiculation, degassing and style of eruptive activity at basaltic volcanoes: the case of the August-December 2006 Etna eruption (Italy)

Dr. Margherita Polacci
Istituto Nazionale di Geofisica e Vulcanologia INGV IAVCEI

Michael R. Burton, Alessandro La Spina, Filippo Mur, Stefano Favretto, Franco Zanini

At active basaltic volcanoes the style of eruptive activity may range from quiescent degassing to quiet lava effusions, mild Strombolian explosions and up to violent fire fountaining. The primary control on the eruptive style is volatile exsolution and transport within the conduit. Despite great improvement in monitoring techniques on active, hazardous volcanoes and in interpreting geophysical and geochemical signals, how gas is transported in basaltic magmas and how this affects and/or determines changes in the eruptive activity is not yet well understood. We address this question by investigating the relationship between vesiculation, degassing and style of eruptive activity in the explosive episodes that characterized the last August-December 2006 Mt. Etna eruption. The nature of the gas phase is recorded in volcanic products as vesicles, which we study in scoria clasts by combining conventional 2D textural analysis with 3D synchrotron X-ray computed micro tomography, a high-resolution, non-destructive imaging technique that provides 3D views of the inner structure of porous materials. We find that all the investigated samples collected during the 2006 eruption exhibit a high degree of vesicle interconnectivity (>95%), implying that coalescence is the dominant vesiculation process. Small (<100 m), spherical, isolated vesicles are however ubiquitously present, with higher abundances in scoria from the more energetic explosive events. We integrate results of the textural analysis with information on the dynamics of degassing obtained by analysing the gas plume composition measured at the South East crater, where most of the explosive activity occurred, and constrain the source depth of the powering gas phase. Using this novel approach, we present a model that explains magma rise and fragmentation along the conduit in 2006 via the superposition of two different degassing mechanisms: separate ascent of a bubble foam layer accumulated at depth and syn-eruptive vesiculation in the thin liquid film that sustains the foam structure. We finally discuss the implications of the model on the shift from low (Strombolian) to high (fire fountaining) energetic activity and on ash formation during the eruption.

Keywords: explosive basaltic volcanism, degassing, vesicles

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VS009 **Oral Presentation** **6801**

Influence of conduit geometry and wall texture on Strombolian activity

Dr. Stephen Lane
Deprtment of Environmental Science Lancaster University IAVCEI

Mike James, Jack Wilcock

Strombolian activity is typified by the mildly explosive decompression of large gas bubbles or slugs. At exsolution depths, water and CO2 from the magma create many small bubbles that must then undergo processes of collision and coalescence to form the larger, but less numerous, bubbles that characterise Strombolian eruptions.Two end-member scenarios, as suggested by Ripepe and Gordeev [1999], can be envisaged under which the coalescence process operates, driven by different degrees of influence from the conduit geometry. For a purely vertical conduit, in which bubbles ascend effectively unimpeded by the conduit geometry, bubble coalescence and expansion can occur continuously during ascent. Under these conditions, comparisons with traditional engineering literature indicate that gas volume fractions in the region of 25% would be required for slug flow to develop. At Stromboli, significant depressurisation-related expansion of coalescing bubbles would be needed in order to achieve such a volume fraction. Consequently, slug flow would be confined to the upper few 10s of metres in the magma column and only short repose periods between individual slug bursts would occur, contrary to seismic and observational evidence. This suggests that slug flow at Stromboli is not the result of bubble collision and coalescence during continuous bubble ascent through the magma. The other end-member scenario is that bubbles are caught in a geometric trap, coalescence occurs whilst they are impeded or stationary and sudden, catastrophic trap overflows release large slug-bubbles to the surface. Jaupart and Verniolle [1989] studied this scenario using small bubbles coalescing under an idealised horizontal roof and periodically released in foam collapse events . In this scenario, the trap geometry is a critical controlling factor, but a horizontal magma chamber roof is an unlikely natural geometry. Here, we investigate an intermediate scenario, under which conduit geometry, and hence bubble interaction with the conduit wall, still plays a critical role in the collision and coalescence process. Inversion of very-long-period (VLP) seismic data indicate that the vent system at Stromboli is fed by a dyke inclined 72 from horizontal, which itself is fed by a dyke inclined 40 from the horizontal [Chouet and Dawson, http://www.es.lancs.ac.uk/seismicflow/]. We hypothesise that bubble trapping at depth occurs, but that this takes place in numerous small traps in the roof of an inclined dyke. Slug-bubble release is initiated as an avalanching of trap overflows, or an increase in the effective interaction time of bubbles negotiating undulose inclined surfaces. Results of exploratory experiments are presented to provide insight into the processes of bubble trapping and periodic release from a rough inclined roof.

Keywords: slug flow, bubble coalescence, conduit geometry

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VS009 **Oral Presentation** **6802**

Crystal content and the fracture behaviour of basaltic melts: an experimental investigation.

Dr. Jacopo Taddeucci
Seismology and Tectonophysics Istituto Nazionale di Geofisica e Vulcanologia IAVCEI

Daniele Andronico, Ralph Bttner, Bernd Zimanowski, Piergiorgio Scarlato

Basaltic explosive activity varies largely in style and type of products, with mild spattering and ash-rich violent Strombolian explosions as the most common end members. Textural and petrographic evidences, as well as theoretical studies, suggest that the crystallinity of the fragmenting melt may have an important role in governing the dominant style of explosions. To investigate the factors governing the styles of basaltic explosive activity, we experimentally fragment basaltic melts under different crystallinity conditions at eruptive temperature. To obtain melts with a range of crystal-liquid ratios similar to those of natural products we melt natural rock samples from Etna along variable time-temperature paths. Compressed gas released below the melt provokes fragmentation, while force, pressure, electric, and seismic sensors, plus high speed camcorders, monitor the experiment. After each run we determine the texture, degree of crystallinity, and nature of the phases crystallized in the experimental products. Natural and experimental particles display the same range of shape, crystallinity, and mineralogical assemblage. All other conditions being the same, the results of fragmentation experiments change dramatically as a function of groundmass crystallization. If poorly crystallized, the bulk of the melt reacts as a liquid when compressed gas is injected. Ductile behaviour reflects in the morphology of the melt left in the crucible and in a high proportion of fluidal morphologies in the clasts erupted. If extensively crystallized, brittle cracking dominates during fragmentation of the melt, as testified by the appearance of large cracks and dominant blocky shape of fragments. We observe an inverse correlation between the crystallinity of the experimental products and the time delay between gas injection and melt fragmentation. This correlation suggests that increased crystallization reduces the ability of the melt to dissipate stress by ductile deformation, possibly by a combination of increased SiO_2 content of the liquid (and thus a longer relaxation time) and earlier interlocking of the crystals during viscous flow.

Keywords: basalt, explosion, fragmentation

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VS009 **Oral Presentation** **6803**

Transient multiphase processes during the explosive eruption of basalt through a geothermal borehole (Namafjall, Iceland, 1977)

Dr. Sebastien Dartevelle
Earth and Environmental Sciences EES-11 IAVCEI

Gregory A. Valentine

Experimental and numerical studies have shown that vertical flows of gas-particle mixtures are characterized by transient behavior, with development of waves of high particle concentration separated by regions of relatively clean gas. In contrast, most models of explosive flow in volcanic conduits either treat the multiphase mixture as a single fluid (pseudo-fluid approximation) or/and assume steady flow, thereby eliminating the potential for time-dependent effects related to multiphase dynamics.The 8 September 1977 explosive eruption of basaltic tephra through a geothermal borehole (Namafjall, Iceland) provides a unique test case for multiphase volcanic processes, given that its vertical extent (~1 km) is similar to that of natural volcanic conduits and its geometry is exactly known. We model this eruption by solving separate governing equations for conservation of mass, momentum, and energy of the gas and particle phases (2 phases), allowing for drag and heat transfer between the phases and for non-linear Reynolds Average Navier-Stokes (RANS) turbulent coupling between phases. Model results are consistent with the development of transient waves of high particle concentration that propagate up the borehole, resulting in complex compressible flow phenomena along with ejection of particles in pulses in a manner that is consistent with observations at Namafjall.These transient processes occur even though the influx of gas and particles at the base of the borehole is treated as constant and steady.Our results indicate that transient multiphase behavior is likely to be common in volcanic conduit flows, and that a key topic of future research is quantifying the types of time-dependent behaviors and their impacts on eruption column dynamics.

Keywords: multiphase, borehole, basaltic explosion

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VS009 **Oral Presentation** **6804**

A new classification system for basaltic eruptions

Prof. Katharine Cashman
Geological Sciences University of Oregon IAVCEI

Danielle Mckay, Laura Pioli, Mauro Rosi, Alison Rust, Paul Wallace

Existing confusion in the classificatio n of basaltic er uptions is generated in large part by the inability of traditional clas sfication schemes, which rely solely on the characteristics of pyroclas tic deposits , to incorporate t he effusive activity that dominate s many basaltic eruptions. Moreover, recent measurements have do cumented a wide variatio n in the H2O co ntent of basaltic ma gma (from ?0.5 wt% in Hawaii an basalts to >7 wt% in arc basalts) that , in turn, gi ves rise to a ra nge of volatile exsolution depths and deg assing histories. Finally, as the low viscosit y of basaltic melt permits bubbles to rise and interact separately from the melt phase, the relative rise rates of magma and gas may var y over several orders of magnitude. The combined resu lt is eruptive activity that ranges from plinian (dominated by convective columns) to strombolian (dominated by ballistic e jecta) to effusive (dominated by passive eru ption of variably vesi cular lavas). Imp ortantly, these three end member eruptive styles represent very different exso lved g as:magma ve locities and produce three morphologically and physically distinct eruptive products - tephra blankets, scoria cones, and lava flows that serve as the axes for our proposed cla ssification system. This classification scheme has the sam e advantages as schemes bas ed solely on pyroclasti c products, in that prehistoric eruptions may be classified using solely field-based data. However, it also provides several advantages over past schemes. First, as basal tic eruptions are often long-lived , our diagram may be used to trace the temporal evolution o f an individual eruptio n. Seco nd, as th e axe s represent eruption product s produced by physically distinct processes, this method of classification provides a simple way to calculate the relative importance of different eruptive mechanisms, which, in turn, may be related to the relativ e velocities of the gas and liquid +/- crystal phases within the co nduit. Third, as each eruptive pro duct po ses a different potential hazard, the addition of such a sche me to probabilistic hazard assessment of basaltic regions provides additional information for volcanic risk management. Finally, o ur su ggested ternar y diagram provides a simple de or of intermediate, or mixed, eruptive styles that have defeated traditional classification schemes.

Keywords: mafic eruptions, classification

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VS009 **Oral Presentation** **6805**

Relative effects of H2O and CO2 in initial interaction of K-foiditic magma with a geothermal system: a study case from the Colli Albani volcanic district, central Italy.

Dr. Jacopo Taddeucci
Seismology and Tectonophysics Istituto Nazionale di Geofisica e Vulcanologia IAVCEI

Danilo M. Palladino, Greg A. Valentine, Guido Ventura

Understanding the factors controlling the recent (<0.1 Ma) Colli Albani (CA) hydromagmatic activity is a critical point to volcanic risk a ssessment in this densely populated ar ea. Here we focus on the Albano multiple maar activity (70-36 ka) preserving evidence of complex interactions between K-foiditic magma and fluid-satur ated limestone country rocks. Esti mations of erupted t ephra volume, by means of integrated field and component analyses, indicate that Albano crater excavation leaded to the disruption of ~0.3 km3 limestone reservoir representing ~15% of total volume erupted. Geochemical data indicate that composition of geothermal fluids trap ped in th e CA limestones reservoir is characterized by hig h CO2 pressure concomitant with strong C O2 degassi ng processes. Moreover, events such as the evacuation of population during the intense CO2 release a fter the 1989-90 CA seismic swarm have t o focus the inter ests on the Albano maar er uptive activity possibly record ing the e ffects of a magm a contact with a CO2 dominated geothermal s ystem. In this perspective, modelling a scenario in which a K-foiditic dyke ascends thro ugh a CO2- H2O satura ted r eservoir is important for understanding the relative role of H2O and CO2 in interaction with magma and for predicting volcanic risk. Previous models (e.g., Wohletz 1983) suggest that the occurrence of a non-condensible phase, such as carbon dioxide in the P and T intervals of the CA geothermal system, inhibits the explosivity of magma-fluids interactions. Here we prop ose a two-sta ges quantitative mode l for t he thermodynamics of magma-water-carb on dioxide interactions. During t he first stage, we model the heat transfer f rom an uprising dyke to fluid-saturated sedi ments leading to an isochoric pore pr essure build-up until the strengt h of surrounding rocks is excee ded. Then, we estimate the relative effects of CO2 vs. H2O mass ratio in explosive interaction with magma in terms of "efficien cy" (i.e., expansion work vs. magma thermal energy ratio). Input data for efficiency estimati ons take into account t he detailed field reco nstruction o f Albano stratigraphy a nd component analyses s howing a wide ra nge of lithic/juvenile clas ts volume ratio (i.e., 0.05 to 0.95) recording diff erent eruptive mechan isms spanning fro m phreato magmatic to mo stly magmatic events. In our model, depending on the e fficiency of heat t ransfer from magma to gas es during gas-pyroclasts mixture expansion to atmospheric pressure, we consider two end members: i) an adiabatic case, in which gase s separate fro m pyroclasts during expansio n and ii) an isothermal case in which pyroclasts and gases maintain the same temperature by a continuous heat flux during expansion. In both cases, water and carbon dioxide are cons idered either as a non-reacting mixture (i.e., superheated s tate) or a re acting mixture (i.e., saturated state). Results of the t hermodynamic calculations show the dependence of efficiency and transition from saturated to superheated state upon the mass ratio of magma to water and carbon dioxide.

Keywords: maar, hydromagmatic, co2

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VS009 **Oral Presentation** **6806**

Magma fragmentation in the conduit: numerical simulation code VERA

Dr. Eisuke Fujita
Volcano Research Depertment Nat'l Res. Inst. for Earth Sci. and Disast. Pre IAVCEI

Mie Ichihara, Takeshi Nishimura, Atsushi Toramaru

We have de veloped a numeri cal simulation code VERA , in which volcanic eruption is simulated as a phenomenon triggered by pressure release due to an opening of a conduit cap at the top. The subsurface magma plumbing system co nsists of cylindrical conduit and spherical magma reservo ir with adequate length and/or diameter. As an initial condition, w e assume an initial radius of a bubble in the magma reservoir, and bubble number densit y. Opening of the conduit cap release the magma pressure and enhance t he growth of bubble. When the void ratio exceeds a threshold, magma is fragmented. Our simulation code VERA reveals the details of t he fragment ation phenomena, significant heterogeneous distribution of gas and liquid components as well as pressure perturbation in the conduit and reservoir. In VERA code, we used VOF scheme for fr ee surface eva luation. VERA development is supported by Akihiko Minato and the project by ACT-JST.

Keywords: fragmentation, pressure release, vera

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VS009 **Oral Presentation** **6807**

Foam disruption as the origin of the subplinian basaltic plume at Shishaldin Volcano (Alaska)

Dr. Sylvie Vergniolle
Institut de Physique du Globe de Paris IPGP IAVCEI

J. Caplan-Auerbach

The 1999 basaltic eruption of Shishaldin volcano (Alaska, USA) produced a plume that reached heights exceeding 16 km. Acoustic measurements have been used to estimate the time evolution of the gas velocity, showing that the Subplinian phase was composed of six plumes. They can be explained by the accumulation and rupture of a sequence of foams, i.e. a closely packed mixture of small bubbles within a liquid magma, in the conduit. The first event corresponds to a foam of 0.45 km in length whereas the five following periods correspond to foams of 0.90 km. Alternatively, the eruption may be viewed as a single foam of 2.0 km that collapses in six events. The small gas acceleration, the absence of a sudden pressure release, a constant gas fraction over the entire height of the foam favor that latter scenario. The pressure release, induced by foam removals, can produce a vesiculation episode within the conduit as observed during the third plume. However vesiculation alone is shown to be not the major source of the gas expelled during the Subplinian plume in contrary to what is accepted for explosive volcanoes. After the first event, the foam experiences a strong decompression induced by the removal of the weight of previous foam. This produces the rupture of the foam and the first plume of the Subplinian phase. The same phenomenon occurs following ejection of that plume, and a cascade of foam rupture follows until foam exhaustion. The foam rupture is modeled by a kinematic wave: a sharp front with discontinuities in pressure, density, velocity and gas volume fraction, propagates downwards. The theoretical ejecta velocity, between 100 and 150 m/s, is in good agreement with the measured one, 82 m/s. The theoretical rupture velocity, 3.0 m/s, agrees very well with the measured one, 2.9 m/s. This suggests that the physics of foam rupture have been well described by this simplified model.

Keywords: subplinian plume, eruption mechanism, acoustic measurements

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VS009 **Oral Presentation** **6808**

Geometry of Shallow Plumbing Systems for Small-Volume Basaltic Volcanoes and Implications for Conduit Formation

Dr. Gordon Keating
Earth and Environmental Sciences Los Alamos National Laboratory IAVCEI

Greg A. Valentine, Don J. Krier, Frank V. Perry, Sebastien Dartevelle

We characterize the subvolcanic geometry of small-volume basaltic volcanoes (magmatic volatile-driven eruptions, 0.1 to 0.5 km3) based on a synthesis of field studies of 5 basaltic volcanoes with varying degrees of erosion exposing feeder dikes, conduits, and vent areas <250 m depth. Study areas include Basalt Ridge, East Basalt Ridge, Paiute Ridge, and Southeast Crater Flat (Nevada, USA), and East Grants Ridge (New Mexico, USA). Basaltic feeder dikes ~ 250 to 100 m deep have typical widths of 4 - 12 m, with smooth host-rock contacts (rhyolite tuff). At depths <100 m, heterogeneities in the host rock form preferential pathways for small dike splays and sills, resulting in a 30-m effective width at 50 m depth. The development of a complex conduit above ~50-70 m depth is reflected in bifurcating dikes and brecciation and stoping of the country rock. The overall zone of effect <50 m depth is <110 m wide (220 m elongated along the feeder dike). Based on comparisons with theoretical conduit flow models, the width of the feeder dike from 250 to 500 m depth is expected to range from 1 to 10 m and is expected to decrease to about 1-2 meters below ~500 m. The flaring shape of the observed feeder systems is similar to results of theoretical modeling using lithostatic pressure- balanced flow conditions. Sizes of observed conduits differ from modeled dimensions by up to a factor of 10 in the shallow (<50 m) subsurface, but at depths >100 m the difference is a factor of two to five. This difference between observed and modeled dimensions is primarily due to the fact that observed eroded conduits record the superimposed effects of multiple eruptive phases while theoretical model results define dimensions necessary for a single, steady eruption phase. The complex details of magma-host rock interactions observed at the study areas (contact welding, brecciation, bifurcating dikes and sills, and stoping) represent the mechanisms by which the lithostatic pressure-balanced geometry is attained. The similarity in the normalized shapes of theoretical and observed conduits demonstrates the appropriateness of the pressure-balanced modeling approach, consistent with the conclusions of Wilson and Head (1981) for this type of volcano. We interpret the observed feeder geometries in the context of a conceptual model of downward propagation of the conduit structure accompanying transients in pressure, vesiculation, and wall-rock failure within the feeder dike.

Keywords: basalt, conduit, dike

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VS009 **Oral Presentation** **6809**

Modeling of volcanic conduit pressurization due to gas bubbles in basaltic magma

Dr. Takeshi Nishimura
Geophysics Tohoku University IAVCEI

Since volcanic explosion is a rapid release of pressure in the conduit, the preparation stage of pressurization in volcanic conduit is crucial to understand the volcanic explosivity. In this study, therefore, I present a pressurization mechanism in volcanic conduit of basaltic magma system that intermittently explodes such as Strombolian-type explosion. The top of magma column in the conduit is considered to be cooled by atmosphere and/or by back-fall of pyroclasts after each explosion. As a result, the viscosity of the top of magma becomes higher than that of deeper magma, and a lid is formed at the top of the conduit. Fresh magma is supplied from a deeper portion so that magma in the conduit migrates upward forcing the lid upward. Since basaltic magma is characterized by low-viscosity, gas bubbles can rise in volcanic conduit with a faster speed than melt. These processes are expressed by the following equations. The motion of lid is controlled by a pressure difference between atmosphere and the top of magma as well as frictional force at the conduit wall due to the viscosity of lid. Magma pressure at each depth is determined by over-burden weight of magma locating above and the volume changes of total magma volume that is controlled by the lid motion and gas bubble growth. In the conduit, gas bubbles migrate upward due to buoyancy forces following Stokes flow. The density and pressure of gas bubbles are assumed to be related by the ideal gas equation. To examine the effect of gas bubbles on the magma pressurization, it is assumed that fresh-magma only provide gas bubbles at a deep location in the conduit. I numerically calculate the pressure changes in volcanic conduit as well as the gas bubble motions. The results show that as the gas bubble migrates upward, its radius increases due to de-pressurization to decrease its density and get large buoyancy force. Hence, gas bubbles increase its volume rapidly and compress the surrounding melt as they ascend. That is, pressure of magma in the conduit rapidly increases with time. Numerical calculations in various settings show that magma pressure can increase more than a few percent of lithosptatic pressure due to the lid of conduit when sufficient amount of gas bubble rise up and/or lid viscosity is large. In case of no gas bubble in the conduit system but a constant magma supply, over-burden pressure makes the pressure of magma in the conduit increase, but constantly. These temporal changes in magma pressure can be detected by recent geodetic measurements closely deployed around volcanoes, which enable us to provide constraints on the conduit process in basaltic magma system.

Keywords: bubble, pressure, magma

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VS009 **Oral Presentation** **6810**

The relationship between the sector-collapse of the South East Crater (Etna, Italy) and the paroxysmal event of November 16 2006

Dr. Carmelo Ferlito
Scienze Geologiche Universit di Catania IAVCEI

Marco Viccaro, Eugenio Nicotra, Renato Cristofolini

The activity at the South East Crater (SEC, 3340 m a.s.l.) was recently characterized by lava flow emission joined to explosive paroxysms, the most violent of which occurred on November 16, accompanied by collapses of the eastern sector of SEC. Rock failures started early in the morning from the eastern flank of SEC and went going on throughout the day for 12 hours. In the meanwhile, an intense explosive activity with lava fountains was taking place at the summit of SEC cone with lava effusion from several vents opened on its eastern flank. At the base of the cone (30 50 m a.s.l.), a fracture opened abruptly at 3:28 p.m. (Local Time) and an eruptive column was then originated. In the days that followed this paroxysm other explosive episodes took place from the same vent, although none of them was as intense as the first one. Field observations joined to petrological considerations and the recent eruptive history of Mt. Etna constitute the base to understand the evolution of the November 16th paroxysm. In particular, petrochemical data show that the erupted magma, very basic and volatile-rich, was similar to the one emitted in the last years and in the previous 2006 eruptive episodes from the SEC system. Moreover, the magma-feed was not continuous but relatively intermittent, with gas-charged pulses, which reached the surface every 2-5 days, as shown by the occurrence of the explosive episodes. The gas exsolving magma rising to the surface was confined within the highest section of the conduit essentially because of hydrostatic equilibrium with the host rocks. Due to the collapses of the eastern sector of the SEC cone, the load on its flank decreased starting from the early morning, and the confining pressure therefore dropped. At this time (3.28 p.m.), the unloaded SEC structure was then unable to restrain a new pulse of gas-rich magma, which was therefore able to work its way out, fracturing the cone in its weakest point. Due to the simultaneous fracturing and magma injection, in a few seconds an eruptive column was formed and accompanied by intense steaming caused by the fast vaporization of ground water and buried snow. The column of gas, finely fragmented magma and water steam, too dense and heavy to rise high, suddenly collapsed and gave rise to a small, but spectacular, pyroclastic flow directed downward along a channel formed by the preceding cone failure episodes. This circumstance, along with the limited extension of the flow, fortunately avoided eventual dramatic consequences. This paroxysm, though short and limited to the summit area of the volcano, is significant in unfolding some crucial phenomena that might be looked at as potentially hazardous.

Keywords: etna, sector collapse, pyroclastic flow

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VS009 **Oral Presentation** **6811**

Sampling and analyzing ash from individual Strombolian explosions at Stromboli: towards an integrated volcanological-geophysical approach to shallow conduit processes.

Dr. Piergiorgio Scarlato
Seismology and Tectonophysics Istituto Nazionale di Geofisica e Vulcanologia IAVCEI

Daniele Andronico

While geophysical observation is well established as the principal tool to monitor volcanic activity, petrological and volcanological observations are usually considered more as a tool to understand volcanic processes "a posteriori", reconstructing past activity from the study of old products. Nevertheless, data from the two systems are fully complementary. Stromboli volcano, with its quasi-permanent, mild, varied, explosive activity constantly monitored by a large geophysical network, is a perfect case study for coupled volcanological-geophysical studies. Eruption variability and adverse logistic conditions often hinder the collection of ash samples from individual explosions/vents. These difficulties can be overcome by using remote controlled, electrically propelled, commercially available aeromodels. From a favorable location close to the volcano summit we fly the aeromodel into the plume of individual explosions. The aeromodel carries a device capable of collecting up to four individual ash samples during the same flight, and we are currently testing a model to be equipped with GPS, camcorder, and thermometer. In this way we aim to couple the textural information of the ash with a precise determination of the plume position and temperature. To analyze ash particles we use a Field Emission SEM equipped with a motorized stage, backscattered electron detector, and EDS. First we identify particles outline and measures their area, perimeter, equivalent diameter, and compactness factor. Then, we acquire a x-ray spectra from the whole surface of each particle, converting it into a standardless, quantitative chemical analysis that provide information on the chemical composition of the products and their degree of crystallinity and alteration. The textural and compositional information thus obtained comes from one single Strombolian explosion, and thus can be readily compared with any geophysical information (e.g., seismic, acoustic, visual. electric signal) from the same explosion.

Keywords: strombolian, basalt, explosion

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VS009 **Oral Presentation** **6812**

The Parcutin eruption: a new look into violent strombolian activity

Dr. Laura Pioli
Department of geological sciences University of Oregon IAVCEI

Katharine Cashman, Hugo Delgado-Granados, Elisabeth Erlund, Mauro Rosi, Paul Wallace

Cinder cones are the most common volcanic landforms on Earth. They are formed by long lasting (months to years) explosive events that emit basaltic scoria and ash, usually accompanied and/ or followed by lava flows, and even though they were not thought to be a large hazard as compared with large stratovolcanoes, they constitute a severe hazard to aviation, population, and economic activities. The dynamics of these eruptions is often complex, including effusive and higher explosivity, transitional or violent strombolian phases that produces ash-charged columns up to a few km high, depositing tephra up to hundreds of km from the source. The explosive phases differ from sub-Plinian eruptions mainly by their pulsatory, non-sustained behavior.We examine the main features and describe basaltic explosive eruption dynamics by analyzing the deposits and the activity of the best documented violent Strombolian eruption of the last century: Parcutin- Central Mexico (1943-1952).Intense explosive activity marked the first three years of the Parcutin eruption, and magma emission rate decreased with time until the end of the eruption (Fries, 1953). Tephra emitted accounted for 86% by volume of total erupted material: only a small fraction (~10%) of the tephra forms the cinder cone (~300 m high), and the remainder is distributed in a continuous blanket extending over tens of km2 (Segerstrom, 1950). Lava emission occurred throughout the eruption from vents located at the base of the cone, forming several flows that eventually covered nearby villages. Tephra deposits of the Parcutin eruption display peculiar features related to prolonged, intermittent activity. The grain size features of the deposit also record for an increased efficiency of magma, compared to Hawaiian and Strombolian activity, with relevant production of coarse fragmentation to fine ash. Moreover, the occurrence within the deposit of a marked heterogeneity of juvenile fragments indicates variable degrees of syneruptive magma degassing and crystallization.The alternation of Strombolian bursts and more intense explosions, forming ash-laden, few km high columns, suggests generally low magma rise speed and variable gas flux. Another fundamental process controlling the eruption dynamics was gas segregation within the shallow reservoir, as demonstrated by effusion of degassed lava flows and lava fountaining at the base of the cone alternating with strongly explosive degassing from the central vent.We infer that the violent strombolian phases at Parcutin (which were referred to as cineritic at the time of the eruption) were determined by rapid accumulation of water-rich magma in the shallow dike system and the onset of churn to slug flow regimes. Moreover, the systematic occurrence of different textural types with the juvenile component suggest that the magma underwent a complex history of crystallization and degassing within the conduit, discontinuous supply of water-rich magma from a lower reservoir, and partial recycling of degassed magma within the shallow system.

Keywords: cinder cone, two phase flow, conduit flow

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VS009 **Oral Presentation** **6813**

Development of anisotropy of permeability in expanding vesicular magma with implications for eruption explosivity

Dr. Ed Llewellin
Department of Earth Sciences University of Durham IAVCEI

The rate of e scape of magm atic gases from vesicu lating, expanding magma is key to control ling the explosivity of an eru ption. Pemeable n etworks of bubbles may develop as magma ris es and bub bles grow and impinge on one another. Whilst isotropic expansion results in is otropic network permeability, anisotropic expansion results in anisotropic permeability. A geometric analysis is presented which shows that, in an anisotrop ically ex panding b ubble suspension, percolation occurs first in t he direction of minimum expansion if capillarity is low (typical of mafic systems). Numerical simulations further show that permeability is enhanced in the direction o f minimum expansion and hindered in th e directio n of maximum expansion. In a volcanic conduit, this implies that gas will flow more easily across the conduit than parallel to the conduit. Enhanced lat eral de gassing facilitates rapid gas escape, reducing t he likelihood of magma fragmentation and mitigating eruption explosivity.

Keywords: permeability, anisotropy, degassing

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VS009 **Oral Presentation** **6814**

Dynamics of the Fontana Lapilli basaltic Plinian eruption (Nicaragua): deposit characterization and microtextural studies.

Mrs. Licia Costantini
Department of Mineralogy University of Geneva IAVCEI

Costanza Bonadonna, Bruce F. Houghton

The Fontana Lapilli deposit was erupted in late Pleistocene from a vent located around Masaya volcano (Nicaragua) and represents the product of one of the largest basaltic Plinian eruptions studied so far. This eruption evolved from an initial sequence of short hawaiian-strombolian pulses via a moderately explosive phase to the main series of quasi-steady Plinian episodes depositing fallout beds of highly-vesicular basaltic-andesite scorias (SiO2 ~ 53 wt%). Regardless the method used, we have obtained a plume height of around 30 km and an associated mass eruption rate of 108 kg/s for the main Plinian phase. In contrast, the estimate of erupted volume is strongly sensitive to the technique considered for the calculation and varies between 1-8 km3 using the exponential method, the power-law method and an inversion technique. The calculation of erupted volume significantly affects the estimate of eruption duration which, in this case, varies between 1-14 hours. Samples collected vertically in our best outcrop show unimodal grain size distribution and a moderate sorting. The juvenile component is predominant in the deposit (more than 96 wt%) and consists of clasts with both sub-angular and fluidal/elongated shape. Fluidal/elongated clasts were mostly observed in clast sizes< 8 mm and many of them are extremely glassy. They usually show highly elongated vesicles parallel to the long axis of the pyroclast. All juvenile clasts are highly microvesicular and show a low and narrow unimodal density distribution (300-1300 kg/m3) relatively to other basaltic Plinian eruptions (e.g. 600-2400 kg/m3 density range for the 122 BC Etna and 700-2400 kg/m3 for the Tarawera 1886 Plinian eruption phase). Results from our microtextural studies show that at least part of the degassing history of Fontana Lapilli melt was characterized by delayed-homogeneous bubble nucleation leading to the formation of fast foaming of volatile-saturated melt. In fact, although all scoria clasts show an intense coalescence signature that partially hides the pattern of nucleation and the early growth of bubbles, they have a significantly higher vesicle number density (in the order of 107 numbers of bubbles per cm3) than typical Strombolian products, permitting a high degree of volatile supersaturation. The high vesicle number density is the only main character that Fontana Lapilli deposit has in common with other well-know basaltic Plinian eruptions. Moreover post-fragmentation expansion indicated by gradual internal textural variation within individual clasts and the common glassy groundmass texture reveals a high eruptive temperature that possibly inhibited syn-degassing crystallization and enhanced plume buoyancy, facilitating the wide dispersal of the deposit.

Keywords: basaltic plinian eruption

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VS009 **Oral Presentation** **6815**

Changing in eruptive styles in basaltic explosive volcanism: examples from Croscat Volcano, Garrotxa Volcanic District (NE Catalunya).

Mr. Federico Di Traglia
Dipartimento di Scienze Geologiche Universit Roma Tre IAVCEI

Corrado Cimarelli, Donatella De Rita, Domingo Gimeno Torrente

Explosive basaltic volcanism shows a great variety of eruptive styles, e.g., low e xplosive Hawaiian and Strombolian, high explosive Violent Strombolian, Plinian and Phratomagmatic. Changes in eruptive style are largely driv en by v ariations in magma and gasses rise speeds and b y the extent of magma-water interaction. Croscat Volcano, a Quaternary complex basaltic scoria cone in the Garrotxa Volcanic District (NE Catalunya) exhibits diff erent types of explos ive de posits from Hawaiian to phreatomagmatic suggesting different eruptive styles during its short lived evolution. We h ave analyzed t he lithofacies, grain size distribution, density, vesicularity, b ubble size distribution and glass shard morphologies of the Croscat pyroclastic succession to define the changing in eruptive style. The oldest prod ucts outcropping are constituted by spatter and welded scori a accumulations related to th e initial fissural phase. Most of the pyroclastic succession is made of Hawaiian- to Strom bolian-type deposits constitut ing the central edifice. Surge deposits rich of dense juvenil e clasts domin ate at the top of the pyroclas tic succession. .At the top of the Strombolia n type layers a peculiar deposit interprete d as represent ing the climatic phase of t he eruption, has b een analyzed in detail. It shows strongly oriented and large dispersion of the products controlled by pr e-existing topography, although grain size d istribution displays exceptional sorting. The d eposit lies on sedimentary lithics and cr ystals rich surge layers and it is constituted by almost three scoria- lapilli beds of variable thickne ss (m to cm) separated by thin ashy la yers. Two end members of juvenile clasts characterize the deposit: i) fluidal- to irregularshaped rounded vesicular glass particles, and ii) trunkshaped, vesiculated stretched scoria. We hypothesize that the first type of shards formed in the central part of the volcanic conduit, while the trunkshaped scoriae formed at the margin of the conduit, where the relatively low tem perature and the higher strain rate produced by the friction on the conduit wall could produce brittle fracture of more viscous magma. In the deposit white vesicular lithics, interpreted as melted host rocks are also pr esent. The types of glass shards together with the fragments of melted host rocks, the strongly oriented and large dispersion of the deposit, and the flow type emplacement suggest a violent eruption (subplinian-type) of an ove r pressured jet determining a n asymmetric fountain that collapsed prod ucing pyro clastic density cu rrents. Waxing -waning of th e Croscat expl osive activity has been related both to pro gressive widening o f the co nduit and to the progressive depletion of volatiles in the magma chamber and conduit by eruptive withdrawal.

Keywords: complex scoriacone, pyroclastic flows, garrotxa

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VS009 **Oral Presentation** **6816**

Modelling magma flow in narrow conduits: the case of Villarrica volcano

Mr. Jose Luis Palma Lizana
Earth Sciences The Open University IAVCEI

Steve Blake, Dave Rothery, Eliza Calder

Basaltic systems are characterised by relatively bi g chambers and long feeding conduits where magma ascends from a deep source to the surface. Villarrica volcano is an exam ple of such a s ystem. It is the most active volcano in the so uthern Andes (33-46 S). The historic eruptive activi ty of Villarrica volcano record strong explosions and volcanic plumes rising over 3000 m a.s.l., as well as lava flows and 400 m high lava fountains. Currently, Villarrica volcano shows persistent gas plume emission and a very active lava lake that exhibits almo st continuous bubble bursting activity.In this presentation, we deal primarily with magma c onvection in the plumbing s ystem and its consequences on the activity at persistent degassing volcanoes of basaltic comp osition. We describe the fluid dyna mics of magma (and gas) flow within narrow conduits, based on new analytical and experimental results, and explain the link with the activity observed at Villarrica volcano. We also compare ou r resu lts with oth er op en-vent basalti c volcanoes such as Mt. Ereb us and Stromboli.Current ly available models that accoun t for convection within narrow conduits use over-simplified c onditions that, as we show, are ina ccurate to represent the dynamics of t wo-fluid flow. They model c onvection as upward and do wnward Poiseuille flow of tw o immiscible fluids. We improved that model by calculating the velocity pr ofile developed during steady state circulation of two immiscible fluids, and constrained the analysis with la boratory experiments. For instance, our results yield volumetric fluxe s that can be orders of ma gnitude lower than the ones predicted by previous models . We conclude that the dyna mics of magm a flow develop ed in narrow conduits can be as impo rtant as the dynam ics of magma chambers and, under certain co nditions, it constrains the characteristics of the outgassing activity observed at the surface.

Keywords: villarrica, magma dynamics, plumbing system

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VS009 **Oral Presentation** **6817**

The GRMSVTN 2004 eruption: volcanic plume transport and tephra dispersal in a basaltic phreatomagmatic eruption

Mr. Bjrn Oddsson
Institute of Earth Sciences University of Iceland

Magns Tumi Gumundsson, Gurn Larsen, Sigrn Karlsdttir

The do minant style o f activity in the most frequently active volcan o in Iceland, Grm svtn within the Vatnajkull ice cap, are small to medium sized phreatom agmatic, basaltic eruptions. The latest eruption occurred in November 2004. The crater wa s located in the southwest corner of the Grmsvtn caldera where the eruption broke through 150-200 m thick ice in about 1 hour. This brief subglacial phase was followed by the main phase of the eruption that lasted about 30 hours. This main phase was monitored by radar and visual observations from aircraft. Duri ng this period the eruption plume was 6-10 km high (relative to vent) and formed a well-defined tephra fan towards the north and northeast. The tephra on the accumulation area of Vatnajku ll was quickly covered by the wint er sn ow. Alth ough teph ra fallou t was recorded over a large s ection of northeast Ic eland, the b ulk of the tephra was deposited on Vatnajkull, whose northern margin is 40-50 km to the north of Grmsvtn. The tephra sector on Vatnajkull was sampled with a snow corer in the su mmers of 2005 and 2006, yielding a compr ehensive map of tephra mass dispersal. The mass of the tephra laye r outside the immediate crater area is 2.5x1010 kg. The total mass of the tephra layer has bee n compar ed with predicted values obtained by integrating empirical relations linking m ass transport a nd plume height. The preliminary results of this excercise suggest that t hese empirical relations, obt ained ma inly from the study of plinian and other magmatic eruptions, yield a reasonable fit to this basaltic, phreatomagmatic eruption.

Keywords: tephra, phreatomagmatic, plume

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VS009 **Oral Presentation** **6818**

Dynamics of ash emission activity at Vesuvius

Mrs. Claudia D'Oriano
IAVCEI

Raffaello Cioni, A. Bertagnini, P.D. Cole

Several eruptions dominated by ash emission have occurred at Vesuvius after the Avellino plinian eruption (3900 y BP). This type of activity has been overlooked in the past, even though it can pose significant problems for emergency planning and hazard assessment. We present the results of a study on the deposits of some of these eruptions, aimed at defining their eruptive dynamics and environmental impact. The deposits of these eruptions are mainly formed by thick sequences of thinly laminated coarse and fine ash, interlayered with minor lapilli beds. This suggests that they are related to periods of continuous ash emission alternated with episodes of violent strombolian activity.All samples are characterized by the contemporary presence of different types of juvenile fragments, from light-brown, highly vesicular, glassy pumice, to black, moderately to not vesicular, microlite-rich scoria. All these fragments show a large textural variability in terms of vesicles content, size, and shape and microlite content. The juvenile products are phonolitic tephrite in composition and have a mineralogical assemblage formed by clinopyroxene phenocrysts set in a variably crystalline groundmass consisting of leucite, pyroxene and plagioclase. Matrix glasses have a foiditic composition, with a clear relation between the composition of the residual glass and crystal content of the groundmass. Different categories of juvenile fragments were distinguished using deive quantitative parameters of clast morphology and textural features, elaborated through Principal Component Analysis and Cluster analysis. Crystal size distribution of the groundmass of the highly vesicular, glassy fragments, representing the most abundant juvenile fraction, was used to assess the timing and the dynamics of magma degassing and magma ascent. The ubiquitous presence of highly vesicular material suggests a primary role of magmatic volatiles in driving magma fragmentation. The only sporadic occurrence of sedimentological evidence of phreatomagmatic activity in the deposits suggests a minor role of magma-water interaction in the dynamics of ash eruptions at Vesuvius.

Keywords: volcanicash, crystalsizedistribution, eruptivedynamic

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VS009 **Oral Presentation** **6819**

Deep-sea pyroclastic deposits on Loihi Seamount

Dr. James White
Geology Department University of Otago, NZ IAVCEI

C. Ian Schipper, Bruce F. Houghton

Loihi seamount is the youngest and southernmost volcano in the Hawaiian Islands group, and its summit is ~1 km below sea level. Previous studies identified widespread volcaniclastic deposits locally >10 m thick, and in October 2006 such deposits were the focus of 5 dives onto Loihi's seamount summit with Hawaii Undersea Research Laboratory's submersible Pisces IV. Two sites are of particular interest. At the first, 20 m of coarse-grained material is exposed abutting and overlying pillow lavas. The basal few metres of the deposit are characterised by decimetre-scale beds of coarse ash with cm-scale internal layering, separated by discontinuous layers of larger fragments, many several centimetres across. Upsection, deposits coarsen to lapilli-dominated lapilli-ash in thicker beds lacking distinct internal stratification. Beds are defined by layers a few clasts thick of coarser fragments, with some beds containing coarse lapilli to small blocks dispersed throughout. Three populations of clasts typify the lapilli fraction of the deposits: ragged, highly vesicular clasts; dense, fluidal clasts with a crusted surface texture; and a variety of lithic clasts showing variable textures indicative of different transport histories. There are also occasional mixed clasts, in which dense fluidal material encloses weathered lithic particles. We infer that all the particles are pyroclasts, in the sense of having been deposited directly by fall or currents from an eruption of a very nearby (but not identified) vent source. Fine ash is a very minor component of the deposits, suggesting weak fragmentation or/and some winnowing during transport or deposition. The fragments' variable vesicularity (<50%) indicates a role for magmatic-gas exsolution in driving the eruption. Very glassy clasts and absence of welding in the deposit suggest that water quenched the fragments prior to deposition at this site. Continuing work will assess vesicle and microlite populations, as well as particle shape and density, to further constrain interpretations of eruption and deposition. The second site of interest has a basal section dominated by thin lava sheets with cavities that contain sideromelane ash deposits with very high proportions of small thin sheet-form fragments termed "Limu o Pele". Several metres of weakly bedded ash and lapilli-ash overlies the basal lava sheets, comprising mixtures in varying proportion of limu fragments and dense blocky sideromelane grains. We infer that these are primary deposits because of the consistency of clast type, absence of apparent seafloor-weathering or cementation surfaces, scouring, or intervening deposits with more polymict grain populations. The dense blocky grains mixed with the limu fragments are considered to result from quench granulation and related processes associated with emplacement of seafloor lavas. Limu fragments have been interpreted as either forming from a fountain-like style of eruption, or from seawater bubbles rising and bursting through thin lavas; here, the close association with sheet lavas favors the latter interpretation.

Keywords: limu, submarine, pyroclastic

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VS009 **Oral Presentation** **6820**

Effusive, explosive, phreatomagmatic, and edifice collapsing events of Jorullo Volcano (Mexico)

Dr. Hugo Delgado Granados
Departamento de Vulcanologa Instituto de Geofsica IAVCEI

Julie Roberge, Isaac A. Farraz Montes, Alfredo Victoria Morales, Julio Csar Prez Bustamante, Juan Carlos Correa Olan, Aarn Gutirrez Jimnez, Nayeli Adn Gonzlez, Edras F. Bravo Cardona

Jorullo volcano was born in 1759 in the middle of crop fields of the old Hacienda El Jorullo near the town of La Huacana in Michoacn, western Mexico. This region is part of the Michoacn-Guanajuato Volcanic Field (MGVF), a region characterized by widespread monogenetic volcanism although polygenetic volcanism is also present in the region. The volcanism of the MGVF is related to the subduction of the Cocos plate beneath the North American plate. It is important to notice that MGVF is the westernmost volcanism related to this plate assemblage, because further west volcanism is related to the subduction of Rivera plate beneath North America. Other important features to notice about Jorullo volcano are that it is located near the volcanic front of the arc and at the edge of a tectonic and sedimentary depression (part of the Chapala-Oaxaca lineament) where groundwater has been ponding during the Holocene. The activity of Jorullo volcano 1759-1774 affected strongly the region in spite of the low population present at the time. Small villages were abandoned after being burried with ashes although the damage was minor and people got back later. Nevertheless, the population of the Michoacan 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 likelyness of future eruptions. During the birth of the volcano several lava flows were emitted and several cones were constructed. The main cone is the Jorullo proper, but there is a smaller cone on the north (Volcn del Norte), and three much smaller cones on the south (Unnamed cone, Volcn de Enmedio and Volcn del Sur), all aligned north-south. In this work we present the results of detailed study of the tephra deposits from the 1759-1774 eruption of Jorullo, its lava flows and the distribution and products of its parasitic cones. Luhr and Carmichael (1985) stated that during the course of this eruption, lavas evolved from primitive basalt to basaltic andesite. In addition to effusive activity, Jorullo erupted explosively, depositing a thick blanket of tephra whose volume we have calculated using distribution patterns on an isopach map. The composition of the tephras and the lavas show the same unusual evolution pattern found at Parcutin (Johnson et al., 2006, Luhr and Carmichael, 1985). The cone of Jorullo volcano is made up of tephra and lava flows erupted from the crater. The other three cones south of Jorullo show very interesting histories. The Volcn de Enmedio erupted highly vesiculated tephras including xenoliths from the granitic basement. The Volcn del Sur is made of spatter and bombs having at the summit the remains of lava fountains <40m long. Both cones collapsed towards the west and the debris avalanche deposits still show a hummocky morphology. After the collapses, phreatomagmatic activity took place at the Unnamed cone blanketing Volcn de Enmedio and Volcn del Sur and the southern flank of the Jorullo cone with sticky surge deposits. Observers of the ruling government at the time described the eruption of Jorullo volcano. They mentioned the occurrence of hot muddy flows flowing along the ravines during the first two months of activity of the volcano, which was indicative of the interaction of groundwater with the magma to form bursts of mud, but there was no mention to further water/magma interactions. The deposits we report did not occur at the beginning of the eruption, and hence do not correspond to the descriptions of the observers, but occurred at an advanced stage (after formation of the 3 southern cones). These processes at Jorullo volcan o (con e colla pse, ph reatomagmatic activity) have not been previousl y described and are of great importance because of their implications for hazards assessment.

Keywords: ashfall, phreatomagmatism, collapse

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VS009 **Poster presentation** **6821**

Dynamics of low energy explosive activity at Stromboli volcano (Aeolian Islands, Italy).

Dr. Vittorio Zanon

Marco Neri, Emilio Pecora

Twenty low-energy (0.0077 0 .625 kgs-1) explosions from the Northeast Crater of Stromboli Volcano, recorded by a thermal camera, were studied in detail to better understand their dynamics. Each single burst consists of three different jets of different material which come one after another: at first, cold vapour flashes above the crater, expands and then disappears within 0.6 s after the onset of the explosion, at a velocity of 40-113 ms-1. This air shock wave is immediately followed by the expansion of a jet of hot magmatic gas, at a velocity of 35-75 ms-1. Colder coarse tephra (bombs and scoriae) appear about 1.6-2 s after the onset of explosion, moving at a reduced velocity (28-60 ms-1). Further on, some of these data were utilized to calibrate a set of flow simulation in a 220-260-m-long conduit, which validates the model of slug flow for these kinds of eruptions. Finally, coupling all the collected data with the stratigraphy of the volcano, we hypothesized that a physical barrier might be responsible for the formation of slugs of gas and their ascent to ward the surface at regular intervals. This barrier acts as a siphon and seems to be generated by the displacement of the upper conduit due to summit instability. This model justifies the ~constant interval between explosions, the insensitivity of this behavior to the occurrence of effusive episodes and highly explosive events, as well as the generation of fairly constant petrochemical characteristics of the magma which is commonly erupted, with time.

Keywords: explosions, camera, stromboli

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VS009 **Poster presentation** **6822**

The turbulent shedding mechanism of hydromagmatic fragmentation: physical evidence from Kīlauea volcano, Hawaii

Dr. Larry Mastin
Cascades Volcano Observatory U.S. Geological Survey IAVCEI

Oliver Spieler

Fine (<130 m), blocky Surtseyan pyroclasts are conventionally thought to result from discrete, powerful vapor explosions termed fuel-coolant interactions (FCIs). Such fragments have been produced by FCIs in the laboratory; however the possibility remains that they could also result from other types of vigorous but less explosive mixing. To address this possibility, we examine surface textures of pyroclasts composing a small littoral cone along Kīlaueas southeast coast (located at 19.33119N, 155.04887W, Old Hawaiian Datum). This cone is thought to have formed from vigorous but not highly explosive mixing when lava entered the surf through broken lava tubes, was impacted by waves, quenched, broken, and thrown back onto the shore to form piles of loose debris (Mattox & Mangan, 1997, JVGR 75:1-17). The tephra contains millimeter-sized glassy fragments with fluidal surface textures and broken ends, and olive-colored glass plates tens to hundreds of microns thick. Glassy particles a few microns to tens of microns across commonly adhere to surfaces. Significantly, some fluidal surfaces exhibit partially detached skins or flakes microns to tens of microns thick; in our experience, such flakes are not present on surfaces of dry lava-fountain pyroclasts. On littoral clasts, the flakes occur in patches hundreds of microns across and commonly exhibit stretch marks resulting from extensional strain. Broken flakes are blocky and of the size inferred for FCI-generated Surtseyan clasts, but they compose an insignificant fraction of the deposit. We interpret the flakes to represent glassy rinds that formed during wave or droplet impact, and the blocky particles to represent detached and disintegrated remnants of these rinds. Published studies indicate that water droplets impacting surfaces whose temperatures are nearly magmatic remain in direct liquid contact for many milliseconds before an insulating vapor film develops. Conductive heat transfer during that time should form glassy rinds microns to tens of microns thick. We infer that small blocky fragments are rare in this deposit owing to the brief (<1 s) duration of rapid cooling and intense turbulence during and just after wave impact. During large Surtseyan eruptions, on the other hand, jets of magma, gas and water hundreds of meters high may mix turbulently for many seconds or minutes, allowing time for many generations of rind growth and removal to create blocky particles. We refer to the formation of fine blocky clasts by rind growth and removal as turbulent shedding. This process may occur during the expansion phase of discrete explosions, but also during less explosive types of turbulent mixing. We will test this hypothesis in the laboratory at the Ludwig Maximillians University inMunich by injecting basaltic magma into water sprays.

Keywords: fragmentation, hydrovolcanism, explosive volcanism

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VS009 **Poster presentation** **6823**

Morphoscopy of pyroclasts (optical and SEM approach) as a tool in magma-water interaction understanding: a case study from Puig de La Garrinada Volcano, Olot (NE Spain)

Mr. Guillem Gisbert
Geoqumica, Petrologia i Prospecci Geolgica Postgraduate student IAVCEI

Domingo Gimeno

The development of civil works in the flanks of one of the three basaltic pyroclastic cones present in the town of Olot has allowed for a detailed observation and sampling of the pyroclastic deposits related to the volcano activity, reaching the local substratum (an older basaltic lava flow). The volcanic succession is 11 meter thick and is constituted, from bottom to top by 7 levels (named A to G): level A is a thick-coarse grained strombolian deposit formed by a dense packing of bombs up to a meter in size and thick lapilli. Term B is a thinner continuation of A with centimetric thin-granulometry layers present among the thicker layers made of fine-sized lapilli and ash. C is a one-event deposit, half meter thick with a basal layer of coarse lapilli and an upper part formed by fine sized lapilli showing cross lamination. D is a light brown-coloured bomb-bearing matrix-supported oligomictic deposit about 2 meters thick with load marks at the bottom. E is thin level formed by several centimetre-thick layers well differentiated because of changes in cohesivity and colour. Material is fine lapilli and coarse ash, with layers alternating in colour from dark grey (soft levels) to light brown and pink (hard levels). Lapilli colour is given by very fine particle coatings. F is a half-meter homogeneous layer of thin lapilli-sized scoriaceous fragments. Sequence ends with G, term of 2 meters formed by a very thin lamination of thin lapilli and ash. Finer grained fraction was studied under the binocular and a selection of samples by SEM, characterising the different populations of materials that form the cone and their distribution throughout the sequence. This part of the study was conducted by means of a questionnaire specifically designed in order to discriminate diagnostic morphoscopic features of fine sized pyroclasts. Petrography and geochemical characterization of pyroclasts, lava flows and bombs shows the basanite and sodium alkaline basalt composition. Eruptive model: Volcanic cone substratum consists of basanitic lava flows expanded near to and within a shallow lacustrine environment. Eruptive centre started with strombolian activity, while base of the cone grew by coarse strombolian pyroclasts fall (A to B). Thus, interaction of magma with water from a pyroclastic aquifer caused phreatomagmatic activity to appear (B) and to dominate till the end of the eruptive event (C to G). During the phreatomagmatic activity pyroclasts typical of such activity and of strombolian activity were formed simultaneously as a result of the magma/water contact geometry in the eruptive conduct. A main conclusion of this work is that morphoscopic studies are useful in order to reconstruct the eruptive evolution and magma- water interaction processes, and that no evident correlations can be done with previously published work on this subject

Keywords: phreatomagmatism, pyroclast morphologies, sem

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VS009 **Poster presentation** **6824**

Interactions between rising bubbles and a crystal network: insights from analog experiments

Mrs. Isolde Belien
Geological Sciences University of Oregon IAVCEI

Katharine Cashman, Alan Rempel

Strombolian eruptions require the upward m ovement of bubbles, often through crystal-rich liquids. We present the results of a set of analog experiments investigating the interaction of a ris ing bubble with a loosely packed crystal layer. In our model, an ai r bubble rises through a viscous liqui d (a corn syrup water mixture, simulating magma) until it reaches a layer of irregularly shaped plastic beads (simulating crystals). The layer of beads is buoyant, so that its top boundary is a free surface. The interaction of the bubble with th e crystal layer is described . Experiments were carried out for bubble volumes varying from 0.2 to 5 mL and for crystal layers of d ifferent thicknesses. Depending on the size of the bubble relative to the size of the por es in the crystal layer, different kinds of interactions occur. Small bubbles, with sizes approximately the s ize of the pores in th e crystal layer, move through the laye r with minimal deformation to both the bubble and the layer. The bubble is delayed underneath and inside the layer as it finds its way to the nearest pore pathway. With increasing bubbles size, the bubble may do one of two things: 1) forcefully displace the crystal-liquid layer to move through or 2) deform and trave l laterally. The second case can lead to three different scenarios. i) Relatively small bubbles may deform to mo ve upwa rds thro ugh the po res. ii) La rger bubbles can flatten o ut significantly underneath th e crystal-liquid layer. When the flattened bubble a pproaches the width of the container, the bubble may rise to the surface along the side walls. iii) bubbles of intermediate size can bre ak up into smaller bubbles that then move through the crystal netw ork in b ubble trains. The latter mechanism may be important for bubble percolation through a crystal mush.

Keywords: bubble, crystal liquid layer, analog model

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VS010 **6825 - 6851**

Symposium
Modeling the plumbing system of active volcanoes by integrated petrological, geophysical and fluid inclusion studies

Convener : Prof. Benedetto De Vivo, Prof. Angelo Peccerillo

An understanding of the internal structure of active volcanoes is a major though often overlooked objective of volcanology. The composition of the primary melts, the depths and conditions at which magmas are stored, the way they differentiate, and the residence time of melts at different crustal levels have important effects on the style and magnitude of volcanic eruptions. These issues are crucial to understand the behavior of active volcanoes and to establish more reliable basis for monitoring strategies and for forecasting volcanic eruptions. To date, geophysical studies have been mainly used to investigate the internal structure of volcanoes. However, the complexity of volcanic systems cannot be adequately investigated by employing a single technique, but requires a multidisciplinary approach. Investigation of major, trace element and isotopic data of volcanic rocks and their constituent phases can furnish significant information on the nature and effects of magma evolution processes, allowing inferences on chemicophysical conditions of magma storage and differentiation. Petrological and geochemical studies can provide basic information on how volcanoes have been working in the past and, presumably, in the future. Seismic and gravimetric data have been widely used to have information on the structure of the basement beneath the active volcanoes, on the depth and size of magma chambers and on melt migration within the volcano plumbing systems. Finally, composition and density of fluid inclusion in phenocrysts and xenoliths are able to give quantitative constraints on depth (i.e. pressure) of fluid inclusion entrapment, i.e. on depth of magma storage systems. It goes without saying that the maximum of information on single active volcanoes can rise from studies that integrate the results of these different disciplines. Integrated, multidisciplinary investigation has the potential to furnish the most reliable models for volcanoes plumbing systems. This symposium has the aim of collecting scientists with different expertise (Petrology, Geochemistry, Fluid Inclusion Petrology, Seismology, etc.) to discuss the potentiality of integrated research in the modeling of volcanic plumbing systems and how this can help in establishing better strategies of volcano monitoring and in obtaining more reliable forecasting of volcanic eruptions. The symposium could be of interest to IAVCEI, IASPEI and possibly other IUGG associations.

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VS010 **Oral Presentation** **6825**

A simplified EOS for the density of silicate hydrous magmas: an application to a popocatpetl buoyancy-driven dome-growth process model

Mr. Alex Onar Gonzalez-Mellado
Instituto de Geofisica Universidad Nacional Autonoma de Mexico

De La Cruz-Reyna, Servando

The dome-forming activity of high-gas output volcanoes, as Popocatpetl in Central Mexico, may be explained in terms of a process involving the buoyancy of the magma column in the volcanic conduit produced by the combined effect of the content of dissolved volatiles and its temperature. This combination may produce density contrasts with the country rock capable to generate neutral, positive, or negative buoyancy. We present a simplified, easy to integrate, equation of state for calculating the density distribution of a hydrous siliceous magma in a volcanic conduit, in a range of pressure, temperature and water concentrations useful to explain the hydrostatic equilibrium of the magma column in the conduit and for other hydrodynamic studies. A simpler linear form, and a more precise non-linear form of the equation, both valid in the ranges 0 to 0.25 GPa, 800 to 1200 K, and 0 to 7 wt% H2O are proposed to model the Popocatpetl dacitic and andesitic magma melt density distribution with depth. The calculated height of domes and the depths of volatile saturation from the model require realistic volatile concentrations and temperature values for the range of possible conduit lengths of Popocatpetl. In fact, for the longest conduits (i.e., deeper magma reservoirs), even modest water concentrations, lower than 2 wt% may produce significant buoyancy for a dense andesitic country rock. Lower, more likely country rock densities, corresponding to porous, fractured strata of dacite and andesite, require somewhat larger amounts of dissolved water in the magma to produce buoyancy, but still well below saturation. For a given magma composition and temperature distribution, the observed maximum height of domes may thus provide a direct estimate of the volatile content of the magma in the conduit, and the likelihood of a stronger dome-destruction explosion. Intense degassing of a magma column may also produce a density increase, stopping the dome growth, and even reversing it, as sometimes has been observed at the Popocatpetl dome in the form of depression or collapse of the dome top surface.

Keywords: equation of state for density, dome growth, popocatpetl

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VS010 **Oral Presentation** **6826**

D/H Isotope Ratios of Olivine-hosted Melt Inclusions in Mount Etna Primitive Basalt

Dr. Patrick Allard
Earth Sciences CNRS IAVCEI

N. Mtrich, E. Deloule, O. Belhadj, N. Spilliaert, C. Mandeville

Mount Etna, in Sicily, is a very active and rare volcano erupting OIB -type Na-rich alkali basalts at the collision boundary of the African-European continental plates. Its huge ga s emissions and the abnormal richness in vol atiles of its alkali basalts suggest its feeding from a peculiar mantle source, possibly influenced by regional subdu ction processes. In 2002-2003, a highly explosive flank eruption of Etn a produced the most primitive basalt since 24 0 years. The high initial volatile content and the press ure-related degassing pattern of this basalt could be tr acked by measuring th e chemical concentrations of H2O, CO2, S, Cl and F dissolved in olivine-hosted melt inclusions entrapped from as deep as ~15 km depth [1,2]. Here we report on the D/H isotope ratio of water dissolved in these melt inclusions and in glass embayments (~40-200 ˜m), which provides new co nstraints on th e source of the basalt and its degassing pattern. Isotopic a nalyses were p erformed in CRPG with a Cam eca IMS1270 ion microprobe, using Etna gla ss samples of similar comp osition but dope d with known amounts of water and with known D/H ratio for calibration. ˜D valu es (˜5- 12) are referred to V-SMOW standar d. The results reveal interesting features. The most primitive an d best preserved inclusions, entrapped prior to significant H2O exsolution from the basaltic melt (≥10 km depth), contain 3.4˜0.3 wt% H2O, 0.2-0.4 wt% CO2, and have a mean ˜D of - 20 (range: -50 to 0). This mean ˜ D value is much higher than the range for MOR B-type upper mantle (-6015) and compara ble to the valu es for arc volcanism. It thu s suggests a prevalent arc-type derivation of water in Etna mantle so urce. Starting fro m this value, a series o f inclusio ns sho ws a ˜D evo lution with de creasing H2O and CO 2 contents that fits well with closed-system degassing of the basalt d uring fa st dec ompression from 15 km, followed by ope n degassing at sub-surface level (with ˜D d own to -140 in water-poor ev olved inclusion s). This trend is characteristic f or powerful lava fountaining that occurred during th e initial phase of the 2002 eruption [1]. A mixed degassing trend evolving from closed to open conditions can also explain the ˜D values of -45 to -50 previously measured in high temperature Etna volcanic gases [3]. However, we also find intriguingly positive ˜D values of between 0 and +40 for a group of quite primitive inclu sions that are still rich in H2O but depleted in CO2 (˜0.1 3 wt %). These inclusions we re trapped at 2 0020 MPa (~3-5km depth), where a magma ponding zone likely exists at the interface between the Iblean carbonate platform and t he upper N umidian flyschoid series. Ca reful petrologic and textural observations suggest that their anomalous ˜D could reflect deut erium enrichment due to eith er H2 degassing or/and proton diffusion while the ponding magma is flus hed by a dee ply derived CO2-rich gas phase [1]. The alternative possibility of an ex ternal contribution of D-rich crustal water ca nnot be exclud ed, but seems less likely. These isotopic res ults, combined with chemical data for majo r, trace and vola tile elements in same melt inclusio ns, thus pro vide further insight into the magma degas sing processes controlling the eruptive activity of Mount Etna. [1] N. Spilliaert et al., JGR, 2006; [2] N. Spilliaert et al., EPSL, 2006; [3] P. Allard, State Thesis, Paris University, 1986.

Keywords: magmaticinclusions, water, isotopes

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VS010 **Oral Presentation** **6827**

High MG-mineral relicts in the Ciomadul dacite: evidence for the influence of primitive mantle-derived melt on the magma evolution

Mrs. Anna Paula Vinkler
Department of Earth Sciences Universit degli Studi di Milano IAVCEI

Szabolcs Harangi, Theodoros Ntaflos

The Ciomadu l volcan o is th e site of th e last volc anic e ruption (ca. 2 0-30 ka) in the Carpathian-Pannonian region. The Ciomadul dacitic lava dome complex is situated at the southern ed ge of the East Carpathian volcanic chain, at a peculiar ge odynamical setting, close to the seismically active Vrancea zone. The phe nocrysts assemblage of the dacite is com posed by plagioclase (An 22-70 mol%) and amphibole (Al2O3=5-15 wt%, mg# 0.50-0.90), both sh owing v arious zoning and dissolution patterns. Remarkably, phenocrysts with different zoni ng patterns and composition occur in the same samples. In addition, the dacite contains less amount of biotite (phlogopite) and rarely strongly rounded quartz, and potassic feldsp ar. The peculiarity of the Ciomadul daci te is the presence of high Mg minerals, such as olivine (mg# 0.80-0.92), orthopyroxene (mg# 0.57-0.92) and clinopyroxene (mg# 0.65-0.92). They can be found either enclosed by amphibole phenocrysts or in crystal clots. Mafic minerals w ith the highest mg-values (0.89-0.92) occur in the core of t he amphiboles. Olivine relicts are found either without any reaction rim or th ey are su rrounded by orth opyroxene followed by clinopyroxene or a mixture of the following minerals: orthopyro xene, clinopyroxene, phlogopite, amphibole and ilm enite. The presence of high Mg minerals (mg#>0.89) in the dacites is interpreted as either being xenocryts from the upper mantle or liquidus crystals of a mafic magma. However, they cannot be in equilibrium i n a basaltic melt, but we invoke lamproitic or high-Mg andesitic primitive magma. Lamproitic magma erupted cca. 300 km far from the Ciomadul, but those olivine phenocrysts contain also significant amount of P2O5. The mafic xenocrysts could be incorporated into the Ciomadul dacitic magma either via intrusion of small volume of fresh mafic magma o r th ey were picked up fro m a mush zo ne sta gnating in lo wer crustal levels. Petrographic and mineral chemistry investigations, espe cially focusing on the reaction rims aro und high Mg-minerals a nd amp hiboles are used to r eveal the pre-eruptive history, the timescal e of the ope n-system processes and the nature of the p lumbing system of the Ciomadul magma. All of this ar e important to understand the youngest volcano of the Carpathian-Pannonian Region and to evaluate the possible renewal of the volcanic activity.

Keywords: high mg olivine, dacite

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VS010 **Oral Presentation** **6828**

The plumbing system of Vulcano Island (Italy): an integrated petrological, fluid inclusion, and geophysical approach

Prof. Angelo Peccerillo
Scienze della Terra University of Perugia IAVCEI

Peccerillo A., De Astis G., Ventura G.

Combined petrological, geochemical, fluid inclusion and geophysical studies have been performed with the aim of proposing a model of the plumbing system of the active Vulcano Island (Southern Tyrrhenian Sea). Petrological and geochemical data on volcanic rocks erupted through the stratigr aphic sequence allowed to constrain the roles of evolutionary processes at various stages of volcano evolution. Data on fluid inclusions entrapped into mineral from xenoliths provided constraints on depths of magma storage and differentia tion. Ge ophysical data allowed to recognise zones of crustal discontinuities where magmas had the maximum probability to rest and differentiate. Integrated petrological , fluid inclusion and geophysical data sugges t that the structure of the m agma storage system consist s of two major deep accumulation zones located at 17-21 km and 8-13 km depth in the crust, plus a minor one lying at 5-1 km depth beneath the Fo ssa Co ne. These th ree zones corres pond to three main physical discontinuities within the continen tal crust. The deepest magma accum ulation zone is located at the granulitic lo wer crust/mant le bo undary. Here, mafic magmas un dergo co ntinuous fractio nal crystallisation, plus crustal as similation and mixing with primary melts fro m the ma ntle. They feed the shallower magma chambers, or are occasionally erupted at the surface. Entering of these melts into the shallowest reservoir, located at 5-1 km dep ths, occurs shortly before magma ou tbreak at the surf ace, and may repre sent the trigger of eruptions. Change s in t he geochemical and geophysi cal parameters observed in the last century at Vulcano may not be related to magma chamber processes but simply t o modification of the uppermost part of th e volcano, as a respon se to mo dification of re gional tecton ic stress. Bibliography A. PECCERILLO, M.L. FREZZOTTI, G. DE ASTIS, G. VENTURA (2006)) Modeling the magma plumbing system of Vulcano (Aeolian Islands, Italy) by integrated fluid inclusion geo-barometry, petrology and geophysics. Geology, 34, 17-20.

Keywords: modelling, vulcano, hazard

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VS010 **Oral Presentation** **6829**

Linking the petrology of magmas with surface monitoring data at active volcanoes. a perspective from Volcan de Colima, Mexico.

Dr. Olivier Reubi
dpt. of Earth Sciences University of Bristol IAVCEI

Varley Nick, Blundy Jon

Linking magmatic processes and surf ace monitoring data, such as ground deformation, seismicity and gas flux recod ed prior to the eruption is f undamental to understand the behaviour of active volcanoes and is a major step toward quantitatively interpreting the monitoring record. Investigation of the current eruption at Vo lcn de Co lima demonstrates the potential of combining petrological and monitoring data to address this elusive link. Volcn de Colima curre nt phase of activity started in November 1998 and continues to date. It is chara cterized by effusive periods of dome growth and la va flows (in 1998-1999, 2001-2003 and 2004), alternating with periods of interm ittent explosive vulcanian e vents. All erupted magmas are andesitic in composition (5 9-61 wt% SiO_2). The chemi stry of pheno crysts and me lt inclusions show that despite the andesitic bulk co mposition, the magma crystallising in the feedi ng system is a da citic melt that contains entrained gabbro ic fragments. Volatile content of melt inclusio ns are distinctively low (<2.5 wt% H_2O, 360 ppm CO_2) and in conjunction with experimental petrology data (Moore and Carmicheal, 1998) indicate crystallisation occurs in a volatile saturated system between 900 and 0 bar s (<7 km in d epth). Seismic swarms pr ior to the 1998 er uption were evenly distributed between 0 and 8 km in depth and beca me shallowe r with time (Z obin et al., 20 02). The strong correlation between the seis mic and melt inclusion records suggests that the former record the ascent, degassing and crystallisation of a magma column that initially extend to the press ure of volatile saturation of the melt. The chem ical composition of fumarolic ga ses also sugg ests increasing contribution from less degassed magma starting in the summer 1997 (Taran et al., 2002). On the other hand, the SO_2 flux recorded by COSPEC remain ed low (<100 tons/day) until 1 month before the eruption and drastically incre ased (to 1600 tons/day) only two days befor e the appeara nce of the ne w lava, suggesting that degassi ng of the asce nding ma gma in the conduit is essentially closed system. Preliminary inv estigations of temporal variations of the petrology and monitoring data since 1998 suggests a correlation betwe en melt inclusion volatile content, the SO_2 flux recorded b y COSPEC, and depth of seism ic swarms. Ov erall, this suggests that the e ruption is fed by a ≤7 km d eep column of volatile saturat ed, crystallisin g dacitic mag ma. Th e maximum depth o f tapping varies thro ughout the eruption. It re ached a minim um in 2001, when dega ssed and viscous m agmas formed an unusual (for Colima) spine. Major vulcani an explosive events co rrespond to periods of maximum depth of tapping but do not ex ceed the dept h of preceding effusi ve events, indicating that ascent r ate is a more important parameter than maximum vo latile content in controlling the transition between explosive and effusive activity. Moore & Carmicheal, 1998, Contrib. Mineral. Petrol., 130 , 304-319; Taran et al., 2002 , J. Volcanol. Geotherm. Res., 117, 105-119; Zobin et al., 2002, . Volcanol. Geotherm. Res., 117, 47-60.

Keywords: meltinclusion, degassing, mexico

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VS010 **Oral Presentation** **6830**

Magmatic processes that triggered the 10.5 KA upper Toluca pumice eruption from Nevado de Toluca, Mexico

Dr. Victoria Smith
Department of Earth Sciences University of Bristol IAVCEI

Jon Blundy, Jos Luis Arce

Nevado de Toluca forms part of the Mexican Volcanic Belt and is a large stratovolcano situated 80 km southwest of Mexico City. The dacitic 10.5 ka Upper Toluca Pumice (UTP) eruption is one of the largest recorded in central Mexico during the Quaternary. More than 8 km3 of magma was erupted explosively generating 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 17 million people. The aim of this study is to establish what magmatic processes triggered the UTP eruption and gain more of an understanding of the magmatic systems that feed dacitic volcanoes. Here we present SIMS and EMP analyses of melt inclusions (MI), matrix glasses, and phenocrysts. These provide constraints on crystallisation and degassing history of the magma and imply that the dacitic magma system was primed by hotter, more mafic, CO2-rich magma prior to eruption. Matrix glass and MI compositions are generally rhyodacitic and range between 71.5-75.5 wt.% SiO2 and 0.9-2.8 wt.% CaO. However, some of the shards from pumice clasts, mostly in the upper sequence, are more mafic (54.0-66.7 wt.% SiO2, 3.7-7.9 wt.% CaO). The compositional range of these analyses most likely record the mixing of a more mafic melt with the dominant rhyodacitic melt. Further evidence for the mafic input are: (1) the mafic ~60 wt% SiO2 whole-rock compositions of some pumices in the upper sequence than those erupted earlier (62.6-65.0 SiO2); (2) calcic rims (An>45) of some late erupted plagioclases (cores An<40); and (3) slightly higher (~15oC) average Fe-Ti oxide temperatures of late deposits (880oC). MI data indicate that the magma was extremely H2O rich, up to 7.5 wt%. Other volatiles were much lower in abundance, CO2 <1300 ppm, SO2 <900 ppm, F <4000 ppm, and Cl 200-1600 ppm. Gas saturation pressures of up to 380 MPa were estimated suggesting the magma crystallised over a wide range of depths (<9 km). Although CO2 is low there is considerable variation in XCO2 throughout the eruption sequence. This variation is consistent with gas fluxing, and we infer that the high XCO2 (~50 mol%) record the gas influx from a deeper CO2-rich magma. It is likely that this is volatile transfer from the mafic magma, which subsequently mixed with the rhyodacite melt during the eruption. Although, most evidence for a mafic input is late in the eruption sequence there is considerable variation in composition, temperature and pressure throughout the eruption sequence. It suggests that the eruption did not sequentially tap the magma system from the top to the base and the eruption violently evacuated magma from all levels in the chamber almost simultaneously.

Keywords: magma mixing, volatiles, dacite

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VS010 **Oral Presentation** **6831**

Studying of the possibility of recovery of thermal energy of the magmatic chamber of the Avachinsky volcano by means of deep wells

Dr. Alex Sobissevitch
IAVCEI

O.A. Povarov, S.A. Fedotov, V.M. Sugrobov, Ju.P. Trukhin, I.S. Utkin, L.I. Utkina

The analysis of geological and geophysical data, including recent research results, has revealed the existence of the non-solidified magmatic chamber under the Avachinsky volcano (Kamchatka) and to estimate its depth and approximate size. The estimation of accumulated heat in dry rocks surrounding the magmatic chamber of the Avachinsky volcano is given with respect to variable sizes of the magmatic chamber during evolution and heat accumulation from the moment of its origin until now. The investigated geological and geophysical preconditions provide clear evidence to a basic opportunity of use of thermal energy of the dry heated up rocks containing the magmatic chamber for purposes of supply of heat and electricity for the city of Petropavlovsk-Kamchatsky. Development and implementation of an interstitial heat exchanger (underground geothermal circulation system) by means of drilling of deep wells is suggested.

Keywords: avachinsky, thermal, energy

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VS010 **Oral Presentation** **6832**

Solubility of sulfur and chlorine in hydrous phonolitic melt at 200 MPa and 890-990C

Dr. Maria Francesca Sintoni

James D. Webster, Benedetto De Vivo, Annamaria Lima

Volatile behavior in volcanic systems plays a fundamental role in magmadegassing and eruption, and therefore, for volcanic hazard assessment. Besides H2O, which is the main component in volcanic fluids, Cl and S are important constituents in particular because of their effect on H2O solubility in melt and on climate changes on local and global scales. Hydrothermal experiments have been performed at 200 MPa, temperatures of 890-990C and DeltaNNO from about + 0.5 to + 1.5, to investigate the solubilities of H2O, S, and Cl in a phonolitic melt (sample S(9)2 from Ottaviano eruption of Vesuvius) in equilibrium with multi-component (H-O-Cl-S) fluid(s). The concentration of Cl and S in the melt was determined with electron microprobe, and the abundance of H2O in melt with FTIR. Chlorine and sulfur contents of the fluids were determined with a chloridometer and with a weight loss method, respectively. This latter technique involves a small apatite canister with lid encasing a single CaSO4 crystal; the anhydrite-bearing apatite canister is accompanied by phonolitic rock powder, chloride salts, and distilled H2O, all contained in a gold capsule. The solubility of S in the fluid is determined by weight loss of the CaSO 4 crystal, using the simple relationship ([mass S dissolved from CaSO4 + mass S in rock sample] - [mass S in melt] = [mass Sfluid]). The fluid/melt partitioning coefficients calculated for S are quite variable and range from 10 to 33 for experiments at temperature > 980 and from 23 to > 200 for runs conducted at lower temperature. The fluid/ melt coefficient for Cl ranges from 12 and 87, and shows little correlation with temperature. The variability observed for S partitioning between fluid and melt can be related to temperature, to small variations in the oxygen fugacity above the NNO buffer and to melt composition. The partition coefficients for lower T experiments are equivalent to the lower values found for silicic to andesitic arc magmas by Scaillet and Pichavant (2003). In addition from our data the sulfur content in phonolitic melt is between 0.01 to 0.19 wt%, which is higher compared to an average S content of 0.01 wt% for silicic to andesitic magmas. Considering also the mutual relation between S and Cl in oxidized alkaline systems, which suggests that the presence of S reduces the solubility of Cl in melt (Webster et al. 2006), we would expect that such high value of S in melt would favor greater exsolution of Cl-enriched magmatic hydrosaline liquid, implying in this way a different degassing behavior among calc-alkaline and alkaline systems. Scaillet, B., Pichavat, M., (2003) Experimental constraints on volatile abundances in arc magmas and their implication for degassing processes. In: Oppenheimer, C., Pyle, D.M., and Barclay, J, (eds), Volcanic Degassing. Geol. Soc. Lond. Spec. Pubs. 213, pp. 23-52 Webster, J.D., Sintoni, M.F., and De Vivo, B., (2006) The role of sulfur in promoting magmatic degassing and volcanic eruption at Mt. Somma Vesuvius. In: De Vivo, B., (ed), Volcanism in the Campanian Plain: Vesuvius, Campi Flegrei and Ignimbrites. Series: Development in Volcanology, Vol. 9 , Elsevier, Amsterdam, pp. 219-233

Keywords: sulfur, chlorine, phonolite

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VS010 **Oral Presentation** **6833**

Magma plumbing system in Asama Volcano (Japan) during these 50 years

Prof. Setsuya Nakada
Earthquake Research Institute University of Tokyo IAVCEI

Nozomi Kawamura, Taketo Shimano

Mount Asama, one of the most active volcanoes in Japan, frequently causes vulcanian explosions and experienced two major plinian explosions in 1108 and 1783 (0.5 and >1 km3 respectively). In the early 20th century, vulcanian explosions were repeated every year, such that eruption occurred in days over a half of the year. In contrast, the volcanic activity was relatively quiet in the second half of the 20th century. Small to moderate magmatic eruptions occurred in 1958, 1959, 1961, 1973 and 2004. Understanding the magma plumbing system under the volcano and the present condition is important to expect the future potential of large eruptions at Asama. All of eruption products during these 50 years showed mixing of phyric rhyolite magma with olivine-bearing basaltic andesite magma prior to the eruptions. This process is similar to the model for the AD 1108 and AD 1783 eruptions proposed by previous investigators. It is likely that the magma mixing system has been maintained, not depending on the scales of eruptions about one thousand year. That is, the ratio of mafic and felsic magmas had not largely changed. Mafic and felsic endmember magmas are similar chemically to the Kurofu and Hotokeiwa volcanic rocks, respectively, which were activated in old stages of this volcano. The mafic endmember magmas are variable chemically probably due to fractional crystallization, whereas the felsic endmember magmas are nearly constant. Partially melted rhyolitic tuff found in the lava of the AD 2004 eruption, which contain sometimes cordierite and orthopyroxene phenocrysts, may represent the felsic endmember magma. Geodetic monitoring before and during the AD 2004 eruption suggested magma intrusion in form of vertical dyke more than 4 km below west of the summit just prior to the eruption. A-type earthquakes nested only at the top of the estimated dyke, being associated with inflation of the volcanic body during eruption of 2004. Similar seismicity was recorded in the earliest stage of the AD 1973 eruption. It is considered that intrusion of magma into the dyke-shaped magma chamber triggered these eruptions. The electromagnetic investigation of this volcano, carried out in 2006, found the existence of a vertical thick plate of low resistivity, extending downward from about 5 km below the west of the summit, corresponding to the dyke. Although storage relation of two endmember magmas is not clear, at least, the above dyke seems to represent the storage of mafic magma. Since geodetic monitoring and electromagnetic investigation do not show any possible location for another magma storage, the felsic magma might be stored in the upper portion of the dyke.

Keywords: magma mixing, dyke intrusion, geophysical monitoring

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VS010 **Oral Presentation** **6834**

Toward a common plumbing system of recent eruptions of Lipari and Vulcano (Aeolian islands, Italy)

Dr. Marcella Dav
Dipartimento di Scienze della Terra Universit della Calabria IAVCEI

De Rosa Rosanna, Donato Paola

Lipari and Vul cano are adjac ent islands of the Aeol ian Ar chipelago sepa rated by a nar row sea strait (800-900 m).The recent er uptive history of these is lands has bee n ch aracterized by simultaneous or sequential eruption from ve nts showing different erupt ive styles and magma type s. There are stratigraphic evidences that during histo rical ti mes lat ites, trachytes and rhyolites were emitte d contemporaneously from an eruptive vent in the north sector of Lipari (Mt. Pilato eruption) and at Fossa cone in Vulcano (Palizzi succession, Dellino & La Volpe, 1997). Almost in the same period shoshonitic to latitic magmas built up t he Vulcanello pen insula (Arrighi et al., 2006). Both Palizzi and Mt. Pilato eruptions started with an ephimeral phreat o-magmatic activity o f rhyo litic co mposition and co ntinued with th e emiss ion of rh yolitic pu miceous ob sidian lava flo w co ntaining latitic and trachytic enclaves o f different shape and size. A ne w explosive ep isode and a final trachytic lava end the Palizzi succession. Major and trac e elements composition and phases ch emistry of both enclaves and hos t lavas suggest that rhyolites can be obtained by AFC processes starting from the associated enclaves. Enclaves, in their turn, probably fractionated from a mafic magma with a composition similar to the Vulcanello shoshonite. All the data are consistent wi th the hypothesis that, at lea st during the eruptive period comprising the Mt. Pilato, Vulcanello and Palizzi activity (1050-1250 AD, Arrighi et al ., 2006), eruption s on Lipari and Vulcano are fe d by the same magmatic syst em. A shoshonitic magma from a deep reservoir (~20 km, Peccerillo et al., 2006) can reach directly the surface (i.e. Vulcanello) or can evolve and stop in the crust generating lati tic to rhyolit ic zoned magm a cham bers. A sudden arrival of a new input from dept h interacts with these resident magmas and triggers the eruptions (Mt. Pila to and Palizzi). REFERENCES Arrighi S., Tan guy J.C., Rosi M. (2006). Eruptions of the last 2200 years at Vulcano and Vulcanello (Aeolian Islands, Italy) dated by highacc uracy archeomagnetism. Physics of Earth and Planet ary Interiors,159, 225-233. Dellino P., La Volp e L. (1997). S tratigrafia, di namiche eruttive edeposiziona li, scenario eruttivo e valutazioni di pericolosit a LaFossa di Vulcano. In: "CNR-GNV Progetto Vulcano 1993-1995" La VolpeL., Dellino P., Nuccio M., Privitera E., Sb rana A. (Ed), Felici, Pisa,214 -237. Peccerillo A ., Frezzotti M.L., De Astis G., Ve ntura G. (2006).Modeling the magma plumbing sys tem of Vulcan o (Aeolian Islands, Italy) by int egrated fluid-inclusion geo barometry, petrology, and geop hysics.Geology, 34 (1), 17-20

Keywords: plumbing system, magma evolution, rhyolites

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VS010 **Oral Presentation** **6835**

A hybrid magma feeding a pre-minoan scoria-fall eruption of Santorini Volcano, Aegean Arc, Greece: inferences from primitive tholeiitic melt inclusions in olivine

Dr. Gloria Vaggelli
IAVCEI

Pellegrini Maura, Vougioukalakis George, Francalanci Lorella

A small scoria-fall deposit of Santorini volcano, found intercalated between the huge Cape Riva (21 ka) and Minoan (3.6 ka) pyroclastic deposits, has been studied by mineralogical, geochemical, isotopic and silicate-melt inclusion analyses. This deposit was emplaced by an ephemeral Strombolian-type eruption, from a subaerial vent close to Imerovigli, as derived by the absence of relevant sorting and the flattened shape of tephra. Scoria samples are basaltic-andesites with normally zoned olivine, reversely zoned pyroxenes and variably zoned plagioclase. Olivine contains two types of melt inclusions. Type I inclusions, hosted by cumulated Fo 87-89 olivine, are primitive low-K basalts with MgO 5-6 wt.%, CaO 13-14 wt.% and high volatile contents (F~350, Cl~900, S~1300 ppm, major element totals ~ 96 wt.%). The low contents of incompatible elements and REE patterns indicate an arc tholeiitic composition. d18O is low (5.3) and lower than the whole-rock value (6.5), whereas 87Sr/86Sr is rather high (0.70579) and higher than whole-rock and groundmass values (0.70465 and 0.70468, respectively). Type II inclusions, hosted in Fo80-83 olivine rims, are andesites with low volatile contents; they have similar compositions to the interstitial glass. Type II inclusions cannot derive from Type I inclusions by simple fractional crystallisation. The primitive tholeiitic magma, represented by Type I melt inclusions, is considered to be generated by high partial melting degrees of a MORB-like mantle wedge metasomatised by subducted sediment melts, responsible for the low 143Nd/144Nd. The amount of sediment melts involved in the magma genesis decreased with time, together with the degree of mantle melting. The magma feeding this scoria-fall eruption is hybrid, resulting by mixing of several components, with polybaric growth of olivine and plagioclase. The entire data set leads to speculate that a mafic magma, during its ascent to the surface, extracted cumulate olivine crystals from a deep reservoir. As a consequence olivine crystals were resorbed. At a shallower level, this magma mixed with a more evolved and degassed magma producing less forsteritic olivine rims and phenocrysts with Type II melt inclusions. This magma probably rested in a small eccentric reservoir, distinct from those feeding the Cape Riva and Minoan explosive eruptions.

Keywords: santorini, scoria fall, hybrid magma

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VS010 **Oral Presentation** **6836**

The 1739 AD - Pietre Cotte lava flow (Vulcano Island, Italy): constraints to the volcanic structure through the integration of textural, geochemical and fractal analysis

Dr. Gianfilippo De Astis
Osservatorio Vesuviano Istituto Nazionale di Geofisica e Vulcanologia IAVCEI

Piochi Monica, Petrelli Maurizio, Ventura Guido, Alberto Zanetti

Vulcano Island is an active volcano of the Aeolian archipelago. The most recent activity occurred at La Fossa Cone between 1500 and 1890, was characterized by eruptions generating a sequence of alternating rhyolitic to latitic explosive and effusive products. The Pietre Cotte volcanic unit is often the most intriguing among these rocks, being a rhyolitic lava flow containing dark-grey to reddish trachytic enclaves which allow the interaction between different magmas and their effects on eruptive dynamics to be studied. Field, textural and petrological data have been integrated in order to define the behavior of the magmatic system and the eruption mechanism. The rhyolite lava is phenocrysts-free, contains abundant mm-sized spherulites and few microlites arranged by flow. Furthermore, it shows an extreme low percentage of tiny vesicles. Trachytic enclaves mostly occur at the front of the lava flow. They range from mm- to dm-size dimensions and have both angular and spherical shape; the smaller ones appear plastically deformed by flow and are often at the core of rhyolitic spherulites. Trachytic clasts contain mostly plagioclase and Fe- rich diopside, and minor olivine, magnetite, biotite and K-feldspar phenocrysts set in a glassy low-vesicular groundmass characterized by variable percentage of alkali-feldspar and plagioclase microlites. The analyzed glasses overlap the chemical composition of volcanic rocks erupted from La Fossa in the last 500 years. The trachytes (SiO_2=57-63 wt.%) show higher alkali, Ba, Sr and Eu with respect to the rhyolitic lava (SiO_2=71-77 wt.%). However, both trachytic and rhyolitic glasses contain very low residual water content. On the whole, the collected data suggest the occurrence of mingling process between an uprising rhyolitic magma and a partly crystallized trachytic magma plug at shallow level. Based on fractal dimension analysis the mingling processes occurred in a heterogeneous regime characterized by both laminar and turbulent flows. The proposed eruptive dynamics allows constraints to the structure of the shallow volcanic system at the Volcano Island with implication on both interpretation of monitoring data and volcanic hazards assessment.

Keywords: lava flow, eruptive dynamics, volcano structure

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VS010 **Oral Presentation** **6837**

The evolution of the Campi Flegrei magma: thermodynamic modeling of the Fondo Riccio and Minopoli 1 eruptions using melt inclusion data.

Dr. Claudia Cannatelli
Department of Geosciences Virginia Tech

Fedele Luca, Spera Frank J., Bohrson Wendy A., De Vivo Benedetto, Lima Annamaria, Bodnar Robert J.

The magmatic evolution of the Fondo Riccio (9.5 ka) and Minopoli 1 (11.1 ka) at Campi Flegrei (Italy), has been investigated using MELTS and data from melt inclusions in olivine and clinopyroxene phenocrysts. Fondo Riccio was an explosive strombolian eruption that occurred near the center of the Campi Flegrei caldera, while Minopoli 1 was primarily hydromagmatic and occurred along the regional fault system in the northern portion of the caldera. Melt inclusions having the highest Mg concentration in olivine were assumed to represent the parental liquid for MELTS calculations. The MELTS model was designed to test the hypothesis that the parental melt for both eruptions was approximately trachyandesitic melt, and that the main evolutionary process was low pressure fractional crystallization with a possible minor influence of crustal rock contamination or magma mixing. To test the hypothesis and to constrain the physical and chemical parameters of the eruptions, we carried out a series of isobaric runs using different pressures, initial water content and oxygen fugacity buffers. The results were compared with observed crystal, bulk rock and melt inclusion compositions to evaluate whether MELTS could reproduce observations under the imposed physico-chemical conditions. MELTS simulations showed that it is likely that Fondo Riccio and Minopoli 1 magmas evolved from parental trachyandesitic melts (closely represented by the composition of melt inclusions in olivine) which underwent fractional crystallization at 0.15 GPa (~5 km depth), were buffered along the QFM + 1 (quartz-fayalite-magnetite oxygen buffer), and had and initial H_2O content of at least 3 wt %. MELTS simulations also helped to highlight the following points: 1) a fractional crystallization process alone does not fully explain the final observed melt and mineral compositions; 2) the parental magmas likely did not undergo extreme fractionation before eruption; 3) melt inclusions in clinopyroxene often plot away from the chemical trends generated by MELTS; 4) melt inclusions in olivine seem to represent well the parental magma and tend to follow MELTS-generated evolutionary trends (with exception for Fe content due to oxidation), especially for Fondo Riccio; 5) the evolution of Minopoli 1 seems to be more influenced by processes other than fractional crystallization, while for Fondo Riccio these processes seem to be less important; 6) bulk rock data have probably been affected by hydrothermal processes (i.e. Na enrichment) and post deposition alteration; 7) it is very likely that crustal contamination and/or mixing have to be taken into consideration to fully explain the observed melts and mineral compositions. Further simulations with MELTS are under way to define the extent of contamination/mixing and to constrain the composition of contaminants and/or mixed magma.

Keywords: melt inclusions, campi flegrei, modeling magma evolution

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VS010 **Oral Presentation** **6838**

In-situ determination of H2O content of melt inclusions using reflectance-µ-FT-IR

Mr. Wesley Fraser
Department of Earth Sciences The Open University IAVCEI

Kirti Sharma, Ben Ellis

Because of the importance of volatiles in magmatic systems, it is crucial to make accurate measurements of pre-eruptive volatile contents (H2O and CO2). Reflectance-micro-Fourier Transform-Infrared (R-µ-FT-IR) spectroscopyprovides the opportunity for rapid, inexpensive analysis of volatile content in volcanic glass (specifically H2O). Traditionally, transmission-µ-FT-IR (T-µ-FT-IR) has been used to determine volatile content; however this approach requires intricate sample preparation of glass wafers and requires additional measurements of the bulk chemical composition and density of the glass, and of the sample thickness. Other recognized analytical techniques (e.g. electron microprobe; ion microprobe) also have limiting factors associated with them, such as; specific sample preparation, high running costs and relatively low sample throughput. The use of R-µ-FT-IR eliminates the need for time-consuming preparation of doubly-polished sample wafers. In addition, electron microprobe analysis of total volatile content (volatiles by difference) produces low precision H2O values. Here we present H2O content analyses of volcanic matrix glasses and melt inclusions using R-µ-FT-IR from a variety of sample mount types (e.g. microprobe blocks, thick sections (~100 µm), glass separates). FT-IR spectra were collected using a Thermo Nicolet Nexus FT-IR spectrometer, integrated with a Continuum IR-enabled microscope. Total O-H content was determined by measuring the height of the peak at ~3600 cm-1 due to O-H bonds. The method was calibrated using a suite of rhyolitic glasses with independently determined H2O contents ranging from <0.01 wt% to 8.49 wt%. We performed R-µ-FT-IR on a variety of samples with known H2O content, i.e. determined by other techniques, and compared these results to our calibration curve. Our results show a strong correlation between H2O contents (R2 = 0. 9) obtained using R-µ-FT-IR and other techniques, thus confirming this method as a valuable tool for rapid, non-destructive volatile analysis.

Keywords: r micro ft ir, volatiles, melt inclusions

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VS010 **Oral Presentation** **6839**

A re-assessment of Central-Italian Kamafugite compositions from melt inclusions and mineral chemistry

Dr. Igor Nikogosian
Petrology Urtecht University IAVCEI

Manfred Van Bergen

Meteorologists from arou nd th e world h ad sh ared informMinor volumes of kamafugitic rock types occurring in the Intra-Apennine V olcanic Province of Central Italy (IAV) have rais ed lo ngstanding debates concerning petrogenetic processes and geod ynamic contro ls. A key problem in solving these issues is the difficulty to unravel potential effects of processes operating in the plum bing systems of individual centers on primary melt comp osition(s). Till date, proposed hypotheses have largely hinged on bulk-rock data. Here we present results of a detailed melt-inclusion and mineral-chemical study on a representative San Ve nanzo kamafugite, aimed at id entifying primary compositi ons and source characteristics of the IAV kamafugitic melt s. Olivin e phe nocrysts show complex textu res indicative of drastic late-sta ge changes in the crystallization re gime, in cluding irregular and patchy compositional zoning and increasing amounts of inclusions. Pristine parts of olivines have compositions of Fo93-90 and low CaO contents of 0.2-0.3 wt. %, and contain Cr-spinel inclusions (Cr# ~0.7). We consider this to be an ass emblage that crystalliz ed from prima ry mant le-derived melt. Mod ified zones tha t occur mostly towards rims, near cracks an d around encl osed crys tal-melt aggregates show a strong composit ional gradient o f decreasing Fo do wn to 70 and increasing CaO co ntents up to 1. 8 wt. %. These zo nes appear to be the result of re-e quilibration in response to dras tic compositional changes in the surrounding melt, involving i nward diffusion of calciu m. Compositionally and texturally different groups of melt inclusions were found, indicative of complex involvement of heterogeneous melts in the plumbing syst em. One prominent group, situated in unmodified central part s of the olivines, has compositions a pproaching th at of th e host rock and published data on other IAV kamaf ugite samples, but is distinct in having lower Mg and highe r Na, P and Ti contents. Considering their high CaO/Al2O3 and K2/O/Na2 O ratios and larnite- normative signature, they represent the original parental kamafugit e melt. Trace-ele ment patterns largely follow t hat of th e bul k rock, confirming earlier noted similaritie s with K-rich melts from the adjacent Roman Magmatic Province Other groups of melt inclusions are most abundant in (but not always restricted t o) outer port ions of olivine phenocrysts, and are particularly marked by depletion or enrichment of volatile elements.We conclude that San Ve nanzo bulk rocks deviate significantly from melt compos itions due to crystal accumulation and, to a lesser extent, interaction with carbonate at shallow crustal levels, although these processes had little effect on overall trace-element signatures. The primary kam afugitic melt contained abou t 9 wt.% MgO, 2.5% Na2O, 1.5% P2O5 and 2.5% TiO2, values that are clearly distinct from earlier reports. Compositional variability among melt inclusio ns po ints to (subordinate) involvement of othe r melts as well, suggesting contributions f rom a heterogeneo us mant le so urce.ation since the mid- 19th century- an abso lute necessity fo r this budding in ternational science. However, except for a few simultaneous balloon launches in early 20th century Europe, the IGY presented the first opportunity for atmospheric scientists to simultaneously collect a wide variety of data from arou nd the world that could then be stockpiled for later analysis. The success of the IGY for atmospheri c research, combined with advanc es in numerical weather prediction in the late 1950s an d early 1960s , inspired atmospheric scientists to continu e coordinating multi-national exercises whereby massi ve amou nts of data from a variety of platforms could be colle cted in a relatively short per iod of time an d then an alyzed. St arting w ith the Global Atmospheric Research Project (GARP) in the 1960s, multi-national proje cts and exercises continued throughout th e end o f the century, pro viding th e data needed for a dvanced atmo spheric models.

Fundamentally, all of these projects were based on the IGY model of national and scientific cooperation and data sharing, and enabled participants to successful execute the exercises that followed.

Keywords: central italian magmatism, kamafugite, melt inclusions

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VS010 **Poster presentation** **6840**

Multiple magma feeding systems for radial fissure eruption inferred from dike intrusion direction

Dr. Nobuo Geshi
Geological Survey of Japan AIST IAVCEI

Combined analysis of the intrusion direction and petrological character of a radial dike swarm of Komochi volcano, a andesitic stratovolcano in the central Japan, reveal multiple magma supply system for its flank fissure eruptions. Komochi volcano has a set of central conduit and radial dike swarm in its dissected volcanic edifice and the radial dike swarm shows distinct horizontal and vertical feeding systems. In Komochi volcano, a volcanic neck about 50 m across filling the central conduit is exposed at the structural center of the volcanic edifice and a radial dike swarm consisting of more than 50 vertical andesitic dikes surrounds the neck within an area 1.5 km from the neck. Intrusion direction of dikes determined by anisotropy of magnetic susceptibility, preferred orientation of microlite, and orientation of sheared bubbles in their chilled margin, shows that the dikes can be divided into a horizontal intrusion group (H-group) and a vertical intrusion group (V-group). Magma of the H-group intruded laterally from the central conduit to outside of the volcanic edifice. By contrast, the V-group dikes, intruded mainly in the peripheral portion of the dike swarm, show nearly vertical and upward intrusion direction. The V-type dikes are generally thicker than the H-type dikes at a same SiO_2 content, suggesting the higher magmatic pressure for V-type dike. Whole-rock composition of H-group dikes coincides to that of the central conduit, clearly indicating that the magmas evolved in the central conduit were fed into the H-type dikes by rupturing of the central conduit. The V-group dikes, contrary, have less-evolved composition than the central conduit and are abundant in pyroxene and olivine phenocryst, suggesting the direct feeding from the deeper reservoir by increasing of excess pressure in the magma reservoir beneath the conduit system. Vertical intrusion of a dike disconnected to the central conduit has been recognized in some volcanoes, e.g. the 2001 eruption of Mt Etna, and may be a common process in a radial fissure system in a stratovolcano. Understanding of the mechanism of vertical migration of dike from a pressurized deeper source is critical not only to Volcanology but to the hazard mitigation against a sudden flank fissure eruption.

Keywords: dike, eruption, conduit

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VS010 **Poster presentation** **6841**

Structural controls on the magma movements and eruption locations Observational evidence in Usu volcano, Japan

Dr. Shinya Onizawa
Geological Survey of Japan AIST

Hiromitsu Oshima, Hiroshi Aoyama

Mt. Usu is one of the most active volcanoes in Japan. Nine eruptions of felsic magma have been recorded since 1663 until the latest eruption in 2000. In the past activities, the eruption locations have varied from the summit to foot areas. Eruptive craters and upheavals were distributed such that an arc is delineated in the northern foot, while no traces are found in the southern foot. Directions, locations, styles and so on of magma movements and eruptions are determined by interaction between magma and host medium. Therefore, in order to understand the dynamic magmatic activities, it is important to reveal subsurface structure as well as behavior of magma itself. In order to obtain the background structure of magmatic activities, an active seismic survey was conducted at Usu volcano in 2001 under the National Project for the Prediction of Volcanic Eruptions in Japan. We also intended to enhance accuracy of hypocenter locations, because the past eruptions accompanied intense precursory earthquakes, which can help clarifying subsurface magma movements. Three- dimensional P- wave velocity structure down to Pre-Neogene basement is revealed below the volcano by using first arrival time data of the survey. The most prominent feature of the velocity model is the deepening of the basement toward south-southwest. The resultant velocity model also contributes to relocations of the 2000 eruption precursory earthquakes. The precursory seismic activity, which reflects pre-eruptive magma movements, is divided into three parts; (1) a sub-vertical distribution indicating a magma ascent to beneath the summit of the volcano, (2) a northward migration which indicates a magma movement resulting in the subsequent eruptions at the northwestern foot, and (3) a horizontal southward migration possibly indicating an intrusion of a sill. The northward and southward migrating earthquakes are constrained by the dipping basement structure so as that most of the events occurred within middle Miocene or Pre-Neogene layer. On comparing the migrating hypocenters with the velocity model, it was revealed that the magma movements were controlled by the subsurface structure. Geographical distribution of craters and upheavals of past eruptions are also correlated to the subsurface basement structure. In northern foot, the craters and upheavals distribute as to be enclosed by the subsurface basement, which gets shallower toward north. Contrary, no traces of eruptions are found in southern and southwestern foots, where the basement deepens toward south-southwest. This suggests the eruption locations have also constrained by the subsurface structure.

Keywords: subsurface structure, magma movement, usu volcano

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VS010 **Poster presentation** **6842**

Silicate inclusions into restitic xenoliths from lavas and pyroclasts of Aeolian Islands (southern Italy): properties of alkaline anatectic melts

Dr. Vittorio Zanon

Aeolian magmas show different degree of crustal contamination. Among all possible contaminants there are several silica rich-melts produced by crusta l melting of micaschist s and gneisses of Calabro-Peloritano range. Evidences o f this pro cess can be found into restitic quartz- rich xeno liths that ca n be found main ly i n poorly evolv ed compositi ons (both lavas and pyroclasts) and exceptionally also into evolved compo sitions in the Vulcano Island. Mineralo gy of these xenolit hs is represented by 98% o f quartz a nd 2 % clinopyroxene, plagioclase, titani te, apatite and zircon. Quartzes som etimes trapped carbonic fluid and silicate melts bo th separately and as two immiscible components. Mineral phases a nd REE pattern of coexisting sil icate melts trapped into inclusio ns po int to different epi sodes o f melt production, in presence of CO2, du ring th e ascen t of xenoliths. Simulati ons with MELTS code tracked the progressive chemical vari ations of these crustal melts and indicated a generalised i mmiscibility with the host magma due to the high differenc e in viscos ity. Only evolved magmas (latites, ryholites) ha ve comparable values of viscosity, and the scarce amount of xenoliths contained, points to a greater extent of assimilati on. A comparis on with the te xtures of similar quartz-rich xeno lith ho sted into recent lavas erupted from Mt. Etna can tell something a bout the speed of dissolution/assimila tion process with time, revealing a high ascent speed of these xenolith-bearing magmas. In this framework, only fast-ascending magmas from the source zone and with short rests in storage areas (from few weeks to a few years) can preserve the most primitive and fertile xenoliths. The occurrence of crustal xenoliths is also linked to styles of eruptions: high output rate event s (l ava floodin g and pyroclastic flow) show the greatest amount of xenoliths, while st eady state activity, such as co ntinuous strombolian eruptio ns with almo st no drainage of lava doesnt allow the survival of these xenoliths.

Keywords: anatexis, xenoliths, aeolian archipelago

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VS010 **Poster presentation** **6843**

Evolution of dome-forming peralkaline silicic magmas at Santa Brbara and Pico Alto volcanoes (Terceira Island, Azores)

Mr. Adriano Pimentel
Centro de Vulcanologia e Av. de Riscos Geolgicos Universidade dos Aores IAVCEI

José Pacheco, Vittorio Zanon

Terceira Island (Azores) distinguishes from all the other islands of the archipelago for its noteworthy abundance of lava domes. These silicic lavas are the most expressive volcanic product in the recent (< 20 ka) eruptive history of the island, which occurred mainly in the two active volcanoes: Santa Brbara and Pico Alto. The rocks show a relatively narrow compositional range (65 - 70 wt% SiO_2), with peralkaline index (P.I.) from 1.1 to 1.8, corresponding to peralkaline trachytes (comenditic and pantelleritic) and rhyolites (comendites). They vary from almost aphyric to porphyritic (2.4 - 20.1 vol% crystal content), with trachytic or glomeroporphyritic textures. Alkaline feldspar (0.4 - 16.8 vol%) is the most abundant phase, followed by plagioclase (0 - 6.3 vol%), clinopyroxene (0 - 1.4 vol%), olivine (0 - 0.3 vol%) and oxides (0 - 0.6 vol%). Amphibole (0 - 0.9 vol%) is only present in Pico Alto samples. The same mineral phases occur also as microphenocrysts. These lavas show a general decrease in TiO_2, Al_2O_3, MgO, CaO, P_2O_5, Ba, Sr and Eu and a strong enrichment in incompatible elements such as Cs, Rb, Th, U, Nb, Ta, LREE, Zr and Hf, in respect to SiO_2 content. However, diagrams of FeO_t, MnO and K_2O vs. SiO_2 reveal opposite trends in Santa Brbara and Pico Alto series. Major and trace elements variation patterns observed are indicative of fractionation of the mineral phases described previously. Though, the different behaviour of some major oxides , in the series of the two volcanoes, was attributed to distinctive fO_2 conditions during the final stages of differentiation, resulting from differences in the degassing process. The FeO_t and MnO enrichment in the Pico Alto series is typical of magmas that evolved by fractional crystallization at low fO_2 conditions (< FMQ) while the Santa Brbara series seems to reflect slightly higher fO_2 conditions. This may be interpreted as the effect of the loss of volatiles during the more efficient degassing of Santa Brbara magma. In turn, the low fO_2 conditions in Pico Alto magma suggests it retained their volatiles (H_2O), which is compatible with the presence of amphibole in the lavas. The petrological and geochemical data obtained in this study allowed to corroborate the role of fractional crystallization as the dominant process in the evolution of peralkaline silicic magmas of Terceira. Moreover, the differences observed in the final stages of differentiation of the two magmatic series may have significant implications for the eruptive behaviour of these volcanoes in the future.

Keywords: peralkaline, magma, azores

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VS010 **Poster presentation** **6844**

Melt and fluid inclusion investigation in the AD 472 Magma chamber of Vesuvius: inferences on fluid exsolution and magmatic degassing

Dr. Paola Marianelli
Dipartimento Scienze della Terra Universit di Pisa

Paolo Fulignati

This study is the first to investigate the volatile content of magma erupted from Vesuvius during the 472 AD subplinian Pollena eruption. In particular, we traced th e evolution of volatiles from magma hosted within the 472 AD chamber to si licate me lt presen t in th e upper marginal portions of the chamber (solidification front). Here we report the vol atile contents of melt in clusions from ju venile (Lc-phonolite to phonotephrite) and cognate xenoliths from the 472 AD eruption of Vesuvius. This ena bles us to infer on pre-eruptive volatile c ontent of magmas that fed the eruption and to trace the vol atile behavior i n the chamber and at its peripheral parts. Different types of inclusions were identified within both juvenile fragments and cognate xenoliths and subse quently analyzed for major e lements and volatile contents. The water co ntents of melt in clusions from juvenile fractions indicate that th e 472 AD Pollena eruption was fed by magma characterized by high pr e-eruptive volatile content that was stored within a magma chamber located at approximately 4 km depth. Variat ion of volatile content in MIs indicates volatile saturation for the 472 AD magma with the loss of H2O, Cl, and S with in the magma chamber. In contrast, dissolved F behav ed as an incom patible element and was concentrated in m elt within th e upper portion of the chamber and within upper marginal portions where Lc-phonolitic melts were further differentiated to yield exotic compositions. The chem istry of MIs within f oid-bearing syenites suggest s that this change in composition, accompanied by an increase in Cl concentration, drove the system to saturation in a hydrous chloride ph ase (Webster and De Viv o, 2002) that d irectly exsolved from melt as a hy persaline aqueous fl uid phase, as alre ady do cumented by Webster et al. (2001) for medieval eruptions of Vesuvius. As a consequence, such residu al melts may be envisaged as f orming part of a continuum be tween pho nolitic magmatism and a ssociated magmati c-hydrothermal activity. The reported natural example provides insights into de gassing processes that occur wit hin an alk aline magma ch amber and at its si de walls, representing a piece in the puzzle of th e reco nstruction o f the pre-eruptive conditions of the magma chamber within this famous active volcano. References: Webster, J.D., Raia, F., De Vivo, B., R olandi, G., 2001. The behavior of chlorine and sulfur durin g differentiation of the Mt. Som ma Vesuvius m agmatic system. Mineral. Petrol. 73, 177-200. Webster, J.D., De Vivo, B., 2002. Experimental and mo deled solubilities of chlo rine in aluminosilicate melts, consequences of magma evolution, and implications for exsolution of hydrous chloride melt at Mt. Somma-Vesuvius. Am . Mineral. 87, 1046-1061.

Keywords: volatiles, melt inclusions, vesuvius

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VS010 **Poster presentation** **6845**

The Campi flegrei feeding system at the time of the Campanian Ignimbrite eruption

Dr. Paola Marianelli
Dipartimento Scienze della Terra Universit di Pisa

Alessandro Sbrana

At ~39 ky BP, a supereruption known as the Campanian Ignimbrite (CI) occurred in the Campi Flegrei area, with regional- and global-scale environmental impacts. The eruption began with a Plinian phase, followed by a succession of pyroclastic density currents that deposited ashes and pumice flows, and densely welded ignimbrites that covered the Campanian Plain and surroundings hills. A lithic-rich breccia unit (Breccia Museo Unit) represents the proximal deposit related to the final caldera-forming phase. This work attempts to shed light on critical aspects of the eruption (depth of magma chamber, intensive preeruptive magma conditions) on the basis of information derived from melt inclusion (MI) data (homogenization temperatures and values of dissolved H2O) from pumices erupted during different phases of the CI eruption. MIs are all of similar trachytic to phonolitic composition, even for MIs from different units. The H2O content of MIs is highly variable, with most data indicating 23 wt% and maximum values of 6 wt%, indicating pressures of water saturation of 40-40 to 150 MPa. Melt inclusions in salitic crystals homogenized between 950 C and 1080 C. Rare inclusions in diopsidic cores recorded higher temperatures, in excess of 1100 C, whereas few MIs hosted in Fe-rich clinopyroxene homogenized at temperatures as low as 870 C. Here we propose a new model for the CI feeding system, based on the evidences from this MI study. At ~39 ky BP, a very large magma chamber, emplaced at ~ 69 km depth was present beneath the Campi Flegrei Volcanic District. MI data indicate that a relatively homogeneous overheated (1000 C) and water-rich (up to 6 wt%) trachytic magma resided within a relatively deep magma chamber. Variation in dissolved water contents in MIs indicates that prior to the eruption the magma chamber underwent radical changes related to differential upward movement of magma. Decompression of the rising trachytic magma caused a decrease in water solubility and crystallization, and trachytic bodies were emplaced at very shallow depth. These apophyses fed the initial Plinian phase of the eruption that generated 20 km3 DRE of fallout deposits of pumices that were more crystal rich than those erupted during the ignimbritic phase. From the main, deeper reservoir the overheated subaphyric and water-rich trachytic magma fed the main phase of the eruption in which ~130 km3 DRE of magma was emitted as pulses of ignimbrites spread over 300 0 km2; the underlying basalts were never erupted. The partial emptying of the magmatic feeding system led to the collapse of a caldera that was 14 km in diameter. Widespread lithic-rich breccias mark this final phase of the eruption that simultaneously involved crystal-rich trachytes from the low-pressure apophyses and subaphyric trachytes from the deep main magma chamber.

Keywords: volatiles, melt inclusions, feeding systems

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VS010 **Poster presentation** **6846**

Deep input at the origin of the historic violent strombolian eruptions at Vesuvius

Dr. Paola Marianelli
Dipartimento Scienze della Terra Universit di Pisa

Alessandro Sbrana, Nicole Metrich, Alessandra Cecchetti

Mt Vesuvius has experienced a period of semipersistent volcanic activity over the last three centuries, producing mainly lava effusions and some mixed effusive-explosive eruptions of higher magnitude. We present a systematic study on major and volatile elemen ts of melt inclusions trapped in olivine crystals peculiar to lapilli fallout emp laced during the more intense episodes of ex plosive ac tivity. Studied samples contain evidence for magma mixing in that Mg-rich phases (Mg-rich olivine, diopside and minor Cr-spinel) in e quilibrium with K-tephrites c oexist with a more evolved mineral assem blage (leucite, salite, Fe-r ich olivine, minor plagioclase and biotit e) in e quilibrium with K-phonotephrites. Here, we focus on the primitive assemblage. The olivine commonly contain one or several melt inclusions, varying in size from 50 to 200 m, and consisting of br own gla ss and only one shrinkage bubble. These inclusions sho w predominantly K-tephrit ic composi tion, with some of them representing the most primitive magma (Mg #> 60; CaO/Al_2O_3 = 1.10.84; K2 O = 4.65.1 wt%) ever found at Vesuvius. The dissolved volatile content in the melt inclusions ex ceeds 5 wt% (H_2O, CO_2, Cl, F, S), in particular H_2O and CO_2 co ntents o f melt inclusio ns are systematically high and varia ble from 2.3 to 4.9 wt.% and 1500-3500 pp m; relationships between ma jor element compositions and H_2O-CO_2 contents of melt inclusions suggest magma equilibration w ith a vola tile phase ha ving variable CO_2/H_2O ratio . The calculated to tal fluid pressur e fo r o livine-hosted melt inclusio ns ranges between 200 and 4 00 M Pa, corresponding to depths of ?8 km considering a me an cr ustal density of 2.6 g/cm3. The absence of relationship between the extent of melt differentiation and the trapping fluid pressures, corroborates the hypothesis of melts equilibration with a gas phase wi th variable H_2O/CO_2 ratio, at high pressure, in a mush co lumn. It is wo rth no ting that the abo ve-mentioned variability of volatile di ssolved in melt inclusions is present in single eruptive layers, in dicating th at a single-erupted magma batch entrains crystals formed at different pressures. On the other hand, millimeter-sized euhedral olivines with thei r lack of significant zoning and the occurrence of large melt inclusions indicate olivine crystallization along the wall of the feeding conduits and local formation of mafic cumulates, rather than crystallization upon magma ascent. Combining these observations and pressure estimates we propose that the deep feeding system at Vesuvius might have been formed by a vertically extended volume of crust containing pockets or interconnected cracks filled by magma, settlin g as mush columns (Marsh 2000), at pressures >20 0 MPa. The rise of deep CO_2 -H_2O-rich magma blobs from this system triggered the high Volcanic Explosivity Index (VEI) eruptions, provoking the emission of intense lava effusions of degassed magmas and abrupt transition to intense lava fountains and sustained columns.

Keywords: volatiles, melt inclusions, feeding systems

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VS010 **Poster presentation** **6847**

The feeding system of the 1944 eruption (Vesuvius) from petrological and melt inclusion studies

Dr. Paola Marianelli
Dipartimento Scienze della Terra Universit di Pisa

Paolo Fulignati, Alessandro Sbrana

Mount Vesuvius experienced a period of semipersistent volcanic activity over the last three centuries that produced mainly lava effusions and some mixed effusive-explosive eruptions. The activity stopped abruptly with the 1944 eruption, during which drastic changes in the eruption styles where observed. The aim of this work is to synthesize results to present a complete description of the feeding system of the 1944 eruption that marks the transition of the volcano to the present quiescent status. Geochemistry and mineralogy of both juvenile clasts and xenoliths ejected during the 1944 eruption of Mt Vesuvius, provide major contraints on the magmatic feeding system. Melt inclusions in phenocrysts of juvenile scoriae highlight that the magmas feeding the eruption underwent differentiation at different pressures. A K-tephritic volatile-rich melt evolved to reach K-phonotephritic composition, at pressures higher than 300 MPa, before being fed into a very shallow reservoir (P< 100MPa) in which it mixed with the low-volatile resident K-phonotephritic magma. The newly arrived magma forced the transition from the effusive to the lava fountain phase of the 1944 eruption. The outer portion of the shallow reservoir is formed by a crystallizing margin. From this, the transition to the carbonate country rocks occurs throughout a front of infiltration of magmatic melts in porous decarbonating host rocks. Magmatic melts are contaminated by the addition of Ca and Mg deriving from decarbonation reactions and/or melting of host rocks. These modified melts metasomatize the carbonates inducing skarn reactions and forming an endoskarn shell. Isotope (Sr, O) composition of juvenile products and xenoliths marks the amount of magma-carbonate interaction. Isotopic data pointed out that the crystallizing margin of the chamber may present a very limited contamination by carbonates. This suggests that the main volume of magma hosted in the magma chamber did not suffer any mass exchange with the wall rocks.

Keywords: vesuvius, feeding system, meltinclusions

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VS010 **Poster presentation** **6848**

Crustal and mantle magmatic processes during Kilaueas prolonged PUU ŌŌ eruption, Hawai'i

Mr. Jared Marske
Department of Geology and Geophysics University of Hawaii, Manoa IAVCEI

Michael Garcia, Aaron Pietruszka, Marc Norman, J. Michael Rhodes

The Puu Ōō eruption is Kīlaueas longest, most voluminous (~3.1 km3), and compositionally variable (5.6-10.1 MgO wt. %) eruption. Nearly 24 years of continuous geochemical monitoring of lavas from the current Puu Ōō eruption allow us to probe the crustal and mantle processes beneath Kilauea Volcano in unparalleled detail. Here we present new measurements Pb, Sr, and Nd isotope ratios and major- and trace-element abundances for lavas from episode 55 (1997-2006), which marks the longest and most voluminous interval of this eruption. Olivine fractionation and accumulation is important process for this eruption, however clinopyroxene fractionation has been relatively significant during episode 55.The MgO contents of Puu Ōō lavas and overall lava effusion rate have systematically decreased during episode 55, suggesting Puu Ōō magmas are becoming more fractionated and/or are experiencing a longer residence time in the crust. Puu Ōō lavas erupted since 1985 display systematic decreases in their TiO2, K2O, P2O5 and CaO abundances (normalized to 10 wt. % MgO to correct for olivine control) due to rapid changes in the parental magma composition delivered to Puu Ōōs shallow reservoir. Earlier erupted Puu Ōō lavas displayed the most significant decrease in incompatible element ratios with near constant SiO2 contents, and a gradual increase in 87Sr/86Sr ratios. However, episode 55 lavas record significant increases in MgO-normalized SiO2 contents and 87Sr/86Sr with nearly constant (e.g. Ba/Nb) or a slightly reversed (e.g., TiO2 and K2O) trends in incompatible element ratios and abundances. These geochemical variations suggest Puu Oo magmas are not derived from partial melting of the lithosphere or asthenosphere. Neither a single mantle source composition nor a change in partial melting conditions alone can explain these observations. Instead, two distinct mantle source components are required to explain the combined isotopic and chemical variability in Puu Ōō lavas since 1985: (1) a recently depleted component (i.e., a component that was recently depleted by prior melting in the Hawaiian Plume) with low abundances of incompatible elements became increasingly important from 1985-1994 (Garcia et al., 2000; Pietruszka et al., 2006), and (2) between 1995-2003 Puu Ōō had tapped greater proportions of a new Kīlauea-Mauna Loa hybrid source (with highest 87Sr/86Sr ratios observed during the eruption). The hybrid source component lies within typical Pb, Sr and Nd isotopic space for Kilauea, but represents a new source composition for the Puu Ōō eruption. The systematic geochemical evolution of Puu Ōō lavas reflects changes in the proportions of the mantle source components tapped throughout the eruption. The significant isotope variations (on a time scale of years) suggests that Puu Ōō magmas are rapidly extracted from compositionally distinct melts in Hawaiian plume into chemically isolated channels, and quickly transported to Kilaueas primary magma conduits.

Keywords: kilauea, geochemistry, magma

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VS010 **Poster presentation** **6849**

The magma Chamberwall rock interface of an active volcano through melt and fluid inclusion investigations: the Vesuvius example

Dr. Paola Marianelli
Dipartimento Scienze della Terra Universit di Pisa

Paolo Fulignati, Roberto Santacroce, Alessandro Sbrana

The frozen snapshots (xenoliths) of the magma chamber-mirroring skarn halo erupted from Vesuvius give a rare opportunity to describe the instantaneous state of a chamber and its sidewalls, and to get new and significant advances in knowledge of metasomatic aureoles linked to different actively growing magma chambers. Xenoliths from the disruption of magma chamber walls are relatively common in the deposits of Vesuvius eruptions. This work presents data on well-preserved glasses, and melt and fluid inclusions in crystals in selected samples. These xenoliths include highly crystallized rocks representative of the outer margins of the magma chambers: glass-bearing fergusites (1944 eruption), foid-bearing K-syenites (AD 472 and AD 79 eruptions), and cumulus clinopyroxenites (all three eruptions), as well as skarn (all three eruptions). A nearly complete chemical and mineralogical gradation of glass-bearing fergusites and foid-bearing syenites to salite-bearing clinopyroxenites is observed. The sharp contact, between skarn and foid-bearing syenites (AD 79) or glass-bearing fergusites (1944) or clinopyroxenites (AD 79, AD 472, 1944), is sometimes seen in collected ejecta. Furthermore, widespread skarn veins are commonly found in several AD 79 marble xenoliths. Near the highly crystallized peripheral portions of the chambers, represented by magmatic xenoliths (fergusites, syenites and pyroxenites), skarn aureoles form. Processes involved in the skarn genesis at the walls of Vesuvian magma chambers are controlled by the characteristics of magma reservoirs. The volatile-phase saturation and exsolution of hypersaline fluid phases from the crystallizing phonolitic upper parts of the young (AD 472), and mature (AD 79) Vesuvius magma chambers is one of the key processes that strongly constrains the development of the thermometamorphic-metasomatic aureole around the magma chambers. This is because the exsolved fluid phases are responsible for the transfer of reactants from the chamber into the wall-rock. The infiltration of these fluids, and their interaction with carbonate, represents an effective mechanism for the development of endoskarn (magmatic protolith) and exoskarn (carbonate protolith). Less differentiated, hotter, modified melts, not having exsolved hypersaline fluid phases, promote the generation of magmatic skarn, through melt-solid diffusion processes in the 1944 reservoir, and in the lower and hotter parts of more evolved magma chambers of Vesuvius. In conclusion. The thermal and compositional conditions of Vesuvius magma chambers constrain the type and complexity of their metasomatic aureoles.

Keywords: melt and fluid inclusions, magma chamber, vesuvius

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VS010 **Poster presentation** **6850**

The Plumbing System at the Initial Period of the Young Cone Formation, Avachinsky Volcano (Kamchatka)

Dr. Alexandr Maximov
Far East Division Russian Academy of Sciences Institute of Volcanology and Seismology
IAVCEI

Puzankov Michael, Bazanova Lilia

We have carried o ut a detailed research o f Plinian eruptio ns products from Young cone of Avachinsky volcano, Kamchatka (Holocene age). The Y oung cone is co mposed mainly basic andesite s but enoug h long period andesitic exp losive activity preceded its formation (7250-3700 yrs BP). At the intermediate stage of this change d uring 5000 3700 yrs 14C BP in th e eruption products both ma gmas occurred accompanied by the gradua l increase of basic ande sites part an d fu rther omission of compos ition contrast. The main peculiarity o f the evo lution tenden cy of phenocrists and microlites associations of these rocks is regular decre ase of the hor nblende significance.During t he in itial phase of the Young cone edifice formation two largest eruptions (>4and >1 km3 of pyroclastics) of the basic andesites took place(~3500 and ~3280 14C yrs BP). Plinian-type eruptions with basic compositions of the products are rare enough. Such eruptions concer ned wi th transitional periods of volcanic activity are of special interest. Petrol ogy of these eruptive produc ts was studied.Main pro ducts o f the st udied eruptio ns are presented by the pyroclastics of the dark b asic an desites with minor light andesite-like pumice. These rocks belong to the medium-low-K tholeiitic island arc series. They have relatively high FeO*/MgO relations, low contents and the flat chondrite mode l of the REE. The phenocrysts and microphenocrysts are plagioclase , augite, salite (rare, only a s th e ph enocrysts), or thopyroxene, and hornblende. Ti-magnetite and ilmenite are pr esent as microphenocrysts. The fine-grained matrix consists of very small microlites of Pl, CPx, subcalcium augite, pigonite, magnetite and gla ss.These rocks have some essential petrologic peculiarities in contrast with the other basic andesites of the Young cone. (1) There is fresh hornblende bo th rare large phenocrysts a nd n umerous small elo ngated micro phenocrysts (the leas t across size is 0.03 μm). (2) T he fresh Hb is in comb ination with th e well-defined two-pyroxene association. (3) Cores of the Hb phenocrysts are less Mg than their rims and the microlites. (4) Similar, sometimes cores of the Pl ph enocrysts are less Ca th an their rims and th e microlites. (5) There are two groups of OPx phenocrysts (Opx1,2) that differ in composition and zo ne mode; OPx micro phenocrysts are between t hese gro ups.The ro ugh e stimations o f P- T-H2O co nditions at differe nt stages o f t he magma crystal lization were made. They p oint at two depth levels of the phenocryst crystallization. Probably phenocrysts of Na-Pl, Hb an d Opx1 crystallized at lower c rust (Ptotal ~ 4-6 k bar) in H2O-rich melt. The mos t part of phenocryst s and the all microphenocrysts were formed at shallow depth (~1-3 kbar). Pl- CPx-Opx2 pheno cryst a ssociation has been crystallizing at m oderate water-undersatur ated conditions. The micro phenocryst crystallizatio n too k place at one time with the sharp increasing of oxygen fugacit y up to 1. 5-2 lo g units abo ve the NNO. Simultaneously the melt rea ch near water-saturated conditions.These re sults assume the next mo del. During the initial perio d of the Y oung cone edifice formation its magma f eeding system consisted of two different-depth chambers. The lower crust chamber produced andesite magmas and in the shallow one more basic magma has been stored. Plinian eruptions of basic andesites are likely to be r esult of ascent of the active degassing andesite magmas to the upper chamber and their mixing with the basic magma. Later on, activity of the Young cone i s controlled mainly by only shallow chamber. Suggested scheme coincided with geophysical data concerning existence two magma chambers at the different depths under Avachinsky volcano

Keywords: magma chamber, plinian eruptions, magma mixing

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VS010 **Poster presentation** **6851**

Plumbing system evolution in the final activity of Nisyros Volcano, Greece, as inferred by mineralogical, petrochemical and isotopic data

Dr. Eleonora Braschi
Scienze della Terra Universit degli Studi di Firenze IAVCEI

Lorella Francalanci, Jeorges E. Vougiokalakis

Undestanding the interaction between different magmas is very important to reconstruct the dynamic of the eruptions and the plum bing system f eatures of a volcano. One of the best evi dence of thes e processes is represented by mafic enclave s inside evolved h ost lava fl ow or domes. M afic en claves represent fragment of mafic magma that crystallize rapidly on contact with the cooler more evolved host magma. These two terms are , therefore, considered as the end-menbers of a system where different liquids interact and generate a vari ety of f eatures that re flect different co ndition (P, T , co mposition). The active volcano of Nisyros, in th e eastern part of the South Aegean volcanic arc, is one of the best place to study this processes because its last evol ution (<24 ka) is characterized by the extrusio n of rhyo-dacitic domes rich in mafic enclaves. Six post-c aldera domes were e mplaced after the last caldera collapse associated to the Up per Pumice ex plosive eruption. This wo rk s hows new dat a of major and trace elements, Sr and Nd isotopes and mineral ch emistry of domes and related enclaves. The samples were collected from all the six domes in order to ob serve the evolution wit h time. The e nclaves have a composition r anging from basaltic-andesite to andesite and show different pe trographic and geochemical feature compared with the hos t rock. Th e different enclave s show variabl e textures and composition. O ne of th e topics of these enclaves is the pre sence of chilled margins which also insure their origin fr om a magmatic liquid. Major a nd trace elements of the whole rock show clear differences between dome s and enclaves. For example , K_2O in th e enclaves vary from 0.9% to 1.5% and from 2.4% to 3% in domes; Sr contents in the en claves vary from 850 to 1000 ppm and from 320 to 530 in domes. Among the enclaves the silica cont ents de crease from the older domes (70% SiO_2) to the youngest ones (66% SiO_2). Minerals are also characterized by distinct features: plagiocla se phenocrysts of th e h ost magma sh ow oscillatory z oning an d range in composition between An% 25-60, whereas plagioclase of the enclaves a re mainly microcry sts and ha ve An% between 70-90. Few intermediate compositions are also present suggesting more comple x processes. Presence of enclaves and the major and trace elements trends de monstrates that mixing, with generation of hybrid magma s, did not occur. This seems to indicate that the two magmas rema ined in con tact for a sh ort peri od of time. T he plumbing syste m of the last activity of Nisy ros ca n be figure out of a complex system with a zoned magma chamb er where sever al events of re newed in trusion of mafic magma took place over a sh ort time with a clear tendency of the system towards more mafic composition.

Keywords: nisyros, enclaves, mingling

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VS011 **6852 - 6862**

Symposium
Modeling and simulation of volcanic related phenomena for hazard mitigation

Convener : Prof. Salvatore Di Gregorio

Volcanic activities give rise directly or indirectly to many dangerous phenomena: lava flows, pyroclastic flows, lahars, pyroclastic surges, release of volcanic gases and tephra into the atmosphere, debris avalanches, landslides and tsunamis. They represent a not exhaustive list of induced volcanic hazards, which pose serious risk conditions for the human environment in many parts of the world. In typical risk analyses, after defining the type and severity of a given dangerous phenomenon, a fundamental task is to determine the area influenced by the hazardous phenomenon, together with its evolution in space and time, once it has become activated. Eventually, the presumed effects on the elements at risk can be estimated. Modelling and computer simulation of such complex phenomena becomes a fundamental task. Computational methods are crucial: new approximated numerical techniques are greatly extending the class of problems which can be solved in terms of differential equation systems, while alternative approaches emerge from innovative computational paradigms such as cellular automata, neuronal nets, genetic algorithms, etc. The session deals with computer hazard analysis by applying new methods of modelling and simulating volcanic related phenomena. We invite the submission of contributions on such types of approaches of simulation, as well as on case studies.

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VS011 **Oral Presentation** **6852**

Magma flow instabilities: implications for long-period seismicity

Dr. Alina Hale
ESSCC The University of Queensland IAVCEI

Volcanic eruptions are typically accompanied by repetitive long-period (LP) earthquakes which originate from a small region of the upper conduit. These signals have the capability to predict eruptions since they often precede a change in the eruption vigour. Shear bands forming along the conduit wall where the shear stresses are highest are thought to be capable of providing the seismic trigger. But models have been unable to develop shear bands to the depths at which LP signals occur using simple magma strength models. Presented here is a model in which the magma strength is determined from a constitutive relationship dependent upon crystallinity and pressure. This results in a depth dependent magma strength analogous to planetary lithospheres. Therefore, as for the lithosphere, in shallow highly-crystalline regions a macroscopically discontinuous brittle type of deformation will prevail, whilst in deeper crystal-poor regions there will be a macroscopically continuous plastic deformation mechanism. This will result in a depth where the brittle-ductile transition occurs, and here shear bands may develop. We utilize the Finite Element Method and use axi-symmetric coordinates to simulate shear localization and the generation of shear bands in a conduit. Model results constrained to the Soufrire Hills Volcano, Montserrat show the generation of two types of shear bands: upper shear bands (forming between the free-surface to a few 100 metres below it) and discrete shear bands forming at the depths where LP seismicity occurs corresponding to the plastic shear region. Plastic shear has been proposed to explain deep earthquakes in subduction zones as a result of instabilities in flow and this may also be the case for LP seismicity. The viscosity within these discrete shear bands suggests a failure and healing cycle time that supports the observed LP seismicity repeat times. In addition, this shear band model allows LP events to be present during the different lava extrusion regimes, endogenous and exogenous, with exogenous growth occurring when upper conduit shear bands are present and endogenous growth occurring when upper conduit shear bands are not present. Shear bands are also found to have a large effect upon the ascending magma extrusion rate because shear-induced flow alters the over-pressure predominantly in the upper conduit. This model provides a method for pressure increase and decrease in the upper-conduit possibly responsible for flank tilt due to the generation of shear bands. Pressure changes as large as several MPas develop at depths of 100s m, values suitable to generate the observed tilt.

Keywords: shear bands, seismicity, lava flow

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VS011 **Oral Presentation** **6853**

The volcanic ash cloud risk to aviation: modelling the sensitivity of eruption height and fine ash fallout to tropospheric instability.

Mr. Andrew Tupper
Northern Territory Region Bureau of Meteorology, Australia IAVCEI

Christiane Textor, Michael Herzog, Hans Graf

A critical factor in successfully monitoring and forecasting for volcanic ash dispersion for aviation safety is the height reached by eruption clouds. In the past, conceptual models have had a very strong association between eruption strength and maximum height reached. More recently, there has been a developing understanding that environmental factors such as wind shear and tropospheric moisture can affect the height of eruption clouds. Following earlier work using the Active Tracer High Resolution Atmospheric Model (ATHAM) for strong Plinean eruptions, this study used ATHAM in axisymmetric mode for a range of mainly sub-Plinean eruption strengths in different atmospheres. The results suggest that, for weaker eruption strengths and in convectively unstable atmospheres, the height of the tropopause is the dominant determining factor in eruption height; relatively weak volcanic eruptions in the tropics can trigger deep tropospheric convection that transports volcanic material to 15-20 km. Thus there can be very marked differences, 10 km or more, between the heights reached by eruption clouds in moist tropical and dry sub-polar environments. This supports the earlier work but is a much larger height difference than previously suggested. Consistent with this, satellite observations of tropical eruptions show a marked bimodal distribution of cloud heights in the tropics, with not many mid-troposphere maximum heights observed. Because ash aggregation is promoted by hydrometeors, with liquid water being a stronger glue than ice, the smaller modelled eruptions also produce a relatively small proportion of fine ash in and below the umbrella cloud compared to eruptions in a dry atmosphere. This in turn makes ash much more difficult to detect in remote sensing using the infrared reverse absorption technique, although day-time only reflectivity techniques and sensing of coincident cloud components such as sulphur dioxide detection can still be used to track the cloud.

Keywords: volcanic ash, cloud modelling, aviation

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VS011 **Oral Presentation** **6854**

Lava flow simulations using effusion rates from thermal infrared satellite imagery during the 2006 Etna eruption

Dr. Annamaria Vicari
INGV - Sezione di Catania INGV - Sezione di Catania

Alessia Ciraudo, Alexis Herault, Ciro Del Negro

Timely predictions of the areas likely to be inundated by lava flows are of major interest to hazard managers during a volcanic eruption. In order to estimate the amount of damage that can be caused by a lava flow, it is useful to be able to predict the size and extent of such flows. Numerical simulation is a good tool to examine such events. With such simulations, one can explore various eruption scenarios and these can specifically be used to estimate the extent of the inundation area, the time required for the flow to reach a particular point and resulting morphological changes. We developed the MAGFLOW Cellular Automata model which involves a steady state solution of the Navier-Stokes equations coupled to heat transfer due to radiative losses 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. We already applied the MAGFLOW model to reproduce flow fields formed during the 2001 and 2004 eruptions at Mt Etna. Despite the satisfactory results, 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. These features are of special interest, particularly as effusion rates can be highly variable. Indeed, lava effusion rates can vary by orders of magnitude over a matter of hours, and are difficult to determine in-situ. However, lava effusion rates can be estimated using thermal infrared satellite imagery obtained from low spatial/ high temporal resolution remote sensing data (e.g. MODIS, AVHRR). To this end, we developed an automatic system that uses near-real-time infrared satellite data acquired by MODIS and AVHRR sensors to drive numerical simulations of lava flow paths. We describe and show the operation of this system by using an analysis of the recent lava flow-forming during 2006 Etna eruption.

Keywords: lava, flow, simulation

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VS011 **Oral Presentation** **6855**

Three dimensional numerical simulations of viscous debris flows and comparison with laboratory experiments A hybrid modeling approach for complex phenomena

Mr. Dipl.-Ing. Stefan Walder
Unit of Hydraulic Engineering University of Innsbruck

Dipl.-Ing. Christian Volgger, Univ.-Prof. Di Dr.Techn. Peter Rutschmann

This contribution focuses on three dimensional simulations of viscous debris flows and dense flow avalanches respectively. For hazard assessment different methods depending on basic conditions and desired accuracy exist. The different alternatives are distinguished by complexity and physical description. For combined empirical and statistical approaches morphological parameters related to debris flow volumes are necessary. In order to use an alytical approaches simplifications of the governing equations are necessary which reduces the generality of the original approach. For continuum simulations numerical methods are used to solve the Navier-Stokes-Equations, a system of non linear, partial differential equations. The equations used for pure water flows have to be slightly modified for debris flows to take into account the physics of a multi-phase approach. Namely internal friction losses due to interaction of solids and water have to be incorporated into the source terms in order to avoid an even more complex multi-phase simulation where conservation laws have to be considered for each single phase. Considering the computational efforts and the difficulty to incorporate multi- fraction granular flow into a multi- phase continuum approach the following paper deals with single phase Bingham and Herschel-Bulkley models respectively. At the Hydraulic Engineering Unit, University of Innsbruck, , the commercial code Flow3D from Fluid Science Inc., Santa Fe, California, is used for complex three-dimensional simulations of water flows, avalanches and debris flows. Debris flows with a high concentration of fine material show a pseudo-plastic behaviour. Therefore a Herschel-Bulkley and an even simpler Bingham approach were implemented as external routines into the Flow3D code. With this additions debris flows in a vertically rotating drum were computed and compared with laboratory experiments. These were performed by Prof. Rickenmann and his team at the University of Natural Resources and Applied Life (BOKU), Vienna, . The experimental setup of a rotating drum has the advantage that quasi-steady debris flows can easily be observed. From a numerical point of view the setup requires an additional complexity, namely a geometrical boundary which can be rotated with a prescribed rotational speed. Experiments and therefore also numerical computations were performed with a synthetic, visco-plastic material, called Carbopol Ultrez 10 for a fluid volume of 40,1 litres to 42,5 litres and a rotating velocity of 1,36 to 10,02 rpm. The water levels which were measured in the laboratory experiments with an ultra sonic sensor were compared with the three dimensional numerical calculations. Apart from the debris flow head the analysis shows good agreement for flow heights with a slightly better fit for Bingham computations.The present hybrid (numerical/experimental) approach helps to determine gross parameters for a rheological Bingham or Herschel- Bulkley simulation reproducing a prototype debris flow with heterogeneous material properties. It is therefore a useful combination towards improving prediction with simple currently yet feasible mathematical models.

Keywords: hybrid modeling, debris avalanches

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VS011 **Oral Presentation** **6856**

Large landslides at Mt.Etna and related tsunami impact

Dr. Massimiliano Favalli
ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA Sezione di Pisa IAVCEI

Maria Teresa Pareschi, Enzo Boschi, Francesco Mazzarini

Mt. Etna, the largest volcano in Europe, grew on the continental crust of eastern Sicily, at the tectonic boundary marked by the subducting Ionian oceanic slab. Its structural dynamics are principally characterized by volcanic spreading, which results in an overall seaward movement of its eastern sector, accomplished mostly by movements along extensional fault systems bordering this mobile portion. Sector collapses characterize the evolution of Mt. Etna, as testified by the Valle del Bove (VDB) scar and by the occurrence of local Pleistocene and Holocene debris-avalanche and debris-flow deposits exposed inland on the eastern flanks of the volcano, but only recently collected high-resolution offshore seismic data show that failure events from Mt.Etna volcano and/or more ancient eruptive centres evolved into long run-out offshore events.Numerical simulations support the occurrence of a catastrophic tsunami impacting all of the Eastern Mediterranean in early Holocene, related to the most recent Mt. Etna failure event (that related to the Valle del Bove scar). The tsunami was triggered by a debris avalanche from Mt. Etna (Sicily, Italy) which entered the Ionian Sea in the order of minutes. Simulations show that the resulting tsunami waves were able to destabilize soft marine sediments across the Ionian sea floor. This generated the well-known, sporadically located, "Homogenite" deposits of the Ionian Sea, and the widespread megaturbidite deposits of the Ionian and Sirte Abyssal Plains.

Keywords: etna, landslide, tsunami

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VS011 **Oral Presentation** **6857**

Thin-layer simulation of Lahars at VOLCN IRAZ, Costa Rica: hazard considerations for CARTAGO

Mr. Adam Stinton
Geology University at Buffalo IAVCEI

Michael Sheridan, Elicar Duarte, Erick Fernndez, Tomas Marino

The remobiliza tion of ashfall deposits by rai nfall during an d after t he 19 63-65 eruption of Volcn Ira z resulted in the generation of lahars t hat c aused sign ificant ch anges in th e geomorph ology of th eir emplacement channels. Aaggradation filled channels wh ich resulted in o verbanking of subsequent flows and increased the effective hazard. To m odel this process, a series of computer simulations using Titan2D using data on the la hars ge nerated during the las t eruption Iraz in 1963-65. This event was characterized by phreatomagmatic activity that depo sited up to 2 m of fine ash o n the steep uppe r slopes of the southwestern flank. Rainf all then re mobilized the as h for ming debris flows and followed the topography down slope. The Ro Reventado basin was one of the mos t strongly affect ed areas with several hundred small to moderate lahars recorded during the eruption. The largest and most damaging flow occurred on December 9th, 1963, killing 20 peop le, and destroying 300 houses, f actories, bridg es and roads in t he city of Cartago. With a volume es timated at 4 x 106 m3, this event is assumed to be the worst-case scenario in the event of r enewed activity at Volcn Ir az similar to that of 1963-65.Simulations were initiated as a thin she et with a maximum thickness of 2 m locate d on the uppe r slopes of th e Rio Reven tado basin . Flow parameters (e.g. volume percent solid and liq uid) come from observations of the 1963-65 fl ows. The initial simulati on was calibrated to approximate the runout a nd distribution of the December 9th, 1963 e vent, with subsequent simulations ru n over DE Ms modified by addition of the deposits from the previous run. Maps of maximum inundation for e ach flow were generated and the high flow lines transferred to topographic profile s colle cted in the field using differential GPS. Results show that for a si milar eve nt in the future, aggradation of the Rio Reventado channel will lead to over banking of flows. This wi ll caus e the in undation o f areas be yond the limits affected by ea rly flows. There are several narrow co nstrictions in the c hannel of the Rio Reventado, some of which coincide with road bridges. Channel aggradation upstream of these locations is likely to result in localized flooding an d potential bridge de struction. Following the 1963-65 activity, protective dikes were bui lt within the city of Cartago i n or der to pre vent a repeat of the Decemb er 9th, 1963 event. However, communities located next t o breach es in the dikes that allow roads an d railroads to cross the Ro Reventado face po tential hazardo us co nsequences. Debris flo ws that are co nfined within the dike walls would be able to develop distributary lobes that pass through the breaches and into the protected zones on either side.

Keywords: titan2d, lahars, geomorphology

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VS011 **Oral Presentation** **6858**

Using Titan2D to model lahars for the southern drainage of Volcan Cotopaxi: Production of a probabilistic hazard map for the city of Latacunga, Ecuador.

Mrs. Rebecca Williams
Department of Geology University of Leicester IAVCEI

Michael F. Sheridan

Lahars triggered by mobilizati on of deposits from volcanic explosions have occurred at Volcn Cotopaxi, Ecuador on the average of once every cent ury over th e last two millennia. Lahars fro m Cotopaxi have flowed down three main dr ainages, that impact a pres ent day population of around 3 million inhabitants. Ro Cutuchi, the main drainag e to the so uth o f Co topaxi, headwaters on the flanks of Rumiahui and Cotopaxi Volca noes. This river flows southwards through several communities, including the city of Lat acunga (population 52,000). Its path is generally adjacent to the Pan American highway. Many small scale lahars have followed this drainage, as well as some large scale historical flows, such as the great 1877 debris flow th at severely impacted the population along the Ro Cutuchi. This study used the Titan2D c ode to simulate lahars of various volumes along the R o Cutu chi in the vicinity of Latacunga. The purpose wa s to investigate the ha zard that lahars might present t o the current population should Cotopaxi b ecome active again and produce debris flows. The stud y area is restricted to the region adjacent to Latacunga where detailed field data are combined with the model results. Simulations utilized topograp hic, stratigraphic, and historical data t o determine pro babilistic lahar inundation zones for the debris flo ws of various sizes to create a pro babilistic hazard ma p. This hazard map has bee n analyzed i n co njunction with infrastr ucture data for Lat acunga so that the impact of various scale lahars on the city can be assessed.

Keywords: titan2d, lahar, hazardmap

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VS011 **Oral Presentation** **6859**

Ashfall and tephra problems on volcanic islands

Dr. Henry Gaudru
volcanology EUROPEAN VOLCANOLOGICAL SOCIETY -UNISDR IAVCEI

Leng Leng Lim

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.

Keywords: ashfalls, hazard, volcanic island

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VS011 **Oral Presentation** **6860**

Lava flows invasion susceptibility: a method with application to the eastern flank of Mt Etna

Dr. William Spataro
Dept. of Mathematics & HPCC Dept. of Mathematics & HPCC

Avolio Maria Vittoria, Crisci Gino Mirocle, D'ambrosio Donato, Di Gregorio Salvatore, Iovine Giulio, Lupiano Valeria, Neri Marco, Niceforo Giancarlo, Rongo Rocco

The objective of this work is the application of a technique for the defi nition of maps for lava flows invasion susceptibility of the Eastern flank o f Mt Etna (), one of the most dangerous are as in Europe in terms of vol canic hazard. The method relie s on a "vir tual laboratory", namely the lava flows s imulation model SCIARA which, when adequately calibrated and validated, allows to well forecas t the paths of new hypothetical events on present morphological data. The Eastern flank of Mt Etna was subdivided in different areas, each one characterised by a different probability of activation of eru ptive vents (vents probability), and their union "covered" by a regular gr id of vents. From each vent, different simulations were executed , each one with a particular effusi on rate and duration. As for the ar eas, even the effusion rates were characterised by a prob ability of occurrence. For both cases, such probabilities were devised by analysing the be haviour of Mt Et na in t he past 400 years. By considering the extent of the considered flank of Mt Etna, t he density of t he grid and the number of si mulations executed for each vent, a total of 40000 simula tions were carried out (that is, 100 differe nt effusion r ates for 400 la va source points). As it ca n be easily suppose d, the execution of a so elevated number of simulations required the massive adoption of pa rallel computing. A "w eight" was a ssigned to each of them (i.e . to each point in t he DEM of the considered area intere sted by the lava flow), which was set greater for those simulations having the source point located in areas characterised by a high proba bility of vents activation, and a highly prob able emission rate. Mo reover, other criteria can be consid ered, e.g. one related to the vent altitude, as it was observ ed that the more probable events are those more near to the summit of the volcano. The final map for evalua ting the lava flows invasion sus ceptibility was therefore compiled by considering each cell of the Etnean Eastern flank DEM and, for e ach of them, by adding the weights of all the simulations that interested it. Therefore, if the DEM is characterised by an elevated level of detail (as in this case), even the obtained map is so , as it is possible to determine an exact measure of the chance to be hit by a lava flow for each cell of the DEM itself.

Keywords: lava flows, susceptibility analysis, simulation

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VS011 **Poster presentation** **6861**

Unified view of numerical simulation method for debris/bed-load laden flow and landslide movement

Dr. Takahiro Itoh
Research and Development Center Nippon Koei Co., Ltd.

Kuniaki Miyamoto

Authors have proposed a set of constitutive equations for the mass movement of sediment-water mixture based on the consideration on kinematic energy balance in the motion, and suggested that Coulomb types static friction stress were dominant. In the present study, we would like to demonstrate the numerical simulation methods for both of debris/bed-load laden flow and landslide movement using the same governing equations employed our constitutive equations. The difference of the two kinds of mass movements reflects the state of static shear stress in the simulations as shown below. In case of debris flow, the flow usually run over the erodible bed, and the depth averaged sediment concentration of the mixtures is uniquely determined by the bed slope, therefore the termination usually appears as the deposition of sediment; because the static friction stress should be balanced with the external shear stress on the bed surface. On the other hand, in case of landslide, the landslide mass moves over a rigid sliding surface, and the sediment concentration is unchangeable, and then the termination appears as over all stopping. This means that it is not necessary to be in balance between the static friction stress and external shear stress on the sliding surface. The refore, the static friction stress changes discontinuously in the direction and the magnitude before and after the termination of movement.

Keywords: mass movement, static shear stress, numerical simulation

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VS011 **Poster presentation** **6862**

Tephra hazard analyses incorporating potential multi-stage volcanic events

Mrs. Susanna Jenkins
Risk Frontiers (NHRC) Macquarie University IAVCEI

Christina Magill, John Mcaneney, Tony Hurst

While volcanic events are commonly characterised by multiple eruptive stages, most previous probabilistic te phra hazard analys es have only considered the major (paroxysmal) stage for eac h simulated eve nt. To test the validity of this appr oach, we simulate events in the traditional manner (single-stage a nalysis) and th en also incorp orate pr obable smaller-magnitude explosive stages (multi-stage analysis). This builds upon the results of a glob al statistical study of multi-stage explosive events and uses the Okataina Volcanic Centre in New Zeal aand as a case stu dy. The two s ets of resultan t hazard - in the form of spa tial tephra thi ckness, the associated cumulative du ration of expl osive behaviour and the duration of the entire eruptive sequence - are compare d to assess t he difference in approaches. The multi- stage analysis shows an increa sed hazard when compared with the single-stage analysis and we found the greatest difference in duration and tephra thic kness to lie at middlin g distances from the vent. In some places, te phra thickness increased by one order of ma gnitude and up to 25% more of New Zealands North Island was impacted, while the probabil ity of an event lasting longer than 1 month increased sevenfold. The mo re traditional single- stage approach is recommended where little pre vious eruptive history has been establ ished, so that the modell ing does n ot become too dependant upo n 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.

Keywords: tephra hazard analyses, multi stage volcanic events, hazard and risk

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VS012 **6863 - 6884**

Symposium
Cities on Volcanoes: looking at the links between volcanology and communities issues around volcanoes (merged with VS020)

Convener : Prof. Giovanni Orsi, Dr. Jan Lindsay
Co-Convener : Dr. Claire Horwell, Dr. Peter Baxter

Urban vulnerability to natural hazards is one of the most underestimated issues in urban development. By 2050, the world population is expected to grow by three billion people. Almost all this growth will take place in developing countries, and particularly within their cities and towns. By more than doubling the urban population, large numbers of people will be concentrated in megacities and their increasingly fragile landscape, with huge impacts on the natural resources surrounding them. There are currently almost 450 cities worldwide with a population of more than one million inhabitants. The stresses and strains of rapid urbanization are nowhere more apparent than in the local areas in developing countries. From today to 2025 about 80 % of the urban population will be in the developing countries. Resulting population densities place many more people at risk to any hazards, and in particularly volcanic hazards. The Cities and Volcanoes session will explore the links between the volcanology community, emergency managers and city officials. It will focus on the role of multi-disciplinary applied research and need for collaboration between physical and social scientists in reducing volcanic risk and improving community resilience to volcanic hazards.

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VS012 **Oral Presentation** **6863**

What counts most? Extreme volcanic hazards versus everyday hardship in Southeast Asia

Dr. Jc Gaillard
UMR 5194 Pacte - CNRS Universit de Grenoble

Pauline Texier

The slopes of Southeast Asian volcanoes are often densely populated. To prevent pending disasters, scientists, politicians and media frequently refer to the extreme (in magnitude) and rare (in time) character of hazards threatening communities living on the flanks of volcanic edifices. Studies of people's response in the face of those dangers thus largely emphasize people's perception of extraordinary volcanic phenomena. Experiences from the Philippines and Indonesia however show that the vulnerability of those communities rather lies in their everyday hardship. In facing Mt Pinatubo lingering lahars and Mt Merapi recurrent eruptions, people consciously chose to remain in hazard-prone areas to sustain their daily needs and maintain social links with their native towns and villages. Yet, the current discourse on volcanic risk management still often encloses prevention and mitigation measures around hazards and consider risk out of the regular social fabric. This approach leads to dissociate volcanic risk from everyday life and thus to overlook underlying structural constraints such as difficulty to access resources, historical and cultural heritage and the political economy context. Experiences from Mt Pinatubo and Mt Merapi provide enough evidences to suggest that efficient volcanic risk mitigation goes far beyond the sole, still essential, prevention of "rare" and "extreme" hazards prevention and requires poverty alleviation, fair access to resources and adapted social and societal protection.

Keywords: vulnerability, everyday life, southeast asia

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VS012 **Oral Presentation** **6864**

Increasing population and tourism attractions around Copahue volcano, North Patagonia, Andes of Argentina. Volcanic growing hazard.

Dr. Elizabeth Ivonne Rovere
Servicio Geologico Minero Argentino (SEGEMAR) IUGG 2nd Argentina Delegate in 2003 IAVCEI

At scarce 11 Km. from the active volcano of Copahue and within the Del Agrio caldera, the Caviahue village is l ocated. Summer and winter spor ts, resort centers and adven ture safaris attract more th an 30,000 travelers every season . Copahue village (located 6 km from the active crater) a nd the Therma l Hospital (2.500 m.a.s.l.) attract aged people from overseas for youthful m uddy and sulphurous bathes, after a health and blood pressure control, led by medical expertise. In a r atio of 5 0 Km. from the volcano, Loncopu (6,000 inha bitants) is the main city; El Cholar (popula tion: 800); El Huec (1,200); Copahue (600 seasonal inhabitants and 1080 tour beds) and Caviahue with 800 inhabitants (400 in year 2000, 100% population increasing) 46 commercial si tes and 750 be ds -in crescen do- became a n important pole for tourism international investments. On July 1st 2000, one day befor e the starting of winter vacations, a phreatomagmatic eruption to ok place (VEI~ 2). Between July and October 2000, more than 30 explosions occurred, covering wi th ashes and p yroclastic eject over 2,000 Km2 an d damaging properties, vehicles and machiner y. In July 2000, snowing wa s so intense that covered the routes, iso lating Copahue and Caviahue village for several days. Two exit roads from Caviahue and Copahue exist, both cross the volcano valleys, only the southern one is paved. In case of an eruption, a pyroclastic flow or a lahar would cross the route through the valleys after 20 minutes. It is necessary to generate consciousness and a volcanic hazar d planification. An episode similar to year 2000 could be repeated, but with different consequences.

Keywords: volcanic hazard copahue andes, caviahue village year 2000, argentina growing population

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VS012 **Oral Presentation** **6865**

BET at Campi Flegrei and Vesuvius

Dr. Warner Marzocchi
Sezione di Bologna Istituto Nazionale di Geofisica e Vulcanologia IAVCEI

Laura Sandri

The high urbanization of the Neapolitan area forces both scientific community and public authorities to address as accurately and precisely as possible short- (e.g., for evacuation) to long-term (e.g., for land use planning) volcanic hazard assessment at Campi Flegrei and Vesuvius. The general scarcity of data about explosive volcanoes imposes the implementation of multi-disciplinary approaches as well as the extensive usage of different expertises and qualitative information. Within the framework of the Italian projects funded by the Italian Civil Protection, the Bayesian Event Tree (BET) model has been applied to assess the probabilistic volcanic hazard for Neapolitan volcanoes by 1/ merging all of the available knowledge, 2/ summarizing expert opinions and 3/ evaluating the aleatory and epistemic uncertainties. Here, we present the state of the art and the experience gained by the implementation of BET for Campi Flegrei and Vesuvius.

Keywords: volcanic hazard, campi flegrei, vesuvius

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VS012 **Oral Presentation** **6866**

Planning for a future eruption from the Auckland Volcanic Field, New Zealand

Dr. Jan Lindsay
Geology Programme University of Auckland IAVCEI

David Johnston, Jane Olsen, Michelle Daly

The Auckland Volcanic Field (AVF) is a small-volume, intraplate monogenetic basaltic field located directly beneath New Zealands largest city, Auckland (pop. 1.3 million). The last eruption occurred c. 700 years ago, and planning for a future event involves a multidisciplinary, multi-organisational approach. The Field is currently monitored by GeoNet, via a 5-station telemetered seismograph network. Any unusual activity is reported to emergency management agencies, both nationally and locally. Ongoing geological and geophysical studies are constantly improving our understanding the nature and style of past eruptive activity, and likely future hazards. In particular, in recent years, a strong programme of drilling through paleolake sediments in Auckland is providing critical information regarding the frequency and magnitude of past eruptions. Also in recent years there has been a strong focus on examining the communitys resilience to hazardous events, including volcanic eruptions. This research has developed a model of community resilience in the context of a volcanic eruption. Validation of the model also allowed exploration of the communities understanding of the risk and levels of preparedness as well as evaluation of methods for improving awareness and preparation for a future eruption. Traditional public education methods (e.g. advertising, pamphlets) have been shown to have had limited success, and more innovative strategies to engage, empower and motivate the community are being developed. The responsibility for emergency management in Auckland, including warnings and outreach, lies with the Auckland Civil Defence Emergency Management Group (CDEMG), which incorporates representatives from a range of organisations, such as emergency services, local government, health agencies and utility companies. A range of mechanisms has been established to provide effective liaison between the CDEMG and the scientific monitoring and research agencies. An ongoing assessment process is in place across all aspects of the integrated response. For example, the Auckland CDEMG has recently undertaken a major assessment of their capability and capacity to respond to a disaster in Auckland. The results of this assessment will help steer continued improvement and refinement of the system. Another project has recently reviewed options for effective public notification of warning messages for the Auckland region. In early 2008 a simulated AVF eruption will be used as part of a nation-wide emergency management exercise to test both local and national disaster response capability.In an emergency situation it is important that all stakeholders have established relationships and that trust exists between all involved parties. To facilitate this, as well as exchange information, regular (annual) meetings of representatives from all agencies have been initiated.

Keywords: preparedness, resilience, auckland

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VS012 **Oral Presentation** **6867**

International warnings for volcanic clouds - experiences in the Asia/Pacific region

Mr. Andrew Tupper
Northern Territory Region Bureau of Meteorology, Australia IAVCEI

The risk posed to aviation by drifting volcanic clouds is greatest where the source volcano is close to a major city, because of the convergence of aircraft towards that city's airport, the lower flying altitude of the aircraft, and the chance that the volcanic ash may be affecting the airport itself. The worldwide warning system for volcanic ash clouds, the International Airways Volcano Watch, is designed primarily for aircraft at cruising levels, but should also function on the local scale. In the Asia/Pacific, we have found many challenges in working towards a fully functioning International Airways Volcano Watch, including great resource disparities between nations, widespread equipment failure, communications issues, language issues, and even different safety policies between airlines. Based on our experiences, aircraft are not yet safe from damage or worse from volcanic cloud encounters. To improve the International Airways Volcano Watch, we can further develop aviation-funded enhanced service arrangements with local volcanological observatories, link the nine international Volcanic Ash Advisories Centres more closely with the local meteorological and aviation authorities, and ensure that there is a consistent suite of warnings to cover the small-scale as well as large scale dispersion of ash clouds. There are also many scientific issues to consider such as defining the relative risk of old versus new ash clouds to aircraft, enhancing our modelling and dispersion capabilities and significantly improving our remote sensing techniques.

Keywords: aviation safety, volcanic ash

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VS012 **Oral Presentation** **6868**

Tuffaceous deposits in the Lake Biwa, central Honshu, Japan

Dr. Chang-Hwa Chen
Institute of Earth Sciences Academia Sinica, Taipei, Taiwan IAVCEI

Kuei-Chih Fang, Keiji Takemura, Sheng-Rong Song

The 142 2 m l ength core was drilled in southern basin of the Lake Biwa (3513'06"N, 13600'49"E) in central Honshu, Japan. The results of previous researches indicated that the most upper 250 m part of core consisted of the lacustrin e clay and ages of th is part were dated as within 430 ka (Meyers et al., 1993). The m ajor 18 tephra l ayers (> 1 cm thickness) in upper 250 m of core were chosen for this study. Pure and cleaned glass shards and minerals picked under stereo-microscope in ea ch tephra layer were analyzed in chemical and isotopic compos itions by the EPMA and t he TI MS in the IE S, respectively.Major dispersive mechanism of tuffaceou s materials in the Lake Biwa was caused by the eastern ward wind. The K2O vs. SiO2 plot and Sr isotopic values of the glass shards were used to verify the sources of tephra layers. There can be identi fied that three layers from the Daisen and Sanb e caldera o f so uthwestern Ho nshu a nd thirte en layers from central and s outhern Kyus hu. The 9.3 ka Ulreungdo eruptio n (U-Oki) in J apan Sea was also detected in the core. In contrast, three tephr a sources were identified from the Norikura a nd North Izu volcanic zo nes (central Honshu) in the upper wind direction.Based on the tephrostratigraphy of the Lake Biwa, the sedi mentation rates of the upper 250 m of core were estimated from 0.16 mm/yr to 1.24 mm/yr. It is notable that there obviously revealed a four times lower s edimentation rate (~0.2 mm/yr) in the period of 55 ka and 105 ka, which should reflect the paleo-climate change.

Keywords: tephra, lake biwa, japan

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VS012 **Oral Presentation** **6869**

Raman-SEM: A new technique for identification of toxic minerals in volcanic samples

Dr. Claire Horwell
Earth Sciences University of Durham IAVCEI

Ben Williamson

The presence of crystalline silica in volcanic ash has been a cause for concern since its discovery in the 1980 Mt St Helens deposits. In industrial settings, crystalline silica can cause silicosis and lung cancer but it is not yet clear if volcanogenic silica can cause chronic disease. Different crystalline silica polymorphs are known to have varying pathogenic potential. For example, cristobalite is thought to be more toxic than quartz. The quantity of different silica polymorphs in an ash sample is distinguished using x-ray diffraction (XRD) but accurate quantification is hampered by the need for accurate prior characterisation of the mineral assemblage. In andesitic dome-forming eruptions, such as the Soufrire Hills eruption, cristobalite is thought to form by vapour-phase deposition and devitrification of volcanic glass. Here we have used a state-of-the-art technique developed by Renishaw: Raman spectroscopy combined with SEM-EDX for the analysis of micro-crystalline silica in the Soufrire Hills dome rock. This technique allows polymorphic characterisation of individual crystals at the micron-scale enabling identification of the mechanisms of crystalline silica formation in a volcanic dome. We have confirmed that cristobalite crystals are present, emplaced in vesicles in the dome rock. We believe these euhedral crystals are formed by vapour-phase deposition. Raman-SEM also confirms the presence of a second, 'platey' vapour-phase form of cristobalite. Patches of glass are also observed to contain microlites of crystalline silica and plagioclase, which may be formed by devitrification. Raman-SEM has identified that this silica, in some samples, is cristobalite, whereas in other samples it is quartz. We conclude that the cristobalite observed in the Soufrire Hills ash is formed by several mechanisms which will affect its potential toxicity. Fragmentation during dome- collapse events will cause euhedral crystals to fracture into smaller, pure cristobalite particles whereas platey crystals may fragment into a more acicular morphology. Crystalline silica present within glass patches is unlikely to fragment as clean crystals, thereby posing the possibility that some respirable particles, previously identified as crystalline silica by SEM-EDX, are actually combinations of silica, glass and plagioclase. This may substantially reduce a particles pathogenic potential in the lungs.

Keywords: volcanic health, crystalline silica, raman spectroscopy

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Volcanic Risk perception in the Phlegraean area (southern Italy)

Dr. Roberto Isaia
Osservatorio Vesuviano Istituto Nazionale di Geofisica e Vulcanologia IAVCEI

Franco Barberi, Mattew Davis, Rosella Nave, Tullio Ricci

The Campi Flegrei which includes part of the city of Naples , is an active volcanic system whose last eruption occurred in 1538 AD. More recently two significant crises occurred between 1969-72 and 1982-84 and were a ccompanied by ground movements (brady seism) and seismic activity, forcing people of the town of Po zzuoli to be ev acuated. Since 1984 development of a volcanic emergency plan has been underway. In the 2000 Civil Protection published a risk map which defined the Red Zone, an area highly at risk from py roclastic flows which would be evacuated befo re an eruptio n.The first study to evaluate the volcanic risk perceptions of the people living within the Campi Flegrei area was completed in spring 2006. A 46 item questionnair e was distribut ed to 2000 of the approximately 300.000 re sidents of the Campi Flegrei Red Zone, which includes 3 towns and 4 neighborhoods within the city of Naples . A total of 1161 questionnaires were returned, for an overall response rate of 58%. Surveys were distributed to junior high an d high scho ol students, as well as to adult members of the general population.Results indicated that unlike issues such as crime, traffic, trash, and unemplo yment, volcanic hazards are not spontaneously mentioned as a major pro blem facing t heir co mmunity. However, when asked specifi c questions about volcanic ris ks, respondents believe th at an eruption is likely and could have seriou s consequences for themselves and their com munities and they are quite worried about the threat. More than 70% of t he people iden tified Vesuvio as the major volcanic threat, but the Pozzuoli inhabitants recognized Solfatara volcano as th e most active and dange rous local threat. Considering the events of 1969-72 and 1982-84, it was not sur prising that re spondents indicated earthquak e and ground deformations as more serious threats than e ruptive phenomena. Of signi ficant importance is that only 17% of the sample knows about the Emergency Plan and 65% said that they have not received enough information about the possible effects of an erupti on. In addition, residents Se nse of Community was significantly, positively correlated with confidence in local authorities and Civil Protection and feelings of self efficacy regarding their ability to pr otect them selves in the event of an eruption.These results indicate that most residents of Campi Flegrei, while aware of the volcanic threat posed by Vesuvio, are not familiar with more local volcanic hazards in their area. This, coupled with little knowledge about the Emergency Plan and the very low level of information about the effects of a possible eruption, suggests that authorities, in collaboration with the scientific community, should direct their efforts to educate the public about the risk and the Emergency Plan, and that such efforts could be fa cilitated by trying t o encourage stronger community bonds.

Keywords: campi flegrei, volcanic hazards, risk perception

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Volcanic risk mitigation and eruption responses by the office of U.S. Foreign Disaster Assistance: case studies in Africa, Asia, and Latin America

Mrs. Gari Mayberry
USAID Office of Foreign Disaster Assistance US Geological Survey IAVCEI

Marion Pratt

As the principal United States government humanitarian aid donor, the Office of U.S. Foreign Disaster Assistance (OFDA), located within the U.S. Agency for International Development (USAID) is responsible for responding to natural and human-caused disasters that occur outside of the U.S. Volcanic eruptions have killed tens of thousands of people and adversely affected millions during the past 100 years, and OFDA works to mitigate and respond to the effects of eruptions on vulnerable populations in developing countries. By providing humanitarian aid and technical assistance before, during, and after volcanic disasters, OFDA has played a pivotal role in responding to and mitigating the impacts of volcanic eruptions worldwide since 1964, when the office was created. For several decades OFDA responded to volcanic disasters on an ad hoc basis. Beginning in 1986, OFDA began funding the Volcano Disaster Assistance Program (VDAP) through a partnership with the United States Geological Survey. OFDA's collaboration with VDAP allows a team of volcanologists to begin crisis response prior to a disaster in order to mitigate possible hazards. VDAP has provided sustained technical assistance to countries threatened and affected by volcanic disasters, responded to 23 volcanic crises, and helped build local capacity at volcano observatories and institutions in 11 countries. From OFDA's point of view, an eruption becomes a disaster when it is beyond a country's ability to respond to the impacts without foreign assistance. OFDA and its partners work to alleviate the two main types of negative effects of volcanic eruptions: human morbidity and mortality, and damage to local, regional, or international economies. The type and degree of response to volcanic disasters depends on OFDA's perception and analysis of volcanic threats in a worldwide context, taking into account the needs of those affected and assistance offered by others. Since its inception, OFDA, including VDAP, has provided assistance for volcano-related emergencies most often in Ecuador (15), followed by the Philippines (11), Indonesia (11), Colombia (6), the Democratic Republic of the Congo (DRC) (6), Papua New Guinea (6) and in 16 other countries. The most repeat responses for individual volcanoes have been for Tungurahua in Ecuador (6), Nyiragongo in the DRC (5), and Mayon (5) and Pinatubo (5) in the Philippines. Case studies of responses to deadly carbon-dioxide degassing episodes at Lakes Nyos and Monoun in Cameroon, multiple eruptions at Tungurahua in Ecuador, lava inundating the highly-populated city of Goma during an eruption at Nyiragongo in the DRC, and multiple eruptions at Merapi in Indonesia, describe the various types of necessary responses and mitigation efforts by OFDA to reduce the volcanic risk to highly-populated areas in developing countries. OFDA responses and mitigation efforts have included, monitoring technology, hazards analysis, engineering solutions, long-term capacity building, addressing social issues, prioritization with ongoing civil unrest, addressing altered land-use patterns, and providing education and outreach to local communities.

Keywords: mitigation, volcano, assistance

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VS012 **Oral Presentation** **6872**

Superstition and mythology an undervalued component of community resilience

Prof. Katharine Cashman
Geological Sciences University of Oregon IAVCEI

Shane Cronin

Volcanic eruptions can overwhelm all senses of observers in their violence, spectacle and sheer incredibility. When eruptions are catastrophic or unexpected, neither individuals nor communities can easily rationalize or contextualize the events within their world view. Psychological studies in disaster aftermath have shown that trauma can shake the very foundations of a persons faith and trigger a search - super natural, religious, scientific for answers. Thus an important component of community resilience is the ability to rapidly comprehend a traumatic event. One method of developing an explanation is shared discussion and multiple expressions of individual and communal perceptions of the event, a process that may lead myth-like explanations. In many past societies, such stories made there way into oral tradition, suffering on the way further modification to allow transmission through generations. We demonstrate here a link in language, imagery and metaphor in the present and past search for understanding of volcanic catastrophes. Responses to modern eruption descriptions (1980 St Helens and 1995-2000 Montserrat) provide a baseline for examining the progression to older historic events that have already developed oral traditions (1886 Tarawera) and through to oral traditions of events 400 yrs to many thousands of years old in both the Pacific Northwest US and New Zealand. We contend that the oral traditions related to volcanism trace their roots to societal and individual attempts to find meaning in the aftermath of volcanic disasters, whereby myths are born from eye-whiteness descriptions. Repeated volcanism in an area produces rich webs of cosmology and history that include explanations of the causes of events and their effects. Personification of volcanoes as beings allows their activities to be placed in human contexts of love, jealousy, family relationships, and conflict. NZ Maori have incorporated volcanoes and their landscape into the lineage of tribes and individuals, thus they comprehend good and bad outcomes from volcanism as part of long-term cycles of reciprocity and balance involving themselves and their own ancestors. These examples of cosmologies and mythologies not only show the attempts of past cultures to bounce-back from the impacts of past volcanic disasters, but also provide a safety-net for following generations to understand, contextualize, and therefore more readily recover from future volcanic catastrophes. In the face of an increasing reliance on modern monitoring and warning technologies, such local traditions, where they exist, can provide both a valuable additional community education tool and an important aid to the psychosocial recovery of individuals and communities.

Keywords: volcanic eruptions, oral traditions, community resilience

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VS012 **Oral Presentation** **6873**

Can the Fantale area in Ethiopia, be counted among the Cities On Volcanoes?

Prof. Giovanni Orsi
Osservatorio Vesuviano Istituto Nazionale di Geofisica e Vulcanologia IAVCEI

Ayalew Dereje, Dellerba Francesco, Di Vito Mauro Antonio, Yirgu Gezahen

Fantale is an active volcano in the Main Ethiopian Rift, characterised by an elliptical summit caldera. The rocks younger than the caldera collapse, have been e rupted both inside and outside the caldera. Trachytic lavas erupted within the caldera, are cut and tilted by 120-150E trending faults, parallel to the caldera elongation. This activity wa s followed by t he eruption of pa ntelleritic pumice cones and lava domes, both inside the caldera and along the sl opes of the edifice, aligned along NNE and WNW directions. The last activity occurred in 1810 and generated basaltic lav as and scoria cones, in the vicinity of the Metahara town. It was likely accompan ied by activation of NNE trending fractures. The persistent state of activity of the volcano is testified by recent volcanic activity, faults cutting recent rock bodies and likely feeding younger volcanism, alignment of fumaroles along recent and likely active faults, probable subsidence of the Beseka lake area along faults of the Wonji Fault Belt. These features and the explosive character o f the volcanism, clearly show that the volcanic haz ard at Fantale is very high. The Fant ale area hosts a larg e population. Although most of the pe ople are conce ntrated in the town of Meta hara, at the base of the southern sl opes of th e volcan o, a sign ificant popu lation of pastoralists is distributed over and around the volc ano. Other people live in two sugarcane and banana plantations, cl ose to the vol cano. In addition to and inte racting wi th people, in the area there are infrastructures which have a nationwide importance. The mentioned plantations, locat ed to the Nort h and South of the volcano, along the Awash river, are a mean of subsistence for local population and for the entire country. The main road and the only railway connecting to the sea, at Djibu ti, run through Methahara. T he Awash N ational Par k is also located in the vicinity of t he volcano. According to the present knowledge of the volcano, it cannot be ex cluded that a future eruptio n could be a high-magnitude explosive event. The vulnera bility of the va lue exposed to the volcanic hazards is very high, due to lack of any organisation able to guarantee their protection and to constructional typologies. Such an eruption could cause considerable loss of human lives and damage at local scale and for the entire country as it would effect the connection with the sea and the plantations, which generate a significant portion of the natio nal income. Taking into acco unt the above mentioned volcanological and socio-economical characteristics of the Fantale area, we co nclude that it can be co unted among the cities on volcanoes. Fu rthermore we urge th e volcan ological community and civil authorities to engage in a common effort to reduce volcanic risk.

Keywords: main ethiopian rift, volcanic hazards, caldera

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VS012 **Oral Presentation** **6874**

Naples, a large city within an active volcanic area

Prof. Giovanni Orsi
Osservatorio Vesuviano Istituto Nazionale di Geofisica e Vulcanologia IAVCEI

De Vita Sandro, Di Vito Mauro Antonio, Heiken Grant

The metropolitan Neapolitan area forms an urbanised continuum within an active volcanic area. In fact, the city of Naples, founded by Greek settlers in the 7th century BC and called Parthenope, has merged with the surrounding towns within the Phlegraean Fields caldera and along the slopes of the Somma-Vesuvius strato-cone, to form the Parthenopean Megacity. This densely-populated urban area has spread across two active volcanoes, each highly dangerous for their explosive character, and is one of the best known examples of a high risk volcanic area.The Phlegraean Fields caldera, which last erupted in 1538 and is the site of intense hydrothermal activity, is affected by recurrent unrest episodes related to ongoing resurgence. The Somma-Vesuvius strato-volcano has had continuing seismic and hydrothermal activity since its last eruption in 1944.The Parthenopean Megacity is a good example of interaction between active volcanoes and humanity for thousands of years. It has been growing through time, because of soil fertility, a temperate climate, and favourable strategic position within the Mediterranean basin, in spite of the volcanic hazards. The presence of active volcanoes is a continual source of hazards. Volcanic activity, accompanied by side effects such as seismicity and diffuse gas emission, and their constructive (new rock formation) and destructive (volcano tectonic deformation) actions have generated the conditions for further hazards. An increasing population and growing economic activities have increased the risk.The Parthenopean Megacity is exposed to natural hazards in addition to volcanic activity, related to both geological setting and millenary human habitation. The present geomorphic setting of the area, determined by the volcanic activity, generates erosion and landslides. The use of the territory and volcanic rocks by humans for thousands of years has generated the conditions for further hazards. Fulfilment of basic needs such as housing, access to water, building and maintaining fortifications, required excavation of quarries, wells, and cavities in lavas, tuffs and loose pyroclastic rocks. The results of this activity are sources of hydrogeological hazards such as landslides, and flooding.Historically, urban planning in the Neapolitan area as well as all over the world, has not considered the catastrophic effects of a volcano, which has a longer recurrence time than that of a human lifetime. During the last decade, Naples civic authorities, solicited by the scientific community, have realised that volcanic hazards must be assessed and risk mitigation actions be planned. Urban planning for the greater Naples area includes support for continuing volcano monitoring, research, and education.

Keywords: natural hazards, naples

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Spore chemistry as a proxy for volcanically-induced atmospheric perturbations

Mr. Wesley Fraser
Department of Earth Sciences The Open University IAVCEI

Mark Sephton, Steve Self, Jon Watson

Ultra-violet-B (UV-B) radiation is found to have a num ber of detrime ntal effects on the health of terrestrial organisms, including skin cancer, DNA damage, ocular degradation and immunosuppression. UV-B is absorbed by stratosp heric ozone, which acts as an external filter providing Earths biota with a degree of protection. The stratospheric ozone layer has been a hot topic for the past t wo decades due to a global-wide depletion of the ozone column by as much as 4 % compared with tha t of 1980 (WMO, 2002) and this decrease is attributed to the anthropogenic emission of chlorofluor ocarbons (CFCs). The eruptions of El Chichn in 198 2 and Mt. Pina tubo in 1991 revealed that e xplosive volcan ic activity can cause a signifi cant reduction in to tal oz one colu mn for 3- 4 years afte r the event, and such depletions are superimposed on the alr eady a nthropogenically perturbed atmosphe re. However, t he atmospheri c impact of oth er explosive eru ptions on oz one prior to E l Ch ichn is u nknown du e to a scarcity of measurements. Here we pre sent an innovative new approach to this problem whereby we use biochemical changes in plant spore wall composition to track UV-B flux through time. Chemical analyses were performed using a Thermo Electron Nexus FT-IR, integrated with a Co ntinuum microscope. Spore samples spann ing the eruption of Mt. Pinatubo (1991) at near-annu al resolution were obtained from plant specimens held at the h erbarium of Kew Gardens, London, UK, thus pro viding a test o f whether spore wall composition changes with respect to st ratospheric ozone abundance. Plant spore walls are found to prima rily comprise of two classes of comp onent, forming a co-polymer; the first group being centred on an aromatic ring, the second group are si mple long-chain fatty acids. Our an alyses show a distinct increas e in aliphatic content (fatty acids) of the spore wall , co incident with an increase in unsaturation of the aliphatic c omponents, whilst the relative abundance of aromatic- based components decreases. We believe these chemical shift s are a response to increas ed UV-B reaching the plants. Therefore we attribute the observed shifts in spore wall chemistry to an internal response mechanism to changes in UV-B flux (i.e. an internal UV filter) caused by the volcanically-induced ozone depletion after the eruption of Pinatubo.

Keywords: atmosphere, uv b, ozone

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VS012 **Oral Presentation** **6876**

Contribution to volcanic risk mitigation in Southern Peru through an original approach of public education and awareness.

Mr. Guillaume Levieux
Universit de La Runion - LSTUR Institut de Physique du Globe de Paris IAVCEI

J. Arnaud, G. Avard, S. Barde-Cabusson, M. Benbakkar, L. Bennati, J.A. Chvez, N. Cluzel, V. Cruz, A. Finizola, N. Fournier, K. Gonzales, M. Lacarin, R. Lebti, C. Lefaure, F. Lefaure, F. Legros, P. Llerena, O. Macedo, J. Machar, J. Marino, M. Moreau, G. Ma

The CVZ is the most volcanic explosive area in the Andean Cordillera. The Huaynaputina alone was responsible for the largest historical eruption in South America. Owing to their level of volcanic activity and to the high population density around them, two stratovolcanoes are considered as significant threats for southern Peru: the El Misti volcano, the crater of which is 3.5 km above and 17 km away from the centre of Arequipa, the second largest city of Peru (900,000 people), and Ubinas, 2.3 km above and 6 km away from several villages located in the Ubinas valley (5,000 people). Volcan-Explor-Action (VEA) is a NGO promoting international solidarity in volcanology by supporting students who want to set up projects in countries exposed to volcanic risk. At the same time, we lead actions to raise public awareness of development issues. From 2004 to 2007, our actions aim to improve the response in case of a volcanic crisis along three axes which complement each other: (i) improve the instrumental monitoring, and train Peruvian scientists; (ii) initiate a working group on risks assessment; and (iii) attempt to raise public awareness of volcanic risk issues. These three points have been considered as an integral part of the volcanic risk mitigation chain. Practically, (i) to make a contribution to the instrumental monitoring tools already installed on Misti and Ubinas volcanoes, VEA, thanks to a scientific material manufacturer, has donated a high-performance liquid chromatography (HPLC) to the Instituto Nacional Geolgico, Minero y Metalrgico (INGEMMET). VEA also partly supports two Peruvian scientists following training courses in France, thus enabling INGEMMET to monitor the chemical composition of springwater from these two volcanoes. (ii) In September 2004, thanks to a close collaboration with the Peruvian institutions as Instituto Geofsico del Per (IGP) and French institution as Alliance Franaise dArequipa, a relevant meeting was held on volcanic risk awareness-rising, which brought authorities, scientists, civil defence, NGOs, school pupils and lay people together. This meeting was the first opportunity to make an appraisal of their ability to face a volcanic crisis situation, in order to develop an action plan for volcanic risk management. One presenter simulated awakening of the Misti volcano, step by step, so as to allow every person and public organisation to publicly express their abilities, limitations and questions. The aim of this event was to create a risk management work group. (iii) At the same time, the first free permanent Centro de sensibilizacin al riesgos volcanicos in Arequipa was opened, in collaboration with Universidad Catlica de Santa Mara and Osservatorio Vesuviano. One room of the biggest museum of Arequipa is dedicated to Earth and volcanic risk. In keeping with the school programs, the CSRV could be used as a new dedicated medium for teachers and their classes. Along the same lines, the entire project was shared with four Peruvian and French schools, all located near volcanoes. Thanks to an IBM support, the Volcan-Explor-Action website hosts real-time blogs from participants. A forum and weekly video conferences enable live communication in order to discuss living conditions and risk assessment in volcanic areas. All these activities aim to foster local initiative, in order to build up a widespread awareness of volcanic risk. Since the Ubinas eruption in late March 2006, INGEMMET has been greatly investing in volcanic risk management. Now, VEA is contributing to sustainable development by cooperating with INGEMMET and fulfilling some of its needs.

Keywords: risk, mitigation, education

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VS012 **Oral Presentation** **6877**

Hazard from endogenous gas release in the Alban Hills near Rome

Dr. Maria Luisa Carapezza
INGV-Roma1 INGV IAVCEI

Franco Barberi, Tullio Ricci

The north-western flank of the Alban Hills, a quiescent volcano near Rome, is characterized by the presence of zones with strong emissions of endogenous gas from the soil mostly composed by CO2 (about 98 % vol.) with minor H2S (1%vol.). The shallow aquifer, contained in the vocanic rocks, is locally overpressured as indicated by several dangerous gas blowouts occurred during drillings (S. Palomba,1986; Valle Cupella, 2003; S. Maria delle Mole, 2006). The area mostly interested by gas release is located around Ciampino and at Cava dei Selci, where lethal accidents to animals and to one person have occurred. A serious gas hazard exists in morphologically depressed zones and also in basements. Since the year 2000 the main gas emission site of Cava dei Selci has been monitored by seasonal CO2 flux surveys (106 points over 6000 m2) and shows strong variations in time from 25 to 3 tons/day reflecting both a seasonal trend and changes in the rate of deep degassing. Since December 2003 is operational at Cava dei Selci, near the houses, an automatic station that records every hour the CO2 soil flux, environmental parameters and [CO2] and [H2S] in air, at 1.5 m. Results show that H2S concentration frequently reaches hazardous values of about 50 ppm. In 2006, a geochemical survey was carried out on some other urbanized areas, measuring the CO2 soil flux, indoor [CO2] and [H2S]. results indicate the presence of high gas release zones inside gardens and sport-grounds. In particular, a detailed study was carried out at Vigna Fiorita (Ciampino). More than 450 houses were investigated and some dangerous indoor conditions were found, with [CO2] values up to 10 %. In some cases also H2S indoor reached dangerous values (30 ppm). In December 2006, two continuous monitoring devices for indoor [CO2] were installed in the one of these houses; one in a bedroom at 50 cm and the second in a work-room at 25 cm. During a two month-recording period, a [CO2] background value was 2.5 % with daily peaks up to about 8 %. When windows remained closed for some days, indoor [CO2] raised to lethal long persisting values (up to 22%). In 15 days of observation the threshold of 3% was exceeded 1194 times and that of 5% 618 times. These data indicate that there is a severe gas hazard for people living on the gas emission sites of Colli Albani, and appropriate precaution measures must be adopted by residents.

Keywords: gas hazard assessment, colli albani volcano

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VS012 **Poster presentation** **6878**

Preparing for the 40 anniversary of Arenal volcano reawakening: Bringing memories from the past to shine the future of new generations.

Mr. Eliecer Duarte
Universidad Nacional - Costa Rica OVSICORI-UNA

On july 29, 1968 Arenal volcano woke up from its long near500 years nap. Some 90 human lives were taken alo ng with impo rtant patches o f grass and agriculture land. Livesto ck, ho uses a nd ro ads were swepted in a matter of few minutes. 40 years seem too far in the past to remember. Nonetheless testimonies from witnesses remain fresh in t heir me mories. Days a nd nig hts of horror will be brought vividly by those who suffered the loss of beloved ones. Su rvivors will have a chance to tell their stories. A national and international effort can brin g reso urces for a well deserved remembrance to visitors, entrepreneurs and friends of Arenal volcano. Activities will have to 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 act ivity has given researcher a p ile o f findings, do cuments a nd o pportunities to share with the co mmunity and o ther interested ones. Tourists and bystanders will be asked to participate and become involv ed in all sort of activities to ta ke place in th e mo st developed co mmunity aro und Aren al; Fo rtuna. A co mprehensive campaign sho uld include am ong others; social and cult ural activities, of ficial acts, scie ntific exhibits, meetings from different audi ences, etc. OV SICORI-UNA al ong with gove rnmental institutions, private businesses and locals will rece ive suggestions from all those participating at ci ties on volcanoes 2007 of how to better r ecall a gray pa ssage in the re cent Costa Rica's history to transform it in a fruitful lessons for the new generations.

Keywords: arenal volcano, survivors, community

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VS012 **Poster presentation** **6879**

Rapid growth of tourist infrastructure around Arenal Volcano. Implications for hazard reduction.

Mr. Eliecer Duarte
Universidad Nacional - Costa Rica OVSICORI-UNA

Rapid growth of tourism in the vicinity of Arenal volcan o provokes a pressure for a reas that ar e considered hazardous. Significant natio nal and intern ational investment is injected on a s ustained basis in all lower are as around the active cone. It is in ev erybodys advantage that this, similar to the rest of volcanoes, have been declared national parks. Despite that a land zo ning map was pro duced and ordinances implemented by the National Eme rgency Commission of Costa Rica infrastructure within and outside the saf e areas, extends. Compared with on ly two decades ago th e amou nt of shops, h otels, houses and tourist infrastructure this areas has experienced an amazing expansion. Regular agricultural and dairy hand labor has being forced to a rapid conversion along with the acceptance of qualified skills and knowledge from national and inte rnational outsiders. Measures will be needed in the near future to avoid the invasion of areas considered, up to now, safe due to the dir ection of constant pyroclasti c activity. Areas not considered in the original plan must be assessed a nd put in a risk map, sooner or later. Despite the great e conomic resou rce that an active volcano implies; safe ty of settlers, businessmen a nd tourist should be prior itized. Direct and indirect v olcanic hazards, no t co nsidered in previous studies and o ther land regulations, must be included, based on new eruptive activity patterns and new scientific findings. This study collects information fro m o ur own vo lcano mo nitoring gro up based on som e 30 ye ars of work in the ar ea. It also will combine tourist studies carried out by social researchers and other profes sionals interest ed in the top ic. Finally, a p oster will gath er graphic and textual information to visualiz e infrastructure growth in dif ferent stages of the rapid tourist boom . Use of recent aerial photographs and fieldwork data will be core to show the above mentioned changes.

Keywords: arenal volcano, tourism arenal, hazards arenal

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VS012 **Poster presentation** **6880**

Sulphur dioxide (SO2) measurements at Pos volcano using MINIDOAS. Pre, during and post phreatic activity.

Mr. Eliecer Duarte
Universidad Nacional - Costa Rica OVSICORI-UNA

Erick Fernandez, Bo Galle, Rodolfo Olmos, Mattias Johansson, Wendy Saenz, Maria Martinez

Pos volcano (10 12 00 N, 84 13 58W, elevation 2708m) is a basalto-andesitic strato volcano located 45 km N of San Jos, Capital city of Costa Rica. Its active crater hosts a hot, hyperacidic lake that shares its basin with a pyroclastic con e. There are historical accounts since 1 828 although the last phre ato-magmatic period took place in the early 1 950s. It s inten se and sustain ed degasification process ha s kept a acidifica tion alley towards the SW of about 3 km long, 1 km wide . At the end of march 2006 a series of phreatic eruptions occurred prod ucing sign ificant geomorph ologic ch anges in th e crater an d expelling mate rial ranging from fine sedi ments to met ric blo cks. Three Mini-doas campaigns are compared in different eruptive conditions, hence purpose of data collection was twofold; to gather data that feeds a database and t o compare this new da ta with precedent data from different degassing conditions. A s ulphur dioxide baseline is bei ng incorporated into volcano monitoring routines for cross control with other different methods routinely used at OVSICORI. In March 2002 the first campaign took place under what can be des cribed normal conditions. An average estimate for this cam paign is set t o 61 ton/day. In April 2006 a second campaign was depl oyed only few days after the p hreatic episode mentioned above took place. For similar traverses than those from 2002 t he estimate av erage ranges from 69 to 14 5 ton/day. Th e volume of SO2 estima tes will be later used to compare with impact assessed in the vicinity of the emission source. So me reports from th e volcano monitoring group have informed in the past about i mpact on vegetation, infrastructure an d human life. The first and thir d campaigns were carried ou t on foot wh ile the second one combined a ve hicle making tra verses beyond the summit are a. Traverses o n foot were made coveri ng about 50% of th e circumference of th e crater rim, starting in the S side, walking clockwis e. A po ster will show text and graphic infor mation about these three Mini-doas campaigns. It will also show some of the impacts on infrastructure and vegetation documented for periods between visits.

Keywords: poas volcano, human impact, sulphur dioxide

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VS012 **Poster presentation** **6881**

Do standard air filter systems protect from volcanic aerosols?

Dr. Johannes Obenholzner
NHMVolcanology NHM IAVCEI

M. Edwards, J. Parks

We could demonstrate that even after ca. 0.5 years past a fumarole vent clogging experiment, pre-filtered ambient air at room temperature could mobilize arsenic from the exposed glass wool (ca. 4000 cm). Arsenic (nanoparticles or AsH3?) passed a 0.02 m track-etch membrane filter at ca. 1L/min and got adsorbed in H2O-filled bubblers. Detected amounts of As after 3 days are very low (ca. 1 ppb). FESEM/EDS could not detect As-bearing particles on the glass wool, only on quartz surfaces exposed to the fumarole. Leaching experiments at 100C of the glass wool document 6- 4000 ppb of As. A preliminary conclusion of these data is that air filters commonly made from glass fibers can release toxic species even after a long time past a limited exposure to volcanically polluted air. It has to be emphasized that our experiment had been performed in a fumarole vent at ca. 300C for 4 hours. It is possible that many air conditioning systems designed for normal atmospheric conditions but operated in volcanic or hydrothermal areas cannot guarantee healthy in- door air quality. Our group detected phosphine (PH3) at the crater rim fumaroles and at the fumaroles along the beach at Vulcano island, Italy, as an unknown, toxic gas beside the known gas species (Obenholzner et al., 2006). A TEM copper grid exposed at the helicopter landing site at the rim of La Fossa v. dissolved after ca.3 hours pumping fumarole vapors and ambient air (ca. 1L/h). As volcanic clouds or aerosols can reach all places on Earth, a detailed chemical and physical testing of air filters and air conditioning systems is suggested. New air filter systems might be necessary to design. Natural materials i.e. peat-based products, known for excellent filtration quality of reduced S species, should be tested. Ref.: Obenholzner et al., (2006). Filtering volcanic gases: Non-random, heterogeneous nucleation on single fibers, chemical composition of adsorber fluids and a link to the hydrogen economy. Geophysical Research Abstract, vol. 8, 05721

Keywords: volcano, aerosol, filter

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VS012 **Poster presentation** **6882**

Emissions of Fogo Volcano, Cape Verde - first results of SO2, CO2 and temperature measurements

Mrs. Kerstin Pfeiffer
unemployed unemployed

EMISSIONS O F FOGO VOLC ANO, CAPE VERDEFIR ST R ESULTS OF S O2, CO2 AND TEMPERA TURE MEASUREMENTSKERSTIN PFEIFFER Grotn Felln 11, 23899 Kehrsen, GermanyIn Jan uary and Februar y 2004 first real-time measurements of volca nic gas em issions on Fogo volcano were carried out. The observations were focused on the Caldera of Fogo that is s ituated 1700 m above se a level and where the 1995 eruption site Pico Pequeno, the 2829 m high Pi co de Fogo and two villages are located. Both, the 1995 erup tion site and the Pico de Fogo show significant degassin g activity by fumaroles. The emissions of SO2, CO2 and t emperature were measured at various fumaroles as well as in the areas of settlement in order to get estimation about t he background level inside the Caldera. At each site time-series from 24h up to one week with a frequency of 30 seco nds were taken fo r CO2 and temperature. The SO2 emissions were measured by means of Mini MaxDoas. Vertical profiles were taken at the fumarole fields at Pico Peque no and Pico d e Fogo. Horizontal profiles were measured over the whole Caldera. These first investigations show significan t evidenc e fo r a high background deg assing fo r the whole Caldera. This is shown best by the CO2 va lues, which are lying above the Pett enkofer-Value (1000 ppm) even in the areas of settlement and is therefore of relevance to the population, especially if the same pathways are used by toxic me tals, which have been observed in incrustations and sublimates at Pico Pequeno [1]. Comparing the two fumaroles fiel ds at Pico Pequeno and Pico de Fogo, significant difference in their characteristics could be determined. Temperatures up to 600C were measured at Pico Pequeno wher eas the fum aroles at Pico de Fogo only reached lower temperatures up to 150C. I n contrary to Pi co Pequeno, h igh water c ontent an d the presence of H2S could be d etected at the fumaroles of P ico de Fogo . Temporal variations of the observed emissions will be shown and discussed in their relation to potentially i nfluencing factors.

[1] T. Pereira da Silva, K. Pfeiffer and M.O. Figueiredo (2005). Magma water degassing at Fogo volcano, Cape Verde: The case s tudy of hydrat ed sulphates i n fumarole sublimates and incr ustations. Ocean Island V olcanism, International Worksho p, Cape V erde, 2005.

Keywords: co2, so2, capeverde

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VS012 **Poster presentation** **6883**

A further analysis of causes of excess mortality in Central England at the time of the Laki eruption

Prof. Stephen Self
Earth Sciences The Open University IAVCEI

Linda Mcardell

We present further analysis of demographic data, temperature records, and local contemporary observations for Central England during the unusual summer of 1783, coincident with the Laki eruption in. Previous work suggested that Laki gas and/or aerosol clouds had an affect on health in and (Grattan & Durand 1998) and that anomalously high mortality in rural populations occurred coincident with the hot summer of 1783 and the ensuing cold winter of 1783 -1784 (Whitham & Oppenheimer 2005). A recent climate modelling study of the impact of Laki volcanic aerosols (Oman et al. 2006) indicated that low temperatures in winter 1783-4 could be related to Laki aerosols, but that the exceptional warmth of July-August 1783 remains unexplained (hottest July and 6th hottest July-August between 1770-1869). Our work centres on the comparatively well-documented county of Bedfordshire and on original data from parish records taken from that county. Bedfordshire is one of the counties in Central England that will record the warmest temperatures in any year.The main conclusions of this study are: 1) Excess mortality in summer 1783 was related mainly to the high summer temperatures; the time lag of peak mortality is consistent with heat related causes. 2) Earlier, summer 1781 also had high temperatures (5th hottest July and August between 1770-1869) and similar elevated mortality (see also Wrigley & Schofield 1981). However, in 1783, temperatures soared coincidentally with arrival of the volcanic haze or dry fog in central , (the 3rd hottest July in the period 1659 to present), thus a greenhouse effect by aerosols or gas in the lower atmosphere cannot be ruled out. 3) Gender and age data for rural parishes in Bedfordshire show that children suffered worse in both 1783 and 1781. We note that this is different to deaths during recent hot summers, e.g., 2003, when mainly older people died. Total numbers of deaths in summers 1781 vs 1783 in the parishes studied were similar over a four month period (July-October) but the distribution differed, each closely following the pattern of highest temperatures. Although sulphurous smells, a smoky haze, and blue air were reported from June-August 1783, it is difficult to attribute any deleterious health effects directly to these (as concluded previously by Whitham & Oppenheimer 2005). The effects of excessive heat (followed by cold in the next winter) remain the most likely causes of the extra deaths during 1783-1784.It will be difficult to form conclusive arguments for a direct volcanic cause for the high mortality reported in summer 1783 from the available demographic data as many other local factors (such as prior mortality highs or lows , and the violent storms) may play a role. However, other types of information may be forthcoming that bear on such incidents of disastrous, long-distance eruption-related effects on populations.

Keywords: laki, mortality crisis, heat

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VS012 **Poster presentation** **6884**

Public awareness - a preliminary element of risk reduction for cities

Dr. Henry Gaudru
volcanology EUROPEAN VOLCANOLOGICAL SOCIETY -UNISDR IAVCEI

Public awareness and the creation of widespread understanding about disaster reduction must be a key element in risk mamagement 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

Keywords: volcanic risk assessment, public awareness

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VS013 **6885 - 6892**

Symposium
Quantifying and expressing volcanic risk: a challenge for the Millennium

Convener : Dr. Peter Baxter
Co-Convener : Prof. Augusto Neri

The Millennium Development Goals of United Nations include halving extreme poverty and hunger by 2015, and natural disasters are recognised as potent inhibitors of development. As well as being the causes of huge economic losses. Volcanic risk is a growing problem for cities near volcanoes, especially where urbanisation is unplanned, and for many small island developing states. Eruptions can have regional and global climatic impacts which affect environmental sustainability, economic activity, travel and communications and, in this regard, risk reduction strategies are as important as early warning systems. Recent progress has been made in developing structured multi-disciplinary methods for quantifying the consequences of eruptions on human settlements and human activities. The theme of this session is methodological advances for quantifying and expressing volcanic risk for decision-making, and new approaches for reducing vulnerability. Contributions on the integration of hazard, vulnerability and exposure studies into formalised risk assessment, on ways of interfacing with civil authorities within a risk-informed approach as well as presentations of real cases are particularly welcome.

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VS013 **Oral Presentation** **6885**

Volcanological Support for Evacuation Decision-Making

Dr. Gordon Woo
Natural Hazards Risk Management Solutions IAVCEI

One of the most challenging decisions to be made in the domain of natural hazards is whether to evacuate a densely populated region around a volcano that appears to be threatening a major eruption. The economic expense of mass evacuation is high, yet the cost in possible human casualties is potentially much greater if an evacuation is not called, or is called late. Traditionally, volcanologists have communicated their expert scientific views on volcano hazard to civil protection officials, leaving the problem of decision-making to them. With the recent development of probabilistic methods for quantifying volcano hazard, and stochastic simulation of mass evacuation, volcanologists can support civil protection officials further by establishing probabilistic criteria for evacuation decision-making. Such criteria may be quantitatively expressed in terms of the proportion of evacuees owing their lives to the evacuation call.

Keywords: volcano, evacuation, decision

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VS013 **Oral Presentation** **6886**

Quantifying the risk to scientists monitoring active volcanoes

Dr. Gill Jolly
Wairakei Research Centre GNS Science IAVCEI

Brad J Scott

Volcano scientists are often perceived to be taking extreme risks in the interests of their science, and this has resulted in the tragic deaths of ca. 81 scientists in the field since 1893. Volcanoes are dangerous working environments, but are the risks as high as they seem to be? There are several active and potentially active volcanoes in North Island, New Zealand and in the Kermadec Islands. GNS Science is tasked with monitoring these volcanoes, largely through the Geonet project funded by the Earthquake Commission of New Zealand. In order to carry out monitoring activities, GNS scientists often work in potentially hazardous environments, which may be subject to a range of volcanic hazards from high levels of toxic gases to sudden onset of explosive activity. Unfortunately in March 2006, a Department of Conservation worker was sampling a crater lake on Raoul Island in the Kermadecs on advice from GNS Science when a sudden small phreatomagmatic eruption occurred. As a result, the worker is missing, presumed dead. As a consequence of this accident, it was decided to better quantify the risks to which GNS scientists are exposed whilst they are carrying out routine volcano monitoring tasks. This analysis will inform decisions about when and how monitoring should be undertaken before, during and after a volcanic crisis. The first step in quantifying risk at an active volcano is to investigate the return period for different magnitude eruptions. The 2006 Raoul Island eruption was a very small eruption, but the consequences for a person working close to the active vents were enormous. Most studies of frequency-magnitude relationships of active volcanoes have been limited to large (VEI>4 or 5) eruptions since the historical and/or geological database is limited by observations and preservation of deposits. Most volcanoes have only had detailed surveillance for a few years or decades, so detailed observations of small eruptions are few. Also, small eruptions often leave minor deposits close to the vent area which are readily eroded. In New Zealand, the frequently active volcanoes (White Island, Ruapehu and Ngauruhoe) have excellent observational records for ca. 50 years and less complete records for a further 100 years. Although the database is not perfect, particularly for earlier eruptions, average eruption rates for different magnitude eruptions can be calculated which can give likelihoods of fatalities during monitoring operations. Survival analysis of repose periods can also be achieved to give a better idea of return periods of activity that would be hazardous to a monitoring scientist close to the vent area. Results will be presented that show that routine monitoring operations on New Zealand volcanoes are within tolerable levels of risk (less than 1 in 1000 chance of a fatality per year).

Keywords: volcano, risk, monitoring

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VS013 **Oral Presentation** **6887**

Short-term oscillations on hydrothermal systems as a source of prolongated unrest at caldera volcanoes: multi-parameter insights from Nisyros, Greece

Mr. Nicolas Coppo
Institute of Geology and Hydrogeology University of Neuchtel - Switzerland IASPEI

Joachim Gottsmann, Roberto Carniel, Luke Wooller, Stefanie Hautmann

Gravity and deformation time series data are employed to quantify long term subsurface dynamics at restless calderas and for forecasting volcanic activity. Critical to the interpretation of residual gravity data in terms of magma dynamics, is the assessment of signals stemming from phenomena such as, for instance, secular variations in the level of the ground water table and the mass/density changes in active hydrothermal systems. Our earlier study at the restless Nisyros caldera in Greece revealed short-term (40-60 min) gravity variations with amplitudes similar to those observed during annual microgravimetric surveys. We speculated that these short-term variations might be caused by the hydrothermal/magmatic degassing processes. In this paper, we report results from multi-parameter observations made at the caldera in May 2006, using one continuously recording gravimeter, two field gravimeters, three GPS receivers, one seismometer and one very-low-frequency (VLF) receiver. The obtained multi-parameter time series reveal non-steady short-term oscillatory signals. The dominant period of oscillation (40-60 min) indicates short-term processes most likely associated with instabilities in the degassing process, causing thermohydromechanical disturbances of the hydrothermal system. These disturbances constitute the majority of geophysical signals recorded at the ground surface and hence dominate activity at this restless caldera. Our analysis presents an important quantitative study of the background dynamic processes at a restless caldera. Aqueous fluid migration must be regarded as an important mechanism for prolongated unrest periods and efforts should be made to obtain multi-parameter continuous time series. Magmatic signals must exceed shallow hydrothermal signals in order to be seen during geophysical monitoring programs.

Keywords: short term oscillations, hydrothermal system, multi parameters surveys

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VS013 **Oral Presentation** **6888**

Real time volcanic hazard evaluation during a volcanic crisis: BET_EF and MESIMEX Experiment

Dr. Warner Marzocchi
Sezione di Bologna Istituto Nazionale di Geofisica e Vulcanologia IAVCEI

Laura Sandri, Jacopo Selva, Gordon Woo

We have developed a fully Bayesian method called BET_EF (Bayesian Event Tree for Eruption Forecasting), useful for computing and visualizing volcanic hazard and eruption forecasting. Physical and volcanological models, past data from Vesuvius and "analog" volcanoes eruptive history, and monitoring measures commonly taken at Vesuvius have been used to set up the parameters of the probabilistic model. 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. We have applied the method in real time during the MESIMEX (Major Emergency Simulation Exercise) exercise, held in Naples during 18-23 Oct. 2006, in order to upgrade the probabilities of interest according to the evolving scenario assumed during the experiment. On purpose, no personal communication between the monitoring personnel or other people in Naples and our group running BET_EF in Bologna has occurred during the experiment. Thus, BET_EF results are based, regarding the input of monitoring data, only on the official communications published on MESIMEX web site in real time. No substantial correction has been made after the end of the experiment. This was the first time a quantitative volcanic hazard estimate in real time has been provided in Italy, based on all the available information including real time monitoring. Such quantitative estimates of volcanic hazard in real time might significantly help Civil Protection Authorities in managing a real volcanic crisis. For example, where stochastic simulations of mass evacuation and cost/benefit analysis are available, a probabilistic hazard assessment can quantitatively support Authorities in evacuation decision-making.

Keywords: eruption forecasting, vesuvius, mesimex

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VS013 **Oral Presentation** **6889**

A comprehensive hazard and risk map for the areas exposed to active volcanoes in Campania Region (southern Italy)

Dr. Ines Alberico
C.I.R.AM. Univeristy of Naples Federico II IAVCEI

Lirer Lucio, Petrosino Paola

The active volcanoes of Campania, Somma-Vesuvio, Campi Flegrei and Ischia is land are located in the most densely populated area of the region, where ab out 3,5 milli on of people live. By comparing the volcanic hazard maps available at present, the presence of some areas exposed to risk from more than one volcanic s ource emerges. Among these areas, we can highlight part o f the city of Napoli, with its very high population rate.For this reason, a comp rehensive vo lcanic ha zard map, mer ging the area s possibly endangered by the si ngle volcanic sources, is fundamental for Local Authorities and Territorial Agencies that deal with territorial planning and risk mitigation.For dra wing this map all the areas reached by the explosive products of the past 10 ky B.P. eruptions were considered exposed to hazard, taking into acc ount the whole set of eruptive mech anisms occurred. In the investigated age range the Somma-Vesuvio reveals the recurrence of highly ex plosive events (VEI: 4, 5) followed by repos e periods, during which low VEI strombolian and/or vulcanian (VEI: 3) events took place. At Campi Flegrei the most frequent eruptions, with VEI of the order of 3 and 4, are characterised by the emplacement of pyroclastic flow and surge deposits erupted from different vents scattered over a 150 km2 wide caldera; only two eruptive events emplacing widespread fall products are recorded. The Ischia Islandin the last 10 ky B.P., mainly encompass ed both magmatic and hydromagmatic monogenic eruptions, whose most recurrent VEI was 3, and only rare episodes exceeded this threshold.The results of about 80 simulations of VEI =4 events pyroclastic density current s at both volcanic fields and t he emplacement areas of the pyroclastic flows occurred in the last 10 ky B.P at Somma Vesuvio were taken into account for drawing the comprehensive map. At t he same aim, the thickn ess data of the fall products emplaced by Camp i Flegrei and Somma-V esuvio were suitably processed. In the map the high hazard areas correspond to the plains for both volcanic field, and the ar ea most endangered by Somma-Vesuvio is located East of the volcano. Furthermore, the occurrence of an ar ea, located east and nort h-east of Somma-Vesuvio, reached by both the Somma-Vesuvio and C ampi Flegrei pyroclastic fall d eposits can be highlighted.The exposed value , expressed a s the populati on density distribution, displays a high variability in the investigated ar ea. This parameter strongly controls the volcanic risk, since municipalities falling in the same hazard z one often display very differe nt risk values as a consequence of the diff erent population rates.The reliability of the vo lcanic risk map here pr esented is guaranteed by the usage of analysis of data distribution, an univocal and objective criterion for the definition of volcanic hazard and exposed values classes.

Keywords: campanian volcanoes, volcanic hazard, volcanic risk

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VS013 **Oral Presentation** **6890**

Probabilistic digital hazard maps for avalanches and pyroclastic flows using TITAN2D: application to Pico de Orizaba, Mexico

Prof. Michael Sheridan
Geology Department University at Buffalo IAVCEI

Abani K. Patra, Keith Dalbey, Bernard Hubbard

Geologists create volcanic hazard maps using scientific data to portray potential future geological events; the end users are principally public safety officials. Typical maps use a few simple polygons to outline areas of potential inundation or cover by a few categories of flows based on past frequency and size. Uncertainties in data regarding flow characteristics complicate the construction of accurate hazard maps. Generally there are inadequate exposures of good sections, poorly known extents of units, and imprecise volumes for deposits. Crisis conditions limit the time available for field and laboratory work. Computer models can simulate possible scenarios, but the volumes, styles of emplacement, and locations of starting locations are poorly known in many cases. The large uncertainty in initial conditions is seldom taken into account in the construction of hazard maps and these uncertainties are rarely passed on to the end-users of the maps. Titan2D is a new computational model for volcanic block and ash flows and rock avalanches of various types and scales and forms the core of the new Titan environment for volcanic hazards analysis that can integrate modeling, high-performance computing, database management, visualization, and collaborative environments to a very sophisticated level. Titan provides a solution to mapping problems by providing a probabilistic calculation of inundation depth that takes into account many of the critical uncertainties using a PCQ methodology to reduce computation time. We show that a useful hazard map can be based on a probability analysis in which the uncertainty in initial parameters and boundary conditions is specified. We illustrate the case of mapping potential inundation areas for future block-and ash flows at Volcn Citlaltpetl (Pico de Orizaba), . The probabilistic hazard mapping assumes a uniform distribution of input initial volumes of flow ranging from 0.5 to 4.0 x108 m3. Basal friction angle is a very sensitive parameter. For this reason we created another map illustrating the uncertainty in basal friction with a uniform probability distribution between 22 and 12 degrees. The results for the PCQ analysis can be directly compared with the earlier methodology used for the existing hazard map.

Keywords: titan, probabilistic, hazard

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VS013 **Oral Presentation** **6891**

The 1530 A.D. sub-Plinian eruption of La Soufrire (Guadeloupe): Eruption scenario and modelling of tephra dispersal with implications for hazards assessment

Dr. Jean-Christophe Komorowski
volcanology Member Executive Committee of IAVCEI IAVCEI

Yoann Legendre, Benoit Caron, Georges Boudon

La Soufrire de Guadeloupe is a complex stratovolcano characterized in the last 15 000 years b y recurrent of dome eruptions alternating with numerous flank-collapse events. Only 6 phreatic explosions occurred in the last 372 years without direct involv ement of magma separate d by periods of hydrothermal activity and seismic unrest of variable intensity and duration. The last magmatic eruption of Soufrire of Guadeloupe dated at 1530 AD (Soufrire eruption) was accompanied by flank-collapse and emplacement of a debris-av alanche followed by an explosive eruption. It produced a bout 0,059 km3 DRE (dense-rock equivalent) o f magmatic pro ducts. We use field d ata and a wind field mode l ellaborated from atmospheric radiosoundings to be tter reconstruct for the dynamics of the explosive phase of the Soufrire eruption. The subplinian VEI 2-3 phase 1 produced a short-lived column that reached a height between 9 and 12 km and that lasted from 32 minutes to 1h13 during which about 3.9 x 10^6 m3 DRE of juvenile products where explos ively erupted. The column recurrently collapsed generating scoriaceous pyroclastic flows in radiating valleys up to a distance of 5-6 km with a maximum interpolated bulk deposit volume of 11.7 x 10^6 m3 (5 x 10^6 m3 DRE). We estimate the subplinian magma DRE mass eruption rate between 5.4 4 x 10^6 to 2.39 x 10^6 kg.s-1 and a magma volumetric DRE flux of 2027 to 891 m3.s-1 and a total DRE erupted mass of 1.72 x 10^10 kg (juvenile+accidental) typical of moderate sub-plinian eruptions. The eruption ended with growth of a lava dome (50 x 10 ^6 m3). We have used HAZMAP, a numerical simple first-order model of tephra dispersal (Macedonio et al., 2005) to reconstruct to a first approximation the pote ntial dispersal of t ephra and associated tephra mass loadings and static load generated by the 1530 A.D. Phase 1 eruption. Our results provide volcanological input parameters for scenario and even t-tree definition, for assessing volcanic risks and evaluating their impact in case of a future sub-plinian eruption which could affect up to 60 000 people in southern Basse-Terre island and the region. They also provide a framework to aid decision- making concerning land managemen t and develo pment. This is o f particular relevance beca use a subplini an eruption is the most likely magmatic scenario in case of a future eruption of this volcano which has shown, since 1992, increasing signs of low-energy seismic, thermal, and acid degassing unrest without significant deformation.

Keywords: la soufriere, tephra, hazards

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VS013 **Oral Presentation** **6892**

A decison model for evacuation planning at Nyiragongo volcano, DR Congo

Dr. Peter Baxter
Public Health & Primary Care Cambridge University IAVCEI

William Aspinall, Jean-Christophe Komorowski, Wally Gilks

Volcanologists first advised humanitarian agencies on the risk to refugees camped on the flanks of Nyiragongo volcano, Democratic Republic of Congo (DCR), after thegenocide and exodus in 1994-96. In recentyears over 4 million people have died inEastern DCRin one of the worlds worst humanitarian crises. Nyiragongo has threatened the population of Goma ever since the eruption of 17 January, 2002, when two lava flows devastated the city centre and the homes of 120,000 people, leading to the loss of about 150 lives. About 300,000 people fled the city. The competing risks to life from a future eruption and the dangers of a planned evacuation of 500,000 people, even for short periods, in an area of humanitarian crisis was studied using a decision model and an event tree developed from a comprehensive risk assessment by an international team of scientists. Estimates of deaths from infectious diseases and conflict in a planned relocation by humanitarian agencies along the lake shore were compared to the estimated average loss of life from a maximum credible eruption in a failed evacuation. The worst most likely eruption scenario is a phreato-magmatic explosion with base surge occurring in a rifting lava eruption close to theshoreofLake Kivu. A catastrophic gas burst of carbon dioxide and methane accumulated over time in the lake depths could be triggered by a lava eruption at the bottom of the lake, but this has a much lower probability. A simple mathematical definition of expected loss incorporating the event tree probability of a base surge was used in the decision model to show the extent to which planning was needed to reduce the loss of life in temporary camps, in order to justify the decision to evacuate to protect against the volcanic threat once the rifting eruption started. The role of scientists in risk assessment in natural disasters occurring in the setting of complex emergencies is poorly understood by humanitarian workers and decision tools need to be more widely used in disaster mitigation.

Keywords: evacuation, decision, model

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VS015 **6893 - 6918**

Symposium
New Techniques using Remote Sensing Data for Volcano Monitoring and Analysis: Observations, Integration, Hazard Assessments and Modeling

Convener : Prof. Ken Dean
Co-Convener : Dr. David Rothery

The use of remote sensing data and modeling to monitor and analyze volcanoes, and to assess hazards, has significantly improved over the past few years. These data provide a better understanding of eruption processes, distribution of eruption deposits and hazard assessments. New sensors have been launched that provide various facets of resolution not previously available. The number of satellites with hourly to daily coverage has increased, and some of these have pixels as small as 250 m pixels and as many as 36 spectral bands. Moderate spatial resolution sensors provide multi-spectral bands in visible and IR wavelengths with pointing capabilities that can provide coverage every few days. Data with spatial resolution up to 60 cm are also available. Due to these improvements, subtle increases in activity and volcanic processes can now be detected, measured and analyzed, such as increases in thermal flux and details in the structure and composition of volcanic clouds and deposits. Modeling has also become an important tool for prediction of activity using DEMs to analyze topographic change and wind-fields to predict the movement of volcanic clouds. New field-instruments, such as TIR cameras, radiometers, and webcams detect volcanic processes not seen from satellites and provide calibration and validation of satellite data. Parallel to sensor developments, improvements in connectivity, infrastructure and web browsers have resulted in better and more timely analysis capabilities and data distribution. Satellite data are now received by local stations to provide real-time images to monitor and assess volcanoes in Italy, Central America, Alaska, Hawaii, Kamchatka and other regions. Contributions on the use of these new remote sensing systems and techniques to analyze or model volcanoes, eruptions and hazard assessments are encouraged for this session. Also, with the aging of moderate resolution sensors (e.g. ASTER and Landsat), we encourage presentations on replacement or development of new sensors to fill this void.

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VS015 **Oral Presentation** **6893**

Monitoring Remote Volcanoes: Satellite Remote Sensing at the Alaska Volcano Observatory

Dr. John Bailey
Alaska Volcano Observatory Postdoctoral Researcher IAVCEI

Kenneson Dean, Jonathan Dehn, Peter Webley, Ray Skoog, Lovro Valcic

The Alaska and Aleutian Arc area of the North Pacific represents one of the most volcanically active regions in the world. It is home to over 100 Holocene volcanoes, over 40 of which have experienced observed eruptions, which represents almost 10% of the worlds active volcanoes. Although many of these volcanoes are located far from Alaska s population centers, volcanic activity still poses a serious threat to human life and activities due to the high volume of air traffic passing over the region. Millions of dollars of freight and over 20,000 passengers fly over the Aleutian Arc every day (Miller and Casadevall, 2000) on air routes between Asia and North America, and following circum-polar routes to Europe. The problem with monitoring these volcanoes is that they are spread across ~3 000 km, with many lying in remote areas that often experience poor weather conditions. Currently less than half of the regions volcanoes are monitored by seismic networks, with the logistical and financial restraints making expansion a difficult proposition. Direct ground or airborne observations would be a sporadic and unproductive method of monitoring. Conversely, Alaskas high latitude location, allows frequent satellite coverage as the tracks of polar orbiting satellites converge and overlap near the pole, providing a robust means to regularly observe activity across all of the regions volcanoes. The Alaska Volcano Observatory Remote Sensing Group (AVORS) primarily operates using data from three groups of satellites sensors: Geostationary Operational Environmental Satellites (GOES) imager, Advanced Very High Resolution Radiometer (AVHRR) on the NOAA satellites, and Moderate Resolution Imaging Spectroradiometer (MODIS) on NASAs Terra and Aqua EOS satellites. The AVHRR and MODIS data are acquired through onsite receiving stations at the Geophysical Institute (GI), University of Alaska Fairbanks (UAF). Additional AVHRR coverage is provided by NOAAs Gilmore Creek Tracking Station. GOES data is supplied by the Naval Research Laboratory at Monterey Bay, California, USA. For analysis purposes automated processing systems divide the datasets into 10 sectors that cover the volcanic regions. All images for each region are then checked by AVORS analysts to identify any new or ongoing volcanic activity. These checks are made twice daily under normal conditions, more frequently during times of elevated alert status or eruption. Constant monitoring is also performed by automated algorithms designed to identify possible volcanic activity, and generate emails and text messages alerting duty personnel. During each monitoring shift the analyst views all new data acquired since the previous session, using a proprietary image analysis software package. The analyst identifies thermal anomalies and volcanic clouds/plumes, recording their observations in a database accessed through a web-based interface. This interface is one of several new tools that have been developed by AVORS to support viewing and interpretation of the data using web-based Graphical Users Interfaces (GUIs). Further interpretation is also aided by modeling programs (e.g. Puff, a volcanic ash tracking model) and visualization tools (e.g., Google Earth).

Keywords: aleuatians, avhrr, air traffic routes

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VS015 **Oral Presentation** **6894**

Volcanic Ash Modeling for North Pacific Volcanoes: Automated Operational Monitoring

Dr. Peter Webley
Arctic Region Supercomputing Center (ARSC) University of Alaska Fairbanks (UAF) IAVCEI

Kenneson G. Dean, Rorik Peterson

There are over 100 active volcanoes in the North Pacific (NOPAC) region, most of which are located in uninhabited areas. The region is remote and vast (5,000 km by 2,500 km) but sparsely populated. These volcanoes erupt many times per year, from 1975 2006 there were over 100 separate volcanic ash clouds reaching at least 20,000 ft and ejecting ash to a range of altitudes and jeopardising aircraft safety. The Alaska Volcano Observatory (AVO) operationally monitors these volcanoes and is a joint program of the United States Geological Survey (USGS), the Geophysical Institute of the University of Alaska Fairbanks (UAF/GI), and the State of Alaska Division of Geological and Geophysical Surveys (ADGGS). Satellite imagery and dispersion models are critical to detect and track the movement of eruption clouds. Dispersion models predict ash cloud movement while satellite images provide ground truth and model initialization parameters. The integration of dispersion modeling and satellite imagery will assist operationally in determining the airborne hazards that ash clouds can cause. Puff is a three dimensional dispersion model used at AVO and is primarily designed for forecasting volcanic ash dispersion. Model simulations place hypothetical particles of various sizes above a selected volcano and track particle movement in a gridded wind field. Numerical weather prediction (NWP) model wind fields are used for real-time operational predictions and re-analysis wind fields for post event analysis. We show how remote sensing data and dispersion modeling predictions from Puff can be integrated to provide more accurate forecasts of ash cloud movement. Operationally, as of February 2007, Puff is used to monitor potential eruptions at nine volcanoes within the NOPAC region and six more worldwide. The predictions are generated automatically every three hours for the NOPAC region and every six hours for the other volcanoes. Initial predictions are made for initial ash plumes at heights ranging from 4 to 20 km and for a 24 hr forecast period. This information is then made available via the Puff website, updating automatically without any user interactions. Virtual Globes have become widely used for visualization in the scientific environment, displaying two/three dimensional geophysical data operationally and retrospectively. Here we show how the automated predictions are generated and displayed for operational monitoring. In addition, we show operational Puff predictions in three dimensions in Google Earth, both as iso-surfaces and as particles, and study past eruptions to illustrate the capabilites that Virtual Globes provides.

Keywords: ash, modeling, dispersion

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Comparison of field- and satellite-derived thermal flux during the May-July 2003 eruption at Piton de la Fournaise

Dr. Diego Coppola
Dipartimento Scienze Mineralogiche e Petrologiche University of Turin IAVCEI

Mike James, Thomas Staudacher

We present thermal flux measurements made by high resolution ground-based (a hand-held FLIR camera) and low resolution space-based (MODIS) techniques of the active lava field during the last days of the May-July 2003 summit eruption at Piton de la Fournaise (La Runion). Ground-based thermal images were merged (to provide full coverage of the flow-field), corrected for viewing distance and then orthorectified, allowing the at-surface radiance emitted by the lava field during the ongoing eruption to be estimated. Radiance values of MODIS pixels alerted by the MODVOLC algorithm were used to estimate the at-sensor heat flux from the same flow field. The comparison reveals that the MODIS-derived heat fluxes were only 40-65% of the ground-based measurements. We interpret this discrepancy as a consequence of atmospheric attenuation effects on the radiance reaching the MODIS sensor, coupled with the effect of high satellite zenith (>40). Finally, we show that due to the exponential temperature distribution of the lava fields (obtained from thermal images), the MODIS-derived heat flux is very sensitive to the heat released by flow surfaces between 1 and 50 hours old. This supports the idea that effusion rates estimated from MODIS data represent values averaged over the preceding few days, and do not necessarily accurately represent the instantaneous effusion rate at the time of data acquisition. Our results reveal the importance of ground-based thermal monitoring for aiding the interpretation of satellite measurements, particularly in terms of calculating effusion rate trends.

Keywords: field thermal imaging, modis radiance, thermal flux

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Detecting and discriminating volcanic terrains on Mercury: a MIXS message

Dr. David Rothery
Earth Sciences Open University IAVCEI

James Carpenter, George W Fraser, The Mixs Team

MIXS is the Mercury Imaging X-ray Spectrometer. Orbital X-ray spectrometry relies on X-ray fluorescence of the surface stimulated by incident solar coronal X-rays. It works only on airless bodies, and so far has been done on the Moon (famously by Apollo 15 and 16) and on two near-Earth asteroids. MIXS will fly to Mercury on BepiColombo, which is a major European Space Agency mission scheduled for launch in 2013.and insertion into orbit about Mercury in 2019. The only mission to Mercury so far was Mariner 10, which provided panchromatic visible images of less than half the surface and extremely limited colour information. A NASA mission called MESSENGER will fly past Mercury in 2008 and achieve orbit in 2011. Our knowledge of Mercury is thus currently extremely limited. Mercury is the innermost terrestrial planet. It is smaller than Mars but bigger than the Moon. It has a very high uncompressed density, suggesting a large core, but its mantle and crust are silicates. Spectroscopic data obtained by telescope show a surprising deficiency of Fe-O at the surface (1-3% at most). We do not know how much of its crust is primary crust (crystallized from a magma ocean) and how much is secondary crust (originated by partial melting if the mantle, and emplaced volcanically). Mercury lacks the clear albedo contrast displayed on the Moon between pale highland primary crust and darker maria secondary crust. Terrains that appear on Mariner 10 images to be relatively young (on the basis of having fewer superposed impact craters) might be volcanic but they could also have been resurfaced by sheets if impact ejecta. Elemental abundance mapping by MIXS and mineralogical mapping by BepiColombos visible and infrared imaging spectrometers should resolve this ambiguity and enable models for magmagenesis and eruption processes on Mercury to be put on a sound basis. The conventional non-imaging collimated channel MIXS-C will allow for low resolution mapping but high sensitivity whereas MIXS-T, the first true imaging X-ray telescope to be used in planetary science, will achieve spatial resolution of smaller than 20 km under favourable solar flare conditions. Detectable elements will be Si, Ti, Al, Fe, Mn, Mg, Ca, Na, K, P, S, Cr and Ni. There is thus no element that is likely to be more abundant than about 0.1% that MIXS will be incapable of detecting.

Keywords: mercury, volcanism, x ray

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Near realtime monitoring of active volcanoes in east Asia using satellite data

Dr. Takayuki Kaneko
Earthquake Research Institute University of Tokyo IAVCEI

Kenji Takasaki, Atsushi Yasuda, Martin J. Wooster

We developed a near real- time monitoring system for 15 0 active volca noes in east A sia. The system uses visible and infrared images from the MODIS and MTSAT sensors mounted onboard the Terra/Aqua series of polar orbiting satellites and the MTSAT series geostationary satellites, respectively. MODIS data being down-linked to Institute of Industrial Science, University of Tokyo and also those stored at the NASA site are used. MTSAT data are directly received and processed at Earthquake Research Institute, University of Tokyo. The results and analyse s of the MODIS infrared observations, essentially thermal images and time-series radiance trends of each vo lcano targeted, are automa tically uploaded on the WWW. Both visible and infrared images of MTSAT are renewed every 60 minutes on the WWW, which is useful for early detecting vo lcanic eruptions. In th is way it is planned that volcanologists and other interested parties might use the MODIS data as a broad check on the surface therm al state of the volcanoes they are studying and may apply their own interpretations to any identified heating or cooling trend. Using this system, we analysed the 2004-2005 eruption of Asama, in conjunction with the data from ground-based instruments obtained simultaneously. In the time-series variation of the MODIS data in this period, four thermal pulses were observed, each of which occurred several weeks after the dyke intrusion at a deep level, as suggested by the GPS ground deformation measurements. The first and the second pulses involved Vulcanian or Strombolian eruptions, whereas the third and the fourth ones were non-eruptive activity. This means that m agma prob ably reached a s hallow level of the conduit (1km bellow sea level) even if eruption did not occur, once magma was supplied to a deep level. On the other hand, the first thermal pulse started rising a co uple of we eks ahead of t he beginning of the eruption. This indicates that magma had reached a shallow level then. Such a pre-eruption thermal anomalies is important for detecting a sign of co ming volcanic eruption, with the satellite-based monitoring system. This will be particularly useful in the remote areas of east Asia. The web site for the MODIS and MTSAT-based system is accessible at the URL: http://vrsserv.eri.u-tokyo.ac.jp/REALVOLC/.

Keywords: volcanoes, remote sensing

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VS015 **Oral Presentation** **6898**

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

Dr. Sonia Calvari
Sezione di Catania Istituto Nazionale di Geofisica e Vulcanologia IAVCEI

Thermal imaging has recently 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 then to reveal volcanic activity within the craters even through the thick curtain of gases usually released by active volcanoes such as Mt Etna and Stromboli. 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 from helicopter 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. Thermal cameras have also been used to calculate the effusion rate, the most important parameter to estimate maximum lava flow length, and also to detect ash plumes on Etna in good weather conditions. However, the three most recent eruptions on Etna, occurred on 2004-05, July 2006 and August-December 2006, did not show evident thermal anomalies on the summit craters before the opening of eruptive fissures. Thus, the role of thermal anomalies and their meaning should be compared to and discussed with other geophysical data in order to understand when and if these data can be used to forecast eruptions.

Keywords: monitoring, basaltic eruptions, thermal surveys

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VS015 **Oral Presentation** **6899**

Rapid Response to Volcanic Eruptions with an Autonomous Sensor Web, as Demonstrated with EO-1 during the December 2006 Nyamulagira, DR Congo, Eruption.

Dr. Ashley Davies
IAVCEI

Robert Wright, Philip R. Kyle, Rebecca Castano, Steve Chien, Daniel Tran, Jean-Christophe Komorowski, Mahinda Kasereka Celestin, Daniel Mandl, Stuart Frye

In a volcanic emergency, time is of the essence. The response time between dete ction of volcan ic activity and the retasking of spacecraft to obtain observations of an eruption, is greatly reduced through use of autonomous systems, for seeking out alerts, pl anning spacecraft operations, processing the data, generating results, and disseminating the info rmation. These capabilities have been demonstrated by the Volcano Se nsor Web, bas ed at NASA s Jet Propulsi on Laboratory. This autonomous s ystem collates information of volcanic activity from numerous a ssets and retasks the EO-1 spac ecraft to obtain observations of the target volcano as soon as practicable. The use o f a ground-based planner allo ws rapid insertion or replacement of new observations, with no huma n intervention. End-users are notified automatically by email. Hyp erspectral data collected by the Hyperion onboard EO-1 are processe d onboard, and indications of the extent and magnitude of thermal emission are delivered to scientists on the ground, typically within 2 hours of data acquisition. The system proved its worth in December 2006, rapidly responding to the detection of an as h plume from Nyamulagira, DR Congo, retasking the EO- 1 spacecraft, obtaining and pro cessing the Hyperion spectrometer data, and sending the result to the ground. The f ull dataset was transmitted to users within 24 ho urs. M anual pro cessing (now bein g automated) allowed precise location of the main ve nt, at t he time not known to within a few km. This information was transmitted to volcanologists in the field within 30 hours of the observation. These data allowed preliminary estimate s of the number and a lignment of ve nts and th e resulting lava flow, resulting in useful estimates of potential lava flow volume and flux rate in terms of initial risk assessment by local volcanologists, who had difficulties accessing the vent. This work was carried out at the J et Pro pulsion Labo ratory-California Institute o f T echnology, under co ntract to NASA. W e acknowledge the contributions to this work of Paolo Papale and colleagues at INGV-Pisa, and a grant to AGD from the NASA AIST Program.

Keywords: remote sensing, volcanoes, sensor web

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VS015 **Oral Presentation** **6900**

Satellite monitoring of volcanoes at the global scale

Dr. Robert Wright
Hawaii Institute of Geophysics and Planetology Hawaii Institute of Geophysics and Planetology IAVCEI

Andrew Harris, Luke Flynn

To accommodate the wide geographic, and sporadic temporal, distribution of volcanic eruptions requires a monitoring s ystem that employs a sensor with a 100% duty cycle, and an analysis s ystem that can process hundreds o f images (equivalent to hundreds of gigabytes o f data) in nearrealtime. Effectiv e communication of results to e nd-users requires that such a system provides quantitative data regarding the physical properties of the detected therma l anom alies in a sta ndardized for mat, and at a manageable data rate. In this pres entation, we wi ll descr ibe the f undamental properties of a system designed with these goals in mind. MODVOLC, whic h uses infrared dat a acquired by NASAs MODI S sensors to detect volcanic th ermal anomalies at Ea rths s urface, has be en o perational since February 2000. Since this time, over 1.5 million MODIS images (~300 terabytes) ha ve been analyzed, the results of any positive identification even ts being made av ailable on the inte rnet within ~12 hours of satellite overpass. We will describe s ome of th e p ros an d con s of th is gl obal volcano mon itoring system. Advantages st em from the f act that the algorithm is embedded in the NASA/Goddard Space Flight Center MODIS pro cessing chain (PGE-03.) As a resu lt, MODVOLC has acc ess to the entire MODIS data stream within hours of primary data collecti on. This has al lowed us to a) provide a tool for passively monitoring all of Earths activ e and po tentially active volcanoes in near-r eal-time, and b) to build up a seven year ar chive of therm al emission fr om almost 70 volcanoes around the globe. We will show examples of how such long-term monitoring, at the glo bal scale, provides unique insig hts in to the styl e and intensity of terrestrial v olcanic activity . Ho wever, dir ect and near-real-time acces s to the entire MODIS d ata stream comes at a cost, most evident as a relatively high detection threshold, a result of the restrictions placed on dev elopment of MODVOL C by GSFC Detecting and documenti ng radiant flux from an erupting volcano provides, in itself, limited insights into volcan ic processes. We will conclude by discussing how value can be added to satellite-derive d radiance data of active volcanoe s via a) their incorporation into near-real-time lava flow forecasting models, and b) th eir use as one node of a mor e comprehensive volcano "sensor-web".

Keywords: satellite, volcanology, radiometry

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Remote sensing of volcanic clouds in the moist tropics for aviation safety

Mr. Andrew Tupper
Northern Territory Region Bureau of Meteorology, Australia IAVCEI

Fred Prata, Simon Carn, Daniel Rosenfeld

Three things are essential for detecting and tracking volcanic ash clouds for aviation safety: good ground-based information about the eruption or potential for eruption, good dispersion and trajectory modelling, and good remote sensing. All are problematic. Remote sensing of volcanic clouds in the moist tropics can be particularly difficult because large eruptions with clearly detectable ash using the reverse absorption technique are the exception rather than the rule in the tropics, although the technique itself remains highly useful. The use of reflective wavelengths at 3.9, 2.1, 1.6 & 0.415 m all help detect ice-rich and opaque volcanic clouds during the daytime. Retrieval of the effective particle radii, despite the limiting assumption of particle sphericity, is a very powerful technique for detecting ash-polluted clouds. SO2 detection in ultra-violet and infrared wavelengths is also very effective in tracking ice-rich, ash-poor volcanic clouds. Some ice-rich clouds, such as from the eruptions of Manam, Papua New Guinea, can be tracked for many hours by following the strongly positive reverse absorption signal, caused by a combination of ice content and small particle size. Despite this, our remote sensing is still not adequate to track volcanic clouds for aviation purposes. For example, diffuse volcanic cloud from Reventador in Ecuador, South America, most likely caused minor damage to a commercial aircraft north of Papua New Guinea on the other side of the Pacific. Our best practice remote sensing was able to track the ash cloud for 7 days, but not for the full 20 days between the eruption and the encounter. Detection of both eruption clouds and volcanic hot-spots can also be severely inhibited during monsoonal periods, to the point of being completely unreliable.

Keywords: remote sensing, volcanic ash, aviation safety

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Coincidental subsidence during cryptodome formation revealed by precise DEM analysis - Mt. Usu (1977-82) and Mt. St. Helens (1980)

Dr. Jun Okada
Institute of Seismology and Volcanology Faculty of Science, Hokkaido University, Japan
IAVCEI

Hiromu Okada

Mt. Usu is an active dacite volcano in Japan. Three lava domes and nine cryptodomes have been emplaced on the edifice since 1663. A new crypto dome Usu-Shinzan (maximum apparent height change: +273 m by DEM) was born during the 1977-82 activity. The doming deformation was investigated by means of Digital Elevation Model (DEM). Precise DEM (1 m grid) were newly developed by large-scale topographic maps (1:2,500 and 1:5,000 with contour interval: 2 m and 5 m) for several periods. The analysis of differential DEM before and after the 1977-82 intrusive episode 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 lava domes, Ko-Usu, Oo-Usu, and Ogariyama. Asymmetric graben was formed along the merge of Usu-Shinzan U-shaped block. Lava domes subsided in the graben significantly (-10 m to -70 m). The central part of Ko-Usu lava dome (300 m in diameter) subsided. Total volume loss of Ko-Usu was estimated as 2.3X106 m3. Most of the subsidence occurred from August to early November, 1977 accompanying with the occurrence of intensive earthquake swarms (earthquake family) beneath Ko-Usu. Similar volcanic subsidence has been reported at Mt. 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 Mt. St. Helens on March-May in 1980, DEM was also created for Mt. St. Helens.The remarkable bulging of north flank, significant subsidence of the pre-existent summit lava dome, and the occurrence of intensive shallow earthquake swarm were quite similar phenomena in both doming activities between Mt. Usu in 1977-82 and Mt. St. Helens in 1980. Rapid intrusion rate (1-3X106 m3/day) and graben formation were a clear evidence of the progressive dike intrusion beneath the summit in the early doming stage. Remarkable lateral ground movement such as U-shaped faulting (Mt. Usu) or north flank bulging (Mt. St. Helens) strongly suggested the following lateral growth of cryptodome. Fortunately, 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. The dike intrusion allowed not only the summit graben formation, but also repeated slips at the root of lava domes which may produce the shallow earthquake swarms beneath the lava dome. The total increased volume was nearly equivalent in order between Mt. Usu in 1977-82 and Mt. St. Helens March-May in 1980. The common physical process of dacitic magma intrusion exists between them, that is a rapid dike intrusion and the 108 m3 orders of the lateral growth of cryptodome (J. Okada, 2007). The topographic analysis utilizing precise DEM is one of the most powerful tools for evaluating huge amount of deformation such as doming deformation.

Keywords: usu, mount st helens, dem

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VS015 **Oral Presentation** **6903**

Characterization of Volcanic Eruptions using Remotely Sensed Data

Prof. Jonathan Dehn
Alaska Volcano Observatory University of Alaska Fairbanks IAVCEI

Ken Dean, John Bailey

Decades of remotely sensed data of volcanic eruptions world-wide have allowed us to characterize their patterns in spectral, temporal and spatial domains. Beyond the use of brightness temperature to determine if a volcano is on or off, it is now possible to estimate and detect changes in ground temperature, and classify the type of activity. Recently automated alarms using satellite data have been developed to warn of thermal anomalies and even ash eruptions at volcanoes. Here we will review published models of detecting thermal activity (MODVOLC, VAST, RAT and Okmok), and unveil the Okmok II algorithm. This new model detects anomalies, effectively filters noise, calculates effusion rates and suggests eruption type based on the temporal, spectral and spatial features of the thermal anomaly. The algorithm is being run retrospectively through an archive of 15 years of data for the North Pacific. In addition a volcanic- ash detection algorithm has been developed based on the Okmok II model. This model goes beyond looking at a split-window signal, and performs rudimentary pattern recognition to eliminate erroneous signals caused by weather. Both of these models are in use at the Alaska Volcano Observatory.

Keywords: thermal imaging, ash clouds, remote sensing

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VS015 **Oral Presentation** **6904**

Monitoring of Mt. Etna 2006 eruption using AVHRR data

Dr. Valerio Lombardo
Istituto Nazionale di Geofisica e Vulcanologia Centro Nazionale Terremoti IAVCEI

Stefania Amici, Maria Fabrizia Buongiorno, Laura Colini, Stefano Corradini, Fawzi Doumaz, Massimo Musacchio, Claudia Spinetti

Between July and December 2006 an eruption occurred on Mt. Etna volcano. During this eruption the spaceborne advanced very high resolution radiometer (AVHRR) acquired about 1000 images on which the activity could be detected. Herein, the different eruptive phases have been monitored and analysed using AVHRR time series coupled with ground measurements. Quantitative analysis of the AVHRR data enabled estimation of lava flow areas (hot spot), effusion rates and allowed to retrieve direction, geometry and altitude of volcanic plume. Moreover the Temperature Brightness Difference (TBD) algorithm has been applied to detect volcanic ash. The temporal AVHRR series shows an initial effusion rate of about 3-4 m3/s, a peak of activity cantered at the end of November, and a sudden decrement on December 14 when the eruption stopped. Our estimates and effusion rates derived from other satellite data such as MODIS images are in good agreement. The TBD algorithm confirms the presence of a strong volcanic ash plume that spread over live areas surrounding Mt.Etna and the Catania airport. The synergic use of different remote-sensing techniques allows lava-flow to be monitored and various plume parameters to be measured.

Keywords: etna, avhrr

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VS015 **Oral Presentation** **6905**

Distribution and Movement of Volcanic Ash and SO2 Observed in Satellite Data from the 2006 Eruption of Augustine Volcano, Alaska

Prof. Ken Dean
Remote Sensing Commission Leader IAVCEI

Kristi L.Wallace, Catherine F.Cahill, Dave Schneider, Fred Prata

Augustine Volcano is an island volcano located in the Cook Inlet, 275 km south-southwest of Anchorage, Alaska, that erupted explosively on 11, 13, 14, 17, and 27-30 January 2006 (UTC). A continuous phase of activity occurred on Jan. 28- Feb.1 (UTC). Ground based ash and aerosol samples were collected, and LIDAR, radar and satellite observations were made, providing one of the most complete data sets describing airborne ash and SO2, and validating model predictions during an eruption in Alaska. Visible and infrared wavelength satellite data detected and tracked the movements of volcanic clouds and plumes. Transport of these volcanic clouds was predicted using the Puff dispersion model and validated by samples collected up to 3,000 km to the southeast and Lidar measurements up to 1,300 km to the north. Ash clouds ascended to heights up to 14 km ASL but most were in the 9 to 10 km range. The longest transport distance seen in satellite data was over 500 km to the east. Multi-temporal composites of satellite images showed that these clouds covered most of Cook Inlet and Northwest Gulf of Alaska. The 11 and 17 January eruptions were relatively short and discrete explosive events with detected ash clouds impacting areas within approximately 100 km of the volcano. The 13-14 January and 28 January to 2 February eruptions consisted of multiple explosive events and continuous activity with detected ash clouds impacting areas 100s km from the volcano. Much of the ash-fall produced during these eruptions was deposited in Cook Inlet and the Gulf of Alaska. Ash-fall on land surrounding Augustine Island and within 300 km of the volcano, was very light (≤ 1 mm) and was composed of very fine to medium ash with an estimated size range of 6.25500 micron. A volcanic cloud from the continuous phase of the eruption during 29-30 January was transported north. The Puff model predicted this movement although satellite data was only able to detect SO2 and not ash. Ground based aerosol samplers and Lidar in Fairbanks, approximately 700 km north of the volcano, collected samples that coincided in space and time with dispersion model predictions of the movement of volcanic ash from Augustine Volcano. The ash concentration at ground-level in Homer (to the northeast of Augustine across the Cook Inlet), was 80 times larger than that at Fairbanks in the 1.15-2.5 micron size fraction. The concentration of SO2 could not be measured since no ground based nor airborne COSPEC instruments were deployed. The satellite data and observations presented here were contributed by an AVO team from the University of Alaska Fairbanks and USGS that currently includes 5 students, 2 staff and 9 scientists.

Keywords: ash, satellite, detection

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VS015 **Oral Presentation** **6906**

H2S emission from Santa Ana (El Salvador), Masaya (Nicaragua) and Pos(Costa Rica) and Sierra Negra (Galpagos) volcanoes

Dr. Nemesio Prez
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Pedro A. Hernndez, Jos Barrancos, Gladys Melin, Benancio Henriquez, Ral Mora, Theofilos Toulkeridis

Volcanic sulfur dioxide (SO2) and hydrogen sulfide (H2S) emissions ar e significant sources of sulfur release to the atmosphere (Bates et al., 1992; Bern er and Berner, 1996). Current global volcanic SO2 flux estimates (Bluth et al., 1 993; Andres and Kasgnoc, 1998; Halmer et al., 2002) vary from 10 to 20 Tgyr-1, corresponding to 10% of total SO2 emission s (Berner and Berner, 1996). In contrast, the total volcanogenic H2S flux (estimated to be 137 Tgyr -1) is only poorly constrained (Berresheim an d Jaeschke, 1983; Halmer et a l., 2002). Very few determ inations of H2S abundance in volcanic plumes have been reported to date. Recent investigations on H2S emission rates from Mt. Etna, Stromboli, and Vulcano revealed H2S flux values of 50 to 113, 3 to 6, and 6 to 9 td-1, respectively. H2S contribution to the total sulfur budget is relatively insignificant (5%) at b oth Mt. Et na and Stromboli , but it is about 40% in the case of volcano (Aiuppa et al., 2005). We present here new measurements of SO2 and H2S emissions from Latinamerican volcanoes: Santa Ana (), Masaya (), Pos (), and Sierra Negra (Galpagos). These H2S emission rates were estimated by combining COSPEC and miniDOAS SO2 flux measurements with H2S/SO2 ratio plume measurements by means of a portable multisensor system (Shinohara, 2005). Observed H2S/SO2 molar ratios were about 0. 17 (Sep., 2005), 0.17 (December 200 6), 0.26 (April, 2005) and 0,64 (July 2006) f or Santa Ana , Masaya, Po s and Sierra Negra, respectively . SO2 emision rates during p lume gas r atio measureme nts were about 2102, 1223, 8 5 and 11 td-1 , respectively. Therefore, H2S emission rate were about 189, 110, 12 and 7 td-1. T hese results revealed that H2S contribution to the total sulphur budget is relatively minor for Santa A na (8%), Masa ya (8%), Pos (12%) volcanoes, but it is qui te significant in the case of Sierra Ne gra volcano (64%). These additional results on H2S emission rates support also that future investigation take into account the potential H2S contribution to total S emissions. References Ai uppa et al ., (2005). Geochim. Cosmochim. Acta, 69, 18611871. Andres et al., (1 998). J. Geoph ys. Res. 103, 2525125261. Bates et al., (1 992). J. Atmos . Chem. 14, 31 5337. Berner et al., (1996) Global En vironment: Water, Air and Geochemical Cycles . Prentice Hall Inc. Berresheim et al., (1983). J. Geophys. Res. 88, 37323740. Bluth et al., (1993). Nature 366, 327329. Halmer et al., (2002). J. Volcanol. Geotherm. Res. 115, 511528.

Keywords: h2s, emision, volcanoes

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VS015 **Oral Presentation** **6907**

Comparisons of OMI and AIRS sulphur dioxide retrievals in volcanic eruption clouds

Dr. Fred Prata
Atmosphere and Climate Norwegian Institute for Air Research IAVCEI

Simon Carn

The Ozone Monitoring Instrument (OMI) on NASAs Aura satellite produces global, daily total column retrievals of SO2 using scattered and reflected ultra-violet light and can detect tropospheric and stratospheric emissions from volcanic sources. The Atmospheric Infrared Sounder (AIRS) on the Aqua satellite is an infrared spectrometer with high spectral resolution and capability to monitor many gases in the troposphere and stratosphere. Aura and Aqua overpasses occur within a 15-minute time window, permitting near-coincident OMI and AIRS SO2 retrievals in daytime. By using infrared radiation, AIRS can also make measurements during the night. However, unlike OMI, AIRS does not deliver a standard SO2 product. A retrieval scheme for determining SO2 total column from AIRS has been devised and the results are compared to OMI measurements for several volcanoes with different styles of eruptive activity. We have investigated the performance of AIRS for boundary layer, lower troposphere, upper troposphere and stratospheric injections of SO2 and report the first results of these intercomparisons here. Future work will focus on independent measurements of SO2 for comparisons with the satellite retrievals and investigations into performance issues, limitations and vertical resolution of SO2 retrievals from both OMI and AIRS.

Keywords: sulphur dioxide

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VS015 **Oral Presentation** **6908**

Observation of water vapor distribution in the fumaroles with a portable Raman lidar

Dr. Takuji Nakamura
Research Instiitute for Sustainable Humanosphere Kyoto Univ. IAGA

Naohiro Sugimoto, Takeshi Hashimoto, Akihiko Terada, Makoto Abo, Yuichi Katsube, Toshitaka Tsuda

Observation of water vapor density and flux in the fumarolesis very important because the latent heat by water vapor is the majorsource of energy input from volcanos into the atmosphere. However, remote sensing measurement technique of waver va por in th e fumaroleshas not yet been de veloped, because of the difficulty to distinguish water vapor inside an d outside of the plume by means of p assive remote sensings such as DOAS and FTIR. A lidar (laserradar) is capable of measuring atmospheric quantities as a fu nction ofline- of-site distance (range), and therefore could be used to measurewater vapor distribution ins ide and outside the plume.A transp ortable Raman lidar with a pulsed Nd:YAG laser (SHG(Second harmonic generation):532 nm) and a telescope with a 35.5 c m diameter has been built in order to monit or water vapor profiles in the atmo spheric bo undary la yer in RISH (Research Institute forSustainable Humanosphere), Kyo to University. We have applied this lidar to measuring water vapor distributionin t he fumaroles. The first experiment was carried out at Nakadake of Mt. Aso, in Kyushu, Japan in November 2005. Alternating observation of horizontal distribution ofwater va por was carr ied out in the directions towards the plume and theamb ient atmosphere. The fumarole was located at a distance of 500 m fromthe lidar with a half maximum width of 200 m. The difference of the two beams indicated that the water vapor mixing ratio was ab out 1g /kg larger in t he plume com pared with the ambientatmosphere. The water vapor flux was roughly estimated to be about 100 kg/s using an upward velocity o f 4 m/s measured with a video camera o bservationof the plume. This flux value is no t to o different from that estimated by the plume rise meth od (200 kg/s).We further developed a smaller lida r system by using moresensitive PMTs (pho tomultiplier tu bes) and a s maller telescope, whichshows higher portability without deg rading the sensitivity. The se cond experiment using the new system wa s carried out in January2007 at the sa me location at Mt. Aso. The increase of the water vaporwas not observed in the plume in this experiment under the con ditionof relativ e humidity of ~100 % in the ambient atmosphere in the m idwinter. More recent results from this portable system plannedin summer will also be reported in the paper and the capability ofthe developed system will be discussed.

Keywords: water vapor, raman lidar, portable lidar

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VS015 **Oral Presentation** **6909**

Rise dynamics and ash absorbance in vulcanian eruption plumes at Santiaguito Volcano, Guatemala, revealed using a UV-imaging camera

Dr. Jeremy Phillips
Department of Earth Sciences University of Bristol UK IAVCEI

Hiroko Yamamoto, Matthew Watson, Gregg Bluth

Volcanic activity at Santiaguito volcano, Guatemala, is characterised by periods of Vulcanian eruptions occurring at intervals of 1 to 2 hours. This volcano forms an ideal natural laboratory for studying the dynamics of small volcanic ash plumes and for developing ground-based monitoring methods for volcanic gas and ash. During a short field campaign in March 2006 we measured the rise dynamics of the ash plumes at Santiaguito using video photography, and their absorbance using a novel UV-imaging camera (UVICAM). The absorbance is computed by deriving a proxy for the amount of radiation leaving the source (in this context the sky) and then solving for absorbance using the Beer-Lambert Law, with appropriate correction for path-length effects. Analysis of the rise velocity of the plumes shows that the plumes produced by small Vulcanian eruptions at Santiaguito are short-duration discrete releases of buoyant mixtures of gas and ash, known as thermals. Buoyancy controls the rise dynamics from very close to the thermal source, and the momentum due to the eruption does not contribute significantly to the rise dynamics, consistent with previous observations of eruptions through a porous capping layer at the summit of Santiguito. Measurements of the shape and rise dynamics of the thermals provide a constraint on the horizontal cross-sectional shape of the thermal, and in the case of Santiaguito these were found to be circular. Constraining the cross-sectional shape of the thermal, coupled with appropriate calibration of absorbances within the plume, enables a simple algorithm for ground-based volcanic ash monitoring to be developed. Although further development is required, this system has wide potential to investigate dynamics of volcanic ash transport in the vicinity of the source. This study is an example of how combining fundamental dynamics and volcano monitoring enables development of a new measuring method.

Keywords: vulcanian, uvcamera, ash

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VS015 **Oral Presentation** **6910**

A Comparison of Lava Flow Measurements at Colima Volcano using a TIR Camera and AVHRR Real-Time Data

Dr. Ignacio Galindo
CUICA UNIVERSIDAD DE COLIMA IAVCEI

Nick Valery

Pyroclastic flows generated from dome collapses pose a potential threat to surrounding communities. Active effusion can be monitored by thermal infrared surveillance like AVHRR multispectral images and infrared camera imaging. The goal of this research was to compare both measurements. In this study a hand held camera was used to investigate the thermal emission associated with effusion in September-December 2004. Radiant heat flux was also estimated from AVHRR multispectral images for the same period. For comparison, dimensionally derived eruption rates were estimated by photogrammetry using a digital elevation model (DEM). Lava area is determined by identifying an area of active lava on image specific threshold-temperature and lava surface temperature is given by a histogram-generated mean temperature corrected for solar heating and reflected sunlight. Effusion rate trends estimated from IR camera imagery and AVHRR are broadly consistent with eruption rate trend estimates from the DEM but IR camera results contain large errors arising from inconsistent view geometry. Insights gained from this research will help improve future monitoring of active effusion.

Keywords: pyroclastic, satellite, monitoring

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VS015 **Oral Presentation** **6911**

The Aster Volcano archive a global perspective

Dr. David Pieri
Science Division Jet Propulsion Laboratory IAVCEI

Michael Abrams, Patrick Ko, Howard Tan

The systematic study of the world's most frequent volcanic activity is a compelling arena for ASTER and its sisters MISR and MODIS, the importance of which extends from basic volcanology to societal risk assessments. A significant emerging challenge for all EOS instruments is how to effectively access a burgeoning data archive in a way that allows the survey, extraction, and distribution of important information in a timely way. This issue is particularly acute in general for ASTER, which has produced a multi-spectral, high spatial resolution, feature-specific targeted global data base of over 1 million data granules; and specifically for our volcano effort, which is systematically observing over 1500 active volcanoes worldwide. To promptly and efficiently access and manage voluminous volcano data within a large ASTER image library, and to house other ancillary correlative volcanological data from MISR, MODIS, EO-1 data sets, SRTM, and related in situ data, we have created a specialty domain called the JPL ASTER Volcano Archive (http://ava.jpl.nasa.gov), and the Volcano Data Acquisition and Analysis System (VDAAS). VDAAS provides a fast and powerful search engine to organize and provide JPL intranet and internet access to these data. We will discuss the myriad challenges and opportunities that this unprecedentedly large and accessible global volcanological remote sensing data set represent in terms of data mining, data analysis, and data distribution to the scientific community, to disaster responders, the general public, and to educators.

Keywords: aster, volcano archive, data mining

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VS015 **Poster presentation** **6912**

Study of changes in the Popocatepetl volcano geologic deformations caused by microseismicity, by applying the lineament analysis to the Aster (Terra) satellite images

Dr. Alonso Arellano-Baeza
Mining Department Universidad de Santiago de Chile IASPEI

Roxana Ortega-Bustamante, Fernando Machuca Perez

Over the last decades strong efforts have been made to apply new spaceborn technologies to the study of volcanic act ivity. ASTER/TERRA multispe ctral sate llite i magery was used to detect changes in the number a nd o rientation o f lineaments, ass ociated wi th t he microseismi c activity of t he Popocapetl volcano, located close to the Mexico City. For this study, a lineament is a straight or a somewhat curved feature in a satellite image, which it is pos sible to detect by a special p rocessing of images based on directional filtering and or Hough transform. A temporal sequence of high ASTER (VNIR) images with 15 m resolution covered the sa me zone of the volc ano during 2000-2005 was analyzed. It was found that the lineament system is unstable and strongly affe cted by microseis micity. It was found that, t he number and orientation of lineaments is aff ected by number, depth, and magnitude o f earthquakes. In particular, it was fo und that t he number o f earthquakes ten days ah ead from the date of image has a power low de pendence on the density of lineamen ts, e xtracted from it. The results obtained are important for developing of new methodology of quick monitoring of volcanoes.

Keywords: lineament, microseismicity, aster

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VS015 **Poster presentation** **6913**

Ash plumes at MT. Etna during the 2006 eruption: observations from satellite to microscope

Dr. Claudia Spinetti
CNT INGV

Daniele Andronico, Jacopo Taddeucci, Antonio Cristaldi, Maria Fabrizia Buongiorno

Mt. Etna, in Sicily (Italy), is one of the most plume-maker volcanoes in the world during both degassing and eruptive periods. In the last ten years, Etna exhibited more than a hundred lava fountaining episodes producing copious tephra fallout that afflicted the inhabited and cultivated areas around the volcano, also jeopardizing the air traffic related to the International Catania Airport. Most recently, in the complex eruptive period from July to December 2006, Etna produced again ash plumes potentially dangerous for air traffic. We studied some of these ash plumes at different scales, coupling remote sensing, field and laboratory investigations of the volcanic ash. We detected the ash by testing a near real time NOAA-AVHRR observation together with ground volcanological observations. The satellite images were analysed using the well-known ash detection approach temperature difference model. We found a good correlation between field observation and sampling of the ash and the plumes detected by AVHRR. This correlation allowed us to classify the plumes according to their width, length, height and wind intensity, thus validating future satellite detection of plumes. The detection and characterization of plumes via satellite depends on the textural and chemical properties of the ash. In order to better retrieve this information from plumes of Etna, we analyzed the ash from three different explosive episodes recorded by NOAA-AVHRR. The ash samples were characterized by componentry analysis at binocular microscope and chemical composition and morphology under EDS-equipped Scanning Electron Microscope. This integrated approach delineates the limit and the validity of the remote sensing ash detection method, specifically for ash plumes from Mt. Etna volcano.

Keywords: plume, ash, satellite

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VS015 **Poster presentation** **6914**

Investigation of LIDAR signal intensity on volcanic products of the Stromboli Volcano, Italy

Dr. Alessandro Fornaciai
Pisa Istituto Nazionale di Geofisica e Vulcanologia

Marina Bisson, Massimiliano Favalli, Patrizia Landi, Francesco Mazzarini, Maria Teresa Pareschi

LiDAR (Light Detection and Ranging) is an active technique for acquiring high resolution and high accuracy terrain information. Moreover LiDAR instrument produces a laser image of the land surface derived from measurements of the intensity of each backscattered laser pulse. We have investigated and documented LiDAR potentiality for identifying and characterising volcanic products. In October 2005 an airborne LiDAR survey, using an Optech ALTM 3033 laser altimeter, was performed at Stromboli volcano (Italy) and the calibrated LiDAR intensity was compared with the field characteristics of the volcanic products.The backscattered intensity depends on several parameters. Some depend on acquisition conditions such as the emitter-target distance and the atmospheric attenuation, others on the spectral and textural properties of the illuminated surface. From this study, we conclude that the most common volcanic products, fallout deposits, epiclastic sediments and lava flows, show distinctive intensity LiDAR responses. In particular, in the area of study, fallout deposits display the lowest intensity, lava flows have the highest intensity and the epiclastic sediments are characterised by a low intensity but greater than that of fallout deposits.

Keywords: lidar, intensity, stromboli

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VS015 **Poster presentation** **6915**

On ground tir camera for volcanic plume detection: sensitivity study on sulphur dioxide and volcanic ash retrieval

Dr. Sergio Pugnaghi
Ingegneria Materiali e Ambiente Universit di Modena e Reggio Emilia

Corradini Stefano, Tirelli Cecilia, Gangale Gabriele, Amici Stefania, Buongiorno Maria Fabrizia, Carboni Elisa

In this work a sensitivity study on sulphur dioxide and volcanic ash retrieval using on ground TIR camera (named BIRD) has been carried out. BIRD, a new Semi Conductor Device (SCD) uncooled camera is composed by a matrix of microbolometric sensors with pixel pitch of 25 microns. The spectral range is between 8 and 14 microns with Noise Equivalent Delta Temperature (NEDT) better than 50 mK at 300 K. The camera will be used to monitor and assess hazards of Mt. Etna volcano, in particular it can be used to mitigate the risk and impact of volcanic eruptions on the civil society and transport (Highway and International Airport of Catania are about 20 km from the craters). A minimum number of filters (right bandwidth and effective wavelength) have been selected for SO2 and ash retrievals. The sensitivity study has been carried out to determine either the SO2 and ash minimum concentration detectable by the system then the better altitude to locate the camera. The sensitivity analysis has also been used to show the possibilities to discriminate from volcanic and meteorological clouds varying the effective radius and the optical thickness.

Keywords: tir camera, volcanic plume, mt etna

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VS015 **Poster presentation** **6916**

Environmental Radioactivity Monitoring of Volcanoes

Prof. Wolfango Plastino
of Physics University of Roma Tre IASPEI

Environmental radioactivity monitoring o f volcanoes co uld be an use ful to ol to characterise so me geodynamical processes induced in sub-soil gases and endogenous fluids. At this mo ment, the intrinsic limit of such technology was the low performance for stability and reliability of the equipments, affected by the severe chemical-physical conditions in volcanic areas. This was the reason of lacking information of such dynamical processes and the reason to adopt a grab sampling approach in radioactivity analysis. Then, the light yield propertie s of some sc intillator have been tested for r eal-time volcano monitoring. Finally, the de tection pr operties of YAP:Ce scintillator have been selecte d. The crystal response has been studied under severe extreme conditions (hot water and different acid solutions) to s imulate environments of geophysical interest, particularly those fo und in geothermal and volcanic areas. Also, a portable equipment with this crystal has been planne d and realise d for alpha a nd gamma-ra y spectrometry. This new technique shou ld provide for the first time the opportunity to realize a real-time monitoring network in volcanic areas of the environmental radioactivity.

Keywords: environmental radioactivity, nuclear spectrometry, endogenous gases and fluids

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VS015 **Poster presentation** **6917**

An Integrated Suite for Forecasting Volcanic Ash Dispersal: The MAFALDA Procedure

Dr. Sara Barsotti
Sezione di Pisa INGV IAVCEI

Augusto Neri, Luca Nannipieri

Forecasting volcanic ash disp ersal is a fund amental go al in order to mit igate its potential impact on urbanized are as and transpo rt ro utes surrounding ex plosive volcanoes. To this aim we developed an early-warning procedure named MAFALDA (Modeling And Forecasting Ash Loading and Dispersal in the Atmosphere). Such tool is able to quantitatively forecast the atmospheric concentration of ash as well as the grou nd deposition as a function of ti me over a 3D spatial domain.The dispersa l code behind MAFALDA is na med VOL-CALPUFF, an hybrid Lagrangian -Eulerian code able to descr ibe both the rising column phase and the atmo spheric ash tran sport as functio n of weather co nditions. In MAFALDA high-resolution weather forecasting data are cur rently used an d the VOL-CALPUFF's sho rt e xecution time allows to analyse a set of default scenari os. Th e results are visualized through a web-based CG I software application (written i n Perl program ming la nguage) that shows t hem in a sta ndard grap hical web interface and, finally, makes it suitable as an early-warning system during volcanic crises.MAFALDA is composed b y a computational part that si mulates the as h cloud dynam ics and a grap hical interface for visualizing the modelling results. The c omputational part includes the codes for elaborating the meteorological data (CAL ITA, CAL MET), th e disp ersal code (VOL-CALPUFF) and the post-processing programs. The main pro ducts are ho urly 2D maps o f aerial ash co ncentration at several vertical levels, extension of threat area on air and 2D maps of as h deposit on the gr ound, in addition to graphs of hourly variatio ns o f co lumn height.The pro cessed results are a vailable on the web by the graphica l interface and the users can choose, by drop-down menu, which dat a to visualize.A first partial application of the procedure has been car ried out for M t. Etna (Italy). In this case, the procedure simulates four volcanological scen arios characterized by different plume intensities and uses 48- hrs weather forecasting data with a resolution of 7 km provided by the Italian Air Force.

Keywords: explosive eruption, ash cloud dispersal, early warning

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VS015 **Poster presentation** **6918**

Regional earthquake triggers of enhanced volcanic activity: examples from Modvolc data 2000-2006

Dr. Dario Delle Donne
Scienze della Terra Universit di Firenze IAVCEI

Andrew J.L. Harris, Maurizio Ripepe, Robert Wright

Data output by the Moder ate Resolution Imagin g Spe ctroradiometer (MODIS) Volcanic hot spot detection algorithm (MODVOLC), allow constructio n of heat flux time-series for on -going effusive volcanic eruptions. Using MODVOLC-derived heat flux time-series we can asses the heat flux associated with on-going volcanic activity before, durin g and after major regi onal earthquakes. During May-June 2006 we witnessed a coupled increase in heat flux at two Javanese volcanoes (Mer api and Semer u) three days following the magnitude 6.4 ea rthquake that occurred ju st off-sh ore of Java on 26 May 2006. The response lasted 9 days at both volcanoes, a fter which heat flux levels r eturned to pre-response values. This led us to conclude that regional earthquake events are not always able to trigger an eruption itself, but do have s ufficient influence to modify the int ensity of activity at on-going eruptions (Harris & Ripepe, GRL, 2006). This result pr ompted us to search the entire, seven-year-long, MODVOLC volcano hot spot data base to search for other potential correlati ons between regional earthquakes a nd vo lcanic heat flux. This in volved an an alysis of 65 volcanoes, distributed across the globe, each of which showed detectable hea t flux at the time of an earth quake within a 500 km radiu s of the volcano. Our results show a positive correlation between eart hquake magnitude and percentage of volcanoes showing heat flux response within a 2 week period following the earthquake. During 2000-2006 we found possible hea t flux response s to regi onal e arthquakes for 23 cases. As at Merapi an d Semeru, however, the effects were always short-l ived, wi th heat fluxes returning to values typical of those prior to the earthquake after ~15 days. This indicates a potential, short-lived earthquake effect on volcanic syste ms that are already open and erupti ng, and that the effect (change in the pressure differential) and symptom (increase in heat flux) is some what transient and short- lived. In addition, postive corre lations only app ear to occur when the focal mechanism of the earthquake points t owards the volcano. W e relate our tr ansitory volcanic re sponses to the dynamic stre ss change induced by the earthquake. In particular, passage o f seismic wa ves can trigger bubble diffusion that act as a vesciculation pump: pressurization pumps magma up wards, causing a near-immediate (lagged by a few days) increase in the eruption rate (and thus heat flux) at the open, erupting system.

Keywords: modis, volcano earthquakes, interaction

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VS016 **6919 - 6935**

Symposium
Volcanic-plutonic provinces: a tool to understand magma genesis and geodynamics

Convener : Prof. Giampiero Poli, Prof. Bernard Bonin

Volcanic-plutonic provinces are of great importance in understanding genesis and evolution of magmas in the context of crustal accretion and structuring. They can be found in all geodynamic environments with magmas spanning a large range of compositions and geochemical affinities. However, despite recent advances in trace element geochemistry, isotope systematics and chronology, and experimental petrology, the link between tectonic setting and petrogenetic processes in volcanic-plutonic provinces is not yet fully understood. This session is aimed at discussion of the physical and chemical mechanisms responsible for the genesis and evolution of volcanic and plutonic magmatism, and how these mechanisms are reflected in the mineralogy, and the chemical and isotopic composition of rocks. The idea is to bring together specialists in the fields of geodynamics, volcanic and plutonic geology, petrology, and geochemistry with experience in volcanic-plutonic provinces in different geodynamic settings, from Archean to recent, in order to gain a more comprehensive knowledge on the genesis, evolution, and interrelationships between volcanism and plutonism.

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VS016 **Oral Presentation** **6919**

Uturuncu Volcano, Bolivia: volcanic unrest due to mid-crustal magma intrusion and pluton growth

Prof. Stephen Sparks
Earth Sciences University of Bristol IAVCEI

Folkes, C.B, Humphreys, M.C.S, Barford, D, Clavero, J., Mayel S, McNutt, S, Pritchard, M

Uturuncu volcano, SW Bolivia, is a dormant stratovolcano (~ 85 km3) dominated by dacitic lava domes and flows, 39Ar/40Ar ages show that the volcano has been active between 890 ka and 271 ka with the lavas becoming younger and less extensive at higher elevations. There are current signs of unrest. Geodetic satellite measurements record an ongoing 70 km deformation field from 1994 to the present with a central uplift rate of 1-2 cm/year. Deformation models indicate a source at depths of 17 to 29 km beneath current local relief. Deformation indicates volume changes of 400 x 108 m3 over 12 years, an average of ~ 1 m3/s (10-2 km3/yr). The deformation is attributed to magma intrusion into the Altiplano-Puna regional crustal magma body. In a reconnaissance survey, seismic activity was recorded at about 4 km depth below the centre of the uplift, 4 km SW of the volcanos summit. The seismic data has normal b values and is attributed to brittle deformation in the elastic crust above the active deep magma intrusion. The porphyritic dacite lavas (64- 68% SiO2) have a plagioclase-orthopyroxene-biotite-magnetite-ilmenite assemblage and commonly contain juvenile silicic andesite inclusions, cognate norite nodules and crustal xenoliths. Temperature estimates are in the range 805-872oC for the dacites and about 980oC for the silicic andesites. Compositions and zoning patterns of orthopyroxene and plagioclase phenocrysts indicate compositional variation in the dacites is caused by magma mixing with the silicic andesite. Reversely zoned orthopyroxene phenocrysts in the andesitic end-member are explained by changing oxidation states during crystallisation. Fe3+/Fe2+ ratios from orthopyroxene crystals and Fe3+ in plagioclase provide evidence for a relatively reduced melt that subsequently ascended, degassed and became more oxidised. The geophysical and petrological observations suggest that magma is being intruded into the Altiplano-Puna regional crustal magma body at 17 km or more depth. In the Late Pleistocene dacitic and andesitic melts have rise from the regional crustal magma body to a shallow magma system where they crystallize and mingle together. The late-stage oxidised character of andesite magmas may reflect volatile-rich melt that degassed, leaving the melt more oxidised before mixing with a more voluminous dacitic melt. The current unrest together, geophysical anomalies and 270 ka of dormancy indicate that the magmatic system is in a prolonged period of intrusion. Uturuncu is thus inferred to be an example of current pluton growth. Such circumstances might eventually lead to a large eruption of the large volumes of intruded magma with potential for caldera formation.

Keywords: pluton, dacites, unrest

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VS016 **Oral Presentation** **6920**

Porphyritic lava domes generated by remobilization of igneous protoliths from arc crust

Dr. Georg Zellmer
Institute of Earth Sciences Academia Sinica IAVCEI

While volcanic explosivity may largely be a function of magmatic water co ntent and volatile exsolution, differences in the style of effusive volcanism can mainly be attributed to variations in magma viscosity. However, the controls of petrogenetic processes on the style of effusive eruptions at subduction zones have so far no t been constrained on a global scal e. Here, 238U-230Th and other geochr onological and geochemical d ata from young arc volcanics are combin ed with information on eruptive style to show that porphyritic lava domes are commonly generated by remelting of previously intruded young igneous protoliths th at are in or clo se to U-T h equ ilibrium. Surface heat flux estimates at co ntinental and transitional arcs indicate that crustal tempe rature plays a significant role in this process and therefore influences eru ptive style. The data su ggests that rem obilization o f young igneo us intrusio ns is a common phenomenon in cool arc crust.

Keywords: geochronology, eruption style, arc volcanism

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VS016 **Oral Presentation** **6921**

The relationship between Ordovician vocanic and plutonic rocks: a case study in Northwestern Argentina

Mr. Jose Maria Viramonte
Geology Instituto Geonorte, University of Salta, Argentina

Pimentel, Marcio M., Viramonte, Jose German, Becchio, Raul Alberto

The geodynamic evolution of the Proto-Andean margin of Gondwana during Lower Paleozoic is still a subject of controversy. On one hand, it was characterized as the result of repeated subduction events associated with the docking of several terranes (Ramos et al., 1986; Ramos 1988; Rapela et al., 1998; Coira et al., 1999). On the other hand, Damm et al., 1990; Becchio et al., 1999; Lucassen et al., 2000; Zimmermann and Bahlburg 2003 and Franz et al., 2006 among other authors, suggest a geodynamic evolution dominated by intracrustal recycling processes with minor contribution of juvenile magmatism. The Puna region of NW-Argentina, records sedimentation, deformation, metamorphism and magmatism events during the period between ca. 510 to 440 Ma (Bahlburg and Furlong 1996; Moya 1999; Hongn and Mon 1999; Becchio et al., 1999; Lucassen et al., 2000; Hongn et al., 2005) in which it is difficult to discriminate different tectono-thermal cycles. Structural, petrological (Hongn et al., 2005; Kirschbaum et al., 2006) and sedimentological (Zimmermann and Bahlburg 2003) studies suggest that during the Lower Ordovician period the central- eastern Puna region evolved in an extensional intracontinental setting. This idea supports previous works based on field observations, petrological, geochemical and isotopic data from metamorphic basement (ca. 510- 500 Ma) to Andean rocks (Miocene) (Becchio et al., 1999; Lucassen et al., 2000; Lucassen and Franz 2005; Franz et al., 2006; Viramonte et al, accepted). The evolution of magmatism started during the Early Tremadocian and it comprises mainly intermediate and acidic plutonic rocks as well as volcano- sedimentary sequences. In general, this magmatism forms two N -S trending belts about 600 km long. In this work new geochemical and isotopic data for Ordovician magmatic rocks of the south eastern border of southern Puna is presented. In this area a voluminous and widespread plutonic unit is exposed. It is composed of three silica-rich facies with U-Pb zircon and monazite ages of 475 to 463 Ma (Viramonte et al., accepted). Spatially associated with this plutonic unit, a thick volcanosedimentary sequence of bimodal metavolcanic rocks, metabasites and felsic metarhyolites and metadacites, intercalated with phyllites and metagreywackes is also exposed. A metarhyolite forming the base of the sequence yields an age of 485 Ma (Viramonte et al., accepted). The bimodal nature of the magmatism in the volcano-sedimentary unit is evident as the metavolcanic rocks have basalt and rhyolite compositions. Bimodality is also shown by trace elements and Sr and Nd isotope data. Amphibolites yield positive εNd(T) values between +0.3 and +2.5 and initial 87Sr/86Sr ratios of 0.7067. These values and the observed enrichment in LILE with Nb anomaly suggest they were derived from a mantle source in a subduction setting. Also, the flat REE pattern (LaN/SmN = 1.23 to 1.43 and LaN/YbN = 1.39 to 1.48) on a chondrite-normalized diagram resemble transitional midocean ridge basalts (TMORB). On the other hand, felsic plutonic and metavolcanics rocks are mainly subalkaline and display peraluminous character (ASI index between 1.1 and 1.5). They are enriched in LREE relative to HREE (LaN/SmN = 2.17 to 3.26 GdN/ YbN = 0.94 to 1.47) with negative Eu anomalies and show negative Nb and Ta anomalies on mantle normalized multielement diagram. Plutonic rocks yield negative εNd(T) values between -5.1 to -6.3 , initial Sr ratios between 0.7216 to 0.7372 and Mesoproterozoic model ages (T DM values in the interval between 1.5 and 1.6 Ga), whereas volcanic rocks yield negative εNd(T) values between -3.1 to -7.5, initial Sr ratios between 0.7089 to 0.7259 and TDM model ages between 1.5 and 1.7 Ga. Isotopic and trace elements data indicate that these felsic magmas represent the product of melting of different protoliths, where the orthogneisses and / or metapelites / metagreywackes of the basement represent these protoliths. Our data combined with the

literature about sedimentation, deformation and metamorphism suggest that a retroarc basin represents the most likely tectonic setti ng for the origin of the eas tern magmatic ro cks in so utheastern P una. According t o t his, the felsic magmatism co uld be re lated to e xtensive crustal melting associated t o astenosphere upwelling after tectonic switching occurring in the suprasubduction zone in the frame of a long lived Hot Orogen (Collin s, 2002; Hongn et al., 2005).

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Keywords: magmatism, ordovician, northwestern argentina

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VS016 **Oral Presentation** **6922**

Petrology and geochemistry of Mafic and Ultramafic rocks of Masule, Western Alborz, Northern Iran

Mr. Abdullah Kosari
petrology sector Geological survey of Iran

Emami, Mohammad Hashem, Haghnazar, Mastaneh, Moharami, Farhad

Mafic and ultramafic rocks of Masule, southern Fuman, Iran, including gabbro, alkaline gabbro, olivine gabbro, gabbrodiorite, melegabbro, clinopyroxinite and wehrlite, have intruded on Gasht metamorphic complex which was related to paleotethys closing, Shemshak and Shal formations. These mafic and ultramafic rocks were also considered as a part of the metamorphic complex of the area. Mafic part of the area can be seen in isotropic and anisotropic forms. Having medium to very coarse grain texture, they are composed of olivine, clinopyroxene and plagioclase as major minerals and brown hornblende, sphene and apatite as minor minerals. They were intersected by monzonitic dikes and also have altered and metamorphosed to Prehnite-Pumpellyite facies and greenschist subfacies. Static metamorphism and alteration have changed their alkaline and subalkaline trend to tholeiitic trend by removing alkaline elements. Trace elements studies, focusing on high field strong elements, display that they have originated from a depleted mantle source and fractional crystallization has taken place in them. These geochemical relationships dont correspond with metabasite of surrounding metamorphic rocks (Asalem-Shanderman and Gasht metamorphic complex). They Genetically associate with Cretaceous and early Cenozoic volcanic rocks of Central Alborz. Hence it can be concluded that they were formed as feeder chambers along graben- like fractures and faults in passive oceanic margins and continental platform side. In another word, they were formed in continental margins of Cretaceous rifting in Alborz Mountains. This conclusion can be verified by comparing their spider patterns with similar rocks of other part of the world which were formed in similar tectonic regimen.

Keywords: geochemistry, continental, rifting

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VS016 **Oral Presentation** **6923**

Magma underplating formed new crust-mantle transition zone--evidence from Xenoliths in Hannuoba basalt

Mr. Jianli Sui
Institute of Geology and Geophysics Chinese Academy of Sciences IAVCEI

Qicheng Fan

Magma underplating is one of the essential mechanisms to the geodynamic evolution of the North China Craton lithosphere in Mesozoic. It is well known that the lithosphere of North China thinned in Mesozoic, from ca. 200 km to less than 80 km, and hence the Paleozoic stable craton of North China was activated in Mesozoic. Xenoliths, including granulite facies and eclogite faceis, from Hannuoba Basalt revealed the occurrence of magma underplating in North China. Xenoliths of granulite facies are mainly websterite (plopxcpxgt), which represent the typical composition of the lower crust, while the eclogite facies are mainly garnet pyroxenite. Eclogite facies, pyroxenite and spinel olivine together dominate the transition zone. Accumulate structure, banded structure and geochemical characteristics provide strong evidence of magma underpalting. P-T condition revealed the high-temperature genesis of these granulite facies xenoliths compared to the terrestrial granulites. Calculated depth of the granulite facies are 33-40 km, which is the accreted lower crust; and that of the eclogite facies are 40-45 km, which is the depth of the newly formed transition zone. These facts described the significance of magma underplating in North China: (1) magma uderplating mainly occurred beneath the lower crust, and formed a thick layer (~7 km) of mafic granulites in the bottom of the crust; (2) magma underplating also occurred in the upper mantle, formed slim veins (only ~10 cm thick) of eclogite facies rocks in the typical upper mantle rocks of spinel olivine; (3) magma underplating occurred in ca.140-120 Ma by zircon U-Pb dating, hence the crust-mantle transition zone of North China was newly formed, not inherited from the old craton. Hence the geodynamic evolution of the North China lithosphere is that, silicic magma was very active in Mesozoic and part of the magma underplated beneath the crust; while the whole lithosphere of North China was thinning and lost most its thickness, the crust grew ~7 km by accretion of magma underplating. Crust-mantle transition zone is one of the most important boundaries in lithosphere, and xenoliths from Hannuoba Basalt provide a natural case of a newly formed transition zone by magma underplating in a thinned, destroyed or reformed lithosphere, and also provide a good chance to understand the geodynamics of the special craton North China.

Keywords: magma underplating, hannuoba, cm transition zone

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VS016 **Oral Presentation** **6924**

Generation of late cretaceous strongly peraluminous and peralkaline to mildly peraluminous silicic rocks in SE China coastal areas: age, geochemical, SR and ND isotopic and numerical constraints

Prof. Cheng-Hong Chen
Dept of Geosciences National Taiwan University IAVCEI

Chi-Yu Lee, Hsueh-Yu Lu, Pei-Shan Hsieh

Rhyolite-dominating bimodal volcanic suites (rhyolite/basalt), mafic dikes and A-type granites distribute from N Zhejiang to S Fujian over 800 km in the Southeast Coast Magmatic Belt (SCMB)the Late Yanshanian (LY) orogenic belt in SE China. Data of 40Ar/39Ar and K-Ar whole-rock ages and LA-ICPMS U-Pb zircon ages indicate that rhyolitic volcanism (101-72 Ma) is contemporaneous with the A-type granitic intrusions (100-90 Ma) and mafic dike injections (94-77 Ma). In terms of ASI and A/CK values, rhyolites in the SCMB distribute a linear variation different from some large rhyolite provinces worldwide: many are strongly peraluminous (SP) and others, mostly restrict in Fujian, are peralkaline to mildly peraluminous (P-MP). Geochemical characters of P-MP rhyolites, such as high Ga/Al and Zr and low Ba, Sr, P, Eu and Ti, resemble A-type granites. Based on a common thermal regime, experimental works and inherited zircon information, we suggest that P-MP and SP rhyolites represent lower pressure melting of the trondhjemitic, tonalitic and granodioritic core complexes as well as their metapelitic country rocks to account for the increasing peraluminality. This interpretation is supported by the similarity of Sr and Nd isotope compositions between rhyolites and the core complex (ISr= 0.707 to 0.712 and εNd(T) = -0.6 to -10.6). Plate subduction and lithosphere extension processes, respectively, are numerically simulated for the magma genesis of these rhyolites using the mafic underplating model. Results suggest that the most effective controlling factor to generate P-MP (A-type) and associated SP magmas is thinning of the lithosphere thickness most probably due to a high exhumation rate.

Keywords: strongly peraluminous rhyolite, a type granites, mafic underplating

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VS016 **Oral Presentation** **6925**

Genesis of Miocene-Pliocene intrusive and effusive rocks from the Tuscan Magmatic Province (Italy): implications for the structure of Apenninic lithosphere

Prof. Giampiero Poli
Earth Sciences University of Perugia IAVCEI

Diego Perugini

Intrusive and effusive rocks belonging to the Miocene-Pliocene Tuscan Magmatic Province (Italy) crop out on continent, some islands of Tuscan archipelago, and are also found in boreholes. Intrusive rocks range in composition from granodiorite to alkali-granite, with a strong predominance of monzogranites, whereas effusive rocks are mainly rhyolites, with few amounts of basaltic and lamprophyric rocks. Both types of rocks bear mafic microgranular enclaves in variable amounts. Petrological and geochemical investigations indicate that interaction between acid and basic magmas is the main process leading to differentiation of both volcanic and plutonic rocks. Major and trace elements and isotopic systematics allow us to recognize the basic end-members as compositionally akin to Capraia and Monte Amiata lavas. Their origin is likely related to partial melting of a heterogeneous mantle, strongly metasomatized both by fluids released from oceanic lithosphere and by slices of continental crust. The acid end-members are crustal anatectic melts derived by partial melting of gneiss and garnet micaschists of the Tuscany basement having a greywacke protolith. Residual assemblages of the partial melting process for the acid magmas, calculated by geochemical models, agree with experimental petrology data, and help to envisage two different depths of melting, below and above garnet stability fields.The understanding of geochemical features of primary basic and acid end-members as well as their relative sources allows us to advance a geodynamical reconstruction of the lithosphere in this segment of Northern Apennines (also known as Etruscan Belt). During Eocene the mantle wedge was metasomatized by fluids released from oceanic lithosphere in response to the Alpine East dipping subduction. In Oligocene times the same mantle wedge was possibly metasomatized also by European and/or African continental crust. From Oligocene an ensialic west dipping subduction started in the area and an Oligocene-Early Miocene polyphasic compressive regime built up the Etruscan Belt, concurrently with the Corsica rotation. Starting in Middle Miocene the Etruscan belt underwent a strong extension which was responsible of its own collapse. Soon after, from Middle Pliocene onward, the western Tuscany underwent an almost generalized strong regional uplift, still active today. During the extension-uplifting stage an important role was played by an asthenospheric intrusion that occurred beneath the Etruscan belt. This event thinned the crustal stack and, strongly interacted with it, completely restructuring the crust-mantle boundary, so that the present Tuscan Moho is a brand new one. At this stage, in response to the asthenospheric intrusion the poly-metasomatized mantle wedge partially melted and originated basaltic magmas with geochemical imprints of either continental crust and subduction related fluids. During the compressive regime that built up the Etruscan Belt, slices of upper crust were superimposed with intermediate/lower crust at different pressures. Partial melting of such slices at pressures in the stability fields of cordierite and garnet produced the acid anatectic magmas of TMP.

Keywords: petrology, geodynamics, tuscan magmatic province

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VS016 **Oral Presentation** **6926**

Growth, eruption, solidification, fractionation, and rejuvenation of a large felsic magmatic system, Eldorado-Newberry Mountains, Nevada (USA)

Dr. Jonathan Miller
Geology San Jose State University IAVCEI

James Faulds, Calvin Miller, Joe Wooden, Michele Dodge, Deborah Bazar, Shannon Leslie, Jugdeep Aggarwal

Subvolcanic plutons provide an important record of magma processing in the upper crust but rarely can they be compared with related volcanic rocks. In the Colorado River extensional corridor of southern Nevada (USA), steep tilting caused by extension has exposed large Miocene intrusions that lie structurally beneath overlying coeval volcanic sections. One of the best examples is the 10 km thick Searchlight pluton and its overlying volcanic cover. Early work in the pluton established a generalized petrogenesis wherein crystal accumulation (lower mafic quartz monzonite) and roof-down solidification (upper quartz monzonite) resulted in segregation of evolved felsic melt in the pluton interior (middle granite), and late intrusion of gabbro/diorite.More recent work in the pluton and in the overlying volcanic sections reveal a protracted and detailed record of the Searchlight magmatic system, and several data sets establish a petrogenetic relationship between volcanic eruption and growth and solidication of the pluton. These data include the following: (1) volcanic sections that show an evolutionary sequence from silicic trachyandesite and porphyritic trachydacite to rhyolite that mirrors the compositional variation and solidifcation sequence observed in the pluton; (2) trachydacite and rhyolite porphyry dikes with near E-W strike and irregular trachydacite pods in the upper part of the pluton, which appear to have emanated from the pluton and fed overlying volcanic strata; (3) published Ar-Ar age data and over 400 ion microprobe U/Pb zircon ages on 22 samples demonstrating that volcanism and plutonism spanned 2 Ma, and that early intermediate volcanism is generally coeval with the quartz monzonite units and rhyolite is coeval with later granite; (4) concave up or inflected crystal size distributions for the intermediate porphyry dikes and pods within the pluton that are similar to erupted trachydacite lavas; (5) whole rock geochemical continuity between lavas and pluton and distinctive trace element geochemical signatures (whole rock and zircon) linking erupted rocks with plutonic units; (6) matching whole rock Sr and Nd isotopic data for the plutonic and volcanic rocks.The data above establish that the pluton and volcanic rocks were cogenetic and part of a unitary Searchlight magma system that was continuously active (melt present?) for a minimum of 1 m.y. and possibly for 2 m.y. The general evolutionary history is as follows: (1) initiation of the Searchlight magmatic system by intrusion of trachybasaltic/andesitic magma around 17.5-18.0 Ma and eruption of some magma as lavas; (2) growth of a quartz monzonitic pluton by repeated intrusion of trachydacite/trachyandesite magma from about 17.0 Ma to 16.0 Ma, with periodic venting of crystal-rich (accumulative?) magma as flows and domes; (3) closed system fractionation to granite and coalescence of rhyolite in sheets and irregular dikes and magma body rejuvenation by mafic input into granitic and quartz monzonitic cumulates with eruption of rhyolite domes, flows, and tuffs (16.0 to 15.8 Ma).

Keywords: volcano plutonic, nevada, miocene

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VS016 **Oral Presentation** **6927**

The formation of sills controlled by rigidity contrasts and its implications for the growth of laccoliths and plutons

Dr. Thierry Menand
Earth Sciences Univeristy of Bristol IAVCEI

Despite a wealth of available field data, the mechanisms by which magmas stall in the crust and the physical processes that lead to the formation of magma chambers and plutons remain unresolved. Field measurements of the geometry and dimensions of sills, laccoliths, plutons and batholiths suggest the existence of different growth processes that are related to the size of the intrusions considered. Many field and geochronological data indicate also that laccoliths, plutons and magma chambers develop and grow by amalgamation of numerous sills, and that the time-scale associated with their growth is somehow related to their size. In many cases sills appear to be the building blocks of larger laccoliths and plutons. Yet, the mechanics and dynamics of sill emplacement remain poorly understood. Different hypotheses for the formation of sills have been proposed decades ago but it is only recently that they have been tested seriously. These hypotheses have been tested by means of analogue experiments involving the injection of fluid into a solid of gelatine. The experiments reveal that under hydrostatic conditions the formation of sills requires the presence of layers of different rigidity, and that sills form only when their feeder dyke intersects an interface between an upper more rigid, stronger layer and a lower less rigid, weaker layer. That lithological discontinuities and rigidity contrasts can control sill formation provides a mechanism for the growth of laccoliths and plutons. The formation of a sill provides favourable rigidity anisotropy for the emplacement of subsequent sills so that laccoliths and plutons can grow by over-accretion, under-accretion or even mid-accretion of successive sills. In accord with field data, this model predicts that laccoliths and plutons grow mainly by vertical expansion, representing the cumulative thickness of their internal sills, while maintaining a comparatively constant lateral extend. The model also predicts that the time-scale over which laccoliths and plutons form is essentially determined by the cumulative time between successive sill intrusions. The experiments also show that sill dynamics are controlled by viscous dissipation of the fluid along their length, which have consequences for their size and shape. Viscously-controlled dynamics enable sills to propagate further and thus to grow thicker than dykes of similar magmas. These dynamics enable sills to propagate faster and thus to induce non-elastic deformations in surrounding rocks that will deviate them from the lithological discontinuity they originally follow. This would allow them to feed new sills along other discontinuities and thus would provide a mechanism for their trangressive character as well as the saucer-like shapes that are commonly observed in sill complexes.

Keywords: sills, laccoliths, plutons

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VS016 **Oral Presentation** **6928**

Magmatism and tectonics in the Easternmost sector of a transversal fault system in Central Andes: a contribution for Miocene geodynamical evolution of the Andean margin at 24S

Prof. Roberto Mazzuoli
Dipartimento di Scienze della Terra di Pisa DST, Pisa University

Luigina Vezzoli, Ricardo Omarini, Valerio Acocella, Anna Gioncada, Massimo Matteini, Herv Guillou, Hauser Natalia

The Central Andes between 22 and 27S are affected by NW-SE-striking transversal transcurrent fault systems, extending inland from the Pacific coast for 600/700 km. One of the most important of these is the Calama-Olocapato-El Toro fault system, at 24S. Since Miocene time, widespread volcanism mainly with a calcalkaline signature emplaced along these structures. We present stratigraphic, structural, petrochemical and geochronological data on the Middle Miocene Las Burras-Almagro-El Toro magmatic complex, located in the Eastern Cordillera of Central Andes at 24S, at about 300 km back of the volcanic arc, in the easternmost sector of the Calama-Olocapato-El Toro fault system. This complex consists of a monzogabbro to monzogranite laccolith-like intrusion and of basaltic andesitic to dacitic volcanic rocks. The emplacement of the intrusion was linked to N-S trending strike-slip structures in a context of convergence, and was thus marginally controlled by the Calama-Olocapato-El Toro fault system. This important structure seems instead to have closely controlled the rise and emplacement of the younger volcanic rocks, erupting along WNW-ESE and N-S structures, which were probably reactivated as extensional systems. Seven lithostratigraphic members have been identified in the Miocene volcano-sedimentary sequence of the Las Burras-Almagro-El Toro area. New radiometric K-Ar data have given ages of 14 Ma for intrusive rocks and of 12.8 to 6.4 Ma for volcanic rocks. Two magmatic phases were recognized. Intrusive and volcanic rocks of the older magmatic phase (14-12 Ma) are characterized by Ba/Nb,La/Ta and isotopic ratios (87Sr/86Sr: 0.704339-0.705281, 143Nd/144Nd: 0.512713-0.512598) approaching intraplate characteristics. Their primitive magmas could have been generated in an isotopically depleted lithospheric mantle rich in K, Rb and Th, and evolved with a moderate crustal contamination during fractional crystallization. The products of the younger magmatic phase (11-6 Ma), have higher Ba/Nb, La/Ta and 87Sr/86Sr (0.706738-0.708729) and lower 143Nd/144Nd (0.512433 - 0.512360). Their compositional characteristics are indicative of a change in the magma source after 12 Ma, which may correlate with the crustal thickening associated with the Eastern Cordillera compressional evolution and the Brazilian shield underthrusting at the back of the Andes. The magmatic evolution of this complex is discussed in the framework of Miocene magmatism developed along the transversal structure Calama-Olocapata- El Toro. The results of this study suggest a geodynamical model concerning the evolution of Central Andes during the Miocene time at around 24S.

Keywords: central andes, petrogenetic processes, structural geology

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VS016 **Oral Presentation** **6929**

A-type granites of the cretaceous Damaraland intrusive Complexes, Namibia: salient members of the Paran-Etendeka large igneous Province

Prof. Ilmari Haapala
Department of Geology University of Helsinki IAVCEI

Stephen Frindt, Robert B. Trumbull

The Cretaceous Paran-Etendeka bimodal volcanic-plutonic province is represented in northwestern Namibia by the Etendeka volcanic series and the Damaraland intrusive complexes. These were formed at 124137 Ma in connection of rifting of Gondwana and upwelling of the Tristan mantle plume. The lavas are predominantly tholeiitic to alkaline basalts and andesites, quartz latites, rhyolites and trachytes. The intrusive complexes contain tholeiitic to alkaline gabbroic rocks, carbonatites, alkaline felsic rocks as well as metaluminous, peraluminous and peralkaline A-type granites. The complexes are confined by deep NE-trending fracture zones within the Pan-African Damara orogenic belt between the Proterozoic Congo and Kalahari cratons. Among the granite-bearing complexes, the Gross Spitzkoppe and Klein Spitzkoppe stocks are composed of marginally peraluminous topaz-bearing granites, whereas the Brandberg pluton comprises metaluminous hornblende-biotite granite, minor monzonite, biotite granite and peralkaline granites. Bimodal magmatic association is indicated by synplutonic mafic dikes and mafic magmatic enclaves. The Messum and Cape Cross ring complexes contain gabbros, nepheline syenites and metaluminous granites, and the huge caldera-like Erongo volcanic-plutonic complex contains a central peraluminous cordierite-bearing granodiorite pluton and stocks of tourmaline- and topaz-bearing granite in association with basaltic lavas and dacticrhyolitic tuffs. The volcanic-subvolcanic Paresis ring complex consists mainly of metaluminous to peraluminous rhyolitic rocks, peralkaline to metaluminous comendites, and basalt, and the intrusive rocks include microgranite, quartz syenite, syenite, nepheline syenite and gabbro. Lamprophyric dikes are associated with most of the Damaraland complexes. Isotopic (Nd, Sr, O) compositions of the Damaraland intrusive rocks vary widely, even within the same complex, roughly following the variation trends of the bimodal lavas. The origin of the parental magmas for the A-type granites is related to the interplay between plume-derived mantle magmas and two crustal sources: Damara and pre-Damara basement (Frindt et al., 2004; Trumbull et al., 2004). Overall, the diverse magmatic association is related to mantle plume activity, rifting and zones of deep fracturing, where mantle degassing most likely initiated alkali metasomatism and carbonation of the uppermost mantle and melt-depleted lower crust. This chemical ground preparation, in turn, contributed to partial melting producing parental magmas for the subalkaline and alkaline mafic and felsic rocks, peralkaline to peraluminous A-type granites, and carbonatites (Martin, 2006; Haapala et al., 2007). Although partial melting of more or less alkali metasomatized lower crust probably was the main process in producing the granite magmas, some may have developed from mantle magmas by crustal assimilation and fractional crystallization. Frindt, S.,Trumbull, R.B., Romer, R.L., 2004: Chemical Geology 206, 4371. Haapala,I., Frindt, S., Kandara, J., 2007: Lithos (in print). Martin, R.F., 2006: Lithos 91, 125136. Trumbull, R.B., Harris, C., Frindt, S., Wigand, M., 2004: Lithos 73, 2140.

Keywords: a type granites, continental rifting, alkali metasomatiam

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VS016 **Oral Presentation** **6930**

The Miocene volcano-plutonic suite of the northern Colorado River Corridor, Nevada-Arizona, USA

Prof. C.F. Miller
Earth & Environmental Sciences Vanderbilt University IAVCEI

J.E. Faulds, J.S. Miller, J.L. Wooden, R.V. Metcalf, D.J. Furbish, L.L. Claiborne, B.A. Walker, D.S. Perrault, K.F. Hodge

South of Las Vegas, Nevada, the Colorado River flows southward through a trough that separates Arizona and Nevada and marks the center of the northern portion of the Colorado River extensional corridor. This tectonic corridor underwent rapid E-W extension during mid-Miocene time, from ~13-16 Ma, with less intense extension continuing until ~9 Ma. Voluminous magmatism, marked by thick volcanic sequences, spanned a longer interval, from ~19-12 Ma. Steep tilting that accompanied extension reveals fossilized plumbing systems that fed the volcanoes for several million years spanning the onset of rapid extension. This system is manifested by small stock- to batholith-scale intrusions, dike swarms, and hypabyssal pods and sills. We focus here on a 70 km long zone that exposes three major magmatic systems on the west side of the river, centered respectively on Spirit Mountain batholith; Searchlight pluton; and Aztec Wash and Nelson plutons. All centers include abundant hypabyssal intrusions; the erupted products of Searchlight are clearly exposed, but connections between the other systems and volcanic sequences, while very likely, remain less certain because of lack of exposure and removal by faults. Roofs of the major plutons are exposed at paleodepths of 3-6 km; floors are poorly exposed, owing in part to mid-crustal ductile deformation, at ~10-13 km. SHRIMP U-Pb dating demonstrates that plutonism at each center remained active until about 15.6-15.8 Ma; at Spirit Mountain and Searchlight, the earliest dated phases are ~17.5 Ma. Nelson pluton is not well dated, but field relations document that it predates Aztec Wash (15.6-15.8 Ma) and Ar-Ar results suggest an age of ~16-17 Ma. The final intrusive pulse at each center is a 15.5+/-0.1 Ma dike swarm. At each center, the later stages (post-16.0 Ma) of intrusion are marked by input of basalt that mingled extensively and locally mixed with granite (low-silica rhyolite). Mafic input into the systems pre-16.0 Ma is largely cryptic, manifested by widely distributed, fine-grained, mafic-intermediate enclaves with localized early hornblende gabbro. The dominant magmas during this stage were granite (possibly with qtz monzonite) at Spirit Mountain and quartz monzonite (trachydacite +/- trachyandesite) at Searchlight and Nelson. The volcanic sequence and dikes in the roof at Searchlight also reveal the shift from intermediate (trachydacite/trachyandesite) to felsic (rhyolite, with quenched mafic magmatic inclusions) at ~16 Ma. The plutonic portions of all centers reveal dynamic and protracted histories, with multiple replenishments of intermediate to felsic and mafic magma; spreading and disaggregation of mafic magma within a more felsic host; transport and deposition of fragments of earlier magmatic products and roof and wall rocks; and accumulation of crystals from both the mafic and the intermediate to felsic magmas. The older (pre-16 Ma) portions appear to have been multiply replenished, long-lived crystal mushes in which details of histories were obscured. Relationships in the youngest portions of Spirit Mountain and Aztec Wash plutons indicate emplacement of replenishments as subhorizontal sheets. Earlier parts of the intrusions were probably also emplaced as sheets, both vertical and horizontal, mostly into the weak crystal mush. Highly siliceous fractionates (~high-silica rhyolites) were extracted and emplaced at all centers as dikes, localized sheets, and/or repeated accumulations at roofs. Elemental zoning in zircons provides a record of fluctuating T and melt composition in the Spirit Mountain system through time that is consistent with the inferred history; U-Pb work suggests similar histories for zircons in the other centers (elemental studies are underway).

Keywords: volcano plutonic, granite, emplacement

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VS016 **Oral Presentation** **6931**

Investigating the evolution of the Mount St. Helens plumbing system using SHRIMP-RG U-Pb, U-series, and trace element analysis of zircon

Mrs. Lily Claiborne
Earth and Environmental Sciences Vanderbilt University

Michael A. Clynne, John S. Pallister, Calvin F. Miller, Joseph L. Wooden, Frank K. Mazdab, Jacob B. Lowenstern

Zoned zircons record the time-temperature-composition history of the magma in which they grew. Recent development of trace element analysis techniques using SHRIMP-RG (Mazdab and Wooden, 2006), combined with in situ U-Pb and U-series geochronology and the new Ti-in-zircon thermometer (Watson et al., 2006), provides a powerful tool for extracting this information. We have used this approach to delineate the complex history of the Spirit Mountain batholith in southern Nevada, including repeated episodes of crystallization, melt evolution, differentiation, recharge, and transport of magma between storage zones in the shallow, Miocene intrusive system (Lowery Claiborne, et al., 2006; Walker et al., in press). Zircons from individual samples, and even single zircon grains, record temperature variations of up to 100C and order-of-magnitude variations in trace element concentration. Unfortunately, the timescales of closely-spaced events recorded by zoning are beyond resolution of in situ (SHRIMP) U-Pb geochronology (>105 years for Miocene zircons). By applying these methods to zircons erupted from very young volcanic systems, including U-series geochronology with its much higher age resolution (~104 years), we anticipate better constraining the timescales of pre-eruptive magmatic processes such as rejuvenation and differentiation, and providing insight concerning the connections between volcanic and plutonic systems. While the recent history of Mount St. Helens is one of the most thoroughly investigated volcanic systems in the world, its more distant past is just beginning to be unraveled. No studies have yet attempted to read the magmatic history of the system recorded in zircons from its erupted units. The relatively low diffusivity of Zr in melts limits zircon growth and dissolution rates. Thus, analyzable zircon zones are likely to reflect relatively long-term growth (order of 103 years), and zircon grains may survive periods of undersaturation (5 years, depending on conditions), for example in response to reheating immediately prior to eruption. This record, therefore, may provide clues as to how the magmas that erupted from Mount St. Helens were stored, differentiated, and mechanically interacted prior to eruption, both in the recent active history of the system and in less well known, earlier stages. The dacites from Mount St. Helens, by far the most voluminous product throughout its history, appear somewhat monotonous in bulk composition, but studies of 1980-1986 and 2004-2006 mineral assemblages and phenocryst and trace-element compositions hint at a more complex history that may also be reflected in zircons from units throughout its existence. We have collected a suite of samples that span the eruptive history of Mount St. Helens, from the Ape Canyon Stage, beginning ~300 ka, to the most recent eruption (December 2005), and have extracted zircons from five samples thus far. A single analyzed sample, an Ape Canyon Stage quartz-biotite dacite, yielded a complex 238U-230Th age spectrum indicating multiple ages of growth ranging from ~50 ka to 300 ka or more. Elemental as well as U-series analyses of our samples (scheduled for May '07) will provide further insight into the evolution of the magmatic plumbing system sustaining Mount St. Helens since its beginnings ~300 ka.

Keywords: helens, zircon

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VS016 **Oral Presentation** **6932**

Miocene extensional and arc-type calc-alkaline volcanism in Guti Volcanic Zone (Eastern Carpathians)

Dr. Marinel Kovacs
Mineral Resources and Environment North University Baia Mare IAVCEI

Miocene extensional and arc-type calc-alkaline vol canism in Gu ti V olcanic Zone (Eastern Carpathians)MARINEL KOV ACS, Alexan drina Fu lop .Nort h Un iversity Baia M are, V . Babes S tr. 62A, 430083 Baia Mare, RomaniaGuti Volcanic Zone [GVZ] belongs to Neogene-Quaternary Inner Carpathians volcanic chain representing one of the most complex volcanic area of the Carpathian-Pannonian region. The volcanic chain has bee n built up in c onnection with the Tertiary geotectonic ev olution o f the Carpathian-Pannonian region. The magmatis m has been associated with t he Miocene subduction of the European Plat e beneath the two microplates- ALCAPA an d Tisza- Dacia/Tisia.Two types of volcanism developed in t he GVZ. A felsic rhyoliti c calc-alkaline volcanism consisting of caldera-related ignimbrites and associated reworked volcaniclastics developed in the so uth-western and so uthern part of the area. The f elsic volcanism represe nts the onset of the volcanic activity in GV Z (~15.4 Ma) and h as bee n correlated with the areal felsic extensi onal/back-arc vo lcanism developed in the Pannonian and Transylvanian Basins (Pecskay et al. 2006). An intermediate andesiti c calc-alkaline volcanism following the felsic one, overlaying the ignimbrites developed in the entire GVZ during a much longer time interval (13.4-7.0 Ma). It consists of predominant effusive vo lcanics-typical CA se ries from basalts to rhyolites- and associated subvolcanic intrusions. A ma fic intrusive ph ase consisting of high Al b asalts ceased the intermediate volcanic act ivity in GV Z (8.1 -7.0 Ma). The in termediate vol canism is typic al subduction-related/arc-type with stro ng LILE a nd LREE enrich ments, HFSE depletion and Sr-Nd isotopes negative correlation. Cr ustal assimilation involving AFC processes has bee n st rongly constrained by trace elements geochemistry and isotopic da ta. (87Sr/86Sr = 0.7070- 0.7094; 143Nd/144Nd = 0.5125-0.5123). A depleted MORB type mantle wedge as mantle source for GVZ intermediate/arc-type magmas was asserted based mainly on HFSE geochemistry (Nb/Ta=16.1, Zr/Hf=34.6, and strong Nb depletion in the NMORB normalized diagrams). Th e main mantle source-related pr ocess involved in the arc-typ e magma genesi s was the mantle source enrichment by addition (3-7 %) of subducted sediments (constrained by low U/T h(0.28) re ported to high value s of Th, th e low Ce/Pb(3.5), the high Th/Ce (0.15) and Pb/Nd (0.58) and enriched Pb isotope co mposition). The felsic extensional vo lcanism shows geochemical signatures rese mbling subductio n zo ne-related volcanics: chondritic patt erns with LRE E enrichments and Eu negative anomaly, high LILE / LREE (Ba/La = 12 25) , LILE and LREE enrichments and Nb depletion in NMORB normalized diagram. These geochemical evidences are similar with those of the intermediate arc-type volcanics of GVZ. The s ame si milarity was emphasized in the Pb isotope composition, s uggesting mantle-source enri chment wi th subduction com ponents also for the parental magma of the felsic extensio nal volcanism. The magma genesis of the two dist inct volcanism of GVZ, extensional and arc- type is related to the MiddleMio cene geo tectonic evolution o f the Carpathian-Pannonian regio n. The felsic extensio nal volcanism was triggered by extensio ns in the ALCAPA microplate (Pannonian Basin / back-arc site) related to the subducti on roll-back. Magma genesis could be related to the uprise of an enriched (by subduction co mponents) asteno spheric mantle belo w Pannonian Basin. The continuous northwestward translation and rotation of the ALCAPA microplate has changed the positi on of the hinterla nd extensional felsic centers relati ve to subduction fr ont. The onset of the arc-type/intermediate volcanism on the same area (ancient border of ALCAPA) in what means now GVZ explains the spatial coincidence of the extensional and arc-type center locations (overlapped volcanic so urces/centers). The arc- type vo lcanism develo ped co ntinuously during th e co mplete sinking of the subducted slab before the continent-continent collision in the Carpathians arc.

Keywords: calc alkaline, felsic, arc type

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VS016 **Oral Presentation** **6933**

Reappraisal of the 'Late Caledonian' magmatic episode in SW Scotland: inter-relations of tectonism, volcanism and assembly of a batholith

Dr. Peter Kokelaar
Earth and Ocean Sciences Department University of Liverpool IAVCEI

Joanne Neilson, Quentin Crowley

The intense burst of 'late Caledonian' magmatism in is enigmatic in having a destructive plate margin signature and yet reaching a climax after ocean closure, during collision-related foreland basin development and strike-slip tectonism. The magmatic episode lasted for ~22 my and we are testing the hypothesis that it resulted from slab break-off, involving melting of 'wet' (metasomatised) lithospheric mantle due to heating by hot but 'dry' asthenosphere. In the SW Grampian Highlands the magmatic flare-up, during 430 - 408 Ma, involved the emplacement of plutons (the 'Newer Granites'), vast lava fields, centralised caldera volcanoes and the extensive Etive Dyke Swarm, all registering mainly intermediate to silicic magmas. Small volumes of lamprophyre and appinite were emplaced throughout. We have established a detailed time series of magmatic events from fieldwork and new U-Pb zircon dates (ID-TIMS). The uppermost dacite lava from near the top of the Lorne Lava Pile is of Wenlock age, at 424.96 ± 0.65 Ma, and conglomerates beneath the pile include clasts of previously unroofed coeval granite. The Rannoch Moor Pluton was emplaced at 422.48 ± 0.47, uplifted and unroofed before development of the Glencoe caldera volcano at ~419 Ma. The former 'northern lobe' of the Etive Pluton (Cruachan intrusion), which cuts the Glencoe volcano, is now recognised as a separate pluton, Clach Leathad Pluton, dated at 417.99 ± 0.46 Ma. The Cruachan body of the Etive Pluton is 414.96 ± 0.38 Ma and the Inner Starav Intrusion of the Etive Pluton is 408.12 ± 0.40 Ma. Contrary to previous notions, we find that the Etive Dyke Swarm has a protracted history that in part predates the Etive Pluton. The swarm extends NE-SW for 100 km, is up to 20 km wide, and locally represents crustal extension of up to10-20%. It records ~10 my of magmatism and initiated as part of the plumbing of a substantial volcano that was centred at the position of, and was ultimately obliterated by, the Etive Pluton. Field relations between the plutonic and volcanic elements in this region require substantial rates of both general and local differential uplift (several km/my), and also that this occurred during the span when regional extension-transtension accompanied emplacement of the dyke swarm. The Etive Dyke Swarm seemingly formed 'oblivious' to the strong basement structural controls of the previous activity, which is best reconciled with progressive assembly of a batholith (Lochaber Batholith) beneath the region. Our study suggests that an extensive field of lavas and central volcanoes originally extended from Shetland to Donegal. We favour occurrence of a 'deep-crustal hot zone'; new Nd-Sr data (with JG Fitton and MF Thirlwall) suggest that with time the magmatism evolved to incorporate more and more crust.

Keywords: pluton, volcano, tectonism

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VS016 **Poster presentation** **6934**

Magma/Enclave interaction in the Neogene Calc-Alkaline Magmatism from the subvolcanic zone of the East Carpathians: a mineralogical and isotopic integrated study

Mrs. Eugenia Nitoi
IAVCEI

The Neogene calc-alkaline magmatism of the East Carpathian Arc is related to the Miocene continental collision of the Alcapa and Tisia blocks with the East European Plate. The arc consists of two volcanic segments separated by a median subvolcanic zone. The subvolcanic intrusive host rocks comprise a wide range of petrographic types, from basaltic andesites to rhyolites. Most intrusive bodies contain enclaves. The enclaves belong to the metamorphic and sedimentary basement or to the deep-seated magmatic rocks (mafic cognate enclaves). Many of the enclaves are in all stages of partial melting and the major factor in enclaves evolution is their assimilation by the host magmas. The occurrence of the enclaves was used to decipher the genesis and evolution of calc-alkaline magmas. Samples of basaltic andesites, microdiorites, quartz biotite amphibole andesites, quartz garnet andesites, dacites, rhyodacites and rhyolites, as well as metamorphic, sedimentary, and mafic cognate enclaves, were selected for microscopic investigations and for chemical and isotopic analysis. Mechanical, thermal and chemical interactions between the enclaves and their rocks had been observed. Partial assimilation of the enclaves was observed on the sedimentary enclaves, on the metamorphic enclaves, on the monomineral siliceous enclaves, and on the garnets of metamorphic origin. At the contact, the ionic and thermal diffusion led to mineralogical transformations (reaction coronas). The reactions between the enclaves and their host rocks had as effect the disappearance of the mineralogical limits. At the first stage, melting zones occurred around the enclaves (sometimes two compositionally different liquids formed around the enclaves). As the assimilation progressed, local contamination and hybridizations took place and new mineralogical phases formed: amphibole, pyroxene, plagioclase, tridimite, and apatite. The metamorphic enclaves usually exhibit angular shapes, bordered by fine-grained margins or reaction coronas and are rich in refractory phases such as corundum, cordierite, garnet, sillimanite and kyanite-type spinel. Similarities in mineralogy of the main mineral species, in P-T conditions of amphibole crystallization, in incompatible trace element patterns, and in strontium, oxygen and hydrogen isotope composition between mafic cognate enclaves and their host rocks, clearly indicate that cognate enclaves formed from the same magmatic source. Parental magmas showing a depleted oxygen and hydrogen isotope signature (18O vary from 3.8 to 5.7; D vary from -98 to -66) relative to average MORB (18O~5.5; D ~-75) are a special feature of the Neogene calc-alkaline magmatism from the subvolcanic zone. They are interpreted in terms of assimilation of hydrothermally altered lower crust rocks.

Keywords: magma enclave interaction, calc alkalin magmatism, east carpathians

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VS016 **Poster presentation** **6935**

The applicability of using apatite geochemistry for differentiating Mesozoic I- and S-type and intermediary granitoids in S China

Mrs. Pei-Shan Hsieh
Department of Geosciences National Taiwan University IAVCEI

Cheng-Hong Chen, Huai-Jen Yang, Chi-Yu Lee, Han-Wen Zhou

The immensely distributed Mesozoic granitoids in S China (~197,000 km2) can be geochronologically grouped as Triassic, Jurassic and Cretaceous rocks. Jurassic granitoids, although the most widespread, are uncertain for their contribution to crustal growth as compared with Triassic Darongshan (DRS) and Cretaceous Fuzhou-Zhangzhou Complex (FZC) granites that are typical S- and I-type, respectively. In this study, apatites separated from seven representative plutons of vast Jurassic Nanling Mountains (NLM) granites (ASI = 0.91-1.21, CaO = 0.71-3.68 wt%, Na2O = 2.42-4.00 wt%, Isr = 0.7123-0.7223 and eNd(T) = -6.6 to -12.4) as well as one gabbro and three syenites (ASI = 0.70-0.92, CaO = 1.70-9.44 wt%, Na2O = 2.55-7.45 wt%, Isr = 0.7048-0.7075 and eNd(T) = 3.0 to -2.6) are used to compare with those collected from DRS and FZC granites for their elemental abundances, especially the rare earth elements (REEs). The apatite geochemistry reveals that Na, Si, S, Mn, Sr, U, Th concentrations and shapes of the REE distribution patterns for apatites from DRS and FZC granites basically follow the S and I granite types of the Lachlan Fold Belt (Australia), but those from NLM granites (SiO2 = 63-77 wt%) are closely related to the ASI and eNd(T), rather than the mafic-felsic relationship, of the host rock. Apatites from NLM granites with ASI >1.1 and eNd(T) <-11.6 (e.g., Zengchen and sample 99GD18 of Guidong) have elemental abundances and REE patterns similar to DRS apatites (high Na and Mn, low S, Sr and Th, and near flat REE distribution patterns), whereas those with ASI <1.0 and eNd(T) > -6.6 (e.g., Qitianling) as well as gabbro and syenite are similar to FZC apatites (high Si, Sr and Th, low Na and Mn, and right-inclined REE distribution patterns). The majority of NLM samples (ASI = 0.97-1.08 and eNd(T) = -8.8 to -11.5) cannot be correlated straightly to the granite types by having intermediate properties on apatites. In light of the Sr and Nd isotope mixing model, magmas of NLM granites fit the melt derived largely from modified DRS granites with only minor involvement of mantle-derived melts (5-20%). This supports the idea that the vast NLM granites were formed mainly through a large scale in-situ remelting or anatexis of the overlying crust materials under the relaxation of a continental lithosphere and the accompanied mafic undrplating.

Keywords: apatite geochemistry, mesozoic granitoids, nanling mountains

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VS017 **6936 - 6942**

Symposium
Pedagogical and didactical methods in earth science education and geopark concepts in demonstrating volcanic processes

Convener : Dr. Ulrike Martin

Methods in ed ucation to demo nstrate the complex interr elationships between animal, plant and non-living environments should be a to ol to lear n living with and in our envir onment. In thi s point of view there is a good connection between the Geopark concept developed under the UNESCO and e arth science education. Through the creation of a wo rld network of natural par ks with significant geologica l features, label led UNESCO Geopark, UNE SCO prom otes the twin goals of conserving a healthy environment and enhancing sustainable eco nomic de velopment. Geopar ks are designed to become a tool fo r a better understa nding o f the geological heritage and wise use o f the Ea rth's crust, by increasing publ ic awareness for a balanced relationship between huma nkind and t he ea rth. Especially multi level programmes, e.g. to demonstrate the variation of volcanic features are necessary to transfer the feeling of responsibility for our environment already i n the ch ildhood. M ethods are n ecessary to transfer scienti fic information about volcanic pr occesses including vo lcanic hazards to the gener al popolation. Contributors are encouraged to consider these key topics and contributions are invited on all aspects of the complexity of pedagogical and di dactical methods to transfer knowledge about understanding volcanoes and their hazards.

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VS017 **Oral Presentation** **6936**

Geodiversity in the East Carpathian Arc; the use of geological sites in education

Dr. Delia Cristina Papp
Cluj-Napoca Branch Geological Institute of Romania IAVCEI

Eugenia Nitoi

Recent efforts to record, upgrade and exploit a number of geological monuments in the East Carpathians have produced significant results. A survey of interesting geological sites has identified many sites or geotopes possessing high scientific values. These geological sites comprise of: different rock types (e.g. garnet bearing andesites, nepheline sienites, olivine basalts, piroclastic deposits, flish deposits, mud stones); fossils (e.g. foraminifera, nummulites, fish skeletons); sedimentary structures (e.g. salt domes, salt mines, cross-bedding); tectonic structures (e. g. folds, thrust and normal faults); lakes (salty lake, volcanic lake); landscapes (e.g. volcanic cones, mud volcanoes, keys, cliffs, caves); and a wide range of postvolcanic phenomena (e. g. mineral and thermal water springs, dry and wet mofettes, CO2, H2S exhalations, caverns with intense native sulfur and alums depositions on walls). Preliminary evaluation has identified several sites that could be stated as geological heritage sites based on their unique characteristics. Further detailed studies will need to be carried out in order to promote areas as potential Geoparks. The use of volcanic landscape and of post volcanic phenomena from the East Carpathian Arc in education is materialized into an ongoing EU Socrates/Comenius School Project a joint project between schools from several European countries. Cooperation between geoscientists and science school teachers is needed in order to determine how best the geological sites could be used in earth science education. The expected impact to be achieved is to raise students interest in the study phenomena by understanding the mechanism of their formation, to make them aware of the value of the objectives to be studied and to enrich their knowledge in the field of Earth Science. Yet, students are expected to change their attitude towards environment and towards science. By selecting similar phenomena in the participating countries, the convergent/divergent elements of the same phenomena in different volcanic environments can be followed by the students. Transfer of knowledge between students from different countries is viewed. The participating students are encouraged to make decisions on selecting the objectives to be studied, to enrich existing biography through fieldwork, to elaborate texts oriented towards the geological explanation of processes, to release multimedia products (photos, short films), to disseminate the results during science lessons. The projects impact upon teachers and upon schools could materialize through optional courses on geodiversity and geoconservation organized in the following years.

Keywords: geodiversity, east carpathians, education

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VS017 **Oral Presentation** **6937**

Volcanoes from Malarge (Mendoza-Argentina), proposed to promote geotourism.

Dr. Corina Risso
Geologic Sciences Universidad de Buenos Aires IAVCEI

Kroly Nmeth, Ulrike Martin

Through the creation of a world network of natural parks with significant geological features, labelled UNESCO Geopark, UNESCO promotes conservation of the geological heritage. The Llancanelo and Payn Matru Volcanic Fields with about 800 small mafic volcanoes near Malarge, in southern Mendoza are among those volcanic fields on the South-American continent that has highest density of volcanoes. It is suggested to be a candidate as an UNESCO Geopark in Argentina, one of the first in South America. The heritage status, an origin as complex development and erosion of two distinct volcanic fields, extraordinary variety of volcanic cones as well as a relationship with central volcanoes (stratocones and calderas) make this volcanic field an attractive place to present geoscientific topics to the public. To begin with, 7 geotops have been selected to demonstrate the diversity of volcanic and erosional phenomena associated with both volcanic fields. Hawaiian to Strombolian type eruptions build up spatter, and scoria cones ready to study at the geotop of Santa Maria cone, Coral cone and Los Morados volcano. Large and successive lava flows are well represented in La Pasarela geotope. Yardangs geotope that have been developed on ignimbrite blanket highlight the power of wind erosion in La Calle site. Even in a magmatic explosive eruption dominated field phreatomagmatic volcanoes may develop such as the Carapacho tuff ring. The successive eruptive dynamics from Malacara volcano geotop ranging from phreatomagmatic to mafic sub-Plinian, indicates the role of water in initiating the eruptions without which the mafic magmas probably would not have erupted. Malarge is a traditional touristic place in the south of Mendoza province. Argentinians are friendly people and they feel proud of their country and its attractions. So they get delight showing them off to visitors, and having governmental policies to promote them. This small-volume mafic volcanoes with exceptionally well preserved forms are present and would be a good base to achieve a complex and well-coordinated geoeducational program.

Keywords: geotopes, volcanic fields, malargue

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VS017 **Oral Presentation** **6938**

Russian scientific-educational center

Dr. Alexander Gusev
Geopysics Kazan University, Russia IASPEI

Tatarstan is the most northern frontier between Muslim and Orthodox Christian worlds, a secular republic with stability based on a high percentage of mixed marriages, official support for two languages and cultural tolerance. Kazan, the capital of Tatarstan, is a city of over one million people and the largest port on Volga river, referred to as "the port of five seas". About the size of Ireland or Portugal, Tatarstan has four million inhabitants. As a transportation hub, Kazan serves a region encompassing over 80 million people. The beautiful city Kazan (1005yr), situated 800 km East from Moscow, is one of the most remarkable and ancient towns at the left bank of the greatest river Volga, Russia. The ancient monuments of Kazan, together with its beauty and cultural and scientific atmosphere, made it historic centre as a Russian Treasure. The history of the Kazan University (1804yr) is the history of Russian science, social thought and culture: N.I. Lobachevsky - the founder of non-Euclidean geometry (1826); N.N.Zinin obtained aniline (1842), K.K. Klauss - discoverer of ruthenium (1844), A.M. Butler ov propounded the theory of composition of organic compounds; I.M. Simonov discovered the Antarctic during the round-the-world expedition of 1819-1821 led by F.F. Belinsghausen and M.P.Lazarev. For the further successful development of scientific-educational of the Russian Federation, the Republic Tatarstan, Kazan is offered the national project - the International Center of the Science, Education and the Internet of Technologies "GeoNa" (Geometry of Nature – "GeoNa" is developed wisdom , enthusiasm, pride, grandeur) , which including: original designs building "GeoNa" - "Lobachevsky 's surface", 59 floors, height 215 m (with a spike 302 m), the general area in 148,000 sq. meters, a modern complex of conference halls (up to 4 thousand seats), center the Internet of Technologies, Computer center, 3D Planetarium, training complex "PhysicsLand", active museum of natural sciences, cognitive system "Spheres of Knowledge", oceanarium with a fresh-water segment (5 million liters), botanical and landscape oases, business-hotel, where will be hosted conferences, the congresses, fundamental scientific researches, educational and recreation-tourist actions at a world organizational level. Expositions of museum -geopark "Travel to center of the Earth" will be presented of 3D and sensual demonstration of fundamental processes inside the Earth: movement of continents and tectonic plates, rotation of a liquid terrestrial core and generation of a magnetic field, magnetic storms, solar flashes and the polar lights, destructive earthquakes and fantastic eruptions of volcano, global warming of the Earth, tsunami and tornado, formation of the Earth and minerals, generation of oil and gas deposits, paleontology, occurrence of the first plants, animal, Human. Center "GeoNa" (http://www.geona.ksu.ru) will enable scientists and teachers of the Russian universities to join to advanced achievements of a science, information technologies; to establish scientific communications with foreign colleagues in sphere of the high technology and educational projects with world scientific centers.

Keywords: scientific education center

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VS017 **Oral Presentation** **6939**

Using tailored problem-based learning and volcanoes to teach undergraduate geoscience

Dr. Kelsie Dadd
Earth and Planetary Sciences Macquarie University IAVCEI

Theresa Winchester-Seeto, Richard Flood

We have redesigned units of study in our geoscience program to incorporate a modified form of problem-based learning that we call Tailored Problem-based Learning (TPBL). TPBL is an effective way to involve students in an active-learning environment, instill the principles of scientific research, and incorporate generic skills into the curriculum. While some form of PBL has been a component of senior years, it is the development of this technique for use in first and second years that is our innovation. Students work in small groups with each problem extending over several weeks. Tests of content retention give similar results to the use of more traditional teaching methods, but with the weaker students performing at a higher level. Cooperative efforts in small groups particularly benefit weaker students but all benefit from increased engagement with the content. TPBL provides a lecture series and fact sheets that give background to the problem and help to focus the direction the students take. A tutor facilitates each class and helps to guide the students. This method has been introduced into single units rather than the whole program due to the flexible nature of the degree program at Macquarie University. The problems place the students in the role of a geoscientist with topics that they might encounter in industry or a research role. Several problems were designed using volcanoes in Australia and the nearby western Pacific to cover a range of key concepts in plate tectonics, igneous and sedimentary geology and geochemistry. The use of volcanoes helps to engage students with the content and students typically complete these problems with enthusiasm. One problem, set for second year undergraduates, examines islands in the Bismark Sea and the results of a cruise that dredged on hummocks around the islands produced by sector collapse. The students are placed as part of a team of marine geoscientists working for a United Nations taskforce on volcano-related disasters. They are asked to describe the volcanic islands in terms of their shape, type and tectonic setting, to identify how they build from the seafloor and how they are destroyed. Students are presented with topographic and bathymetric maps of the area and a set of rocks from the cruise. The data set includes chemical analyses of the igneous rocks. While these rocks match those of the island chain, they are taken from the departments teaching collection. Students are asked to write their report so that it can be circulated to other scientists on the taskforce. This problem incorporates skills in map reading, constructing profiles, graphically representing and interpreting chemical data, rock identification, and report writing for a specific audience. The students are required to synthesise all aspects of the project in the final report.

Keywords: problem based, generic skills, volcanoes

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VS017 **Oral Presentation** **6940**

The Campi Flegrei geopark as a tool to awaken population to volcanic risk

Dr. Paola Petrosino
Scienze della Terra Universit di Napoli Federico II IAVCEI

Armiero Valentina, Lirer Lucio

The Campi Fle grei area combines fascinati ng geology with its unique natural lo ng hi story, individual customs and t he outstanding ancient Greek and Roman civilization. Wit hin this territo ry all kind o f volcanic products are visible from a small to regi onal scale. This area comprises a good number of geological s ites of particu lar importan ce in terms of their scientific qualit y, rarity, aesthetic appeal or educational value, most of which are part of the ge ological heritage, b ut their intere st may also b e archaeological, ecological, historical or cultural. Mo reover, Campi Flegre i volcan ic field is one of the highest volcanic risk area of t he world, but this is hardly k nown even to the inhabitants of the towns that share the territory. All the previously quoted feat ures render Campi Flegrei a very s uitable area for a volcanological geopark, in which geolog ical and archaeological reco rds can co ncur to help yo ung people to come in touch with the volcanoes. Main aim of this project is to promote the knowledge of the weight of the active volcanoes in the territ ory where the young students live. It is well known that the first step to re duce the volcanic risk is to l et yo ung gene rations actively participate in the territorys cultural revitalization as a whole. The reduction of e xposed value, in fact, com es as a direct consequence of both being aware of the volcanic hazard and understanding that such a valuable area is not worth only the violence of the present unruled buildings.In this fra mework we here propose an itinerary from Cuma to Solfat ara, passing through Averno and Monte Nuovo volcanoes. Starting from a new detailed geological survey of the area, whichmad e us also possible to identify many sites with a strong pedagogical and educational value, we poin ted out the four Geosites of Cuma,Averno,Monte Nuovo and Solfatara. All these area s ar e part of geological heritage, but their i nterest is als o archaeological and historical, as testified by the numerous ancient documents collected and investigated during the research. Each geosite satisfied t he criteria adopted for the m ost recent italian geosites, i.e. representativity, scientific interest , rarity, landscape value, educationa l value, accessibility, preservation and vulnerability, which c orrespond to the c riteria of European Geoparks. Within each g eosite at least two p ossible itineraries with many stops were planne d. At each st op posters illustrating both the geological and archeological valuables can be set for self -guided to urs. We hypo thesize a Western Campi Flegrei Geopark linking the four geo sites: the passages from one to another ar e guaranteed by present ro ads and, where possible, by ro man tunnels cav ed in ancient times fo r military aims. This geopark could represent a st ep forward for both the preservation of th e geological h eritage an d the awakening of younger generations to the impendent volcanic risk.

Keywords: campi flegrei, geopark, volcanic hazard

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VS017 **Oral Presentation** **6941**

Iron and sulphur flows in Central Andes, northern Chile

Dr. Jose Antonio Naranjo
Applied Geology Servicio Nacional de Geologia y Mineria IAVCEI

Henrquez Fernando, Andrade Belisario

Although silicate lavas formed by silicate m inerals are the most comm on material produced by volcanic activity, other magmatic phe nomena also g enerate rare lavas as of iron oxide, carbon atite and sulphur type. In addition to the geotectonic and petrologic characteristics, the hiperarid conditions of the central Andes of n orthern Ch ile, h ave allow th e ge neration an d preservation of volcanic produ cts of iron an d sulphur, as iron oxide lava flows at El Laco vo lcano (4.700 to 5.300 m asl, 2348S/6730W) and sulphu r flows at Lastar ria volcano (5.700 m asl, 25 10S/6830W). Seven iron oxid e deposits have been mapped on the flanks of El Laco, a 30 km2, Pliocene volcano, as magnetite deposits. Except for th ese iron units, El Laco volcano is similar t o other volcanic complexes in th e central And es, mainly compound of silicate lavas that are partially hydrothermally altered. T he occu rrence of iron oxide magmas is also documented in Chile in Creta ceous formations hosting the iron ore be lt of the Coastal C ordillera to the south of the Atacama Desert. With similar Mesozoic ag es they occur in Mexico and of Precambrian ages in Sweden (Kirunav aara) USA (Missouri), but the iron oxide lavas of El Laco are the yo ungest and best preserved, used as reference to explain ancient em placement models. On the o ther hand, Lastarria is a typical central Andean volcano with constant and intense fumaro lic activity. It shows unique large scale 50 to 350 m long sulphur fl ows as well a s tiny few centimetres long flows, notably similar surficial features to pahoehoe basaltic lavas. They look fresh and resently formed, being one of the last eff usive activity of this volcano. Their origin was c aused by removilisati on of prec ipitated sulphur deposits, apparently mo re common in andesitic central Andea n volcan oes th an in other volcan o provin ces. T he pristine featur es showed by the iron oxide and su lphur flows of El L aco and Lastarria volcanoes, respectively, make them world class exampl es that de serve protection from mining and preservation a s unique site of esthetic, touris t and scientific value. Detailed mapping is being carried out in order to catalogue the main features, morphologic evolution of their origin sources, pretending them to b e declared as natural geology monuments by the Chilean State. Other occurrences of this kind in different volcanic environments are expected to be discovered. T his is a c ontribution of F ondecyt P roject No. 1070428.

Keywords: iron, sulphur, lavaflows

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VS017 **Poster presentation** **6942**

Training to teach: how to plan a didactic unit about volcanic hazard. An experience in the Neapolitan region, Italy.

Dr. Maddalena De Lucia
IAVCEI

Maria Rosaria Strollo

Volcanic hazard is a strong feature of the Neapolitan region. Vesuvius, Campi Flegrei and the island of Ischia are active volcanoes that will awaken in the future. School is a key tool to improve the level of the volcanic risk awareness in population. The present work deal with the experience developed during a training to teach programme for students of the University of Naples Federico II. The teacher programme consisted of conventional courses and workshops. One of these has been focussed on volcanic hazard and volcanic risk, and has been carried out in a cooperation between researchers of the Osservatorio Vesuviano INGV and of the Dipartimento Scienze Relazionali of the University of Naples. A bright debate among scientists, students, and education experts has been the base above which a didactic unit on volcanic hazard has been developed.

Keywords: teacher training, didactic unit, volcanic hazard

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VS018 **6943 - 6955**

Symposium
New advances in understanding phreatomagmatism: from experiments to volcanic facies analyses

Convener : Dr. Karoly Nemeth

The record of the eruption is complicated by complex interactions between magmatic and phreatomagmatic processes in the conduit, transport processes in the vertical and lateral currents, and depositional processes. Many new and old techniques are being applied to understanding these processes. This session invites papers presenting new information on phreatomagmatism. Phreatomagmatic explosions and eruptions represent the key mechanism for the formation of maar-diatreme volcanoes, irrespective of magma composition or host rock type. However, there are environmental conditions (including magma and host-rock characteristics) that apparently cause quite a variability in size and shape of maars and the characteristics of their deposits. Furthermore, phreatomagmatism in maar volcanoes can occur with eruptive stages of purely magmatic explosivity, mixed magmatic/phreatomagmatic eruptions, or even final stages of lava lake effusion. The aim of this session is the discussion of physical processes of phreatomagmatism, how such processes lead to eruption variability, and the environmental factors that influence them.

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VS018 **Oral Presentation** **6943**

Experimental injection of particles and gas into non-fluidized granular material: implications for debris jets in Maar-Diatreme Volcanoes

Dr. Pierre-Simon Ross
Geological Survey of Canada Geological Survey of Canada IAVCEI

James D.L. White, Bernd Zimanowski, Ralf Bttner

In diatremes and other volcanic vents, steep bodies of volcaniclastic material having differing properties (particle size distribution, proportion of lithic fragments, etc.) from those of the surrounding vent-filling volcaniclastic material are often found. It has recently been proposed that such cylindrical or cone-shaped bodies result from the passage of debris jets generated after phreatomagmatic explosions or other discrete subterranean bursts (McClintock and White, 2006, Bull. Volc. 68:215-239; Ross and White, 2006, J. Volcanol. Geotherm. Res 149:62-84). To learn more about debris jets, we modeled experimentally the injection of gas-particulate dispersions through non-fluidized, dry particles. Analogue materials (glass beads or sand) and a finite amount of compressed air were used in the laboratory. The gas was made available by rapidly opening a valve therefore the injection of gas and coloured particles into a granular host was a brief (<1 s), discrete event, comparable to what occurs in nature following subterranean explosions. The two-phase injection assumed a bubble shape while expanding and propagating upwards. In reaction, the upper part of the clastic host moved upward and outward above the bubble, forming a dome. The doming effect was more pronounced for shallow injection depths. What happened next depended on the depth of injection and nature of the host material. With shallow injection into a permeable host (glass beads), the compressed air in the bubble was able to diffuse rapidly through the roof. Meanwhile, the coloured beads sedimented into the transient cavity, which was also closing laterally because of inward-directed granular flow of the host. Depending on the initial gas pressure in the reservoir, the two-phase flow managed to erupt or not; regardless, a conical or cylindrical body of coloured beads was emplaced. If repeated several times such injections whether erupting or wholly subterranean, accompanied by collapse-capture of a central zone of initially upward-driven material, provide a compelling explanation for the origin and characteristics of multiple cross-cutting bodies that typify diatreme deposits.

Keywords: maar, diatreme, experiments

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VS018 **Oral Presentation** **6944**

Hawaiian-type lumps as distal indicators for hydroclastic eruptions of andesitic magma associated with shallow level voluminous sill emplacement into wet sediments in the Ferrar LIP, Antarctica

Dr. Lothar Viereck-Goette
institut fuer geowissenschaften friedrich-schiller-universitaet jena IAVCEI

Robert Schoener, Benjamin Bomfleur, Joerg Schneider, Michael Abratis, Martin Elsner, Hans Kerp, Reinhard Gaupp

We report on intrastratigraphically widespread vesicular magma lumps that are the most distal indications for shallow level emplacement of massive sills into wet sediments as well as associated hydroclastic eruptions and peperite formation during initiation of the Jurassic Ferrar Large Igneous Province in Antarctica. Below the effusive section of the Ferrar LIP, extensive sections of fluvial and lacustrine sandstones are exposed in Northern Victoria Land, Antarctica, overlying crystalline basement. The sediment succession can be subdivided into 250m of quartz sandstones of Triassic age overlain by 50m tuffaceous sandstones of reworked, well sorted, distal rhyolitic fall out ashes of Early Jurassic age. The fluvial sediments are intruded by massive, columnar andesitic sills, several 10m to a few hundred meters in thickness. The older quartz sandstones are fractured by these intrusions and occur as angular fragments in the magma. The younger tuffaceous sandstones, however, show soft sediment deformation and fluidization that lead to igneousblocks-bearing sediment dikes intruding the sills as well as the fluvial sediments. Locally, the mafic sills protrude as meter to deca-meter sized plugs. Where these plugs reach the tuffaceous sandstones at a paleo-depth of < 50m, diatremes with a width to depth ratio of 2:1are formed.). They are filled with chaotic volcaniclastic breccias and block bearing tuffs that sill protrusions, grade upward into block bearing tuffs. Often such a sequence is capped by black (carbonaceous) lacustrine shales. Proximal intrastratigraphic expressions of these diatreme forming eruptions are massive layers of hydroclastic breccias and block-bearing tuffs. While in the basal layers the matrix is formed by desintegrated tuffaceous sandstone the matrix grades upward into quartzose sand. This indicates a downward propagation of the diatreme forming hydroclastic fragmentation center. The breccias are, however, free of any basement clasts and only contain angular, sill-type igneous clasts of variable crystallinity as well as vesicular lumps of bomb-size. In proximal facies these breccias are interbedded with layers enriched in collapsed lumps, which sometimes develop into welded spatter of bombs. The andesitic magmas seem to have been characterized by an extraordinary fluidity that allowed a steady hawaiian-type eruption component during diatreme forming eruptions . While the hydroclastic sediments can be traced only for a few km, the distal facies of these explosive events are marked by abundant lapilli- to ash-sized magma lumps embedded in the stratigraphic succession of fluvial tuffaceous sandstones.

Keywords: sill, phreatomagmatic, diatreme

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VS018 **Oral Presentation** **6945**

Nonisothermal water and vapor filtration flows in superheated porous media

Mr. Andrej Afanasiev
Lomonosov Moscow State University Institute of Mechanics

Oleg Melnik

Volcanic eruption is closely related to processes in the surrounding geothermal systems. Geothermal system consists of a hot permeable or fractured rock that is filled by water and vapor. Both natural convective and forced flows develop in the geothermal layer and are accompanied with boiling of water and vapor condensation. During the filtration processes different zones can arise: zones saturated with water, vapor or water-vapor mixture. These zones are separated by the migrating through the porous media phase fronts. Phase transfer occurs both in zones of continues flows and on the fronts. At the beginning of an eruption temperature in a volcanic conduit increases and gets larger than in surrounding rocks. This causes significant conductive heat flow to the geothermal system and leads to water evaporation. Generated vapor is injected to the volcanic conduit. The latter may lead magma supply to increase and even to change in eruption style from extrusive to explosive. This paper focuses on the description of filtration processes in geothermal system with allowance for heat conduction and phase transitions. The presence of the conduit is taken into account by boundary conditions. Discontinuities in flows between both single-phase zones saturated with water and vapor and single- and two-phase zones saturated with an equilibrium vapor-water mixture are studied. The structure of these fronts is considered and a condition supplementary to the conservation laws and necessary for the well-posed problems formulation is found. This condition allows to find a unique solution when several solutions with phase transition fronts are possible. One-dimensional classical discontinuity break-up problem is considered. It is shown that for different initial parameters the problem can have different solutions in qualitative sense with combination of water, water-vapor and pure vapor zones with non-monothonic parameter distribution. For considered parameters solution of the problem exists and is unique. This simple solution produces some fascinating results. For example, if pressure in the volcanic conduit rises then superheated vapor can filtrate in the surrounding rocks saturated with water-vapor mixture. One might expect in this case the coexistence of only vapor and water-vapor zones. However, the calculation shows the presence of water zone in between. The morphological stability of phase fronts is considered in shortwave approximation and the stability criterion is developed. This criterion is proved by two-dimensional simulations. It is shown that instabilities of plane phase discontinuities produce fingering. The evolution of such fingers can increase amount of water that penetrates into a conduit and burst magma discharge rate. The interaction between magma and geothermal system can lead to strong, non-linear feedback effects. These effects must be considered by a coupled flow model.

Keywords: geothermal system, filtration, vaporization

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VS018 **Oral Presentation** **6946**

Phreatomagmatic volcanoes at the rift edge of Ambae Island (Vanuatu, New Hebrides) and their potential role for volcanic hazard on ocean islands

Dr. Karoly Nemeth
Volcanic Risk Solutions, INR Massey University IAVCEI

Shane J. Cronin

Ambae Island is a mafic strat ovolcano located in the northern Vanuatu volcanic arc and has an NE-SW rift-controlled elongated shape. Along its long-axis several hundred scoria cones and fissure-fed lava fields occur. After many decades of quiet, Ambae Island erupted on the 28th of November 2005, disrupting the lives of its 10 000 inhabitants. Its activity remained focused at the central (crater lake filled) vent and this is where initial hazard assessment focus was concentrated. These assessments initially neglected that at each tip of the island, <500 and <300 yrs B.P. maars, tephra cones and rings occur. These results of explosive phreatomagmatic activity are located at the extension of the rift axis in to the sea. In the NE edge of the island, a phreatomagmatic volcanic field includes 5 tephra rings, each comparable in size to those on the summit of Ambae. Along the NE coastline, a near-continuous cliff section exposes an up to 25 m thick succession of near-vent phreatomagmatic tephra units derived from closely spaced vents. This can be subdivided into 2 major lithofacies associations. PH1 comprises matrix-supported, massive to weakly stratified beds of coarse ash and lapilli. These are dominant in the lowermost part of the sequence and contain common coral fragments, indicating that the fragmentation level of magma-water interaction must have been in a reef or coral sediment near the syn-eruptive shoreline. These beds are overlain-by and alternate-with fine-grained tephra of undulating thickness, containing fine cross-lamination as well as dune beds (PH2). PH2 beds are more common in the uppermost stratigraphy and form a few-m thick pile, interpreted to have been deposited from high-to-low particle concentration base-surges along with minor phreatomagmatic falls. A soil horizon separates the lower contact to an older tephra succession of similar character that also contains buried in situ trees in standing position, along with those flattened within base surge beds. The processes implied by these deposits are amongst the most violent forms of volcanism on this island. In addition, the lowland and coastal areas affected by these events are the most heavily populated on the island. This circumstance is mirrored on many similar volcanic islands, including the nearby SW Pacific examples of Taveuni (Fiji), Samoa, and Ambrym (Vanuatu). These locations are paradoxically often considered safe areas during summit/central-vent eruptions, simply because they are located at the greatest distance from central sources of ash-fall and lahar hazard. The observations presented here necessitate a revision of this view.

Keywords: phreatomagmatic, sideromelan, maar

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VS018 **Oral Presentation** **6947**

The relation between volatile-rich magma and phreatomagmatism: an example from Birket Ram, the Northern Golan

Mr. Uri Shaanan
Institute of Earth Scienes The Hebrwo University IAVCEI

Ram Weinberger, Oded Navon

Birket Ram is a maar lake located at the northern edge of the Golan volcanic field (western Arabia Plate), next to sedimentary rock exposures of Mt. Hermon. Phreatomagmatic phenomena are rare in the Golan and its existence in this site is attributed to the relatively shallow groundwater table and perhaps to karstic syst ems, which ar e common in t he limesto ne of this area. The maar was cr eated between 100-200 ka, and it cuts into a variety of host rocks, including Pleistocene basalts and Upp er Cretaceous sedimentary ro cks. The tuf f ring aro und t he maar is composed mainly of accide ntal, lapili-size li thics, mostly basaltic from distinct flows and scoria iden tified at the surface around the lake . The freque nt occurrence of Lower Cretaceous quartz lithics indica tes that the impact of the vexplosion reached a depth of at least 400 m ben eath the surf ace. The tu ff ca rries large amount of xenoliths that sample various levels in the lower crust and upper mantle . This includes mafic granulit es, pyro xenites, amphibole pyroxenites and megacrysts of kaersutitic amphibole. Both the wide variety and the amount are incomparable to any other site in the Golan. Kaersutite phenocrysts of very similar composition were also found in basaltic flows t hat preceded the form ation of the maar. This is the only observation of amphibole phenocrysts in Ce nozoic basalts from this region. The co-occu rrence of phreatomagmatism, large content of xenoliths a nd amphiboles both as xenoliths and megacrysts in the tuff and as phenocrysts in the basalt s uggest a genetic relation between the arrival of xenoliths, the occurrence of amphiboles and the explosiv e character of the erupti on. The high ab undance of xeno liths is pro bably connected to the volatile-rich nature of the host magma. The amphibole phenocrysts also indicate tha t the water activity of the magma was high compared with co mmon Go lan bas alts. Su ch vo latile-rich magma may vesiculate more vigorously and reach better interaction with groundwater at shallow depth, leading to the phreatomagmatic event.

Keywords: maar, xenoliths, amphibole

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VS018 **Oral Presentation** **6948**

Phreatomagmatic dynamics during the Astroni eruptions (Campi Flegrei, Italy): implications for the expected eruptive scenario

Dr. Roberto Isaia
Osservatorio Vesuviano Istituto Nazionale di Geofisica e Vulcanologia IAVCEI

Pierfrancesco Dellino

The eruptive phenomenology that generated Astroni volcano are among the most representative in terms of hazard assessment at the Campi Flegrei caldera (CFc). Astroni volcano is a well preserved elliptical edifice that formed in the central sector of the CFc during the final stage of the most recent period of activity (4.8-3.8 ka). It was constructed by at least 7 eruptions of variable intensity, two of which ended with low-energy explosions and lava extrusion. The eruptions were closely timed, emitted a total amount of magma of 0.45 km3(DRE), and in the stratigraphic record they are represented by a sequence of 7 eruptive units. The eruptive units show complexities in their architecture that suggest a rapid alternation of eruptive events characterized by diverse eruptive mechanisms. Phreatomagmatic explosions, which generated dilute and turbulent pyroclastic density currents, were the prevailing type of events and alternated with subordinate magmatic activity that formed fallout deposits from low eruptive column. The fragmentation mechanisms of the Astroni eruptions can be interpreted in terms of magma water interaction processes occurring on a vesiculated melt. The particles directly fragmented by magma-water interaction are one component and the pumice fragments represent the second component that is passively fragmented by the pressure wave of the explosion. As a result, a rapid alternance of fallout dynamics and pyroclastic density currents is registered during the eruption. The great amount of fine ash represents an additional source of hazard for such a type of activity that is frequently reported in the CFc eruptive history. Fluid-dynamic parameters of the phreatomagmatic base-surges were reconstructed both by using turbulent boundary layer approximation and by numerical simulations. These data are fundamental to define the impact parameters associated to Astroni eruptions which are considered as the most probable future eruptive scenario at CFc.

Keywords: astroni volcano, phreatomagmatic explosions, eruptive scenario

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VS018 **Oral Presentation** **6949**

Phreatomagmatism in the Garrotxa Volcanic District: spatial distribution of the vents, volcanoes architectures and characterizations of the deposits.

Mr. Federico Di Traglia
Dipartimento di Scienze Geologiche Universit Roma Tre IAVCEI

Corrado Cimarelli, Domingo Gimeno Torrente, Donatella De Rita

The Quaternary Garrotxa Volcanic District (GVD), NE Catalunya, developed in a trans- tensional continental basin originated during the Alpine post-collisional extension of the southern Pyrenees. Volcanism in this area is represented by at least 40 basaltic monogenetic centres. Monogenetic centres include mainly scoria cones together with tuff cones and tuff rings. Voluminous lava flows and basaltic lava domes are also present. Several scoria cones show transition between magmatic and phreatomagmatic activity, displaying different architectures. Field data on facies distribution of major volcanic centres and DEM-derived morphometric parameters have been merged together into a GIS in order to define volcanoes architectures. On the base of the relationship between volcano architecture and its stratigraphy, at least four types of monogenetic edifices have been distinguished: i) spatter and welded scoria mounds; ii) scoria cones; iii) complex scoria cones, iv) tuff rings. The interpolation of field and water wells data has allowed the reconstruction of the prevolcanic palaeotopography, giving new insights on the spatial distribution of volcanic centres respect to the main features of the sedimentary basement. The influence of the main tectonic lineaments on volcano shapes and their spatial distribution has also been investigated. Different setting of the sedimentary basement and its lithology deeply conditioned the evolution of the volcanic centres. The occurrence of phreatomagmatism appears to be related both to the vent location within the basin and to the temporal change in magmatic input. Volcanoes placed at the margin of the basin predominantly experienced phreatomagmatic eruptions resulting from the interaction between magma and structurally confinated deep aquifers, producing tuff-ring/maar volcanoes. Milder magmawater interaction occurred at younger volcanoes located in the central part of the basin. Here the interaction between magma and minor shallower aquifers produced phreatomagmatic activity characterizing their final eruptive phases and resulting in the edification of complex scoria cones.

Keywords: scoriacones field, volcanoes architecture, garrotxa

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VS018 **Oral Presentation** **6950**

Investigation into the mechanics and dynamics of phreatomagmatic eruptions and their resulting deposits: comparison of sinker Butte Tuff Cone (Idaho), Narbona Pass Maar (New Mexico), and Table Rock Complex (Oregon) USA

Mrs. Brittany Brand
School of Earth and Space Exploration Arizona State University IAVCEI

Amanda B Clarke, Steven Semken, Craig M White

The objectives of this research are to establish relationships between depositional characteristics and vent conditions of mafic phreatomagmatic eruptions with different sources and proportions of external water. We present results from three studies: Pleistocene emergent Sinker Butte tuff cone (SB; southern-west Idaho); Mid- Tertiary Narbona Pass maar (NPM) which erupted through a sandstone aquifer (northwest New Mexico); and Plio-Pleistocene Table Rock Complex (TRC) which is composed of one large tuff cone, one large tuff ring, and 5-6 smaller flank vents (Christmas Valley, Oregon). Depositional features at SB consist of accretionary lapilli, vesiculated tuff, cross strata with stoss-side accretion, and abundant soft sediment deformation. Juvenile ash-lapilli fragments dominate the clast compositions, with 20-45% accidental lithics. Several wet-to-dry cycles throughout the deposits indicate that the influence of external water at the vent fluctuated during the eruption. The bedding consists of finely laminated planar-to-cross-stratified fine- to-medium ash beds. Beds coarsen and thicken, and exhibit a gradual increase in juvenile material until they resemble Strombolian deposits, indicating that vent conditions dried through time. Downward coring is suggested by a change in the dominant accidental lithics vertically in the stratigraphy. The deposits gradually transition into a final effusive stage. The NPM sequence is dominated by symmetrical cross strata with heavy accretion on the lee-sides, no accretionary lapilli, little soft sediment deformation, highly fragmented juvenile material, and fine-lapilli juvenile pumice. Clasts are 70-80% accidental and vary little throughout the stratigraphy, suggesting that downward coring, if any, remained within the 300m-thick Chuska sandstone. The lack of variation in the proportion of juvenile material and the vertical consistency of the deposits indicate that the influence of external water at the vent did not fluctuate much throughout the eruption. Asymmetry around the edifice, in both accidental composition and bedding style, suggests multiple vents or a migrating vent. These dry characteristics suggest that external water was efficiently converted to steam, resulting in little to no evidence of liquid water in the deposits. TRC, first documented by Heiken, 1971, J.GeophyRes,76, is characterized by a low proportion (<40%) of accidental clasts, fining-up sequences, scour and fill deposits, massive tuff breccias, and abundant soft sediment deformation suggesting deposition within standing water. Up sequence, surge deposits consist of 50-200m wavelength hummocks, occasionally form large U-shaped features (10-100m deep), and are plastered up and around pre-existing obstacles. Exposed inner-craters show near-vertical plastered beds, convolute bedding, and large plastically deformed and overturned folds (20-120m). These features, along with abundant accretionary lapilli and vesiculated tuffs, are consistent with a high water-magma ratio. This work exemplifies the ambiguity in describing phreatomagmatic deposits as wet versus dry. We propose a new classification scheme to describe deposits of mafic volcanism where external water has varying degrees of influence on the eruptive style.

Keywords: phreatomagmatic, field comparison, classification scheme

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VS018 **Poster presentation** **6951**

Los Loros trachytic tuff ring in northwestern Patagonia-Argentina

Dr. Corina Risso
Geologic Sciences Universidad de Buenos Aires IAVCEI

Francisco Nullo, Kroly Nmeth, Pablo Leal

Los Loros volcano is a phreatomagmatic ce nter stands above the alluvial plain of the Colorado River. The basement of the volcanic edifice consist s of red fossiliferous sandstones and pelites of the Neuqun Group (Upper Cretaceous). T he nearest large volume volcanic centers are Sierra Negra in Neuqun province and Chachah un Hills in the so uth of Mendo za pro vince abo ut 35 km away. Previo us wo rks suggested that volcanic rocks of Los Loros are basalt ic in composition (Puente Formation) and their age mid-upper Pleistocene. Los L oros today had a circular shape, with 1 kilometer wide cra ter. The edifice forms a 100 m high moderat ely eroded volcanic land form. The fla nk of the volcano ha s a low profile , while the inner crater wall is steep. The r adial gully network in the crater channels rain-water to the centre of the crater forming ephemeral lake. The base of the volcanic succession of Los Loros volcano is a basaltic pahoehoe flow that gradually intercalated wi th pyroclastic breccias in up section. This pyroclastic breccias unit is overlain by rounded, white pumice (SiO_2 59.76%) lapilli-dominated beds with erosive base and top. Large pumice reaches 12-14 cm in diameter and the beds are well-sor ted, and lack of internal structure. The well- rounded nature of the pumice, the s orting characteristics, lack of internal structure and the fa cies relationship toward cross -bedded te xture in up- section suggest high particle co ncentration pyro clastic density c urrent origin. These coarse- grained, pumic e bearing b eds covered by a c omplex succession of fine-grained, lami nated lapilli tuff a nd tuff beds w ith mega-ripples and cross lamination indicating depo sition from low particle concentration pyroclastic density currents. The entire sequence is capped by at least three uni ts of trachytic (SiO_2 60.22%) lava and pyroclastic breccias. The pyroclastic bre ccias are rich in black ba saltic clasts and chilled lithoc lasts inferred to be part of the Ne uquen Group. The eruptive s equence prese rved in the er osion remanan t of Lo s Lo ros volcano indicates an initia l basaltic effusive to Hawaiian to Strombolian style eruptions. The er uption then switched to trachytic-ma gma dominated, more explosive eruptions enhanced by gas-rich trachytic magma interac ting with shallow sub- surface water. Initial pumiceous de posits of high concentration pyroclastic density current deposits gradually transf orming into low particle co ncentration pyro clastic density current deposits such as base surge beds. This succession then preserved by trachytic lava flows and tuff breccias. The later deposits recor d phreat omagmatic fragmentation of the trachytic magma. The Lo s Lo ros tuff ring sequence reco rd a no t yet do cumented scen ario fro m the no rthwestern Patagonian having trachytic composition and pro ducing pumices pyroclastic density current deposit dominated phreatomagmatic succession. This finding highlights the role of phreatomagmatism in production of relatively large ph reatomagmatic edif ices with eruptive pr oducts in evolved magmatic composition.

Keywords: tuff ring, trachytic, phreatomagmatism

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Primary versus secondary and subaerial versus submarine hydrovolcanic deposits in the subsurface of Jeju Island, Korea

Prof. Young Kwan Sohn
Earth & Environmental Sciences Gyeongsang National University IAVCEI

Ki Hwa Park, Seok-Hoon Yoon

Numerous borehole drilling has been carried out for decades in Jeju Island, which is a Quaternary shield volcano built upon the Yellow Sea continental shelf off the Korean Peninsula. It was found that hydrovolcanic deposits, about 100 metres thick and named the Seoguipo Formation, are present in the subsurface throughout the island, showing diverse depositional features. Five facies associations are identified in the formation, including (1) primary hydrovolcanic deposits formed by pyroclastic surges and co-surge fallouts in a tuff ring (facies association PHTR), (2) primary hydrovolcanic deposits formed by Surtseyan fallouts and related flows in a tuff cone (facies association PHTC), (3) secondary hydrovolcanic deposits formed by debris flows, hyperconcentrated flood flows, sheet floods, and rill flows in subaerial settings (facies association RHAE), (4) secondary hydrovolcanic deposits formed in submarine settings under the influence of waves, tides, and occasional mass flows (facies association RHMAR), and (5) non-volcaniclastic and fine-grained deposits formed in nearshore to offshore settings (facies association NVMAR). The primary hydrovolcanic facies associations (PHTR and PHTC) could be distinguished from each other because of distinct differences in lithofacies characteristics and vertical sequence profiles. They could be distinguished from the secondary hydrovolcanic and non-volcaniclastic facies associations (RHAE, RHMAR, and NVMAR) because of their distinctive sedimentary structures, textures, and compositions. The depositional processes and/or the settings of some massive and crudely stratified volcaniclastic deposits, which occur in many facies associations alike, could not be discriminated unambiguously even with microscopic observations. Nevertheless, these facies associations could be distinguished from one another with some certainty because they occur mostly in packets or sequences that are several metres to tens of metres in thickness, bounded by distinct stratigraphic discontinuities, and comprise generally distinct sets of lithofacies. The overall characteristics of the Seoguipo Formation suggest that it is composed of numerous phreatomagmatic volcanoes that are superposed one upon the other and intercalated with marine or nonmarine and volcaniclastic or non-volcaniclastic deposits. It is also interpreted that there were widespread and continual hydrovolcanic activity and attendant volcaniclastic sedimentation for more than a million years under the influence of fluctuating Quaternary sea levels before the effusion of the shield-forming lavas of Jeju Island.

Keywords: tuff ring, tuff cone, facies analysis

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VS018 **Poster presentation** **6953**

The relative role of magmatic and phreatomagmatic explosions in the Averno eruption

Mrs. Cline Fourmentraux
IAVCEI

Prof. Mauro Rosi, Dr N. Metrich, Dr A. Bertagnini, Dr K. Cashman

Most of the Campi Flegrei caldera eruptions have been explosive, variable in magnitude and also characterised by alternation of magmatic and phreatomagmatic phases. These eruptions led to the formation of a variety of volcanic structures such as calderas, tuff ring and tuff cones. Several authors have considered the explosivity to result in part from the exsolution of magmatic volatiles and in part from magma-water interaction. However recent studies of the physical properties of juvenile fragments have shown that during a classical hydromagmatic eruption, the magma-water interaction played a major role only in determining depositional features of deposits (DOriano et al. 2005). The aim of this work is to understand the eruptive dynamics of the Campi Flegrei eruptions in general, and the Averno eruption (3700 years BP) specifically. The eruption consisted of magmatic and phreatomagmatic phases that produced pyroclastic fall and surge deposits . Previous workers have suggested that the upper members are dominated by wet and dry surges beds and that the explosions were be driven by variably efficient magma-water interaction. This research has two objectives. The first is to evaluate the relative importance of magmatic and phreatomagmatic explosions in the Averno 2 eruption. For that, we analyse the dissolved water and carbon dioxide contained within melt inclusions and matrix glasses. The second is to investigate the mechanisms responsible for the evolution in eruptive style through time (from plinian to surge-producing events). Textural studies on juvenile fragments (density, vesicularity, measure of vesicle content, abundance and size distribution of the microlite) provide information on the conditions of magma ascent. This topic represents a fertile areas of research since it improves our understanding of the phenomenology of Campi Flegrei eruptions and thus may be important for volcanic hazard and risk management

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VS018 **Poster presentation** **6954**

Study new pregress on volcanic phreatomagmatic eruption

Mr. Qian Sun
Institute of Geology China Earthquake Administration IAVCEI

As an essential and important type of volcanic eruption on earth, phreatomagmatic eruption is characterized by groundwater-related explosive eruption and subsequent base surge deposit and maar lakes. Base surge deposit and maar lakes are widely distributed all over the world, and also in the Northeast China and the southern China. Study of phreatomagmatic eruption maybe dated back to 1921, and in the following over 80 years, many works have been done on phreatomagmatic eruption, using various of methods of volcanic geology, petrology, sedimentology, physical volcanology and digital modeling, to discuss its origin and mechanism. In this paper, we focus on the geological feature of the base surge deposit and dynamic mechanism of the phreatomagmatic eruption. When ascending basaltic magma meets with ground (surface) water, violent explosion would occur, this action was called phreatomagmatic eruption. The main product of this kind of eruption are maars and base surge. As to the base surge, it has long been treated as sedimentary tuff by mistake. Usually, base surge is distributed around maar, different from the distribution of sedimentary tuff. Typical phenomena of base surge caused by phreatomagmatic eruption can be observed through the detail field work, such as large-scale and low-angle cross-bedding, slaty-bedding, current-bedding and distal facies accretionary lapilli. In order to explain the dynamic mechanism of phreatomagmatic eruption thoroughly, we propose a simple model in this paper in light of the elasticity theory. Some conclusions can be drawn as follows: the larger the radius of maar, the larger the explosive wallop needed for the formation of maar is; provided that the radius of maar and depth of explosive point are limited, then the larger the area of contact surface between magma and groundwater, the stronger the explosive energy will be; if the explosive energy and area of explosive point are restricted, the larger the radius of maar, the greater the depth of explosive point can be inferred; when the explosive energy and radius of maar are qualified, the depth of explosive point decreases with increasing of the area of contact surface between magma and groundwater. As for the maximum stress, undoubtedly it should occur on the surface of the overlying formation.

Keywords: phreatomagmatic eruption, maar, base

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VS018 **Poster presentation** **6955**

Growth and evolution of So Roque offshore tuff cone, So Miguel Island (Azores): geomorphological evidences and facies analysis

Dr. Vittorio Zanon

José Pacheco, Adriano Pimentel

The sin-eruptive and post-eruptive history of So Roque tuff cone, its geological setting and volcanological parameters were studied in detail, to understand the role of tectonic activity in the birth and morphological evolution of a relatively simple and small volcanic edifice.This centre is located westward of the town of Ponta Delgada, inside the village of So Roque, in the island of So Miguel, and it is composed by two main bodies characterized by the different steepness of their slopes and numerous islets measuring only a few square meters. All these bodies are aligned along a curve that constitute overall a segment of an ellipse and represent the remnant of a tuff cone.The tectonic setting of the area follows a regional trend, defined by extensional NW-SE trending faults which probably represent the emerged segment of the Terceira Rift. The morphology of this area is in fact dominated by the diffuse presence of numerous scoria cones with basaltic composition, some times aligned along fissural fractures. The volcanic rocks which constitute these outcrops have a hydromagmatic origin and were erupted between 20890 (240) and 8700 (200) years ago. Judging from the different beddings of surge layers, it seems that magma emissions occurred along a fissure that probably opened progressively from SE to NW, forming small edifices through the rapid accumulation of wet sediments. Sin-eruptive partial collapses greatly modified the original morphology of these edifices, probably also allowing sea water to continuously flow into the eruptive fissure. The complex interaction of these two factors controlled the depth of fragmentation alongside the fracture, producing different kinds of deposits, in which the ash-lapilli ratio varied considerably. In these circumstances, also tide cycles probably played a major role, even causing periods of subaerial eruptive conditions, in which small-lived fire fountaining episodes generated agglutinated scoriae. The high water content of these deposits caused sin-eruptive and post-eruptive remobilization that resulted in collapses and some small-scale landslides. Furthermore, the post-eruptive accumulation of heavy tephra over unconsolidated tuff and littoral sands caused the selective sinking of some parts of the deposits, which resulted in the total destruction of all the southeasternmost deposits and in the formation of numerous small islets, separated by radially arranged channels in the northwesternmost sector. Fractures produced during these local partial collapses interested also a lava flow unit, emplaced several years after the end of So Roque centre, indicating that this process went on for a long time.Finally, a transtensive fault and a set of direct faults with local importance, all WNW-ESE trending, operated the last dissection of the outcrops, generating high instability in the main bodies, where falling and rolling of blocks are still frequently occurring.

Keywords: tuff cone, hydromagmatism, tectonic activity

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VS019 **6956 - 6962**

Symposium
Large Igneous Provinces

Convener : Dr. Richard Ernst

Large igneous provinces (LIPs) represent large volume, generally short duration mafic-ultramafic events not asso ciated with 'no rmal' plate bo undary pro cesses. They consist of cont inental flood basalts, volcanic rifted margins, ocea nic plateaus, ocean basin flood basalts, su bmarine ridges and seamount chains. In the pre-Mesozoic r ecord their plu mbing system of dyke swarms, sill pr ovinces and layered intrusions is ty pically exposed by erosion. Ar chean analogues may be rep resented by gr eenstone belts of the tholeiite-komatiite assocation. Many LIPs are linked to regional-scale uplift, continental rifting and breakup, and climatic crises. They can be useful as precisely dated time markers in the stratigraphic record, and are key targets for Ni-Cu-PGE e xploration. LIPs have also become a focus in the debate o n the existence and nature of mantle plumes. Contributions on any of these themes are welcome.

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VS019 **Oral Presentation** **6956**

A mantle-plume trigger for delamination beneath the source region of the Columbia River Flood Basalts

Dr. Victor Camp
Geological Sciences San Diego State University

Barry B. Hanan

Most workers have relied on a mantle-plume genesis to explain the derivation of continental flood-basalt provinces. Plume skeptics, however, believe that a plume is not necessary, preferring instead a shallow-mantle origin associated with the delamination of mantle and lower crust. We contend that these competing models are not mutually exclusive, and that plume emplacement can provide a trigger for delamination. Here, we show that the tectonic history and the progressive sequence of source melting in the Columbia River Basalt Group (CRBG) are consistent with a model of plume-induced delamination beneath the main CRBG source region. Unlike all other continental flood-basalt provinces, which are dominated by olivine tholeiites and subordinate picrites, 65 % of the CRBG is composed of high-silica basaltic andesites of the Grande Ronde Formation. These high- silica, high- Fe/Mg rocks cannot have been generated by partial melting of mantle peridotite, nor can they be easily derived from any combination of fractional crystallization or crustal assimilation. Several workers have suggested instead that they were derived from the melting of an eclogitic or pyroxenitic source at mantle depths. As demonstrated by Pb, Nd, Sr, Os, and He systematics, the CRBG petrochemical stratigraphy is consistent with the sequential melting of several source components arriving in the following order, but with variable degrees of mixing between each: depleted mantle (Steens Basalt), plume (Imnaha Basalt), mafic crust (Grande Ronde Basalt) and Archean lithosphere (Wanapum and Saddle Mountains Basalts). We can envision only three mechanisms capable of generating the large-scale melting of a mafic component necessary to produce the voluminous Grande Ronde lavas: (1) melting of an ecolgite - entrained mantle plume (e.g., Takahahshi et al., 1998), (2) plume interaction with oceanic crust in the Juan de Fuca plate, and (3) plume-induced delamination. The first two mechanisms are inconsistent with the progressive sequence of source melting, and neither is capable of providing an adequate explanation for the step-function chemical change from an OIB source component in the Imnaha Basalt to a mafic source component in the Grande Ronde Basalt. Plume-induced delamination appears to be the only mechanism capable of generating a time- line of melting events consistent with these age-progressive chemical variations evident in the stratigraphic record. Such a model, based on the geochemical.isotopic stratigraphy, is also supported by geophysical data (Hales et al., 2005), and by numerical experiments showing that delamination is a predicted consequence of plume emplacement (Burov et al., in press). Plume- induced delamination may provide a new, realistic mechanism for generating the chemical diversity and high magma supply rates of other continental flood-basalt provinces in similar tectonic settings.

Keywords: mantle plume, delamination, flood basalt

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VS019 **Oral Presentation** **6957**

Highly alkaline magmatism associated with the Emeishan mantle plume: Evidence for an open system evolution of plume-derived magmas

Prof. Yigang Xu
LArge Igneous Province Chinese Academy of Sciences IAVCEI

Sun-Lin Chung, Jin-Long Ma, Xiao-Long Huang, Ji-Feng Xu, M. F. Thirlwall

Recent sedimentologic and geochemical studies have established the role of mantle plume in the generation of the massive Emeishan flood basalts (He et al. 2003; Xu et al., 2004). The mantle plume model is in contrast with the rift model previously preferred by many Chinese geologists. The N-S trended Panxi paleo-rift, which is located in the middle of the Emeishan LIP was widely considered as the center of lava eruption and accumulation. Characterization of lava sequence accumulated within this rift zone is therefore of critical importance in defining the relative roles of mantle plumes and rift-related extension model. In this paper we document petrology and geochemistry of a lava succession of over 2000 m at Longzhoushan, which display an extremely wide compositional spectrum ranging from tholeiites, alkali basalts to phonolite. Such a lithological variety within the Panxi rift zone contrasts with the uniformly sub-alkaline tholeiites in the typical continental flood basalt province. Chemical discontinuity between basalts and phonolites indicate that they cannot be linked by fractional crystallization along a continuous line of liquid descent. REE modeling suggests that the least-fractionated basalts resulted from mixing between small melting of garnet and from spinel stability field, with over 70% garnet facies melts. This is consistent with a dynamic melting mechanism in which melts resulted from pooling of melts from a melting column. Phonolite series may have formed via partial melting of underplated magmas. Crystal fractionation is coupled with crustal assimilation as indicated by the correlation between SiO2 and radiogenic isotopic data. Presence of the abundant evolved lavas indicates a stable, shallow- level magma chamber with decreasing magma supply. The volcanism could be related to the combined effect of lithosphere extension and plume activity.

Keywords: basalt phonolite, plume riftinteraction, emeishanlip

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VS019 **Oral Presentation** **6958**

Volatile contents of lip magmas from Deccan and Columbia River: implications for atmospheric gas release from flood basalt eruptions

Prof. Stephen Self
Earth Sciences The Open University IAVCEI

Kirti Sharma, Stephen Blake, Mike Widdowson, Thor Thordarson

We present the first data on sulphur (S) and chlorine (Cl) contents of magmas from a major flood Mesozoic basalt province measured directly on rare, preserved glass inclusions within crystals and on glassy selvages in these ancient lava flows. Lava flows of the Deccan Traps, , were emplaced around 66-65 Ma ago. S and Cl concentrations range from high values of ~ 1400 ppm S and 500 ppm Cl in inclusions down to a few hundred ppm in lava selvages. The data indicate that the basaltic magmas of the Deccan eruptions would have emitted up to 0.15 wt % SO2 and up to 0.03 wt % HCl, using an approach that accounts for the variable degree of melt evolution. Such values imply atmospheric releases of ~ 4 Tg of SO2 (and 0.8 Tg HCl) per cubic kilometer of basaltic lava erupted, with most of this being released above the vents. Although eruptive volumes of individual Deccan flood basalt lava fields are not known, the SO2 masses released are indicated to be around 4000 Tg for a 1000 km3 eruption. This picture of gas releases in the ancient Deccan flood basalt eruptions is comparable with new data from three huge-volume (> 1000 km3) eruptions in the younger Columbia River flood basalt (CRB) province (~ 16 Ma), showing that they released similarly huge masses of S and Cl (up to 6 Tg S and 2 Tg HCl per cubic kilometer of magma erupted). Total masses of SO2 released at the vents by the three CRB eruptions were immense, in excess of 12,000 Tg for the largest (or 1,200 Tg per year for a decade-long duration) down to < 5,000 Tg for the smallest. These values show that the previously documented case of gas release by the CRB Roza eruption, ~ 10,000 Tg SO2 (Thordarson and Self, 1996), was typical for CRB volcanism. These results provide a solid basis for interpretation and modeling of the environmental impact of gas releases from past flood basalt activity, which has long been assumed to have been severe. The significance of flood basalt (LIP) volcanism is that the erupted volumes, and hence the potential environmental pollution caused by the gases released, were immense on a scale compared to smaller-scale historic and Quaternary basaltic eruptive activity.

Keywords: flood basalt, volatiles, sulphur dioxide

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VS019 **Oral Presentation** **6959**

Intra-lava flow geochemical heterogeneity: constraining magmatic processes generating continental flood basalts

Mrs. Charlotte Vye
Earth Sciences The Open University IAVCEI

Abdelmouhcine Gannoun, Stephen Self, Tiffany Barry, Kevin Burton

The origin and evolution of continental flood basalts are contentious issues. Central to many debates is the assumption that individual lava flows repr esent compositionally ho mogenous, rapidly erupted products of l arge well-mix ed reservoirs of magm a. Pr evious wo rk has o ccasionally do cumented geochemical heterogeneity vertically wi thin single lava sheet lobes, however little has been done to assess variation across the flow field formed duri ng one eruptive event. This is essential to interpretations of the genesis of these provinces and chemostratigraphic investigations. A new approach to investigating temporal-spatial composit ional variation during one er uptive event, usi ng the i nflation model to pr ovide a volcanolo gical framework, is presented. The inflation model has been proposed as the most common way of e mplacing large pahoehoe flow fields. This provides an understanding of the temporal relationship of lava emplacement within a lobe, i.e. the lava selvages form initially, the crusts form subsequently, and the last-emplaced lava constitutes the lobe core. This framework can be applied over the flow field con structed during one flood basalt eruption. Such a detailed study provides insight into sequential magmatic evolution during the time scale of one eruption. We present results from one flow field formed during a single eruption in the Columbia River Basalt Province, USA. Our findings show that small but statistically significant systematic variation in major and trace elements vertically through single sheet lo bes and latera lly between di fferent lobes were present at the time of emplacement. Results show typical trends indica tive of fractional cry stallisation but the trace el ements do not distinguish between other fa ctors such as source va riations and conta mination. Re-Os isotopes offe r significant information to constrain this. Initia l 187Os/188Os ratios ra nge from 0.287 (lava core) to 1.569 (lava cr ust) within one 35 m thick sheet lobe. Th ese values are more radiogenic than known enriched sources (normative mantle ~0.127, HI MU ~0.15) and sh ow that the sub-continental lithospheric mantle was not si gnificantly involved. The data show an unprecedented degree of variation within th e timescale of on e flood basalt eru ption which can be attr ibuted to pro gressive crust al contamination of the magma.

Keywords: flood basalt, emplacement, geochemistry

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VS019 **Oral Presentation** **6960**

Assessing the evidence for pre- and syn-eruptive uplift: the Deccan CFBP, India

Dr. Mike Widdowson
Dept. of Earth Sciences The Open University IAVCEI

The timing and duration of surface uplift associated with large igneous provinces provide important constraints on mantle convection processes. The widely accepted plume model predicts pre-volcanic regional uplift and associated erosion prior to the onset of eruption. However, it is the inter-relationships between erosion, sedimentation, tectonics and magmatism that provide evidence of whether or not uplift has occurred, and for constraining the timing of any such uplift. Those models attempting to describe the emplacement of LIPs without hot mantle supplied by plumes often have difficulties in explaining the observations of surface uplift, rifting and magmatism. Nevertheless, any apparent absence of regional uplift, erosional, or sedimentary indicators has been used to substantiate such models (e.g. Sheth, 2005). White et al. (1987) and White and McKenzie (1989) argue that rifting above an incubating plume head plume triggered the rapid eruption of the Deccan volcanic province (DVP). If the models of Griffiths and Campbell (1991) and Farnetani and Richards (1994) are correct for the DVP, then the maximum transient uplift preceding the main Deccan eruptions should have occurred in the Kutch - Cambay - western Narmada-Son rift valley region, with broadening but diminishing uplift further to the east and south. To test these models, the current work investigates the basement-basalt contact at key localities around the periphery of the DVP. Each locality offers a different geological setting and, when considered together, record the development of pre-, syn-, and early-stage volcanic environments.The DVP succession youngs southward, with the earliest lavas preserved in the Narmada Rajpipla area (c. 22N), and the youngest preserved near Belgaum (15N). These data support models invoking a southward migrating locus of volcanism in response to having passed over a (proto-Reunion) plume head. In the north, early lavas lie with angular unconformity upon Late Cretaceous marine limestone fluvial sandstone successions and, in some instances, thick conglomerate sheets intervene between the tilted sedimentary succession and overlying lavas. These provide evidence of significant erosion having occurred in the very earliest phases of Deccan eruption. By contrast, finer sediments accumulated in shallow lakes around the periphery of the most distal lava fields, consistent with their remoteness from any locus of uplift. Offshore, the sedimentary records of the Kutch Basin of the north-west Indian coast (i.e. offshore of the western Narmada-Son rift valley), and the Krishna-Godavari and Cauvery Basins on the east coast, are all characterized by a three- to five-fold increase in the rate of sedimentation during the late Campanian to early Maastrichtian (Halkett et al., 2001). These successions indicate a significant Late Cretaceous denudation in the continental hinterlands which is entirely consistent with regional uplift effects.

Keywords: uplift, deccan, plume

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VS019 **Poster presentation** **6961**

Field characteristics of dikes in the Allan Hills & their implications for magma emplacement, Ferrar large igneous province, Antarctica

Dr. Giulia Airoldi
Otago University geology department

Jdl White, J Rowland, J Muirhead

Dikes exposed at Allan Hills, South Victoria Land, Antarctica belong to the Ferrar Large Igneous Province (FLIP), which formed by ascent of voluminous magma during Gondwana break-up. Large volumes remained trapped in the crust as shallow dikes and sills whose physical features and emplacement dynamics remain poorly known, despite exposure over ~3000 km along the youthful Transantarctic Mountains. Allan Hills "dolerites" are fine- textured tholeiitic rocks in sub-vertical and sub-horizontal bodies, and were emplaced into Beacon Group sedimentary rocks < 2 km below the paleosurface. Dikes are ~0.2 m to ~6 metres wide, ranging from small segments extending only metres into the country rock, to large intrusions up to several hundred metres long. Rare sills > ~ 10 m thick crop out on cliff faces, but most are no more than 2 m thick, and exploited bedding contacts during emplacement. Three main sets of dikes show crosscutting relationships indicating at least two generations of intrusion. Dikes striking NW-SE and E-W are older, and cut by a third set striking NE-SW. In detail, intrusions exhibit a chaotic pattern of steps, bends, stubs, sill-like structures, en-echelon segments and bridging structures. Near dike tips, short but abundant en-echelon-segments occur. Many dikes have internal chilled contacts. Dike contacts with Beacon rocks range from hardened and sharp, to diffuse; abundant calcite veins suggest considerable fluid movement along the dikes' margins. Deformation bands and damage zones formed parallel to intrusions as they propagated, but have no clear relationship to intrusion width or length. Two main sub-orthogonal, NW-SE and NE-SW striking, joint sets occur in the Beacon rocks and produce chessboard-like exposure surfaces. Individual joints are continuous for up to several hundred metres. Dikes propagated orthogonally to least compressive stress (i.e. extension direction) during emplacement, and were in part able to exploit pre-existent fractures, whereas dike-marginal parallel joints formed to relieve excess tensile stresses from intrusion-generated high pore fluid pressures. The NW-SE oriented dikes and dike-parallel joint sets are interpreted to represent initial NE-SW extension. The younger dike set reflects subsequent NW-SE extension. E-W-striking dikes and en-echelon segments developed to accommodate local rotation of the stress field during the main NW-SE dikes' emplacement. Thin sills exploiting bedding contacts formed in response to localised stress-field changes resulting from dike propagation. Chilled internal contacts within dikes indicate re-injection of dikes and dilation of magma-filled fractures. The overall regularity of dike and joint sets is the result of systematic break-up of the host Beacon rocks, and at this stage of the present study the chessboard-like array at Allan Hills is interpreted as a consequence of stress field rotation during magma emplacement. Further study will address paleomagnetic characteristics, and anisotropy of magnetic susceptibility, of Ferrar Dolerite intrusions at Allan Hills.

Keywords: largeigneousprovinces, ferrardolerite, dikesandsills

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VS019 **Poster presentation** **6962**

Magnetostratigraphy of the lower part of the Karoo continental flood basalt Province: attempting to constrain eruptive pulses.

Dr. Anne Jay
Paleomagnetisme IPGP

Continental flood basalt provinces (CFBP) and mass extinction events have been shown to occur almost simultaneously throughout the Phanerozoic, leading to the suggestion that CFBP could be the cause of the extinctions. The volumes of SO2 erupted are thought to be the most important factor: if large enough volumes are injected into the stratosphere and converted into sulphate aerosols, climate perturbations significant enough to cause mass extinctions could occur. CFBP are emplaced in c. 1 million years and are usually composed of between 1-2 106 km3 of lava, made up of hundreds of individual sheet lobes. If the lava had erupted at a constant rate during the 1 million years, it is probable that this would not have been high enough to cause major global climate change. However, it is unlikely that the lava was erupting constantly as major red soil -like horizons, thought to represent long periods of quiescence, are found between some lava flows. It is therefore possible that the majority of the lavas were erupted by a few very large eruptions and that the majority of the 1 million years of a CFBPs life is spent dormant. Recent work on the Deccan Traps (which was coeval with the Cretaceous-Tertiary mass extinction; KTB), , by A-L Chenet et al., has identified eruptive packages produced by these very large eruptions. These can be identified from detailed magnetostratigraphy, using geomagnetic secular variation as a century-scale clock. In this work we have taken orientated cores from 70 sites along the Naudes Nek traverse of the Karoo CFBP to study the magnetostratigraphy of its southern part. We chose this CFBP because it is thought to have been larger than the Deccan Traps, yet the extinction associated with it, the end-Pliensbachian, was much smaller than the KTB extinction. We suggest that detailed magnetostratigraphy, and hence secular variation study of the Karoo CFBP will shed light on the reasons for the much smaller extinction. This in turn will help us to further understand CFBPs in general and their impact on the global climate. We will present the first results of this new study at the meeting.

Keywords: karoo, paleomagnetism, climate

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VS021 **6963 - 6974**

Symposium
Eruptions of Stromboli Volcano, Italy, March 2007

Convener : Prof. Roberto Scandone

This session is "invited contributions only".

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VS021 **Oral Presentation** **6963**

The chronology of the 2007 Stromboli eruption and the activity of the scientific synthesis group

Prof. Franco Barberi
Dipartimento Scienze geologiche Dipartimento Scienze geologiche IAVCEI

Rosi M

On 27 February 2007, at 12.49 GMT, a new eruption of Stromboli took place with the effusion of a lava flow from a fra cture on the N E crater, which rapidl y reached the se a. The eruption had been heralded by an increase in the amplitude of tremor and flank movement since at least the 1 4th of Februar y. Short-term precursors were an increase in the rate of occu rrence of small lan dslide on th e North ern flank of the volcano: the "Sciara del Fuoco". A new vent opened at 18.30 GMT on the Sciara del Fuoco at an h eight of 400 m asl. Th e new lava em ission caused the sudde n termination of the summit lava flow and initiated a period of non-stationary lava outpouring which ended on 2 April, 2007. The eruption has been characterized by a rapid decrease in the eruption rate after the first days and subsequently by episodic pulse increases. On the 15th of March, the increase in lava outpouring, monitored by a thermal camera, heralded by 11 minutes the occurrence of a violent paroxismal explosion with the formation of an impulsive eruption column and the emission of small pumices mingled with black scoriae. The pumice had a composition similar to that of the lava and black s coriae, but ha d a distinct lo wer content of micro-crystals in the ground mass. A similar featur e has been repeatea dly observed d uring the majo r explosive paroxisms of Stromboli. Short term precursors of the paroxysm were recorded by strainmeter and tiltmeter statio ns. The mo nitoring activity has bee n made by a joint team of resear chers from the INGV sections of Catania, Napoli, Palermo and Rome, along with researchers from the University of Florence, Pisa, Roma T re, and Palermo. The scientific activity was coordinated within a Synthesis Group made up by the responsibles of the different monitoring techniques of INGV and Universities and by the volcanic experts of Commissione Nazionale Grandi Rischi of the Prime Minister Office. The group made a daily evaluation of the state of the volcano and transmitted its recommendations to the Dipartimento di Protezione Civile (DPC). Several prevention measures were adopted by DPC, the main of which were the evacuation of the coast zone when strong accelerati on of t he Sciara del F uoco slope mo tion (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 400m asl.

Keywords: stromboli, eruption, monitoring

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VS021 **Oral Presentation** **6964**

Volcanological and thermal monitoring of the 2007 Stromboli eruption

Dr. Sonia Calvari
Sezione di Catania Istituto Nazionale di Geofisica e Vulcanologia IAVCEI

Bertagnini A, Cristaldi A., Landi P., Lodato L., Marotta E.

The last flank eruption on Stromboli volcano started on 27 February and finished on 2 April 2007. Compared to the previous 2002-03 flank eruption, lava effusion was roughly an order of magnitude greater, whereas the total volume of emitted lava was similar. The greater effusion rate resulted in a much shorter duration, and this confirms the steady supply of this volcano. An eruptive fissure opened on the NE flank of the NE-Crater and the emitted lava formed three branches that rapidly reached the sea. Late on the first day, the three initial flows stopped and a new vent opened on the Sciara del Fuoco at about 400 m a.s.l., at the eastern margin of the Sciara del Fuoco. In a few days, a lava flow fed by this vent formed a lava bench, several tens of meters wide, which significantly modified the coastline. Between 4 and 9 March, important changes occurred in the summit area, with significant widening of the crater rim due to crater collapses and ash explosions. The 400-m-vent stopped for a few hours on 9 March, when another vent opened at about 550 m a.s.l. on the north flank of the NE-Crater, almost in the same position as one of the vents of the 2002-03 eruption. The 550-m-vent was active for less than 24 hours, and when it closed, the 400 m vent again opened issuing lava down to the sea. On 15 March 2007, while the effusion from the 400 m vent was still on-going, a major explosion occurred. This event was similar to the 5 April 2003 paroxysm, and was recorded by all the INGV-CT monitoring web cams. A number of monitoring systems, including thermal and visual web cameras, direct field surveys, and daily helicopter flights using a portable thermal camera, enabled characterizing the different phases of the eruption.

Keywords: stromboli, eruption, thermal monitoring

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VS021 **Oral Presentation** **6965**

Insar monitoring of deformation on the Stromboli volcano during the 2007 eruption

Prof. Nicola Casagli
dipartimento scienze della terra università di firenze

Antonello Giuseppe, Catani Filippo, Fortuny-Guasch Joaquim, Guerri Letizia, Leva Davide, Rivolta Carlo, Tarchi Dario

In February 2003, following the major volcanic crisis culminated on December 30th 2002 with the triggering of a large landslide on the Sciara del Fuoco in the Stromboli volcano, a ground-based interferometric synthetic aperture radar (GB-InSAR) was installed on the NE flank of the volcano to ensure a continuous monitoring of the displacements to the National Civil Protection. Through the analysis of radar images produced every 10 minutes, with a 2 x 2 m pixel resolution, it is possible to obtain deformation maps with millimetre accuracy. Since then, four years of nearly uninterrupted radar monitoring have permitted to reconstruct the temporal and spatial evolution of deformations on this part of the volcano, revealing two main areas with different deformation rates: the Sciara del Fuoco and the upper part of the flank of the NE crater. In January 2007 the radar showed a progressive acceleration in the flank of the NE crater, forerunning the volcanic eruption occurred in February 2007. In the middle of February, the acceleration involved the upper portion of the Sciara and on February 27th a new effusive phase occurred on the Sciara and several landslides were triggered. The effusive phase finished on April 2th 2007, after a paroxysm that took place on March 15th. During the whole period the GB-InSAR system provided real-time monitoring data of crucial importance for the emergency management carried out by the Italian National Civil Protection Department. The analysis of the entire dataset of GB-InSAR measurements allowed us the assess the deformation field over a large portion of the target area due to six different processes: 1. rapid lava flows, usually channellized into morphological depressions and sometimes diverting over the slope; 2. slow gravitational flows of cooling lava masses accumulated on the Sciara; 3. gravitational sliding of volcanoclastic materials on the Sciara along one or more deep-seated slip surfaces; 4. the opening of a volcanic vent in the upper sector of the Sciara; 5. alternations of deflaction/inflaction phases in the upper part of the crater; 6. retrogressive landslides and falls inside the crater. Few minutes before the violent explosion of March 15th 2007, the system showed a clear acceleration that can be considered as a precursor. The results of the analysis confirm that the technique is particularly useful for an operational use, aimed at monitoring slow slope deformations and to understand complex deformation patterns during a volcanic crisis.

Keywords: stromboli, eruption, ground interferometry

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VS021 **Oral Presentation** **6966**

Petrochemical composition of the products erupted during the February-April 2007 eruption at Stromboli volcano

Dr. Rosa Anna Corsaro
ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA SEZIONE DI CATANIA IAVCEI

Bertagnini A., Boari E, Freda C., Landi P., Metrich N., Miraglia L., Petrone C.M., Polacci M., Pompilio M., Tesoro R., Tommasini S.

On 27 February 2007 a new effusive eruption started at Stromboli volcano from a fissure opened on the NE crater which emitted lava flows going down the Sciara del Fuoco and rapidly reaching the sea. A few hours after the onset of the activity, the lava emission began from a vent opened at about 400 m a.s.l., on the eastern margin of the Sciara del Fuoco. On 15 March, while the effusion from the 400 m vent was still going on, a paroxysmal explosion occurred from the NE crater, ejecting ballistic blocks towards Stromboli village and producing an eruptive plume which deposited ash and pumiceous lapilli/bombs in the SW sector. Sampling of the lava flow was not a simple task because the eruptive vent at 400 m a.s.l. was located on the steep flank of the Sciara the Fuoco, where the danger of landslides continuously impended. The sample collection during the different activity phases, was assured by the weekly turnover of INGV researchers and by University researchers supported by volcanological guides and Civil Protection personnel. The lavas erupted from the beginning to the end of the effusive event and lapilli/bombs emitted on 15 March, have been preliminary studied. In particular: textural observations, compositional analyses (major elements) on minerals (ol, pl, cpx) and groundmass glasses have been carried out under the optical microscope and with SEM-EDS and electron microprobe; Sr and Nd isotope ratios have been performed at the Department of Earth Sciences of the University of Florence and at the INGV-OV of Naples, using standard chemical separation techniques and Thermal Ionisation Mass Spectrometers - Finnigan Triton TIÓ. Further studies are previewed and will include: - Additional textural and compositional analyses; - Determination of volatiles contents (H_2O, CO_2, S, Cl) and major elements in melt inclusions hosted in olivine crystals in pumice of the 15 March paroxysmal event. - Major and trace element analyses on whole rocks, glasses and minerals. Preliminary results indicate that lavas and scoriae have high phenocryst content close to that of the crystal-rich scoriae and lavas usually erupted from Stromboli. Glass matrix is on the whole homogeneous and has shoshonitic composition like the products erupted during Strombolian activity and also during 2002-03 effusive event. However, the occurrence of few crystals with rounded shape and rim composition not in equilibrium with the groundmass is worthy noticing and could suggest mixing events between different magmas. Whole rock Sr isotope ratios of the beginning 2007 lava flows are similar to those of the beginning 2002-2003 lava event, thus suggesting the persisting steady state conditions of the present-day plumbing system at Stromboli. Pumices erupted on 15 March has low phenocryst abundance, and glassy matrix with basaltic composition. These features are comparable with the products erupted during previous paroxysmal explosions. Texture and composition of olivine and clinopyroxene separated from pumices are also akin to those studied in previous events.

Keywords: stromboli, eruption, petrography

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VS021 **Oral Presentation** **6967**

Civil protection organization and emergency cycle management

Dr. Chiara Cardaci
Dipartimento di Protezione Civile Dipartimento di Protezione Civile IAVCEI

Bernardo De Bernardinis, Pierluigi Soddu, Riccardo Colozza, Antonella Scalzo, Stefano Ciolli, Vittorio Bosi, Chiara Cristiani, Luciano Cavarra, Domenico Mangione, Antonio Ricciardi

After a few weeks of intense volcanic activity, characterized by a very high level of rate of the meaningful parameters, on the 27th of February the national monitoring centres (National Institute of Geophysics and Volcanology and University of Florence) communicate to the Operative Center for Volcanic Risk (CFRV - the scientific decision-support unit of the National Civil Protection) significant variations of the state of volcanic activity especially regarding blocks rolling along the Sciara del Fuoco flanks. CFRV, in alert condition since January 2007 noticed, throughout the survey cameras, at 12.30 GMT p.m., an explosive phase followed by the opening of an effusive vent at the NE crater's base that triggered several landslides along the Sciara del Fuoco. Immediately all the warning procedures began to work and the Advanced Operational Centre (COA) of Stromboli was instructed to launch acoustic signals in order to warn people to move out from the coastline, according to the tsunami's risk emergency procedures. CFRV contacted the Responsible of the national monitoring centres and the experts of the High Risk Committee for a preliminary evaluation of the phenomena, then started to operate a no stop surveillance. At the same time a Crisis Unit was gathered to coordinate the emergency activities. It sent two operative teams by helicopter that in a few hours reached Stromboli and Lipari Islands to enlarge Stromboli COA's activities and verify the readiness of local Operative Centres regarding the Aeolian archipelago emergency procedures. Volcanic surveillance activities are normally carried out by remote monitoring centres; in emergency condition, Stromboli COA becomes the unique surveillance centre hosting all monitoring sectors' researchers. In the same way, Police Officers, Mountain Rescue Unit of Guardia di Finanza Officers, an Air Force air-traffic controller, Coast Guard seamen and the Official Volcanic Guides also take part in COA's activities. So at the Stromboli COA all emergency operative functions are activated (direct surveillance, monitoring data collection, events synthesis and evaluation, emergency management activities, population support, radio links control, logistic supports and mass-media communications). At the COA all monitoring and assessment activities reported to a Synthesis Group, composed by volcanic experts of the High Risk Committee and monitoring managers, that constantly evaluated the hazard status of the volcano providing the basis for all emergency procedures. During the first emergency phase, according to the fast evolution of volcanic dynamics and the consequent variation of the hazard status, the population was precautionary moved out several times, from the dangerous areas of the coastline. Moreover the safety altitude limits were also modified for hikers, accompanied by volcanic official guide. Stromboli COA continuously reported the situation to the Neighbourhood Committee and several meetings with Stromboli's and Ginostra's village or Panarea Island population were organized to ensure a correct information to population. A multi-language brochure was arranged to inform visitors and hikers about behaving and self-safety rules.

Keywords: stromboli, eruption, risk managment

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VS021 **Oral Presentation** **6968**

VLP sources and vulcanian explosions from broadband seismic and volumetric strain records on Stromboli volcano

Dr. Marcello Martini
Istituto Nazionale di Geofisica e Vulcanologia Istituto Nazionale di Geofisica e Vulcanologia IAVCEI

L. D'Auria, F. Giudicepietro, W. De Cesare, M. Orazi, R. Peluso, G. Scarpato, M.A. Esposito, A. Caputo, B.A. Chouet, P.B. Dawson, R. Scarpa

During the 2007 Stromboli effusive eruption remarkable changes in the typical seismicity of the volcano have been observed. We present the results of preliminary analyses of the seismic signals recorded by the permanent broadband network and by two recently deployed volumetric strainmeters . The first interesting feature is the progressive lowering of the Very Long Period (VLP) seismic source centroid, starting at the beginning of the eruption. This shift is evidenced both by the changes in the VLP signal polarization and in the radial semblance location of the sources. The shift is accompanied by a significant variation in the VLP waveforms, location and occurrence rate. Their average duration changes from 20-30 s in the pre-eruptive stage to more than 100 s in the syn-eruptive period. These variations in the VLP seismic waveform are associated to similar variations in the high frequency recordings of the strainmeters. The overall pattern of the seismicity seems to indicate in the first phase a progressive emptying of the shallow conduit, followed by a progressive collapse of the upper conduit walls (marked by swarms of hybrid events).We will also show the recordings of the March 15th major explosion evidencing the feasibility of an early warning system for these phenomena.

Keywords: stromboli, eruption, seismology

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VS021 **Oral Presentation** **6969**

Stromboli 2007: Shallow Dyke propagation, fracturing and conduit collapse

Dr. Marco Neri
Istituto Nazionale di Geofisica e Vulcanologia Istituto Nazionale di Geofisica e Vulcanologia IAVCEI

Tibaldi A.

During the beginning of the February-April 2007 eruption, an eruptive fissure propagated following a NE-SW alignment from the northernmost summit crater, opening vigorously fed effusive vents at 650 - 570 m elevation above sea level (asl). Successively, the fracture propagated downslope, meeting and paralleling the northern wall of the Sciara del Fuoco collapse depression, reaching a minimum elevation of about 400 m asl, where a new eruptive vent opened. During the propagation of the dike, the highest portion of the fracture system collapsed, forming a graben about 1 30 m wide and over 30 m deep, showing a component of translation toward NW, i.e. seaward. The opening of the 400 m vent drained the magma from the central conduit, causing the progressive foundering of its internal walls and the enlargement of the summit craters area. Moreover, this collapse produced the occasional, partial obstruction of the central conduit and, for few hours (8 March), interrupted the feeding of the 400 m vent too, with the generation of shallow magma overpressure inside the system and the progressive, strong deformation of the summit portion of the Sciara del Fuoco. This potentially dangerous situation was resolved by the opening of a new eruptive vent at about 500 m asl (9 March), located in a similar position as the NW-SE eruptive fissure of the 2002- 2003 eruption, and with the reactivation of the 400 m vent, which produced the rapid decrease of the internal magmatic pressures and the deformation processes. The partial obstruction of the central conduit and a temporary rise of a more consistent magma batch caused an explosion at the summit craters on 15 March. The eruption ended on 3 April 2007, following the progressive diminution of the magma output at the 400 m vent. The 2007 Stromboli eruption showed similarities and differences in the eruptive behaviour and the deformation pattern, with the 2002-2003 eruption, which foremost was characterized by the triggering of a large landslide and a consequent tsunami. The position of the two 2007 effusive vents is remarkably similar to those of the 2002-2003 eruption. On the other hand, the 2007 eruptive activity was not followed by the dramatic mass-wasting events of the 2002-2003 eruption, confining the deformation to the magmatic feeder system itself.

Keywords: stromboli, eruption, deformations

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VS021 **Oral Presentation** **6970**

Monitoring the eruption by an integrated Geophysical network

Dr. Maurizio Ripepe
Scienze della Terra Universita' di Firenze IAVCEI

G. Ulivieri, R. Genco, G. Lacanna

Stromboli volcano has erupt ed on Februar y 27, 2007, after an intense strombolian activity lasted a couple of months. The eruption was characterized by a series of rapid evolving phenomena, like the propagation of the effusive fracture along the crater rim, the opening of effusive vents along the flank, an unusually large effusive flux (>10 m3/s), the collapse of the crater system and a major strombolian explosion. We have monitored this eruptive phenomena with an integrated network of multiparameters instruments: broad-band seismometers, infrasonic array, thermal cameras and bore-hole tiltmeters. All the information collected and processed in real-time has allowed to draw a quite clear picture of the eruption dynamics. Thermal imagery have documented in real-time how the effusive fracture propagated along the crater rim and how the lava flow was not stable in time but fluctuated following some of the main volcano instability. Intense harmonic tremor was associated to the dyke intrusion before the opening of the effusive vent along the Sciara del Fuoco slope, which was clearly detected by the infrasonic array. Tiltmeters have traced the inflation/deflation mechanisms associated to the magma intrusion and to the large discharge during the effusive phase. The response of the volcanic structure to this large drainage of lava has probably induced the collapse of the crater terrace, which was acting in two main steps as evidenced by an intense sequence of hybrid seismicity (>1000 events/day), eventually merging in harmonic tremor. Thermal images have shown how lava flux has increased ~11 minutes before the major strombolian explosion of March 15 that was detected ~3-4 minutes before also by the tiltmeters as a large inflation process. The typical explosive activity of Stromboli has ceased during the eruption and at the moment has still to recover. This seems the obvious response to the large discharge of the feeding system associated to this short, but intense, effusive eruption and it is confirmed also by the unusual change of VLP seismicity, which has drastically deepen during the eruption.

Keywords: stromboli, eruption, geophysics

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VS021 **Oral Presentation** **6971**

The Stromboli 2007 eruption: discrete and continuous Geochemical monitoring of thermal waters and soil degassing.

Dr. Salvatore Inguaggiato
Istituto Nazionale di geofisica e Vulcanologia Sezione Geochimica Palermo

S. Bellomo, N. Bobrowski, L. Brusca, L. Calderone, G. Papasso, S. De Gregorio, C. Federico, S. Francofonte, V. Francofonte, F. Grassa, M. Lotta, M. Longo, P. Madonna, A. Mastrolia, S. Morici, M. Ranaldi, T. Ricci, G. Riccobono, A. Rizzo, F. Salerno, A. So

The geochemical surveillance of an active volcano is aimed to recognize possible signals related to changes of volcanic activity. In fact, as a consequence of magma rising inside the plumbing system and/or refilling of new batches, volatiles dissolved into it are progressively released as a function of their relative solubility. Approaching the surface, these fluids discharged during magma degassing may interact with shallow aquifers and/or may be released along the main volcano-tectonic structures. Under these conditions, mineral and thermal waters as well as diffusive degassing soil zones are strategic sites to be monitored. Stromboli volcano, the northernmost island of the Aeolian arc (Tyrrhenian Sea), is characterized by an open system degassing and by a persistent mild explosive activity episodically interrupted by paroxistic and effusive events such as during the 2002-2003 crisis. It has a hydrothermal system located in the NE part of the island, recognized through some drilled wells discharging hot waters (≈40°C) with dissolved magmatic-derived fluids (mainly CO2 and 3He). Wide soil degassing areas, sometimes associated with thermal anomalies, are located in the summit area as well as along the flanks of the whole volcanic edifice. At Stromboli, the geochemical surveillance has been carried out since 1999 with discrete and continuous monitoring of thermal waters and soil degassing. Particularly, we analyzed the chemical and isotopic composition of fluids dissolved in hot waters and from some fumarolic vents. The CO2 fluxes emitted from soil at Pizzo Sopra la Fossa and Scari village area were also measured. On the basis of the obtained results, we proposed a geochemical model of fluids circulation, including gas- rock-water interaction processes and diffusive soil degassing. Such a model allowed us to recognize significant changes in the monitored parameters before and during the 2002-2003 eruption. Noteworthy geochemical signals of volcanic unrest were clearly identified in the physical-chemical parameters and in the chemical composition of some thermal waters as well as in the soil degassing from the summit area. In view of that, we decided to implement the acquisition of these parameters for a better comprehension of the processes inducing the observed variations. Since the end of 2006 we hourly record temperature data at three different depths (10, 30 and 50 cm) in a soil thermal anomaly along the summit area. Furthermore, in January 2007 an automatic station for the continuous measurement of CO2 content dissolved in water has been installed at Ossidiana thermal well. This year, a new eruption began on February 27 and lasted until April 2, being characterized by effusive activity on the Sciara del Fuoco and also by a paroxistic event (March 15). This crisis has represented for us an opportunity to refine the developed model as well as to improve the understanding of the relationship existing between the magmatic dynamics of the volcano and the geochemical variations with the final aim to evaluate the level of criticality of the volcanic activity.

Keywords: stromboli, eruption, geochemestry

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VS021 **Oral Presentation** **6972**

Measurements of plume CO2 and SO2 flux during the 2007 Stromboli eruption

Prof. Alessandro Aiuppa
Dip. CFTA Università di Palermo IAVCEI

Burton M., Caltabiano T., Federico C., Giudice G., Guida R., Gurrieri S., Murè F., Liuzzo M., Randazzo D., Salerno G.

A breakout of lava from the central conduit of St romboli on 27th February 2007 heralded the start of a 35 day lava effusion which co ncluded on 2nd April. This eruptio n pro duced an unprecendented opportunity to examine volcanic processes on St romboli using new te chniques dev eloped since the 2002/03 eruption. In this work we present SO2 flux and CO2/SO2 ratio data for gas emissions from the summit craters, measured usi ng automatic systems. Th e combination of these data yiel ds, for the first time, the CO2 flux emitted fr om Stromboli, a paramete r that gives deep insight into the workings of a volcanic system due to the low solu bility of CO2 in magma. In this paper we will present the major results from this work, which include the o bservation of enhanced CO2 and SO2 degassing prior to the start of the eruption, sustained high degassi ng rates during the eruption and a net reduction in gas flux after 2 April. Most importantly, we observed a period of ~5 days of unprecedently high CO2 flux prior to the 15th March paroxysm, which was immediately preceded by a drop in SO2 flux and a final increase in CO2/SO2 ratio. These obser vations sugges t that mo nitoring CO2 flux may well allo w us to better constrain when paroxystic explosions will occur on Stromboli.

Keywords: stromboli, eruption, monitoring

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VS021 **Oral Presentation** **6973**

Ground deformation monitoring at Stromboli : insights on recent eruptions

Dr. Alessandro Bonaccorso
INGV Istituto Nazionale di Geofisica e Vulcanologia IAVCEI

Aloisi M, Bonforte A, Gambino S., Guglielmino F, Mattia M, Palano M, Puglisi G

Keywords: stromboli, eruption, monitoring

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VS021 **Oral Presentation** **6974**

Evolution of the Sciara Del Fuoco slope after the instability phenomena triggered by the february 2007 eruption

Dr. Maria Marsella
DIPARTIMENTO DI IDRAULICA TRASPORTI E STRADE DIPARTIMENTO DI IDRAULICA TRASPORTI E STRADE IAVCEI

Sonnessa A., Bernardo E, Proietti C., Tommasi P., Coltelli M, Chiocci F, Romagnoli C, Bosman A.

Keywords: stromboli, eruption, monitoring

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VS022 **6975 - 6980**

Symposium
Mt Ruapehu (NZ) breakout lahar, 18 March 2007

Convener : Dr. Karoly Nemeth

On the 18th of March 2007 a crater lake outburst lahar from Mt Ruapehu, New Zealand, was observed and sampled as it flowed through the Whangaehu valley, from the medial reaches at c. 44 km from crater, to the coast (> 150 km). The 2007 Ruapehu lahar represented a unique chance to understand qualitatively the relationship between the unsteady motion of a lahar wave progressing through an existing stream-flow and its resulting deposit. Past lahars on Mt Ruapehu have been estimated to entrain up to four times their initial bulk in sediment, and therefore the event of March 2007 provides an exciting opportunity to study the interaction of this process with the downstream progression of the lahar. In this session presentations will be focusing on the observation, sedimentology, geophysical parameters and numerical modelling of the March 2007 Ruapehu (New Zealand) lahar.

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VS022 **Oral Presentation** **6975**

Mt. Ruapehu Lahar HAzards - an historical context

Dr. Shane Cronin
Institute of Natural Resources Massey University, New Zealand IAVCEI

V.E. Neall, J.A. Lecointre, V. Manville

Mt Ruapehu at 2797 m is a persistently snow-capped volcano located within the central North Island of New Zealand. Over its active vent, the 7-10 million m3 Crater Lake is located at c. 2530 m, apart from two brief periods during the 1945 and 1995-96 eruption episodes. Ruapehu is one of New Zealand 's most active volcanoes and since 1861, has produced over 60 individual lahars, within 16 episodes. Historic lahars have caused damage in four catchments affecting ski -fields, recreational areas and infrastructure up to 150 km distant. The most important lahar path, affected on at least 55 known historical occasions is the Whangaehu River, the natural outlet of the Lake, which flows down the eastern flanks of Ruapehu. Around 80% of historic lahars were generated by phreatomagmatic or phreatic eruptions through Crater Lake that either, explosively ejected water/debris onto the upper slopes, or expelled waters out of the natural outlet. Another c. 16 % of flows were triggered by rainfall, and two events (1953 and 2007) were generated when temporary dams of volcaniclastic ejecta and ice over the outlet area catastrophically failed. The largest historic flows involved loss of >1 million m3 of Crater Lake water, in 1861, 1925, 1953 and 1995 (2). By comparison, many late Holocene flows in this catchment were probably up to 10 times this volume and thus must have involved the entire volume of Crater Lake being released in one event. All the historic lahars in the Whangaehu River have been clay-poor non-cohesive flows that changed their rheology, volume, stage height and discharge dramatically with distance by erosion (bulking) and deposition (debulking) of sediment along their paths. The Whangaehu can be split into: a steep and deep gorge for the first c. 9 km; followed by a sudden break in slope onto a broad flat fan area between 9-18 km, a gravely shallow channel up to c. 42 km; and a sinuous channel confined and cut to increasing depths within Tertiary-aged mudstone up to c. 150 km from source; before terminating in a low-gradient tidally influenced lower stretch. Eruption-produced lahars in 1995 typically bulked to debris flow rheologies (and their highest volumes) within 5 km, but then spread and thinned across the fan to transform into hyperconcentrated flows (containing 30-55% by volume sand-dominated sediment) up to c. 85 km from source. Further transformation downstream into muddy streamflows was caused by the gradual loss of suspended sediment. A peculiar feature of these lahars is their distinctive chemistry, inherited from the extremely acidic Crater Lake. Contrasts between chemistry of invading lahars and the pre-exisiting streamflows in this catchment have shown that the passage of a lahar wave involves four main phases. A head (1) of stream water and floating debris, where stage rapidly rises to a peak; (2) a portion where sediment concentration rises to a peak while stage drops; (3) a portion where the water chemistry reaches the purest representation of Crater Lake; followed by (4) a long tail where stage, water chemistry and sediment concentration slowly returns to normal levels. The lag between peak stage and peak sediment increases with distance downstream from c. 15 to up to 45 mins. Rainfall-generated flows were simpler, forming hyperconcentrated flows that slowly transformed to streamflows as they lost sediment. The dam-break lahars appear also to have never bulked to the point of debris-flow rheology, reaching hyperconcentrated flow rheologies at their maximum sediment concentrations and maximum volumes, at locations considerably farther from source than the eruption-produced events.

Keywords: lahars, volcano sedimentology, volcano hazard

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Characterising the initiation of the 18th March 2007 Ruapehu crater lake Lahar: reconstructing the dam failure mechanism

Dr. Vern Manville
CVS member IAVCEI

Massey C., Hancox G.T., Keys H.J.R.

In 1995-96, the largest eruption sequence in 50 years at the andesitic Ruapehu volcano in the central North Island of New Zealand expelled the summit Crater Lake. As well as generating a series of eruption- and rain-triggered lahars, this episode constructed a 7. 6 m thick barrier of unconsolidated tephra over the stable lava rock that formed the former outlet. Over the following 11 years the c. 9 million m3 lake refilled at an irregular rate from a combination of precipitation and juvenile inputs, mediated by climatic and geothermal heating cycles that influenced the lake's water mass balance. This situation was effectively a repeat of one between 1945 and 1953 when a refilling Crater Lake broke-out 8 years after a magmatic eruption resulting in New Zealand's worst volcanic disaster through the loss of 151 lives. In late December 2006, as the lake rose above the level of the hard rock rim, seepage appeared for the first time on the downstream toe of the tephra dam. As part of an accelerating research plan a number of instruments were installed on the margins of Crater Lake at an altitude of 2530 mASL, in addition to the existing ERLAWS (Eastern Ruapehu Lahar Warning System) equipment operated by the Department of Conservation. This equipment included a bubble-in lake level system logging lake level to a +/- 3 mm precision at 10 second intervals, and an automatic digital still camera overlooking the downstream face of the tephra dam storing images to an on-site flashcard at 1 minute intervals during daylight hours. On 18 March 2007, the tephra dam was breached by the rising lake, triggering the release of c. 1.3 million m3 of 28 oC water over a period of a few hours. This outflow bulked by entraining ice, rock and alluvium in the steep upper gorge of the Whangaehu River to produce a significant-sized lahar, estimated to have been c. 25% larger than the 1953 event. Despite poor weather conditions, the fixed camera captured a unique time-lapse sequence of the failure of the tephra dam, while the early rate of lake level drawdown was obtained from the bubble-in and ERLAWS lake level sensors. Meanwhile ERLAWS geophones at the tephra dam detected ground-shaking caused by sequential collapse of the tephra dam and the escaping water. These observations confirm the results of finite element stability modelling of the tephra dam based on its geotechnical properties derived from scalar penetrometer and granulometric data. Once the lake had risen above a critical level (brought about by the first storm of autumn), increased seepage through porous scoria layers interbedded with less permeable finer-grained ashes caused increased pore pressures in the dam toe, reducing the factor of safety and triggering small retrogressive failures that stepped back towards the dam crest. Large-scale failures were presaged by opening up of tension cracks, before breaching through the eastern erosion scarps allowed surface outflow at c. 5 m3/s for 16 minutes. This outflow destabilised the western side of the dam, resulting in a second major collapse of the dam crest and formation of a large breach at 11:22 NZT. Numerical modelling indicates that the breach grew to close to its final dimensions in c. 10 minutes, with only limited breach enlargement occurring during the latter part of the outflow hydrograph. Breach discharge peaked at c. 530 m3/s.

Keywords: lahars, ruapehu, dam break

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VS022 **Oral Presentation** **6977**

Dynamics of the 18 March 2007 Ruapehu Lahar from geophysical and geochemical observations

Dr. Shane Cronin
Institute of Natural Resources Massey University, New Zealand IAVCEI

S.E. Cole, H.K. Mcmillan, V. Manville

One of the major difficulties in understanding lahar dynamics and downstream progression is a lack of quantitative information on the bulking and debulking process which is so critical to flow characteristics such as stage, velocity and energy. Past lahars on Mt Ruapehu have been estimated to entrain up to four times their initial bulk in sediment, and therefore the event of March 2007 provides an exciting opportunity to study the interaction of this process with the downstream progression of the lahar. In order to monitor the changing nature of the flow, observations during and immediately after the event were used to create a unique archive of information. This includes stage, pore pressure and seismological records, together with sediment concentration and chemical analyses. Post-event GPS surveys collected tideline and cross-sectional data used for calculations of maximum flow velocity, using both slope-area and superelevation methods. Cross- sectional data enables these to be extended to include discharge estimates. Amplitude and spectral data from seismological records are used to draw conclusions about bulk flow excitation and the movements of particles within it colliding with each other and/or the bed. The early stages of flow – as measured at 7.4 km from source shows a very rapid onset on stage, pore pressure and broad-band seismograph. Seismic energy rises to a peak within 1 min of flow arrival and is strongest over the initial few minutes, which may indicate that there was a boulder-rich front. For the remainder of the lahar wave (3+ hrs) the pore pressure values compared to a nearby radar-measured stage indicate that the flow contained relatively low sediment concentrations – which is also indicated by photos of the waning flow and the deposits remaining. By 28 km from source, it took around 4 min to reach peak seismic energy, and this dropped substantially after another 3-4 minutes. At 85 km, the onset of peak seismic energy took over 16 minutes and significantly lagged behind the peak stage of flow. This corresponded with visual observations of this site where sediment concentrations began to increase around 10 min after arrival of peak flow. Comparisons between data sources are also extremely valuable. In many cases correlations between data types are strong and suggest possible uses of proxy variables for data-poor scenarios. In other cases the variations between records are more telling; for example the changing relationship between stage and pore pressure may give clues on characteristics such as flow dilation or ponding. As the observational data begins to be understood in terms of mutating physical properties, the applications to modelling and hazard assessment will be extremely important.

Keywords: lahars, volcano sedimentology, volcano hazard

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VS022 **Oral Presentation** **6978**

Flow observations and their relationship to the depositional record of the 18 Mar 2007 Ruapehu Lahar

Dr. Gert Lube
Volcanic Risk Solutions - INR Massey University IAVCEI

S.J. Cronin, J-C. Thoret, A.V. Zernack, P. Kellman, K. Holt, V.E. Neall, J.N. Procter, M. Irwin, S.E. Cole, A. Moebis, I. Chapman, M. Turner, H.K. Mcmillan, C. Robertson, K.M. Martelli, K. Nemeth, J.A. Lecointre

On the 18th of March 2007 a lahar from Mt Ruapehu, New Zealand, was observed and sampled as it flowed through the Whangaehu valley, from the medial reaches at c. 44 km from crater, to the coast (> 150 km). We present video footage along with data on sediment concentration, stage height, water chemistry and flow velocity from various locations to illustrate the space- and time-dependence of flow behaviour. We distinguish three major phases of flow behaviour which can be directly related to the resulting deposit and the longitudinally and laterally varying mode of deposition. The first phase, lasting for c. 30 minutes, includes the arrival of the watery lahar front accompanied by a steady increase in stage height and sediment concentration. Towards the end of this initial phase, standing waves become frequent and increase in amplitude. During this time, the flow deposits a basal, crudely stratified unit 1 that grades and thins laterally into an overbank facies. In some places there is a clear transition between this first phase and the second phase, resulting from a retreat of flow into the channel and deposition of a mm-scale (slack-water) silt layer. The second phase, lasting for about 30 to 45 minutes, represents the period of maximum sediment concentration. During this period up to three separate pulses, 10 to 15 minutes apart occurred, each with increasing audible collisions from boulders transported as bedload, increasing concentration of floating debris at the surface, and increasing amplitude of standing waves. This part of the flow deposited an up to 2 m thick, massive, inversely graded unit that drapes over unit 1 (except in sites highest above the channel). During the third (waning) phase, stage height and sediment concentrations decrease and the flow erodes into near-channel unit 1 and 2 deposits. Over the next 24 hrs the flow receded to abandon several terraces, the fronts of which being partially eroded by successively later phases of flow. The deposits of these late-stage terraces become progressively more stratified and fine-grained. The 2007 Ruapehu lahar represented a unique chance to understand qualitatively the relationship between the unsteady motion of a lahar wave progressing through an existing stream-flow and its resulting deposit.

Keywords: lahars, ruapehu, dam break

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VS022 **Oral Presentation** **6979**

Evaluation of TITAN2D modelling forecasts of the anticipated "Breakout Flood" at Ruapehu

Prof. Michael Sheridan
Geology Department University at Buffalo IAVCEI

J.N. Procter, S.J. Cronin, A. Patra, B. Pitman, V. Manville, H.J.R. Keys

Following the 1996 eruptions of Ruapehu, the chances for a dam-breakout lahar were immediately recognised, because an unstable 7-9 m pile of volcaniclastic ejecta had accumulated over the former stable outlet of Crater Lake. As the refilling lake rose and was dammed behind this debris, authorities increasingly demanded answers on the range of likely scenarios for lahars should the dam collapse. Of particular focus was a protection structure (the bund) built alongside the Whangaehu River at c. 9.5 km downstream of Crater Lake in order to stop lahars spilling northward and into the Tongariro catchment. The bund effectiveness was tested by running a range of flow scenarios in this channel reach using two versions of the Titan2D mass flow modelling code. Titan-2D is a depth averaged, "shallow water" flow model, simulating either a dry granular flow, or a two-phase viscous fluid + granular flow developed by the Geophysical Mass Flow Modelling group at SUNY Buffalo. The major innovative feature of this code is that it solves the movement of a granular or two-phase flow of initially specified volume over natural terrains by using an adaptive grid. We present here a comparison of these scenarios, run before the 18 March 2007 break-out lahar to details from the actual event. The Titan2D models were extremely accurate in predicating both the inundation areas and travel times of the lahar at various points along the upper flow channel down to the bund. The velocities and discharges predicted at the bund were up to 20% higher than those of the 2007 flow, but matched closely those of the largest 1995 event in this area. Predicted paths of flow, including side-channel spill-overs all correlated with those in the March 2007 event. In addition the simulations showed features such as flow superelevation in corners and hydraulic ponding that correspond well to actual observations and measurements: In addition to these pre-event simulations, new high-fidelity simulations using pre-event LiDAR data and actual volumes of the 2007 event will be presented and discussed.

Keywords: lahars, volcanosedimentology, volcano hazard

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VS022 **Oral Presentation** **6980**

Modelling hydrodynamics of the March 2007 crater lake outburst, Mt Ruapehu, New Zealand

Dr. Vern Manville
CVS member IAVCEI

J. L. Carrivick, S.J. Cronin

Ice-covered volcanoes produce many potentially devastating phenomena due to the thermal interaction between hot volcanic materials and ice. Examples include glacial outburst floods or 'jökulhlaups' and volcaniclastic debris-laden flows or 'lahars'. An improved understanding of these phenomena, and thus effective hazard management and mitigation solutions, can only be advanced through multidisciplinary research, which should draw together remote sensing, geomorphology and sedimentology, and numerical modelling. This project therefore makes an opportunistic examination of the recent lahar from Mt Ruapehu, New Zealand. It seeks to quantify processes and mechanisms of the flow and achieves this through application of a fully integrated hydrodynamic - sediment transport model. The modelling utilises very high-resolution topographic data (LiDAR) to route a user-specified hydrograph down-slope, given data on roughness, pre-existing sediment fill, and grain size fractions. The model (Delft3D) is a fluid dynamics model, so whilst considering sediment transport, it does not consider granular interactions. Flow hydraulics varied considerably in space and time, and are primarily controlled by slope and degree of topographic confinement. Considerable downstream attenuation of peak discharge occurred due to high channel roughness, and frontal speeds were much slower than main body velocities. Flow pulses occurred as minor obstacles caused hydraulic ponding and were subsequently over-run. Patterns of erosion and deposition were consequently very complex. Validation of this modelling is essential for land management and engineering solutions to lahar and outburst flood hazards and is currently a key gap in numerical analysis of high-magnitude outburst floods and lahars.

Keywords: lahars, ruapehu, dam break

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Via della Madonna Alta, 126 - 06128 Perugia - Italy

e-mail: protocol@iugg2007perugia.it

website: www.iugg2007perugia.it

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