However, there is little information about the population in the species level, even the phylogenetic type. In this study, microbial community structure in the hydrothermal plume inside a Suiyo Seamount caldera was investigated both qualitatively (16S rDNA phylogenetic analysis) and quantitatively (16S rRNA targeted fluorescent in situ hybridization: FISH). From transmissivity data, hydrothermal plume was detected in the depth layer of 1100m to 1250m. In this plume layer, more than 90% of Bacteria-probable cells belonged to only one phylotype (SUP05) of the gamma-Proteobacteria, which were strongly related with sulfur utilizing symbiontes of mytilids and mussels in hydrothermal areas. A vertical profile of SUP05 cell numbers corresponded well with that of some chemicals, as well as transmissivity. However, cell morphology analysis revealed that there was an obvious boundary at the depth of 1200m, suggesting that plume history may be different between above and below this depth. Another representative Bacteria-probable cells were specified to a group within the epsilon-Proteobacteria (SUP01), showing a close relationship with environmental clones from deep-sea sediments. In addition, the both SUP05 and SUP01 phylotypes of Bacteria were strongly stainable, i.e., very active, in FISH analysis. These microbes may be not negligible in both primary production and sulfur cycling in this deep-sea hydrothermal system.

V11C-11 1120h

Biological nitrogen fixation in the subseafloor associated with mid-ocean-ridge hydrothermal vent systems

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Thermophilic and hyperthermophilic microorganisms that have been isolated from diffuse hydrothermal vent fluid are assumed to reside within hot, anaerobic zones in the subseafloor. These microorganisms can be metabolically versatile or highly specialized, and utilize a variety of carbon and energy sources that are available in hydrothermal vent fluid. However, the nitrogen sources that support subseafloor microbial communities remain unknown. Chemical analyses indicate that nitrate and nitrite are depleted in diffuse hydrothermal vent fluids relative to deep seawater and are absent in reduced fluids above 30°C. Ammonium concentrations in low temperature vent fluid are similar to the low concentrations in deep seawater, with the exception of sedimented hydrothermal vent systems such as Guaymas Basin and the aberrant, unsedimented Endeavour Segment on the Juan de Fuca Ridge. The largest reservoir of nitrogen in the ocean is dissolved dinitrogen gas, which is abundant in deep seawater and slightly elevated in hydrothermal fluids. Biological nitrogen fixation was first suggested as a potential source of nitrogen to hydrothermal vent ecosystems based on the nitrogen isotope ratios of low trophic level vent fauna, which are much lower than the nitrogen isotope ratios of deep sea organic nitrogen, ammonium and nitrate, but resemble those of deep-ocean dinitrogen gas and marine biota associated with nitrogen fixation. We have detected the genetic potential for nitrogen fixation by amplifying and sequencing one of the genes responsible for nitrogen fixation, *nifH*, from diffuse hydrothermal vent fluid. The *nifH* genes present in hydrothermal vent fluid originate from a diverse *nifH* assemblage in the subseafloor as well as a phylogenetically distinct *nifH* cluster in deep seawater. While there was no major difference in the *nifH* populations between nitrogen-rich and nitrogen-poor diffuse hydrothermal vents, we will attempt to detect the expression of *nifH in situ* and in nitrogen-fixing isolates cultured from vent fluids.

V11C-12 1135h INVITED

Colonization by pioneer populations of ϵ-*Proteobacteria* and community succession at mid-ocean ridge hydrothermal vents as determined by T-RFLP analysis

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Terminal-restriction fragment length polymorphism (T-RFLP) patterns were used to track populations of bacteria occurring within multiple bacterial growth chambers (BGCs) deployed at eight diffuse-flow (Tmax=78°C) hydrothermal vent orifices located within the caldera of Axial Volcano, Juan de Fuca Ridge. For comparison, two distal diffuse vents located at the Magic Mountain area on the Explorer Ridge were also examined. Over a five-year sampling period in conjunction with the NeMO (New Millennium Observatory) program, 52 BGCs were recovered after either a short-term (days) or long-term (annual) deployment. Upon recovery, genomic DNA was extracted and amplified using bacterial-specific PCR primers to generate 5' fluorescently-labeled amplicons of small subunit rRNA genes (i.e., SSU rDNAs). These PCR amplicons were digested with multiple tetrameric restriction endonucleases and the respective community diversity and succession patterns were characterized. The average number of populations (a measure of species richness) within the community that developed in short-term deployed BGCs was significantly lower than those detected in long-term deployed BGCs. All short-term BGC communities were dominated by primary colonizers or pioneer populations indicative of ϵ-*Proteobacteria*, of which, specific phylogenetic groups were recognized at vent sites throughout the five-year sampling period. The long-term BGCs showed evidence of successional events by an increased occurrence of numerous other populations accompanying the pioneer populations of ϵ-*Proteobacteria*. The discovery that all primary colonizing populations were most similar to known lineages of ϵ-*Proteobacteria* detected from hydrothermal vents located worldwide provides further evidence that a few cosmopolitan populations are capable of acting as the primary microbial successors of newly-formed hydrothermal vent systems.

V11C-13 1150h

Evaluation of microbial community in hydrothermal field by direct DNA sequencing

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Many extremophiles have been discovered from terrestrial and marine hydrothermal fields. Some thermophiles can grow beyond 90°C in culture, while direct microscopic analysis occasionally indicates that microbes may survive in much hotter hydrothermal fluids. However, it is very difficult to isolate and cultivate such microbes from the environments, i.e., over 99% of total microbes remains undiscovered. Based on experiences of entire microbial genome analysis (Y.K.) and microbial community analysis (A.M.), we started to find out unique microbes/genes in hydrothermal fields through direct sequencing of environmental DNA fragments. At first, shotgun plasmid libraries were directly constructed with the DNA molecules prepared from mixed microbes collected by an in situ filtration system from low-temperature fluids at RM24 in the Southern East Pacific Rise (S-EPR). A gene amplification (PCR) technique was not used for preventing mutation in the process. The nucleotide sequences of 285 clones indicated that no sequence had identical data in public databases. Among 27 clones determined entire sequences, no ORF was identified on 14 clones like intron in Eukaryote. On four clones, tetra-nucleotide-long multiple tandem repetitive sequences were identified. This type of sequence was identified in some familiar disease in human. The result indicates that living/dead materials with eukaryotic features may exist in this low temperature field. Secondly, shotgun plasmid libraries were constructed from the environmental DNA prepared from Beppu hot springs. In randomly-selected 143 clones used for sequencing, no known sequence was identified. Unlike the clones in S-EPR library, clear ORFs were identified on all nine clones determined the entire sequence. It was found that one clone, $H4_052$, contained the complete Aspartyl-tRNA synthetase. Phylogenetic analysis using amino acid sequences of this gene indicated that this gene was separated from other Euryarchaea before the differentiation of species. Thus, some novel archaeal species are expected to be in this field. The present direct cloning and sequencing technique is now opening a window to the new world in hydrothermal microbial community analysis.

V12A MCC: Hall C Monday 1330h

Lessons Learned From Santa Maria/Santiaguito, Guatemala: Implications of Long-Lived Silicic Eruptions II Posters *(joint with S)*

Presiding: **W Rose,** Michigan Technological University**; L P Flynn,** University of Hawaii

V12A-1399 1330h POSTER

The extrusion of lava dome and block lava flow units at Santiaguito, 1922-2002

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Persistent extrusion at Santiaguito during 1922-2002 has been cyclic. Each cycle begins with a 3-6-year-long high (0.5-2.1 $m^3\ s^{-1}$) extrusion rate phase followed by a 3-11-year-long low (0.2 $m^3\ s^{-1}$) phase. The 8th cycle began in 1996 and was still in its high extrusion rate phase in January 2002. With time, the duration of the low extrusion rate phase has increased, peak extrusion and time-averaged eruption rates for each cycle have decreased, and the difference between extrusion rates during high and low extrusion rate phases of each cycle has decreased. These trends may be explained by continued depressurization and exhaustion of an aging source or by transition to a period of extrusion fed by an increasingly stable magma supply.

The current high extrusion rate phase has been characterized by the emplacement of a 3.75 km long block lava flow field. This flow length is consistent with a trend that has been developing since 1970 whereby successive block lava flows have extended greater and greater distances. This trend is coincident with a 2 wt % decrease in SiO_2 content of erupted products. The associated decrease in lava viscosity may (i) explain the increase in flow length and (ii) be further evidence of chamber exhaustion. However, during 2002 we measured an extrusion rate of 1.4 $m^3\ s^{-1}$, a rate not witnessed at Santiaguito since 1963. It is possible that time averaged estimates made to date have missed such high effusion rate spurts. We note, however, the highest extrusion rate obtained from frequent satellite-based measurements during the previous high extrusion rate phase of 1986-89 was 0.95 $m^3\ s^{-1}$. Thus such high extrusion rate spurts must either be of short (<1 year) duration or Santiaguito is currently reversing an 80-year-long trend of declining extrusion.

V12A-1400 1330h POSTER

The Development of Preferred Pathways in Lava Flow Interiors: Insights from Analog Experiments

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We examined the development of preferred pathways in lava flow interiors using a unique experimental procedure. Various colors of an analog fluid, polyethylene glycol (PEG), were sequentially extruded from a point source into a tank containing a cold sucrose solution to better image the internal structure of the flows. The setup was videotaped from the top, side and bottom to provide time-lapse views of the developing flow. The top- and side-mounted cameras showed the development of the surface morphology, and the bottom-mounted camera captured the interaction of the different PEG colors in the flow interior. We conducted

20 experimental runs under various emplacement conditions, and these clearly show the development of interior flow pathways as a function of extrusion rate, cooling rate and time. Analysis of the videotapes also shows the relationships between surface flow morphology and interior pathway development.

High effusion rate combined with slow cooling rate produced flows with little or no surface crust. Interior flow outward from the point source was generally radial early in the experimental run, with this radial flow breaking into smaller broad fronts as the run proceeded. We suggest that fluid instabilities within the flow interior are responsible for the breakdown of radial flow with time. Where crusts developed on some of these flows late in the experimental run, interior instabilities became more pronounced and were visible on the flow surface as well. Lower effusion rates and higher cooling rates produced crusted flows with highly complex interior pathways that developed early in the experimental run. These crusted flows grew as fluid migrated through narrow fronts and tubes, lifting the crust and inflating the flow. Occasional breakouts of interior material onto the crusted flow surface were observed, and were typically comprised of flow material that had resided in the interior for some time, rather than the hotter, most recently injected fluid. This work suggests that the development of fluid instabilities in lava flow interiors governs the formation of thermally preferred pathways and associated surface morphology, and that crusted flows are inflated through a network of anastomosing pathways rather than through broadly advancing fronts.

V12A-1401 1330h POSTER

Downstream Aggradation Owing to Lava Dome Extrusion and Rainfall Runoff at Santiaguito Volcano, Guatemala

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Persistent, but variable, lava dome extrusion at Santiaguito ensures that rivers heading at this dome complex are subject to sedimentation, erosion and stream capture. This activity affects densely populated and heavily cultivated catchments. In these areas, profound geomorphological changes destroy or damage settlements, farmland, and infrastructure and cause millions of dollars of damage every year. The town of El Palmar, ∼8 km downstream of Santiaguito, has been destroyed and its residents displaced. Initially, lahars inundated and partially buried El Palmar and caused a stream capture. Then intense erosion and incision formed a 30-m-deep ravine that now divides the community.

In an attempt to quantify these effects and to examine the relationship between extrusion rates (E), rainfall (R), and aggraded area (A), we used a time series of Landsat Thematic Mapper images along with generally available rainfall data to examine the statistical relationship between these parameters. For the proximal reach of the drainage basin, we find a positive correlation between extrusion rate (E), aggradation area 12 months later (A_{prox}) and rainfall during the intervening 12 months (R_{12}): $A_{prox} = 3.9 + 0.5\ E + 0.3\ \ln(R_{12})$. This describes a situation in which an increase in sediment supply (extrusion rate) and a means to mobilize the sediment (rainfall runoff) causes increased lahar activity (area aggraded). For the medial reach, we find a positive correlation between extrusion rate at the volcano and area aggraded, but the correlation between rainfall and area aggraded is negative. In the medial reach, increased sediment supply increases lahar activity but increased rainfall increases the sediment transport efficiency of rivers flowing through it and into the distal reach. These analyses allow us to derive empirical predictive relationships that use extrusion rate at Santiaguito and yearly rainfall to estimate the area that will be aggraded 12 months hence. The January 2000 extrusion rate of 0.48-0.69 $m^3\ s^{-1}$ and a mean annual rainfall of 18.8 cm can be used to predict a proximal area of inundation as 4.6±0.6 km^2 for January 2001. This result compares with a measured value of 4.85±0.65 km^2 for January 2001.

V12A-1402 1330h POSTER

Continuous Monitoring of Periodic Eruptive Cycles at Santiaguito Dome Complex, Guatemala

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Recent activity at Santiaguito dome complex has been characterized by degassing, extrusion of dacite lava to feed block flows, as well as periodic small-scale eruptions of blocks and ash from the active El Caliente vent. Our objective was to study the behavior of the active vent and characterize the short-term periodic eruptions that take place. Three overlapping data sets have been collected from the top of Santa Maria looking down onto the active vent 2.5 km away within a cumulative observation time of 2.5 hours. Approximately 600 spectral curves were collected using the ASD field spectrometer, while continuous integrated temperature measurements were made using the Raytek radiometer. Both instruments have a 1°field of view. Digital video footage was also collected concurrent with other observations. We used Plancks Law and applied a two-component thermal model to the spectral curves to produce a time series revealing crust and crack temperatures, as well as the fractional area of the hot thermal component. Using the two temperature timeseries, we can distinguish several different phases of dome activity: (1) individual exposures of hotter lava within data collection time period, (2) cooling of the recently extruded surface, and (3) disruption of that surface by events. Three individual exposures of hotter material can be observed from the temperature time series. The newly extruded surface shows extremely rapid initial cooling (8°/s) followed by a gently sloped cooling curve for 45 minutes before the next extrusion occurred. During one cooling phase, the surface can be characterized by a two-component model, a cooler crust with temperature range of 120 to 350°C, and hot cracks with temperatures of >700°C. During the explosive event, the fractional area of the hot component increased to nearly 90% with temperatures in excess of 800°C. Following the rapid initial cooling after the extrusion event, the dome behaved as a single component surface with temperatures ranging from 300-500°C. We postulate three scenarios could be partially responsible for these characteristic: (1) new cracks opening during the explosive events, exposing a hot core which cool rapidly upon exposure, (2) low energy stirring of the dome materials, exposing hotter sides of the blocks to the surface, or (3) disruption of the surface where theres enough energy to overturn blocks as well as physically ejecting materials into the air.

V12A-1403 1330h POSTER

Impacts of river-bed aggradation and lahar activity downstream of Santiaguito Volcano, Guatemala: a Landsat Thematic Mapper perspective

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Lava extrusion at Santiaguito volcano, Guatemala and rainfall runoff cause lahars and river-bed aggradation downstream of the volcano. We present a method that uses vegetation indices extracted from Landsat Thematic Mapper (TM) data to identify zones of impact. The method differentiates vegetation-free and vegetated pixels, constrains areas affected by aggradation, and generates catchment-wide aggradation maps. Application of the technique to 22 TM images acquired between 1987 and 2000 helped us to measure, map and track temporal and spatial variations in the area of lahar impact and river aggradation. To verify our TM-based analyses we carried out 3 field campaigns between 2000 and 2002, during which we focused on a segment of aggraded river beds 8 km from Santiaguito. We then used our TM and field-based studies to document and validate changes at this location, as follows: (1) Time varying effects of aggradation. The main river to head at Santiaguito is Ro Nima II. The TM analysis indicated development of a new channel cutting across farm land on the western edge of Ro Nima II between 1996 and 2000. Field checking showed that development of an aggraded, convex, bed profile caused channels to flow westward away from the aggraded river-channel system. (2) Emplacement of lava flows. The TM time series indicated that a new lava flow extended into the upper reaches of the Rio Nima I during 1996 and triggered aggradation. Field checking confirmed that a new supply of volcaniclastic material had extended aggradation into this previously unaffected drainage. (3) River capture. Capture of Ro Nima I by Ro Samal has increased aggradation of along new sections of Ro Samal, an effect evident in our TM mapping. Field checking showed that, although Ro Samala does not head at Santiaguito, the new supply of material from Ro Nima I triggered rapid aggradation of Ro Samal after 1996.

V12A-1404 1330h POSTER

Hydrogen Isotopic Composition of Amphiboles by Ion Microprobe: Implications for the Explosive-Effusive Transition at Santa María volcano, Guatemala

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Santa María volcano has exhibited a three-phase history of activity. A long period of composite cone growth was followed by a plinian eruption and a dome-extrusion period. The 1902 plinian ash was sharply different in composition from the andesitic composite cone lavas. The 1902 hornblende dacite has 65-69 wt% SiO_2, a crystallinity of 20-30%, and a phenocryst mineralogy consisting of plagioclase, hornblende, orthopyroxene, clinopyroxene and titanomagnetite. The chemistry of the Santiaguito lavas is very similar, but slightly more mafic (63-68 wt% SiO_2) than the 1902 dacite. The Santiaguito crystalline dacites also have not shown any significant compositional changes with time, despite construction of the dome complex by a pulsating series of extrusions. Mineralogically, the Santiaguito lavas have slightly higher crystallinities compared to the 1902 ash and amphibole that have been oxidized to oxyhornblende. The eruptive style at Santa María volcano has obviously undergone a dramatic change from explosive to effusive, yet detection of compositional changes remains elusive. Hydrogen isotopic data are sensitive measures of degassing and may more effectively distinguish between the different phases of the eruption.

Consequently, amphiboles from both the 1902 Santa María ash and the Santiaguito lavas were measured for their H_2O content and hydrogen isotopic composition using the Cameca 6f ion microprobe at Arizona State University. The ion microprobe has a distinct advantage over bulk isotopic methods in allowing the determination of small-scale spatial variations in δD. Whereas, hornblende in the Santiaguito lava flows have H_2O contents ranging from 0.34-1.04 wt%, the 1902 hornblende have elevated H_2O contents (1.03-1.26 wt%). Two different types of amphibole crystals were observed based on the preliminary hydrogen isotopic data on Santiaguito lavas. Multiple analyses on individual hornblende crystals commonly show a relatively homogeneous distribution of δD values. Also present were amphiboles with heterogeneous δD values where the core was similar in composition to the homogeneous crystals, but the rim was significantly heavier. Amphiboles in the 1902 ash were heavier (mean δD of $-26.4^o/_{oo}$, n=9) compared with the homogenous amphibole and the cores of the heterogeneous amphibole in the Santiaguito lavas (mean δD of $-59.4^o/_{oo}$, n=18). The higher H_2O contents and enriched δD values of the hornblende erupted during the historic 1902 eruption are consistent with higher magma ascent rates during

V

the plinian phase and smaller amounts of attendant degassing.

V12A-1405 1330h POSTER

Rheological Estimates of Santiaguito Lavas From Analog Experiments With Bingham Plastic Materials

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Laboratory simulations with temperature-dependent Bingham plastics have been used to relate the morphology and underlying slope of silicic lavas to their emplacement conditions and rheology through the use of a dimensionless scaling parameter Ψ_B. Ψ_B defines a sequence of four flow morphologies (spiny, lobate, platy, and no-crust), associated with progressively higher effusion rates, lower cooling rates, and lower yield strengths. Given the morphology of a silicic extrusion and the slope it was emplaced on a range of Ψ_B values can be assigned. If the effusion rate of this extrusion is known then a yield strength can be estimated.

We apply this method to the Santiaguito Dome Complex where detailed observations have been made of the effusion rates and morphology of the erupted products since extrusion began in 1922. The Complex has grown through a series of 3-5 year spurts of high (0.6-2.1 m^3s^{-1}) extrusion separated by 10-12 year intervals of lower ($\sim$0.2 m^3s^{-1}) extrusion. The morphology of the erupted lavas has varied since the onset of the eruption. The opening phase, from 1922-25, was dominated by dome emplacement, between 1925-58 both domes and block flows were emplaced, and block flow emplacement began to dominate after 1958. During the transitional phase between 1925 and 1958 we find within each cycle there is an increase in the estimated yield strength corresponding to a decrease in effusion rate, which is in agreement with our scaling analysis and laboratory experiments. Since 1958, activity has been dominated by block flow extrusion with high effusion rate phases producing longer block flows than low effusion rate phases. Across the entire history of the eruption we see a gradual decrease in yield strength consistent with the general increase in block flow length observed during high effusion rate phases since 1958, which may indicate that the magma chamber is becoming exhausted and tapping more mafic lavas. This is corroborated by a 2 wt % decrease in SiO_2 of the erupted products since 1970.

V12A-1406 1330h POSTER

Search for Eruptive Patterns at Santiaguito Crater, Santa Maria Volcano, Guatemala

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More effective understanding of long-lived silicic volcanism, such as at Santiaguito, requires the establishment of baseline data, including gas emission rates. Many gas emission rates have been made at Santiaguito in the last three decades but the data record is punctuated with long gaps. In the last four years SO_2 emissions were measured on 12 days with a maximum of 30 measurements in one hour in an intense measuring day. More continuous and higher temporal resolution measurements would assist in pattern recognition, and through careful statistical analysis, could alert scientists to impending changes in eruptive activity. Specifically, continuous data gathering would help illustrate that different patterns precede different types of activity (e.g. lava extrusion, ash eruptions, magma movement). Preliminary results from a field campaign in January 2002 have shown possible patterns of activity at the volcano. The data include measurements of SO_2 gas emissions, temperature variations and direct observations. SO_2 emissions ranged from approximately 10 ($\pm$ 1.5) to 169 ($\pm$ 25) tonnes/day in the three days of measurement in 2002. During short time periods (1.5 hours) on the mornings of January 10 and 11, clusters of four explosions occurred approximately every 30-60 minutes. On January 10, temperature and SO_2 emission rates seem to correlate as they both show decreases over time. The results obtained suggest the potential of these data sets to show possible patterns of eruptive activity if measurements are taken continuously and over long periods of time. The current rapid advancement in gas studies, specifically the reduction of size and cost of SO_2 monitoring equipment, will facilitate major improvements in gas emission rate data quality over the next few years. We plan to undertake a lengthy (> four weeks) campaign at Santiaguito early next year with a pair of Differential Optical Absorption Spectrometers (DOAS), in order to investigate Santiaguitos regular ash venting episodes, particularly if there is any change in gas emission rates that might be symptomatic of changes in pressurization. There are also plans to deploy a continuously recording infrasonic, seismic and thermal experiment within 2 km of the vent to further constrain hour-to-week long trends in eruptive activity.

V12A-1407 1330h POSTER

Monitoring the Surface Changes and Growth of the Soufrire Hills Lava Dome: Thermal Infrared Analyses of Field and Spaceborne Data

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The Advanced Spaceborne Thermal Emission Reflectance Radiometer (ASTER) is the only high resolution multispectral thermal infrared (TIR) imager currently in Earth-orbit. The data being returned are ideal for discerning physical variations on the surface of active lava domes such as Soufrire Hills, Montserrat. The 90 meter spatial resolution of the TIR data provides accurate measurements of the surface temperature and emissivity. This information can be used to map the glass, vesicle and petrological distribution on the domes surface, and therefore provide fundamental insights into lava emplacement processes. For this study, six nighttime ASTER scenes of the dome and surrounding region captured over the past two years were chosen. These images show the entire dome, are relatively cloud-free and have significant thermal anomalies present, including summit and pyroclastic flow deposits. In order to validate the image data, detailed field-based information was collected including temperature, GPS and spectroscopic data (similar to the ASTER spectral band passes). In addition, a searchable database of activity based on Montserrat Volcano Observatory (MVO) reports has been created and used as a framework for the image data.

Field measurements were taken in conjunction with a nighttime overpass of ASTER. Active areas were determined both visually and with the aid of high resolution radiometers. The heightened activity precluded close field measurements; therefore, long range laser profiling and GPS were used to locate anomalies on the dome surface. A CIMEL spectro-radiometer with identical TIR wavelengths to ASTER and a FRIR were used to map surface temperature and spectral variations. Numerous target areas were chosen including spines, lobes, incandescence, and fresh pyroclastic deposits. Samples of the most recent pyroclastic deposits have been collected and are being analyzed for mineral, phenocryst, and vesicle content using both petrographic and infrared analyses. This is the most detailed suite of thermal infrared data collected at an active silicic dome and is providing a more complete understanding of the capabilities of remotely acquired TIR data to accurately describe active dome processes. This approach can easily be applied to other active areas that have the potential of transitioning from effusive to explosive dome growth, subsequent collapse and ensuing pyroclastic activity.

V12A-1408 1330h POSTER

Magma Reservoir Processes at Unzen Volcano: A Result of Unzen Scientific Drilling Project

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Drilling core samples (USDP-1) at Unzen (Japan) showed, at least, three stratigraphically-repeated magmatic differentiation with the intervals of several thousand years around 20 ka. In each differentiation (chemical) cycle, the rock became more silicic and richer in crystals upward. As a whole, however, the SiO2 range shifts to the lower side, becoming wider upward in the well. Each chemical cycle probably resulted from magma mixing; magnesian olivine coexists with quartz even in the highest SiO2 rocks, and plagioclase phenocryst rims, chemically bimodal at the bottom, become unimodal upward, as well as plagioclase microlites become sodic upward. Relative proportion of dusty plagioclase phenocryst decreases upward, while the thickness of clear margin on it increases. The chemical cycles can be explained in a model where a crystal-mushy evolved magma reservoir was underplated repeatedly by mafic magma. Each chemical cycle began with the input of high-temperature mafic magma into the magma reservoir. Effective mixing occurred only along the interface of mafic magma with mushy magma. As the zone of mixing migrated upward in the reservoir with time, the composition of mixed magma (erupted magma) became rich in SiO2 due to its successive dilution with evolved mushy magma. Repeating this cycle, the whole composition of the reservoir became poorer in SiO2. This kind of magma processes may have been repeated here during several tens of thousand years.

Faint zoning in Ba/Sr and La/Nd but strong oscillation in An, for plagioclase phenocrysts from recent eruption products at Unzen (<0.3 ka), may suggest their growth in a stagnant reservoir of chemically stable melt, but changeable only in water-pressure sensitive to the An change. The Sr isotopic ratios of the same grains using micro-drilled (0.3 mm across) sampling indicate isotopic disequilibirum commonly between phenocryst margins and groundmasses. The gradual decrease in the isotopic ratios from phenocryst core to rim (0.70454 to 0.70442) found throughout different lavas implies a common origin of plagioclase phenocrysts (xenocrystic). Since plagioclase phenocrysts are thought to have derived from the evolved mushy magma, the reservoir may have evolved mainly from partially-melted country rocks.

URL: http://hakone.eri.u-tokyo.ac.jp/vrc/usdp/index.html

V12A-1409 1330h POSTER

Lava Dome Growth at Volcan de Fuego MEXICO (Colima Volcano), October 2001 to May 2002

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The Volcan de Fuego (19.512 N, 103.617 W) is located on the border between the States of Jalisco and Colima, Mexico, it is also known as Colima Volcano or Zapotln Volcano, is a stratovolcano rising nearly 4000 m above sea level, and is the most active volcano in Mexico. Recent activity has been characterized by at least 3 different phases since January 1998 when seismic swarms began and ended with the extrusion of blocky lava in November 22, 1998 by the West vent as the 1991 eruptive process. That extrusive period lasted until the end of January, 1999 when was possible to observe a change in the seismic pattern, which mark the beginning of a new eruptive regime, an explosive one. On February 10, 1999 at approximately 0154 local time, 0754 gmt, an explosive event happens at the summit dome of Volcn de Fuego, four more big explosions took place at the summit the last one at dawn February 22, 2001. These explosions opened a new crater at the summit with a elliptical form with radius of 260 x 225 m and depth between 40 m and 15 m. A small dome structure inside the new crater was reported by March 2001. A reconnaissance flight in August 2001 shows two main features in the main crater an steep-sided mound(scoria cone) over the West vent and an inner crater on the NE vent. On October 31 Civil Defense members at Nevado

Base on Nevado de Colima observed a neddle over the main crater rim, reconnaissance flight shows a spiny, 40 m high with a diameter of 20 m grows from the NE vent, the spiny seems to formed by material of the 1976 eruption. Continuous aerial observations allow us to follow the growth of a new dome pushing out the spiny. On November 23 the dimensions of the dome under the spiny were a radius of about 14 m and 21 m high for a total extrusion of 86,000 m3 which implies a extrusion rate of 0.027m3 /seg. By December the dome push out the spiny and began to grow from the NW vent. By December 29 an increase in the rate of extrusion was observed reaching a value of 0.29 m3/seg. By the end of January 2002 the dome reach the south and the northeast borders of the crater, two lava front began to develop in this sites. The avalanches starte on February 14, these were observed and registered until May of this year.

V12A-1410 1330h POSTER

A Model of the November 1998 Eruption of Colima Volcano, Colima, Mexico

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We analyzed the seismicity from March 20, 1998 to 28 February 1999, a period covering the seismicity occurring before and after the eruption of November 18, 1988 of Colima Volcano in western Mexico. The event was characterized by the destruction of a small summit dome and block-and-ash pyroclastic flows. We counted more than 3000 events and located some 320, which were clearly recorded in at least three stations. Most of the hypocenters of these events fall within 7 km from the surface and the rest in within the next 18 km. Within these set we could distinguish several earthquake families. These events plotted together with the gravimetric model of Medina et al.(1) give information on the possible location of the magma source and its dimensions. We used this data in a model of magma erupted based on the visco-elastic response of the country rock, the exsolution of volatiles (2,3) and the estimated emissions of the volcano during the eruption. We explain the characteristics of the seismicity based in this model.

(1) Medina, F. et al., 1996, Geofs. Intern., 35, 4, 409-414

(2) Bower, S.M., and Woods, A.W.: 1997, J. Geophys. Res, 102, B5, 10273-10290

(3) Sacandone R, L Giacomelli, J Volcanol Geotherm Res, 110,121-136, 2001

V12A-1411 1330h POSTER

Description of Seismicity at Volcan de Colima, MEXICO, in the Period 2001-2002

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After the february 2001 explosive activity at Volcan de Colima, Mexico, the seismic activity decreased to its lowest level since november 1997 when the actual period of activity started. However, a few months later several researchers reported important morphologic changes inside of the crater formed by the explosive activity, which did not have related seismic activity. During the rainy season it was not possible to follow the development of the changes inside the crater and no significative seismicity was detected. Starting october 2001, a seismic swarm started to develop consisting mainly by high frecuency, very low amplitude seismic events usually detected by the closest seismic station to the summit, at about 1 km. By the end of the month the seismicity almost disappeared, but then it was possible to view again the volcano and for the first time it was possible to observe a huge spine extrusion. From november and until february 2002 it was possible to visually follow, by flying in helicopter, the process. Asismically, new lava was extruded until it filled the crater and a new lava dome was emplaced on the volcano. On february 5, 2002 the new material started to flow down the slopes of the volcano forming lava fronts mainly toward the southwest sector. Apparently the lava extrusion rate was almost constant. Beginning april, short periods of tremor started to appear sporadically and later it begun increasing continuosly in duration, amplitude and spectral content to levels not previously seen at Volcan de Colima. Such situation prompted a preventive evacuation of the people living close to the volcano and at greater risk. However, ending may, 2002 the seismic activity suddenly decreased in a stepwise way and later slowly decreased until a new minimum was reached by the end of june. However, starting july, seismicity started to increased again until a stable level was reached and continues until now. During the whole process, low level, small explosive type events have been detected.A detailed discussion is presented in that presentation.

V12A-1412 1330h POSTER

The origin of the silicic domes in the Macolod Corridor, Philippines

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The petrogenesis of silicic magmas in areas that do not contain continental crust is often unclear. This study examines the composition of domes associated with Mount Makiling stratovolcano, Philippines, to understand the generation of silicic magmas, in an island arc setting. Makiling volcano and associated domes are located in the Macolod Corridor. The corridor is a tectonic depression between the West Luzon Arc (produced by east dipping South China Sea plate) and the East Luzon Arc (produced by the west dipping Philippine Sea plate) with numerous volcanic features. The volcanism in this part of the Macolod Corridor has occurred sporadically over at least the past million years.

Sampling of Makiling volcano indicates a continuous range in composition from basaltic andesite to dacite. The range in composition in the domes is wider, from basalt to rhyolite. The chemical variation in samples from individual domes is small, and may be an indication of monogenetic nature of the magmatic activity. However, most of the domes have similar compositions, with SiO_2 modes of 70% and with little variation of other chemical parameters that may indicate derivation from a larger silicic magma system. At least one dome has bimodal composition, one set of samples ranges in composition form basalts-basaltic andesite and the other set of samples consists of dacites.

There is a dubious association among the magmas from the Macolod corridor with subduction zone magmatism, the rocks from Makiling volcano and most of those sampled from the domes are calc-alkaline with large Nb and Ti depletion on spider diagrams. Conversely, one dome has tholeiitic characteristics with higher FeO/MgO ratios for a given SiO_2 content. The major and minor elements data in the samples from Makiling volcano plot on trends that show little scatter. All the samples follow on a single trend for Mg, Fe, and Ca. Though, for other elements (Ti, Al, Sr, Na, K, Rb, and Zr) the samples from the northeastern part of the volcano consistently fall off the trend delineated by the samples for other sections of the volcano.

The geochemically diverse data set will be used to model the origin of the dacitic and rhyolitic volcanic products in an area void of continental crust.

V12A-1413 1330h POSTER

Modeling the Distribution of Airborne Volcanic Ash Within the North Pacific Region

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There are over 100 active volcanoes in the North Pacific (NOPAC) region, most of which are located in uninhabited areas along the Aleutian Islands, Kamchatkan Peninsula, Russia, and Kurile Islands. The NOPAC contains 20% of the worlds active volcanoes and on an estimated 4-5 days per year volcanic ash is at major flight levels. This project analyzes the distribution of airborne volcanic ash within the NOPAC region by simulating volcanic clouds from 22 volcanoes using the PUFF ash-dispersion model, which is run hourly using archived wind field data between 19941995 and 19972001. Airborne ash probability distribution (AAPD) maps at low and high aircraft flight levels and subsequent statistics are generated revealing the cumulative distribution of simulated airborne ash particles at 6 and 24 hr intervals.

The AAPD maps and subsequent results provide critical information regarding the potential distribution of airborne ash in the NOPAC region, and may be useful in planning future aircraft routes and airport locations. Wind field and statistical analyses show NOPAC ash cloud distribution is strongly affected by the intensity, migration, and location of the Polar jet stream and associated cyclones. The results indicate eruption cloud-travel distance is latitude dependent over the Kamchatkan Peninsula, and longitude dependent over the Aleutians, Alaskan Peninsula, and Cook Inlet. The AAPD maps and subsequent statistics imply that eruptions originating from the Kamchatkan Peninsula would very likely travel due east into the NOPAC air-traffic routes during summer. During the winter, however, wind directions over the Kamchatkan Peninsula are highly variable resulting in ash being distributed in a variety of directions. In contrast, AAPD maps and subsequent statistics show that eruptions originating from the Aleutians and Alaskan Peninsula are more likely to travel SE during the summer and E-NE during winter. Although often used operationally during an eruption crisis, the PUFF ash-dispersion model can also be used as an effective research tool and aid in providing airborne ash hazard mitigation for towns, airports, and air traffic within the NOPAC region.

V12A-1414 1330h POSTER

The Tephra Layer From the Plinian Eruption in rfajkull 1362, Southeast Iceland

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Pyroclastic fallout from the 1362 eruption of rfajkull forms one of the volcanic marker horizons of the North Atlantic. This contribution reports the mineralogical and geochemical characteristics of the rfajkull 1362 fallout and its grain-size distribution. A nonrifting 120 km long volcanic lineament some 50 km east of the Eastern Rift-Zone of Iceland is defined by transitional and alkalic volcanic rocks resting unconformably on late Tertiary strata. rfajkull which forms the southern termination of this off-rift liniment is an ice-covered stratovolcano (2200 masl) composed mostly of subglacially formed hyaloclastite ranging from basalts to rhyolites. The two historical (1100 yrs) eruptions of rfajkull include a small explosive eruption in 1727 and a large devastating Plinian eruption associated with major lahars and a caldera collapse in 1362. Between 1 and 2 km^3 dense rock equivalent or 5-10 km^3 of rhyolitic pumice was erupted and the fallout was mainly towards ESE. Tentative modelling of the PT-conditions of the magma formation, based on glass/mineral equilibria, indicates that the source was a near-eutectic melt in equilibrium with fayalite, hedenbergite, oligoclase and hematite at some 0.2 GPa pressure.

A profile through the fallout was sampled at elevation of about 1100 masl on the SE flank of the volcano. A deposit of 1.8 m thickness was collected in 14 units for examination of composition, mineralogy and grain-size distribution during the eruption. In the profile the fallout is fine grained vesicular glass (1-3% minerals, 3% lithic fragments) with bubble wall thickness in the low micron range. The high and even vesiculation of the glass indicates fast magma ascent and explains the extreme mechanical fragmentation within the eruptive column, yielding between 50 and 80 wt% of less than 0.25 mm grain size.

A reconstruction of the Plinian phase, based on grain-size analysis and abundance of lithic fragments, reveals that the eruption proceeded in three successive phases. An initial explosion produced phreatomagmatic debris associated with up to 35

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V12A-1415 1330h POSTER

Complex Proximal Deposition During the Plinian Eruptions of 1912 at Novarupta, Alaska

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Proximal (<3 km from vent) deposits of the 60-hour-long Novarupta 1912 eruption exhibit a very complex stratigraphy and diverse depositional mechanisms. They contrast as such with relatively simple stratigraphy and emplacement mechanisms inferred for the medial-distal fall deposits and the accompanying Valley of Ten Thousand Smokes ignimbrite. The proximal products include alternations and mixtures of locally and regionally dispersed fall ejecta, and numerous thin complex deposits of pyroclastic density currents (PDCs) with no regional analogs. The locally dispersed fall deposits form sector-confined wedges of material whose thicknesses halve radially from and concentrically about the vent over distances of 100-300m (cf. several km for the medial-distal fall deposits). This locally dispersed fall material (and many of the associated PDC deposits) is rich in andesitic and banded pumices and richer in shallow-derived wall-rock lithics in comparison to the widespread fall units. Associated PDC deposits form a spectrum of facies from fines-poor avalanched beds through thin-bedded landscape mantling beds to lobes of block-rich ignimbrite.

The origins of the Novarupta proximal deposits are considered within a spectrum of four transport regimes: (1) sustained buoyant plume, (2) fountaining with cocurrent flow, (3) fountaining with counter current flow and (4) direct lateral ejection. The Novarupta deposits suggest a model where stable regime-1 plumes were accompanied by transient and variable partitioning of clasts into all three remaining regimes. During Plinian activity, margins of the jet and perhaps lower plume were strongly affected by short-lived instabilities, inferred to be associated with heterogeneities in the emerging mixture of gas and pyroclasts. Of the parameters that control explosive eruptive behavior, only such sudden and asymmetrical changes in the particle concentration could operate on time scales sufficiently short to explain the rapid changes in the proximal 1912 products.

V12A-1416 1330h POSTER

Multiple generations of tuffisite veins record repetitive ductile-brittle deformation of rhyolitic magma rising within an effusive vent: a source of flow banding in silicic lavas and repetitive seismic signals?

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Multiple generations of tuffisite veins within the obsidian margins of a 10 m-wide effusive rhyolite vent at Torfajkull, Iceland record episodic ductile-brittle deformation of rising magma[1]. The vent is dissected 30 m beneath the 10^6 m^3 subaerial lava flow that it fed, contains vesicle-free obsidian and devitrified rhyolite, and intrudes poorly-consolidated pumiceous rhyolite breccia. The youngest veins are anastomosing, irregular and filled with annealed fragments of obsidian and broken crystals ripped from their walls. These cut through earlier veins, which have undergone ductile shear parallel to the vent margins and are identifiable by their pale colour and abundance of crystal fragments. Axial strain (delta L/L) in earlier veins ranges from <2 close to the outer margin of the vent to >1000 towards the centre, where sheared veins resemble the flow bands seen in the overlying lava flow. The orientation of each tuffisite vein is unrelated to that of previous veins, indicating that the magma annealed sufficiently between brittle events to recover mechanical isotropy. ICP-MS and FTIR analyses of the youngest veins and surrounding obsidian show that major element compositions are homogeneous, but vein material is relatively degassed (0.14 vs. 0.21 wt % H_2O). This suggests that vein formation briefly increased the vent wall permeability, and allowed escape of magmatic volatiles into the country rock[2].

We argue that such repetitive ductile-brittle deformation reflects the strain rate dependent behaviour of viscous magma[3] and is likely to be restricted to silicic compositions. Parameters such as the magma flow rate, the gradient of viscosity and pressure across the vent, strength of magma and country rock, and the annealing rate may control the depth and frequency of brittle events. This process is important because it is a primary mechanism for the formation of flow banding in compositionally homogeneous silicic magmas, through the introduction of bands with different volatile contents and thermal histories. Furthermore, it is potentially a non-destructive, repetitive source of shallow seismicity during effusive silicic eruptions, which does not depend upon the mechanical coupling of a pressured fluid phase with a solid[4], but instead reflects the deformation of material capable of solid-like and fluid-like behaviour on different timescales.

[1] Tuffen H (2001)Unpub. PhD thesis, Open Univ., UK [2] Jaupart C (1998) J Geol Soc London Spec Publ 145:73-90 [3] Dingwell DB (1997) J Petrol 38:1635-1644 [4] Chouet B (1996) Nature 380:309-316

V12A-1417 1330h POSTER

Integrating TOMS and TOVS retrievals of sulfur dioxide in volcanic clouds

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Ultraviolet backscatter data from the series of Total Ozone Mapping Spectrometer (TOMS) instruments have been used to construct a time series of volcanic sulfur dioxide (SO_2) emissions covering the past ~24 years, except for an 18-month data gap in 1995-96. Recently a new technique for retrieving SO_2 from infrared data collected by the High-Resolution Infrared Sounder (HIRS) on the TIROS Operational Vertical Sounder (TOVS) platform has been developed, based on a strong SO_2 absorption band centered around 7.3 μm. The TOVS data are global, cover almost 22 years, have a spatial resolution of 18 km at nadir (compared to 25-50 km for TOMS) and can be used by day or night (TOMS requires sunlight), and therefore provide a unique opportunity to independently cross-validate and evaluate the TOMS SO_2 retrievals. The nighttime capability of TOVS and the uninterrupted dataset also permit extension of the TOMS volcanic SO_2 record (e.g. to include eruptions at high latitudes in the winter months) and coverage of the TOMS data gap in 1995-96.

As a case study of the relative merits of the UV TOMS and IR TOVS methods, we will present retrievals of SO_2 in the stratospheric volcanic cloud produced by the August 1980 eruption of Hekla volcano, Iceland. This was a relatively modest eruption, producing ~470 kilotons of SO_2 (measured by TOMS), but the resulting volcanic cloud was unusually long-lived and could be tracked by TOMS and TOVS for ~5 days as it circumnavigated the North Pole. Detailed intercomparison of SO_2 retrievals from TOMS and TOVS, taking into account the different sensitivities and biases of the two methods, allows a thorough examination of the evolution of this SO_2 cloud. Merging of the TOMS and TOVS datasets may also provide sufficient information on the movement of the volcanic cloud to permit validation of trajectory models (e.g. CANERM, HYSPLIT).

URL: http://skye.gsfc.nasa.gov

V12A-1418 1330h POSTER

FLYSPEC: A new Ultraviolet Correlation Spectrometer for the Detection of Volcanic SO_2

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A new miniature, lightweight and low cost ultraviolet Correlation Spectrometer, the FLYSPEC, has been developed as a replacement for the COSPEC, which has previously been the mainstay for the monitoring of volcanic SO_2 emissions. The total mass of this battery operated prototype system, including computer/PDA, power, cabling, and GPS is less than 2 kg and can be mounted in a 25 x 15 x 10-cm protective case. The FLYSPEC can be used in a similar fashion to the COSPEC (e.g., mounted on a ground vehicle or stationary tripod - a similar instrument, the mini-DOAS, is now being routinely used by the Montserrat Volcano Observatory for near-continuous stationary measurements). Field experiments were conducted at Masaya (Nicaragua), Poás (Costa Rica), Kilauea (USA), Vulcano, Mt Etna, and Stromboli (Italy) volcanoes as well as at industrial stacks in Hawaii. A number of these measurements were made simultaneously with COSPEC and showed statistically identical results. Unlike the COSPEC, the FLYSPEC also has the ability to simultaneously measure and perform real-time analyses of a number of UV-absorbing gas species (e.g., NO_x) making it a valuable instrument for environmental monitoring of industrial plumes. Furthermore, the small size and low cost lend the FLYSPEC to novel deployment modes such as hand-held, multi-instrument continuously recording networks, or flown on small Unmanned Aerial Vehicles. This instrument has the potential to revolutionise the manner in which volcanic, industrial, and environmental monitoring is performed.

V12B MCC: Hall C Monday 1330h

Volcanology Posters

Presiding: **C E Gregg,** University of Hawaii

V12B-1419 1330h POSTER

Pressure changes of volcanic systems derived from seismic signals

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Seismic low-frequency events from Soufriere Hills volcano in Montserrat are a superposition of single interface waves travelling along the conduit and leaking into teh volcanic edifice at the upper end of a conduit section where magma properties change rapidly. These low-frequency signals are largely characterised by the intermittency of the interface waves, as well as by the dispersion effects they encounter.

Using finite difference modelling of the seismic wavefield together with simultaneous modelling of magma properties in time and at depth, allows us to link the seismic signature directly to magma and conduit parameters.

We retrieve a relationship between frequency content of seismic signals and governing pressure in the magma which enables us to determine the pressure changes in the magma from spectral characteristics and their temporal changes.

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Microgravity Changes Associated With the July-August 2001 Etna Eruption

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On the 17th of July, 2001 a new flank eruption (the first in nearly 10 years) started at Mt. Etna. It lasted 24 days (until the 9th of August) producing about $48*10^6$ m^3 of lava. For about 5 month before the eruption, a progressive gravity decrease was evidenced by measurements along a profile of 19 stations running from the town of Zafferana (at the eastern edge of the profile; 450 m a.s.l.) to the town of Adrano (at the western edge of the profile; 600 m a.s.l.) through the Rifugio Sapienza (1890 m a.s.l.). The gravity decrease, with a wavelength of about 15 km, reached its maximum amplitude (80 mGal) at a station very close to