V11A-1384 0830h POSTER

Sr, Nd and Pb Isotope Geochemistry for the Volcanic Rocks From the Aono and Abu Volcanic Groups in the SW Japan arc

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Although, there is no deep seismic activity beneath the W. Honshu Island in the SW Japan arc, recent seismic studies have revealed the existence of an aseismic slab beneath the area. Thus, the volcanism in the W. Honshu Island is considered to be related to the subduction. Since the subducting Philippine Sea plate caused inter-arc spreading, the volcanism of the Aono and Abu volcanic groups in the W. Honshu Island are inferred to be produced at the high temperature condition. The Aono volcanic group is one of volcanic groups, which comprise the volcanic front on the SW Japan arc, while the Abu volcanic group is on rather backarc side of the Aono volcanic group. In order to evaluate the origin of the volcanic rocks from the Aono and Abu volcanic groups, Sr, Nd and Pb isotopic and trace element compositions were determined. Nb troughs on a spider diagram indicate that these rocks are related to subduction process. Furthermore, high Sr/Y ratios and low Y concentrations of these rocks indicate that these are adakitic magma, which suggests that the magmas were produced by altered oceanic crust melting. Isotopic compositions of these rocks are situated between those of the Shikoku basin basalt and mantle xenoliths from the SW Japan arc on 87Sr/86Sr vs. 143Nd/144Nd and Pb-Pb diagrams. These show that geochemical characteristics of these rocks were produced by the mixing of a depleted slab derived component with an enriched mantle component. A 1/Sr vs. 87Sr/86Sr diagram designates that the depleted and enriched components have high and low Sr concentrations, respectively. Considering phase assemblages during melting processes of mantle peridotite and subducting altered oceanic crust, lower and higher Sr concentrations reflect lherzolite and eclogite melting respectively. This is consistent with the isotopic composition. To test the altered oceanic crust melting as a possible mechanism for the production of Aono and Abu volcanic rocks, melting calculations were conducted. The result reproduces trace element compositions of the Aono and Abu volcanic rocks without sediment contribution. Thus, we conclude that subducted Philippine Sea plate melting produced the Aono and Abu volcanic rocks.

V11A-1385 0830h POSTER

Geochemistry of Obsidian from Northern Hokkaido

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The northern half of Hokkaido forms the back-arc side of the Kurile arc. Two phases of volcanic activity are present here; the first phase is dated to 10-15 mya, and the second phase to 2-9 mya. Coeval andesites, basalts, granites and rhyolites were all formed during these two phases of volcanic activity. While the geochemistry of the rhyolites and basalts of northern Hokkaido was the subject of numerous studies, there has been a paucity of studies on the massive obsidian deposits. From a geologic and economic perspective, obsidian may be of limited importance, but for archaeologists they are of major significance. The purpose of this paper is to report on the results of a geochemical study of 133 obsidian samples collected from the six deposits at Oketo Mountain, Shirataki Mountain and the Shirataki valley, and Tokoro Mountain. Energy dispersive x-ray fluorescence (EDXRF) was the analytical technique used to quantitatively measure the minor and trace elements.

On the Rb-(Y+Nb) discrimination diagram, the composition of the obsidians indicates that they are from an I-type silicic magma. As with other island-arc volcanics when compared to N-MORB, the LIL elements are enriched, and there is a depletion of Nb and other HFS elements. For this particular set of samples though, most are also depleted in Sr. A plot of the Sr/Y vs. Y places all the samples within the Island Arc field. Examination of Rb/Y-Nb/Y and Nb/Zr-Th/Zr plots suggests that there is very little melt related enrichment, and fluid related enrichment is dominant. While there was no directional gradient found in the elemental ratios associated with the fluid-related enrichment, the Sr/Y content does decrease as one goes northwards and eastwards. The results presented here would support the arguments in favor of a hydrous metasomized origin for the Hokkaido rhyolites.

For the archaeologist, the quantitative data presented here can be used to source obsidian tools found in the Japanese archipelago and the Russian Far East. Examination of bi-variate plots of the incompatible elements, or incompatible element ratios, or the principal component scores illustrates that there are 4 statistically distinct, geochemical groups in the data. Two groups consist of the obsidian from the Shirataki Mountain and valley, while the other two groups are Oketo and Tokoro Mountain respectively. Stepwise discriminant analysis indicates that Rb, Sr, Y, and Zr are the most discriminating elements for these 4 groups.

V11A-1386 0830h POSTER

Origin of the Silicic Ash-flow Sheets in Southern Nicaragua

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Abundant silicic ash-flow sheets occur in southern Nicaragua yet little is known about their distribution, age, and geochemistry. Their origin is a matter of considerable interest because the generation of silicic magma is generally attributed to the assimilation and/or melting of an underlying continental crust. However, no continental crust occurs in this area. This southern part of the Central American Volcanic Arc is located in the Chorotega block, which is composed of a thickened oceanic crust (Hauff et al., 2000). This is in contrast with the northern section of the arc, the Chortis block, which is underlain by continental crust. Here, we describe the occurrence and composition of silicic ash-flow sheets in southern Nicaragua. Seven ash-flow sheets were identified based on their chemical characteristics. These ash-flow units are Apoyo, Las Maderas, Las Sierras, and 4 informally named units referred here as: Coyol, Monte Galan, Ostocal, and San Rafael, all belonging to the Coyol Formation. The age of the Apoyo unit is 23,000 (Sussman, 1982) whereas the other ash-flow units maybe as old as Miocene (Ehrenborg, 1996). The composition of pumice fragments from these sheets range from 50.9 to 71.5 wt. % SiO_2. The most frequent occurring compositions (mode) in six of these units ranges from 65 to 70 wt. % SiO_2, whereas the Las Maderas unit has a mode at 63% SiO_2. Plots of Rb, Sr, Zr, total alkalies, $Fe_2O_{3(t)}$, MgO, and K_2O versus SiO_2 for each of these ash-flow sheets define distinct chemical trends. REE spider plots are relatively flat. Some ash-flow sheets (Ostocal, Las Maderas and Las Sierras) contain a small negative Eu anomaly (0.77 to 0 .90), whereas the Apoyo contains a slight positive Eu anomaly (1.09 to 1.13). Chemical variations among these sheets cannot be related by fractional crystallization. Overall the trace element variations (e.g. U/Th, Ba/Nb ratios) of these silicic sheets mimic the variation in the trace element variations in the modern arc, which to us, means there is a genetic relationship between the modern arc and the silicic magmatism. Because it is difficult to generate large-volume silicic magmatism by fractional crystallization of mantle melts, we are evaluating models where silicic magmas are produced by partial melting of previously emplaced arc-related igneous rocks.

V11B MCC: Hall C Monday 0830h

From Magma to Tephra: Crystallization, Fragmentation, and Flow II Posters

Presiding: **D Sahagian,** University of New Hampshire

V11B-1387 0830h POSTER

Volatile Concentrations in Pyroclastic Obsidian: Two Case Studies

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Pyroclastic obsidian is abundant in fall deposits associated with Mt. Mazama's Cleetwood eruption and South Sister's Rock Mesa eruption. Measured concentrations of H_2O_{total} and CO_2 in >300 obsidian samples from these two eruptions provide important information about both the style of degassing (open- vs. closed-system) and changes in eruptive conditions through the course of both eruptions. Obsidian clasts preserve a range of total H_2O contents, with samples from lower stratigraphic levels displaying a wider range of water concentrations than those from the uppermost tephra layer sampled. All samples from the Cleetwood section contain $\leq$1 wt% water, with those from the top of that deposit containing <0.4 wt%. Obsidian from the basal ash layer of the subsequent climactic eruption contains 0.1 - 0.8 wt% water. Obsidian fragments from the Rock Mesa eruption show a broader range in H_2O_{total} contents (from 0.1 to >3 wt%) than those from the Cleetwood eruption. At Rock Mesa, maximum total water contents generally decrease with increased stratigraphic height. However, this decrease is not strictly monotonic: fluctuations in maximum total water contents correspond to stratigraphic unit boundaries. In addition, the Rock Mesa event produced abundant obsidian with very low H_2O_{total} concentrations throughout the eruption. Dissolved molecular CO_2 levels are below the detection limit in all of the Cleetwood and Mazama samples. This is not surprising, given the low initial CO_2 measured in Cleetwood and Mazama melt inclusions by Bacon et al. (1992). CO_2 concentrations in the Rock Mesa clasts range from <5 ppm to ~44 ppm, and are positively correlated with H_2O_{total} concentrations. Fluorine concentrations in Cleetwood and Mazama climactic obsidian clasts vary between ~510 and ~695 ppm, with climactic samples averaging slightly lower concentrations than Cleetwood samples. Fluorine concentrations in Rock Mesa obsidians are uniformly low (~300 to ~510 ppm). Chlorine contents of Cleetwood and Mazama climactic samples range from ~1400 ppm to ~1610 ppm. The Rock Mesa samples all contain less chlorine (~510 to ~1120 ppm) than the Cleetwood and climactic samples, and in the Rock Mesa obsidian, chlorine and total water are positively correlated.

Stratigraphic variations in the volatile contents of pyroclastic obsidian support previous work suggesting that obsidian forms along the margins of the volcanic conduit and is eroded from the conduit walls by fragmenting magma. Both the Cleetwood and the Rock Mesa deposits indicate initial evacuation of shallow vanguard magma followed by a rapid increase in fragmentation depth. Both deposits also show a gradual decrease in the fragmentation depth through time, consistent with subsequent effusive activity in both cases. More puzzling is the apparent closed-system degassing trend defined by the H_2O-CO_2-Cl relations in the Rock Mesa obsidian samples, despite the loss of volatiles required for obsidian formation. This suggests that volatile data may also provide information on the relative time scales of volatile exsolution and loss and obsidian formation.

V11B-1388 0830h POSTER

Determination of 3D Crystal Size Distributions From 2D Measurements: an Application of Stereological Correction Routines to Prismatic Microlites in Obsidian

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Crystal size distributions (CSD) in igneous rocks are traditionally constructed on the basis of measurements of two-dimensional (2D) intersection length and crystal area number density. Transformations of 2D data into "true" three-dimensional (3D) CSDs are complicated by errors arising from the cut effect and intersection probability problem. Correction routines have been developed to alleviate these stereological effects. Here we test published CSD conversion techniques by applying them to intersection length measurements made on prismatic microlites in obsidian for which we have corresponding 3D data. Our results show that large systematic errors in population density arise from shape (aspect ratio) variability in the population. Aspect ratio varies by more than an order of magnitude owing to relatively rapid growth of the long crystal dimension. Thus, aspect ratio varies strongly with length and weakly with width. Conversion programs, which assume a constant shape, overestimate the number of small crystals due to a large number of intersections along the short crystal dimension. In the real population, these intersections correspond to a wide range

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of true lengths. Consequently, CSDs based on intersection length measurements are kinked rather than linear. Kinked and curved CSDs have been interpreted to result from mixing of distinct crystal populations, sharp variations in growth and/or nucleation rate, or from crystal settling. Our results suggest that nonlinear CSDs may also arise as an artifact of shape variability in the natural population. In light of these complications, we suggest that the 3D size and shapes of prismatic microlites in obsidian are measured directly, using a technique presented here. Our technique yields accurate measures of 3D crystal length, width, orientation, and number density. CSDs may also be accurately determined from projection length measurements if prismatic crystals are well aligned within the plane of measurement.

V11B-1389 0830h POSTER

Sensitivity of Eruption Dynamics to Volcanic Conduit Geometry: A Sensitivity Study Using the "Bubbledrive" Numerical Model

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Numerical models provide powerful tools for the investigation of volcanic eruption processes. A number of models has emerged in recent years and steps are being taken to compare and assess performance of the models to shed light on the contrasting results of different analytical and numerical formulations. In addition, models can be used to test the sensitivity of eruption processes to variations or uncertainties in the values of the relevant volcanic parameters such as diffusivity, rheology, composition, geometry, etc. One such model is "Bubbledrive", based on interactive diffusive and decompressive bubble growth in the context of magma hydrodynamics within a volcanic conduit. We have developed and now apply this model to case of a rhyolitic system and explore the sensitivity of eruption style to conduit geometry. We hold other factors (e.g. composition, external conditions, rheology, etc.) the same between model runs so as to isolate the role of geometry. Two basic geometries are explored. The first is a simple cylinder, testing sensitivity to width and length. The second is more complex and includes a cylindrical magma chamber at specific depths in the cylindrical conduit. The position and size of the chamber are variable. In all cases, there is no recharge of fresh magma from below. Also, the triggering mechanism is instantaneous decompression at the top of the conduit (as from a landslide). These results, in concert with the large number of additional emerging sensitivity studies may provide insights regarding the most critical observational parameters on which to focus in the field and in the lab.

V11B-1390 0830h POSTER

Eruption Dynamics of the KS1 caldera eruption of Ksudach Volcano, Russia

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The 240 A.D. KS1 eruption of Ksudach volcano, which dispersed ash across most of the Kamchatkan peninsula, resulted in a 6-7-km^3 caldera. Prior work showed the deposit consists of 15 km^3 of tephra falls and 3-4 km^3 of pyroclastic flows. New details reveal the eruptive dynamics of the eruption. A sharp change from white to gray pumices and ash in the upper part of the deposit defines a distinctive timeline. Proximally, KS1 deposits consist of a white pumice fall deposit with interbedded ash layers, followed by thick, white pyroclastic flow deposits with interspersed thin falls, which are overlain by gray fall and flow deposits. Medial and distal sites consist mainly of pumice falls and thin ash layers. Pumices in many of those fall layers are coated with ash, and the ash layers contain abundant pumices. At all sites, the lowermost fall layer is reversely graded. The lithic content of the white pumice falls increases upward until the uppermost fall is dominantly lithics. The gray fall layer contains fewer lithics. We interpret the changing deposits with distance and height to reflect differences in simultaneous deposition from buoyant (fall) and non-buoyant (pyroclastic flow) parts of an eruption column. Early on, most material came from a buoyant plume, whereas later in the white pumice phase of the eruption material from the non-buoyant part of the plume increased in abundance. A buoyant plume again became important during dispersal of gray pumice. The dispersal of lithics in the fall deposits reveals that the buoyant plume increased in height from the base to the middle of the white falls, when production of pyroclastic flows also increased, and then decreased to the white-gray shift and gray pumice deposition. The combination of a greater column height for the middle white fall and greater production of pyroclastic flows shows that the total mass flux of the eruption peaked during that stage of the eruption and waned afterward.

V11B-1391 0830h POSTER

A Numerical Study on Transition between Eruption Column and Pyroclastic Flow by a 2-D Fluid-Dynamics Model

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The dynamics of eruption clouds during explosive eruptions is diverse; it either rises as an eruption column or collapses to generate pyroclastic flows depending on source conditions such as upward velocity, mass of vapor or mass discharge rate. Previous 1-D numerical models (e.g. Woods,1988) predict that there is a critical mass discharge rate for a column collapse when the vent velocity is constant. We numerically studied the transitional conditions between these two regimes using a 2-D pseudo-gas fluid-dynamics model of eruption columns.
We calculated the motion of an eruption column from a circular vent on the flat surface of the earth. When the relative velocity of gas and ash particles is sufficiently small, we can treat an eruption cloud as a single gas. Equation of state (EOS) for the mixture of the magmatic component (i.e. volcanic gas plus pyroclasts) and air can be approximated by EOS for an ideal gas, when the volume fraction of the gas phase is very large. It is assumed that the dynamics of eruption clouds is based on the Euler equations of a compressible gas. The partial differential equations are solved numerically by the Roe scheme, which is a general TVD scheme for compressible flow and can simulate the generation of shock waves correctly.
Our results are qualitatively consistent with 1-D models; eruption columns become unstable to form pyroclastic flows as the mass discharge rate increases. In addition to these two regimes, our 2-D model suggests that there are two transitional flow patterns between the eruption column and pyroclastic flow regimes. For a constant vent velocity, the flow pattern changes from (A) to (D) with the increasing mass discharge rate as follows:
(A) Eruption column regime: The cloud entrains sufficient air to form a buoyant plume.
(B) Column with dense core regime: The column consists of an inner dense core surrounded by a dilute shear layer near the vent. At approximately 2km above the vent, the dense cloud entrains air rapidly due to a large eddy and becomes buoyant.
(C) Partial collapse regime: A part of the cloud rises as a buoyant plume directly from the vent. At the same time, a part of the cloud collapses and forms a pyroclastic flow.
(D) Pyroclastic flow regime: Most of the material of the cloud spreads radially as a pyroclastic flow. Subsequently, a part of the pyroclastic flow entrains ambient air and becomes buoyant co-ignimbrite ash clouds.

V11B-1392 0830h POSTER

Numerical Simulation of Magma Fragmentation in the Shock-tube Model

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Fragmentation of bubbly magma in a conduit is a key process that governs transition from effusive eruption to explosive one. Fragmentation mechanisms have been experimentally investigated using "shock-tube" apparatus. Because of difference in scales, phenomena observed in the experiments do not necessarily represent phenomena in natural volcanic system. In order to compare the experimental results with observations in nature, we developed a numerical model which can cover both the experimental and natural conditions.

A coupled model for 1-dimensional time-dependent flow and bubble expansion is applied to describe dynamics of bubbly viscous magmas. Gas-overpressure and hoop stress around each bubble are calculated by applying the cell model; a single bubble surrounded by a small shell of incompressible melt expands against viscous resistance of the melt. It is assumed that magma fragments and the flow changes from bubbly flow to gas-particle dispersion when the hoop stress reaches a given threshold. Numerical instabilities due to a steep pressure gradient and/or other discontinuities such as fragmentation surface and initial magma-air contact could be successfully avoided by applying CIP-1 and C-CUP methods, in which pressure balance is iteratively calculated in each time-step.

We considered the 1-D shock tube problem. Initially a bubbly magma at a high pressure is separated from air at the atmospheric pressure by a diaphram. At t=0 the diaphram is removed, as a result shock wave propagate into the air and rarefaction wave propagate into the bubbly magma. The front of the bubbly magma fragments due to rapid decompression. The boundary between fragmented magma and bubbly magma (i.e. fragmentation surface) propagate into the magma. The velocity of fragmentation surface is determined by competing effects of the flow due to expansion of the bubbly magma and the propagation of rarefaction wave, and strongly depends on initial conditions and magma properties; it increases as (1) initial pressure increases (2) strength of magma decreases, and (3) viscosity of magma increases. It is also suggested that large wall friction tends to suppress the fragmentation.

V11B-1393 0830h POSTER

Dynamics of Bubbly-magma Flow in Conduits: Stress and Expansion Regimes of Magma Fragmentation

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Explosive volcanic eruptions are characterized by magma fragmentation, that is, the process through which a bubbly magma is changed into a gas-pyroclast dispersion. Two criteria of mechanisms have been proposed for the magma fragmentation so far. First, magma fragments when stress or strain rate of magma around bubbles exceeds a critical value. Second, magma disrupts due to the instability of thin magma-foam. Which criterion is actually applicable is not yet known. In order to clarify the physics of the magma fragmentation, we numerically study one-dimensional steady flows with bubble growth in conduits. The spherical cell model is used to calculate expansion of bubbles in ascending visco-elastic magma.

The stress around bubbles generally grows as magma ascends and the pressure difference between bubbles and surrounding magma increases. In some conditions, the stress becomes critically large only when the flow velocity approaches the sound speed meeting the choking condition. In other conditions, the stress becomes large enough as magma pressure drops with bubble pressure kept almost unchanged. These two distinct types may correspond to the above two criteria of fragmentation mechanisms. In the former case, void fraction becomes close to unity before the stress reaches the strength of magma. In such case, the magma does not fragment due to the visco-elastic deformations but fragments by the instability of the thin magma-foam ('expansion' regime). In the latter case, on the other hand, the stress reaches the magma strength at much lower void fractions. In such case, the magma fragments due to the visco-elastic deformation around bubbles ('stress' regime). The 'expansion' and 'stress' regimes occur when the ratio of the initial wall-friction stress to the magma strength is sufficiently smaller and greater than unity, respectively.

V11B-1394 0830h POSTER

Kinetic Energies in Oblique Pumice-Pumice Impacts and Coefficient of Restitution

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The coefficient of restitution is an important parameter in granular flows because it describes particle-particle and particle-ground interactions. For example, when the coefficient of restitution increases, the granular temperature increases and during the motion on a rough ground surface it affects the conversion of the slope-parallel translational momentum into the slope-normal fluctuation momentum. The restitution coefficient is usually measured dropping a small sphere of a given material onto the horizontal surface of a large rigid body and varies from 1 for perfectly elastic materials to 0 for perfectly inelastic ones. However, in real pyroclastic flows, oblique collisions and angular particles occur. For this reason, we have recorded pumice-pumice impacts of fragments whose trajectory lies in a plane perpendicular to the sight direction of a high-speed video camera. Using the high-speed videos, we measured the linear and angular velocities of the pumice fragments that allowed the computation of the ratio of the sum of the translational and rotational kinetic energies after and before these oblique impacts. We examined 100 collisions of fifty different pumice clasts on flat pumice surfaces. The pumice fragments have irregular shape and are sub-rounded to sub-angular, their density is between 0.5 and 1 g/cm^3, their mass is between 0.13 and 1.15 g, and their bubble diameters mode is approximately equal to 1 mm. The horizontal flat pumice surfaces were obtained cutting a large piece perpendicularly to the maximum stretching direction of the bubbles (pumice density 0.53 g/cm^3; bubble diameters mode less than 1 mm). These pumice fragments come from the fall deposits of the Little Glass Mountain in northern California, USA. For our range of linear impact velocities (5.6 and 18.6 m/s) and our range of impact angles (52 and 76°) we obtained a range of the square root of the ratio of the kinetic energies between 0.3 and 0.7 with a mean value equal to 0.5 (this does not include particles that roll or slide on the targets). During impact, the kinetic energy can be dissipated by frictional heat generation, surface erosion, particle breakage and particle deformation. For the same collisions, we computed also the ratios of the components normal to the target surface of the linear velocities after and before impact that range from 0.46 to 0.11 with a mean value equal to 0.24 (again without including particles that roll or slide on the targets).

V11B-1395 0830h POSTER

Analysis and Optimization of a Lagrangian Volcanic Ash Particle Tracking Model called Puff

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Volcanic ash tracking models are important for airborne and ground hazard mitigation. Volcanic ash can have devastating effects on aircraft during flight, and ground sedimentation is potentially hazardous in populated areas. Because ash dispersion is controlled primarily by atmospheric winds, analytic solutions are impractical and must be numerically solved. Two distinct modeling techniques, Lagrangian and Eulerian, are currently used for both regional and global tracking models. Recently, the Lagrangian technique has appeared to be more accurate and efficient for tracking volcanic ash plumes, particularly for small eruptions and at early times during the eruption.

Modeling ash plume dispersion is complicated by several factors including particle sedimentation and aggregation, and varying wind-field dynamics from the near surface to upper atmosphere. Furthermore, there exists a very limited data set pertaining to past eruptions with which tracking models can be tested and validated. Due primarily to this dearth of data on past eruptions, tracking models have erred on the side of excess when including potentially important factors in describing particle dynamics. The most recent version of Puff includes eleven distinct, adjustable parameters that are intended to describe various processes that effect airborne particle dynamics. The analysis described here was undertaken to better understand the sensitivity of the model to each of the eleven parameters independently. As a result, an improved understanding of how best to parameterize the model has been gained, as well as several methods to optimize performance and the predictive capability has been discovered.

Since Puff includes random perturbations in the ash particle trajectories using a Monte Carlo-type technique, large numbers of successive simulations were performed in the analysis, and the averaged overall behavior was analyzed. Model run groups of 100, 500, and 5000 simulations were performed. The eleven adjustable parameters were varied in a Gaussian distribution around a "best-guess" mean value. Each sensitivity analysis was based on a pass/fail test of the model for predicting the ash cloud distribution of a past eruption for which fairly reliable satellite imagery was available. Each model run was classified as "pass" or "fail" for a specific array of parameter values. Comparison of the normalized distribution of these results as a function of each parameter indicates relative sensitivity of the model to that parameter.

Results from these analyses indicate that vertical diffusion of ash particles is negligible except near the ground surface. Ash particle size can be extremely important in cases of vertical wind shear because sedimentation dynamics influence the elevation and speed at which particles descend. Initial plume height can be important for similar reasons, indicating that early detection of maximum plume height is vital for both short and long term ash tracking. Initial plume shape, model timesteps in the 1-10 minute range, particle size distribution and the number of model tracer particles have minimal influence relative to the above. As a result, a suitable set of constant parameter values has been determined based on the global volcano location. Windfield resolution of the atmospheric model used as input has negligible effect for most common regional and global models.

V11B-1396 0830h POSTER

Emplacement of Megacrystic Basalt Flows in the Northern Galápagos Archipelago: Rheologic Parameters and Analog Flow Experiments

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The volcanoes of the northern Galápagos Islands, Wolf, Darwin, Pinta, Marchena, and Genovesa, share petrologic characteristics that distinguish them from those of the main archipelago. Field mapping in 2002 revealed that Wolf and Darwin Islands are dominated by basalt flows with abundant coarse plagioclase crystals up to several centimeters across, referred to here as megacrysts. Similar flows are observed to a lesser extent on Pinta, Marchena, and Genovesa, but at Wolf and Darwin they make up 25-50% of exposed lavas. Lavas are generally horizontal (<10°) pahoehoe flows with greater than 50% modal abundance of megacrystic plagioclase crystals, which make the rheologic parameters and emplacement processes of these flows unusual. Yield strength calculations using high crystal abundances result in larger than expected values for the megacryst-bearing flows (10^3-10^4 Pa), which significantly exceed the 10^1-10^2 Pa values for other (non-megacryst bearing) Galápagos pahoehoe flows. Instead, values suggest the megacrystic lavas of the northern islands have yield strengths comparable to aa flows. Yield strengths calculated from flow dimensions are up to an order of magnitude larger. Estimated viscosities for the northern megacrystic flows range between 10^2-10^3 Pa-s, comparable to other pahoehoe flows in the Galápagos Archipelago. Detailed rheologic effects of the megacrysts during flow emplacement are difficult to quantify because flows have limited exposure on Wolf and Darwin (most are buried), permitting only rough estimates of flow dimensions; calculations utilizing crystal contents disregard phenocryst abundances and rely on groundmass crystallinities instead. Rather than depending on calculated rheologic factors to describe emplacement conditions of the megacrystic flows, a series of analog experiments are used to model flow behavior. Experiments utilize analog materials with scaled rheologic properties similar to natural basalts to constrain the emplacement morphology of the megacrystic basalts of the northern Galápagos Islands.

V11B-1397 0830h POSTER

Volcanic Landslide Basal Friction as Measured by Seismic Waves

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The long runout of large landslides, and therefore apparently low basal friction, has long been a subject of intense debate. Volcanic landslides have even longer runouts than other avalanches, perhaps due to the importance of hot gases as a driving force or basal lubricant. We invert seismic data from the March 30, 1956 Bezymianny, Russia for an equivalent force source. We then compare the results with the May 18, 1980 Mount St. Helens, USA eruptions in order to directly measure the basal friction of these landslides that both uncapped juvenile magma.

Following previous work on landslides as seismic sources, we assume the Bezymianny landslide generated seismic waves by acting as a subhorizontal single force with the azimuth in the opposite direction (180^0) from the landslide runout direction. We also assume a sinusoidal source-time function. We invert a regional record of the surface waves in the 0.01–0.055 Hz bandpass. Preliminary results indicate a single force source azimuth of 267^0 from North with an amplitude 4.5×10^{11} N at a source period T=23 s. This azimuth indicates that the landslide runout was due East within 30^0 of the current major axis of the explosion crater.

The amplitude of the basal force is the most robustly determined parameter in the inversion. It is a factor of 15 smaller for Bezymianny than for Mount St. Helens. Bezymianny's low force cannot be explained simply by the smaller mass of its landslide as the ratio of the landslide masses for the two eruptions is only 5. Therefore, the effective coefficient of friction for Bezymianny is 1/3 that of Mount St. Helens. Bezymianny had a higher proportion of blast to landslide material (40–80%) than Mount St. Helens (<10%), which could explain the reduced friction as the hot, expanding magmatic gases released in the blast lubricate the basal layer. Alternatively, the reduced friction could be associated with the larger percentage of water in the landslide from the snow and glaciers at Bezymianny.

V11B-1398 0830h POSTER

Welded-tuff dikes were the vents for major ignimbrites of the Sierra Madre Occidental, Mexico

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It has been a major unsolved problem to identify the sources of the voluminous ignimbrites of the Sierra Madre Occidental (SMO), NW Mexico, which is considered the largest continuous ignimbrite province in the world. A conservative estimate of the physical volume of the SMO ignimbrites is about 360,000 km3. At least 250 calderas the size of those at San Juan Volcanic Field in Colorado would be needed to have produced these ignimbrites, but there are less than 10 calderas identified so far in the SMO. Field evidence indicates that much of the ignimbrites volume was related to fissure-type eruptions, most of them coinciding with Basin and Range faults. These fissures are several kilometers long and are marked by welded-tuff dikes. In some cases co-ignimbrite lithic-lag breccias occur next to these dikes confirming that the tuff dike was the source of the adjacent ignimbrite. Tuff dikes reach up to 50 m wide and can be followed for tens of km within, or at, the shoulders of large grabens of the SMO. Fiamme and other ignimbrites planar features are aligned vertically or semi-vertically in these dikes. Shearing along margins and wall-cooking are also evident. Some dikes are composite and include up to three distinct ignimbrites with differences in welding, pumice contents, and general aspect. Each ignimbrite shows variations in welding degree, from poorly- to highly-welded. In some cases, the dikes are lithics-poor and in others are lithics-rich. In a regional scheme, ignimbrite flare-up and Basin and Range faulting overlap in time and space in many places of the SMO. On this basis, we propose a model in which batholith-sized magma chambers reached shallow crustal levels, and were evacuated when Basin and Range normal faults cut the roof of these chambers; this caused fast decompression when the system was opened, and voluminous

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silicic magmas were erupted explosively through these faults. The fissures were filled by the pyroclastic material and closed the vent after cooling, producing the welded-tuff dikes.

V11C MCC: 106 Monday 0830h

Linking Chemistry and Microbiology in Seafloor Hydrothermal Systems II

(joint with B, OS)

Presiding: **D Butterfield,** University of Washington/NOAA Pacific Marine Laboratory**; J Ishibashi,** Kyushu University**; A Maruyama,** National Institute of Advanced Industrial Science and Technology

V11C-01 0830h

Sub-seafloor Processes and the Composition of Diffuse Hydrothermal Fluids

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High-temperature water/rock reactions create the primary hydrothermal fluids that are diluted with cool, "crustal seawater" to produce low-temperature, diffuse hydrothermal vent fluids. By knowing the composition of each of the components that combine to produce diffuse fluids, one can compare the composition of calculated mixtures with the composition of sampled fluids, and thereby infer what chemical constituents have been affected by processes other than simple conservative mixing. Although there is always uncertainty in the composition of fluids from the sub-seafloor, some processes are significant enough to alter diffuse fluid compositions from the expected conservative mixtures of hot,primary fluid and "crustal seawater." When hydrothermal vents with a wide range of temperature are sampled, processes occurring in different thermal and chemical environments potentially can be discerned. At Axial Volcano (AV) on the Juan de Fuca ridge, methane clearly is produced in warm sub-seafloor environments at temperatures of $\sim 100^{\circ}$ or less. Based on culturing and phylogenetic analysis from the same water samples at AV, hyperthermophilic methanogens are present in water samples taken from vents ranging in temperature from 15 to 78° C. Ratios of hydrogen sulfide to pseudo-conservative tracers (dissolved silica or heat) at AV decrease when primary fluids are highly diluted with oxygenated seawater. Phylogenetic signatures of microbes closely related to sulfide-oxidizers are present in these same fluids. Hydrogen sulfide oxidation represents the dominant source of energy for chemosynthesis at AV, as in most hydrothermal systems, but a relatively small proportion of the total hydrogen sulfide available is actually oxidized, except at the very lowest temperatures.

V11C-02 0845h

Changes in Subseafloor Bacterial Diversity Following the 1998 Volcanic Eruption at Axial Volcano, Juan de Fuca Ridge

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The subseafloor associated with hydrothermal systems is a dynamic environment in which habitat characteristics change over time, especially with disturbances such as diking-eruptive events and earthquakes. Little is known about the microbial ecology of the subseafloor at active deep-sea volcanic sites and in particular whether or not there are bacterial and archaeal phylotypes that are unique to this environment or how the microbial communities respond to changes in the geochemistry and temperature of vent fluids. In this study, 16S rRNA gene sequence analysis were used to follow changes in bacterial diversity in subseafloor fluids from a single diffuse flow vent shortly after a volcanic eruption at Axial Volcano, Juan de Fuca Ridge, created the site in 1998 and again in 1999 and 2000. Our results show that bacterial diversity is high in diffuse fluids, and that it changes with the post-eruptive evolution of vent fluid chemistry and temperature. The data also show increases in species richness with time within the ϵ-proteobacteria, the dominant phylotype found to be unique to the subseafloor environment. Other phylotypes unique to the subseafloor included high temperature groups such as *Desulfurobacterium*, gram-positive bacteria, and members of novel candidate divisions WS-6 and ABY-1 that have not previously been detected from deep-sea vents. Phylotype richness was highest in the particle-attached populations ($>3\mu$m) from all three sampling periods, and diversity appeared to increase over that time, particularly among the ϵ-proteobacteria. Over this time period, temperature, hydrogen sulfide concentrations, and chlorinity of vent fluids reflect a cooling of the system according to post-eruptive fluid evolution models. Despite this cooling trend, significant numbers of anaerobic hyperthermophiles, including heterotrophs and methanogens, were cultured from all three years. This suggests that while the system is cooling, there remains a hot biotope where indigenous subseafloor hyperthermophiles are maintained. A preliminary model will be presented that attempts to relate bacterial and archaeal diversity to chemical characteristics of diffuse flow fluids and the degree of mixing of seawater.

V11C-03 0900h

Influence of Magmatic Volatiles to Hydrothermal Activity at Suiyo Seamount, Izu-Ogasawara Arc, Western Pacific

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A high-temperature hydrothermal activity related to dacitic arc magmatism of Suiyo Seamount ($28^{o}34$'N, $140^{o}38$'E), Izu-Ogasawara Arc, western Pacific has been drilled in June 2001 and July 2002 using a tethered, submarine rock-drill system BMS (Benthic Multicoring System) on-board the *R/V Hakurei-Maru # 2* as a part of **Archaean Park Project***. Impermeable sheath or cap-rock which consists of clay and anhydrite develops beneath the vent field and traps the end-member fluid within the soft sediment layer 1-3 meters thick beneath the seafloor (Urabe et al., 2002). The sheath is likely to be formed by self-sealing process of anhydrite through cementation of sand grains. Most of the anhydrite from upper part of the cap-rock has sulfur isotopic composition similar to seawater value (+20-21 permil). However, those coexisting with pyrite beneath the cap-rock often have δ^{34}S value as low as +17 permil. Besides, carbon isotope fractionation temperature between CH_4 and CO_2 is as high as 700^{o}C (Tsunogai et al., 1994). These lines of evidence strongly suggest that the magmatic volatiles are incorporated into end member fluid as important components. Homogeneous chemistry and stable temperature of the end member fluid for a decade indicate that the hydrothermal circulation system is in quasi-stable condition and the oxygenic nature of the dacite magma has strong influence on the relatively higher redox condition of the fluid compared to that of mid-ocean ridge hydrothermal activity. Such a nature may reduce the extent of hydrogen-based sub-vent biosphere at submarine arc volcanoes such as Suiyo Seamount.

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V11C-04 0915h

Do sulfur isotope compositions of sulfate minerals and occurrence of framboidal pyrite indicate the subvent biosphere at the Suiyo Seamount in Japan?

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Detailed morphological studies and sulfur isotope analyses were performed on sulfides and sulfates in the drilled core samples from the Suiyo Seamount in Japan. Petrographic studies indicate that drilled samples were extremely altered by the submarine hydrothermal process. Notable feature of the examined samples is the high abundance of sulfide (e.g., FeS2, CuFeS2, ZnS and PbS) and sulfate minerals (e.g., CaSO4, BaSO4). The euhedral shape of sulfides is most common morphology in the examined samples. Sulfur isotope compositions of these sulfides are ranging from +1 to +6 per mil, suggesting that sulfides were directly precipitated from isotopically homogeneous H2S in hydrothermal fluids. On the contrary, framboidal form of pyrite was found in subsurface samples (2 m depth) of APSK 03 site (drilled site near eastern edge of caldera wall). Detailed SEM observation indicates that the framboidal pyrite is aggregate (ca. 100 micro-meter in diameter) of small grain of pyrite crystals (5 micro-meter in diameter). Such morphological nature is quite similar to these found in the modern marine sediments. Sulfur isotope compositions of individual framboids were determined using the Nd-YAG laser microprobe system at Tohoku University. Their isotopic compositions are ranging from <ETH>1 per mil to +2 per mil and slightly lighter than these of the contemporary hydrothermal sulfides. Two possibilities are considerable for the origin of framboids: (1) biogenic origin or (2) abiogenic origin. If (1) is the case, sulfate-reducing bacteria in subvent region was responsible for the formation of framboidal pyrite. Average sulfur isotope compositions of sulfate minerals are closed to +20 per mil in entire region. This suggest that the progressive introduction of sea water sulfate into the shallow hydrothermal system. Some sulfate minerals have lighter isotopic compositions (+17 to +19 per mil) than the sea water sulfate value. These lighter values indicate the mixing process between sea water sulfate (+20 per mil) and sulfate formed by oxidation of hydrothermal H2S (1 to 2 per mil). Two possibilities are considerable for oxidation of H2S: (3) biological oxidation and (4) simple mixing between oxic sea water and reduced hydrothermal fluids. Sulfur-oxidizing microorganism in subvent region may be responsible for oxidation of H2S, if (3) is the case.

V11C-05 0930h

Concentration of Biologically Important Chemical Species in Hydrothermal Fluids from Submarine Arc Volcano Suiyo Seamount

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During dive programs conducted by Archaean Park Project (2000-2002), fluid samples were extensively collected from both high-temperature (up to 300^{o}C) and low temperature vents within submarine arc volcano Suiyo Seamount. Concentrations of chemical species are explained by simple mixing between the hydrothermal endmember and ambient seawater, with only some exception. This suggests a single aquifer distributes beneath the caldera floor. Major elements chemistry agrees with the model that the hydrothermal fluid is equilibrated with surrounding alteration minerals by fluid rock interaction at high temperature.