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The mechanism causing columnar jointing has remained an enticing mystery since the basalt columns of the Giant's Causeway in N. Ireland were first reported to science in the 17th century. This phenomenon, in which shrinkage cracks form a quasi-hexagonal arrangement, has been shown to produce columns in starch, glass, coal, sandstone, and ice, as well as in a variety of lava flows. This suggests that this pattern-forming process is very general in nature. However, most studies of columnar jointing have been confined to field studies of basalt flows. Following Muller, we have experimented with desiccating corn starch in an effort to understand this pattern from a more general point of view. The diffusion and evaporation of water in starch is thought to be analogous to the diffusion and extraction of heat from a basalt flow. By combining direct sampling and x-ray tomography, fully 3D descriptions of columnar jointing were obtained with starch samples. We have characterized the pattern with several statistical indices, which describe its structure and relative disorder. These methods can resolve the ordering of the colonnade near the free surface. We identified two distinct mechanisms by which the mean column area increases during pattern evolution. We found both a slow, almost power-law increase in column area, as well as episodes of sudden catastrophic jumps in scale. The latter suggests that the column scale is not a simple single-valued function of drying rate, but rather a metastable state subject to hysteresis. Such metastable behaviour might explain a fundamental question about columnar jointing – why the columns are so regular in the direction of their growth. Moreover, these experiments may help discriminate between the various theoretical models of this pattern forming process. Finally, our results lead to predictions that could be tested by field measurements on basaltic colonnades.

URL: http://www.physics.utoronto.ca/nonlinear

V51E-0329 0830h POSTER

Effects Of Conduit Flow Parameters On Vulcanian Explosion Characteristics

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Previous work produced numerical models of Vulcanian explosions which occurred in 1997 at Soufrière Hills Volcano, Montserrat. Plume evolution and velocities were calculated for the well-documented and typical explosions of August 6th and 7th 1997, and these data and other observations were compared to transient, axisymmetric, multi-phase flow simulations of coupled conduit evacuation and pyroclastic dispersal. Pre-explosion conduit conditions were estimated from Montserrat data, using a simple gas solubility law and assuming that conduit magma flow had stagnated with a constant overpressure prior to the explosions. The numerical simulations of the explosions resolved highly unsteady vent exit conditions such as velocity, pressure and mass flux. Our simulations produced behavior which generally mimicked the observed explosions. The best match to the observed and measured explosion parameters employed an intermediate conduit permeability value. Results suggest that a modest amount of volatile depletion in the conduit was an important factor in influencing the strength and style of the Vulcanian explosions on Montserrat. Ongoing work, which is presented here, uses a dynamic model of the conduit, rather than assuming that flow had stagnated. The new conduit model allows for magma viscosity and density changes due to degassing, crystallization and the presence of bubbles as the magma rises in the conduit, creating a non-linear overpressure gradient with depth. The first aim of this project is to examine conduit model parameters to determine which significantly affect the steady-state conduit pressure and gas volume fraction profile. Important parameters presented here are permeability (both vertical and horizontal), chamber crystal volume fraction, crystal growth function (curve fits of experimental results), magma flux rate and bubble-bearing rheology parameters, such as bubble size. The second aim is to determine to what degree such added complexity in the conduit model controls the resulting explosion simulation results. The first round of comparisons suggests that added rheological complexity does not significantly affect the energy of the explosion. For example, plume ascent velocities and collapse timing and height of a simulation with initial conditions determined by a rheologically complex model, but without permeability, were quite similar to those derived from our original, stagnated, non-permeable conduit. However, plume shape and collapse style were affected by the new conduit formulation. These results suggest that the strength of the explosion is particularly sensitive to the permeability of the conduit system, but is not sensitive to vertical pressure profile, while, on the other hand, the style of the explosion plume and fountain collapse is sensitive to both the conduit permeability and pressure profile. Simulated Vulcanian explosions resulting from the more complex dynamic conduit model, including effects of permeability, are therefore presented and compared against simulations derived from the simple stagnated, yet also permeable, conduit profiles. Again, results suggest that water vapor volume fraction is more important than complex rheology in predicting explosion strength.

V51E-0330 0830h POSTER

Exploration of eruption mechanisms through parametric sensitivity analysis: Using a numerical model as a diagnostic tool

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Numerical models can be useful for exploring the dependence of eruption timing and style to variations in magma chemical and physical characteristics, as well as to geometry of the system. We have developed a model that can be used for this purpose ("Bubbledrive") and have applied it to a number of scenarios involving rhyolitic systems. We have tested the sensitivity of eruption style to variations in conduit depth and radius, volatile diffusivity in the melt, melt viscosity, magma recharge from below, and decompression triggers. The results show that after the initiation of eruption, there is a gradual acceleration stage in case of cylindrical conduit shapes. Exit velocity is approximately a linear function of time, and discharge rate is close to constant. The difference between velocity and discharge reflects the increasing vesicularity of the erupting magma during degassing and bubble growth. After a climax in exit velocity, the eruptions quickly cease. As such, these results suggest that an empirical equation can be formulated that describes exit velocity in terms of eruption duration and an acceleration factor, which, in turn are functions of conduit radius, depth, diffusivity, viscosity, etc. The above relations do not apply to magma systems with more "realistic" or complex conduit geometries, such as those that include a magma chamber. In the latter case, initialization is followed by quasi-steady state eruption of different intensity over extended time (about 80% of eruption cycle). This relatively uniform stage of eruption is maintained by the degassing of magma within the chamber that feeds the upper conduit. The uniform stage of eruption ends abruptly when the magma chamber is degassed. An eruption spike appears as an explosion near the end of degassing of the chamber. This spike begins when the overlying conduit is filled with foam or gassy spray that provides little overburden; this leads to rapid decompressive degassing of the chamber with little resistance to the flow from the overlying conduit. The maximum explosion occurs as the foam layer moves into the chamber. These results of numerical modeling suggest that observations or monitoring systems could be used most fruitfully in the areas of conduit geometry. At present, it is simpler to develop numerical models of specific conduit geometries than it is to directly probe and map them in natural systems. This highlights the importance of monitoring systems for specific volcanic systems.

V51E-0331 0830h POSTER

Do the fractal dimensions of evolved lava-flow margins distinguish endogenous and exogenous growth?

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Although there are recorded observations of active dacitic domes at Mount St. Helens, Soufriere, St. Vincent and Santiaguito, there is as yet no direct observation of an active rhyolite flow, dome or coulee. Thus, we must use numerical models and/or laboratory simulations to constrain the emplacement of evolved lavas. We have used fractals to describe the planforms of evolved flows and domes (both naturally occurring and simulated laboratory flows) in an attempt to quantify their emplacement styles. Bruno et al. [1994] used fractal analysis of basaltic lava flow margins and determined that a´a flows correspond to a fractal dimension (D) of 1.05-1.09 and pahoehoe flow margins display D = 1.13-1.23. Based on only a few examples, they concluded that evolved flow margins are not fractal. However, only a small number of evolved flows were examined and these were emplaced on relatively steep (>5°) slopes. More recently it has been suggested that the D ranges allocated to a´a and pahoehoe actually describe simple or complex emplacement, respectively. We have measured aerial images of evolved lava flows in the Cascades, the Inyo domes and the Andean Central Volcanic Zone to test the hypothesis that D values for lava flow margins reflect emplacement style rather than surface morphology. Preliminary results indicate that some evolved flows and domes do indeed exhibit a fractal behavior. A flow margin is determined to show fractal behavior if the R^2 value calculated on a Richardson plot of the margin is >0.95. The flows/domes that do exhibit fractal behavior fall within the range of 1.055 and 1.097. This range is almost identical to that of the simple flow emplacement (a´a-like), which may be indictative of endogenous (rather than exogenous) growth. Analyses of simulated flows in the laboratory will be used to further test this hypothesis.

V51F MCC: Level 1 Friday 0830h

Applied Volcano Hazards Assessments and Methods Posters

Presiding: **R Wessels,** U.S. Geological Survey Alaska Volcano Observatory

V51F-0332 0830h POSTER

Forwards and Backwards Modelling of Ashfall Hazards in New Zealand by Monte Carlo Methods

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We have developed a technique for quantifying the probability of particular thicknesses of airfall ash from a volcanic eruption at any given site, using Monte Carlo methods, for hazards planning and insurance purposes. We use an established program (ASHFALL) to model individual eruptions, where the likely thickness of ash deposited at selected sites depends on the location of the volcano, eruptive volume, column height and ash size, and the wind conditions. A Monte Carlo formulation then allows us to simulate the variations in eruptive volume and in wind conditions by analysing repeat eruptions, each time allowing the parameters to vary randomly according to known or assumed distributions. Actual wind velocity profiles are used, with randomness included by selection of a starting date. We show how this method can handle the effects of multiple volcanic sources by aggregation, each source with its own characteristics. This follows a similar procedure which we have used for earthquake hazard assessment. The result is estimates of the frequency with which any given depth of ash is likely to be deposited at the selected site, accounting for all volcanoes that might affect it. These numbers are expressed as annual probabilities or as mean return periods. We can also use this method for obtaining an estimate of how often and how large the eruptions from a particular volcano have been. Results from ash cores in Auckland can give useful bounds for the likely total volumes erupted from the volcano Mt Egmont/Mt Taranaki, 280 km away, during the last 140,000 years, information difficult to obtain from local tephra stratigraphy.

V51F-0333 0830h POSTER

Lava extrusion rates from handheld infrared imagery

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During the extrusive phase of the ongoing eruption at Stromboli in the early part of 2003, the development of an a´a lava flow down the steep slope of the Sciara del Fuoco provided an ideal opportunity to use infrared imagery to estimate lava effusion rates. The method for extrusion rate calculation follows that used in satellite imagery, setting constant values for the conductive and convective heat loss, as well as the latent heat of fusion. The radiative component is measured using the FLIR (forward looking infrared radiometer) images. Measurements were made with a FLIR systems Thermacam 595 and 695, accuracy between instruments fell to within 10%. Using this method, effusion rates raging from 0.1 to 0.6 m^3/s were measured, with an error of about 0.1 m^3/s. These rates are typical of the magma supply to Stromboli, suggesting an open steady system, and that though the surface expression of the volcanism had changed, the deep system remained unchanged. When effusion rates waned, an increase in the temperatures recorded at the summit craters was observed. Conversely, an increase in effusion rate would result in a decrease of summit crater temperature. This inverse cycle would hold for about one week, then a cycle where the rates and temperatures increased and decreased together would occur, followed again by the inverse cycle. Though it is unclear what this means about the shallow conduit geometry, it is clear that the vents are linked. The use of handheld infrared imagery has become a useful tool to monitor and mitigate volcanic hazards, and will continue to supply rapid useful data about eruptions at eruptions worldwide.

URL: http://flir.images.alaska.edu

V51F-0334 0830h POSTER

A First Look at Volcanic Ash Detection From GOES-12: Coping Without the 12μm IR Band

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On 1 April 2003, Geostationary Operational Environmental Satellite (GOES)-12 became the primary East spacecraft to monitor weather and environmental hazards over North and South America. An important instrument modification to the GOES-12 Imager was the replacement of a 4 km resolution 12μm Infrared (IR) band with a lower resolution (8 km) IR band centered near 13.3μm. There has been a concern that the loss of the 12μm band will negatively impact volcanic ash detection and aviation safety, since that channel has been effectively used for this purpose for nearly a decade, in combination with other spectral bands on GOES. The first opportunity to evaluate GOES-12 capabilities occurred with several moderate eruptions of Soufriere Hills Volcano on Montserrat in the Eastern Caribbean from 12-15 July 2003. The eruptions were triggered by a major lava dome collapse, followed by pyroclastic flows (Montserrat Volcano Observatory). Ash was dispersed throughout the Troposphere across the region, with maximum ash top heights estimated to range from 8-16 km (Washington Volcanic Ash Advisory Center). A new algorithm has been developed to detect ash using an arithmetic combination of GOES-12 IR brightness temperature data in Bands 2 (3.9μm), 4 (11μm) and 6 (13.3μm). The latter channel has shown the ability to discriminate volcanic ash from ice-laden cirrus cloud layers. Examples of the multi-spectral images for these events, including estimation of ash cloud top heights using a "CO2/IRW ratio" technique will be provided, along with an assessment of their reliability.

URL: http://orbit-net.nesdis.noaa.gov/arad/fpdt/volc.html

V51F-0335 0830h POSTER

Volcanic Ash Image Products from MODIS for Aviation Safety and Natural Hazard Mitigation

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Multi-spectral volcanic ash image products have been developed using Moderate Resolution Imaging Spectroradiometer (MODIS) data from the NASA Terra spacecraft (Ellrod and Im 2003). Efforts are now underway to integrate these new products into the MODIS Data Retrieval System at NESDIS, for use in the operational Hazard Mapping System (HMS). The images will be used at the Washington Volcanic Ash Advisory Center (W-VAAC) in the issuance of volcanic ash advisory statements to aircraft. In addition, the images will be made available to users in the global volcano and emergency management community via the World Wide Web. During the development process, good results (high detection rate with low Sfalse alarms) were obtained from a tri-spectral combination of MODIS Infrared (IR) bands centered near 8.6, 11.0 and 12.0 μm (Bands 29, 31, and 32). Optimum Red-Green-Blue false color composite images were developed to provide information on ash cloud location, as well as cloud phase and surface characteristics, to aid in interpretation both day and night. Information on volcanic ash derived from the tri-spectral product was displayed using the red color gun. This information was combined with visible (0.6 μm) and near-IR (1.6 μm) data for green and blue, respectively, during daylight periods. At night, the 8.6–11.0 μm combination and 11.0 μm band were used for the green and blue colors in the RGB product. Currently, raw MODIS data in five minute granules are processed for the following regions: (1) southern Alaska, (2) Mexico, Central America and the Caribbean, and (3) northern Andes region of South America. Image products are converted to Geo-spatial Information System (GIS) compatible formats for use in the HMS, and to Man-Computer Interactive Data Access System (McIDAS) SArea File format for use in currently configured W-VAAC display systems. The installation of a high speed, fiber optic line from NASA Goddard Space Flight Center to the World Weather Building, Camp Springs, Maryland (scheduled for completion by Fall, 2003) will allow a full set of data to be processed from both Terra and Aqua spacecraft.

V51F-0336 0830h POSTER

Evaluating the Split Window Volcanic Ash Detection Method Using the Numerical Dispersion Model Puff

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Use of remote sensing data is one of the few techniques for monitoring the movement of volcanic ash clouds during and after an eruption. The widely used "split window", or band 4 (10.3-11.3 um) minus band 5 (11.5-12.5 um) technique has proven capable of discriminating volcanic clouds following an eruption. However, the detection limits of this technique are difficult to assess due to the limited availability of corroborating data. As part of the Solid Earth Geophysics Summer REU program at the Geophysical Institute, University of Alaska, Fairbanks, the volcanic ash dispersion model Puff was used to quantify the ability of the split window technique to monitor the ash cloud produced by the September 17, 1992, eruption of Mt. Spurr, Alaska. Eight split-window images of the ash cloud were created using Advanced Very High Resolution Radiometer (AVHRR) imagery from 09-17-1992 12:40Z to 09-20-1992 17:04Z. Correspondingly, a 78-hour simulation of the eruption was produced using the Puff volcanic ash dispersion model. Simulation results typically overlap satellite images only in the more dense regions, which leads to the hypothesis that there is a concentration limit to the split-window technique below which the technique fails to discriminate ash clouds from normal clouds. This limit was quantified by systematically filtering out low concentration areas from the simulation results and comparing with the satellite imagery. Results indicate that masking areas with 3% or less of the maximum cloud density produce model results that best resemble satellite imagery. Furthermore, this technique permitted assessing different model input parameters for best simulating this eruptive event. Results indicate that initializing the model with a linear distribution of material above the vent produced better results than using a non-linear distribution more heavily weighted at higher elevations. The implications of these results for using remote sensing data and dispersion model results for monitoring future volcanic eruptions will be presented.

V51F-0337 0830h POSTER

Influence of the Geotechnical Properties of Dacite Domes on the 1980 Failure of Mt. St. Helens

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The largest historical rockslide-avalanche occurred on May 18th, 1980 as part of the eruption of Mt. St. Helens. The slide had a volume of approximately 2.8 km^3, and decreased the elevation of the volcano by about 400 m. The flank collapse prompted a reappraisal of theories regarding volcano morphology, construction, and hazard assessment. Previous stability assessments of the volcano used small-scale (36 cm^2) shear tests on the reworked avalanche deposits to obtain strength data. Our approach utilized strength data from 1) large (0.15 m^2) and small-scale shear testing on reworked avalanche deposits, 2) uniaxial, triaxial and joint shear strength of collected in-situ samples of fractured domes and associated dykes, and 3) calculated or back - analyzed strength values of the 1980 cryptodome. Field investigations included collection of data from safe, accessible areas within the crater, breach and summit rim. Field mapping, photogrammetry, spatial correlation of geologic structures, and the collection of representative rock samples for the laboratory testing were accomplished. Laboratory strength data and rock mass characterization information were combined in order to obtain strength parameters for different failure scenarios. Once a simplified cross section of the volcano had been produced, strength values, earthquake loadings, and theorized pore pressures were inputted into a limit equilibrium stability program. The results show the crucial role that the highly fractured dacite domes in the northern portion of the volcano have in determining failure direction, and nature of the collapse.

V51F-0338 0830h POSTER

Landsat TM and ETM+ Time Sequence of Lahar Hazards on Fuego Volcano, Guatemala

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Volcanic hazards pose a threat to a large number of the world's population, especially secondary hazards due to remobilization of volcanic material such as landslides and lahars. Many hazard-prone areas would benefit by remote sensing tools for hazard mitigation. In this study, we propose to use remote sensing and GIS techniques to map these hazard prone areas around Fuego volcano, Guatemala and provide information to local organizations to assist in mitigation. Fuego is a steep sided volcano with a history of large eruptive events, including the well-studied 1974 eruption, that have extruded a large amount of material onto the upper reaches of its watersheds. The volcano is well studied, but historically more emphasis has been placed on eruption processes. A study of the way material moves down Fuego and to the extent that it moves is needed to help mitigate the range of potential hazards. We propose an in-depth remote sensing survey to map the hazard-prone areas. The study will consist of processing 20 years (15 cloud-free images) of Landsat TM and ETM+ data to look at changes in landforms and vegetation. Vegetation indices will be calculated to locate areas devoid of vegetation and a masking process will be used These area changes will be related to field measurements to create GIS to measure the area of these zones. layers denoting geometry changes in the channels around Fuego. These changes will be loaded into a GIS, along with regional climate data, DEMs, hydrologic data, infrastructure, and information about the known volcanic activity recorded in the area by the local volcanologists. Modeling of lahars using LAHARZ and climate data will also be done to determine an estimate of the amount of material moved and to what distances it can be transported. A field survey undertaken in January 2003 acquired GPS ground truth data of landslide boundaries and channel volumes for the GIS. The deposits that were seen in the channels 10 km from the source of the sediment ranged in thickness from 1.5-8 m.

V51F-0339 0830h POSTER

Multi-parameters Analysis Tracks Changes From the Effusive to The Explosive Behaviour of Volcanic Activity at Stromboli.

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The Dec. 2002 eruption of Stromboli volcano was followed by almost six months of lava flow characterized by several effusive vents active in the Sciara del Fuoco, at an elevation of 650 m and by the absence of explosive activity at the summit craters. At the end of May 2003, the effusion rate decreased leading to a transition from the effusive to the explosive activity. This transition was a long and smooth process, which took place over a period of 2-3 months, and it was nicely evidenced by continuos seismic, infrasonic and thermal data. We monitored seismic, infrasonic and thermal amplitude and the time delays between their onset recorded at a station deployed at an elevation of 750 m and a distance of 500 m from the active craters. This station was provided with a CMG-40T Guralp broadband seismometer, a pre-amplified Monacor condenser microphone sensitive 46 mV/Pa in the 1-20 Hz infrasonic band, and a 15 degree FOV OMEGA infrared thermometer with a sensitivity of 1 mV/C, in the range between -40 and 1100 C. The Position of the radiometer allows to detect emissions of hot gas and material from both NE and SW craters. The transition from effusive to explosive behaviour is associated with a general increase in the amplitude of the seismic VLP, infrasonic pressure and thermal variation and with a decrease in the delay times calculated for the seismic, infrasonic and thermal onset. Thermal amplitude is proportional to the temperature and the quantity of the hot material covering the instruments FOV and is then representative of the size of the explosions. Amplitude of the infrasound is related to the gas overpressure while amplitude of the VLP is most likely due to the volume changes induced by gas expansion in the magma. Monitoring the seismic, acoustic and thermal amplitude is then equivalent to monitor the degree of gas exsolved in the system. Moreover, the time delays between these 3 parameters depend on several factors like gas jet velocity, and position of the magma level in the conduit. Therefore, amplitudes and delay times are somehow representative of the explosivity level of the system. We show that the decrease in the effusion rate was followed by the gradual increase of the seismic, acoustic and thermal amplitude and by a sensitive reduction in the time delays suggesting the progressive uprise of the magma level in the conduit.

V51F-0340 0830h POSTER

Volcanic Hazards Associated with the NE Sector of Tacaná Volcano, Guatemala.

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Tacaná volcano, with a height of 4,030 m above sea level, straddles the southern Mexico/Guatemala border. Last active in 1986, when there was a small phreatic event with a duration of a few days, this volcano presents an impending hazard to over 250,000 people. The NE sector of the volcano reveals the violent volcanic history of Tacaná that may be indicative of a serious potential risk to the area. Its earliest pyroclastic history appears to consist of fall, flow, and surge deposits, together with lavas, that have formed megablocks within a series of old debris avalanche deposits. This sector collapse event is overlain by a sequence of pumice fall and ash flow deposits, of which the youngest, less-altered pumice fall deposit shows a minimum thickness of > 4 m, with a dispersal axis trending toward the NE. A second debris avalanche deposit, separated from the above deposits by a paleosoil, is dominated by megablocks of lava and scoriaceous dome material. The current topography around the northeastern flank of the volcano is determined by a third, and most recent debris avalanche deposit, a thick (> 20 m) sequence of six block and ash flows dated at around 16,000 years BP, each separated by 1-10 cm thick ash cloud surge deposit, together with secondary lahar deposits. These are followed by a at least 4 lava flows that extend 2 km down the flank of the volcano. It appears that the most recent pyroclastic event at Tacaná is also recorded in this sector of the volcano: above the block and ash flows occurs a > 1 m thick ash flow unit that can be seen at least 5 km from the vent. Lastly, the Santa Maria Ash fall deposit, produced in 1902, has capped most of the deposits at Tacaná.

V51F-0341 0830h POSTER

Comparition and implications to volcanic risk of last effusive activities of 1997-2000 and 2001-2003 at Volcan de Fuego de Colima, Mexico

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Volcán de Colima is one of the most active volcanoes Mexico and is an andesitic stratovolcano located along the western front of the Trans-Mexican Volcanic Belt. Last eruptive activities at Volcán de Colima, Mexico occurred in 1997-2000 and 2001-2003 periods. Both eruptive periods are characterized by the formation of a lavadome, that were destroyed by explosions. Both process shown different behavior of the lava emission rate, reaches of explosions and originated pyroclastic flows. While lava dome of 1998-2000 activity was formed in 24 hours the 2001-2003 activity was formed in 6 months. Volcan de Colima monitoring parameters as seismicity, deformation and SO2 - flux emission rate shown different tendencies before and during these activity periods. In the last 500 years four big explosions are identified in this volcano. Statistically it is possible to identify a big explosion each 100 year (Luhr 1990a). The last big explotion occurred in 1913, for this reason the comparison of two eruptive periods are important to evaluate the risk and prevent to the community located around the volcano edifice.

V51F-0342 0830h POSTER

The Rise and Fall of the Soufriere Hills Volcano Lava Dome, Montserrat, BWI, July 2001-July 2003: Science, Hazards, and Volatile Public Perceptions

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Days after the major collapse (45 x 10^6 m^3) of the eastern flank of the lava dome on 29 July 2001, new dome growth was observed within the 200-m deep collapse amphitheatre. accompanied by cyclic seismicity. By January 2002 the summit was broad with an altitude of 990m. A switch in dome activity occurred in April, but Growth nearly stagnated in June and part of July, with the top of the extrusion lobe at 1048m. but GPS monitoring suggested that the magma reservoir continued to inflate, and growth resumed in late July. In August, a lobe grew toward the north and buried the northern buttress and an important drainage channel that formerly led to the east. One of the regular six-monthly meetings of the Risk Assessment Panel (RAP) took place on 3-4 Sept 02 and concluded that if a NW switch in dome growth were to occur, the margins of the Belham Valley on the west could be at high risk; a flow and surge hazard line was provided to officials, crossing the populated area near Salem. Shortly after the RAP Report was finalized, a switch in growth direction toward the northwest in fact occurred. On 7 Oct, the RAP were asked to re-appraise Belham Valley risks given the altered but not unanticipated circumstances; they judged that a potential existed for a hazardous flow down Belham Valley, although RAP emphasized that their assessment did not predict that a large flow would occur soon, nor in that sector. On 8 Oct the Governor ordered an evacuation of an exclusion zone defined by the RAP's hazard line as adjusted to permit administrative control, and the boundary remained in force until Aug 03, with growing public discontent toward the Governor's exercise of Emergency Powers, and toward MVO, as expressed by a caustic vocal minority with provocative exacerbation by the local newspaper and some politicians. Meanwhile, dome growth continued with some switches in direction, a collapse of 5 x 10^6 m^3 occurred eastward on 8 Dec to Spanish Point, and pyroclastic flows occurred in several drainages, mostly in Tar River to Tuitts Ghaut on the east, but also to Tyers Ghaut on the west, a tributary to Belham Valley. By late March the general summit area was at 1090m. In early June activity declined, but a hybrid earthquake swarm began on 9 July at a time of low SO2 emission and intensified generally in size and frequency to the morning of 12 July, when dome/talus collapses leading to pyroclastic flow activity began, building up during the day and peaking with larger flows in the evening. Mechanisms inducing collapse include a new pressurized growth pulse heralded by the hybrid events, and heavy morning rains. When the retrogressing collapse slices exposed conduit magma, explosions occurred, with the strongest (before midnight) causing a strong acoustic signal and an ash column to about 50,000 ft (VAAC). Heavy ash and lapilli fall (thickness to 15 cm) from these events affected all inhabited areas, and a hot pyroclastic surge destroyed monitoring equipment and killed many animals between Spanish Point and Tar River. The collapse volume greatly exceeded that of 2001, and the events were detected on MVO and CALIPSO monitoring systems, including three strainmeters. The exclusion zone restriction was lifted on 1 Aug 03.

V51F-0343 0830h POSTER

The Mount Rainier Lahar Detection System

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To mitigate the risk of unheralded lahars from Mount Rainier, the U.S. Geological Survey, in cooperation with Pierce County, Washington, installed a lahar-detection system on the Puyallup and Carbon rivers that originate on Mount Rainier's western slopes. The system, installed in 1998, is designed to automatically detect the passage of lahars large enough to potentially affect populated areas downstream (approximate volume threshold 40 million cubic meters), while ignoring small lahars, earthquakes, extreme weather and floods. Along each river valley upstream, arrays of independent lahar-monitoring stations equipped with geophones and short tripwires telemeter data to a pair of redundant computer base stations located in and near Tacoma at existing public safety facilities that are staffed around the clock. Monitored data consist of ground-vibration levels, tripwire status, and transmissions at regular intervals. The base stations automatically evaluate these data to determine if a dangerous lahar is passing through the station array. The detection algorithm requires significant ground vibration to occur at those stations in the array that are above the anticipated level of inundation, while lower level 'deadman' stations, inundated by the flow, experience tripwire breakage or are destroyed. Once a base station detects a lahar, it alerts staff who execute a call-down of public-safety officials and schools, initiating evacuation of areas potentially at risk. Because the system's risk-mitigation task imposes high standards of reliability on all components, it has been under test for several years. To date, the system has operated reliably and without false alarms, including during the nearby M6.8 Nisqually Earthquake on February 28, 2001. The system is being turned over to Pierce County, and activated as part of their lahar warning system.

V

V51F-0344 0830h POSTER

Simulations of Lahar Propagation Over Variable Topography

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Volcanic debris flows, or lahars, form readily through combination of friable volcanic material with water derived from rainfall, snowmelt, or crater lake release. Lahars are capable of traveling tens of km at velocities of tens of m/s, with depths of 1-10 m. Their highly destructive nature thus demands accurate assessment of flow propagation for hazard mitigation purposes. We have developed a method of applying lahar flow models to topography in digital format (e.g., DEMs), with the goal of improving predictive models. We treat changes in elevation between pairs of adjacent points as a series of N inclined planes having different slopes. Changes in slope from one inclined plane to the next produce discontinuities in flow depth and velocity, such that flow rate boundary conditions must be established repeatedly at the interface between each interval for all timesteps. To demonstrate our approach, we use a time-dependent flow model based on global and local volume conservation equations for a flow whose bulk properties are encapsulated by the dimensionless coefficient, C, the resistance to flow. Flow depth and velocity are solved in each interval, while simultaneously requiring that the sum of each incremental volume matches the total flow volume. We thus compute the time required for a flow front to travel from its source to a given point along the flow path. We derive mathematical conditions on topography and flow parameters that differentiate between gravity- and momentum-driven regimes. Using long-runout lahars from Mt. Ruapehu as examples, we varied the number of increments into which an analog representation of Ruapehu's concave-upward topography was divided, in order to assess the influence of topographic resolution on transit time predictions. We find that as N increases (i.e. as the topography is represented more accurately), predicted transit time decreases asymptotically. This is a result of the nonlinearity of the problem: high velocities over steep upper slopes more than compensate for lower velocities on low, distal slopes. We find that 250 m horizontal resolution is required for computed transit times to converge to an accurate solution. Use of coarser topography will lead to significant overestimates in transit times, leading to erroneous hazard assessments for downstream communities.

V51F-0345 0830h POSTER

Numerical study of segregation mechanism in granular flow on inclined rough surface

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Pyroclastic flow deposits commonly consist of several vertical layers: a reversely graded fine-grained basal ash layer, and a massive main body in which pumice clasts are reversely graded while lithic clasts are normally graded. Most of these structures are thought to be formed during transport processes. Previously, experiments have shown that the normally graded structures can be formed by gas fluidization or hindered-settling. However, pyroclastic flows accompanied by lateral motion on inclined surface with significant velocity shears are dissimilar to both those experiments performed in stationary tanks. Numerical and experimental studies on high-concentration granular flow show that the degree of the shear is important in reversely graded segregation. Other numerical studies show that granular flows are affected by the roughness of ground surface. Additionally, using a classical granular theory implying that the collisions are dominant and the grain concentration is dilute, it is shown that the grain-dispersive pressure induced by the shear is important in the formation of the layer structures. In this study, we numerically analyze the inner structure of granular flows and clarify the relationships between the reversely-graded segregation mechanism depending on the inclination and the roughness of the ground, and the ratios of size and number densities of large and small grains. Simulations are performed using a two-dimensional Discrete Element Method. Since the density is high, we adopt the soft particle method that allows us to treat multi-body collisions. We adopt periodic boundary in order to calculate processes which occur over a long distance. Furthermore, we use a rough ground. Numerical results show that the velocity and number density of grains form layer structures and the number density becomes low near the base as previous studies show. This is because the gravity energy is converted into random kinetic energy (granular temperature) due to the velocity shear that is largest near the ground. As the inclination or the roughness of the ground increases, the granular temperature increases because of the increase of the shear velocity. The granular temperature plays an important role for reversely-graded segregation. In the large granular temperature, there are spaces for small particles to drop under large particles. As the inclination and the degree of the roughness increase, this dynamic sieving effect becomes greater.

V51F-0346 0830h POSTER

Deciphering Silicic Dome Emplacement Processes in the North Pacific: Quantitative Analyses of High Resolution Satellite and Field-Based Data

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Although volumetrically small in comparison to other lava compositions and types of extrusive products, intermediate to silicic domes preserve an enormous quantity of information on the pressure, temperature, flow rate and degassing state of the lava. Remotely acquired data of active domes also provides insights into the duration of continued lava extrusion and the hazards of the volcano/dome system. Numerous techniques for the mapping, monitoring and modeling of lava domes have been developed, with much of that work focused on older inactive domes. However, with the recent launch of new higher spatial resolution satellites imaging in multiple wavelength regions, it is now possible to collect new and highly detailed data of active domes. One of the most promising satellite instruments for volcanology is the ASTER instrument launched by NASA in late 1999. Because it is the first spaceborne sensor to acquire high spatial resolution data from the visible to thermal infrared wavelength region and has the ability to generate digital elevation models, it is particularly useful for numerous aspects of volcanic remote sensing. For example, the multispectral thermal infrared (TIR) capability of ASTER is critical for monitoring low temperature anomalies and mapping both chemical and textural variations on the dome surfaces. However, the ability to derive this level of quantitative information currently relies on accurate field based data collection, laboratory modeling and the development of new computer-based tools. ASTER data have been analyzed in detail for numerous silicic lava domes in the Aleutian-Kamchatkan Arc system over the past three years. These domes have varied from the vigorously-active andesitic domes at Bezymianny and Sheveluch volcanoes to the dacitic dome field at Black Peak volcano, emplaced following the caldera forming eruption ∼4,600 years ago. For the active domes at the Kamchatkan volcanoes, ASTER TIR data were used to monitor eruptions and map the volcanic products. The thermal anomalies vary significantly from Bezymianny to Sheveluch and are being used to derive textural variations on the domes and pyroclastic flow deposits. A field campaign to the Black Peak domes in the summer of 2003 provided one of the first detailed mapping opportunities for this volcano and the chance to collect data on the composition, surface texture, topography and stratigraphy of the domes. These data are now being used to better constrain the modeling of the active domes in preparation for a field campaign to Kamchatka in 2004. In summary, the high spatial and spectral resolution of the ASTER data are extremely useful in discrimination of small surface targets in addition to providing enhanced volcanic mapping capabilities.

URL: http://ivis.eps.pitt.edu/projects/nopac/

V51F-0347 0830h POSTER

Streamlining Spacecraft Observation Response to Volcanic Activity Detection with a Ground and Space-based Sensor Web System.

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Volcanoes affect the lives of millions of people, and so streamlining the process by which data of active volcanism are obtained and processed is an important part of volcano monitoring and hazard assessment. The Volcano Sensor Web is an application of networked sensor technology that is being applied to volcano monitoring. The Sensor Web team will utilize the University of Hawaii automated system for processing data of volcanic thermal emission obtained by GOES (in geostationary orbits) and MODIS (on the Terra and Aqua spacecraft). This yields alerts on timescales of 15 minutes for GOES and less than 24 hours for MODIS data. Additionally, the Hawaiian Volcano Observatory has a network of sensors that can detect not only volcanic activity but also precursors of an eruption, and which can autonomously generate an alert. On notification, JPL automatically generates a spacecraft command sequence that is then transmitted to Goddard Space Flight Center for uplink to the Earth Observing 1 (EO-1) spacecraft. This enables rapid-response, high-resolution multispectral (ALI) and hyperspectral (Hyperion) observations to be obtained of the target volcano as quickly as possible. Extending the use of autonomy, Autonomous Sciencecraft Experiment (Chien et al., 2003, LPSC34 abstract 1458) software onboard EO-1 can then process the data and report the results (e.g., number and location of thermally active pixels).

URL: http://ASE.jpl.nasa.gov

V51F-0348 0830h POSTER

Three Years of Ground-based Thermal Monitoring at Kilauea

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Three permanent ground-based infrared (8 to 14 micron) radiometers, located on Pu'u 'O'o's north crater rim, have provided continuous real-time monitoring of activity within Pu'u 'O'o since March 2001. Our thermal sensors are able to detect lava flows, catastrophic

changes in crater floor morphology, and variations in the style and vigor of volcanic degassing. These continuous, long-term thermal observations, integrated with RSAM and tilt measurements, provide an opportunity to investigate the changing nature of systemic activity at Kilauea. For example, our thermal sensors are able to detect periods of lava effusion on the crater floor, coincident with the termination of the rootless shield to the east and subsequent back-up into Pu'u O'o, before activity transitioned to the Mother's Day flow field. Since June 2001, at least one radiometer has been continuously aimed at the central pit vent of Pu'u O'o, whose thermal record has been dominated by regular gas jetting events, typically referred to as gas pistoning. These events are very often observed in the thermal records, indicating that they are a dominant mode of degassing at Kilauea. During June and July of 2000, gas pistoning from the central pit vent occurred with fundamental recurrence intervals of about 2 to 10 minutes, but since October has slowed to less frequent 20 to 40 minute intervals. We propose that the variation in piston frequency is related to dramatic changes in the geometry of the underground plumbing system at Pu'u 'O'o. Currently thermal monitoring of two individual vents, which are separated by 100 m, provides evidence for linked degassing, further demonstrating the complex and ephemeral nature of the plumbing system beneath Pu'u 'O'o's crater floor.

V51F-0349 0830h POSTER

Analysis of Volcanic Deposits From the 2001 Eruption of Mt. Cleveland, Alaska Using Multisensor Satellite Data and Field Observations

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Eruptive characteristics and histories of Aleutian stratovolcanoes are some of the least understood because of their remote locations, yet they have the ability to cripple the heavily traveled air routes in this region. Remote sensing is useful for gathering information on remote eruption deposits and compliments field observations. Mount Cleveland, on the western part of Chuginadak Island, has been one of the most active of these Aleutian volcanoes over the past century, its most recent eruption disrupted air traffic from February to March 2001. Using field observations of pyroclastic fan deposits preceding an a´a lava flow down the western flank of Mount Cleveland in 2001 this study attempts to associate spectral characteristics of these deposits (from Advanced Spaceborne Thermal Emission and Reflectance Radiometer (ASTER), Landsat 7 Enhanced Thematic Mapper Plus (ETM+), Second European Remote Sensing Satellite (ERS-2), and RADARSAT-1) to similar characteristics around the entire volcano. By also using Advanced Very High Resolution Radiometer (AVHRR) and Moderate Resolution Imaging Spectroradiometer (MODIS) data this study will present a more accurate chronology of the 2001 eruption. Field observations of the pyroclastic fan deposit reveal the existence of two separate stratigraphic deposits, an initial smooth ∼10-30 m thick a´a block and ash deposit overlain by a rougher ∼1-15 m thin breadcrust bomb deposit. The southern and northeastern parts of the fan are dominated by the thin breadcrust bomb deposit with an average bomb area of 2.38 m^2, while the northwestern part is dominated by very large a´a blocks with pull-apart fractures and a much larger average block area of 22.44 m^2. Initial Landsat 7 ETM+ and photographic analysis of this pyroclastic fan displays a slight coloration difference between the two deposits. The stratigraphic sequence of the pyroclastic fan from 2001 suggests that there was 1) a warm to hot debris flow from the collapse of an active a´a flow on top of snow, and 2) a cooler thin flow composed of breadcrust bombs from the summit crater and debris. Here as well, the underlying snow melted and flowed with the bombs down the flank. The pathways provided by these pyroclastic debris flows are later the channels for the overlying a´a lava flows. This is seen repeatedly in older deposits on the island. This study shows that this stratigraphic sequence (pyroclastic debris flow to a´a flow) is an important eruption process on snow covered stratovolcanoes. The pyroclastic debris flows are a primary hazard on high steep-sided inhabited volcanoes due to their relatively high volume (at Mt. Cleveland in 2001 >3.3×10^6 m^3) and rapid emplacement, and thus are potentially tsunamigenic in addition to the direct hazard to nearby residents.

V51F-0350 0830h POSTER

Low-level Volcano Thermal Anomaly Survey of Northern Pacific Volcanoes Using Night Time ASTER TIR

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The Alaska Volcano Observatory (AVO) monitors northern Pacific volcanoes for major thermal anomalies by analyzing frequent Thermal Infrared (TIR) images from the Advanced Very High Resolution Radiometer (AVHRR) and Moderate-resolution Imaging Spectroradiometer (MODIS) sensors at least twice per day. Although 1 km resolution AVHRR and MODIS data have been very useful in detecting large and/or high-temperature thermal signatures such as lava flows, domes, pyroclastic flows, higher spatial resolution is needed to observe and quantify small and/or lower temperature thermal features such as fumaroles. We are currently evaluating all available night time TIR scenes acquired by the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) L1B over Alaskan (475 scenes) and Kamchatka - Kurile volcanoes (606 scenes). While the current archive spans June 2000 to present, most of the data were collected during the last two years. Night time ASTER data over volcanic targets typically provides 5 TIR bands with 90 meter spatial resolution and 6 Shortwave Infrared (SWIR) bands with 30 meter resolution. The ASTER L1B data were first scanned for warm pixels using an application that records the maximum radiance values for all available bands in each image. The scene maximum radiance results were then sorted in order of decreasing radiance. Next, each scene was manually reviewed for thermal anomalies co-located with volcanoes. All scenes with volcanic thermal anomalies were then submitted for ASTER Level 2 Surface Kinetic Temperature processing. The Surface Temperature product provides an estimate of the surface temperature for each of the five ASTER TIR bands. The pixel temperatures are then extracted for each thermal anomaly Our ongoing survey of the ASTER TIR data has revealed many small or low temperature thermal features at several volcanoes in Alaska and Kamchatka. Few of these features were recognized in the daily AVHRR and MODIS reports because the signal was too small to detect easily. The ASTER TIR observations are currently being compared to published and unpublished field temperature measurements. These new observations will be used to assess recent activity as well as add to AVO's database for ongoing activity.

V51F-0351 0830h POSTER

Horizontal rotation of the local stress field in response to magmatic activity: Evidence from case studies and modeling

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A complete understanding of the initiation, evolution, and termination of volcanic eruptions requires reliable monitoring techniques to detect changes in the conduit system during periods of activity, as well as corresponding knowledge of conduit structure and of magma physical properties. Case studies of stress field orientation prior to, during, and after magmatic activity can be used to relate changes in stress field orientation to the state of the magmatic conduit system. These relationships may be tested through modeling of induced stresses. Here I present evidence from case studies and modeling that horizontal rotation of the axis of maximum compressive stress at an active volcano indicates pressurization of a magmatic conduit, and that this rotation, when observed, may also be indicative of the physical properties of the ascending magma. Changes in the local stress field orientation during the 1992 eruption sequence at Crater Peak (Mt. Spurr), Alaska were analyzed by calculating and inverting subsets of over 150 fault-plane solutions. Local stress tensors for four time periods, corresponding approximately to changes in activity at the volcano, were calculated based on the misfit of individual fault-plane solutions to a regional stress tensor. Results indicate that for nine months prior to the eruption, local maximum compressive stress was oriented perpendicular to regional maximum compressive stress. A similar horizontal rotation was observed beginning in November of 1992, coincident with an episode of elevated earthquake and tremor activity indicating intrusion of magma into the conduit. During periods of quiescence the local stress field was similar to the regional stress field. Similar horizontal rotations have been observed at Mt. Ruapehu, New Zealand (Miller and Savage 2001, Gerst 2003), Usu Volcano, Japan (Fukuyama et al. 2001), Unzen Volcano, Japan (Umakoshi et al. 2001), and Mt. St. Helens Volcano, USA (Moran 1994) in conjunction with eruptive activity. This horizontal rotation may reflect pressurization and inflation of a conduit system by an influx of magma, and may be related to physical properties (rheology) of the ascending magma. In this regard, horizontal rotations are not observed at volcanoes erupting low-viscosity basaltic magma (e.g., Miyakejima, Japan, Ukawa and Tsukahara 1996). Numerical modeling of Coulomb stress changes induced by inflation of dike-like and cylindrical conduits supports the hypothesis that conduit dilation results in a local reorientation of the maximum compressive stress axis. Modeling results indicate that faults surrounding the conduit experience an increase in Coulomb stress of ten bars or more in response to $\leq$ 1 m of conduit dilation for a rotated' sense of strike-slip or thrust motion (with respect to the regional stress field), corresponding to the stress field rotation observed in fault-plane solution studies. Furthermore, differences in the patterns of Coulomb stress changes induced by inflating dike-like and cylindrical conduits make it possible to distinguish between these two geometries based on the locations of earthquakes with rotated fault-plane solutions. Finally, although both case study and modeling results indicate that conduit inflation is likely to produce a local reversal of the positions of minimum and maximum compressive stress axes, it is possible that this phenomenon requires the presence of favorably-oriented faults in the volume of rock surrounding the conduit.

V51F-0352 0830h POSTER

Geochemical Monitoring of Vesuvius Aquifer: temporal variations in the chemical and isotope composition of water and dissolved gases

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The cold aquifer hosted in the volcanic sequence of Mt Vesuvius locally receives the input of fluids uprising from the deep hydrothermal system, mostly in correspondence of tectonic lineaments, dissecting both the volcanic edifice and the sedimentary basement (Bianco et al, 1998, Ventura et al., 1999). In particular, the southern flank of the volcano is affected by an intense CO2 degassing, associated to a weak thermal anomaly. Helium isotopes furnish further important clues about the mapping of volcanic degassing, revealing an input of magmatic fluids even on the northern flank of the volcano (Federico et al., 2002). Since 1998, a set of drilled wells (9) and springs (3) are monthly sampled and analysed for their chemical and isotope composition. Time series indicate a fair constant composition for the whole aquifer. Temperature, pH, alkalinity and dissolved CO2 are also rather stable, mostly in deeper wells (piezometric level deeper than 100 m). Shallower water bodies present a stronger temporal variability, caused by seasonal and anthropogenic effects. The present state of dormancy on Mt. Vesuvius offers a good opportunity of measuring background values for most parameters, useful to eventually evaluate a progressive unrest of the volcano. Actually, significant variations in water chemistry were observed in correspondence of the seismic event occurred in October 1999, mostly in a low flux spring, located on the northern flank of Vesuvius. In this site, a strong decrease of pH (0.1 pH unit) and redox potential (from +200 to -150 mV), together with an increase of both dissolved CO2 and 3He/4He ratio, were observed. These variations were attributed to a seismically-induced input of deep He and CO2 to the small water body feeding the spring. Conversely, in the main aquifer, the stress-field produced by the earthquake modified the relationship between superposed water bodies, with the final effect of a change in the water chemical composition. Almost all monitored sites showed a salinity decrease before the October 1999 earthquake, followed by a gradual reestablishment of pre-seismic conditions. In the last period, synchronous variations in the dissolved helium isotope ratios were observed, probably related to either a variable contribution of crustal gases or variable magmatic degassing.

V

V51F-0353 0830h POSTER

Comparing the Hazards From Large Volcanic Eruptions and Impacting Asteroids

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Explosive volcanic eruptions and asteroid impacts leave craters that allow direct comparison of the scale and frequency of these severe events. We have compiled data on large volcanic eruptions over the past 45 million years, and used this to develop an improved quantitative assessment of the frequency of large volcanic eruptions, and to make a comparative assessment of the relative likelihood of the Earth being affected by severe volcanic eruptions, and impact events of equal severity. In terms of volcanic activity, the expected frequency of explosive eruptions involving $> 10^{15}$ kg of rock lies between 1.3 and 22 events per million years. For the events that form terrestrial craters with diameters of order 10 - 25 km, the thermal energy release (during a volcanic eruption) is of the same order of magnitude as the kinetic energy release (from an asteroid impact), and ca. 10^{21} - 10^{22} J (2×10^5 - 2×10^6 Mt equivalent of TNT). Over the past 5 Ma, volcanic activity dominates the production rate of craters < 45 km diameter. This suggests that over short timescales (< 1 Ma), destructive volcanic eruptions are more frequent than impact events of a similar energy. A better comparison of the primary effects of both phenomena may be realised by considering the area destroyed by shock waves (impactors) or hot pyroclastic deposits (volcanoes). Using simple scalings, we show that the primary area destroyed by an impactor is about ten times that for an eruption. Using this area as a measure of severity, we can show that for events with a return period of 100,000 years or less, there are considerably more eruptions of a given severity than there are impact events. Impactor events only dominate for return periods of > 200,000 - 500,000 years. We conclude that smaller (< 10^{12} kg, < 1 km diameter) near-earth orbiters pose a significantly smaller hazard to humans than the regional effects of large (10^{14} - 10^{15} kg) volcanic eruptions.

V51G MCC: Level 1 Friday 0830h

Geologic History of Volcanic Regions I Posters

Presiding: **W J Williams,** University of Arkansas at Little Rock**; L Prueher,** U.S. Geological Survey

V51G-0354 0830h POSTER

Tertiary Volcanic Stratigraphy and Structure of the Sonora Pass Region, Central Sierra Nevada, California

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Mapping north and west of Sonora Pass provides information about the paleogeography and structure of the Sierra Nevada-Basin Range transition in Oligocene to Miocene time. The stratigraphy includes: (1) Late Oligocene-Early Miocene (?) Valley Springs Formation, composed of at least 5-6 petrographically distinctive silicic ignimbrites, overlain with erosional unconformity by (2) Early to Middle Miocene (?) "Relief Peak Formation", here referred to as Mehrten Formation, composed of hornblende andesite volcanic debris flow deposits, overlain with erosional uncomformity by channelized fluvial deposits, in turn overlain with erosional unconformity by block and ash flow tuffs, overlain with erosional unconformity by (3) the Middle or Late Miocene (?) Stanislaus Formation, composed of (a) latite lava flows ("Table Mountain Latite") and interbedded volcanic debris flow and fluvial deposits, overlain with erosional unconformity by (b) the Eureka Valley Tuff (EVT), also of latitic composition, in turn overlain with erosional unconformity by (c) latite flows, volcaniclastic fluvial deposits, or a debris avalanche deposit. The entire section is cut by andesite plugs. The basal ignimbrites are distal facies with source calderas in Nevada. The Merhten Formation is dominated by primary volcanic deposits in the east. The "Table Mountain Latite" is coarsely porphyritic plagioclase- and augite-phyric lava flows and flow breccias; it is only 83 m thick, with two flow units, in the west, and thickens to 344 m, with 21 flow units, in the east, suggesting a source not far to the east of the crest. The EVT consists of two members, each of which grade upward from densely welded to nonwelded latite ignimbrite. Distinctive lapilli- to block-sized clasts in both members are a distinctive mixture of highly flattened and plastically-deformed obsidian and rigid, vesicular bombs cored by obsidian. The tuff was probably erupted from a caldera only 22 km to the east. The Miocene strata generally thicken from west to east (over a map distance of 25 km) but locally thicken dramatically into paleocanyons cut in Mesozoic granitic rocks. A paleocanyon along the present-day Sierran crest trends NNW-SSE from Stanislaus Peak to Sonora Peak; it is sited along NNW-SSE, steeply-dipping faults in the Merhten Formation and filled by undeformed Stanislaus Formation latite flows. Similar relations occur along what is probably the same fault 5 km to the SSE at Sardine Falls. To the west of the crest, a pair of paleocanyons trending ENE-WSW occur at the Dardenelles in the north and the Red Peak-Bald Peak area in the south. This pair of paleocanyons is cut by a series of steeply-dipping NNW-SSE trending faults that include (from west to east): 1) a down-to-the-west fault between the Dardenelles and Dardenelles Cone, along which the Merhten Formation is highly deformed in a 250 m wide shear zone, and thickens from about 60 m to 200 m to the west across the fault, while overlying latite flows are only downdropped 60 m to the west, 2) the Bald Peak fault, also down to the west, where Merhten Formation thickens from 50 to 100 m to the west across the fault, and the base of the Table Mountain Latite is dropped 45 m to the west, and 3) the Red Peak fault, which drops the EVT down to the west approximately 200 m. Miocene strata of the Sonora Pass region record the onset of faulting both during and after deposition of the Merhten Formation, with continued faulting after eruption of the latite flows and tuffs. We speculate that the latites erupted during a phase of rapid extension in an arc otherwise dominated by andesitic volcanism.

V51G-0355 0830h POSTER

Stratigraphy and Structure of Late Oligocene-Early Miocene Ignimbrite-filled Paleovalleys, Northern Sierra Nevada, California

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Mapping of a Late Oligocene-Early Miocene (31-25 Ma) paleovalley system filled with ignimbrites erupted from calderas in present-day Nevada provides relationships necessary to deduce paleotopographic vs. structural controls on the paleogeography of the Sierra Nevada and its transition into the Basin and Range in Early Tertiary time. A paleovalley filled with five distinctive ignimbrites is well-exposed in the Diamond Mountains about 2 -3 km west of the Honey Lake fault zone, a segment of the northern Walker Lane fault zone. We map a N-S trending paleovalley approximately 7.2 km wide, using ignimbrite distributions and thicknesses of ignimbrites and sedimentary rocks, as well as compaction foliation, cooling joints, welding zonation and lateral variations within each ignimbrite. Paleotopographic relief in the metamorphic and granitic basement reaches approximately 223 m; metamorphic roof pendants form steep-sided paleoridges and spires, while the granitic basement forms stepped relief controlled by pre-existing joints. The five ignimbrites are composed of at least nine mappable cooling units that vary laterally, from ca. 260 m thick paleovalley axis deposits to ca. 70 m thick paleovalley wall deposits, with dramatic thickening of vitrophyres toward paleovalley walls. The lowest three ignimbrites are confined to the paleovalley, the fourth passes upward from confined to unconfined, and the fifth is entirely unconfined. All of the ignimbrites are cut by two N-S trending, steeply W-dipping faults; the first, near the axis of the paleovalley, shows maximum 85 m of dip-slip displacement, and the second, near the eastern margin of the paleovalley, shows ca. 40 m of dip slip displacement. These N-S faults parallel the paleovalley and are oblique to the modern (NW-trending) Honey Lake fault zone, suggesting they may be older. Evidence for syndepositional faulting is present along the paleovalley axis fault, where sedimentary rocks between ignimbrites 3 and 4 thicken from several meters to 60 m onto the downthrown block, and along the fault near the eastern paleovalley margin, where ignimbrite 4 thickens from 50 to 90 m onto the downthrown block. We correlate ignimbrite units 3, 4 and 5 of the Diamond Mountains with ignimbrites filling paleovalley erosional remnants near Frenchman Lake (26 km to the SSE), Haskell Peak (52 km to the SSW), and Soda Springs (91 km to the S). At Soda Springs (located 8 km SW of Donner Pass) the N-S trending paleovalley is about 6 km wide. The western paleovalley wall is composed of metamorphic basement rock and is steep, with paleotopographic relief of at least 280 m, whereas the eastern side of the paleovalley is predominantly granitic and is characterized by less dramatic relief. The paleovalley contains seven ignimbrites composed of at least ten cooling units. We correlate units 1, 4 and 7 of the Soda Springs paleovalley with units 3, 4, and 5 of the Diamond Mountains paleovalley, on the basis of petrographic and outcrop characteristics. The ignimbrite sequence is 323 m thick, and has mappable erosional unconformities with relief of up to 30 m between units 4, 5 and 6. The upper three units locally spread beyond the paleovalley walls. We have not recognized any faults in this paleovalley. Late Oligocene-Early Miocene ignimbrite-filled paleovalleys in the Diamond Mountains, Frenchman Lake, Haskell Peak and Soda Springs may represent remnants of a once-continuous valley 117 km long that trended obliquely to, and presumably crossed, the modern range front faults prior to their development.

V51G-0356 0830h POSTER

Tertiary Paleogeography and Paleotectonic Evolution of the Sierra Nevada in the Carson Pass-Kirkwood Area, California

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Volcanic and sedimentary rocks of the Miocene Mehrten Formation in the Carson Pass- Kirkwood Valley-Silver Lake area of Sierra Nevada (California) occupy a paleocanyon cut into Mesozoic granitic rocks. Nine unconformities were recognized within the sequence during recent fieldwork, demonstrating that the canyon was repeatedly incised. The lowest 5 units are dominantly braided stream and minor debris flow deposits with silicic to intermediate-composition volcanic clasts. These clasts, together with interstratified ignimbrites, were probably derived from volcanic centers to the east in Nevada, prior to the Sierra Nevada range front faulting. The upper 4 units are dominated by andesitic volcanic debris flow and debris avalanche deposits, interstratified with andesitic to dacitic lava domes, flow breccias, block-and-ash-flow tuffs and peperite intrusions. These units record the westward sweep of the arc from Nevada into the present-day Sierran crest, and development of high-relief centers that probably blocked sediment supply from the east. No significant faults were recognized in the region, although a N-S trending paleocanyon wall on the north side of Carson Pass was mistaken as a fault by previous workers. Ar/Ar dating in progress on volcanic rocks of units 2, 4, 6 and 8 will constrain the timing of the eight canyon incision events. The origin of the incision events is not yet clear.

V51G-0357 0830h POSTER

Peperite-Fed Andesitic Debris Flows in the Miocene Mehrten Formation, Kirkwood, California, USA

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The Miocene Mehrten Formation is a voluminous predominantly andesitic suite of volcanic rocks erupted along the crest of the Sierra Nevada mountains in northern California. At Kirkwood, California, the Mehrten Formation comprises a sequence of primary volcanic andesitic debris flow deposits, debris avalanche deposits, block-and-ash flow deposits and distal fine-grained rhyolitic ignimbrites, overlying a predominantly reworked sequence of andesitic fluvial debris flow, hyperconcentrated flood and streamflow deposits. The Mehrten Formation in this area is intruded by several andesitic dikes which are both contemporaneous with and postdate the debris-flow deposits. The volcanic debris flow deposits display an unusual internal structure comprising discrete domains of either brittle or ductile-fragmented juvenile blocks in an ash to lapilli-sized matrix. The matrix is locally parallel laminated but where present is often partially