

V21B MC: Hall D Tuesday 0830h**Experimental Volcanology:****Sturtevant Memorial III** (*joint with G, P, T, MR, HG*)**Presiding:** E Brodsky, University of California Berkeley; M Ichihara, Tohoku University; D B Dingwell, University of Munich; H M Mader, University of Bristol**V21B-0971 0830h POSTER****Flank Creeping, Sector Collapse and Formation of Volcanic Rift Zones**Thomas R. Walter¹ (twalter@geomar.de)Valentin R. Troll^{1,2} (vtroll@geomar.de)¹Dept. of Volcanology and Petrology, GEOMAR, Kiel 24148, Germany²Dept. of Geology, Trinity College, Dublin 2, Ireland

The structural skeleton of ocean island volcanoes is commonly formed by rift zones that are marked by abundant dike intrusions and sites of volcanic eruptions. Field data on Tenerife, La Palma and El Hierro (Canary Islands) reveal that single and radial dike swarms form early during volcano evolution and are re-arranged to become triaxial rifts during later stages of volcano growth. These rifts are commonly associated with unstable flanks in-between two axes, however, the relationship between rift initiation and flank instability remains poorly resolved.

Due to rising awareness of local flank creeping, dynamic volcano spreading and the recognition of weak substratum at volcanoes worldwide, we designed analogue experiments to simulate the stress field and intrusive patterns of unstable volcanic edifices. The analogue volcanoes were cone shaped and made of gelatine, whereby different conditions of basal friction were used in various experimental setups. From below we injected colored water and studied the orientation of fractures (dikes) that propagated through the cones.

Situated on uniform substratum, the flanks of the gelatine-cone deformed by gravity-driven extension. The orientation of the fractures was perpendicular to the minimum principal compressive stress, resulting in a radial dike swarm. In a further setup, we reduced the basal shear resistance in one sector, to simulate the stress field close to a locally creeping flank. In these experiments, the dike azimuth diverged largely if injected into a) the non-creeping part of the cone, b) the creeping region, or c) the stable/unstable interface. Case a) produced radial fractures; case b) produced mainly fractures that reflect strong circumferential expansion of the creeping sector. In case c) three main fracture directions formed, two of which were tangential to the stable/unstable interface and a third diffuse one propagated into the stable part of the cone, reminiscent of triaxial rift zones on many natural volcanoes (e.g. El Hierro, Tenerife). The significance and direction of the three rift zones varied systematically with size, eccentricity and creep direction of the unstable sector. Slight eccentricity of the creeping sector focused dike intrusion along two curved axes that were tangential to the stable/unstable interface; a relationship comparable to N Anaga, Tenerife. In contrast, strong eccentricity resulted in one main tangential rift, very similar to the S-rift observed on La Palma.

Based on the experimental results, we propose that the formation and configuration of triaxial rift zones may be a response to near-surface volcano-deformation such as volcano-spreading or flank creeping rather than a simple function of vertical upward loading as commonly assumed for volcanic rifts on ocean islands.

V21B-0972 0830h POSTER**Characterizing the physical properties of solidified PEG, an analog for basaltic lava crust**S. Adam Soule¹ (ssoule@gladstone.uoregon.edu)Kathy Cashman¹ (cashman@oregon.uoregon.edu)Alison Rust¹ (arust@darkwing.uoregon.edu)

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The crust of a basaltic lava flow provides significant resistance to flow and is an important indicator of lava flow dynamics. Analog studies using polyethylene glycol (PEG), such as those by Fink and Griffiths (1990) and Griffiths and Fink (1992), are a useful means to

determine the conditions under which different crustal morphologies are produced. To accurately apply the results of these studies to natural systems, we must understand how to scale between basaltic lava and its analog, PEG. The long-term goal of our study is to characterize the physical properties of both materials for the purpose of developing scaling relationships.

We have designed a set of experiments to determine the strength and viscosity of solidified PEG. We measure the ductile deformation and failure of PEG under tension and in simple shear. Experiments are conducted with either constant stress or constant strain rate and at a range of temperatures (5 to 25 °C). Tension experiments are conducted on hourglass-shaped PEG casts with failure occurring at the midpoint of the hourglass. Tension is produced by hanging weight (constant stress) or by pulling with a DC servo motor (constant strain rate). Simple shear experiments are conducted by turning a gear frozen into a sheet of PEG. A thinned ring of crust centered around the gear controls the failure location. From constant stress experiments, we measure pre-failure ductile deformation of the PEG to determine its viscosity. Constant strain rate experiments allow us to determine the dependence of PEG strength on strain rate. To determine the physical properties of basaltic crust we are building a furnace capable of melting large quantities of basalt and conducting experiments at high temperature. The experiments conducted on PEG will aid in the design of similar experiments on lava.

The results of this study will have applications beyond scaling between analog models and natural systems. The presence or absence of a continuous flow crust dictates the rate of heat loss from a flow surface. Theoretical models of lava flow heat budgets can apply data on the strength of crust to quantitatively determine the fraction of crust free surface. Further, understanding the strength of lava crust as a function of strain rate and temperature will allow the interpretation of lava flow dynamics from solidified flow features.

V21B-0973 0830h POSTER**Explosive Eruption Dynamics: Coupled Effects of Vesiculation Kinetics and Magma Ascent**Massol Helene¹ (massol@ipgp.jussieu.fr)Takehiro Koyaguchi² (tak@eri.u-tokyo.ac.jp)¹Universite Paris-Sud, Departement des Sciences de la Terre Bat. 504, ORSAY 91405, France²University of Tokyo, Dept. of Complex. Sci and Eng., Graduate School of Frontier Sci. 7-3-1 Hongo Bunkyo-Ku, Tokyo 113-0033, Japan

Eruption style often varies in course of a single eruption alternating episodes of explosive eruptions and dome growth. To forecast these changes, we need to couple field data and geophysics measurements with theoretical models of magma ascent. Explosive eruptions involve the fragmentation of magma; however, physics of this process is still poorly understood. The understanding of these two processes, (1) alternation in eruptive style and (2) fragmentation of magma requires the detailed knowledge of the geometry of the gas phase and of the pressure in the bubbles. However, previous models cannot predict any precise data on bubble size distribution or bubble number density for example. Either the decompression rate is assumed to be linear, or the magma decompression path is solved but the magma is considered as an equivalent compressible mixture and hence does not give any indications on bubble sizes. In the present study we solve the dynamics of magma ascent and the kinetics of bubble nucleation and growth simultaneously, which allow us to predict bubble sizes and number density under realistic conditions. As magma rises toward the surface the pressure decreases and eventually becomes less than the solubility pressure. When the difference between the concentration of volatiles in the melt and the concentration at equilibrium is high enough, nucleation of bubbles occurs. Nucleation will stop as the concentration of volatiles in the melt decreases due to growth of existing bubbles. Hence the degree of supersaturation decreases. We show that under some conditions on the mass flux, a second nucleation event can occur just below the fragmentation level as the magma rapidly decompresses. At this level, the degree of supersaturation continuously increases with decreasing pressure. In that case, nucleation will not stop until fragmentation occurs. This late nucleation event may explain the pore size distribution measurements made in true pumices that often shows a fine bubble size population (Sparks and Brazier, *Nature*, 295, 1982). We also show that this late stage nucleated population of bubbles have high internal gas pressure of order of 2 MPa greater than the liquid pressure just before the fragmentation level.

V21B-0974 0830h POSTER**Black Butte Dacitic Dome, Ca: A Study of Ascent Rates Using Amphibole and Plagioclase Reactions and Crystal Size Distribution**Molly McCanta¹ (Molly-McCanta@Brown.edu)Malcolm Rutherford¹ (Malcolm.Rutherford@Brown.edu)Julia Hammer¹ (Julia-Hammer@Brown.edu)¹Brown University, Dept. of Geological Sciences, Providence, RI 02912, United States

Magma ascent rate can be quantified petrologically utilizing measurement of (1) decompression-driven amphibole breakdown rims, (2) compositional changes in plagioclase phenocryst rims and (3) crystal size distribution (CSD) of groundmass plagioclase microlites, that are known to have grown during ascent and cooling. Measurements of these parameters in both natural and experimental samples allows for an investigation into the relative rates and correlations between amphibole breakdown, plagioclase growth (of both phenocrysts and microlites) and magma ascent.

Black Butte, Ca provides a good opportunity to study the effects of ascent rate as determined using the above three methods. Black Butte consists of four overlapping dacitic domes on the southwest flank of Mt. Shasta. At Black Butte the natural phase assemblage consists of amphiboles with well developed breakdown rims, homogeneous An₇₄ plagioclase phenocryst cores decreasing monotonically to An₅₅ rims, and extensive groundmass plagioclase microphenocryst growth. Amphibole breakdown rim widths in natural samples are 30-45 μ m, consistent over all four domes. It is important to note that unlike any other studied dome, these samples exhibit a lack of variable rim thicknesses in any one section, indicating little to no magma mixing in the conduit. Plagioclase phenocryst rim widths, defined by a compositional change, are 10-30 μ m. Textural analysis of the groundmass indicates that crystallization of plagioclase microlites accounts for ~57 volume%, with little variation between samples. CSD plots are approximately log-linear over the size range 1-250 μ m. The characteristic microphenocryst size, volumetric number density, and growth rate are 33 μ m, 1.5E-5, ~1.3E-5, respectively.

Isothermal, constant rate decompression (P₁=200 MPa, P₂=2 MPa, dP/dt=6 MPa/day) experiments were run to determine the conditions necessary to produce the rims measured in the natural samples. The starting material was a partially crushed Black Butte rock which was brought to conditions believed to have existed in the magma storage region prior to ascent (870°C, 200 MPa) and held for 48 hours to remelt and homogenize the holocrystalline groundmass. 30 day decompressions were found to best replicate the plagioclase rim widths and compositions. These runs also produced comparable amphibole rim widths, although previously determined phase equilibria indicates these were only formed over the final 17 days when the pressure was below 100 MPa. Preliminary analysis of groundmass microlite crystallization indicates a compositional match with the phenocryst rims discussed above.

The uniform amphibole rim width throughout all Black Butte samples is consistent with magma ascent from the storage region in a similar way throughout the eruption. Plagioclase phenocryst rim widths are also remarkably similar from crystal to crystal again implying a similar ascent rate throughout the eruption. Any long pause in the ascent would be recorded as a leveling off of the An decrease, rather than the observed monotonic decline. Experimental results suggest the magma experienced a steady ascent rate, rising from ~100 MPa to the surface in ~17 days. Information on ascent from deeper in the storage region can be gleaned from study of the plagioclase phenocryst and microlite growth records. Use of these three techniques in concert allows for deduction of a longer ascent history since plagioclase growth records more of the ascent than amphibole breakdown.

V21B-0975 0830h POSTER**Predicting Yield Strengths and Effusion Rates of Silicic Lavas on Slopes From Analog Experiments With Bingham Plastic Materials**Aaron W Lyman¹ (480-965-0828; aaron.lyman@asu.edu)Jonathan H Fink¹ (480-965-1225; jonathan.fink@asu.edu)¹Arizona State University, Department of Geological Sciences, Tempe, AZ 85287, United States

Laboratory simulations of volcanic processes allow determination of information that is difficult, dangerous, or impossible to obtain by other means. Previous laboratory-based studies have related the morphology of lava domes to their emplacement conditions through

the use of a dimensionless parameter, Ψ_D . Ψ_D defines a sequence of four flow morphologies (spiny, lobate, leaved, and no-crust) associated with progressively higher effusion rates, lower cooling rates, and lower yield strengths. In this study, a new series of 100 experiments was conducted to determine how slope affects the morphology of lava domes. Adding slope allows us to better constrain the range of Ψ_D values that could have produced a particular morphology, thus leading to more accurate estimates of emplacement conditions. Once a range of Ψ_D values for a dome is determined, its yield strength or effusion rate can be calculated based on other available information. In the case of active domes, the effusion rate can be used to calculate yield strength, while for prehistoric domes an assumption of yield strength is used to determine the effusion rate. For active domes we estimate yield strengths from 0.8 to 5.0×10^5 Pa; effusion rates for prehistoric domes are estimated to range from 0.1 to $300 \text{ m}^3 \text{ s}^{-1}$. These estimates compare well with measured yield strength values of 1.0 to 2.0×10^5 Pa and effusion rates of 0.1 to $40 \text{ m}^3 \text{ s}^{-1}$ from historically active domes. Having more precise field-based estimates of the range of yield strengths and effusion rates of silicic lava domes can help constrain their advance rates and potential for explosive collapse.

V21B-0976 0830h POSTER

Experimental Constraints on Degassing and Permeability in Volcanic Conduit Flow

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An often-used assumption in modeling of volcanic conduit flow is that equilibrium degassing occurs throughout magma ascent, causing a rapid increase of the decompression rate shortly before the magma becomes permeable or fragments. This increase occurs because volatile exsolution increases melt viscosity, which causes flow pressure to vary. The highest decompression rates are predicted when equilibrium bubble growth occurs. If equilibrium is not maintained, the density decrease and viscosity increase caused by bubble growth are diminished, hence reducing decompression rates and minimizing flow acceleration. A second limit on possible ascent rates is if the bubbly liquid becomes permeable and loses gas from its bubbles, thus reducing porosity.

To assess the maximum decompression rates that guarantee equilibrium degassing, we have conducted experiments on hydrated natural rhyolitic glass at high pressure and temperature, which were then decompressed isothermally following various time-variant rates. After an initial pressure drop, which ensured the presence of a bubble population to avoid problems related to nucleation kinetics, we decompressed the samples at rates that increased with lower pressure. For each increment, the highest rate that maintained equilibrium was determined. We find that equilibrium degassing can only be maintained at decompression rates much lower than those predicted theoretically.

We also conducted experiments on the same hydrated natural glass to determine the onset of permeability. Using our previous results, we decompressed the samples from high pressure at a rate that ensures equilibrium degassing and quenched them at various lower pressures. Deviation of the porosity value of the quenched samples from the expected equilibrium value indicates the onset of permeability. Initial results show that permeability occurs between 55 and 64% porosity when the decompression rate is 0.025 MPa/s. At this porosity range, the projection of experimental decompression rates is 20 times lower than the theoretical rates. Both this significant difference and the porosity range in which permeability occurs suggest that bubble growth and permeability laws must be included in conduit flow models.

V21B-0977 0830h POSTER

Directly Linking Magma Chamber Dynamics and Crystal Zoning: The Wavelet Based Correlation (WBC) of Crystal Populations

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Igneous rocks often show evidence for repeated mixing of distinctive magmas and/or redistribution of within-chamber chemical domains. This is expressed by hybridization trends and changes in isotope ratios at the outcrop and crystal scale, composite dikes, crystal transfer fabrics, and flow structures. We will demonstrate the use of Wavelet Based Correlation (WBC) of crystal zoning populations as a means of 'inverting' for the schedule of magma generation, mixing, crystal growth, and eruption in a structured time-stratigraphic framework. WBC is a new tool that uses the Continuous Wavelet Transform (CWT) to characterize zoning profiles, correlation coefficients of select sets of zoning features to describe crystal similarity, and cluster analysis of correlation coefficients to group crystals into populations. The integrating concepts are the notions of spatial proximity, both within and between samples, of statistical groupings of crystals (clusters) that have experienced a similar thermo-chemo environment at some previous time, and their dispersal and gathering to form new families of clusters. This allows for the construction of a crystal-based phylogeny for the magmatic system where mixing and fractionation events can be ordered and recognized as acting in sequence or in parallel, and the vigor and duration of a mixing event can be inferred from particle dispersal, gathering and zoning.

CWT decomposition allows direct comparison of specific components of crystal zoning patterns because the locations of individual spectral features are preserved. For example, boundary layer diffusion growth effects, rapid mixing events and pressure changes tend to have small scales. Using WBC, the data can be windowed in scale space to isolate small-scale details in the profile independent of all other scales of features in the profile. Conversely, large-scale features such as fractional crystallization trends can be isolated in the zoning signal. WBC can provide a statistical binding point between geochemical and dynamic studies of igneous systems.

V21B-0978 0830h POSTER

Melt Viscosity at the Glass Transition During Volcanic Processes: Predictions From Calorimetric Studies

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The viscosity of volcanic melts at the glass transition has been determined for 11 compositions ranging from basanite to rhyolite. The temperature-dependence of viscosity, together with the cooling rate dependence of the glass transition, permits the calibration of the value of the viscosity at the glass transition at a given cooling rate for each melt.

We have applied micropenetration techniques to determine viscosities of supercooled melts. In addition, glass transition temperatures have been obtained by rate heating glass samples to supercooled liquid conditions using differential scanning calorimetry. The activation energies obtained from calorimetry and viscometry are identical for each melt composition investigated. This confirms that a simple shift factor can be used for each in order to determine the viscosity at the glass transition for a given cooling rate in nature.

The results of this study indicate that there is a subtle but significant compositional dependence of the shift factor by a factor of 10 (in log terms) from 10.8 for rhyolites to 9.6 for basanites. The composition-dependence of the shift factor is presented here in terms of a compositional parameter, the mol% of excess oxides. Using this parameterisation, we obtain a non-linear dependence of the shift factor upon composition that matches all 11 observed values within error. The resulting model permits the prediction of viscosity at the glass transition, during the cooling of glassy volcanic rocks to within 0.1 log units.

The resultant shear viscosities vary over five orders of magnitude for published cooling rates in the literature between tens of Kelvins per second and few Kelvins per day across the glass transition.

V21B-0979 0830h POSTER

Inferring Volcanic Degassing Processes From Vesicle Size Distributions

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Both power law and exponential vesicle size distributions (VSDs) have been observed in many different types of volcanic rocks. We present results of laboratory analogue experiments, of the type pioneered by Brad Sturtevant, which reproduce these observations, and use experimental results and computer simulations to show that the distributions can be interpreted as the product of continuous bubble nucleation resulting from non-equilibrium degassing. This ongoing nucleation causes the bubbles to evolve through an exponential size distribution into a power law size distribution as nucleation and growth progress. The process of continuous nucleation is a mechanism whereby the volcanic system maintains near-equilibrium in the case of rapid depressurisation and slow volatile diffusion.

V21C MC: Hall D Tuesday 0830h

Trench to Subarc: Diagenetic and Metamorphic Mass Flux in Subduction Zones (GERM/MARGINS Subduction Factory Session) III (joint with OS, T, MR)

Presiding: G E Bebout, Lehigh University; J B Martin, University of Florida; T Elliott, University of Bristol

V21C-0980 0830h POSTER

Physical Properties of Upper Oceanic Crust: ODP Hole 801C and the Waning of Hydrothermal Circulation

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The hydrologic evolution of oceanic crust, from vigorous hydrothermal circulation in young, permeable volcanic crust to reduced circulation in old, cooler crust, is thought to cause a corresponding evolution of geophysical properties such as velocity, density, and resistivity. Ocean Drilling Program (ODP) Hole 801C, which obtained the worlds oldest section of in situ, normal oceanic crust, provides the opportunity to examine relationships among hydrologic properties (porosity, permeability, fluid flow), crustal alteration, and geophysical properties, at both core-plug and downhole-log scales. Within these upper crustal basalts, fluid flux in zones with high porosity and associated high permeability fosters alteration, particularly hydration to smectite. Consequently, porosity is well correlated with both permeability and a variety of hydration indicators. Porosity-dependent alteration is also seen at the log scale: potassium enrichment is strongly proportional to porosity. At Hole 801C, intergranular-scale patterns detectable with core plugs are generally similar to log-scale patterns, despite the fact that log responses are also sensitive to large-scale fractures and voids, or macroporosity.

We extend the crustal alteration patterns observed at Hole 801C to a global examination of how the physical properties of upper oceanic crust change as a function of age, based on global datasets of Deep Sea