K_2O contents (0.3-0.4 wt.%) and thus low radiogenic Ar yields, weathering leading to K loss from matrix glass, or the incorporation of xenocrysts into the enormous ($\sim$ 25 g) whole rock samples melted for the K-Ar analyses. $^{40}Ar/^{39}Ar$ plateau ages indicate that over 85% of the complex, $\sim$ 70 km^3 of material, was erupted almost continuously between 142 ka and 32 ka with pulses of increased activity at 80 and 55 ka, which included the construction of a 5 km^3 andesitic stratocone on the eastern half of the island between 80 and 53 ka. At 7.6 $\pm$ 1.9 ka, the stratocone partially collapsed producing a 0.5 km^3 andesitic ash flow tuff , which was followed by the eruption of several rhyolitic domes in the newly created caldera floor, and continued basaltic eruptions from Pyre Peak to the west. Estimating eruptive rates is complicated by glacial erosion and exposures limited by vegetation or ash. Nonetheless, eruptive rates based on estimates of individual flow volumes and $^{40}Ar/^{39}Ar$ ages were 0.5 km^3/k.y. for the predominantly mafic activity between 142 and 8 ka, but slowed to 0.15 km^3/k.y. for the post-collapse rhyolitic volcanism.

V11I-05 1120h

$^{40}Ar/^{39}Ar$ Geochronology of the Pleistocene to Historic Puyehue-Cordon Caulle Volcanic Complex, Andean Southern Volcanic Zone, Chile

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Linking magma reservoir processes beneath arc volcanoes to their surficial expression as eruptive events is hampered, in part, by an incomplete knowledge of long-term eruptive flux. To address this problem, we have begun to quantify the eruptive history of the 105 km^3 Puyehue-Cordon Caulle Volcanic Complex at 40.5°S in the Andean Southern Volcanic Zone (SVZ) using a combination of $^{40}Ar/^{39}Ar$ dating and geologic mapping. Puyehue-Cordon Caulle has erupted low-medium K basaltic to rhyolitic magma that spans the largest range of major element compositions in the southern SVZ. Low radiogenic argon contents necessitate the incremental heating of multiple aliquots (200-800 mg) of groundmass from each lava using a low-blank resistance furnace. New $^{40}Ar/^{39}Ar$ plateau ages from 26 lavas suggest that volcanism began ca. 250 ka. Numerous Mid- to Late Pleistocene vents were active between 250 and 33 ka and produced at least 85 km^3 of basaltic to andesitic lava, tephra, and ignimbrites. More recently, the large Puyehue stratovolcano, built between 45 and 2.7 ka, erupted 18-21 km^3 of basaltic to rhyolitic lava and tephra. Puyehue began to grow after 45 ka with the eruption of 8-10 km^3 of dacitic and rhyodacitic lava followed by several km^3 of basalt and basaltic andesite that erupted between 15.1 $\pm$ 2.6 ka and 10.0 $\pm$ 1.1 ka. The final stage of cone growth, comprising 1-2 km^3 of rhyolitic and rhyodacitic lava and tephra, began by 10 ka and culminated at 2.66 $\pm$ 0.19 ka (^{14}C date) with the plinian eruption of several km^3 of airfall deposits zoned from dacite to basaltic andesite. The average eruptive rate for Puyehue volcano is 0.4-0.5 km^3/k.y., twice that of Tatara-San Pedro volcano located $\sim$ 500 km to the north. Glaciers eroded extensive parts of the complex between 200 and 15 ka, making our growth rate a minimum estimate. The Cordon Caulle fissural zone, which extends for 15 km to the NW of the modern Puyehue edifice, has erupted 2 km^3 of rhyodacitic to rhyolitic lavas, tephras, domes, and pyroclastic cones during the past 1 kyr, with explosive and effusive historic eruptions occurring in 1921-22 and 1960. In contrast to adjacent Puyehue, historic Cordon Caulle rhyolite and rhyodacite erupted at a much faster rate of 6.7 km^3/k.y.

V11I-06 1135h INVITED

The Plio-Quaternary Volcanic Evolution of Gran Canaria Based on new Unspiked K-Ar ages and Magnetostratigraphy

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The combined use of radioisotopic dating, magnetostratigraphy and field geology is a powerful tool to provide reliable chronological frameworks of volcanic edifices. This approach has been used to investigate the last two stages of the volcanic evolution of Gran Canaria. Fifty samples were dated using the unspiked K-Ar method and had their magnetic polarity measured both in the field and in laboratory. Ages were compared to their stratigraphic positions and magnetic polarities before accepting their validity. The unspiked K-Ar chronology constrains the timing of lateral collapses, eruption rates and the contemporaneity of different volcano-magmatic stages at Gran Canaria. Our new data set modifies significantly the previous chronological framework of Gran Canaria, especially between 4 and 2.8 Ma. Based on these new ages, we can bracket the age of the multiple lateral collapses of the Roque Nublo stratovolcano flanks between 3.5 and 3.1 Ma .This time interval corresponds to a main period of volcanic quiescence. Calculated eruptive rates during the stratovolcano edification are about 0.1 km3/kyr which is significantly lower than the published estimates. The dating also reveals that the two main last stages are not separated by a major time gap, but that the early stages of the rift forming eruption and the vanishing activity of the Roque Nublo strato-volcano were contemporaneous for at least 600 kyrs. These results support that our combined approach provides a rapid first-pass and reliable geochronology. Nevertheless, this chronology can be amplified and made more precise where necessary through detailed Ar-Ar incremental-heating methods. Samples which should be investigated using this method are the oldest and youngest K-Ar dated flows of each volcanic stage, and samples from stratigraphic sections that hold potential to study the behaviour of the earth's magnetic field during reversals (Gauss-Gilbert transition, Olduvai and Reunion events).

V11I-07 1150h

Comparison of U-series ages with (U-Th)/He apatite ages at Damavand Volcano, Iran

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Damavand Volcano, Alborz Mountains, N. Iran is an isolated voluminous (>400km^3) composite volcano, built from small-volume eruptions of trachyandesite. The stratigraphy has been calibrated using Ar-Ar and (U-Th)/He apatite dating to establish a broad volcanic history. Eruptions as young as 7,000 yrs and as old as 445,000 years bracket activity at Damavand; although rocks as old as 1.8 Ma are believed to represent a precursor cone occupying a similar footprint. The lavas and pyroclastic deposits are uniformly porphyritic (fspr + oxide + apatite + px $\pm$ amph $\pm$ bi), representing a very restricted compositional range 57-63% SiO_2. The ubiquitous presence of large apatite crystals has allowed us to compare potential crystallization ages with those of eruption. Apatite strongly concentrates Th, leading to low U/Th ratios (0.13-0.17) compared with the magmas from which they crystallize (0.24-0.28). By analyzing the ($^{230}Th/^{232}Th$) and ($^{238}U/^{232}Th$) activity ratios of coexisting apatite-whole rock pairs we can generate a 2-point isochron, which, in the case of simple closed-system crystallization, should represent the age of apatite crystallization. These ages can then be compared with ages from (U-Th)/He apatite analyses, which represent the time at which alpha particles from U and Th decay begin to accumulate as diffusion is effectively stopped when cooling through temperatures of c. 70°C - i.e. the age of eruption. The results suggest that

1. Damavand magmas are characterized by initial ($^{230}Th/^{232}Th$) = 0.65 - 0.90.
2. There is no significant "residence time" of apatite in the magmas prior to eruption
3. Some of the samples have apparent crystallization ages younger than that of eruption, clearly not a realistic scenario.

The young isochron "ages" can be reconciled with eruption ages, if the isochron slopes represent mixing rather than simply a crystallization event. Given that the whole rock samples are de facto mixtures, the most likely scenario is one of mixing relatively low ($^{230}Th/^{232}Th$) cumulate material lying on the equiline into the whole rock - a suggestion which is consistent with petrographic observations and geochemical data.

V12A MCC: Level 1 Monday 1330h

Modern Trends in Petrography: Textural and Microanalysis of Igneous Rocks III Posters

Presiding: **D A Jerram,** University of Durham**; B D Marsh,** Johns Hopkins University**; J P Davidson,** University of Durham

V12A-0548 1330h POSTER

Textural Constraints on Physical and Chemical Communication in Crystal Dominated Magmatic Systems

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We have developed a set of statistical tools that identify shared characteristics in sets of crystals. This includes a means of addressing the geometric effects of sampling from randomly oriented sections through crystals. Rim-to-core compositional profiles of individual crystals provide a putative record for the evaluation of changes in environment during crystal growth. The profile segments in which chemical characteristics are the same in pairs of profiles imply shared growth history in a common environment. However, crystals sometimes record different patterns of shared history for different chemical tracers. This reflects independent variation of either chemical or physical parameters in the magmatic environment. Thus, comparison of the distribution of shared history between profiles provides a way to observe the relative length scales over which characteristics are homogeneous within magma chambers. Chemical tracers with more shared history are inferred to have a longer relative length scale. This framework provides a way to assess the efficiency of chemical communication between magma volumes- an important constraint in light of the increasing consensus that many magma chambers are dominated by crystal mushes. Application of the technique to Anorthite (An) profiles from plagioclase in mafic enclaves at Chaos Crags, California, show little shared history between crystals. $^{87}Sr/^{86}Sr$ profiles from enclaves (Tepley, 1999) show more similar histories. This indicates that the length scale over which An content of plagioclase varies is shorter than that for $^{87}Sr/^{86}Sr$. If changes in An are compositionally controlled, the An and $^{87}Sr/^{86}Sr$ should show similar shared histories. The shorter length scale for An is more likely due to passage of the crystals through steep thermal gradients. This is consistent with resorption and crystallization near interfaces between the commingling magmas. An profiles from crystals in the host rhyodacite also show little shared history. This implies a heterogeneous magma chamber prior to intrusion of the basaltic andesite.

V12A-0549 1330h POSTER

Windows Into an Open-System Magma Chamber: Cognate Xenoliths From the Kameni Islands, Santorini, Greece

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The composition of the dacite forming the Kameni Islands has been remarkably uniform over the last 2200 years, attesting to significant replenishment and mixing in the shallow open-system chamber. Insights into chamber evolution can be gained from the abundant

cognate xenoliths in the dacite. The xenoliths include both cumulates from the chamber floor and quenched fragments of replenishing magma. They fall into 7 groups distinguishable by differences in chemistry, texture and mechanical behaviour. Quench xenoliths with linear CSDs are thought to have formed on the injection of aphyric magma into the chamber. Since these xenoliths commonly have an andesitic composition, this suggests the expulsion of an aphyric melt from a crystal mush in a lower chamber by filter-pressing during compaction. Those with strongly bi-modal grain size distributions indicate injection of phenocryst-bearing replenishing magma. Quench xenoliths with evolved compositions are typically found as large isolated blocks randomly dispersed throughout the host lava. In contrast, the more mafic xenoliths are distributed in tight, elongate, clusters aligned in the direction of flow, and comprising up to 100 individuals. The contrasting spatial distributions of the xenoliths reflects the different rheological properties of the xenolith types, with implications for the ease of mixing and assimilation of batches of replenishing melt in the magma chamber. The rare cumulate xenoliths are small, and are characterised by coarse grain-size, low glass and vesicle content, and are predominantly found in lava from the last (1950) eruption. They are generally found enveloped by less dense and highly vesicular quench-type xenoliths, which probably provided the buoyancy forces necessary for entrainment. Mapping of the xenolith types shows that each flow forming the Kameni Islands has a distinct xenolith population, reflecting the changing state of the emptying magma chamber. Seismic activity has preceded most recent eruptions on Santorini by approximately 20 months. This activity may signify the movement of magma at depth and the injection of new magma into the dacite chamber. Plagioclase crystal sizes in the quench xenoliths are consistent with growth timescales of the order of a few years, suggesting that these xenoliths derive from the replenishing magma. We suggest that replenishing material exists as a series of sills at the base of the chamber, with later pulses of magma intruding into, and disrupting, the pre-existing crystal pile. The concentration of cumulate xenoliths in the 1950 flow suggests that the replenishment event prior to this eruption intruded through a mature layer of crystal mush.

V12A-0550 1330h POSTER

Insight Into the Magmatic Evolution of Fernandina Volcano, Galapagos, From Olivine- and Plagioclase-Hosted Melt Inclusions

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Lavas erupted subaerially from Fernandina Volcano have previously been characterized as being evolved, well-mixed, and homogeneous (Allan and Simkin 2000), obscuring details of earlier stages of magmatic evolution. In this study, phenocrysts and melt inclusions from recent submarine lava samples and representative subaerial lava samples are investigated to gain insight into earlier stages of Fernandina's magmatic evolution. Olivine is present as three populations: unzoned high-forsterite Type I olivine, unzoned low-forsterite Type II olivine, and normally-zoned Type III olivine with Type I cores and Type II rims. Melt inclusions were rehomogenized at 1180C and drop-quenched to remove the effects of post-entrapment crystal growth. Type I olivine contain highly variable melt inclusions (K_2O/TiO_2 from 0.03 to 0.29, compared to glass and whole rock values of 0.15 plus or minus 0.01). The variability of the inclusions can be produced by 1 to 2 percent fractional melting of a MORB-like mantle source. Plagioclase and Type II olivine contain more homogeneous melt inclusions that define a trend of fractional crystallization of olivine, plagioclase, and clinopyroxene from a parental melt represented by an average Type I melt inclusion. Type I olivine textures and olivine/host glass disequilibrium suggest that this olivine crystallized from primitive, compositionally-diverse magmas and is exotic. Type II olivine most likely grew in the evolving liquid prior to eruption but after homogenization by mixing. All olivine types consistently demonstrate an equilibrium relationship with their reheated melt inclusions. For Type I olivine, the olivine/inclusion equilibrium and the exotic origin suggest that olivine phenocrysts resided at a temperature close to the trapping/crystallization temperature until shortly before eruption. For Type II olivine, the equilibrium with its inclusions and its host glass indicates that crystal growth occurred shortly before eruption. Post-entrapment diffusive transport of potassium between plagioclase and its melt inclusions may have elevated K_2O, and therefore K_2O/TiO_2, in the inclusions. Diffusive transport may occur on a timescale of 10^2 to 10^4 years. These geochemical trends support a picture of early growth of Fo_{86} to Fo_{89} olivine in a dynamic environment, followed by homogenization of compositionally-variable melts and growth of plagioclase and lower-forsterite olivine in a well-mixed chamber. Fernandina's plagioclase-rich and olivine-poor subaerial lavas likely tap the upper part of the chamber, whereas olivine-rich submarine lavas likely tap the lower part of the chamber, where olivine has accumulated.

V12A-0551 1330h POSTER

Amphibole Reaction Rims in Response to Decompression compared to Heating: An Experimental Approach

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Amphiboles are an important magmatic mineral phase common to a variety of volcanic settings, and are especially sensitive to variations in the water content and temperature of the surrounding induced during magmatic ascent or heating accompanying magma mixing events. As magma rises toward the surface hydrous amphiboles, stable at high water pressures, break down in response to degassing of the surrounding melt. Reaction rims also form around amphiboles that are destabilized when mixing with hotter, more primitive magmas occurs. In this study, we compare the thickness, composition, and rate of formation of amphibole reaction rims during a series of isothermal decompression and isobaric heating experiments using dacite and andesite magmas erupted from Redoubt volcano, Alaska in 1989-1990. The 1989-90 Redoubt dacite pumice consists of magnesio-hornblendes, plagioclase, othropyroxene, and Fe-Ti oxides in a high-silica rhyolite glass. In contrast, 1989-90 Redoubt andesite contains pargasitic amphiboles, orthopyroxene, clinopyroxene, plagioclase, and Fe-Ti oxides in a rhyodacite glass. Our results indicate that the reaction rims formed in response to decompression are distinguishable in thickness, grain size, and type of mineral formed in the rims from those formed in response to heating, regardless of the type of amphibole studied. First, decompression induced rims were thinner (5- 50 um) compared to those developing in response to heating (25- 200 um). Decompression induced rim growth rate ranges from 0.3 to 0.6 um/day compared to heating induced rim growth rate, which ranges from 0.4 to 1.6 um/day. Second, decompression rims were finer-grained (5-15 um diameter crystals) compared to heating reaction rims (5- 35 um diameter crystals). And third, decompression rims are predominantly composed of orthopyroxene and plagioclase, with lesser amounts of Fe-Ti oxides, whereas reaction rims that grew in response to heating experiments were composed almost entirely of clinopyroxene and Fe-Ti oxides, with lesser amounts of orthopyroxene, and plagioclase. Because the results are independent of the type of amphibole studied, the physical characteristics of reaction rims around amphiboles from a given eruption may yield important information about the rates and types of pre-eruptive disequilibrium event that was the cause.

V12A-0552 1330h POSTER

Microstructural Analysis of Welding: Deformation and Strain

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Welding in pyroclastic deposits involves the sintering, compaction and flattening of hot glassy particles and is attended by systematic changes in physical properties. Welded materials contain implicit information regarding the total accumulated strain as well as the mechanisms of deformation. Here, we use detailed microstructural analysis of synthetic and natural welded materials to make quantitative estimates of strain and constrain the rheology of these materials during the welding process. Part one of our study comprises microstructural analysis of end products from unconfined high temperature deformation experiments on sintered cores of soda-lime silica glass spheres. This analogue material has relatively simple and well-characterized starting properties. Furthermore, the initially spherical shapes of particles provide excellent strain markers. Experiments were run at a variety of temperatures, strain rates and stresses resulting in end products with varying degrees of total strain. The nature of strain partitioning and accumulation are evaluated using image analysis techniques on scanned images and photomicrographs of thin sections cut perpendicular to the loading direction of each experimental product. Shapes of the individual deformed particles (e.g., oblate spheroids) were determined and the Scion image analysis program was used to create a best-fit ellipse for each particle. Statistics collected on each particle include: axial dimension (a), vertical dimension (c) and angle from the horizontal. The data are used to calculate the oblateness of each particle (1-c/a) and the angle of deformation induced foliation. Furthermore, the relative proportions of visible blue epoxy in the sample scans determine bulk porosity. The average oblateness of the particles is a direct, independent measure of the accumulated strain in each sample. Results indicate that these measured values are equal to calculated theoretical values of oblateness for spheroids undergoing the amount of constant-volume strain as determined by machine displacement. This information, combined with the near horizontal foliation angle for all samples strongly suggests that, in these experiments, all deformation is coaxial. Total strain in these experiments is accommodated by both longitudinal strain (calculated from porosity loss) and axial strain ("bulging" of the sample). A goal of ongoing analysis is to determine the role and proportion of each type of strain with increasing deformation. Furthermore, we are micro-analyzing products from experiments performed on natural pyroclastic materials for comparison with our dataset of results from similar analyses of naturally occurring samples.

V12A-0553 1330h POSTER

3D Petrography - Serendipitous Discovery of Magmatic Vapor Deposition of Anhydrite at Mount Pinatubo by SEM Imaging of Outer Crystal Surfaces

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A standard petrographic technique focuses upon examination of surfaces or planes cut through rock samples, with one approach studying chemical variations in a core to rim traverse using various microprobes, and more recently, another determining the distribution of crystal sizes to obtain information about nucleation and growth. We show that another mineral domain deserves petrographic attention: the outer surfaces of crystals, which are normally relegated to nearly invisible thin lines in a cut section. In studying anhydrite phenocrysts from the 1991 climactic eruption of Mt. Pinatubo, SEM examination of "raw" pumice fragments showed the existence of a Ca-sulfur-rich phase with hexagonal morphology residing upon plagioclase phenocryst surfaces in vesicles (Fournelle et al,1996, Fig 9). In 1992, Terry Gerlach suggested that the Pinatubo anhydrite phenocrysts should be evaluated with XRD to determine if they were indeed orthorhombic anhydrite (β-CaSO4), and not a lower temperature polymorph (i.e., α or γ). In 1998, we recommenced this project, mounting several dozen 100-200 micron-size phenocrysts of the proper density fraction on tape (minerals had been separated from the pumices using standard techniques). They were examined by low resolution SEM with EDS to distinguish the anhydrite from apatite, prior to single-crystal XRD. We were surprised to find that many of the anhydrite surfaces were decorated with small mounds, which upon examination by high resolution SEM turned out to be micron and smaller pyramids, with some surfaces bearing hundreds. Single-crystal XRD verified that the phenocrysts were orthorhombic anhydrite, and EBSD verified that the small pyramids were the same. Eventually we found that these surface pyramids are common phenomena in experimental or industrial chemical vapor deposition processes when nucleation overwhelms growth. Textural relations were consistent with these pyramids being deposited in situ, within the Pinatubo magma chamber, significantly prior to eruption, with geochemical modeling supporting this hypothesis (Jakubowski et al, 2002, Am. Min 87, 1029; download from www.geology.wisc.edu/∼ johnf/Ryan.pdf) As demonstrated here, a polished thin section can entirely miss critical petrographic information present upon the outer crystal surface. Consequently, additional sample preparation may be necessary, including careful separation of minerals or clumps of minerals and matrix, followed by imaging by SEM. We suggest that one impact may be in the study of volcanic materials, where there

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may have been a vapor present at depth prior to eruption, and where magmatic vapor deposition processes may have left evidence on the surfaces of crystals.

URL: http://www.geology.wisc.edu/~johnf

V12A-0554 1330h POSTER

Compaction in the Bushveld Complex

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Compaction in the mush zone of a crystallizing chamber is a model for fractionation, whereby evolved interstitial liquid expelled from the compacting crystal pile is returned to the magma chamber. If compaction was important during crystallization of the Lower and Critical Zones of the Bushveld Complex, certain textural features are expected; and, these features should correlate to position in the section, as well as to the number of mineral phases present. We report on a spectrum of textural data for 30 samples form the Lower and Critical Zones of the Bushveld Complex. Crystal Size Distributions (CSDs) are a semi-log plot of population density against crystal size, and provide information about magmatic processes such as crystal accumulation, removal and aging. Changes to the magmatic system are reflected in the shape of the CSD plot. CSDs of Bushveld rocks show a log-linear trend overturned at smaller grain sizes, a result consistent with both crystal aging, wherein larger grains grow at the expense of small ones in the crystallizing pile, and melt migration, where nucleation is suppressed by the loss of late melt fractions. CSD slope and intercept data vary with stratigraphy. Slopes in the Critical Zone are steeper, indicating less recrystallization and less of a compaction effect. In contrast, slopes in the Lower Zone are shallower, a result consistent with slower cooling and a greater compaction/recrystallization effect. Likewise, lower CSD intercepts are associated with the shallower slopes of the lower zone and vice versa. The extent of foliation is measured as alignment factor (AF), determined by orientation statistics of the major axes of the grains of interest. AF decreases with stratigraphic height and foliation is best developed in the nearly monomineralic harzburgite of the Lower Zone (AF avg=64). At the Lower Zone-Critical Zone transition, plagioclase content increases, decreasing bulk density and thus, the systems ability to accommodate compaction (Upper Critical Zone AF avg=57). There is a positive correlation between the quality of the foliation and mineral aspect ratio, suggesting that recrystallization (crystal aging) demonstrated by CSD plots occurred in a regime of uniaxial stress, wherein selective grain resorption of unfavorably oriented grains and uneven crystal growth results in grains with high aspect ratios. Spatial distribution pattern (SDP) analysis is used to determine the framework structure of spheres in 3-D. Results of R-value analysis (based on nearest neighbor statistics, (Jerram et al., 1996)) are plotted against porosity to compare Bushveld data against fields for touching and non-touching framework structures, and clustered v. ordered crystal distributions. As the Bushveld minerals are not spheres, the applicability of the field boundaries is questionable. Bushveld data form a trend that is coincident with the trend defined either by variable extents of size sorting or by the deformational compaction of spheres. A correlation on a plot of R-value versus aspect ratio clarifies that trend observed on the spatial distribution plot is due to deformational compaction. Phosphorous is a proxy for trapped liquid fraction because it is incompatible in all major phases: it indicates the extent to which late melt has been expelled. Depletion of P in the Lower Zone, where mineral alignment is highest and compaction most efficient, agrees with the hypothesis that compaction was important in redistributing trace elements. Residual porosity calculations based on Y show porosity of 5% in the Lower Zone and 20% in the Upper Critical Zone. R-values plotted against the residual porosity produce a positive trend, relating decreased porosity to grain distribution. Jerram et al., 1996 Contrib. Min. Pet. 125, 60-74.

V12A-0555 1330h POSTER

Magma Ascent Rates Determined Using Multiple Petrographic Methods: A Comparison of Decompression-induced Amphibole and Plagioclase Reactions and Crystal Size Distribution

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Petrographic analysis of crystal-melt reactions driven by decompression induced magma degassing can potentially yield valuable information regarding magma ascent rates. The degassing process causes destabilization of OH-bearing phenocrysts, such as amphibole and biotite, and results in the crystallization of interstitial melts. Magma ascent rates for extrusions of H2O-rich magma can be quantified petrographically utilizing measurements of (1) decompression-driven amphibole breakdown rims [Rutherford and Hill, 1993], (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 [i.e., Marsh, 1998]. 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. The dacitic domes of Black Butte, California, provide a good opportunity to study the effects of ascent rate as determined using the above methods as the pre-eruption magma represents one injection, not repeated cycles, based on the presence of completely unzoned amphibole and plagioclase phenocrysts. The Black Butte phase assemblage consists of phenocrystic amphibole surrounded by rims of breakdown material and phenocrystic plagioclase with compositionally distinct rims in a completely crystalline, high silica groundmass, composed primarily of microlites of plagioclase, pyroxene, and oxides. Measurements of the plagioclase and amphibole rims and the plagioclase microlites can be made for the natural rocks and compared to experimental results in order to determine magma ascent rates. Isothermal, constant rate and one-step decompression (P_1=200 MPa, P_2=2 MPa, dP/dt=0.002m/s, 0.01m/s, or 1-step) experiments were run to determine the conditions necessary to produce the rims and microlite characteristics measured in the natural samples. The starting material was a partially crushed Black Butte rock which was brought to conditions determined 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. Plagioclase compositions and rim widths (natural = 20±10μm, experimental = 30μm) were best replicated in 30-day decompression experiments, which also produced comparable amphibole rim widths (natural = 30-45μm, experimental = 25μm). In addition, plagioclase microlites in the 30-day experiments exhibited a close compositional match with both the natural plagioclase phenocryst rim and microlite compositions (An52 vs. An59 and 50, respectively). Crystal size distribution calculations reveal that the characteristic crystal length in the experimental samples (26μm) is less than that of the natural samples (56μm). Preliminary experiments indicate this to be the result of experimental decompressions starting at slightly lower pressures (shallower depths) than the natural rocks. Ascent rates calculated from both the amphibole and plagioclase methods indicate similar ascent rates (0.002m/s and 0.001m/s, respectively).

V12A-0556 1330h POSTER

The Textural Analysis of Evolved Magmatic Systems; a Case Study on the Fish Canyon Tuff.

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Petrographic inspection of many evolved volcanic and high level plutonic rocks, reveals qualitatively complex crystal populations. The detailed textural analysis of such populations is important as it can be used as a proxy to guide macro and micro-geochemical sampling strategy, and can be employed to gain insight into the history of the magmatic system. A comparison of existing Crystal Size Distribution (CSD) data shows a variety of different scenarios for evolved magmatic systems. Many examples show kinked CSDs which are confirmed by micro-geochemical analysis to consist of mixed populations of crystals. We present new CSD data produced for the Fish Canyon magmatic system, which exhibit mainly kinked-curved trends dominated by two crystal populations, one large and one small. Given simple assumptions for growth rates, residence times may be estimated at between 80-150yrs for the small crystal population and 150-400yrs for the large. The CSD plots for the different units of the Fish Canyon magmatic system have been used to show the evolution of the magma chamber over time. Chamber systematics are shown to change from crystal settling process in the pre-caldera dacitic magmas to magma mixing processes in the Fish Canyon eruptives. In some cases crystal fragmentation due to decompression during eruption may also be an important process in modifying the observed CSDs.

V12A-0557 1330h POSTER

Crystal Sinking and Bubble Rising in the Bishop Tuff Rhyolitic Magma

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The Bishop Tuff is a large volume pyroclastic deposit of rhyolitic composition. We studied five pumice clasts from three early to middle stratigraphic units: fall units F7 and F8, and ash-flow unit Ig2E. Our determinations included pumice bulk densities, crystal contents and size distributions. The latter two were obtained by a crushing, sieving and winnowing procedure, supplemented by X-ray tomography and microscopy. A combination of pumice density and crystal contents was used to determine the volumetric abundances of glass, crystals and vesicles in each pumice clast. Our data suggest a positive correlation between pumice densities and crystal contents. Three stages of evolution are evident based on density and crystal content. The three stages are also distinct in the distribution of crystal mass fraction with size. All samples have similar amounts of small crystals (< 200 microns), but the abundance of large crystals (800-1800 microns) varies greatly and is well illustrated by a marked positive correlation between the mass of large crystals and the total crystal contents (and also pumice density). As a result, there is a strong negative correlation between the volumetric abundance of vesicles (porosity) and the amount of large crystals. Accumulation of large crystals (in accordance with evidence from melt inclusion and sanidine zoning) causes a large increase in the mass fraction in this size category with a corresponding slight decrease in porosity, resulting in a slightly negative slope, much smaller than that observed. The effect of growth is not easily portrayed, but for a magma cooling under gas-saturated conditions, both porosity and crystal mass should increase simultaneously, generating a positive correlation; clearly, this expected behavior cannot explain the observed correlation. Hence, in order to explain the negative correlation between porosity and abundance of large crystals we invoke a combination of crystal accumulation and bubble rising in the preeruptive Bishop magma.

V12A-0558 1330h POSTER

Sedimentation in Magma Chambers: Evidence From the Geochemistry, Microstructure and Crystallography of Troctolite and Gabbro Cumulates, Rum Layered Intrusion, Scotland.

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The formation of igneous cumulates remains poorly understood. In particular, petrologists disagree about the relative importance of crystal accumulation by sedimentation or in-situ growth, partly because post-cumulus processes often overprint evidence for the primary mechanism. We address this problem with a detailed geochemical, microstructural and crystallographic study of gabbros and troctolites from the Eastern Layered Series of the Rum Layered Intrusion, NW Scotland. We collected samples, approximately every 50cm, through the complete 11m sequence of foliated gabbros and troctolites from Unit 9. The samples were quantitatively analyzed for crystal shape and size, shape preferred orientation (SPO), crystallographic preferred orientation (CPO), modal mineralogy, and whole rock and mineral chemistry. We present the following results: Within cumulate layers just cm's apart, olivine crystal shape can vary from sub-equant to tabular, and crystal diameter can vary from 1-8mm. This suggests at least one olivine population was derived elsewhere in the magma chamber. Complex anorthite zoning is also consistent with an extended history of plagioclase crystal transport. A one-crystal thick olivine layer between feldspathic layers of differing grain size is interpreted to be a lag deposit. Two possible examples of cross bedding also

exist. Taken together, these observations suggest sedimentation was the primary method of crystal accumulation. The data also provide constraints on postcumulus processes. Complex plagioclase zoning suggests that processes of viscous compaction and/or recrystallization were not extensive. The preservation of magmatic and deformation twins and absence of a polygonal fabric support this conclusion. In addition, the CPO and SPO are the same. Lacking evidence for compaction and recrystallization lead us to believe similar CPO and SPO are the preserved artifact of a sedimentary foliation. Therefore, we conclude the gabbros and troctolites of Unit 9 formed by crystal sedimentation followed by subsequent overgrowth by porous media convection with limited compaction or recrystallization.

V12A-0559 1330h POSTER

Unraveling Complex Crystal Populations of the Current Eruption of Arenal Volcano, Costa Rica: Key to Understanding 35 Years of Continuous Eruption of Monotonous Basaltic Andesites

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Except for the first two years since July 29, 1968, Arenal volcano has been continuously erupting compositionally monotonous and phenocryst-rich (∼35%) basaltic andesites composed of similar proportions of plagioclase (plag), orthopyroxene (opx), clinopyroxene (cpx), spinel ± olivine. Detailed textural and compositional analyses of phenocrysts, mineral inclusions, and microlites reveal comparable complexities in any given sample and identify mineral components that require a series of growth environments that not only compositionally varied but also likely in P-T-X conditions. Frequency distributions of mafic mineral compositions indicate the current eruption has been mainly tapping a reservoir containing low Mg# silicate phases (< 78) and mainly titanomagnetite which crystallized in at least three different environments to account for the following assemblages: a) low Al_2O_3 (<3 wt.%) cpx + opx, b) high Al_2O_3 (4 to 6 wt.%) cpx (+ opx ?), and c) low Fo olivine + cpx but without opx. Ubiquitous high Mg# (80->86) mafic silicate phases (mainly cpx) with Cr-, Al-rich spinel inclusions indicate that some portions of crystals are derived from more mafic (basaltic?) magmas occurring mainly as growth zones between cores to rims of euhedral phenocrysts. Plagioclase has a wide compositional range (An_{95-55}) and inclusion data in cpx hosts suggest high An plag (An_{90-80}) crystallized from liquids with variable Mg# while low An plag crystallized only from low Mg# (< 47) liquids. Multi-step mixing processes likely facilitated assembling various mineral components as mafic magma from lower crustal levels ascended to subvolcanic depths undergoing at the same time evolution to erupting compositions. The mineralogical record is consistent with ascent-driven evolution of mafic magmas concurrently with the current eruption leading to new increments of basaltic andesite and that may ultimately lead to the continuous volcanic activity and compositional monotony since replenishments may be small and quasi-continuous.

V12A-0560 1330h POSTER

Crystallinity, Petrological, Geochemical Evolution of Explosive Eruptions from Merapi, Java, and Soufriere Hill, Montserrat: A Comparative Investigation

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The types of eruption at Merapi volcano range from gentle lava dome effusions to energetic explosions, with these styles commonly related to open and closed vent conditions, respectively. The closed vent style was dominant in pre-1800 AD times, when eruptions related to dome collapse were infrequent, and explosive eruptions ranged from sub-plinian and plinian to vulcanian. Post-1800 A.D eruptions, mainly of open vent type, have been primarily related to dome collapse events, with occasional vulcanian explosions. The change in activity from plinian events to dome collapses and collapse-triggered explosions is imprecisely defined but occurred about the same time as the Kepuhharjo tephra (c. 250 yrs. ago). Geochemical characteristics of tephra units from pre-1800 AD Merapi eruptions show a range of medium to high K_2O (1.1 to 2.5 wt%), high Al_2O_3 (19 to 21 wt%) and low MgO (1.9 to 3.6 wt%). Silica compositions varied from basalt to basaltic andesite (51-57 wt%). This range in composition may reflect periodic influxes of basaltic magma into crustal reservoirs. Chemically, Merapi tephras show two clear trends in composition: (1) medium-K basalt to basaltic-andesite; and (2) high-K basalt to basaltic-andesite. Through time, the K_2O content evolves from medium-K to consistently high-K, with the transition between 3000 and 1650 yrs BP. Here we examine the petrographic characteristics of the Tegalsruni and Temusari tephras which erupted about 2000 years BP and 1800 years BP, representing the transition period, and the Kepuhharjo tephra (250 years BP) and 1872 AD eruption, which represent vulcanian eruptions related to dome collapses. The pyroclastic fall deposits of Merapi are characterised by pumiceous fragments with subordinate (30%) lithics, low to highly vesiculated pumice, brown to dark brown color, and textures that range from porphyritic, phaneric to aphanitic. The pumices contain up to 50 vol% phenocrysts of plagioclase, clinopyroxene, hornblende and titanomagnetite. In general the Merapi tephras show an increase in crystallinity from the onset to the end of each eruption, reflecting the zonation tapped in the magma reservoir; in the Temusari tephra, this crystallinity change accompanies an increase in SiO_2. Hornblende is more abundant in larger (sub plinian to plinian) eruptions than in dome collapse (vulcanian) eruptions. Volumetric percentage of plagioclase is variable throughout the Tegalsruni eruption but increases through the Temusari eruption, during which time average plagioclase number densities decrease. A preliminary comparison with the products of recent andesite eruptions of Soufriere Hills volcano (SHV), Montserrat, shows similar trends in phase proportions and CSD although the total phenocryst content of SHV exceeds that of Merapi. These trends may reflect variations in the rate of magma ascent and degassing which will affect the microlite crystallinity. The Montserrat magma was reheated by mafic injection and liberation of heat and volatiles, with slower ascent during effusive phases, and residence within the lava dome, permitting more extensive degassing-induced plagioclase microlite crystallization. Viscosities in general were lower at Merapi because of lower SiO_2 content. Similar trends were seen in the explosive and effusive phases of the 1980-1986 eruptions of Mount St. Helens.

V12A-0561 1330h POSTER

Crystallinity, textures and chemistry of "old and youthful" lavas from Merapi volcano, Java, Indonesia: understanding evolving eruptive behavior

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Merapi volcano has erupted frequently over the past 40,000 years, displaying a wide range of eruptive behaviors and posing different types of hazards. Because of its high population density and restless activity, Merapi represents an ideal laboratory for investigating magma reservoir processes and their relation to eruptive mechanisms. This presentation focuses on the recent effusive activity and adds insights from older products of Merapi, providing an early contribution to a larger project that includes the detailed study of changes in the eruptive behavior over time. The bulk geochemistry of lavas spanning ∼8,000 years requires a diversity of comples magmatic processes. Merapi stratigraphy records a compositional range of 49-57 wt% SiO_2, with periodic abrupt changes in K_2O content. Previous studies have demonstrated that Merapi products display a transition from medium-K (*Old Merapi*) to high-K series (*New Merapi*) at ∼2,000 yBP, whereas products of *Very Old Merapi* (>5,000 yBP) contain both medium and high-K series.The most recent activity of Merapi (∼1888 AD to present) is represented mainly by lava dome growth and pyroclastic flows following dome collapse. Products of this activity display a relative uniformity in geochemical, petrographic, and, to a first approximation, textural parameters. Dome lavas are basaltic andesite in composition and almost all belong to the high-K series; they show high crystallinity values (47-60%) that correlate positively with the K_2O content. The phenocryst assemblage is chiefly plagioclase (68-90 vol%), clinopyroxene, orthopyroxene and Fe-Ti oxides, in a microcrystalline groundmass made of feldspars and pyroxenes. Plagioclase shows strong evidence of reheated and resorption textures and has cores with An contents as high as 89%. The relative geochemical uniformity of the recent dome lavas (1888AD-present) provides an opportunity for tentative correlations with textural (including Crystal Size Distribution) parameters, and we compare textures with modern lavas with those from *Very Old Merapi*. The comparison between geochemistry and quantitative textural data, and in particular CSD analyses, provides insight into chemical and physical parameters intimately related to the mechanisms of magma reservoir storage and replenishment as well as eruptive behavior. These relationships also provide a basis for an interpretation of textural parameters in relation to different types of eruptive activity.

V12A-0562 1330h POSTER

The Mafic Holocene Sand Mountain-Nash Crater Chain, Oregon Cascade Range: Preliminary Insights Into Enigmatic Crustal Contamination Processes

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The ca. 3 ka Sand Mtn-Nash Crater chain is a 10 km long bifurcated cinder cone alignment formed during an intra-arc extensional fissure-style eruption in the central Oregon Cascades. Eruptions began with at least 6 separate basalt flows (MgO 6.5 to 8.8 wt %), followed by several flows of two distinct basaltic andesites. Measurable paleomagnetic secular variation is absent (12 of 13 flows sampled; Duane Champion, pers. comm., 2003), suggesting the eruptions spanned at most a few decades. Nash Crater basaltic andesite is similar to the most common Mt. Washington type mafic lava in the Cascades, while Sand Mtn. basaltic andesite is similar to less common Sr-rich (900-1200 ppm Sr) mafic lava. Both basalt and basaltic andesite typically contain olivine and plagioclase phenocrysts, with rare clinopyroxene. Rare glass-bearing gabbroic xenoliths appear to preserve a record of both assimilation and crystallization of plag-oliv-cpx. Each basalt is unique, but basalts collectively record a wide compositional diversity (e.g., K2O 0.65 - 0.90; Ba 230 - 350; Ba/Sr 0.33 - 0.53), which may result from either source variation and/or crustal assimilation. Sr isotopes range from 0.7031 - 0.7034 in basalt whole rocks (WR), and are positively correlated with Ba/Sr ratio. A similar correlation is found in Sr isotopes from Sand Mtn basaltic andesites (WR), which range from 0.7031 - 0.7033. Preliminary laser ablation sampling of Sr isotopes in Sand Mtn. basaltic andesite plagioclase phenocrysts and groundmass demonstrates equilibrium between WR, groundmass, and crystals, strongly suggesting that compositional variation in at least these lavas was acquired below the plagioclase stability field (i.e., in the lower crust or upper mantle). Variations in the more typical Nash Crater basaltic andesites appear to reflect in part mixing with a Sand Mtn type component. Derivation of basaltic andesites from their co-erupted basalts, suggested by the field relations, is not readily apparent. The enigma presented by the compositional variation in these lavas may shed light on common assimilation processes, especially in the deep crust, which likely affect many mafic arc magmas.

V12A-0563 1330h POSTER

Transient Rhyolites: a Fresh Perspective on the Generation of Silicic Magmas Associated with Long Valley Caldera

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The paradigm for the evolution of rhyolitic magma in the Long Valley caldera system includes episodic generation and protracted residence (<350 k.y) of precaldera (Glass Mountain) rhyolites that eventually served as forerunners to the nascent caldera magma chamber that erupted at 760 ka and produced the Bishop Tuff (BT). We present in situ 238U-206Pb ages and U concentrations for zircons from the "late" Bishop Tuff ("late"=Ig2NW) and from representative Glass Mountain rhyolites (domes OD, YG, and YA). Zircons in the three precaldera rhyolites crystallized from 2024±33-1675±43 ka (dome OD), 1023±35-857±27 ka (dome YG), and 1109±34-885±35 ka (dome YA) but, except for dome OD, most crystals grew within <100 k.y. of eruption. These crystallization intervals are independent of assumptions about the affinities between crystals and their host melts and, notably, they support Rb-Sr isotope evidence for differentiation and crystallization well before eruption. Zircons from the "late" Bishop Tuff (LBT) yield a mean age of 824±8 ka that is indistinguishable from that for the "early" Bishop Tuff (EBT). Zircons ages like those expected if there was a significant contribution from the precaldera rhyolites are absent and there is no significant evidence for zircon crystallization >200 k.y. prior to eruption, suggesting that the BT is a new batch of rhyolite. Uranium contents of zircon from the late and early BT pumice are distinct (∼500-3600 ppm and ∼1000-5000 ppm, respectively) even though their age distributions are the same, suggesting that compositional zoning of the Bishop Tuff developed before most zircon crystallized. Given (1) this apparent lack of carry-over of older zircons between older and younger precaldera rhyolites, as well as between precaldera rhyolites and the Bishop Tuff and (2) the compositional differences between precaldera rhyolites and the Bishop Tuff (Metz and Mahood, 1991; Davies et al., 1994; Davies and Halliday, 1998), we envision a magma system where the pre- and caldera-related rhyolites represent isolated and/or transient magmas in a voluminous system of crystal mush rather than periodic tapping of a largely liquid, albeit stratified, magma reservoir.

V12A-0564 1330h POSTER

Insights into the dynamics and timing of crustal contamination of Kerguelen plume magmas using "Crystal Stratigraphy".

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Basalts represented by the 123-130 Ma Bunbury basalt (BB) Casuarina flow (BB), SW Australia, and drill core from the 107-108 Ma ODP Leg 183 Site 1137 (Elan Bank or EB) are purported to be products of the Kerguelen plume. Whole-rock geochemical data indicate these basalts have assimilated continental crust (Frey et al., 1996, EPSL 144:163; Ingle et al., 2002, EPSL 197:35) and combined, these 2 sites represent ∼22 m.y. of plume-crust interactions. In this study we use the crystal stratigraphy of (up to 1 cm) plagioclase phenocrysts in basalts from BB and EB to determine magmatic evolution (cf. Davidson et al., 1998, EOS 77:185). Core-to-rim trace element abundances were measured by LA-ICP-MS, major elements by EPMA, and 87Sr/86Sr compositions were determined by multicollector ICP-MS after computer-controlled microdrilling of discrete zones within each crystal. The BB plagioclase has overall lower Sr, Ba, REE, Ti and Ga abundances than the EB sample. Isotopically, the BB plagioclase contains a less radiogenic I(Sr) core (0.70414) and a more radiogenic rim composition (0.70567). The BB plagioclase exhibits core to rim Ce, Ti, Nd, and Ba enrichments that exceed those expected by fractional crystallization for the observed core-to-rim decrease in An content (66 to 60). It contains several resorption features defined by inclusion-rich zones mirroring crystal shape and a marked decrease in Sr and Ba abundances. Progressive core-to-rim enrichments in major and trace element (An, Sr, Ba, Ce, and Ti) abundances, as well as I(Sr), cut by relatively depleted Sr and Ba zones suggest initial growth in a relatively uncontaminated magma, progressive crustal assimilation, with periodic magma recharge. While a core I(Sr) value has not yet been determined, the EB plagioclase contains a less radiogenic rim (0.70618) relative to an intermediate zone (0.70645), which is adjacent to a resorption surface and also contains relatively enriched abundances of Sr, REE, and Ba. EB plagioclase trace element abundances suggest it initially grew in a highly crustal contaminated magma. The three distinct resorption surfaces observed in the EB plagioclase correspond to increased trace element abundances. We suggest the EB plagioclase initially grew in a highly contaminated magma where mixing with a highly REE enriched and radiogenic Sr end member occurred. Frey et al. (1996, EPSL 144:163) reported I(Sr) isotope ratios of Bunbury Casuarina basalts ranging from 0.70411-0.70534, less radiogenic than our rim I(Sr) value of 0.70567. Ingle et al. (2002, EPSL 197:35) reported I(Sr) isotope ratios for Elan Bank basalts ranging 0.70563-0.70573, again less radiogenic than our two I(Sr) measurements of 0.70618 and 0.70645. Disequilibrium exists between the plagioclase phenocrysts and the whole rock. We attribute the less radiogenic Sr signatures of whole rock samples relative to rims of their respective plagioclase phenocrysts to a large influx of parental plume melt just prior to eruption.

V12A-0565 1330h POSTER

Oxygen Isotope Variation Within a Quaternary, Caldera-forming, Phonolitic Eruptive Sequence; the Diego Hernández Formation, Tenerife, Canary Islands (Spain)

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Much of the work done on oxygen isotopes in volcanic rocks has been based on analyses of whole rock or multiple crystal aliquots, inherently discounting the importance of heterogeneity. Recently, due to advances in technology and the recognition of small-scale chemical disequilibria in magmatic systems, it has proven valuable to measure variations among individual grains to examine the evolution of these systems. Here, we present the results of both single and multi-crystal feldspar oxygen isotope analyses ($1\sigma < 0.1$ $^{o}/_{oo}$) from phonolitic eruptive units of the Diego Hernández Formation (DHF) as part of an on-going study of the evolution of the Las Cañadas caldera complex on Tenerife. δ^{18}O (VSMOW) values of feldspar range from 4.7 to 6.7 $^{o}/_{oo}$ (slightly lower than previously reported) and show a positive correlation with average crystal size (mg) in units that display a range of oxygen isotope values. For example, one unit shows a linear variation of feldspar δ^{18}O values that range from 4.7 to 6.4 $^{o}/_{oo}$, and these ratios are positively correlated with average phenocryst size over a range of 0.7 to 3.6 mg. Overall, intra-unit feldspar δ^{18}O values vary by as much as ∼2 $^{o}/_{oo}$ and are lower than those predicted by fractionation of a basanitic parental magma. Additionally, δ^{18}O values show no coherent relationship with incompatible trace element abundances, an indication that the oxygen isotopic ratios are being controlled by neither fractionation nor recharge of the system by basaltic injections. However, the largest variation in oxygen isotope ratios is found in the most differentiated units, consistent with earlier suggestions that the most highly evolved phonolites may contain a component of hydrothermally-altered wall rock. We propose that oxygen isotope variation in Tenerife phonolites is being controlled by variable amounts of assimilation of hydrothermally-altered syenite country rock (δ^{18}O 0.1 - 5.8 $^{o}/_{oo}$) and that timescales between assimilation and eruption can be constrained by the oxygen isotope disequilibria shown between larger and smaller feldspar phenocrysts.

V12A-0566 1330h POSTER

Physical Parameters of Vulcanian Eruptions at Pichincha Volcano, Ecuador: Bomb Morphologies and Textures

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Vulcanian eruptions are common at many volcanoes around the world. These eruptions occur in energetic pulses and eject relatively small amounts of material. Each blast event (vulcanian eruption) has been inferred to represent a "throat-clearing" process that ejects a conduit plug. As such, we can examine the ejected material to reconstruct the conduit stratigraphy. The recent sequence of vulcanian eruptions at Guagua Pichincha volcano provides an opportunity to learn more about the dynamics of and pressurization conditions preceding vulcanian eruptions. From late 1999 - mid 2000, Pichincha experienced a series of vulcanian eruptions that ejected ballistic bombs, which now cover the surface of the crater. Bomb types range from dense to highly vesicular, with many exhibiting the breadcrusting that is ubiquitous in vulcanian deposits. Clast morphology varies with clast density, with slightly vesicular bombs having thick, glassy crusts and widely spaced cracks, whereas more vesicular bombs have thinner crusts and more closely spaced, regular crack patterns. The wide range of clast types appears to represent the stratigraphy of the conduit prior to each eruptive event, with denser blocks formed from more degassed magma near the top of the pre-eruptive conduit plug and more vesicular blocks representing deeper, less degassed levels in the conduit. This study uses the ballistic bombs, including the abundant breadcrust bombs, to learn more about conduit processes during a typical vulcanian eruption. In particular, we use the rapidly quenched crusts of breadcrust bombs, which preserve pre-eruptive conduit material, to determine gradients in volatile and crystal content in the conduit. The volatile content (both H_2O and CO_2) of the pre-eruptive melt was determined from FTIR spectroscopic analysis of bomb rind matrix glass. These values reach up to 1.2 wt% water and 10 ppm CO_2, equivalent to 15 MPa maximum recorded presusure, or approximately 600 meters maximum depth. Coincident with the volatile gradient, microlite populations in bombs with dense, glassy crusts have uniform tabular shapes, whereas microlites in bombs with vesicular rinds have more variable crystal shapes. Insight into these degassing and crystallization conditions may help us understand pressurization mechanisms for the eruptions. The differences between the ballistic bombs will provide a picture of the conduit prior to eruption.

V12A-0567 1330h POSTER

Quantifying Three-Dimensional Silicate Fabrics in Cumulates Using Cumulative Distribution Functions

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We present a new method for quantifying three-dimensional silicate fabrics and the associated uncertainties from grain orientation data on three orthogonal sections. Our technique is applied to the orientation of crystallographic features and hence yields a fabric related to the lattice preferred orientation, although the method could be applied to shape preferred orientations or strain analysis based on passive linear markers. The orientation data for each section are represented by their cumulative distribution function (CDF), and an iterative procedure is used to find the symmetric second rank strain tensor that will simultaneously satisfy the CDFs observed on each section. For samples with well-developed fabrics, this technique provides a much closer match to the sectional data than do previous techniques based on eigenparameter analysis of two-dimensional orientation data. Robust uncertainty estimates are derived from a nonparametric bootstrap resampling scheme. The method is applied to two cumulates, one with a well-developed fabric and the other with a weak fabric, from the Stillwater complex, Montana. The silicate petrofabric orientations obtained for these samples with this new method compare favorably to independent direct estimates of the volume fabric from electron backscatter diffraction and magnetic techniques.

V12A-0568 1330h POSTER

Contrasting fabrics produced during magmatic slumping and compaction of gabbroic cumulates from the Stillwater complex, Montana

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We conducted a detailed study of the textures of a 70 m stratigraphic section of gabbroic cumulates in the Upper Banded Series of the Stillwater complex, Montana. The lower cumulates have a variably developed and locally strong foliation and fine-scale modal layering alternating on scales as small as 10 cm and are interpreted to have compaction as their main fabric forming process. They are overlain by a modally uniform gabbronorite that hosts anorthositic and pyroxenitic lenses whose fabric is believed to be related to slumping of a crystal mush. This gabbronorite lacks any continuous modal layering and while it has a well-developed foliation the orientation of this fabric is not as uniform as in the lower cumulates. We characterized the fabrics of the cumulates by measuring (1) the silicate fabric on orthogonal sections of 18 oriented blocks and (2) the Anisotropy of Magnetic Susceptibility (AMS) and Anisotropy of Anhysteretic Remanence (AARM) on minicores from the blocks and from sites spaced an average of 50 cm apart. Fabric data from the blocks agrees with the AMS and AARM of their minicores. The foliation planes and lineation directions indicated by the stratigraphic sampling, show good serial correlation and provide insight into where fabric-forming processes differed. The AMS data reveal a strong change in the magnetic character of the cumulates that corresponds with the transition from modally layered to modally uniform cumulates. Samples from the upper section are more magnetically anisotropic than would be inferred from their silicate fabrics. This difference may be related to textural variations present at scales too large to be sampled by minicores.

V12A-0569 1330h POSTER

Three-dimensional fabric and texture analysis in granitic rocks using microfocus Xray-CT

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Microstructure of geomaterials, which are granular sand and/or rocks, has the three-dimensional (3D) structure associated with pore, void and crack, and these structures have induced mechanical and hydrological anisotropy. In order to construct microstructure-based geomechanics for such an anisotropic geomaterials, we need the detail 3D microstructural information. Stereologically analysis is one of estimate method for 3D structure and this method can obtain geometrical properties such as orientation, density and size distribution. Recently, Takemura & Oda (2002) have show that the geometrical property estimated by stereology is in agreement with the optical microscopic observation result using universal-stage. Stereologically method using thin section can obtain useful information about the 3D microstructure, however, it is time-consuming and tedious work. In the past decay, X-ray computed tomography (CT) is available to investigate the 3D microstructure of geomaterials (Fredrich et al., 1995; Ohtani et al., 2001). However, such a conventional X-ray CT is not enough in spatial resolution to observe individual particle and associated void in granular sand and microcrack in rock. Recently, microfocus X-ray CT was developed basis of computer technology, and this equipment can be clearly distinguished particle and microcrack even if it is a few microns in size under. In this study, we observed the 3D microstructure associated with pore and microcrack in rocks using such a microfocus X-ray CT. Using 3D image, and we can measure pore and microcrack aperture and shape under air pressure and confining pressure. Furthermore, the texture of granite expresses tensorial measurement using directional change of scanning line for reconstructed 3D image.

V12A-0570 1330h POSTER

3D X-Ray Imaging Study of Fe-Ti-Oxides of Experimental Partially Molten High-Temperature Pelite Cores

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We present 3D X-ray computer tomography of shape and distribution of oxide minerals in pelite cores which were partially molten at P = 2kbar, T = 700° C, 750° C and 800° C for different run durations (76-508hrs). X-ray absorption images were obtained of the sample in steps of 0.68 and 0.90° for a total rotation of 360°. X-ray tube conditions of 40 kV / 250 μA with a conical x-ray spot size of 5.5 μm was used. The image voxel size is 7 μm [3]. Computed tomography images are recorded in 8-bit grayscale. Image analysis was accomplished with the Aphelion^{TM} software. The results demonstrate prolific nucleation of oxides in all partial melting experiments. The original pelite sample contains a total of 2.3* 10^5 grains per 1 ccm of rock; 81.5 % of grains have a radius smaller than 20 μm. A sample melted at T = 800° C for 76 hrs contains a total number of 6.5 * 10^5 oxide grains per ccm, where the majority of grains (89.7%) are smaller than 20 μm. This demonstrates nucleation of opaque crystals for this short run condition. An experimental run at T = 750° C, and 170 hrs run duration, shows an intermediate number of crystals (total number of 4.1 * 10^5 crystals per ccm, with 85.7% smaller than 20 μm. It shows clear evidence of recrystallization; a maximum in a grain size histogram is observed for a radius of about 50 μm. The reaction leading to oxide nucleation and growth is muscovite + biotite (1) + quartz + andalusite + albite = melt + sillimanite + biotite (2) + k-feldspar + Fe-Ti-oxides at 700° C; at 800° C hercynite is also produced. These initial results demonstrate the usefulness of X-ray tomography in determining nucleation and recrystallization for experimental materials.

V12B MCC: Level 1 Monday 1330h

The Origins of Hot Spots, LIPs, Seamount Chains, and Volcanic Ridges I Posters *(joint with OS, T)*

Presiding: **G R Fouger,** University of Durham**; J H Natland,** Rosenstiel School of Marine and Atmospheric Science, University of Miami

V12B-0571 1330h POSTER

Plume or no Plume, the Case of the Siberian Trap Formation

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The generation mechanism of continental large igneous provinces, such as the Siberian Traps, are matters of recent debate, particularly their relation to mantle plumes derived from the Earth's interior. Alternative models relate the formation of large igneous provinces to bolide impacts or small-scale convection at the boundary of asymmetric lithospheres. Neither of these models is without criticism and each model cannot explain all characteristics of continental flood basalt formation alone. However, strong support for the involvement of a mantle plume comes from the observation that large volumes of basaltic melts (~3 x 10^6 km^3) erupted within a short period of time (< 1 My). Such high magma flux rates can only realistically be produced by decompression melting in the head of an uprising mantle plume. Although several areas surrounding the Siberian craton have been attributed to the Siberian Traps volcanic activity, the entire extent remains conjectural. Basaltic and gabbroic rocks occur throughout the West Siberian Basin (WSB) beneath a thick succession of Mesozoic and Cenozoic sediments. Further to the north of the Siberian craton, on the Taimyr Peninsula, are also basalt and dolerite rocks. We have obtained more than 100 samples from both areas and compared chemical data with data from the Siberian Traps. The basalts have chemical characteristics typical of fractionated, contaminated continental flood basalts (e.g. low Mg#, negative Nb anomaly). Trace element modelling suggests that the basalts represent different degrees of partial melting and crustal contamination. The major and trace element data from the WSB and Taimyr basalts show strong affinities with Siberian Trap basalts that precede the main pulse of volcanism extruded over large areas of the Siberian craton. Although the major and trace element data are consistent with a plume origin for the Siberian Traps, they cannot prove it; however, magma volume and timing constraints do strongly suggest that a mantle plume was involved in the formation of the Earth's largest continental flood basalt province.

V12B-0572 1330h POSTER

Modeling Anomalous Crustal Accretion at Spreading Zones

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The thermal and seismic structure of normal oceanic crust or anomalous crust such as Iceland depends on the mode of melt extraction from the mantle and its emplacement within or on top of the crust. We model crustal accretion by a two fold approach. In a 2D spreading model with anomalous mantle temperature beneath the ridge we solve the Navier-Stokes-, the heat tansport, the mass conservation and the melting equations to determine the enhanced melt production beneath the ridge. This melt is extracted and emplaced on top of the model to form the crust. Two cases are distinguished: a) Extruded crustal material is taken out of the model and is only advected according to the spreading of the plate, b) extruded material is fed back into the model from the top to mimic isostatic subsidence of extruded crust. We find that the feed back of case b) is only moderate. For example, if extruded crustal material as thick as 40 km is fed back into the model, the melting region is depressed downward only by as much as 10km, and the total amount of generated melt is reduced by about 20 %. On the other hand, the upper 30 km of the model is cooled considerably by several 100 degrees. A second set of models focuses on the details of crustal accretion without explicitly solving for the melting and extraction. Knowing the spreading rate, the rate of crustal production can be estimated, but the site of emplacement is not obvious. For an anomalous crust such as Iceland we define four source regions of crustal accretion: surface extrusion, intrusion in fissure swarms at shallow depth connected to volcanic centres, magma chambers at shallow to mid-crustal level, and a deep accretion zone, where crust is produced by widespread dyke and sill emplacement and underplating. We solve the Navier-Stokes-, the heat tansport and the mass conservation equations and prescribe different functions in space and time for crustal production in the four defined regions. The temperature of the imposed material depends on the source region and the process of accretion is monitored by identifying material from different source regions by a marker approach. After some time of spreading and accretion, a characteristic temperature distribution and crustal layering evolves, which is compared to observation data.

URL: http://www.geophysik.uni-frankfurt.de

V12B-0573 1330h POSTER

The Effect of a Major Change in Plate Motion on Hotspot Volcanism

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Noticeable changes in Pacific hotspot volcanic edifice construction appear to have occurred following the change in Pacific plate motion that produced the Hawaiian Emperor bend (HEB). In addition to the Hawaiian Emperor trail, the same bend is also visible in seven other seamount trails across the Pacific Basin. Shortly after the HEB, volcanic edifice construction abruptly decreased along the Hawaiian trail, followed by a gradual increase over the next 10 myrs. Whereas, after the bends in the three collinear Marshall-Gilbert-Tuvalu trails and the two Tokelau trails, edifice construction completely stopped and never restarted. In contrast, after the bend in the Louisville trail, which was only a slight bend because of its distance from the stage pole, volcanic edifice construction actually increased. After the bend in the Tuamoto trail, which formed close to the spreading ridge, the Tuamoto plateau was emplaced. Modern hotspot volcanism appears to be located in upwelling regions formed between upper mantle rolls that are visible as geoid undulations, which are aligned parallel to plate motion. Assuming that plate motion parallel upper mantle rolls were also