

V52D-09 1550h INVITED

Melt Distribution and Magma Plumbing Beneath Ridges

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Efforts to image magmatic systems beneath oceanic ridges focus on several broad issues: The geometry of mantle flow and the distribution of melt in the mantle; the structure of crustal magma bodies; and the nature of the plumbing system that connects the mantle source region with sub-crustal and crustal reservoirs. To address these issues, a variety of geologic settings are studied that differ markedly from one another in terms of spreading rate, magma flux, and the near-axis thickness of the lithosphere. A review of the available results provides insight to the relations between geologic setting and the subsurface structure of magmatic systems.

Where the near-axis lithosphere is both thin and of uniform thickness along the ridge it is apparent that the organization of volcanic features is closely related to the deeper roots of magmatism. This is most evident at the fast-spreading East Pacific Rise, where we have been able to correlate variations in axial depth, seafloor subsidence rates, seamount distribution, morphologic segmentation of rise axis features and hydrothermal venting with the seismic signatures of melt retention at mantle depths. At this end-member of volcanic activity – located where the lithosphere is nearly absent – surface features inherit characteristics of scale from melt transport phenomena originating in the mantle. Seismic constraints on what governs this organization are thus far equivocal, providing a challenge for integrating geophysical results with other data and models.

In contrast, where the near-axis lithosphere is relatively thick and variable, such as the Mid-Atlantic Ridge, volcanic features are less directly related to melt transport processes originating in the mantle. At the regional scale the geometry of the plate boundary influences the thermal structure of the melting column, thus enhancing melt production beneath the relatively thin lithosphere at segment centers. At the local scale, tomographic images and the distribution of axial seismicity indicate that a melt supply originally focused toward a segment center may be redistributed along axis by lithospheric stresses. At the other end-member of ridge volcanic systems – located where the lithosphere is thick and variable – surface features inherit their characteristics from a combination of mantle and lithospheric processes.

The challenges to understanding further the seismic and physical structure of magmatic systems are several: We are just beginning to grapple with the competing effects of seismic anisotropy – induced by crystal texture or melt topology – and heterogeneity. As expected our estimates of physical properties (e.g., melt fraction) are dependent on our knowledge of seismic anisotropy and its causes. Regions of thick and variable crust pose persistent challenges to imaging, requiring the design of novel experiments or new methods capable of resolving lower crustal structure. Few seismic studies of magnetically active regions utilize waveform information, in part because of the degree and scale of heterogeneity and the resulting complexity of the wavefield. Lastly, and particularly promising, seismic data needs to be used more frequently to test directly the predictions of geodynamic models.

V52D-10 1605h INVITED

Physical effects of mantle melting beneath western U.S.

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From a geophysical point of view, the creation and segregation of mantle basaltic melt is important seismically and geodynamically.

Seismically, small amounts of partial melt reduces P and (especially) S velocities by great amounts (relative to common belief). Thus imaged velocity variations at depths of 100-200 km may be caused by small (<1%) melt fractions. Beneath the Yellowstone swell, we have seismic evidence for partial melt to about 200 km depth under the hotspot track, and basalt-depleted residuum under the swell away from the track. We also have seismic evidence for large volumes of basalt emplaced at the base of the crust and in the mid crust beneath the hotspot track. Beneath the southern Rocky Mountains we have seismic evidence for partial melt extending to about 200 km depth within what is thought to be Precambrian North America lithosphere modified during the Laramide orogeny.

Geodynamically, the residuum created by basalt removal can have important geodynamic effects. In particular, because the residuum is relatively buoyant and viscous, it has the long-term effect of making and stabilizing the lithosphere, causing uplift, and controlling asthenosphere flow (e.g., the location of upwelling and hence melting). All these effects are thought to be represented in Yellowstone swell structure and behavior.

V52D-11 1620h

The (generally) Glassy Rocks Revisited: Deciphering The Scales of Open and In-situ Processes From Styles of Compositional Zoning in Volcanic RocksGeorge W Bergantz¹ (bergantz@u.washington.edu)Olivier Bachmann¹ (bachmann@ess.washington.edu)¹Dept. Earth Space Sciences, Box 351310 University of Washington, Seattle, WA 98195, United States

N.L. Bowen clearly understood the importance of 'glassy' rocks as those, "... of which we can say with complete confidence that they correspond in composition to a liquid." (Chap. VIII, The Evolution of Igneous Rocks). He also understood that the compositional clustering of broadly granitic compositions presents an inherent ambiguity as to whether one arrived there coming up or down in temperature (Hayden Medal address, 1953). Work since Bowen's life reveals that both in-situ and open system behavior are fundamental parts of the evolution of a magmatic system, but the processes by which magmas differentiate and interact, as well as the time scales involved, remain poorly known.

Erupted rocks show different styles of compositional zoning (see Hildreth, 1981 for a classification), which are thought to arise from (1) stratification in magma chambers due to in-situ differentiation, and/or (2) encounter of unrelated magma batches shortly prior to eruption. When combined with estimates of residence times, the style of compositional zoning emerges as a previously unused constraint to decipher magmatic processes in the upper crust. For example, a silicic cap generated in-situ can be an ephemeral feature that may only form during a period of significant rheological contrast between the forming cap and the dominant volume. Formation of a silicic cap may also require the absence of convection in the dominant volume, in order to prevent re-assimilation of the cap. Conversely, near-linear gradients in trace elements, isotopes and temperature observed in high-SiO₂ rhyolites do not preclude convection of the whole layer. These results suggest that the popular notion of sidewall convective fractionation leading to a cap over a dominant volume of low-crystallinity may need reevaluation. We will detail alternative hypotheses for the origins of a cap, and more generally in-situ stratification, that are in agreement with repose times, cooling rates and the compositions of co-eruptive sequences. Two of these are the 'rhyolite rain' and volatile over-pressure models. We will also illustrate the conditions by which open-system processes can lead to a persistent stratification, why the largest known pyroclastic deposits (Monotonous Intermediates) are characterized by an absence of gradients in the eruptive products, but a bewildering complexity in textures and crystal zoning, and why plutons often fail to display the extent of stratification seen in volcanic sequences.

Ref: Hildreth, W., (1981), Gradients in silicic magma chambers: Implications for lithospheric magmatism: *Journal of Geophysical Research*, v.86, p.10,153-10,192.

V52D-12 1635h

The Glassy Rocks: Quantifying Petrogenesis Via Melt Physics

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In "The Evolution of the Igneous Rocks", Norman Levi Bowen dedicated a small but succinct chapter to "The Glassy Rocks". His principle points involved the value of variation diagrams from glassy sample sets, their value as proof of liquid origin of igneous compositions, and the unavoidable loss of volatiles during their petrogenesis. In that chapter, and also quantified from his 1934 AGU abstract(!), it seems clear that Bowen was aware of the fundamental nature of igneous glasses as supercooled liquids and of the wide range of glassforming ability represented by the range of chemical composition of igneous rocks. With that insight the principles for the evaluation and quantification of the role of the glassy state in preserving evidence of petrogenetic and volcanic processes had a reasonable starting point for investigation. Nevertheless the significance of melt physics in particular for the quantification of the glassforming process in an igneous context was not vigorously pursued with any significant degree of success until some 50 years after the book. In the meantime, quantification of the glassy state had reached a stage where experimental and predictive methods for quantification of the final petrogenetic stages of vitrophyric rocks was overdue. Today we are in the favorable position that predictive models for many of the most relevant melt properties either exist, or will be within our grasp in the next decade. Similarly, quantification of the glassforming process is being pursued with considerable predictive success. The former allows petrogenetic models of all igneous rocks to

be accompanied by increasingly reliable melt physical constraints whereas the latter affords a quantification of the partitioning of liquid and solid values of thermodynamic properties for melts during the cooling of glassy rocks, as well as all other occurrences of glass in rocks (e.g. melt inclusions, glassy rinds, etc.) Further, such quantification has led to 1) a profound improvement in the interpretation of experimental petrology and geochemistry, and 2) the remarkable conclusion that the glass transition may lie at the heart of explosive volcanism. I speculate that the spirit of this utterly physico-chemical approach to the molten and glassy states in igneous petrogenesis would have greatly appealed to the father of the physico-chemical approach to petrology itself - Norman Levi Bowen.

V52D-13 1650h

Volatile Constituents and Vapor Saturation: Integrating Petrologic and Remote Sensing Perspectives to Understand Magmatic Volatile Budgets

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Over the past 25 years there has been a growing body of evidence based on petrologic, remote sensing, and volcanic gas data that andesitic, dacitic, and rhyolitic magmas in crustal reservoirs are saturated with a multicomponent C-O-H-S vapor phase before eruption. A key piece of evidence for magmatic vapor saturation is the excess S problem: the common observation that much more S is released by explosive eruptions than was originally dissolved in the erupted volume of silicate melt. If all of the excess S is derived from a magmatic vapor phase, then intermediate to silicic magmas must commonly contain several wt% exsolved vapor prior to eruption. The large amounts of volatiles implied by these estimates suggest that exsolved vapor accumulates in the apical regions of magma bodies during repose periods between eruptions. Isotopic studies of S and CO₂ in intermediate to silicic magmatic systems show that these volatiles are largely mantle-derived and are not dominantly related to crustal assimilation. The ultimate source of S and CO₂ in these systems must therefore be from mafic magma because it is well established that silicic magma reservoirs are created and sustained through long-term replenishment by mantle-derived basaltic magma during inter-eruption repose periods. Andesitic, dacitic, and rhyolitic magmas in crustal reservoirs are probably vapor saturated due to recharge and underplating by vapor-saturated basaltic magma. In this regard, vapor saturation in intermediate to silicic magmas can be viewed as a consequence of the relatively high CO₂ concentrations of basaltic magmas coupled with relatively low CO₂ solubility in silicate melts at crustal pressures. Understanding budgets of the major volatiles requires integrating remote sensing and volcanic gas data on fluxes of CO₂, SO₂, and H₂S from volcanoes with petrologic data on temperature, pressure, oxygen fugacity, and dissolved volatiles in both differentiated magma stored in crustal reservoirs and mafic magma recharging these systems. Comparison of repose times, eruptive volumes, and basaltic magma supply rates for a spectrum of volcanic systems suggests that the flux of S, CO₂ and H₂O from explosive eruptions is approximately balanced by the mantle-derived supply rate of these volatiles provided by mafic recharge into the crust. The importance of mafic recharge in supplying volatiles is exemplified by cinder cones surrounding Popocatepetel volcano in central Mexico. Olivine-hosted melt inclusions from these cones contain 1000-6000 ppm S, indicating that mafic magma recharging into the Popo system provides an abundant source of S that may explain the very large SO₂ emissions from the current eruption.

V61A MCC: Hall C Saturday 0830h

Evolution of the Igneous Rocks 2002 Edition III Posters (joint with OS, P)**Presiding:** B R Edwards, Dickinson College; H Guetschow, University of Washington

V61A-1342 0830h POSTER

A new approach to thermodynamic modelling of peridotite melting in synthetic and natural systemsPaula May Smith¹ (psmith@esc.cam.ac.uk)

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Parameterisations of peridotite melting have been very important in understanding magma generation in various tectonic settings. Most have made simplifying assumptions that limit their applicability. As the available experimental data set and computer power increase rapidly an accurate model of (near) fractional melting over a range of P, T and source composition is becoming a realistic possibility. We are developing software for a new thermodynamic model of peridotite melting, with the principal aim that the scheme can easily accommodate new data as it becomes available.

Numerous previous thermodynamic models exist for synthetic systems with limited components. Often these cover a very wide composition space but are limited to 1-atm. In contrast, the widely used models of Ghiorso & Sack (1995; MELTS) and Ghiorso (1998; pMELTS) for the natural system extend over a wide range of pressures and concentrate on a relatively restricted range of compositions. Our intermediate approach is for peridotite melting only but the calibration is suitable for synthetic and natural systems. Although simultaneous modelling of synthetic and natural systems may not be possible, calibration of systems with fewer components should give useful estimates of parameters for the natural system.

The software we present here has several features designed to overcome known problems with MELTS and pMELTS, as well as difficulties encountered in previous work in CMAS (Smith & Holland 1999; AGU abstract) and also to make maximum use of the data and error estimates. A 'forward' model calculates P, T, and composition of coexisting phases for a given set of parameters by optimising the fit to the bulk composition subject to a set of energy and mass balance constraints. Interaction parameters for phases that exhibit solution are derived by minimising the misfit between calculated and observed P, T, and composition (the 'inverse' model). Pure phase end-member data may be varied, if necessary, and additional end-members added. Non-ideality in solution phases may be described by regular or sub-regular models or approximated empirically; this should allow the flexibility of a 'speciation' model without the large number of required parameters. The forward model could be easily incorporated in adiabatic decompression calculations, such as those of Asimow et al. (1997).

V61A-1343 0830h POSTER

Disaggregation of Partially-Molten Materials

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We use a two-dimensional finite-element technique to model the elastic deformation of an individual grain in a partially-molten polycrystal under stresses induced by pore fluid or applied remotely. The model is used to estimate the stress required to allow melt in a network of grain-edge channels to penetrate along the surfaces of contact between adjacent grains under conditions of volumetric expansion by comparing the energy available in elastic deformation to the work necessary to destroy the grain boundary. Such a process may lead to the formation of a high-permeability path for melt extraction through interconnected melt lenses lying between the faces of adjacent grains. The model is also used to estimate the rate of diffusive creep resulting from the applied stresses.

For comparison, we obtain an estimate of the stresses involved in magma solitary-wave flows from a mixture theory of compacting flows. Given material properties for olivine under upper-mantle conditions, these stresses are found to be much too small to lead to disaggregation for solitary waves of reasonable amplitude, indicating that magma solitary waves cannot give rise to disaggregation by this mechanism. We discuss the implications of these results for studies of melt extraction.

V61A-1344 0830h POSTER

Interaction of dissolution channels with a crystallization front in the shallow mantle beneath mid-ocean ridges

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Focusing of melt from a broad melting region beneath mid-ocean ridges to a narrow zone of igneous crustal accretion is still not well understood. Sparks and Parmentier [1991], however, suggested one promising explanation for this process whereby crystallization of melt in the thermal boundary layer beneath the plates forms a sloping permeability barrier along an isotherm which leads to the development of a high porosity channel beneath it. Melt flows along the channel toward the ridge. Crystallization, however, also consumes melt, which is then incorporated into the lithosphere rather than flowing to the ridge. Chemical disequilibrium between mid-ocean ridge basalts and shallow mantle peridotites also indicates that melt is present in focused channels that are chemically isolated from surrounding mantle. One proposed mechanism is formation of high porosity dunite channels, by dissolution of pyroxene in ascending, olivine-saturated melt. By increasing the local melt flux and sheltering part of the melt from thermal equilibration with the surrounding mantle, such channels might be able to "puncture" the crystallization front. On the other hand, crystallization reduces the permeability and may force focused flow in channels to become increasingly diffuse downstream.

We present preliminary numerical models of buoyancy-driven melt transport in the mantle in which a dissolution zone - where high porosity channels form - is overlain by a crystallization zone. In models with a horizontal crystallization front, channels become diffuse where they enter the crystallization zone. Where the crystallization front is inclined, most of the melt migrates diagonally upward in dissolution channels that originate beneath the front. However, if the slope of the crystallization front is small, porosity waves also develop in the crystallization zone. Ongoing work will characterize how the rate of crystallization and the slope of the crystallization front influence the flow geometry, and how much of melt reaches a ridge axis, versus how much crystallizes.

V61A-1345 0830h POSTER

Effects of Dynamic Assimilation: Mineral Dissolution Controlled AFC Paths

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If N.L. Bowen were alive today, he would probably be conducting experiments aimed at understanding one of the great unresolved challenges of igneous petrology: documenting the time scales of non-equilibrium, magmatic processes. Over the last 20 years thermodynamicists (Ghiorso and Sack, 1995) have developed models that compute liquid-solid equilibrium for a broad range of silicate melt compositions undergoing crystallization processes such as assimilation. Unfortunately, the equilibrium world neglects one variable that is critical to a dynamic world - time. The marriage of equilibrium thermodynamics with time-dependent processes occurs within the field of irreversible thermodynamics a field petrologists have ventured into via laboratory experiments aimed at documenting the rates at which minerals react with silicate liquids (e.g., Donaldson, 1985). Such experiments, documenting the temporal effects of magmatic reactions, are critical for the future progress of our science.

As a first step toward understanding the effects of dynamic assimilation, we developed a simple model for predicting rates of mineral dissolution using the thermodynamic potential affinity. The dissolution rate data used in the model was only slightly modified, for geometric consistency, from the reported raw experimental data. The affinities for the dissolution reactions were calculated using the reported experimental conditions as input to the MELTS software. We developed a linear predictive model based on direct comparison of the modified reaction rates and the calculated affinities.

Our model for predicting rates of mineral dissolution, when paired with the MELTS thermodynamic database, predicts the time scales of crystallization and cooling due to dissolution-controlled assimilation. We have applied the model to examine the development of peralkaline magmas at Hoodoo Mountain volcano via AFC processes acting on an AOB parental magma. Given broad age constraints on the formation of the volcano (80 ky), the time scales of the crystallization process predicted by the model are within geological constraints. Rates of mineral dissolution, compared to rates such as magma transport, rates of crystal growth, and rates of chemical diffusion, dictate that mineral dissolution is an important process in many igneous systems. Models for mineral dissolution may also find application in studies of transport of magma in the mantle, where porosity and melt composition may be controlled by rates of mineral dissolution.

Donald CH 1985 Min Mag 54: 67-74
Ghiorso MS, Sack RO 1995 CMP 119: 197-212

V61A-1346 0830h POSTER

A Stochastic Evaluation of the Dynamical and Thermal Response of the Lower Crust to Progressive Basaltic Input: Applications to MASH Zone Dynamics

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Basalt-crust interaction is typically posited as the emplacement of large mafic bodies within and below the crust. However field work (Ivrea, elsewhere) and our recent numerical modeling suggests that this end-member may not be the primary means by which basalt-crust interaction produces petrologic diversity. We propose that progressive basalt diking in the deep crust, overlapping in space and time, is responsible for variable compositions of mixed magmas that share a common locus in the upper crust. Based on geological observations and numerical modeling we demonstrate that the prograde process consists of at least three stages. The fundamental control on the stages is the rate at which rheological contrasts propagate both vertically and horizontally in the heated crust as a consequence of dike injection. The three stages are: 1) Temporally and spatially variable, overlapping, basalt diking that leads to local melting, limited chemical exchange, and the initiation of the reduction in the viscosity contrast of the combined basalt-crust system. Ascending crustal melts from this stage, while mixing (with themselves), may not be very contaminated by mantle material. 2) If diking continues stage two is reached: collapse of this network of basalt dikes of various ages, and the surrounding ductile and partially molten crust. This is a process of slow overturn and mixing, and it is in this stage that hybridization is initiated by non-periodic chaotic advection. 3) Subsequent mafic arrivals may have difficulty penetrating this region of mixed magmas and stall below or within them. This yields larger bodies of mixed magma that are volumetrically dominated by the mafic compositions. Steps (1)-(3) may exist simultaneously at different levels in the crustal column, as the prograde thermal anomaly propagates upward on a variable schedule.

We demonstrate these stages with dynamic heat and mass transfer numerical simulations of combined diking and crustal melting. Since the intrusive progression is not well constrained by direct observations, and has many degrees of freedom, we have adopted a Monte Carlo approach. This involves many realizations with random timing between diking episodes, orientations, sizes and numbers of dikes. We also consider a range of protoliths, paying careful attention to the melt-fraction to temperature relations. We are thus able to consider the statistical significance of a wide range of possible outcomes, as constrained by the total amount of mantle input and the composition of the crust. Modeling reveals the statistical likelihood of the range of possible outcomes - from distributed diking that never reaches stages (2) or (3), to localization of the process producing a focused MASH (mixing-assimilation-storage-homogenization) zone.

V61A-1347 0830h POSTER

Crystal textures as recorders of magmatic processes: Ngauruhoe Volcano, New Zealand

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Magmas in arc volcanic systems can, and commonly do, have complicated differentiation histories, involving open system processes such as magma mixing and assimilation of crust. Further, many arc magmas are disequilibrium mixtures, in which individual components had disparate early histories. Whereas whole-rock chemical and isotopic analyses of lavas and tephra are useful for obtaining general information on the types of processes occurring, they cannot resolve the details of those histories. Recent advances in micro-analysis of plagioclase textures (e.g. Davidson and Tepley (1997) and Ginibre et al. (2002a, 2002b)), using Sr isotopes and calibrated BSE imaging coupled with trace element analyses, respectively, allow access to the detailed magmatic record preserved in phenocrysts.

Ngauruhoe Volcano in the Taupo Volcanic Zone (TVZ), New Zealand is a young, frequently active composite cone, with abundant evidence for the involvement of open system processes in magma evolution.

$^{87}\text{Sr}/^{86}\text{Sr}$ varies by as much as .001 among phases in a single lava; this range is nearly as broad as the observed range in $^{87}\text{Sr}/^{86}\text{Sr}$ for the entire suite of whole rock analyses for this volcano. Whole-rock chemical data do not lie along experimentally derived cotectics, but rather along a mixing line between a high alumina basalt composition and compositions near the system eutectic. The presence of high-An plagioclase hosted within groundmass of rhyodacitic composition provides further evidence for mixing.

Calibrated BSE images of plagioclase crystals indicate a large variety of zoning patterns, some with highly calcic cores ($>\text{An } 85$), and some without. Dissolution horizons are ubiquitous in the crystal record. Trace element concentrations across these unconformities can be used to gauge whether a particular dissolution event was likely initiated by magma recharge or by local changes in P,T, or water content of the crystals immediate environment due to convective transport through a magmatic system.

V61A-1348 0830h POSTER

Intensive Variables in Primary Kimberlite Magmas (Lac de Gras, N.W.T., Canada) and Application for Diamond Preservation

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Crystallization temperatures (T) and oxygen fugacity (fO₂) are not well constrained for kimberlites. Knowledge of these intensive variables of kimberlite melt is important for understanding the origin and evolution of kimberlites and prediction of diamond preservation in the magma. Difficulties in interpreting the equilibrium mineral assemblages in kimberlites and the high degree of secondary alteration usually complicate use of mineral geothermometers and oxygen barometers. Some of Lac de Gras (N.W.T., Canada) kimberlites are extremely fresh and provide opportunity to apply mineral thermobarometers. The presence of numerous chromite inclusions in the rims of olivine phenocrysts allows application of the olivine-spinel thermometer and oxygen barometer to constrain T and fO₂ of the melt.

We performed T and fO₂ calculations on samples from three kimberlite pipes the Leslie, Aaron and Grizzly. The T obtained from olivine chromite pairs for crystallization of olivine phenocryst rims are 1050° to 1100°C ± 50°C (calculated at 1 GPa). Few olivine chromite pairs from Leslie and Grizzly record higher temperatures of 1250° - 1350°C. The cores of olivine phenocrysts usually lack chromite inclusions and their crystallization T and fO₂ could not be estimated. The fO₂ recorded by coexisting olivine and chromite are +0.3 to 1.0 ± 0.4 log units more oxidized than the nickel-nickel oxide (NNO) buffer. The established fO₂ of kimberlites would require fO₂ in their mantle source to be higher than that of cratonic mantle and oceanic lithosphere producing MORBs but comparable to the source of subduction-related magmas.

The T and fO₂ for the Lac de Gras kimberlites constrain the path of any mantle material entrained in these magmas in fO₂-T-P space and provide limits on diamond destructive processes. Diamonds are not stable in kimberlite magma and are oxidized to CO₂ or converted into graphite. The former process is more favorable for their preservation. The results of out thermo-barometric calculations show that at any pressure the Lac de Gras kimberlites were above the Graphite (Diamond)-CCO buffer. Diamonds entrained in these kimberlites were moved into stability field of CO₂ without graphitization, favoring better preservation of diamonds.

V61A-1349 0830h POSTER

A Re-appraisal of Olivine Sorting and Accumulation in Hawaiian Magmas.

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Bowen never used the m-words (magma mixing) in his highly influential book *The Origin of the Igneous Rocks*. Yet, in the past 20-30 years, magma mixing has been proposed as an important, almost ubiquitous, process at volcanoes in all tectonic environments ranging from oceanic basalts to large silicic magma bodies, and as the possible trigger of eruptions. Bowen regarded Hawaiian olivine basalts and picrites as the result of olivine accumulation in a lower MgO magma that was

crystallizing and fractionating olivine. This, with variants, has been the party line ever since, the only debate being over the MgO content of the proposed parental magmas. Although magma mixing has been recognized as an important process in differentiated, low-MgO (below 7 percent), Hawaiian magmas, the wide range in MgO (7-30 percent) in Hawaiian olivine tholeiites and picrites is invariably attributed to olivine crystallization, fractionation and accumulation. In this paper I will re-evaluate this hypothesis using well-documented examples from Kilauea, Mauna Kea and Mauna Loa that exhibit well-defined, coherent linear trends of major oxides and trace elements with MgO. If olivine control is the only factor responsible for these trends, then the intersection of the regression lines for each trend should intersect olivine compositions at a common forsterite composition, corresponding to the average accumulated olivine in each of the magmas. In some cases (the ongoing Puu Oo eruption) this simple test holds and olivine fractionation and accumulation can clearly be shown to be the dominant process. In other examples from Mauna Kea and Mauna Loa (1852, 1868, 1950 eruptions, and Mauna Loa in general) the test does not hold, and a more complicated process is required. Additionally, for those magmas that fail the test, CaO/Al₂O₃ invariably decreases with decreasing MgO content. This should not happen if only olivine fractionation and accumulation are involved. The explanation for these linear trends that approach, but fail to intersect, appropriate olivine compositions is a combination of magma mixing accompanied by olivine crystallization and accumulation. One of the mixing components is a high-MgO (about 13-15 percent) magma laden with olivine phenocrysts and xenocrysts and the other is a consanguineous low-MgO (about 7 percent) quasi steady-state magma, with a prior history of clinopyroxene and plagioclase fractionation.

V61A-1350 0830h POSTER

Shallow fractionation signature of phase chemistry in Taburiente lavas, La Palma, Canary Islands: Results of MELTS modeling

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Depth of crystal fractionation influences the chemical evolution of ocean island basalts and has significant implications for the physical structures of these volcanoes. In contrast to dominantly shallow systems such as Hawaii, a range of fractionation depths have been reported for Canary Islands lavas. Magmas erupted on La Palma preserve fluid- and melt-inclusion evidence for high-pressure (> 10 kbar) crystallization (Klügel et al., 1998; Hansteen et al., 1998; Nikogosian et al., 2002). If high-pressure fractional crystallization were an early and dominant process, it would generate specific patterns in rock and phase chemistry of eruptive sequences.

Alkalic basalts from Taburiente volcano display coherent major element trends consistent with evolution dominated by fractional crystallization while their phenocryst compositions, trace elements, and isotopic trends require mixing between multiple sources. The current model confirms the importance of both fractionation and mixing to achieve the full range of lavas observed.

A low-pressure (1 kbar) thermodynamic fractional crystallization model performed with the MELTS (Ghiorso and Sack, 1995) software closely reproduces major element trends from two stratigraphic sequences. This model also predicts the observed sequence of groundmass clinopyroxene compositions and phenocryst zoning reversals. In all low pressure simulations, olivine remains a modally significant liquidus phase during the first 20% and last 30% of the crystallization sequence, resulting in a negative correlation between the CaO and F_o content of olivine. These results are consistent with the presence of olivine phenocrysts that bear petrographic evidence of early crystallization, as well as observed compositional trends of groundmass olivine and clinopyroxene in Taburiente lavas.

MELTS models that include an initial period of high pressure (12 kbar) clinopyroxene fractionation produce major element trends comparable to the low pressure model, but also produce high modal volumes of low CaO, high MgO clinopyroxene that are not observed in sections we studied. Removal of such a large quantity of clinopyroxene from the liquid increases the TiO₂ and CaO of later-crystallized clinopyroxene to concentrations not observed in our studied sections, and restricts the MgO and FeO* to smaller ranges than observed. Olivine fractionation is restricted to short duration and low abundance late in the crystallization sequence, which is not evident petrographically.

The total compositional range of clinopyroxene and olivine crystals observed throughout this suite of rocks is larger than any generated by a single-source MELTS model. Combined with stratigraphically controlled Pb isotope variations it indicates magma mixing and fractionation at low pressures dominates the petrologic diversity in these sections.

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Nikogosian, I.K., Elliott, T., Touret, J.L.R., 2002. *Chem. Geo.* 183, 169-193.

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V61A-1351 0830h POSTER

Constraints on Geochemistry and Melt Volumes from Metapelite and Metadiorite Partial Melting Experiments

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In this study we present the results from a series of partial melting experiments conducted on fertile metapelite and mafic metadiorite representative of the middle and lowermost crust to determine: (1) the controls on major and trace element geochemistry of the melt phase, (2) the initial trace element concentration of the reactant phases and their influence on melt composition and (3) to compare the effect of static versus dynamic conditions on total melt volume.

Results show that the modal proportion of the reactant phases and the extent of reaction is the principal control on major and trace element geochemistry. However, product phase composition contributes to the small-scale variation observed in melt chemistry as a function of temperature. The initial REE signature in the melt is controlled by trace element abundance of the reacting phases, associated micro-inclusions, and REE mineral sinks (e.g. garnet).

Partial melt volumes from the metadiorite, conducted under static conditions are low (< 2% up to 900°C increasing to 12% at 925°C) compared to the metapelite experiments (<5% at 740°C increasing to 15-20% at 850°C). These results suggest that mafic lowermost crust can remain rheologically strong, however metapelitic-bearing middle to lower crust will be inherently weaker during orogenesis.

Initial major and trace element partial melting signatures are later modified by the mechanisms of melt segregation and the nature of the transport path which influence the degree of equilibrium achieved between melt and source residue. The degree of modification will ultimately depend on tectonic environment.

V61A-1352 0830h POSTER

Experimental Constraints on Magma Ascent During the Usu 2000 Eruption, Japan

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The rate of magma ascent is important in determining eruption mechanisms. One way to estimate such rates is to reproduce volcanic pumice textures by decompression experiments, although such studies are few. Such experiments are under progress on the phreatomagmatic eruption of Usu volcano on 31 March 2000. Geophysical observations of this eruption revealed that the magma reached below West Nishiyama (0.5-2 km deep), the western foot of Usu volcano, after rising from depth beneath the summit without a change in ascent speed.

A previous study (Reference) gave constraints on the timing of vesiculation, crystallization, and gas separation during ascent. The erupted magma was compositionally homogeneous. Variable vesicularity resulted from different times of quenching. Micropumices were quenched in various depths by aquifer (at 200m depth for deepest one), whereas pumices were not quenched. All juvenile material have similar groundmass micro-lite contents and types. Number density of bubbles in juvenile fragments first increases with vesicularity, and then decreases. Changes in the bubble size distribution may indicate variable nucleation events or rates.

We are carrying out isobaric and decompression experiments in order to constrain conditions of the Usu eruption. Isobaric experiments constrain the pre-eruptive conditions of the magma. It is estimated that water pressure was less than 150 MPa at 900C and less than 200 MPa at 850C, based on the criterion that all phenocryst phases (Pl, Opx, Mt) are stable. Once pre-eruptive conditions are verified, decompression experiments will be carried out to replicate the bubble and microlite textures as a function of ascent rate. Furthermore, this study will evaluate the effect of crystals

on bubble nucleation in order to explain the changing manner of bubble nucleation.

(Reference) Suzuki, Y. and Nakada, S., 2002, Bull. Volcanol. Soc. Japan, in press.

V61A-1353 0830h POSTER

Crater Flat, Nevada: An Experimental Investigation of Petrology and Magma Ascent

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The close proximity between the polycyclic volcanic belt of Crater Flat, Nevada, and the proposed Nuclear Waste Repository at Yucca Mountain has increased the interest for a better understanding of volcanic eruptions and magma ascent rates in the region. All three cycles of volcanism have produced hawaiitic tephra and lava flows with limited bulk compositional variation within the erupted magmas. Therefore, samples collected from the Lathrop Wells volcanic center, which is the youngest (30,000 yrs, Shepard et al., 1995) and least evolved (Mg# = 54) of the three erupted cycles, were chosen as an appropriate starting material. Olivine is the dominant phenocryst in all of the erupted units, however, in one of the intermediate cycle erupted units, Little Cone NE, rare amphibole phenocrysts coexist with olivine. These Little Cone NE lavas also contain microphenocrysts of plagioclase and Fe-Ti oxides (0.1 - 0.35 mm) that are larger than the surrounding ground mass, which consists of olivine, plagioclase, clinopyroxene, and Fe-Ti oxide.

Phase equilibria experiments were carried out in T₂M pressure vessels at temperatures of 950 - 1050°C for pressures ranging from 70 - 200 MPa ($P_{total} = P_{H_2O}$) at a constant fO_2 just below QFM, in order to determine the amphibole stability field and phenocryst-melt pre-eruptive equilibrium conditions. At $P_{H_2O} = 200$ MPa, 1015°C, down to $P_{H_2O} = 100$ MPa, 1045°C, olivine is the lone liquidus phase. The composition of the residual melt that is in equilibrium with olivine is hawaiitic, and ranges from Mg# = 46 - 51 with a ratio of CaO/Al₂O₃ = 50. These values are consistent with analyses of 19 melt inclusions found in olivines from Lathrop Wells tephra. At $P_{H_2O} = 200$ MPa, amphibole begins to crystallize upon cooling to T < 980°C, followed by the crystallization of plagioclase and clinopyroxene at lower temperatures. Upon decompression to 175 MPa at 975°C, amphibole and olivine coexist along with plagioclase (An = 68). At $P_{H_2O} = 100$ MPa plagioclase begins to crystallize, after olivine, at 1025°C, followed by clinopyroxene at 1010°C, and finally by amphibole at 965°C. The stability field of amphibole terminates at $P_{H_2O} = 90$ MPa at 950°C, and coexists with more Na-rich plagioclase (An = 60).

All of the amphiboles found at Little Cone NE have developed reaction rims with little variation in thickness (70±5 μm). This reaction takes place due to the loss of water during magma ascent to the surface. Initial results from preliminary isothermal decompression experiments with 2-4 day intervals outside the amphibole stability field have produced amphiboles lacking the development of a typical fine grained reaction rim. This leads us to assume that either the low viscosity of the melt causes the reaction products to recrystallize or that kinetics of the breakdown reaction require a longer decompression time, which correlates to a very slow magma ascent rate.

V61A-1354 0830h POSTER

Pre-eruption Conditions and Magma Dynamics of Recent Amphibole-Bearing Etna Basalt

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An intriguing aspect of the recent eruption of the Etna is the unexpected occurrence of amphibole crystals with breakdown rims in the early erupted magma. Amphibole was common in ancient (>15 Ka) intermediate to evolved Etnean products, but with the exception of rare relics reported in the hawaiite feeding the 122 BC Plinian eruption, amphibole has not been described in the recent volcanics. The presence of amphibole poses several questions about possible changes on the Etnean magma feeding system and the consequences upon eruptive style and hazard. Using analyses of the erupted material and hydrothermal experiments, we have attempted to constrain the physico-chemical conditions under which am-

phibole crystallizes in recent Etnean magmas. Experimental runs have been performed in a T₂M apparatus between 950 and 1035°C of temperature and in the pressures range 50-200 MPa using a natural sample of the amphibole-bearing lava as a starting material. This rock is a trachybasalt with a low abundance of phenocrysts of diopside (cpx), olivine (ol) (Fo83-75), plagioclase (pl) (An83-49), Mg-hastingsite-kaersutite amphibole (amph) and Ti-Magnetite (mt) ($X_{MSP} = 37-46$). 5-10 wt% of water was added to each sample to assure the saturation at the pressures of interest. The fO_2 was controlled by a CH₄-Ar pressurizing gas mixture set to maintain the charge under the NNO buffer. Experimental runs produced samples with a crystal content variable from 5 to 40%. Cpx and mt ($X_{MSP} = 03-31$) are ubiquitous in all the investigated P-T range. At P=140 MPa pl (An57-90) is stable in addition to cpx and mt, but only at T < 980°C, whereas at lower pressure it crystallizes at all temperatures in the investigated range. At his same pressure, ol (Fo82-76) appears at a significantly higher temperature (T>1024°C). Amphibole crystallizes at T<1000-995°C and H₂O pressures >75 MPa. Experimental amphiboles range from pargasite to Mg-hastingsite with less frequent kaersutite crystals; they have a lower silica and an higher alumina content than those measured in natural samples. Experimental glasses in equilibrium with cpx, mt and ol plot along the liquid line of descent observed for natural historical magmas. However, the appearance of the amphibole on the liquidus, induces a significant shift toward compositions with lower MgO-FeO_{tot} and CaO-Al₂O₃ ratios. These compositions were not measured neither in the residual natural glasses, nor in glass inclusion in minerals of recent volcanics. The above preliminary data suggest that some fine-tuning of physico-chemical parameters for the magma (e.g. fO_2) must be still be done in order to reproduce the natural assemblage and the abundance and compositions of minerals observed in natural samples. However these refinements will not significantly modify the field of amphibole stability in these magmas. The crystallization of the amphibole only below 1000°C is in striking contrast with the supposed eruptive temperature (T>1050°C) of the main Etna basalt, and indicates that the amphiboles are xenocrysts or they come from colder portions (roof, walls) of the magmatic reservoir feeding the eruption.

V61A-1355 0830h POSTER

"Excess" Plagioclase and Augite in Mid-Ocean Ridge Basalts: An Observational and Experimental Study

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A fundamental tenet of MORB petrogenesis is that the compositional variations exhibited by erupted MORB lavas are primarily the result of crustal-level fractional crystallization of olivine (or orthopyroxene), plagioclase and augite from slightly hydrous MORB liquids. A corresponding tenet of experimental phase equilibria theory is that any liquid that is generated by fractional crystallization of a given mineral assemblage at a given set of P-T conditions should be multiply saturated on its experimental liquidus with those same minerals at those same P-T conditions. Based on geochemical grounds, Regelous et al (1999) have demonstrated that a suite of MORB lavas from the EPR at 10o30'N are the result of fractional crystallization of olivine, plagioclase and augite. Thus, according to phase equilibria theory, every EPR lava composition should be multiply saturated with these three phases at some set of T-P-H₂O conditions. In contrast, synthetic crystallization sequences for the EPR lavas (generated with MELTS) indicate that most lava compositions are never multiply saturated but, rather, display "early" crystallization of augite and plagioclase followed at much lower temperatures by olivine. This indicates that such lavas contain higher concentrations of liquid augite and plagioclase components than should be present if fractional crystallization is the sole means by which the liquid was generated. We refer to such lavas as containing "excess" plagioclase and augite. A possible means of generating excess augite and plagioclase is through selective assimilation of these minerals from cumulate gabbros as already-fractionated liquids pass through the crust. Selective assimilation can occur only if the dissolution rates of plagioclase and augite are greater than that of olivine. To test this possibility, one-atmosphere dissolution rates were experimentally investigated for spherical crystals of olivine (Fo74), plagioclase (An64) and augite (Wo43En44Fs17) in a moderately evolved (Mg# = 55) MORB liquid. The results yield dissolution rates for olivine of 0.49-4.8 x 10⁻⁶ cm/s, for plagioclase of 1.3-7.5 x 10⁻⁶ cm/s, and for augite of 1.7 to 15.1 x 10⁻⁶ cm/s. These results indicate that a process of selective plagioclase and augite

dissolution may act to produce the "excess" plagioclase and augite in MORB lavas.

V61A-1356 0830h POSTER

Dissolution of Quartz, Albite and K-feldspar Into H₂O-Saturated Haplogranitic Melt at 800oC and 200 MPa: Diffusive Transport Properties of Granitic Melts at Crustal Anatectic Temperatures

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With the aim of investigating the diffusive transport properties of granitic melts at crustal anatectic conditions and obtaining some constraints on speciation and coordination in the melt, we conducted albite, K-feldspar and quartz dissolution experiments in H₂O-saturated metaluminous haplogranitic glass (nominal composition of the 200 MPa H₂O-saturated haplogranite eutectic of Tuttle and Bowen, 1958) at 800oC and 200 MPa. Mineral and glass cylinders were juxtaposed against flat polished surfaces inside platinum or gold capsules, then run for durations in the range 120-960 h. Based on the time dependence of interface retreat dissolution is interface reaction-controlled up to 700 h, and becomes diffusion-controlled afterwards. Upon dissolution of albite, Al and Na entering the melt decouple and Na diffuses away from the interface to maintain a constant Al/Na molar ratio throughout the entire melt column. Potassium from the bulk melt diffuses uphill towards the albite-melt interface to maintain a constant Aluminum Saturation Index (ASI=molar Al₂O₃/Na₂O+K₂O) of 1.00 throughout the entire melt column. Dissolution of K-feldspar results in migration of K away from the interface and uphill diffusion of Na from the bulk melt towards the interface, again maintaining constant Al/Na and ASI ratios in the bulk melt. Dissolution of quartz produces enrichment in SiO₂ versus dilution of the rest of components in the interface melt. These results indicate that in the five-component H₂O-saturated metaluminous haplogranite system, uncoupled diffusion takes place along the following four directions in composition space: SiO₂; Na₂O; K₂O; and a combination of Al₂O₃ and alkalis such that the Al/Na molar ratio is equal to that in the bulk melt, and the Al₂O₃/Na₂O+K₂O molar ratio is equal to the equilibrium ASI of the melt. These observations are in accord with results obtained from corundum and andalusite dissolution experiments in the same system and P-T-X conditions (Acosta-Vigil et al., 2002). These new findings, i.e. (1) the constancy of the Al/Na molar ratio throughout the entire melt at any time and (2) the migration of Al and alkalis in a ratio equal to the equilibrium ASI of the melt, reflect aspects of the speciation and coordination in the melt. Multi-component diffusion modeling applying a solution to Ficks second law that considers a fixed mineral-melt interface and semi-infinite mineral and melt columns (Crank, 1975) provides an eigenvalue for the SiO₂ eigenvector of ? *10⁻¹² cm²/s.

Acosta-Vigil A, London D, Dewers TA, Morgan VI GB (2002) Dissolution of corundum and andalusite in H₂O-saturated haplogranitic melts at 800oC and 200 MPa: constraints on diffusivities and the generation of peraluminous melts. J Petrol 43 (in press)

Crank, J. (1975). The Mathematics of Diffusion. Oxford: Clarendon Press.

Tuttle OF, Bowen NL (1958) Origin of granite in the light of experimental studies in the system NaAlSi₃O₈-KAlSi₃O₈-SiO₂-H₂O. Geol Soc Am Mem 74

V61A-1357 0830h POSTER

The Role of Plume-Ridge Interaction in Magma Genesis I: The Northern Galapagos

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A group of enigmatic volcanoes populates the ocean floor between the hotspot and the Galapagos Spreading Center (GSC), including many seamounts, a few isolated islands (Pinta, Marchena, and Genovesa), and the Wolf-Darwin Lineament (WDL). The WDL is a NW trending bathymetric high between the Galapagos platform and the GSC. Many of the northern Galapagos volcanoes are unusually elongate edifices that trend parallel to the strike of their local lineament. The

seafloor between Pinta and Marchena is cut by fractures and fissures parallel to the WDL, and a major submarine ridge extends NE from fissures that cross-cut Genovesa Island. Elongate volcanic structures are unusual in off-axis seamount provinces and indicate strong deviatoric stresses on a regional scale.

Individual volcanoes in the northern Galapagos generally exhibit homogeneous geochemical signatures, although this may be an artifact of sparse sampling (see Blair et al. abstract). Regionally, however, lavas range from plume-like enrichment (Pinta) to MORB-like depletion (Genovesa, S. WDL), with many volcanoes of intermediate composition (Darwin, Marchena). The WDL volcanoes define two distinct chemical groups; lavas erupted south of Wolf Island are similar to those from the GSC west of 93°W, while the northern WDL resembles lavas from the GSC segment directly to their north. This distribution implies that the WDL is supplied by the same type of plume-affected mantle as the GSC segment that produced the lithosphere underlying the volcanoes.

We propose that the WDL and perhaps other northern volcanoes are primarily the result of tensional stresses emanating from the inside corner of the GSC transform fault at 91°W. The oblique orientation of the fault with respect to the Nazca plate spreading direction may further enhance regional tensional forces. The area is magmatic owing to the overlapping effects of the ridge and the plume. The volcanoes simply tap hybrid products of mixing at the margins of the sub-ridge convection system and the periphery of the plume, resulting in locally homogeneous but regionally variable lava compositions. Essentially, the stress field around the transform fault, normally not observable in a typical mid-ocean ridge setting, is illuminated by the presence of melt from the adjacent hotspot.

V61A-1358 0830h POSTER

The Role of Plume-Ridge Interaction in Magma Genesis II: Wolf Island, Galapagos

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Wolf Island is one of two isolated volcanoes in the NW Galapagos Archipelago. Along with Darwin Island and several seamounts, Wolf is part of an intriguingly linear bathymetric feature (Wolf-Darwin Lineament, WDL) that trends 140° between the Galapagos Spreading Center (GSC) and the main archipelago. Because Wolf is located only 60 km south of the GSC and <200 km north of Fernandina, the most active volcano in the region, Wolf is effectively upstream of the plume center relative to plate motion and not easily explained in the context of a traditional plume model. Most recently, the WDL has been proposed to be the result of tensional stresses caused by the transform fault at 91°W, allowing underlying magmatic material to erupt along these zones of weakness.

Despite its small sub-aerial extent (<5 km²), Wolf has a complex volcanic history, including at least two major eruptive phases. First, the southern part of the island is constructed of horizontal, 1-2 m thick basalt flows. Next, thicker (2-8 m), flat-lying flows erupted after a significant hiatus in activity. Their eruption resulted in a caldera, now eroded to form a bay. Wolf has produced plagioclase ultraphyric basalts throughout its history, with up to 60% plagioclase and crystals nearly 4 cm long. Such basalts are typical of islands from the northern Galapagos and are rarely observed elsewhere. Unlike the other northern islands, however, ultraphyric flows constitute a major fraction of Wolfs sub-aerial volume. Megacrysts are segregated into bands within the thicker flows and are more abundant in the most recently erupted material.

Wolf lavas exhibit some of the most extreme compositional variations observed at a single volcano in the Galapagos, from slightly less enriched than Fernandina to MORB-like depletion. The enriched signatures confirm that plume material is a major component in the mantle underlying the northern Galapagos, likely the result of magmatic communication with the GSC. Early in Wolfs history, lavas peak in enrichment but become abruptly more depleted in later flows. The temporal variation indicates that the intensity of the plume supply may have varied over the lifetime of the volcano. If Wolf is the result of tension-induced volcanism, this further implies that the northern Galapagos mantle is a dynamic mixture of plume and upper mantle, capable of change over relatively short periods (1 m.y.).

V61A-1359 0830h POSTER

The Role of Plume-Ridge Interaction in Magma Genesis III: Darwin Island, Galapagos

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Located only 50 km south of the Galapagos Spreading Center, Darwin Island marks the northernmost extension of the Wolf-Darwin Lineament, a >50 km-long alignment of volcanoes and seamounts north of the main Galapagos Archipelago. Like neighboring Wolf Island, Darwin formed closer to the GSC than to the plume center and sits on younger lithosphere than the rest of the Galapagos volcanoes.

A small (1.5 km²), largely inaccessible island, Darwin has experienced at least two explosive episodes during its history. The base consists of a 20 m-thick tuff layer covered by over 40 meters of predominantly plagioclase ultraphyric basalt flows. The lavas are generally of uniform thickness (1-2 m), but can reach up to 8 m near the top of the sequence. A second tuff layer caps the lava flows, evidence of a later explosive phase. Although sub-aerially Darwin appears to be volumetrically insignificant, bathymetric and field evidence suggest that what is currently visible is merely the eroded remnant of a much larger volcano with an elongate footprint parallel to the WDL. Morphological evidence indicates that Darwin is significantly younger than Wolf Island, which is confirmed by previous age determinations (White et al., 1993).

Darwin lava flows are compositionally homogeneous, in stark contrast to the wide variation observed at Wolf Island, possibly the result of Darwins younger age. Darwin lavas exhibit moderately enriched signatures similar to those erupted along the adjacent GSC, indicating that the Galapagos plume is a significant component of Darwins mantle source. The wide range and erratic distribution of compositions along the WDL further suggest each volcano is tapping mantle that is a spatially variable mixture of depleted and plume material, rather than a sub-lithospheric pipeline transporting plume material to the ridge. We propose that Darwin, along with the rest of the WDL, is the surface manifestation of tensional volcanism induced by ridge-transform stresses along the GSC. Migration of magma to the surface is controlled by regional stress fields, resulting in constructional lineaments such as the WDL.

V61B MCC: Hall C Saturday 0830h

Hydrothermal and Geothermal Posters

Presiding: D R Janecky, Los Alamos National Laboratory

V61B-1360 0830h POSTER

Low Temperature Alteration of Basalts During the Last 9 Ma at 14°15'S on the South East Pacific Rise

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Little is known about the influence of low temperature alteration on the mineralogical and chemical composition of the oceanic crust once it leaves the spreading axis. Yet this crust is one of the major inputs to subduction zones, its composition is therefore highly relevant for the evolution of mantle, crust and biosphere. In addition, any secondary minerals contain a large amount of H₂O (i.e. clays), in consequence they play an important role as a water depot and therefore affect the dehydration reactions during subduction. For a better comprehension of the alteration effects it is important to understand the effects of the initial low temperature alteration. To determine these features, electron microprobe, X-ray diffraction and ICP-MS analyses have been carried out on basalts from the eastern

flank of the East Pacific Rise at 14°15'S. The investigation concentrates on the products of a single spreading segment in a corridor perpendicular to the SEPR over a period from 0 to 9 Ma. Fresh rocks were sampled at the ridge axis (0-0.015 Ma), whereas off-axis basalts contain features of seawater generated alteration, which increases in intensity with time. Celadonite is the main alteration component in 0.12-4.6 Ma old rocks, whereas phillipsite is more abundant in rocks older than 4.6 Ma. The secondary minerals show evidence for a slight change in redox condition with time, from oxidizing, water-dominated to more reducing, rock-dominated environment. Iron-oxyhydroxide and celadonite are the first alteration products filling voids and veins and replacing olivine, partly replaced by saponite under more reducing conditions. The Fe necessary for the formation of these minerals is furnished by the dissolution of glass and the breakdown of olivine. Phillipsite is present in fractures and veins in rocks older than 1 Ma. Analyses also indicate an illite-smectite mixed layer which is believed to be an intermediate between saponite and celadonite and small amounts of a chlorite/smectite mixed layer. The presence of calcite is due to contamination with foraminifera and/or sediment. All samples are characterized by the lack of hydrothermal related minerals. We conclude that the alteration took place under seawater-dominated conditions at low temperature.

A comparison of ICP-MS and XRF analyses from altered whole rock samples and their attendant fresh glass chips provide a record of element flow during alteration. Off-axis basalts show a significant increase of Rb, Cs and Ba which are supplied by seawater and incorporated in or on secondary minerals. The enrichment of U is connected to the oxidative conditions. K₂O is also gained in all altered off-axis basalts, which is believed to be the result of the formation of celadonite.

V61B-1361 0830h POSTER

Hydrothermal Activity on the Southern Mid-Atlantic Ridge

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We present evidence for high-temperature hydrothermal venting along the southern Mid-Atlantic Ridge (MAR) 2-14S. The MAR south of the equator has been identified as a key target for hydrothermal exploration because the large-offset Romanche and Chain fracture zones may act as important barriers to biological communication along the ridge-axis (Van Dover et al., Science, 2002). During RRS James Clark Ross cruise JR65 (Sept-Oct. 2001) we occupied a series of 13 CTD hydrocast stations, one each at the centre of a series of 2nd-order ridge-segments, close to and away from the influence of the Ascension Island "hotspot". Post-cruise laboratory analyses have revealed TDMn anomalies of >2nmol/litre (background = 0.5 nmol/litre) at stations within each of four segments located between the Chain and Ascension Fracture Zones (away from the "hotspot") and in the two northernmost "hot-spot influenced" segments to the south, between the Ascension and Boca Verde Fracture Zones.

Strongest anomalies were observed in the segment closest to Ascension Island itself, where TDMn anomalies measured in bottle-samples coincided with optical back-scatter anomalies measured in situ using a SeaTech LSS light scattering sensor. A weaker TDMn anomaly was also observed adjacent to the Boca Verde Fracture Zone and coincident with a WOCE section which has previously reported evidence for primordial 3He release from the MAR-crest (Ruth et al., Deep Sea Res., 2000). Our survey covered a large section of ridge-crest, comparable to that investigated by Klinkhammer et al. (Nature, 1985) on the northern MAR. Multiple offset segments have been investigated and the data support the presence of multiple discrete hydrothermal sources. To-date, the best positional information we have for any one vent-site is in the segment immediately south of the Ascension Fracture Zone. Water depth in this segment is >3000m yet it is situated <100km from the port of Georgetown, Ascension. We believe this station to be close to a vent-site because this plume is particle laden as well as containing significant TDMn anomalies. Equivalent signals from the Broken Spur or SnakePit hydrothermal plumes (29N and 23N, MAR respectively) are only observed within 2-5km of those active vent-sites (German et al., Deep Sea Res. 1999).