rocks form accumulates at the LAT and along the walls of fracture-conduits within the deep lithosphere. Nd-Sr isotope data on whole rocks and garnet and cpx separates show them to be depleted as well, partially overlapping with the host HV lavas and lithospheric spinel peridotite xenoliths. We view the Oahu lithosphere (below the crustal part) as follows: 20-30 km - depleted harzburgite with veins of plagioclase; 30 - 90 km - spinel peridotite layer (we model the vertical modal variation), 90 -130 km - cumulate garnet clinopyroxenites and "piclogites" with small amounts of (5 percent) intergranular H2O+CO2-rich fluids that may be of kimberlitic-carbonatite affinity. Our inferred compsition of the lithosphere and LAT are generally similar to geophysical models but predict a 200-250oC lower temperature within the LVZ beneath Oahu than the latter. In our model, Hawaiian plume-derived shield-stage magmas have little interaction with the lithosphere, suggesting that these magmas are efficiently transported via dikes. During the post-erosional stage, limited interactions occur between the lithosphere and fluids that escaped from the main HV conduits. We estimate that the post-erosional HV magmas were generated from a minimum depth of about 100-130 km, and that Koolau shield magmas were produced from even deeper levels based on the rarity/absence of cumulate/residue type xenoliths with such compositional affinity.

V42H-06 1715h INVITED

Origin and Evolution of Mantle Lithosphere

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Mantle lithosphere beneath oceanic and continental crust is characterized by mineralogic and chemical variability resulting from extraction of partial melt. Normative mineral and major element composition trends from oceanic and off-craton subcontinental lithosphere intersect at an Mg# of about 89.3, indicating a common fertile lherzolite protolith. A model fertile upper mantle composition is calculated from these trends and has non-chondritic refractory lithophile major element ratios. Phase relations for melting of fertile peridotite are used to deduce melt extraction trends as a function of pressure and temperature. These trends are compared to compositional trends exhibited by mantle lithosphere to constrain the conditions of formation. Reconstructed abyssal peridotite compositional trends are best modelled by moderate degrees (5 to 25%) of combined batch and near-fractional melt extraction at an average pressure of about 1 GPa. Off-craton subcontinental mantle lithosphere, generally Proterozoic in age, is modelled by similar extents of melting but at a higher average pressure of about 2 GPa. Low SiO_2 Archean cratonic lithosphere has compositional features indicating high-degree melt extraction (40 to 50%) at average pressures of 4 to 5 GPa. High-SiO_2 cratonic lithosphere is modeled by melt extraction followed by addition of opx in a secondary process. Based on the assumption of nominally anhydrous melt extraction, estimates for average mantle potential temperature at the time of lithosphere formation indicate secular cooling of the mantle by about 350 $\pm$ 50 $^{\circ}$C since the Archean. This amount of cooling is greater than predicted in models that assume whole-mantle convection, and could indicate transient periods of layered convection and mantle overturn during the first several billion years of Earth history.

V42H-07 1730h

The Relationship Between Partial Melt Composition and Trace Element Partitioning Along the Peridotite Solidus

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Peridotite partial melting occurs primarily within the upper 80 to 90 km of the Earth's mantle, where the fractionation of incompatible trace elements is controlled largely by their relative compatibilities in high-Ca clinopyroxene (Cpx). A significant number of Cpx-melt partition coefficients (D_i) have, therefore, been determined experimentally for geochemically important trace elements over a broad range in pressure, temperature, and bulk composition. These experiments have produced Cpx exceeding the compositional range produced in peridotite partial melting experiments. Collectively, the results from these studies demonstrate that composition-related variations in Cpx structure produce significant changes in D_i by varying the misfit between the lattice site and the substituent cation, or by facilitating the charge balance required for heterovalent substitution. Gaetani and Watson [1,2] determined that the influence of melt structure on trace element partitioning increases with decreasing extent of partial melting at 1.5 GPa due to increasing polymerization of the melt. Systematic changes in the major element composition of peridotite partial melt generated near the peridotite solidus causes this effect to be very significant at 1.0 to 1.5 GPa, but relatively unimportant at higher pressures. This reconciles the large D_i values determined by Blundy et al. [3] with the lower compatibility measured by Salters and Longhi [4]. The compositions of low-degree partial melts of mantle peridotite change dramatically over the pressure range of 1.0 to 2.5 GPa. With increasing pressure, the concentrations of SiO_2, Al_2O_3 and Na_2O in the melt decrease as FeO, MgO and CaO increase. This leads to a systematic decrease in melt polymerization as reflected in the ratio of non-bridging oxygens to tetrahedrally coordinated cations (NBO/T). As the value of NBO/T for low-degree melts increases from a value of $\sim$0.15 at 1.0 GPa to $\sim$0.95 at 2.5 GPa, the compatibility of the rare earth elements in Cpx monotonically decreases. For NBO/T values of $\sim$0.49 or less, melt structure plays a significant role in determining compatibility. In less polymerized melts, trace element compatibility is determined almost solely by the composition of the Cpx. Given these systematics and the range of pressures at which mantle peridotite is thought to cross its solidus beneath oceanic spreading centers, the large partition coefficients determined by Blundy et al. [3] are likely to be relatively unimportant for modeling trace element fractionations during partial melting. References: [1] Gaetani and Watson, 2000, EOS, 81:1383; [2] Gaetani and Watson, 2001, Eleventh Annual V.M. Goldschmidt Conf, Abst 3292. [3] Blundy, Robinson and Wood, 1998, EPSL 160:493-504; [4] Salters and Longhi, 1999, EPSL 166:15-30.

V42H-08 1745h INVITED

Magma Genesis in the Hawaiian Hot Spot: From melting experiments on basalt/peridotite hybrid source

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Melting mantle peridotite is one of the central themes in experimental petrology. Melting studies in CMAS, NCMAS and natural peridotites have extensively documented the magma genesis process at Mid Oceanic Ridges (e.g., Presnall et al., 1979). Magma genesis in OIBs and LIPs, on the other hand, has been poorly constrained by experiments. Evidences from isotope geochemistry indicate that the source materials for basalt magmas in these provinces are not peridotite alone. Based on a geological and geochemical reconstruction of 3 Ma old Koolau volcano, I proposed that the size of eclogite blocks in the Hawaiian plume would exceed 1000km3 (Takahashi and Nakajima, 2002) and therefore the melting interaction of eclogite blocks and the surrounding peridotite would play essential roles in magma genesis in the Hawaiian hot spot. Melting experiments on basalt/peridotite composite starting materials were carried out at 2.5 to 3.0 GPa at temperatures from the peridotite dry solidus to that of basalt for 20 to 100 hours. Three layered starting materials consisting of 1 basalt to 2 peridotite (in volume) were placed in graphite/Pt double capsules. Peridotite KLB-1 (Fo89.6) and two basalt-starting materials (CLG-46 and CRB72-31) were used as starting materials. In temperatures ca.50-100 degrees below the peridotite solidus, silica-rich partial melts are produced in the basalt zone and the boundaries between the basalt and peridotite are coated with a 10 to 50 micron thick opx reaction band. The chemical reactions between the basalt and peridotite domains are controlled by solid diffusions across the opx reaction band and are very slow. In temperatures within 50 degrees of the peridotite dry solidus, a time dependent reaction process takes place. The basalt/peridotite boundary gradually partial melts as the chemical reaction lowers the peridotite solidus locally. At 2.8 GPa and 1450-1470C after 50-100 hours, resultant melt in the basalt layer becomes saturated with oliv + opx + cpx + gar and has 13-15 wt% MgO. Compared with partial melt of KLB-1 at 1500-1525C (Hirose and Kushiro, 1993), the basalt/peridotite hybrid melts are much lower in Al2O3 and CaO but are distinctly higher in K2O and TiO2. Compared with partial melt of KLB-1+50%MORB at 1500-1525C (Kogiso et al., 1998), melt in this study are much higher in SiO2 but lower in Al2O3. Among the three sets of experiments at 2.8-3.0GPa, compositions of the basalt/peridotite hybrid melts are most similar to the primitive Hawaiian tholeiite. Various hypotheses have been proposed to explain the chemical character of the Hawaiian magma (e.g., involvement of a metasomatic component at the base of the Pacific plate, melting of a fertile lower mantle component, melting at much higher pressure, etc). Based on the above experiments, I propose that Hawaiian tholeiite magmas are produced in basalt-peridotite reaction domains in the plume. The systematic change in the SiO2 content of Hawaiian tholeiites (from lower to higher, Loihi, Kilauea and Mauna Loa) could be explained by lowering melting temperatures in magma feeding zones from Loihi to Mauna Loa. This model predicts that the PMT for the Hawaiian plume could be roughly 100C lower than the previous model (PMT=1558C, Watson & McKenzie, 1991) and the involvement of eclogite component in magma genesis in the Hawaiian tholeiite would be 30 to 100%, which is much higher than the previous estimate (0-10%, Hauri, 1996).

V51A MCC: 3006 Friday 0800h

Light Element Geochemistry: Insights Into High-Temperature Processes I

Presiding: **B McDonough,** University of Maryland**; P J le Roux,** Carnegie Institution of Washington

V51A-01 0800h

Li isotope composition of the upper mantle

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Subduction returns altered oceanic crust to the mantle as an integral part of plate tectonics. Yet evidence for recycled material in the mantle remains scarce. Li isotope ratio measurements have the potential to be a highly effective tracer of recycled material. Recent development of measurement procedures on our Finnigan Neptune plasma ionisation mass spectrometer allows us to measure small samples (1ng Li) with a reproducibility (2 sigma standard deviation) of $\pm 0.2^{o}/_{oo}$. This considerably improves our ability to detect small variations in the Li isotope ratios and thus our sensitivity in identifying recycled contributions in mantle derived material. We have used our new technique to analyse the Li isotope ratios of a suite of MORB. The current Li isotope database for MORB is small, but nevertheless ranges from 1.5 to $6.5^{o}/_{oo}$ in samples from normal ridge depth. We wanted to assess the variability of MORB Li isotope ratios at high precision (± 0.2 rather than $\pm 1^{o}/_{oo}$) in a suite of spatially closely related lavas. Thus we analysed samples from two small study areas around 10°30'N and 11°30'N East Pacific Rise (EPR) which comprise a range of compositions from normal (e.g. ϵ(Nd) $\sim$ 10) to enriched (e.g. ϵ(Nd) $\sim$ 8). Our δ^7Li results vary from 3.1-$5.2^{o}/_{oo}$ and correlate with other geochemical indices-positively with $^{87}Sr/^{86}Sr$ and La/Sm and negatively with $^{143}Nd/^{144}Nd$. These correlations suggest shallow contamination is an unlikely cause of Li isotope variations. Thus the sources of these lavas appear to be variability enriched with recycled material with a heavy Li isotope signature. Recent work has suggested that after subduction zone processing the slab is isotopically light and thus is not a likely candidate as this recycled component. We suggest instead that the fluid-fluxed mantle wedge is mixed back into the upper mantle and forms the enriched component in the sources of these MORB and probably other mantle derived magmas.

V51A-02 0815h

Lithium isotopic composition of the lower continental crust: A xenolith perspective

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Study of high-grade metamorphic rocks is important for understanding the lithium isotopic composition of the lower crust and determining the degree to which lithium isotopes fractionate during metamorphism. Here we present Li isotopic data for two well-characterized suites of lower crustal xenoliths from North Queesland, Australia [1, 2]. These xenoliths have average major-and trace-element compositions similar to estimates of the bulk lower continental crust, and can therefore be used to place broad constraints on its Li isotopic composition. Furthermore, the Chudleigh xenoliths are a suite of cogenetic cumulates that formed through AFC of Cenozoic basaltic magma that intruded Proterozoic lower crust, and thus may provide insight into the regional average δ^7Li of the lower crust. The samples display a large range of Li concentrations and isotopic compositions with the average, concentration-weighted δ^7Li value = 0. McBride xenoliths are enriched in Li (7 $\pm$ 4 ppm versus 3 $\pm$ 2 ppm) and have a larger range of δ^7Li values (-13 to +7 versus -9 to +6) than Chudleigh xenoliths, consistent with differences in lithology and genetic diversity: McBride xenoliths range from paragneisses to mafic and felsic orthogneisses whereas the Chudleigh xenoliths are mafic cumulates. Mg#, ^{87}Sr/^{86}Sr and ^{143}Nd/^{144}Nd in the Chudeigh suite correlate with δ^7Li, reflecting assimilation of isotopically light Proterozoic lower crust (δ^7Li < -9) by heavier (δ^7Li $\sim$ +6) mantle-derived basalt. The δ^7Li values of the lower continental crust are heterogeneous, and its average composition is similar to the upper continental crust [3] or lighter; this suggests that the continents are isotopically lighter than the mantle [4]. The isotopically light continental crust is probably derived from two processes involving fluid-rock interactions: surface weathering and metamorphic dehydration. Both processes drive the hydrosphere to heavier (+30) and bulk continental crust to lighter (-1 to 0) δ^7Li than the mantle (+4). 1. Rudnick R. L. et al. (1986) GCA 50, 1099-1115. 2. Rudnick R. L. and Taylor S. R. (1987) JGR 92, 13981-14005. 3. Teng F.-z. et al. (2003) submitted to GCA. 4. Chan L. H. and Frey F. A. (2003) G3, 4 art. no.-8707.

V51A-03 0830h

Boron Isotope Compositions of Selected Fresh MORB Glasses From the Northern EPR (8-10°N): Implications for MORB Magma Contamination

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The petrogenetic role of seawater and seawater-equilibrated altered crust in the magmatic evolution of basalts formed at mid-ocean ridges is not well-constrained. Observed excess Cl in oceanic basaltic magmas led to established models of assimilation of a saline brine component, although the physical form of this component and whether any other components contaminate MORB magmas remain unresolved. Light stable isotopes such as B are valuable in further refining our understanding of these magmatic processes. The light element B has two stable isotopes (mass 11 and 10) and B isotopic ratio ranges significantly in oceanic settings: e.g. depleted upper mantle (δ^{11}B -10$^o/_{oo}$), fresh MORB magmas (δ^{11}B -1.2 to -6.5$^o/_{oo}$), altered oceanic crust (δ^{11}B +2 to +9$^o/_{oo}$), hydrothermal fluids (δ^{11}B +30 to +36.5$^o/_{oo}$), and seawater (δ^{11}B +38.5$^o/_{oo}$). We have developed an in situ laser ablation, multiple multiplier ICP-MS at DTM (see le Roux et al., in press) that has reliable uncertainties for B isotope analyses better than 1$^o/_{oo}$ (2σ) over concentration ranges from 0.3 ppm to above 30 ppm. This technique makes nearly any size glass sample amenable to B isotope study. B isotopic compositions were obtained on 16 fresh MORB magmas from the northern East Pacific Rise (EPR) from 8 to 10°N. This region of the EPR has an extensive, existing MORB glass collection, with well-constrained general geochemistry and petrology, recovered from sites on-axis, off-axis (including young off-axis eruptions; abyssal hills), and the Siquerios fracture zone. Geophysical data from this region imaged the top of the dike section (layer 2A) and the sub-axial magma chambers (AMC). Data for these MORB glasses indicate the variable addition of H_2O, Cl, F, Li and B to these magmas prior to eruption. The excess Cl can be accounted for by variable (<0.5wt%) magma contamination with a saline brine (NaCl 15-50wt%; Kent et al, 1999). Variable magma degassing places the contamination of some of these magmas at depths within the oceanic crust close to the top of the AMC. These MORB samples have 0.56 to 2.61 ppm B, and B isotope compositions that are surprisingly restricted ranging from δ^{11}B -5.50 to -8.96$^o/_{oo}$. The low δ^{11}B values are close to the depleted upper mantle value (-10$^o/_{oo}$). The δ^{11}B data do not correlation with B concentrations, Mg#, Sr, Nd or Pb isotopes, or proxies for brine addition (e.g. Cl/Nb). The lowest δ^{11}B samples are also the most-incompatible element depleted (high B/Nb ratios). The δ^{11}B of the on-axis samples increases slightly with increased levels of magma degassing (i.e. lowest δ^{11}B values in samples extracted undegassed from depths closest to AMC top).Therefore, although the Cl data indicate significant addition of probably a saline brine component to both on- and off-axis MORB magmas, their δ^{11}B compositions were not significantly affected by this process and the observed variations in δ^{11}B may have a different origin. Possibly, the low B/Cl ratio of seawater ($\sim$ 0.001) coupled with preferential partitioning of Cl relative to B into brines during supercritical phase separation (Berndt and Seyfried, 1990) of seawater in hydrothermal system, results in very saline brines with low boron concentrations. The coupled B-Cl data effectively eliminates simple magmatic assimilation of altered Cl-rich high-B isotope composition oceanic crust in this region.

V51A-04 0845h

Boron isotope fractionation during slab dehydration and across-arc δ^{11}B variations

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Boron is one of the most suitable elements to study the fluid driven mass transfer from the subducted slab into arc magmas due to its mobility in aqueous fluids, incompatibility during most magmatic processes and large compositional differences among the main geological reservoirs. Across-arc variations in B-isotopes from western Pacific arcs can be interpreted as mainly the result of a decreasing amount of slab-derived B with a constant AOC-like composition over the arc profiles relative to a constant mantle contribution. However, we present a new model for fluid-mineral B-isotope fractionation that explains δ^{11}B across-arc variations by B-isotope fractionation during progressive slab dehydration alone. A combination of the fractionation model with a temperature model for the Central Andean subduction zone fits the observed across-arc variations of δ^{11}B in volcanic rocks from the Central Andes as well as literature data for slab restites and fore arc fluids from other settings. We conclude that the B-isotope composition of arc magmas in general is dominated by changing δ^{11}B composition of B-rich slab fluids as a result of progressive dehydration during subduction. In contrast to most previous studies, we deny a major role of mantle-derived B, because concentrations in the mantle are too low to affect the B budget of arc volcanics significantly. Our modeled slab restite compositions also offer an explanation for the negative δ^{11}B values of OIB, due to recycling of ^{11}B-depleted subducted slabs into the OIB magma source. A major uncertainty of all B-models is the composition of the input to the subduction zone. We assumed that the AOC chiefly contributes B to the slab-fluid, but as shown by numerous studies, several other major lithologies contribute to subduction zone fluids. In particular, the importance of subducted sediments and serpentinized peridotite within or above the slab is key to refining models of B-isotope fractionation and mass transfer in subduction zones.

V51A-05 0900h

Boron Isotopic Variations in Hydrous Rhyolitic Glasses From Caldera-Forming Ignimbrite and Post-Caldera Domes at Long Valley

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Long Valley, located in central California, is ideal to explore trace element and volatile element systematics in continental silicic magma systems, due to its youthful, accessible and extensive eruptive record. Here we explore boron variations in volcanic glasses from the compositionally and thermally zoned Bishop Tuff and from small-volume post-caldera rhyolites. Ion microprobe measurements of undegassed melt inclusions from early and late erupted Bishop Tuff pumice yielded average δ^{11}B values of +3.5$\pm$0.9$^o/_{oo}$ and +5.0$\pm$0.9$^o/_{oo}$, resp. (2 standard errors; MSWD >1.5). These values overlap with a positive thermal ionization mass spectrometry result for vesiculated groundmass glass from late Bishop Tuff (δ^{11}B = +5.4$\pm$0.9$^o/_{oo}$; 2 standard deviations). Boron concentrations in melt inclusions continuously increase from late ($\sim$48 ppm) to early Bishop Tuff ($\sim$60 ppm). Bishop Tuff results are consistent with experimental evidence that predict only minor ^{11}B depletion in hydrous melts undergoing gas-saturated fractional crystallization. By contrast, undegassed melt inclusions from two crystal-rich post-caldera lavas (Deer Mountain and South Deadman Dome) are comparatively boron-rich (max. 90 ppm B) and have lower δ^{11}B (average +2.2$\pm$0.8 and -0.4$\pm$1.0$^o/_{oo}$, resp.; MSWD >1.1). These values are also distinct from those in coerupted crystal-poor obsidian (average 27 ppm B; δ^{11}B = +5.7$\pm$0.8$^o/_{oo}$; ; MSWD = 0.4). Degassing and/or post-eruptive alteration are unlikely to have caused these variations. Furthermore, variable degrees of country-rock contamination would be expected to cause some correlation between δ^{11}B and radiogenic isotope compositions (e.g., ^{143}Nd/^{144}Nd) and this is not observed. Therefore, we favor assimilation of ^{11}B depleted, but otherwise compositionally similar, chilled magma chamber margin rocks in the genesis of crystal-rich post-caldera rhyolites. Boron isotopes thus complement evidence from low-δ^{18}O rhyolitic suites described for other silicic magma systems and trace the recycling of hydrothermally altered rocks that so far has gone undetected for Long Valley.

V51A-06 0915h

High sensitivity in-situ analysis of light lithophile (Li, Be, B) and alkali (Rb, Cs) elements by laser ablation magnetic sector ICP-MS: application to back arc basin magmatism

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Light lithophile (B, Be, Li) and alkali elements (Rb, Cs) provide many constraints on the origin and evolution of primitive magmatic rocks. However these elements are often present at low abundances, requiring large sample volumes, and may be strongly effected by alteration or sample contamination. We have developed a technique for rapid, in-situ, analysis of B, Be, Li, Rb and Cs abundances in glasses, glass inclusions and minerals using laser ablation microsampling and analysis by magnetic sector ICP-MS. By coupling the high sensitivity, dynamic range and low backgrounds of the ICP-MS with the speed and minimal sample preparation requirements of laser ablation, we can analyze these elements with detection limits that rival many solution-based techniques in 60 s and using << 200 ng of material. Analyses are conducted using a NewWave DUV 193 nm ArF Excimer laser system, with He carrier gas. Samples were ablated at energies of 10-12 mJ/cm^2 with pulse rates between 2-5 hz, and by either translating a 50 μm laser spot over the surface at a rate of 5 μm/s or by maintaining a stationary 50-70 μm spot. Ablated material was analyzed with a VG Axiom single collector ICP-MS using a high-sensitivity sampler cone. All peaks were checked at high mass resolving power for molecular interferences, and analyses were conducted at low resolving power to maximize transmission. Careful monitoring of backgrounds was required for low-abundance measurements. Calculated detection limits are 1-2 ppb (Cs, Be), 5-10 ppb (Li) and 15-20 ppb (B, Rb). Surface contamination was removed with a pre-analysis ablation pass, and the small size of the laser spot allowed us to avoid altered and devitrified areas. Analysis of standard glasses showed excellent agreement with accepted values and repeat analyses suggest external errors are typically < 5-10%. Glasses from the Lau Basin show strong enrichments in B, Rb and Cs that correlate with a slab-fluid signature. B, Be Rb and Cs contents are very low in MORB-like samples from the north of the basin but are enriched in evolved lavas from propagating ridge tips.

V51A-07 0930h

K/Li/Yb Fractionation in Micas

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Island arc basalts (IAB) have been shown to have high Li/Yb relative to mid-ocean ridge basalts (MORB) and ocean island basalts (OIB). In addition, IAB have high K/Li relative to rare earth element (REE) fractionation. A positive correlation between Ba/Ti and Li/Yb has also been observed. Therefore, the generation of IAB must involve interaction with a component having the elemental abundances K, Ba>Li>Yb. Although some subducted sediments or altered oceanic crust may have this characteristic, the control of mica over K mobility in arcs is such that the affect of mica stability and breakdown on all of the above elements must be considered. We have performed mineral/fluid trace element partitioning experiments for two K-bearing micas, phlogopite and phengite, at 2.0 GPa, 900°C. Both K and Ba are strongly compatible in phlogopite (D_K=∼44, D_{Ba}=∼50) and phengite (D_K=∼32, D_{Ba}=∼21), Li is moderately compatible in phengite (D_{Li}=∼2), and Yb is somewhat incompatible in phlogopite (D_{Yb}=∼0.16). Although we do not have Yb partitioning data for phengite, biotite/muscovite partitioning data from natural rocks indicate that REEs are not significantly fractionated between the micas. Previous studies indicate that K mobility in arcs is controlled by mica stability in the subducting slab, and perhaps the overlying mantle wedge. Sediment dehydration and melting experiments have shown that K, Ba, and Li are released following mica breakdown with progressive heating. However, bulk sediment addition cannot explain Li/REE ratios or the extreme K/Li in some arc lavas. Our results indicate that mica (when present) will be the primary host of K, Ba, and Li in the eclogitic assemblage resulting from reactions in the crust and/or sediment layer as subduction progresses. Gradual breakdown of the micas with increasing pressure and temperature will contribute K, Ba, and to a lesser extent Li to the arc lava source, while contributing very little REE. The concentrations and relative fractionation of the REE are primarily determined by the degree and depth of melting in the mantle. The K/Li ratio may be useful as an indicator of relative mica contribution to the slab component, while the Li/Yb ratio may be useful as an indicator of slab vs. wedge contribution to arc lavas.

V51A-08 0945h

B, Cl, Li Variability in the Subducted Oceanic Mantle and in Antigorite-Breakdown Fluids: Implications for Fluid Processes and Light Element Recycling

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We present an inventory of B, Cl, Li in a set of ultramafites featuring the evolutionary stages of the subducted oceanic mantle, and in the fluid inclusions formed at antigorite breakdown. Samples correspond to: non-subducted serpentinites (Northern Apennine); high-pressure antigorite serpentinites (Western Alps; Betic Cordillera); high-pressure olivine-opx rocks (Betic Cordillera). Analyses of Cl, B, Li in the rock forming minerals indicate that the hydrous mantle is an important light element carrier. The estimated bulk-rock B and Cl decrease from oceanic (46.7 B; 729 ppm Cl) to antigorite serpentinites (20 ppm B; 221 ppm Cl) to olivine-opx rocks (9.4 ppm B; 45 ppm Cl), suggesting release of oceanic Cl and B in subduction fluids, likely without inputs from external sources. Li is less abundant in oceanic serpentinites (1.26 ppm) and such concentrations are still preserved in high-pressure serpentinites. High Li contents in the olivine-opx rocks (4.9 ppm bulk Li) suggest income from associated crustal rocks. LAM ICP-MS analyses of fluid inclusions representing the antigorite-breakdown fluid in olivine-opx rocks, enabled an estimate of the trace element composition of this fluid. The inclusion compositions yield maximum average $fluid/rock_{D_B}$ and $fluid/rock_{D_{Li}}$ of 11 and 17.8, respectively. Model calculations of the B and Cl loss form subducting serpentinite suggest $fluid/rock_{D_B}$ and $fluid/rock_{D_{Cl}}$ of about 15-30 and 30-60, respectively, and $fluid/rock_{D_B}$ / $fluid/rock_{D_{Cl}}$ < 1 (0.66-0.5). Cl thus preferentially partitions in fluids relative to B: the fluid B/Cl ratio progressively raises at increasing depths and temperature. Despite light element loss, appreciable B, Cl, Li are still stored in olivine-opx rocks beyond the antigorite stability. This permits a bulk storage of about 10 ppm B and 5 ppm Li, i.e. concentrations much higher than in normal mantle reservoirs. The oceanic mantle may thus retain B and Li deeper than the arc magma sources, potentially creating light element anomalies in the upper mantle.

V51B MCC: 3008 Friday 0800h

Fragmentation of Magma

Presiding: **L G Mastin,** U.S. Geological Survey**; H Gonnermann,** University of California, Berkeley

V51B-01 0800h

A fragmentation threshold for the initiation and cessation of explosive eruptions

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A fragmentation threshold for magma may be defined as the critical gas overpressure required to fragment volcanic materials when decompressed rapidly. There are several potential causes of pressure differentials between bubbles and melts in magma. In fact, bubble growth results itself from the action of bubble overpressure on the melt walls of the bubble. Perturbations of the pressure differential may additionally arise due to sudden decompression, flow pressure gradients in variably viscous magmas in conduits, or external influences such as landslides or gravitational dome collapse. Overcoming such a threshold provides a volcanic system with the possibility to change its behaviour from that of a relatively harmless effusive eruption into a potentially highly destructive explosive eruption The magnitude of the fragmentation threshold is likely to be a controlling factor in initiation and cessation of explosive eruptions. Pressure differentials commonly arise between the gas in bubbles and the ambient pressure of the surrounding melt. If the stress perturbations involved call for viscous strain rates higher than the relaxational strain rate (1/relaxation time) of the melt, brittle fragmentation may ensue. Here, we show results of fragmentation experiments at 850°C performed with volcanic rocks varying widely in porosity, permeability, crystallinity and chemical composition. Increasing porosity decreases the value of the fragmentation threshold. At high porosity values, the influence of permeability becomes increasingly important in defining the threshold. Chemical composition and temperature appear to have relatively minor effects. In contrast with existing models the present parameterization implies that the fragmentation threshold is proportional to the tensile strength of the porous magma in glassy response.

V51B-02 0815h

Shear-Induced Fragmentation in Silicic Volcanism

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Fragmentation of magma, containing abundant gas bubbles, is considered as the defining characteristic of explosive eruptions. When viscous stresses associated with the growth of bubbles and the flow of the ascending magma exceed the strength of the melt, it breaks into disconnected fragments suspended within an expanding gas phase. While repeated effusive and explosive eruptions for individual volcanoes are common, the dynamics governing the transition between explosive and effusive eruptions remain unclear. Magmas for both types of eruptions originate from sources with similar volatile content, yet effusive lavas erupt considerably more degassed than their explosive counterparts. Recent observations suggest that magma fragmentation may not be restricted to explosive eruptions and we find corroborating evidence of magma fragmentation, reannealing and elongation of fragments into flow banding from obsidians from Big Glass Mountain rhyolite dome, California. One mechanism for degassing during magma ascent is the generation of intermittent permeable fracture networks through non-explosive fragmentation near the conduit walls. To gain insight into the mechanics governing fragmentation in silicic volcanoes, we have developed a numerical model for magma ascent in the volcanic conduit. The ascending magma (melt + bubbles) is modelled as steady, isothermal flow of a single-phase liquid at constant mass flux in a cylindrical conduit of constant radius. We specify a pressure, number density of bubbles, and relaxed Newtonian melt viscosity at the base of the conduit and solve the joint problem of bubble growth and magma ascent. Rather than include the transition to fragmentation and flow of fragmented magma, we determine the ascent distance above the conduit entry at which magma fragmentation by viscous shear should first occur. The model is quasi-one-dimensional and for a given depth computes the radially varying vertical component of magma velocity. We show that shear-induced fragmentation can occur in both effusive and explosive eruptions and is consistent with the observed conditions of volcanic systems, with the degassed nature of effusive silicic lavas, and with textural observations at the outcrop to microscale. We suggest that it may be important for magma degassing and inhibition of explosive behavior. This implies that, contrary to conventional views, explosive volcanism is not an inevitable consequence of fragmentation.

V51B-03 0830h

Fault textures in a volcanic conduit

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Fault textures in the obsidian walls of a dissected rhyolitic conduit in Iceland record a history of fracture and healing in rising magma, and may represent fossilised hybrid and long-period volcanic earthquakes [1]. In this contribution we highlight the striking similarities between micro- and meso-scale fault textures in obsidian and those found in seismogenic tectonic faults [2,3]. The conduit walls contain networks of angular shear fractures, which are typically 0.1-2 m in length and filled with banded cataclasites generated by corner abrasion and wear on the fracture surfaces [2]. During continued flow of magma and shear deformation, these networks coalesce [4] and mature into near-planar shear bands parallel to the flow direction. Shear bands are up to 4.8 m long and several centimetres across, and slip is accommodated by distributed deformation in cohesive cataclasites and pseudotachylites. Due to the increasing cohesion of fracture-filling material during displacement, which is attributed to viscous and frictional heating, each fracture system heals, and thus has a limited seismogenic lifetime. The combination of localised slip and distributed flow textures are typical of the repetitive deformation sequences that are characteristic of seismic cycling [2,5]. Earthquakes occurring in highly-viscous magma and elsewhere in the crust are governed by similar physical processes. The material properties of the fractured medium, such as ductile-brittle behaviour, temperature-dependent viscosity and strength, are key to linking field observations and failure theory to recorded seismic events[1,6]. 1. Tuffen, H., Dingwell, D.B, Pinkerton H. (2003) Geology, in press. 2. Chester FM, Chester JS (1998) Tectonophysics 295:199-221. 3. Lin AM (1996) Eng Geol 43: 213-224. 4. Kilburn CRJ (2003) J Volcanol Geotherm Res 125:271-289. 5. Beeler NM et al. (2001) Bull Seis Soc Am 91:1797-1804. 6. Neuberg J, Tuffen H, Jolly A, Green D (2003) Abstract, Fall AGU 2003.

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An Experimental View on the Vesiculation-Driven Fragmentation of Viscoelastic Media and its Implications for Plinian-Style Eruptions

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