of island arc volcanoes. Resolving the CO_2 into component structures (mantle-derived, plus slab-derived organic and limestone CO_2 - following the approach of Sano and Marty, *Chem. Geol.*, 1995), the northern volcanoes contain higher than average slab-derived limestone contributions. For example, limestone-derived CO_2 makes up > 90% of the total CO_2 at Karangetang and ~98% at Awu. These values compare with an average limestone contribution of ~65% in the southern Sangihe arc and ~73% in other arcs worldwide.

We are investigating possible reasons for the enhanced limestone contributions in the northern Sangihe arc. The sedimentary melange wedge is thickest in the north (up to 15km) - where the arcs initially collided. The greater availability of sediment may result in a greater input of subducted sediment, thereby providing enhanced dilution of mantle wedge C inputs. Alternatively, subducted sediments may be more carbonate-rich in the northern segment of the arc. This may reflect obduction of shallow, organic-bearing sediments onto the over-riding plate, leaving only pelagic carbonates to contribute to arc magma sources. Finally, the large carbonate flux may reflect enhanced contributions from sediment fluids and/or melts in the northern arc. Central Mindanao (Philippines), just north of Awu, contains post-collisional, slab-derived melts (adakites) attributed to thermal rebound of previously depressed isotherms upon termination of subduction (Sajona et al, *Lithos*, 2000). Similar thermal processes could be occurring at the northernmost extensions of the active Sangihe arc as a result of the reduced rate of subduction.

V21C MCC: 106 Tuesday 0830h

Melt Inclusions: What Do They Tell Us? I *(joint with OS)*

Presiding: **A Kent,** Danish Lithosphere Center/Oregon State University; **P Wallace,** University of Oregon

V21C-01 0830h

Insights into the architecture of basaltic magmatic systems from melt inclusion studies

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Studies of melt inclusions from basaltic lavas are often aimed at elucidating the nature of mantle source(s) and/or the processes responsible for melt generation. However, melt inclusions also provide unique insights into the architecture of basaltic magma systems, and melt inclusion compositions can potentially constrain the nature, timing, location and rate of the processes which control magma transport, melt aggregation, fractionation, mixing, assimilation and eruption. They are particularly powerful when a complete suite of elements is analysed for and when used in concert with the host lava suite. The availability of large integrated inclusion and host lava datasets covering a range of geodynamic environments (e.g. MORB, IOB, CFB, IAB) also offer the potential to compare and contrast differences in magmatic architecture related to external tectonically-driven factors, such as magma production and upwelling rates, lithospheric and crustal thickness differences and the eruption environment.

Examples of the utility of this approach come from MORB and CFB. Melt inclusions from slower-spreading MOR have been shown to preserve a greater diversity of melt inclusion compositions than inclusions from faster spreading segments. New data from the SWIR extends this observation to ultra-slow spreading centres, which have inclusions that preserve an extraordinary degree of magmatic diversity (K_2O/TiO_2 = 0.01 to 2.8, $[La/Sm]_N$ = 0.15 to 2.0). Overall this observation is consistent with a wider variety of compositions preserved within the less-vigorous and transient magmatic systems that occur at slower upwelling rates. In CFB, the occurrence of mantle-derived trace element variations and those resulting from crustal contamination within the same inclusions, along with the observation that primitive melts may contain highly contaminated inclusions, show that very limited amount of melt aggregation and fractionation occurs within CFB melt systems prior to entering the continental crust. CFB melt transport systems must be able to efficiently transport diverse melts to the crust with little opportunity for aggregation and mixing.

V21C-02 0845h INVITED

The Reliability of Olivine-Hosted Melt Inclusions: Making Ultracalcic Liquids With a CaO Pump.

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Geochemical evidence demonstrates that the extraction of silicate melt from residual peridotite is an efficient process, and that near-fractional partial melting of peridotite in the oceanic upper mantle occurs over a range of pressure-temperature conditions. Silicate melts included in olivine phenocrysts are isolated from most magma chamber process and, therefore, may preserve geochemical information relating directly to the processes of peridotite melting and melt transport in the upper mantle. Unusually CaO-rich (ultracalcic) melt inclusions, with compositional characteristics (CaO 14 wt%; CaO/Al_2O_3 1.0 by weight) that are rare in the global mid-ocean ridge basalt (MORB) population, suggest the involvement of exotic lithologies in mantle melting. However, results from modeling carried out using new experimental determinations of the diffusivity of CaO demonstrate that equilibration of olivine phenocrysts occurs over relatively short timescales. Further, the systematically low Na_2O contents of ultracalcic melt inclusions suggest that their high CaO content may result from diffusive equilibration following magma mixing.

Diffusive equilibration of the CaO content of an olivine-hosted melt inclusion following magma mixing depends upon both the systematics of olivine/melt partitioning and diffusivity. The olivine/melt partition coefficient for CaO increases with increasing Na_2O in the melt. If, following magma mixing, an olivine finds itself floating in a melt with increased Na_2O, but CaO comparable to the melt from which it crystallized, it's CaO content will increase. Further, if the olivine contains a melt inclusion with low Na_2O, the CaO increase of the host olivine will be magnified, producing a CaO "pump". Rapid diffusivity of CaO in olivine allows this process to occur over relatively short timescales. Because Al_2O_3 is likely to be relatively immobile, the CaO/Al_2O_3 will be fractionated. At 1225 °C a 200 μm melt inclusion centered in a spherical host olivine 2 mm in diameter will retain its original concentration of CaO for only ~10 years after magma mixing, after which it increases rapidly. Complete equilibration of the inclusion with the external melt requires ~70 years.

V21C-03 0900h INVITED

The Common Occurence of Melt Inclusions With Exotic Major-Element Compositions in High-Fo Olivine Phenocrysts: A Result of Localised Wall-Rock Assimilation?

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Melt inclusions (MI) hosted by high-Fo olivine phenocrysts from various tectonic settings commonly have unusual major and trace element compositions, unlike any lavas, whereas MI in more evolved olivine phenocrysts are usually compositionally similar to the host lavas. Anomalous MI often have high CaO contents and CaO/Al2O3 values, whereas SiO2 contents are either lower or higher that those in lavas. In some cases, particularly in subduction-related magmatic suites erupted through a thick arc crust, all MI in high-Fo olivines have anomalous compositions, whereas in other suites anomalous and 'normal' MI can be found in a single sample. In samples with dominant anomalous MI, high-Fo olivines usually contain a large number of MI of variable sizes, often > 100 microns. In contrast, in samples with MI of 'normal' compositions, many high-Fo olivines are devoid of inclusions, however when present, inclusions are small and few. The above differences in the size and abundance of 'normal' and anomalous MI imply differences in the rate of crystallisation, with anomalous MI corresponding to faster cooling rates. The fastest cooling rates of a primitive magma are expected at the margins of a magma body where it is in contact with the wall rocks. Interaction of such magmas with cooler wall-rocks will cause localised rapid cooling, facilitating crystallisation at the margins of the magma and also trapping of MI by the growing phenocrysts. The compositions of these MI are likely to record the processes of partial dissolution of the wall rock and mixing of the resulting melt with the primitive magma, and have no bearing on magma generation processes. On the other hand, inside the magma body, far away from the reaction zones, slow cooling rates do not favour trapping of MI, and 'normal' MI are much less common. The population of MI in high-Fo phenocrysts is thus naturally biased towards anomalous compositions, whereas in the macro system these reaction processes are far less important. Large abundant 'normal' MI are found in high-Fo olivine from magmatic suites (eg, boninites, low-Ti arc tholeiites, komatiites) where crystallisation occurred at shallow depths during ascent and was accompanied by degassing, resulting in rapid crystallisation.

V21C-04 0915h

LILE enrichment in MORB melt inclusions: evidence for upper-mantle autometasomatism.

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After corrections for host plagioclase interaction, primitive melt inclusions from Central Indian Ridge basaltic lavas have compositions that can be accounted for by fractional crystallisation of an olivine, clinopyroxene and plagioclase assemblage. Correcting for this fractional crystallisation, the melt inclusions are also found to be depleted in phosphorus, titanium and iron, relative to their matrix glasses. Furthermore, phosphorus and titanium concentrations correlate inversely with sodium and potassium, an effect that is incompatible with either mantle partial melting processes or diffusion between melt inclusions and their external magma. Instead, it is concluded that the melt inclusions were formed from melt increments derived from the depleted shallow mantle melting column during which fusion was promoted by a hydrous fluid carrying sodium and potassium. We suggest the fluid originates during early dehydration melting of the mantle column and is transported rapidly to shallower levels. The common occurrence of similar enrichment in depleted basaltic magmas, melt inclusions and upper-mantle peridotites indicates that this is a globally significant process.

V21C-05 0930h

Melt Inclusions Record Extreme Compositional Variability in Primitive Magmas at Mauna Loa Volcano, Hawaii

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Melt inclusions carry potentially unique information about magmatic processes and the compositional evolution of erupted lavas. Major element compositions of olivine-hosted melt inclusions in submarine tholeiitic picrites from the southwest rift zone of Mauna Loa volcano have been studied to examine the compositional variability of primitive magmas feeding the worlds largest volcano. Approximately 600 naturally quenched inclusions were examined from 8 samples with 3-25 vol% olivine phenocrysts and 9-22 wt% MgO. Olivine compositions ranged from Fo91-Fo82. The inclusions show a continuous variation in FeO contents from near-magmatic values (9 to 11 wt%) in the most evolved olivines to extremely low values (3.5 to 7.0 wt%) in the most primitive olivines. This appears to reflect a complex magmatic history for these crystals involving extensive re-equlibration of melts trapped by early formed phenocrysts with their host olivine. Extreme compositional variability also characterizes incompatible elements that would not be affected by equilibration with the host olivine. Inclusions trapped in relatively primitive olivines (Fo88-91) show a large range of K2O contents (0.1 to 2.1 wt%), whereas inclusions in more evolved olivines converge on whole rock compositions with 0.3 to 0.4 wt% K2O. Similarly, TiO2/K2O, Na2O/K2O, and K2O/P2O5 ratios of inclusions in primitive olivines span a much larger range than do inclusions hosted by more evolved olivines, with TiO2/K2O ratios extending from enriched to depleted compositions (1.2 to 24.7) in primitive olivines, and converging on whole rock compositions (TiO2/K2O = 6-9) in more evolved host olivine. This points toward extreme compositional variability in melts feeding Mauna Loa, and effective mixing of these melt parcels in the shallower summit reservoir to produce the restricted range of whole rock compositions sampled by erupted lavas. Whole rock compositions, therefore provide an integrated view of melting and high-level mixing processes, whereas melt inclusions provide more detailed information about source characteristics.

V21C-06 0945h

Constraining Open-System Processes in the Generation of Basaltic Magma Using $^{87}Sr/^{86}Sr$ of Individual Minerals and Melt Inclusions, Pisgah Crater, Ca

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Basaltic magmas have been extensively used to infer the geochemical nature of mantle sources. Studies which make such inferences typically focus on basalts that are characterized by assumed primary magma characteristics such as high MgO contents. Such characteristics are typically used as justification to discount or suggest only a minimal influence of open-system modifications, such as those resulting from crustal assimilation. Often, very little effort is made to more thoroughly eliminate this possibility because it is very difficult to identify and constrain such effects especially if the assimilated crust is mafic in character. Alkali basalts and hawaiities erupted at Pisgah Crater in the Mojave Desert of California result from open-system processes yet still retain high MgO (6-8%) contents. The specific processes responsible for extensive trace element and isotopic variations in these basalts, however, are in dispute. Glazner et al. (1991) suggest that Pisgah Crater trace element and isotopic variations originate from assimilation of mafic crust while Reiners (2002) suggests that such variations result from mixing of mantle-derived garnet peridotite and garnet pyroxenite magmas.

Large $^{87}Sr/^{86}Sr$ variations among and within individual plagioclase, clinopyroxene, amphibole, groundmass, and melt inclusions in olivine attest to the effects of open-system processes and indicate a complex mixing process (i.e., not two-component mixing) that occurred up to the time of eruption (Ramos et al, in prep). $^{87}Sr/^{86}Sr$ of minerals indicate that early and intermediate erupted lavas retain relatively uncontaminated signatures while the latest erupted lavas reflect much higher $^{87}Sr/^{86}Sr$, consistent with contamination at crustal pressures (i.e., within the plagioclase stability field).

Major element compositions of melt inclusions hosted in olivine confirm the presence of highly evolved magmas (e.g., MgO: 0.5 to 3%, SiO_2: 52-57%) in later erupted lavas. Whole grain olivine analyses, which are assumed to be sampling Sr from melt inclusions, define a large range of $^{87}Sr/^{86}Sr$ (0.7037 to 0.7055) which exceeds that displayed by any other mineral. We intend to demonstrate that in-situ analyses of melt inclusions will also define such extensive variations. Using laser ablation sampling in conjunction with multicollector ICPMS, we will correlate in-situ $^{87}Sr/^{86}Sr$ analyses with major element compositions of individual melt inclusions to test whether highly evolved magmas are also characterized by high $^{87}Sr/^{86}Sr$.

$^{87}Sr/^{86}Sr$ variations in phenocrysts likely result from mineral growth in magma characterized by progressively increasing $^{87}Sr/^{86}Sr$ with time. Major element compositions of melt inclusions indicate an extensive variety of magmas with variable $^{87}Sr/^{86}Sr$ existed during olivine crystallization. Results of this study suggest that crustal contamination, and not mixing of mantle-derived magmas, is responsible for trace element and geochemical variations in Pisgah Crater basalts. In addition, one-dimensional diffusion modeling suggests that plagioclase resided in the magma for less than 900 y, confirming that open-system modifications occurred quite rapidly. Results will demonstrate the utility of measuring $^{87}Sr/^{86}Sr$ of individual minerals, including melt inclusions in olivine, to constrain the effects and timing of crustal contamination of basalts.

1) Glazner et al., JGR, 96, #B8, 13673-13691, 1991.
2) Reiners, P.W., Geochemistry, Geophysics, Geosystems, v.3, #2 30 pages, 2002.

V21C-07 1020h INVITED

Vapor Undersaturation in Primitive MORBs and the Volatile Content of the Earths Upper Mantle

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We present the first report of undersaturated pre-eruptive volatile content for a suite of MORBs from the Siqueiros intra-transform spreading center. The undersaturation leads to correlations between volatiles and refractory trace elements that provide new constraints on the volatile abundances in the depleted upper mantle and their behavior during melting. The constant CO2/Nb ratio of the samples show that CO2 is a higly incompatible element during MORB generation and constrains the abundance of CO2 in the MORB mantle source to (72+/-19) values substantially lower than most previous estimates. This result is supported by the excellent correlation between Cl and CO2 in the Siqueiros melt inclusions. Thus, the CO2-Nb, CO2-Cl correlations permit primitive CO2 and Cl estimates to be made for degassed and Cl contaminated MORBs. The volatile-rich popping rocks that have led to previous high CO2 estimates for the upper mantle have very high volatile contents in large part because of their incompatible element enrichment (e.g. very high Nb contents). Our results and the relatively constant CO2/3He ratio for MORBs allow constraints on the extent of 3He degassing, its flux at ridges and its content in the upper mantle. The constant ratios of H2O/Ce, F/P, S/Dy and Cl/K in Siqueiros glasses and melt inclusions together with previous estimates of the refractory trace element content in the MORB mantle constrain the abundances of H2O (142+/-85), F (16+/-3), S (146+/-35) and Cl (1+/-0.5) in the Earths upper mantle. These abundances are much lower than estimates for the source regions of hotspots, indicating the presence of volatile heterogeneity in the Earths mantle.

V21C-08 1035h INVITED

Volatiles in the Icelandic Mantle: Constraints from Primitive Melt Inclusions

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Abundances of water, carbon dioxide, fluorine, sulfur, chlorine and lithophile trace elements were measured by SIMS in over 100 melt inclusions in olivine, Cr-diopside and spinel from Borgarhraun, a small-volume post-glacial volcano from the Theistareykir segment of northern Iceland. Trace element variations can be modeled by incomplete mixing of melts generated by polybaric dynamic melting of a passively-upwelling MORB mantle, sufficient to generate a crustal thickness of 19 km [Slater et al., 2001; Elliott et al., 1991].

Water abundances in the melt inclusions are nearly uniform despite wide variations in trace element abundance. This could be due to extensive hydrogen diffusion and exchange with the host magma [Hauri, 2002], however D/H ratios are variable and correlated with LREE. Carbon dioxide concentrations in the melt inclusions vary widely (100-1000 ppm), and correlate with abundances of highly incompatible elements (Ba, Nb, La). The melt inclusions must have been trapped at sufficiently high pressures (>3.5 kbar) to prevent degassing and preserve correlations between CO_2 and lithophile trace elements. Trace element correlations with CO_2 demonstrate clearly the highly incompatible nature of carbon during mantle melting.

The CO_2/Nb ratio of the Icelandic melt inclusions is 285; with an estimate for Nb in the depleted MORB mantle of 0.45 ppm, the CO_2 concentration of the depleted mantle beneath Iceland is estimated at 128 ppm. An upper limit of 270 ppm is indicated by those melt inclusions with the highest CO_2/Nb ratios. These estimates are much lower than those derived from CO 2 in "popping rocks" and degassing models based on C isotopes in MORB, but are remarkably consistent with the CO_2 flux at ridges derived from C-He relationships and helium degassing into the oceans [Marty & Tolstikhin, 1998].

V21C-09 1050h INVITED

Melt Inclusions as Windows on Subduction Zone Processes - A Retrospective

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A.T. (Fred) Anderson, in a series of papers in the interval 1972-1984, presented evidence from melt inclusions for high dissolved water and Cl concentrations in many subduction zone basalts through andesites. His observations, subsequently shown to be correct, were not widely accepted because (1) phase equilibrium experiments on Paricutin and Mount Hood andesites indicated moderate water concentrations, and some workers reasoned that potentially parental basalts would have been drier still, (2) common basalts lack hydrous phenocrysts, and (3) water content estimates were indirect (water-by-difference) or involved difficult, unfamiliar measurements (single inclusion manometry) and thus were discounted.

Subsequent development of techniques for the direct and precise measurement of water and CO_2 in melt inclusions (SIMS, FTIR), new hydrous phase-equilibrium studies on arc basalts through rhyolites, and wider appreciation of the diversity of arc magmatic suites changed this situation. Melt inclusion evidence shows that subduction zone basalts can have pre-eruptive dissolved water concentrations as high as ~6 wt% (Sisson and Layne 1993 EPSL; Roggensack et al. 1997 Science), confirming predictions from phase-equilibrium experiments (Sisson and Grove 1993a,b CMP), and supporting the now standard model of water-fluxed melting to drive arc magmatism. An important discovery, presaged in the original Anderson data, is that there is a wide range of pre-eruptive water contents in arc basalts, with some as dry as MORB (Sisson and Bronto 1998 Nature). Nearly dry arc basalts can erupt at the volcanic front (Galunggung, Java) and sporadically along the arc axis over distances of hundreds of km (Cascades, USA), in some cases in proximity to demonstrably water-rich magmatic centers (Mt. Shasta, Crater Lake). To produce dry primitive basalts requires upwelling and pressure-release melting of peridotite in the mantle wedge at temperatures (~1300° C) well above those predicted by common geodynamic models. Pressure-release and water-flux melting probably act together to produce parental arc basalts, but presently there is no evidence establishing the relative dominance of these melt-producing processes in any arc or more local region. Regional studies of melt inclusions in arc basalts have potential for solving this question.

V21C-10 1105h

Subducted Fluid and Sediment Compositions Preserved in Mariana Arc Melt Inclusions

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Melt inclusions (MIs) in arc lavas provide a direct means of measuring the content of volatile species (H_2O, CO_2, etc.) which are critical to the operation of the subduction factory. Besides preserving pre-eruptive, undegassed magma, MIs may also capture liquids prior to mixing in large magma chambers and thus may retain a broad range of slab-derived characteristics. This study focuses on MI populations from five

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basaltic scoria samples from Guguan, Pagan and Agrigan islands of the Mariana arc. The MIs studied are olivine-hosted (Fo 68-82), 50-300 m, clear brown glass with no visible evidence of devitrification. We have analyzed these MIs for H_2O and CO_2 by FTIR, major elements by EMP and trace elements by laser ablation ICP-MS. The MIs range in water content from 1-4 wt.%, but MIs with detectable CO_2 indicate a tighter range of H_2O concentrations in undegassed inclusions from 2.5-4 wt.% and averaging 3 wt.% H_2O. The MIs are broadly similar in both major and trace elements to lavas from the same islands, but these new data extend the range of trace element compositions observed in Mariana arc lavas. We have analyzed MIs from Agrigan with trace element systematics nearly identical in Ba/La and La/Sm to that of bulk subducting sediment in the Marianas, and from Guguan with a composition very close to the inferred slab-derived fluid composition. One Guguan inclusion is of particular interest. It has 3.5 wt.% H_2O with an NMORB REE pattern (La/Sm=0.76), high Ba/La (70) and very high U/Th (1.1). It also has high Pb/U (25) demonstrating a preference for Pb over U in slab-derived fluids. The composition of this inclusion also plots near the y-intercept (zero sediment flux) on global arc-sediment flux correlation diagrams, confirming that it represents close to an average global sediment-free slab fluid composition. Compositions this extreme have never been measured in Mariana arc lavas before. On the other hand, this fluid-rich arc melt has a very different composition from a comparable melt calculated using the H_2O-rich component of Stolper & Newman (1994) for the Mariana back-arc, which has lower Ba/La (11), U/Th (0.4) and Pb/U (4.2). This contrast in arc and back-arc fluids is suggestive of two potential processes. A similar slab-derived fluid may be added to variably depleted mantle, less depleted in the back-arc and more depleted beneath the arc. Alternatively, the slab may undergo progressive dehydration, where sub-arc dehydration removes fluid-mobile elements and depletes the slab of such elements before further dehydration in the back-arc.

V21C-11 1120h

Water Abundance in Arc Magmas: Olivine Melt Inclusions From Central America

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Water and CO_2 variation in arc magmas has been investigated using olivine melt inclusions from nine scoria and ash deposits in Central America. Samples from Nejapa and Granada regions of Nicaragua are among the most primitive (bulk MgO 6.9 to 8.8 wt.%), have moderate Ba/La ratios (30 to 60) and contain olivine phenocrysts of composition Fo_{81-86}. Melt inclusions within these deposits are characterized by low to moderate water and high CO_2 (2 to 3.5 wt.% and 1,000 to 2,500 ppm, respectively; determined by FTIR). Other Nicaraguan (including Momotombo, Cerro Negro, Telica) and Guatemalan (Fuego) samples are more-evolved (bulk MgO 3.4 to 6.4 wt.%), have moderate to high Ba/La ratios (52 to 116) and contain olivine phenocrysts of composition Fo_{78-82}. Melt inclusions are characterized by high water contents (generally 3.5 to 4 wt.%) and CO_2 of 1,200 ppm or less. Many samples (including primitive Nejapa and Granada) show evidence of heterogeneity. For example, high-TiO_2 inclusions are sometimes found in low-TiO_2 magmas and vice versa, or low-B and Ba inclusions are found in units where high-B and Ba inclusions predominate. Also, some individual eruptive units display heterogeneity in water abundance. For instance, some define steep CO_2-degassing trends at nearly constant water while others show significant H_2O variation (1 to 1.5 wt.%; ~30% relative) at elevated CO_2 that cannot be explained by degassing. Instead, the heterogeneity in water and major and trace elements suggests that individual eruptive units are comprised of variably admixed magma batches. In the Nejapa and Granada area, where the arc signature is less pronounced, there is an apparent positive correlation between water abundance (average melt inclusion) and bulk-determined (ICP-MS) incompatible elements (K, Rb, Ba, Sr, Pb, U) with low-TiO_2 magmas having higher water abundance than high-TiO_2 magmas. In contrast, volcanic units with stronger arc signatures show no correlation between water and trace elements. The latter observation may be caused by multiple additions of slab-derived material to the magma source region.

V21C-12 1135h

Pre-eruptive Volatile Concentrations in Rhyodacitic Melt Inclusions From Mt. Mazama: Implications for Eruption Triggering

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At least two (and probably more) episodes of andesite to basaltic andesite magma recharge and differentiation led to the accumulation of the large ~ 45 to 50 km^3 of rhyodacitic magma beneath Mt. Mazama. These recharge events are recognized on the basis of Sr concentrations in plagioclase phenocrysts and matrix glasses in both ryhodacitic pumices and andesitic scoria. Strontium concentrations of plagioclase phenocrysts in rhyodacitic tephra erupted during earlier smaller volume ~ 2 km^3 Llao Rocks 7015 ± 45 yr.B.P. (Bacon, 1983) and shortly preceding Cleetwood eruptions provide some temporal constraints (200 170 years) on the timing of these magma recharge episodes. An electron microprobe and FTIR study of glassy melt inclusions in rhyodacitic tephra from the climactic, Cleetwood and Llao Rocks eruptions was initiated in order to observe the temporal variation in dissolved volatiles (H_2O, CO_2, Cl, S, F) concentrations in the accumulating rhyodacitic magma body. Dissolved volatiles concentrations and trace element data are used to evaluate the effectiveness of magma recharge as a potential eruption trigger for the climactic eruption.

Several samples from various stratigraphic levels of the climactic, Cleetwood and Llao Rocks pumice fall sequences were selected for the melt inclusion study. Rhyodacitic melt inclusions in plagioclase and orthopyroxene in climactic tephra range from felsic dacite (68-69 % SiO_2 anhydrous) to rhyolite (70-73% SiO_2 anhydrous). Total dissolved H_2O concentrations determined by FTIR range from 4.3 wt.% to 6.0 wt.%. Dissolved CO_2, concentrations were below detection level (~ 20 ppm) in all climactic rhyodacitic inclusions. Chlorine concentrations range from 1720 ppm to 3930 ppm in less evolved inclusions. Dissolved sulfur concentrations range from 70 to 300 ppm with highest sulfur concentrations occurring in high Cl and H_2O inclusions. Dissolved fluorine concentrations range from 200 ppm to 900 ppm but do not exhibit any obvious correlation with other volatiles. Cleetwood melt inclusions span the same composition range as observed in climactic samples (68-73% SiO_2). Total dissolved H_2O concentrations by FTIR range from 4.2 to 5.4 wt.%. Dissolved CO_2, concentrations were below detection in most inclusions although one inclusion with 4.22 wt.% H_2O by FTIR has 60 ppm CO_2. Chlorine concentrations are similar to those observed in climactic inclusions and range from 1700 to 3950 ppm. Sulfur concentrations in Cleetwood rhyodacitic to dacitic inclusions range up to 500 ppm with several inclusions in the 330 to 450 ppm range. These high sulfur inclusions generally occur in inclusions with > 5.00 wt. % H_2O and > 2100 ppm Cl. Llao Rock rhyodacitic inclusions exhibit similar H_2O concentrations but typically have much lower dissolved sulfur concentrations in the range of 60 to 130 ppm, with Cl concentrations from 1600 to 1800 ppm. Strontium and barium trace element data indicate that high sulfur, chlorine and H_2O inclusions in Cleetwood and climactic phenocrysts can be attributed to fractionation from high Sr and sulfur basaltic andesite parent liquid(s) which recharged the chamber 170 years (or less) before the climactic eruption.

V21C-13 1150h

Ore Metal-rich Fluids Degassed from a Fractionating Magma Chamber in the Eastern Manus Basin, Western Pacific: Evidence from Melt Inclusions and Vesicles

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Magmatic fluids are found in vesicular volcanic rocks that host several hydrothermal fields in the eastern Manus backarc basin. Dredged samples of fresh lavas, of basalt to rhyolite composition, define a calc-alkalic trend consistent with fractionation of a common source. Their vesicularity decreases with Si, K, Ba and Zr, and increases with Ca, Mg, Fe and Sc of the bulk samples, suggesting that the degassing of volatiles was linked to crystal fractionation of the magma. The felsic rocks have much lower vesicularities (<10%) than the mafic rocks (>30%), indicating that the fractionated felsic magma lost most of its vesicles before its eruption. High concentrations of H_2O (0.9 to 2.5%) and Cl (up to 0.45%) observed in the mafic melt inclusions in phenocryst minerals of the basaltic andesite point to a volatile-rich magma. A separate fluid phase is present in the melt inclusions so the magma must have been saturated with volatiles in the magma chamber. The volatiles exsolved as an immiscible fluid with increasing crystal fractionation, and the composition of the degassed magmatic fluid changed with the evolving magma. The fluid is CO_2-dominated during the degassing of weakly fractionated mafic magma and becomes a mixture of CO_2 and H_2O as H_2O is increasingly exsolved from the highly-fractionated felsic magma. The ore metals in the degassed fluid, as inferred from the compositions (by EPMA, SEM/EDS and TOF-SIMS) of metallic precipitates in the vesicles of melt inclusions and matrix glass, progressively change from Ni+Cu+Zn+Fe in basalt and basaltic andesite, to Cu+Zn+Fe in andesite, Cu+Fe in dacite, Fe in rhyodacite and Fe+Zn (+Pb?) in rhyolite. This trend provides evidence that fluids, released from a fractionating magma, could be an enriched source of metals for various types of ore deposits. In particular, the pre-eruptive degassing of magmatic fluids from felsic magmas could be responsible for the Fe, Cu, Zn and Pb metals in the sulfide chimneys at PACMANUS and Susu in the eastern Manus basin. By analogy, a magmatic fluid can provide a major source of ore metals for large or super large volcanogenic massive sulfides deposits in the geological record of ancient island arcs.

V22A MCC: Hall C Tuesday 1330h

Melt Inclusions: What Do They Tell Us? II Posters *(joint with OS)*

Presiding: **N Shimizu,** Woods Hole Oceanographic Institution**; C Mandeville,** American Museum of Natural History

V22A-1212 1330h POSTER

Nano-Diamonds in melt inclusions in ortho- and clinopyropxene from mantle xenoliths, Salt Lake Crater, Hawaii.

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We observed nanocrystalline diamonds in magmatic rocks from Hawaii (Salt Lake Crater). They occur in mantle xenoliths (Ga-pyroxenites) in melt inclusions in ortho- and clinopyroxene. The xenoliths are incorporated in the host lava and have been transported from the Earth's interior to the surface by volcanic eruptions. Consequently, such xenoliths allow an insight into the structure, the chemical composition and the P-T conditions of the Earths mantle. Salt Lake Crater pyroxenites are interpreted as high-pressure basaltic cumulates trapped and adiabatically cooled within the Hawaiian lithosphere at 1000° - 1150°C and 1.6 2.5 GPa (50-80 km). The melt inclusions were investigated by using TEM and AEM.

Specimen preparation was performed by focused ion beam technique (FIB) at the GeoForschungsZentrum Potsdam (GFZ). Promising melt inclusions in pyroxene have been selected from thin sections. FIB technique uses oil-free vacuum to avoid contamination of the foil. The resulting TEM foil has the dimensions 20 μm x 10 μm x 100 nm. Coating of the TEM ready foil with carbon was not necessary.

Nanocrystalline diamonds are embedded in melt droplets, which are enclosed in pyroxene crystals. The melt inclusions with an average diameter of about 5 m are always associated with a fluid phase or gas. The matrix of the melt inclusion consists of amorphous material (basaltic glass) containing very small inclusions of e.g. ZnS, Fe-Pd-S, Ag and In-rich minerals, native nanocrystalline iron and copper. Most of the diamonds occur in approximately rectangular shaped aggregates of polycrystalline diamonds, between 20 and 500 nm in size. The grain size of individual diamonds within each aggregate varies from 5 to 50 nm. The diamonds have been identified by X-ray analysis, electron diffraction and by EELS. The carbon K-edge in the EEL spectra allows to discriminate diamond, graphite and amorphous