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During May 2001 we simultaneously monitored the eruptive activity of three active vents on Stromboli volcano, Italy using 3 Metek MVR 3 Doppler Radars. Within 10 days, more than 1200 eruptions were recorded. Radar data are used to estimate eruption intervals, activity duration, velocity distribution and the reflected radar power of each event. Typical clast sizes of the events are estimated from clast sinking velocities. A semi-empirical law generally used for rain drop settling forecast converts mean sinking velocities into typical particle diameters. Daily averages of these data are used to infer typical eruption signatures. The reflected radar power allow a qualitative approximation of erupted masses. Crater 3 showed the highest reflected radar power and the most regular activity with typical eruption intervals of 400 s and a mean particle rising velocity of 16 m/s. Craters 1 and 2 showed interval lengths of about 700 s and rising velocities of about 17 m/s. Mean eruption lengths are 7 s for crater 1, 17 s for crater 2 and 13 s for crater 3. Mean particle diameters are 13 mm for crater 1, 9 mm for crater 2 and 12 mm for crater 3 to but they vary strongly with time from about 5 to 30 mm. For crater 3 they show a significant diurnal variation with big diameters during night and the smallest around noon. Currently we are working on the statistical analysis of the whole data set, which we wish to present at the conference.

URL: <http://www.geomar.de/~rseyfrie/index.html>

V51E MC: 304 Friday 0830h

Geochemical and Isotopic Tracers of Earth Processes: Oceanic Mantle/Crust System (a session in honor of Gil Hanson) (joint with H, T, GC, MR)

Presiding: C H Langmuir, Lamont-Doherty; K Mezger, Universitaet Muenster

V51E-01 0830h INVITED

Osmium Isotope Compositions of Komatiite Sources Through Time

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Extending Os isotopic measurements to ancient plume sources may help to constrain how and when the well-documented isotopic heterogeneities in modern systems were created. Komatiites and picrites associated with plume-related volcanism are valuable tracers of the Os isotopic composition of plumes because of their typically high Os concentrations and relatively low Re/Os. Re-Os data are now available for a variety of Phanerozoic, Proterozoic and Archean komatiites and picrites. As with modern plumes, the sources of Archean and Proterozoic komatiites exhibit a large range of initial ¹⁸⁷Os/¹⁸⁸Os ratios. Most komatiites are dominated by sources with chondritic Os isotopic compositions (e.g. Song La; Norseman-Wiluna; Pyke Hill; Alexo), though some (e.g. Gorgona) derive from heterogeneous sources. Of note, however, two ca. 2.7 Ga systems, Kostomuksha (Russia) and Belingwe (Zimbabwe), have initial ratios enriched by 2-3% relative to the contemporary convecting upper mantle. These results suggest that if the ¹⁸⁷Os enrichment was due to the incorporation of minor amounts of recycled crust into the mantle source of the rocks, the crust formed very early in Earth history. Thus, the Os results could reflect derivation of melt from hybrid mantle whose composition was modified by the addition of mafic crustal material that would most likely have formed between 4.2 and 4.5 Ga. Alternately, the mantle sources of these komatiites may have derived a portion of their Os from the putative ¹⁸⁷Os - and ¹⁸⁶Os - enriched outer core. For this hypothesis to be applicable to Archean rocks, an inner core of sufficient mass would have to have crystallized sufficiently early in Earth history to generate an outer core with ¹⁸⁷Os enriched by at least 3% relative to the chondritic average. Using the Pt-Re-Os partition coefficients espoused by our earlier work, and assuming linear growth of the inner core started at 4.5 Ga and continued to present, would yield an outer core at 2.7 Ga with a gamma Os value of only +1.2 and a ¹⁸⁶Os/¹⁸⁸Os enrichment relative to the contemporary upper mantle of only +13 ppm. Greater isotopic enrichments could have been achieved by 2.7 Ga if either the inner core comprised >2.8% of the mass of the core by 2.7 Ga, or if Re and Os solid metal-liquid metal D's for core crystallization

were greater than those applied in the initial calculation.

V51E-02 0845h

Undersaturated Volatile Contents in MORB, Evidence for Re-Melting Episodes

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We present here the first report of undersaturated volatile contents for one of the most primitive suites from the EPR, the picritic lavas from the Siqueiros intra-transform spreading centers. We studied olivine-hosted (Fo 90-91) primary melt inclusions and their host glasses from lavas erupted at approximately 3900 meters below sea level. The study of melt inclusions and deep erupted glasses allows us to determine the primary volatile contents of the Siqueiros lavas, avoiding the effect of degassing occurring during eruption. The melt inclusions and glasses have refractory major and trace element compositions, with the most depleted compositions having strong enrichment in Sr content compared to elements of similar compatibility. The primitive-mantle-normalized trace element patterns of these depleted inclusions resemble those of plagioclase-rich cumulates occurring in the lower oceanic crust and in massif peridotites. The Siqueiros glasses and olivine-hosted melt inclusions are undersaturated in H₂O-CO₂, Cl and F, and range from barely saturated to undersaturated in S contents. The undersaturation in volatile contents of these glasses and melt inclusions is consistent with the low vesicularity of the Siqueiros picritic lavas (<0.1%). The refractory major, trace and volatile compositions of the Siqueiros melt inclusions and glasses can be explained by low extent of melting (1-5 %) of residual peridotite, left after the extraction of MORBs, and Associated veins of plagioclase-rich cumulates generated during MORB differentiation and interaction with the residual mantle. Our results have important implications for our interpretation of MORB geochemistry. For example, melting of young (<10,000 years) depleted peridotite left after the extraction of MORB with associated plagioclase-rich cumulate can give an alternative explanation to the extreme 226Ra excess found in MORBs.

V51E-03 0900h

Determining the Mineralogy of the MORB Source Through Nd-Isotope Analyses of Abyssal Peridotites

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Interpreting the chemical and isotopic systematics of MORBs in relation to details of the melting process and the physical conditions under which melting takes place hinges on the assumption of compositional similarity or regularity between all MORB sources. For example, the interpretations of regular variations in Na8 and Fe8 versus axial ridge depth, thought to reflect a deeper initiation of melting and higher extents of melting beneath shallow ridges, are only valid in the context of chemically and mineralogically homogeneous source mantle. The presence of garnet-bearing mafic compositions with enriched signatures in the mantle has long been discussed. Garnet-bearing eclogite or pyroxenite blobs or veins in the MORB mantle would likely be associated with plume material and thus, would tend to correlate with the degree of "enrichment" in the MORB source. If residual during melting, garnet pyroxenite can further contribute to the chemically enriched character of derivative basalts by trace element fractionations that are characteristic of residual garnet. It has been shown that, in general, the mineralogical, major element and trace element variations abyssal

peridotites are consistent with the major and trace element variations observed in MORB. We have examined the variations in Sr and Nd-isotopic and trace element composition of abyssal peridotites from two ridge segments, the segment near the Atlantis II Fracture Zone (AII FZ) and the 10° to 16°E section of the south east Indian ridge (10-16E) and compared these variations with the Sr and Nd-isotope variations in the basalts. Basalts from the AII FZ show a normal MORB chemistry and have ¹⁴³Nd/¹⁴⁴Nd ratios as low as 0.5130, while basalts from the 10-16E section show an anomalous enriched character and have ¹⁴³Nd/¹⁴⁴Nd ratios ranging from 0.51284-0.51302. The REE pattern of diopsides in the AII Fracture zone peridotite show a strongly light REE depleted pattern indicating they are residues of MORB genesis. In comparison, the REE patterns of the diopsides of the 10-16E area are flat to only slightly light REE depleted and the most enriched REE patterns can be in equilibrium with MORB. The Nd-isotopic composition of the diopsides in the abyssal peridotites confirm the trace element chemistry. Clinopyroxenes from peridotites from the AII FZ have Sr and Nd-isotopic compositions that overlap with those of the basalts and ¹⁴³Nd/¹⁴⁴Nd ratios range from 0.513077 to 0.513409, and ⁸⁷Sr/⁸⁶Sr ranges from 0.70255 to 0.70305, while at the 10-16E section ¹⁴³Nd/¹⁴⁴Nd ratios vary from 0.513031 to 0.513194 and ⁸⁷Sr/⁸⁶Sr varies from 0.70260 to 0.703025. These data show that the Sr and Nd-isotopic composition of abyssal peridotites from both ridge segments have a MORB-source signature. Therefore at the 10-16E segment in which the isotopically "enriched" basalts occur the peridotites only overlap with the depleted endmember and the enriched signature requires the presence of a component other than peridotite. A mafic component in the MORB source of the 10-16E section is the most likely candidate.

V51E-04 0915h

Water concentrations in enriched mantle components in the north Atlantic: Evidence for efficient dehydration of recycled crust and sediments

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A major uncertainty in the earth's water cycle is the amount of water that enters the deep mantle through subduction and recycling of hydrated oceanic lithosphere. We measured H₂O and CO₂ in north Mid-Atlantic Ridge (MAR) glasses dredged by between 33.2 and 40.5°N (FAZAR expedition) between 926 and 3900 m depth. Two distinct geochemical anomalies occur within this region, a long wavelength anomaly associated with the intersection of the Azores archipelago and the MAR at ~38-39°N (Azores Platform) and a short wavelength anomaly centered at 35°N (Great Meteor anomaly). Sr-Nd-Pb isotopic compositions show evidence for mixing of 3 mantle components: (1) depleted MORB mantle (DMM), (2) a common plume source (C) and (3) an enriched mantle component (EM) thought to represent recycled crustal materials. Azores Platform basalts form a linear mixing array between DMM and C. In contrast, basalts from the Great Meteor anomaly form a mixing array between C and EM. Dissolved water concentrations in the poorly vesicular Azores Platform samples correlate positively with K₂O and have H₂O/Ce ratios (253±33) consistent with previously reported values for the north Atlantic. Estimated bulk H₂O/Ce for the highly vesicular samples (247±54) are similar to the values for the nonvesicular samples for all but the shallowest dredge (17), which may have suffered some gas loss. Great Meteor samples have dissolved and bulk water concentrations at a given K₂O ~30% lower than the Azores Platform samples (Bulk H₂O/Ce = 168±29). Extrapolation from C through the Great Meteor H₂O/Ce data yields a value of <100 at a ⁸⁷Sr/⁸⁶Sr of >0.705. Thus, EM components in north Atlantic are depleted in water relative to similarly incompatible elements. The results of this study are consistent with results from the south Atlantic (Leist et al., this volume) and previous work on Hawaii, where the Koolau (EM1) component was found to be depleted in water (Dixon and Clague, 2001, JPet, 42: 627-654; Hauri, 2001, Chem. Geol., in press). We suggest that relatively dry EM components are common and result from >92% extraction of water from crustal materials during the subduction process and their recycling through the deep mantle.

V51E-05 0930h

Olivine/Melt Equilibrium and the Major Element Evolution of Olivine-Hosted Melt Inclusions

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Silicate melts included in olivine crystals preserve compositional variability not found in erupted lavas. The major element compositions of olivine-hosted melt inclusions are susceptible to post-entrapment modification, however, limiting our ability to accurately determine their initial compositions. Although the effects of crystallization can be accounted for through olivine-addition calculations, the combined effects of exchange and diffusive re-equilibration with the host crystal are more difficult to evaluate. A quantitative understanding of the post-entrapment evolution of melt inclusions can be obtained through combining the partition coefficient approach for calculating olivine/melt equilibrium [1] with experimentally determined cation diffusivities in olivine. In order to quantify exchange at the inclusion/host interface, the model for calculating olivine/melt equilibrium developed by Gaetani and Watson [2,3] was extended to include Ca using the method of Beattie [4]. Further, new experiments were carried out to determine the temperature and composition dependence of crystal/melt partitioning for minor olivine components, allowing the effects of exchange between an inclusion and its host olivine to be calculated.

Experiments were carried out to determine olivine/melt partition coefficients for a suite of incompatible elements (Ca, Al, Ti, Na, Cr, Mn) at 0.1 MPa and temperatures of 1225 to 1325 °C. To ensure olivine saturation over the entire temperature range, experiments were carried out in crucibles fabricated from San Carlos olivine. Starting compositions were chosen to maximize the effects of melt composition on partitioning. The major element compositions of all phases were determined by electron microprobe and partition coefficients for most elements were measured by ion microprobe (SIMS).

Using the approach of Beattie [4], the partitioning of Ca between olivine and melt was related to that of Mg through the strain energy associated with expansion of the oxygen octahedra. Experimental data from the literature were used to calibrate the radius of the unstrained M2 lattice site (r_0) at temperatures of 1100 to 1528 °C and pressures of 0.1 MPa to 2.3 GPa. Olivine compositions range from Fo₃₂ to Fo₁₀₀. Values of r_0 derived from the regressions range from 0.599±0.004 to 0.780±0.003 Å, and decrease systematically with increasing MgO in the olivine. The new experiments show that the partition coefficient for Ca (0.0283±0.0007) in Fo₉₀ olivine is larger than that for Ti (0.0137±0.0007) by a factor of 2. The partition coefficients for Al (0.0063±0.0003) and Na (0.0067±0.0012) are indistinguishable at these conditions. The incorporation of Na into olivine appears to involve a nepheline (NaAlSi₃O₈) style substitution.

References: [1] Hanson and Langmuir, 1978, GCA, 42:725-741; [2] Gaetani and Watson, 2000, EPSL, 183:27-41; [3] Gaetani and Watson, 2001, Chem Geol, in press; [4] Beattie, 1994, Chem Geol, 117:57-71.

V51E-06 1005h

Variety is the spice of life: Extreme trace element variability as a consequence of channelized magma transport

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The spatial and temporal variability of chemical signals in lavas, residues and melt inclusions provide important constraints on both source heterogeneity and the efficiency of convection and melt transport processes in the mantle. The past decade has seen an impressive increase in the number, precision and spatial resolution of chemical analyses. However, as resolution has increased, the picture of variation that emerges has become increasingly difficult to understand. For example, we show that mid-ocean ridge basalts can display large trace-element concentration variability with little obvious spatial correlation on all scales from 1000 km of ridge down to the hand-sample scale measured in melt inclusions. These results suggest that melt transport processes do not readily homogenize partially molten regions. While some of this variability is due to source variations, we suggest that a large component could be the consequence of magma transport in channelized systems.

We present results of numerical models that calculate the chemical consequences of reactive flow and melt localization that we have developed previously to

explain the organization of mantle plumbing systems and "replacive dunitites" observed in ophiolites. We show that channelized flow can produce orders of magnitude variation in the concentrations of highly incompatible elements, even for idealized systems with a homogeneous source, constant bulk partition coefficients and equilibrium transport. Most importantly, the full range of variability is found in each channel due to advection of highly depleted melts from the inter-channel regions into the edges of the channels. As these channels may be spaced on scales of 1-100 m in the mantle, this mechanism allows highly variable melts to be delivered to the Moho on very small length scales. We show that the chemical variation produced in the models is consistent with that seen in melt inclusion suites, lavas and residual mantle peridotites dredged from the ridges and sampled in ophiolites.

URL: <http://www.ldeo.columbia.edu/~mspieg/SolFlow/>

V51E-07 1020h

U-series Disequilibria in MORB From Transform and Implications for Mantle Melting

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Transform settings produce greater compositional diversity in erupted basalts than on-axis settings, most likely due to magmas being less subjected to crustal level mixing and fractionation processes. We report U-Th-Ra disequilibria measurements in MORB glasses from three different transform settings from the mid-ocean ridge system. Our goal is to relate the disequilibria to existing U-series data from adjacent ridge axes. We analyzed 25 samples ranging from primitive, depleted basalts to moderately enriched basalts from the Cox Transform, (~32°S latitude on the Mid-Atlantic Ridge), the Blanco Transform (~44°N latitude offsetting the Gorda and Juan de Fuca Ridges), and the Garrett Transform (~13°30'S latitude on the East Pacific Rise) for Th isotopes by ion probe (WHOI), U and Th concentrations by ICP-MS (WHOI) and Ra by TIMS (UIUC).

Samples from the Cox Transform contain 16-272 ppb U and 42-850 ppb Th equating to Th/U ratios that vary between 2.6 and 3.1. (²³⁰Th)/(²³²Th) range between 0.99 and 1.15. Samples have slight ²³⁰Th excesses ranging from 1-4%. Samples from the Blanco Transform have between 50-300 ppb U and 140-900 ppb Th with a restricted range in Th/U (~2.9). These samples have (²³⁰Th)/(²³²Th) ranging between 1.1-1.2 resulting in small ²³⁰Th excesses (6-12%). (²²⁶Ra)/(²³⁰Th) range from 1.0 to 1.3, most likely reflecting the effect of significant age since eruption. Samples from the Garrett Transform have 9-75 ppb U and 14-215 ppb Th and large variations in Th/U (1.5 to 2.9). (²³⁰Th)/(²³²Th) vary from 1.2 to 1.5 such that (²³⁰Th)/(²³⁸U) range from ~15% excess ²³⁰Th in high Th/U samples to 4 samples with 3-7% ²³⁸U excess at low Th/U. Garrett samples also have large ²²⁶Ra excesses, with (²²⁶Ra)/(²³⁰Th) varying between 1.3 and 4, including several samples between 3 and 4.

The data from the Cox and Blanco Transforms do not form simple binary mixing relationships among the disequilibria as observed previously in the Siqueiros Transform (Lundstrom et al., JGR 1999). Part of this reflects the relatively restricted range in Th/U of the samples and part may reflect significant age since eruption. Data from the Garrett Transform are consistent with previous observations with high ²²⁶Ra excesses observed in basalts having low to no excess ²³⁰Th. This observation is consistent with a reactive porous flow melting process in which large ²²⁶Ra excesses are generated and maintained to shallow depths (<30 km) in the melt column.

V51E-08 1035h

Isotope and Trace element Variations Along the Southern Chile Ridge and Valdivia Fracture Zone System

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During the 1998 Panorama 4 Expedition, we mapped and sampled the three northern segments of the southern Chile Ridge (SCR; Segs. S5-S7) and the six short, deep, and stable intra-transform spreading centers of the Valdivia Fracture Zone System (VFZS; Segs. V1-V6). Hand-picked basaltic glasses were analyzed for low-abundance trace elements by ICP-MS and for Nd, Sr and Pb isotopes. Our previous sampling of the SCR (Segs. S1-S4) yielded an unusual suite of lavas, segmented geochemically by transforms or propagating rifts into distinct geochemical provinces with distinct source histories. Trace element and isotopic systematics of the lavas are consistent with incorporation of recycled pelagic or terrigenous sediment into their sources (e.g., low Ce/Pb, Nb/U), and show strong affinities with EMII-type (Segs. 1 and 3) or EM1-type (Seg. 4) OIB. Our analysis of samples from the northern segments of the southern Chile Ridge reveals that this remarkable diversity of magma compositions persists to the north, but is of a different geochemical character. Notably, Seg. 5 has trace element systematics which differ dramatically from those to the south, including unusually high Nb/U and Ce/Pb and low Rb/Nb, chemical characteristics that have been previously identified in HIMU-type ocean island lavas. Our initial isotopic results are consistent with the trace element findings in that Seg. 5 extends toward high 206Pb/204Pb but at only moderately enriched Nd and Sr isotope ratios, characteristic of the HIMU isotope end-member. In regard to the southern Chile Ridge, the close proximity of EM1, EMII and HIMU source compositions is reminiscent of the occurrence of these three end-members in close proximity in the islands of French Polynesia, where previous studies have suggested that they may represent components of a common recycling event. In contrast to the great diversity of the southern Chile Ridge, our trace element and isotopic results for the VFZS reveal relatively uniform and depleted N-MORB compositions, and suggest that the diversity of enriched compositions is confined to the near-trench, southern Chile Ridge.

V51E-09 1050h

Are Melt Migration Rates Through the Mantle Universally Rapid?

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Significant enrichments in ²²⁶Ra over ²³⁰Th have been observed in basalts erupted in nearly all tectonic settings. These enrichments generally are greatest in lavas with low concentrations of U, Th and other incompatible elements, including those from mid-ocean ridges and "depleted" volcanic arcs. Excesses of ²²⁶Ra over ²³⁰Th in mid-ocean ridge settings are commonly attributed to smaller bulk partition coefficients for Ra with respect to Th during mantle melting, and extraction of ingrown Ra into melts slowly migrating through interconnected pore space. In contrast, ²²⁶Ra excesses in basalts from volcanic arcs have been attributed to fluid additions from subducting slabs to the sources of the basalt and rapid (10² - 10³ y) melt migration to the surface (e.g. Turner et al., 2001). Such rapid melt velocities imply channeled flow rather than diffuse porous flow, and suggest that basalts from other tectonic settings migrate similarly rapidly. Here, we show that the compositions of basalts from both arc and mid-ocean ridge settings indeed can be explained by melting models involving rapid transit times to the surface. Simple fluxed melting models and rapid transfer of melt to the surface explain the U-Th-Ra systematics and incompatible trace element compositions of arc basalts. The U-Th-Ra and trace element data for young MORB from the East Pacific Rise (Sims et al. 2001) and the Siqueiros transform (Lundstrom et al. 1999) are modeled using simple 2-d polybaric melting based on Braun et al. (2000) and rapid melt migration rates. Successful models mix small-degree fractional melts derived from a broad cross-sectional area of mantle at depth with high-degree melts derived from a small cross-sectional area of shallow mantle that is the aged residue of the small degree melt.

V51E-10 1105h

The Origin of Alkali and Ocean Island Basalts: Contradictions and Solutions

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OIB are generally thought to be derived as melts of subducted ocean crust. Nd and Sr isotopes are consistent with this model and require long term source depletion. But this model is difficult to reconcile with OIB chemical compositions. (1) Sun and Hanson (1974), in the first attempt at trace element inversion, showed that the OIB mantle source is LREE enriched. But recycled MORB are LREE depleted. (2) OIB incompatible element ratios are not consistent with recycled MORB converted to eclogite or pyroxenite, which would melt to large extents in the upwelling mantle, and highly incompatible elements would not be fractionated. (3). Primitive OIB have magnesian major element compositions that suggest equilibration with peridotite, and are generally inconsistent with being partial melts of recycled MORB. (4) Volatiles are released during subduction, so recycled materials should be volatile poor, and primitive noble gas signatures should be absent. Instead, OIB are volatile- and 3He-rich. These are the geochemical aspects of the OIB Paradox. There are also geological contradictions. While OIB are believed to come from plumes derived from recycled ocean crust, the OIB magma type is not restricted to hot spot locations. OIB-like lavas occur throughout the ocean floor, in and behind convergent margins, in continental rifts, and elsewhere - as also pointed out by Sun and Hanson.

A solution to these contradictions is that OIB reservoirs form by addition of low degree melts of subducted ocean crust to surrounding mantle. Generically, this model accounts for the problems listed above. Low degree melts contain most of the radiogenic elements and therefore impart the isotope signature of the recycled materials. The low degree melts do not modify the major element composition of the mantle significantly, and therefore allow OIB to be melts of peridotite. Very low extents of melting are able to fractionate highly incompatible elements and create relatively constant incompatible element ratios because F is as low as D. Low F melts would transport volatiles and have them be incorporated into the source. Therefore a low F melt source solves the OIB problem in ways that recycled ocean crust cannot.

There is then the geological question of where the source is created. It could be created above subduction zones where slabs are hot enough to melt subducted crust at depths greater than the volcanic front. Large contiguous volumes of melt-metasomatized mantle could be created in this way. In this environment, the fertilized mantle wedge overlying the slab could be carried to depth in the mantle where it acquires a high 3He signature and rises to form plumes. Minor amounts of volatile-depleted eclogite could also be involved directly in some cases (e.g. perhaps Hawaiian tholeiites). But what we find striking about ocean island geochemistry is the rarity of the eclogite signature. Koolau is an outlier, not a paradigm.

Similar alkali basalt source compositions could be created from any eclogite that reaches shallow levels in the mantle, because the eclogite has so much lower a solidus temperature than does peridotite. Given the mantle thermal structure, this process allows alkali basalt sources to be created throughout the upper mantle as an inevitable consequence of mantle convection. The uniform character of the OIB magma type then comes from the relative partition coefficients of trace elements in garnet and pyroxene, which imparts a commonality to low F melts in diverse environments. This model accounts for the petrological and geochemical features of OIB, and also permits the ubiquity of their geographical occurrence.

V51E-11 1120h

A New Pb Isotope Perspective on Oceanic Basalts: Reading Between the Lines

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Recent high-precision Pb isotope analyses (~100 ppm) obtained using double and triple spikes demonstrate that much of the scatter in previous, conventionally obtained data is analytical in origin. Here we pool together all the currently available high-precision Pb isotope data on oceanic basalts to provide a new "sharpened up" picture of the gross Pb isotope heterogeneity in the mantle. These Pb isotope data are from

MORB glasses from the East Pacific Rise (EPR) and South Atlantic (26°S, Ascension), seven Hawaiian volcanoes, Pitcairn, Rurutu, the Azores (all MPI data), Mangaia (Woodhead, 1996), and St. Helena and Iceland (Thirlwall, 2000), totalling around 250 samples.

The high-precision data for a given location do not form the "clouds" in Pb-Pb isotope space seen in conventional literature data. Rather, each data set forms tight linear arrays in both Pb isotope spaces. More surprising, though, is that the samples lying on a given array cover a limited geographic extent: (1) In the case of the EPR, six distinct arrays are found, each of which is confined to a particular range in latitude along the ridge, corresponding to length-scales of ~100 to 5000 km. The same is true of MORB samples from the South Atlantic (2) Distinct arrays are resolved for individual volcanoes along the Hawaiian chain, indicating that the heterogeneities within the Hawaiian plume are tapped in a long-lived and highly systematic fashion.

It is also quite clear that these data are not readily interpretable in terms of mixing between notional end-member "components" in the mantle. For example, the EM1 "component" present in Pitcairn is quite clearly different in Pb isotope space from that sampled by Koolau. Similarly, the HIMU "component" present in the Austral-Cook chain is distinct in the islands Mangaia and Rurutu, and is not the same as that found in St. Helena. In all of these cases it is impossible to find common crossing points of the arrays in both Pb isotope spaces. Moreover, none of the arrays "point" towards any of the putative end-member "mantle components." If such common end-members do exist in the mantle, almost perfect premixing between them would be required to form viable intermediate end-members to each of the arrays observed.

Overall, these new Pb isotope data pose the questions: (1) What is the significance of the linear arrays and why are there so many of them?, and (2) how can such heterogeneities survive intact in the convecting mantle over long periods of time?

V52A MC: Hall D Friday 1330h General Volcanology

Presiding: C F Waythomas, USGS,
Alaska Volcano Observatory

V52A-1032 1330h POSTER

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Geologic mapping and a gravity study of the Black Point tuff cone located on the NW shore of Mono Lake, near Lee Vining, California (38°02' latitude, 119°06' longitude) was performed in this study. Black Point is a Surtseyan-style tuff cone that erupted approximately 13,300 years ago beneath glacial Lake Russell. The goal from the gravity study was to test models for the subsurface geometry. Specifically, to determine the distribution of consolidated versus unconsolidated tephra observed near the summit of Black Point. These models were developed based on observations of the consolidation of extruded tephra by a process called palagonitization following the eruption of the Surtsey tuff cone in Iceland in 1963. Measurements using a Worden gravimeter were captured over a three-day span, covering 185 individual stations. Stations were spaced at 5-20 meter intervals across the principal area of the main vent. Two perpendicular arrays were followed, striking approximately N56E and N34W respectively. Both arrays transect suspected main vent area for Black Point. Rock samples were obtained and analyzed for their densities, which were then used to generate best-fit models matching the observed gravity using the Grav-2D program. The observations (in mgals) collected using the Worden gravimeter have been corrected for elevation above the geoid, local topography, local mass and density of rock, drift of Earth, and terrain, to provide an anomaly without background noise. Two simple models were generated to demonstrate the idealized two-dimensional subsurface of Black Point in proximity to the suspected main vent. These models imply that palagonitization occurs to significant depths, and, occurs on either side of the suspected main vent at Black Point. Both models assume that surface densities can be extrapolated to a depth of at least 300 meters. Further southeast of the vent, the tuff cone is underlain by a deep-rooted, high-density (approximately 3.0 g/cm³) body suggesting a dike swarm or feeder dike system bypassing the Mono Craters magma chamber. The correlation of the consolidated tephra alongside the vent implies that palagonitization may have occurred in direct response to localized hydrothermal activity near the vent. The models are in direct contrast to work by others who suggest that this phenomenon will only occur after all heat is lost via the interaction of rainwater percolation. Clearly, by gravity models constructed, this is not so.

V52A-1033 1330h POSTER

Western Alborz Volcanic Rocks, a new Geochemical Viewpoint

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Volcanic and pyroclastic rocks of Eocene age comprise vast outcrops of Alborz Mountain Range, a fold-thrust structural unit extending across northern Iran for 2000 km in a curvilinear pattern. In his account of structural evolution of Iranian plateau, Berberian (1983; p. 55) ascribed these rocks to a subduction-type magmatism. Based on a tectonostratigraphic study, these rocks are attributed to an arc-type magmatism (Alavi; 1996; p. 29).

Recently a new data set of major and trace element (including REE) analyses of volcanic rocks from western Alborz, some 50 km west of city of Qazvin, has been made available (Asiabanha, 2001). Careful examination of the data (i.e., those of basic-intermediate rocks) in present study revealed, for the first time, some geochemical characteristics which have important implications on the geodynamic synthesis of this structural unit. The rocks contain 50-60 wt% SiO₂. They lie in the midalkaline-to-subalkaline domain of TAS diagram (Middlemost, 1997; p.216) and fall in the calcalkaline field of AFM diagram.

The volcanic rocks display two distinct chondrite-normalized REE patterns, one is MREE-depleted while the other is a rather smooth uniform M-HREE pattern. These are called MREE-depleted and smooth M-HREE series. Basic rocks from the latter contain higher silica than the former (>53 vs. >50 wt%), yet they show lower incompatible elements (e.g., K and Rb) and HFSE contents. These features can not be explained by differentiation and might be interpreted as implying the involvement of two source regions. Chondrite-normalized trace element patterns of the MREE-depleted series is more akin to the island arc calcalkaline (ACA) basic rocks than the basic rocks from any other tectonic settings. However, island arc products, known for being depleted in HFSE relative to other incompatible elements, differ from the MREE-depleted series which is rich in both HFSE and incompatible elements. One may advocate the role of OIB-type mantle components to explain the HFSE-enrichment of the MREE-depleted series. Alternatively higher Zr/Y ratios and MREE-depletion in the series might be considered as indicating amphibole presence in its source region.

Selected Reference:

Asiabanha, A. 2001. Geology and petrogenesis of volcanic facies in Youzbashichay region. PhD thesis, Tarbiat Modares Uni., in Persian, 320 p.

V52A-1034 1330h POSTER

Groundwater Flow System of Unzen Volcano, Japan

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Unzen volcano (peak 1486 m) is developed on the western part of Beppu-Shimabara Graben (20 km NS wide and 200 km EW long) located at Kyushu island, SW Japan. We have been studied groundwater system of the volcano using geochemical and hydrological technique in order to estimate flux of magmatic volatiles through the groundwater. We have collected over 150 sample waters from springs, rivers, and wells, and they are analyzed for major chemistry and stable isotope ratios. Over 50 pore waters were extracted from 100-1200m-deep drilled cores at the eastern flank of the volcano by a centrifugal separator. The results are summarized as follows:

1) Flow rates of springs and rivers indicate that most of the groundwater recharged at Unzen volcano flew down the slope directed to the east, which is restricted by graben structure.

2) All the groundwaters and spring waters collected inside the graben area are isotopically homogeneous, i.e., -48 -45 permil for hydrogen isotope ratio, indicating that the groundwater is well mixed during flowing.

3) In spite of the isotopic homogeneity, the groundwaters are chemically different from each other. In particular, bicarbonate concentration ranged from 20 to 180 mg/l, and it is inconsistent with the isotopic results. There are some active faults parallel to the