V71C MCC: 106 Sunday 0830h

Contemporary Chemical Geodynamics II *(joint with T)*

Presiding: **J C Lassiter,** Max-Planck-Institut fuer Chemie**; Y Niu,** Cardiff University

V71C-01 0830h

An Alternative Hypothesis for the Origin of the High 226Ra excess in MORBs

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Complex melting and percolation models with one or two porosity system have been proposed to explain the high (226Ra) excess and the inverse correlation between (226Ra/230Th) and (230Th/238U) observed in MORBs. In here, we present the alternative hypothesis that shallow processes such as interaction of MORBs with plagioclase-rich cumulates could be responsible for those isotopic signatures. Our model calculations indicate that bulk plagioclase assimilation by primitive plagioclase-undersaturated basalt or diffusive re-equilibration of Ra and Th between plagioclase cumulate and mafic lavas can explain the observed high (226Ra) excess and the inverse correlation between (226Ra/230Th) and (226Th/238U) observed in MORBs. Our calculation require melt/rock ratios ranging from 0.5 to 40% depending on the composition of the melt and the plagioclase respectively. These melt/rock ratios are consistent with the observed magma chamber reflectors and the decrease in the P wave velocity of a 10% in the low velocity zone below ridges. Flux calculations show that a minimum of 500 years will be require to replenish the melt in the low velocity zone; a much longer time than the 300 years of plagioclase/melt interaction required to produce the observed isotopic variations in MORBs. Thus, the data can be explained by interaction of primitive melts with young (less than 2000 years) gabbros or troctolites formed by differentiation of previous MOR magmatism in the mush zone at the top of the melting column. Moreover, a new diffusion model by Van Orman et al., (this volume) indicates that the cumulates do not necessarily have to be young, but they could also be several millons of years old and still produce the (226Ra) excess observed in MOR lavas by basalt/cumulate interaction.

V71C-02 0845h

A New Model for U-Series Isotope Fractionation During Igneous Processes, With Finite Diffusion and Multiple Solid Phases

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U-series radioactive disequilibria in basaltic lavas have been used to infer many important aspects of melt generation and extraction processes, including the porosity of the melting zone, the mantle upwelling rate, and the melt transport rate. These inferences are based on simplified models for the fractionation of U-series isotopes during melting and melt transport. The commonly used "dynamic melting" and "equilibrium porous flow" models neglect solid-state diffusion and do not consider the influence of multiple solid phases on the initial distribution and subsequent fractionation of U-series isotopes. These factors can be very important, particularly for ^{226}Ra which has a short half-life (1600 yrs) and is strongly partitioned into minerals like plagioclase, amphibole, and mica while being almost perfectly excluded from clinopyroxene and garnet, the major U and Th bearing minerals in peridotite. Ignoring diffusion and multi-phase effects can lead to conclusions about the melting process that have no basis in reality.

We have developed a numerical model that takes into account the effects of solid-state diffusion and considers the distribution of U-series isotopes among multiple solid phases and melt at each step of the melting process. In an undisturbed rock in secular equilibrium, daughter isotopes will tend to be transferred among the component phases until they reach a steady state in which diffusive fluxes are balanced by radioactive production and decay. In general the individual minerals will be neither in secular equilibrium (on the equiline) nor in partitioning equilibrium with each other (on a horizontal line on the equiline diagram), unless diffusion is very slow or very fast relative to the daughter decay rate. We start with an arbitrary distribution of daughter isotopes among the phases in the system, then turn on diffusion and allow isotopes to redistribute themselves until the steady state is reached (on a time scale comparable to the half-life of the isotope). Next, partial melting begins, or a foreign melt is introduced into the system, and isotopes are again redistributed among the phases via diffusion. U-series isotopes can be strongly fractionated during this stage due to differences in diffusivity. The diffusive fractionation can be much larger than equilibrium fractionation, and may even be in the opposite sense.

We performed a series of calculations to simulate interaction of MORB liquids with "old" cpx+plag bearing gabbro in bulk secular equilibrium. In the gabbro at steady state, most of the U and Th reside in the cpx, and most of the ^{226}Ra resides in the plagioclase. Because Ra diffusion in plagioclase is much faster than Th diffusion in cpx, large fractionations of ^{226}Ra and ^{230}Th can take place. If the MORB is more depleted than a melt that would be in equilibrium with the gabbro, then it acquires excess ^{226}Ra; if it is more enriched, it acquires a ^{226}Ra deficit. Interaction with gabbros will tend to produce large Ra excesses in D-MORB (> 5), but small Ra excesses (or even Ra deficits) in E-MORB. This is consistent with observations, and suggests that ^{226}Ra-^{230}Th disequilibria in MORB can be explained by shallow-level processes, and may give no information on processes of mantle melting.

V71C-03 0900h

Niobium in Planetary Cores: Consequences for the Interpretation of Terrestrial Nb Systematics

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In order to search for a hidden container for the 'missing' Nb in the Earth's mantle, we measured Nb, Ta, V and Cr in magmatic iron meteorites thought to be fragments of metallic cores of asteroid-sized bodies. We found high Nb/Ta (> 75) with Nb concentrations (0.007-0.04 ppm) that are correlated with V and Cr, thus supporting the hypothesis of Wade and Wood (2001) that Nb entered the Earth's core as a weakly siderophile element. From our data of terrestrial samples, SNC meteorites and eucrites, we estimate Nb/Ta ratios of the bulk silicate phases of Earth (14±2), Mars (16±1) and Vesta (17), all of which are lower than the chondritic value of 17.5. Assuming that these lower-than-chondritic ratios are caused by partitioning of Nb into the cores, and that the precursors of the planetary bodies have a chondritic composition, we calculate the mass fractions of the Nb budget of 20%, 9% and 2% for the cores of Earth, Mars and Vesta. These values correspond to Nb concentrations of 0.3 ppm, 0.2 ppm, 0.03 ppm, respectively. Metal/silicate partition coefficients of Nb, calculated from our estimates of the bulk silicate phases and from our Nb data of the iron meteorites increase strongly with increasing pressure consistent with the experimental data of Wade and Wood (2001).

These results have important consequences for the interpretation of terrestrial Nb systematics. The lower primitive-mantle Nb abundance of 0.55 ppm means that primitive-mantle ratios such as Nb/U will be lowered by 20% (Nb/U=24 instead of 30). This, in turn, changes conventional mass balance estimates of the major terrestrial silicate reservoirs (Hofmann et al., 1986). Using new estimates for continental crust U and Nb (Rudnick and Fountain, 1995) in conjunction with the classical three-reservoir Silicate Earth model, we now obtain a primitive reservoir of about 30% consistent with recent mantle models assuming a primitive reservoir of relatively low volume located in the deep mantle (Kellog et al., 1999). If the non-depleted reservoir is enriched rather than primitive, the results are also consistent with the model of Tolstikhin and Hofmann (this volume) invoking an enriched reservoir at the base of the mantle.

V71C-04 0915h

Vestige of a Beginning: a Quest for ^{142}Nd Anomalies in the Earth

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Although seismic tomography evidence leaves no room for fully layered mantle convection, it is still arguable that over Earths history convection has efficiently homogenized mantle composition. We first searched for remains of the early differentiation of the planet in the 3.8 Ga rocks from Isua, Greenland. A sensitive indicator is the extinct radioactivity of ^{146}Sm which decays to ^{142}Nd with a half-life of 103 Myr. From the ^{142}Nd excess of about +2 epsilon observed in chondrites (Prinzhofer et al., 1992) and differentiated meteorites (Nyquist et al., 1994), we can expect that differentiation events older than ca. 4.2 Ga left measurable isotopic effects in parts of the mantle. Three mafic samples from Isua analyzed by MC-ICP-MS in Lyon show a distinctive ^{142}Nd anomaly of +0.3 epsilon unit, while all other samples are isotopically normal. Replicate values ($2\sigma = 0.15\ \varepsilon$) show that they are significant and confirm the magnitude of the single anomaly found by Harper and Jacobsen (1992). At 3.8 Ga, some mantle domains had escaped full homogenization. We also searched for ^{142}Nd anomalies in samples originating from parts of the mantle with a potentially primitive character. The isotopic composition of Nd has been determined on a number of samples from high ^{3}He/^{4}He volcanic centers (Iceland, Ethiopia, Loihi). Typical uncertainties of 15 ppm were obtained by at least three repeat analyses. Eight Icelandic samples and nine Ethiopia samples have normal ^{142}Nd abundances. In contrast, 3 of 6 Loihi samples indicate ^{142}Nd anomalies in excess of 0.5 ε. Replicate analyses of these samples are in progress. Excess ^{142}Nd in the mantle source of Loihi basalts would signal the presence of pristine early mantle in the very same place where the O, Os, and Hf isotope systematics (Lassiter and Hauri, 1998; Blichert-Toft et al., 1999) seem to call for the recycling of material that formed in a low-temperature hydrous environment. In spite of active subduction down to the core-mantle boundary, the lower mantle appears to retain some primordial material as manifested by both high ^{3}He/^{4}He ratios and ^{142}Nd anomalies.

V71C-05 0930h

Evidence for Re Loss during Magma Degassing: Implications for Re Concentration Variations in OIB and MORB

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Although Re should behave as an incompatible element during partial melting, average Re concentrations in MORB (~930 ppt) are considerably higher than in OIB (~300 ppt). This is surprising, because the high ^{187}Os/^{188}Os ratios in many OIB suggest derivation from Re-enriched sources, and because OIB are thought to be generated through smaller degrees of partial melting than MORB. Previous studies have shown that Re is compatible in garnet [1], and have suggested that greater garnet or sulfide abundances in the sources

of OIB could account for the lower Re abundances in these lavas. However, measured D(garnet) for Re is < D(garnet) for Yb, yet average OIB Re/Yb ratios are lower than for MORB, opposite the trend expected for garnet retention of Re (and Yb). Greater sulfide retention of Re in OIB sources is also inconsistent with Os-Ni trends in OIB and MORB. Because Os is highly compatible in sulfides [2], greater residual sulfide in OIB sources should result in lavas with lower [Os] for a given Ni concentration than in MORB, yet the opposite is observed. The source of low Re abundances in OIB therefore cannot simply reflect greater Re retention by garnet or sulfide during melt generation.

Recently, Bennett et al. [3] observed that Re abundances in submarine Hawaiian lavas are higher than in subaerial lavas, and suggested that Re may be lost during shallow magma degassing. Re abundance variations in subaerial and submarine portions of the ∼3 km deep HSDP-2 Mauna Kea drill core on Hawaii provide a unique opportunity to examine the effects of magma degassing. The upper 1 km of the drillcore is composed primarily of subaerial Mauna Kea lavas, whereas the lower 2 km are submarine, grading from predominantly hyaloclastites to predominantly pillow lavas and massive flows with increasing core depth. Os-isotopes are nearly constant throughout the core with $^{187}Os/^{188}Os$ = 0.128-0.130. Combined with minor variations in other isotopic and trace element signatures, this suggests that the source composition and melting process remained relatively constant throughout the period sampled by the drillcore. Re abundances in the subaerial lavas are consistently low (Ave. Re = 180 ppt). In contrast, Re abundances in the submarine lavas increase systematically with increasing depth, ranging from an average of ∼300 ppt in the 1000-2000 m depth interval up to ∼755 ppt in lavas from > 2000 m. This trend is best explained by progressive Re loss in the subaerial and shallow submarine lavas during melt degassing. The least-degassed Mauna Kea lavas have Re abundances approaching those observed in MORB. The systematic difference in Re abundances in OIB and MORB may therefore reflect the fact that most analyzed OIB samples are subaerial and therefore degassed whereas MORB retain a greater fraction of their volatile inventory.

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V71C-06 0945h

New Estimates of Rhenium in the Crust: Implications for Mantle Re-Os Budgets

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The ^{187}Re-^{187}Os isotopic system has provided a new probe of mantle chemical structure with, for example, now numerous studies balancing estimates of the Os isotopic compositions of the upper modern mantle with sizes and ages of proposed conjugate reservoirs stored within the deep mantle. This style of modeling is dependent upon estimates of the parent Re in the various reservoirs including total crust, upper mantle, MORB and ocean island basalts.

New laser ICP-MS in situ and ID whole rock results from OIB, arc and back-arc basalts suggest Re concentrations in oceanic and crustal domains may have been greatly underestimated. For example Hawaiian OIBs show a clear distinction between subaerial and submarine erupted samples with the latter having Re much closer to the higher MORB estimates (1) than to previous OIB estimates. This difference has been attributed to Re volatility and loss during syn- and post-eruption degassing of subaerial samples. Recent work has produced similar results for submarine arc samples using both dredged glasses and melt inclusions in olivines from primitive basalts. Both have much higher average Re (ca. 1.5 and 3.4 ppb; 2,3) than literature values for arcs (ca. 0.30ppb) determined largely from sub-aerial samples, or for average crust estimated from loess (0.2 ppb; 4). If the undegassed arc samples are representative, then the total crust may have more than 5 times the Re previously estimated. Re lost during arc eruptions may ultimately be concentrated in anoxic seafloor sediments. Prior under-estimates may be linked to the extremely heterogeneous concentration (> 5 orders of magnitude) of the chalcophile, redox sensitive Re in crustal environments.

If the residence time of high Re in the crust is long (>1 Ga) then, 1) much smaller reservoirs of stored Re in the deep mantle are required to balance Re depletions in the upper mantle, and 2) significant portions of the upper mantle are likely Re depleted. Alternatively Re may be rapidly recycled in oceanic sediments (short residence time) resulting in a smaller affect on Re-Os budgets, but creating areas of extreme Re heterogeneity in the upper mantle.

Refs: 1. Bennett, Norman and Garcia, EPSL 2000. 2. Sun et al. (in press, Chemical Geology) 3. Sun et al. (submitted). 4. Peucker-Ehrenbrink and Jahn, G3, 2001.

V71C-07 1020h

Metal/silicate partitioning of Pt and the origin of the "late veneer"

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Highly siderophile elements (HSEs) are perfect tools for investigating core forming processes in planetary bodies due to their Fe-loving (siderophile) geochemical behavior. Tremendous scientific effort was invested into this field during the past 10 years - mostly in 1 atm experiments. However, little is known about their high-pressure geochemistry and partitioning behavior between core and mantle forming phases. This knowledge is essential to distinguish between equilibrium (Magma Ocean) and non-equilibrium (heterogeneous accretion, late veneer) models for the accretion history for the early Earth.

We therefore chose to investigate the partitioning behavior of Pt up to pressures of 140 kbar (14 GPa) and temperatures of 1950°C. The used melt composition - identical to melt systems used in 1 atm experiments - is the eutectic composition of Anorthite-Diopside (AnDi), a pseudo-basalt. A series of runs were performed which were internaly buffered by the piston cylinder apparatus, and were followed by duplicate experiments buffered in the AnDi-C-CO2 system. These experiments constitute reversals since they approach equilibrium from an initially higher and lower Pt solubility (8 ppm in the non-buffered runs, and essentially Pt free in the buffered runs). Experimental charges were encapsulated in Pt capsules which served as source for Pt. Experiments up to 20 kbar were performed in a Quickpress piston cylinder apparatus, while experiments at higher pressures were performed in a Walker-type (Tucson, AZ) and a Kawai-type (Misasa, Japan) multi anvil apparatus.

Time series experiments were performed in piston-cylinder runs to determine minimum run durations for the achievement of equilibrium, and to guarantee high-quality partitioning data. 6 hours was found to be sufficient to obtain equilibrium. In practice, all experiments exceeded 12 hours to assure equilibrium. In a second set of runs the temperature dependence of the partitioning behavior of Pt was investigated between the melting point of the 1 atm, AnDi system and the melting point of the Pt capsule material. Over 150 piston cylinder and 12 multi anvil experiments have been performed.

Pt solubility is only slightly dependent on temperature, decreasing between 1800 and 1400°C by less than an order of magnitude. In consequence, the partitioning behavior of Pt is mostly determined by its oxygen fugacity dependence, which has only been determined in 1 atm experiments. At 10 kbar, metal/silicate partition coefficients (D's) decrease by about 3 orders of magnitude. The reason for this is not understood, but might be attributed to a first order phase transition as found for, e.g., SiO2 or H2O. Above 10 kbar any increase in pressure does not lead to any further significant decrease in partition coefficients. Solubilities stay roughly constant up to 140 kbar.

Abundances of moderately siderophile elements were possibly established by metal/silicate equilibrium in a magma ocean. These results for Pt suggest that the abundances of HSEs were most probably established by the accretion of a chondritic veneer following core formation, as metal/silicate partition coefficients are too high to be consistent with metal/silicate equilibrium in a magma ocean.

V71C-08 1035h

Os Isotope Bimodality of Alkalic Lavas from the Siberian Flood Basalt Province

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The Siberian flood basalt province is unusual for its abundance of high-Mg, silica-undersaturated lavas, including the unique meymechites, erupted late in the stratigraphic sequence in the Maymecha-Kotuy area of Siberia. (e.g. Fedorenko and Czamanske, Int. Geol. Rev. 39, 1997). If flood basalts derive from plumes, the first melts are derived from the plume whereas later melts may be generated in the lithosphere by a combination of uplift and heating caused by the underlying plume. Lithosphere stretching will produce melts first in hydrous lithosphere followed eventually by sublithospheric melts at high degrees of lithosphere thinning. Os isotopic compositions of the Maymecha-Kotuy lavas offer the potential to discriminate between plume and lithospheric sources, and thus the ultimate cause of this major flood basalt province. Initial Os isotopic compositions of the lavas split into 2 groups. Melanephelinitic lavas have relatively radiogenic initial Os isotopic compositions (γOs (250 Ma) = +8 to +18), whereas the stratigraphically younger meymechites have unradiogenic Os (γOs (250Ma) = -1.2 to -5.9), as found previously by Horan et al. (GCA 59, 1995). The low initial 187Os/188Os of the meymechites is consistent with a source in old Re-depleted lithospheric peridotite, but the isotopic compositions are higher than expected for Archean lithospheric peridotite. The initial Os isotopic compositions of the melanephelinites are within, to the high end, of the range seen for oceanic basalts, and thus are consistent with a plume source. Alternatively, the relatively high Al, Na, Ba and initial 187Os/188Os and lower Mg, Ni and Os contents of the melanephelinites in comparison to the meymechites could reflect a pyroxene-rich lithospheric source for the former and an olivine-dominated lithospheric source for the latter. The strong lithospheric mantle signature in the meymechites, which have been argued to be small degree melts of mantle at 250-300 km depth (Arndt et al., Lithos 35, 1995) is consistent with these late stage magmas being generated by melting of deep lithospheric mantle in response to the rising geotherm created by the high temperatures of an underlying plume.

V71C-09 1050h

Nd-Sr-Hf-Pb Isotope Evidence for HIMU Source Evolution in the Western Canary Islands

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Pb isotope ratios of Canary Island (CI) lavas tend toward radiogenic compositions that indicate the presence of HIMU (high $^{238}U/^{204}Pb$) mantle sources, although the ratios are not as extreme as for some HIMU volcanoes such as Tubuai, Mangaia and St. Helena. Most published isotope data for the Canary Islands are from the eastern islands where the isotopic signature may be complicated by interaction with continent-derived material. We have focused our study on the westernmost islands of La Palma, La Gomera and El Hierro to minimize effects of interaction with continental material. In addition, for each island we analyzed stratigraphic sections within well-constrained time intervals to resolve temporal variations and the importance of intravolcano vs. intervolcano heterogeneities.

The range of ϵNd and ϵHf isotope compositions is fairly restricted (4.5 to 6.5 and 6.0 to 9.0, respectively). Isotopic variability within single volcanoes is nearly as large as among all three islands. CI basalts have, for a given Nd isotope composition, Hf isotope compositions at the lower limit of oceanic basalts observed worldwide. The magnitude of this offset is similar to that for extreme HIMU basalts, however the CI basalt Pb compositions ($^{206}Pb/^{204}Pb$ = 19.5 to 20.0) are not as radiogenic as extreme HIMU basalts. In 207/204Pb vs. 206/204Pb isotope space, nearly all analyzed samples lie below the NHRL of Hart (1984) (Δ7/4 = -1 to -4). High-precision MC-ICP-MS Pb analyses of La Gomera lavas show this offset is consistent and tightly defined (Δ7/4 = -1.2 to -2.4). There is no evidence for a component with relatively high $^{207}Pb/^{204}Pb$, as observed in the eastern CI, and interpreted as interaction with enriched lithosphere (Hoernle et al., 1991) or African-derived sediment (Thirlwall, 1997).

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HIMU sources are reasonably attributed to ancient recycled oceanic crust. CI source evolution to relatively high $^{206}Pb/^{204}Pb$ for a given $^{207}Pb/^{204}Pb$ (i.e., $\Delta 7/4 < 0$) requires fractionation to a high U/Pb environment relatively recently (a few hundred Ma to < 1 Ga). In contrast, evolution to relatively low ϵHf isotope compositions in the CI source requires storage of oceanic crust for at least 1 Ga. Models satisfying both isotopic systems have a small range of overlapping values for age and parent/daughter fractionation indicating aging of a reservoir enriched compared to normal MORB. Candidate sources are recycled E-MORB or the upper (non-cumulate) parts of recycled oceanic plateaux.

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V71C-10 1105h

Evidence for Recycled Crustal Material Within the Upper Mantle Beneath the St Paul Fracture Zone, Equatorial Atlantic

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Several samples of basalts collected along intra-transform ridges (ITR) within the St Paul Fracture Zone in the Equatorial Atlantic, have been studied. They were carefully collected using the submersible Nautile and the R/V Nadir. They come from two well identified intratransform ridge segments A and C at 25°27W and 27°42W respectively.

All samples are tholeiitic basalts in terms of major element composition although samples from segment C (K20 about 0.4%) are more alkalic than those from segment A (K20 < 0.2%). The same contrast is observed for the REE patterns: Segment C samples exhibit mildly enriched patterns (La/SmN of 1.6) whereas segment A samples are mostly depleted (0.4 < La/SmN <1.0) Ce/Pb ratio is elevated in segment C (35) and "normal" in segment A (20-25). Isotopically, Segment A samples fall within the general North Atlantic trend in a plot of 87Sr/86Sr vs 143Nd/144Nd whereas segment C samples fall below it towards the "1°7N anomaly" identified by Schilling et al. (1994). A comparable distribution is observed for Pb isotopes when 206Pb/204Pb is ploted versus 207Pb/204Pb. Combining Pb and Sr isotopes shows that segment C and 1°7N anomaly samples plot toward an HIMU component. This is supported by the elevated Ce/Pb ratios which are typical of true HIMU basalts (Devey and Hmond, unpublished data on St Helena seamount glasses).

These data are in agreement with the presence of an HIMU component within the mantle beneath the Equatorial Atlantic. This component is classically thought to reflect the presence of recycled oceanic crust within the mantle for a long time. This supports the model proposed by Maia et al. (2001) of the existence of recycled lithosphere within the upper mantle based on chemical evidence described by Esperana et al. (1999) using Os isotopes. Studying abyssal peridotites from this area, Esperana et al. have calculated isochron ages of 0.6-1.1 Ga for the recycled component. This relatively young age would explain why this potential HIMU component has not developed yet the characteristic Pb isotopic composition whereas its elevated Ce/Pb ratios agree with such origin. This model is also supported by seismic tomography (Maia et al.2001) which shows the existence of a cold mantle beneath this area within the upper mantle. This thermal anomaly may be also due to the presence of a recycled lithosphere in this region of the mantle.

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V71C-11 1120h INVITED

Fertility of the Mantle beneath the Ocean Basins: Harzburgite, Lherzolite, and Eclogite in Depleted to Enriched Sources of Abyssal Tholeiites, Ocean Islands, and LIPs

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Current models for the origin of MORB and OIB invoke different degrees of partial melting of a homogeneous lherzolitic source, and a heterogeneous deep mantle source, respectively. In the ocean basins, MORBs are only part of a spectrum of geochemically diverse depleted to enriched basalts that erupt at or near ridges, off-axis seamounts and large igneous provinces. Even at ridges, mantle is locally enriched (e.g. E-MORB). The gradation in compositions from MORB to slightly less depleted tholeiites at LIPS, to variably enriched tholeiitic and alkalic basalts, basanites and olivine nephelinites of many ocean islands requires only differences in depth and degree of partial melting of shallow mantle lherzolite upon which trace-element and isotopic heterogeneity are superimposed. Alkalic basalts and differentiates in the oceans occur along nearly every seamount ridge rising >2000 m above the seafloor, a distribution too extensive to be explained by any number of plumes; this makes a plume origin for similar lavas on linear island chains questionable. Tapping along fractures of a shallow asthenospheric layer of variably enriched and fertile mantle that develops beneath the lithosphere through time is more likely. The long-term differentiation of the Earth, magmatism, recycling, continental rifting, and subduction insure that the upper mantle cannot be well mixed and homogeneous, a common but fallacious assumption in much petrogenetic theory. Mantle major-element and isotopic heterogeneity and variable temperature is a consequence of plate tectonics. Every association of ultramafic rocks in the ocean crust, ophiolites, and xenolith suites demonstrates significant bulk heterogeneity that survives partial melting. Thus sources of modern abyssal tholeiites must be variably fertile with respect to a basaltic melt fraction, and range from average harzburgite to fertile lherzolite , on both local and regional scales. In addition, subduction guarantees that most abyssal basalt and gabbro is returned to the mantle, there transforming to eclogite of diverse lithology and mineralogy. Eclogite distribution in the upper mantle cannot be uniform owing to the localized occurrence of trenches. Eclogite-rich mantle can be an important source of magma where the crust is thick (LIPs, Iceland) or volcanic structures very large (Hawaii). There is no need for plume-induced heterogeneity of the shallow mantle or for high temperatures. The absence of heat-flow and thermal anomalies at hotspots implies the presence of athermal mechanisms to explain melting and geochemical anomalies. Fertility spots, wetspots and lithospheric stress heterogeneity are a natural result of plate tectonics and may explain 'hotspots' without assuming deep-mantle thermal plumes. The non-fixity of hotspots, the occurrence of erratic age progressions and 'hotlines' and the orientations of volcanic chains have a natural explanation if lithospheric architecture, subduction and asthenospheric heterogeneity control magma volumes and chemistry. The case for a depleted eclogitic MORB-like source for Icelandic tholeiites will be discussed as an example.

V71C-12 1135h

Partial Melting Experiments of Bimineralic Eclogite and the Origin of Ocean Island Basalts

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There is considerable evidence that mafic lithologies (pyroxenites) are present in the mantle and play important roles in the genesis of ocean island basalts (OIB). A problem in quantitative understanding of the role of pyroxenites in OIB genesis is pyroxenites' compositional diversity, which results in a wide range of melting behaviors. Though MORB may be the volumetrically dominant source for mantle pyroxenite, experimentally produced melts from MORB-like pyroxenite are silica-saturated at high pressures [1], and cannot be silica-undersaturated like most OIB suites. On the other hand, most pyroxenites are more Mg-rich than MORB [2]. Our previous study on partial melting of Mg-rich garnet clinopyroxenite [3] demonstrated that pyroxenite partial melting can explain silica-undersaturated and Al-depleted signatures of OIB magmas if its bulk composition has normative olivine and its residual solid contains significant garnet and lacks olivine. However, it is unclear whether pyroxenites that meet the above requirements are commonly present in OIB source regions.

Bimineralic eclogites are common in worldwide xenolith suites [2] and are the likely consequence of extraction of small degree partial melts or siliceous hydrous fluids from subducted oceanic crust, suggesting that they may be an important type of heterogeneity in the mantle. We have done partial melting experiments on a bimineralic eclogite (B-ECL1) at 5 GPa using a multi-anvil apparatus at the Magma Factory, Tokyo Inst. Tech. The composition of B-ECL1 is similar to residues from hydrous eclogite partial melting [4]. The experimental results show that the solidus temperature is above 1550 °C, which is higher than that of MORB composition [5]. In contrast, the liquidus temperature is between 1650 and 1700 °C, which is close to the peridotite solidus. Thus, B-ECL1 has quite narrow melting interval (<100 °C), and is not more refractory than peridotite as suggested by previous experiments on bimineralic eclogites [6,7]. The subsolidus assemblage is garnet and clinopyroxene only, and the liquidus phase is garnet, suggesting that partial melt compositions could be depleted in Al at higher degrees of melting.

[1] Pertermann & Hirschmann 2002, JGR, in press. [2] Hirschmann & Stolper 1996, CMP 124, 185. [3] Kogiso et al. 2001, EOS 82, S429. [4] Rapp & Watson 1995, J.Petrol. 36, 891. [5] Yasuda et al. 1994, JGR 99, 9401. [6] O'Hara 1963, Yb. CIW 62, 76. [7] Ito & Kennedy 1974, J. Geol. 82, 383.

V71C-13 1150h

Mantle Plumes are *NOT* From Ancient Oceanic Crust

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One of the advances in modern geochemistry is the recognition of compositional heterogeneities in the Earth's mantle through studies of oceanic basalts. Ocean island basalts (OIB) are particularly variable in composition such that several isotopically distinct mantle source end-members are required to explain the variability. It is generally considered that the mantle compositional heterogeneity is a consequence of plate tectonics by means of crust-mantle recycling. Among many contributions endeavoring to understand the origin of mantle compositional heterogeneity is the classic model by *Hofmann and White* [Mantle plumes from ancient oceanic crust, *Earth Planet. Sci. Lett.*, *57*, 421-436, 1982.]. While some details are considered conjectural, the principal idea of the model has been widely accepted by the solid-Earth geochemical community as being, to a first order, correct. Here we offer arguments based on well-understood petrological processes, geochemical observations, and recent experimental data on mineral physics that ancient subducted oceanic crusts cannot be the source materials supplying OIB. Melting of oceanic crusts with basaltic/picritic compositions cannot produce high magnesian (> 15 wt. % MgO) melts parental to most OIB. Ancient oceanic crusts (> 1 Ga) are isotopically too depleted to produce the isotopic signatures (e.g., for the simple Sr, Nd and Hf isotopic systems) of most OIB. Subducted oceanic crusts that have passed through subduction-zone dehydration reactions should be depleted in water-soluble incompatible elements (e.g., Ba, Rb, Cs, U, K, Sr, Pb and, to a lesser extent, light rare earth elements) relative to water-insoluble incompatible elements (e.g., Nb, Ta, Zr, Hf, Ti and heavy rare earth elements). Melting of *residual* crusts with such trace element composition cannot produce OIB. OIB Sr-Nd-Hf isotopes preserve no signature that indicates previous subduction-zone histories. Oceanic crusts subducted into the lower mantle will be > 2% denser than the ambient mantle at shallow lower-mantle depths. This negative buoyancy will impede return of the subducted oceanic crusts into the upper mantle. If subducted oceanic crusts melt at the base of the mantle, the resultant melts are even denser, by up to ∼ 15%, than the ambient peridotitic mantle. Neither in the solid state nor in the melt form can subducted bulk oceanic crusts return to upper mantle source regions of oceanic basalts. Small fragmented components of subducted oceanic crusts could be returned to the upper mantle source regions of oceanic basalts provided they were carried along with streams of ascending buoyant material, but there is no convincing evidence for the presence of bulk subducted crust in the source regions of oceanic basalts. This irreversible process requires a hidden component deep in the mantle unsampled by known volcanism, and would also lead to chemical stratification of the mantle with the mean composition of the lower mantle becoming progressively enriched in *residual* ocean crust lithologies (i.e., compositionally lower in Ca/Al, and higher in Fe/Mg, Si/Mg, Al, and water-insoluble incompatible

elements such as Ti, Nb, Ta, Zr and Hf etc.). Deep portions of recycled oceanic lithosphere (refertilized previously depleted peridotites) are the most likely candidates for OIB sources [*Niu et al.*, Geochemistry of near-EPR seamounts: importance of source vs. process and the origin of enriched mantle component, *Earth Planet. Sci. Lett.*, *199*, 327-345, 2002] in terms of petrology, geochemistry and mineral physics.

V72A MCC: Hall C Sunday 1330h

Linking Chemistry and Microbiology in Seafloor Hydrothermal Systems I
Posters *(joint with B, OS)*

Presiding: **T Urabe,** University of Tokyo**; R Embley,** NOAA Pacific Marine Environmental Laboratory

V72A-1279 1330h POSTER

Broad-Host Range Vector-Particle: Gene Transfer Particles From Thermal Vents

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Viruses or virus-like particles (VLPs) are common in aquatic ecosystems, however, VLP-host interactions and its commitments to gene transfer in the environment is yet unclear. We have proposed that at least some of the widely distributed VLPs could be general gene transfer agents among a wide range of microbial host cells, and might function as a universal vector (1-4).

To elucidate such a broad host range gene transfer mediated by "VLP", the sampling site was extended to the hyper hydrothermal vent, and boring cores. VLP (v) and cell (b) abundances per ml water samples from drilling holes of Suiyo seamount were: APSK04 ($28^\circ 34.303' N, 140^\circ 38.618'$E, 1385 m deep, $21^\circ C, b = 8.26 \times 10^6$, v = 6.03×10^6); APSK07 ($28^\circ 34.299' N, 140^\circ 38.690'$E, 1386 m deep, $250.5^\circ C, b = 5.33 \times 10^4$, v = 2.52×10^4); a natural vent near APSK05 ($28^\circ 34.322' N, 140^\circ 38.594'$E, 1382 m deep, $304.7^\circ C, b = 3.23 \times 10^4$, v = 1.85×10^4).

A boring core sample was obtained from APSK06 ($28^\circ 34.313' N, 140^\circ 38.617'$, 1386 m deep), from which a hyper thermophilic Archaean, *Thermococcus kodakaraensis* was successfully cultivated in sulphur supplemented medium between 70 and $90^\circ C$.

VLP production was observed from *T. kodakaraensis*, whose VLP (v) and cell (b) abundances per ml at 480 h culture at $70^\circ C were : b = 3.61 \times 10^9$, v = 3.46×10^9.

Transduction experiment at multiplicity of infection of *ca* 0.2 using particles from APSK07 and *T. kodakaraensis* showed a plate efficiency on recipient *Escherichia coli* AB1157 by *ca* 72 % and *ca* 89 % regardless of UV treatment of the particle. Gene transfer frequency of APSK07 particle was ($\times 10^{-5}$ cfu/particle) between 2.4 and 0.92, and that of *T. kodakaraensis* particle was between $\times 10^{-4}$ and $\times 10^{-5}$ cfu/particle.

These findings suggest the non-specific gene transfer by such particles may be a ubiquitous event in the natural environment. Such gene transfer particles may have mediated gene flux among phylogenetically diverse microbial communities since the early age of the Earth. This research was partly supported by "Archaean Park Project", through MEXT, Japan.

1). Chiura H.X. (1997) Aquat Microb Ecol. 13:75-83. 2). Chiura H.X. et al. (2000) Microbial Biosystems: Bell C.R., et al. (eds) A. Can. Soc. Microb. Ecol., Halifax, Canada, pp 167-173. 3). Chiura H.X. et al. (2002) Microb. Environ. 17:48-52. 4). Chiura H.X. (2002) Microb. Environ. 17:53-58.

V72A-1280 1330h POSTER

Archaeal Community in the Hydrothermal System at Suiyo Seamount on the Izu-Ogasawara Arc

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Archaeal communities in extreme environment have been analyzed by phylogenetic analysis using 16S rDNA gene and fluorescent whole cell in situ hybridization method. These culture-independent methods revealed archaeal communities with much higher diversities than those found by conventional culture methods. In this work we have extended the culture-independent method to the analysis of microbial diversity in a deep-sea hydrothermal system at Suiyo Seamount.

In the Archaean Park Project supported by Special Coordination Fund, several holes were bored and cased in the crater of the Suiyo seamount on the Izu-Ogasawara arc (about 1,400 depth) in 2001 and 2002. Hydrothermal fluids form these cased holes and black smoker chimneys were sampled at various sites on Suiyo seamount. The fluids were filtered to collect the microbial cells. Filters and black smoker chimney samples were crushed and DNA was extracted and purified. The DNA was used to amplify archaeal 16S rDNA fragments by PCR using an archaea specific primer set. The PCR fragments were cloned and sequenced. Archaeal PCR clones of different samples will be compared.

V72A-1281 1330h POSTER

Characterization of a Novel Thermococcus sp. from a Hydrothermal Vent of the Suiyo Seamount

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The Suiyo seamount is located at 210 km north-northwest of Chichijima Island of the Izu-Bonin Arc. The hydrothermal vents of the Suiyo seamount discharges hot water as high as 308 degrees. We obtained a novel Thermococcus sp. from the hydrothermal vent and partially characterized it. The Thermococcus sp. was observed as usual coccus in initial stages of culture, but changed to transparent cells, within which one or a few spots exist. In the present study, the process of the alteration of the appearance was studied. Materials and Methods: Hot water (maximum temperature of 100 degrees) from a hydrothermal vent of Suiyo seamount was filtrated with a Nuclepore filter (pore size 0.2 micro m) on a research vessel. The filter was brought back to the laboratory, being kept at ?20 degrees, and inoculated into the Thermococcus medium (JCM280, pH 7.0) under anaerobic conditions (nitrogen:hydrogen:carbon dioxide=80:10:10). This was cultured at 80 degrees. For observation by fluorescent microscopy, fluorescent dyes Live/Dead (Molecular Probes) were used. Results and Discussion: The Thermococcus sp. was purified by a series of dilutions to extinction. Analysis of 16S rDNA indicated that this organism belongs to Thermococcus, showing the highest homology of 99.5 percent with T. sulfurophilus. This organism showed a peculiar characteristic; in growth curve, the cell density once declined in an early stage of growth, and then, increased again. We took the culture at the point of the first peak and saw it by phase contrast microscopy. Some cells are singular, but the others are in pairs. Surprisingly, the paired cells fused in 1 h under microscopic observation, which could explain the decline in the growth curve. The steady state of the coccus was very short, and it soon changed to transparent cells, which looked transparent under phase contrast microscopy, and within which one or a few spots exist. These spot green-fluoresced under fluorescent microscopy with Live/Dead. This finding suggests that the transparent cells are live and the spots contain DNA. The possibility that the spots represent spores is discussed; there have been no reports of spores of Thermococcus.

V72A-1282 1330h POSTER

Euryhaline Halophilic Microorganisms From the Suiyo Seamount Hydrothermal Vents.

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The euryhaline halophilic microorganisms grow in a wide salinity range from <3% NaCl (seawater equivalent) to >15% NaCl or to even saturation (about 30% NaCl). A number of euryhaline halophiles have been found in a wide range of habitats from oceanic and terrestrial regimes, from deep-sea vents and seeps, and from Antarctic sea ice and terrains. We have isolated the euryhaline strains independently from a Mid-Atlantic Ridge vent fluids and Antarctic terrains are closely related species of the genus Halomonas.

Some euryhaline halophiles maintain intracellular osmotic balance by controlling the concentration of compatible solute such as ectoine. This compatible solute not only stabilizes the proteins from denaturation caused by high salt concentration but also serves as a protectant against stresses such as heating, freezing and drying.

The sub-seafloor structure of a hydrothermal vent is highly complicated with mosaic heterogeneity of physicochemical parameters such as temperature and salinity. This premise led us to the hypothesis that some euryhaline halophiles including Halomonas species well adapt to a wide salinity-ranged habitat in the sub-vent.

To test this hypothesis, isolation and characterization of euryhaline halophiles from the Suiyo Seamount hydrothermal vents were conducted the drill-cored rock samples from the sites APSK-02, 03, and 07 and the filter-trapped fluid particle samples from the sites APSK-01 and 05 were used. For initial cultivation, a heterotrophic bacterial medium of 15% NaCl was used. The samples was added to the medium and incubated under both aerobic and anaerobic conditions at room temperature.

A total of 5 euryhaline halophilic strains were obtained and phylogenetically characterized: two strains (both related to Marinobacter) from APSK-02 core section 2; one strain (related to H. meridiana) from APSK-07 core section 3; and two strains (related to H. meridiana and H. variabilis) from APSK-01 trapped particles. In addition, some thermophilic halophiles that grow at 20% NaCl and 90 degree C were isolated from APSK-02, although phylogenetic and physioloigcal studies are under way. This research was supported by Archean Park project.

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