judiciously filtered line is the result of mixing of two end-members: (1) initial Pb and (2) in-situ produced Pb (through U & Th decay). A system of a single age can have multiple lines, each corresponding to a specific K = Th / U for the in-situ component. If such a system is not complicated beyond recent mobilities, the lines would converge to intersect at a point corresponding to initial Pb (see Fig. 3, Tera, 1983). The 206, 207, 208Pb plots mentioned are referred to here as *Quasi Differential Diagrams*.

When the data of the filtered lines, obtained as described above, are plotted on an age-producing diagram of 206Pb/208Pb Vs 207Pb/208Pb they would produce a single line, the slope of which yields the age as is conventionally calculated. Thus without measuring the often hopelessly non-correlated U (mostly because of prevalent recent U-Pb mobility), a uranium-enriched mineral (e. g., zircon), may be accurately dated. Furthermore, two other aspects of evolution-history may be revealed: (1) In a case where determination of initial Pb on a Quasi Differential Diagram was possible, the age of the source is calculable in a straightforward fashion from the radiogenic ratio of 207Pb/206Pb; (2) Events resulting in coexisting re-equilibrated domains may be resolvable into discrete dates.

The filtered Pb-Pb results of a given geologic system can be contrasted with the U-Pb data plotted (on a concordia diagram) as a superposition of a deformation on a pre-existing frame (inferred from the Pb-Pb data). Illumination of processes and mechanisms may follow. Applications demonstrating the practicality of the method (termed *Lead-Uranium Conjunctive Isotope Depiction* or *LUCID*) exist and will be presented. Collectively, they expose all the above mentioned features.

A note of caution: as it stands *FTR* is mediated through pattern-recognition by a human, thus it may carry within a potential component of bias. Bias may be eliminated or minimized through the adoption of a statistical approach, which has yet to be developed. References: Tera, F.(2000a) Lunar Planet. Sci. conf., (2000b) AGU Spring Meeting V22B, (2002) Geochim. Cosmochim. Acta, in press; Tera F. (1983) Earth Planet. Sci. Lett. 63, 147-165.

V52B-1293 1330h POSTER

The ^{176}Lu Decay Constant Controversy

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The Lu-Hf systematics of Earth´s earliest zircons and rocks provide clues about the differentiation of the mantle into depleted and enriched reservoirs. However, initial ϵHf values and the interpretations derived from them hinge on the accuracy and precision of the ^{176}Lu decay constant. At present, there is still a serious discrepancy between 1) ^{176}Lu decay constants determined by physical counting methods and age comparisons of terrestrial samples, and 2) those determined by age comparisons of meteorite suites. The mean Lu decay constant determined by of the two most recent physical decay counting experiments [1, 2] together with 4 independent geological age comparisons [3] is 1.87 x 10^{-11}yr^{-1}. In contrast, decay constants determined by age comparisons in meteorites are systematically higher, with a mean value of 1.95 x 10^{-11}yr^{-1} (including eucrite data from [4, 5, 7, and this abstract] and chondrite data from [6]). The slope of a Lu-Hf isochron for four eucrites (Juvinas, Millbillillie, Pasamonte, and Moama) analyzed at Mnster by MC-ICPMS would suggest a decay constant of 1.97 x 10^{-11}yr^{-1}. Since the terrestrial age comparisons in [3] were made using the same methods and spike calibrations as for the Muenster eucrite isochron, the disagreement between the two sets of decay constants is apparently not an inter-laboratory artifact. Rather, a possible explanation for the disagreement may be that the meteorites do not conform to all of the assumptions required for an isochron (e.g., that all samples have the same age, all have the same initial Hf isotope composition).

The Lu decay constant discrepancy must be resolved before any robust interpretations can be drawn from the initial ϵHf of Archean or Hadean samples with Lu/Hf ratios that differ significantly from the chondritic value (e.g., zircons). The existing Hf data viewed in light of a high decay constant would suggest substantial mantle depletion in the early Archean without much evidence for a complimentary enriched reservoir. On the other hand, the low decay constant would provide evidence for small volumes of enriched reservoirs, but no large-scale mantle depletion.

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V52B-1294 1330h POSTER

Assessment of Instrumental Mass Bias and Isobaric Interference Corrections for Hf-Lu-Nd Isotopic Geochemistry on Zircon by MC-ICP-MS

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We present (1) a simple approach to correct the mass bias as well as isobaric interferences for Hf-Lu isotopic geochemistry of spiked and unspiked zircon samples, (2) new Lu and Nd isotopic data on the zircon standard 91500, and (3) a new ^{176}Hf/^{177}Hf reference value on the zircon standard 91500 specific for MC-ICP-MS instruments. The chemical procedure follows that reported previously for determining the Hf isotopic composition in zircon by MC-ICP-MS (Goolaerts et al., AGU, 2001). Potential Hf-Yb-Lu isobaric interferences and instrumental mass bias were investigated by chemical simulations, which were carried out on different mixed standard solutions with variable elemental ratios (Lu/Hf, Lu/Yb, Hf/Yb). All of the data collected from these experiments were then used for iterative modeling of either ^{187}Re/^{185}Re or ^{176}Yb/^{173}Yb to optimize the correction procedures.

These experiments highlight the stability of the Nu Plasma MC-ICP-MS with respect to isobaric interferences and complex external normalization. The results also show that instrumental mass bias and strong isobaric interferences due to high Yb/Hf or Yb/Lu ratios are not simply corrected. This is an especially important issue for chemically untreated zircons (i.e. laser ablation studies) or pelagic sediments and Mn-nodules. The instruments were calibrated using standard solutions for Hf (JMC-475 250 ppb: ^{176}Hf/^{177}Hf = 0.282161 $\pm$ 16), Nd (Rennes 300 ppb: ^{143}Nd/^{144}Nd = 0.511934 $\pm$ 23; 50 ppb: ^{143}Nd/^{144}Nd = 0.511952 $\pm$ 16) and Lu (JMC 50 ppb: ^{175}Lu/^{176}Lu = 37.72 $\pm$ 2); all errors are 2sd. The entire analytical method was calibrated by processing 59 Hf measurements on the zircon standard 91500, including four independent complete dissolution procedures and two Nu Plasma MC-ICP-MS instruments (Nu15-ULB, Nu21-UBC). The average ^{176}Hf/^{177}Hf is 0.282302 $\pm$ 8 (2sd) and the Gaussian distribution of our data confirms the absence of systematic analytical error. These high precision data external error: 27.3 ppm (2sd) for 59 measurements and 10 ppm for a single day; internal error: 10 ppm (2sd) show excellent reproducibility between duplicates and underscore the stability of our analytical protocol.

Comparison with published data on the zircon standard 91500 highlights the significant improvement in precision provided by our method and suggests that the previous reference value (^{176}Hf/^{177}Hf = 0.282284 $\pm$ 14 (2sd), Wiedenbeck et al., Geostand. Newslett., 1995) should be revised for MC-ICP-MS instruments. We have also determined precisely the Lu and Nd isotopic compositions on the zircon standard 91500. With the growing use of in situ measurement techniques using MC-ICP-MS technology, such precise reference values will become critical for the calibration of laser ablation-MC-ICP-MS analyses in the future.

V52C MCC: Hall C Friday 1330h

Osmium and PGEs Posters

Presiding: **H Watson,** Carnegie Institution of Washington

V52C-1295 1330h POSTER

A Rhenium-Osmium Study of Sulfides from the Bagdad Porphyry Copper Deposit: Implications for the Duration of Hydrothemal Systems and Source of Metals in Porphyry Deposits

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The timing and duration of hydrothermal systems is one of the remaining issues of central importance to ore geology. The rhenium-osmium (Re-Os) isotopic system has proven to be a useful geochemical tool in not only determining the timing of mineralization but also the long standing question of the source of the ore-forming elements. Here we use Re-Os isotopes to address these fundamental questions in the Bagdad porphyry Cu-Mo deposit.

The Bagdad deposit is composed of a quartz monzonite stock that intrudes Proterozoic (>1.75 Ga) basement rocks. We sampled mineralization (pyrite, chalcopyrite and molybdenite) from the quartz monzonite and porphyritic quartz monzonite units within a zone characterized by moderate to strong potassic alteration (secondary biotite and K-feldspar). We analyzed these samples for Re-Os in order to obtain genetic and geochronologic information. Molybdenite ages provide evidence for two separate mineralization episodes within the Bagdad deposit. The first event occurred at ~76 Ma and a later episode at ~72 Ma. Pyrites have Os and Re concentrations ranging between 8-17 ppt and 3.9-6.8 ppb, respectively. Chalcopyrite samples contain 6 to 12 ppt Os and 1.7 to 4.1 ppb Re; ^{187}Os/^{188}Os initial ratios range between 0.1 and 0.8. The results presented here support the notion that porphyry-type mineralization is often produced by long-term multiple episodes of magmatism with associated episodic mineralization. The data also agree with previous Pb and Nd isotopes studies and support the hypothesis that a significant part of the metals are derived from a crustal source.

V52C-1296 1330h POSTER

Evolution of Deccan Lavas: Insights From Re-Os Isotopes and Platinum Group Elements

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We are investigating the extent to which crystal fractionation/crustal assimilation has affected the segregation of Platinum Group Elements in Deccan Traps. A series of picrites and basalts from the Deccan Traps were examined for Re-Os isotopes along with PGE contents. The samples cover a range of compositions from picrites with up to 22.4 wt.% MgO to tholeiitic basalts with MgO content down to 6.8 wt.%. The ^{187}Os/^{188}Os ratios of high MgO samples are 0.1271-0.1274, close to the value of the upper mantle, indicating very little crustal contamination of the primitive samples. The PGE (Os, Ir, Ru, Pt) concentrations are near mantle values for the most primitive picrites and decrease with decreasing MgO and Ni. PGE concentrations in the low MgO samples (<10.2%) are more than an order of magnitude lower than for the lavas with MgO >12.7%, indicating PGE removal by fractionation of olivine and possibly PGE alloys and/or segregation of a sulfide melt between 12.7 and 10.2 wt.% whole rock MgO. The Os/Ir ratio is suprachondritic in the most primitive picrites and decreases with decreasing MgO and becomes subchondritic at around 12.7 wt.% MgO, suggesting a role for Os-Ir alloy nuggets in the fractionation assemblage.

V52C-1297 1330h POSTER

A Comparative Os Isotopic Study of Al-undepleted Komatiites From the Abitibi Greenstone Belt and Ti-enriched Komatiites From the Finnish Lapland

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The komatiites from ~ 2.7 Ga Alexo Township, in the Abitibi Greenstone Belt, Canada are dominantly of Al-undepleted type (AUK; Al_2O_3/TiO_2 ~ 19-21), whereas those from the ~ 2 Ga Finnish Lapland are Ti-enriched komatiites (TEK) that translate into significantly lower Al_2O_3/TiO_2 ratios (typically ~13). Also, the TEKs are more differentiated (MgO typically 14-18 wt.%) relative to the AUKs (MgO > 30 wt.%). We have compared the Os isotopic compositions, and Re and Os concentrations of the whole rocks and chromite separates from these two chemically distinct types of flows. Our objectives were: [1] to understand the differences, if any, in the partitioning behaviors of both Re and Os in these two types of komatiites; and [2] to determine if the observed heterogeneities in trace elements and REE characteristics for the TEKs (Hanski et al., 2001) are accompanied by any evidences for heterogeneities in their initial Os isotopic compositions.

The whole-rock TEKs have significantly higher concentrations of both Re and Os (0.5-1.4 ppb of Re and 1-6.9 ppb of Os) relative to the AUKs (typically 0.2-0.3 ppb of Re and between ~1-2 ppb of Os). Also, the concentrations of Os (~63-161 ppb) and Re (up to ~ 13 ppb) in chromites in the TEKs are significantly higher, as compared to the AUKs (~11-27 ppb and <1 ppb, respectively). For the AUKs, Os was moderately compatible with the mantle residue ($D_{Os}^{mantle-melt}$ ~ 2.1), whereas, Re was incompatible ($D_{Re}^{mantle-melt}$ ~ 0.20). The apparent $D_{Os}^{olivine/liquid}$ and $D_{Re}^{olivine/liquid}$ in Alexo komatiites are 1.7 and 0.66, respectively. Our results, therefore, suggest that Os is slightly compatible whereas Re is moderately incompatible in olivine or a coprecipitating phase during magmatic differentiation of komatiitic liquids. On a plot of MgO versus Re and Os, the AUKs from the Alexo and Munro Townships, and the TEKs show a consistently incompatible behavior of Re in olivine, whereas the apparent compatibility of Os during the magmatic differentiation of the TEKs seems to be controlled by multiple factors, in addition to olivine fractionations.

The initial $^{187}Os/^{188}Os$ for whole rocks and chromites in the AUKs are essentially chondritic (γ_{Os} = -0.1±1.0). Similarly, six chromite separates with the lowest $^{187}Re/^{188}Os$ ratios (<0.1) in the TEKs define a narrow range of γ_{Os} (between -0.3 to +0.1). The absence of significant crustal contamination is consistent with a LREE-depleted (ϵ_{Nd} ~ +4) mantle source for the TEKs. Combined, our results suggest that the mantle sources for either of these two komatiite types have not undergone any long-term fractionation in Re/Os ratio from the putative chondritic composition. These results also suggest an absence of any large-scale Os isotopic heterogeneity in the respective mantle sources for these two komatiite types.

V52C-1298 1330h POSTER

Rhenium Loss During Outgassing of Hawaiian Lavas

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Ocean island basalts have on average lower Re contents than MORB, which has been thought to reflect primary compositional variations in the plume source, or the presence of residual sulfide and/or garnet. We have measured the concentrations of Re, Pt, Cu, Bi, Cd, and Sb by laser ablation ICPMS, and S and major elements by electron microprobe in a suite of moderately evolved (6-7% MgO) tholeiitic glasses from Koolau volcano, Hawaii, to test our previous suggestions that Re can be lost from subaerial basaltic lavas during magmatic outgassing, and that the lower Re contents of OIB vs. MORB may be a geological artifact acquired during eruption rather than a primary magmatic feature (Bennett, Norman, and Garcia, 2000, EPSL 183, 513). Our new data on the Koolau glasses show clear correlations between Re, Bi, Cd and S contents that are consistent with loss of these elements as volatile species during outgassing of the magmas. Glasses with primary S contents (800-900 ppm) have 1.3-1.5 ppb Re, with Cu/Re (100-110 ppm/ppb) and Re/Yb (0.65-0.75 ppb/ppm) ratios close to primitive mantle values (107 and 0.63, respectively). In contrast, outgassed melts with low S (100-200 ppm) have about a factor of two lower Re, with Cu/Re (200-250) and Re/Yb (0.2-0.4) ratios significantly fractionated from mantle values. Pt/Re ratios in the outgassed melts are also higher than those with primary S contents (6-11 vs. 3-6, respectively). Copper and Pt contents of these glasses show no correlation with S, ruling out removal of an immiscible magmatic sulfide phase as a cause of the Re variations. However, Cu and Pt are well correlated with each other, with decreasing Cu/Pt ratios at lower Cu contents, consistent with a variably depleted mantle source. Antimony behaved as a non-volatile, incompatible lithophile element in these magmas. This study provides direct evidence for Re-loss associated with outgassing of S from basaltic lavas, and supports interpretations that relate the lower Re contents of OIB relative to MORB to subaerial vs. submarine eruptions. Global budgets for Re and other volatile elements need to be revised to account for these effects.

V52C-1299 1330h POSTER

Evaluation of the Re-Os Geochronometer in Organic-rich Mudrocks as a Method for Constraining the Absolute Ages of Neoproterozoic Glaciogenic Deposits

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Absolute-age constraints on the Neoproterozoic glaciations are generally poor due to a paucity of suitable plutonic and volcanic igneous rocks that are temporally and spatially related to Neoproterozoic glaciogenic deposits and are amenable to radiometric dating methods. In this study, the Re-Os isotope systematics of dark gray, sulfidic slates from the Old Fort Point Formation (OFP) of the Windermere Supergroup (near Jasper, Alberta) were examined to test the ability of the Re-Os geochronometer to provide an absolute age constraint for a Neoproterozoic glaciogenic deposit. The OFP has been interpreted as the deep water expression of post-glacial sea level rise and therefore is comparable stratigraphically to cap carbonates that immediately overlie glaciogenic deposits worldwide. Despite the relatively low Re (6-16 ppb) and Os (0.07-0.14 ppb) concentrations and total organic contents (~ 0.5% TOC) of the slates compared to other organic-rich mudrocks used in previous Re-Os isotope studies, precise well-fitted Re-Os isochrons have been obtained with two different dissolution methods. An age of 620.8 ± 8.1 Ma (MSWD = 0.9; initial $^{187}Os/^{188}Os$ = 0.68 ± 0.06) is obtained using conventional aqua regia dissolution. Using a method designed to selectively dissolve organic matter alone, an age of 609.0 ± 8.3 Ma (MSWD = 1.5; initial $^{187}Os/^{188}Os$ = 0.62 ± 0.05) is obtained. These absolute age results are in accord with existing age constraints (e.g., stratigraphically younger Hamill Group with a U-Pb zircon age of 569 Ma). The well-defined Re-Os systematics of the OFP slates demonstrates for the first time that the Re-Os system is not disturbed in organic-rich sediments during lower greenschist (-chlorite) grade metamorphic conditions. The whole-rock analysis of each individual sample yields consistently higher initial $^{187}Os/^{188}Os$ isotope ratios than the corresponding organic matter analysis and suggests that a significant radiogenic detrital Os component is present within the OFP slates. Because organic matter is likely dominated by the hydrogenous (seawater) Os budget, the initial $^{187}Os/^{188}Os$ ratio of 0.62 ± 0.05 calculated from the organic matter regression represents the best estimate of the Os isotopic composition of the contemporaneous seawater at the time of sediment deposition. The corresponding age of 609.0 ± 8.3 Ma is then considered to be the best depositional age determination for the OFP and provides a minimum absolute age constraint on the stratigraphically underlying glaciogenic Mount Vreeland Formation (northeastern British Columbia) and the correlative Ice Brook diamictites (Mackenzie Mountains, northwestern Canada). Thus, we conclude that the Mount Vreeland and Ice Brook diamictites are older than the ~ 580-570 Ma glaciogenic deposits of Eastern North America and may thus be considered as lower Marinoan in age. Further application of the Re-Os geochronometer to other organic-rich mudrock horizons spatially and temporally related to Neoproterozoic glaciogenic deposits will allow further opportunities for their correlation and provide better age constraints on the timing, number, and duration of the Neoproterozoic glaciations. This will allow a further assessment of the Snowball Earth Theory and its prediction of global, synchronous glaciations.

V52C-1300 1330h POSTER

Re-Os Evidence for Archean Depletion and Proterozoic Fertilization of Mantle Peridotites in the Scandinavian Caledonides

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The Western Gneiss Region (WGR) of the Scandinavian Caledonides is a high pressure/ultrahigh pressure metamorphic terrane containing hundreds of locally garnetiferous peridotite bodies. They were collected from the subcontinental mantle during subduction of the WGR into this mantle during the Caledonian Orogeny at ca. 405 Ma. Model ages obtained by lasar ablation Re-Os analyses of sulfides (pentlandite +/- heazelwoodite) from garnet-bearing peridotites and pyroxenites indicate two or more generations of sulfides within most samples. Plots of all sulfide ages on a cumulative probability diagram, yield two significant Precambrian peaks at ca. 1700 Ma and 2900-3200 Ga. The younger peak correlates with the 1600-1750 Ma Gothian Orogeny, recorded both by ages from the gneisses of the WGR and by Sm-Nd ages from garnet-peridotites and pyroxenites. The Gothian cycle was therefore not only a major crust forming event but also a period of mantle fertilization leading to the formation of garnet-bearing assemblages. The Archean event is not recorded by ages from WGR crustal rocks. But 11 of 13 sulfides from an orthopyroxenite on the island of Fjortoft define a linear array on a Re-Os diagram, that, if interpreted as a near-isochron, defines an "age" of 3.15 +/- 0.66 Ga (MSWD = 4.1). Furthermore chemical Re-Os analyses of six depleted (i.e. garnet-free or garnet-poor) and sulfide-free dunites yield Archean model ages of 2.6 to 3.2 Ga (TCHUR). Thus, there is credible evidence of a major depletion event in the mantle at ca. 3 Ga, an event so overprinted that it is recorded only by a few residual sulfides and in the most depleted peridotites.

V52C-1301 1330h POSTER

Diffusion of Siderophile Elements in Fe-Ni Alloys at High Temperature and 10GPa

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Diffusivities of siderophile elements in an iron-nickel alloy comparable to model composition of the earths core, (90%Fe and 10%Ni), have been obtained at temperatures ranging from 1400°C-1600°C and 10 GPa through experiments in a multi-anvil apparatus.

Alloys were prepared by synthesizing mixtures of pure metal powders in a piston cylinder at 1400°C and 1GPa. The resulting homogeneous alloys were then sectioned into wafers approximately 1mm thick, and the faces were polished to prepare for diffusion experiments. Diffusion couple experiments were conducted by mating a pure alloy wafer and a doped wafer, and placing the couple directly into a MgO sleeve for pressurization and heating in the multi-anvil apparatus. The duration of the diffusion experiments ranged from 0.5 hours to 48 hours. Upon run completion, the couples were extracted, sectioned lengthwise, and polished for analysis. Diffusion profiles were measured using an electron microprobe. Preliminary results of these experiments show that the diffusivities of Au and Pd are slowed by approximately an order of magnitude when pressure is increased from 1GPa to 10 GPa.

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It is recognized that diffusion of siderophile elements in the metal phase could be an important rate-limiting factor in partitioning behavior. These preliminary results will lead to a more comprehensive understanding of siderophile diffusion in iron-rich metal and could help in placing important time constraints on element partitioning and possibly on models of core formation. It could also aid in understanding the siderophile element distribution observed in nature, in both terrestrial and extra-terrestrial materials.

V52C-1302 1330h POSTER

Re-Os and Pt-Os Isotopic Systematics of 3.81 Ga Metamorphosed Pillow Basalts and Layered Mafic/Ultramafic Units in the Isua Supracrustals Belt (W Greenland) and Adjoining Gneiss Areas.

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Re-Os isotopic data from basalts formed at different times in Earths evolution yield a fairly clear picture of how upper mantle magma sources have evolved through time. However, significant uncertainty remains with regard to mantle evolution in the Pt-Os system. Because of the different siderophile/chalcophile properties of daughter and parents, these two isotope systems provide sensitive information about mantle processes involving metal-silicate or sulfide-silicate reactions. The presence of coupled enrichments in $^{186}Os/^{188}Os$ and $^{187}Os/^{188}Os$ in some mantle-derived materials reflect long-term elevation of Pt/Os and Re/Os relative to the primitive upper mantle. In one scenario, such coupled enrichments are thought to derive from interaction between outer core and lower mantle material that subsequently is transported to the upper mantle by deep-rooted plume systems. Within the framework of this model, existing data from young (recent) as well as ancient (mid to late Archean) plume-derived magmas imply that crystallization of the inner core is likely to have happened fast and to have been completed already in the Hadean period. In order to precisely discern different core crystallization schemes, it is of vital importance to obtain coupled Os isotopic data on very early Archean mantle-derived rocks.

Re-Os isotope data of the least altered pillow basalts from the NE section of the Isua Supracrustals Belt (ISB; W Greenland) yield an average initial $^{187}Os/^{188}Os$ ratio of 0.1042 $\pm$ 0.0008 (2σ; n=7) at 3.81 Ga, which is the minimum extrusion age of these basalts. This corresponds to a γ Os[T=3.81 Ga] value of $+3.4\pm0.8$, which is broadly consistent with a value of $+1.3 \pm 2.5$ for chromites from layered mafic/ultramafic units 20 km to the S of the ISB and from the ISB itself (Frei and Jensen, in press). These data suggest that parts of the early Archean mantle was characterized by a slightly suprachondritic 187Os/188Os ratio. Two high-precision unspiked Os isotopic analyses of chromites of the units S of the ISB yielded suprachondritic $^{186}Os/^{188}Os$ ratios of 0.119838 $\pm$ 0.00007 ($2\sigma_{pop}$) and 0.119837 $\pm$ 0.000008 ($2\sigma_{pop}$). In situ correction of these ratios with appropriately obtained Pt and Os concentrations from spiked aliquots lead to consistent slightly suprachondritic $^{186}Os/^{188}Os$ ratios of 0.119831 $\pm$ 0.000008 at 3.81 Ga, which at this stage cannot discriminate between a chondritic (or primitive upper) mantle evolution and inner core crystallization models that involve rapid, delayed, or constant growth schemes along with their possible effects on the PGE budget of the early Earths mantle.

Frei, R., and Kastbjerg Jensen, B., in press, Chemical Geology.

V52D MCC: 106 Friday 1330h

Evolution of the Igneous Rocks 2002 Edition II: Experimental Results at High Pressure, Petrogenesis, and the Physics of the Earth *(joint with OS, P)*

Presiding: **M Ghiorso,** University of Washington**; G Bergantz,** University of Washington

V52D-01 1330h INVITED

Mantle Melting Controls on Liquid Lines of Descent in Magmatic Systems

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Compositional variations in basaltic rock suites preserve information on the conditions of high-pressure mantle melting and low-pressure fractional crystallization (e.g. pressure, temperature and volatile content). The significance of compositional variations in igneous rock series was of considerable interest to N.L. Bowen, and the famous Bowen Fenner controversy was a protracted discussion that concerned the possibility of the existence of multiple liquid lines of descent (LLD) in magmatic systems. Miyashiro (1974) introduced the FeO*/MgO vs. SiO_2 diagram and used it to demonstrate the existence of more than one LLD in arc and tholeiite suites. In detail, Miyashiro recognized that there was not a single calc-alkaline or tholeiitic suite, but that a continuum existed from tholeiitic to calc-alkaline. Each arc has its own distinctive signature produced by an interplay of varying melting and crystallization conditions. Subsequent experimental work (Sisson and Grove, 1993) demonstrated that the different LLDs were caused by variable H_2O contents (calc-alkaline = hydrous, tholeiitic = anhydrous). Sisson and Grove (1993) found that the calc-alkaline trends characteristic of a large volume of the Earths current output of arc magmatism represent fractional crystallization that occurs at high magmatic H_2O contents (4 to 6 wt. %). These hydrous fractional crystallization trends are ones expected to result when the starting point for fractionation is an H_2O -rich, high pressure mantle melt saturated with oliv + opx + cpx + spinel or oliv + opx + cpx + garnet. A rarer calc-alkaline differentiation trend exemplified by lavas from the Mt. Shasta region, USA, Adak, Aleutians and Setouchi Belt, Japan lie in a portion of the diagram that is not as commonly represented by modern arc environments. These important magmas, plot in the low FeO*/MgO and high SiO_2 portion of the Miyashiro diagram. This unique compositional signature is imparted by unusually high degrees of melting (oliv + opx saturated) of shallow, hot mantle at the top of the mantle wedge, fluxed by an H_2O -rich and trace element-rich fluid component released by dehydration of the subducting ocean lithosphere. The coexistence of tholeiitic and calc-alkaline trends in many arc volcanoes (e.g. Hakone region, Japan and the Nasu volcanic zone, northeast Japan) indicates variable inputs of H_2O in the mantle melting process.

V52D-02 1345h

Partial Melting of a Heterogeneous Mantle - Progress and Prospects

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Whereas Bowen concentrated on the differentiation of basalt, much effort in petrology is now focussed on the origin of basalt. Simple models for basalt petrogenesis are well-developed, but one area of active research is the role of petrologic heterogeneity in the source. This remains a vexing problem in part because of poor constraints on the effect of lithologic heterogeneities on melting relations and the distribution and length scales of heterogeneities, which likely have a critical effect on their role.

Pyroxenites are one (but not the only) likely type of heterogeneity in basalt source regions. Recent experimental studies have provided considerable constraints on the melting behavior of pyroxenites. Compositions similar to recycled oceanic crust melt at much lower temperatures than peridotite, resulting in contributions to basalt genesis much greater than their mantle abundance. Just 1-2% such materials in MORB source regions could account for 10-25% of the volume of crust created and could provide 10-60% of highly incompatible elements such as U. However, partial melts of recycled lithologies are far from equilibrium with peridotite, and so they probably have complex interactions with the predominant mantle lithology, possibly involving reaction, freezing, and remelting.

Oceanic island lavas with strong geochemical indications of recycled crust generally are strongly undersaturated, and this is not petrologically consistent with partial melting of quartz tholeiite protoliths. Mg-rich garnet pyroxenites, perhaps derived from crust-peridotite hybridization, do produce strongly undersaturated liquids, though the temperatures required to form partial melts of these lithologies may be unreasonably high. Alternatively, carbonated pyroxenites and peridotites may be plausible sources of OIB magmas, but detailed partial melting studies needed to test these hypotheses are not yet available.

Field exposures and modelling of convective remixing of crust suggest that many pyroxenites in basalt source regions could have widths of less than a meter, and it is unclear how (if at all) melting and melt extraction from such bodies imparts petrologically and geochemically distinct signatures to aggregated basalts. Perhaps larger bodies play an important role. On the other hand, the preferential melting of small fertile domains likely has a profound influence on the physical properties of partially molten regions and on the melt extraction process, but this remains largely unexplored.

V52D-03 1400h INVITED

Evolution of MORB Generation Models

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Early debate on MORB petrogenesis focused on a low-pressure (<1.1 GPa, basaltic primary melts) *vs.* high-pressure (1.5-3.0 GPa, picritic primary melts) origin. This unresolved issue was later supplanted by the widely accepted model of Klein and Langmuir (1987) involving polybaric melting columns of varying length, with the initial pressure of melting ranging from 1.2 to 4.0 GPa (Langmuir *et al.*, 1992). The KL87 and other models (*e.g.* McKenzie and Bickle, 1988) rely on phase relations free of H_2O and CO_2. For H_2O, this appears to be a good approximation at all pressures because of the low H_2O concentration in the MORB source (~90-230 ppm) and the probability that these concentrations are less than the bulk solubility of H_2O in nominally anhydrous mantle phases. At low pressures, CO_2 can also be neglected, to first order, because of its low solubility in melts. However, at P>~2.3 GPa, CO_2 dramatically modifies solidus phase relations and abruptly lowers solidus temperatures by $\geq$300°C (*e.g.* Falloon and Green, 1989; Dalton and Presnall, 1998). Presnall *et al.* (2002) addressed the issue of CO_2 by using phase relations in the CaO-MgO-Al_2O_3-SiO_2-Na_2O-FeO (CMASNF) system at 1-1.5 GPa (plagioclase/spinel lherzolite transition interval) to model the major-element characteristics of MORBs and phase relations in the CaO-MgO-Al_2O_3-SiO_2-CO_2 system to produce very small amounts of carbonatitic melts at 2.3-7 GPa, which would mix with the more shallow melts and produce some of the trace element signatures. Asimow *et al.* (1995, 2001) showed the importance of near-isentropic melting and found that strong variations in isentropic melt productivity occur as a function of pressure. Although Asimow *et al.* found from MELTS calculations that melting is suppressed by isentropic decompression through the plagioclase/spinel lherzolite transition, Presnall *et al.* showed that the CMASNF experimental data require enhanced melting. KL87 explained the global inverse correlation of Fe(8) with Na(8) by large variations of potential temperature (1260-1530°C) in a relatively homogeneous peridotitic mantle, but Presnall *et al.* explained them by a much narrower range of potential temperatures (average ~1260°C) in a heterogeneous peridotitic mantle. Thus, the original disagreement over a low- *vs.* high-pressure origin for primitive MORBs has been transformed into a debate over the magnitude of potential temperature variations and the role of mantle heterogeneity. The outcome of this debate has important implications for temperature variations in the Earth's interior and for geodynamics.