Fe-Mg substitution on the dodecahedral site in pyrope-almandine. This new data set allows us to place improved constraints on the effect of chemical variation on seismic wave velocities at upper mantle pressures.

V32E-06 1455h

Deep Recycling of Sedimentary Lithologies in Subduction Zones: Geochemical and Physical Constraints from Phase Equilibria and Synchrotron-Based Multi-Anvil Experiments at 15-25 GPa

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Ocean island basalts (OIBs) provide geochemical evidence for the presence of crustally-derived sedimentary material in the deep mantle plume source region for EM-type OIBs, and global seismic tomography provides us with dramatic images of subducted slabs, presumably carrying a sediment component, penetrating through the transition zone and into the lower mantle, in some cases to the core-mantle boundary. In an effort to better constrain the geochemical effects of deeply recycled sedimentary material in subduction zones, and their role in the petrogenesis of EM-type OIBs, we have undertaken a series of phase equlibria experiments in the multi-anvil apparatus at 10-25 GPa, using natural sediment lithologies as starting materials. The goal of these experiments is to identify the dominant phases in deeply subducted sediments, constrain their P-T stability limits, and to assess their role in crustal recycling and element redistribution in the deep mantle during subduction. The phase equilibria experiments were performed in a 2000-ton Kawai-type apparatus, using tungsten carbide cubes with 3 mm TEL and Cr-doped MgO and zirconia pressure media. A cylindrical lanthanum chromite heater was used, along with short (< 1 mm), thick-walled, pressure-welded gold capsules to minimize thermal gradients and to retain the small amounts of water (< 1 wt%) present in the starting material, and long run-durations (12-48 hours) in order to facilitate future analyses of the dominant phases for key trace elements using the ion microprobe. Our preliminary results at 10-25 GPa indicate that K-hollandite ($KalSi_3O_3$) and stishovite are the primary high-pressure phases in the sediment composition, with subordinate garnet and an as-yet-unidentified (possibly hydrous) Al-silicate phase present as well. These results suggest that K-hollandite is the primary repository for incompatible elements (e.g., La, Ce, Sr, Ba, Rb, etc., and the heat-producing elements K, U and Th) in sedimentary material recycled into the deep mantle via subduction. In-situ synchrotron-based multi-anvil experiments were performed on synthetic, pure K-hollandite at pressures up to 25 GPa to determine the equation of state parameters of this phase into the lower mantle. From these experiments, we derive the bulk modulus at room temperature for K-hollandite, $K_0 = 183(2)$ GPa, and coefficient of thermal expansion, $a_{20.5} = 2.18(3) \times 10^{-5} K^{-1}$. Although the overall buoyancy of deeply subducted metasedimentary lithologies will be determined by the modal proportions of high-pressure phases, the calculated density of K-hollandite under lower mantle conditions is less than that of Mg- or Ca-perovskite, and approximately equal to that of magnesiowustite.

V32E-07 1510h

Elasticity of $MgSiO_3$ Polycrystalline Perovskite by Brillouin Spectroscopy

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Magnesium silicate perovskite is the most abundant mineral phase in the lower mantle of the Earth. Even though it is probably the most studied high-pressure phase, its elastic properties at ambient conditions (bulk, and especially, shear modulus) remain uncertain. We have carried out a Brillouin spectroscopy study of $MgSiO_3$ perovskite to try to resolve discrepancies surrounding its elastic properties. The polycrystalline sample of perovskite was synthesized from pure $MgSiO_3$ glass starting material at SUNY, Stony Brook. The synthesis was performed at 25 GPa and 1873 K in USSA-2000 high-pressure apparatus, with an 8/3 cell assembly and rhenium heater. The perovskite structure was confirmed by X-ray and Raman spectroscopy. The Raman spectroscopy did not reveal any non-perovskite phases in the sample. The Brillouin measurements were performed on samples polished plane-parallel to 30 mkm. The measurements were performed in platelet symmetric scattering geometry, which yields compressional and shear velocities independently of the refractive index of the sample. Despite the polycrystalline nature of the sample, all spectra were of excellent quality, and the measured velocities showed very little variation from run to run. The measured aggregate velocities and elastic moduli differ significantly from those, calculated from single-crystal elastic constants measured earlier by Brillouin spectroscopy. The implications of new data to mantle mineralogy will be discussed.

V32E-08 1525h

Effect of Plasticity on Stress Heterogeneity at High Pressure

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It has become routine to measure the differential strain field in both diamond anvil and multi-anvil cells using synchrotron x-rays. In these experiments, the x-rays pass through the sample along a path perpendicular to the compressive axis of a cylindrical stress field. Then the diffracted x-rays sample the lattice spacings both parallel and perpendicular to the maximum stress. Detection can be by means of a 2-D system such as an imaging plate or a CCD detector with monochromatic x-rays, where the Debye rings are recorded as a function of the azimuthal angle. Then the lattice spacings parallel to the maximum stress axis can be compared with those parallel to minimum stress axis. White x-rays provide the same results with multiple solid state detectors, used in conjunction with a conical slit. These measurements have been possible with the use of x-ray transparent gaskets, usually Be for the diamond cell, and x-ray transparent anvils, such as cubic boron nitride, for the multi-anvil system. Each diffraction line will give rise to a measure of the stress field in the sample, giving stress measures for distinct populations of grains, namely those whose orientations meet the necessary diffraction conditions. If the sample has been compressed and strained elastically, then the Reuss - Voight bounds become the defining relationship among the stress - strain fields of the different populations of grains that are sampled by x-ray diffraction lines. Singh indicates the relationship between the strain field and the average stress field using the parameter, alpha = 1 to indicate a Reuss solid (uniform stress) and alpha = 0 indicating a Voight solid (uniform strain). A value between 0 and 1 indicates a mixed boundary condition solid. However, when the polycrystal is plastically deformed, several important changes occur. First, the x-ray diffraction is only sampling a portion of the total strain field. It does not reflect the plastic portion. Second, the stress in an individual grain is no longer controlled by the elastic properties, but rather by the plastic properties. The Schmidt factor, which represents the ratio of a stress on a dislocation to the stress on the grain, becomes the relevant measure of anisotropy and the stress fields in the different grain populations now evolve to maintain the necessary stress on the dislocations as to enable plastic deformation. The Taylor V Sachs bounds replace the Reuss - Voight bounds. In general, the stress field of the various populations of grains will change radically. Calculations, using a self-consistent polycrystalline model indicate that once plastic deformation has occurred in the sample, it will generally be no longer possible to use the Singh formalism to define the single-crystal elastic properties.

V32F MCC: 3006 Wednesday 1340h

Birth, Growth, and Death of Magmatic Arcs: Comparisons Among Arcs in Different Settings II

Presiding: **S B Mukasa,** University of Michigan**; C Kincaid,** University of Rhode Island

V32F-01 1340h

Spatial and Temporal Variability in the Circulation and Thermal Evolution of the Mantle in Subduction Zones: Insights From 3-D Laboratory Experiments.

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The subduction of oceanic lithosphere plays a key role in plate tectonics, the thermal evolution of the mantle and recycling processes between Earth's interior and surface. The majority of subduction models are two-dimensional (2-D), assuming limited variability in the direction parallel to the trench. Observationally based models increasingly appeal to three-dimensional (3-D) flow associated with trench migration and the sinking of oceanic plates with a translational component of motion (rollback). We report results from laboratory experiments that reveal fundamental differences in 3-D mantle circulation and temperature structure in response to subduction with and without a rollback component. In our experiments the upper mantle is simulated with glucose syrup and the subducting plate is represented with a Phenolic sheet that is forced to sink into the glucose along prescribed trajectories. An array of 40 thermisters embedded within the plate is used to monitor slab surface temperatures (SSTs). We vary the relative magnitude of downdip and translational components of slab motion and also consider cases where the plate steepens with time. Another parameter is the initial thickness of the thermal boundary layer (TBL) beneath the overriding plate. Without rollback motion, flow in the mantle wedge is sluggish, there is no mass flux around the plate, and plate edges heat up faster than plate centers. Rollback subduction drives flow around and beneath the sinking plate, velocities increase within the mantle wedge and are focussed towards the center of the plate and the surface of the plate heats more along the centerline. In addition to lateral variability in flow and mantle temperatures, results highlight temporal variability in SSTs and 3-D mantle flow trajectories associated with the initiation of subduction and variations between periods of predominantly downdip versus rollback sinking.

V32F-02 1355h

Melting due to Buoyant Migration of Water in the Hot Mantle Wedge Above a Subducting Plate

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Water-bearing magma generated at convergent plate boundaries is thought to be due to the release of water carried to depth by the subducting crust and mantle. The objective of our study is to create models of the buoyant upward migration of water-rich fluids from the slab, through the hot mantle wedge, and consequent mantle melting. Fluid in the models is assumed to migrate buoyantly along mineral grain edges with a prescribed melt fraction-grain size-permeability relationship (e.g. Wark et al., 2003). Pressure gradients in the solid mantle flow should be important to melt migration only if the mantle viscosity exceeds about 10^{18} Pa-s. The model results thus far neglect the effect of solid deformation on melt permeability, including the possible effects of the dependence of grain size on stress and the anisotropic permeability created by solid deformation (e.g. Kohlstedt and Zimmerman, 1996). The volume of melt generated by the interaction of water with the mantle is parameterized using results

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from MELTS (Ghiorso and Sack, 1995). The volume of water released from the slab between depths of 80 to 150 km is derived from the estimates of Schmidt and Poli (1998). The models consider a range of slab velocities and grain sizes using solid flow and temperature distributions from an earlier model with temperature-dependent viscosity (Kelemen et al., 2003). Melt distribution in the wedge is strongly dependent on both grain size and slab velocity. For a grain size of 2 mm at slab velocities of 2-6 cm/yr, fluid rises from the slab to generate melt. At higher plate velocities or smaller grain sizes, water released from the slab is carried downward into the deeper mantle, in which case melting is not triggered. As a consequence, melt flux at the top of the mantle wedge also varies significantly with convergence rate. At slow to intermediate rates, calculated melt fluxes are comparable to values observed in island arcs. Thus, in the absence of other effects, significant differences in volcanic flux between fast and slow convergence rates would be expected. In appropriate nondimensional form, the ratio of slab velocity to the square of the grain size controls the distribution of fluids in the wedge. In nature, the absence of such a strong convergence rate dependence on magmatic flux might indicate that grain size in the mantle wedge varies with plate velocity. Thus, future work should consider the effect of variable grain size on melt permeability. Accounting for hydrous mineral stability limits may also introduce a convergence rate and plate age dependence to predicted volcanic flux.

V32F-03 1410h

Sediment/Fluid Contributions and Element Transport Deduced from Elemental and Isotopic Data From the Luzon-Bicol arc Systems, Philippines

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Melting and mass transfer processes in arcs are poorly understood. The Luzon/Bicol arc system, Philippine archipelago, provides the opportunity to gain insight into these processes. Volcanism in the Bicol arc (eastern arc) is associated with the westward subduction of the Philippine Sea Plate, with thin pelagic sediment cover, while volcanism of the Luzon arc (western arc) is associated with the eastward subduction of the South China Sea Plate, including a thick terrigenous sediment cover from Eurasia. Here we present U-series, Nd and Sr isotopic and trace element data of lavas from both arcs: Pinatubo and Taal [Luzon arc], Bulusan, Iriga and Mayon [Bicol arc]. Lavas from both volcanic fronts have typical (230Th/238U) $<$ 1 associated with arc volcanism, except for Mayon volcano, which has up to 15% 230Th enrichment. Bicol arc lavas have 87Sr/86Sr = 0.70371-0.70400 and ϵ d = + 7.9 to +6. Lavas from the Luzon arc have higher 87Sr/86Sr = 0.704227-0.70458 and lower 143Nd/144Nd, ϵ d = + 3.4 to +6.6. Bicol arc lavas have consistently higher Ba/Th = 122-208, than Luzon arc lavas, Ba/Th = 42-133. Consistent with previous inferences, the isotopic data support strong sediment involvement in Luzon arc lavas. Lavas from the Bicol arc reflect more complex melting histories. Mayon lavas, showing 230Th over 238U enrichment and the most radiogenic Nd isotopic values ($\sim$ +8), most likely reflect the result of dynamic melting of the mantle wedge under the Bicol arc. The combination of high Ba/Th ratio ($\sim$ 200, in contrast to MORB or Bulk Earth values of $\sim$ 75) and lack of 238U enrichment suggest that the wedge was modified long before the recent melting events. In contrast to Mayon, lavas from the other Bicol arc volcanoes show some fluid and possibly some sediment involvement. Although the contrast in the U-series data among volcanoes from the Bicol arc may reflect differences in melting styles (dynamic melting vs. hydration melting), the cause of the difference is not clear.

V32F-04 1425h

Transition from back-arc rifting to oceanic arc associated Kuroko formation in late Cenozoic NE Honshu, Japan

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The volcanic-hosted massive sulfide deposits named Kuroko deposits in Japan is one of representative VMS deposits in the world. More than hundred deposits are distributed within Neogene volcanic belt along present Honshu arc. The deposits have been generated in association with felsic volcanic activities of bi-modal volcanism in back-arc rifting zone started from middle Miocene and have been overlain by progressive caldera forming felsic activities at oceanic arc setting. The present study will show petrological and petrochemical differences between pre-ore (back-arc) to post-ore (oceanic-arc) volcanisms in the Hokuroku district. The district is located in NE Honshu arc and economically the most significant mineral province where had been produced eleven Kuroko deposits from 1886 to 1991. Restructuring of detailed stratigraphy by field observations including drill cores and reconsideration of dating results with micro fossil data indicates that the felsic volcanisms are divided into three sequences. Pre-ore dacite group is composed of regionally extended dacite lavas (D4) and massive pyroclastics with rhyolitic domes (D3,WR) adjacent to Kuroko deposits during 16-13.4Ma. The lower unit of post-ore felsic volcanism (D2 group) consists of dacite lavas and pumice tuff alternating with black colored mudstone during 12.7-11Ma. The last one consists of pumice to fine tuffs alternating to siltstone emplaced with dacite domes, quartz-porphyries and granitoids (D1 group) during 11-10 Ma. Regionally extended pre-ore dacite (D4, in other word, footwall dacite) are distinguished as plagioclase phyric dacite with lower TiO2 and CaO contents and rhyolitic members (D3 and WR, so-called white rhyolite) closely related to Kuroko formation can be distinguished by peculiar aphyric texture with higher aluminum content than that of the other dacites. On the other hand, post-ore felsic rocks are characterized by various amounts of quartz-plagioclase phyric texture in aphanitic groundmass. The secular variation of major chemical compositions and those normative compositions suggest that (1)Kuroko deposits have been formed at the final stage of pre-ore dacite sequence associated with the most differenciated magma in the sequence and another felsic magmatism commenced immediately after Kuroko formation, and (2)Pre-ore felsic rocks would be derived from a deeper magma chamber under extentional stress field and post-ore ones had taken place as caldera-forming eruption on gradually upheaving seafloor derived from shallower magma chamber in weakly compressional field. By trace element investigation, each rock types in post-ore volcanism reveal higher LIL/HFS element ratio than that of pre-ore volcanic sequence. The difference cannot explain by fractionation of magma, therefore, it would be a reflection of the source characteristics related to the change of tectonic setting from back-arc to oceanic arc. The tectonic evolution deduced from petrological, chemical and chronological results are correspond to the petrotectonic history in late Cenozoic NE Honshu arc. Considering with previous studies regarding VMS deposits in the world and present submarine hydrothermal sulfides, the tectonic transition from back-arc to oceanic arc may be common and essential geologic event related with the formation of large VMS deposits.

V32F-05 1440h

Continental Arc Magmatism and its Abrupt Termination by Ridge Subduction or Ridge Jump Along the Proto-Pacific Margin of Gondwana, Marie Byrd Land, Antarctica: A Zircon U-Pb Study

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The Paleozoic and Mesozoic development and subsequent fragmentation of Gondwanaland's Pacific margin is recorded in igneous and metamorphic rocks cropping out in the Marie Byrd Land (MBL) continental block of West Antarctica, recognized on geologic and paleomagnetic grounds to comprise a distinct microplate. Widespread occurrence of metaluminous granitoids dated by the zircon U-Pb method as mid-to late Paleozoic shows that convergence-related magmatism dominated the early evolution of this margin. Dates for granodiorites, monzogranites and granites from the Ruppert and Hobbs Coasts of western MBL reveal a prolonged period of subduction-related calc-alkaline magmatism between at least 320 $\pm$ 3 Ma (age of the oldest granodiorite dated) and 110 $\pm$1 Ma (the age of the Mt. Prince granite). The latter is intruded by swarms of mafic and intermediate dikes believed to record the onset of rifting that led to separation of the New Zealand microcontinent from MBL. The dikes have been dated by zircon U-Pb at 101 $\pm$ 1 Ma. Thus, the regime along the Ruppert and Hobbs Coasts had shifted from subduction-related to rift-related magmatism within a mere 9-m.y. period. In the Kohler Range and the Pine Island Bay areas of eastern MBL, the calc-alkaline magmatism did not terminate until 96 $\pm$ 1 Ma, based on U-Pb dating of zircons from one granitoid sample, or 94 $\pm$ 3 Ma based on zircons from another. No continental separation occurred to the east of MBL. The margins of the Thurston Island and Antarctic Peninsula blocks went directly from convergent to inactive. With their zircon U-Pb ages clustering around 100 $\pm$ 2 Ma, dike-free "anorogenic" syenites and quartz syenites along the Ruppert and Hobbs Coasts show that the transition to extensional magmatism was rapid in the west. This is also reflected by the fact that from the onset of rifting at 101 $\pm$ 1 Ma to formation of oceanic crust between MBL and Greater New Zealand (Campbell Plateau, Chatham Rise, North Island and South Island) prior to chron 33o at 81 Ma required only 20 m.y. For comparison, this is only two thirds of the 30 m.y. it took for the Central Atlantic to open after initial rift-related magmatism. The swiftness of the separation between MBL and Greater New Zealand demonstrated by these data is consistent with ridge subduction or segmented ridge jumps being the primary cause of the break-up, as is the west to east diachroneity in the cessation of subduction.

V32F-06 1455h

Geochronologic and Isotopic Constraints on Arc Dynamics, North Cascades, WA

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The metamorphic core of the North Cascades arc records the Cretaceous to Paleogene history of crustal growth along a segment of the North American margin. The application of high precision U-Pb geochronology and isotope geochemistry to the study of this arc has revealed rapid changes in arc dynamics. Terrane accretion/assembly in the North Cascades predates the main phase of arc magmatism at 96-88 Ma, and is followed by magmatism in the eastern half of the core from 78-46 Ma. The 9-12 kbar, Swakane Gneiss underlies these island arc and oceanic terranes, but lacks arc-related plutons. U-Pb analyses of detrital zircons from the Swakane Gneiss reveal that the sedimentary protolith of the gneiss was deposited later than 72.6$\pm$0.6 Ma, the age of the youngest detrital grain, and post-dates voluminous arc magmatism. The gneiss was deeply buried $\sim$5 m.y. later as indicated by a 68.5 Ma dike that cross-cuts fabric in the gneiss, and this deep burial is coincident with a decrease in the volume of arc magmatism. Between 68 and 48 Ma, plutonism appears to be restricted to the eastern margin of the core near the Ross Lake fault zone. By ca. 45 Ma, the Swakane Gneiss was unroofed to near the surface, and several ca. 46 Ma arc plutons were emplaced throughout the eastern half of the core. Nd isotope data from granodioritic, tonalitic and gabbroic plutons that are spatially and temporally distributed within the arc indicate that all of the plutons were derived from or interacted with an older crustal component. Initial ϵNd values of the ca. 46 Ma plutons (+1.5 to +2.9) are lower than ϵNd values of the 96-65 Ma plutons (+2.9 to +6.0 when calculated at 46 Ma) and are consistent with the younger plutons either being derived from a more evolved crustal source or being composed of a greater proportion of crustally-derived melt. Changes in the Nd isotope signature may reflect changes in crustal architecture after burial of the gneiss. The mechanism of this rapid burial is not well-constrained, but two potential mechanisms include overthickening during closure of an arc basin or underthrusting of fore-arc sediments during subduction. Rapid burial of the Swakane sediments is coincident with burial of sediments that formed the Pelona and Orocopia schists in southern California, suggesting that similar processes may have occurred along the length of the continental margin from 73-68 Ma.

V32F-07 1510h

The Origin of Continental Crust by Intracrustal Differentiation of Basalt in Magmatic Arcs: Trace and Major Element Evidence From Lower Crustal Eclogites Beneath the Sierra Nevada Batholith

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Continental crust (CC) is defined as that part of the crust that is unsubductable. Based on geologic observations, CC originates from island arcs or from intraplate magmatism (e.g., oceanic plateaus). However, the CC is andesitic in composition whereas island arcs and intraplate magmas are basaltic and represent direct mantle melts. The CC is therefore not mafic enough to be a direct mantle melt. Another fundamental imbalance is the low Nb/Ta (∼12) of CC with respect to primitive mantle (PM) (∼14). Nb and Ta do not fractionate during anhydrous mantle melting, such as beneath mid-ocean ridges. This suggests that during formation of CC, Nb is fractionated from Ta. Key to understanding the origin of CC is finding the "missing" high Nb/Ta and mafic reservoir(s). The two dominant hypotheses solving these chemical imbalances are direct melting of subducted eclogitized oceanic crust to form silicic melts, and intracrustal differentiation of basaltic crust into complementary felsic and mafic components, followed by physical removal of the mafic component. One attraction of the intracrustal differentiation model is that it is viable throughout geologic time, whereas the slab melt model is largely restricted to the Archean. The intracrustal differentiation model, however, is nearly impossible to test if the putative mafic complement to the CC has already been lost as is required by the model. "Eclogite" xenoliths (garnet-clinopyroxenites) erupted in Miocene diatremes in the Sierra Nevada arc, California represent one of extremely few localities where this "missing" mafic complement has been sampled. Here, we show that these "eclogite" xenoliths indeed have the necessary major element and HFSE (Nb, Ta, Zr, Hf) compositions to balance the andesitic composition of CC with respect to a basaltic parent. Ten "eclogites" were analyzed by XRF for major elements and by ICP-MS for trace elements. Preliminary results show that most of these xenoliths have Nb/Ta and Zr/Hf exceeding chondrite and recent PM estimates. On a Nb/Ta vs. Zr/Hf diagram, they lie off the terrestrial array towards anomalously high Nb/Ta. These Nb/Ta ratios are similar to those of Archean oceanic eclogites (AOEs), but differ distinctly in that the AOEs have largely subchondritic Zr/Hf. Mg and Ca concentrations are significantly higher than typical basalt whereas Al and Si concentrations are lower. The Sierran "eclogites" are therefore more mafic than typical basalts in contrast to the currently accepted average composition of the less mafic lower crust. On a MgO versus SiO2 diagram, a simple two-stage model for the origin of CC arises. Crystallization of average Sierran "eclogite" from primitive basalt can drive the composition of the residual melt towards the average composition of bulk CC, which subsequently undergoes further intracrustal differentiation to generate the petrologic differences we see in CC. The lack of Eu anomalies in the Sierran "eclogites" argues against an origin by subsolidus transformation from plagioclase cumulates to garnet-bearing lithologies. Instead, the Sierran "eclogites" represent high pressure cumulates where garnet and clinopyroxene are on the liquidus. We further propose that this "eclogitic" cumulate delaminates or founders back into the convecting mantle, imposing a deficit in mafic component in the CC. Alternatively, the "eclogite" may simply be seismically invisible. Because this simple model can explain most of the geochemical "paradoxes" of the CC and could have operated throughout Earth's history, we suggest that most of the continental crust originates from differentiation of basaltic magmas in arcs.

V32F-08 1525h

Generation of Sulfur-rich, Sulfur-undersaturated Basaltic Melts in Oxidized Arc Sources.

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Although sulfur is a minor element in the Earth, it has a disproportionate impact because it commonly occurs as sulfide. Sulfides largely control the behavior of chalcophile (e.g., Cu, Ni) and highly siderophile elements (Ru, Rh, Pd, Re, Os, Ir, Pt, and Au) that are of interest because either they are economically important or because they provide valuable information about geochemical processes. Island arc basalts are more oxidized than basalts from other tectonic settings and therefore, in these settings, sulfur maybe present not as sulfide but as sulfate. In addition to the impact on the behavior of chalcophile and siderophile elements, sulfur speciation as sulfate may have a role on the occurrence of sulfur-rich explosive volcanism, which has been linked to significant short-term variations in global climate. However, little is known about the range in oxygen fugacity for the transition from solubility as sulfide to solubility as sulfate. We used experimental data on the solubility of sulfur in basaltic melts saturated with either sulfide or sulfate at different oxygen fugacities to model this transition. Our model shows that the ten-fold increase in the solubility of sulfur (from 0.14 wt.% to 1.5 wt.%) observed experimentally occurs at oxygen fugacities between ∼FMQ+1 and ∼FMQ+2, conditions under which many arc magmas are thought to be generated. The increase in the solubility of sulfur with increasing oxygen fugacity implies that in oxidized arc sources very low degrees of partial melting are sufficient to generate basaltic melts that are simultaneously sulfur-rich and sulfur-undersaturated. In the absence of sulfides, oxides and metallic alloys may influence the behavior of some (but not all) the highly siderophile elements whereas the chalcophile and some siderophile elements become incompatible. As a consequence, melting of oxidized sources in which sulfides are not stable would favor incorporation of metals such as Cu, Ni, Au and Pd in the melts and increase the ability of those melts to generate Au-rich and Pd-rich ore deposits. In addition, partitioning of sulfur into a hydrous phase upon decompression and mixing of a sulfur-rich basaltic melt with water-rich felsic magmas provides a feasible mechanism to explain the sulfur-rich degassing observed in some volcanoes. We emphasize the importance of accounting for the oxidation state of sulfur when modeling magmatic processes in which sulfur is a key component, specially in arc magmas where sulfur is likely to be present both as sulfide and sulfate.

V32G MCC: 3008 Wednesday 1600h

Frontiers in High-Pressure Research: Earth's Deep Interior II *(joint with GP, MR, DI)*

Presiding: **B Kiefer,** New Mexico State University**; R J Hemley,** Carnegie Institution of Washington

V32G-01 1600h INVITED

Experimental and Theoretical Mineral Physics Challenges Posed by Core Formation and Evolution Models

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The current state of Earth's core is a legacy of its formation and evolution. It is likely that many of our notions of this are simplistic and arise from an ignorance of what took place, but this does not reduce the merit of considering the relevant experiments and calculations that are motivated by current ideas. The perspective I will adopt is that Earth's core is an ensemble of different sources: A source that may have formed in precursor bodies and thus reflects relatively low temperature, low pressure equilibration at a very early stage; a source that experienced high T and maybe P created immediately after a giant impact, a source that arises from equilibration at the base of a magma ocean (the most popular current idea) and perhaps a source that arises from core-mantle boundary interactions. I will accordingly focus on three kinds of challenges: (1) What is the behavior of metallic iron-liquid silicate mixing and equilibration under extreme temperature? This may be needed to understand some aspects of what happens during the prompt Rayleigh-Taylor instabilities that follow giant impacts. On general thermodynamic grounds, we expect immiscibility to decrease at high temperature. I will discuss likely estimates of critical temperature and how solubility should scale as temperature decreases.(2) What is the nature and consequences of dissolution from the core as the outer core cools? On quite general thermodynamic grounds, we can expect that the least soluble mantle constituent (probably MgO but not really known) is also the one most likely to become saturated in the outer core as the core cools. Silica or the combination with MgO (Mg perovskite) may also become saturated. I will discuss how this would show up in earth properties (e.g., seismology, geodesy) and how this would be important for the energy source for the dynamo. (3) How is the siderophile pattern of residual mantle affected by the likely equilibration between mostly solidified mantle and core-forming melt? This is relevant to the bottom of a magma ocean and the last equilibration of core forming liquid with mantle. The "bottom" of the magma ocean is rheologically defined and is therefore mostly solid, not liquid. In each of these cases I will describe what kind of experiments or calculations are needed to make progress.

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Expanded Stability of the hcp Structure in Iron-Rich Alloys

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The Earth's core is composed of an Fe-rich alloy, with a solid inner core probably in the hcp structure. However, in pure Fe the hcp structure exists only at pressures too high, or temperatures too low, for many important geochemical measurements to be applied to the phase most relevant to the core, using standard multi-anvil apparatus. In the present work it is demonstrated that the stability of the hcp phase can be enhanced by alloying Fe with Ru or Os, permitting experimental investigation of Fe-rich hcp metal at lower pressures and/or higher temperatures than is possible in the pure Fe system. Pure metal starting materials were mixed with alumina to limit annealing and loaded in the 250 ton multi-anvil press at beamline 13-BMD at the Advanced Photon Source. The metal compositions were homogenized in situ at high P and T, and the phase diagram of the alloy composition was determined by synchrotron x-ray diffraction. Pressures were calibrated using the Au equation of state. At each P,T condition the sample was allowed to diffusively equilibrate; this was essential to obtaining reliable results. In the pressure range 5-15 GPa, it was found that 17 at% Ru, 26 at% Ru, and 29 at% Os in the alloy elevated the temperature limit of the hcp phase region by 250 K, 700 K, and 650 K, respectively, relative to pure Fe. At still higher T the hcp phase persists in fcc+hcp coexistence regions. An alloy containing only 10 at% Os had a fcc+hcp phase region extending 600 K above the hcp/fcc boundary of pure Fe, but the pure hcp phase region was not significantly expanded at this composition. The slopes of the phase boundaries are similar to that of the hcp/fcc boundary in Fe. The enhanced stability of the hcp structure demonstrated here is sufficient to permit investigation of chemical and physical properties of Fe-rich hcp alloys when the properties of pure hcp-Fe are inaccessible to experiment.

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Frontiers of High-Pressure Research: Next Generation Large Volume Gem Anvil Devices

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By any measure, the diamond anvil cell has revolutionized static high-pressure research, and in particular experimental study of Earth and planetary deep interiors. Despite the prowess of the technique, however, its range of applicability is in many ways quite limited and its potential not yet fully realized. We have embarked on a program to develop the next generation high-pressure devices that will allow new classes of in situ high *P-T* measurements critical to understanding the structure, dynamics, and evolution of planetary bodies. A crucial component of this effort is the enlargement of sample volume without sacrificing the unmatched pressure range and versatility of diamond anvil cells. In conventional studies, pressures to several hundred GPa are generated on sample volumes down to the picoliter range. The small sample size is determined by the availability of perfect diamonds as anvils, which are currently of order of 0.2-0.4 up to a few carats. The small sample size has precluded, or greatly limited the accuracy of, certain classes of high pressure experiments. The production of high-quality single-crystal

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