On decompression, the hysteresis of the phase transition was reduced from 3 GPa for the dry sample, to 1.5 GPa for the hydrous sample. We studied upper-mantle discontinuity structures below the western U.S., South America, and in the Tonga subduction zone using receiver functions calculated from P-to-S converted arrivals. Within each region, there are multiple reflectors between 100 and 300 km depth, but their depths vary and not all of them are present at each station. In the western US, there is a sporadic and relatively weak reflector varying in depth between about 250 and 300 km depth. In S.A. along the Andean belt, a moderate to strong arrival is observed at around 290-300 km-depth, but below the craton strong arrivals appear at 245-280 km depth. At Tonga, the strongest reflector occurs at around 100 km depth, with only weak evidence for arrivals from 300 km. Mantle discontinuity structure in the upper 300 km of the mantle is considerably more complicated than for the transition zone, but if the effect of water on the LCEN to HCEN transition pressure observed in these experiments is comparable to that for OEN to HCEN in the mantle, any corresponding seismic discontinuity would be shifted to lower depths by about 40-60 km, or, extinguished altogether by widening of the divariant loop in the (Mg,Fe)SiO_3 system.

U53A-05 1435h

Incorporation of Hydrogen and Aluminum in Perovskite: A First Principles Investigation

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The incorporation of water into nominally anhydrous silicates is associated with mechanical weakening and lowered melting points such that even small amounts of water in mantle minerals can serve as a significant volatile reservoir in the planet. Experimental attempts at water incorporation in $MgSiO_3$-perovskite have met with varied success, with little agreement in solubility or the frequency of the OH band. Here we present first principles, pseudopotential calculations of fully relaxed structures on $MgSiO_3$-perovskite with aluminum and hydrogen substitutions. We find three symmetrically distinct stable arrangements for the location of hydrogen in the unit cell given the coupled substitution of Si^{4+} for Al^{3+} + H^+ in perovskite. These three stable hydrogen locations have OH bond lengths of 1.09Å, 0.96Åand 0.99Åat 0 GPa, and less than 2 kJ/mol difference in the energy distinguishing each arrangement. These multiple substitutions with small energy differences may explain the variable OH frequencies found for hydrated perovskite, with sensitivity to the synthesis conditions. This substitution is associated with a 2.2% softening of the equation of state for structure containing 3.1 mol% H_2O and Al_2O_3, comparable to recently reported results for softening in SiO_2-stishovite containing 2.1 mol% H_2O and Al_2O_3 [Panero and Stixrude, 2004]. We calculate that the enthalpy of solution of $Mg^{2+}+Si^{4+}=2Al^{3+}$ is slightly less than the Si^{4+} for Al^{3+} + H^+ reaction, but both solution enthalpies are generally independent of pressure between 0 and 100 GPa. Further, we confirm previous theoretical results that aluminum incorporation with oxygen vacancies is not favored ($2Si^{4+}+O^{2-}=2Al^{3+}+V_O^{**}$). Assuming ideal entropy of solution, at 2000 K we find Mg-perovskite saturated in aluminum and water to contain 0.13 wt% H_2O.

U53A-06 1450h

Oxygen Fugacities of Lavas From Iceland and Implications for Mantle Redox States.

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The oxygen fugacities of magmas provide information about the redox states of their mantle source regions. In principle, it is possible to use oxygen fugacities for magmas erupted in different tectonic environments to map variations in the redox state of the underlying mantle. Published data have been interpreted to indicate that the mantle source of MORB is reduced relative to that of OIB. In fact, oxygen fugacities calculated from analyzed Fe_2O_3/FeO for some OIB fall in the range of those for MORB (ΔQFM=0.402 to -1.305). For example, ΔQFM=0.188 to -1.212 for Hawaii, and ΔQFM=0.293 to -0.881 for Loihi. This suggests that the mantle source of at least some OIB is similar to that of MORB. To further compare the redox states of OIB and MORB mantle source regions, we have calculated oxygen fugacities for lavas from various volcanic centers on Iceland from the compositions of coexisting olivine and glass. Iceland lies across the Mid-Atlantic Ridge, but magmatism is thought to be related to the presence of a mantle plume. Hence oxygen fugacities for plume-derived magmas may be compared with those of magmas erupted along the nearby MAR. For the latter, oxygen fugacities calculated from olivine-glass pairs agree with those calculated from analyzed Fe_2O_3/FeO (ΔQFM=-0.562 to -2.212). Calculated oxygen fugacities for Icelandic lavas fall within this range (ΔQFM=-0.107 to -2.088), and broadly agree with those calculated from mineral equilibria for volcanoes such as Thingmuli. This confirms that oxygen fugacities for some OIB are virtually identical to those of MORB. The major implication of this study is that there is no evidence that the redox states of the mantle sources of OIB and MORB are substantially different. It follows that if OIB are derived from deep mantle plumes, there is no evidence that the redox state of the lower mantle differs from that of upper mantle. However, if the redox states of the lower and upper mantle are indeed different, this difference is not recorded in the oxygen fugacities of magmas erupted from these sources.

U54A CC: 517 A Friday 1530h

The Importance of Water and Melt in Mantle Dynamics: Developing Constraints From Interdisciplinary Studies II

Presiding: **W R Panero,** University of Michigan**; S D Jacobsen,** Carnegie Institution of Washington

U54A-01 1530h

Numerical Modeling of Melt Generation and Migration in Subduction Zones

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Using a two-phase flow model, we investigate the generation and migration of melt in the mantle wedge of a subduction zone. Our model consists of a deformable solid matrix, and melt that flows through the matrix. It allows for compaction and decompaction of a partially molten rock. We solve the equations of conservation of mass and momentum for the solid matrix and the melt, heat transport, and advective transport of the depleted mantle rock in a subduction model that extends to the bottom of the upper mantle. It is thought that transport of water from the slab to the mantle wedge can lower the melting temperature to around 1000 C. We investigate the generation of melt in the presence of dry, as well as, wet peridotite. We do not study the actual mechanism of water transport. We simply assume that such flux of water exists and affects the dry peridotite. We then study the amount of melt generated and its migration under varying parameters such as slab age, velocity and dip, viscosity, etc. We assume that water can flow to a maximum distance of 100 km from the surface of the slab. We also study batch and fractional melting conditions. We use the melting curves for dry and wet peridotite obtained by Iwamori et al. (EPSL, Vol. 134, 1995). The results show that voluminous melt production is possible only for wet peridotite and reasonable thermal evolution models. Both batch and fractional melting result in the melting of wet peridotite and the differences are, for the most part, of second order. The movement of the melt is governed by its vertical upwelling, and the wedge flow that works to keep the melt close to the slab. As a result, the melt has a tendency to accumulate near the corner of the mantle wedge. The models show a wide variety of melt flow behavior, ranging from circulating motions in the wedge, to entrainment of a significant part of it into deep mantle. In constant-viscosity models the melt is able to reach to the surface, whereas in models with temperature-dependent viscosity, it accumulates under the rigid lithosphere.

U54A-02 1545h INVITED

Estimates of Water Concentrations in the Mantle

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This talk will review estimates of mantle water concentrations as determined by studies of mantle-derived melts. A major uncertainty in the earth's water cycle is the effect of subduction and recycling of hydrated lithosphere on deep mantle water concentrations. There is general agreement that the earth accreted "wet" and that post-accretion influx of water to Earth from comets is limited to <~20%. A minimum value of ~1000 ppm H_2O in the primitive mantle can be estimated by adding exosphere water (ocean, atmosphere, and crust) to the depleted mantle, assuming that this water comes from degassing of half the mantle and that the depleted mantle has ~100 ppm H_2O. Lower values of primitive mantle water (330 ppm for the Pacific and 430 ppm for the north Atlantic) are obtained by calculating the value required to produce a smooth depletion trend for highly incompatible elements in MORB. A similar phenomenon noted for Pb has been interpreted as preferential partitioning of Pb into the exosphere during subduction. I suggest that the same is true for water. Water concentrations in various mantle end-member components support this hypothesis. Mantle plumes enriched in recycled lithosphere (EM1, EM2, LOMU, and HIMU; H_2O/Ce<=100) have lower ratios of water to similarly incompatible elements than plumes dominated by the common plume component (FOZO; H_2O /Ce=210 to 300). High H_2O /Ce in FOZO plumes cannot be derived from recycled lithosphere; therefore, a significant amount of water must be juvenile, left over from planetary accretion. Thus, dehydration during subduction effectively partitions water into the exosphere (mantle wedge, crust, ocean, atmosphere) resulting in time-integrated depletion of water relative to other incompatible elements in recycled (deeply subducted) lithosphere and sediments and, ultimately, the majority of the mantle. Entrainment of hydrated suprasubduction zone mantle (0.025 to ~2 wt% H_2O) may lead to water enrichments in the upper ~400 km, as evidenced by seismic tomography. Mantle below this depth is likely to be quite dry (<0.08 wt%), regardless of the existence of high pressure hydrous phases observed in laboratory studies.

U54A-03 1605h INVITED

Lateral Variation in Upper Mantle Viscosity: Role of Water

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Differences in the viscosity of the earth's upper mantle beneath the western US (10 18-10 19 Pa-s) and global average values based on glacial isostatic adjustment and other data (10 20-10 21 Pa-s) are generally ascribed to differences in temperature. We compile geochemical data on the water contents of western US lavas and mantle xenoliths, compare these data to water solubility in olivine, and calculate the corresponding effective viscosity of olivine, the major constituent of the upper mantle, using a power law creep rheological model. These data and calculations suggest that the low viscosities of the western US upper mantle reflect the combined effect of high temperature and high water concentration. Our model is compatible with temperature estimates in the western US based on P-wave seismic tomography, but not with S-wave seismic tomography, suggesting that the latter could be biased to high values by the presence of fluid and/or partial melt. The high water content of the western US upper mantle may reflect the long history of Farallon plate subduction, including flat slab subduction, which effectively advected water into the upper mantle as far inland as the Colorado Plateau.

U54A-04 1625h INVITED

Seismic Attenuation Constraints on Temperature and Water Content of the Mantle Wedge

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TThe mantle wedge in subduction zones produces arc volcanism, receives devolatilized fluids from subducting slabs, and controls the coupling between the earth's surface and descending plates. Still, few constraints exist on either its temperature (T) or water content, which together control melting and wedge viscosity. We show here new advances in the use of

seismic attenuation (1/Q) to constrain these quantities. Recent high-resolution attenuation measurements in Alaska, Japan and the Andes show variations in 1/Q at scales of a few tens of km, in the wedge at 50-150 km depths. The Alaska results show that shear attenuation greatly exceeds bulk attenuation in the wedge, and that 1/Q exhibits weak but measurable frequency dependence, consistent with high-T laboratory measurements. Hence, the laboratory measurements should provide a reliable link between 1/Q and T. Variations of 1/Q between subduction zones show that the Japan wedge and that of the Andes are 100-150 degrees hotter than that beneath Alaska. This T variation is consistent with the observation that volcanism is absent beneath Alaska, although present beneath the other arcs. However, absolute estimates of T from laboratory calibrations appear to be too high, by 100-200 degrees, compared with other estimates of wedge temperature. Temperature is estimated in two ways, through the anharmonic part of S-wave velocity (Vs), and, in Japan, through analysis of mantle xenoliths. The resulting T estimates can be reconciled with 1/Q observations either by assuming unrealistically small grain sizes (less than 100 microns) or by incorporating water into the T-1/Q relationships. For reasonable grain sizes, preliminary estimates suggest that on the order of 1000 ppm H/Si may be needed to explain the 1/Q-T discrepancy, albeit with large uncertainties. This water content is consistent with several wt% H2O in arc magmas, as observed. The combination of information on T and H2O can be used to infer the extent to which melt should be present within the wedge.

U54A-05 1645h

A new, high-resolution seismic profile of the central-Alaskan subduction zone

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Subduction of the Pacific plate beneath central Alaska is responsible for extensive regional uplift and vigorous seismic activity. The oceanic lithosphere involved in this subduction complex is relatively old (~40 Ma at the trench) and has a convergence rate of ~55 mm/yr relative to North America. Intraslab seismicity indicates that prograde metamorphism in the basaltic oceanic crust occurs down to depths of ~150 km - at a distance of 650km NW (landward) of the trench, but structural features in the subducted crust and mantle wedge associated with these reactions are still poorly constrained. Here, we investigate the 2D seismic velocity structure of the central-Alaskan subduction complex between 450-650 km to the NW of the trench. We use data recorded by the BEAAR passive seismic array, which was operational between 1999-2001 and consisted of 36 broadband stations deployed at ~10km spacing. High-resolution images are generated by inversion of teleseismic scattered waves in the P-coda for material property perturbations of the subsurface (dVp/Vp, dVs/Vs). Resulting profiles outline a low-velocity layer (LVL) extending between 50-140 km depth, with a northwestward dip of ~ 23° and 15-20% Vp and Vs reductions relative to the overlying mantle wedge. The thickness of the LVL varies from 20km at shallow depths, where it is interpreted as oceanic crust plus an overlying serpentinized zone or coupled exotic terrane, to 8-10 km at 140 km depth, where it is interpreted as only oceanic crust. The LVL signature decreases rapidly near 140 km depth, implying a sudden increase in seismic velocities associated with eclogitization of the oceanic crust. These results are in good agreement with a previous receiver function study of the BEAAR data. In addition, the new image uncovers a sub-horizontal, ~15% Vp-Vs discontinuity marking a sudden downward reduction in velocities in the NW portion of the profile. This enigmatic structure is located at ~50km depth in the mantle wedge, between the subducted crust (80-150km) and the continental Moho (30km), and may represent the upper boundary of exotic terrains that were underplated earlier in the history of the subduction complex.

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