MREE-enriched phase such as clinozoisite, but incompatibility of the LREEs in garnet precludes a record of changes in LREEs directly from garnet. Depletions in the LREE and HREE about MREE such as Gd in matrix CPX reflect the influence of growth coeval with garnet and the general compatibility of REEs in the CPX structure. Corroborating such inferences, CPX inclusions in garnet generally display higher HREE contents than matrix CPX. Fluid-mobile elements such as the LILEs and B are generally hosted by white micas in these eclogites. Both phengite and paragonite are present in the eclogites and record distinct TE partitioning. Phengite is the primary host for Cs and Ba, with Ba/Sr ratios >20, while Sr is more strongly partitioned into paragonite, with Ba/Sr ratios <0.1. While Li contents for paragonite and phengite are indistinguishable, B preferentially resides in paragonite, creating B/Li ratios of ∼10 in paragonite versus ∼1 in phengite. These data indicate that mobility of individual LILEs during devolatilization in the eclogite facies will be strongly controlled by the stability of distinct phases. Our results indicate eclogite-facies minerals can provide detailed geochemical information regarding trace element behavior during metamorphism and, when combined with traditional thermobarometric data, will provide a powerful record of devolatilization in subduction zones. Our approach also allows characterization of overprinting mineral parageneses and trace element redistribution related to the complex exhumation histories of these rocks.

T32A-0920 1330h POSTER

Hydrothermal Venting in the Southern Most Portion of the Mariana Backarc Spreading Center at 12.57 Degrees N

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The southernmost portion of the Mariana Trough is a complex zone of deformation and magmatism. The centerpiece of the trough is the Malaguana-Gadao Spreading Center Ridge, which has a morphology that is inflated relative to all of the other spreading segments in the Mariana Backarc Basin. This inflated morphology is similar to that of the EPR and is consistent with a high rate of eruption. Samples of lavas from the spreading center are island arc tholeiites, which typically contain higher concentrations of CO2 relative to MORBs. In February 2003 the NOAA VENTS program conducted two CTD tow-yos in this area, revealing a hydrothermal plume consistent with the presence of a high temperature hydrothermal site. In May 2003 we used the ROV Jason II to survey a hydrothermal site at 12 degrees 57.214'N, 143 degrees 37.147'E in a water depth of 2860 m. Here we collected vent fluids, sulfides, basalt, microbial mats, and macrofauna. Two styles of venting were identified within an 80 m by 70 m area. Higher temperature venting was located in cracks among extinct mounds that were 2-5 m high and wide and are nearly monomineralic (sphalerite) in composition. The exterior is soft and vuggy in contrast to the interior that has crystalline layers with bladed habit lining the orifices. Maximum temperatures of 248 degrees C were recorded 30 cm into these cracks, which were covered with abundant large provannid snails, Alvinoconcha Hessleri, and crabs. In contrast, lower temperature diffuse venting (77 degrees C) emanated from mounds that have a porous structure that is composed of amorphous iron oxide and opal. These mounds are covered with microbial mats, which exhibit a high degree of biomass as detected by Cyto-13 nucleic acid epifluorescent staining. Filament and amorphous particulate morphotypes are observed in association with microbial cells, but sheaths have not been detected. These mats have a morphology that is similar to that of neutrophilic Fe-oxidizing bacteria. Fluid chemistry is consistent with a single source and with other back-arc derived hydrothermal fluids that are enriched in alkalinity relative to bottom seawater. Extrapolated concentrations per kg of seawater are 0 mmol Mg, 36.2 mmol Ca, 7.3 mmol alkalinity, 544 chlorinity, 414 mmol Na, 32.2 mmol K, 0 mmol sulfate, 165 umol Sr, and 575 umol Li. Additional analyses are ongoing.

T32B MCC: Level 2 Wednesday 1330h

Causes and Consequences of Lateral Heterogeneity in the Earth's Mantle II Posters *(joint with S, V, MR, DI)*

Presiding: **C Lithgow-Bertelloni,** University of Michigan**; L Stixrude,** University of Michigan

T32B-0921 1330h POSTER

Geophysical Signatures of Chemical Depletion in Slave Cratonic Peridotite.

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Variously depleted peridotites of the Slave craton (Northwest Canada) provide an excellent natural laboratory that allows us to investigate effects of depletion on the chemical and physical characteristics of rocks. We computed seismic velocities for the variously depleted peridotites of the N and SE Slave based on single-crystal elastic moduli and volume fractions of constituent minerals. The depleted peridotites enriched in MgO have lower Vp and higher Vs, where lower Poisson's ratios are due to orthopyroxene enrichment. The predicted effect on seismic wave speeds would be up to 0.05 km/s, or 0.6 rel.% of Vp. The correlation observed on the Slave craton contradicts the established view that peridotite depleted in basaltic magmaphile elements has higher seismic wave velocities. However, evidence amassed in the past 15 years suggests that cratonic mantle peridotite is chemically distinct from off-cratonic peridotite. In cratonic peridotite, the Mg-number of olivine is negatively correlated with its mode, and Ni in olivine is positively correlated with orthopyroxene mode and olivine Mg-number. These patterns hint that depletion in the cratonic mantle may have a distinct seismic signature compared to the off-cratonic mantle. Our data suggest that chemical depletion of peridotites should also affect their redox state. The shallow, more depleted spinel peridotite of the N Slave shows a distinctly lower bulk Fe2O3 abundance and lower Fe3+ concentration in spinel, consistent with a lower oxygen fugacity. Moreover, different types of peridotite that coexist at a given depth have different redox states, and the redox state of peridotitic mantle changes sharply between the layers with different bulk compositions and oxide mineralogies. Such a pattern of oxygen fugacity is expected if oxygen is controlled intrinsically by Fe equilibria. In an Fe-buffered peridotitic mantle, domains depleted in Fe3+ following partial melting should be more reduced and therefore should contain more elemental carbon. A larger abundance of graphite may explain the higher EM conductivity of the ultra-depleted layer mapped in the Central Slave mantle.

T32B-0922 1330h POSTER

Invisible Slabs: The Influence of Phase Boundary Deflection on Velocity Anomalies of Stagnant Slabs in the Transition Zone

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A primary constraint on the dynamics of subducting slabs comes from images produced by seismic tomography. The interpretation of the seismically fast anomalies in tomographic models as being cold bodies allows a comparison of behaviours in geodynamic models and the Earth's mantle. However, the inference of seismic anomalies as purely thermal in origin neglects the contribution of olivine phase changes in the transition zone to the seismic manifestation of subducted slabs. To demonstrate the potential importance of phase change effects, we use a numerical routine to simulate the sinking of subducted lithosphere in a convecting mantle. We pay particular attention to the behaviour of the slab around the endothermic phase change associated with the 660-km seismic discontinuity. The time-dependent temperature fields from the flow simulation are used to derive perturbations from a radially stratified seismic velocity model. We show that the positive velocity anomalies of the cold descending slabs may be significantly decreased at the phase change owing to the slab-induced downward phase boundary deflection and associated velocity discontinuity across the boundary. The slab may be completely or partially rendered seismically undetectable, depending on the amount of phase boundary deflection. Gaps in the seismic images of subducting slabs (van der Hilst [1995]) may reflect this effect. These results have implications for the observation and interpretation of the dynamics of subducted slabs in the transition zone.

T32B-0923 1330h POSTER

Receiver Function Imaging of the upper mantle seismic discontinuities beneath the Japan Islands and the Korean Peninsula -Lateral variation in the depths and the Ps amplitudes-

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In the Japan Islands, high density short-period and broadband seismic networks have recently been installed. In this study, we apply Receiver Function (RF) analyses to teleseismic P-wave coda portions observed at 63 J-array, 64 F-net, 4 IRIS and 7 KIGAM (Korea) broadband stations and investigate the detailed structure of the upper mantle velocity discontinuities beneath the Japan Islands and the Korean Peninsula. The results indicate that there are large lateral variations in visibility of the 410 km discontinuities, and the 410, 660 km discontinuities are affected by the subducting Pacific (PAC) slab.

We examine the observed waveforms from the teleseismic events with the magnitudes greater than 5.5, which occurred during a period from 1998 to 2003. We discard almost 35,000 RFs with low signal-to-noise ratios, and finally keep a total of 8,825 RFs from 389 events.

RFs are constructed through frequency domain division of radial components by vertical ones with a water level of 0.01. The low-pass Gaussian filters of 0.1, 0.3, 1.0 Hz are also applied to examine the frequency dependence of the visibility of the discontinuities. Assuming the phases in RFs are produced by Ps converted ones at depths, we transform the time domain RFs to the depth domain ones using recent P- and S-wave tomographic velocity models. Then, SVD filtering is applied to the depth domain RFs. We keep largest 6 eigenimages to construct SVD-filtered RFs. Finally, we construct 2-D stacked RF images projected on cross-sections along several profiles to see the detailed velocity discontinuity structure.

Beneath the Japan Islands, the dipping positive RF amplitude traces can be recognized to a depth of 200 km or more, which coincides with the distribution of deep earthquakes occurring within PAC. In contrast, the Philippine Sea slab has not been confirmed clearly. 660 km discontinuity is confirmed clearly and uniformly beneath the whole Japan Islands. Similarly, 410 km discontinuity is detected clearly in Kanto area (central Japan). However, in Tohoku (northern Japan) and southwest Japan area, 410 km one is not detected clearly. We consider that the reasons are both the density differences of the stations and the regional differences of the thickness of the 410 km discontinuity. Also, the 410 and 660 km discontinuities are undulated due to the subducting cold PAC slab. That is, in our results, the 410 km discontinuity seems to be locally affected where the PAC penetrates, and the 660 km discontinuity is broadly and gradually downwarped westwards by 50 km, which is consistent with the stagnated PAC on the 660 km discontinuity.

We are grateful to the J-array, F-net, IRIS, KIGAM project for providing the data, and we are especially thankful to Prof. D. Zhao in Ehime University and Prof. K. Koketsu in Univ. of Tokyo for giving us 3-D P- and S-wave velocity models, respectively.

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T32B-0924 1330h POSTER

Seismic Heterogeneity Caused by Oceanic Crust Differentiation and Segregation in the Convecting Mantle

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This presentation focuses on the seismic signature of mantle heterogeneity associated with crustal differentiation and segregation in the lower mantle. Segregation of subducted oceanic crust above the CMB has often been invoked as a way of explaining the isotopic signature of OIB geochemical endmembers such as HIMU. Here a mantle convection model that includes melting-induced differentiation and plate tectonics is run for billions of years and the resulting thermo-chemical heterogeneity is studied. Statistical diagnostics such as radial correlation functions (Jordan et al., 1993) and spectral heterogeneity maps (Tackley et al., 1994) are used to characterize the observational signature of the thermo-chemical structures and compare them to global seismic tomographic models. In the reference case, crust is denser than the background mantle at the CMB. Due to this density contrast, the crustal material forms a thick and dense layer at the bottom of the mantle, although the layer interface is not sharp as is commonly obtained in models where a layer is inserted a priori. An enormous amount of long-wavelength volumetric heterogeneity is found in the lower mantle. The presence of oceanic crust near the surface also contributes to heterogeneity at the top of the mantle. In cases where the subducted crust is neutrally buoyant or buoyant in the deepest mantle, a large amount of heterogeneity instead exists in the the mid-mantle region, which is not observed in tomographic models of the real Earth. Unlike the reference case with a thick layer at the bottom of the mantle, these cases have heterogeneity right at the CMB, and this strong heterogeneity exists at both short and long wavelength. When comparing to Earth, it appears that models in which dense subducted crust settles into a layer above the CMB are consistent with constraints from seismic tomography; such a layer is therefore a viable location for the storage of geochemical endmembers.

T32B-0925 1330h POSTER

Evidence for Chemical Heterogeneities Derived From Poisson's Ratio in the Lower Mantle Beneath Alaska.

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Deep mantle composition can be investigated from seismic velocities only by considering both P-wave and S-wave velocity anomalies. Using a waveform cross-correlation technique we have measured ∼17,000 P and S wave differential travel times from earthquakes and stations near a great circle path from Japan, across Alaska, to North America. We jointly invert the data for variations in shear and bulk sound speed and derive Poisson's ratio variations in the mantle. We explore the model space using different levels of regularization and we keep a range of models that give acceptable data fits. These models are discussed only in the lower mantle well resolved areas. The correlation between Vs and Vp variations is good to ∼1500 km depth but gradually degrades in the bottom 1000 km, whereas the ratio R=dlnVs/dlnVp is between 1.5 and 2.0 at most depths. Our data suggest that there is no significant correlation between bulk and shear wave speed, but they appear anti-correlated in several regions. We estimate the effect on the Poisson's ratio of changes in temperature, iron content, and the magnesiowustite (mw) to perovskite (pv) ratio. At all depths the effect of temperature is largest, and that of pv and mw ratio smallest. Our data cannot resolve the trade-off between thermal and compositional effects, but explaining the Poisson's ratio variability by temperature alone would require unrealistic perturbations and it would not explain the inferred anti-correlation between shear and bulk sound speed. Our results suggest that the elastic parameter variations in the deep mantle beneath Alaska reflect a combination of thermal and compositional effects, with dT of ∼300-800K, variation in Fe contnet of ∼4%, and Pv enrichment (or depletion) of up to ∼10% just sufficient for explaining the data.

T32B-0926 1330h POSTER

Combined Constraints From Seismic and Mineral Physics Data on the 1D Velocity Structure of the Mantle: Towards a Physical Reference Model

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The knowledge of thermal and compositional structure of the mantle is fundamental to understand many aspects of Earth dynamics. Seismic tomography provides an uncomparable tool to explore the Earth's deep structure. But, seismic velocity models obtained from inverting seismic data are not unique solutions. This is also the case for spherical reference models that constitute the background model for most velocity structures in one, two and three dimensions. In particular, upper mantle structure in both PREM and AK135, the most used 1-D Earth models, is not strongly constrained by the data used to define these models. In this study, we combine mineral physics and seismic data (travel-times from the re-processed ISC catalog of Engdahl et al., 1998 and the most recent normal mode frequency measurements to define a physical reference model for the Earths mantle. For the construction of this reference model, a pyrolitic composition and thermal structure for 60 My old oceanic lithosphere and a mantle adiabat with a potential temperature of 1300°C are assumed. Within the range of uncertainties of elastic and anelastic parameters from our recent compilation (Cammarano et al. 2003), we find a family of models that provide a fit to both normal mode frequencies (surface waves frequency range included) and travel-times (P- and S-phases) that is similar to PREM and AK135. The best-fit models can be used as reference model for tomographic inversions, where the family of models allows for uncertainty evaluation. The advantages of using a physical reference model are that: (1) anomalies relative to it represent deviations from an adiabatic pyrolite mantle, rather than from an average velocity; (2) the chosen physical model is based on a set of mineral parameters which can also be used to for interpretation of velocity structure in terms of temperature and compositional variations.

T32B-0927 1330h POSTER

Heterogeneous lowermost mantle: compositional constraints and seismological observables

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Several seismological indicators strongly suggest the existence of compositional heterogeneity in the lowermost mantle. Indeed, the observed anticorrelation between bulk sound and shear wave velocity anomalies as well as the high values (i.e., > 2.7) of the ratio $R = dlnV_P/dlnV_S$ are difficult to be explained by purely thermal convection. We use a compressible thermo-chemical convection model to study the stability of a chemically denser material, located in the lowermost mantle.Considering two phases for the lower mantle: (Fe,Mg)SiO3 perovskite and (Fe,Mg)O magnesiowüstite, we use geodynamical and seismological considerations and mineral physics data to constrain the composition of chemically denser material in the lower mantle. We show that the denser material has to be enriched in both iron and silica with respect to a pyrolitic lower mantle. The required enrichment is reduced if we consider that at high pressure Al-perovskite decreases the iron-magnesium partition coefficient between magnesiowüstite and perovskite. Our estimated composition of the dense material in then applied to the distribution of chemical heterogeneities calculated by our thermo-chemical convection model. In the deep mantle we predict broad seismic velocity anomalies and strong lateral velocity variations. Moreover, we find that areas of anticorrelation are associated with upwelling mantle flow. The calculated R ratio varies laterally and may locally have values greater than 2.7, often associated with areas of anticorrelation. Our results compare well with seismic observations and provide a way to reconcile apparent discrepancies between global tomographic models. This suggests that only an enrichment in iron and silica in the lowermost mantle is required to explain seismological observations.

T32B-0928 1330h POSTER

Thermochemical Structures Within a Spherical Mantle: Superplumes or Piles?

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Heterogeneous compositional mantle models are frequently invoked to explain some observations obtained from geochemistry and seismology. In particular two regions in the Earth's lower mantle - under the Pacific and Africa - are often interpreted as being either piles or superplumes of dense material. We perform numerical modeling of thermochemical convection in a three-dimensional spherical geometry to investigate whether the presence of a dense chemical component can lead to the formation of rounded piles or superplumes of material. In addition, we investigate whether a dense component can lead to degree-two structure, leading to two distinct thermochemical features. We study the effect of temperature and compositionally-dependent viscosity, and we find 2 different modes of dense layer deformation. Temperature-dependent rheology leads to a low viscosity dense layer which is passively swept aside by downwellings into linear piles spread throughout the entire lower mantle. The addition of compositionally-dependent rheology in which the dense layer is more viscous, results in active deformation of the dense material, forming large isolated superplumes. Our results indicate that piles and superplumes are separate features which in general, do not occur together, and in order for isolated,rounded superplumes to form, an intrinsic compositional viscosity increase is required for the dense material.

T32B-0929 1330h POSTER

Thermal Signatures and Deformation of Detached Slabs in the India-Asia Collision

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Seismic tomographic studies have revealed the existence of cold patches at depths of one to two thousand km below the Indian sub-continent. These are believed to be the residuals of former subducting slabs detached from India when it collided with Eurasia at about 45 Ma. If this interpretation is correct, something must have slowed their natural rate of descent; otherwise the remnants of the sinking slab would have sunk to the base of the mantle during this period of time. In the present study we investigate the effects of a depth-dependent viscosity as a potential explanation for the retarded sinking process. We have employed finite differences in a full cylindrical shell model in order to eliminate side-boundary effects. The material properties are set on a Lagrangian grid which initially comprises a series of regular four-node elements in polar coordinates. This information is then mapped to an Eulerian mesh on which the momentum and energy equations are solved. The Lagrangian grid deforms on the basis of the updated velocity field obtained at each time step. The information exchange between the Eulerian frame and its Lagrangian counterpart is repeated at each time step and provides a new material configuration on the Eulerian mesh for the subsequent step of time evolution. The path of the slab remnants is precisely tracked by the Lagrangian grid. The deformation style of the tracker grid demonstrates how and where the resistance occurs which holds the slab in mid-mantle depths for a geological time of 50 to 100 My. Our numerical results suggest that a step-like viscosity change at depth of 700 km could account for the observed slow rate of descent of the slab remnants.

T32B-0930 1330h POSTER

What Spherically Symmetric Viscosity Structure Produces the same PGR as a Realistic 3D Earth?

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Observations of isostatic adjustment of the earth's surface due to transient loading provide important constraints on the mantle viscosity structure. However, most studies of this response have assumed a spherically symmetric (1D) earth. This study is motivated by the following question: when a one-dimesional viscosity model is derived from post-glacial rebound (PGR) observations, how does this 1D structure correspond to the three-dimensional structure of the earth? Using the 3D spherical finite element software CitcomSVE [Zhong et al., 2002], we are able to compute the earth's response to realistic glacial loading when the earth has a truly 3D viscosity structure. We generate a realistic viscosity structure by converting seismic shear wave tomography models to a 3D temperature field, and then to viscosity. The isostatic response of this earth is computed when subjected to the glacial history Ice-3G (Tushingham & Peltier, 1991). We then measure typical PGR observables: relative sea level change and J_2. These measurements are treated as synthetic data, and we search for 1D (radially stratified) viscosity models, forced with the same glaciation history, that best fit these synthetic PGR observations. We find that the viscosity structure beneath the ice load may serve as a reasonable 1D proxy, even when observing sea levels away from the loaded region. We also perform a Monte Carlo type inversion for a 1D viscosity by running thousands of forward models and minimizing the misfit to observations from the 3D earth. The 1D structure found to best fit the PGR observations does not, in general, look very much like the true viscosity. This may be due to uniquely three-dimensional effects. We also find that attempting to invert for too many parameters (for example, viscosity in more than four layers) may yield a *worse* recovery of the true viscosity structure than an inversion for fewer parameters.

T32B-0931 1330h POSTER

Hydration and Velocity Heterogeneity in the Mantle

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Olivine, wadsleyite, and ringwoodite are the mineral phases generally believed to compose the majority of the upper mantle and transition zone. Although nominally anhydrous, these phases can incorporate enough hydroxyl to significantly affect their P and S seismic velocities and to compose the planet's largest reservoir of water. Using single crystal X-ray diffraction, we have measured the effect of hydration on compression of Fo_{90} ringwoodite to 12 GPa. Using powder diffraction of synchrotron radiation we have measured compression to 50 GPa. Using GHz ultrasonic measurements on single crystals containing about one percent water by weight, we observe a reduction of P-wave velocity equivalent to an increase in temperature of 600°C and on S-wave velocity of 1000°C at ambient pressure. Single-crystal velocity measurements at pressure are in progress. The data obtained to date indicate that hydration of ringwoodite will have a larger effect on velocities in the Transition Zone (TZ) than does temperature within the uncertainties of each. We have measured the isothermal bulk moduli of hydrous wadsleyite by single-crystal X-ray diffraction and find a similar effect of hydration on the bulk modulus. Lateral velocity variations in the TZ are therefore more likely to reflect variations in hydration than variations in temperature, at least in regions distant from subduction zones. In tomographic images of the TZ in regions distant from active subduction, red is more likely to mean wet' than it is to mean hot'. Observed seismic velocities in the TZ are consistent with a pyrolite composition with 0.5 to 1.0 percent by weight H_2O, but are not consistent with dry pyrolite compositions. This degree of hydration would allow for TZ storage of two to three times the amount of water currently in the hydrosphere.

URL: http://ruby.colorado.edu/˜smyth/Research/Puball.html

T32B-0932 1330h POSTER

Thick Upper Mantle Transition Zone beneath Taiwan and the Surrounding Region

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The deep mantle structure beneath Taiwan and the surrounding two subduction systems remains poorly understood. In south Taiwan the eastward-subducting Eurasian plate outlined by the Wadati-Benioff zone seismicity disappears to the north of 23°N. Because of the lack of tomographically-imaged velocity structure in deep mantle, it remains unclear whether an aseismic slab extends to greater depths or mantle downwelling occurs as a result of gravitational instability of the thickening lithosphere beneath the Taiwan orogen. One approach to address the problem is to map the thickness of the transition zone from differential times between two P-to-S conversions at the discontinuities near 410 and 660 km depth. The corresponding seismic velocity jumps have been respectively attributed to the transitions from α-phase to β-phase of $(Mg,Fe)_2SiO_4$ and from γ-phase to perovskite plus magnesiowustite. Decreasing temperature shoals and depresses the boundaries of the phase transformations near the 410-km and 660-km discontinuities, respectively; thus increases the thickness of the transition zone. Therefore, variations in the discontinuity depths provide constraints on the thermal state in response to cold slabs or downwelling mantle. The data used for the study are receiver functions derived from teleseismic body waves recorded in the broadband BATS network on Taiwan and off-shore islands. Pds (referring to a P-to-S conversion at the depth *d*) paths with common piercing points are binned together in square patches of 260×260 km. The stacked receiver functions show that P660s-P410s differential times are greater than in the IASP91 model throughout the entire study area, indicating a relatively thicker and colder transition zone. The most anomalous region with a 6-s excess differential time is centered at (22°N, 121.8°E) near Lanyu island, about 250 km east of the southern end of Taiwan. The delays of P660s-P410s times decrease toward the north and the west; only ∼1.5-s delay remains beneath north Taiwan and the western Taiwan Strait. Lateral variations in the thickness and temperature of the transition zone will be explored after correcting the signature associated with upper mantle heterogeniety.

T32B-0933 1330h POSTER

Low Velocity Zone atop the 410 km Seismic Discontinuity in the Northwestern US

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Waveform modelling at triplication distances of 15-23 degrees indicates a low velocity zone (LVZ, shear wave velocity drop of 5 %) atop the 410 km seismic discontinuity beneath the northwestern United States, extending from southwestern Oregon to the northern Basin and Range. The LVZ has thickness varying from 20 to 70 km and has sharp western and southern boundaries. We did not find such anomaly from paths sampling offshore Washington-Oregon coast, the central Basin and Range and the Gulf of California. The spatial extent of the LVZ coincides with anomalous receiver function determinations and the region with distinct high alumina olivine tholeiite (HAOT) volcanisms. We interpret the LVZ directly above the 410 km seismic discontinuity as a compositional anomaly, possibly due to a dense partial-melt layer, which may be linked to prior Farallon plate subduction and back-arc extension. We also investigate P-wave triplications with exactly the same ray paths that are used to constrain the LVZ. Preliminary results show probably less variations in P-wave velocity at depths near the 410 km seismic discontinuity. Further detail modelling will help constrain the P-wave velocity and the Vp/Vs ratio in the LVZ.

T32B-0934 1330h POSTER

Origin of the intraplate volcanism and the fate of the subducting Pacific slab under Northeast Asia

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Recent global tomographic results show that the subducting Pacific slab becomes stagnant in the mantle transition zone under Northeast (NE) Asia. Receiver function analyses revealed that the 670 km discontinuity under NE China shows a complicated multi-discontinuity feature caused by the interaction between the subducting slab and the mantle transition zone. In addition, two active intraplate volcanoes, Changbai and Wudalianchi, exist in NE China. It is unclear whether these intraplate volcanoes are hotspot or not. To clarify the fate of the subducting slab and the origin of the intraplate volcanism, we determined a high-resolution 3-D whole-mantle structure under the region using the ISC data set as well as arrival times recorded by 24 portable and permanent seismic stations installed recently in NE China. A large number of arrival times of P, pP, PcP, PP are picked from over 100 teleseismic events (epicentral distances 25 to 100 degrees). Our results show that the subducting Pacific slab is clearly imaged under the Japan Islands and the Japan Sea, and deep earthquakes occurred within the slab. The slab-related fast anomalies extend toward the west, which are clearly visible in the transition zone under NE Asia. Pieces of fast anomalies are visible in the lower mantle down to the CMB. These results suggest that the subducting Pacific slab becomes stagnant in the transition zone under NE Asia before finally collapsing down to the lower mantle as a result of very large gravitational instability from mantle phase transitions. Very slow anomalies exist in the upper mantle right beneath the Wudalianchi and Changbai volcanoes, right above the stagnant Pacific slab in the transition zone. These results suggest that the active volcanoes in NE China are not hotspot but a sort of back-arc volcanoes which are closely related to the subduction process of the Pacific slab. Slow velocity anomalies in the back-arc region are generally associated with the back-arc magmatism and volcanism caused by the deep dehydration process of the subducting slab and the convective circulation process of the mantle wedge. These processes lead to the large-scale upwelling of the asthenospheric materials under NE Asia and cause intra-plate volcanism and continental rift systems in the region.

URL: http://www.ehime-u.ac.jp/˜grc/

T32B-0935 1330h POSTER

Sensitivity of Lower Mantle Seismic Anisotropy Beneath Subduction Zones to Mantle Viscosity Structure

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Observations of seismic anisotropy can provide insights into the style of mantle dynamics near the 660km discontinuity. Wookey et al (2002) report up to 6 seconds of shear-wave splitting for rays generated by deep focus events from the Tonga subduction zone and recorded in Australia. Initial wave propagation modelling through different anisotropic slab regions, using ray theory, shows evidence that the anisotropic region is in the topmost lower mantle, with only a minimal contribution from above the 660km phase transition. Hence, the Wookey et al observations are direct evidence that the mid-mantle can exhibit anisotropy. In this study, we examine the effect mantle viscosity has on the generation of shear-wave splitting and thus, attempt to explain the observations from Tonga of top lower mantle seismic anisotropy. We use finite element (FE) modelling to calculate slab-induced models of fluid flow, total stress and deviatoric stress. Large deviatoric stresses (maximum values 40 MPa) are generated in the topmost lower mantle when the subducting slab encounters a viscosity increase at the 660km phase transition. These stresses could induce mineral alignment in a broad region (lateral wavelength 800km) in the topmost lower mantle below the slab. We model finite strain accumulated by a mantle parcel as it propagates through the FE fluid flow models. The computed strain ellipsoids align in a similar region as that of the deviatoric stresses. Strain fields are then mapped into seismic anisotropy. We ray trace from depths comparable to those observed in the Tonga

subduction zone through our anisotropic models along similar travel paths as those observed by Wookey et al. We find that the magnitude of the generated shear-wave splitting is significantly dependant on the mantle viscosity structure. A subduction model with viscosity increases at 410km and 660km generates up to 6 seconds of shear-wave splitting from a source placed at 660km depth and rays traced to epicentral distances of 25°-65°. The magnitude of this shear-wave splitting is similar to the Wookey et al observations. A sensitivity analysis of shear-wave splitting to mantle viscosity structure requires a 10-fold viscosity increase at 410km and 660km depth and supports a viscosity structure similar to that proposed by Steinberger (2000). Observations of topmost lower mantle shear-wave splitting have the potential to constrain mantle viscosity structure.

T32B-0936 1330h POSTER

Self-Consistent Formation of a low Viscosity Zone

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The role of a low viscosity zone in stabilizing plate motion has been proposed by convection models in which a low viscosity zone (LVZ) below the surface has been prescribed. In this case a plastic yield stress serving as deformation mechanism for the stiff surface is combined with a viscosity drop below the thermal boundary layer. As a result regions of constant velocity and continuous motion was observed.In contrast to models that prescribe the formation of the LVZ, we combine a three-dimensional numerical mantle convection model with a temperature-, stress- and pressure-dependent rheology. The additional variation of viscosity with pressure yields the self-consistent formation of a low viscosity zone. However in pressure-dependent viscosity convection not automatically a low viscosity zone forms. The LVZ only appears under a certain parameter combination. Depending on the parameter combination different regimes of convection arise. A stagnant lid type of convection prevails at high yield stresses and a mobile lid type at low yield stresses. In between an episodic regime occurs in which regions of constant velocity are observed on short timescales. These regimes have already been discussed in studies considering a temperature and stress dependence. But for additional pressure dependence of the viscosity a further regime results. In this regime a plate-like (i.e. rigidly moving) surface is observed and plate motion is stable on long timescales. The variation of viscosity with pressure thus is of capital importance in the generation of the LVZ, but furthermore the interaction of all rheological parameters is relevant. In none of the regimes apart from that showing stable plates a viscosity drop beneath the surface was observed even though a pressure dependence was assumed. Thus the existence of continuously moving plates and the presence of a low viscosity zone are two coupled phenomena.

T32B-0937 1330h POSTER

3D Postglacial Rebound With Lateral Rheological Heterogeneities

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We study the Earth response to the melting of the Pleistocene ice sheets by a numerical 3D FE approach. Starting from a reference spherically symmetric Earth model, which has been successfully benchmarked with available solutions based on the viscoelastic normal modes, we include laterally varying structures to discriminate which kind of heterogeneities can be revealed by relative sealevel and geodetic datasets. We focus on the lateral variations in the lithosphere and upper mantle, and we assume a viscoelastic Maxwell linear rheology in all of our computations. In the lithosphere we include a global regionalization which accounts for oceanic, continental and cratonic provinces, whereas in the upper mantle the main feature studied is a low-viscosity region beneath the oceanic plates. Since a high-resolution analysis is not possible due to the huge computer requirements of the FE model, our present analysis is adequate to the study of the effects of the long-wavelength mantle heterogeneities. Our preliminary results suggests that the departure from the spherical symmetry can affect both the predicted relative sealevel curves and the present-day rates of deformation measured by geodetic methods.

T32C MCC: 3005 Wednesday 1340h

Mantle Dynamics and Continent-Mantle Interaction II *(joint with S, V, MR, DI)*

Presiding: **L Moresi,** Monash Cluster Computing, Monash University**; C Jaupart,** Institut de Physique du Globe de Paris

T32C-01 1340h

Effects of Model Geometry on the Dynamics of Mantle Plumes

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Mantle upwelling plumes are derived from thermal boundary layer instabilities at the bottom boundary of convective mantle. They play an important role in cooling the core and producing hot-spot volcanism. Most previous studies of plume dynamics have employed either 2D or 3D Cartesian models. In this study, we formulated models in Cartesian and spherical geometries to investigate the effects of model geometry on the plume dynamics. For each type of models, we explored a large parameter space of Rayleigh number and temperature-dependent viscosity. From the modeling, we determined scalings for the number and radius of plumes and spacing between plumes. We also determined the heat transferred through upwelling plumes or plume buoyancy flux. We found that plume dynamics are sensitive to model geometry. In 2D Cartesian models, the sensitivity of the number of plumes to Rayleigh number appears different from that in 3D models. This is mainly because that in the 2D models, upwelling plumes have a sheet-like structure, while they display quasi-cylindrical structure in the 3D models. For the same Rayleigh number, upwelling plumes are more vigorous in 3D spherical models than in 3D Cartesian models. This results from the fact that with different surface areas between the top and bottom boundaries in spherical models, the temperature difference across the bottom thermal boundary layer in spherical models needs to be significantly larger than that across the top thermal boundary layer and that in Cartesian models, leading to more unstable bottom thermal boundary layer in the spherical models. As a result, upwelling plumes in spherical models transfer a significantly larger fraction of the core-mantle heat flux than those in Cartesian models do.

T32C-02 1355h

Thermal Perturbations Caused by Large Impacts and Consequences for Mantle Convection

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We consider the manner in which large impacts, with projectile radii in the range of 50-500 km and incident velocities of 10-20 km/s, may perturb circulation in the mantles of solid planets with dimensions comparable to those of the Earth and Mars. In particular, we address the possibility that such impacts may initiate or disrupt deep mantle plumes. We consider three mechanisms whereby these impacts may initiate instabilities in a thermal boundary layer (TBL) at the core-mantle boundary (CMB) and lead to the formation of plumes: (1) direct heating of the CMB-TBL; (2) the lifting of TBL isotherms by relaxation of impact-related thermal perturbation; and (3) local or global disruption of circulation patterns in the CMB-TBL, causing motion to slow or stagnate and instabilities to grow. In order to evaluate the merits of mechanism (1), we first determine under what circumstances the CMB-TBL is heated significantly by large impacts. The projectiles are assumed to impinge upon a chemically homogeneous layer with an STP-centered shock equation-of-state (EOS) that is reasonable for lower-mantle materials in the Earth and Mars. We make several estimates of waste heat with increasing distance from the impact's isobaric core, using a range of peak-pressure decay laws, and also considering the effects of gravity: i.e., of increasing density and pressure with depth. The consequences of gravity are addressed by calculating re-centered Hugoniots and impedance match solutions for a shock wave propagating through a stack of layers whose densities and interface pressures increase with depth. The consequences of adding a chemically distinct upper-mantle layer with a different shock EOS is also considered. In order to complete our evaluation of mechanism (1) and in order to assess the merits of (2) and (3), we estimate the two-dimensional structure of thermal perturbations caused by large impacts, and add these to the temperature-field solutions of 2-D finite-element calculations of mantle convection. We then use this code to simulate the subsequent evolution. Our perturbations have the geometry of a squashed inverted hemisphere with a two-fold structure: (i) an inner hemisphere of partial melt; and (ii) an outer region characterized by the power-law decay of shock-related temperatures. The subsequent evolution may be summarized as follows: (a) the volume affected by the perturbation relaxes by rising and flattening; (b) the lateral motion of this relaxation locally stabilizes the mantle-lithosphere, inhibiting the initiation of downwellings and disrupting the local circulation pattern; and (c) the relaxation stalls and a new pattern is established. For the models considered, plume initiation by mechanism (3) appears to be far more important than (1) and (2). We find a range of Rayleigh numbers and impact energies for which the pattern reorganizes significantly, causing the extinction and initiation of plumes and even periods of chaotic global reorganization during which volcanism may intensify dramatically.

T32C-03 1410h

Conversion of Poloidal Energy in the Mantle to Toroidal Motions of Surface Plates - A Numerical Investigation

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Equal partition of poloidal and toroidal energies of surface plates has been reported by many investigators. It has also been pointed out that convection within a constant viscosity mantle is unable to produce toroidal motions at the surface. Thus, surface plate rotation remains a problem of considerable interests in the theory of plate tectonics. Several investigators have suggested subsequently that lateral viscosity variations can excite toroidal motions. Because mantle viscosity is strongly temperature-dependent and lateral temperature variation is the main driving mechanism of mantle dynamics, a source to produce toroidal energies appears readily available in the mantle. Unfortunately, numerical simulations of convection with strong temperature-dependent viscosity show that the amount of toroidal energy produced can only reach about 20% of the poloidal energy using a viscosity contrast of 5 orders of magnitude. Simulations with greater viscosity contrasts are computationally difficult at present. Here, instead of treating the mantle and the lithosphere as a single system, we decide to model the lithosphere as a rigid lid resting on a dynamic mantle. We seek to study the interactions between a circular solid top and a cylindrical impinging plume. In addition, we also wish to examine the effects of a solid lid with bottom topographic variations to the generation of rotational motions at the surface. Our results indicate that rotational torques of a rigid lid is dependent on the separation between the center of mass of the lid and the stagnation point of the impinging plume. If a plume impinges at the center of mass of a rigid lid and if the lid possesses a plane of symmetry that goes through its center of mass, no net torque is produced. Thus, as long as up-welling and down-going currents of the mantle occur away from the center of mass of a surface plate, net torques can be realized to produce plate rotation and show toroidal motions at the surface.

T32C-04 1425h

Is the Wilson Cycle Caused by the Memory Effect of Water?

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