Seismology

S51A MCC: Hall C Friday 0830h

Seismic Discontinuities, Phase Transitions, and Mantle Dynamics I Posters *(joint with T, V, DI, MR)*

Presiding: **V Levin,** Rutgers University**; S S Gao,** Kansas State University

S51A-1008 0830h POSTER

Stress Field in the Subducting Lithosphere and Comparison With Deep Earthquakes in Tonga

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We present a numerical model of the subducting lithosphere that provides an alternative explanation for stresses causing deep earthquakes. Our model lithosphere is composed of alpha-olivine, beta-spinel, gamma-spinel, and perovskite+magnesiowustite. The heat conduction equation is solved to determine temperature conditions in the slab and to locate the equilibrium phase transformations in pressure-temperature space. Volumetric strains in the subducting lithosphere are calculated from the density of individual phases and the heat released or consumed in the phase changes. These strains are used as sources of stress in the subducting lithosphere. Dislocation creep and Peierls stress creep laws are included in the viscoelastic rheology.

Volumetric reductions due to equilibrium phase transformations cause high shear stress in the transition zone because of the variable viscosity inside the subducting slab. Aspects of the model shear stresses are in agreement with observations of high seismic activity in the Tonga-Wadati Benioff zone. Compression is oriented along the dip of the slab and extension is oriented in the plane perpendicular to the compression axis. Since our model stresses agree with the seismic observations and because the model stresses are larger than those caused by buoyancy forces, our model provides a possible explanation of stresses causing deep earthquakes. Also, our model does not need metastability of olivine to explain the occurrence of high shear stress in the transition zone.

S51A-1009 0830h POSTER

An Algorithm for Estimating a Dipping Interface of a Velocity Discontinuity From the Horizontal Slowness Vector and Travel Time of a Converted Wave

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Last two decade depth distribution of velocity discontinuities such as the Moho and upper boundary of a subducting slab have been deduced by analyzing some converted waves observed on the seismograms. In this study we consider a problem to determine the location and tangential plane (facet) of a velocity discontinuity from the horizontal slowness vector and travel time of a seismic phase converted there. We formulate this problem as a one-dimensional algebraic problem, and show a simple algorithm to solve it, which is similar to the scheme for the reflector estimation proposed by Takenaka (2000). The present algorithm employs vertically heterogeneous structure models different between the source and receiver sites.

Next, we consider the influence of the error contained in the observation data when this method is applied to the estimation of a slab upper boundary or the Moho boundary. We first setup the inversion problem for estimating the slab upper boundary or Moho@boundary. We consider the structure model (true model), and create imitation data that are travel time and horizontal slowness vector of a converted wave generated at the boundary at an observation point. We change supposed velocity structure model or add some errors to the data and apply the estimation scheme mentioned above to these data. We think of the following as data including the errorFconverted phasefs data at an observation point (horizontal slowness, azimuth, travel time), distance of epicenter, and source depth. Changing the error levels added to the data and structure models used for the estimation scheme, we check the results to evaluate the influence of the added errors.

When using SP converted wave, as a result, we find that the estimated depth of the conversion point, dip angle, and dip direction are affected fairly by all kinds of the error. There sometimes exist no solution for data with some errors. On the other hand, when using PS converted wave, the solution hardly depends on the error and, is near the true model. It varies with only parameter (the rate of increase of the velocity) of the supposed velocity structure. As the distance between the converted point and the hypocenter closes, the precision becomes better.

S51A-1010 0830h POSTER

Thermal Interpretation of the Spherically Symmetric Seismic Structure of the Upper Mantle

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One-dimensional global seismic models form the background or starting model for most seismic models. Since velocity depends non-linearly on temperature, absolute velocity models are crucial for a thermal interpretation, underscoring the importance of understanding the background models. Furthermore, the average temperature profile of the mantle provides constraints on the style of convection, for example on the extent of layering. To a first order, adiabacity and olivine phase-transitions can explain spherically symmetric seismic models of the mantle. However there are some systematic differences between the velocities observed and those predicted for a pyrolitic (or piclogitic) mantle following an adiabat with a foot temperature of around 1300°C. Small deviations in velocity translate into large variations in temperature. But it is a question how well such differences between predicted and observed 1D profiles are resolved since they are similar in size to the differences between various global 1D seismic models. We present the first results of a comparison of the travel times predicted by synthetic velocity models calculated for an assumed thermal structure with the data from the reprocessed ISC catalog of Engdahl et al. (1998). The assumed temperature profiles are converted into P- and S-velocity structure taking into account the effect of temperature, pressure, an average mantle composition including phase transitions and anelasticity on the seismic velocities. For each thermal structure a range of seismic profiles is calculated by taking into account uncertainties in elastic and anelastic properties of the mantle minerals. The fit of the forward models will be compared with the fit of commonly used spherically symmetric models. We focus our investigation on the upper and shallow lower mantle.

S51A-1011 0830h POSTER

Computing Density and Seismic Velocity of Subducting Slabs

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The partial melting of mantle source material under mid-oceanic ridges leads to a chemical differentiation of oceanic crust (MORB) and residual lithosphere. As differentiated oceanic lithosphere subducts into the mantle, it undergoes successive complex phase transformations with increasing depth, depending on its chemical compounds and its thermal environment. However, the fate of the subducted slabs is still controversial (e.g. Hirose et al. 1999) and only little is known about the exact mineralogy of the transition zone (pyrolite or piclogite ?) and the lower mantle (e.g. Nishihara and Takahashi 2001). In this study, we use a free-energy minimization technique for continuously computing the equilibrium mineralogy of a subducting slab and its bulk properties (density, adiabatic incompressibility and bulk sound velocity) throughout the transition zone and the lower mantle. We first focus on computing the phase relations of various mantle-like compositions, taking especially care of constraining the sequences of the pyroxene-garnet system and the high-pressure Al-bearing phases. To constrain the nature of the transition zone, we compare the resulting profiles to those given by seismological models (e.g. PREM, AK135). We also use an inverse method to test whether or not the observed discrepancies may be explained in terms of chemical and temperature variations. We then consider an idealized slab model composed of three superposed complementary layers: MORB, harzburgite and pyrolite. We show corresponding phase diagrams and associated bulk properties along various P-T paths. We find that basaltic crust is denser than both pyrolite and harzburgite (typically by 4.5% in the transition zone and by 2.6% in the lower mantle). The computed high resolution image at the bottom of the transition zone shows that in the depth range from 640 to 740 km, it becomes buoyant and allows us to identify precisely the role of each phase transition. Finally, our thermodynamic model is used to study lateral variations of bulk properties induced by the heterogeneous thermal structure of a subducting slab. In order to compare our results with tomographic observations, we compute synthetic tomographic images ($\delta V_P/V_P$ and $\delta V_S/V_S$) of a subducting slab using a simple μ-K_S relationships given by Stacey (1992).

S51A-1012 0830h POSTER

A Global Survey of Stress Orientations in the Slab as Revealed by Intermediate-Depth Earthquakes

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Several mechanisms have been proposed as contributors to the states of stress in downgoing slabs at intermediate depths (70-300 km). To appraise these models, we first determine the regional strike and dip of subducting slabs from relocated seismicity (Engdahl et al., 1998) for the circum-Pacific area. Cylindrical projections are adopted for arcuate areas (e.g., Mariana and Ryukyu arc, etc.). The regional slab coordinates thus derived are used to project the P and T axes of intermediate-depth earthquakes, using seismicity from the Harvard CMT catalogue enhanced by pre-1976 events inverted from hand-digitized seismograms (Chen et al., 2001). We characterize each region as either down-dip-stress-dominant or non-down-dip-stress-dominant, according the number of events. For the former regions, we find that: (1) The regional seismic distributions associated with down-dip compression or down-dip extension are consistent with a thermo-mechanical model, except for the Ryukyu arc. (2) Slab thermal parameters indicate that colder slabs are more likely to exhibit down-dip compression, suggesting a role for thermally induced perturbations of phase transition boundaries. (3) In most regions, conjugate P (or T) axes are oriented in a slab-normal direction, supporting the hypothesis of earthquake occurrence by reactivation of fossil faults. For the latter regions, we find that lateral extension is associated with regions of both small arc radius and steep dip angles (e.g., Mariana arc and South Sandwich islands), and that lateral compression is associated with linear arcs and shallow dips, consistent with the predictions of the punctured-ping-pong-ball model (Frank, 1968).

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S51A-1013 0830h POSTER

Lower Mantle Seismic Anisotropy Generated by Subduction Body Force Stresses Beneath the 660km Phase Transition.

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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 7 seconds of shear wave splitting for rays generated by deep focus events from the Tonga subduction zone and recorded in Australia. The results suggest a transversely isotropic symmetry with the symmetry axis in the vertical plane, perpendicular to the ray direction. Thus, for horizontally travelling waves this would imply horizontally polarised shear waves (SH lead SV). They show that a topmost lower mantle model with anisotropy between 660-900km could produce theoretical shear wave splitting similar to that observed. Therefore, the seismic anisotropy observed by Wookey

et al., can be explained by an anisotropic region between 660-900km, with only a minimal contribution from above the 660km phase transition.

Kusznir (2000), has shown that large deviatoric stresses (maximum values $\sim$ 40 MPa) are generated in the topmost lower mantle when the subducting slab encounters an increase in viscosity at the 660km phase transition. These stresses may induce mineral alignment in a broad region (lateral wavelength $\sim$ 800km) in the topmost lower mantle below the slab. Perovskite may therefore be aligned with a rotated symmetry axis conformal to the shape of this region of high deviatoric stress. Aligned Perovskite rotated more than 30° predicts SH-waves faster than SV-waves for horizontally travelling S-waves. The goal of this study is to test whether subduction generated deviatoric stresses within the uppermost lower mantle can create the necessary anisotropy to explain the observed shear wave splitting in the topmost lower mantle in the Tonga region.

We use finite element modelling to calculate slab-induced models of fluid flow, total stress and deviatoric stress. A simple 2D subduction zone model with a prescribed viscosity structure and slab density is used. Calculated fluid flow vectors and the formulation of Malvern (1969) are used to determine the finite strain accumulated by a mantle parcel as it traverses a streamline. After 40My of subduction ($\sim$ the age of the Tonga subduction zone), the strain ellipsoids align in a similar region (wavelength $\sim$ 800km and depth $\sim$ 660-900km) as that of the deviatoric stresses. The strain fields are then mapped into seismic anisotropy. We initially assume that the anisotropy has hexagonal symmetry, with a symmetry axis aligned with the major axis of the finite-strain ellipse. The magnitude of the anisotropy is scaled by the degree of finite-strain ellipticity. Theoretical shear wave splitting is then calculated by ray tracing through the seismic anisotropy model. Modest amounts of anisotropy can explain the seismic observations.

S51A-1014 0830h POSTER

Accurate Corrections for Lateral Velocity Variations in SS-$S_{660}S$ Traveltime Inversions for 660-km Dicontinuity Topography

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Lateral variations in the depths of 410-km and 660-km discontinuities provide important constraints on the nature of mantle flow and the composition in the upper-mantle transition zone. An effective way to study global topographies of these discontinuities is the inversion of differential traveltimes between SS wave and its underside reflections from these discontinuities, i.e. $S_{410}S$ and $S_{660}S$. Since the observed SS-$S_{410}S$ and SS-$S_{660}S$ traveltime anomalies are mainly caused by the lateral variations in shear speed in the upper mantle, corrections are made before inversion based on ray theoretical traveltimes of these waves in a three-dimensional (3-D) global model. The validity and accuracy of using ray theory in making corrections of these long-period SS wave and its precursors remains to be tested.

An algorithm was developed recently for computing the traveltime perturbations of seismic waves in laterally heterogeneous structures (Zhao, Jordan & Chapman 2000). Their normal-mode coupling approach accurately accounts for the non-geometrical behavior of long-period waves. We use this algorithm to investigate the effect of lateral velocity variations on SS-$S_{660}S$ traveltime anomalies. Taking the typical period of 30 sec and epicentral distance of 130°, we computed corrections to SS-$S_{660}S$ traveltimes by both ray theory and the normal-mode algorithm for a large number of paths randomly selected in published 3-D global models such as S16B30 (Scripps) and SAW24 (Berkeley). We found a systematic discrepancy between the corrections predicted by the two methods. There is also a clear trend that this discrepancy increases with the degree of the lateral heterogeneity in the 3-D model. For the degree-24 model SAW24, this discrepancy amounts to an average of 2 sec, which translates to a perturbation of 8 km in the depth of 660-km discontinuity. This indicates that for the real Earth structure ray theory is inadequate in making SS-$S_{660}S$ traveltime corrections for lateral velocity variations. We also found a non-trivial result that for a given path in a heterogeneous Earth (fixed positions of the source and receiver), SS traveltime depends on the focal mechanism. When the observation is made at a station close to the node of SS radiation, ray theory can not be used to make traveltime correction. The observation should be either excluded from the inversion or corrected using a more accurate approach.

S51A-1015 0830h POSTER

Seismic singularities at upper mantle discontinuities: A site percolation model

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Mineralogical phase transformations are widely considered responsible for globally observed, upper mantle seismic discontinuities. We propose a percolation-based model of the elastic properties of the phase mixture in the coexistence regions associated with these transitions. The major consequence of the model is that the elastic moduli (but not the density) display a cusp-like singularity near the percolation threshold of the high-pressure phase, i.e., they undergo a sharp but continuous change whose abruptness is characterized by an exponent expressing the transitions scale-invariance. Using the receiver function approach and new, powerful signal processing techniques, we quantitatively determined the singularity exponent from recordings of converted seismic waves at two Australian stations (CAN and WRAB). Using the estimated values, we constructed velocity depth-profiles across the singularities and verified that the calculated converted waveforms matched the observed ones. Finally, we point out a series of additional predictions that provide new insights into the physics and fine structure of the upper-mantle transition zone.

S51A-1016 0830h POSTER

Imaging Properties of the Moho and Upper Mantle Discontinuities Under the Sea of Okhotsk

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Teleseismic observations of precursors to depth phases (surface reflections above the source) for intermediate and deep focus earthquakes in subduction zones provide a sensitive probe of Moho and upper mantle discontinuity characteristics. The depth and impedance contrasts of discontinuities above the sources can be well resolved using long period or broadband observations because the precursors to depth phases are well isolated and readily modeled. The signal-to-noise ratio can be enhanced by stacking stations with nearby reflection points as well. We apply this approach to study discontinuities beneath the Sea of Okhotsk using deep focus earthquakes in the Kurile slab. Strong azimuthal variation of the amplitude of underside P reflections from the Moho, pmP, relative to the surface reflection, pP, can be seen clearly in long period WWSSSN data and digital broadband data. For data reflecting from the Moho beneath the eastern Sea of Okhotsk close to the Kamchatka Peninsula, waveform modeling of stacked observations from North American stations indicates that the P wave impedance contrast at the MOHO is very large, about 40%. Data sampling the Moho under the western and southern Sea of Okhotsk indicate that the Moho contrast is smaller, with average impedance contrasts about half as large as in the east. This indicates a possible structural or compositional anomaly at the Moho under the eastern Sea of Okhotsk. A Moho impedence and crustal thickness map is developed through extensive analysis of pmP, smP and smS precursors relative to pP, sP and sS, respectively. We also stack the data to detect upper mantle discontinuti ties, mapping occurrence of and properties of structures at depths ranging from the Moho to the '410-km' discontinuity.

S51A-1017 0830h POSTER

Cluster Analysis of Long Period Waveforms: Implications for Global Tomography

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Picking travel times from seismic data manually results in data sets that have high quality and reliability, however, these data sets require years of tedious work to produce. Automated methods can make picking faster, but reduce data quality. Therefore, methods that combine the speed of automation with the quality of manually picked data are desirable.

We have taken advantage of the similarity of long period waveforms for a particular event to apply a "Cluster Analysis" method to the combined data from global and regional networks. The waveforms recorded at all stations for an event are displayed and a time window for cross correlation of all waveforms with each other is chosen by the user. The correlations between waveforms are used to group the waveforms based on similarity. Each group is called a cluster and, often, most teleseismic waveforms for an event can be grouped into one or two clusters. The relative times between all records within each cluster are then measured using a second cross correlation. These relative times are, of course, insensitive to errors in the origin time, and the relative times between closely spaced stations are sufficiently accurate to detect (and fix) timing errors (which are more numerous than generally thought). Data that would take years to process manually can now be picked in just a few weeks.

We have used the Cluster Analysis to pick P, PP, S, and SS arrivals. Methods that record the travel time difference of P from PP and S from SS to remove source and station effects limit the available distance range of the data (typically 40 to 98 degrees). However, when measuring difference times between PP arrivals for a single event, we can use data out to at least 170 degrees, improving our coverage of the lower mantle.

We have combined the Cluster Analysis data with our traditional manually picked differential travel time data and surface wave data to obtain high-resolution images of compressional velocity, shear velocity, and bulk sound speed as well as discontinuity topography in the mantle. A resolution analysis reveals the improvement gained by adding the new data.

S51A-1018 0830h POSTER

Seismic Slow Anomalies in the Deep Upper Mantle Oceanward of Subducting Slabs

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Our P-wave tomographic study indicates existence of significant slow anomalies oceanward of the subducting slabs along the South Kurile, Japan and Izu-Bonin trenches at depths 350-500 km. The subducting slabs are therefore sandwiched by slow anomalies in the wedge mantle and those in the deeper upper mantle oceanward. Synthetic recovery tests and resolution tests indicate that these slow anomalies are a resolvable feature and not an artifact due to the strong slab anomalies. The existence of these slow anomalies is also supported by the analysis of the P wave records of the J-array (large-aperture seismic array in Japan) records for a Bonin earthquake. The P waveforms at stations in Northern Honshu ($\Delta = \sim 14.0°$) are strongly triplicated because of the 410-km discontinuity. The first arrivals along the prograde branch of the triplication are anomalously fast, the later arrivals along retorograde branch are anomalously slow. The ray paths indicate that the first arrivals are refractions through the subducted slabs, while the later arrivals are reflections at the 410-km discontinuity oceanward of the subducted slab. Thus, the anomalously fast first arrivals and the anomalously slow later arrivals of the triplicated P waveform are consisted with our tomographic images of the subducted slabs and the slow anomalies on their ocean side.

S51A-1019 0830h INVITED POSTER

Observation of Subducted Oceanic Crust in the Upper Mantle Transition Zone?

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Recycling of oceanic crust has large consequences for the chemical evolution of the Earth. Subducted oceanic crust or its high-pressure assembly (garnetite) is denser than peridotite in the upper mantle, but is less dense than perovskite in the lower mantle. It has been suggested that subducted oceanic crust may accumulate above the 660-km discontinuity as a consequence of neutral buoyancy. Observational evidence for this scenario, however, remains elusive.

In this study, we synthesize observations from several regional studies to search for evidence for or against subducted oceanic crust in the transition zone. Teleseismic body waves recorded at the southern East Pacific Rise reveal a prominent P-to-S conversion between the converted phases from the 410- and 660-km discontinuities (P410s and P660s, respectively). This arrival has a polarity opposite to those of P410s and P660s, indicating a decrease in velocity with depth at a discontinuity near 600 km depth. This negative-polarity phase is observed intermittently beneath Iceland, but consistently beneath the Hawaiian Islands and South Africa. Stacking along reverberation moveout curves greatly reduces the amplitude of this negative-polarity phase as well as those of P410s and P660s, confirming that this negative-polarity phase is not a reverberation from shallower mantle. Because subducted oceanic crust has lower seismic velocities than pyrolitic mantle in the transition zone, we conclude that the negative-polarity phase is consistent with a layer of subducted oceanic crust accumulated above the 660-km discontinuity in various regions.

S51A-1020 0830h POSTER

A narrow 660 km depression area and multiple seismic discontinuities co-existence beneath northeast China

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Beneath northeast China, the pacific plate is subducted into the upper mantle transition zone area along the Japan trench, and anomalies of the 660 km discontinuity may be present due to plate and mantle interaction. The transition region beneath northeast China is not well constrained in the past because of the lack of seismic stations there. Seismic stations coverage has been improved rapidly in the recent years with the deployment stations from NE China Seismic Experiment-Changbai and China National Digital Seismic Network. Here, we have used data from 24 boradband stations in northeast China and studied the upper mantle structure using receiver function common conversion point stacking technique. In this study, 987 high-quality receiver functions are obtained by maximum entropy deconvolution method. The stacking results have shown that the 660 km discontinuity is locally depressed in the region from longitude 128°E to 130.5°E and latitude 40°N to 44°N, and is spilt into multiple discontinuities in surrounding regions. On the other hand, we have also found slabs images between the depths 550 km to 600 km east of 128°E. At the tip of the subducting slab beneath northeast China, the maximum depressed the 660 km discontinuity can reach 700 km. The results suggest that the 660 km discontinuity is not simply a dissociation of γ-spinel, and non-olivine components reactions such as reaction from garnet to ilmenite and reaction from ilmenite to perovskite are also occurred. We deduce that the deflection or flattening of the subducted lithosphere near the bottom of the upper mantle causes the multiple discontinuities structure and the slabs penetrating the 660 km discontinuity into the lower mantle cause the narrow 660 km depression area.

S51A-1021 0830h POSTER

Seismic Evidence for Olivine Phase Changes as the Primary Cause of the 410- and 660-km Discontinuities

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The view that the seismic discontinuities bounding the mantle transition zone (TZ) at 410 and 660 km depths are caused by isochemical phase transformations of the olivine structure is debated. Combining converted-wave measurements in East Asia and Australia with seismic velocities from regional tomography studies we observe a correlation of the thickness of and wavespeed variations within the TZ that is consistent with olivine structural transformations. Moreover, the seismologically measured Clapeyron slopes are in agreement with the mineralogical Clapeyron slopes of the spinel and post-spinel transformations. We also show that the correlation of the thickness of and wavespeeds within the TZ is high on a global scale as well, provided that the scalelengths and uncertainties of the variations in the two observables are taken into account. Finally, we demonstrate that P660s phases converting within the subducting NW-Pacific slab beneath the station MDJ in Northeast China are clear and coherent, with no additional arrivals in the vicinity. P660s conversions at the edges of the slab produce distinctly more complex, multiple arrivals, but these are more likely to be caused by small-scale topography rather than previously proposed “multiplicity” of the “660”. This suggests that if any non-olivine transformations occur near 660-km depth, then they do not have sharp onsets and are spread over tens of kilometers. Our results confirm that it is the transformations in olivine structure that give rise to the 410- and 660-km discontinuities globally.

S51A-1022 0830h POSTER

Calculated Thermal Conductivity of Mantle Garnets

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The thermal conductivity at ambient conditions (k_0) is calculated across the majorite-pyrope [$Mg_3(MgSi)Si_3O_{12}$ - $Mg_3Al_2Si_3O_{12}$] binary from new measurements of IR reflectance, thin-film absorbance, and Raman scattering from polycrystalline samples. For tetragonal or cubic garnets, k_0 depends on various physical properties that are well-known (e.g. sound speeds) and on F, the averaged full width at half maximum of peaks obtained from Kramers-Kronig analysis of IR reflectivity and/or Raman spectra. Because F has a maximum near 50 mol % majorite, k_0 goes through minimum of 3 W/(m-K). Mantle garnets are not simple binaries and have impurities (e.g., Fe, Cr, Ti, Ca, Na) which further increase widths. We estimate k_0 as 3 W/(m-K) for garnets with 60 to 70 mol % majorite, substantial Fe, and other minor elements, similar to measurements and calculations of k_0 for upper-mantle and crustal garnets (Giesting and Hofmeister, 2002 Phys. Rev B, paper 144305), but only half that of other mantle phases. From the formulae in Hofmeister (1999, Science) and recent measurements, the change with pressure d[ln(k)]/dP equals 0.04/GPa, close to that of other mantle phases. The temperature dependence should be similar to conventional measurements of olivines and pyroxenes for which $k(T)/k_0 = (298/T)^{1/3}$, because their Gruneisen parameters are similar. The k_0 values indicate the relative effectiveness of different mantle minerals in transporting heat. Heat transfer is impeded by high garnet content in Earth’s transition zone, but promoted by ringwoodite with its high k_0 (Hofmeister, 2001 Am. Min.). For a pyrolite composition (40% garnet), the transition zone is a better conductor of heat than the upper mantle, but for a piclogitic composition, k_0 is the same in both zones. Layering and lateral heterogeneity are important because regions enriched in garnet will retain heat. Thus, the amount and chemical composition of garnets in the mantle is critical for deciphering Earth’s thermal state and dynamics.

S51A-1023 0830h POSTER

High-Resolution Receiver Function Imaging of the Crust and the Uppermost Mantle Structure beneath the Japan Islands - Inclusion of Hi-net Data -

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We are executing array analyses of Receiver Functions (RFs) to map the seismic velocity discontinuities especially in the crust and the plate interface of the Philippine Sea Plate (PHS) under the Japan islands using short-period J-array and new Hi-net data, whose stations are closely distributed (J-array:269 Hi-net:634). Inclusion of Hi-net data enables us to get far clearer image than J-array data only.
For imaging of the crust and the uppermost mantle, SVD-filtered (Chevrot and Giardin, 2000) RFs after transformation from time to depth domain are projected on to 2-D profiles, which show average values for cells within ±25km (at the best) from each cross section. We describe here the results in southwest Japan, where the stations are most closely distributed.
In the Chugoku-Shikoku line, which is perpendicular to the strike of the dipping PHS, we have got clear image of the configuration of the Moho and the dipping PHS. The Moho is dipping northwards from Shikoku to Chugoku, the inland area in Honshu, and has the bottom under Chugoku Mountains. Then, it is getting shallower towards the Sea of Japan. On the other hand, the PHS with a low dip angle of 10 degrees, which can be traced also by seismic activity, suddenly changes its dip to 35 degrees just under Chugoku Mountains, and subducts deep as an aseismic slab. . Though recent tomographic studies have shown the same structure, our RF analysis provides far clearer image of the dipping interface of PHS.
Then we compare our RF image with the seismic profile obtained by explosion seismology along the W-E striking Kurayoshi-Hanabusa line in the inland area, southwest Japan. As in the explosion study, the eastward dipping Conrad has been detected from Kurayoshi to the Lake Biwa with low gravity anomaly. The Moho slightly inclines from the west of the Lake Biwa to Kurayoshi, which is opposite to the explosion result. Finally, we show a new 3-D RF image of the crust and the uppermost mantle under the Japan islands, whose best spatial resolution reaches less than 5km.

S51A-1024 0830h POSTER

Progressively Improved Receiver Function Images of Upper Mantle Discontinuities beneath the Japan Islands

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For these three years, we have accumulated receiver functions (RFs) observed at broadband and short-period stations closely installed over the whole Japan Islands to reveal the fine structure of the crust and the upper mantle including velocity discontinuities. In 2000, we could use 269 short-period and 32 broadband stations in J-array and 15 FREESIA broadband ones. Recently, a short-period Hi-net has been installed; the station number is 561 in 2002. Also the number of broadband stations of F-net, previously called as FREESIA, is 61 in 2002. Thus, during our study, the number of stations has greatly increased, which has progressively improved the spatial resolution of RF image year by year. In this talk, we report RF image of the upper mantle down to a depth of 800 km based on the broadband data.

Broadband data in J-array and F-net are from 23 STS-1, 58 STS-2 and 12 CMG-1T stations in 2002. However, most of stations in F-net were installed in 2001, and the there are not enough data at present. Accordingly, our present results are mostly from J-array and old F-net stations.

We produce RFs, retaining longer periods greater than 3 sec, and convert the time axis to the Ps converted depth, assuming the reference model of iaspei91. Then we apply SVD filtering to the depth-domain RFs to make clear the coherent discontinuities at depth. As in Li et al.(2000), we project RFs onto vertical planes along several profiles to produce 2-D RF images. Beneath northeast and southwest Japan, are clearly delineated the upper interface of the subducting Pacific slab, and the 410 and 660 km discontinuities. The 410 km discontinuity seems to be elevated in the slab by 50 km, and the 660 km one deepens from the Japan trench side. Beneath northeast Japan, multiple discontinuities seem to exit at a depth of 600-700km, though a large lateral variation of velocity should be considered. Augmented RFs produced from new F-net stations will enable us to reveal 3-D images of discontinuities instead of 2-D ones.

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S51A-1025 0830h POSTER

The 660 km Phase Transitions: New Measurements on MgSiO3

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The measured and calculated phase boundaries of the presumed transition zone minerals in the Mg2SiO4 and MgSiO3 systems show very large variation. In particular, the perovskite phase boundaries, linked to the 660 km discontinuity, vary by as much as 3.5 GPa, equivalent to a depth variation of 87 km.

We have developed new techniques for measuring mineral phase transitions in the laser-heated diamond cell in order to narrow the brackets for both the pressure and temperature measurements compared to multi-anvil techniques. Additionally, diamond cells provide a larger temperature range to circumvent kinetic problems and inert noble gas pressure media provide nearly hydrostatic pressure conditions. Previous problems associated with temperature gradients are eliminated by placing small samples into metallic (Re or Ir) micro-furnaces which are heated with high power lasers. Forward and reverse transitions can be readily observed by Raman spectroscopy on the temperature-quenched samples.

The slope of the MgSiO3-ilmenite − perovskite phase boundary, measured in the range of 21-25 GPa and 1800-2300 K, has a strongly negative value of -0.006±0.002 GPa/K. An effective Clapeyron slope at 660 km depth of that value causes layering in mantle convection. At the pressure of the 660 km seismic discontinuity (23.7 GPa) this phase boundary yields the same temperature of 1900 ± 150 K as the γ-spinel to perovskite + MgO transition in the Mg2SiO4 system measured previously. At higher temperatures the phase boundary between β-phase + stishovite and perovskite continues with negative slope, and MgSiO3-garnet transforms to perovskite above 20.7 GPa up to the melting temperature. Thus MgSiO3-garnet is not stable at lower mantle conditions.

S51A-1026 0830h POSTER

Bullen parameter and relaxed properties across the olivine to wadsleyite phase transition

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Numerical simulations of mantle convection have shown that the detailed structure and properties of the observed discontinuities in the transition zone may have significant influence on global dynamics and composition (e.g. Christensen and Yuen, 1984; Tackley et al., 1994) and on post-glacial mantle relaxation (e.g. Johnston et al., 1997). The evolution of the bulk properties across a mantle phase transitions is only deduced indirectly using various observables related to propagation of seismic waves, to free-oscillations, to post-glacial rebound or to mantle convection. These different physical probes sampling the Earth interior have however very different time characteristics : high frequency (fast) seismic waves, on one hand, and low frequency (slow) convection processes on the other hand. The rate of re-equilibration of mantle mineralogy with varying pressure and temperature conditions imposed by these probes depends on the kinetics of phase transitions and/or elemental exchanges between coexisting phases. The bulk properties can thus be sampled differently by different probes. We present an equilibrium reference frame that provides an analysis of time dependent chemical relaxation phenomena. We first compute evolution of bulk properties across the olivine to wadsleyite phase transition for two limiting cases: fully relaxed and unrelaxed frozen properties and show that, across the phase change, these two limits are strikingly different. A free-energy minimization method is used to compute the equilibrium mineralogy and the isentropic P-T path self-consistent with the thermodynamic equilibrium. We also evaluate precisely the "Verhoogen effect" associated with the phase transition and analyze its impact on the bulk properties. We show that the relaxed adiabatic incompressibility is lowered by a factor of 25 within the transformation zone and that the Bullen parameter η significantly differs from 1 even in the case of isentropic phase change and reaches values up to 25 due to strong chemical gradients. The knowledge of the fully relaxed and unrelaxed incompressibilities across a phase change allows us to obtain directly the value of maximum attenuation Q^{-1}_{min} induced by the kinetics of associated chemical reactions. In the case of olivine to wadsleyite phase change, Q^{-1}_{min} is found to be close to 4 indicating thus that the attenuation of seismic probes propagating through a sequence of phase changes may be strongly affected by their kinetics.

S51A-1027 0830h POSTER

Fine Structure of Transition-Zone Discontinuities beneath the Arabian Shield.

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We estimate fine structure within the regions of seismic velocity increase ("410" and "660" discontinuities) in the upper mantle transition zone beneath the permanent seismic observatory in Ar-Rayn, Saudi Arabia. Using a multitaper spectral coherence (MTC) tool for receiver function (RF) analysis, we identify PdS converted waves (d=410, 660) within the coda of compressional waves (P, Pdiff, PKP) arriving from teleseismic earthquakes. We migrate resulting waveforms to improve alignment of the converted-wave pulses. Large data volume, superior noise handling of the MTC tool, and alignment of phases via migration all contribute to the excellent definition of both the "410" and the "660" discontinuites beneath the station.

We find that as we raise the effective bandpass of radial RF timeseries from 0.25 Hz to 1 Hz, the pulse of the P410s phase sharpens, while the pulse of the P660s phase remains broad and asymmetric. Furthermore, at higher frequencies the P410s pulse becomes complex, suggesting at least 2 interfaces separated by no more then 10 km. We also observe a well-defined phase in the time frame of the P410S on the transverse RF. This phase is multicyclic, and exhibits a clear polarity reversal about a backazimuthal direction of 50-60 degrees. Such behaviour is consistent with the presence of a thin layer of effectively anisotropic material at the 410 km discontinuity. Transverse energy within the P660S time frame does not appear coherent enough to warrant a similar interpretation. We will discuss implications of our findings for the nature of upper-mantle discontinuities, and place them in the framework of the regional geodynamics (i. e. plume impacting upon a stable continental block).

S51A-1028 0830h POSTER

Receiver function probing of the crust in northern Iran

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Preliminary results of a receiver function analysis made on the teleseismic earthquakes recorded by ILPA(Iranian Long Period Seismic Array) and TTSN (Tehran Telemetry Seismic Network) indicate crustal thicknesses of more than 45 km across the region. Our observations also give evidence of a major increase in seismic impedance at depths between 20 and 30 km underneath the recording stations.This intracrustal seismic discontinuity is the sharpest in the area where the Damavand Volcano is located.

S51A-1029 0830h POSTER

Upper mantle structure in the European Arctic from seismic waveform modeling of far-regional P-waves

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We use nuclear explosion sources at the former soviet test site on the island of Novaya Zemlya recorded at Scandinavian stations to constrain the upper mantle structure in the European Arctic. Novaya Zemlya events recorded at these stations cover a distance range of approximately 10° to 30° where body wave signals are strongly influenced by structure between the Moho and 700km depth. Using the reflectivity method with an earth-flattening transformation, we develop a 1-dimensional, P-wave, upper-mantle model by fitting displacement seismograms in the 0.5 to 2 second band. The new model features P-wave velocity reaching 8.5 km/s in the mantle between depths of approximately 70 km and 100 km. Modeling also suggests a velocity discontinuity at approximately 70 km depth, which we interpret as the Hales (H) discontinuity. Decreasing amplitude of the first arrival between 10° and 16° requires a decrease in velocity below 110 km. Seismic amplitudes and arrival times are best fit with a broad (ranging over 100 km), low amplitude (decrease of 0.2 km/s) low-velocity zone (LVZ). Between the LVZ and the '410' discontinuity our model is approximately 0.15 km/s slower than the iasp91 model. Arrival times associated with the '410' discontinuity favor a depth of approximately 420 km for this transition.

Like models of the Eurasian continent, we interpret the high velocity in the upper mantle as continental lithosphere. In the Barents, however, the high velocity mantle lithosphere extends to a depth of approximately 100 km, whereas mantle lithosphere in continental Russia extends to depths greater than 200 km. Also similar to the Eurasian continent, the H discontinuity is well developed. In our model the velocity below the H discontinuity is well constrained (8.5 km/s). Within the uncertainty of velocities between the Moho and the H discontinuity, the velocity increase at the H discontinuity is consistent with previous studies (3%). There is no evidence in the data for a sharp velocity decrease at the top of the LVZ, suggesting that the bottom of the lithosphere is a gradational boundary.

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S51A-1030 0830h POSTER

The 410 km discontinuity on Russian PNE data

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We observe arrivals at longer offsets on the KRATON-1 PNE profile that have high amplitude and a reverbatory character. at locations with respect to other arrivals which suggests an arrival coming from above and around the 400 km discontinuity. It is however not a simple refracted or reflected arrival because its apparent velocity does not fit either of these possibilities; it is an arrival which we believe has not been documented before and is only easily noticed as part of the PNE profiles with their short station spacing. This arrival is visible on the BATHOLITH and QUARTZ PNE profiles. Its offset range is from 2500 to 3500 km and it can be seen on records of the PNE profiles recorded outside the former Soviet Union. The coda runs for some 10 to 15 seconds. It is visible both on NORSAR and Grafenberg array data which rules out many of the possible causes of reverbatory behaviour such as near station structure or recording instrument characteristics. It also suggests that the phase observed is not a function of azimuth and confined coincidentally to the PNE profiles raising the possibility of looking for this phase in other locations outside Siberia. The origin of the arrival is above the 400 km transition and the arrival times and moveout of the arrival fit that of a whispering gallery phase in a layer in 1-D travel-time modelling. This layer starts at about 320 km and extends down to the 400 km transition. With velocity fluctuations of 0.5 percent, a reverbatory arrival similar to the data can be generated using a reflectivity based 2-D model based on a 1-D velocity model. The maximum offset of the arrival varies with the thickness of the layer above the 400 km transition. A thicker layer produces larger offsets whereas a deeper thinner layer (e.g from 360 km and down) does not reproduce the offset range or the reverbatory nature which requires a large layer thickness to buld up to the observed duration. On the BATHOLITH-2 PNE profile this arrival is visible but only out to 400-500km (3100 km) shorter offsets. The phase is also less reverbatory on BATHOLITH-2.

S51A-1031 0830h POSTER

Strong seismic reflectors at mid-mantle depth beneath the Mariana and Indonesia subduction zones

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The nature of heterogeneities in the the lower mantle is important in understanding Earth's evolution. The seismic signatures of the lower mantle heterogeneities generally appear to be more subtle than those of the upper mantle except for the lowermost several hundreds of kilometers, while strong seismic reflectors and scatterers at depths around 1000 km (hereafter mid-mantle) and 1400-1700 km (hereafter mid-lower mantle) have been observed beneath the western Pacific subduction zones. The physical nature of these reflectors and scatterers is poorly understood, partly due to their seismic properties are not well constrained.

We have observed clear later arrivals 40-90 seconds after P wave at seismic stations in Japan (J-array) from deep earthquakes that occurred in the Mariana and the western end of the Indonesia subduction zones. We have shown that these later arrivals are generated at underneath velocity discontinuities (reflectors) at depths around 1000 kilometers. The lateral extension as well as detailed profile of the velocity variation across the reflectors remain unconstrained, however. In these study, we have collected more data from seismic arrays around the world and applied an inversion technique to map the geometry of the reflectors. Preliminary analysis of the data confirms our previous results and further investigation are expected to reveal more details of the lateral extension of the mid-mantle reflectors. We will discuss possible candidate mechanisms capable of producing these seismic structures.

S51A-1032 0830h POSTER

Systematic Measurements of Splitting Parameters of P-to-S Converted Phases from Mantle Discontinuities

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Due to the near-vertical incidence of XKS (SKS, SKKS, and PKS etc.) phases, the techniques that measure XKS splitting parameters have an excellent horizontal resolution, but have a very poor vertical resolution. In principle, the anisotropy responsible for the observed splitting could exist anywhere from the CMB to the surface. Most previous studies assume that the anisotropy is mostly located in the upper mantle in the subcrustal lithosphere, the asthenosphere, or both. Some studies, however, found anisotropy in the crust, mantle transition zone, or lower mantle.

The depth of anisotropy can be constrained by splitting of P-to-S converted phases (PdS) from velocity discontinuities at different depths in the mantle. We have developed a semi-automatic procedure to measure PdS splitting parameters by stacking hundreds of source-normalized seismograms at a station. The procedure include the following steps:

1). Computing radial and transverse receiver functions (RFs) by deconvolution for all the available seismograms with strong P-arrivals;

2). RFs from a narrow (10-30 degrees, depending on the event population) back-azimuthal range are stacked based on the predicted moveout time of PdS at a range of candidate depths;

3). The results of the stacking (amplitude versus depth) are converted into amplitude versus time;

4). The stacked radial and transverse components, together with the mean backazimuth of the events participated in the stacking, are used to obtain optimal splitting parameters at various depths.

By comparing the results with those from XKS, the contributions of the major layers (e.g., lower mantle, mantle transition, and upper mantle) can be separated.

S51A-1033 0830h POSTER

Structure of the 660-km discontinuity below a deflected slab: complex or simple?

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Previous studies using GDSN stations in NE China, Mongolia, and East Siberia suggested a multiple-discontinuity structure from about 660 km to a depth of 780 km in an area occupied by the horizontally deflected Pacific slab. Such complex structure, if confirmed, could lead to new insights into the mineralogical and geodynamic processes related to the interaction between subducted slabs and the 660-km discontinuity (d660).

We have collected several hundreds broadband seismograms for each of the GDSN stations (MDJ, HIA, BJT, and ULN) and computed receiver functions. We then stacked the receiver functions based on the predicted travel time of P-to-S converted phases. When teleseismic events from all the back-azimuths are used, there is indeed a multiple-discontinuity structure in the depth range of 650 to 750 km beneath station MDJ. BJT, HIA, and perhaps ULN show a sharp d660. This observation is consistent with previous studies.

However, when events from narrow back-azimuthal bands are stacked, the depth of d660 beneath MDJ shows a systematic variation with back-azimuths, ranging from 660 km for events from the west, to 700 km for events from the south. Such a variation is the result of a broad NS-striking depression of d660 associated with the cold slab. We estimated that the magnitude of the depression is about 60 km over an EW distance of about 350 km.

For most of the back-azimuthal bands, d660 is a sharp, simple feature. The two bands from the SE show two arrivals at the depths of about 680 and 740 km, respectively.

S51A-1034 0830h POSTER

Mantle discontinuity structure beneath the western United States from PASSCAL arrays

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Imaging of mantle discontinuity structure beneath the western United States from five high station density PASSCAL broad-band arrays (CD-ROM, Deep Probe, Billings, Lodore, Laramie) reveals a pervasively heterogeneous transition zone. This heterogeneity is manifest by the 20-30 km of 410 and 660 km topography at 200-500 km scale-lengths. Assuming this topography manifests thermally modulated pure-Olivine phase boundaries, rather short-wavelength 200-300 degree thermal variations would be required. However, seismically observed discontinuity topography about the 410 and 660 km depths could also be significantly modulated via: chemical coupling between the Olivine and Garnet-Pyroxene components; changes in average geotherm; and water content. Chemical layering also remains a possibility, especially between 660-900 km depth, given that tomography often images slabs stagnated in this depth range. Our most robust observation is that the spatial correlation between these two discontinuities varies significantly, inconsistent with the simplest hypothesis that a thermally coherent transition zone is thermally modulating the pure-Olivine phase boundaries. Beneath two of the arrays, a strong 770 km discontinuity appears where the 660 km discontinuitys amplitude is greatly reduced. The great depth of this discontinuity suggests that it cannot be the pure-Olivine phase transformation that occurs nominally at 667 km depth, but must derive from strong variations in major element chemistry. Beneath most arrays strong arrivals between 250-300 km are observed whose origin (P-to-S conversion or a reverberation) is not well constrained due to poor phasing resolution of our dataset at this depth. However, all things considered, this arrival most likely manifests a discontinuity at this depth whose origin requires either crystal fabric or chemical layering. Most interestingly, our images of a heterogeneous transition zone beneath the western U.S. contrasts sharply with the images of a homogenous transition zone beneath the Canadian Craton from others

S51A-1035 0830h POSTER

Receiver Function Analysis of the Crust and Upper Mantle Beneath Puerto Rico

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We preformed receiver function analysis of seismograms recorded at the Puerto Rico GDSN station SJG. Receiver functions were computed from P and PP arrivals. This resulted in a more uniform distribution (in back azimuth) of receiver functions than available from most other regions in the world. We found crustal layering at 18 km depth and the Moho at 25 km. Additional Ps phases were observed at time delays consistent with depths of 50 km and 75 km. In general these layers are consistent with previous work in this region. The Ps phase from 75 km is negatively polarized which would indicate a velocity inversion. This may be at the base of a subducted slab in which the ray path would move from a hotter (and therefore slower mantle) into the cooler slab. Partial melting due to water injection could also cause a velocity inversion in the upper mantle. This negatively polarized phase was extremely variable in depths; it was observed at about 75 km depth for northern azimuths, sloping to a depth of almost 100 km to the south. Additional Ps phases at depths consistent with depths of 300, 400 and 660 km but the amplitudes of these phases were extremely variable or commonly absent depending on azimuth. We suspect the topography on these features is sufficient as to preclude stacking using single station techniques. Alternatively the large azimuthal variation in the depth to the shallower layer could scatter P410s and P660s phases and therefore diminishing their stacked amplitudes.

S51A-1036 0830h POSTER

Direct mapping of seismic discontinuities by deformable-layered tomography

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Seismic discontinuities and interfaces in the Earths interior at different scales are indicative of variations in lithology, mineral phase, or rheological transitions. In order to directly map seismic discontinuities, a deformable-layered tomography (DLT) method is presented. Conventional traveltime tomography seeks to determine velocity values on a regular grid of nodes or cells that are fixed in space. This does not allow a direct constraint on the geometry of seismic discontinuities, and it introduces more along-raypath smearing artifact. It is better to constrain seismic discontinuities directly, because that the range of velocity values is known before most velocity studies. The DLT solves for the fittest topography of all model interfaces with traveltime data of turning rays and/or reflection rays. With the DLT, the geometry of velocity discontinuities can be better constrained, and a significant reduction in the along-raypath smearing is achievable. The method will be illustrated with numerical and real data examples in local, regional, and global scales.

S51A-1037 0830h POSTER

Change in the coda envelope decay before and after the ScS arrival

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Examining seismogram envelopes of regional earthquakes in the world in periods from 1s to 20s for a wide lapse time range up to 2000s, we classified them focusing on the envelope characteristics before and after the ScS arrivals. We found that the coda decay gradient became smaller after the ScS arrival for all the period bands irrespective of focal depths; however, the change of coda decay gradient becomes smaller as the period becomes shorter and the hypocenter becomes shallower. We also found that envelopes have offsets before and after the ScS arrivals at 10s and 15s periods for deep focus earthquakes (>150 km) at some stations. It is prominent in seismogram envelopes recorded in Central Asia. Such a change in envelope around the ScS arrival is not clear in seismograms of shallow events (<50 km). These observations suggest that scattered waves of the ScS waves sometimes dominate scattered S waves and scattered surface waves. Such a regional variation of coda decay after the ScS arrival may reflect the difference in the medium heterogeneity of mantle.

S51A-1038 0830h POSTER

Full Three-Dimensional Approach: Seismic Structure of the Mantle Beneath Western Pacific Using 3-D Fréchet Kernels

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We present a full three-dimensional (3-D) model of the shear-speed structure for the mantle beneath western Pacific Ocean. Over 800 three-component recordings of earthquakes (Mw > 5.5) from the seismic zones around the western Pacific rim to station HON/KIP in Hawaii, MIDW in Midway, MAT/MAJO and ERM in Japan, and GUMO in Mariana Island were processed to obtain ~20,000 frequency-dependent phase delays for various of seismic waves, including S, SS, upper-mantle guided and surface waves, and ScS reverberations. The 3-D Fréchet kernels for these delay times are computed by the coupled normal mode theory described by Zhao, Jordan, and Chapman (2000), and the measurements were inverted for a 3-D radially anisotropic shear-speed model using a linear Gaussian-Bayesian scheme. The model parameters include shear-speed variations throughout the mantle and perturbations to radial shear-wave anisotropy in the uppermost mantle. The resolving power of the inversion has been investigated through a series of checkerboard and other tests, which indicate that the horizontal and vertical resolving lengths of about 700 and 200 km or less in the upper mantle. Our results for the large-scale variations in the isotropic shear speeds are generally consistent with published global tomographic models. For example, the uppermost mantle (< 200 km depth) shows fast anomalies in the interior of the Pacific plate and slow anomalies in the marginal basins along the Pacific rim, while this pattern is reversed in the transition zone (400-700 km). Our model reveals greater lateral heterogeneity than the global models, especially in the 200-400 km depth range, suggesting a complex 3-D mantle flow in the western Pacific upper mantle.

S51B MCC: Hall C Friday 0830h

Seismic Structure in Asia Posters

Presiding: **G Ichinose,** URS Group, Inc.**;** **M E Pasyanos,** Lawrence Livermore National Laboratory

S51B-1039 0830h POSTER

Velocity and Q structure in and around northeast India

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We used P- and S-wave travel-times recorded by the RRLJ seismic net and those merged from the ISC catalog to relocate earthquakes and investigate the relationship between seismicity and fault lineaments. Events were relocated using the joint hypocentral determination technique. Estimates of M_L and M_d from the RRLJ and NGRI were compared with mb estimated from the USGS. The relationship between mb and M_d from regression analysis is mb = (1.486 ± 0.0149)M_d + (0.6724 ± 0.00073) and between mb and M_L is mb=(0.525 ± 0.274)M_L + (0.9313 ± 0.0013). We also measured the anelastic attenuation from Lg waves using spectral analysis for frequencies between 1 to 6 *Hz*. We examined two northeast India datasets, earthquakes recorded within 1000 *km* from the broadband station at Lhasa, China (LSA), and earthquakes recorded within 400 *km* of the short-period RRLJ local net. The frequency dependence of Lg *Q* for the LSA dataset is $Q = 42 f^{0.80}$ and for the RRLJ dataset is $Q = 37 f^{0.89}$. We inverted broadband seismograms recorded at LSA from 10 earthquakes which occurred in northeast India to estimate the depths and focal mechanisms by fitting separate waveform windows of P_{nl} and surface waves using a grid-search technique. We also estimated surface-wave group velocity dispersion between 1 and 50 seconds for six moderate-sized shallow earthquakes. We inverted the dispersion to estimate the 1-D crustal structure surrounding LSA. Synthetic seismograms were generated using these velocity models and validated with recorded data for $f < 1$ *Hz*. Some of the inverted crustal models contain a deep low-velocity zone at depth but they did not indicate influence on the full waveform synthetics, however, the low-velocity channels in the mid to upper-crust were necessary for predicting the complexity of the body and surface-waves. As expected, paths to the southeast have a thinner crust and paths to the northeast across Tibet have thicker crust.

S51B-1040 0830h POSTER

Lg Attenuation in the Tibetan Plateau

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Lg Q_0(Q at 1 Hz) in the Tibetan Plateau is estimated using data from the 1991-1992 PASSCAL Tibetan Plateau and INDEPTH experiments. The dense distribution of stations along the INDEPTH II and III profiles is particularly suited for measurements of the lateral variation of Q. Lg Q_0 is estimated in the frequency domain using a two-station method. Interstation Q_0 values from many station pairs are then used to invert for lateral changes of Lg attenuation along the profiles. In addition, a method for simultaneous inversion of source M_0, fc and path-variable Q_0 and η (the frequency dependence of Lg Q) values is applied to Lg in central Tibet. Lg Q_0 in a broad region in central Tibet is found to be 100-120 with the spectral inversion method, similar to the two-station inversion result of Xie (2002) (Lg Q_0 = 126 ± 9). Using two-station inversion, we find low Lg Q_0 values (80-110) along the INDEPTH III profile. Although there is a major difference in crustal structure between northern and southern Tibet, there is no sudden lateral change in Lg Q_0. We find regions of extremely low Lg Q_0 values in southernmost Tibet. The Lg Q_0 values from the Indus-Yarlung Suture (IYS) to 200 km north of it are very low (60-90), with the lowest Q_0 found in the vicinity of IYS (∼ 60). The crustal structure does not vary significantly north of Kangmar Dome (southern limit of the partially melted middle crust). The very low Q_0 value in southernmost Tibet is probably an effect of intrinsic attenuation and is consistent with the presence of partial melt in the middle crust where bright spots, anomalously conductive layer and a mid-crustal low velocity zone have been found. The southernmost Tibet is also characterized by high heat flow (> $100 mW/m^2$). The very high attenuation in the crust found in southernmost Tibet explains the elimination of Lg when path travels across this region. Previously suggested explanations such as an abruptly change in structure beneath the southern Tibetan Plateau boundary is insufficient for a complete blockage of the Lg signal.

Xie, J., 2002, Lg Q in the eastern Tibetan Plateau, *Bull. Seism. Soc. Am., 92*, 861-867.

S51B-1041 0830h POSTER

Seismic Structure of India from Regional Waveform Matching

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The Indian Institute of Astrophysics, the National Geophysical Research Institute, and Cambridge University have now operated broadband seismographs on the Indian Shield since 1997. We use a neighbourhood algorithm adaptive grid search procedure and reflectivity synthetics to model seismograms from regional earthquakes recorded on these seismographs, FSDN seismographs, and seismographs operated by the Indian Meteorological Department. This procedure results in 1-D path average crust and upper mantle velocity and attenuation models whose propagation characteristics closely match those of the real Earth. The portions of the regional waveform that are most influenced by shallow crust and upper mantle Earth structure are the P_{nl} and the 20–100s period surface waves. We use our adaptive grid search algorithm to match both portions of the seismograms simultaneously. We find that the structure of the Indian shield is both simple and uniform, and that both P_{nl} and the surface wave portions of most of the regional seismograms are well matched by reflectivity synthetics for a halfspace mantle (β ∼4.65 km/s) overlain by a crust with a linear gradient in shear wave velocity between 3.0–3.6 km/s at the surface and 3.8–4.2 km/s at the Moho, which is at 35–40 km depth.

S51B-1042 0830h POSTER

Measurements of Frequency Dependent Lg Attenuation in India

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The Indian Institute of Astrophysics, the National Geophysical Research Institute, and Cambridge University have operated broadband seismographs at several sites on the Indian Shield since 1997. We use seismograms from local and regional earthquakes recorded at these sites, FSDN seismographs, and seismographs operated by the Indian Meterological Department to measure the spatial decay of spectral amplitudes of the higher-mode seismic surface wave train Lg for numerous paths which provide a good average sampling of the shield and northern India. After correction for instrument response and geometrical spreading, we analyze the frequency dependency of Q by measuring the decay of Lg amplitude with epicentral distance over discrete frequency bands in the range 0.5 < f < 10.0 Hz. The average Lg Q for the Indian Peninsular shield region can be expressed as $Q(f) = 850 f^{0.61}$. This preliminary result is comparable to the apparent Q values found by Singh et al., 1999 for the Indian shield and similar to the Lg attenuation observed in eastern North America. We observe anomalous Lg amplitudes and frequency behavior that implies the presence of regional spatial variability in the crustal attenuation structure.

S51B-1043 0830h POSTER

Crustal Structure Beneath the Foreland Spur in Northeastern India

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Northeastern India, one of the most seismically active region of the globe, is wedged between the northern Indo-Tibetan collision zone and the eastern, most likely now inactive, Indo-Burman collision boundary that have jointly carved its remarkably acute angled northeastern extremity. A spur of Precambrian crystalline basement, exposed over a large area in the Shillong plateau and Mikir Hills as well as smaller outcrops in the Brahmaputra valley, is elsewhere covered by gently dipping Tertiary beds that reach prodigious thicknesses of several thousand metres in the eastern Himalayan foreland. We use broadband teleseismic data recorded at 5 sites along a 300 km long N-S profile from stations sited on this foreland spur consisting of the Shillong plateau and other basement exposures across the Brahmaputra, right up to a few Km south of the Main Central Himalayan thrust in the region, to glean the seismic characteristics of the crust underneath. Receiver Functions at the above sites show that crustal thickness under the Shillong plateau changes from about 55 km at its southern extremity at Cheerapoonji to 55 km at Barapani about 70 km north of it. Crustal thickness further north along this profile, at Gauhati and Tezpur in the Brahmaputra valley, is found to be 60 km, and the crust appears to gently dip northward reaching a thickness of 65 km in the Lesser Himalaya at Bomdila which is only a few km south of the Main Himalayan Central thrust in this region.

S51B-1044 0830h POSTER

A Pilot Earthquake Seismic Network in Bhutan: Preliminary Results

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