We observe significant variations in shear wave splitting parameters using teleseismic S and regional ScS waves recorded on an L-shaped array of nine stations (with 10 km spacing) situated above the fore-arc region of the Hikurangi subduction zone, New Zealand. This is in marked contrast to a previous study which found no variation in average SKS splitting values at a network of nine stations with a spacing of 100 km in the same area. Two of the stations were co-located with stations in the array we are using. In a previous study using local earthquakes recorded at the array, station to station variations in splitting were seen, suggesting variations in near surface anisotropy. SKS splitting was also previously studied at the array, but the seismograms were stacked to try to improve the signal to noise ratio, which meant that it was not possible to study any variation in splitting. In this study we have used S and ScS phases, whose frequencies are intermediate between local and SKS events and we are able to obtain high quality splitting measurements at the individual stations without stacking. In general, significantly higher delay times are observed at the three stations on the down-dip arm compared to the other six stations aligned sub-parallel to the strike of subduction. For one of the ScS events (with a wavelength of around 10 km) the delay times change from 1 ± 0.1 s to 1.5 ± 0.1 s over a distance of 26 km. The fast polarisation directions also vary between stations but there is no clear trend, and there is evidence for variations in the splitting parameters obtained from different events. The variation in splitting seen across the array suggests that the anisotropy can not be on the source side. The S and ScS waves have similar raypaths beneath the stations as SKS but have higher frequency content. This suggest there is a frequency dependence in the splitting parameters, which is inconsistent with standard models of olivine LPO causing the anisotropy.

S31D MCC: Level 2 Wednesday 0830h

Deep Earth Posters *(joint with V, DI)*

Presiding: **H Tkalcic,** Lawrence Livermore National Laboratory**; H Thybo,** University of Copenhagen

S31D-0784 0830h POSTER

Seismic Detection of the α-β Quartz Transition Provides Precise Temperature Estimation in the Tibetan Crust

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In the deep crust, temperature, which is among the key parameters controlling lithospheric dynamics, is inferred by extrapolation from the surface using several assumptions that may well fail in regions of active tectonics and fluid migration. In the rare case that temperatures of 700°C or higher are exceeded in the upper/middle continental crust composed of quartz-rich felsic rocks, the α-β quartz transition (ABQT) will occur, generating a measurable seismic signature and offering the possibility for precisely estimating temperature from the known ABQT phase diagram. Here it is shown that all expected seismic features of the ABQT are met by the boundary at 18-32 km depth below the INDEPTH III profile in central Tibet. Thus, this seismic boundary more probably represents the signature of (recent) geological processes rather than a lithological boundary.

S31D-0785 0830h POSTER

Upper Mantle and Transition Zone Discontinuities by Comparison of PP and SS Precursors

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A number of previous studies have confirmed the global existence of the major mantle discontinuities by aligning seismograms on a surface reflection phase. Stacking large numbers of traces aligned this way yields signals from precursor phases, which have amplitudes too low to be seen in individual traces. Previous comparisons of PP and SS precursor data sets have considered global discontinuities (Flanagan & Shearer [1999]). Here we also study the lateral variations in mantle discontinuities by considering PP and SS precursors from certain -well sampled- regions. The stacking procedure utillises a slant stack in which traces with varying offsets are aligned to a reference distance using a range of slownesses. The slant stacks are then converted to a trace in which the stacking slowness is time dependent, the time dependence being chosen to maximise the stacked amplitude corresponding to reflections from a continuous range of mantle depths. The weak precursor signals are enhanced using deconvolution techniques. We present stacks for PP and SS precursors which contain bounce points within a specified region. We observe and compare the observations of PP and SS precursors consistent with reflections from upper mantle and transition zone discontinuities. By comparison with WKBJ synthetics we attempt to constrain the variations in seismic parmeters which can explain the precursor arrival times and ampilitudes. The comparison of S-wave and P-wave underside reflections from mantle discontinuities allows better constraints to be placed on the discontinuity characteristics such as impedance contrast and discontinuity thickenss. Such information is a prerequisite for the integration of results from seismology and mineral physics to establish the causes of mantle discontinuities.

S31D-0786 0830h POSTER

High frequency local reflections and conversions from upper mantle discontinuities in the Fiji-Tonga subduction zone

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Recordings of deep Fiji-Tonga earthquakes from an array of 15 broadband seismographs in Fiji are stacked and searched for reflections and conversions from upper mantle discontinuities near the Fiji-Tonga slab. The Fiji array operated as part of the SAFT (Seismic Arrays in Fiji and Tonga) experiment from July 2001 to August 2002. In comparison with the commonly used teleseismic approaches, the short path lengths for the local data provide smaller Fresnel zones and high frequency content for precise mapping of discontinuity topography and sharpness. This is particularly important for a subduction zone, where variations in temperature and water content may be expected which should cause changes in the elevation and sharpness of the discontinuities. We study the phases $s410p$, $P660p$ and $S660p$ where they arrive at least 10 seconds after the direct P wave and prior to the S wave accross the array. To anhance low-amplitude reflections/conversions, deconvolved seismograms from each event are aligned on the maximum amplitude of the direct P wave and slant stacked. Preliminary results indicate that for the northern part of the Fiji-Tonga subduction zone, the 660-km discontinuity varies between 660 and 670 km in depth. In the central part we observe converted phases consistent with a "410" depth of 380 km, indicating the effect of the cold subducting plate. The reflections/conversions show only a slight frequency shift relative to the direct P waveforms, suggesting the discontinuities are relatively sharp. The thickness for the 660-km discontinuity is estimated as between 2 and 6 km.

S31D-0787 0830h POSTER

Waveform Modeling of 3D Structure of D" Region Using A Coupled SEM/Normal Mode Approach

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The presence of strong lateral heterogeneity in D" is now well documented and presents challenges for seismic modeling. The main challenges are the limited global sampling of D" and the theoretical limits of validity of the present modeling tools, such as standard ray theory and mode approaches. We use coupled normal mode/Spectral Element Method (SEM) to compute synthetic seismograms of Sdiff in the D" part of a tomographic model(SAW24b16, Mégnin and Romanowicz, 2000) down to corner frequency 1/12s. SEM allows to take into account strong heterogeneity in a rigorous manner. The coupled method is much faster than standard SEM, when the numerical part of the computation is restricted to the D" region. In the rest of the mantle, the wave field is computed using efficient normal mode summation. As a first step, we consider a radially symmetric model outside of the D" region, and compare Sdiff synthetics with observed waveforms for a collection of deep earthquakes, for which the effect of strong heterogeneity in the crust and upper mantle is avoided. Observed and synthetic travel time trends are very consistent and in many cases the observed residuals are significantly larger. This indicates that the tomographic model only represents the smooth features of the real structure. Observed waveform amplitudes and SEM synthetics are somewhat less consistent. We compare the predictions for 800 Sdiff phases using SEM with those obtained by more approximate methods : ray theory and NACT (Non-linear asymptotic coupling theory, a normal mode perturbation approach). We discuss systematic trends in the travel times predicted by the different methods, compared to observations. Starting with the tomographic model, and correcting for mantle structure outside of D" using approximate NACT predictions, we next invert for perturbations to the tomographic model, using the coupled SEM/mode computation for the forward part of the modeling, in several regions of D" under the Pacific, which are well sampled by available Sdiff data. We discuss the resulting changes in the D" model.

S31D-0788 0830h POSTER

Transition Zone Heterogeneity Imaged on Long Range Explosion Data

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Standard models of the upper mantle transition zone do not explain the complexity of arrivals observed on long range explosion profiles collected in Siberia and North America. We observe reverberative arrivals on high-resolution, nuclear (Peaceful Nuclear Explosions - PNEs) and conventional explosion seismic profiles in two offset ranges which have moveouts and traveltimes which cannot be explained by reflected or refracted arrivals from a simple transition zone with boundaries at 410 km and 660 km. The phases we observe are also visible on short period recordings of PNEs made outside the former Soviet Union, notably on NORSAR and Grafenberg array data. In addition to anomalous secondary arrivals, first arrival traveltime misfits suggest anomalous velocities above and in the transition zone. Additional complexity is required to explain several features of the long-range profiles: 1) a reverberative arrival between the first arrivals and the reflected arrival from the 410 discontinuity in the offset range 1500 to 2500 km; 2) a coda after the reflected 410 discontinuity arrival in the same offset range as above; 3) a previously unreported reverberative arrival with a long 10 to 15 second coda observed after the first arrivals in the offset range 2500 to 3500 km and 4) increased amplitudes close to the first arrivals in the offset range 2600 to 3000 km. To fit these observations we need a 520km discontinuity and two separate zones of small-scale heterogeneity : one from 320 km down to 410 km and one below 410 km down to at least 460 km and possibly as deep as 520 km. Both 2-D visco-elastic waveform modeling and reflectivity modeling suggest that local heterogeneity in the form of seismic scatterers with typical scale lengths of 20 km horizontally and 5 km vertically and velocity fluctuations of 0.2 km/s can explain the character of the arrivals. The cause of the heterogeneity may be local variations in composition interacting with the several phase transformations

expected in the transition zone or the transformation of pyroxenes into the garnet mineral majorite. A further possibility is locally high iron content in the lower upper mantle leading to small scale heterogeneities.

S31D-0789 0830h POSTER

Seismic Scattering from Heterogeneity in the Continental Crust and Upper mantle

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We document pronounced seismic scattering from three heterogeneous zones in the continental crust and upper mantle under Eurasia: (1) The lower crust, (2) The mantle low-velocity zone, and (3) An interval around the top of the mantle transition zone. We model the scattering by use of viscoelastic, full wavefield, 2D finite-difference synthetic seismograms. The calculations are for large models of seismic velocity (2500 by 550 km), which include by heterogeneous layers, defined by random fluctuations of the elastic parameters and Q-values. Our primary data source is Peaceful Nuclear Explosion (PNE) seismic data sets collected in the former Soviet Union. High-frequency signals (up to 10 Hz with centre frequencies of 2-4 Hz) from the PNEs were recorded with a nominal receiver spacing of 10-15 km along profiles of up to 4000 km length. (1) Lower crustal scattering explains the characteristics of the teleseismic (or long-range) Pn wave at all frequencies in the data. This wave propagates as a whispering-gallery phase to more than 3000 km offset from the sources with apparent mantle velocity. It requires a large, positive vertical upper mantle velocity gradient. The model is consistent with outcrop and seismic observations. We reject a previously published model for the teleseismic Pn in terms of upper mantle scattering which only explains the wavefield characteristics at high frequency, but not at low frequency. It also leads to strong damping of later arrivals, in disagreement with observations. (2) Heterogeneity in the mantle low-velocity zone below the 8^{o} discontinuity at 100 km depth causes scattering of the main frequencies (2-4 Hz) of the seismic wavefield. The scattering is primarily observed directly behind the first arrivals in the 800-1400 km offset range. Pronounced delay of the first arrivals beyond ca. 800 km offset demonstrates the presence of the mantle low velocity zone. The best fit to observations is obtained by including an 80 km thick heterogeneous low-velocity zone below 100 km depth. The heterogeneity is represented by fluctuations described by a von Karman distribution function with a Hurst number of 0.5 and spatial correlation lengths of 5-10 km (horizontally) and 3-5 km (vertically). (3) Pronounced reflectivity before and after the '41" reflection in the seismic sections constrains heterogeneity around the top of the mantle transition zone. The 2-4 Hz scattered signals may be explained by fluctuations in the 320-460 km depth interval with horizontal and vertical correlation lengths on the order of 20-40 km and 5-10 km, respectively. We present synthetic seismograms that include the effects from all three heterogeneous depth intervals. They explain most of the characteristics of the observed wavefield from the PNE sources.

S31D-0790 0830h POSTER

Using Array Seismology to Probe the Deep Earth With Core Seismic Phases

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Much work is undertaken to investigate the structure of the deep Earth, i.e. the core and lower mantle. Researching these regions is important, as they are thought to govern the generation of the Earth's magnetic field, as well as mantle convection. The deep mantle region includes the core-mantle interaction zone, and is potentially the origin of plumes, and the graveyard for slabs. Much controversy exists regarding the nature of the inner core, in particular its anisotropy and rotation. Up to now, seismological studies of the Earth's core have focused primarily on travel time deviations. These locate anomalous regions, but cannot determine the nature of the anomaly. The rays may have been deviated along an anomalous path (backazimuth deviation), or travelled at an anomalous phase velocity (slowness deviation). The work presented here utilises array seismology to further examine anomalies previously located by studying travel time deviations. The slowness and backazimuth of core seismic phases are calculated, and compared with global velocity models. Deviations of the different phases are analysed to resolve the location of the anomalous regions. The results are then compared with travel time deviations. This method will be employed globally, utilising arrays that lie at a suitable epicentral distance from relatively deep, strong events. Currently two arrays have been used, the German Regional Seismic Network (GRSN) and the Alaska Seismic Network (ASN). Earthquakes in Tonga-Fiji are received by the GRSN, and data from the ASN is used to further investigate the anomalous South Sandwich Islands to Alaska path. This path has been shown in recent studies to have strong anisotropy and is also used to study rotations of the inner core. Results show that deviations are present in all three phases (PKPab, PKPbc and PKPdf); deviations vary for the different paths. The Tonga-Fiji to Germany path has particularly deviated backazimuth values for all three phases, possibly indicative of lower mantle structure. The South Sandwich Island to Alaska path shows deviations particularly in the PKPdf branch (the branch that travels through the inner core).

S31D-0791 0830h POSTER

Constraints on Density and Shear Velocity Contrasts at Inner Core Boundary

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The density jump ($\Delta\rho_{ic}$) at the inner core boundary (ICB) is an important constraint on the dynamics and history of the earth's cores. Two types of seismological data sensitive to $\Delta\rho_{ic}$ have been studied since the 1970's: free oscillation eigenfrequencies and amplitudes of core reflected phases (PKiKP/PcP). The reference PREM model (Dziewonski and Anderson, 1981), based largely on normal mode data, has a relatively low value of $\Delta\rho_{ic} = 0.65g/cm^3$, whereas most studies based on PKiKP/PcP amplitude ratios find significantly larger values, sometimes in excess of $1.0g/cm^3$. It has been argued that, because PKiKP is rarely observed in the distance range considered ($10-70^o$), the latter type of measurement provides only upper bounds on $\Delta\rho_{ic}$ (e.g. Shearer and Masters, 1990). We have analyzed 10 years of high quality global broadband data accumulated since the work of Shearer and Masters (1990). We systematically analyzed over 4500 seismograms from intermediate/deep events (depth > 70 km) and nuclear explosions, in the distance range $10-70^o$. The data were filtered in the band-pass 0.7-3 Hz. We performed a rigorous data selection: 1) we only considered observations of clearly identified PKiKP and PcP (within 5s of theoretical arrival time) with signal to noise ratio > 4; 2) we rejected data for which one or more of 7 other phases may be present within 15 s in front of PKiKP or PcP (P,pP,PP,PPP,S,SS,ScS). We identified 5 pairs of very clear (Quality A), and 16 possible (Quality A-) PKiKP and PcP arrivals. In addition, 62 records showed no PKiKP but a clear PcP. Together, we obtain a much less dispersed dataset than previously available, with the quality A data following the lower bound of the ensemble of amplitude ratios versus distance. We combine our high quality measurements with 2 measurements from the literature that fell within our rigorous selection criteria and obtain unbiased estimates of $\Delta\rho_{ic}$ in the range $0.65-0.91gcm^{-3}$. We discuss trade-offs between $\Delta\rho_{ic}$ and the corresponding velocity jumps at the ICB.

S31D-0792 0830h POSTER

On the Existence of Seismic Discontinuities in the Inner Core

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We evaluate the possibility of seismic discontinuities within the inner core using a data set of precritical PKiKP waveforms assembled during a previous study. Recent work has suggested the presence of such structures within the inner core, relating them to either changes in anisotropy at shallow depths or at deeper locations. Another explanation is the existence of a crust below the inner core boundary and a low velocity zone, based on geophysical models of inner core growth. Because any phase reflected from a discontinuity within the inner core will have a very small amplitude, we combine source and receiver stacks in our search. For a given event we use cross-correlation to align the data from a short-period, small-aperture seismic array and then construct a receiver stack using linear summation. Next we use one of two procedures (deconvolution by an empirical source time function and envelope formation) to eliminate the signature of the source from each receiver stack. Finally, we stack the receiver stacks from each event using time shifts appropriate for a velocity model with a discontinuity at some depth below the inner core-outer core boundary. We compare the results with synthetic computations done by means of generalized ray theory and appropriate attenuation operators. We perform resolution tests to determine our capability of finding these types of structures, varying the impedance contrast, position of this discontinuity and attenuation inside the inner core. Our results show that the inner core lacks a sharp (thickness less than 4-5 km) global transition to at least 700 km below the boundary with the outer core.

S31E MCC: Level 2 Wednesday 0830h

Global and Regional Tomography I Posters *(joint with DI)*

Presiding: **M West,** New Mexico State University**; E Sandvol,** University of Missouri

S31E-0793 0830h POSTER

Geographical ISC data Characterization with Parallel Ray-tracing

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In order to improve the accuracy of existing seismic tomography methods, huge quantities of information must be computed. Our objective is to build an adaptive mesh of the Earth so it can translate to an inverse problem of tractable size. The mesh cells size will be adapted depending on the "illumination" quality, that is regions where rays have brought more information will be modeled precisely, yielding small cells, whereas cells traversed by few rays are covered by large cells . These considerations lead us to develop software programs to take into account the computational resources needed for the 3D ray tracing step and the huge quantity of data to store into the cells mesh. These per-cell data are characteristics such as the ray length, the ray density, the number of ray hits by cell face, and the quality of the spatial repartition of rays in the cell. Our parallel programs made possible to process the entire ISC data set recorded for year 1999. We ray-traced 399,406 out of the 817,101 ray records, in an Earth mesh with 11 layers of $1^{\circ} \times 1^{\circ}$ cells (712,800 cells). First we observe, that nearly half the data set cannot be traced because rays were not given a precise enough seismic signature. Secondly, we produce from the computed results, graphical 3D maps highlighting geographical zones where information brought by rays are noticeable. The graphical tool enables to visualize maps corresponding to any of the above cited characteristics. Several hardware equipments were tested (PC cluster, parallel computer, Grid computing) to run the experiment. An acceptable processing time of 400s was reached with 64 processors on SGI Origin 3800 parallel computer. Our programs showed a good scalability when the number of processors increase. Another interesting feature is our capability to process data sets by slice to overcome memory limitations, but nonetheless obtain aggregated mesh results. We think the processing of the entire ISC catalogue from 1964 to 2002 with several millions of rays is attainable.

URL: http://guenievre.u-strasbg.fr/ray2mesh

S31E-0794 0830h POSTER

Local Earthquake Tomography at the Active Tongariro Volcanic Centre, New Zealand

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Back-arc spreading caused by subduction of the Pacific plate beneath the Australian plate ranges from full oceanic spreading north of New Zealand to continental extension in the North Island. The Tongariro Volcanic Centre (TVC) in the North Island of New