Our preliminary results from time picks of earthquake bulletins suggest that most of the station pairs have a a very small increase of differential P residuals with time and some station pairs have a decrease of residuals with time. After removing all the means of the residuals of different station pairs, the combined data suggest an increase of 0.1 to 0.2 s per decade. Assuming the time shift is caused by mislocation, the corresponding time shift for the differential BC-DF times at Alaska stations would be less than 0.02 s per decade, which is much less than the observed time shift of the BC-DF times. We have also collected P waveforms of a selected few stations. Results from the precise time picks of these stations will be presented.

S31B-08 0945h

Three-dimensional structure of inner core anisotropy from PKP differential travel times and waveforms

Xiaodong Song (217-333-1841; xsong@uiuc.edu)

Department of Geology, University of Illinois, Urbana, IL 61801, United States

Discussion with Prof. Don Anderson was one of the most inspiring and stimulating experiences in my science career when we were searching for evidence for inner core anisotropy a little over ten years ago. At the time, the hypothesis of inner core anisotropy was not fully accepted. Now models of 3D inner core anisotropy have been proposed. Recent studies suggest that the uppermost inner core is nearly isotropic and western and eastern hemispheres of the inner core are different in both velocity and anisotropy. Yet differential PKP travel times at near antipodal distances show convincingly that significant anisotropy exists in the bulk of the inner core at both hemispheres. Recently Xinlei Sun and I assemble differential PKP travel-time measurements at distances of 145 to 180^{o}, obtained by us and others over the years, to investigate the 3-D structure of the inner core anisotropy. These differential times reduces the biases from earthquake mislocations and heterogeneous upper mantle. We invert for 3D inner core anisotropy by dividing the inner core into four layers in radius and six sectors in longitudes. The top 100 km of the inner core is assumed to be isotropic. Our inversion suggests that at depth of 100-500 km below the inner core boundary, the quasi-eastern hemisphere (40 to 160^{o}E) is nearly isotropic (less than 1% of anisotropy) while the western hemisphere is strongly anisotropic (3 to 5% anisotropy). However, at depth of 500-900 km, both hemispheres are anisotropic (about 3% anisotropy). At the innermost 300 km of the inner core, the form of anisotropy seems distinctly different. One of the most dramatic manifestations of changes in anisotropy is the observation of seismic triplication of inner core waves; a type of multipathing effect due to heterogeneity that Don challenged to think about even in the early days. The best example is the seismic triplication observed from South Sandwich Islands earthquakes recorded at stations in Canada and Alaska.

S31C MCC: Level 2 Wednesday 0830h

Splitting and Anisotropy I Posters

(joint with T, MR)

Presiding: **M D Long,** Massachusetts Institute of Technology**; D L Schutt,** University of Wyoming

S31C-0779 0830h POSTER

Shear-wave polarization anisotropy in the mantle wedge beneath the southern part of Tohoku, Japan

Junpei Shimizu[1] (shimizu@aob.geophys.tohoku.ac.jp)

Junichi Nakajima[1] (nakajima@aob.geophys.tohoku.ac.jp)

Akira Hasegawa[1] (hasegawa@aob.geophys.tohoku.ac.jp)

[1]RCPEV, Graduate School of Science, Tohoku University, Aramaki-aza-Aoba, Aoba-ku, Sendai 980-8578, Japan

We investigated shear-wave polarization anisotropy in the mantle wedge beneath the southern part of Tohoku, Japan, by using waveform data of intermediate depth earthquakes with M>2.5 recorded by the seismic networks of Tohoku University and Japan Meteorological Agency (JMA). We selected waveform data with ray paths whose incident angles to the surface are 35 degrees or less to avoid contamination of particle motions by converted phases. All the seismograms thus selected were filtered with bandpassed ranges of 2-8 Hz. Cross-correlation method [Ando et al., 1983] was used for determining delay time between the leading and following shear-waves (delay time) and the leading shear-wave polarization direction (fast direction). Two horizontal components of observed seismograms were rotated with the direction from 0 to 180 degrees with an interval of 5 degrees, and shifted one horizontal component by a time lag. The time lag varied from 0 to 1 s with an interval of 0.01 s. The length of time window used to calculate correlation coefficient was set to be nearly equal to one cycle of the shear-wave. We do not use the data whose maximum correlation coefficient is less than 0.8. Obtained results show that most of the fast directions at stations in the back-arc side are nearly E-W, whereas those at stations in the fore-arc side are N-S. We infer that the anisotropy caused by lattice-preferred orientation of olivine, which is probably produced by flow in the mantle wedge, is a likely candidate for the observed shear-wave splitting with E-W trend fast directions in the back-arc side. Although it is not certain what causes the N-S trend fast directions in the for-arc side, the same trend is seen in the previous studies of other areas in Tohoku [Okada et al.,1995; Nakajima, 2002]. Observed delay times are mostly 0.1-0.3 s, which is consistent with the results of Okada et al. [1995] and Nakajima [2002]. Acknowledgments: We are grateful to the staff of the JMA for allowing us to use their data.

S31C-0780 0830h POSTER

Array Averaged Particle Motion and Polarization for Southern California

Jose D Otero[1] (858-534-2562; jdotero@ucsd.edu)

Frank L Vernon[1] (flvernon@ucsd.edu)

Gary Pavlis[2] (pavlis@indiana.edu)

Vera Schulte-Pelkum[3] (veraschulte-pelkum@colorado.edu)

[1]Institute of Geophysics and Planetary Physics, Scripps Institution of Oceanography: University of California, San Diego, 9500 Gilman Dr, La Jolla, Ca 92093-0225

[2]Department of Geological Sciences Indiana University, 1001 East 10th St, Bloomington, IN 47405-1405

[3]University of Colorado at Boulder, 216 UCB, Boulder, CO 80309-0216

We measure array-averaged particle motion and polarization for teleseismic P-waves within the large aperture (∼ 70 km) Anza Broadband Array (http://eqinfo.ucsd.edu). Using three component Anza seismic data and a multi-wavelet method developed by *Bear, et al.*, we compare our results to *Schulte-Pelkum, et al.* more traditional cross correlation techniques. The applied multi-wavelet technique, a hybrid of Fourier and time-domain principal component methods yields insights into the relationships between phase velocity (i.e. the slowness vector) and particle motion which are not as attainable from traditional techniques. As seen in previous studies, we expect to find longitudinal departures in P wave particle motion due to regional anisotropy. Examination of thirteen events (5.1< Mb <6.1) yields comparable particle deviations for both methods, yet significant differences exist in frequency dependence of these events.

S31C-0781 0830h POSTER

Rayleigh wave phase velocities, shear wave structure and azimuthal anisotropy beneath southern California

Yingjie Yang[1] ((401) 863-1701; Yingjie_Yang@brown.edu)

Donald W Forsyth[2] ((401) 863-1699; Donald_Forsyth@brown.edu)

[1]Yingjie Yang, 324 Brook street Brown University Gelogy Department, Providence, RI 02912, United States

[2]Donald W. Forsyth, 324 Brook street Brown University Gelogy Department, Providence, RI 02912, United States

We use normal mode Rayleigh wave phase and amplitude data recorded at the TriNet network in southern California to invert for phase velocities at periods from 25 to 143 s. These phase velocities were used to obtain 3-D S-wave velocity structure in the upper mantle. Phase velocities on the Pacific plate side of the plate boundary are systematically higher than on the North American side, suggesting that seismic velocity contrast between these two plates extends to the upper mantle. In the upper mantle, there is a pronounced low velocity anomaly beneath the Long Valley/Mono Lake region, which has not been observed by previous tomographic studies. This low velocity anomaly is consistent with melting extending to the base of the crust beneath this part of the western Basin and Range province, as suggested based on the composition of late Cenozoic basalts (Wang et al., JGT, 2002). There is a high velocity anomaly under the Transverse Range and a slightly slow velocity anomaly under the Salton Trough, both of which have been observed in previous body and/or surface wave tomographic studies. Assuming uniform anisotropic structure in the whole study area, the strength of anisotropy is about 2.5% at all periods. However, the fast direction varies with period. The fast direction of apparent anisotropy is nearly W-E at periods less than 50 s, consistent with the fast polarization axis of SKS splitting measurements in Southern California. At periods larger than 67s, the fast direction changes to NW-SE, subparallel to the plate boundary. This two-layer azimuthal anisotropy structure is in contrast to the one-layer SKS splitting model for southern California, implying that lateral heterogeneity may affect the apparent anisotropy of long-period surface waves. If anisotropy is allowed to vary laterally in our models, we find a minimum in azimuthal anisotropy in the vicinity of the Transverse Range, suggesting possible more vertical alignment of the olivine a-axis in a region of downwelling.

S31C-0782 0830h POSTER

Mantle Anisotropy Beneath the Alaska Range Inferred From S-wave Splitting Observations: Results From BEAAR

Douglas H Christensen[1] (907-474-7426; doug@giseis.alaska.edu)

Geoffrey A Abers[2] (617-353-2616; abers@bu.edu)

Toni L McKnight[3] (906-487-9613; tlmcknig@mtu.edu)

[1]Geophysical Institute, University of Alaska Fairbanks, P.O. Box 757320, Fairbanks, AK 99775-7320, United States

[2]Boston University, Department of Earth Sciences, Boston, MA 02215, United States

[3]Michigan Technological University, Department of Geology, Houghton, MI 49931, United States

The tectonics of southern and central Alaska are dominated by the subduction of the Pacific plate beneath the North American plate. The Broadband seismic Experiment Across the Alaska Range (BEAAR) was a 2.5-year PASSCAL deployment utilizing 36 closely spaced (10-15 km) broadband sensors. These instruments were deployed across the Alaska Range and above the subducting Pacific plate in roughly north-south and east-west lines. Much of the study region is underlain by a mantle wedge, which gradually pinches out at the southernmost stations. The depth of the subducting slab increases to the northwest with the deepest earthquakes occurring at 150 km, just north of the Alaska Range. Teleseismic SKS and S phases, in addition to S waves from local earthquakes in the subducting plate, were used to study the anisotropic behavior of the upper mantle in central Alaska. Two distinct regions of anisotropy are observed, reflecting both flow in the direction of plate convergence and flow parallel to the strike of the subducting plate. The transition between these two zones appears to be very sharp occurring near the 70-75 km contour of the subducting plate. Waves arriving through material southeast of this line (through the shallow corner of the mantle wedge) show fast directions that are parallel to the plate convergence direction. North of the 70-75 km slab contour the fast directions abruptly change orientation to roughly parallel the strike to the subducting plate. This direction is also parallel to the trend of several major tectonic features in the area, including the Alaska Range, and the right-lateral strike slip Denali and Tintina faults. Stations that are located above the 70-75 km contour of the subducting Pacific plate show characteristics of both regions, depending on the back azimuth of the arrivals. These observations set strong constraints on the location of the transition zone between the two regions. While teleseismic observations may represent anisotropy (or flow) in the mantle wedge, in the subducting Pacific plate, or beneath the subducting plate, observations from local slab events indicate that a significant portion of the signal comes from the mantle wedge and that the sharp change in direction is a feature of the mantle wedge.

S31C-0783 0830h POSTER

Variations in S-Wave Splitting Across an Array in the Fore-arc Region of the Hikurangi Subduction Zone, New Zealand

Katrina Marson-Pidgeon[1] (katrina.marson-pidgeon@vuw.ac.nz)

Martha Kane Savage[1] (Martha.Savage@vuw.ac.nz)

Ken Gledhill[2] (k.gledhill@gns.cri.nz)

[1]School of Earth Sciences, Victoria University of Wellington, Box 600, Wellington 6015, New Zealand

[2]Institute of Geological and Nuclear Sciences, Box 30368, Wellington 6000, New Zealand

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

James Mechie[1] (49-331-288-1237; jimmy@gfz-potsdam.de); Stephan V. Sobolev[1]; Lothar Ratschbacher[2]; Andrey Yu. Babeyko[1]; Alan G. Jones[3]; Kurt D. Solon[4]; Larry D. Brown[5]; Wenjin Zhao[6]

[1]GeoForschungsZentrum Potsdam, Telegrafenberg, 14473 Potsdam, Germany

[2]Institute for Geology, Technical University Freiberg, 09599 Freiberg, Germany

[3]Geological Survey of Canada, 615 Booth Street, Ottawa, ON K1A 0E9, Canada

[4]ExxonMobil Exploration Company, GP-3, Room 348, Houston, TX 77060, United States

[5]Department of Earth and Atmospheric Sciences, Cornell University, 3124 Snee Hall, Ithaca, NY 14853, United States

[6]Chinese Academy of Geological Sciences, 26 Baiwanzhuang Road, Beijing 100037, China

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

Kit Chambers[1] (+44-1865-272016; Kit.Chambers@earth.ox.ac.uk)

John H Woodhouse[1] (John.Woodhouse@earth.ox.ac.uk)

Arwen Deuss[1] (Arwen.Deuss@earth.ox.ac.uk)

[1]Dept. of Earth Sciences, University of Oxford, Parkes rd, Oxford OX1 3PR, United Kingdom

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

Rigobert Tibi[1] (314-935-7965; tibi@wustl.edu)

Douglas A. Wiens[1] (314-935-6517; doug@seismo.wustl.edu)

[1]Washington University, Department of Earth and Planetary Sciences, One Brookings Drive, St. Louis, MO 63130, United States

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

Akiko To[1] (toh@seismo.berkeley.edu)

Yuan-Cheng Gung[1] (gung@seismo.berkeley.edu)

Yann Capadeville[2] (yann@seismo.berkeley.edu)

Barbara Romanowicz[1] (barbara@seismo.berkeley.edu)

[1]U.C. Berkeley Seismological Laboratory, 215 McCone Hall, UC Berkeley, Berkeley, CA 94720-4760, United States

[2]Institut de Physique du globe de Paris, 4, place jussieu, Paris 75005, France

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

Andrew R Ross[1] (4535322477; ross@seis.geol.ku.dk)

Hans Thybo[1] (ht@seis.geol.ku.dk)

Lars Nielsen[1] (ln@seis.geol.ku.dk)

Edward Perchuc[2] (per@igf.edu.pl)

[1]Geological Institute, University of Copenhagen, Oester Voldgade 10, Copenhagen DK-1350, Denmark

[2]Institute of Geophysics, Polish Academy of Sciences, ul. Ksecia Janusza 64, Warsaw PL-01452, Poland

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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