the next time segment. In reality, we conduct a preliminary scan at a time interval of 5 s with a spatial resolution of 1 km to identify coherent seismic events. The scanning is subsequently done at shorter time intervals (down to 0.1 s) to locate the brightest spot. The two biggest advantages of this algorithm are (1) it is completely free from human picking errors and thus is perfect for automatic analysis, and (2) it maps out the geometric configuration of the finite source rather than just outputs a single point in the model space. Control tests using synthetic waveform data indicate that this algorithm is robust even under a high level of background noise. We apply this algorithm to a local earthquake (Mw 4.3) in the northern Cascadia subduction zone. The scanned image shows a vertical rupture plane striking E-W, consistent with one of the nodal planes determined from moment-tensor inversion of regional broadband waveforms. The point with the maximum brightness is remarkably close to the hypocenters determined by conventional earthquake location methods. Application of this algorithm to the tremor activity of the latest Episodic Tremor and Slip (ETS) event beneath the southern Vancouver Island indicates that the ETS tremors have east-dipping sources located in the vicinity of the inferred plate interface.

S21D-0338 0830h POSTER

Using Waveform Cross-correlation to Detect and Identify Regional Seismic Phases Based on a Reference Event Set

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It is widely observed that earthquakes and mining blasts occurring very close to each other can share very similar waveforms. An adaptive waveform cross-correlation automated phase detection method based on a reference event set of waveforms and picks has been developed and applied to process daily seismicity in New Mexico. This method can produce robust initial seismic phase estimates while greatly improving the handling of false triggers due to telemetry or other transient noise. 72 well-picked earthquakes and mining explosions in New Mexico during 1997-2003 were collected as an initial reference event set covering most historically active source regions. Each waveform in the reference event set has a high signal to noise ratio and accurately-picked P and S phases. All waveforms are converted to analytic time series envelopes before processing in order to increase the signal to noise ratio. If a new earthquake or mining blast occurs, it has a high probability of occurring close to a reference event. New event waveforms are compared to reference waveforms across all available stations using envelope cross-correlation. If the cross-correlation coefficient is sufficiently large, the phases of the most similar waveform in the reference set are assigned to the lag-aligned unknown waveform as initial picks for subsequent refinement. If cross-correlation coefficients are low, the new waveforms are either from a noise event or possibly from a seismic event occurring in a new source region. New source region events can readily be added to the reference event set following identification and picking. The NMT-SC network real-time data acquisition system, using the EarthWorm STA/LTA pick_ew/binde_rew modules, identifies hundreds of events per month, and most of them are noise transients. We have recently integrated this waveform cross-correlation phase detection and classification method into the Earthworm data flow and into Matseis (a Matlab-based analysis package developed at Sandia National Laboratories). The method makes adaptive use of evolving earthquake catalogues of waveforms and phases, improves the handling of false triggers, and increases the accuracy of initial P and S phases picking and automatic location and event classification.

S21D-0339 0830h POSTER

Automatic picker of P & S first arrivals and robust event locator

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We report on further development of automatic all distances location procedure designed for a regional network. The procedure generalizes the previous "loca l" (R < 500 km) and "regional" (500 < R < 2000 km) routines and comprises: a) preliminary data processing (filtering and de-spiking), b) phase identificatio n, c) P, S first arrival picking, d) preliminary location and e) robust grid-search optimization procedure. Innovations concern phase identification, automa tic picking and teleseismic location. A platform free flexible Java interface was recently created, allowing easy parameter tuning and on/off switching to t he full-scale manual picking mode. Identification of the regional P and S phase is provided by choosing between the two largest peaks in the envelope curve. For automatic on-time estimation we utilize now ratio of two STAs, calculated in two consecutive and equal time windows (instead of previously used Akike Information Criterion). "Teleseismic " location is split in two stages: preliminary and final one. The preliminary part estimates azimuth and apparent velocity by fitting a plane wave to the P automatic pickings. The apparent velocity criterion is used to decide about strategy of the following computations: teleseismic or regional. The preliminary estimates of azimuth and apparent velocity provide starting value for the final teleseismic and regional location. Apparent velocity is used to get first a pproximation distance to the source on the basis of the P, Pn, Pg travel-timetables. The distance estimate together with the preliminary azimuth estimate provides first approximations of the source latitude and longitude via sine and cosine theorems formulated for the spherical triangle. Final location is based on robust grid-search optimization procedure, weighting the number of pickings that simultaneously fit the model travel times. The grid covers initial location and becomes finer while approaching true hypocenter. The target function is a sum of the bell-shaped characteristic functions, used to emphasize true pickings and eliminate outliers. The final solution is a grid point that provides maximum to the target function. The procedure was applied to a list of ML > 4 earthquakes recorded by the Israel Seismic Network (ISN) in the 1999-2002 time period. Most of them are badly constrained relative the network. However, the results of location with average normalized error relative bulletin solutions e=dr/R of 5% were obtained, in each of the distance ranges. The first version of the procedure was incorporated in the national Early Warning System in 2001. Recently, we started to send automatic Early Warn ing reports, to the EMSC Real Time Bulletin. Initially reported some teleseismic location discrepancies have been eliminated by introduction of station corrections.

S21D-0340 0830h POSTER

How to pick depth phases

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Determining accurate hypocenter depth is scientifically challenging and is important because it is a useful discriminant between nuclear explosions and earthquakes. Shallow events (depths < 50 km or so) are especially difficult to determine with accuracy if only teleseismic P arrivals are used. Depth phases, pP and sP can help greatly in that aspect. The effect of using depth phases is like adding a station directly above the hypocenter. Depth phases, however, are used infrequently by institutes monitoring global seismicity such as USGS, IDC, and USNDC. The problem may be due to a lack of clear guidance for depth phase picking for the seismic analysts. The purpose of this paper is to review theoretical properties of depth phases and illustrate with examples how to pick depth phases. With Gaussian beam modeling, it is found that the focal mechanism orientation plays a major role in deciding if a station is going to see depth phases or not. Based on the relative location (azimuth and distance) of the stations to the source and focal mechanism orientation, a station may see just P, or just P and pP, or P, pP, and sP, or just P and sP. Without the focal mechanism being available at the time of picking for location, the identification of depth phases becomes tricky. Many researchers have tried special data processing, such as cepstral analysis, on single station data to identify depth phases. Our study shows that depth phases are best identified with data from an entire network data under scrutiny. The paper will also address issues of double explosions designed to mimic depth phases and multiple earthquakes separated by a very short time interval.

S21D-0341 0830h POSTER

Relative propagation parameters and source locations of similar events using seismic antennas

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We introduce a method to accurately determine the relative propagation parameters (apparent slowness and propagation azimuth) of events with similar waveforms recorded on seismic antennas. This relative slowness estimate (RelSE) method is based on precise measurements of the differences among arrival times of different earthquakes to the receivers of the antenna. Delays are determined using interpolations of the cross-correlations of the seismograms. Given the resemblance of waveforms, this method allows for an accuracy higher than the sampling rate. We apply the RelSE method to a multiplet composed of sixteen similar earthquakes recorded during the 1999 seismic crisis at Deception Island volcano, Antarctica. Relative apparent slowness vectors are determined for the P-wave onset. Results show that the slowness vectors are closely distributed in a narrow, north-south trending band on the apparent slowness space centered at about 0.27 s/km and 245°N. We estimate the source locations of these events using the S-P delays and an inverse ray-tracing procedure through a velocity model. The obtained solutions define two plane structures that can be regarded as the fractures originating the recorded earthquakes. We conclude that the RelSE method, combined with other source location techniques, may be very useful for the analysis of microearthquake series recorded on seismic antennas. Furthermore, it is well suited for the analysis of long-period seismicity in the field of volcano seismology.

S21E MCC: Level 1 Tuesday 0830h

Theories of Earth's Interior V Posters

(joint with T, V)

Presiding: **F J Simons,** Princeton University**;** **D D Jackson,** University of California, Los Angeles

S21E-0342 0830h POSTER

Next-generation marine instruments to join plume debate

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Whether hot spot volcanism is the consequence of plate tectonics or has a deep origin in a mantle plume is debated. G. Foulger (Geol. Soc. London Lett. Online, accessed 9/3/2003), writes that *carefully truncated cross sections, with color scales cranked up, give noisy images the illusion of strong anomalies traversing the mantle.* **Don Anderson**, the *big daddy of non-plume hypotheses* (R. Kent, Geol. Soc. London Lett. Online, accessed 9/3/2003) has written that *the resolution of regional tomography experiments must be improved in order to successfully determine whether (...) the deep mantle is the controlling factor in the formation of proposed hot spots* (Keller et al., GRL 27 (24), 2000). In particular for Iceland, at issue is the inherently limited aperture of any land-based seismometer array on the island: *(...) the resolution of such images could be increased (...) by using ocean bottom seismometers (...) (ibidem).* These problems are not unique to the plume debate. Coverage, resolution and robustness of models of the wave speed distribution in the interior of the Earth obtained by seismic tomographic inversions are limited by the areal distribution of seismic stations. Two thirds of Earth's surface are virtually inaccessible to passive-source seismometry, save indeed for expensive ocean-bottom seismometers or moored hydrophones. Elsewhere at this meeting, Montelli *et al.* describe how an improved theoretical treatment of the generation and survival of travel-time anomalies and sophisticated parameterization techniques yield unprecedented resolution of the seismic expression of a variety of "plumes" coming from all depths within the mantle. On the other hand, the improved resolution required to settling the debate on the depth to the seismic origin of various hot spots will also result from the collection of previously inaccessable data. Here, we show our progress in the development of an independent hydroacoustical recording device mounted on SOLO floats. Our instrument is able to maintain a constant water column depth below the sound channel and will surface only periodically for position determination and satellite data communication. Using these low-cost, non-recovered floating sensors, the aperture of arrays mounted on oceanic islands can be increased manifold. Furthermore, adding such instruments to poorly instrumented areas will improve the resolution of deep

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Earth structure more dramatically than the addition of stations in already densely sampled continental areas. Our progress has been made in the design of intelligent algorithms for the automatic identification and discrimination of seismic phases that are expected to be recorded. We currently recognize teleseismic arrivals in the presence of local P, S, and T phases, ship and whale noise, and other contaminating factors such as airgunning. Our approach combines continuous time-domain processing, spectrogram analysis, and custom-made wavelet methods new to global seismology. The lifespan and cost of the instrument are critically dependent on its ability to limit its power consumption by using a minimum amount of processing steps. Hence, we pay particular attention to the numerical implementation and efficiency of our algorithms, which are shown to be accurate while approaching a theoretical limit of efficiency. We show examples on data from ridge-tethered hydrophones and expect preliminary results from a first test deployment in October.

S21E-0343 0830h POSTER

The Transition From Fault-Slip to Cataclastic Flow in Gypsum Under Hydrous and Dehydrating Conditions: An Experimental Investigation on the Faulting Process at Intermediate Depth

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It has been suggested that intermediate-depth earthquakes occur on reactivated preexisting faults that were created at shallow depth. Fluids released by dehydration of serpentinized rocks within the fault plane could build up pressures that act against the fault normal stress eventually promoting localized unstable slip. We performed conventional triaxial friction experiments on natural gypsum samples having saw-cut and surface-ground fault planes inclined by 37.5° to the vertical. At room temperature dry and wet samples were either strained up to 10 % at constant axial strain rates of 4×10^{-6} to 1×10^{-5} s^{-1} cycling the confining pressure or statically loaded varying the pore pressure. The maximum confining and pore pressures were 50 MPa. Argon and water were used as pore fluids for dry and wet samples respectively. At constant strain rate the samples showed stick-slip only up to 10 MPa (dry) and 15 MPa (wet) confining pressure. At static load the onset of stress drops occured below 10 MPa and 15 MPa effective pressure for undeformed dry and wet samples respectively, in agreement with Terzaghi's principle. At higher pressures the faults locked and deformation occurred through bulk cataclasis as if the samples were intact. A locked fault could not be reactivated by lowering the confining pressure. Instead, a secondary fault formed at approximately 30° to the vertical (dry) or bulk deformation continued (wet). Undrained static load experiments at 150 °C and 50 MPa confining pressure on initially dry samples showed that once dehydration started both un- and predeformed samples weakened drastically. Only the former samples showed stress drops, stick-slip upon subsequent straining and a visible offset of the two loading blocks. The predeformed samples did not show any secondary fault development. The transition from fault-slip to cataclastic flow is interpreted as the point where the shear stress necessary for frictional sliding becomes larger than the shear stress that corresponds to the yield strength of the samples. The inability to reactivate locked faults is interpreted to mean that such faults have become welded at high normal stress, increasing their slip resistance. Our results demonstrate that dehydration assisted unstable slip on preexisting faults is indeed possible. Although some of the observations might be particular to gypsum they also indicate that strong mechanical locking of the fault may continue to promote ductile flow unless new, more favourably oriented faults are formed either by leaking of fluid into the surrounding rock or a new, yet unknown process.

S21E-0344 0830h POSTER

Finding Order in Chaos: Complexity in the Career of Don L Anderson

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Don Anderson's career has been marked by a long standing interest in plate tectonics and the earth's interior. But from time to time, he has departed from these major themes to investigate related topics. For example, during the 1970's, he proposed several seminal ideas, such as the applicability of cracks and fracture theory to earthquakes, and the idea of accelerated plate tectonics. Although on the surface, these topics might seem quite disparate from mantle convection, seismic structure of the earth's interior, and thermodynamics of mineral phases, they nonetheless are now known to share common theoretical underpinnings. In particular, the concepts of nonlinear dynamical systems, complexity, chaos, and energy and fitness landscapes can be used to describe the evolution of all complex nonlinear systems. The principle of minimum free energy (maximum fitness) is frequently used to obtain Langevin-type equations for such systems, and ideas of statistical field theory are employed to obtain scaling exponents and other features. In this talk, we describe these ideas and relate them to the types of problems in which Don Anderson has been primarily interested.

S21E-0345 0830h POSTER

Modeling Shear Instabilities With Block Sliders: Brittle and Ductile

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Block slider-type models have been succesfully used for almost 35 years to describe the spatio-temporal development of shear instabilities in the brittle crust (Burridge & Knopoff, 1967; Olami et al., 1992). More recently, increasing attention is paid on the extension of the classical Burridge-Knopoff model (based on a pure Mohr-Coulomb rheology) with a viscous component, either to include depth-dependent properties into the model or aiming at a more accurate description of fore- and aftershock sequences of a main earthquake event (e.g. Hainzl et al., 1999). On the other hand, viscous feedback mechanisms of various types have become an increasingly attractive mechanism for the generation of intermediate-depth and deep-focus earthquakes in the ductile mantle lithosphere (e.g. Wiens & Snider, 2001). Heat generated during viscous deformation provides a positive feedback to creep and eventually faulting under high pressure (Karato et al., 2001, Bercovici & Karato, 2003). The present paper discusses the specific properties of block slider-type models that are extended with a viscous component and compare their behaviour with the pure brittle ("classical") case. Block slider-type models for ductile instabilities are numerically much less demanding than solutions based on the corresponding, thermal-mechanically coupled, continuum equations. They allow for the inclusion of possible non-equilibrium effects associated with mineral phase transformations in a subducting slab (kinetic overshoot, grainsize reduction, latent heat release) in a straightforward manner. They may therefore serve as an effective tool to study the coupling of viscous heating, temperature-dependent viscosity and brittle stress transfer that are thought to cause the specific spatial-temporal clustering of intermediate-depth and deep-focus eartquakes. References D. Bercovici and S. Karato "Theoretical Analysis of Shear Localization in the Lithosphere", in: Reviews in Mineralogy and Geochemistry 51, eds. S. Karato and H.-R. Wenk, Chapter 13 (2003) 387-421 R. Burridge and L. Knopoff "Model and theoretical seismicity", Bull. Seism. Soc. Am. 57 (1967) 341-371 S. Hainzl and G. Zöller and J. Kurths "Similar Power-Laws for Fore- and Aftershock Sequences in a Spring-Block Model for Earthquakes", J. Geophys. Res. 104 (1999) 7243-7253 S. Karato, M. R. Riedel, D. A. Yuen, "Rheological Structure and Deformation of Subducted Slabs in the Mantle Transition Zone: Implications for Mantle Circulation and Deep Earthquakes", Phys. Earth Planet. Inter. 127 (2001) 83-108 Z. Olami and H. J. S. Feder and K. Christensen "Self-organized criticality in a continuous, nonconservative cellular automaton modeling earthquakes", Phys. Rev. Lett. 68 (1992) 1244-1247 D. A. Wiens and N. O. Snider "Repeating Deep Earthquakes: Evidence for Fault Reactivation at Great Depth", Science 293 (2001) 1463-1466

S21E-0346 0830h POSTER

Largest Expected Magnitudes During Finite Time Intervals on California Faults

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We estimate the largest magnitude expected with a given probability in a given time interval, for individual faults in California. We refer to such a quake as the "Functional Evaluation Earthquake, and to its magnitude as MFEE. For selecting scenario earthquakes in engineering studies, our approach provides an alternative to the "maximum credible earthquake" magnitude, MMCE [Mualchin et al., Caltrans Technical Report, 1996]. We assume a truncated Gutenberg-Richter magnitude distribution. We estimate the upper magnitude limit MMCE for each fault segment from the Wells and Coppersmith [1994] empirical relation between magnitude and fault length. We combined fault slip rates from the USGS/CDMG and the CALTRANS fault databases to estimate tectonic moment rate for each fault. We then assume a uniform b-value (1.0) and determine the a-value, which matches the tectonic moment rate for each fault. By definition, the estimated MFEE is lower than MMCE. It depends on the magnitude-frequency distribution, assumed probability level (P), considered time interval (T), and indirectly on the upper magnitude limit. The a-value decreases as the MMCE increases, and for some cases, this causes the MFEE to decrease as well. We summed the magnitude distributions for all faults to obtain a theoretical magnitude distribution for California. This distribution forecasts a significantly higher rate than reported in the Toppozada [2000] catalogue for earthquakes in the magnitude range 6-7. The same discrepancy occurred in the SCEC Phase II model, the 1996 CDMG/USGS hazard model, and others in which the maximum earthquakes size is assumed limited by fault length or area. A better fit would require significantly lower coupling (0.6 to 0.7) and substantially larger MMCE. For example, the theory and observations would agree well if the MMCE for each fault were increased by more than half a unit, or if the MMCE had a uniform value 8 and the coupling coefficient were 0.6. To consider possible effects due to large uncertainties in geologically determined fault slip rates, we are now using optimized estimates of fault slip rate to improve our estimation of MFEE. We estimate optimal slip rates for all faults in California from kinematic modeling (by finite elements) and including geologic slip rates, GPS measurements, and most compressive stress directions. Our final goal is to construct contour maps of MFEE for various P, T in California, compare with other seismic hazard approaches (geodesy, past seismicity), and test our prediction against future earthquakes.

S21E-0347 0830h POSTER

A Fluid–Injection Triggered Earthquake Sequence in Ashtabula, Ohio: Implications for Seismogenesis and Hazard in Stable Continental Regions (SCR)

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A persistent earthquake sequence in northeast Ohio includes many distinct fore–main–aftershock sub–sequences, illuminates two faults, and was triggered by fluid injection. The first known earthquake from within 30 km of Ashtabula was an mb(Lg) 3.8 mainshock that shook the downtown area in 1987. Seismicity has continued at an average of about one felt event per year. The largest magnitude so far, mb(Lg) 4.3, caused slight damage (MMI VI) 26 Jan. 2001. The latest subsequence started July 2003 with mb(Lg) 2.6. Accurate hypocenters and focal mechanisms are available from three local seismograph deployments in 1987, 2001, 2003 and from regional broadband seismograms. These hypocenters are in the Precambrian basement, 0–2 km below the 1.8 km deep Paleozoic unconformity, and illuminate two distinct planar E-W striking sources zones 4 km apart, one in 1987 about 1.5 km long, the other in 2001 and 2003 about 5 km long. We interpret them as steep sub–parallel faults slipping left–laterally in the current regime. Like many of the faults that ruptured in hazardous SCR earthquakes, these faults were previously unknown and probably have small post–Precambrian displacements. The 1987 source was active a year after onset of class 1 fluid injection only 0.7 km north of the fault. The second fault, 5 km south of the injection well, became active in 2000, while the 1987 source was inactive. The well injected about 164 m^3/day of waste fluid into the 1.8 km-deep basal sandstone with about 100 bars of well head pressure from May 1986 to June 1994. An annular high pore–pressure anomaly is expected to expand along this hydraulically

confined horizon at the top of the basement even after injection ends and pressure drops near the well. Over 16 years, seismicity has shifted southward from ∼1 to 5–8 km from the point of injection. It seems to initiate when and where a significant pore pressure rise intersects pre–existing faults close to failure and to be turned off when pressure starts dropping back. The largest earthquakes postdated the end of injection at both Ashtabula and at the Rocky Mountain Arsenal near Denver, Colorado. Anthropogenic earthquake hazard may thus persist after the causative activity has ceased but can generally be closely monitored. High–stress and low strain rates in the eastern US and other SCRs can account for a larger proportion of triggered earthquakes in these regions than in active ones. Unlike hazard from natural SCR earthquakes, hazard from potential sources of anthropogenic earthquakes could generally be precisely identified in time and space. Anthropogenic triggering may have raised significantly the overall level of SCR seismicity during the last half century. Models that assume constant seismicity through the historic period may thus underestimate the overall hazard.

S21E-0348 0830h POSTER

The Relation of the Grenville/Appalachian Boundary to the April 20, 2002 Au Sable Forks, New York and the April 29, 2003 Fort Payne, Alabama Earthquakes

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On April 20, 2002, an M=5.1 earthquake occurred near Au Sable Forks, New York at 10:50AM UTC (6:50AM locally). The significance of this event is twofold: first, such moderate earthquakes are relatively rare in this part of the North American continent, and second, the structure of the crust is well-known here because a major seismic investigation [Musacchio et al., 1997] took place before the Au Sable Forks event. That seismic survey derived detailed information about the deep subsurface, including the Champlain thrust fault, which was possibly the causative fault for this earthquake. The Champlain fault marks the local boundary between the Grenville and the Appalachian Provinces. On April 29, 2003 another event (M=4.6) occurred along the province boundary, this time in Fort Payne, Alabama. This second event is believed to have occurred on a nearly-vertical strike-slip fault. These two earthquakes are examples of the kind of temblors that the Grenville/Appalachian boundary is capable of producing, and we explore these events as they relate to seismic zones and background seismicity.

S21E-0349 0830h POSTER

Global finite-frequency surface-wave tomography

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We investigate finite-frequency effects in global surface-wave tomography. We compare two-dimensional phase-velocity maps inverted using ray theory and sensitivity kernels based on Born approximation. The same comparison is also made for three-dimensional upper mantle shear-wave velocity structures. The 3-D sensitivity kernels are computed using a fast kernel computation approach (Zhou et al, 2003). We incorporate the forward-scattering approximation, and take sidelobes fully into account when calculating the 2-D sensitivity kernels for phase-velocity perturbations.
The global phase-delay measurements used in this experiment has a frequency range from 3 mhz to 20 mhz (Laske & Masters, 1996). The same local parameterization (average grid spacing $\sim 4^\circ$) is applied in both the ray theoretical inversion and the finite-frequency kernel inversion. In general, inversions based on ray theory and finite-frequency sensitivity kernels show similar large-scale geographic pattern, both in the 2-D phase-velocity maps and the 3-D shear-wave structures. However, the difference is significant in the amplitude of the anomalies and in the small-scale structures. In 2-D phase-velocity maps, the difference becomes more apparent at long periods, due to the increasing width of the Fresnel zone. Theoretically, finite-frequency kernels are expected to converge to ray theory whenever the scale of the anomaly is much larger than the wavelength. However, due to limited path coverage in tomographic practice, inversions based on ray theory often introduce considerable artifacts in both the amplitudes and locations of the anomalies even when the real structure is large in scale.

S21E-0350 0830h POSTER

Theoretical And Numerical Investigations Of Seismic Anisotropy

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Azimuthally anisotropic Earth models have been determined from surface-wave dispersion measurements. Such anisotropic models have been compared to tectonic plate spreading directions and the associated mantle flow. To first order, the fractional surface-wave phase-speed perturbation $\epsilon = \delta c/c$ in an anisotropic Earth model may be written in the form of an even, degree-4 Fourier series: $\epsilon = \epsilon_0 + \epsilon_1 \cos 2\zeta + \epsilon_3 \sin 2\zeta + \epsilon_3 \cos 4\zeta + \epsilon_4 \sin 4\zeta$ where ζ denotes the local azimuth. We demonstrate that the associated compressional and shear body-wave speeds v are determined by equations of the form $\rho v^2 = \alpha_0 + \sum_{n=1}^{4} [a_n(i) \cos n\zeta + b_n(i) \sin n\zeta]$, where ζ denotes the local azimuth and i the local angle of incidence. Note that the azimuthal dependence is governed by a degree-4 Fourier series with even and odd terms. The coefficients $a_n(i)$ and $b_n(i)$, on the other hand, are an even, degree-4 Fourier series in the local angle angle of incidence i. Surface-wave anisotropy is governed by 13 independent elastic parameters, but body-wave anisotropy involves all 21 independent elements of the elastic tensor. We use the spectral-element method to simulate full waveforms of body- and surface-wave propagating in anisotropic Earth models, and use a phase-matched-filtering method and cross-correlation to measure the effects of the major elastic parameters on surface- and body-wave phase and arrival angles. We also derive explicit expressions for the phase and arrival angle anomalies using ray theory, whose predictions are compared to measurements from numerical simulations.

S21E-0351 0830h POSTER

Initiation of subduction by small-scale convection

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Initiation of subduction by small-scale convection is investigated with the help of Fowler's theory, numerical constraints on the lithospheric stresses generated by convection and direct numerical simulations of subduction. The derived scaling laws suggest that the critical yield stress for initiation of subduction by small-scale convection is of the order of 30 MPa. On the one hand, this value is at least one order of magnitude smaller than the estimates of the lithospheric strength suggested by laboratory experiments on dry rocks. This implies that initiation of subduction must be very problematic under conditions different from those existing on the present-day Earth which has plenty of water and globally occurring plate tectonics. On the other hand, the critical yield stress for initiation of subduction by small-scale convection is comparable with the critical yield stress for initiation of subduction by plate forces and with the estimates of stresses in the subduction zone. Thus small-scale convection can play an important role in the initiation of subduction on the present-day Earth.

S21E-0352 0830h POSTER

Mineralogical Models of Subduction Zone Tomography

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Subduction zones have long been recognized by their significant role in the Earth's dynamics and plate tectonics. Mantle seismicity and volcanoes highlight their importance. Seismic tomographic studies and thermal models have been built. Here we model the seismic velocity and density of subduction zones using different thermal profile models, mantle chemical composition models, laboratory phase diagrams, and elasticity data from previous studies. With these we calculate the velocity and density impact and the buoyancy in the subducting slab region. This allows us to understand the effect of different physical and chemical parameters on the distribution of mineral phases in this area. Two major discontinuities have been globally observed at average depths 410km and 660km respectively by seismic wave data study. The 410 discontinuity occurs at a shallower depth within the colder subducting slab compared to the warmer surrounding ambient mantle. This phenomenon agrees well with seismic models based on deep earthquake velocity observations (Krishna & Kaila, 1995). The generally known discontinuity at 660km is shifted deeper down to 700km in our model. Similar results were presented by previous seismology studies (Thirot et al., 1998). By considering different mantle chemical models, the P-wave velocity jump at 410km in the middle region of the subducting slab is considerably larger for a harzburgite composition than for a pyrolite one. We also find a significant signature of the ilmenite forming reaction within the slab.

S21E-0353 0830h POSTER

β–Phase Rheology of Olivine Using the α–β Transformation: Implications for Modelling Metastable Wedges

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Transformation kinetics determine the structure of the metastable wedge of low–pressure α–phase in cold subducting lithosphere; through it, they may influence deep focus earthquakes, and slab penetration into the lower mantle. Experiments in which single crystals are transformed show that rapid nucleation on the sample surface creates a thin rim of dense β–phase, which then grows into the α–phase core at a speed decreasing in time (Kubo *et al* 1998; Mosenfelder *et al* 2000). That time–dependence is inconsistent with analyses assuming isobaric, mechanically passive phases. We apply a growth model coupling interface kinetics to transformation–induced viscoelastic deformation within the rim (Morris 2002 *J. Mech. Phys. Solids*, **50**). The creep component of that deformation is taken to follow the Guyot–Dorn equation for creep by dislocation glide; the zero temperature flow stress σ_o and ratio $q = Q/RT_s$ of activation energy to the product of the gas constant and solidus temperature T_s are found empirically. Though existing data are fitted by the model with an error of less than 15%, they do not determine σ_o precisely, being consistent with a range of values from 15 to 30 GPa; allowable values of q range from 30–35. We use our model to suggest how experiments might be performed to narrow this range. Lastly, we use the model to argue that coupling of kinetics and transformation–induced strain must be included when modelling metastable wedges.

S21E-0354 0830h POSTER

The P-wave Velocity Structure Beneath East Asia

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Because of poor resolution in the upper mantle, the relationship between the lower mantle structure and recent tectonic processes beneath East Asia is not readily inferred from published P-velocity models. In order to improve the resolution of upper mantle structure beneath East Asia, we combine P-wave travel time data from the Annual Bulletin of Chinese Earthquakes (ABCE) with reprocessed International Seismologic Centre (ISC) data. To the 44 stations in China that report to ISC we thus add data from 105 stations that were previously unavailable. The combined station coverage is substantially denser and more uniform than that used in any previous tomographic study of this region. We recalculate the travel time residuals of ABCE relative to the hypocenter from the catalog by Engdahl et al (1998). We parameterize the upper-mantle structure beneath East Asia with an irregular grid with a grid size that is adapted to sampling density. This allows us to resolve the structure with scale length less than 70 km in regions of dense sampling. We use an a priori 3D crustal model to reduce the artificial mapping of the crustal structure into the upper mantle, which improves the accuracy of the images of upper mantle structure. Our tomographic inversions reveal high-velocity continental roots beneath several continental blocks in East Asia. Beneath the Ordos Plateau and Sichuan Basin the fast seismic velocities continue to at least 200 km depth. These areas are located near a topographic boundary with the Tibetan plateau and Cenozoic crustal thickening has not affected these areas. Beneath the Himalayas a high-velocity anomaly may be associated with the subduction of Indian lithospheric material. This structure is visible near the 410 km discontinuity and seems to be separated from the old sinking ocean slab in the

lower mantle. A large-scale high-velocity structure is observed beneath Yangtze Craton in mantle transition zone, which can possibly be explained by the ocean slabs subducted from different directions. In contrast, the low-velocity mantle structure is visible beneath the island of Hainan and south coast of China.

S21E-0355 0830h POSTER

Three-Dimensional Velocity Structure in Southern California from Teleseismic Surface Waves and Body Waves.

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Analysis of teleseismic waves generated by large earthquakes worldwide across the Southern California TriNet Seismic Broadband Array has yielded high quality measurements of both surface waves and body waves. Rayleigh waves and Love waves were previously analyzed using a spectral fitting technique (Tanimoto. and Prindle-Sheldrake, GRL 2002; Prindle-Sheldrake and Tanimoto, submitted to JGR), producing a three-dimensional S-wave velocity structure. Features in our velocity structure show some regional contrasts with respect to the starting model (SCEC 2.2), which has detailed crustal structure, but laterally homogeneous upper mantle structure. The most prominent of which is a postulated fast velocity anomaly located west of the Western Transverse Ranges that could be related to a rotated remnant plate from Farallon subduction. Analysis indicates that, while Rayleigh wave data are mostly sensitive to mantle structure, Love wave data require some modifications of crustal structure from SCEC 2.2 model. Recent advances in our velocity structure focus on accommodation of finite frequency effect, and the addition of body waves to the data. Thus far, 118 events have been analyzed for body waves. A simple geometrical approach is used to represent the finite frequency effect in phase velocity maps. Due to concerns that, for seismic phases between 10-100 seconds, structure away from the ray theoretical is also sampled by a propagating surface wave, we have adopted a technique which examines a normal mode formula in its asymptotic limit (Tanimoto, GRL 2003 in press). An ellipse, based on both distance from source to receiver and wavelength, can be used to approximate the effect on the structure along the ray path and adjacent structure. Three models were tested in order to select the appropriate distribution within the ellipse; the first case gives equal weight to all blocks within the ellipse; case 2 incorporates a Gaussian function which falls off perpendicular to the ray path, allowing the amplitude to peak at the receiver; case 3 is the same as case 2, yet removes the effect of the peak at the receiver. A major improvement is that the locale under consideration has expanded due to the effect of ray paths spreading over a larger area than the ray theoretical. Comparison of the three techniques yields very similar results, and all techniques show an exceptional correlation to the ray theoretical phase velocity maps. After analyzing our data in terms of the finite frequency effect, we find that little change has occurred as a result of employing this technique other than expanding our region of study. P-wave measurements were obtained from the data set for 118 events. Preliminary results show systematic patterns. We have successfully measured 30 S-wave events which we plan to incorporate into our velocity structure. Our goal is to proceed with a joint inversion of P-waves, S-waves and Surface waves for a collective Southern California velocity structure.

URL: http://www.geol.ucsb.edu/projects/seismic

S21E-0356 0830h POSTER

Probing the nature of 410- and 660-km discontinuities beneath hotspots using the SS-precursors

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The seismic wave SS is accompanied by precursors resulting from underside reflections off the upper mantle discontinuities, most notably off the 410 and 660 km phase boundaries (S410S and S660S, respectively). These precursors potentially provide important seismic constraints on the depth, topography, and sharpness of upper mantle discontinuities, which translates to useful information on mantle dynamics, rheology, and composition; for instance, a thinned transition zone is expected in the vicinity of a hot plume, based upon the anti-correlation of the Clapeyron slopes at the 410- and 660-km discontinuities. In this work, we use the SS precursors to explore the regional seismic structure of 410- and 660-km discontinuities beneath major mantle hotspots (e.g. Iceland, Hawaii), by selecting station-earthquake geometries in the 100-160 degree distance range with SS bounce points at or near each hotspot. For example, we used over 500 broadband records (collected from the IRIS and the CNSN data centers) with bounce points located within several degrees of the Hawaiian hotspot to study the underlying discontinuity structure. We stacked data using a variety of geographical binning methods, and corrected the data for time perturbations predicted by tomographically derived mantle heterogeneity prior to stacking. S410S and S660S energy is detectable in some broadband stacks without low-pass filtering. We will present these data compared to finite-difference synthetics computed using axi-symmetric geometry, for models of upper mantle discontinuity perturbations, including predictions for discontinuity perturbations for upper versus whole mantle plumes.

S21E-0357 0830h POSTER

Compressional Wave Velocities in Fe-Ni-Si Melts to 1650°C: Contrasting Results Compared to Fe-Ni-S Melts

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Using high-precision high temperature ultrasonic interferometric techniques we have measured V_P in three molten Fe-Ni-Si alloys containing varying amounts of Fe (75-89 wt % Fe), 5 wt % Ni, and varying amounts of Si (6-20 wt %) in the temperature range $1190 - 1650^{\circ}$C and in the frequency range 9-13 MHz. The temperature dependencies of V_P for all the compositions are linear, and no dispersion is observed in the temperature and frequency ranges of the experiment. However, increasing amounts of Si cause a decrease in V_P and an increase in the (dV_P/dT) value. The results for the Fe-Ni-Si melts are also compared with those previously obtained for Fe, Fe-Ni and Fe-Ni-S melts. Whereas in the Fe-Ni-S melts, addition of S was observed to cause anomalous elastic behavior $(+dV_P/dT)$, the behavior in Fe-Ni-Si is normal. The results from these studies, although carried out at ambient pressure, may provide useful constraints on the composition of the Earth's outer core.

S21E-0358 0830h POSTER

Nanocrystalline inclusions of ilmenite and ilmenite with perovskite structure in olivine from an ilm.-ga.-peridotite, kimberlite pipe Udachnaya, Yakutia.

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Oriented olivine grains (010) from a mantle-derived xenolith from the kimberlite pipe Udachnaya have been studied by transmission electron microscopy (TEM). The host xenolith is an ilmenite-garnet peridotite with the mineral assemblage gt + ol + cpx + accessory ilm. The investigated olivine grains exhibit a typical grain size of about 1–2 mm. Crystallisation of the ilm-ga-peridotites occurred at 35-40 kbar and 1300-1400°C according to graphite pyrope facies conditions [1, 2]. The investigated olivine contains inhomogeneously distributed nanometer sized inclusions of ilmenite always intergrown with a small lamella of magnetite. The grain size of ilmenite is in the range of 50-70 nm and the magnetite lamella is about 10-20 nm thick. The orientation relationship between olivine-ilmenite and magnetite is given by: [010]ol // [112]mgt // [1-210]ilm (00-1)ol // (11-1)mgt // (000-1)ilm A second type of inclusions has the chemical composition of ilmenite, however, the electron diffraction pattern suggests a different structure, that of perovskite. The diffraction pattern can only be indexed assuming a monoclinic perovskite structure with doubled ao lattice spacing. The doubled ao spacing is present in the diffraction pattern as additional weak reflections with 1.1 nm spacing, equivalent with 2ao. The orientation relationship between ilmenite with perovskite structure and olivine is given by: [010]ol // [0-10]perovskite (10-1)ol // (100)perovskite It is suggested that in a first step Fe-rich ilmenite with monoclinic perovskite structure exsolved from olivine. The high Fe concentration causes the monoclinic distortion of the lattice. During uplift the perovskite structure is transformed into the ilmenite structure exsolving the excess iron as a small platelet of magnetite. [1] Lazzko E.E. (1979) Nedra, Moscow, 192 pp (in Russian.[2] Sobolev, V.S., Dobretsov,N.L.,Sobolev, N.V. (1972) Classification of deep seated xenoliths and the type of the upper mantle. Geol. Geophys. N12, 37-42 in Russian)

S21E-0359 0830h POSTER

Correlation Length Scales of Isotopic Variations Along Mid-Ocean Ridges and Upper Mantle Dynamics

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How isotopic variations in basalts erupted at the Earth's surface are linked to convective mixing in the underlying mantle is a central problem in geodynamics. The objective of this study is to quantify the length scales of upper mantle heterogeneity through spatial statistical analysis of MORB. We define a characteristic length scale, the scale of segregation L, computed from the spatial self-correlations for $^{3}He/^{4}He$, $^{87}Sr/^{86}Sr$, $^{143}Nd/^{144}Nd$ and $^{206,207,208}Pb/^{204}Pb$ in "zero age" lavas from mid-ocean ridges. Our working hypothesis is that small scale convection in the upper mantle controls dispersion of geochemical tracers. Differences in L between ocean basins may then be quantitatively related to unsteadiness in this convection, due to thickening of the lithosphere, plume impingement, or lateral temperature/compositional differences between continental and oceanic lithosphere induced by batholith formation. The correlation coefficient R, and the separation distance r, are calculated for every i,j pair of points. $R_{i,j}$ is given by the product of the deviations in isotope composition from the population mean, normalized to the population variance, and R(r) is computed as an ensemble average. The total number of point pairs (N) for n sample locations is given by N=n(n-1)/2. For the global MORB data set (n=1265 and 735 for Sr and He, respectively), N exceeds 10^5 (799480 and 269745, respectively). A value of R(r) close to 1 indicates that an isotope ratio above (or below) the population average is likely to be associated with an above (or below) average value at a distance r away. A value of R(r) close to zero implies a random relationship, and a value close to -1 implies an anti-correlation. R(r) approaches unity at small r by definition, as points close together are from the same "clump" of mantle. The value of r at which R first goes to zero is denoted as r*. On a diagram of R(r) vs. r (the correlogram), the integral of R(r) from r=0 to r=r* is the scale of segregation L, a characteristic length related to "clump" size. Within the Earth's interior compositionally distinct regions may vary in size and shape and their boundaries may be diffuse. Lithosphere recycling at subduction zones and plume input from the lower mantle or transition zone are two ways by which compositionally distinct materials are introduced to the upper mantle. We use the L concept because it is a quantitative estimate of size which is precisely defined from spatially referenced geochemical data. Only a narrow range of L values is found within each ocean basin. In general, the isotope tracers have L values between 350-750 km for the N Atlantic, S Atlantic. and Indian Oceans. For the Pacific Ocean, L appears to be significantly less, between 100-180 km, indicating that mantle clumps in this region are smaller, in agreement with inferences based on the standard (non-spatial) statistical approach. Our results provide supporting evidence that dispersion of isotopic anomalies in the upper mantle is primarily controlled by small-scale convection. On a geological time scale, mantle flow is certainly unsteady. Small-scale convective cells, having their long axes aligned subparallel to the plate scale flow, are one simple manifestation of this unsteadiness. In Rayleigh-Bénard convection, the amplitude and frequency of cellular wobble controls the extent of lateral mass transport (dispersion) between convective cells. Based on the spatial self-correlation of isotopic tracers, this dispersion ap-

pears to be more efficient in the Pacific upper mantle than elsewhere.

S21E-0360 0830h POSTER

Origin of Upper Mantle Mid-Ocean Ridge Basalt Source Isotope Signatures: Hafnium and Lead Isotope Constraints

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The origins of the geochemical heterogeneity of the upper mantle are fundamental constraints for mantle dynamics. An important requirement to understanding the composition and origin of mantle plumes is a knowledge of the extent and origin of MORB source heterogeneity. The Australian-Antarctic Discordance is a geochemical boundary between Indian-type and Pacific-type upper mantle provinces that is unaffected by plume-ridge interaction. The juxtaposition of the two distinct mantle domains makes this an excellent location to explore and contrast the nature and extent of upper mantle geochemical heterogeneity. Indian and Pacific Ocean MORB define two distinct bisecting arrays in a diagram of $^{206}Pb/^{204}Pb$ versus ϵHf. Basalts with ultra-depleted trace element signatures (e.g., low La/Sm) from the Indian side of the boundary represent one end-member of the Indian MORB array. These Indian ultra-depleted MORB have a unique isotope signature, with very high ϵHf and ϵNd and low $^{206}Pb/^{204}Pb$. Similarly, ultra-depleted Pacific EPR-MORB define one end-member of the Pacific MORB array. Although these Pacific ultra-depleted MORB have very similar ϵNd and $^{206}Pb/^{204}Pb$ to the ultra-depleted Indian-type, they have significantly lower $^{87}Sr/^{86}Sr$, ϵHf and $^{207}Pb/^{204}Pb$ and $^{208}Pb/^{204}Pb$ (for a given $^{206}Pb/^{204}Pb$). All of these ultra-depleted MORB may represent re-melting of a heterogeneous source that previously supplied MORB melt to the adjacent mid-ocean ridges. The divergence of the isotope signatures of Indian- and Pacific-type MORB, including the ultra-depleted basalts, requires long-term differences in Rb/Sr, U/Pb, Th/Pb, Sm/Nd, and Lu/Hf parent-daughter ratios. The isotopic contrasts could be explained by different source compositions and/or ages of origin. Alternatively, the crossing quasi-linear isotopic trajectories are consistent with different pollution mechanisms of the upper mantle by recycled components. The Indian-type isotope signature may result from delamination and stirring of garnet facies continental material during rifting, while the Pacific-type may originate from processes associated with slab subduction, or by pollution with plumes containing recycled slab material.

S21E-0361 0830h POSTER

The Effect of Iron Content on the High-Pressure Elasticity of Olivine: Implications for Chemical Heterogeneities in the Upper Mantle

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Olivine is a major component in mineralogical models for the Earth's upper mantle (Ringwood, 1975; Duffy and Anderson, 1989). The thermo-elastic properties of olivines with compositions between Mg_2SiO_4 and $(Mg_{0.8}Fe_{0.2})_2SiO_4$ have been the subject of extensive study, but this compositional range is too limited to reliably constrain the effect of Fe - Mg substitution on the elastic properties. The combined effect of Fe - Mg substitution in olivine and garnets is probably the most important factor to connect detectable seismic anomalies to chemical heterogeneities in the upper mantle. In the tectosphere model of Jordan (1978), Fe-depletion as a result of basaltic melt extraction from peridotite plays an important role in stabilizing the continental lithosphere. However, the effect of Fe - Mg substitution on seismic wave velocities is not well constrained at high pressures (e.g., Karato and Karki, 2001). In order to better understand how pressure influences compositional effects, we have determined the single-crystal elastic constants of natural Fe-rich olivine $(Fe_{0.94}Mn_{0.06})_2SiO_4$ by Brillouin scattering to 12.1 GPa at ambient temperature. The aggregate bulk modulus, shear modulus and their pressure derivatives are: K_{0S} = 136.3 (2) GPa, G_0 = 51.2 (2) GPa, $\partial K_{0S}/\partial P$ = 4.9 (1), $\partial G_0/\partial P$ = 1.8 (1), $\partial^2 G_0/\partial P^2$ = -0.11 (1) GPa^{-1}. These results greatly improve our knowledge of the high-pressure elastic properties of fayalite, which was previously based on limited ultrasonic data and on static compression experiments often performed under non-hydrostatic conditions. Our results also show a strong compositional effect on the pressure dependence of the bulk modulus of olivine, which increases 17% from forsterite ($\partial K_{0S}/\partial P$ = 4.2) to fayalite ($\partial K_{0S}/\partial P$ = 4.9). Changes in Fe content can have large effects on seismic velocities. For example, an increment in Fe content from 10 mol% to 20 mol% would produce a 2.4% decrease of compressional velocity and 3.8% decrease of shear velocity in olivine at a pressure of 5 GPa along the 1673 K adiabat. The scaling coefficient for shear velocity as a function of Fe content, $\partial lnV_S/\partial \chi_{Fe}$ is found to be -0.39 at ambient conditions and to decrease in magnitude by 10% at 8 GPa. These results differ by as much as 20% from the earlier estimate of Karato and Karki (2001).

S21E-0362 0830h POSTER

Viscosity of silica-rich water at high pressure and temperature

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Water released from subducting slabs into the mantle wedge due to pressure-induced dehydration reactions will contain small amounts of dissolved oxides. These fluids are ultimately responsible for magma generation above the slab resulting in arc volcanism. The viscosity of this super-critical fluid will affect the rate of mass transport into the overlying mantle. Small particles ($\sim$1 micron) in a fluid exhibit Brownian motion. The slope of the mean square displacement versus time is inversely proportional to the fluid viscosity. Three minutes of videotape data, digitized at 7 pixels per micron, allows for viscosity measurements with a precision of 0.5 log units for fluids with viscosities between 1 and 10^{-5} Pa-s. Particles observed in the hydrothermal diamond anvil cell can then provide constraints on viscosities for transparent fluids at high pressures (up to 5 GPa) and temperatures (up to 1300 K), a range ideal for the study of fluids released from a subducting slab. Observed Brownian motion of tracer particles in silica-saturated water shows that 4 wt% dissolved silica (saturation at 1 GPa and 950 K) has the effect of increasing the fluid viscosity relative to that of pure water by a factor of 1000. Fluids released at 100 km through dehydration reactions contain up to 8 wt% silica. Pressure and concentration induced interconnectivity of silica tetrahedra in the fluid should further increase the viscosity of the fluid. Therefore, a continuum of behavior between fluid and melt is expected in the metasomatized mantle wedge despite the supercritical nature of the water.

S21E-0363 0830h POSTER

The Effect of Critical Points in Radiative Thermal Conductivity (With Grain Size and Temperature) on the Transition Zone and Lower Mantle

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When temperature (T) exceeds 2000 K inside the Earth, transfer of heat by diffusion of photons is important. However, the effective thermal conductivity (k_{rad}) associated with this process does not follow a T^3 law. The dependence of scattering and emission spectra on grain size (d), and the non-linear dependence of absorption and emission spectra on frequency, result in a complex dependence of k_{rad} on T and d. Specifically, for large grains, k_{rad} rises to a local maximum near 1300 K, followed by a local minimum near 2000 K, followed by a gentle rise towards high temperature. For small grains, k_{rad} depends quadratically on T. Above 2000 K, k_{rad} is largest for d near 1 mm. Irrespective of possible grain sizes, k_{rad} has a minimum for the temperatures expected near 670 km: this critical point must impact convection above 670 km, as negative dk/dT iis destabilizing. The effect of a critical point in the transition zone on mantle convection is being investigated through geodynamic models. Below 670 km, radiative transport dominates over phonon scattering and is stabilizing. To compare the relative importance of k_{rad} to that of viscosity, numerical simulations were made of constant k or of k_{rad} strongly depending on T, each with a range of lateral viscosity contrasts due to T spanning from 10^2 to 10^6. The lower bound is characteristic of what is expected in the lower mantle due to the high background temperature in the Arrhenius argument of the viscosity. We found that krad exerts greater control. In particular, for the low viscosity contrast and high krad expected for the lower mantle, convection is substantially weakened. Based on this result, we interpret the low heterogeneity inferred from the tomographic images of the middle of lower mantle as the signature of a stagnant layer.

S21E-0364 0830h POSTER

Comparison of gold and MgO pressure scales at 22-56 GPa and 300-1150 K and its implications for mantle models

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Recent developments in mineral physics enable in-situ measurements of the phase boundaries and the equations of state of the mantle minerals. Nevertheless, existing experiments for the post-spinel transition in Mg_2SiO_4 show a discrepancy (2 GPa, 60 km) with the seismologically inferred depth of the boundary. Inconsistencies in the pressure scales at high temperature may be responsible for much of the discrepancy. We investigated the consistency of the gold (Jamieson et al. 1982, Shim et al. 2002, Heinz et al. 1984, and O.L. Anderson et al. 1989) and MgO (Speziale et al. 2001) scales through in-situ measurements using resistant heated diamond cells at 22-56 GPa and 300-1150 K. Angle-dispersive X-ray diffraction was performed for gold+MgO mixtures in a neon medium at the GSECARS sector of APS. Above 900 K and below 27 GPa, both Jamieson's and Shim's gold scales are consistent with the MgO scale within 0.5 GPa, whereas O.L. Anderson's gold scale underestimates pressure significantly (1 GPa) compared with the MgO scale. A greater magnitude of discrepancy is found above 30 GPa: 300 K isotherms for gold are discrepant by 1 GPa with the isotherm for MgO. In addition, thermal pressure calculated from the gold scales is systematically smaller than that from the MgO scale by 3 GPa. Possible reasons for the discrepancies at high temperature are: (1) electronic and anharmonic contributions, (2) different equations of state used, and (3) differential stress in the samples. Because of their consistency and use of higher quality data over a wide P-T range, it is legitimate to use Speziale's MgO and Shim's gold scales at 20-30 GPa and above 1000 K. When these scales are used, the earlier in-situ study for the post-spinel boundary becomes consistent within 1 GPa with the 660-km discontinuity. One of the most important studies (e.g., Funamori et al. 1998) for thermal equation of state of $(Mg,Fe)SiO_3$ perovskite is calibrated with Anderson's gold scale. The use of Shim's gold and Speziale's MgO scales tends to increase the Gruneisen parameter of the Mg-perovskite in the lower mantle.

S21E-0365 0830h POSTER

The Effect of Al on the Compressibility of Silicate Perovskite

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Experimental data on compressibility of aluminous silicate perovskite show widely disparate results. Several studies show that Al causes a dramatic increase in compressibility[1−3], while another study indicates a mild decrease in compressibility[4]. Here we report new results for the effect of Al on the room-temperature compressibility of perovskite using in situ X-ray diffraction in the diamond anvil cell from 30 to 100 GPa. We studied compressibility of perovskite in the system $MgSiO_3$-Al_2O_3 in compositions with 0 to 25 mol% Al. Perovskite was synthesized from starting glasses using laser-heating in the DAC, with KBr as a pressure medium. Diffraction patterns were obtained using monochromatic radiation and an imaging plate detector at beamline BL10XU, SPring8, Japan. Addition of Al into the perovskite structure causes systematic increases in orthorhombic distortion and unit cell volume at ambient conditions (V_0). Compression of the perovskite unit cell is anisotropic, with the a axis about 25% and 3% more compressive than the b and c axes, respectively. The magnitude of orthorhombic distortion increases with pressure, but aluminous perovskite remains stable to at least 100 GPa. Our results show that Al causes only a mild increase in compressibility, with the bulk modulus (K_0) decreasing at a rate of 0.7 GPa/0.01 X_{Al}. This increase in compressibility is consistent with recent ab initio calculations if Al mixes into both the 6- and 8-coordinated sites by coupled substitution[5], where 2 Al^{3+} = Mg^{2+} + Si^{4+}. Our results together with those of [4] indicate that this substitution mechanism predominates throughout the lower mantle. Previous mineralogic models indicating the upper and lower mantle are compositionally similar in terms of major elements remain effectively unchanged because solution of 5 mol% Al into perovskite has a minor effect on density. 1. Zhang & Weidner (1999). Science 284, 782-784. 2. Kubo et al. (2000) Proc. Jap. Acad. 76B, 103-107. 3. Daniel et al. (2001). Geophy. Res. Lett. 28, 3789-3792. 4. Andrault et al. (2001). Earth Planet. Sci. Lett. 193, 501-508. 5. Brodholt (2000). Nature 407, 620-622.

S21E-0366 0830h POSTER

P-V-T Equation of State of Al-bearing Silicate Perovskite and its Implications for Mantle Composition Models

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Accurate measurements of P-V-T equations-of-state of mantle minerals are of fundamental importance for developing compositional and mineralogical models of the Earth's interior. Recent studies on Al-bearing silicate perovskites reported significantly different bulk moduli for Al-bearing perovskites. The discrepancy among the measured bulk moduli for the Al-bearing perovskite may be related to its defect chemistry and the substitution mechanism of Al in $MgSiO_3$ perovskite. In this study, we report new compression data on Al-bearing perovskites up to 65 GPa. The experiments were performed at the GSECARS 13-ID-D beamline (Advanced Photon Source), using monochromatic X-radiation and a CCD area detector. The Al-bearing perovskite starting materials were synthesized in a multi-anvil apparatus at 27 GPa and 2023 K. The synthesized perovsites mixed with Pt powder were compressed to 65 GPa in an externally-heated diamond anvil cell with neon or NaCl as the pressure medium. The samples were annealed in the stability field of perovskite by laser heating. The experiments were designed to examine the compression behavior of Al-bearing perovskites synthesized in the multi-anvil apparatus and re-synthesized by laser-heating in the diamond anvil cell. The results provide direct observations to address the effect of defect structure on the unit cell parameters at high pressures. In addition to the room-temperature compression data, we also obtained isothermal compression curves for Al-bearing perovskite at 700, 800, 900, and 1000 K. The data were used to establish a reliable thermal equation of state for Al-bearing silicate perovskite, which is critical for modeling the density profile of the lower mantle.

S21E-0367 0830h POSTER

The Pressure and Compositional Dependence of the Shear modulus of Magnesiowustite

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One-dimensional seismic Earth models such as the PREM show discontinuous jumps of about 4.5% in compressional velocity, 6.3% in shear velocity, and 8.8% in density at 670km depth. At the pressure and temperature appropriate for this depth, (Mg,Fe)2SiO4 spinel (ringwoodite) dissociates into (Mg,Fe)SiO3 in the orthorhombic perovskite structure and magnesiowustite (Mg,Fe)O. All three phases are solid solutions between magnesium and iron end-members, and their properties are a function of pressure, temperature, and iron content. The discussion of whether or not the mantle is chemically stratified, involves matching compressional and shear velocities, and densities from seismic Earth models to mantle mineral assemblages. Magnesiowustite is presumed to be the second most abundant mineral in the lower mantle behind silicon-magnesium perovskite. It has no structural phase transitions throughout the silicate Earth. A series of experiments carried out at GeoSoilEnviroCARS Sector 13 of the Advanced Photon Source at the Argonne National Laboratory explored the shear properties of magnesiowustite as a function of pressure and iron content. Radial x-ray diffraction along with Singh's model for deviatoric strain was used to determine the full elastic tensor for (Mg25,Fe75)O, (Mg40,Fe60)O, (Mg60,Fe40)O, (Mg75,Fe25)O as a function of pressure to 50 GPa. The compositional dependence of the elastic tensor was determined from these combined experiments. The seismic equation of state is fitted to calculated bulk and shear moduli at room temperature. High temperature contributions to the elasticity of the end-member MgO are provided from ab initio calculations. The resulting compressional and shear velocities are extrapolated to the core-mantle boundary.

S21E-0368 0830h POSTER

The Elastic Constants of Monoclinic Diopside at High Temperature

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Knowledge of the elastic properties of all candidate mantle minerals and how these properties vary with temperature and pressure is required to accurately describe the composition and structure of Earth's upper and lower mantle. It is generally believed that the four dominant minerals of Earth's upper mantle are olivine, orthopyroxene, clinopyroxene, and pyrope garnet, even though different compositional models ascribe varying amounts of these four minerals to the upper mantle. Olivine has received the most experimental attention, in part, because it is considered by most investigators to be the most abundant mineral of Earth's upper mantle. Conversely, clinopyroxene has received relatively little experimental attention even though 15-25 percent of the upper mantle likely consists of a clinopyroxene component. Indeed, there are no available data on the temperature dependences of the elastic constants of any single-crystal monoclinic clinopyroxene material. New resonant ultrasound spectroscopy (RUS) data on the temperature dependences of elasticity for a high quality single-crystal diopside specimen are presented. We measured and identified 38 of the 62 lowest modal frequencies from room temperature to 1300 K in order to determine the 13 elastic constants of monoclinic diopside over that temperature range. The temperature dependences of the bulk and shear moduli of diopside, calculated from the single-crystal data, are also discussed and are compared with other pyroxene results.

S21E-0369 0830h POSTER

Extension of $(Mg_{0.64}Fe_{0.36})O$ Ferropericlase Equation of State Measurements to 25 GPa and 2173 K

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We present an updated equation of state (EOS) for $(Mg_{0.64}Fe_{0.36})O$ ferropericlase (FP), the most voluminous oxide in the Earth's lower mantle, based on a new set of PVT measurements. FP volumes were determined *in situ* in a multi-anvil apparatus, at pressures up to 25 GPa and temperatures up to 2173 K, with energy-dispersive X-ray diffraction at the SPring-8 synchrotron facility. Au and MgO were used as pressure markers. Including previous measurements by Fei et al. (PCM 1992) and Zhang and Kostak (PEPI 2002), 165 PVT points are now available for this material. Data were fitted to high-temperature Birch-Murnaghan and Mie-Grüneisen-type EOS. As an example of the attainable accuracy, our Birch-Murnaghan EOS reproduces experimental pressures for all 165 data points to within 0.28 GPa (1σ), with a maximum deviation of 0.8 GPa. The revised FP EOS is compared with recent EOS data for pure MgO, to assess possible variations in FP thermodynamic properties at lower mantle PT conditions as a function of FP iron content.

S21E-0370 0830h POSTER

Molding Electron Density at High Pressures: Chemical Bonding and Valence at Planetary-Interior Conditions

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Recognizing that terrestrial planets consist of a metallic core surrounded by an oxidized shell, we examine the oxidation state of minerals at the high pressures characteristic of planetary interiors. Ion valences are often considered fixed within a crystal of given composition, such that the stability of a mineral phase is determined through equilibration with surrounding gas species (e. g., as quantified by oxygen fugacity). One effect of pressure is to alter the nature of chemical

bonding, however, so we consider whether it is possible to change the valences of ions within a crystal merely through compression. ^{57}Fe Mössbauer spectroscopy shows that the electron density in magnetite is shifted from octahedral (B) to tetrahedral (A) sites with increasing pressure. This order - disorder transition, from inverse ($[Fe^{3+}]_A[Fe^{2.5+}Fe^{2.5+}]_BO_4$) to normal spinel ($[Fe^{2+}]A[Fe^{3+}Fe^{3+}]_BO_4$), occurs at 10 GPa at 300 K with no movement of ions. Iron in the octahedral and tetrahedral sites are respectively oxidized and reduced, without any chemical reaction with the surrounding medium. The samples were studied in a gasketed diamond-anvil cell over the pressure - temperature range 0-40 GPa and 80-410 K, and with Ar as a pressure medium. Oxidation and reduction need not be coupled, as demonstrated by experiments on $Fe^{2+}(OH)_2$, the iron analog of brucite. Mössbauer spectroscopy documents that the iron is oxidized upon compression, with 10-70 percent conversion of Fe^{2+} to Fe^{3+} as pressure is increased above 10-40 GPa at 300 K. In this process, an electron is liberated into the unit cell. X-ray diffraction at 300 K confirms that there is no structural change over this pressure range, but temperature-dependent measurements show a drop of 2.5 orders of magnitude in electrical resistance at 50 GPa with the sample going to a narrow-gap semiconducting state. Our experiments documenting pressure-induced internal oxidation demonstrate that such external variables as oxygen fugacity do not constrain ion valences within minerals. Instead, we propose that the chemical potential of the bonding electrons represents a more useful variable.

S21E-0371 0830h POSTER

Insights on the thermochemical state of the lower mantle

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The thermochemical state of the lower mantle is still a underdetermined problem. The increasing availability of first principles results on partitioning coefficients and thermoelastic properties is helping to reduce the number of independent unknowns and to improve the accuracy of predicted aggregate properties at pertinent conditions. In a first step, the information contained in seismic models should be interpreted in light of mineral physics results. In a second step, the outcome should be tested against constrained inferences and observables. We report here some steps taken in this direction. The procedure is based on a comparison between results from 1D seismic models and calculated thermoelastic properties of multi-component systems in thermal equilibrium. Presently the analysis is restricted primarily to systems with three components and two phases only ((Mg,Fe)O and (Mg,Fe)SiO3-perovskite) for which detailed first principles thermoelastic properties are available.

S21E-0372 0830h POSTER

Mineralogical and Chemical Models of Earth's Lower Mantle: Where are We Heading to?

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$(Mg,Fe,Al)(Al,Si)O_3$ perovskite and (Mg,Fe)O magnesiowüstite are the most important phases of the Earth's lower mantle. Knowledge of their elastic properties is essential to understand the mineralogy, chemical composition, and thermal structure of the lower mantle. A wealth of data available for the $MgSiO_3$ perovskite end-member and periclase MgO end-member provides a good starting point for understanding the mantle. However, in the mantle the chemistry of those compounds is certainly far more complex, and this may greatly affect the physical properties. Inferences concerning Earth's lower mantle will depend upon how accurately we can address the chemical composition dependency of perovskite's elasticity. At present, the properties of perovskite with realistic mantle compositions are highly uncertain. For example, it has been shown in recent years that knowing properties of aluminium-bearing silicate perovskite was essential for constraining the chemical and physical state of the deep Earth. To our knowledge, there is no information on the single-crystal elastic properties or aggregate sound velocities for Al and Fe-bearing $(Mg,Fe,Al)(Al,Si)O_3$-Pv. Most of what we know about the effects of Al and Fe in perovskite comes primarily from compression studies, and existing results are contradictory. In the same manner, recent experiments evidenced a spin transition in iron in magnesiowüstite $(Mg_{0.83}Fe_{0.17})O$ occurring in the 60-70 gigapascal pressure range, corresponding to depths of 2000 km in the Earth's lower mantle, and greatly affecting iron chemistry in magnesiowüstite and magnesium silicate perovskite and showing that composition itself is susceptible to drastically change with depth. This observation is compatible with seismically observed heterogeneities in the lower mantle. While bulk modulus (K) of perovskite or magnesiowüstite can be constrained by static compression experiments, this property constrains only the density and bulk sound velocity in the lower mantle. Information on the shear moduli (G) and acoustic velocities for these phases would allow a better interpretation of the seismic properties of the lower mantle, including average longitudinal and shear velocity structure, anisotropy, and heterogeneity, provided these properties can be measured as a function of composition. We will show that such data are within the reach of mineral physics, and offer fresh perspectives in our attempt to formulate a comprehensive theory of deep-Earth dynamics and composition.

S21E-0373 0830h POSTER

Exploring the effect of variable material properties at depth on deep mantle convection

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Recent experiments on perovskite at high pressures suggest that conductive and radiative thermal transport prosesses may be substantially more efficient near the base of the mantle than near the surface (Badro et al., Science, v. 300, 789-791, 2003.) Experiments suggest that mantle viscosities will increase substantially in the lower mantle if the mantle has an adiabatic thermal gradient. Although the magnitude of these effects in the mantle remains to be established, a large increase in thermal conductivity and viscosity with depth could slow the rate of heat and mass transfer due to mantle convection and help maintain long-lived geochemical reservoirs in the lower mantle. In the extreme case, heat transport by convection might be negligibly small. However, the increase in viscosity will be somewhat offset by a reduction in viscosity due to increased temperature. We explore the possible effects of a substantial increase in thermal conductivity and viscosity on mantle flow, using finite-element models of mantle convection with strongly depth-dependent and temperature-dependent material properties. Tracer particles are included in the model to determine whether isolated reservoirs can be maintained in the lower mantle in this scenario. Since the magnitude of any viscosity and conductivity increase is not well-established in the mantle, we examine a wide range of possible material properties. A higher thermal gradient in the lower mantle can explain the large super-adiabatic gradient required for the whole mantle by core-mantle temperature constraints.

S21E-0374 0830h POSTER

Viscosity and S-Wave Conversion Factor for the Earth's Mantle Based on CHAMP Gravity Data and New Tomography Models

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The viscosity structure and the internal buoyancy forces of the Earth's mantle are essential for understanding the convective flow pattern. These buoyancy forces are directly related to density inhomogeneities. With the use of seismic tomography it is possible to determine the seismic velocity distribution in the Earth - but the conversion factor between the seismic velocity and density is still not properly known. This is mainly due to uncertainties in the chemical cmposition of the mantle. If the origin of lateral heterogeneities in seismic wave velocity is purely thermal, the conversion factor should be around 0.2 to 0.4 as deduced from mineral physics. However, recent studies to relate mantle dynamics and gravity data reported even negative values for the conversion factor in the uppermost and lowermost mantle. For the uppermost mantle this finding has been explained by depletion in iron during partial melting. In the presented study the equation of motion is solved for an incompressible 6-layer shell model and the response function for geoid, dynamic topography, and (poloidal) surface velocity is determined. The internal load is derived from 4 different tomography models (sb4l18, Masters et al., 1999; s362d1, Gu et al., 2001; s20rts, Ritsema & van Heijst, 2000; saw24b16, Megnin & Romanowicz, 2000). In a large forward search we determined models with a correlation > .85 between the synthetic geoid and the CHAMP hydrostatic geoid for L<16 and correlation > .6 for gravity and surface velocity. The findings for the various tomographic models are quiet similar: If only the geoid fit is considered, successful models show a negative conversion factor between 100 and 300 km depth. However, if the fit to gravity and surface velocity is also taken into consideration, the conversion factor is small, but remains positive. In the deeper part of the mantle the conversion factor is reduced to values of about 0.1 between 700 and 1200 km depth, and otherwise roughly constant with values around 0.28. The viscosity is slightly reduced (compared to the scaling value of 10^{21} Pa s) in the asthenosphere and even stronger decreased in the mantle transition zone between 410 and 670 km where major changes in mineral geometry occur and the release of water was recently proposed in the upper part of the transition zone. Resolution for both, viscosity and conversion factor, is poor below the transition zone down to about 1500 km, but well confined in deeper parts of the mantle, where a viscosity between 30 to 40 10^{21} Pa s and a conversion factor of 0.28 to 0.32 is found.

S21E-0375 0830h POSTER

Transversely Isotropic D" shear velocity structure beneath Central America studied using waveform inversion

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We (Kawai et al., 2002) have developed the methodology and software for accurately and efficiently computing synthetic seismograms for transversely isotropic (TI) laterally homogeneous media using the Direct Solution Method (DSM). We apply these techniques to study the TI shear velocity structure in the D" shear region beneath Central America using waveform inversion. This region is of great interest because of the existence of the D" discontinuity (Lay & Helmberger 1983) and anisotropy (e.g., Kendall & Silver, 1996). The velocity structure has been studied by many research groups (e.g. Ding & Helmberger, 1997). Ding & Helmberger suggested an isotropic D" shear velocity structure model (SDH model), using the transverse component of broadband network seismograms in USA and Canada. However, they pointed out that the radial component data could not be explained by the SDH model, especially at epicentral distances > 85 degrees. We investigate the extent to which a TI shear velocity structure beneath Central America can explain both the radial- and transverse-component data.

URL: http://www.eps.s.u-tokyo.ac.jp

S

S21E-0376 0830h POSTER

Electronic spin state of iron in lower mantle perovskite

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Thirty years ago, Gaffney and Anderson (JGR 1973) were among the first to discuss the effect of low-spin iron on the lower mantle composition. Only during the past few years, breakthroughs in synchrotron X-ray technology allowed detection of low-spin iron under high pressures by using high-resolution X-ray emission spectroscopy. We present experimental evidence for a gradual electronic spin-pairing transition of iron in two perovskite samples over the lower mantle pressure range. Given the difference in the electronic structure of iron between the initial high-spin state and the intermediate spin state at 100 GPa, the observed spin-pairing transition would have significant influences on the physical properties and chemical differentiation of the deep interior of the Earth.

S21E-0377 0830h POSTER

New Experimental Evidence of "Low" Melting Temperatures of Iron

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There is still large disagreement in the properties of iron at core pressures derived from diamond cell experiments, shock compression, and theory. Theoretical estimates of the melting temperatures of iron show considerable disagreement and shock data are in disagreement with regards to the onset of melting and the question of a solid-solid transition near 200 GPa. There is, however, growing agreement on the melting temperatures among diamond cell groups using a variety of different methods to detect melting. In view of recent claims (1) that a possible hcp-bcc transition in iron could have been misinterpreted as melting, we present new evidence of melting at Megabar pressures. Visual observation of motion of molten iron is combined with the microscopic analysis of surface textures. The observed features cannot be explained by solid-solid transitions, clearly demonstrating that indeed melting temperatures were reported in the earlier diamond cell work. New high pressure X-ray measurements on laser-heated iron demonstrate a complex phase behavior which is most likely due to the small differences in the free energies of the various high pressure phases. 1) Belonoshko et al. (2003) Nature 424, 1032.

S21E-0378 0830h POSTER

An Andersonian Theory of Earth's Outer Core

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Conventional wisdom holds that the geodynamo operating in Earth's core is in a state of vigorous turbulent convective motion. This talk presents an alternative model in which the motions are vigorous but not turbulent. Turbulence in the outer core is inhibited by three independent effects. First, the Coriolis force inhibits motions which are not invariant in the direction of the rotation axis. Second, the Lorentz force quickly dampens motions which are not invariant in the direction of the magnetic field. Third, the conduction of heat down the (nearly) adiabatic temperature gradient causes material to cool as it descends, thereby becoming stably stratified. It follows that motions in the outer core must be directly driven, either by buoyant material rising from the inner core boundary (ICB) or dense material descending from the core-mantle boundary (CMB). It will be shown that the ICB is more a more likely source of motions than the CMB. Vigorous convection driven by sources of buoyancy at a boundary invariably consists of narrow rapid motions away and broad slow motions toward the boundary. It is plausible that buoyant fluid leaves the ICB, either in the form of continuous plumes or discrete parcels, at preferred locations and rises through an otherwise quiescent outer core. The possible forms of these plumes and parcels will be surveyed, and their ability to sustain the geodynamo will be investigated.

S21E-0379 0830h POSTER

Anomalous top layer in the inner core beneath the eastern hemisphere

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Recent studies reported hemispheric variations in seismic velocity and attenuation in the top of the inner core. It, however, remains unclear how the inner core hemisphericity extends deep in the inner core. Here, we analyze PKPbc-PKIKP and PKiKP-PKIKP waveforms collected from the Global Seismographic Network (GSN), regional recordings from the German Regional Seismic Network (GRSN) and Graefenberg (GRF) sampling along the equatorial path (the ray path whose ray angle is larger than 35° from the Earth's rotation axis). The observed global and regional PKPbc-PKIKP differential traveltimes and PKIKP/PKPbc amplitude ratios suggest a simple W2 model (Wen/Niu:2002) in the western hemisphere with a constant velocity gradient of 0.049(km/sec)/100km and a Q value of 600 in the top 400 km of the inner core. In the eastern hemisphere, the data require a change of velocity gradient and Q value at about 235 km below the inner core boundary (ICB). Based on forward modeling, we construct radial velocity and attenuation models in the eastern hemisphere which can explain both the PKiKP-PKIKP and PKPbc-PKIKP observations. The inner core in the eastern hemisphere has a flat velocity gradient extending to about 235 km below the ICB. We test two solutions for the velocity models in the deeper portion of the inner core, with one having a first-order discontinuity at 235 km below the ICB with a velocity jump of 0.07(km/sec) followed by the PREM gradient, and the other having a gradual velocity transition with 0.1(km/sec)/100km gradient extended from 235 km to 375 km below the ICB followed by the PREM gradient. The observed traveltimes exclude the sharp discontinuity velocity model, as it predicts a kink in differential traveltimes at distance of 151°-152° which is not observed in the global and regional datasets. The observed PKIKP/PKPbc amplitude ratios can be best explained by a step function of attenuation with a Q value of 250 at the top 300 km and a Q value of 600 at 300-400 km below the ICB. The top portion of the inner core in the eastern hemisphere is anomalous compared to the rest of the inner core, in having a flat velocity gradient, higher velocities and higher attenuation.

S21E-0380 0830h POSTER

Regional Variations in the Earth's upper inner core

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Strong regional variations in seismic velocity and attenuation have been observed in the uppermost layer of the inner core. Different studies suggest hemispherical differences within this transitional layer, with eastern hemisphere faster than the western (e.g. Garcia, 2002; Wen and Niu, 2002). The scale and the depth dependence of the heterogeneities are still in debate. In order to systematically study smaller scale heterogeneities we selected a data set of PKIKP and PKiKP phases with epicentral distances between 120° and 140°. The upper layer of the inner core was divided into bins' and the seismograms were gathered into these bins according to the ray turning points. After correcting for source, site and propagation effects we stacked traces with close epicentral distance within each bin to improve signal-to-noise ratio. Finally we performed full 3D modeling of the obtained waveforms.

S21F MCC: Level 1 Tuesday 0830h

Crustal Structure From Reflection/Refraction Seismology Posters

Presiding: **B P Luyendyk,** Institute for Crustal Studies**; L Liu,** University of Connecticut

S21F-0381 0830h POSTER

Three-dimensional seismic modeling of crustal structure in the West-Pannonian basin (Trans-Danubia) based on CELEBRATION 2000 data

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The Trans-Danubian part of the survey was designed to obtain not only in-line recordings along five profiles, but also fan recordings of the off-line shots. The station spacing was changing between 1,5 and 5 km, the average charge of the seismic shots were 500 kg TNT. The use of 409 single channel (Texan, PRS) recorders and 20 seismic sources provided a sufficient 3D ray coverage over an 250km * 240km area, and allowed for construction of a 3D model of the crustal structure. The seismic sections show clear first arrivals up to a distance of 180-200 km. For tomographic modeling 5700 picks of first arrivals were used. The P-wave velocity model was defined at equidistant nodes of the 3D rectangular grid. The distance between nodes was 0.5 km. The initial model used was established by apriori velocity data of the pre-Tertiary sediments. For the tomographic inversion of the areal data we used FAST package developed by C. Zelt (1998). The results of the 3D modeling of the CELEBRATION data were supplemented by inversion of previous seismic and other geological- geophysical data, which may enhance our understanding of the deep structure and evolution of the Trans-Danubian region.

S21F-0382 0830h POSTER

Seismogenic Layer and Seismic Reflectors in the Crust With Reference to Large Earthquakes

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Most of large crustal earthquakes break out at the base of the seismogenic layer. Therefore, the heterogeneous structures, such as seismic velocity difference and/or seismic reflectors near the cutoff depth of seismicity are important to reveal the process of the large inland earthquakes. Seismic surveys in the source region of the 2000 Western Tottori earthquake of M7.2 (JMA-scale) in southwest Japan, show reflectors near the base of the seismogenic layer (Nishida et al., 2002) . Besides, high velocity patches are found nearly the same region of the aftershock area by using seismic tomography from data of a dense network observation of aftershocks just after the main shock (Shibutani et al., 2002).We analyzed seismic refraction and wide angle reflection data in southwest Japan to examine the lateral extension of the reflectors with relation to the cutoff depth of seismicity. As a result, we found reflectors at about 4-5s, 7-8s and 10-12s in two-way travel times along four measure lines. One of them passes the aftershock are of the 1995 Kobe earthquake. The 4-5s reflectors correspond roughly to the cutoff depth of seismicity at about 12-15km deep. The amplitudes of the reflected waves vary from place to place, though the reflectors exist in all areas in inland area of southwest Japan, where local seismicity of small earthquakes are relatively high. The 7-8s reflector is located in the middle crust and the 10s reflector at around the Moho discontinuity. In general, the middle to lower crust is reflective and the above described reflections are distinct. In addition, the cutoff depth changes its depth near the hypocenter of the main shock for the 2000 Western Tottori earthquake, 1995 Southern Hyogo prefecture earthquake and some other large inland earthquakes. Thus the seismogenic layer, in particular, the base of it plays an important role of the nucleation process of the large events. An fluid or gas seal-and-break effect may occur at the reflectors.

S21F-0383 0830h POSTER

Crustal Structure Derived From Refractions and Wide-Angle Reflections in The Mizuho Plateau, East Antarctica

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In 1999-2000, the 41st Japanese Antarctic Research Expedition (JARE41) conducted high density seismic experiments from the coast and inland on the Mizuho Plateau, East Antarctica, along a 180km line with station spacings of 1km. In the record sections, we can pick direct waves through the ice sheets along with refracted and reflected waves from the crust and the Moho boundaries. Previously in 1980-1981, JARE21 and JARE22 conducted large seismic explosion experiments that extended along a 300km line in the same area, although the station spacing is larger, about 10km. Some of the recorded data show especially clear waves refracted and reflected from the crust and the Moho boundaries, and the coverage of first arrivals extends from about 50 to 300km. These travel time data provide good information for investigating the deep structure in the crust. Therefore, we tried to determine a more detailed P-wave velocity model from analysis of the combined data of these two experiments using the ray tracing technique of Zelt (1992, 1994). From the results of the analyses, we conclude that the