Jean A Tangeman[3] (tangeman@containerless.com)

Sujatha Sampath[2,4] (ssampath@anl.gov)

[1]University of California at Davis, Department of Geology, University of California at Davis, Davis, CA 95616, United States

[2]Argonne National Laboratory, Intense Pulsed Neutron Source, Argonne National Laboratory, Argonne, IL 60439, United States

[3]Containerless Research Inc., 906 University Place, Evanston, IL 60201, United States

[4]University of Wyoming, Department of chemistry, Laramie, WY 82071, United States

Understanding the structure of magnesium silicate liquids is important for interpreting the behavior of liquids produced by melting processes in the Earth and Lunar mantles. Glasses produced from $MgO-SiO_2$ liquids ranging in composition from forsterite to enstatite have been studied by combined neutron and X-ray diffraction to constrain their structure and related transport and thermodynamic properties.

Neutron diffraction measurements were made on the Glass and Amorphous Materials Diffractometer at the Intense Pulsed Neutron Source, Argonne National Laboratory (ANL). The collected data yield real space pair correlation functions which show the coordination environments for the main structural units in these glasses.

The neutron diffraction data are dominated by the scattering from oxygen so complementary high energy X-ray diffraction data was collected at the 11-ID-C beamline at the Advanced Photon Source at ANL. The X-ray and neutron diffraction data can be combined to eliminate the contribution of Si-O correlations to the pair correlation function and serve to highlight the changes in Mg-O coordination which occur as the composition changes from forsterite to enstatite.

The combined data show abrupt changes in liquid stucture close to forsterite composition. This change invoves an increase in the Mg-O coordination number and a distortion of the Mg-O unit in forsterite liquids. Such structural changes imply a large change in configurational entropy over a small compositional range. Similar changes in structure are to be expected for the more silica-rich liquids as pressure is increased.

MR72B MCC: Hall C Sunday 1330h

Elasticity and Constitution of the Earth's Interior III Posters *(joint with G, GP, P, S, T, V, DI)*

Presiding: **D E Smylie,** York University**; A M Hofmeister,** Washington University

MR72B-1026 1330h POSTER

Analysis of Non-Equispaced VLBI Nutation Measurements

Andrew Palmer[1] ((416)-736-2100 ext.66438; Palmer@core.yorku.ca)

Douglas E. Smylie[2] ((416)-736-2100 ext.66438; Doug@core.yorku.ca)

[1]Department.of Physics and Astronomy, York University York University, 4700 Keele Street,, Toronto, ON M3J 1P3, Canada

[2]Department of Earth and Atmospheric Science, 4700 Keele Street, Toronto, ON M3J 1P3, Canada

VLBI nutation measurements offer a unique opportunity to evaluate very small relative motions of the Earth's axis of rotation. This, in turn, can allow us to deduce properties of the Earth's deep interior. However, since VLBI nutation measurements can only be taken when the radio sources being observed are visible, the data is inherently non-equispaced. One of the fundamental problems posed in spectral analysis is the approach one should take when dealing with unevenly spaced sampling - the conventional Discrete Fourier Transform and the Fast Fourier Transform Algorithm for its computation, for example, strictly require a constant interval between successive data points.

It is shown that a Discrete Fourier Transform can be obtained directly from a non-equispaced record by minimizing an objective function which weights the error energy terms in inverse proportion to the square of their standard deviations. The conditional equations have a coefficient matrix of Toeplitz form, and can be solved by any of a variety of linear algebra routines, including the Levinson algorithm. By its nature the fitting matrix can be highly ill-conditioned. This problem can be overcome by re-evaluating the result after setting the reciprocal of the smallest singular values in the fitting matrix to zero using the Singular Value Decomposition technique.

The sampling in the non-equispaced case is modelled by multiplication of the record in the time domain by a Dirac comb with non-equispaced teeth. The effect of this sampling in the frequency domain is to convolve the Fourier Transform of the comb with the true frequency spectrum. Correction of the effect of non-equispaced sampling can be accomplished by convolving the computed spectrum with the frequency domain inverse of the Fourier Transform of the sampling comb. Using synthetic non-equispaced time series the results are shown to compare highly favorably with the traditional approach to non-equispaced data, a polynomial interpolation onto an evenly spaced time grid.

The forgoing methods are used to provide a spectral analysis of a 16 year long VLBI nutation residual sequence in the search for the Retrograde Free Core Nutation and the numerically predicted Prograde Free Core Nutation. The results are then used to obtain a reappraisal of the viscosity of the outer core at the core-mantle boundary by determining the Q factor of the Free Core Nutation resonance.

MR72B-1027 1330h POSTER

Viscosity of Fe-FeS Liquids at High Pressure

Richard A. Secco[1] (519-661-4079; secco@uwo.ca); Michael D. Rutter[1] (mrutter@uwo.ca); Hongjian Liu[1] (hliu@uwo.ca); Takeyuki Uchida[2] (uchida@cars.uchicago.edu); Mark L. Rivers[2] (rivers@cars.uchicago.edu); Yanbin Wang[2] (wang@cars.uchicago.edu); Stephen R. Sutton[2] (sutton@cars1.uchicago.edu)

[1]Department of Earth Sciences, University of Western Ontario, London, ON N6A 5B7, Canada

[2]Consortium for Advanced Radiation Sources, University of Chicago 5640 Ellis Ave., Chicago, IL 60637, United States

We present results of high P, T viscosity measurements on Fe-FeS liquids up to 6GPa and 2050K based on synchrotron experiments carried out at the Advanced Photon Source. Radiography was used to image, in-situ, the velocity of a composite probe sphere, consisting of a Pt inner core and a ruby mantle, rising through the sample melt. Viscosity was calculated with a modified form of Stokes' equation using the terminal velocity of the probe sphere. Measurements on pure Fe and on Fe-8.5wt%S liquids show that viscosity is constant along the pressure dependent melting boundary - consistent with a prediction based on semi-empirical formalism. Using the viscosity value along the melting boundary of Fe-8.5wt%S of $1.6x10^{-2}$ Pas as the viscosity at the inner core boundary we calculate a new viscosity profile for Earth's outer core.

MR72B-1028 1330h POSTER

The Upper Mantle: Misunderstood or Just Complicated?

Christopher F Larsen[1] (907 474 5661; chris@giseis.alaska.edu)

Jeffrey T Freymueller[1] (907 474 7286; jeff@giseis.alaska.edu)

Keith A Echelmeyer[1] (907 474 7477; kechel@gi.alaska.edu)

Roman J Motyka[1] (907 586 1994; jfrjm@uas.alaska.edu)

[1]Geophyical Institute University of Alaska, 903 Koyukuk Dr, Fairbanks, Ak 99775, United States

The advent of space-based geodesy has revealed solid Earth deformation acting on timescales in-between those classically found through seismology and studies of glacial isostatic adjustment (GIA). Maxwell viscoelastic models of the mantle are typically employed to explain long-period Earth response to forcings such as surface load changes and fault rupture, yet the range of well-determined values for upper mantle viscosity now spans several orders of magnitude. Despite the relative accessibility and numerous studies of the upper mantle, a generalized understanding of its response to forcings remains elusive. We present here a study of extreme, ongoing uplift in southern Alaska that requires an upper mantle viscosity of $3\text{-}5x10^{19}$ Pa s.

Using campaign style GPS techniques, we have measured uplift over an area of $2x10^5$ km^2 with a peak rate of 35 mm yr^{-1}. Elastic response to present day surface load changes (melting glaciers) is insufficient to account for these observations. The Little Ice Age, lasting from AD 1200 to 1900, witnessed the largest glacial expansion in southern Alaska since the late Pleistocene and resulted in total surface loading on the order of $8x10^{15}$ kg. Rapid melting over the past century has removed roughly all of this surface load. We have modeled the response to this cycle, and find that the changes in loading over the last 1000 yrs can explain the magnitude and pattern of the extreme present day uplift rates, but only when invoking an upper mantle viscosity that is 10-15 times smaller than indicated by classic studies of GIA associated with the Last Glacial Maximum. The range of viscosities that allows our model to match the observed uplift rates is very narrow, suggesting that our study has precisely determined this anomalous upper mantle viscosity.

Our results are roughly in the middle of the range found in other studies that have also tightly constrained upper mantle viscosity. Recent studies have found values as low as $3\text{-}8x10^{17}$ Pa s from postseismic deformation in southern California, and as high as $0.5\text{-}1.0x10^{21}$ Pa s from GIA in Fennoscandia. Such a wide range of values is typically explained by inferred lateral variations in the upper mantle, but a trend is building that appears to correlate modeled upper mantle viscosity with the timescale of the forcing involved. Is this an indication that we are overly manipulating the Maxwell viscoelastic model to fit all observations, or is the upper mantle truly such a widely varying region?

MR72B-1029 1330h POSTER

Geodetic Constraints on Mantle Q at Periods from a Fortnight to 18.6 Years

David Benjamin[1] (David.Benjamin@colorado.edu)

John Wahr[1] (303-492-8349; wahr@lemond.colorado.edu)

Shailen Desai[2] (Shailen.D.Desai@jpl.nasa.gov)

[1]Dept of Physics and CIRES, U of Colorado, Boulder, CO 80309

[2]Jet Propulsion Laboratory, California Insititute of Technology, Pasadena, CA 91109

Seismic observations have provided numerous constraints on the earth's spherically-averaged mantle anelasticity at periods of tens of minutes and shorter. Meanwhile, post-glacial rebound and other geodynamic studies provide information at periods of a few thousand years and longer. However, constraints at intermediate periods are scarce. Such constraints could be useful in trying to connect the seismic anelastic models with the longer-period visco-elastic behavior.

Here we will describe constraints on anelasticity in this intermediate range of periods as obtained from earth tide and earth rotation observations. We discuss results from: (1) VLBI observations of the monthly and fortnightly tidal variations in rotation rate; (2) satellite laser ranging observations of the 18.6-year tidal variations in the earth's gravitational field; and (3) astrometric and geodetic observations of the 14-month Chandler Wobble period and damping. We find that these observations are consistent with a nearly frequency-independent mantle Q stretching from seismic periods all the way out to the 14-month Chandler Wobble period; but that Q appears to decrease significantly between 14-months and 18.6-years.

MR72B-1030 1330h POSTER

Earth's Heat Flux and Links to Chemistry

Robert E Criss[1] (314-935-7441; criss@levee.wustl.edu)

Anne M. Hofmeister[1] (314-935-7440; hofmeist@levee.wustl.edu)

[1]Dept. Earth and Planetary Sci., Washington U., 1 Brookings Dr., St. Louis, MO 63130, United States

The global heat budget (or power, Qtot) and its change with time are needed for models of planetary evolution. The latest Qtot of 44 TW is 2.3 times radiogenic power provided by various chondritic (CI) models. To account for this difference, additional heat sources, processes, and various chemical models have been proposed. Most of the discrepancy originates in methods of estimating Qtot. Estimates of the continental flux since 1965 are consistent, and if scaled to represent the whole Earth provide 31-32 TW for Qtot, even though the number of heat flux measurements has increased 10-fold. In contrast, post-1965 estimates of the oceanic flux have markedly increased and have become increasingly disparate from the growing database. We develop two independent methods, based on minimal assumptions, to ascertain Earth's mean oceanic heat flux. One model uses mid-cell heat flux to derive oceanic power; the other depicts the oceanic crust as a conveyor belt. The results are congruent, insensitive to uncertainties in the dataset, and indicate that oceanic and continental heat fluxes are equivalent, giving Qtot as 311 TW. Various observations coupled with recent time-dependent geodynamic models (Van den Berg and Yuen, EPSL, 2002: Van den Berg et al., PEPI, 2002), suggest that heat production is radioactive and steady-state at present. A graphical method is devised to ascertain proportions of K, U, and Th from Qtot and the mass of the mantle. If Earth's bulk silicate composition is like that of enstatite chondrites (EH), radiogenic elements supply all the heat, whereas C1 models require that primordial heat dominates mantle flux. EH, but not C1, meteorites provide sufficient iron for

Earth's huge core and have appropriate oxygen isotopic ratios; thus, an EH-based model can explain Earth's gross chemical characteristics, such as the radioactive contents, and can thus provide the change in Qtot with time.

MR72B-1031 1330h POSTER

Avalanches at the Core-Mantle Boundary: Possible Role in Geomagnetic Reversals, Mantle Plumes, and Superchrons

Richard A Muller[1] (510 486-7430; ramuller@lbl.gov)

Jonathan Levine[1]

Robert Rohde[1]

[1]Dept. of Physics, University of California, B50-R5032 LBL, Berkeley, CA 94720, United States

Avalanches at the core-mantle boundary have not been directly observed, but if they exist they could affect many geophysical phenomena. Avalanches occur in ?sediment? accumulating on the inner surface of the mantle (according to the theory of Buffett et al.). Because the sediment is not evenly deposited, avalanches could provide the primary mechanism to redistribute sedimentary material evenly over the core-mantle boundary.

Core-mantle avalanches, like turbidity flows in the ocean, consist of both solid material and entrained liquid. Such flows can occur at shallow angles (less than a few degrees) and could continue for many kilometers or hundreds of kilometers, depending on the topography. However, these avalanches are upside-down: they flow upward, propelled by buoyancy, into inverted valleys on the mantle surface.

The avalanches mix relatively cool sediment with hot liquid iron, creating a redistribution of heat near the boundary. If the avalanche is sufficiently thick (100 m) then the cold pulse will create a downward plume in the core which can disrupt the convective cells that maintain the Earth?s dipole field. When the cells reestablish, the result is a geomagnetic reversal or excursion. We predict a reversal pattern different from that of the chaotic reversals seen in simulations by Glatzmeier. Avalanche-triggered reversals begin with a rapid drop in the dipole moment (but with higher order moments increasing), followed by a period with low dipole moment lasting from hundreds to thousands of years, followed by a rapid build-up of the reversed dipole field. Studies of the detailed time structure of reversals can test the model.

As with turbidity flows, we expect a spectrum of avalanche sizes. The largest avalanches are the least probable. The sudden removal of a sediment blanket exposes the lower mantle to a pulse of heat, and for sufficiently large avalanches (>> 100 meters thick) this can contribute to the conditions needed for a mantle plume. A large avalanche could trigger sympathetic avalanches at other locations, wiping clean the topography of much of the boundary. No further avalanches could occur until the slopes rebuild, tens of millions of years later. The Cretaceous superchron (no reversals from 120-85 Ma) could have been initiated by such a super avalanche. In this interpretation, the Ontong-Java Plateau is identified as the result of the mantle plume triggered from the same 120 Ma event. A similar quiet period, the Kiaman reversed superchron, occurred from ca. 320-250 Ma. Our interpretation predicts a large mantle plume at the beginning of this superchron.

Oblique extraterrestrial impacts impart high shear to the boundary, and could trigger one or more simultaneous avalanches. Such events could account for reported coincidences of reversals with impact craters and tektite fields. Triggered avalanches could also provide a mechanism for the reported coincidences between large flood basalts and extinctions. In our picture, it is the impact that caused both the extinctions and the flood basalts.

Small avalanches, occurring every few years, might be detectable by synthetic aperture seismic analysis. Phase lags can be introduced at many seismic detectors that focus on the core-mantle boundary. The resulting map can then be compared to maps just above and below the boundary. It might even be possible to detect the motion of the avalanche.

Avalanches could also change the Earth?s dynamic oblateness and be detectable as changes in the Earth?s gravitational field moments, J2 and higher. Such avalanches might contribute to the variations recently reported in J2.

URL: http://muller.lbl.gov

MR72B-1032 1330h POSTER

Problem in Interpretation of Global Seismological Models of the Lower Mantle Based on Mineral Physics Data

Sergey V. Churakov[1,2] (+41 (91) 610 8222; sergey@cscs.ch)

Stephan V. Sobolev[3] (+49 331 2881248; stephan@gfz-potsdam.de)

[1]CSCS - Centro Svizzero di Calcolo Scientifico, Via Cantonale, Manno CH-6928, Swaziland

[2]Department of Chemistry, ETH, Hnggerberg HCI, Zurich CH-8093, Swaziland

[3]GFZ-Potsdam, Telegrafenberg, Potsdam D-14473, Germany

In this work we test the internal consistency of the available experimental data on thermoelastic properties of major mantle minerals and their ability to interpret seismological models of the lower mantle in terms of composition and temperatures. The lower mantle was assumed to consist of four oxides: MgO, CaO, Al2O3, SIO2, distributed between three high pressure phases: (Mg1-x-u,Fex,Alu)(Si1-uAlu)O3 - perovskite, (Mg1-yFey)O- wuestite and CaSiO3- perovskite. The equation of state (EOS) for (Mg,Fe, Al)-Pv based on the model developed by Hama and Suito (2001) was calibrated using all available experimentally obtained and theoretically calculated (ab inito quantum mechanic calculations) thermoelastic data. The EOS parameterisation provided by Hama and Suito (2001) was adopted for Mg-Wu and Ca-Pv.

The experimental data available for (Mg,Fe)SiO3 perovskite cover reasonably well the P-T range of lower mantle and are sufficient to constrain the EOS. However, a strong discrepancy is observed between experimental PVT data for Al-rich perovskite obtained at low and high pressures. Recent ab initio calculations of the K and G moduli for mantle minerals at high P strongly constrain the EOS parameters and lead to higher K and G values for MgPv and MgWu then were previously thought.

EOS-model fitted to reproduce all experimental data for minerals appears to be not consistent with the PREM for any geochemically realistic composition of the lower mantle. We discuss different ways to solve this problem. For instance, by adjusting the EOS parameters for the Al-rich perovskite between the values suggested by low and high-P experimental data it is possible to fit the PREM with the pyrolite mantle model. Thus defined EOS-model predicts smaller dependence of density and seismic velocities on chemical composition as well as higher temperature dependence for Vs and lower for Vc than previous studies.

Hama, J. and K. Suito (2001). Thermoelastic models of minerals and the composition of the Earths lower mantle, PEPI, 125: 147-166.

MR72B-1033 1330h POSTER

Thermal and Compositional Variations Inferred from Global Mantle Tomography

Jeannot Trampert[1] (jeannot@geo.uu.nl)

Frédéric Deschamps[1] (deschamp@geo.uu.nl)

[1]Faculty of Earth Sciences, Utrecht University, POBOX 80021, Utrecht 3508 TA, Netherlands

A method is provided to constrain lateral variations of temperature and composition in the lower mantle from global tomographic models of shear and compressional wave speed. We assume that the lower mantle consists of a mixture of perovskite and magnesiowüstite and used recent mineral physics data together with a careful equation of state modeling to compute sensitivities of velocities to temperature and composition. In a first stage, we directly invert Vp and Vs anomalies for variations of temperature and composition, using the appropriate sensitivities. However, uncertainties in the tomographic models and in the sensitivities are such that variations in composition are not robust. At present, a deterministic calculation of lateral variations of temperature and composition seems unfeasable. We therefore turn to a statistical approach, which allows us to infer some robust features. We compute synthetic histograms of the ratio R of the relative shear to compressional velocity variations for many different combinations of anomalies of temperature and composition. Comparisons of these complete histograms (not only averages) with those predicted by global tomography show that the origin of seismic anomalies cannot be purely thermal. In the bottom of the mantle, strong anomalies of composition, due to changes in the amount of perovskite and/or iron, are clearly present. R alone is unable to resolve all existing trade-offs between anomalies of temperature and composition. An accurate determination of temperature and composition requires knowledge of density variations. We show that anomalies of iron can be resolved from the additional analysis of histograms of the ratio of relative shear velocity to density anomalies.

MR72B-1034 1330h POSTER

What is the Influence of Anisotropy on Tomographic Images of the Mantle

Brian L N Kennett (+61 2 6125 4621; brian@rses.anu.edu.au)

Research School of Earth Sciences, The Australian National University, Canberra, ACT 0200, Australia

The primary source of information on heterogeneity within the Earth comes from seismic tomography. A powerful tool for examining the character of heterogeneity comes from the comparison of images of bulk-sound and shear wavespeed extracted in a single inversion, since this isolates the dependencies on the elastic moduli. The relative behaviour of bulk-sound and shear wavespeed has proved a useful tool in the definition of heterogeneity regimes. However, a basic assumption in this approach is that the Earth is isotropic. There is abundant evidence for anisotropy in the lithosphere and upper mantle, near the core-mantle boundary, and hints of complications near the 660 km discontinuity. What then are the likely influences of anisotropy on our interpretation of tomographic structure? The passage time of seismic body waves through the potentially anisotropic regions will generally be a small enough part of the total that the effects should not be large in the bulk of the mantle. It is possible though that the narrow structures in the lower mantle interpreted as remnant subducted slabs may carry some anisotropic signature. In the upper mantle, for younger subducted slabs, the large apparent signature of bulk-sound speed may be influenced by anisotropic effects. Similarly, the anti-correlation of bulk-sound and shear wavespeed variations near the base of the mantle needs to be assessed against the likelihood of contamination by anisotropy.

MR72B-1035 1330h POSTER

A forward model of the seismic anisotropy of the mantle transition zone based on experimentally observed slip systems and polycrystalline plasticity modeling

David Mainprice[1] (+33-67143602; David.Mainprice@dstu.univ-montp2.fr)

Andrea Tommasi[1] (+33-67143602; Andrea.Tommasi@dstu.univ-montp2.fr)

Patrick Cordier[2] (+33-320-434341; Patrick.Cordier@univ-lille1.fr)

[1]Labo de Tectonophysique, Universite Montpellier II, Montpellier 34095, France

[2]Labo de Structure et Proprietes de l'Etat Solide, U.S.T.L., Villeneuve d'Ascq 59655, France

The principal constituents of the transition zone (410-660 km) have well defined stability fields. Recent high PT deformation experiments designed to simulate transition zone conditions have provided deformed crystals for the characterization of the slip systems of the major phases using conventional transmission electron microscopy (CTEM) and large angle convergent beam electron diffraction (LACBED). So far wadsleyite, ringwoodite, garnet and stishovite have been studied. The slip system of other important phase, cpx, has been previously studied by CTEM and its crystal preferred orientation (CPO) has been reported in naturally deformed eclogites. In a study of eclogites we have successfully simulated the CPO of cpx and garnet using the slip systems determined by CTEM. Now we propose a forward model of CPO development in high-pressure phases where only the slip systems have been reported. From the polycrystalline plasticity models of each phase we develop a detailed picture of the seismic anisotropy of the transition zone as a function of depth, composition and deformation. For example the slip systems of wadsleyite (101)[11-1], (011)[100], (001)[100] and (010)[100] have been used to model the CPO in simple shear, the [100] axes have strong concentration near the shear direction and the [001] axes near the shear plane normal. The seismic anisotropy is strong for Vp (5 percent) with Vp max parallel to the shear direction and Vp min parallel to the shear plane normal, Vs anisotropy max. is 5 percent normal to the shear direction in the shear plane. In simple shear cpx develops a similar geometry of Vp anisotropy to wadsleyite which results in these two phases combining to produce significant anisotropy between 410 and 520 km with Vp horizontal > vertical for horizontal flow in agreement with global seismic models (e.g. IASP-F). High volume fractions of ringwoodite and majorite will produce low CPO related anisotropy between 520 and 660 km.

MR72B-1036 1330h POSTER

Fabric Development in Deformed (Mg,Fe)O Aggregates and Implications for Seismic Anisotropy in D"

Maureen D. Long[1] (617-253-0741; mlong@mit.edu)

Shun-ichiro Karato[2] (shun-ichiro.karato@yale.edu)

Brian Evans[1] (brievans@mit.edu)

Zhenting Jiang[2] (zhenting.jiang@yale.edu)

MR

Xiaohui Xiao[1] (xhxiao@mit.edu)

[1]Department of Earth, Atmospheric, and Planetary Sciences, Massachusetts Institute of Technology, 77 Massachusetts Ave., Cambridge, MA 02139, United States

[2]Department of Geology and Geophysics, Yale University, Kline Geology Laboratory P.O. Box 208109, New Haven, CT 06520, United States

Magnesiowüstite [(Mg,Fe)O] is an important constituent of the lower mantle and laboratory and theoretical studies have shown it to be highly elastically anisotropic, especially at high pressures. At pressures typical of the lower mantle, the elastic anisotropy of (Mg,Fe)O is likely to be much stronger than the anisotropy of (Mg,Fe)SiO_3 perovskite, the other major lower mantle constituent. Therefore, the strain-induced formation of lattice preferred orientation (LPO) in magnesiowüstite is a strong candidate for the origin of seismic anisotropy in D". The LPO of (Mg,Fe)O is controlled by the dominant slip systems and the processes of dynamic recrystallization both of which likely change with physical conditions, particularly pressure. In this study we investigate the LPO of (Mg,Fe)O as a function of Fe/(Fe+Mg). Since the Fe/(Fe+Mg) ratio changes the melting temperature and the nature of chemical bonding (and hence elastic anisotropy), changes in LPO likely occur as a result of a change in Fe/(Fe+Mg). The effects of Fe/(Fe+Mg) ratio on LPO may provide us with insight into the applicability of laboratory data on LPO to the deep lower mantle.

We perform simple shear deformation experiments in the dislocation creep regime using a gas-medium deformation apparatus over a range of compositions: the MgO and FeO endmembers, and three intermediate compositions. Samples were deformed at 1473K and confining pressure of 300MPa to large shear strains. After deformation, the LPO was measured using the electron backscatter diffraction (EBSD) technique. The pattern of LPO was found to be different for different compositions, indicating that slip systems in (Mg,Fe)O are affected by composition and/or homologous temperature. Predicted patterns of anisotropy were calculated from the measured LPOs and theoretically determined single crystal elastic constants for MgO. Anisotropic behavior predicted from LPO agrees well with seismological observations of D" anisotropy, so the LPO hypothesis appears to satisfy the seismological constraints. However, the physical conditions explored in this study are limited, and the effects of the large change in elastic anisotropy in (Mg,Fe)O on LPO that occur at deep lower mantle conditions remain to be explored.

MR72B-1037 1330h POSTER

Thermoelasticity of the Lower Mantle from First Principles: Implications for the Origin of Lateral Heterogeneity

Lars Stixrude[1] (stixrude@umich.edu)

R. M. Wentzcovitch[2] (wentscov@cems.umn.edu)

[1]University of Michigan, Department of Geological Sciences, Ann Arbor, MI 48104, United States

[2]University of Minnesota, Department of Chemical Engineering and Materials Science, and Minnesota Supercomputer Institute, Minneapolis, MN 55455, United States

First principles results on thermoelasticity of MgSiO3-perovskite and periclase, throughout the expected pressure/temperature regime of the lower mantle have allowed us to compare predicted values of relative velocity-to-velocity and density-to-velocity heterogeneity ratios with those inferred from seismic observations. The effect of temperature on density and shear- and longitudinal-wave velocities is computed within the quasi-harmonic approximation which we have shown to be valid for these phases at lower mantle conditions; anelastic effects are ignored. The predicted trends in shear-to-longitudinal and bulk-to-shear velocity, and density-to-shear velocity scalings are consistent overall with their seismic counterparts, except in the deep LM (deeper than 2100km depth). These results seem to suggest: 1) anelastic effects are less significant than previously assumed; 2) thermal effects can account for most of the observed heterogeneities up to 2100 km depth, Compositional and/or phase heterogeneities seem inevitable to explain the observations beyond 2500 km depths.

MR72B-1038 1330h POSTER

Deformation of silicate perovskite aggregates up to 30 GPa

Sebastien Merkel[1,2] (sebastien.merkel@ens-lyon.fr)

Hans-Rudolf Wenk[3] (wenk@seismo.berkeley.edu)

Philippe Gillet[2] (philippe.gillet@ens-lyon.fr)

Russell J Hemley[1] (r.hemley@gl.ciw.edu)

Ho-kwang Mao[1] (mao@gl.ciw.edu)

[1]Geophysical Laboratory, Carnegie Institution of Washington, 5251 Broad Branch Road, NW, Washington, DC 20015, United States

[2]Laboratoire des Sciences de la Terre, Ecole normale superieure de Lyon, 46 allee d'Italie, Lyon 69007, France

[3]Dept. Earth and Planetary Science, Univ. Calif., Berkeley, CA 94720, United States

Considerable progress has been made in establishing deformation mechanisms for minerals and rocks from the Earth's crust and and upper mantle. However, much less is know about the deeper Earth's minerals because the pressures are beyond the conditions reached by ordinary deformation apparatus such as the Griggs, Heard or Paterson apparatus. Diamond anvil cells allow investigations of the whole pressure and temperature range of the lower mantle. In recent years, we developped new techniques in order to study shear stress and preferred orientations in polycrystalls in situ at lower mantle pressures. In this study, we apply this technique to magnesium silicate perovskite under ambient temperature to pressures of 30 GPa. The uniaxial stress component in the polycrystalline perovskite sample is found to increase continuously with pressure up to 11 GPa at the highest pressure. Our measurements show no development of significant lattice preferred orientations which indicates that deformation by dislocation creep is not dominant under these conditions. The data demonstrate the feasability of studying deformation mechanisms and shear strength at pressures corresponding to the Earth's lower mantle. This approach can now be extended to investigate variations of these mechanical properties with both pressure and temperature and can also be used to study other deep Earth's materials.

MR72B-1039 1330h POSTER

Anelasticity of Perovskite at Seismic Frequencies: DMA Measurement of Twin Wall Internal Friction in $LaAlO_3$

Simon A. T. Redfern[1] (+44-1223-333475; satr@cam.ac.uk)

Richard J. Harrison[1] (rjh40@esc.cam.ac.uk)

[1]Department of Earth Sciences, University of Cambridge Downing Street, Cambridge CB2 3EQ, United Kingdom

The low-frequency mechanical properties of single crystal $LaAlO_3$ have been investigated as a function of temperature, frequency, and applied force using dynamical mechanical analysis in three-point bend geometry. $LaAlO_3$ shows a cubic to rhombohedral phase transition below 550°C. The response in the low-temperature rhombohedral phase is dominated by the motion of transformation twin domain walls, resulting in a factor of ten decrease in the elastic storage modulus relative to the high-temperature cubic phase (super-elastic softening) and a significant increase in attenuation. Super-elastic softening is observed down to 200°C, below which temperature the mobility of the domain walls decreases markedly, causing a rapid increase in storage modulus and a pronounced peak in attenuation (domain wall freezing). The frequency-dependence of the elastic modulus close to the freezing temperature is accurately described by a modified Burgers model with a Gaussian distribution of activation energies with mean value 84.1(1) kJ/mol and standard deviation 10.3(1) kJ/mol. This value indicates that domain walls are pinned predominantly by oxygen vacancies.

Detailed analysis of the dynamic force-deflection curves reveals three distinct regimes of elastic response. In the elastic regime, the domain walls are pinned and unable to move. The elastic response is linear with a slope determined by the intrinsic stiffness of the lattice, the initial susceptibility of the pinning potential, and the bending of twin walls between pinning sites. In the super-elastic regime, the domain walls unpin and displace by an amount determined by the balance between the applied and restoring forces. The value of the apparent super-elastic modulus is shown to be independent of the spontaneous strain, and hence independent of temperature. At high values of the applied force, adjacent domain walls come into contact with each other and prevent further super-elastic deformation (saturation). The strain in the saturation regime scales with the spontaneous strain and the resulting modulus is strongly temperature dependent.

It is concluded that, if these results are directly transferred to mantle-forming (Mg,Fe)(Si,Al)O_3 perovskite, the strain amplitude of a typical seismic wave would be sufficient to cause super-elastic softening. However, pinning of domain walls by oxygen vacancies leads to very short relaxation times at mantle temperatures. If translated to (Mg,Fe)(Si,Al)O_3, these would be too short to amount to significant seismic attenuation. Increased pinning of ferroelastic domain walls by defects, impurities, and grain boundaries in real mantle perovskite, or a significant positive activation volume for oxygen vacancy diffusion, would be sufficient to increase the relaxation time to values resulting in seismic wave attenuation, however.

MR72B-1040 1330h POSTER

Seismic Wave Attenuation in Partially Molten Olivine Aggregates: Laboratory Measurements and Seismological Implications

Ian Jackson (61 2 6125 2498; Ian.Jackson@anu.edu.au)

Ulrich Faul[1] (61 2 6125 8846; Uli.Faul@anu.edu.au)

John Fitz Gerald[1] (61 2 6125 4176; John.FitzGerald@anu.edu.au)

Benhua Tan[1] (61 2 6125 8252)

[1]Research School of Earth Sciences, Mills Road Australian National University, Canberra, ACT 0200, Australia

Texturally mature melt-bearing olivine specimens, prepared by hot-isostatic pressing of natural or synthetic Fo_{90} powders mixed with powdered basaltic glass, have been tested in torsional forced oscillation at 50°C intervals during staged cooling from peak temperatures of 1240-1300°C. Mean grain sizes and melt fractions at peak temperature for five specimens are 9-52 μm and 0.4-3.7%, respectively. The melt is distributed throughout an interconnected network of grain-edge tubules, some larger pockets and wetted grain boundaries, in accord with previous observations. Quenching experiments on one sample annealed after testing showed that between 1300°C and 1200°C the melt distribution survives largely unaltered. Between 1200°C and ~1130°C orthopyroxene, clinopyroxene and plagioclase crystallise from the melt, leaving small fractions of a silica-rich glass. The measured dissipation 1/Q for each of these specimens consists of a broad peak superimposed upon a monotonic background that is enhanced relative to that for melt-free materials. The peak moves systematically across the observational window from 1 to 1000 s period without changing its shape as T decreases from 1170-1220°C (depending on grain size) to 1020-1050°C. The melt-related dissipation peak is attributed to the enhancement and localisation in frequency-temperature space of elastically accommodated grain-boundary sliding in the melt-bearing materials. It is suggested that the rounded olivine grain corners at grain-edge triple junctions in these specimens may play an influential role by allowing more sliding and hence increased anelastic relaxation. A model has been developed that adequately represents the variation of 1/Q with frequency, temperature, grain size d and maximum melt fraction ϕ for this suite of materials. Extrapolation to conditions of partial melting beneath mid-ocean ridges [$P = 2$ GPa, $T = 1250$-1350°C, $d =$ 1-10 mm, $\phi = 0.001$-0.03) suggests that the melt-related dissipation peak may perturb the frequency and temperature dependence of 1/Q resulting in nearly frequency-independent behaviour within the seismic frequency band.

URL: http://rses.anu.edu.au/petrophysics/AR2001/Home.html

MR72B-1041 1330h POSTER

Numerical Models of Mantle Convection Based on Thermodynamic data for the $MgO - SiO_2$ Olivine-Pyroxene System

Arie P van den Berg[1] ((+31)30-2535072; berg@geo.uu.nl)

Michel H. Jacobs[1] (jacobs@geo.uu.nl)

Bernard H. de Jong[2] (bernard@geo.uu.nl)

[1]Dept. Theoretical Geophysics, Inst. Earth Sciences, Utrecht University, Budapestlaan 4, Utrecht 3584 CD, Netherlands

[2]Dept. Petrology, Inst. Earth Sciences, Utrecht University, Budapestlaan 4, Utrecht 3584 CD, Netherlands

Recent experiments of Chudinovskikh and Boehler (pers. com. 2002) on the phase transition of $MgSiO_3$ ilmenite to perovskite have shown a strong negative Clapeyron slope of -6 MPa/K. For a representative geotherm this phase transition occurs near 660 km. This is close to the transition depth of γ-spinel to perovskite+periclase in the olivine Mg_2SiO_4 subsystem of the magnesium endmember olivine-pyroxene $MgO - SiO_2$ system.

We have performed numerical modelling experiments on 2-D mantle convection in the the magnesium endmember olivine-pyroxene $MgO - SiO_2$ system, to investigate the impact of the recently obtained Clapeyron slope in this system characterized by closely spaced multiple phase transitions (Zhao et al.,1992, Phys. Earth Planet. Inter., 72, 185-210).

The numerical model applied uses a database of thermodynamic properties obtained by adapting an existing database for the $MgO - FeO - SiO_2$ system (Saxena, 1996. Geochim. Cosmochim. Acta, 60, 2379-2395). To this end Saxenas database was adapted for

the recently obtained more negative Clapeyron slope of Chudinovskikh and Boehler (Jacobs et al., 2002, Fall AGU Meeting).

The mantle convection code uses an anelastic liquid approximation and a tabulated representation of the thermodynamic quantities: density, thermal expansivity and specific heat (van den Berg et al., 2001, EOS, Trans. AGU, 82(47), F1133). Convection experiments were done for a 2-D cartesian model of aspect ratio 2.5.

We present results comparing models applying the original Saxena (1996) database and the modified database, adapted for the new value of the Claperyron slope for the ilmenite to perovskite transition (Jacobs et al, 2002), showing an increased degree of layering in the style of mantle convection resulting from the introduction of the more negative Clapeyron slope.

MR72B-1042 1330h POSTER

More negative Clapeyron slope in the perovskite-ilmenite $MgO-SiO_2$ system can be accommodated in existing data bases

Michel H Jacobs[1] ((+31)30-253 5066; jacobs@geo.uu.nl)

Bernard H de Jong[1] (bernard@geo.uu.nl)

Arie P van den Berg[1] (berg@geo.uu.nl)

[1]Institute of Earth Sciences, Vening Meinesz Research School for Geodynamics, Utrecht University, Budapestlaan 4, Utrecht 3584 CD, Netherlands

Recent measurements of Chudinovskikh and Boehler (2002) show that the $MgSiO_3$ Ilmenite-Perovskite phase boundary has a Clapeyron slope of -6 MPa/K, substantially more negative relative to previous determinations (e.g. Ono et al., 2001, Kato et al., 1995). Such negative slope has major implications for the style of mantle convection above and below the 660 km discontinuity.

We have modified the thermodynamic parameters of the magnesium endmembers of the olivine-pyroxene system contained in the database of Saxena (Saxena, 1996). Our results indicate that the more negative Clapeyron slope can be accounted for, using these modified parameters, with minor perturbations to the phase diagrams and the material properties such as expansivity and density, of the pyroxene $MgSiO_3$ and olivine Mg_2SiO_4 subsystems.

The ensuing data base has served as starting point for a mantle convection experiment in which the impact of the more negative Clapeyron slope on the degree of layering in mantle convection has been evaluated (van den Berg et al., 2002, Fall AGU Meeting).

Chudinovskikh & Boehler, (2002, pers.com.)
S. Ono et al., Geophys. Res. Lett., 28, 835 (2001).
T. Kato et al., J. Geophys. Res., 100, 20475 (1995).
S.K. Saxena, Geochim. Cosmochim. Acta, 60, 2379-2395 (1996).

MR72B-1043 1330h POSTER

Avalanches Revisited: Does the Pyroxene-Garnet System aid or Abet Phase Change-Induced Mantle Layering?

Paul J Tackley (310-206-9180; ptackley@ucla.edu)

Earth and Space Sciences Department and Institute of Geophysics and Planetary Physics, University of California Los Angeles, 595 Charles Young Drive East, Los Angeles, CA 90095-1567, United States

Much research in the early-to-mid 1990s was directed towards understanding the extent of mantle layering caused by the endothermic gamma-spinel to perovskite+magnesiowustite phase transition at around 660 km depth, and the consensus that emerged was that of basically whole mantle convection with some temporary inhibition and avalanching of downwelling slabs today, with a potentially much greater effect in the past. However, published models assumed that the mantle is made of 100% olivine and its high pressure phases, whereas it is well known that the garnet-pyroxene system accounts for at least 40% of the mantle. Phase changes in the latter system occur over a wider depth range, and the equivalent 660 transition was thought to have a neutral or even positive Clapeyron slope, leading to the expectation that it would dilute or even act against the dynamical effect of the endothermic olivine-spinel transition [Weidner and Wang, 1998].

However, recent measurements by Chudinovskikh and Boehler indicate a strongly negative Clapeyron slope (-6 MPa/K) for the ilmenite to perovskite transition, which is likely to be the relevant one at temperatures near the 660. Furthermore, when compositional effects are considered, subducted oceanic crust is likely to be buoyant in the depth range 660-740 km [Ringwood, 1994; Ono et al., 1991]. Thus, the situation warrants careful investigation.

Here these matters are examined using high-resolution numerical convection calculations that incorporate both the olivine and pyroxene-garnet systems, and comparing to calculations with only the olivine system. The Clapeyron slopes of each phase transition are varied within the current range of uncertainty. Both isochemical models, and models that incorporate chemical differentiation, are considered. Preliminary results that include chemical differentiation indicate a substantial chemical stratification induced by the combined phase system even with a neutral Pyroxene-Garnet system Clapeyron slope. But overall, does the pyroxene-garnet system aid or abet phase change-induced mantle layering? The answer will be revealed during this presentation.

MR72B-1044 1330h POSTER

Primitive submantle beneath Africa

Sidao Ni[1] (626-395-6910; stone@gps.caltech.edu)

Don Helmberger[1] (helm@gps.caltech.edu)

[1]seismological laboratory, caltech 252-21, pasadena, ca 91125, United States

A recent study of the lower mantle structure beneath Africa revealed strong lateral changes in S-velocity extending upward from the core-mantle boundary (CMB) to about 1500 km. SKS travel times observed on the South African Array display jumps of about 6 sec when ray paths cross these nearly vertical boundaries. The abrupt changes in SKS travel times are sometimes associated with complicated waveforms which require sharp boundaries. Forward modeling suggests that the boundary should be sharper than 60km. A sharp boundary suggests chemically distinct structure (submantle) as compared to the ambient mantle. Back projecting the above SKS delays onto the core-mantle -boundary for many events allows a clear image of the horizontal extent of this structure starting at mid-Africa (15 degree South, 5 degree East) where it strikes roughly northwest to beyond the tip of South Africa (45 degree South, 55 degree East) where it bends toward the Indian Ocean. Waveform sections of S, ScS, SKS, and SKKS are modeled along two corridors, one along strike and one at right angles to establish its uniformity. S and ScS waveforms with epicentral distances larger than 85 degree are used to constrained the bottom 300km structure of the super plume, where we did not find evidence for ultralow velocity zone. The structure is about 1200 km wide and has about a 3% drop in S-velocity although some small-scale features are apparent in the roof structure and midsection. The broadness of this structure is consistent with Davaille's (1999) experiment on chemical plumes. This 7000 km long ridge-like structure appears to be closely related to surface observables, South African geoid-high and the Dupal isotropic anomaly thought to be derived from old isolated mantle. All these observations argue for a distinct portion of mantle existing beneath Africa which could be very primitive.

MR72B-1045 1330h POSTER

Elastic Wave Velocity Measurements on Mantle Peridotite at High Pressure and Temperature

Gregory W Mistler[1] (828-262-3049; gm40626@appstate.edu)

Masahiro Ishikawa[2] (ishikawa@edhs.ynu.ac.jp)

Baosheng Li[3] (Baosheng.Li@sunysb.edu)

[1]Appalachian State University, Department of Geology, Boone, NC 28608, United States

[2]Yokohama National University, Department of Enviromental Sciences, Yokohoma 240-8501, Japan

[3]SUNY Stony Brook, Mineral Physics Institute, Stony Brook, NY 11794, United States

With the success of conducting ultrasonic measurements at high pressure and high temperature in large volume high pressure apparatus with in-situ measurement of the sample length by X-ray imaging, it is now possible to measure elastic wave velocities on aggregate samples with candidate compositions of the mantle to the conditions of the Earths transition zone in the laboratory. These data can be directly compared with seismic data to distinguish the compositional models in debate. In this work, we carried out velocity measurements on natural peridotite KLB-1 at the conditions of the Earths upper mantle. Fine powered sample of natural KLB-1 was used as starting material. Specimens for ultrasonic measurements were hot-pressed and equilibrated at various pressure and temperature conditions along geotherm up to the transition zone. The recovered samples were characterized with density measurement, X-ray diffraction and microprobe analysis. Bench top P and S wave velocities of KLB-1 sample sintered at 3-4 GPa and 1400 degree centigrade showed a very good agreement with the VRH average of pyrolite. High pressure and high temperature measurements was conducted up to 7 GPa and 800 degree centigrade using ultrasonic interferometric method in a DIA-type high pressure apparatus in conjunction with X-ray diffraction and X-ray imaging. The utilization of X-ray imaging technique provides direct measurements of sample lengths at high pressure and high temperature, ensuring a precise determination of velocities. The results of P and S wave velocities at high pressure and high temperature as well as their comparison with calculated pyrolite model will be presented.

MR72B-1046 1330h POSTER

Isotopic Evolution of the Mantle in Numerical Convection Models

Shunxing Xie[1] (sxie@ess.ucla.edu)

Paul J. Tackley[1] (ptackley@ess.ucla.edu)

[1]Dept. of Earth & Space Sci. Univ. of California (UCLA), 595 Charles Young Drive East, Los Angeles, CA 90095, United States

To investigate dynamical mechanisms that have been proposed to explain geochemical observations, a model of mantle convection that combines a treatment of major and trace element geochemical evolution with a dynamically-consistent mantle convection-plate tectonics is presented. Melting is simulated using a realistic solidus and is responsible for the generation of heterogeneity including the partitioning of trace elements between oceanic crust and residue; the subsequent hydrothermal alteration of element concentrations in the crust is also included. Trace elements studied are the $U-Th-Pb$ and $Sm-Nd$ isotope systems, helium and argon. Both olivine and pyroxene-garnet system phase transformations are included, with the relative density profiles of basalt, pyrolite, and harzburgite following those of Ringwood (1990) and Ono et al (2001) up to 800km depth, but varied in the deeper mantle to reflect present uncertainties.

A suite of numerical experiments has been run to systematically investigate the sensitivity of the results to uncertain physical properties such as the density of subducted crust in the deepest mantle and elemental partition coefficients. Results indicate that the system can self-consistently evolve regions that have a HIMU-like signature (by segregation of subducted crust at the CMB) and regions with high $^3He/^4He$. Low $^3He/^4He$ ratios evolve in crustal material even though He may be more incompatible that U, due to outgassing of He to the atmosphere. Some parameter combinations simultaneously lead to Earth-like distributions of $^3He/^4He$ ratios, Pb-Pb and Sm-Nd ratio plots for erupted material, and $\sim$ 50% outgassing of radiogenic ^{40}Ar consistent with geochemical constraints. In the preferred model, helium is highly incompatible and crust is dense near the CMB. The Sm-Nd age is 1-2 billion years. Earth-like $^3He/^4He$ histograms are produced (in erupted material) when sufficient subducted crust mixes back into the shallow mantle to bring its He ratio down to the MORB-like range.

URL: http://www.ess.ucla.edu/∼sxie/agu-f2002

MR72B-1047 1330h POSTER

Modeling the bulk- and shear-elasticity of a multi-phase mantle

C. Lithgow-Bertelloni[1] (734-647-9938; crlb@umich.edu)

Lars Stixrude[1] (stixrude@umich.edu)

[1]University of Michigan, Department of Geological Sciences, Ann Arbor, MI 48104, United States

In the 50 years since the classic paper of Birch, two major advances have transformed our view of the earth's elasticity and constitution: the imaging of the three-dimensional structure of the mantle, and the discovery and mapping of multiple high-pressure polymorphic phase transformations in mantle compositions. These breakthroughs have revolutionized our understanding of the composition, mineralogy, thermal state, and dynamics of the mantle. In order to explore the relationship between phase transformations and three-dimensional earth structure, we have been developing a unified description of the petrology and thermoelasticity of mantle assemblages. This approach allows us to construct models of the mantle that specify the variation of mineralogy and seismic wave velocities with pressure and temperature, and which are directly comparable to seismological observations. Our method begins with the concept of fundamental thermodynamic relations, which permits straightforward computation of phase equilibria, and, at the same time, all isotropic thermodynamic properties through volume and temperature derivatives of the appropriate thermodynamic potential. The integrated form of the Mie-Gruneisen equation of state provides an excellent starting point for an account of what is currently known of mantle phase equilibria and elastic properties. We have now generalized our approach to account for anisotropic properties. By generalizing the Gruneisen parameter and its volume derivative, q, to their appropriate tensorial forms, we are able to describe the pressure and temperature dependence of the shear (S) and longitudinal (compressional, P) wave velocities as well as the bulk sound velocity and density of mantle assemblages.

MR

We have applied our method to modeling of one-dimensional seismic wave velocity profiles of the mantle in various tectonic regimes, including old and young ocean, and shields. We compute the equilibrium phase assemglage and its seismic wave velocities along geotherms that account for lithospheric cooling and, in the case of shields, radioactive heat production. Seismologically determined shear velocity profiles are characterized by a distinct minimum in velocity at depths of 100-200 km. Comparison with our computed seismic wave profiles quantify the influence of attenuation and dispersion of seismic wave velocities in this depth range, which is found to be large and comparable to the influence of mantle composition (difference between basalt and harzburgite). Isochemical mantle compositions do not show a G discontinuity, as observed seismically in oceanic regions. We explore the possibility that this feature is caused by variations with depth in bulk composition, possibly due to basalt extraction.

MR11A MCC: 274 Monday 0830h

Elasticity and Constitution of the Earth's Interior IV *(joint with S, T, V, DI)*

Presiding: **G D Price,** University College London**; P J Tackley,** University of California, Los Angeles

MR11A-01 0830h INVITED

Birch's Mantle

Don L Anderson (626 395 6901; dla@gps.caltech.edu)

California Institute of Technology, Seismology Lab-M/C 252-21, Pasadena, CA 91125, United States

Francis Birch's 1952 paper started the sciences of mineral physics and physics of the Earth's interior. Birch stressed the importance of pressure , compressive strain and volume in mantle physics. Although this may seem to be an obvious lesson many modern paradoxes in the internal constitution of the Earth and mantle dynamics can be traced to a lack of appreciation for the role of compression. The effect of pressure on thermal properties such as expansivity can gravitational stratify the Earth irreversibly during accretion and can keep it chemically stratified. The widespread use of the Boussinesq approximation in mantle geodynamics is the antithesis of Birchian physics. Birch pointed out that eclogite was likely to be an important component of the upper mantle. Plate tectonic recycling and the bouyancy of oceanic crust at midmantle depths gives credence to this suggestion. Although peridotite dominates the upper mantle, variations in eclogite-content may be responsible for melting- or fertility-spots. Birch called attention to the Repetti Discontinuity near 900 km depth as an important geodynamic boundary. This may be the chemical interface between the upper and lower mantles. Recent work in geodynamics and seismology has confirmed the importance of this region of the mantle as a possible barrier. Birch regarded the transition region (TR ; 400 to 1000 km) as the key to many problems in Earth sciences. The TR contains two major discontinuities (near 410 and 650 km) and their depths are a good mantle thermometer which is now being exploited to suggest that much of plate tectonics is confined to the upper mantle (in Birch's terminology, the mantle above 1000 km depth). The lower mantle is homogeneous and different from the upper mantle. Density and seismic velocity are very insensitive to temperature there , consistent with tomography. A final key to the operation of the mantle is Birch's suggestion that radioactivities were stripped out of the deeper parts of Earth and placed in the crust and upper mantle. This resolves the lower mantle overheating paradox but the stratified mantle slows down the cooling of the Earth. A completely thermodynamically self-consistent treatment of mantle dynamics, with volume and temperature-dependent parameters has not yet been attempted but the essence of this approach is contained in the 1952 paper, which is must reading for all students of Earth's interior. One implication of this paper is that lower mantle structures should be gigantic and long-lived, a prediction spectacularly confirmed by modern seismic tomography.

MR11A-02 0845h INVITED

Challenging the Standard Model: Equation of State of Natural Peridotite at Lower-Mantle Conditions

Raymond Jeanloz[1] (jeanloz@uclink.berkeley.edu)

Kanani K. M. Lee[1] (leeka@uclink.berkeley.edu)

Sang-Heon Shim[1] (sangshim@seismo.berkeley.edu)

[1] Department of Earth and Planetary Science, University of California, Berkeley, CA 94720-4767

High-resolution x-ray diffraction of natural peridotite, before and after (subsolidus) laser heating at pressures as high as 107 GPa, yields results challenging the paradigm that the Earths mantle is a homogeneously mixed layer having the bulk composition of pyrolite.

The starting material for the experiments is representative of fertile upper mantle, and is indistinguishable from Ringwood's pyrolite compositions. It transforms to an assemblage of 76 (2)% $(Mg_{0.88}Fe_{0.06}Al_{0.12}Si_{0.94})O_3$ orthorhombic perovskite (opv) by volume at zero pressure, 17 (2)% $(Mg_{0.80}Fe_{0.20})O$ magnesiowstite (mw) and 7 (1)% $CaSiO_3$ perovskite (cpv), and room-temperature isotherms for each phase within the assemblage are in good agreement with past results on the individual mineral phases. Different measurement techniques yield reproducible results, with the observed scatter being well explained by the (small) compositional variations within the mineral phases of the natural starting material. We find values of the opv/mw Fe/Mg partition coefficient consistent with prior results, 0.20 (0.10) with no evidence of any pressure dependence, and recent work on $CaSiO_3$ perovskite shows that its structure exhibits slight tetragonal distortion at lower-mantle pressures.

The thermal equation of state of the high-pressure assemblage, described in terms of the Debye temperature, Gruneisen parameter and its volume dependence, is well determined if past measurements at high pressures and temperatures are reanalysed in terms of internally-consistent calibration standards. In particular, one model for the thermal equation of state of gold that has been used to calibrate several key experiments is faulty and yields biased results. Our reanalysis shows that all experiments point to relatively high values for the thermal expansion of opv (hence of the entire high-pressure assemblage), compatible with earlier rather than more recent analyses.

The resulting high-pressure, high-temperature bulk modulus of the high-pressure assemblage is constrained to about 5% at lower-mantle conditions, and is expected to be relatively insensitive to Fe abundance. Minimum temperatures of about 2000 K at 700 km depth rising to about 3000 K at 2500 km depth are required for the bulk modulus of the high-pressure assemblage to match the seismologically observed bulk modulus of the lower mantle. These values of temperature are in good accord with current estimates. The density of the pyrolite-composition high-pressure assemblage is then found to be at least 2 (1)%, (and plausibly 4 (2)%) lower than the seismologically determined density at corresponding depths. The density mismatch is partly attributable to the effect of Al on the volume of opv, as also found by others. Uncertainties in the measurements and analysis appear to be well constrained, and rule out pyrolite as a viable bulk composition for the preponderance of the mantle.

MR11A-03 0900h

A New Perspective on Seismic Constraints for 3D Mantle Density Suggests Strong Variations in Iron Content.

Joseph S Resovsky[1] (resovsky@geo.uu.nl)

Jeannot Trampert[1] (jeannot@geo.uu.nl)

[1] University Utrecht, Earth Sciences Faculty Budapestlaan 4, Utrecht 3508 TA, Netherlands

We have used model space mapping to produce probability distributions for various characteristics of long wavelength models of v_s, v_p, ρ, and boundary topography in the mantle. This is a new approach to translating the global seismic inverse problem into constraints on geodynamic and geochemical modeling. Our distributions reveal that typical results for velocity-density correlation and scaling from seismic inversions are neither robust nor representative of the true nature of the seismic constraints. The data clearly favor density perturbations in most of the mantle that are uncorrelated or negatively correlated with velocity heterogeneity and have amplitudes several times larger (yielding $\delta \ln v_s / \delta \ln \rho < 1.0$) than damped seismic inversions usually allow. These characteristics are most pronounced in the upper mantle transition zone and the top and bottom of the lower mantle. This is strong seismic evidence for broad regions of elevated chemical heterogeneity in the deep mantle, and suggests that variable iron content is a dominant component of such heterogeneity.

MR11A-04 0915h INVITED

Fluid Mechanics and the Dynamics of the Earth's Interior

Richard J. O'Connell (617-495-2532; oconnell@geophysics.harvard.edu)

Harvard University, 20 Oxford St, Cambridge, MA 02138, United States

Flow in the Earth's mantle is directly inferred from the motion of lithospheric plates on the surface. The rheology of the mantle has been directly estimated from observations of postglacial rebound. However, it was the determination of lateral variations of seismic velocities and their interpretation as density anomalies that has allowed the modelling of density driven convective flow in the mantle. Matching the geoid has allowed depth variations of rheological structure to be better inferred. Current models of mantle flow can account for plate motions and observed polar wander reasonably well. Flow in the mantle distorts and moves mantle plumes, which provides a test of the plume origin for hotspots, as well as predictions of hotspot motion. Rheological models based on rebound, the geoid and hotspot motion all show an increase in effective viscosity in the lower mantle, which should diminish convection there. Models of isotopic evolution require a range of reservoirs that have been separate for geologically long times. Flow and stirring rates in a convecting mantle will allow chemical heterogeneity to persist over geologic times, especially if rheologic heterogeneities exist. The determination of the nature and location of geochemical heterogeneity and reservoirs remains one of the outstanding problems in understanding the dynamics and evolution of the mantle, although recent models have illuminated new approaches to the problem.

MR11A-05 0930h

STRUCTURE, ELASTICITY, AND WAVE-VELOCITIES OF MgSiO3-PEROVSKITE AT LOWER MANTLE CONDITIONS

Renata M Wentzcovitch[1,2] (612 625 6345; wentzcov@cems.umn.edu)

Bijaya B karki[1] (612 625 1313; karki@cems.umn.edu)

Matteo Coccocioni[2] (93 040 3787411; matteo@sissa.it)

[1] Department of Chemical Ungineering and Materials Science, University of Minneaota, 421 Washington Ave SE, MInneapolis, MN 55455, United States

[2] International School for Asdvanced Studies, Via Beirut 4, Trieste, TS 34014, Italy

The crystal structure, elastic constants, and wave-velocities of MgSiO3-perovskite (Mg-pv) have been determined throughout the lower mantle's (LM) pressure/temperature (P,T) regime by means of first principles computations of its vibrational density of states at various strained configurations and free energy calculations within the quasi-harmonic-approximation (QHA). The latter is tested "a posteriori" and shown to be valid at expected conditions. This completes the series of calculations on the thermoelastic properties of Mg-pv that are necessary to 1) narrow down constraints on LM's composition and thermal state, 2) shed light on the relative role of temperature on 3D velocity structures, and 3)on the anisotropy of this phase.

MR11A-06 0945h INVITED

Geochemistry and Mantle Structure: Still Crazy After All These Years

Donald J DePaolo (510-643-5064; depaolo@eps.berkeley.edu)

U C Berkeley, Department of Earth and Planetary Science, Berkeley, CA 94720-4767, United States

Geochemical evidence suggests that the modern mantle is layered, or at least zoned, such that the uppermost mantle is more depleted in incompatible elements than the deeper parts of the mantle. The inference of vertical stratification is based largely on the idea that volcanism associated with passive upwelling at mid-ocean ridges provides a sampling of the shallow mantle, while plumes that support volcanism at hot spots provide a sampling of the deep mantle. This geochemical evidence has so far been difficult to reconcile with what is currently understood about mantle convection and seismic structure. Numerical convection models show little indication that stratification can be preserved, or that the upper and lower mantle differ much in terms of mixing efficiency. Seismic and mineral physics data suggest that there may be no barriers to radial flow. Progress has been made in defining problems, but in many ways the issues facing the community now differ little from the situation in 1982.

The mid-ocean ridge basalt (MORB)ocean island basalt (OIB) dichotomy may or may not fairly represent the current geochemical state of the mantle. The degree to which it does is an important issue to resolve. The apparent layering, if not an illusion, may be either a longstanding feature of the deep earth or something more like a dynamically maintained steady state. What we can assume is: (a) chemically fractionated material (continental crust and oceanic crust) has been extracted from the mantle in a semi-continuous way over the entire history of the earth, leaving domains in the mantle with complementary depletions; (b) continental material, as well as ocean floor, is currently being