separates the 4 km-thick Plio-Pleistocene South Wanganui Basin from the recently uplifted North Island axial ranges, to the west and east, respectively. The KMFS represents the westernmost expression of upper plate deformation associated with Hikurangi subduction over the last 2 million years. A seismic reflection network of lines acquired 1.5 km apart across the KMFS provides a way of constraining the Plio-Pleistocene tectonic activity in the region. Strike-projected, vertical separation profiles (D/L) demonstrate the interplay between faults, and indicate a regional southeast migration of the compressive system with time. Basement fault geometry suggests reactivation of a normal fault system and a minor amount of strike-slip motion. Fault terminations suggest that these faults have remained fixed with no lateral propagation since at least 1350 kyr. Cumulative D/L profiles have clear bell shapes, which contrast with the asymmetric shapes of individual D/L profiles. This suggests that the KMFS is a mature fault system with fault lengths initiated early in the evolution of the fault zone due to the pre-existing crustal heterogeneities under a constant regional strain regime. Long-term slip rates were derived from vertical separations across horizons dated 120, 620, 1000, 1350, 2400 and 3000+ kyr, for 21 fault segments. The maximum vertical slip rate on any one fault is less than 1 mm/yr, but the maximum long-term (1350 kyr) cumulative slip rate across the whole KMFS reaches 2.1+/-0.6 mm/yr. Late Quaternary deformation suggests slip rate magnitudes ranging from 0.1-1.4 mm.yr-1 over the last 10,000 years. Slip rates for the 0-120 kyr period increased, and the cumulative maximum slip rate for the KMFS reaches 5.0 +/- 1.5 mm/yr.

T21E-06 1145h

Fault System Evolution and Fault Reactivation During Large-Scale Distributed Deformation in Continental Lithosphere

Mousumi Roy (505-277-2580; mroy@unm.edu)

Department of Earth and Planetary Sciences, University of New Mexico, MSC-03-2040, 1 Univ. of New Mexico, Albuquerque, NM 87131, United States

Deformation within continents involves multi-scale responses such as localized brittle faulting (mainly in the upper crust) and more distributed deformation commonly modeled as elastic, viscous, or viscoelastic behavior (within the lower crust and upper mantle). This study investigates the interaction between localized faulting and distributed elastic flexure within intra-plate extensional settings. The geodynamic models presented are inspired by deformation observed at the Rio Grande rift, where Neogene extension appears to have been controlled by pre-existing lithosphericscale heterogeneities and where pre-existing (Laramide) structures show evidence of rift-related extensional reactivation. The idealized models explore the evolution of new and pre-existing brittle faults in an upper crustal layer during flexural bending of the lithosphere. Particular attention is devoted to understanding how flexure interacts with faulting within both the hanging wall and footwall blocks of asymmetric half-graben (such as the Espanola or Albuquerque basins of the central Rio Grande rift). The model results suggest that the combination of flexure and faulting within a bending plate can explain certain enigmatic features of the central Rio Grande rift, including topographically high rift-flanks on both the hanging wall and footwall blocks of asymmetric basins.

T21E-07 1200h

Detail Structure of San Andreas Fault Jog in Cholame Valley From Small-Scale Topography and Sesmic Data

Valeri Korneev (510-486-7214; vakorneev@lbl.gov)

Lawrence Berkeley National Laboratory, 90-1116, 1 Cyclotron Rd.,, Berkeley, CA 94720, United States

The significance of the Parkfield area is in it being a transition zone between creeping NW and locked SE sections of San Andreas Fault (SAF), which makes it a most likely spot defining future seismic activity of the region. The detailed studies of seismicity generated by Parkfield 1996 M6 event revealed very high seismic activity in Cholame valley region SE of the Parkfield and ruptures along Cholame valley tracing the fault along the surface. In the middle of the valley SAF has about 1.5 km jog to SW after which it continues to go in SE staying parallel to the original direction. The jog geometry had no surface evidence and was determined on the basis of epicenter locations of multiple events in this area. Seismic and theoretical studies (Hanna, et. Al. 1972; Eaton et. Al. 1970; Harris and Segall, 1986) suggested a complex structure of the jog area, being and interacting segment of two parts of SAF. Such segments usually represent wide zones with multiple fractures oriented at 45 degrees with respect to main fault orientation and which connect isolated segments of a fault. The corresponding micro-fracturing was observed in multiple locations of Cholame valley. Extent and mechanical properties of interacting segments have strong impact on accumulated strain release. The fault structure studies in Cholame valley are mostly based on seismic information since valley sediments cover bedrock and do not allow accurate fault mapping. Nevertheless we have found that low amplitude topography features of the valley apparently affected by bedrock surface geometry. The fault can be traced along both sides through an existing point of connection of jog with SW strand of SAF. Also there is a wide shear zone of interaction between upper and lower parts of SAF. Multiple NS oriented faults which make 45-degree angles with traces of SAF are quite visible. Image features also suggest a straight continuation of NW part of the SAF in SE direction after passing the jog. In the same time the NW straight extension of SE part of the SAF connects it with mapped part of the South-West Fracture Zone (SWFZ). This result suggests the Cholame valley fault structure represent two faults SAF and SWFZ, which were separate at some point in history but began interacting through development of zone of shear faulting in the middle of the valley leaving some of their old parts temporarily inactive.

T21F MCC: 3007 Tuesday 1020h

New Views of the Structure and Composition of the Deep Earth III

(joint with GP, S, V, MR, DI)

Presiding: **D L Farber,** Lawrence Livermore National Laboratory**; J Badro,** University Paris VI - Institut de Physique du Globe

T21F-01 1020h INVITED

Lower Mantle Composition From Mineral Physics Data

Jay D Bass[1] (1-217-333-1018; jaybass@uiuc.edu)

Jennifer M Jackson[1] (jmjackso@uiuc.edu)

Estelle Mattern[2] (estelle.mattern@ens-lyon.fr)

Jan Matas[2] (jan.matas@ens-lyon.fr)

Stanislav V Siogeikin[1] (sinogeik@uiuc.edu)

[1]University of Illinois, Geology Department 1301 W Green St., Urbana, IL 61801, United States

[2]Ecole Normale Superieure de Lyon, LST 46 allee d'Italie, Lyon cedex 07, ced 69364, France

The questions of lower mantle composition and thermal structure pose a considerable challenge for mineral physics. The pressures and temperatures of this region are difficult to simulate and measure accurately in the laboratory, and the phases likely present in this region are difficult to synthesize as high quality samples for accurate physical properties measurements. Nevertheless, over the last decade there has been enormous progress on characterizing the elastic and thermal properties of lower mantle phases. We review some of the recent experimental breakthroughs. These results have been used to infer the average composition of the lower mantle by extrapolation of mineral properties to lower mantle conditions and comparing them to global 1D Earth models, and also via formal inversion of seismic velocity and density profiles for composition. Inversions of density and bulk sound velocity are able to place constraints on the Mg/Si and the Mg/Fe ratios, but are less sensitive to Al and insensitive to Ca contents. This is in part due to recent experimental results which indicate that the bulk modulus of (Mg,Fe,Al)(Si,Al)O3 perovskite does not change much with Al content (contrary to previous experiments). However, the shear properties of aluminous perovskite differ substantially from those of Al-free perovskite, making the shear properties of the lower mantle a sensitive indicator of Al content. We discuss the range of compositional models consistent with the present laboratory results, and the most critical mineral physics results needed to further refine compositional and thermal models for the lower mantle.

T21F-02 1035h

Inversions for lower mantle composition and temperature from elasticity parameters and thermodynamic modeling

Estelle Mattern[1] (estelle.mattern@ens-lyon.fr)

Jan Matas[1] (jan.matas@ens-lyon.fr)

Jay Bass[2] (jaybass@uiuc.edu)

Yanick Ricard[1] (yanick.ricard@ens-lyon.fr)

Jennifer Jackson[2] (jmjackso@students.uiuc.edu)

[1]ENS Lyon, LST CNRS, 46 allee d'Italie, Lyon 69007, France

[2]Department of Geology, UIUC, 1301 W Green Street, Urbana, IL 61801, United States

Most constraints on lower mantle composition come from comparison of seismic profiles with their equivalents deduced from mineral physics. For seismologists, the parameters of primary interest are the velocities V_P and V_S and their lateral variations, whereas the most readily determined properties experimentally are K_S and ρ. Therefore, the two sets of results cannot be directly compared. Additional data analysis and thermodynamic modeling are then necessary. In this study, we apply a generalized inverse method and recent and highest quality experimental and seismological observations to compute the lower mantle composition and corresponding temperature profile. This method calculates the parameters (composition and temperature) which minimize a misfit function (density and bulk sound velocity) to best match global 1-D seismological profiles. We demonstrate that the Fe/Si and Mg/Si (molar) ratios are well constrained, and that there is a degree of covariance between the Ca/Si ratio and the Mg/Si ratio. The Al/Si ratio is only poorly constrained. The physical properties we have chosen yield a lower mantle model which is chemically homogeneous from 800 to 2700 km. Our method also gives the a posteriori uncertainties on the inverted parameters and, therefore, allows us to precisely evaluate how the experimental uncertainties on elastic parameters affect the composition and temperature. We show that if the bulk modulus of Mg-perovskite is 246 GPa instead of 261 GPa (5% difference), the resulting perovskite fraction is increased by 30%. Finally, if the temperature profile and composition are not simultaneously inverted, then the resulting lower mantle composition is highly dependent of the choice of the thermal regime.

T21F-03 1050h

Direct Measurements Of The Elastic Properties Of Iron To 115 GPa

Jonathan C Crowhurst[1] (925 422 1945; crowhurst1@llnl.gov)

Joseph M Zaug[1] (zaug1@llnl.gov)

Alexander Goncharov[1] (goncharov1@llnl.gov)

[1]Lawrence Livermore National Laboratory, 7000 E Avenue, Livermore, CA 94550, United States

The velocity of an acoustic wave propagating at the interface between diamond and polycrystalline iron has been measured using impulsive stimulated light scattering (ISLS) to 115 GPa in a diamond anvil cell. Our data provide the first direct measurements of the elastic properties of hexagonal close-packed iron at pressures comparable to that at the boundary between the Earth's core and mantle. The corresponding compressional and shear velocities are found to be linearly dependent on density, and consequently suggest a reliable extrapolation to inner-core conditions. Velocities thus obtained are compared with those of the Preliminary Reference Earth, and implications for core composition and structure are discussed.

T21F-04 1105h

Sound Velocity Measurements in Textured hcp-Iron and the Anisotropy and Structure of Earth's Inner Core

Daniele Antonangeli[1] (33-4-76-88-23-92; antonangeli@esrf.fr); Florent Occelli[2] (occelli1@llnl.gov); James Badro[3] (james.badro@ens-lyon.fr); Herwig Requardt[1] (requardt@esrf.fr); Guillaume Fiquet[3] (fiquet@lmcp.jussieu.fr); Michael Krisch[1] (krisch@esrf.fr)

[1]European Synchrotron Radiation Facility, 6 rue Jules Horowitz B.P. 220, Grenoble 38043, France

[2]Lawrence Livermore National Laboratory, P.O. Box 808, L-364, Livermore, CA 94551-9900, United States

[3]Laboratoire de Minéralogie-Cristallographie, Université Paris VI, Institut de Physique du Globe de Paris, 4 place Jussieu, Paris 75252, France

Seismological studies show that the Earth's inner core is elastically anisotropic. The anisotropy has an axial symmetry and an amplitude of about 3-4%, with the fast direction oriented parallel to the Earth's rotation axis. Several hypotheses have been proposed to explain this feature, but the lack of evidence from mineral physics does not allow to address them.
Indeed, the experimental determination of sound velocity anisotropy in hcp-iron, the main constituent of

the inner core, is of primary importance. Studies include first-principle calculations [1-5] and x-ray radial diffraction measurements [6], but the results show general disagreement, not only in magnitude, but in direction as well.
We will report new inelastic x-ray scattering (IXS) data on polycrystalline hcp-iron as a function of pressure, complementing and extending previous IXS data [7]. The derived longitudinal and transverse sound velocities will be compared with the calculations and the experimental results present in literature.
Furthermore, the issue of elastic anisotropy will be addressed. Taking advantage of the texturing developed by uniaxially compressed hcp-metals [8], and making use of a properly designed diamond anvil cell characterized by an angular aperture of more than 90^o, we measured the sound velocity at 22 and 112 GPa in two different geometries with respect to the compression axis, probing the longitudinal sound propagation at 50^o and 90^o with respect to it. A difference in acoustic sound velocity of about 5% has been detected at the highest pressure. This effective anisotropy on a textured polycrystalline sample is comparable with the one observed in the Earth, further relaxing the requirement of a nearly perfect alignment of iron crystal grains sustained by previous theoretical investigations [1,4].
[1] L. Stixrude, R.E. Cohen, Science 267, 1972 (1995). [2] P. Soderlind et al., Phys. Rev. B 53, 14063 (1996). [3] R. E. Cohen et al., Phys. Rev. B 56, 8575 (1997). [4] G. Steinle-Neumann et al., Phys. Rev. B 60, 791 (1999). [5] G. Steinle-Neumann et al., Nature 413, 57 (2001). [6] H.K. Mao et al., Nature 396, 741 (1998); correction Nature 399, 280 (1999). [7] G. Fiquet et al., Science 291, 468 (2001). [8] H. R. Wenk et al., Nature 405, 1044, (2000).

T21F-05 1120h

Chemical relaxation and seismic attenuation across a phase transition

Jan Matas[1] (+ 33 4 72 72 86 82; jan.matas@ens-lyon.fr)

Francois Guyot[2] (guyot@lmcp.jussieu.fr)

Yanick Ricard[1] (yanick.ricard@ens-lyon.fr)

[1]ENS Lyon / CNRS, 46 allee d'Italie, Lyon 69007, France

[2]Universite Paris 6 /IPGP, 4 place Jussieu, Paris 75005, France

Values of mantle thermodynamic properties are often deduced indirectly through seismological and geodynamical experiments that cover a large range of characteristic times. We show that due to phase transitions, the incompressibilities obtained by these experiments could be very different. Experimental probes faster than phase transformation kinetics sample unrelaxed properties at constant compositions. On the contrary, slow experiments sample relaxed properties at compositions maintaining thermodynamic equilibrium. We illustrate these concepts by using the example of the olivine-wadsleyite phase change that takes place around 410 km depth. We compute the incompressibility, attenuation and Bullen parameter as a function of kinetic rate of the transformation. We show that the compressional quality factor Q_K of mantle material undergoing a phase change can be as low as 0.6 when characteritic times of the phase kinetics and geophysical probes are comparable. Assuming that the characteristic time of olivine to wadsleyite transformation under average mantle temperatures is between 3 hours and 3 months, we show that the chemical relaxation can be a significant source of dissipation and of energy sink for slow processes (normal modes, tides or Chandler wobble). Using the example of normal modes we show that the compressional quality factor can be significantly low (Q_K ∼100) even if the sampled values of K_S are close to the unrelaxed ones. If the phase change kinetics is faster than 3 hours, the chemical dissipation can significantly affect probes even on seismic periods.

T21F-06 1135h INVITED

Seismological Constraints on Mantle Structure and Composition

Rob D van der Hilst[1] (1-617-253-6977; hilst@mit.edu)

Jeannot Trampert[2] (+31-30-253-5088; jeannot@geo.uu.nl)

Eleonore Stutzmann[3] (+33-1-4427-2413; stutz@ipgp.jussieu.fr)

[1]Massachusetts Institute of Technology, 77 Mass Av., Cambridge, MA 02139, United States

[2]Utrecht University, Budapestlaan 4, Utrecht, MA 3508 TA, Netherlands

[3]Institute de Physique du Globe, 4 Place Jussieu, Paris, 05 75252, France

Results of travel time tomography suggest that some slabs of subducted lithosphere are severely deformed between 400-1000 km depth - which is loosely referred to as the transition zone (Layer "C" according to Bullen's classification) - and that beneath some convergent margins subducted slab material has sunk to larger depths in the mantle, some perhaps to near the CMB. The transition zone may be marked by enhanced levels of anisotropy. These inferences all suggest that mantle convection is more complex than suggested by the canonical end-member models of either convective stratification at 660 km or unhindered whole mantle overturn. Over the past 5 years the emphasis has shifted from mapping wavespeed patterns to constraining spatial variations in temperature and composition, and there is now mounting seismological evidence for the existence of compositional heterogeneity in the deep mantle. P and S wave travel times suggest that the ratio of relative variations in shear- and compressional wavespeed (R=dlnVs/dlnVp) increases more rapidly with depth than can be explained by temperature effects alone, in particular away from major convergent margins (i.e., in the regions with the lowest wavespeeds). Furthermore, combined with constraints from mineralogy, normal mode studies based on full model space searches indicate that in the deep mantle the most likely ratios between variations in elastic parameters and density require variable composition. Both lines of study suggest that variations in perovskite and iron are needed to explain the seismological data. These inferences are qualitatively consistent with main aspects of the thermo-chemical mantle model proposed by Kellogg et al. (Science, 1999), but lack of observations of scattering off the implied interface (e.g., Castle & Van der Hilst, JGR, 2003) renders existence of a distinct layer in the deep mantle unlikely. Diffuse boundaries due to hitherto unknown phase transitions or gradual, pressure induced changes in composition cannot yet be ruled out, however, and in thermo-chemical convection vertical mixing gradients may exist over long periods of geological time, with rapid recycling in the shallow mantle and a lowermost mantle that is much less often involved in convective overturn. We will speculate on the possible origin of the compositional heterogeneity in the mantle beneath 1000 km depth.

T21F-07 1150h

Diamond Formation in Core Segregation Experiments : a key for Estimating the Carbon Content of Planetary Cores

Julien Siebert[1] (33-1-49-32-91-03; sieb2001@hotmail.com)

Francois Guyot[2] (guyot@lmcp.jussieu.fr)

Valerie Malavergne[1] (malaverg@univ-mlv.fr)

Marc Chaussidon[3] (chocho@crpg.cnrs-nancy.fr)

[1]Laboratoire Geomateriaux, Universite de Marne la Vallee. Cite Descartes. Champs-sur-Marne, Marne la Vallee 77454, France

[2]LMCP-IPGP, 4 place Jussieu, Paris 75005, France

[3]CRPG, 15 rue ND des Pauvres, Vandoeuvre 54501, France

High-pressure experiments were performed in a multi-anvil press at 1700 °C and pressures between 10 and 25 GPa on assemblages of iron carbonate (siderite) and silicon. The relative proportions of the two phases were varied in order to investigate different conditions of oxygen fugacities in the run products. The relevance of the investigated experimental conditions to core formation models is discussed. Samples were studied by Raman spectroscopy, electron microscopy, ion and nuclear microprobes. In all samples, siderite was reduced to (Fe,Si) metallic alloy and to diamond whereas silicon was partially oxidized to stishovite. The diamonds formed are euhedral crystals with characterisitc sizes of 20 micrometers. The carbon content in the metal phase equilibrated with those diamonds (diamond saturation) has been measured by ion microprobe to be of 1.5 wt %. This number would be an upper bound for the carbon content of planetary cores formed under such conditions. This suggests that the carbon content in the Earth's core is low when compared to the cosmic abundance of this element, but large enough for the inner core to be constituted of iron carbide (see Wood et al 1993, Earth and Planetary Science Letters, 117, 593-607). Moreover, this study brings new constraints on the relative position of silicon-stishovite and carbon-carbonate buffers at high pressure and provides experimental evidence of diamond formation from reduction of carbonates by reaction with Fe-Si alloys.

T21F-08 1205h

Some Geochemical Implications of the Mantle Transition-Zone Water-Filter Model

Shun-ichiro Karato[1] (203-432-3147; shun-ichiro.karato@yale.edu)

David Bercovici[1] (david.bercovici@yale.edu)

[1]Yale University, Department of Geology & Geophysics, New Haven, CT 06520, United States

Geochemical observations are usually interpreted in terms of the Earth's initial composition and subsequent differentiation, including (1) core-mantle separation, (2) continental crust formation and (3) partial melting at mid-ocean ridges and/or subduction-zone upper mantle. In this traditional picture, significant chemical differentiation occurs only in the shallow upper mantle [process (3)], in which case it is difficult to reconcile geochemical evidence for isolated mantle reservoirs with geophysical evidence for mantle-wide convective circulation. However, we recently proposed [Bercovici and Karato, Nature, Sept 4, 2003] that dehydration-induced partial melting at 410km will act as a filter for incompatible elements which are extracted into a dense melt that is then returned to the deep mantle; the trace-element circulation is thus partially decoupled from the convective circulation of the bulk of the mantle which occurs at the whole-mantle scale. In this model, the OIB source materials are drawn directly from the undepleted and heterogeneous deep mantle (deeper than 410km), while the MORB source materials are processed through the putative 410km dehydration-melting "filter". The separation of MORB and OIB source materials is thus assumed to occur at 410km and therefore it is important to examine if our hypothesis is consistent with observations of isotopes with very slow radioactive decays (i.e., $^{87}Sr/^{86}Sr$, $^{143}Nd/144Nd$). The $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ ratios are distinct between OIBs and MORBs (i.e., OIBs have a wider distribution than MORBs, and MORB isotopic ratios correspond to "depleted" chemistry). These isotopic ratios are controlled by (i) the chemical composition (Rb/Sr and Sm/Nd, respectively) and (ii) the long-term radioactive decay (half-life of 48 and 106 Gyrs, respectively). A simple analysis was made to calculate the contrast in the $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ ratios between OIBs and MORBs corresponding to our model. Two factors control these isotopic ratios in our model: (i) chemical differentiation at 410km between Rb/Sr and Sm/Nd and (ii) the volume fraction of OIB sources with different isotopic ratios (and the degree of mixing of these materials in the 410km dense melt layer). We find that the observed isotopic ratios are consistent with our model if (i) the source region of OIBs is volumetrically dominated by materials with isotopic ratios similar to Hawaii or FOZO source regions (but not EM1 or HIMU), (ii) significant chemical fractionation occurs by partial melting at 410km for Rb/Sr but not for Sm/Nd and (iii) the mixing at 410km is extensive. Implications for other geochemical signatures including isotopic ratios of rare gas elements and their volumetric amounts and the trace element distribution pattern will also be discussed.

T22A MCC: Level 1 Tuesday 1330h

Development of Fault Systems Through Time: Process and Rates III Posters

Presiding: **P Cowie,** Edinburgh University**; N Dawers,** Tulane University

T22A-0487 1330h POSTER

A High Resolution Geophysical Study of the Offshore Western Gulf of Corinth Rift

Lisa McNeill[1] (lcmn@soc.soton.ac.uk); Carol Cotterill[1] (cjc3@soc.soton.ac.uk); Aristofanis Stefatos[2] (A.Stefatos@upatras.gr); Tim Henstock[1] (then@soc.soton.ac.uk); Jon Bull[1] (bull@soc.soton.ac.uk); Richard Collier[3] (richard@earth.leeds.ac.uk); George Papatheodorou[2] (A.Stefatos@upatras.gr); Aggeliki Georgiopoulou[1] (ag1000@soc.soton.ac.uk); George Ferentinos[2] (gferen@upatras.gr)

[1]Southampton Oceanography Centre, University of Southampton, Southampton SO14 3ZH, United Kingdom

[2]Laboratory of Marine Geology and Physical Oceanography, University of Patras, Patras 26500, Greece

[3]School of Earth Sciences, University of Leeds, Leeds LS2 9JT, United Kingdom

The western Gulf of Corinth has generated recent debate in terms of distribution of extensional strain, interactions between active faults and fault geometry. Onshore data suggest that faults do not accommodate extensional strain of the magnitude suggested by geodetic measurements. Recently acquired high resolution