extended the accessible pressure range and sound velocities have now been reported in iron and other materials to pressures up to 1 MBar. New high-precision studies of compositional variations in garnets, olivines, and high-pressure silicates are placing tight constraints on compositional and structural effects on seismic velocity at upper mantle pressures. In the $(Mg,Fe)_2SiO_4$ system, there is now broad agreement among different research groups on the relevant pressure and temperature derivatives of the aggregate elastic moduli. To first order, the results support Anderson's long-standing proposal for an olivine-poor transition zone, although the presence of volatiles and the non-linear nature of the transformation have been used to argue for more olivine-rich compositions. New synchrotron x-ray diffraction capabilities together with advanced laser heating techniques have also led to important developments in understanding of phase relations in the mantle. In the transition zone, new in situ studies have reopened controversy surrounding the location and slope of the post-spinel transition in Mg_2SiO_4. Phase relations in $MgSiO_3$, SiO_2, and $CaSiO_3$ have been carefully explored at deep lower mantle pressures as have some more chemically complex systems. Broadly speaking, these studies have revealed the existence of structurally subtle phase transitions that nevertheless could have important geophysical implications. Minor chemical elements may also have a major effect on physical and chemical properties under deep mantle conditions. A few key advances and some of the outstanding problems will be highlighted.

S12D-03 1430h

What Mantle Processes Determine Isotopic

Paul J Tackley[1,2] (310-206-9180; ptackley@ucla.edu)

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

[1]Department of Earth and Space Sciences, UCLA, 595 Charles Young Drive E, Los Angeles, CA 90095-1567, United States

[2]Institute of Geophysics and Planetary Physics, UCLA, 595 Charles Young Drive E, Los Angeles, CA 90095-1567, United States

Isotopic measurements on Mid Ocean Ridge Basalts and Ocean Island Basalts indicate effective 'ages' (from e.g., U-Pb or Sm-Nd systems) in the range 1-2 billion years- much less than the age of the Earth, even though melting should have been much more vigorous early on and skewed the mean time since melting to older values. This relatively young 'age' has generally been explained in terms of stretching of heterogeneities by mantle convection, which might reduce them to dimensions too small to be individually distinguishable in short timescales of less than 1 Gyr. On the other hand, published numerical models that use tracers to track differentiated material (Christensen and Hofmann, 1994, Davies, 2002) suggest that Earth-like 'ages' can be obtained without taking stretching-induced erasure of tracer signatures into account, although this might effectively happen if the lengthscale for sampling the isotope systems was large enough. In those models, the only explicit mechanism for resetting isotope systems was re-melting, but for this to explain the isotopic ages observed for basalts, the global rate of melting in the recent past would have had to be very much higher than present-day values. To investigate stretching vs. re-melting we have conducted numerical experiments of a cooling mantle with plate tectonics, differentiation and evolution of important isotopic systems. The time of last melting and the total strain is tracked on each tracer (in addition to isotopic information). The results confirm that a model matching today's crustal production rate and with a reasonable secular cooling history generates ages' that are substantially larger than those observed, with the extent of crustal settling above the CMB making some difference but not enough. The effect of sampling lengthscale on observed age' is also tested and found to be insufficient to explain the data. Thus, these results reaffirm the importance of stretching as a key mechanism for effectively deleting older heterogeneities. From analysis of strain vs. age and matching of the observed ages, it is estimated that erasure of heterogeneities occurs at strains of 10^3-10^4, somewhat larger than has often been assumed.

S12D-04 1445h

Partitioning of Oxygen During Core Formation on Earth and Mars

David C Rubie[1] (+49 921 553711; dave.rubie@uni-bayreuth.de)

Christine K Gessmann[1] (christine.gessmann@t-online.de)

Dan J Frost[1] (dan.frost@uni-bayreuth.de)

[1]Bayerisches Geoinstitut, Universitaet Bayreuth, Bayreuth D-95440, Germany

Core formation on Earth and Mars involved the physical separation of Fe-Ni metal alloy from silicate, most likely in deep magma oceans. Although core-formation models explain many aspects of mantle geochemistry, they do not account for large differences between the compositions of the mantles of Earth (~8 wt% FeO) and Mars (~18 wt% FeO) or the much smaller mass fraction of the Martian core. Here we explain these differences using new experimental results on the solubility of oxygen in liquid Fe-Ni alloy, which we have determined at 5-23 GPa, 2100-2700 K and variable oxygen fugacities using a multianvil apparatus. Oxygen solubility increases with increasing temperature and oxygen fugacity and decreases with increasing pressure. Thus, along a high temperature adiabat (e.g. after formation of a deep magma ocean on Earth), oxygen solubility is high at depths up to about 2000 km but decreases strongly at greater depths where the effect of high pressure dominates. For modeling oxygen partitioning during core formation, we assume that Earth and Mars both accreted from oxidized chondritic material with a silicate fraction initially containing around 18 wt% FeO. In a terrestrial magma ocean, 1200-2000 km deep, high temperatures resulted in the extraction of FeO from the silicate magma ocean, due to the high solubility of oxygen in the segregating metal, leaving the mantle with its present FeO content of ~8 wt%. Lower temperatures of a Martian magma ocean resulted in little or no extraction of FeO from the mantle, which thus remained unchanged at about 18 wt%. The mass fractions of segregated metal are consistent with the mass fraction of the Martian core being small relative to that of the Earth. FeO extracted from the Earth's magma ocean by segregating core-forming liquid may have contributed to chemical heterogeneities in the lowermost mantle, a FeO-rich D" layer and the light element budget of the core.

S12D-05 1500h

Prograde and Retrograde Free Core Nutations Observed with VLBI

Andrew Palmer[1] (416-736-2100 x66438; palmer@core.yorku.ca)

Doug Smylie[1] (416-736-2100 x66438; doug@core.yorku.ca)

[1]York University, 4000 Keele Street, Toronto, ONT M3J 1P3, Canada

VLBI nutation measurement series from Goddard Space Flight Center and the United States Naval Observatory have been analyzed for Free Core Nutation resonances. Our analysis implements Singular Value Decomposition to solve the least squares problem of fitting the Discrete Fourier Tranform to the non-equispaced VLBI nutation observations. A novel feature of our procedure is to use the Parseval relation to determine the number of singular values of the coefficient matrix to be eliminated. We report the observation for the first time of the prograde mode predicted by Jiang (1993). The long series of observations allow the determination of the time evolution of the Free Core Nutation. We report a ring down of the large retrograde mode. In addition to providing a value for the viscosity just below the Core-Mantle Boundary, it suggests an impulse excitation rather than a continuous excitation. The interest of one of us (DES) in the rotational dynamics of Earth's core was stimulated by a conversation with Don Anderson about the possibility of the inner core being titled with respect to the shell and that a gravitational restoring torque might result. Indeed a large gravitational coupling exists and plays an important role in the rotational dynamics of the inner and outer cores.

S12D-06 1515h INVITED

Seismic Wave Attenuation and Dispersion: Insights From the Earth and the Laboratory

Barbara Romanowicz[1] (1 510 643 5690; barbara@seismo.berkeley.edu)

Ian NS Jackson[2] (61-6-1252498; ian.jackson@anu.edu.au)

[1]U. C. Berkeley, BSL, 215 McCone Hall, Berkeley, CA 94720, United States

[2]Research School of Earth Sciences, Australian National University, Canberra ACT0200, Australia

The study of the 3D anelastic structure and its frequency dependence using seismological tools, combined with experimental data on Q provide potentially powerful constraints on the rheology and dynamics of the earth's interior. Since the pioneering work of D.L. Anderson and his colleagues in the 1970's and 1980's, progress has been hampered on the seismological side, by the difficulty of separating the effects of intrinsic attenuation from those of elastic scattering and focusing, and on the experimental side, by the difficulty of performing measurements in the combined relevant frequency, temperature, and pressure ranges. The last decade has seen the progressive build-up of a large global dataset of high quality seismic broadband data, as well as significant improvements in processing techniques. In parallel, there has been progress in our ability to model 3D elastic structure as well as its effects on the amplitudes of seismic waves. We focus on discussing recently developed global and regional models of lateral variations in Q in the crust and upper mantle. In particular, we illustrate how, for the first time, 3D global models obtained using different types of waves and processing techniques result in compatible Q distributions in at least the upper 250km of the mantle, which correlate well with global tectonics as well as higher resolution regional results. We discuss future challenges and directions. In parallel with seismological studies, there has been dramatic recent progress in laboratory study of seismic wave dispersion and attenuation - particularly in olivine-dominated upper-mantle materials. Torsional forced-oscillation and microcreep tests of fine-grained synthetic Fo90 polycrystals have revealed a broad absorption band within which Q^{-1} varies smoothly and monotonically with period (with a power-law exponent 0.3), temperature and grain size. Similar studies of melt-bearing olivine polycrystals typically reveal an enhanced level of background dissipation along with a clearly resolved dissipation peak. Superposition of the frequency dependences associated with the background and the long-period side of the dissipation peak results in nearly frequency-independent Q^{-1} for suitable combinations of period, temperature, grain size and melt fraction. The Q^{-1} peak for the melt-bearing materials is apparently not the result of melt squirt; instead it is plausibly attributed to elastically accommodated grain-boundary sliding. However, the behaviour of the melt-free materials is difficult to reconcile with classical models of grain-boundary sliding - suggesting that these need to be re-evaluated. Seismic-frequency laboratory data, extrapolated to the larger grain sizes and higher pressures of the upper mantle, are finally beginning to provide a robust basis for understanding the wave speed variability and attenuation in the mantle. The state-of-the-art will be illustrated with laboratory-based models for the depth dependence of shear wave speed and attenuation for the oceanic upper mantle.

S12E MCC: 3007 Monday 1600h

Seismic Hazards in the Great Basin II

(joint with G)

Presiding: **C M Snelson,** University of Nevada,, Las Vegas**; I G Wong,** Seismic Hazards Group, URS Corporation

S12E-01 1600h INVITED

Quaternary Extensional Tectonics of the Basin and Range Province

Michael N Machette (303 273-8612; machette@usgs.gov)

U.S. Geological Survey, MS 966, Box 25046, Denver, Co 80225-0046, United States

The Basin and Range province is experiencing rapid growth, increasing water demand, and an average of about 11 mm/yr of NW-directed extension. None of these trends are compatible. Most Quaternary faults trend N, have a normal-dip movement, and border strongly uplifted or tilted ranges. Although these faults are spectacular, the slip rates and recurrence intervals for M 6.5+ ground ruptures are ca. 0.1 mm/yr and 10^4 yr, respectively. Obviously, some faults are considerably more active, such as the Genoa fault (2-3 mm/yr) and the Wasatch fault (1-1.5 mm/yr). However, the many hundreds of less remarkable Basin and Range (B&R) faults are poorly documented. Paleoseismic studies of some of these faults reveal average slip rates of 0.05-0.15 mm/yr and recurrence intervals measured in tens of thousands of years. Offsetting this relatively benign hazard are the sheer bulk of faults that riddle the province. A new USGS compilation of faults found ca. 600 structures in Nevada and 150 in New Mexico, 15% of which have been active in the past 15 k.y. Except for historic ruptures in the province, there is little spatial association of faulting and recorded seismicity. For example, the Wasatch fault zone is poorly expressed on Utah seismicity maps, and the Thousand Springs fault was aseismic well before 1983 Borah Peak, Idaho earthquake. Similar examples are common in the B&R, especially its southern half. For the most part, the normal faults are aseismic and locked, but can be loaded to near the point of failure. Conversely, the CNSB has been the preferred site for historic earthquakes larger than M 6.5. From 1872 to 1954, seven large earthquakes ripped through this NNE-trending belt: an average of one rupture every 14 years. Paleoseismic investigations of the CNSB have shown that this rate and spatial pattern of activity is anomalous. There is no evidence for similar precursory activity in the past 50 k.y. and there has been almost 50 years of quiescence since the last large earthquake. So one of the most perplexing questions is "why here and where next". With the advent of GPS monitoring we are starting to better identify

the active faults of the B&R. Now the challenge is to compare geologically determined rates and styles of deformation to contemporary strain fields determined by GPS and see if the regions of accelerated extension are relicts of the recent past or precursors of the future.

S12E-02 1620h

Challenges in Seismic Hazard Mapping of the Great Basin

Mark D. Petersen[1] ((303) 273-8546; mpetersen@usgs.gov)

Arthur D. Frankel[1] ((303) 273-8556; afrankel@usgs.gov)

Chris H. Cramer[2] ((901) 678-4992; cramer@usgs.gov)

[1]U.S. Geological Survey, Denver Federal Center, MS 966, Box 25046, Denver, CO 80225, United States

[2]U.S. Geological Survey, 3876 Central Ave., Suite 2, Memphis, TN 38152, United States

The Great Basin has hundreds of seismically active faults. Most of these earthquake sources have low to moderate slip rates, and only rupture in large earthquakes every few thousand to tens of thousands of years. In spite of these low activity rates several faults have generated large earthquakes; ten earthquakes have ruptured the surface during the past two centuries, and several of those ruptures are attributable to faults that did not have evidence of Holocene displacement. The large number and vast areal extent of these faults cause a significant hazard that must be considered in engineering, emergency response planning, and other public policy applications. We recently updated the USGS National Seismic Hazard Maps which are now available on the USGS website (http://geohazards.cr.usgs.gov/eq/). This update involved reassessment of fault slip rates, magnitudes, magnitude-frequency distributions, geodetic data, and attenuation relations. Several issues are being evaluated for future versions of these maps: (1) Alternative source models: We compare the hazard calculated using an alternative multi-segment rupture model for the Wasatch fault with the individual segment rupture models that were used in the 2002 update. (2) Alternative recurrence models: Time-dependent hazard at sites along the Wasatch front have been calculated using the Brownian Passage Time recurrence distribution. This distribution is characterized by mean recurrence and aperiodicity that are computed from the paleoseismic data. Geodetic data was evaluated to analyze strain rates across the Great Basin and influenced modeling of the Central Nevada Seismic Zone. (3) Updated attenuation relations: Current studies are focusing on the attenuation properties of the crust across the Great Basin. (4) Monte Carlo uncertainty analysis: We have calculated uncertainty for the hazard at several sites by varying the characteristic magnitude, fault slip rate or recurrence rate, fault length, magnitude-frequency distributions, and attenuation relations. This uncertainty is about +/- 50% of the mean value at one standard deviation. (5) Urban hazard maps: We have begun collecting data along the Wasatch fault to develop a community 3-D velocity model. Evaluation of these important issues by working groups from the Earth-science and engineering communities will lead to products that incorporate the best science available and that are useful for public policy applications.

URL: http://geohazards.cr.usgs.gov/eq/

S12E-03 1640h

Pattern and Rates of Faulting in the 1932-1954 Portion of the Central Nevada Seismic Belt

John W Bell[1] (775-784-1939; jbell@unr.edu)

S. John Caskey[2] (caskey@sfsu.edu)

Alan R Ramelli[1] (ramelli@unr.edu)

Luca Guerrieri[3] (guerrier@anpa.it)

[1]Nevada Bureau of Mines and Geology, University Of Nevada, Reno, NV 89557, United States

[2]Department of Geosciences, San Francisco State University, San Francisco, CA 94132, United States

[3]Agenzia Nazionale per la Protezione dell'Ambiente, Via Brancati, 48, Roma 00144, Italy

The 1932-1954 portion of the central Nevada seismic belt (CNSB) is a concentration of historical surface faulting in the Basin and Range province, forming a linear, nearly continuous 300-km-long rupture zone. We have integrated the results of previous studies with new paleoseismic and exploratory trenching data from seven faulting sites to investigate the seismogenic behavior of the CNSB. In particular, we looked for evidence of older, similar, belt-like patterns or elevated slip rates that could indicate whether this part of the CNSB is a zone of focused, long-term crustal strain. Our results show that the continuous rupture belt produced by six earthquakes in 1932 and 1954 was not replicated in at least the last 10-20 kyrs. Based on the timing and mapped distribution of paleoseismic rupture zones, several similar, but not identical, belt-like combinations are possible, though each requires apparent gaps in the along-strike pattern. Faults in this portion of the CNSB have moderate- to low-slip rates in the range of 0.09-0.50 mm/yr, similar to most late Quaternary faults in the western Basin and Range. Although long-term (Holocene) strain accumulation does appear to increase from east to west into the CNSB at the latitude of the 1954 sequence, the CNSB is not a belt of concentrated or elevated crustal strain compared with areas to the west. We conclude that the results best support the belt migration model proposed originally by Wallace (1984) in which temporal tectonic pulses migrate regionally, and perhaps activate different belt-like combinations of late Quaternary faults in an as yet unknown pattern of migration. The increase in the distribution of Holocene fault activity from east to west into the CNSB is consistent with a marked increase in the GPS velocity field at the latitude of the 1954 rupture sequence. However, a comparison of the total paleoseismic extension rate across the belt (0.57-1.22 mm/yr) with the published GPS rate (2.56-2.91 mm/yr) shows that there is a factor of 2 to 5 discrepancy in the rates.

S12E-04 1655h

Seismotectonics and Seismic Hazard of the Sierran Nevada Great Basin Boundary Zone and Yucca Mountain Region

Ken Smith[1] (75-784-4218; ken@seismo.unr.edu)

David von Seggern[1] (775-784-4242; vonseg@seismo.unr.edu)

Glenn P. Biasi[1] (775-784-4576; glenn@seismo.unr.edu)

Diane dePolo[1] (775-784-4576; diane@seismo.unr.edu)

[1]Nevada Seismological Laboratory, MS 174, University of Nevada Reno, Reno, NV 89557, United States

Geodetic data indicate that the Sierra Nevada block is moving at about 14 mm/yr N40-450W relative to stable North America. This motion accounts for about 20-25% of the current western North American plate motion budget and is oblique to active faults along the Sierra Nevada-Great Basin boundary zone and Walker Lane belt in a transtensional deformation field. Faulting over the past few million years has been concentrated along faults of the Eastern California shear zone, and the Walker Lane belt. Linear strike-slip faults of the Eastern California shear zone terminate near the Long Valley Caldera region marking an abrupt transition in the deformational style between the southern and northern western Great Basin. These tectonic transitions are reflected in the distribution and character of the historical and instrumental seismicity. North of Long Valley, through going strike-slip faulting is concentrated outboard from the Sierran Range front in the Central Walker Lane belt, whereas normal faulting in a series of left-stepping range bounding faults exhibiting E-W extension characterizes the Sierra Great Basin Boundary region from Long Valley to about the latitude of Reno-Lake Tahoe. Seismicity in the Lake Tahoe region is primarily concentrated in the transition between left-stepping normal faults in zones of high-angle conjugate strike-slip faulting. These observations suggest potential shortening as a mechanism of slip transfer between normal fault systems along the range front. Also, these slip transition zones show different recurrence behavior, activity rates and maximum magnitudes than the adjacent primary normal fault systems. One important kinematic problem is how to reconcile extension directions observed from instrumental seismicity and Sierran motion in the central western Great Basin. An upgrade to a digital seismic network in southern Nevada under the DOE Yucca Mountain Project has increased the detection threshold by about 1 magnitude unit (the catalog is complete to about M -0.5 near Yucca Mountain) improving resolution of tectonic features near the potential high-level nuclear waste repository. Slip rates of Quaternary faults in the Yucca Mountain area are more than 2 orders of magnitude less than those of the Furnace Creek fault zone 75 km to the west. With the increase in the number of earthquakes that can now be located within the NTS regional network we propose that the observed distribution of seismicity in southern Nevada in the NTS area primarily reflects the remnant of a Miocene tectonic fabric consistent with low Quaternary strain rates. With increased urbanization of Las Vegas and the implications of significant seismic amplification in valley sediments, the understanding of the regional tectonics, fault slip rates and background seismicity becomes increasing important for seismic hazard assessment in southern Nevada.

S12E-05 1715h

Issues in Evaluating Seismic Hazards in the Basin and Range Province: An Example From Yucca Mountain

Ivan G. Wong[1] (510-874-3014; ivan_wong@urscorp.com); J. Carl Stepp[2] (830-833-5446; cstepp@moment.net); John Whitney[3] (303-236-7803; jwhitney@usgs.gov); Richard Quittmeyer[4] (702-295-4371; richard_quittmeyer@ymp.gov); Norman Abrahamson[5] (510-428-9823; naa3@pge.net); Robert Robert[6] (510-663-4100; byoungs@geomatrix.com); Kevin Coppersmith[7] (925-974-3335; kevin@coppersmithconsulting.com); Gabriel Toro[8] (978-266-2639; toro@riskeng.com); Project Members of the Yucca Mountain PSHA

[1]URS Corporation, 500 12th Street, Suite 200, Oakland, CA 94607, United States

[2]URS Corporation, 871 Chimney Valley Road, Blanco, TX 78606, United States

[3]U.S. Geological Survey, Denver Federal Center, MS 980, Denver, CO 80225, United States

[4]ISSI, 1180 Town Center Drive, MS 423, Las Vegas, NV 89144, United States

[5]Consultant, 152 Darcena Avenue, Piedmont, CA 94611, United States

[6]Geomatrix Consultants, Inc., 2101 Webster Street, 12th Floor, Oakland, CA 94612, United States

[7]Geomatrix Consultants, Inc., 2121 North California Blvd., Suite 290, Walnut Creek, CA 94596, United States

[8]Risk Engineering, Inc., 3 Farmers Row, Acton, MA 01720, United States

Evaluating seismic hazards in the Basin and Range Province poses significant challenges due, in large part, to an inadequate empirical database. Despite a dramatic increase in paleoseismic investigations of Basin and Range faults in the past decade, long inter-event times, limitations associated with age-dating, and geologic, financial, and physical constraints in excavating the necessary deep paleoseismic trenches have hindered our ability to decipher the seismic cycles along the vast majority of Basin and Range faults. The almost nonexistent strong motion database also poses challenges in characterizing strong earthquake ground motions. Due to an intensive program of seismic hazard-related investigations and seismic monitoring, particularly in the past 10 years, Yucca Mountain, the site of the first U.S. underground nuclear waste repository has become the most analyzed site in the Basin and Range Province. These studies culminated in an expert judgment probabilistic seismic hazard analysis (PSHA) for ground motion and fault displacement. Despite the relative abundance of seismological and paleoseismic data, the ranges of expert interpretations and uncertainties in characterizing the earthquake potential of Quaternary faults and ground motion estimation were still very significant. Significant seismic source issues included: (1) the role of planar block faulting versus detachment faults; (2) the seismogenic potential of listric and detachment faults; (3) rupture models for closely-spaced faults both along strike and downdip; (4) identification and characterization of multiple fault segment ruptures; (5) depth of seismogenic faults and rupture in large events; (6) recurrence models for faults; (7) the role of Walker Lane-style shear deformation; and (8) approaches to addressing the hazard from "background" earthquakes. Issues in characterizing ground motion estimation included: (1) whether ground motions in extensional regimes are smaller than in compressional regimes (e.g., California) possibly due to lower earthquake stress drops; (2) hanging wall versus footwall effects; (3) ground motions from multiple parallel faults and detachment faults; and (4) the value of the near-surface attenuation parameter kappa. How these issues were addressed by the PSHA experts and their relative significance to the seismic hazard at Yucca Mountain are presented.

S

S12E-06 1730h

Quaternary Faults and Basin-fill Sediments of the Las Vegas Basin, Southern Nevada

Wanda J Taylor[1] ((702) 895-4615; wjt@unlv.nevada.edu); Eric Fossett[1] ((702) 895-1133; efossett@hotmail.com); Barbara Luke[2] (bluke@egr.unlv.edu); Catherine Snelson[1] (csnelson@unlv.edu); Tiana Rasmussen[3] (tiana@seismo.unr.edu); Dave McCallen[4] (mccallen2@llnl.gov); Arthur Rodgers[4] (rodgers7@llnl.gov); John Louie[3] (louie@seismo.unr.edu)

[1]Geoscience, University of Nevada Las Vegas, 4505 Maryland Parkway, Las Vegas, NV 89154-4010, United States

[2]Civil & Environmental Engineering, University of Nevada Las Vegas, 4505 Maryland Parkway, Las Vegas, NV 89154-4015, United States

[3]Seismological Laboratory, University of Nevada, 1664 N. Virginia Street, Reno, NV 89557-0141, United States

[4]Lawrence Livermore National Laboratory, 7000 East Ave., Livermore, CA 94550-9234, United States

The N-S elongated extensional Las Vegas basin, southern Nevada, contains 100's of meters of Cenozoic basin-fill sediments that are cut by several Quaternary (Q) faults. These faults define or influence the basin geometry. The basin is generally an asymmetrical half graben defined by the W-dipping, Q Frenchman Mountain fault (FMF) along its E side and a series of smaller offset E-dipping faults to the W. The N terminus of the basin is controlled by the Las Vegas Valley shear zone, along which the majority of the offset occurred prior to the Q. Here, we asses the influence of the Q faults on the distribution of the sedimentary units. Well, exposure, seismic reflection and seismic refraction data show that sedimentary units of different grain sizes or seismic velocity dominate different parts of the basin. Sections dominated by coarse clastic deposits occupy a narrow area along the E side of the basin. Coarse clastic sediments are mixed with finer grained sediments in a broader area along the W side of the basin. Based on provenance and alluvial fan distribution, the coarse deposits along the E side of the basin appear to be trapped in close proximity to the W-dipping FMF. The coarse-grained deposits along the opposite, W side of the basin, are sourced from the nearby Spring Mountains. Because of the structural asymmetry of the basin, these sediments traveled farther from their source area than those on the E side. Some of these E-dipping faults influence the depth to Paleozoic bedrock and some faults form small sub-basins filled with finer grained sediments. Along a WNW trend near the center of the basin and near the present-day Las Vegas Wash, a change in the grain size distribution occurs up stratgraphic section: continuous clay layers are less common and coarse-grained deposits are more common. This difference may reflect a change from internal drainage early in the basin history to external drainage through the Las Vegas Wash in the latter history of the basin-fill sedimentation. This interpretation implies that the FMF was breached by a wash connected to the Colorado River drainage system during basin development. The basin fill deposits suggest an early history of alluvial fan dominated deposits showing internal drainage. That depositional system was followed by E- and W-sloping alluvial fans cut by a NW-trending external drainage system that probably flowed to the Colorado River. The greatest structural influence on sediment distribution was from the Q FMF on the E side of the basin and the dominantly Miocene Las Vegas Valley shear zone on the north, but the structural influence is reduced as Colorado River system and base level imposes on the basin up section.

S12E-07 1745h

Is Microseismicity Relevant to Estimating Seismic Hazards in North Central New Mexico?

Leigh House[1] (505-667-1912; house@lanl.gov)

Peter Roberts[1] (proberts@lanl.gov)

Jamie N Gardner[2] (jgardner@lanl.gov)

[1]Los Alamos National Laboratory, MS D443, Los Alamos, NM 87545, United States

[2]Los Alamos National Laboratory, MS D462, Los Alamos, NM 87545, United States

The Rio Grande rift extends south from southern Colorado through central New Mexico and into northern Mexico. It is a major tectonic feature in New Mexico, yet seismicity in the rift is comparable to or lower than in the adjacent stable Great Plains and Colorado Plateau provinces (Sanford, et al, 1991). In north-central New Mexico, thirty years of microearthquake monitoring have provided more than 650 epicenters in an area of about 28 000 sq km. The largest earthquake was about magnitude 3. Epicenters show only a slight association with recently active faults, and most lie away from faults (mislocation of epicenters could produce this scatter, though we think it is unlikely). The Pajarito fault system is presently the western boundary of the Rio Grande rift in the area of the Espanola Basin (from Santa Fe to Espanola), yet has little seismicity associated with it, and only for 15 km of its 50 km length. That seismicity includes five earthquakes that were been felt in the Los Alamos area since 1991 (most recently in April 2003). Paleoseismic studies (Gardner et al, 2001) found evidence for large slip events along that same 15 km portion of the Pajarito fault system as recently as 2 ka. Recurrence times of these events are not known, but may be 10 ka or longer. The remainder of the rift boundary in north-central New Mexico is not discernable from seismicity. A simple model of opening of the rift (at an assumed rate of 0.1 mm/yr) produces an estimate of seismic moment release that is several orders of magnitude greater than seen in the seismicity. Microseismicity seems to have little relation to the macroseismicity that may occur on long time intervals (perhaps thousands of years) and may not be relevant for understanding seismic hazards in this part of the Rio Grande rift. Sanford, A.R., L.H. Jaksha, and D.J. Cash (1991), Seismicity of the Rio Grande rift in New Mexico, in Slemmons, D.B., E.R. Engdahl, M.D. Zoback, and D.D. Blackwell (eds), Neotectonics of North America, Geological Society of America, Boulder, CO. Gardner, J.N., S.L. Reneau, C.J. Lewis, A. Lavine, D. Katzman, L. Goodwin, J. Wilson, and K.I. Kelson (2001), Paleoseismic trenching in the Pajarito Fault system, Rio Grande rift, New Mexico, EOS (Trans. AGU), 82(47) Fall Meet. Suppl., Abstract S52C-0643.

S12F MCC: 2002-2004 Monday 1600h

Theories of Earth's Interior IV *(joint with T, V)*

Presiding: **J Korenaga,** Yale University**; T Tanimoto,** Institute for Crustal Studies

S12F-01 1600h INVITED

Broad-band Seismology for Understanding Earthquake Physics and Developing a Modern Practice for Seismic Damage Mitigation

Hiroo Kanamori[1] (626-395-6914; hiroo@gps.caltech.edu)

Thomas H. Heaton[1] (626-395-4232; heaton@gps.caltech.edu)

[1]California Institute of Technology, Seismological Laboratory, Pasadena, CA 91125, United States

In 1987, immediately after the 1987 Whittier Narrows earthquake, the Caltech broad-band regional seismic network project, TERRAscope, was launched under the direction of Don Anderson. At the time, UC Berkeley had also embarked on such a project. The objectives included: 1) Collect high-quality seismic data for developing theories of Earth's interior and exterior, 2) Develop a physics-based earthquake damage mitigation method, 3) Provide a test-bed for novel approaches in real-time seismology, 4) Provide an infrastructure for cultivating new directions in seismology. The data from TERRAscope, combined with those from other networks such as GDSN, IDA, IRIS, GeoScope networks were used to study various seismological problems, some of which had not been commonly investigated. We focus on three areas. The interaction between the solid earth and atmosphere had been the subject of considerable interest. The broadband networks detected interesting atmospheric waves from a few Hz (N waves from space shuttles) to 0.001 Hz (Morning-glory waves. At the time it was not recognized as such). Also, it recorded monochromatic (period $\sim$ 230 sec) Rayleigh waves which were generated by the near source atmospheric oscillations excited by the 1991 Pinatubo eruption. These waves were not immediately recognized as such, because they had not been observed yet. This represents one of few cases in which significant energy transfer occurred from the atmosphere to the solid earth. These observations eventually led to the more ambitious ongoing projects for detecting ionospheric signature of acoustic and internal gravity waves in the atmosphere that couple into the solid earth. Gutenberg, together with Richter, published a series of papers on the energy of earthquakes in the 1940's to 1950's. The intent of these studies was to determine the most important quantity necessary for understanding the fundamental physics of earthquakes. Unfortunately, because of the overwhelming observational difficulties, the method remained largely empirical. One of the important objectives of the regional broad-band networks was to make a significant advance in this area. Early efforts turned out to be unsatisfactory, but the high-quality data obtained for the 1999 Hector Mine earthquake brought about significant progress. In the meantime, the methodology for determining earthquake rupture patterns made rapid progress, and details of rupture patterns were determined for many events. The patterns are all extremely complex reflecting the heterogeneities of fault-zone properties, and variations of the physical processes involved. The improvements in energy estimates (macroscopic parameter) and understanding of small scale, microscopic, structure and physics suggest a statistical mechanics approach to a better understanding of earthquake physics. An important objective of seismology is mitigation of earthquake damage. The complexity of earthquake physics, and the resulting unpredictability of exact rupture behavior make accurate prediction of earthquakes difficult. However, once the rupture occurs and seismic waves are generated, the behavior is controlled by elastic properties of the earth, and becomes more predictable. This concept, combined with the improved understanding of earthquake physics would lead to a novel approach to earthquake damage mitigation through real-time seismology, earthquake early warning, and predictive control theory for structures.

S12F-02 1625h

Asperity Model of an Earthquake

Lane R Johnson (510 4864173; lrj@ccs.lbl.gov)

Lawrence Berkeley National Laboratory, One Cyclotron Road, Berkeley, CA 94720

An asperity model of an earthquake that is based on the static solution for the exterior crack problem is described. The boundary integral method is used to explore both static and dynamic aspects of the model. The main features of the model include a strong asperity patch that retards motion on the fault and a weak surrounding shadow region where a displacement deficit develops. Failure commences when the stress intensity on the boundary of the asperity patch reaches a critical value, with the asperity patch failing first and causing a slip pulse to propagate out over the shadow region. The rise time of the slip on the fault and the rupture velocity are controlled by the type and amount of friction. The model is in general agreement with scaling relationships for repeating earthquakes and with waveforms from a nearby earthquake in both the time and frequency domains.

S12F-03 1640h

Evolving Earth Models and Nuclear Explosion Monitoring

Terry C Wallace (wallacet@lanl.gov)

Los Alamos National Laboratory, ms B446, EES Division, Los Alamos, NM 87545, United States

One of the most important problems in nuclear explosion monitoring is accurate seismic event location. Traditional location methods rely on estimating travel times in a known Earth model and accounting for heterogeneity through various empirical corrections. The history of location accuracy and precision is closely coupled to evolving theories of the nature of the Earth's interior. LONG SHOT was a 80 Kt explosion conducted on Amchitka Island on October 29, 1965. The travel times recorded from LONG SHOT deviated strongly from a radially symmetric Earth, and in fact showed a pattern consistent a tabular body of relatively high seismic velocity (the subducting North American Plate) validating certain concepts of the then new theory of plate tectonics.
Each subsequent advance in conceptual models for the dynamics of the Earth's interior has impacted explosion monitoring. Many of the advances in the theory of the Earth's interior have been spurred by the ideas and work of Don Anderson. These include anelasticity, anisotropy, tomography, the Lehmann discontinuity, and mantle plumes (or lack of). The present state-of-the-art monitoring paradigm incorporates a dynamic Earth model, and the synergy between verification research and basic research on the Earth's interior is quite important.

S12F-04 1655h

Jet Stream, Roaring Ocean Waves, and Ringing Earth

Toshiro Tanimoto[1] ((805)893-8375; toshiro@geol.ucsb.edu)

Douglas ReVelle[2] ((505)667-1256; revelle@lanl.gov)

[1]Institute for Crustal Studies, University of California, Santa Barbara, CA 93106, United States

[2]Los Alamos National Laboratory, EES-8, LANL MS-J577, Los Alamos, NM 87545, United States

During the last few decades, it has become clear that Earth's components, i.e. the atmosphere, the ocean and the solid Earth interact in complex ways on various time scales. Seismograms have been known to show such interactions but one of the surprising observations in the last 5-6 years is the discovery of continuous oscillations for frequencies 2-7 mHz; a sequence of fundamental spheroidal modes are excited continuously and display seasonal variations. The cause of these oscillations has been speculated to be an atmosphere-solid Earth interaction until recently (e.g., Kobayashi and Nishida, 1998; Tanimoto and Um, 1999; Fukao et al., 2002). In this talk, we present a case for an alternative mechanism that these oscillaitons are caused by oceanic (infragravity) waves. The original source of energy is in the atmosphere, because ocean waves are generated by atmosphere-ocean inteactions, but the essential point is that this energy must be filtered through an ocean process in order to explain the characteristics in seismic signals. We present two main points that support the oceanic infragravity-wave hypothesis. The first is a theoretical modelling