Coda waves are generated from singly and multiply-scattered primary waves in the Earth. The scattered wavefield is composed of converted phases, transmissions, and reflections arising from three dimensional fluctuations in seismic velocities and density. Statistical models of the complex medium are customarily used to explain seismic scattering. Our goal is to invert the coda directly for stochastic properties of the medium through which the seismic energy travels. We characterize the medium with the von Karman autocorrelation model which can accurately model the statistical distribution of velocity/density variations of the crystalline portions of the Earth's crust. Synthetic data generated through von Karman media closely resemble real data. The von Karman autocorrelation model mimics the Earth's self affine nature and can be described in two-dimensions by three parameters; 1) the horizontal characteristic length, 2) the vertical characteristic length, and 3) the Hurst exponent, which describes the roughness of the statistical model. We present two inversion schemes to estimate von Karman parameters. In the first scheme, we show that inverting seismic array data for the lateral characteristic length is possible, but that the inversion has to be calibrated against the central frequency of the input seismic wavelet. In the second inversion scheme, we make use of the multiplicative relation between the power spectra of the observations and that of the source pulse and the stochastic medium. Thus, if we have a good estimate of the seismic pulse, we can invert directly for von Karman parameters. In the absence of complete knowledge of the pulse, we can formulate a nonlinear inversion and estimate the seismic pulse and the von Karman parameters simultaneously. The products of our inversions are cross sections of stochastic properties that can define different areas of texture and/or fabric in the Earth. We demonstrate our inversion on synthetic data as well as a seismic reflection section from the CDROM experiment in the western U.S. With two dimensional, synthetic seismic reflection data, we show that we can recover the dip-dependant lateral characteristic length. Additionally, we present results of inverting for the lateral characteristic length using the CDROM seismic reflection dataset. We claim that inverting for lateral characteristic length can be a useful tool to place bounds on the base of the crust, which is difficult to interpret deterministically in the processed seisic line. Although preliminary results of inverting for the vertical characteristic length with synthetic data are promising, we are still in the process of refining the process. Namely, we find that the primary limitation of the inversion is accurate information of the source pulse. However, with a reasonable estimate of the source pulse power spectrum non-linear inversion holds promise.

S12G-04 1645h

Green's Functions, Source Signatures and the Normalization of Teleseismic Wavefields

Michael G Bostock (604-822-2082; bostock@geop.ubc.ca)

Department of Earth and Ocean Sciences, The University of British Columbia, 6339 Stores Road, Vancouver, BC V6T 1Z4, Canada

We examine the canonical source/Green's function separation problem within the context of teleseismic body wave propagation and scattering from receiver-side lithospheric/upper-mantle structure. Our principal objective is the recovery of the intramodal *P*-impulse response for use in multi-parameter wavefield inversions. The time-normalized transfer operator that describes the response of a 1-D stratified, elastic half-space to a plane wave incident from below, can be factored into pure transmission and free-surface reverberation parts. Assuming pre-critical interactions, the intramodal entries of the reverberation operator are always minimum phase. The intramodal entries of the transmission operator are not generally minimum phase, but they will be for *P*-waves in weak to moderate contrast stratification; a characteristic that, we argue, persists for the class of laterally heterogeneous media representing real Earth environments. Transformation to minimum phase thus provides a means of normalizing the source within teleseismic *P*-seismograms and serves to emphasize weaker secondary arrivals. The shaping filter derived from this transformation can, moreover, be applied to additional non-minimum-phase wave components to effect a similar source normalization. Minimum-phase normalization facilitates the implementation of simultaneous, source-receiver, multichannel deconvolution within the log-spectral domain through the provision of statistical constraint equations, and facilitation of phase unwrapping. Examples using both synthetic data and seismograms from the Canadian National Seismograph Network demonstrate the recovery of accurate and reproducible estimates of the intramodal *P*-impulse response.

S12G-05 1700h

Energy Scaling for the Hector Mine and Landers Sequences Using Coda-Derived Source Spectra

Kevin M Mayeda[1] (925-423-5913; kmayeda@llnl.gov)

William R Walter[1] (925-423-8777; walter@kaboom.llnl.gov)

[1] Lawrence Livermore National Laboratory, P.O. Box 808, L-205, Livermore, CA 94551, United States

Unlike the well-established techniques of long-period waveform modeling for seismic moment (Mo), the measurement of radiated seismic energy (E) requires corrections at and beyond the corner frequency of the event. At these shorter length scales the Earth is considerably more complicated making path and site response corrections the two most important considerations. To minimize the problem of determining path corrections, we have chosen the 1992 Landers and the 1999 Hector Mine sequences in southern California for study using broadband recordings from both local and regional broadband stations. To minimize the effect of source heterogeneity (e.g., directivity and source radiation pattern effects) we have used the coda methodology of Mayeda et al. (2003) to obtain stable, broadband source spectra which are a factor of 3-to-4 more stable than those derived from the direct waves. This methodology also uses small empirical Green's function events to derive site corrections to account for near-site attenuation and amplification. We independently validate our source spectra by comparing against network averaged moment estimates using long-period waveform modeling. Results for events ranging between Mw 3 to 7+ for both sequences using the same methodology and stations clearly shows the scaled energy, e=E/Mo, increases with increasing magnitude. This departure from constant energy scaling had been observed elsewhere but has been questioned because of the large uncertainties in the path, site, and source heterogeneity corrections. We believe that this current study clearly points to a difference in rupture dynamics between small and large events in this sequence. This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.

S12G-06 1715h

Detection of Seismic Stress-Drop Anomalies in the Mendocino Transform Using Coda-Derived Source Spectra

Gilead Wurman[1] (gwurman@seismo.berkeley.edu)

Kevin Mayeda[2] (kmayeda@llnl.gov)

Douglas S Dreger[1] (dreger@seismo.berkeley.edu)

[1] Seismological Laboratory, University of California at Berkeley, 215 McCone Hall, Berkeley, CA 94720, United States

[2] Lawrence Livermore National Laboratory, Ground-Based Nuclear Explosion Monitoring Group University of California, Livermore, CA 94551, United States

The amplitude and decay rate of L_g or S_n phase coda waves can be measured over a range of narrow frequency bands to determine reliable source moment-rate spectra (*Mayeda and Walter,* JGR 1996). These spectra can be used to measure seismic moment and S-wave energy radiation using data from a single station. This information can in turn be used to calculate Orowan stress drop and investigate E_s/M_0 scaling. Events along the Mendocino transform show considerable variation in static stress drop, which is apparent in large magnitude differentials ($M_w - M_L$ as much as 1 order). Events with such large differentials exhibit enriched low frequencies as observed by examination of displacement seismograms and fourier amplitude spectra. Moment-rate spectra from the coda method confirm the anomalous properties of these events. In this study we discuss seismicity in the Mendocino transform region as observed using the coda method, in terms of static stress drop and E_s/M_0 scaling. We investigate possible explanations for the anomalous seismicity.

S12G-07 1730h

Separating Scattering from Intrinsic Attenuation

Kasper van Wijk[1] (303 273 3733; kasper@acoustics.mines.edu)

John A Scales[1] (303 273 3733; jscales@acoustics.mines.edu)

[1] physical acoustics laboratory, dept. of GP, CSM, 1500 illinois street, golden, CO 80401, United States

The subsurface appears disordered at all length-scales. Therefore, wave propatation at seismic or ultrasonic frequencies is subject to complicated scatterings. A pulse propagating in the subsurface loses energy at each scattering off an impedance contrast, but also decreases in amplitude as the impulse interacts with fluids in the rock. We call the latter non-elastic effect "intrinsic Q", while the former is "scattering Q". It is often the fluids in the rocks that are of interest, but conventional reflection and transmission of the incident pulse only cannot deceipher the individual components of Q due to scattering and fluid movement in the pore-space. We present an approach that can unravel these two mechanisms, allowing a separate estimate of absorption. This method treats the propagation of the average intensity in the framework of radiative transfer (RT); the arrival of (what is left of) the incident pulse is modeled as the coherent energy, whereas the later arriving multiply scattered events form the incoherent intensity. The coherent pulse decays exponentially due to a combination of scattering and absorption, and so does the incoherent intensity. However, multiple scattering can re-direct energy back to the receiver, supplying a gain-term at later times that makes up the incoherent intensity. Strictly speaking, one can invert for scattering and absorption from the intensity at late times only, often modeled with the late-time equivalent of RT, diffusion. However, we will show that fitting both early- and late-time signal with RT constrains absorption and scattering constants more rigorously. These ideas are illustrated by laboratory and sonic-logging measurements.

S12G-08 1745h

Characterization of the Spectrum of a Random Medium from Trace Measurements

Michael Fehler[1] (505 667-1925; fehler@lanl.gov)

Haruo Sato[2] (81-22-217-6532; sato@zisin.Geophys.Tohoku.ac.jp)

[1] Los Alamos National Laboratory, PO Box 1663 MS D443, Los Alamos, NM 87545, United States

[2] Geophysics, Science, Tohoku University, Sendai 980-77, Japan

Imaging provides the ability to determine the geometrical structure of the Earth. However, some portion of the structure cannot be reliably determined from seismic imaging so other approaches must be taken for characterization. Characterization of some portions of the structure can best be done using a random media approach. Such approaches provide valuable tools for understanding scattering and attenuation in the Earth. We have used numerical modeling of wave propagation through random media to better understand what characteristics of the medium can be inferred from analysis of seismic traces. We have recently developed an approach for using traces recorded along a receiver array within a 2D heterogeneous medium to characterize the spatial heterogeneity in the medium. We compare the spectrum of the spatial fluctuation of medium velocity with the spectrum of the spatial fluctuation in integrated rectified trace amplitudes measured along the receiver array. We find that the two spatial spectra are coincident over a wide spatial wavenumber range. We have also investigated the application of the method to surface reflection data calculated in simulations of a homogeneous layer over a heterogeneous half space. The method can determine not only information about the random component of structure but has also been shown to be capable of providing information about fracture characteristics, which is important in petroleum exploration and fluid-flow modeling.

S21A MCC: 3011 Tuesday 0800h

The Fate of Seismic Waves: Measurement and Interpretation of Q of the Earth I

Presiding: **J Xie,** Lamont-Doherty Earth Observatory**; C A Langston,** Center for Earthquake Research and Information, University of Memphis

S21A-01 0800h INVITED

Q in Earth's Core

Vernon F Cormier (860-486-1391; vernon.cormier@uconn.edu)

University of Connecticut, Geology and Geophysics, 354 Mansfield Road, Storrs, CT 06269-2045, United States

Observations of high frequency PKnKP waves, multiply reflected by the underside of the core-mantle boundary, place a lower bound of 10,000 on the Q_K of the outer core. Hence, for most applications Q_K of the outer core can be assumed to be infinite, consistent with the expected behavior of a low viscosity fluid. Observations of high (>1 Hz) frequency PKPPKP coupled with the high Q_K of the outer core, suggest a strong (ω^{-1}) frequency dependence of attenuation in the mid-mantle begins between 0.1 to 1 Hz. In contrast to the outer core, significant seismic attenuation is observed in the inner core over a broad band of frequencies, with a mean Q_α at 1 Hz of 307±90 determined from waveform modeling of PKIKP in the distance range 130° to 180°. A strong depth dependence of Q_α is observed, with attenuation much stronger (Q_α much lower) in the upper 300 km. The attenuation of PKIKP waveforms is frequency dependent with very weak velocity dispersion. Either the effects of viscoelasticity or scattering can model the pulse broadening and dispersion of PKIKP. Observations of the backscattered coda of PKiKP suggest that a significant fraction of the attenuation in the short-period (1 Hz) band may be due to scattering. A pure scattering model requires velocity perturbations on the order of 6 to 10% and scale lengths on the order of 1 to 10 km. The velocity perturbations are larger for polar than equatorial paths, decrease with depth, and show anisotropy in both global and regional data. For paths beneath North America, the smallest scale lengths (1-5 km) tend to lie in either the upper 200 km of the inner core or along paths close to the rotational axis. The depth dependence of attenuation inferred from a scattering mechanism is roughly similar to that inferred from a viscoelastic mechanism, except a more abrupt transition is seen between higher attenuation in the upper inner core and lower attenuation in the lower inner core. This transition may be sharp enough to produce either a first or second order discontinuity with depth in the long-wavelength (composite) elastic moduli. A fabric that may satisfy the observed depth dependence and anisotropy of attenuation is one composed of iron crystals having high (>10%) intrinsic anisotropy, which are progressively ordered with increasing depth in the inner core. Reported hemispherical differences in the attenuation and seismic velocities of the upper inner core, together with a high regional variance in measured Q_α emphasize the importance of globally dense ray-path coverage of the inner core for imaging the viscoelastic and elastic fabric of the inner core, which has been left as the signature of its solidification from the liquid outer core and the operation of a compositionally driven dynamo.

URL: http://www.sp.uconn.edu/∼cormier

S21A-02 0815h INVITED

Compressional-Wave Studies on the Frequency Dependence of and Lateral Variations in Mantle Attenuation

Linda M. Warren[1] (warren@igpp.ucsd.edu)

Peter M. Shearer[1] (pshearer@ucsd.edu)

[1]IGPP, SIO, UCSD, 9500 Gilman Drive, La Jolla, CA 92093-0225, United States

We study the frequency dependence of and lateral variations in P wave attenuation in the mantle by analyzing the spectra from >18,000 P and >14,000 PP arrivals. We select seismograms from large, shallow earthquakes at epicentral distances of 40°–80° for P waves and 80°–160° for PP waves and compute the spectrum for a 12.8-s-long window around each arrival. Each spectrum is the product of source, receiver, and propagation response functions as well as local source- and receiver-side effects, and we use a stacking procedure to isolate the propagation effects. Using separate absorption bands in the upper and lower mantles, we model the average depth and frequency dependence of mantle Q by combining measurements of the amplitude decay of the propagation log spectra between 0.16 and 0.86 Hz with long-period Q_β values of other workers. We find that the upper mantle is more attenuating than the lower mantle and that this contrast is greater at higher frequencies. At 1 Hz, the top 220 km of the mantle is ∼6 times more attenuating than the lower mantle. In addition, our results indicate that the upper corner frequency of the absorption band is higher for the upper mantle than at greater depths; the lower layer is about twice as attenuating at 0.1 Hz than at 1 Hz, whereas upper mantle attenuation is relatively constant across this band. Since lower-mantle attenuation is small, we interpret deviations in spectral decay as lateral variations in upper mantle attenuation. The resulting map of more and less attenuating regions generally correlates with previously-published attenuation models and surface tectonics. Continents are usually less attenuating than the global average, whereas oceanic regions tend to be more attenuating.

S21A-03 0830h INVITED

Modelling of 3D Attenuation Structure in the Mantle Using a Waveform Approach: Successes and Challenges

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

Yuancheng Gung[1] (gung@seismo.berkeley.edu)

[1]Berkeley Seismological Laboratory, Univ. of California at Berkeley, 215 Mc Cone Hall,, Berkeley, CA 94720, United States

The study of lateral variations in Q in the upper mantle at the global scale is generally addressed using isolated phases in the seismogram (for example fundamental mode surface wave spectra), which limits the sampling and therefore the resolution of Q structure that can be achieved. The use of isolated phases has the advantage of working directly with amplitudes, thus making it easier to detect contamination of the anelastic attenuation signal by elastic focusing and scattering, a key problem in attenuation tomography. We here discuss recent progress on a waveform modeling approach, which allows us to work with entire seismograms and exploit the information contained both in fundamental mode surface waves, overtones and body waves. The method is based on a normal mode approach and proceeds iteratively. In the first step, we invert for 3D elastic structure using the NACT approach (Non-linear Asymptotic Coupling Theory; Li and Romanowicz, 1995), which aligns the phase part of the observed and synthetic seismograms. In the second step, we invert for Q. The crucial issue is how to account for elastic effects in the amplitudes (focusing)- we discuss asymptotic versus more exact methods to address this problem and illustrate the effects on the resulting models. We discuss prominent features in the lateral variations in Q in the upper mantle, their evolution with depth, and their relation with elastic structure, in particular from the point of view of resolving upwellings and the large scale signature of plumes.

S21A-04 0845h INVITED

Shear-wave Q and it Frequency Dependence in the Crust of the Middle East and China

Brian J Mitchell[1] (mitchbj@eas.slu.edu)

Alemayehu L Jemberie[2] (ajemberie@memphis.edu)

Lianli Cong[3]

[1]Saint Louis University, Dept. of Earth & Atm. Sci. 3507 Laclede Avenue, St. Louis, MO 63103, United States

[2]University of Memphis, CERI 3876 Central Avenue, Memphis, TN 38152, United States

[3]Yunnan University, Department of Earth Sciences, Kunming 10000, China

Models of Q determined using single-station measurements usually have an advantage over methods that use station pairs along a great-circle path in that they are more likely able to utilized relatively short paths, sometimes within a single tectonic province. Waves that travel short paths are therefore less likely to be contaminated by effects of lateral refraction and multipathing, but have the additional requirement that the mechanism and depth of the earthquake used be known. A single-station method that utilizes pairs of amplitude spectra, one corresponding to the fundamental Rayleigh mode and other corresponding to a superposition of higher Rayleigh modes, provides a means to determine models of shear-wave Q at crustal depths. It is especially effective in regions where Q is low. The method has been applied to portions of the Middle East and China and has yielded the lowest values of crustal shear-wave Q yet found in continents. Coverage is best in China, allowing the first detailed maps of shear-wave Q variations at different depths in the crust. In the depth range 0-10 km Q varies between about 40 in the western part of the Tibetan Plateau and about 250 in southeastern China. In the depth range 10-30 km Q varies between about 60 beneath parts of Tibet and about140 in central China. Determinations of the frequency dependence of shear-wave Q almost all lie in the range 0.4-0.7, but are 0.1-0.3 in parts of Tibet where shear-wave Q is low. The regional distribution of Q generally agrees with variations of Q obtained using Lg coda and correlates well with the tectonics of southern Asia.

S21A-05 0900h

Q Tomography in the Yellowstone Region: Effects of Mantle Water Content

David C Adams[1] (307-739-9740; dadams@onewest.net)

Eugene D Humphreys[1] (gene@newberry.uoregon.edu)

[1]University of Oregon, Department of Geological Sciences, Eugene, OR 97403-1272, United States

Estimation of t* in continental settings is especially hampered by signal-generated noise. To deal with this problem in our study of S-wave attenuation in the Yellowstone-Snake River Plain region, we apply a linearizing filter that estimates the polarization direction of the teleseismic S-wave, and we then remove that portion of the signal whose polarization differs from the estimated direction. We also use two separate methods for estimating t* (spectral ratio and cross-correlation of synthetically attenuated traces) and compare the results. As our main interest is the expression of the mantle "plume" which drives the Yellowstone system, we concentrate on the area beneath Yellowstone and the Snake River Plain, which also is where ray coverage is best. Inversion of data from the linear array across the Snake River Plain and of those for the 2-D Yellowstone array reveal a central upper mantle region of high attenuation (low Q). This is flanked and partially overlain by a region of low attenuation (high Q) that is best expressed to the NW. Beneath Yellowstone Park the low-Q zone extends upward to the base of the crust. If attenuation in this region is controlled more by intracrystalline water content than by temperature, these high-Q regions could represent a cap of depleted, relatively dehydrated residuum overlying hydrous "plume" material. Low-degree partial melting may serve to increase Q by partitioning water into the melt. Some high-Q regions within the cap may reflect such melts. The low-Q region extending to the base of the crust beneath Yellowstone Park may reflect high-degree partial melts where temperature effects or grain-boundary sliding may become important. Diffraction effects may be present in our data but are most likely secondary; areas of most anomalous t* typically occur source-ward of the "plume" and tend not to change polarity for events of opposite back-azimuth.

S21A-06 0915h

New Insights into Crustal Attenuation from Deep Borehole Studies

Stephanie G. Prejean[1] (650-329-5083; sprejean@usgs.gov); Rachel E. Abercrombie[2] (rea@bu.edu); William L. Ellsworth[1] (ellswrth@usgs.gov); Kazutoshi Imanishi[3] (hisao.itou@aist.go.jp); Hisao Ito[3] (hisao.itou@aist.go.jp); Anna Stork[3] (anna@blacknest.gov.uk)

[1]US Geological Survey, 345 Middlefield Rd., Menlo Park, CA 94025, United States

[2]Boston University, Dept. of Earth Sciences; 685 Commonwealth Avenue, Boston, MA 02251, United States

[3]National Institute of Advanced Industrial Science and Technology, AIST Tsukuba Central 7; Higashi 1-1-1, Tsukuba 305-8567, Japan

Teleseismic and regional attenuation studies commonly find that S-waves are more attenuated than P-waves. Four recent studies that have estimated Q as part of the process of determining local earthquake source parameters using data recorded in deep boreholes (800 m to 2500 m), however, find the opposite result for ray paths that sample the seismogenic crust: P-waves are more strongly attenuated than S-waves. The difference in Qs/Qp between the borehole, regional, and teleseismic studies reflects the depth dependence of attenuation in the crust. In this presentation, we summarize attenuation measurements from the SAFOD Pilot Hole in Parkfield, California, the Long Valley Exploratory Well (LVEW) in eastern California; the Cajon Pass borehole in southern California; and the Ontake borehole in western Nagano, Japan, and we discuss the implications these measurements have for physical properties of the seismogenic crust. The seismometers in all four boreholes were installed well below the water table in competent basement rock and were used to observe nearby earthquakes with focal depths from 2 to 10 km. At all sites S-waves are less attenuated than P-waves (Qs/Qp = 1.2-2). The ratio Qs/Qp does not vary systematically with the overall degree of attenuation; at Cajon Pass Qp∼900 and at SAFOD Qp∼250, yet Qs/Qp = 1.2 in both areas. In the case of Ontake, the only site where frequency dependent attenuation was estimated, Qs/Qp also does not vary with frequency. Furthermore, at all sites, neither Qp nor Qs varies systematically with corner frequency, as it would were Q to have a strong frequency dependence. Because these four boreholes are located in widely varying tectonic and lithologic environments, Qs>Qp may be a common property of the Earth's crust in the 1-10 km depth range. The two boreholes in geothermally active provinces that we have studied have higher Qs/Qp ratios than the other sites (LVEW Qs/Qp∼2 and western Nagano Qs/Qp ∼1.7 versus Cajon Pass and SAFOD Qs/Qp∼1.2). Theoretical calculations and laboratory rock mechanics experiments suggest that Qs/Qp reaches a maximum of 2-2.5 when pore spaces are 70-90% saturated (see Winkler and Nur, *Geophysics*, 1995 V. 47, p.1 for summary). Although it is not clear if these rock-physics observations are applicable to the

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crust at seismogenic depths, they suggest that pore spaces are not fully saturated. Particularly high Qs/Qp in Long Valley Caldera and Ontake might reflect the presence of a steam phase trapped in pore spaces.

S21A-07 0930h

Seismic Frequency Attenuation and Fluid Motion

Gautam Kumar[1] (91-124-256-0235; gautam.kumar@lycos.com)

Michael L Batzle[2] (1-3-3-384-2067; mbatzle@mines.edu)

Ronny Hofmann[2] (1-303-384-2094; rhofmann@mines.edu)

[1]British Gas India Pvt. Ltd., 3rd Floor, Tower B, First India Place Sushant Lok - I Mehrauli - Gurgaon Road, Gurgaon, Del 110092, India

[2]Colorado School of Mines Geophysics Department, 1500 Illinois St, Golden, CO 80401, United States

The relations among the different modes of attenuation (1/Qk, 1/Qp, 1/Qs, 1/Qe) are controlled by the mobility of the pore fluid within rocks. Attenuation covering the exploration seismic band (20 -1000 Hz) was derived at low amplitudes by measuring the phase angles between the applied stress and sample strain. Assuming that attenuation can be defined from the complex moduli as the ratio between imaginary part and real part.of the complex moduli. , Winkler and Nur (1979) showed that one of three relations must hold: (1) 1/Qs < 1/Qe < 1/Qp < 1/Qk; or (2) 1/Qs = 1/Qe = 1/Qp = 1/Qk; or (3) 1/Qs > 1/Qe > 1/Qp > 1/Qk. The applicable relation is controlled by the compressional to shear velocity ratio or Poisson's ratio. In partially saturated rocks with high fluid mobility, 1/Qk is a maximum and 1/Qs is minimum (relation 1). At 100% liquid saturation with no fluid motion, 1/Qs is now the maximum and 1/Qk is the minimum (3). In contrast, for the same liquid saturated sample, if macroscopic fluid motion is permitted across an open boundary, the 1/Qk can again reach the maximum. However, the fluid mobility and attenuation mechanisms are strongly frequency dependent and interrelated. Thus, the scale of partial saturation or diffusion lengths and fluid mobility will control the attenuation relationships.

URL: http://crusher.mines.edu/Atten

S21A-08 0945h

Is Seismically Determined Q an Intrinsic Material Property?

Charles A. Langston (901-678-4869; clangstn@memphis.edu)

Center for Earthquake Research and Information University of Memphis, 3876 Central Ave., Suite 1, Memphis, TN 38152, United States

The seismic quality factor, Q, has a well-defined physical meaning as an intrinsic material property associated with a visco-elastic or a non-linear stress-strain constitutive relation for a material. Measurement of Q from seismic waves, however, involves interpreting seismic wave amplitude and phase as deviations from some ideal elastic wave propagation model. Thus, assumptions in the elastic wave propagation model become the basis for attributing anelastic properties to the earth continuum. Scientifically, the resulting Q model derived from seismic data is no more than a hypothesis that needs to be verified by other independent experiments concerning the continuum constitutive law and through careful examination of the truth of the assumptions in the wave propagation model. A case in point concerns the anelasticity of Mississippi embayment sediments in the central U.S. that has important implications for evaluation of earthquake strong ground motions. Previous body wave analyses using converted Sp phases have suggested that Qs is 30 in the sediments based on simple ray theory assumptions. However, detailed modeling of 1D heterogeneity in the sediments shows that Qs cannot be resolved by the Sp data. An independent experiment concerning the amplitude decay of surface waves propagating in the sediments shows that Qs must be generally greater than 80 but is also subject to scattering attenuation. Apparent Q effects seen in direct P and S waves can also be produced by wave tunneling mechanisms in relatively simple 1D heterogeneity. Heterogeneity is a general geophysical attribute of the earth as shown by many high-resolution data sets and should be used as the first litmus test on assumptions made in seismic Q studies before a Q model can be interpreted as an intrinsic material property.

S21B MCC: 2000 Tuesday 0800h

Earthquake Alerting Systems: From Rapid Hazard Determination to Societal Response I

Presiding: **R M Allen,** University of Wisconsin-Madison**; T Teng,** University of Southern California

S21B-01 0800h INVITED

Earthquake Early Warning

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

Richard M. Allen[2] (608-262-7513; rallen@geology.wisc.edu)

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

[2]University of Wisconsin, Dept of Geology and Geophysics, Madison, WI 53706, United States

The complexity of earthquake physics, and the resulting unpredictability of exact rupture behavior makes 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. If the ground motion information detected near the source is transmitted immediately as an early warning for ground motion to sites at some distance away before the ground motion begins there, the information could be utilized for various damage mitigation measures. An early warning system has been used in practice in Japan, Mexico, and Taiwan. Two approaches are possible: (1) Regional warning, and (2) Site-specific warning. In (1), the traditional seismological method is used to locate an earthquake, determine the magnitude, and estimate the ground motion at other sites. In (2), the beginning of the ground motion (mainly P wave) observed at a site is used to predict the ensuing ground motion (mainly by S and surface waves) at the same site; no attempt is made to locate the event and estimate the magnitude. The first approach is more reliable, but takes a longer time and cannot be used for the sites at short distances. In contrast, the second approach is less reliable, but very fast, and could provide useful early warning to sites even at very short distances where an early warning is most needed. The first approach has been already used in Japan, Mexico, and Taiwan. Here, we investigate the second approach in some detail from the point of view of rupture physics, and practical applications. The basic principle is that P wave carries the information of the source, but not much energy. S wave and surface waves carry most of the energy and cause the damage. Thus, if we can extract critical information regarding the size of an earthquake from the first few seconds of P waves, the information can be used to predict the severity of ground motion at the site. In general, if P wave is small, the event is either small or large but at large distances, and no warning is warranted. However, a large P wave does not necessarily warrant a warning, because the event can be a nearby small earthquake with short duration of slip motion. Thus, it is important to determine whether the event's slip motion has stopped or keeps growing. To determine whether the event is growing or not, the parameter τ used by Nakamura provides a good diagnostics. τ can be interpreted as a spectrally- weighted period during the first few sec (3 sec in this study). Using simulated records computed for an earthquake rupture model, we have verified that τ is a good measure of the lower-bound of the size of an earthquake. We have determined τ for events with $M_W = 3$ to 7.6 (1999 Chi-Chi earthquake), and the results are consistent with the simulation results. If $\tau < 1$ sec, the event has already ended or is not likely to grow. If $\tau > 1$ sec, it is likely to grow, but how large it will eventually become cannot be determined. In this sense, this method provides a threshold warning. Thus, a combination of the amplitude and τ from the first 3 sec can provide a useful site-specific early warning. A use of multiple sites is desirable to increase the reliability. This approach can provide a very rapid warning that strong ground motions are imminent, but does not provide the ground-motion time history. For the next step of early warning applications, it is desirable to develop a method to estimate the time history which can be incorporated in predictive structural control in engineering practice.

S21B-02 0820h

The Mexican Sistema de Alerta Sismica (SAS) Experience

Juan Manuel Espinosa-Aranda[1] (52 555 523 7394; maranda@servidor.unam.mx)

Francisco Humberto Rodríguez[2] (52 555 575 4156; humberto.rodriguez@roconsultores.com)

[1]Centro de Instrumentacion y Registro Sismico, A. C., Anaxagoras 814 Col, Narvarte, Mexico, DF 03020, Mexico

[2]Ro Consultores Especializados, S.C., Providencia 1206-2 Col, del Valle, Mexico, DF 03100, Mexico

The Mexico City's SAS is an Early Warning System developed in accordance with recommendations of foreign and national seismology experts, after the disaster generated in 1985 by the M8.1 Michoacan earthquake. The SAS aim is to help mitigate future seismic disasters in Mexico City (MC), mainly if the big forecast "Guerrero Earthquake" hits. In 1991 the SAS started its service in an experimental basis for evaluating its performance both with a group of basic education students in public schools, and with the emergency stop function for the Mexico City Metropolitan Subway System (METRO of MC); after this The Federal District Government (FDG) opened the SAS as a public service in August, 1993, shortly after the SAS warned, with more than 60 seconds of anticipation, the incoming effect of May 13, 1993, M5.8, and M6 double earthquake originated more than 300 Km from MC between Guerrero and Oaxaca, on the coast. That year, an initial technical flaw generated one false alert signal; the cause was readily corrected. The SAS has 12 seismic sensor stations covering a stripe close to 400 X 100 Km on the Guerrero's coast, between Papanoa and Punta Maldonado, that send information through a dedicated radio relay system to the SAS Central Control in MC., using the valuable support of some TELMEX field installations. Until August, 2003, the SAS sensor system has detected more than 1550 earthquakes in the 2.5<M<7.3 range, being capable to discriminate M>5 magnitude events, which are the ones felt in MC. The SAS has generated 57 warning signals with an average of 60 sec in advance to earthquake effects: 46 of restricted use for M<6, and 11 of public use for M>6 events. Public warnings have the automatic broadcast support of many commercial radio AM/FM and TV stations in Mexico City and Toluca valleys. The FDG controls the SAS signal service that includes the more frequent events (from M>5 up), asking the user to develop procedures and practice useful actions to mitigate seismic disasters. Each validated SAS seismic warning automatically generates and sends the event information by fax and e-mail to the DFG and Civil Protection Authorities, users and news media; it also sends information about the SAS operating conditions to service technicians, via radio, and phone.

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Real Time Earthquake Information System in Japan

Keiji Doi[1] (81-3-5841-2498; keijidoi@eri.u-tokyo.ac.jp)

Takashi Kato[2] (+81-3-3211-8684; tkato@met.kishou.go.jp)

[1]Earthquake Research Institute, University of Tokyo, 1-1-1 Yayoi, Bunkyo, Tokyo 1130032, Japan

[2]Seismological and Volcanological Department, Japan Meteorological Agency, 1-3-4 Otemachi, Chiyoda, Tokyo 1008122, Japan

An early earthquake notification system in Japan had been developed by the Japan Meteorological Agency (JMA) as a governmental organization responsible for issuing earthquake information and tsunami forecasts. The system was primarily developed for prompt provision of a tsunami forecast to the public with locating an earthquake and estimating its magnitude as quickly as possible. Years after, a system for a prompt provision of seismic intensity information as indices of degrees of disasters caused by strong ground motion was also developed so that concerned governmental organizations can decide whether it was necessary for them to launch emergency response or not. At present, JMA issues the following kinds of information successively when a large earthquake occurs. 1) Prompt report of occurrence of a large earthquake and major seismic intensities caused by the earthquake in about two minutes after the earthquake occurrence. 2) Tsunami forecast in around three minutes. 3) Information on expected arrival times and maximum heights of tsunami waves in around five minutes. 4) Information on a hypocenter and a magnitude of the earthquake, the seismic intensity at each observation station, the times of high tides in addition to the expected tsunami arrival times in 5-7 minutes. To issue information above, JMA has established; - An advanced nationwide seismic network with about 180 stations for seismic wave observation and about 3,400 stations for instrumental seismic intensity observation including about 2,800 seismic intensity stations maintained by local governments, - Data telemetry networks via landlines and partly via a satellite communication link, - Real-time data processing techniques, for example, the automatic calculation of earthquake location and magnitude, the database driven method for quantitative tsunami estimation, and - Dissemination networks, via computer-to-computer communications and facsimile through dedicated telephone lines. JMA operationally monitors earthquake data and analyzes earthquake activities and tsunami occurrence round-the-clock on a real-time basis. In addition to the above, JMA has been developing a system of Nowcast Earthquake Information which can provide