lifelines. The frequency of intraslab earthquakes (1949 M 7.1, 1965 M_w6.7, and 2001 M_w6.8) makes it important in understanding as much as possible about the source characteristics so that the hazards can be more reliably quantified. We inverted 0.05 to 0.5 Hz strong ground motion, teleseismic, and geodetic data for the 2001 Nisqually earthquake to obtain a variable slip and rake model using the multiple time window method and Green's functions calculated from a regionally calibrated 1-D velocity model. The earthquake has a 12 km^2 sized asperity between 59 and 62 km depth with an average slip of 1.5 m ($M_o = 1.59 \times 10^{26} dyne \times cm$; M_w 6.74). We also inverted teleseismic P- and SH-waves digitized from WWSSN film records for the 1965 Seattle Tacoma earthquake slip and rake model. There are two asperities with areas of 4 and 8 km^2 near the hypocenter. Average slip for these asperities were 2 and 2.8 m ($M_o = 9.43 \times 10^{25} dyne \times cm$; M_w 6.63). Simulating near-source strong ground motions from historical and modern earthquake slip models adds more realism not possible with random or stochastic scenarios. We used a time domain approach to generate PGA and S_a shake-maps for the 1965 and 2001 earthquakes. These shake-maps included the spatial and temporal evolution of slip estimated from the multiple time window inversion of seismic and geodetic data. We added a Kostrov source time function to improve the ground motion spectra at higher frequencies. The shake maps also included site and basin depth corrections based on California geology. The corrections helped reduce the bias in residuals between observed and simulated PGA and Sa but corrections that are more specific to the Puget Sound are needed to reduce the scatter. The patterns of strong ground shaking from the 1965 Seattle-Tacoma earthquake were very different from the 2001 Nisqually earthquake. Strong shaking in urban Seattle by the 1965 earthquake was twice as high (60% g) than by the 2001 earthquake. While retrofitting efforts help limit damages by the 2001 Nisqually earthquake, a future earthquake closer to urban Seattle or larger in magnitude may cause more widespread damage and disruption.

S42H MCC: 3009 Thursday 1600h

Strong Ground Motion Prediction II

Presiding: **H Kawase,** Kyushu University**; B Aagaard,** U.S. Geological Survey

S42H-01 1600h

Effect of Surface Geology on Ground Motions: The Case of Chutzuhu Site (TAP056)

Kuo-Liang Wen[1] (886-3-4227151#5621; wenkl@earth.ncu.edu.tw)

Tao-Ming Chang[2] (886-3-4227151#5652; taoming@s319m.gep.ncu.edu.tw)

Chung-Hsiang Mou[3] (886-3-4227151#5652; serene.mou@yahoo.com.tw)

[1]1. Institute of Geophysics, National Central University, Taiwan, N300, Jung-da Rd, Jung-li, Taoyuan 320, Taiwan

[2]Dept. of Information Management, Hsing Wu College, Taiwan, Linko, Taoyuan 320, Taiwan

[3]3. Institute of Applied Geology, National Central University, Taiwan, N300, Jung-da Rd, Jung-li, Taoyuan 320, Taiwan

Both the two strong motion stations, TAP056 and TAP066, are located in the Yang Ming Shan area. These two stations are not far away, belong to TSMIP strong motion network, and operated by Central Weather Bureau, Taiwan. TAP056 triggered by earthquakes very often, but not for station TAP066. Compared the peak ground accelerations (PGA) recorded at vertical and horizontal components of the station TAP056 are about 3.6 and 9.6 times larger than that of the station TAP066. Most the amplitude spectra recorded at TAP056 have the same response no matter where the earthquakes occurred, but that at TAP066 are different for near-field and far-field events. It shows that local site effects at station TAP056 dominated the spectra shape. From the spectral ratios of TAP056/TAAP066, P-wave potion at vertical component amplified at around 16 Hz and S-wave potion at the horizontal component amplified at 8 10 Hz. After the velocity structure survey and numerical simulation, we can confirm the top soft soil layer dominated the local site response at station TAP056.

S42H-02 1615h

A Quantitative Evaluation of SCEC Community Velocity Model Version 3.0

Po Chen[1] (213-821-2370; pochen@usc.edu)

Li Zhao[1] (zhaol@usc.edu)

Thomas H. Jordan[1] (tjordan@usc.edu)

[1]Department of Earth Sciences, University of Southern California, Los Angeles, CA 90089, United States

We present a systematic methodology for evaluating and improving 3D seismic velocity models using broadband waveform data from regional earthquakes. The operator that maps a synthetic waveform into an observed waveform is expressed in the Rytov form $D(\omega) = \exp[i\omega\delta\tau_p(\omega) - \omega\delta\tau_q(\omega)]$. We measure the phase delay time $\delta\tau_p(\omega)$ and the amplitude reduction time $\delta\tau_q(\omega)$ as a function of frequency ω using Gee & Jordan's [1992] isolation-filter technique, and we correct the data for frequency-dependent interference and frequency-independent source statics. We have applied this procedure to a set of small events in Southern California. Synthetic seismograms were computed using three types of velocity models: the 1D Standard Southern California Crustal Model (SoCaL) [Dreger & Helmberger, 1993], the 3D SCEC Community Velocity Model, Version 3.0 (CVM3.0) [Magistrale et al., 2000], and a set of path-averaged 1D models (A1D) extracted from CVM3.0 by horizontally averaging wave slownesses along source-receiver paths. The 3D synthetics were computed using K. Olsen's finite difference code. More than 1000 measurements were made on both P and S waveforms at frequencies ranging from 0.2 to 1 Hz. Overall, the 3D model provided a substantially better fit to the waveform data than either laterally homogeneous or path-dependent 1D models. Relative to SoCaL, CVM3.0 provided a variance reduction of about 64% in $\delta\tau_p$, and 41% in $\delta\tau_q$. Relative to A1D, the variance reduction is about 46% and 20%, respectively. The same set of measurements can be employed to invert for both seismic source properties and seismic velocity structures. Fully numerical methods are being developed to compute the Fréchet kernels for these measurements [L. Zhao et. al., this meeting]. This methodology thus provides a unified framework for regional studies of seismic sources and Earth structure in Southern California and elsewhere.

S42H-03 1630h

Through Thick and Thin: The Effect of Sediment Deposits on Central US Ground-motion Predictions

Chris H. Cramer (901-678-4992; ccramer@memphis.edu)

U.S. Geological Survey, 3890 Central Ave, Memphis, TN 38152-3050

Local geology and the presence of soils affects the frequency content, amplitude, and duration of ground shaking, and thus also seismic hazard estimates (both scenario and probabilistic). As part of the U.S. Geological Survey's (USGS) efforts to produce state-of-the-art seismic hazard maps in the central US (CUS), techniques have been developed for estimating site amplification distributions from local and regional 3D geological and geophysicsical observations (Gomberg et al., 2003; Cramer, 2003). The estimation of site amplification distributions as a function of input rock ground motion has been completed for the Memphis, TN urban area and is underway for the upper Mississippi embayment. These distributions are used to incorporate the effect of site geology into the USGS national seismic hazard maps for these regions. They also are being incorporated into CUS ShakeMaps and to analyses of seismograms at ANSS sites. Overall uncertainty and sensitivity of site amplification estimates to input data are also being investigated. For the 1 km thick sediments in the Memphis area, the overall standard deviation (sd) varies from 28% to 52%, depending on the input peak ground acceleration (pga) (0.05 - 1.0g). The largest contribution comes from the ground motion variability in the 16 M7-8 seismograms at rock sites that are scaled and used as input ground motions at the base of the soil column (max. sd of 36%). The next largest contributor is the uncertainty in the soil profiles (mostly in shear-wave velocity) derived from a 3D geological model (max. sd of 27%). The third largest contributor is the uncertainty in the dynamic properties of the soils (max. sd of 17%). The effect of equivalent-linear versus non-linear estimates of soil amplification at high frequencies is also being investigated.

S42H-04 1645h

Site Amplification Characteristics and Their Relationship with Averaged S-wave Velocities Derived From K-NET and KiK-Net Strong Motion Records in Japan

Hiroshi Kawase[1] (81-92-642-3331; kawase@arch.kyushu-u.ac.jp)

Hidenori Matsuo[2] (81-3-3763-1111; matsuo@seis.arch.kyushu-u.ac.jp)

[1]Kyushu Univeristy, 6-10-1 Hakozaki, Higashi-ku, Fukuoka 812-8581, Japan

[2]Hitachi Systems and Services, 3-2-16 Ohmori-kita, Ohta-ku, Tokyo 143-8545, Japan

To predict strong ground motions for future scenario earthquake in a broad-band frequency, we need to characterize both source spectra and site amplification. For high frequency we can use statistical method based on the observed records and the summation technique. Thanks to the advent of the K-Net and KiK-net (by NIED) in Japan, we have now plenty of weak motion data, enough to construct statistical Green's functions. In order to represent long- and intermediate period nature of the strong ground motion in the near field region, we want to use theoretical technique such as three-dimensional finite difference method. Any theoretical methods need S-wave velocity structures that should reproduce the observed site amplification quantitatively. In this study we perform first the analysis to separate the so-called source spectra, attenuation coefficient, and the site amplification factors from about 15,000 K-NET, KiK-Net, and JMA records observed at 1,700 stations in Japan. The separation method is the well-established one of Andrews (1980) and the resultant source spectra are modeled as omega-square spectra. As a reference site we use one rock station of KiK-Net in Yamaguchi Prefecture, from which we remove amplification of shallow surface deposits. Once we obtain site amplification factors, we try to reproduce them by using one-dimensional S-wave velocity structures below each site of K-NET and KiK-Net (in total, 1,300). We use Genetic Algorithm to invert the S-wave structures with fixed S-wave velocities in the shallow part. We succeed to reproduce site amplification factors at about one thirds of the sites very well. The majority of not-so-good sites need modification of S-wave velocities in the shallow part based on logging data. We also perform the same kind of separation analysis for PGA, PGV, and JMA Seismic Intensity. We found that PGA site factors correlate best with 5.0 Hz spectral amplification and PGV 2.5 Hz spectral amplification. We also found that the best correlation of site factors can be obtained with the average S wave velocity only for top 5 m for PGA and 10 m to 20 m for PGV. Since we have a space for better representation of velocity structures, the results reported here are not conclusive. Once we get better S-wave velocity structures at as many sites as possible, we expect to extrapolate them and construct an initial model of the three-dimensional basin structure of the whole Japanese islands.

S42H-05 1700h

A Transect of 200 Shallow Shear-Velocity Profiles Across the Los Angeles Basin

Weston A. Thelen[1] (wethelen@seismo.unr.edu); Matthew Clark[1] (mclark@seismo.unr.edu); Christopher Lopez[2] (ctlopez@unr.edu); Chris Loughner[1] (loughner@seismo.unr.edu); Hyunmee Park[2] (hpark@unr.edu); Jim B. Scott[1] (jscott@seismo.unr.edu); Shane B. Smith[2] (sbsmith@unr.edu); Bob Greschke[3] (passcal@passcal.nmt.edu); John N. Louie[1] (775-784-4219; louie@seismo.unr.edu)

[1]Nevada Seismological Lab, Mackay School of Mines, University of Nevada 174, Reno, NV 89557, United States

[2]Dept. of Geological Sciences, Mackay School of Mines, University of Nevada 172, Reno, NV 89557, United States

[3]IRIS-PASSCAL Instrument Center, New Mexico Tech, 100 East Road, Socorro, NM 87801, United States

In July 2003 we evaluated a 60 km transect for shallow shear wave velocities along the San Gabriel River, in the San Gabriel Valley and Los Angeles Basin of southern California. The purpose of the experiment was to evaluate spatial variability of earthquake shaking hazard, and any velocity correlations to mapped geological and soil units. We recorded urban microtremor on 300-m linear arrays, analyzing Rayleigh-wave dispersion curves to forward-model 200 shallow shear-velocity profiles to depths exceeding 100 m. Each 300-m array had 15 seismometers at 20-m intervals. We used IRIS/PASSCAL "Texan" single-channel recorders

with 4.5-Hz vertical geophones. Shear velocities, vertically averaged to 30-m depths (V30), provided NEHRP soil classifications of ground shaking potential. We also performed P-wave refraction analyses at several points along the transect. Arrays in a highway cut on the gneissic bedrock of the San Gabriel Mts. yielded V30 between 520 and 640 m/s, NEHRP hazard class C. Measurements approach NEHRP-B (>760 m/s) only at the locations of the coarsest surficial alluvium in Azusa, below the mouth of San Gabriel Canyon, and near Santa Fe Dam. The maximum V30 along the transect was 730 m/s. Our results suggest much of the line north of Whittier Narrows is NEHRP class C (350-760 m/s), or on the C/D boundary. We find NEHRP-D values for V30 (150-350 m/s) from Whittier Narrows south to Seal Beach. The lowest velocities from the transect, 230 m/s, are still well above the NEHRP-E range. The lowest velocities occur near the south end of the line at Alamitos Bay. At Seal Beach, in the littoral sands, velocities rise slightly toward the NEHRP-C/D boundary. We interpret a lesser shaking hazard in the northern San Gabriel Valley and at Alamitos Bay than do assessments based on existing geologic maps. In San Gabriel Mts. bedrock on the other hand, rated NEHRP-B/C on maps, we interpret a somewhat elevated hazard, finding a NEHRP-C velocity of 640 m/s at most. Variations in V30 we measured may well be explained by the presence of a steep hydraulic gradient and a large average clast size near the San Gabriel Mts., with the gradient decreasing and the sediments fining downstream to Alamitos Bay. Corroborating measurements near Alamitos Bay, Long Beach, and Azusa, at locations removed from the active river channel, proved to match results from the transect.

URL: http://www.seismo.unr.edu/hazsurv

S42H-06 1715h

Nonlinear Dynamic Rupture Inversion of the 2000 Western Tottori, Japan, Earthquake

Kim B Olsen[1] (805 893 7394; kbolsen@crustal.ucsb.edu)

Sophie Peyrat (805 893 2820; peyrat@crustal.ucsb.edu)

[1]Institute for Crustal Studies, University of California at Santa Barbara, Santa Barbara, CA 93106-1100, United States

Such inversion has traditionally been carried out kinematically, which has some important limitations, in particular unphysical constraints on the rupture velocity and the choice of source-time function. A more physically correct inversion would therefore take into account the dynamics of the rupture, i.e., the stress, and friction parameters. While the radiated waves are highly sensitive to the distribution of stress and friction parameters on the fault, an essential requirement for the inversion to work, such inversion is highly complicated due to the strong nonlinearity of the dynamic problem. We have developed a fully systematic, nonlinear inversion method to estimate dynamic rupture parameters using a Neighbourhood algorithm and a finite-difference technique for the forward modeling. The method provides an objective means of routinely estimating dynamic rupture parameters for large earthquakes. We test the method by estimating the initial stress within 32 regions on the causative fault for the 2000 M6.6 Western Tottori, Japan, earthquake. The synthetics for the dynamic models with the smallest misfit provide a good fit to 0.5 Hz strong motion data recorded at 12 near-field stations. The dynamic models with the smallest misfit agree with the slip distributions from conventional kinematic analyses in the location of the largest asperity. In the surrounding areas on the fault, where kinematic inversions generally produce only one, final model, our method provides an ensemble of nearly equally acceptable rupture models.

S42H-07 1730h

Rupture Process Inversion Using 3-D Green's Functions: The 1995 Kobe Earthquake Revisited

Kazuki Koketsu[1] (+81-3-5841-5782; koketsu@eri.u-tokyo.ac.jp)

Taichi Ohno[2] (ohno@feg.co.jp)

Yasushi Ikegami[3] (y-ikegami@crc.co.jp)

[1]Earthquake Research Institute, University of Tokyo, 1-1-1 Yayoi, Bunkyo-ku, Tokyo 113-0032, Japan

[2]Faculty of Science, Ibaraki Univ., 2-1-1 Bunkyo, Mito 310-8512, Japan

[3]CRC Solutions Corp., 2-7-5 Minamisuna, Koto-ku, Tokyo 136-8581, Japan

In order to reliably simulate and predict strong ground motions, we need accurate models of the earthquake source and rupture process. The models are usually determined by inversion of strong motion, teleseismic or geodetic data, and the choice of Green's functions (GFs) greatly influences the inversion results (Graves and Wald; Wald and Graves, 2001). In particular, this problem should be critical for situations such as the 1995 Kobe earthquake where strong velocity variations are known to exist, but all the previous studies (e.g., Yoshida et al., 1996) used only 1-D (horizontally layered or halfspace) GFs. The GFs in this study are calculated for strong motion and geodetic data from the 1995 Kobe earthquake using a 3-D crustal structure with surface topography (Afnimar et al., 2002) and the voxel FEM code (Koketsu et al., 2003). The comparison of the 3-D GFs to the 1-D ones used in Yoshida et al. (1996) shows that the strong motion GFs are greatly deformed by the 3-D structure. The Green's seismograms at stations in the Osaka basin have surface wave codas with large amplitudes and long duration, and the basin sediments delayed the arrival of the S wave train. However, the geodetic GFs are not changed so much by the crustal structure, though some amplification can be found in horizontal displacements at the basin stations. The results of inversions reflect this difference in sensitivity. The slip distribution recovered by a strong motion inversion with the 3-D GFs is significantly different from the result of Yoshida et al. (1996). The most distinct feature in the 3-D strong motion result is that the asperity under the downtown of Kobe is more intensified than the asperity close to the rupture initiation. The slips under the Awaji island are now concentrated in a shallow part along the Nojima fault as in the other studies. On the other hand, the 3-D geodetic result is not so different from the counterpart in Yoshida et al. (1996), except that the slips in the asperities become a little larger. We will also compare our 3-D results with those by inversion with a hybrid set of 1-D rock and soil GFs (Sekiguchi et al., 1996; Wald, 1996).

S42H-08 1745h

How do near-source ground motions change when ruptures go super-shear?

Brad Aagaard[1] (baagaard@usgs.gov)

Thomas Heaton[2] (heatont@caltech.edu)

[1]U.S. Geological Survey, 525 South Wilson Ave, Pasadena, CA 91106, United States

[2]California Institute of Technology, 104-44 Caltech, Pasadena, CA 91125, United States

We simulate long-period near-source ground motions from kinematic ruptures of Mw 7.4 events on a strike-slip fault with different rupture speeds, including ruptures that propagate below the shear-wave speed (subsonic), between the shear-wave speed and the dilatational-wave speed (intersonic), or above the dilatational-wave speed (supersonic). The strong shear-wave directivity present in scenarios with subshear rupture speeds disappears in the scenarios with ruptures propagating faster than the shear-wave speed. Furthermore, the maximum horizontal displacement and velocities rotate from generally fault-perpendicular orientations at subshear rupture speeds to generally fault-parallel orientations at supersonic rupture speeds. For rupture speeds just above the shear-wave speed, the orientations are spatially heterogeneous as a result of the random nature of the slip assumed in the model. The polarization of the horizontal ground motion time histories provides a much more robust feature than maximum amplitude orientation with which to gauge the rupture speed; subshear ruptures are associated with significant fault-perpendicular motion *before* fault-parallel motion and super-shear ruptures are associated with fault-perpendicular motion *after* significant fault-parallel motion. Based on these simulation results, we examined the near-source recordings from the 1979 Imperial Valley and 2002 Denali fault earthquakes, for which there is some evidence for super-shear rupture. In the Imperial Valley earthquake, the long-period ground motions contain much more energy in the fault-perpendicular direction than in the fault-parallel direction, suggesting predominantly subshear rupture. The polarity of the velocity waveforms are also consistent with subshear rupture. This is consistent with previous studies that found predominantly subshear rupture but leaves open the question of super-shear rupture over a limited area. On the other hand, in the 2002 Denali fault earthquake, the recording closest to the fault (pump station 10) exhibits characteristics found in the simulations with rupture propagation slightly above the shear-wave speed, including orientation of the peak velocity away from the fault-perpendicular direction and nearly simultaneous arrival of large-amplitude motion in the fault-perpendicular and fault-parallel directions. Thus, these simulations and recordings provide additional support for the existence of super-shear ruptures in earthquakes but illustrate the difficulty in obtaining definitive evidence without an extremely dense seismic network along the surface trace of the fault.

S42I MCC: 3011 Thursday 1600h

New Views of Seismic Hazard in Cascadia II *(joint with G, T, V)*

Presiding: **T M Brocher,** U.S. Geological Survey**; A J Calvert,** Simon Fraser University

S42I-01 1600h

Evidence for a Tear in the Juan de Fuca Plate in the Vicinity of the 2001 Nisqually Earthquake

Patricia A McCrory[1] ((650) 329-5677; pmccrory@usgs.gov)

Fred F Pollitz[1]

J Luke Blair[1]

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

Deep earthquakes within the Juan de Fuca (JdF) plate beneath western Washington define a linear trend that may mark a tear within the subducting plate. This earthquake trend is oriented ENE, in the direction of plate convergence. Earthquakes within the zone reach depths approaching 100 km—20 km deeper than seen elsewhere in the JdF plate. The earthquakes bound the south flank of an arch in the slab and mark an abrupt change in seismicity rate, with many earthquakes to the north and few to the south. All the large historic earthquakes in the Puget Lowland—including the 2001 (M6.8) Nisqually earthquake—have occurred along this linear trend. We interpret the earthquake zone to result primarily from flexural stresses associated with unbending the arch. The high background seismicity and large earthquakes observed along this zone may also denote localized stress concentrations between contrasting strain segments in the slab. The zone marks an abrupt change in slab dip, from a very shallow dip on the north side ($\sim 8^{\circ}$) to a less shallow dip ($\sim 15^{\circ}$) on the south side. We hypothesize that the flatter slab to the north resists subduction, promoting strain segmentation between the two regions. Furthermore, an accommodation structure—such as a tear zone—may exist at the segment boundary. We speculate that such a discontinuity would concentrate stress locally, and thus expect future earthquakes to occur in the same vicinity. Tomographic data depict an abrupt 10-km step in *p*-wave velocity isocontours (south side down) in the vicinity of the earthquake trend. Geodetic data depict a perturbation in rate of surface elevation change along the trend, with slower subsidence to the north and faster subsidence to the south. These regional elevation changes are consistent with the slab geometry. The contrast in slab pull forces expected from the change in dip should lead to left-lateral, strike-slip focal mechanisms along the segment boundary, allowing a test for whether a through-going tear has yet formed or slips aseismically.

S42I-02 1615h INVITED

Mapping Great Earthquake Rupture Area

Mladen R. Nedimović[1] (845-365-8561; mladen@ldeo.columbia.edu)

Roy D. Hyndman[2] (rhyndman@nrcan.gc.ca)

Kumar Ramachandran[2] (kumaran@eos.ubc.ca)

George D. Spence[3] (gspence@uvic.ca)

Thomas M. Brocher[4] (brocher@usgs.gov)

[1]LDEO, 61 Route 9W, P. O. Box 1000, Palisades, NY 10964, USA, Palisades, NY 10964-8000, United States

[2]PGC, 9860 W. Saanich Rd, Sidney, BC V8L 4B2, Canada

[3]UVic, P.O. Box 3055, Victoria, BC V8W 3P6

[4]USGS, 345 Middlefield Road, Menlopark, CA 94025, United States

At the northern Cascadia margin, the Juan de Fuca plate is underthrusting North America at about 45 mm/yr. Thermal and deformation studies indicate that, off southern Vancouver Island, the interplate interface is presently fully locked for a distance of some 60 km downdip from the deformation front. Great thrust earthquakes on this section of the interface, with magnitudes of up to 9, have been estimated to occur at an average interval of about 590 yr. Further downdip there is a transition zone from fully locked behavior to aseismic sliding, with the deep aseismic zone exhibiting slow slip thrust events. We show that at the northern Cascadia margin there is a change in the reflection character on seismic images from a thin reflection

S