cell size about to 1/20 of the size that slip-weakening zone would have in very low-speed rupture.

S42E MCC: Level 1 Thursday 1330h

Magnum Force: Earthquake Source Posters *(joint with T)*

Presiding: **P Reasenberg,** U.S. Geological Survey**; J N Louie,** Nevada Seismological Laboratory, Mackay School of Mines

S42E-0202 1330h POSTER

Seismic Moment From Regional Surface Wave Amplitudes of Recent and Historic Earthquakes

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Accurate, consistent earthquake size estimates are important for seismic hazard assessment. In central Europe, seismic activity is low and long-term seismicity, available as intensities from written historical records, has to be incorporated for meaningful assessments. We determined the seismic moment M_o of 25 stronger 20^{th}-century earthquakes in Switzerland from surface wave amplitude measurements; these 25 events link the instrumental with pre-instrumental data and can be used to calibrate intensity-moment relations. We derived our amplitude-moment relation using digital regional data from 18 earthquakes in and near Switzerland for which we had obtained M_o estimates from regional moment tensor analysis. The surface wave amplitude measurements were carried out at empirically determined, distance dependent dominant reference periods T_Δ. The distance attenuation term of the standard surface wave magnitude (M_S) relation $S(\Delta) = log\,(A/T)_{max} + 1.66\,log\Delta$ is distance independent for maximum amplitudes measured at periods T_Δ. Assuming a linear relation between $log\,M_o$ and M_S, we obtain $log\,M_o = S(\Delta) + 21.90$ for the digital data. Uncertainties of ± 0.3 for the 21.90-constant term translate into M_o uncertainties of a factor of 2, which were verified with an additional, independent data-set. Our relation allows fast, direct M_o estimation for current earthquakes and, after re-calibration of the constant, can be applied in other regions of the World. We applied our relation to analog seismograms of 25 early-instrumental earthquakes in Switzerland. The analog data, recorded on mechanical and electromagnetic seismographs, were collected from several European observatories. Amplitude measurements from scans were performed at large amplifications on a computer screen and corrected for differences between T_Δ and the actual measurement periods. The resulting size estimates range from moment magnitude $M_w = 4.5$ to 5.8. The $M_w = 5.8$ 1946 event was the largest earthquake in Switzerland during the 20^{th}-century. Uncertainties for the early-instrumental events are on the order of 0.4 magnitude units.

S42E-0203 1330h POSTER

On the Characterisation of a PGA Virtual Distribution of Historical Earthquakes.

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The proposed procedure is aimed at the characterization of a virtual PGA distribution of historical earthquakes occurred in a given seismogenic zone, with respect to a macroseismic approach by which some significant parameters of the earthquakes, as epicentre, strike, felt area, magnitude are analytically deduced with a vectorial characterisation of macroseismic intensity. A geometric representation of a PGA virtual distribution, depicted through ellipses that have centres coinciding with the calculated epicentre of the earthquake and envelope the homonymous points of PGA, represents an important reference for seismic hazard studies and allows a configuration of different levels of seismic vulnerability within a damage scenarios characterisation. A comparison of the PGA and intensity virtual distributions (Teramo et al., 1998) of a same earthquake allows moreover a verification between the damage level depicted for a given intensity level and the corresponding PGA value, that is particularly important within seismic studies of monumental and historical buildings damaged from earthquakes.

S42E-0204 1330h POSTER

DETERMINATION OF THE RUPTURE PLANE FOR SMALL EARTHQUAKES RECORDED BY LOCAL NETWORKS.

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A correct determination of the rupture plane of an earthquake is quite important for seismotectonic studies, particularly for regions, such as northern Baja California, where in many places recorded earthquakes are both small and few. For large earthquakes the rupture plane is readily determined from the aftershock spatial distribution or by fitting observed and synthetic seismograms; but when there are not enough well-located aftershocks and the event is small and, therefore, recorded locally so that there is a large influence of the local structure (including lateral heterogeneity) and site effects on the dominant high frequencies in the seismograms, the above mentioned techniques do not work. In these cases, fault plane solutions from first motion polarity and a (double couple) point source model give two nodal planes among which it is not possible to distinguish the fault plane from the auxiliary one. For a dense network operated in northern Baja California, we found that it is possible to identify the rupture plane from the Doppler effect produced by directivity. We first tried this technique on a ML = 3.6 event that occurred near the NW end of the San Miguel fault some 4km from the Vallecitos fault. For this event, directivity clearly shows the rupture propagating in a NE-SW direction roughly perpendicular to the NW-SE orientation of the nearby large faults. The technique was then applied to sample earthquakes of some of the seismicity patches in northern Baja California, where recorded earthquakes are small and epicenters do not conform to documented faults or to regional seismicity patterns. The tectonics implications of the results are discussed in detail.

S42E-0205 1330h POSTER

Ambiguous Source Radiation in Anisotropic Media and Consequences for the Interpretation of Earthquakes Mechanisms

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Anisotropic material properties are usually neglected during inversions for earthquake source parameters using conventional methods. Here we investigate the effects of homogeneous and heterogeneous anisotropy within the source region on the radiated wavefield. Based on formulations for the moment tensor and the Green's function in anisotropic media, we find that anisotropy can greatly influence the radiation pattern. For example, apparent non-double-couple components can be produced for pure shear sources when the axes of anisotropic symmetry are oriented arbitrarily with respect to the fault plane. The direction of slip on the fault may affect the total seismic moment, which is in contrast to the isotropic case. Furthermore, similar moment tensors can be created by either pure shear or tensile faulting in anisotropic host media, if the fault plane is generally oriented. When anisotropy in the source region is not accounted for, erroneous conclusions regarding the source mechanisms may be drawn. We find that the source mechanisms infered from synthetic radiation patterns for pure shear sources in anisotropic media may show characteristics which are similar to those deduced in recent studies on microearthquakes. However, the latter have been interpreted to show evidence of tensile faulting under the assumption of an isotropic host medium.

S42E-0206 1330h POSTER

Surface-wave Derived Focal Mechanisms in Mid-America

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In regions of low-to-moderate seismic activity, quantitative estimates of source size and faulting mechanism are important for definition of regional tectonics and for notification of the public. This task is challenging because the lack of low-frequency signal content, often due to a low signal-to-noise ratio, precludes the use of standard waveform inversion techniques, which would require detailed path-dependent velocity models to describe the high-frequency waveforms. Surface-wave spectral amplitudes, chosen using an expected Love- and Rayleigh-wave group velocity can be used to determine the source depth, seismic moment and to provide four candidate focal mechanisms from which the final solution is selected using the few waveforms with good signal-to-noise. The advantage of fitting the surface-wave spectral amplitudes is that the source parameter estimates are much less sensitive to the details of the Earth model than are time-domain waveforms. We have successfully determine source for moment magnitudes as small as 3.9 for mid-America and 3.4 elsewhere. As a result of determining focal mechanisms for 8 recent earthquakes, details of automatic processing will be presented.

S42E-0207 1330h POSTER

Moment Tensor Summation in the Mediterranean Area Revisited: Comparison Between CMT and non-CMT Mechanisms Catalogs

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The analysis of focal mechanisms of the earthquakes is routinely carried out in all seismotectonic studies. For the Mediterranean area, a recently published database (EMMA) of checked first-motion focal mechanisms available from the literature allows to extend back in time, and to a lower magnitude threshold the data coverage of CMT and RCMT on-line catalogs (Harvard Seismology, Istituto Nazionale di Geofisica e Vulcanologia and Eidgenössische Technische Hochschule). On a regular grid with mesh of one degree, we mapped the behavior of cumulative moment tensor in terms of both equivalent mechanism and horizontal projections of P and T axes. We correlate the patterns resulting from CMT catalogs and EMMA database to verify the ability of the formers to well describe the seismic deformation in this area. We also analyzed the completeness of different datasets comparing their cumulative scalar moment release (seismic flux) with those resulting from the ISC and PDE catalogs. The contribution of EMMA database is found to be particularly significant in areas characterized by low or moderate seismicity.

S42E-0208 1330h POSTER

Surface-Wave Focal Mechanism of the 30 March 2003 Yellow-Sea Earthquake Event

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The Yellow-Sea earthquake event of 30 March 2003 was reported by the USGS as follows: mb = 4.7, Origin Time = 11:10:55.98, Latitude = 37.57 N, Longitude = 123.82 E. In this study, the focal mechanism of this event will be shown. Corrected Love-wave and Rayleigh-wave amplitude data from ten CDSN stations and the station TATO were used in the search for focal mechanism employing the technique of Nguyen and Herrmann (1992, SRL). Eigenfunctions were computed from the average crustal model that was obtained by inversion from surface-wave group velocities of these stations. Surface-wave attenuation coefficients were obtained using the technique of Tsai and Aki (1969). The focal mechanism of this event has a nodal plane with dip= 70 deg., slip = 50 deg., and strike = 35 deg. P-wave first motions were used to constrain the nodal planes. The seismic moment obtained is 5.50E+22 dyne-cm. The source depth is 6 km. Velocity and Q models obtained by inversions and synthetic seismograms to predict the observed will also be presented.

S42E-0209 1330h POSTER

Tectonic implications of 1998 Ruey-Li, Taiwan earthquake Sequence

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We have investigated the 1998 M6.2 Ruey-Li earthquakes. It is found that the earthquake is generated by ruptures essentially along nearby sections of a large through-going fault zone along the Western Foothills of Taiwan. The rapid termination (in ten days) of the M6.2 Ruey-Li sequence is interpreted by the presence of an asperity in terms of the Peikang basement high, which dominates the tectonic deformation in central western Taiwan. We have carried out the relocation of the aftershocks, their fault-plane solutions, plus stress inversion, waveform source slip inversion, Coulomb stress change calculations and regional strain energy calculations for the Ruey-Li sequence. We have concluded that the event is results of the regional stress accumulation due to the plate convergence, the Ruey-Li earthquake sequence would likely have escalated into a much larger rupture including the Chelungpu fault had it not been for the presence of the Peikang basement high.

S42E-0210 1330h POSTER

Moment Tensor Solutions for the 2002 Molise (southern Italy) Earthquake Sequence: New Insights for Tectonic stress field.

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On October 31, 2002 a M_l = 5.4 earthquake occurred in southern Italy, between Molise and Puglia regions, at margin between the Apennine fold and thrust belt (at west) and the Adriatic subducted lithosphere (at east). In this area no historical event nor seismogenic fault are reported in the literature. In spite of its moderate magnitude, the event generated severe damage in the cities close to the epicentral area and 27 people were killed by the collapse of a primary school in S. Giuliano di Puglia. We computed moment tensor solutions for 15 events, as small as M_l=3.5 (M_w=3.7), inverting broadband regional waveforms. The obtained focal mechanisms display pure strike-slip geometry, mainly with focal planes oriented NS (sinistral) and EW (dextral). Several solutions display a counterclockwise rotation of the planes, in particular for later events, west of the mainshock. Waveform analysis indicates that the major events ruptured the EW planes, while the local stress field resulting from the inversion of the focal mechanisms show NW-SE compression. Imaging the aftershock distribution and moment tensor solutions, it appears that several structures have been initiated rather than a single fault due to the mainshock. How is the Molise sequence related to the normal faulting system at west (along the Apennines) and the dextral strike-slip structure at east (the Mattinata fault)? We attempt at the interpretation of role played by this sequence in the framework of regional tectonics.

S42E-0211 1330h POSTER

Detection And Location Of Long Period Surface Wave Energy Sources

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Low-frequency surface waves are usually the dominant phases in waveforms generated from earthquakes. They have been widely used for determining global earth structure and for the retrieval of earthquake source parameters. In addition, they can be used for detecting the existence of special types of seismic sources, such as slow/silent earthquakes(*Beroza and Jordan*, 1990), back ground free oscillations (*Ekström*, 2001) and other unknown sources. Usually, the low-frequency surface waves generated from these kinds of sources are too weak to be detected by a single station. We developed an array-based method which can detect Rayleigh type surface wave energy by using a regional array. For preliminary test of the method, we applied band pass filter between 50 and 200 sec but several different pass bands will be used to look at the frequency content of detected energies. Weak surface wave energy can be enhanced by stacking waveforms over an array. Waveforms are stacked by taking into account the dispersion of surface waves with respect to relative propagation distances between stations in one array and the center of the array. This method is designed to provide a rough estimate of arrival time and back azimuth of weak surface wave energy. Three different arrays in Northern California (BDSN), Germany (GRSN), and Japan (F-net) are then used to constrain the location ofthe sources. Our preliminary results over several years of data show that this method can locate reliably most seismic sources which have magnitude larger than 5.5. There are other detections that can be correlated across the three arrays and are not associated with known earthquakes as listed in the Harvard CMT catalog. We systematically analyze these detections in an effort to distinguish possible spurious errors from true surface wave energy, and discuss their temporal and geographical distribution, and in particular their possible relation to silent earthquakes as well as the source of the earth's continuous background free-oscillations.

S42E-0212 1330h POSTER

Source Characteristics of the Loreto, Mexico Earthquake of March 12, 2003 (Mw=6.4) that occurred in a transform fault in the Gulf of California.

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We analyzed the Loreto earthquake of March 12, 2003 (Mw=6.4) that occurred in the transform fault that joins the Guaymas and Carmen Basins in the middle of the Gulf of California, Mexico. This event was recorded by two networks of autonomous continuous recording broad-band seismographs (the NARS-Baja network of Utrecht University and the RESBAN network of CICESE). These seismic networks are located along the Baja California Peninsula, and the Sonora and Sinaloa provinces of Mexico. The main event was located at 26.5°N and 111.05°W at a depth of 5.0 ± 2 km. One foreshock and 40 aftershocks were located southeast of the main shock over a fault of approximately 60 km of length. A statistical analysis of the aftershock sequence gives a b value of 0.68. Focal depth and fault geometry were estimated from body-wave form modeling of S-waves. Synthetic seismograms were calculated using the computer codes developed by Herrmann (1987). We used a triangular source time function of 6 seconds, as inferred from the record at station NE77, located 72 km from the epicenter. The best match between syntetics and recorde S-Waves were obtained with a fault geometry given by a strike of 117° ± 4°, a dip of 79° ± 2° and a slip of 168° ± 2°. This fault geometry agrees with the solution reported by NEIC. S-wave spectra (uncorrected for seismic attenuation) at station NE77, shows an omega-square decay at high frequencies. We calculated, from the spectral analysis of S-waves, a seismic moment of $4.6x10^{18}$ N-m , a source radius of 9.7 km and a static stress drop that may vary in the range from 13 to 23 bars, assuming a circular source model.

S42E-0213 1330h POSTER

The 1897 Shillong earthquake, northeast India: A new perspective on its seismotectonics and earthquake history

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The 1897 Shillong earthquake, northeast India is considered to be one of the largest in modern history. Oldham's memoir on this event widely considered as a classic treatise opened new vistas in observational seismology; many questions on the associated faulting mechanisms however remain unresolved. While most previous studies have suggested that the earthquake originated on a gentle north-dipping thrust that is considered to be associated with the Himalayan tectonics, a recent geodetic model by Bilham and England (2001) invokes a steep, south-dipping reverse fault, close to the northern topographic edge of the Shillong Plateau. This model, derived mostly from extant triangulation records, deviates from the conventional understanding of the faulting mechanism of this earthquake. Here, we interpret the available database on seismotectonics of the region and coseismic deformation associated with the 1897 earthquake, together with independent geomorphologic observations, to further understand the nature of faulting. Our interpretation of the morphologic features and coseismic level changes in the Brahmaputra valley, well logs, Bouguer gravity and earthquake data are consistent with a major, steep south-dipping fault, but it spatially conforms to the extreme northern margin of the Shillong massif, which occasionally outcrops on the northern bank of the Brahmaputra River. Our analysis of historical, archaeological and geological data implies a possible 1000-year-interval between the 1897 earthquake and its predecessor and we identify the northern boundary fault (named here as the Brahmaputra fault) as historically more active among other potential faults in the region. The overall tectonic scenario also indicates the critical role of the Brahmaputra in the progressive denudation of the northern plateau margin compared to its southern part (Dauki fault) and its impact on the seismotectonic processes associated with plateau uplift.

S42E-0214 1330h POSTER

Aftershock Study of the 2003 Armeria, Colima, Mexico, Earthquake (Mw = 7.4).

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On January 22, 2003 an earthquake (Mw7.4) took place in the southeastern limit of the Jalisco Block(JB) offshore of the town of Armeria, Colima; an area aside of where a great shallow thrust earthquake (Mw8.0) occurred in 1995 and has been proposed as a seismic gap. We analyze two aftershocks periods, the first 72 hours after the main shock (MS) using data from the two permanent local networks in the region (RESCO and RESJAL). The second period, from 25 to 31 January, when seven portable digital triaxial stations were deployed at the epicentral area. Analysis from first period data shows epicentral distribution of aftershocks in two small clusters, one around and north of the MS and the second on the 1995 Earthquake epicentral area. Hypocenters are very shallow (between 2 and 10 km depth) in a distribution almost vertical, this suggest an early aftershock area roughly rectangular, about 42 x 25 km, and dipping about 40° in an almost EW direction, located at 70 km NE of the trench axis; assumed to correspond to the rupture area. The focal mechanism for the MS agrees with these data. For the second period epicentral distribution is similar to MS cluster, however a migration in depth is observed, most of the hypocenters are at a depth between 14 and 24 km, and seems to be distributed along the interphase between JB and Rivera Plate assuming a 12° dipping. Our results indicate that the Earthquake was a continental intraplate inverse fault event. These data do not support the possible rupture of the Colima Gap.

S42E-0215 1330h POSTER

Rupture process of the Mw=6.9 Boumerdes (Algeria) earthquake of May 21, 2003 from seismological data

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The understanding of the destructive earthquake that struck northern Algeria on May 21, 2003 is complicated by the fact that it most likely ruptured the earth surface offshore. Notwithstanding, a number of observations, measurements, and recordings can be used to constrain the main aspects of the rupture process of the event. We use seismological data, specifically teleseismic body and surface waves, to determine how slip was distributed in space and time relative to the mainshock hypocenter. Our preliminary results indicate that the essential part of the reverse faulting rupture occurred at shallow depth (< 10 km) on a south dipping fault plane and was associated with a strong directivity effect toward the SW. We intend to improve the determination of the hypocenter itself by carrying out a relative location with respect to the aftershocks which were recorded by OBS deployed in the epicentral area a few days after the mainshock. Onland ground deformation, such as coastal uplift, as well as offshore imaging of the activated fault (MARADJA cruise) are also used to constrain further the spatial properties of the rupture, in particular its absolute location and geometry.

S42E-0216 1330h POSTER

Active Deformation Along the Algerian Margin (MARADJA Cruise): Framework of the May 21, 2003, Mw-6.8 Boumerdes Earthquake

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The May 21, 2003, Mw=6.8 Boumerdes earthquake (Algeria) ruptured a ∼60 km long fault, previously unknown, located a few km off the coast of Algeria, causing major damage and casualties on land. The MARADJA cruise (Suroit R/V, Aug.-Sept. 2003), dedicated to a survey of the Algerian margin in order to determine its present-day tectonic regime and identify potentially active faults, allowed for a detailed study of the Boumerdes earthquake rupture area. From a high-resolution multibeam bathymetry and back-scattering data, 3.5 kHz profiles (Chirp), 6 and 24-channel seismic reflection lines, we produced the first detailed morphotectonic map of the central Algerian margin and deep basin. The margin and the proximal part of the deep basin show a series of north-verging reverse faults and folds, probably developping over south-dipping ramps. The northern front of this compressional deformation zone reaches ∼20 km into the deep basin, where it interacts with salt-related deformation of the Messinian evaporites, possibly gravity driven in part, widespread in the deep basin. In the area of the May 21, 2003, earthquake, we found active fault scarps delineating a ∼60 km long fault zone at the bottom of the continental slope and at midslope, ∼17 km offshore and roughly parallel to the coast. The fault consists of at least two major segments striking N65 and N71. It might represent the place of rupture of the Boumerdes earthquake. Its location is consistent with the aftershock distribution and with preliminary dislocation models based on GPS data and uplfit observations onland. The MARADJA Scientific Party: Bouillin J-P., Bracene R., Gaullier V., Kherroubi A., Mercier de Lepinay B., Le Roy P., Pauc H., Savoye B.

S42E-0217 1330h POSTER

An Empirical Relation among Magnitude, Felt Area and Fault Rupture Parameters

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A non-linear analysis of macroseismic data has been performed to determine an empirical relation between macroseismic magnitude and fault rupture parameters, based on a vectorial modelling of macroseismic intensity distribution (Teramo et al., 1995, 1997) that allows the determination of magnitude through the earthquake felt area (Termini et al., 2003). The goal is therefore to characterise an earthquake macroseismic size with respect of observational data through the felt area of earthquakes, in terms of rupture length and width not related to the fault type. Such a relation, tested on several historical and recent earthquakes which occurred in Calabria and Sicily (Southern Italy), shows a good agreement with both the parameters taken from catalogues, previous studies and the Wells and Coppersmith's formula.

S42E-0218 1330h POSTER

Rupture Velocity of the 2001 Kunlun, China, Event Estimated From SEM Waveform Modeling

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The rupture speed during an earthquake is controlled by the energy dissipated mechanically during faulting. Rupture velocities close to the limiting speed imply that very little energy is going into the fracture and thus has implications for whether the rupture will continue to grow or stop. The M_w 7.9, November 14, 2001, Kunlun, China, strike-slip event ruptured unilaterally over 400 km along the Kunlun fault. The long rupture combined with worldwide broad-band instrumentation provides us with a unique opportunity to estimate the rupture speed. Unfortunately, the strike-slip nature of the faulting causes the body waves recorded at teleseismic distances to be nearly nodal, making body-wave modeling very difficult. We use the spectral-element method (SEM) and a 3D Earth model to accurately compute waveforms at periods of 18 seconds and longer for this event. We compute synthetics for two source models. We use (a) a body-wave model with an average rupture speed of 3.5 km/s, similar to the model reported by Kikuchi and Yamanaka (2001) and (b) a surface-wave model proposed by Bouchon and Vallée (2003) with an average rupture speed of 4.3 km/s and a slip distribution constrained by measured surface offsets. Both models show similar fits to the surface-wave radiation pattern at periods above 100 seconds and thus we turn to long-period body waves to discriminate between the two. The event comprised several smaller subevents, with the largest subevent occurring about 60 seconds after the initiation of rupture. The azimuthal variation in arrival time of this phase depends on the rupture velocity. Using the Bouchon and Vallée model we find that shear waves from the large subevent arrive about 10 seconds earlier than observed in the direction of rupture, whereas they arrive on time in the anti-rupture direction. A similar phase shift is observed in the short period surface waves. As this azimuthal variation is not evident for the Kikuchi and Yamanaka model, we conclude that the rupture velocity is too high in the Bouchon and Vallée model. Note that by using the 3D SEM synthetics we account for the effect of 3D structure on the arrival time of the shear-waves. A lower bound of the rupture speed is being investigated in a similar manner.

S42E-0219 1330h POSTER

A teleseismic analysis of the Tecoman, Colima earthquake (22/06/2003, Mw7.4), by using surface and body waves inversion

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We studied the rupture process of the Tecoman, Colima, Mexico, earthquake (01/22/2003, Mw = 7,4), using surface and body wave inversion at teleseismics distances. In the case of body waves we used a classical approach of amplitude and waveform inversion. The point source solution gives a thrust fault plane of strike=274, dip=27, rake=75, h=26 km, and a scalar moment of Mo=1.3E+20 N m. This event shows a small directivity effect, possible because rupture occurred mainly along dip. Thus, is contrary to most mexican subduction earthquakes which propagate along the trench. The propagation path could be the reason this earthquake affected a large area of the Mexican territory. The source time function for point source solutions shows a duration of 20 s. In order to complete the solution we also inverted surface waves by obtaining the seismic moments of order 2, for intermediate periods between 50 and 100 s. This method has been successfully applied to intraplate earthquakes under the assumption of weak crustal variations. In the case of interplate earthquakes the crustal complexity is increased by the subducting plate, so we test the resolution of the method under more complex conditions. The surface waves solution is close to what we obtained by body waves having a strike=313, dip=33, rake=114, h=28 km and a Mo=1.0E+20 N m. In addition, the higher order moments define an integral duration of the 10 s, an instantaneous centroid velocity 3.2 km/s, a major axis length of 50 km, and a smaller axis of 18 km. The signal fitting in both cases is reasonably good. We also describe the seismic behavior of the earthquake, and calibrate the surface wave method in order to know its contribution to the study of subduction earthquakes.

S42E-0220 1330h POSTER

Effects of Crustal Layering on Source Parameter Inversion from Coseismic Displacement Data

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Usually source parameters are obtained by the inversion of coseismic displacements assuming a homogeneous half-space. Under this assumption, coseismic surface displacements for an assigned source depend on the ratio between the Lamè parameters μ and λ. Since rocks often behave like a Poisson solid, actual values of the elastic moduli do not affect the results. When crustal layering is taken into account, coseismic displacements depend on the values of the elastic moduli in all the layers, even if the ratio μ/λ is constant. Inversion of coseismic data assuming a layered medium is however impractical, because resolution of the inverse problem requires solving many direct problems. We have studied the effects of layering on inversions of coseismic displacements for finite dip-slip faults by computing surface displacements with different 3-D analytic codes and inverting them using a nonlinear inversion algorithm based on the homogeneous half-space assumption. Some source parameters (mainly fault dip, width and depth) noticeably depart from their "real" values.

S42E-0221 1330h POSTER

Stratigraphic imaging of sub-basalt sediments using waveform tomography of wide-angle seismic data

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The oil industry is interested in imaging the fine structures of sedimentary formations masked below basalt flows for commercial exploration of hydrocarbons. Seismic exploration of sediments hidden below high-velocity basalt cover is a difficult problem because near-vertical reflection data are contaminated with multiples, converted waves and scattering noise generated by interbeds, breccia and vesicles within the basalt. The noise becomes less prominent as the source-receiver offset increases, and the signals carrying subsurface information stand out at the wide-angle range. The tomography of first arrival traveltime data can provide little information about the underlying low-velocity sediments. Traveltime inversion of wide-angle seismic data including both first arrivals and identifiable wide-angle reflected phases has been an important tool in the delineation of the large-scale velocity structure of sub-basalt sediments, although it lacks the small-scale velocity details. Here we apply 2-D full-waveform inversion ("waveform tomography") to wide-angle seismic data with a view to extracting the small-scale stratigraphic features of sedimentary formations. Results from both synthetic data, generated for a realistic earth model, and field dataset from the basalt covered Saurashtra peninsula, India, will be presented. This approach has potential to delineate thin sedimentary layers hidden below thick basalt cover also, and may serve as a powerful tool to image sedimentary basins, where they are covered by high-velocity materials like basalts, salts, carbonates, etc. in various parts of the world.

S42E-0222 1330h POSTER

A Study of the Shallow Seismicity (1971-1999) in the Anchorage, Alaska, Region

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Previous earthquake studies in the Anchorage region (60 to 62N, 148 to 152W) have shown little to no correlation between shallow earthquakes (depths less than 30 km) and known large-scale faults. The Double Difference earthquake relocation technique is utilized in this study to identify seismogenic structures in more detail, thus contributing information needed for future seismic hazard assessment. These hypocenter relocations indicate a number of linear, seismogenic features, some of which appear to correlate with mapped faults. The nearest concentration of crustal seismicity to the city of Anchorage is located within Upper Cook Inlet. This seismicity seems to involve deformation along several smaller en echelon structures. These structures do not appear to be associated with mapped faults and anticlines but may correlate with longer wavelength features seen in filtered aeromagnetic data. The principal orientations of stress determined from the inversion of first motion data for these events show that the regional principal stress orientation is not aligned with the regional direction of plate convergence. This principal stress orientation, however, is not uncommon for the region when compared to borehole breakout and other focal mechanism studies. The stress results are also consistent with geodetic studies that suggest that the North American plate is not strongly coupled to the down going Pacific plate within the Upper Cook Inlet/western Kenai Peninsula region.

S42F MCC: 3009 Thursday 1340h

Strong Ground Motion Prediction I

Presiding: **R Graves,** URS Corporation**; P M Mai,** Institute of Geophysics, ETH Hoenggerberg

S42F-01 1340h

Seismic Shaking Maps of Osaka Sedimentary Basin, Southwest Japan (Preliminary Version)

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Active Fault Research Center, Geological Survey of Japan/AIST conducts a project of ground motion prediction in the Osaka sedimentary basin, southwest Japan, for hypothetical large earthquakes that would cause considerable damage in the future. Our ground motion prediction is characterized by a detailed 3D structure model of the Osaka sedimentary basin and rupture scenarios based on dynamic rupture simulations under constraints of geological data of active faults (Kase et al., in this meeting). A 3D Osaka basin structure model is constructed based on geological and geophysical data obtained by seismic reflection surveys, borings, and gravity measurements. The model area is 90 km in EW direction, 85 km in NS direction and down to 3 km depth. Medium constants are given in mesh data of 100 m and 50 m intervals in horizontal and vertical directions, respectively. Geometry of key sedimentary layers and basement floor, including overhang at reverse faults, are realistically expressed. Medium constants such as P- and S-wave velocities and density are given to each grid point based on empirical relations among P- and S-wave velocities, density, depositional age and depth. For active faults with enough paleoseismological information, we take the following two steps to construct rupture scenarios. First, we estimate heterogeneous slip distributions from surface displacement distributions of past earthquakes measured along an active fault. We assume that long-wavelength component of heterogeneity in rupture process is stable over geological (10e+6 yrs) time scale In the slip distribution model, slip varies along fault strike in a similar way to coseismic displacement. Along the downdip direction, it varies similar to those of source models for recent, well-analyzed earthquakes. The slip distribution thus estimated is converted into static stress change. Second, the static stress change is incorporated into dynamic rupture simulations as a variation of initial stress. Ground motion in the 3D Osaka basin structure model from the rupture scenarios is computed by the 3D finite difference method incorporating medium with S-wave velocity larger than 0.55 km/s. Response of subsurface structure shallower than engineering basement (portion with S-wave velocity lower than 0.55 km/s) is evaluated with multiple reflection theory in 1D media. For the earthquakes on active faults within the target area, we compute ground motion up to 1Hz by the 3D finite difference method with the smallest grid size of 100 m.

S42F-02 1355h INVITED

Simulations of Ground Motion in Southern California based upon the Spectral-Element Method

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We use the spectral-element method to simulate ground motion generated by recent well-recorded small earthquakes in Southern California. Simulations are performed using a new sedimentary basin model that is constrained by hundreds of petroleum industry well logs and more than twenty thousand kilometers of seismic reflection profiles. The numerical simulations account for 3D variations of seismic wave speeds and density, topography and bathymetry, and attenuation. Simulations for several small recent events demonstrate that the combination of a detailed sedimentary basin model and an accurate numerical technique facilitates the simulation of ground motion at periods of 2 seconds and longer inside the Los Angeles basin and 6 seconds and longer elsewhere. Peak ground displacement, velocity and acceleration maps illustrate that significant amplification occurs in the basin. Centroid-Moment Tensor mechanisms are obtained based upon Pnl and surface waveforms and numerically calculated 3D Frechet derivatives. We use a combination of waveform and waveform-envelope misfit criteria, and facilitate pure double-couple or zero-trace moment-tensor inversions.

S42F-03 1415h INVITED

Recipe of Strong Ground Motion Prediction for Senario Earthquakes

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From recent development of the waveform inversion analysis for estimating rupture process during large earthquakes, we have understood that strong ground motion is relevant to slip heterogeneity inside the source rather than the entire rupture area. The source characterization was made defining the entire rupture areas with a certain criterion in slip, and the asperities as regions that have two times slip as large as the average slip over the rupture area (Somerville et al., 1999). The important aspect from the source characterization is that the asperity areas as well as total rupture areas are expressed as a function of seismic moment. Based on the above scaling relationships, the source model for the prediction of strong ground motions is constructed by three kinds of parameters, outer, inner, and extra fault parameters. The outer fault parameters are defined as entire rupture area and total seismic moment. The inner fault parameters are defined as slip heterogeneity inside the source, i.e. area of asperities and stress drop on each asperity. We examined that strong motion generation areas approximately coincide with the asperity areas where stresses are strongly released (Miyake et al., 2001). A source model satisfying such characteristics is expressed as a dynamically-constrained multi-asperity model that is a extension a single-asperity model proposed by Das and Kostrov (1986). We have developed a recipe for predicting strong ground motions, which is to characterize the source model for scenario earthquakes. For the outer fault parameters, at first the total fault length is given as a sum of active fault segments. The fault width is related to the thickness of seismogenic zones. The entire source area is defined as a product of the length and width, and then the total seismic moment is derived following the empirical scaling relationship. For the inner fault parameters, the area of asperities is estimated from the scaling with the total seismic moment. Stress drop on each asperity is estimated by the ratio between the asperity and total rupture areas, and average stress drop over the entire rupture area. We found that the slip of the asperities is dynamically constraint depending on the number of the asperities. The pattern of rupture nucleation and termination as the extra fault parameters are related to geomorphology of active faults and plates. We have examined the validity of the earthquake sources constructed by the recipe, comparing simulated and observed ground motions for recent large earthquakes, such as the 1995 Kobe, 1999 Kocaeli, 1999 Chi-chi, 2000 Tottori, and other earthquakes.

S42F-04 1435h

Physically Self-Consistent Earthquake Source Models for Strong Ground Motion Prediction

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