S42A-0149 1330h POSTER

The Cottage Lake Lineament, Washington: Onshore Extension of the Southern Whidbey Island Fault?

Richard J. Blakely[1] (650-329-5316; blakely@usgs.gov); Craig S. Weaver[2] (craig@usgs.gov); Brian L. Sherrod[2] (bsherrod@usgs.gov); Kathy G. Troost[3] (ktroost@u.washington.edu); Ralph A. Haugerud[2] (rhaugerud@usgs.gov); Ray E. Wells[1] (rwells@usgs.gov); David H. McCormack[4] (dmccormack@aspectconsulting.com)

[1]U.S. Geological Survey, 345 Middlefield Road, MS 989, Menlo Park, CA 94025, United States

[2]U.S. Geological Survey, Box 351310, University of Washington, Seattle, WA 98195, United States

[3]University of Washington, Department of Earth and Space Sciences, Box 351310, Seattle, WA 98195, United States

[4]Aspect Consulting, 811 First Avenue, Suite 480, Seattle, WA 98104, United States

The northwest-striking southern Whidbey Island fault zone (SWIF) is reasonably well expressed by borehole data, marine seismic surveys, and potential-field anomalies on Whidbey Island and beneath surrounding waterways. Johnson et al. (1996) described evidence for Quaternary movement on the SWIF, suggested the fault zone is capable of a M 7 earthquake, and projected three fault strands onto the mainland between the cities of Seattle and Everett. Evidence for this onshore projection is scant, however, and the exact location of the SWIF in this populated region is unknown. Four linear, northwest-striking magnetic anomalies on the mainland may help address this issue. All of the anomalies are low in amplitude and best illuminated in residual magnetic fields. The most prominent of the magnetic anomalies extends at least 15 km, is on strike with the SWIF on Whidbey Island, and passes near Cottage Lake, about 15 km south of downtown Everett. The magnetic anomaly is associated with linear topography along its entire length, but spectral analysis indicates that the source of the anomaly lies principally beneath the topographic surface and extends to depths greater than 2 km. The anomalies are likely created by northwest-trending, faulted and folded Tertiary volcanic and sedimentary rocks of the Cascade foothills, which rise from beneath the Quaternary lowland fill to the southeast of the SWIF. High-resolution Lidar topography provided by King County shows subtle scarps cutting the latest Pleistocene glaciated surface at two locations along the magnetic anomaly; scarps are parallel to the anomaly trend. In the field, one scarp has 2 to 3 m of north-side-up offset; paleoseismic trench excavations are planned for Fall 2003 to determine their nature and history. Preliminary examination of boreholes, recently acquired as part of an ongoing sewer tunnel project, show anomalous stratigraphic and structural disturbances in the area of the magnetic anomalies. Analyses are underway to determine if faulting causes these disturbances. Taken together, the SWIF and the Cottage Lake lineament extend >50 km. Thus defined, the SWIF is spatially associated along its length with an arcuate (convex to the southwest) zone of deep (>10 km) crustal earthquakes, one of several arcuate alignments of epicenters between the SWIF and Olympia, Washington.

S42A-0150 1330h POSTER

Crustal Velocity Structure From First Arrival Seismic Tomography in the Strait of Georgia, British Columbia and Washington

Ranjan K. Dash[1] (250-721-6188; rdash@uvic.ca); George D. Spence[1] (gspence@uvic.ca); Michael Riedel[2] (mriedel@pgc-gsc.nrcan.gc.ca); Roy D. Hyndman[1,2] (rhyndman@nrcan.gc.ca); Thomas M. Brocher[3] (brocher@usgs.gov); Thomas L. Pratt[4] (tpratt@usgs.gov)

[1]School of Earth and Ocean Sciences, University of Victoria, Victoria, BC V8W 3P6, Canada

[2]Pacific Geoscience Centre, Geological Survey of Canada, Sidney, BC V8L 4B2, Canada

[3]U.S. Geological Survey, 345 Middlefield Road, M/S 977,, Menlo Park, CA 94025, United States

[4]U.S. Geological Survey, School of Oceanography, Box 357940, Univ. of Washington, Seattle, WA 98195, United States

Seismic refraction/wide-angle reflection data were collected in May 2002 in the Strait of Georgia, southwestern British Columbia and northwestern Washington. The experiment, part of the Georgia Basin Geohazards Initiative, provides knowledge about potential geohazards associated with near-surface crustal faulting in the strait. The last significant earthquake (M = 4.6 in 1997) within the strait reflects the regional seismic hazard. The seismic survey was aimed at studying the three-dimensional (3D) velocity structure of the shallow upper crust particularly the Cenozoic sedimentary basins, the Outer Island fault and the Lummi Island fault. The data were acquired using 48 Reftek stations deployed onshore to record the signals from a 120 cu. in. airgun fired at a nominal interval of 5 sec or 12 m. Single channel reflection data were collected simultaneously. The experiment provided useful data from 42 of the 48 stations deployed. The data quality at many receivers was very good. The average maximum source-receiver offset for first arrivals was 17 km with a maximum offset of 35 km. Preliminary 2D velocity modeling indicates three layers in the shallow upper crust down to a maximum depth of 3 km. The uppermost layer in the strait represents recent unconsolidated sediments. The second layer consists of basin fill sediments (velocity 4.1- 4.4 km/s) associated with the Upper Cretaceous Nanaimo Group. These sediments occur at the surface within the Canadian Gulf Islands but at a depth of about 700 m within the strait. The underlying basement layer (velocity 5.3 - 5.7 km/s) at a depth of 1.7 km possibly represents the volcanic Wrangellia terrane, extending from Vancouver Island beneath the strait. The wide distribution of receivers in the islands and shots in the surrounding waters provides excellent constraints for 3D inversion of first arrival travel times and hence for a high-resolution 3D image of the shallow structure.

S42A-0151 1330h POSTER

Structure of the Juan de Fuca Plate and Forearc Mantle below Vancouver Island

Kumar Ramachandran[1] (250 363 6441; kramacha@nrcan.gc.ca)

Ron M Clowes[2] (604 822 4138; clowes@lithoprobe.ubc.ca)

[1]Pacific Geoscience Centre, Geological Survey of Canada 9860 West Saanich Road, Sidney, BC V8L 4B2, Canada

[2]Department of Earth and Ocean Sciences, The University of British Columbia Room 357 Geological Sciences 6339 Stores Road, Vancouver, BC V6T 1Z4, Canada

LITHOPROBE multichannel seismic reflection data, recorded on Vancouver Island in 1984, provided the first images of the subducting Juan de Fuca (JdF) plate. At the western edge of the island, Line 84-01 identified the top of the JdF plate at 10 s two-way time (TWT; 30-33 km depth); in the southern part, Line 84-02 showed the plate at 11.5-12.5 seconds TWT (35-42 km depth). Data from these and two other short lines on the island plus Line 88-16, effectively a continuation of 84-01 on the mainland across Georgia Strait, have been reprocessed. Reflections from the top of the JdF crust and Moho are observed on NMO-corrected shot gathers. The new results extend mapping of the top of the subducting JdF crust and Moho to eastern Vancouver Island, where the top of the plate is identified at 13 s TWT (44-47 km depth). Our interpretation is consistent with locations of earthquake hypocenters. The results also show the position of the Cascadia forearc mantle wedge beneath southern Vancouver Island. At the end of Line 84-01 on eastern Vancouver Island, the forearc crust-mantle boundary is delineated at 11 s TWT (37 km depth). Across Georgia Strait, the forearc Moho also is identified at 11 s TWT (37 km depth) on the western end of Line 88-16. Previous seismic receiver function and refraction studies have estimated similar depths to continental Moho in this region. On the western end of Line 88-16, a band of NE-dipping upper mantle reflections is observed between 13-15 seconds TWT. This reflective unit seems to correlate with the prominent E' reflections observed on Line 84-01. To strengthen this interpretation, further processing to improve the signal coherency of E' reflections on the eastern end of Line 84-01 is in progress. Velocity models along the reflection lines on Vancouver Island are extracted from a 3-D P-wave tomographic study of onshore-offshore wide-angle data [1998 SHIPS (Seismic Hazards Investigation of Puget Sound) experiment] and earthquake data acquired north of the Strait of Juan de Fuca. Low P-wave velocities (7.2-7.4 km/s) characterize the mantle wedge at depths of 40-50 km beneath eastern Vancouver Island. We attribute these low velocities to metamorphic dehydration reactions in the crust of the JdF plate and subsequent release of aqueous fluids, resulting in hydration and serpentinization of the forearc mantle. Silent-slip earthquakes recently have been detected within this zone through continuous GPS studies.

S42A-0152 1330h POSTER

Using the Local Magnitude Scale to Determine Seismic Site Response in the Pacific Northwest

Anthony Qamar[1] (206-685-7563; tony@ess.washington.edu)

Amy Wright[1] (amyw@ess.washington.edu)

George Thomas[1] (george@ess.washington.edu)

[1]University of Washington, Dept. of Earth and Space Sciences, PO Box 351310, Seattle, WA 98195, United States

Using new wide dynamic-range digital seismographs and accelerometers of the Pacific Northwest Seismograph Network in Washington and Oregon we have reevaluated the magnitudes of earthquakes in the Pacific Northwest using the Local (Richter) Magnitude scale, ML. We have done this by synthesizing Wood-Anderson Seismograms from broadband instruments. This procedure is a departure from our traditional use of the coda-magnitude scale. We have computed the ML of 76 earthquakes that occurred from 2000-2003 with 2.5<M<6.8 using observations from a total of 2812 seismograms. We utilized a method of Joint Magnitude Determination in which earthquake magnitudes and station corrections are determined simultaneously for all earthquakes. The computed magnitude corrections at the stations range between -0.4 to +0.4 magnitude-units. On average, the magnitude corrections are correlated with, and can be reasonably predicted from, the NEHRP soil classification assigned to each site. Computed magnitudes tend to be higher at sites where the estimated surface shear wave velocity is low. The variations in computed magnitude do not seem to depend on the presence of deep-basin structures in the subsurface. On the other hand, such structures have been shown to affect the amplitudes of very low frequency seismic waves. We suspect that this discrepancy is caused by the fact that Richter magnitudes (ML) are intrinsically sensitive to higher frequency ground motions. We conclude that variations in Richter magnitude can be used to detect shallow subsurface site conditions likely to affect earthquake shaking.

S42B MCC: Level 1 Thursday 1330h

Earthquake Alerting Systems: From Rapid Hazard Determination to Societal Response II Posters

Presiding: **Y Wu,** Central Weather Bureau, Taiwan**; C Gurbuz,** Bogazici University

S42B-0153 1330h POSTER

Istanbul Earthquake Early Warning and Rapid Response System

Mustafa O Erdik[1] (90-216-332-6560; erdik@boun.edu.tr); Yasin Fahjan[1] (fahjan@boun.edu.tr); Oguz Ozel[1] (ozeoguz@boun.edu.tr); Hakan Alcik[1] (alcik@boun.edu.tr); Mert Aydin[1] (mertay@boun.edu.tr); Muzaffer Gul[1] (gulmuzaf@boun.edu.tr)

[1]Bogazici University, Kandilli Rasathanesi 81220 Cengelkoy, Istanbul 81220, Turkey

As part of the preparations for the future earthquake in Istanbul a Rapid Response and Early Warning system in the metropolitan area is in operation. For the Early Warning system ten strong motion stations were installed as close as possible to the fault zone. Continuous on-line data from these stations via digital radio modem provide early warning for potentially disastrous earthquakes. Considering the complexity of fault rupture and the short fault distances involved, a simple and robust Early Warning algorithm, based on the exceedance of specified threshold time domain amplitude levels is implemented. The band-pass filtered accelerations and the cumulative absolute velocity (CAV) are compared with specified threshold levels. When any acceleration or CAV (on any channel) in a given station exceeds specific threshold values it is considered a vote. Whenever we have 2 station votes within selectable time interval, after the first vote, the first alarm is declared. In order to specify the appropriate threshold levels a data set of near field strong ground motions records form Turkey and the world has been analyzed. Correlations among these thresholds in terms of the epicenter distance the magnitude of the earthquake have been studied. The encrypted early warning signals will be communicated to the respective

end users by UHF systems through a "service provider" company. The users of the early warning signal will be power and gas companies, nuclear research facilities, critical chemical factories, subway system and several high-rise buildings. Depending on the location of the earthquake (initiation of fault rupture) and the recipient facility the alarm time can be as high as about 8s. For the rapid response system one hundred 18 bit-resolution strong motion accelerometers were placed in quasi-free field locations (basement of small buildings) in the populated areas of the city, within an area of approximately 50x30km, to constitute a network that will enable early damage assessment and rapid response information after a damaging earthquake. Early response information is achieved through fast acquisition and analysis of processed data obtained from the network. The stations are routinely interrogated on regular basis by the main data center. After triggered by an earthquake, each station processes the streaming strong motion data to yield the spectral accelerations at specific periods, 12Hz filtered PGA and PGV and will send these parameters in the form of SMS messages at every 20s directly to the main data center through a designated GSM network and through a microwave system. A shake map and damage distribution map (using aggregate building inventories and fragility curves) will be automatically generated using the algorithm developed for this purpose. Loss assessment studies are complemented by a large citywide digital database on the topography, geology, soil conditions, building, infrastructure and lifeline inventory. The shake and damage maps will be conveyed to the governor's and mayor's offices, fire, police and army headquarters within 3 minutes using radio modem and GPRS communication. An additional forty strong motion recorders were placed on important structures in several interconnected clusters to monitor the health of these structures after a damaging earthquake.

URL: http://www.koeri.boun.edu.tr/depremmuh/EWRR/EWRRMain.htm

S42B-0154 1330h POSTER

An Earthquake Alarm System for the Marmara Region,Turkey

Mehtap Ekinci[1] (ekinci@boun.edu.tr)

Cemil Gurbuz[1] (gurbuz@boun.edu.tr)

Richard M. Allen[2] (rallen@geology.wisc.edu)

[1]bogazici University, kandilli observatory and earthquake researh institute,cengelkoy, istanbul 81220

[2]University of Wisconsin-Madison,Department of geology and geophysics, 1215 W Dayton St,Madison WI 53706, Madison 53706

An Earthquake Alarm System For the Marmara Region, Turkey. M.Ekinci, C.Gurbuz, R.M. Allen Marmara region is tectonically very active and destructive earthquakes occurred in the past. Istanbul and other major cities around the Marmara region can face a significant earthquake hazard in the next thirty years the main Marmara Fault can create an earthquake moment magnitude as week as 7.5 A short-term seismic hazard mitigation in the Marmara region can be very useful.Shot-term hazard mitigation requires information on coming groun motion a few seconds to tens of seconds prior to its arrival.A proposed earthquake alarm system using the MARNET and NANOMET seismic networks could issue a warning a few seconds ahead of damaging groun motion.We proposed system uses the frequency content of P arrival to determine earthquake magnitude, an aproach that allows magnitude determination prior to any damaging ground motion. In this study we applied this method to earthquakes with a magnitude range of 3.0 and 5.1 between 2002 and 2003 in the Marmara region.

S42B-0155 1330h POSTER

Artificial Neural Networks for Earthquake Early-Warning

Maren Boese[1] (maren.boese@gpi.uni-karlsruhe.de)

Mustafa Erdik[2]

Friedemann Wenzel[1]

[1]Institute of Geophysics, Karlsruhe University, Hertzstrasse 16, Karlsruhe 76187, Germany

[2]Dept. of Earthquake Engineering, Bogazici University, Kandilli Observatory and Earthquake Engineering, Cengelkoy 81220, Turkey

The rapid urbanization and industrial development in areas of high seismic hazard increase the threat to human life and the vulnerability of industrial facilities by earthquakes. As earthquake prediction is elusive and, most likely, will not be achievable in near future, early-warning systems play a key role in earthquake loss reduction. Seismic waves propagate with significant lower velocity than information on these waves can be passed along to a vulnerable area or facility using modern telemetry systems. Within shortest time an earthquake early-warning system estimates the ground motion that will be caused by the oscillating seismic waves in the endangered area. Dependent on the predicted possible damage appropriate automatisms for loss reduction (such as the stoppage of trains or the interruption of gas pipelines) are triggered and executed some seconds to minutes before the devastating waves actually arrive. The Turkish megacity Istanbul faces a seismic hazard of particular severity due to its proximity to the complex fault system in the Marmara region. The likelihood for an seismic event of moment magnitude above 7.2 to occur within the next 30 years is estimated to be 70%. The Istanbul Earthquake Rapid Response and Early-Warning System (IERREWS) is an important contribution to be prepared for future earthquakes in the region. The system is operated by the Kandilli Observatory and the Earthquake Research Institute of the Bogazici University in cooperation with other agencies. The early-warning part of IERREWS consists of ten strong motion stations with 24-bit resolution, communication links and processing facilities. The accelerometers are installed on the shoreline of the Marmara Sea and are operated in on-line mode for continuous and near-real time transfer of data. Using the example of the IERREWS station configuration and seismic background of the Marmara region we present an approach that considers the problem of earthquake early-warning as a pattern recognition task. The seismic patterns are defined by the shape and frequency content of the parts of seismograms that are available at each time step. From these, parameters that are relevant to seismic damage, such as peak ground acceleration (PGA), peak ground velocity (PGV), response spectral amplitudes at certain periods and macroseismic intensity, are estimated using Artificial Neural Networks (ANN). We combine pattern recognition with an additional rule-based system in order to detect inconsistencies between ground motion estimations and measurements. This combination provides a reliable and accurate system for early-warning that is demanded by its huge social and economic impact.

S42B-0156 1330h POSTER

An Operational Alert System for the European-Mediterranean Region

Gilles Mazet-Roux[1] (+33 169267813; mazet@emsc-csem.org)

Rémy Bossu[1] (+33 169267814; bossu@emsc-csem.org)

Emilio Carreno[2] (emilio@ign.es)

Jocelyn Guilbert[3] (jocelyn.guilbert@cea.fr)

Stéphanie Godey[1] (+33 169267813; godey@emsc-csem.org)

[1]European-Mediterranean Seismological Centre, Bât. Sables BP 12, Bruyères le Châtel 91680, France

[2]Instituto Gepgrafico Nacional, General Ibanez Ibero 3, Madrid 28003, Spain

[3]Laboratoire de Détection Géophysique, CEA BP 12, Bruyères le Châtel 91680, France

The European-Mediterranean Seismological Centre (EMSC) has been running for several years an operational alert system for potentially damaging earthquakes which occur in the European-Mediterranean region. This alert system, - sub-part of the EMSC real time information service available on the web site (www.emsc-csem.org) - is based on parametric data provided through the Internet by 40 different networks representing 800 stations in the Euro.-Med. region. In case of potentially damaging earthquake, the seismologist on duty connects to EMSC facilities, merges and processes all available data and, as soon as a reliable solution is available, disseminates alert messages by fax and email. Alert messages are sent by fax to official organisations (e.g., Civil Protection Agency, rescue teams, Council of Europe, ECHO, etc.), to the seismological community and to the public by emails (800 emails). Furthermore, data and results are made automatically available in real time on the web. In case of technical problems or maintenance activities, the duty is taken over by IGN (Madrid, Spain), which runs full back-up procedures. EMSC commits itself to a maximum dissemination time (time lag between the occurrence of the earthquake and the messages' dissemination) of 1 hour. This delay is respected in the vast majority of cases with a median dissemination time of less than 40 minutes. We will give an overview of this system and its performances and put a special emphasis on the processing of the recent earthquake in Algeria.

S42B-0157 1330h POSTER

Latest Development of Real-Time Strong-Motion Monitoring System in Taiwan

Nai-Chi Hsiao[1] (+886-2-2349-1350; naigi@scman.cwb.gov.tw)

Yih-Min Wu[1] (ym.wu@socmail.cwb.gov.tw)

Tzay-Chyn Shin[1]

Ta-liang Teng[2]

[1]Central Weather Bureau, 64 Kung Yuan Road, Taipei 100, Taiwan

[2]University of Southern California, University of Southern California, Los Angeles, CA 90089-0740, United States

Based on the experience of the 1999 Chi-Chi Earthquake, the Central Weather Bureau (CWB) has made substantial improvements to the earthquake rapid report system. Besides the current use of digital lease phone line and internet transmission, the satellite link for station to center is setup for backup. The station is also equipped with UPS to prevent the failure of electricity power. This backup link system is designed as automatically switching in case of ground link interrupted. On the other hand, two real-time seismic sub-network are deployed stand alone at Hualein (East coast of Taiwan) and Tainan (south Taiwan) stations separately. The sub-network only manipulates real-time seismic data of nearby stations to shorten the procession time. The configuration and function of sub-network can be monitored and changed by Taipei center through computer link. Results from sub-network can be sent to Taipei center simultaneously. The collective use of these redundant systems significantly improves the capability and reliability of seismic emergency response. It will provide more robust foundation to develop earthquake early warning system. To safeguard train transportation from a disaster earthquake, the CWB assists Taiwan Railway Administration (TRA) to establish a seismic alert system including 44 3-component accelerographs along the track of the round-the-island Taiwan railway system. The configuration of the system is similar to the use of sub-network of CWB. It becomes the third backup of earthquake report system. In addition, ground vibration of a TRA instrument exceeds 180 gals, the power of the railway will be automatically cut-off to slow down the nearby train.

S42B-0158 1330h POSTER

Development of quick and accurate automatic hypocenter location system for the earthquake alarm

Shigeki Horiuchi[1] (horiuchi@bosai.go.jp)

Aya Kamimura[1] (kamimura@bosai.go.jp)

Hiroaki Negishi[1] (negishi@bosai.go.jp)

Shunroku Yamamoto[1] (syama@bosai.go.jp)

[1]National Research Institute for Earth Science and Disaster Prevention, 3-1 Tennodai, Tsukuba 305-0006, Japan

Most earthquake damage occurs after arrival of the S wave, whose amplitude is about five times larger than the P wave. Because the P wave travels faster than the S wave, the interval between their arrival times creates an opportunity to activate an earthquake alarm and take preemptive safety measures. We developed an automatic system which transmits the earthquake shaking intensity before S wave arrival. Since the alarm system is used to control transportation, industry, business, etc, at a time of a large earthquake occurrence, false alarms cost huge. We solved the technical difficulty of determining earthquake parameters very quickly and without errors, by developing a novel method using not only P wave arrival times but also time data of P wave not yet arrived. We also developed filters which can distinguish seismic signal from large amplitude noise generated by many kinds of reasons. The system can eliminate extraneous arrival-time readings during the process of hypocenter location by checking automatically measured readings, P wave not yet arrived data, and their station distribution. We use waveform data of Hi-net (High Sensitivity Seismograph Network Japan, National Research Institute for Earth Science and Disaster Prevention) composed of ca. 700 very high quality stations covering whole Japan with space density of 20 to 30 km. All seismometers are installed on observation wells deeper than 100m. Our system can locate precise hypocenters for 97 % felt events occurring in and near Japan Islands within a few seconds and transmits earthquake alarm information before most of seismic energy has arrived even to the station closest to the hypocenter. We are broadcasting earthquake alarm information for all destructive earthquakes by using the satellite system developed by ERI (Earthquake Research Institute, Univ. of Tokyo), and hoping to promote the development of many kinds of automatic control systems which stop cars, factories, etc to protect people from earthquake damage.

S

S42B-0159 1330h POSTER

Real-time Operation System for Earthquakes (ROSE)

Mizuho Ishida[1] (+81-29-863-7776; ishida@bosai.go.jp)

Masahiro Ooi[1] (+81-29-863-7661; ooi@bosai.go.jp)

Hiroyuki Fujiwara[1] (fujiwara@bosai.go.jp)

[1]National Research Institute for Earth Science and Disaster Prevention, 3-1 Ten-nodai, Tsukuba 305-0006, Japan

Three kinds of nationwide seismic network have been established and operated by the National Research Institute for Earth Science and Disaster Prevention (NIED) after the 1995 Kobe, Japan, earthquake (M7.3): (1) The short period seismic network (Hi-net); (2) The strong motion network (K-NET and KiK-net); And (3) the broad band seismic network (F-net). The Hi-net consists of about 700 short period (1 Hz) borehole seismometers distributed over Japan with average station interval of 20 km. The K-net consists of about 1030 strong motion seismometers; the KiK-net includes about 660 strong motion seismometers installed at the bottom and top of the same borehole as the Hi-net station. And the F-net has about 70 broad band seismometers covering Japan with station interval about 100 km. Furthermore, during the end of 1970' to the beginning of 1980's, NIED had already established about 60 short period borehole stations (KT-net) in the Kanto-Tokai district, central Japan. Real time data from Hi-net, F-net and KT-net are continuously transmitted to the NIED Data Center and event data from K-NET and KiK-net are transmitted to the NIED by a dial-up telephone link. Based on those data we have developed the Real-time Operation System (ROSE) to quickly and accurately determine earthquake parameters including epicentral location, focal depth, magnitude, focal mechanism and moment tensor solution. Furthermore we had developed the real-time ground motion monitoring system, indicating the maximum velocity and intensities in each 30 to 60 sec. The recently developed system (ROSE II) determines, automatically, not only the above parameters but also the fault plane solutions and the geographical distribution of strong ground motion for an earthquake. The strong ground motion map can be automatically revised with the increasing of the number and the accuracy of earthquake information available after a large earthquake begins. Using the ground motion map, the ROSE II will be able to estimate the possible damage of the structures and buildings and display all information together in the same map by using GIS. The earthquake parameters and maps are notified through the home page of NIED as soon as they are determined for timely assessment of overall impact of the disaster and to allocate available resources.

URL: http://www.agu.org

S42B-0160 1330h POSTER

Today and Tomorrow of the Real-time Earthquake Information Equipment

Yutaka Nakamura (+81-042-574-4536; yutaka@sdr.co.jp)

System and Data Research, 3-25-3, Fujimidai, Kunitachi-City, Tokyo, JAPAN, TOKYO 186-0003, Japan

UrEDAS, Urgent Earthquake Detection and Alarm System, can realize the real-time early earthquake detection and alarm system in the world. Although this system is actually working for mostly railroad relations, such as the Shinkansen and subway lines, it is not the system limited to the railroad field. For example, there is a local government that has realized a tsunami warning system using real-time estimated earthquake parameters as magnitude and location, distributed by UrEDAS. UrEDAS is characterized by the serial processing without storage of seismic waveform for processing. For this reason, the procedure of data processing hardly changes with usual operation also in case of an earthquake, so the system does not carry out a system failure in case of an earthquake. And also UrEDAS does not require a network and is an autonomous distributed system strong against a natural disaster or cyber-terrorism. On 26 May 2003, the Sanriku-Minami earthquake of Mj 7.0 was occurred. It was so large that the maximum acceleration of about 600 Gal was observed along the Shinkansen line and 22 columns of the rigid frame viaducts (RC) were severely cracked. This earthquake occurred on the business hours of the Shinkansen. As expected, coastline Compact UrEDAS took out the early P wave alarm before the destructive earthquake motion and the validity of this system was proved for the first time. UrEDAS on the place where many faults exist has a problem in accuracy, especially for the epicentral azimuth. UrEDAS has been observing to consider on the situations of operation under such an unfavorable condition and tried to shorten the calculation time and improve the accuracy. On the other hand, UrEDAS has examined to distribute the earthquake information via Internet. At the time of Colima, Mexico earthquake on January 2003, UrEDAS in Mexico City detected this earthquake over one minute before the large motion and sent an information for persons concerned. The above systems are large-scale and requires high-cost, so it is impossible for general people to install this system easily. Considering on this situation, development of "FREQL" which aimed at epoch-making low cost and miniaturization is progressing to unite "UrEDAS" and "Compact UrEDAS", and to progress the processing time and presumed accuracy. FREQL, Fast Response Equipment against Quake Load, is pronounced furekkulu and it means coming shake in Japanese. On the other hand, the maximum acceleration is the physical value indispensable to grasp earthquake force and the seismic intensity is important to know the destructive power of an earthquake motion. Aiming to develop a small seismometer which can be installed in all residence and structures, instrumental seismic intensity corresponding to MMI was proposed and the small digital seismometer AcCo (Acceleration Collector) which can display the proposed objective seismic intensity data and the maximum acceleration on real time was developed. Although AcCo is small and cheap, it has an alarm function other than an earthquake observation function, and can widely use as not only for alarm but also for education. AcCo is the first seismometer as a new type of a realtime earthquake information equipment, which has a possibility of changing completely the view of future real-time earthquake disaster prevention.

URL: http://www.sdr.co.jp

S42B-0161 1330h POSTER

Rapid Magnitude Determination Using P-Wave Arrivals: Magnitude-Period Relations for Japan and the Pacific Northwest

Andrew B Lockman[1] (608-262-9784; drew@geology.wisc.edu)

Richard M Allen[1] (608-262-7513; rallen@geology.wisc.edu)

[1]Department of Geology and Geophysics, University of Wisconsin-Madison, 1215 West Dayton St., Madison, WI 53706, United States

Recent efforts to mitigate earthquake hazards in Southern California using earthquake early warning demonstrate the utility of using the frequency content of P-wave arrivals to rapidly estimate earthquake magnitude. Studies have shown the P-wave period increases with magnitude, a relationship observed by applying a 10.0 Hz low-pass filter for events with magnitudes between 3.0 and 5.0, and applying a 3.0 Hz low-pass filter for events greater than magnitude 4.5. These findings indicate that P-wave detection and analysis could be used to issue a warning before ground motion begins in areas where population centers and active faults are co-located. Although the magnitude-period relationship for Southern California has been identified, the limited availability of large magnitude events necessitates analysis of earthquakes in other regions to determine if the relationship is consistent in different geologic settings. Here we present the findings of a study performed using earthquakes in the Pacific Northwest and Japan. Our results show a similar behavior when the same 3.0 Hz and 10.0 Hz filters are applied, suggesting the attenuation characteristics of different regions do not significantly affect the magnitude-period relations. Although the trend observed in Southern California earthquakes remains for the Japan and Pacific Northwest earthquakes, we find that optimal sensitivity to magnitude is achieved by applying different filters for each region. Earthquakes in Japan show the greatest magnitude sensitivity by applying a 5 Hz low-pass filter for low magnitude events, and a 2.5 Hz low-pass filter for large magnitude events. Earthquakes in the Pacific Northwest show the greatest sensitivity by applying a 0.3 Hz low-pass filter for low magnitude events, and a 0.1 Hz low-pass filter for large magnitude events.

S42B-0162 1330h POSTER

ElarmS: Earthquake early warning for southern California

Richard M Allen[1] (rallen@geology.wisc.edu)

Hiroo Kanamori[2] (hiroo@gps.caltech.edu)

[1]University of Wisconsin, Dept. Geology and Geophysics 1215 W Dayton St, Madison, WI 53706, United States

[2]California Institute of Technology, Seismological Laboratory MC 252-21, Pasadena, CA 91125, United States

The location of faults directly beneath metropolitan areas in southern California requires any earthquake early warning system to make use of the first arriving energy, the P-wave, to estimate the hazard potential of the earthquake. Using the P-wave arrival maximizes the warning time available and may also make it possible to issue a warning before peak ground motion at the epicenter where the warning is most needed. We present a methodology that could potentially provide an earthquake early warning system for southern California. The necessary components include rapid detection and location of earthquakes, magnitude estimation using the P-wave, and prediction of peak ground motion variations across the affected region. As a result of the dense distribution of seismic stations in the region (TriNet), typically two or three stations trigger within one second of the first station to detect an earthquake. This allows for accurate location of the event within a second of the first trigger. Magnitude is estimated from the predominant period of the P-arrival at each triggered station. At any given time after the P-trigger, the maximum period observed thus far is converted to a magnitude. This magnitude represents a minimum estimate; a larger predominant period observation at some later time would indicate a larger magnitude earthquake and the magnitude estimate would be updated. For smaller earthquake (less than magnitude 4.5) the maximum period is usually observed within 1 sec, for larger events up to 4 sec of data is needed to capture the best magnitude estimate. Given the location and magnitude estimates, the distribution of peak ground motion is predicted using simple 1D attenuation relations. As time progresses observations of the peak ground motion at stations close to the epicenter are used to adjust the attenuation relations and improve predictions of ground motion for more distant regions.

URL: http://www.geology.wisc.edu/~rallen/ELARMS/

S42B-0163 1330h POSTER

MQUAKE multicast software early warning demonstrated for 31 October 2001 Anza Ml5.1 earthquake

Jennifer A Eakins[1] (jeakins@ucsd.edu)

Todd Hansen[2] (858-822-0929; tshansen@ucsd.edu)

Frank L Vernon[1] (858-534-5537; flvernon@ucsd.edu)

Hans-Werner Braun[2] (858-534-5000)

[1]IGPP, SIO, Univ. of California, San Diego, MC-0225 9500 Gilman Drive, La Jolla, CA 92093-0225, United States

[2]SDSC, Univ. of California, San Diego, MC-0505 9500 Gilman Drive, La Jolla, CA 92093-0505, United States

MQUAKE distributes real-time multicast parametric information from individual sensors as well as a summarized location and magnitude based on the data recorded from sensors of the ANZA seismic network with the goal of providing event notification prior to arrival of the actual shock wave at the client's location. The program gathers detection and triggering information from an operational Antelope real-time data collection system and sends them to clients via multicast and unicast UDP packets. Multicast packets are preferred as they allow multiple people to receive event packets in the fastest time possible (however, a unicast mode is available since most IP networks do not support multicast). These packets are decrypted in a client software which then produces a list of triggers/events that will be used in future versions of the code to generate wavefront estimate plots and approximate maximum shock wave travel times based on the client's location and limited current information. This systems works in both a wired and wireless environment, such as HPWREN, the High Performance Wireless Research and Education Network. A real-time example of this system was obtained during the Ml5.1 31 October 2001 earthquake that occurred directly under the ANZA seismic network, approximately 70 km away from an MQUAKE client. The MQUAKE program was able to deliver a warning of a significant "event" 10 seconds after the initial ground motion was recorded and about 4 seconds prior to ground motion reaching the client. An actual event location and magnitude approximation was received 71 seconds after the local ground shaking at the client's location (85 seconds after the event). Had the client been located along the coast of San Diego, they would have had additional warning time prior to the shaking. Clients in San Diego, the closest major metropolitan area to this event, could have received up to 12 seconds of early warning.

S42B-0164 1330h POSTER

An Envelope-Based Paradigm for Seismic Early Warning

Georgia B. Cua[1] (1-626-395-4236; georgia@caltech.edu)

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

[1]California Institute of Technology, Department of Civil Engineering 1200 E. California Blvd., Pasadena, CA 91125, United States

We present a waveform envelope-based paradigm for seismic early warning. As suggested by theoretical scaling relations and as observed from data, acceleration saturates with increasing magnitude at a faster rate

than does velocity or displacement. Thus, ratios of velocity or displacement to acceleration should be indicative of the magnitude of an earthquake. We introduce an evenlope-based parameterization of ground motion, where the observed ground motion envelope is decomposed into independent P-wave, S-wave, and ambient noise envelopes. The body wave envelopes, in turn, are parameterized by a rise time, an amplitude, a duration, and two decay parameters. We apply this parameterization to a database of over 30,000 records of horizontal and vertical acceleration, velocity, and displacement recorded on digital Southern California Seismic Network stations within 200 km of 80 regional events ranging in magnitude from M2.0 to M7.3. We derive attenuation relationships that account for magnitude-dependent saturation for vertical and horizontal acceleration, velocity, and displacement for P- and S-wave amplitudes, obtain station corrections relative to the mean hard rock response, and use these relationships to examine trends with magnitude and distance of ratios of different components of ground motion. An important consequence of our parameterization is the insight it provides into P-wave characteristics. We find that various ratios of P-wave velocity and displacement to acceleration are indicative of magnitude, and may have potential as another quick method to estimate magnitude for seismic early warning.

S42B-0165 1330h POSTER

Real-time Seismic Warning With a 2-Station Subarray

Paul A Rydelek[1] (901-678-4883; par@ceri.memphis.edu)

Jose M Pujol[1] (901-678-4827; pujol@ceri.memphis.edu)

[1]Center for Earthquake Research and Information, The University of Memphis, 3890 Central Ave., Memphis, TN 38152, United States

One of the most basic problems in seismology is earthquake location. In particular, the ability to quickly locate a large, potentially devastating earthquake is of fundamental importance in a real-time warning system where speed is a key factor in determining the level of success of such systems. We have developed a simple method that uses only the two earliest P-wave arrival times in a seismic array. Assuming a simple velocity model, these arrivals are used to construct a hyperbolic curve on which the approximate epicenter of the earthquake is expected to lie. Epicentral location along this hyperbola is further constrained by using the fact that the P-waves arriving at the other stations in the array are not first arrivals. When applied to P-wave data from seismic networks in the central US and California, model results show agreement with actual earthquake locations. Although there is an inherent uncertainty in the subarray method of locating large earthquakes, this may be an acceptable trade-off in an early warning system in view of the time (few to tens of seconds) saved by not waiting for other P-arrivals.

S42B-0166 1330h POSTER

Wireless Structural Sensing for Health Monitoring and Control Applications

Jerome Peter Lynch (734-615-5290; Jerome.Lynch@umich.edu)

University of Michigan , Department of Civil and Environmental Engineering, 2328 G. G. Brown, 2350 Hayward Street, Ann Arbor, MI 48109

The economic and societal impact of civil structures under-performing during large earthquakes can be significant. While in recent years the structural engineering community has made great strides in advancing knowledge of structural behavior under extreme loads, a need still exists for the rapid assessment of structural performance during seismic events. Numerous options are commercially available to facility owners who wish to install a structural monitoring system within their structures. However, these structural monitoring systems are defined by their use of coaxial cables for the transfer of response measurements from sensors to centralized data servers. The installation and maintenance of cables within a civil structure often drive system costs high thereby preventing widespread industry adoption. In response to these limitations, the integration of information technologies such as wireless communications and microcontrollers have been explored for the creation of alternative structural monitoring systems defined by low installation costs and decentralized computational frameworks. In particular, a novel wireless structural monitoring system assembled from a dense network of inexpensive wireless sensing units has been designed and fabricated. The wireless sensing unit architecture consists of three functional components: a data acquisition interface for the collection of data from attached sensors, a computational core for data interrogation, and a wireless communication channel for the transfer of data to the sensor network. The use of wireless modems drastically reduces the efforts and costs of system installations rendering the technology attractive for widespread adoption in a broad class of civil structures. A second innovation of the system is the inclusion of computational power within each wireless sensing unit allowing for local execution of embedded engineering analyses. In particular, analyses for the detection of damage in structures (structural health monitoring) have been included in the unit's computational core. Additionally, an actuation interface has recently been added to the sensing unit design to allow for direct operation of structural actuators. With a computational core capable of real-time data processing, the data acquisition and actuation interfaces can be coupled through discrete-time feedback control loops implemented in software. Looking to the future, this intelligent monitoring infrastructure can possibly tune a structural control system in real-time after early warning of a pending seismic disturbance has been communicated to the wireless sensor network.

S42B-0167 1330h POSTER

Near-Real-Time Loss-Estimation for Instrumented Buildings

Keith A. Porter[1] (626-395-4141; keithp@caltech.edu)

James L. Beck[1] (626-395-4132; jimbeck@caltech.edu)

Jianye Ching[1] (jyching@caltech.edu)

Judith Mitrani[1] (judith@caltech.edu)

[1]California Institute of Technology, 1200 E California Blvd MC 104-44, Pasadena, CA 91125-4400, United States

Building owners make several important decisions in the hours after an earthquake occurs: whether to engage a structural engineer to inspect the building; what to tell investors, rating agencies, or other financial stakeholders; and how to assess the safety of tenants. A current research project seeks to develop the means to perform an automated, building-specific, probabilistic evaluation of detailed physical damage, safety, and loss to instrumented buildings. The project relies on three recent developments: real-time monitoring, an unscented particle filter, and the assembly-based vulnerability (ABV) technique. Real-time monitoring systems such as COMET and R-Shape continuously record and analyze accelerometer and other building data for several instrumented buildings. Potentially sparse response information can be input to a new, unscented particle filter to estimate potentially highly nonlinear structural response at all the building's degrees of freedom. The complete structural response is then input to the ABV framework, which applies a set of empirical component fragility functions to estimate the probabilistic damage state of every damageable component in the building. Damage data are then input within ABV to standard safety-evaluation criteria to estimate the likely action of safety inspectors. The probabilistic damage state is also input in ABV to a construction-cost-estimation algorithm to evaluate probabilistic repair cost. The project will combine these three elements for software implementation so that damage, safety, and loss can be calculated and transmitted to a decision maker within minutes of the cessation of strong motion. The research is illustrated using two buildings: one in California, the other in Japan.

S42B-0168 1330h POSTER

An Empirical Method for Rapid Estimation of Housing and Life Losses from Earthquakes in Taiwan

Yi - Ben Tsai[1] (011-886-3-426-7113; ybtsai@geps.gep.ncu.edu.tw)

Tsung - Ming Yu[1] (011-886-3-426-7113)

Shi - Yi Liao[1] (011-886-3-426-7113)

[1]National Central University, 300 Jungda Road, Jungli, TAO 32054, Taiwan

The disastrous 1999 Chi-Chi, Taiwan earthquake of M7.6 provided an excellent database for us to develop an empirical method for rapid estimation of the amount and spatial distribution of housing and life losses from future strong earthquakes in Taiwan. On the one hand, strong ground motion data were very well recorded throughout Taiwan to provide a detailed seismic shaking intensity map for the earthquake. One the other hand, high spatial resolution data on the amount of housing collapse and life loss were avilable at village level. We used these loss data, coupled with data on total housing stock and population, to calculate the corresponding rates of housing collapse and human fatality. It was found that housing and life losses began to take place when MMI was greater than 7. So we made statistical analyses of the housing collapse rate and human fatality rate for all the villages in MMI7, MMI8, and MMI9 zones, respectively. By using these empirical loss rates, we can make rapid estimation of the total amount of housing collapse and life loss in any village once its MMI intensity is given by either a rapid reporting or early warning system. As an example, we have applied this method to estimate the amount and distribution of losses from a future large earthquake in the Chianan area of Taiwan.

S42B-0169 1330h POSTER

Five Years of Citizen Science: Macroseismic Data Collection with the USGS Community Internet Intensity Maps ("Did You Feel It?")

Vincent Quitoriano[1] (626-583-6802; vinceq@usgs.gov)

David J Wald[1] (303-273-8441; wald@usgs.gov)

James W Dewey[1] (303-273-8419; dewey@usgs.gov)

Margaret Hopper[1] (303-273-8564; hopper@usgs.gov)

Arthur Tarr[1] (303-273-8570; atarr@usgs.gov)

[1]U.S. Geological Survey, P.O. Box 25046 MS-966, Denver, CO 80225, United States

The U.S. Geological Survey Community Internet Intensity Map (CIIM) is an automatic Web-based system for rapidly generating seismic intensity maps based on shaking and damage reports collected from Internet users immediately following felt earthquakes in the United States. The data collection procedure is fundamentally Citizen Science. The vast majority of data are contributed by non-specialists, describing their own experiences of earthquakes. Internet data contributed by the public have profoundly changed the approach, coverage and usefulness of intensity observation in the U.S. We now typically receive thousands of individual questionnaire responses for widely felt earthquakes. After five years, these total over 350,000 individual entries nationwide, including entries from all 50 States, the District of Columbia, as well as territories of Guam, the Virgin Islands and Puerto Rico. The widespread access and use of online felt reports have added unanticipated but welcome capacities to USGS earthquake reporting. We can more easily validate earthquake occurrence in poorly instrumented regions, identify and locate sonic booms, and readily gauge societal importance of earthquakes by the nature of the response. In some parts of the U.S., CIIM provides constraints on earthquake magnitudes and focal depths beyond those provided by instrumental data, and the data are robust enough to test regionalized models of ground-motion attenuation. CIIM invokes an enthusiastic response from members of the public who contribute to it; it clearly provides an important opportunity for public education and outreach. In this paper we provide background on advantages and limitations of on-line data collection and explore recent developments and improvements to the CIIM system, including improved quality assurance using a relational database and greater data availability for scientific and sociological studies. We also describe a number of post-processing tools and applications that make use of the extensive intensity data sets now gathered. These new applications include automatic location and magnitude determination, estimating ground motions from the intensity observations thereby augmenting ShakeMap, automatic geocoding to allow for more refined intensity localization, and recovering higher precision decimal intensities rather than limiting intensities to integer values. Because of differences in the data and procedure, CIIM intensities are not strictly comparable to intensities assigned with the Modified Mercalli scale. Hence, continued collection of traditional macroseismic data will be essential to calibrate our understanding of CIIM intensities, and, conversely, CIIM data will improve our understanding of conventional macroseismic intensities. CIIM can be found online at http://earthquake.usgs.gov under "Did You Feel It?".

URL: http://earthquake.usgs.gov/

S

S42B-0170 1330h POSTER

Rapid Assessment of Shaking Impact Following Global Earthquakes

Paul S Earle[1] (pearle@usgs.gov)

David J Wald[1] (wald@usgs.gov)

Lynda A Lastowka[1] (llastowka@usgs.gov)

Matthew J Donnelly[1] (mdonnelly@usgs.gov)

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

The US Geological Survey's National Earthquake Information Center (USGS/NEIC) is developing a system to rapidly assess the overall impact of earthquakes around the globe. NEIC's near realtime global-earthquake solutions will be monitored to automatically identify quakes that likely caused human suffering or damage to infrastructure or will attract significant media attention. Our goal is to help the NEIC fulfill its mission to provide critical earthquake-related information to emergency response agencies, government agencies, the scientific community, the media, and the general public. The system will fill the gap between

the time the hypocenter and magnitude are determined (minutes to an hour) and the time that onsite information is available through the media and other organizations (typically several hours to days). When complete, the system will provide an assessment of the situation based on estimated and any observed ground motions, total population exposed to varying degrees of shaking, and fragility of the impacted region. We expect that an automatic summary impact statement and associated alarms can be made within seconds of computing the ground-motion estimates, well before onsite damage estimates arrive. Development of the system is proceeding in stages, with each stage adding an increased level of detail and robustness to the impact statements. The initial system will be basic and empirical. It will issue alarms when an earthquake occurs where historical earthquakes of similar magnitude and depth have seriously impacted human life or infrastructure. This basic system will miss some significant events, but it will be relatively easy to implement and it will provide a baseline for further enhancements. Subsequent enhancements will include estimates of ground motion, population exposure, and regional fragility. Ground motion estimates will initially use regionally specific, empirical ground-motion attenuation relations. As details about the source are recovered, the estimated motions will evolve from point-source-based empirical to finite-fault-based empirical and to finite-fault-forward modeled synthetic amplitudes, augmented with empirical predictions. To this end, we are working collaboratively with C. Ji and D. Helmberger (Caltech) to expedite and automate the finite-fault inversion process (see abstract this meeting). Any ground motion observations (strong motions stations or Community Internet Intensities) will be used as constraints. Site amplification will be simple at first. We will use soil classification where known; otherwise, generic site terms will be used. The use of topography as a proxy for site conditions will also be investigated. Worldwide population databases in gridded form (e.g., LandScan developed by Oak Ridge National Laboratory) will be used to determine the total population exposed to various levels of shaking. For events not having significant populations at risk (e.g., off-shore or very deep earthquakes), it will be easy to determine when no response is warranted. However, when a large population is exposed to potentially damaging levels of shaking, the fragility of the region will be evaluated to constrain the likely overall impact. Fragility can be addressed in a several ways, but we will initially derive regionalized estimates based on the NEIC database of historical damaging earthquakes. We will later use socioeconomic considerations, as well as a qualitative assessment of construction and engineering practice.

S42B-0171 1330h POSTER

Quick Finite-Fault Inversion and Strong Motion Prediction: Feasibility, Process, and Developments

David J Wald[1] (303-273-8441; wald@usgs.gov)

Chen Ji[2] (626-395-6950; jichen@gps.caltech.edu)

Donald V Helmberger[2] (626-395-6998; helm@gps.caltech.edu)

[1]U.S. Geological Survey, P.O. Box 25046 MS-966, Denver, CO 80225, United States

[2]Seismological Laboratory, Caltech MS 252-21, Pasadena, CA 91125, United States

As part of a larger, concerted effort to rapidly assess the impact of major earthquakes globally and to provide input into other post-earthquake analyses (e.g., ground motions, stress changes, tectonic implications, etc.), we are developing and testing a new system to automatically determine finite-fault characteristics by inversion of teleseismic body waveforms. Although initially constrained from teleseismic data alone, which currently are the only rapid and reliable available data after major events worldwide, additional data will be used (either directly or as constraints) as they become available, including aftershock locations, geodetic displacements, and regional waveforms. Our ultimate goal is to provide well-constrained, estimated peak ground motions for input into a global ShakeMap, which in turn will allow automatic, reliable estimates of losses and overall impact. To evaluate the feasibility of such a system, we inverted for slip variations on a single plane for the 1999 ChiChi (M7.6) earthquake using only teleseismic data and then compared the 2-sec peak ground velocity map predicted by this model with the observations (constrained by over 400 stations). Even though the fault geometry of this earthquake was more complex than our simple approximation, as would be the case for our initial, automated solution, the predicted map matches the overall observed amplitude variations. While successful in that case, a fully automated system requires overcoming additional, significant hurdles, many of which we are discovering and addressing as we develop the processing system. One such hurdle addressed was the choice of the causative rupture plane from the two nodal planes of a moment tensor solution. We simply conduct finite fault inversions on the two planes simultaneously, and select the solution with a smaller error function. This approach worked well for recent the 2003 Carlsberg Ridge earthquake (M7.6), for which the inverted result matches the trend and extent of its aftershock sequence. Among the more challenging hurdles is compensating for travel time anomalies within an automated system. Using the 2002 Denali earthquake as an example, we show the importance of this correction and how we calibrated the teleseismic path effects with proximal fore- or aftershocks. We also show how an improved fault geometry based on a high-resolution DEM map enhanced the solution. Finally, we discuss ongoing developments, further results, and plans for this system.

S42C MCC: Level 1 Thursday 1330h

The Energy Budget of the Earthquake Machine III Posters *(joint with G, T, NG)*

Presiding: **R E Abercrombie,** Boston University**; A McGarr,** U.S. Geological Survey

S42C-0172 1330h POSTER

Constraints on the Energy Budget of Deep Earthquakes

Heidi Houston[1] (heidi@quake.ess.ucla.edu)

Steven Persh[1] (spersh@moho.ess.ucla.edu)

[1]UCLA, Dept. of Earth and Space Sciences, Los Angeles, CA 90095

Processes such as melting and thermal shear instability have been suggested as mechanisms for deep earthquake generation, which is still not understood. If such displacement-driven processes are important in deep earthquake rupture, then an effect on the energy budget may be expected. Therefore, we determine seismically-radiated energies and stress drops (from corner frequency), and examine these for moment-dependence of the seismically-radiated energy to moment ratio and seismic efficiency estimates. We calculate source spectra for 111 globally-distributed earthquakes with depths from 100 to 650 km and Mw from 6.3 to 8.3. The spectra are computed from teleseismic broadband P waves recorded by the GSN. We correct for instrument response, depth-dependent attenuation, radiation pattern, geometrical spreading, and near-source velocity. Squared velocity spectra are integrated and scaled to yield the seismically-radiated energy. The ratio of radiated seismic energy to moment times rigidity gives the apparent stress. For these earthquakes, this parameter has more than an order of magnitude scatter. A modest change in apparent stress over this moment range could occur, but is not resolvable in the scatter. Apparent stresses appear to increase by about a factor of two with depth. Static stress drop can be estimated from the spectral corner frequency, but it is well to bear in mind that this requires the assumption of a rupture velocity. Static stress drops estimated from corner frequencies vary more than two orders of magnitude for these events. An upper bound on the seismic efficiency can be computed from twice the apparent stress divided by the static stress drop. This bound, the Savage-Wood efficiency, is found to be greater than 0.25 for all events, and may increase slightly with moment. The Savage-Wood efficiency of events in the 350 to 550 km depth range is about three times higher than that of events above and below, mainly because static stress drops are smaller. Our previous studies have found events from 350 to 550 km depth to rupture longer with measurably more complexity, and with far fewer aftershocks. In these results, independent, but scarce, evidence that rupture velocity may differ significantly from 0.8 of shear velocity (such as for the 1994 Bolivian earthquake) was not taken into account. The difficulty in separating static stress drop from rupture velocity using only durations or corner frequencies remains. In some ways seismically-radiated energy is more reliably estimated than static stress drop, unless independent information on the spatial extent of rupture is available from surface rupture or aftershocks. To the extent that rupture velocity does not vary systematically with moment, our preliminary assessment is that the effect on the energy budget of displacement-driven processes such as melting or thermal shear instability does not change markedly and systematically for deep earthquakes over the magnitude range studied here.

S42C-0173 1330h POSTER

Quantifying properties of seismic spectra: an examination of 100's of spectra from southern California earthquakes recorded by the ANZA seismic network

Debi Kilb[1] (dkilb@ucsd.edu)

Glenn Biasi[2] (glenn@seismo.unr.edu)

James Brune[2] (brune@seismo.unr.edu)

John Anderson[2] (jga@unr.edu)

Frank L. Vernon[1] (vernon@epicenter.ucsd.edu)

[1]UCSD/IGPP/SIO, MS 0225, La Jolla, CA 92093

[2]Univ. Nevada Reno, Seismology Laboratory 174, Reno, NV 89557

Unraveling earthquake source properties from seismic spectra requires an understanding of the inherent uncertainties that can be introduced from site and path effects. Here, we quantify properties of hundreds of earthquake spectra, and the associated uncertainties, from 0<Ml< 3 earthquakes in southern California recorded by the ANZA seismic network. From the spectrum that meet our data-quality and data-fit requirements we: (1) Determine the influence of site effects on the spectral decay characteristics; (2) Estimate the distance that site effects can be reliably extrapolated using data from small aperture arrays; and (3) Investigate the hypothesis that earthquakes behave as partial stress drop events. For each seismogram with an analyst-identified S-wave arrival, we test a range of viable corner frequencies and identify the one that minimizes the squared error fit of the data spectrum to the synthetic spectrum, which is computed assuming a Brune (1970) omega-square fall off. From this we can then compute the associated stress drop, seismic moment and AH-kappa, where AH-kappa is the residual slope to an omega-squared spectrum (Anderson & Humphries, 1991). Small values of AH-kappa indicate a greater percentage of high frequency energy. Using our highest quality data, we find that AH-Kappa measurements from sites on hard-rock can, in general, be 20 ms smaller than those from sites on unconsolidated rock. The uncertainty in AH-Kappa at a single station is 10 ms; assuming the site effect is constant for common source-receiver paths, we attribute this variability to deviations in the seismic source. Based on the theory of Brune (1970), we then used an iterative method that makes spectral corrections to account for potential partial stress drop events. Because the spectral shape of the partial stress drop model is less than omega-square model we expect the AH-kappa values to increase, and indeed we find this to be true. For an assumed full stress drop of 100 bars, our results typically show an increase of 10 ms in AH-kappa measurements, a value that is consistent with the 10 ms observed scatter. If variable stress drops are responsible for the 10 ms scatter in AH-kappa measurements, then, for engineering purposes, an additional 10 ms should be added to the mean observed AH-kappa values. Using AH-kappa to summarize small-scale site effects shows a +/-10 ms variation in AH-kappa measurements from individual event recordings at stations that are only 10s of meters apart. This implies that small-scale (10s of meters) heterogeneous site properties play a key role in a seismogram's frequency content.

S42C-0174 1330h POSTER

Relation between Corner Frequency and Seismic Moment for Shallow Earthquakes in Japan

Yasuo Izutani (81-26-269-5323; tdp0000@gipwc.shinshu-u.ac.jp)

Shinshu University, 4-17-1 Wakasato, Nagano 380-8553, Japan

Strong motion records for three groups of shallow earthquakes in Japan (20 Kagoshima events with $M_w = 3.6 \sim 6.1$, 47 Tottori events with $M_w = 3.3 \sim 6.6$, and 16 Miyagi events with $M_w = 3.4 \sim 6.1$) are analyzed to investigate the similarity of earthquakes. A lot of high-quality close-in records at K-NET and KiK-net stations operated by the National Research Institute for Earthquake Science and Disaster Prevention, Japan (NIED) are available for these events. Spectral ratio of transverse component accelerograms observed at the same station is calculated between the largest event and each one of the other events in the same group to remove the station site response and the attenuation effect along the wave propagation path. Spectral ratios at stations around the epicenters of the events are averaged to remove the effect of small differences in the hypocenter location and the focal mechanism. The source spectrum is assumed to have omega-squared decay in the frequency range higher than the corner frequency, f_0. The seismic moment, M_0, determined by NIED is used in this study. Fitting the theoretical source spectral ratio to the observed spectral ratio, f_0 is estimated for each event. The rela-