whether seismic noise is likely to present difficulties for optical or infrared interferometers at sites with noise characteristics lying between the Peterson high and low noise curves.

URL: http://www.ees.nmt.edu/~ralvarad/mro.html

S52D-0165 1330h POSTER

A beam-forming experiment of airgun array in seismic experiments

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Seismic experiments with airguns, which are useful to understand the crustal structure, have been widely used. Multi-channel seismic reflection (MCS) method using multi-channel hydrophone streamer is an effective method to image highly resolved geological structures. Tuned-array composed by several airguns is often used for the signal source of the MCS. It has a significant vertical directivity of energy, which effectively enables to observe airgun signals reflected just beneath the airgun array. However in two-ship survery, which uses two ships for shooting and recording independently, the airgun signals recorded ineffectively since the large incident angle in large offset distance. In OBS reflection and refraction survey, the oblique incidence waves may generate high amplitude P-S converted waves which travel through the basement by shear waves.. In order to record PS converted phases, airgun signals with vertical directivity are less effective. Therefore, two seismic experiments have been conducted using beam forming airgun array to develop the signal source with oblique directivity (beam forming). The first experiment was conducted during a MCS survey off Boso in 2001. The signal source directivity was successfully changed from vertical to oblique in the seafloor reflection amplitude records with shooting delay between airgun arrays. The second experiment was carried out in a two-ship and ocean bottom seismometer (OBS) experiment off Kii in 2002. In the OBS data, the amplitudes of airgun signals with beam forming are improved not only vertical component but also horizontal components. From the experiment, the effectiveness of beam forming airgun signal was confirmed in OBS records. Seismic survey using the beam forming source, two-ships and/or OBS is probably an effective way in secondary experiments as S-wave velocity structure or amplitude variation with offset (AVO), which are associated with the physical property.

S52D-0166 1330h POSTER

Earthquake Waveforms Recorded By Ocean-bottom Seismometers In The South Tyrrhenian Sea

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An array of seven ocean bottom seismometers (OBS) and seven ocean bottom hydrophones (OBH) was installed for 5 1/2 month in 2001 in the Tyrrhenian Sea in the scope of the DFG(German research foundation)-project 'Tyrrhenian Sea'. Ten deep-focus events (between 150 and 300 km) with a hypocenter directly beneath the array and several teleseismic events were recorded. Multiple PwP-phases in the coda of the P-wave are typical for OBS recordings and are caused by multiple reflections in the water layer. These echos occur in regular intervals of 2 to 4 seconds depending on the thickness of the water layer. The amplitude and the waveform of the PwP-phases are controlled by the impedance contrast between water and sediments and by the structure and thickness of the sediment layer. The observed waveforms on the seismometer and the hydrophone were inverted simultaneously to derive a structural model for the shallow and deeper subsurface beneath some of the OBS stations.

S52D-0167 1330h POSTER

Enhancement of Fourier Amplitude Spectra by Composing 3-Component Records

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Modern seismographs produce a large amount of high-quality digital seismic data. They can accurately record the small earthquakes of magnitude down to ? or less. In case of the small earthquake, however, the majority of the data are abandoned after just picking P- or S-wave arrival times because of low signal-to-noise ratios. We suggest a method to enhance the seismic signal out of the noise for the spectral analysis of the small earthquake data. The method is based on the composed amplitude spectrum that is calculated by taking the norm of 3-component complex vectors of the Fourier-transformed seismic records. The composed amplitude spectrum provides two advantages. First, it enhances the shape of the Fourier amplitude spectrum to provide more accurate estimates of seismic moment, corner frequency, and high-frequency decay trend than the single component amplitude spectrum. Second, it eliminates the vector-partition terms appearing in the single components to provide a more accurate estimate of seismic moments. The latter is especially useful when dealing with the seismic waves of a wide range take-off angle such as Lg waves. Unlike some previous studies (e.g., Andrews, 1986; Snoke, 1987), our method improves the shapes of the Fourier amplitude spectra themselves. Therefore, our method can accommodate all the techniques proposed by the previous studies.

S52E MCC: Level 1 Friday 1330h

Fluids and Gases Posters

Presiding: **D H Abbott,** Lamont-Doherty Earth Observatory**; K C Creager,** University of Washington

S52E-0168 1330h POSTER

Groundwater Carbon Decrease During a Slow Earthquake Swarm in Central Italy

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Several pre-earthquake and earthquake-induced groundwater anomalies have been reported in the past. During the slow-earthquake swarm recorded by an underground geodetic interferometer (Gran Sasso Massif - Central Italy) in 1997 (Crescentini et al., 1999; Amoruso et al., 2002) a strong positive pH anomaly was observed in the groundwater collected at 1400-m depth nearby the interferometer and close to the source region (Bella and Plastino, 2000; Amoruso et al., 2000). Here we use the PHREEQC code to infer change in the groundwater carbon content during the anomaly. The pH anomaly suggests a decrease in initial CO_2 content comparable with the concentration of deeply derived CO_2 present in the groundwater from the springs close to the study area (0.2 to 0.5 meq l^{-1}, Chiodini et al., 2000) thus indicating a strong temporary diminution of the upward flux of CO_2. Comparison with chemical data of groundwater collected at different sites tens to hundreds of meters from the interferometer supports simulation results.

S52E-0169 1330h POSTER

Far Offset P-to-S "Elastic Impedance" for Identifying Partial Gas Saturation (Fizz Water).

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We present a formulation of P-to-S "elastic impedance" (PSEI), and demonstrate the possibility of using PSEI to discriminate between commercial gas saturations and fizz water. Attempting to seismically differentiate fizz water with low gas saturation from higher gas saturations is difficult. The abrupt reduction in Vp with the first few percent of gas controls the seismic response. Therefore, usually only the presence of gas but not the saturation can be detected with PP seismic. P-to-S converted waves has been suggested as a source of additional information. Wu (2000), and Zhu et al (2000) propose using PP and/or PS reflectivity. Landro et al (1999) derived "shear wave elastic impedance" (SEI), assuming weak contrast and small incidence angle. We use a formulation of PS "elastic impedance" (PSEI) not limited to small incidence angles, which at one specific angle (theoretically) gives a direct estimation of density. Although theoretically it is possible to get a direct value of density from PSEI at a single angle, clearly in practice it will be very difficult. Nevertheless, for mid-to-large offsets the density term dominates PSEI behavior. The "decoupling" between Vs and density contributions to PSEI can be exploited to discriminate different reservoir properties. As noted by Berryman et al. (2002) the linear behavior of density with saturation makes attributes that are closely related to density useful proxies for estimating saturation. To test the possibility of discriminating between fizz water and commercial gas saturations with PSEI, we used log data from an Eastern Venezuela well. PSEI values for incidence angles of 10^o and 50^o were calculated with original (Sw=1) and Gassmann simulated logs. Using correlated Monte Carlo simulations we calculated bivariate pdfs for all modeled Sw situations to estimate the Bayesian classification success rate. An advantage of using two PSEI attributes, instead of a combination of PP-PS is that the PP and PS time matching is avoided. The important result here is the real possibility of discriminating between different homogeneous gas saturations. Values of PSEI monotonically decrease with reduction of gas concentration. Consequently, it is possible to discriminate between fizz water and commercial gas concentration using PSEI.

S52E-0170 1330h POSTER

Signals of fluid and stress triggering in local earthquake clusters

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The spatiotemporal clustering of earthquakes is of special interest because it probably contains significant information about the structural environment and the triggering mechanism of earthquakes; neither of which are well understood so far. One type of strong earthquake clustering is aftershock activity; another is the occurrence of earthquake swarms. The underlying mechanism is often assumed to be stress triggering in the former and fluid intrusions altering the resistance of faults in the latter case. However, these explanations are oversimplifications, because aftershock sequences can include swarm-like subclusters and earthquake swarms partly consist of embedded aftershock sequences. In general, stress transfers and fluid flows are expected to be coupled and it is not straightforward to reveal the dominant mechanism. The aim of this presentation is to explore which characteristics of the spatiotemporal seismicity patterns, such as rate changes or migration of activity, can be used to draw reliable conclusions. For that, we analyze seismicity patterns in response to fluid intrusion in elastic half-space models. The increase of pore pressure drives such model systems close to the critical state where stress triggering becomes important. The initial stress state is crucial for the evolving seismicity patterns. The results are compared with characteristics of aftershock sequences and earthquake swarms.

S52E-0171 1330h POSTER

Numerical Seismic Studies of Fault Detection in Geothermal Reservoirs

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A finite-difference modeling study of seismic wave propagation was conducted to determine how to best investigate subsurface faults and fracture zones in geothermal areas. The numerical model was created based on results from a previous seismic reflection field experiment. A suite of fault models was investigated including blind faults and faults with surface expressions. The seismic data suggest that blind faults can be detected by a sudden attenuation of seismic wave amplitudes, as long as the fault is located below the receiver array. Additionally, a conversion from P- to S-waves indicates the reflection and refraction of the P-waves while propagating across the fault. It was found

that the initial P-waves interfere with the tip of the fault and their energy is scattered in the process (elastic scattering) leading to a reduction in amplitude of the wave front in the shadow of the fault tip. However, the P-waves experience wave front healing during their propagate away from the fault. The drop in amplitudes and the excitation of S-waves can be used to estimate the location of the fault at depth. The accuracy of the numerical modeling depends on the availability of a priori in situ information (velocity and density) from borehole experiments in the geothermal area.

S52F MCC: Level 1 Friday 1330h

Not-So Sudden Impact: Earthquake Recurrence and Spatial Patterns

Posters *(joint with T)*

Presiding: **J E Ebel,** Weston Observatory**; G A Abers,** Boston University

S52F-0172 1330h POSTER

Seismicity at Jalisco-Nayarit Border, Mexico

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Since 2002 a regional seismic network from Jalisco Civil Defense and University of Guadalalajara is monitoring seismicity at the northwest border of Jalisco block. With the installation of a seismic station on Ceboruco Volcano, by Nayarit Civil Defense, coverage of the network extends to east. Ceboruco Volcano is located on the Tepic-Zacoalco graben, the east border of Jalisco block, this allow us to begin to monitoring this area. The zone of Bahia de Banderas, between the north coast of Jalisco and south coast of Nayarit, probably on a tectonic triple point, is a region of high seismic potential. Activ tectonic structures and clusters in the zone of El Tuito and the Dam Cajon de Peñas have been identified. The seismicity in the north area of the bay is low, meanwhile in the south, where the bay is deeper, the seismicity level is higher with an East-West tendency. At the east, the Amatlan de Cañas-Ameca zone presents continue activity, here have been possible to locate events with local magnitude between 2 and 4. Tectonovolcanic events registred at Ceboruco station presents waveform with scattering. The seismic distribution of the coast of Jalisco shows parallel alignments to the trench throughout al the coast. Other perpendicular alignments to the coastline show active morphologic structures within the Jalisco block related to the subduction of the Rivera plate under the Jalisco block.

S52F-0173 1330h POSTER

Relocation of Some Large far Offshore Earthquakes of Taiwan and its Aftershocks Using the Beam-Forming Method

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The Taiwan orogeny is a result of the collision of the Philippine Sea Plate and the Eurasian Plate, and therefore there is high seismicity in onshore-offshore Taiwan. The location of the earthquake inside the seismic is well resolved, however the location of the offshore earthquake far from the seismic network would be some uncertain because of its small observational aperture of seismic network. In this study the beam-forming method (Capon, 1973) is used to relocate the epicenters of some large events to determine its high resolution of source parameters and to discuss its tectonic implications. We will determine three large earthquake sequences far from Taiwan offshore. One is the 16 September 1994 earthquake occurred in the Taiwan Strait where is situated west on the Taiwan island with a low seismicity. This event is the largest event in this area in modern history. Another eastern Taiwan offshore earthquake occurred on 3 May 1998 with a magnitude of 7.5 and located in the Philippine Sea Plate, only a few small shallow events occurred. The other offshore earthquake occurred on 31 March 2002 with a magnitude of 7.0 and induced large seismic amplification in Taipei basin but not in Hualien area. Accurate locations of the main shocks and their aftershocks would help us to understand its source properties. Based on results of this study and other information, we will discuss the stress conditions of source areas and its tectonic implications.

S52F-0174 1330h POSTER

Local Seismicity at the Cocos Ridge - Osa Peninsula Subduction Zone, Costa Rica

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A local seismological network was operated from May, 1998 to November, 2001 to monitor the seismic activity in southern Costa Rica, where the Cocos Ridge is currently being subducted under the Panama block at the terminus of the Middle America Trench (MAT), leading to a rapid uplift of the Osa Peninsula. Although previous works assumed a shallow subduction angle (20-30°) or no evidences for subduction, the new seismological data show for the first time a well-defined, thick steepslab (50-55° at depths > 40 km), reaching depths up to 67 km, 60-75 km landwards from the trench. With this configuration, the subducting ridge could not be projected underneath the Caribbean coast, thus it is difficult to explain the uplift of the Cordillera de Talamanca with current models. Besides, the Talamanca adakites, located betweeen 80 to 110 km over the down-dip aseismic projection of the subducted slab, could not be produced by flat subduction, as previously suggested. A better constraining of the Cocos Ridge arrival time (models varying from 0.5 to 8 m.y.) is crucial to associate the observed geological features with the slab-window, crustal thickening by shortening due to the collision of the Panama block, or other models. The present work discuss these models in the framework of new seismological and geological data. Anomalously deep intracrustal seismicity (up to 40 km) in the Panama block was detected below the thrust belt of Fila Costeña and the piedmont of the Cordillera de Talamanca. It could indicate an anomalously cold crust with no astenospheric wedge underneath, and perhaps continuous crustal shortening. N-S dextral strike-slip faults and NW-SE thrust faults and related seismicity result from the complex stress pattern generated by the indentation effect of the Cocos Ridge in an oblique subduction, together with the Panama block movement. At least 4 strong destructive subduction-related earthquakes (M>7) in the last two centuries, and two more in the last century related to the Panama Fracture Zone, together with several seismic sequences, represent the potential seismic hazard of the region.

S52F-0175 1330h POSTER

Relationship Between Quasi-static Slips and Rupture of Asperities in the Northeastern Japan Subduction Zone: Insights From Small Repeating Earthquake Data Analyses

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We have examined relationships between quasi-static slips and rupture of asperities on the plate boundary off Sanriku in the northeastern Japan subduction zone. We assumed that cumulative slips for small repeating earthquakes expressed the quasi-static slip histories on the plate boundaries surrounding them (Igarashi et al., 2003; Uchida et al., 2003) and compared them with occurrence times of larger events. We found that repeating earthquakes near the epicenters of 1989 (M7.1), 1992 (M6.9) and 1994 (M7.6) events had been activated since 6 days, 2 days, and 8 months before the respective events. These results indicate that the areas near the hypocenters of those earthquakes had already slipped quasi-statically before the main shocks. The stresses on the asperities for the main shocks concentrated by the quasi-static slips are probably responsible to the rupture of the asperities. We also found prominent repeating earthquake activities during earthquake swarms including the 1989 and 1992 events and aftershock activities of the interplate events with M>=6. Moreover, the quasi-static slip accelerations migrated during the 1989 and 1992 earthquake swarms and after the 1994 event. These results show that the quasi-static slips play an important role for the generation of earthquake swarms and the expansion of aftershock area off Sanriku. After the 1992 earthquake swarm, the quasi-static slip acceleration further migrated toward west to reach the asperity of the M4.8 characteristic earthquake sequence off Kamaishi (Matsuzawa et al., 2002) about 2 years later. After the arrival of the acceleration, the next characteristic earthquake occurred in 1995. The recurrence interval before the last event in this case is the shortest among the 8 recurrence intervals ever known. Thus, the 1995 event was probably advanced by the quasi-static slip acceleration. These observations obtained in this study indicate that the quasi-static slips affect the occurrences of larger interplate events as well as the small repeating earthquakes.

S52F-0176 1330h POSTER

Initiation Process of Moderate Earthquakes in the Northern Miyagi, Japan, Earthquake Sequence.

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Scaling relationships between the durations of the beginning portion of P-waves and final sizes of earthquakes have been reported by several studies (e.g. Iio [1992]). These studies mainly targeted microearthquakes and moderate to large earthquakes have been analyzed in only few studies. We tried to determine whether such scaling relationships hold for larger events, because it especially important for understanding the initiation processes of large earthquakes. We analyzed several moderate (magnitude up to 5) earthquakes and two large (magnitude 6 to 7) earthquakes and concluded that there may be a scaling relationship for small to moderate events but the scaling probably does not hold for the larger events. An earthquake sequence including several moderate earthquakes (magnitude up to 6.2) began on July 26, 2003 (JST) in the Northern Miyagi region, Japan. To study characteristics of initial phases of the moderate earthquakes, we analyze 4 < M < 6.2 events in the sequence. In this study, we employ the method which we used in the past study, a source model of Sato and Kanamori [1999]. The initial rupture of an earthquake is described with two parameters in this model: trigger factor and initial crack size. The trigger factor represents the contrast of surface energy on the edge of a crack and off of the crack. A large value for the trigger factor means that very high surface energy exists only on the edge and smaller surface energy off of the edge and rupture propagates spontaneously. A smaller value means that similar values of surface energy exists on and off of the edge and rupture propagates gradually depending on the initial crack size. We can use clearly recorded data from several near source borehole stations which are operated by Hi-net, NIED. We analyze 11 events with magnitude between 4.0 and 6.2. Hypocenter locations determined by the Japan Meteorological Agency and focal mechanisms determined by F-net, NIED are used. For these events, we obtain the results that all events can be explained by a small trigger factor and their initial crack sizes are between 15 and 50m. We can see a scaling relationship that the largest event (M6.2) has the largest initial crack size. However, we can also see that similarly sized events began from various initial cracks.

URL: http://www.rcep.dpri.kyoto-u.ac.jp/~sato/

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