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The Alaska Volcano Observatory (AVO) currently operates 140 seismic stations that are used to monitor 24 active volcanoes in Alaska. Each volcano generally has 6 to 10 short-period stations within 25 km of the summit. From October 1989 through February 2002, seismic events were detected and digitally recorded using an IASPEI acquisition system. In March 2002, the IASPEI system was replaced by an Earthworm acquisition system running in event detection and continuous modes. We have compared seismicity rates, magnitude of completeness and the proportion of low frequency to volcano-tectonic (VT) events detected at Mount Wrangell, Makushin Volcano, and the Katmai volcanic cluster for representative time periods using both acquisition systems. These volcanoes were chosen because each had minimal station outages, significant seismicity with no eruptive activity, and represented different tectonic regimes. The comparison indicates that the Earthworm system detects more events and a greater number of low frequency events than the IASPEI system. With the increase in detected events, a corresponding decrease in false triggers was also observed. For Wrangell there was an increase in the proportion of low frequency events detected (90.9% to 98.9%) and a decrease in magnitude of completeness from 1.8 to 0.9. For the Katmai volcanic cluster the proportion of low frequency events detected (3.8% to 1.4%) and the magnitude of completeness (0.8 to 0.7) both declined. At Makushin, the proportion of low frequency events detected increased slightly (6.4% to 7.7%) and the magnitude of completeness dropped from 1.4 to 1.0. Further, the magnitude of completeness for all 24 monitored volcanoes either declined or remained constant with the introduction of the Earthworm system, resulting in a greater total number of detected events. The increased numbers of detected VT earthquakes and low frequency events allow for more accurate assessments of the seismicity of Alaskan volcanoes.

S52C-0155 1330h POSTER

Comprehensive Processing of the Apollo Lunar Seismic Data

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The Apollo Passive Seismic Experiment consisted of four seismic stations deployed on the lunar surface between 1969 and 1972. We have successfully read and processed all of the lunar seismic event tapes available from the IRIS Data Management Center. Our studies have focussed on the long-period data, and have included filtering and despiking noisy data, event classification, cluster identification, and robust methods for amplitude estimation. We have completed cross-correlation analyses for known groups of deep events. In these analyses, every event in a previously-classified group was cross-correlated with every other event in that group. We find good correlation between events, confirming earlier visual classifications. By combining the cross-correlation approach with a robust median despiking algorithm, we have produced greatly improved differential times and amplitudes, enabling us to construct much cleaner stacks. Because of the inferior signal-to-noise ratio exhibited by a majority of the traces, we have tested several methods of calculating the amplitude of an event. These include relative amplitudes calculated through cross-correlation and several different estimates of absolute amplitude. Our preferred amplitude estimate (the 75th percentile of the absolute deviation about the median) produces the best x-component vs. y-component correlation when plotting events from a single deep event group. Because of the small geographical area spanned by the stations, deep events from the same source region should produce similar amplitudes on the horizontal channels at different stations. Both our previous "grading" technique (in which each event is assigned a grade of A, B, or C based on such factors as signal-to-noise and initial impulse coherence) and our new amplitude estimates indicate that stations 12 and 16 have the greatest number of "visible" events with the most consistent amplitudes. We will begin our search for more events using the continuous data from these stations. Each deep event group can be represented by a stack of its constituent members, appropriately despiked and time-shifted. This will permit new waveform cross-correlations. Instead of using the time-consuming event-by-event method employed earlier, each event group, represented by a single waveform stack, can be correlated with the continuous time series. Using this approach, we hope to identify additional events that can be associated with previously-defined deep clusters.

S52C-0156 1330h POSTER

An homogeneous seismological bulletin for the European-Mediterranean region

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The Euro-Mediterranean Seismological Center (EMSC) has been working on the production of an homogeneous seismological bulletin for the European-Mediterranean region. Such a catalogue could be useful as a reference for seismic hazard studies in the region. The 3 main objectives are to rapidly (with few months delay) provide a bulletin for events with $M > 3$ occuring in the Euro-Med region (from Iceland in the North-West to the Arabic Peninsula in the South-East) by merging parametric data, to obtain better location accuracy in border regions and to improve data availability. The different tools (data merging, data exchange procedures...) have been developed during a 2-years EC funded project carried out in collaboration with 10 partners including the ISC. The developement period ended with the EC project by the end of 2002. Seismological data from 1998 to 2003 have been gathered from about 60 contributors (mainly national networks) providing data from 1500 stations. Up to now, nearly 5,000,000 arrival times for more than 340 000 events were reported (both values including redundancies). Numerous tests have already been performed to validate the automatic processing of the bulletins. To finalize this test period and start the operational production, we have decided to create a 2 years catalogue for 1998 and 1999 and to carry out a careful comparison of the results with the ISC catalogue. More precisely, the station distribution and data coverage obtained with the EMSC database is presented in parallel with the ones provided by the ISC. A statistical analysis is performed to assess the accuracy of the EMSC relocation. For specific regions (ie. Poland, Italy, North Africa), we present the improvements made using larger dataset than the one provided by national organisations. Finally, we will analyse the performances, point out possible weaknesses and present the necessary improvements before starting the operational production, probably by early 2004.

URL: http://www.emsc-csem.org

S52C-0157 1330h POSTER

InSAR Seismic Wave Imaging In Real Time: Inversion Theory

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Synthetic Aperture Radar (SAR) can detect surface deformation resulting from seismic events by phase comparison (SAR interferometry or InSAR) of two images acquired before and after the event. We present here theoretical analysis of the application of InSAR to imaging seismic surface waves as they propagate, that is, where one of the two image acquisitions occurs in 'real time' during an earthquake. (This notion was brought to our notice by Dr. Paul Vincent of Lawrence Livermore National Laboratory.) The full problem is that of inverting an InSAR image of a surface-propagating earthquake to a characterization of the source seismic event. We consider the seismicity and the SAR to comprise a coupled system which produces an output as a function of both ground motion and imaging parameters; a system which only under some circumstances behaves linearly. The important recent accomplishments in this analysis are twofold: First, derivation of interferometric phase as a function of seismic and SAR parameters, and second the characterization of the system impulse response. This latter is expressed as output in response to a spike-wave propagating at seismic speed across flat terrain as it is swept by a SAR antenna beam. These results give us considerable insight into the non-linear aspects of the system behavior and more generally permit us to invert interferometric phase to seismic motion, to the extent that this is possible. A second inversion from seismic motion to source event characteristics–yet to be completed–will complete the solution to the full inversion problem. We present here theoretical results, model anlaysis, and remarks on practical implementation of a seismic imaging system.

URL: http://www.vexcel.com

S52D MCC: Level 1 Friday 1330h

Ocean Bottom Noise Posters *(joint with OS)*

Presiding: **G J Fryer,** School of Ocean and Earth Science and Technology, University of Hawaii**; R N Hey,** University of Hawaii

S52D-0158 1330h POSTER

Seismic background noise and signal detection near Yucca Mountain, Nevada

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The seismic monitoring network for Yucca Mountain, Nevada, a potential high-level nuclear waste repository, consists of thirty 24-bit, 3-component digital stations located within a ring of approximately 50 km radius around Yucca Mountain. This network has operated since October 1, 1995; and a catalog of nearly 20,000 earthquakes has been compiled thus far. The network has an extremely low threshold, with apparently complete detection to ML = 0.5 for earthquakes within the network. Within the denser part of the network at less than 25 km from Yucca Mountain, the complete detection threshold is ML = -0.2. The major reason for this low threshold is the low seismic background noise in the region. To characterize this noise, a sampling of all channels was made at hourly intervals for a period of one year. This provided data to quantify the background noise behavior and its statistics. Most stations have average rms noise levels of 10 nm/s or less. Day-night differences in average noise levels are present; some stations show up to a factor of four while most stations show much less than a factor of two. The distribution of noise samples at a given station is roughly log-normal, but usually with a tail on the upper side. The correlation matrix of noise rms shows significant values for almost all station pairs in the network, largely due to the day-night variations. The correlations are weakly dependent on inter-station distances. Noise samples taken regularly over one month were used to compute power spectra. These spectra confirm that noise levels are among the lowest in North America. The magnitude bias at each station (station correction) was computed from the large database of station ML's. A model of signal detection was coded by using the noise statistics derived in this study for mean, standard deviation, and inter-station correlation, by incorporating the station magnitude corrections, and by simulating the STA/LTA detection algorithm. A synthetic catalog of earthquakes was created from this model to compare predicted detection thresholds with those of the actual catalog. The thresholds derived from the synthetic catalog agree well with the actual ones seen for the network. A slight upward bias in estimated magnitude exists for small magnitudes where only a few stations detect; this is due to the fact that stations with positive magnitude bias added to a positive random component detect events preferentially.

S52D-0159 1330h POSTER

Temporal Variation of Ambient Seismic Noise of the Seafloor Borehole Broadband Seismic Observatory WP-1 in the West Philippine Basin

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The seafloor borehole seismological observatory WP-1 is positioned in the west Philippine Basin west of the Kyushu-Palau Ridge. The observatory was installed in April 2001 to fill observational gaps for global seismological networks. The two identical seismometers (Guralp Systems Ltd., CMG-1T) were cemented into the hole as required to assure good coupling. All the necessary power is supplied from lithium batteries. The system has two units of batteries. The data recorder and control unit are placed on the sea floor and a remote operated vehicle (ROV) services the station. We usually operated only one seismometer to reduce the consuming power of the system. The WP-1 observatory was activated in March 2002 using an ROV KAIKO and long-term observation was started using first lithium battery unit. In October 2002, the KAIKO re-visited

the WP-1 site and we obtained about six-months continuous data (Mar. 26th, 2002 - Oct. 6th, 2002). The KAIKO visited the WP-1 site again in May 2003 and seven-months continuous data (Oct. 7th, 2002 - May. 7th, 2003) were retrieved. During the third visit, the KAIKO changed an electric connection and the second battery unit started to supply the power to the system. At present, seismic records of 408 days in total have been obtained from the WP-1 observatory. The long-term variations of broadband seismic noise spectra (3mHz - 10 Hz) in the west Philippine Basin were revealed. The noise levels at periods of greater than 10 s are stable all the year round. It is found that the noise levels of the vertical component at the WP-1 reach -180 db (re: 1 m**2/s**4/Hz) at periods between 10 s and 100 s. On the other hand, temporal small variations (maximum fluctuation is 10 dB) of noise levels for periods around a few seconds are seen; the WP-1 station has large noises in summer and fall. The small island (Okinotori-shima) lies about 100 km northeast of the WP-1. The meteorological station is being operated at Okinotori-shima and we can compare the meteorological data at Okinotori-shima and the noise spectrum of the WP-1. The speed of wind looks to be related with the noise levels for periods around a few second.

S52D-0160 1330h POSTER

Nature of Microseism and its Use for Shallow Structure Study

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Microseism is a well known ambient seismic noise that peaks around 0.14 Hz and 0.07 Hz. It has been studied for over half a century (e.g., Gutenberg, 1936; Longuet-Higgins, 1950; Hasselman, 1963; Haubrich, 1967) but there are many features that are still unclear, including the locations of excitation. With emergence of dense, broadband seismic networks as well as availability of ocean wave data, there exist some opportunities to make progress in our understanding of microseism and its potential use for shallow seismic structure. In this talk, we will focus on two features of observation that we have confirmed so far, using microseism observation by a network in Southern California (TriNet) and the buoy data off the coast of Southern California (NDBC). The first point will be on the correlation between ocean wave behaviors, observed by buoys and its relation to microseismic activity. Examination of both types of data over three years shows that correlation is very clear; an interesting aspect of correlation is that there is better correlation between microseisms at, for example, Pasadena and buoy data in the outer Pacific ocean. Ocean wave behaviors just off the coast of Los Angeles, such as those in the Santa Monica basin, do not correlate well. Excitation of microseism seems to be mostly occurring along the outer ocean of the Pacific coast. The second observation is related to particle motion of microseisms which are mostly Rayleigh waves. The ratio of the horizontal to the vertical amplitudes indicate clear seasonal variations that reach its maximum in February (winter) and its minimum in August (summer). Sensitivity of this ratio (horizontal amp./vertical amp.) with respect to seismic parameters inside the Earth show that it is sensitive to seismic structure in the upper 10km, especially in the top-most 1 km. The result suggests an existence of seasonal variations in seismic velocity (as well as density change to some extent) at shallow depths and points to a possibility that temporal changes of shallow seismic structure can be monitored by analyzing microseisms.

S52D-0161 1330h POSTER

Joint Seismic and Compliance Constraints on S-Wave Structure

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Seafloor compliance – the pressure–displacement transfer function of the seafloor under forcing from long period ocean waves – provides a useful complement to conventional marine seismic techniques. Synthetic modeling of compliance shows that it is principally sensitive to regions of low shear modulus, and inversions of compliance measurements can therefore be used to calculate S-wave structure. Existing inversions of compliance data assume a one-dimensional velocity model, whereas in reality there may be significant lateral velocity variation. The effect of this two-dimensional structure on compliance measurements and subsequent inversions can be investigated by calculating (quasi-analytically) the compliance over a cylinder. The compliance displays the same sensitivity to regions of low shear modulus as is seen for one-dimensional situations, generating a strong peak over the low-velocity zone. The width of this peak, which is a measure of the horizontal resolution of compliance, is approximately proportional to the depth of the cylinder, while its amplitude is controlled both by the cylinder's radius, its depth and the background velocity. Minimum structure one-dimensional inversions of the compliance measured above a fluid cylinder recover distinct low velocity zones, although the recovered shear wave velocity is much greater than zero, and the low velocity zone is smeared out over a greater depth range than that occupied by the cylinder. Including *a priori* information from seismic reflection and refraction studies provides important extra constraints on the shear wave velocity structure. Furthermore, a joint analysis of seismic and compliance data can also be used to provide information about intrinsic attenuation structure: the seismic waves recorded by compliance have frequencies several orders of magnitude lower than those used in conventional reflection and refraction experiments, and are thus sensitive to velocity dispersion produced by attenuation. This effect is demonstrated by an example from 9°33'N on the East Pacific Rise, where the differences in on-axis S-wave structures derived from seismic and compliance data can be explained by attenuation due to fluid inclusions in the fractured upper crust.

S52D-0162 1330h POSTER

MOBB: Data Analysis from an Ocean Floor Broadband Seismic Observatory

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MOBB (Monterey bay Ocean floor Broad Band project) is a collaborative project between the Monterey Bay Aquarium Research Institute (MBARI) and the Berkeley Seismological Laboratory (BSL). Its goal is to install and operate a permanent seafloor broadband station as a first step towards extending the onshore broadband seismic network in northern California, to the seaside of the North-America/Pacific plate boundary, providing improved azimuthal coverage for regional earthquake and structure studies. The MOBB station was installed on the seafloor in Monterey Bay, 40 km offshore, and at a depth of 1000m from the sea surface, in April 2002, and is completely buried under the seafloor level. The installation made use of MBARI's Point Lobos ship and ROV Ventana and the station currently records data autonomously. Dives are scheduled regularly (about every three months) to recover and replace the recording and battery packages. Some data were lost in the first half of 2003 due to hardware and software problems in the recording system. The ocean-bottom MOBB station currently comprises a three-component seismometer package (Guralp CMG-1T), a current-meter, a digital pressure gauge (DPG), and recording and battery packages. The seismometer package is mounted on a cylindrical titanium pressure vessel 54cm in height and 41 cm in diameter, custom built by the MBARI team and outfitted for underwater connection. Since the background noise in the near-shore ocean floor environment is high in the band pass of interest, for the study of regional and teleseismic signals, an important focus of this project is to develop methods to a posteriori increase signal to noise ratios, by deconvolving contributions from various sources of noise. We present results involving analysis of correlation of background noise with tide, ocean current and pressure records, combining data from MOBB and regional land based stations of the Berkeley Digital Seismic Network (BDSN). We also present preliminary results of modeling of the signal generated noise due to reverberation in the near surface sedimentary pile. The experience gained in MOBB will be valuable, in particular, for future long term or temporary deployments of buried broad-band seismometers such as are envisaged in the context of the Ocean Mantle Dynamics Initiative.

S52D-0163 1330h POSTER

Designing a Deep-Towed/Seafloor Repetitive Sound Source

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A seafloor (or deeply towed) sound source has the fundamental advantage over a surface source of releasing its energy much closer to its sub-sea target, resulting in improved resolution. If used on the seafloor, it produces abundant shear-wave energy, useful for differentiating between solid and gas-producing areas. Since marine mammals spend most of their time near the surface, a seafloor source reduces their exposure to damaging acoustical signals. With funding from the NSF, we designed and built an implosive source for deep/seafloor use. Our existing device is designed to operate down to a depth of 2000 meters. It uses a two-stage valve that allows rapid flooding of a 20-liter cylinder. This volume is equivalent to 1/4 kg of explosive fired at 800 meters depth. It is, however, a single-shot implosive device and must be returned to the surface between firings, and is thus unattractive for track-line surveying. Through insight gained using this imploder, we have come up with a novel approach to seafloor signal generation that has the potential to open a new chapter in seismic prospecting, moving in the direction of higher spatial resolution and better measurements of shear velocities. We are designing a new model, powered by compressed air, which need not be returned to the sea surface between firings. It will possess an improved source spectrum for deep-water exploration. Modeling the hydrodynamic flow is an important step in the design process for finding optimal initial bubble volumes, valve closing rates, and chamber geometries that produce strong seismic signals largely confined to the 0 to 200 Hz bandwidth.

S52D-0164 1330h POSTER

Seismic Background Noise Characterization at the Magdalena Ridge Observatory Interferometer Site

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We performed a seismic site characterization in central New Mexico for the ∼350-m baseline Magdalena Ridge Observatory (MRO) astronomical interferometer, which will operate at wavelengths between 600 nm and 2400 nm. The operation of an interferometer requires that optical path lengths be stable to within considerably less than one wavelength over the measurement timescale. The study analyzed 1-hour absolute and differential background noise windows at element locations between February and October of 2003. Data were acquired with IRIS PASSCAL stations consisting of four 3-component broadband 120-s STS-2 sensors in shallow vaults and Quanterra Q330 digitizers with both real-time 802.11 telemetry and on-site Baler14 recorders. Sensors were deployed at the ends of each of the three interferometer arms, and at the center of the array. The analysis focused on seismic noise during local night-time hours. Night-time noise levels at the site typically reside in the lower half of the Peterson (1993) Global Seismic Network noise model. With the exception of noise inside the microseismic band (∼0.1 to 0.7 Hz), background noise is generally incoherent at both longer and shorter periods. Differential noise in the short-period band (< 1 s) is of particular interest, as it poses the greatest challenges for active optical systems. In general, differential displacements are well below 25 nm, even during periods of high wind. Noise produced by a 150-kW generator run by a V12 Detroit Diesel engine, about 0.6 km from the site, produced maximum RMS absolute and differential displacements of approximately 6 nm and 7 nm, respectively. In comparison, noise spikes produced by medium-sized trucks passing near the site typically result in maximum RMS absolute and differential displacements of about 60 nm and 80 nm, respectively. We conclude that teleseisms (e.g., the Algiers earthquake of 2003 May 21, M_w 6.7) and local earthquakes ($M_d > 1$) from the Socorro seismic region are the only naturally-occurring events likely to produce differential displacements larger than 25 nm and thus capable of inducing loss of interferometer coherence. We will further assess the general issue of

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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.

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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.

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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