S51C-0070 0830h POSTER

Environmental Impact of Controlled-Source Explosions in Ethiopia (Project EAGLE): Geochemical Effects on Lakes and Streams

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Controlled-source seismologists seek to detonate charges in lakes or rivers because source coupling is an order of magnitude larger in water than in drill holes. Previous studies have documented the biological impact of dynamite explosions on small fish populations; however, little attention has been paid to the potential chemical changes associated with the dispersal of a dynamite charge in a body of water. At the request of the Ethiopian Environmental Protection Authority, we sought to examine the effects on water chemistry resulting from the detonation of one tonne dynamite charges used during the Ethiopia-Afar Geoscientific Lithospheric Experiment (EAGLE), an active source seismic survey of the Main Ethiopian Rift. Water samples from two Ethiopian lakes and six Ethiopian streams were collected in January 2003. Samples were collected immediately preceding and following the detonation of the 2 lake shots and those 6 of our 19 borehole shots for which a stream was present in the surrounding area. Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) analysis has provided concentrations of 16 elements, including: As, B, Ba, Be, Ca, Cd, Co, Cu, Mg, Mn, Mo, Na, Ni, Sr, V, Zn. Additional elements were also examined, however elements such as Cr, Fe, and Pb, had concentrations residing close to the detection limits of the ICP-OES, and the certainty of these numbers is not reliable. We plan to make measurements of Cl and S using the Ion Chromatograph (IC) method. The sites from which the water samples were collected include: (1) Lake Shala, a 12 by 15 km lake, 266 meters deep, (2) Lake Arenguade, an approximately 800m diameter crater lake, 32 m deep, and (3) six streams, each located within close proximity to one of the 19 borehole shots. All samples were filtered using a 2 micron nalgene filter to remove any biotic material. Prior to each shot, water samples were collect. To the extent possible, lake samples were taken 1 hour before the shot, 10 minutes post shot, 1 day after the shot, and 10 days later. Samples where collected every 10 meters in depth from 1 to 30 m, and for the deeper lake, Shala, samples were also taken at 60 m and 90 m. Samples were collected both at the location of the shot as well as 300 m away from the shot (Lake Arenguade) and 1 km from the site of the shot (Lake Shala). Elemental concentrations were plotted both as a function of time and as a function of depth. Preliminary results suggest that while some elemental concentrations varied slightly after each shot, no concentrations were drastically altered from their pre-shot values. The elemental concentrations tended to revert to pre-shot values within a few hours to a few days after the initial explosion. The explosions of the two dynamite lake shots and the borehole shots do not seem to have significantly impacted the water chemistry of the surrounding lakes and streams.

S51C-0071 0830h POSTER

Seismicity of the Northern Main Ethiopian and Southern Red Sea Rifts: EAGLEII

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The northern Main Ethiopian rift (MER) developed within the Paleogene flood basalt province of NE Africa, and forms the youngest arm of the Afar triple junction. High angle, large-offset border faults formed after 12 Ma, providing a linkage between the East African rift system and the southern Red Sea-Gulf of Aden rifts. However, active subsidence migrated to a narrower zone in the central rift by 3.5 Ma. Since 1.8 Ma magmatism and faulting has become more localized to 20 km-wide, 60 km-long 'magmatic segments' marked by aligned eruptive centers, fissures, and small offset normal faults. Local seismicity in the northern Main Ethiopian rift is studied using data recorded on an array of up to 80 broadband instruments operational during the period Oct 2001 - Feb 2003, thus providing a glimpse of activity within a rift transitional between continental and oceanic in style. Earthquakes are relatively sparse on rift border faults and are of low magnitude (<3.5). Activity is concentrated around faults where the northern Main Ethiopian and southern Red Sea rifts link and around Quaternary eruptive magmatic centres within the rift. This seismicity in magmatic segments is mostly as swarms of shallow events that form clusters of concentrated activity in the northern Main Ethiopian rift. Seismicity is less common in the south, a reflection of a difference in the stage of rift evolution.

S51C-0072 0830h POSTER

Atypical Normal Faults Morphology in the Main Ethiopian Rift

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The seismically active northern part of the Main Ethiopian Rift (MER) is one of few sites worldwide showing the transition between continental and oceanic rifting. The northern MER has been active since 12 Ma, with increased activity in a narrow belt of faulting and magmatism since 2 Ma. This approx 20 km-wide zone of magmatic construction and closely-spaced faults lies within the central 70 km-wide rift valley bounded by relatively inactive border faults. Within these segments we observe an intimate relationship between the generation of faults and the localisation of basaltic flows and eruptive centers. The atypical morphology of these faults can be quantitatively described on Displacement/Length (D/L) and cumulative dimensions frequency diagrams. The faults are very long (up to 20 kms) with relatively extremely small vertical displacements (10-20 m) and a relatively large horizontal displacements (1-20 m), composed of numerous segments, flat hanging-walls, and convex foot-walls. These patterns suggest that the extension on the faults is not directly related to the fault lengths; the lateral growth of a fault is due to hard linkage of segments which origin maybe linked to low-depth dykes.

S51C-0073 0830h POSTER

Deformation Distribution and Type in the Main Ethiopian Rift

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The Main Ethiopian Rift central graben is magmatically segmented and seismically active. These magmatic segments are about 50 km long and up to 20 km wide, oriented about N10-20, and therefore oblique to the main direction of Mid-Miocene border faults (N35E). We use the association of the high spectral resolution of Landsat data and the very high spatial resolution of digitized aerial photographs to characterize and quantify the deformation along the rift. Several Digital Elevation Models of metric resolution have been produced at different locations along the segments in order to quantify and describe the fault deformation. We have analysed the Landsat data (texture analysis, PCA, classifications) in order to refine the existing geological maps and to propose a relative chronology of the deformation. The deformation within the segments varies from their centres, usually highly faulted and mainly rhyolitic and trachytic calderas (Gedemsa, Bosetti, Fantale, Dofan), to their tips where the deformation is brittle at the surface and associated to recent basaltic flows and aligned cones. There we propose that the atypical (by their morphologies and Displacement/Length ratios) faults are dyke induced (see Gloaguen et al., same session). The overlap of the segments, the cross-cuttings of faults on the rift margins and the associated seismic activity are in agreement with the longitudinal growth of the magmatic segments via along-axis magma injection.

S51C-0074 0830h POSTER

Temporal compositional variation of early syn-rift rhyolites along the western margin of the southern Red Sea and northern Main Ethiopian rift

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New structural and geochronological analyses indicate that the felsic volcanism at the top of the Oligocene flood basalt sequences along the western margin of the Afar Depression marks the onset of rifting in the southern Red Sea. Geochronological studies show a pattern of riftward migration of the locus of magmatism and faulting from 28 Ma to present-day. Preliminary geochemical analyses (trace and major elements; Sr, Nd and O isotopic compositions) of syn-rift rhyolites ranging in age from 28 to 2.5 Ma indicate that the rhyolites are derived from mantle-sourced basaltic magma through fractional crystallization accompanied by variable amounts of crustal contamination (e.g. $^{87}Sr/^{86}Sr$ = 0.705445-0.706508; $^{143}Nd/^{144}Nd$ = 0.512576-0.512836). The input of crust tends to increase with time, which suggests the weakening and heating of the crust in response to lithospheric thinning and magma injection in the past 30 My. These results support earlier structural and thermo-mechanical models for rift formation in the southern Red Sea rift and the younger, less-evolved northern Main Ethiopian rift system.

S51D MCC: Level 1 Friday 0830h

Red Heat: Volcano Seismology and Small-Scale Tomography I Posters

(joint with V)

Presiding: **B R Julian,** U.S. Geological Survey**; J Pujol,** Center for Earthquake Research and Information, University of Memphis

S51D-0075 0830h POSTER

3-D Shallow Shear-Wave Velocity Structure around the Source Area of the 1999 Chi-Chi (Taiwan) Earthquake by Tomographic Inversion of Short-Period Rayleigh Waves

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By a tomographic inversion of short-period Rayleigh waves, we constructed a detailed 3-D shallow-depth shear-wave velocity structure around the source area of the 1999 Chi-Chi earthquake. Results show that the velocity systemically increased from the west to the east, and the Chelungpu fault and the Shuilikeng fault were two main boundaries to clearly divide the source area into three different geological provinces. Also, the velocity heterogeneity on the eastern side of the Chelungpu fault was stronger and more complicated than on its western side. These results could appropriately interpret the thin-skinned thrust model. For the shallow depths, the northern part of the hanging wall had a lower velocity, i.e. a lighter land, considered one of the reasons that resulted in anomalously large rupture and crustal deformation in the northern segment of the fault. In addition, results also reveal that the Chi-Chi earthquake might be initiated not only near the border on which large velocity-gradient varies but at the position where the fault plane is changed from a sharp dip-angle to a gradual one. Such this study shows that the strongly heterogeneity around the source area enables us to understand a few phenomena on seismic observations, and, then, might be likely to play an important role during the Chi-Chi earthquake rupture.

S51D-0076 0830h POSTER

Velocity field in Taiwan area derived from seismic moment tensor before and after the 1999 Chi-Chi earthquake

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We apply the method of Haines and Holt to investigate the temporal variation in horizontal velocity field of Taiwan due to co-seismic deformation. We find that long-term (1906-1996) velocity field suggests a NW movement, which is consistent with the convergence direction of the Philippine Sea plate. However, in terms of magnitude, the long-term velocity is only about one tenth of what reported from GPS surveys. Large discrepancy is found in southwestern Taiwan, which implies aseismic creep is significant in that area. After the Chi-Chi earthquake sequence the velocity field has changed from northwest to due west in central Taiwan and southwest in southwestern Taiwan, which suggests counterclockwise rotation is ongoing during the collision of the Eurasian and the Philippine Sea plates.

S51D-0077 0830h POSTER

Source Mechanism Inversion of Very Long Period Strombolian Eruption Signals at Mount Erebus, Antarctica

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Oscillatory, repeatable, very-long-period signals (25 s > T > 5 s) associated with strombolian eruptions of Mt. Erebus, Antarctica have been recorded by near-field broadband seismometers for several years. The eruptions are typically single, large (up to 10-m diameter), explosive bubble decompressions occurring at the surface of a phonolitic lava lake that eviscerate the lake to a depth of approximately 10 m. Associated VLP signals begin several seconds before, and continue for several minutes after, eruptions, becoming indistinguishable as lava lake recovery is achieved. We have performed waveform inversions of high signal-to-noise stacks to recover equivalent point-source moment tensor parameters and associated source time functions. Solutions are obtained by minimizing 2-norm residuals between synthetic and three-component observed seismograms using a modified version of the iterative inversion technique of Lay and Wallace (1995). We allow for varying degrees of source freedom, ranging from pure Mogi (explosive/implosive) to a complete set of six double couples and three single forces. Results suggest a shallow ($\leq$ 200 m) source region and negligible non-volumetric couple and single-force terms. During the VLP coda, the source model evolves in time towards an increasingly subhorizontal resonating crack. We will address the accuracy of using simple half-space Green's functions in such inversions and discuss source mechanism possibilities in terms of slow elastic, dynamic recharge, and other processes.

S51D-0078 0830h POSTER

The 2002/12/30 Stromboli volcano landslides: a seismological description

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We analyse the seismograms of the slump episodes occurred at Stromboli on December 30, 2002. By using a simple single force model, generally adopted for landslides, we estimate the volume involved in the single subevents and attempt at a chronological reconstruction of the whole process. Our results indicate the occurrence of two main events at 12:15:08 and 12:22:45 UT, respectively. These could be interpreted as a first submarine slump, causing the observed tsunami, and a second one above the sea level, not producing destructive sea waves. A total volume of about $20 \times 10^6 m^3$ results for the submarine event, which developed in about 2 minutes with several distinct detachments, the first and largest one displacing a volume of $10.8 \times 10^6 m^3$. The second, subaerial, mass sliding sequence interested $2.5 \times 10^6 m^3$ at minimum, in about 90 s. These estimates are in good agreement with independent results from bathymetric and topographic surveys. A large long period pulse is also recognizable in the seismograms of the Stromboli station. We tentatively interpret this feature as corresponding to the tilt caused by the water load associated with the ingression in the Ficogrande area, in the northeastern side, close to the recording site.

S51D-0079 0830h POSTER

Active Crustal Structures in the Southern Rhine Graben: From Local Earthquake Tomography and Reflection Seismics to Numerical Modelling.

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A better understanding of the seismogenic structures in the southernmost Rhine Graben is needed for future seismic hazard assessment studies. It has been proven difficult to link seismic activity to known geological structures in this region. The seismogenic part of the crust of the southern Rhine Graben is investigated with the use of a detailed Local Earthquake Tomography (LET). This tomography is combined with seismic profiles to come to a 3D image of the structures in the crust. The calculated velocity model can be compared with the results from P_n anisotropy calculations, gravimetry, deep reflection seismic profiles, and industry seismic sections to retrieve the exact location of the faults. Interpretation of the crustal velocity structure of the Rhine Graben shows a dominance of inherited Variscan structures, some of which were not recognised as seismically active until today. The velocity model and the interpretation of seismic sections show that the tectonics of the northeastern extend of the Jura Mountains are influenced by the presence of a Permo-Carboniferous trough system that is activated today. The involvement of the pre-Triassic basement contradicts the pure thin-skin development of the mountain belt. The faults that are derived from the geophysical imaging serve as input for a numerical modelling experiment. Aim of this experiment is to obtain insight in the kinematics of the various faults, and the associated stress and strain localisation inside the crustal model.

S51D-0080 0830h POSTER

A New Tomographic Study of the Western Corinth Rift (Greece) Using Local Seismicity

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A large dataset of more than 5,000 microearthquakes recorded in 1991 has been revisited in order to image the middle crust structure of the western Corinth Rift.Detailed three-dimentional P and S velocity structures and earthquake locations have been obtained by using an improved travel-time tomography method. This method is based on an iterative scheme in which, at each iteration, travel-time computation is performed using an accurate finite-difference technique and both models and location parameters are inverted simultaneously. The sensitivity of tomography results to the model parameterization and to the starting velocity model have been analyzed with different synthetic tests. Retrieved Vp and Vs models are used to deduce Vp/Vs and Vp*Vs images. The interpretation of these images allows to delineate the distribution of lithological variation, porosity and fluid saturation in the first 9 km of the crust beneath the Gulf of Corinth. Velocity images point out different features between the shallower and the deeper crust. The shallow 5 km thick structure shows WNW-ESE trending features that are related to the present-day N-S extention of the Rift. Althought extentional rate is very high in this region (about 1.5 cm/year), quite no microseismicity is observed in the first 4 km depth. On the contrary, velocity distribution changes beneath 5 km depth down to 9 km depth, where two high Vp/Vs anomalies are detected. These anomalies are located beneath the northern part of the Gulf in correspondance of a thin zone where very intense microseismicity is located. Previous magnetotelluric investigations allow us to suggest a possible correlation between this high Vp/Vs zone and a relative conductive layer identified at 9 km depth. This layer have been associated to the presence of fluid-filled cracks in the tectonometamorphic Phillite series, an inherited structure of the Hellenic mountain belt. This ductile series may constitute with the upper carbonate series of the Hellenic mountain belt a strong brittle/ductile transition.

S51D-0081 0830h POSTER

Vibration Response as an Indicator of Ground Fall Hazards in Mining: An Investigation Using Laser Doppler Vibrometry

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Unexpected falls of ground are one of the leading sources of injuries and fatalities in U. S. underground mines. A primary means of assessing mine-roof integrity is the age-old method of roof sounding where a miner taps on the roof and listens to the resulting seismically coupled acoustic response. Impacts to loose, hazardous blocks of rock generally produce a hollow drummy sound that is anomalously low in frequency and long in duration compared to sounds from competent rock. In this study, a noncontact laser Doppler vibrometry (LDV) method is used to record vibrations on rock surfaces to (i) evaluate the feasibility of remotely detecting hazardous ground from safe positions and (ii) delineate the fundamental, and little-studied, mechanical processes attending such gravity-driven failures. During the technique development stage, measurements were obtained on various rock outcrops and other structures with known defects; these included single-point and two-dimensional array recordings. Excitation sources included local and remote impacts, and ambient and forced vibrations. Consistent with predictions from simple models of elastic blocks coupled to solid ground through low-stiffness interfaces, loose rocks were effectively delineated with simple broadband RMS measures of elevated particle velocity. Other narrow-band spectral measures were also investigated

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and observed to be sensitive to block geometry, interface boundary conditions, and excitation source characteristics. In most of the experiments, loose blocks could be identified, in a comparative sense, even without compensating for the attendant vibration of the LDV. To deliver useful vibration response information to miners and others exposed to these hazards, two options are being explored: (i) development of 2-D maps of vibration response superimposed on target images and (ii) conversion of single-point LDV output into audible signals for use in a qualitative comparative mode.

S51D-0082 0830h POSTER

Earthquake Lights and Estimates of Electric Fields and Currents

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Luminous phenomena were observed during a number of earthquakes, e.g. the 1995 Kobe earthquake in Japan. Estimates based on the eyewitness's reports show that to produce lightning-type and corona-type discharges in the air the electric charge delivered to the ground surface should be of the order of several Coulomb. We assume that this charge was formed and transported by "mechanically produced current" flowing through the fault. The most difficult problem is why these charges survive in the highly conductive soil. The electric conductivity may drastically decrease due to heating and evaporation of water, but only in a thin central part of the fault, while the width of the luminous zone, and thus the width of the zone with high electric field strengths is of the order of hundred meters or even several km. So we propose the mechanism of charge localization - the so-called skin effect. Spreading of the currents and charges is described by a system of diffusion-type electromagnetodynamic equations. There are various models of rupturing during earthquakes. In the wrinkle-like self-healing pulse model the porosity and hydraulic and electric conductivity increase at the leading edge of the ruptured segment and decrease at the trailing edge. Assuming the electrokinetic mechanism as the most effective one we find that the charged fluid flows from these wedge-like ends of the ruptured segment to its center. The two currents flowing in the opposite direction produce magnetic fields with opposite rotation and reconnection due to magnetic diffusion decreases magnetic signals at large distances from the source region. Co-seismic electric and magnetic signals obtained during the Kobe earthquake at two stations at distances of about 100 km from the epicenter do not contradict our estimates and 3D numerical simulations based on our model of electric currents, magnetic fields and mechanical processes of rupturing. We suggest that similar current system may be formed even in the cases when earthquake lights are absent. So investigation of electromagnetic phenomena may give insight into the mechanical processes.

S51D-0083 0830h POSTER

High-Resolution Seismic Images and 3-D Seismic Velocities of the San Andreas Fault Zone at Burro Flats, Southern California

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The southern San Andreas fault (SAF) has produced large earthquakes in the past 1500 yrs. Burro Flats, a basin within the San Bernardino Mountains, is bounded on the southwest by the southern San Andreas fault. Burro Flats has been the site of paleoseismological investigations to determine the slip history of the fault. Additional paleoseismic studies at this location are needed to further resolve the structure and slip history of the SAF. In addition to the main trace of the SAF at Burro Flats, there are splay faults, suggesting a complex geometry for the fault. To better understand the structure of the SAF, we acquired a 3-D, combined seismic reflection/refraction profile centered on the main trace at Burro Flats. The seismic investigation included a 60 m by 70 m rectangular array. Sensors were spaced every 5 m; seismic sources, likewise with a spacing of 5 m, consisted of a combination of down-hole explosives and shallow (approximately 0.3 m) Betsy Seisgun shots. Data were recorded without acquisition filters for 5 s at a 0.5-ms sampling rate. To analyze the data for velocity structure, we used a tomographic inversion procedure to invert first-arrival refractions. Preliminary measurements from shot gathers show that near-surface velocities range between 700 m/s and 1500 m/s. We observe apparent travel-time delays of approximately 7 ms near the main surface trace of the SAF, suggesting that seismic imaging methods may be useful in identifying this and other fault traces. These results will be useful for paleoseismic investigations.

S51E MCC: Level 1 Friday 0830h

Strong Ground Motion Prediction III Posters

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

S51E-0084 0830h POSTER

Strong Ground Motion and Liquefaction During the Chi-Chi Earthquake

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Traditional methods of liquefaction risk assessment have focused largely on the evaluation of localized soil characteristics. While this method of risk assessment has proven to be fairly successful, it requires penetration tests or other means of determining the soil properties at a particular site. It would therefore be useful to develop a method to evaluate liquefaction risk in a region without requiring site-by-site measurements of soil properties. One approach to this problem is to examine the correlation between various properties of the ground motion at a site and the likelihood of liquefaction. The 1999 Chi-Chi earthquake in Taiwan offers a unique opportunity to study this relationship because the earthquake caused widespread liquefaction, and data from extensive networks of both seismographs and hydrological wells is available. Using a series of 1-D and 3-D models of the Chi-Chi earthquake, we simulate the ground motion at sites where liquefaction or pore pressure increases were observed. The resulting synthetic seismograms allow us to study which types of ground motion are most likely to cause liquefaction or pore pressure buildup. For the Chi-Chi earthquake, we have found that the correlation between pore pressure changes and the spectral ground acceleration at certain frequencies is stronger than the correlation between pore pressure changes and the peak ground acceleration. Preliminary results show significant differences between the synthetic seismograms and empirical seismograms at seismic stations near liquefaction sites. These differences may in part be caused by the inelastic behaviors of the nearby soils due to liquefaction. If true, this could be used as a method to detect liquefaction that does not have surface effects.

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Seismic Microzonation for the Estimation of Sites Effects in an Urban Area - the Case Study of the City of Mulhouse (NE France)

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The upper Rhine graben is nowadays characterized by a rather low background seismicity and a rather long seismic cycle. However, on 18 October 1356, an earthquake destroyed the city of Basel (Switzerland), and damaged large parts of this area. It had an intensity of IX to X on the MSK scale and an estimated magnitude of 6.0 to 6.5. The upper Rhine graben is characterized by densely urbanized areas and the presence of several sensitive industries (e.g. nuclear power plants, SEVESO chemical industries). The city of Mulhouse (110 000 inhabitants), located 30 km north to Basel, belongs to this seismically risky region. The aim of the research is to study jointly technological and seismic risks in order to assess the impacts of a strong earthquake in this area. To achieve this goal the different parameters involved are integrated within a GIS (seismic data, for example). The set of data will constitute the basic layers of the GIS. This paper focuses on the estimation of site effects in Mulhouse area. A microzonation experiment has been carried out in order to determine fundamental frequencies and site amplification factors which are closely related to near-surface structures. About one thousand measurements have been done on two embedded grid scales. On the first one, 250 measurements are spatially distributed each 500 meters across the whole studied area, covering a surface of about 50 km^2. On the second grid, measurements have been positioned each 100 meters around so-called "sensitive" sites (chemical industries, fire station, hospital, etc.). Nakamura's method - horizontal-to-vertical-spectral ratio technique based on ambient noise - was chosen among others as no reference site is needed. It is well adapted where no outcropping nearby bedrock site is present. In fact the whole area here is covered with sediments. This method consists in recording microseismic noise and in calculating the spectral ratio between the horizontal components and the vertical component of the observed ground motion in the same site by assuming that the vertical component is free of near surface influences. Ambient noise was recorded during 30 minutes using two seismometers having respectively a period of 1s and 20s. For each measurement, Nakamura's method was performed on twenty one-minute time windows. Finally, the average of the site effects was calculated and plotted on a map. The first results will be presented showing a local and significant amplification at several sites of the city, using maps of fundamental frequency and normalized amplification.

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Seismic Amplitude Variations due to Site and Basin Edge Effects in the Los Angeles Basin

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An empirical model of S-wave amplitude variations throughout the Los Angeles and San Gabriel basins is developed using simple attenuation and scattering theory. The model incorporates geometrical spreading, magnitude, and soil effects at the surface and takes into account basin edge effects. The model is developed using data from the 1997 Los Angeles Basin Passive Seismic Experiment (LABPSE). LABPSE was a passive seismic experiment consisting of 18 seismic stations along a line crossing the Los Angeles and San Gabriel basins recording local, regional and teleseismic earthquakes for nine months. The data consist of spectral amplitudes for S waves from 39 local events. Events are chosen for which Sg is the first S wave arrival and at least half the stations had a good signal-to-noise ratio. The spectral amplitude is the mean of the FFT of a +/- 2 sec window around the beginning of the S arrival. The spectral amplitudes are broken into frequency bands (1-5 Hz, 5-10 Hz) to determine the frequency dependence of the model parameters, however little variation is seen across the bands. Raypaths are determined by ray tracing through the SCEC 3D velocity model. The variable parameters of the model include event amplitudes and Q. Station site terms are determined from the S wave coda; 1/r geometric spreading is assumed. The model was fit to the data using a non-linear least-squares inversion. The fit was not improved by inclusion of double couple fault plane radiation patterns. This may be due to the use of spectral amplitudes above 1 Hz and the more difficult detection of radiation patterns in S waves. Fault plane radiation patterns are not included in the final model. The results indicate that for most stations the model is a good first order approximation of the amplitude variation. However arrivals from a restricted range of azimuths for stations near the basin edge have amplitudes that are several times larger than the model predicts. One interpretation of these results is that the Whittier Fault at the edge of the Los Angeles basin creates a zone of increased amplification for earthquakes along the path of the fault. This effect has subsequently been included in the model.