km 3-D rectangular grid with velocities assigned to each grid
Initially the inverse problem was solved using the progressive
sion technique by Thurber (1983). A system of linearized
ions relating travel time residuals with hypocentral and velocity
ments is solved repeatedly using damped least suares. To
ss the issue of non-uniqueness an ensemble inversion procedure
also attempted. This approach is based on the generation of a
andom sequence of models. Models which satisfy the data are
cted into an ensemble. Statistical properties of the ensemble are
to infer features of the velocity model. For example the median
ity of each node may be compared to the conventional
ssive inversion solution Where the resolution is adequate, the
nversion methods produce similar models. A high velocity
naly located southeast of the field corresponds to a mapped
ion of Franciscan metagraywacke. Low velocity anomalies in the
ral and northern regions appear to represent sections of
stone melange. The production zone between depths of 1 and 3
is marked by low velocities and Vp/Vs values suggesting
turation of the reservoir rocks. A region of high Vp/Vs ratio
depth of 4 km located beneath an active injection well suggests
possibility of increased fluid saturation there. Hypocenters within
CPA field lie between 1.5 and 3 km depth, presumably related
production zone. A cluster of events with focal depths between
3 km is located beneath an injector, providing evidence for
ced seismicity.

0830h POSTER

Dimensional Velocity Structure of the Amiata - Volsini Volcanoes
ral Italy)

ha, A Amato (Istituto Nazionale di Geofisica, Via di Vigna Murata
0143 - Roma, Italy, e-mail: chiarabba@in8800.cineca.it), and A.
si (ENEL - VDAG, Via Andrea Pisano, Pisa)

ve calculated the three-dimensional P-wave velocity structure in the
rust beneath Amiata and Vulsini Quaternary Volcanoes (Roman
matic Province, Central Italy) by the inversion of local earthquake
times. The availability of more than 3,000 local earthquakes
ded by two adjacent, dense microseismic networks operating between
and
offers a unique opportunity to image crustal heterogeneities beneath
Quaternary volcanoes. Geological and geophysical data, deriving
the geothermal exploration, give us useful informations to constrain
terpretation of the computed velocity images. We inverted 7,998
ve arrival times using Thurber's local earthquake technique. We
ed the resolving power of the data set, performing a complete analysis
e resolution matrix. In this way, we estabilished the parameterization
llows to reach the more detailed spatial images, maintaining a good
tion of the model parameters. Furthermore, we performed synthetic
that ensured us to be confident with the recovered anomalies. We
d high velocity anomalies beneath Latera, Torre Alfina and Amiata
rmal fields, probably related to positive structures of the limestone
ment in the upper three kilometers of the crust. A negative anomaly
sent beneath the Radicofani Graben between 1 and 3 km depth,
ving a high velocity zone at 7 km depth. This high velocity may be
ed to a fluid-filled crustal level, probably the top of the metamorphic
ment.

0830h POSTER

**-dimensional Seismic Velocity Structure beneath
Volcano, Kyushu, Japan**

Kong (USGS/Hawaiian Volcano Obs., Hawaii National
HI, USA 96718; e-mail: lkong@iniki.soest.hawaii.edu)
o (Aso Volcanological Obs., Kyoto University,
moto 869-14, Japan)

S wave travel time data from earthquakes recorded by
ilon seismic network are used to determine the three-
sional velocity structure of the active Aso volcano,
l Kyushu, Japan. The volcano lies along a tectonic belt
ecting the magmatically-active Kuju and Unzen
oes; its 18 by 25 km elliptical caldera, one of the largest
world, contains more than 17 central cones with steam
scoriae-ejecta activity currently emitted from the crater of
youngest pyroclastic cone atop the composite Nakadake
nic edifice. Previous results have shown that significant
d S waveform attenuation and large P wave travel time
uals exist beneath the central and northward extension
caldera; ray tracing suggests that the low Q region to
ocated at about 6-9 km depth. Seismicity in the region
s isouthwest to northeast, shoaling over a 50 km
nce from 15-20 km depth to less than 5 km depth
eath the caldera. Over the 1981-1989 time period, over
0 earthquakes were recorded; P and S wave data are
lable from 6-8 stations from over 1500 earthquakes.
rthquake swarm activity in both 1985 and 1989 was well-
ciated with Aso volcanic activity. In order to investigate
magnitude and dimensions of velocity heterogeneity
ciated with this active volcano, we have carried out
ography inversions using travel time residuals from over
0 well-recorded earthquakes and 14 explosive shots and
ts for three-dimensional velocity structure over a 30 by 40
area encompassing the seismic network and caldera.

S31C-6 0830h POSTER

Three-Dimensional Seismic Structure of the Hengill Triple Junction, Iceland, From *P*- and *S*-wave Local Earthquake Tomography.

A.D. Miller[1,2], B.R. Julian[1], G.R. Foulger[1,2], J.R. Evans[1] ([1]Branch of Seismology, USGS, 345 Middlefield Rd., Menlo Park, CA 94025; [2]Dept. Geological Sciences, Univ. Durham, Durham, DH1 3LE, U.K.)

The Hengill ridge-ridge-transform triple junction, SW Iceland, is an area of active, persistent, natural seismicity. A 30-station network of continuously recording IRIS/PASSCAL digital recorders was operated in the area in 1991, recording over 3700 local seismic events in 65 days. We have identified 395 earthquakes with at least 10 P-wave arrivals each, yielding a data,set with 7800 *P* times and 5300 *S* times.

The three dimensional velocity structure of the area, including the widespread geothermal field, was determined using the method of Thurber and Eberhart-Phillips (chapters 20 and 22 in *Seismic Tomography: Theory and Practice*, Chapman & Hall, 1993). Their method inverts simultaneously for *Vp*, *Vp/Vs* and hypocenters. *Vp/Vs* is of particular interest in geothermal areas as it is diagnostic of pore fluid conditions. A high average *Vp/Vs* of 1.78 suggests that the geothermal field is largely water dominated.

This study provides rare information on the repeatibility of local earthquake tomography, since a similar study was made by Toomey and Foulger (1989) using P-waves only, from a dataset collected in 1981 on analog tape. The two *Vp* models are compared here, and the new *Vp/Vs* model presented.

S31C-7 0830h POSTER

Locating Earthquakes in a 3D Velocity Model of the Salton Sea Geothermal Field

A L Tesha, C I Montana, and D I Doser (All at Department of Geological Sciences, University of Texas at El Paso, El Paso, Tx, 79968: tel.915-747-5501; e-mail: montana@dillon.geo.ep.utexas.edu.

The Salton Sea Geothermal Field (SSGF) has been the object of study for a number of years. The interest in the region is in addition to engineering applications, due to geothermal potential, due to the character of the Salton Sea through as a pull-apart basin related to the San Andreas fault system as well as the opening of the Gulf of California. The present study involves analysis of the SSGF microearthquake data collected by a temporal network deployed by Lawrence Livermore National Laboratories from September 15, 1987 to September 30, 1988, as well as data collected by UNOCAL's seismograph network during the same time period. Previous work located earthquakes using a 1D velocity model. This work strives to locate earthquakes in a 3D velocity model utilizing seismic data and well log information. Detailed analysis of this data set will investigate the relationship of seismic events to the 1987 Superstition Hills earthquake sequence, as well as geothermal energy production.

S31D CA: 317 Wed 0830h
Strong Ground Motion I
Presiding: **J H Steidl,** Univ of California, SB; **P Spudich,** USGS, Menlo Park

S31D-1 0830h
ESTABLISHING THE "REFERENCE" GROUND MOTION IN SITE-SPECIFIC SEISMIC HAZARD ANALYSIS?

Jamison H. Steidl, Alexei G. Tumarkin, and Ralph J. Archuleta. *Institute for Crustal Studies and Department of Geological Sciences,* University of California, Santa Barbara, California 93106 (steidl@quake.crustal.ucsb.edu)

Understanding and predicting the variation in surface ground motion over small distances is critical to the prevention of costly damage and loss of lives during large infrequent earthquakes. The large variability seen in surface recordings of ground motion can only be understood by first examining the variation in the input motion of the bedrock below the particular site. How coherent is the seismic energy arriving at bedrock borehole instruments separated by distances as small as 5 km. Are these borehole measurements of ground motion true "reference" recordings? The comparison of closely spaced bedrock borehole instruments along the Anza segment of the San Jacinto fault zone in Southern California are crucial to answering these questions. The Garner valley downhole array (GVDA) and USGS borehole at Keenwild (KNW) are separated by only 5 km. The USGS borehole at the Pinon Flat observatory (PFO) is located 20 km further southeast along the San Jacinto fault. Both borehole and surface sensors have been monitored over the past year and many events have been recorded at all three sites. We will present the analysis of this data set with regard to answering this question of establishing the true "reference" site when doing site response studies.

S31D-2 0845h
A Comparative Study of Strong-Motion Records from Large Earthquakes in California and Taiwan

Y B Tsai (Geosciences Department, Pacific Gas and Electric Company, San Francisco, CA 94177; 415-973-2989)

We used large numbers of digitized strong-motion records from the following four large earthquakes in California and Taiwan for a comparative study of the local magnitude (ML) and site-dependent response spectral shapes:

Date	Location	Ms	Records
11/14/86	E. Taiwan	7.8	168
10/17/89	C. California	7.1	123
4/25/92	N. California	7.1	14
6/28/92	S. California	7.6	48

It was found that the existing distance correction functions for ML determination in Central and Southern California would yield too small ML values from the near-source records of these earthquakes. The records from hard rock sites in the Central Mountain Range of Taiwan and in the Mojove Desert of Southern California had low amplitudes at low frequencies, resulting in response spectral shapes of the UBC S1 type and significantly lower than average ML values. Some records from Central California had similar features, but were not readily correlatable with local site geology.

On the contrary, records from soft alluvial sites in Taipei Basin and Lanyang Plain in Northern Taiwan, around the San Francisco Bay in Central California, and in Los Angeles Basin in Southern California had high amplitudes at low frequencies, resulting in response spectral shapes of the UBC S3 type and significantly higher than average ML values. A large majority of records from stiff alluvial or soft rock sites had response spectral shapes of the UBC S2 type and yielded average ML values for the earthquakes. This systematic correlation between the local magnitude and response spectral shape suggests that the ML residual can serve as an effective indicator for site-dependent response spectral shapes.

S31D-3 0900h
Strong Motion Simulation During the 1992 Landers Earthquake

Byau-Heng Chin and Keiiti Aki (Department of Geological Sciences, University of Southern California, Los Angeles, CA 90089).
Mehrdad Mahdyiar (Leighton and Associates, 1470 South Valley Vista Dr., Suite 150, Diamond Bar, CA 91765)

A preliminary GIS-based map of weak-motion amplification factor in Southern California was constructed by combining the empirical amplification factor measured at stations of the Southern California Seismic Network by the coda method with the digitized surface geology data. We then synthesized the strong ground motion by applying the stochastic simulation technique to these available site geological parameters and compared it with the observed to develop the predictive capability based on site parameters. Empirical equations derived from regression analysis by Trifunac and Lee (1989) were also used to predict the shape of spectra. The synthetic records at a Mesozoic rock site (Lucerne Valley) and a deep alluvium site (Indio at epicentral distance of 61 km) both show very good agreement with the observed in both spectral content and duration. However, at a shallow alluvium site (Joshua Tree) in the epicenter region, the predicted peak ground acceleration (PGA) based on the weak-motion amplification factor overestimated the observed by a factor of two. This is in agreement with our nonlinear site response results obtained for the sediment sites in the epicentral area during the Loma Prieta earthquake.

Several geotechnical studies suggest that the maximum horizontal accelerations on alluvium sites tend to saturate with the increasing level of shaking towards a limit of about 0.4-0.5 g. The nonlinear site response in this study is introduced as additional attenuation factor of the form $\exp(-\alpha f)$ to the weak-motion amplification factor. The parameter α is determined for each site based on the estimated bedrock motion for the site and the requirement that the PGA at the surface of alluvium satisfy a given nonlinear relation to the bedrock motion. The predicted pseudo velocity response spectra matched the observations well, suggesting that a site-specific response spectra for future earthquake could be obtained by using the weak-motion amplification factors modified for non-linearity by the above procedure.

S31D-4 0915h
A Parametric Study on the Probabilistic Ground Motion Analysis in Southern California Using the Recent Regional Seismic Information by Southern California Earthquake Center

M Mahdyiar (Leighton & Associates, Inc., 1470 South Valley Vista Dr., Suite 150, Diamond Bar, Ca 91765; 909-860-7772)
A. C. Cornell (Stanford University, Ca 94305; 415-854-8053)
D. D. Jackson (UCLA, Ca 90024; 310-825-0421)

The state-of-the-practice of the probabilistic ground motion analysis (PGMA) in southern California is to define the active and potentially active faults as the major sources of seismicity. However, in the most recent study by the Southern California Earthquake Center (SCEC), the region is divided into sixty five seismic zones. Each zone is characterized based on the available information on the historical and instrumental seismicity and paleoseismic and geodetic data. Following the Working Group report of 1988, SCEC assigns the conditional probability of occurrence to the characteristic earthquakes on the San Andreas, San Jacinto, Elsinore, Whittier, and Palos Verdes seismic zones. Based on the information on the proposed sixty five seismic zones a parametric study on the PGMA for the region was performed.

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