TESTING OF THE SITE AMPLIFICATION HYPOTHESIS ON EARTHQUAKE DAMAGE THAT OCCURRED IN THE SAN FERNANDO VALLEY AND THE CITY OF SANTA MONICA DURING THE 1994 NORTHRIDGE EARHQUAKE AS RELATED TO THE UNDERLYING GEOLOGICAL STRUCTURE OF FAULTS AND SYNCLINAL FOLDS

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Based upon site amplification models that were published in 1996 for the 1994 Northridge Earthquake, scientists at UCLA proposed a fault and fold model to illustrate why earthquake damage that occurred in the relatively level area located in and around the City of Santa Monica. A similar model was proposed by the USGS for the earthquake damage that occurred in the San Fernando Valley in and around the CSUN campus in Northridge, and they tied the previous 1971 San Fernando, 1987 Whittier Narrows, 1991 Sierra Madre, and 1994 Northridge earthquakes were used to estimate site response in the urban Los Angeles, California, area. Later the USGS research scientists proposed a July 2005 ~ AEG NEWS 48 (Program with Abstracts) 87 more complex model for a similar pattern of earthquake damage that occurred in the Sherman Oaks area in the San Fernando Valley. We reviewed numerous referred geological and geophysical studies of the 1994 Northridge earthquake that indicated that surface site effects are related to the structural focusing of earthquake energy at the surface of the earth from the underlying geologic structure.

Based upon available data and published maps of earthquake damaged to buildings, highways, bridges and utilities we checked the underlying geologic conditions using the existing published geologic cross sections for these same areas. We next tested this earthquake damage pattern with similar damage patterns from the 1971 San Fernando Earthquake to study the underlying geologic structure. It appeared that in all cases the underlying structural geology was either related to the synclinal folding of sediments and basement rock due to faulting, or to various models of faulting, segmentation, multiple faults, dense rock, and synclinal folding that caused site-specific amplification. In addition, we tested the available data from several previous California earthquakes starting with the two 1812 earthquakes, 1925, 1927, 1933, 1952 and the 1983 Coalinga, and 1987 Whittier earthquakes and encountered the same results.

TESTING THE HYPOTHESIS OF SITE AMPLIFICATION IN OCEANO, CALIFORNIA AND OTHER AREAS THAT MAY BE RELATED TO AMPLIFICATION AND REFRACTION FROM A NEAR BY FAULT-BOUNDED SYNCLINE

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The December 22, 2003, the San Simeon, California, (M6.5) earthquake caused damage to several houses, to road surfaces, and to underground utilities in the town of Oceano, California. The community of Oceano is located approximately 80 km (50 miles) from the earthquake epicenter. Earthquake damage at this distance from a M6.5 earthquake is considered to be abnormal. Earthquake damage at similar distances occurred during the 1994 Northridge earthquake.

The investigation of the study area identified two earthquake hazards in Oceano that researchers considered to explain the San Simeon earthquake damage–site amplification and liquefaction. As a result, earthquake shaking is felt more strongly in the study area than in surrounding areas without similar geologic conditions. Site amplification in Oceano is indicated by the physical properties of the geologic layers at depth beneath Oceano.

Site amplification may cause shaking from distant earthquakes, which normally would not cause damage, to increase locally to damaging levels. The Wilmar Avenue Fault had been previously mapped in the study area, along with a fault-bounded syncline or monocline of Miocene sediments over Jurassic basement rock. The vulnerability in Oceano is compounded by the widespread distribution of highly liquefiable soils that are encountered near the surface that will reliquefy when ground shaking is amplified from the fault-bounded syncline or monocline.

The site amplification at Oceano appears to be similar to earthquake damage that was observed in the town of Paso Robles during the San Simeon Earthquake, and in other California earthquake such as at the Tarzana Nursery in1994 Northridge, and again in the 1971 San Fernando/Sylmar Earthquake. Site amplification occurred during the 1925 Santa Barbara Earthquake, the 1933 Long Beach Earthquake, and also to the earthquake damage that occurred to many of the California Missions dating back to 1812.

TOMOGRAPHIC INVERSION OF SEISMIC REFRACTION P-WAVE AND S-WAVE DATA AND UTILITY IN ENGINEERING AND ENVIRONMENTAL GEOLOGY INVESTIGATIONS

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The development of a relatively new shallow seismic refraction data analysis technique, seismic tomography, greatly enhances the utility of seismic refraction as an exploration tool for use in engineering and environmental geology investigations. Traditional analysis of shallow seismic refraction data has generally limited the utility of seismic refraction as an investigative tool to those sites with seismic velocity layers anticipated to produce distinct cross-over points or discrete changes in seismic velocity. The seismic velocity contrast necessary to produce such discrete cross-over points is typically witnessed when seismic velocities differ by a factor of at least 1.5 to 2 between velocity layers. In contrast, tomographic analysis of seismic data is not restricted to the requirement of identifying discreet cross-over points. Tomographic models are able to depict gradual velocity changes that empower the investigator’s ability to interpret site conditions.

The utility of tomographic inversion of seismic refraction p-wave and s-wave data is presented in the context of both engineering geology and environmental geology applications. With respect to engineering geology application two case studies will be reviewed: (1) the ability to generate two dimensional shear wave velocity profiles for seismic response characterization as contrasted with standard one-dimensional seismic cone penetrometer tests, and (2) the use of seismic tomography to image a fault. With respect to environmental geology, a case study is reviewed, illustrating the usefulness of seismic tomography in identifying a former oilfield related production pit. During the course of reviewing the engineering and environmental geology investigations, the quantitative analysis and identification, as well as tomographic imaging, of the vadose zone and groundwater surface will also be discussed and illustrated.