S-wave velocity measurement across active faults and the effect of basin geometry on site response, California, USA

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We measured S-wave velocity (Vs) profiles at eleven sites in the east San Francisco Bay area using surface wave methods. The sites were placed around the Hayward fault and the Calaveras fault (Figure 1). The 30-year probabilities of magnitude 6.7 or greater earthquakes on the Hayward-Rodgers Creek and Calaveras faults have been estimated at 32 % and 25 %, respectively. These faults run through densely populated areas and knowledge of a detailed two- or three dimensional Vs structure along the faults is needed in order to estimate local site effects due to a potential earthquake. This presentation summarizes data obtained by the surface wave methods, shows Vs profiles calculated by inversion, and discusses the effect of 2D Vs structure on surface ground motion. Data acquisition included multichannel analysis of surface waves using an active source (MASW), a passive surface-wave method using a linear array of geophones (Linear-MAM), and a two station spatial autocorrelation method (2ST-SPAC) using long-period accelerometers. Maximum distance between stations ranged from several hundred meters to several kilometers, depending on the site. Minimum frequency ranged from 0.2 to 2 Hz, depending on the site, corresponding to maximum wavelengths of 10 to 1 km. Phase velocities obtained from three methods were combined into a single dispersion curve for each site. A nonlinear inversion was used to estimate Vs profiles to a depth of 200 to 2000 m, depending on the site. Resultant Vs profiles show significant differences among the sites (Figure 2). On the west side of the Hayward fault and the east side of the Calaveras fault, there is a low velocity layer at the surface, with Vs less than 700 m/s, to a depth of approximately 100 m. A thick intermediate velocity layer with Vs ranging from 700 to 1500 m/s lies beneath the low velocity layer. Bedrock with Vs greater than 1500 m/s was measured at depths greater than approximately 1700 m. Between the Hayward Fault and the Calaveras Fault, thicknesses of the low velocity layer and the intermediate velocity layer are less than 50 m and 200 m respectively, and depth to bedrock is less than 250 m. To evaluate the effect of a lateral change in bedrock depth on surface ground motion due to an earthquake, a representative Vs cross section perpendicular to the Hayward fault was constructed and theoretical amplification was calculated using a viscoelastic finite-difference method. Calculation results show that the low frequency (0.5 to 5 Hz) component of ground motion is locally amplified on the west side of the Hayward fault because of the effect of two-dimensional structure. The results of this investigation indicate that the phase velocity information obtained using the 2ST-SPAC method with a limited number of high quality sensors provides valuable Vs information over a wide depth range. It offers a robust alternative to widely-used single station methods such as the horizontal to vertical spectral ratio. Though the 2ST-SPAC method and other passive surface wave methods using an anisotropic or linear array cannot equal the performance of an isotropic array in the case of strongly anisotropic ambient noise, they do provide an effective alternative for many urban environments where ambient noise is relatively isotropic and potential sites for array deployment are limited to corridors along roadways. The inversion of surface wave data is essentially non-unique and we cannot remove uncertainty from analyses, the effect of the uncertainty depends on the purpose of investigation and the use of the data. Several different velocity profiles that yield almost the same theoretical phase velocities were examined to evaluate the effect of uncertainty of inversion on amplification calculation. The results shows that the site amplifications calculated from Vs profiles are relatively insensitive to uncertainties in the velocity profiles.

Keywords: Active fault, S-wave velocity, Surface-wave method, Micro-tremor array measurements, Site amplification, Basin edge effect

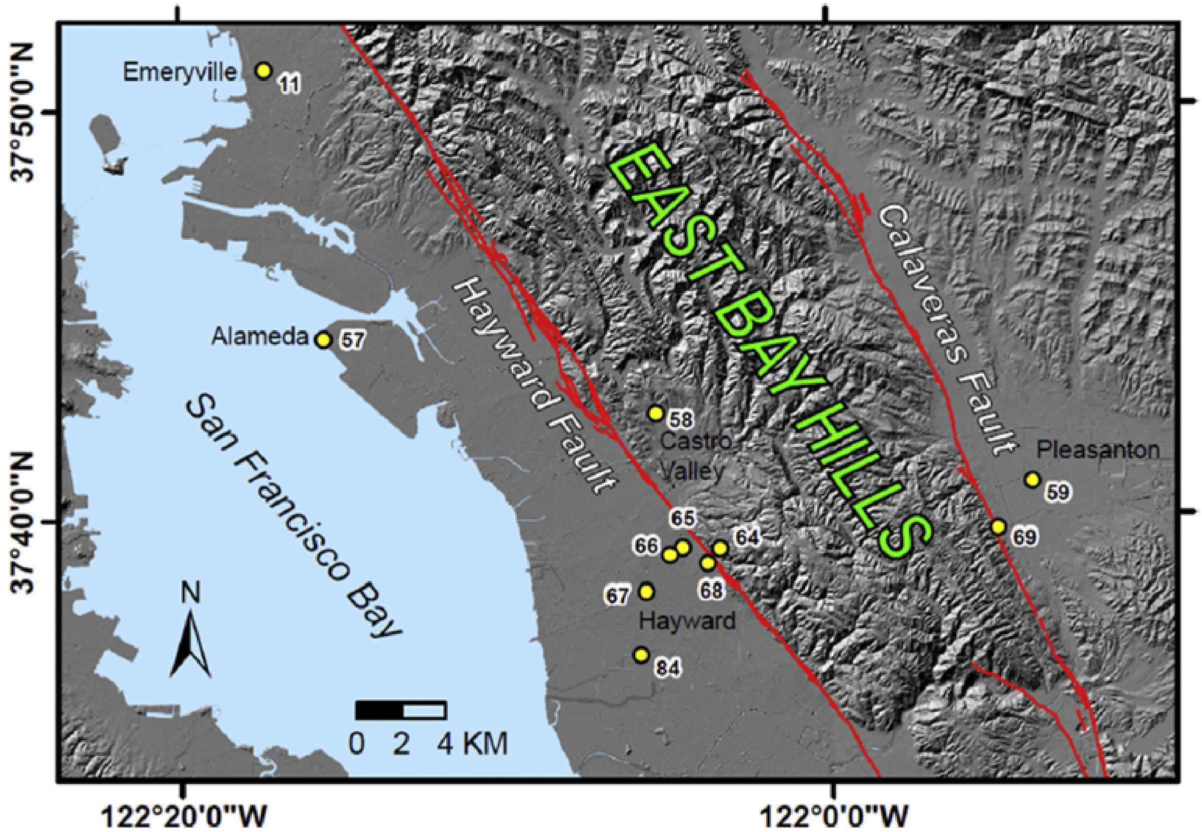

Figure 1. Sites of investigation. 11 : Emeryville, 57 : Alameda, 58 : Castro Valley, 59 : Pleasanton, 64 : CSU East Bay, 65 : Charles Ave, 66 : Huntwood Ave, 67 : Southgate Park, 68 : Cemetary, 69 : Alviso Adobe, 84 : Eden Shores Park.

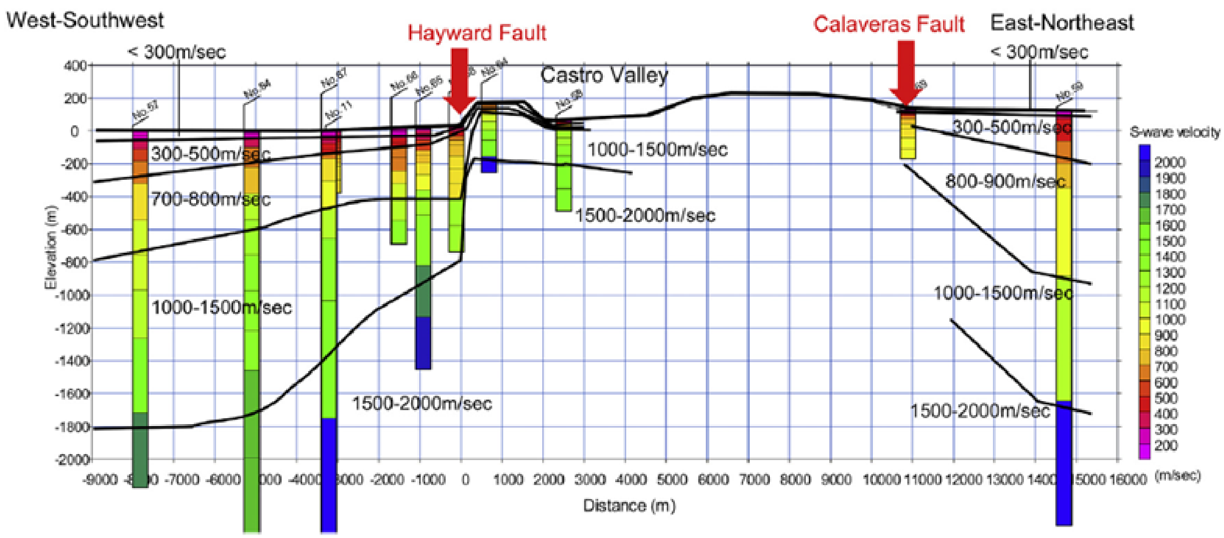

Figure 2. Schematic S-wave velocity section based on the S-wave velocity profiles obtained in this study.

