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VERTICAL STRONG GROUND MOTION CHARACTERISTICS OF THE NORTHRIDGE EARTHQUAKE

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ABSTRACT

The January 17, 1994, moment magnitude 6.7 Northridge earthquake has provided a large set of strong ground motion data, including a significant amount of data near the rupture zone of the earthquake. The ratio of the vertical spectral ground motions to the horizontal spectral ground motions decreases with distance from the fault. In addition, the vertical to horizontal spectral ratio has a drastic increase at short periods, especially for motions recorded closer to the fault. The ratio decreases from the large peak, then begins increasing again at large periods. At large periods, there is no discernible decrease in the spectral ratio with distance. However, at small periods, there is a dramatic decrease in the spectral ratio with distance.

KEYWORDS

Strong ground motions; Northridge earthquake; Response spectra; Vertical ground motions.

INTRODUCTION

The Northridge Earthquake of January 17, 1994, with a moment magnitude 6.7, has provided an opportunity to study earthquake ground motions like never before from a single earthquake; many free field accelerometer stations recorded the ground shaking. Vertical ground motions have been studied increasingly in the last few years (Lew, 1992; Bezorgnia et al., 1995), and the Northridge earthquake records provide an excellent opportunity to continue those studies. Strong motion records from the California Strong Motion Instrumentation Program (CSMIP) network in Southern California and the University of Southern California (USC) seismic network have provided a large set of data for this study.

GROUND MOTION RECORDS USED

The ground motion records used for this study were the stations of the California Strong Motion Instrumentation Program (CSMIP), operated by the California Division of Mines and Geology (Shakal et al., 1994), and the stations of the University of Southern California (USC) Seismic Network (Trifunac and Todorvska, 1994). The CSMIP records have for the most part been corrected and processed, and the available Volume II data was used to compute response spectra for 5% of critical structural damping. The USC records have not been processed yet; the Volume I digitized records were used by the authors to develop 5% damped response spectra. Because unprocessed records are not as reliable in the long period range, spectral ordinates for periods greater than 1 second are not discussed in this paper. Many of the records from both the CSMIP and USC networks were available for this study. Figure 1 shows the locations of the stations used in this study.

VERTICAL SPECTRAL RATIO

It has been observed in recent research that the ratio of the vertical spectra to the horizontal spectra is a strong function of distance. Therefore, the mean horizontal spectra and the mean vertical spectra were computed for various groupings of distance from the fault rupture. The distance measurement used in this paper is the closest horizontal distance to the vertical projection of the fault rupture to the ground surface. For this purpose, the area of fault rupture as outlined by Wald and Heaton (1994), was used as shown in Fig. 1. The records were grouped into categories of stations less than 5 km, 5 to 10 km, 10 to 20 km, and 20 to 40 km. The ratio of the vertical to horizontal spectra are shown in Fig. 2 through 6. In these figures, both the mean ratios and the mean plus one standard deviation ratios are shown. Figures 3 shows the same data as Fig. 2, but with a reduced vertical axis for consistency with Fig. 4 through 6. The number of stations used for each figure are indicated on the figure. It can be seen that the ratio of vertical to horizontal spectral ordinates is greatest in the small period range, decreases to a minimum, and begins increasing again as the period approaches 1 second. The ratio is larger for the groupings of distances closer to the earthquake. The increase in the ratio at short periods is dramatic, especially for smaller distance from the fault. The ratio is greatest at periods from 0.04 to 0.08 seconds, with greater periods corresponding to greater distances from the fault.

SPECTRAL RATIO ATTENUATION WITH DISTANCE.

To further illustrate the attenuation of the spectral ratio with distance, the computed ratios for each record versus distance for the 0.01 second spectral ratio, 0.1 second spectral ratio, 0.4 second spectral ratio, and 1.0 second spectral ratio are shown as scatter plots in Figures 7 through 10. These figures illustrate the great variation in computed spectral ratios. However, curves fitted as least square fits of exponential functions show that there are trends in the data, toward smaller ratios with greater distance. The intermediate period (0.1 second) shows the greatest variation with distance, whereas the longer periods show very little or no variation with distance. The 0.01 second period shows an intermediate level of decrease with distance. The larger ratios of vertical to horizontal spectra at short periods for near fault distances can exceed unity; this observation may be due to the blind thrust style of faulting for this earthquake.

CONCLUSIONS

The vertical ground motions have been compared to the horizontal ground motions for the Northridge Earthquake. Prior earthquakes had been investigated for the ratio of vertical to horizontal spectra, but the Northridge Earthquake provided the most comprehensive set of ground motion data yet recorded for a single earthquake event. Both the California Strong Motion Instrumentation Program and the University of Southern California networks provided outstanding coverage of the earthquake ground shaking. However, the vast majority of the sites are located on alluvial materials. Therefore, for this study, differentiation between the vertical response on soil as compared to rock could not be made.

The data supports previous studies which indicate a decrease in the ratio of vertical to horizontal spectral ordinates with distance from the fault. However, this study has shown a dramatic increase in the ratio of vertical to horizontal spectra at short periods, especially for smaller distance from the fault. The ratio is

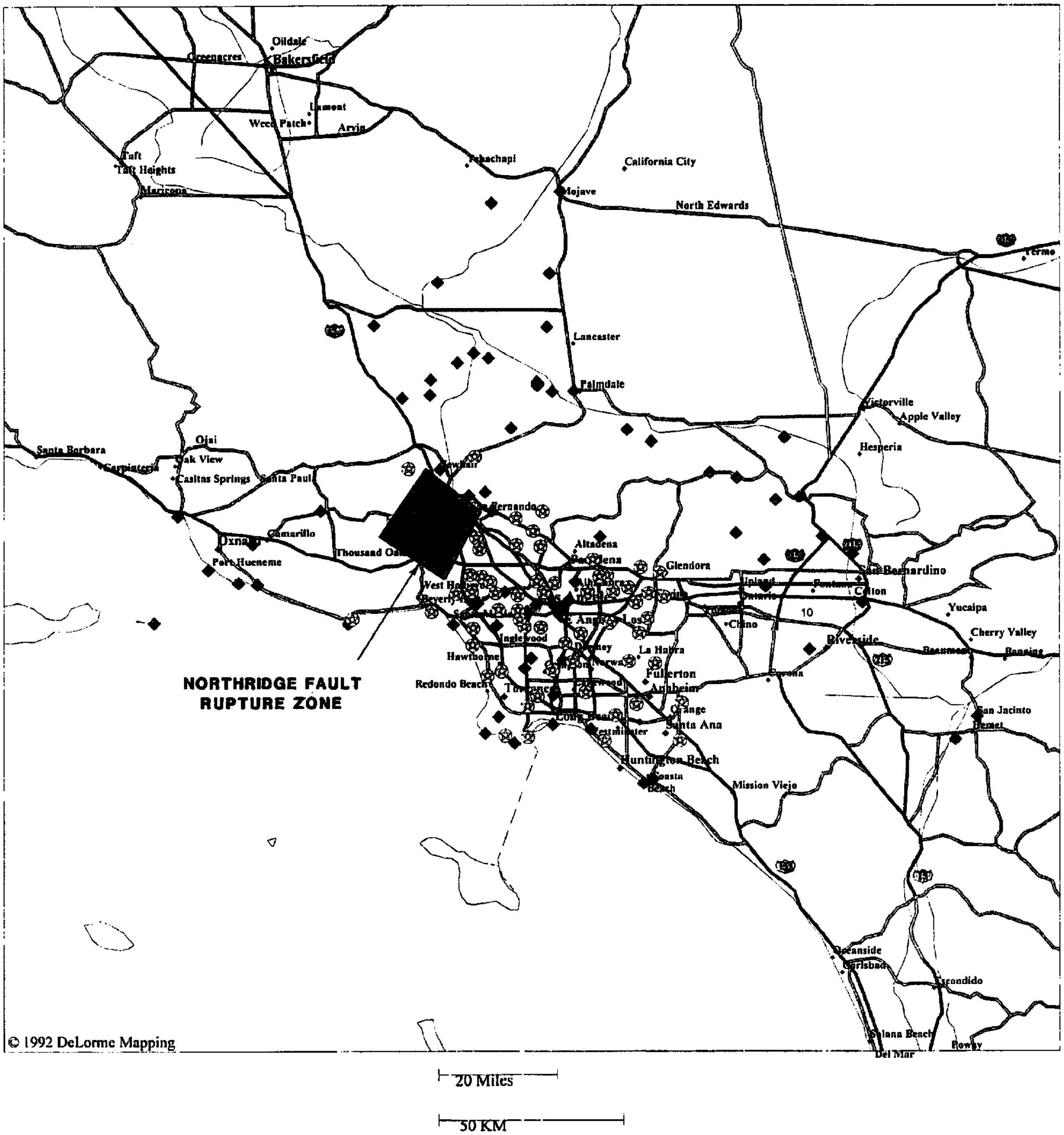

Fig. 1. Strong motion accelerometer locations

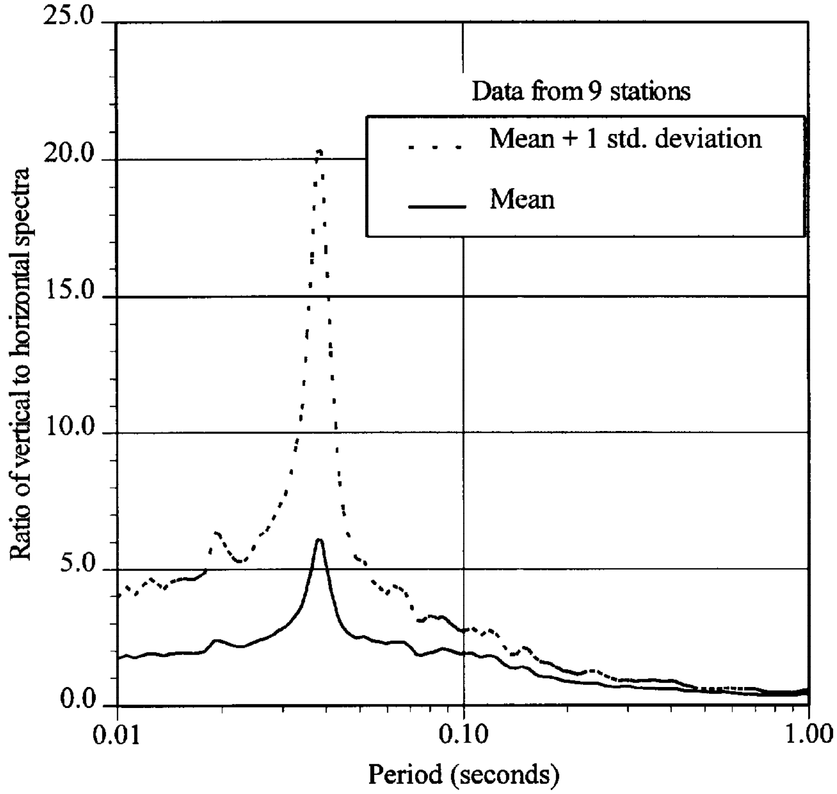

Fig. 2. Vertical to horizontal spectral ratio for distances less than 5 kilometers

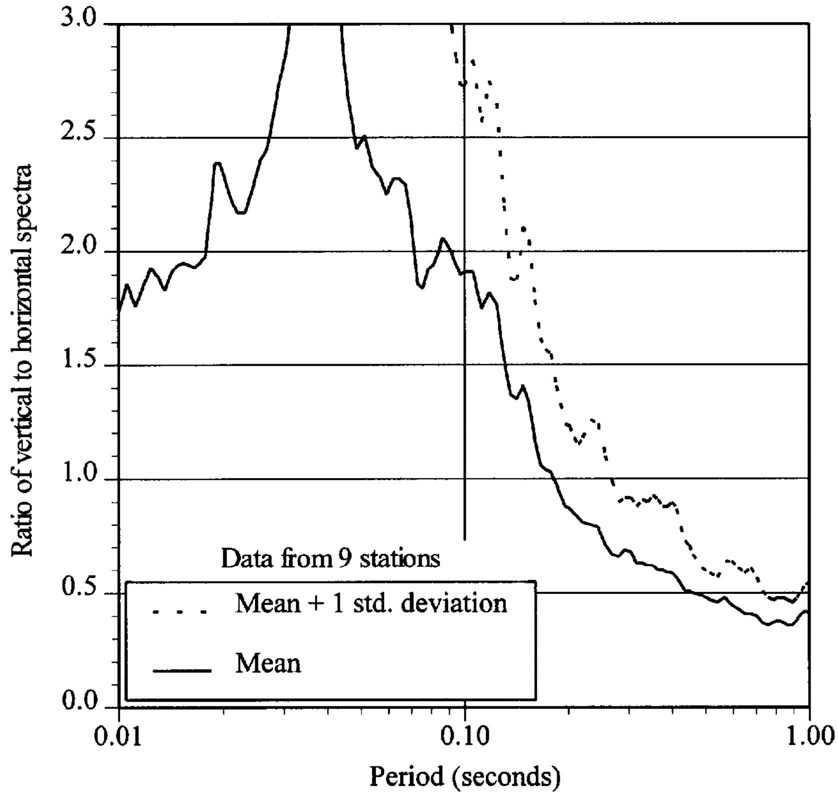

Fig. 3. Vertical to horizontal spectral ratio for distances less than 5 kilometers

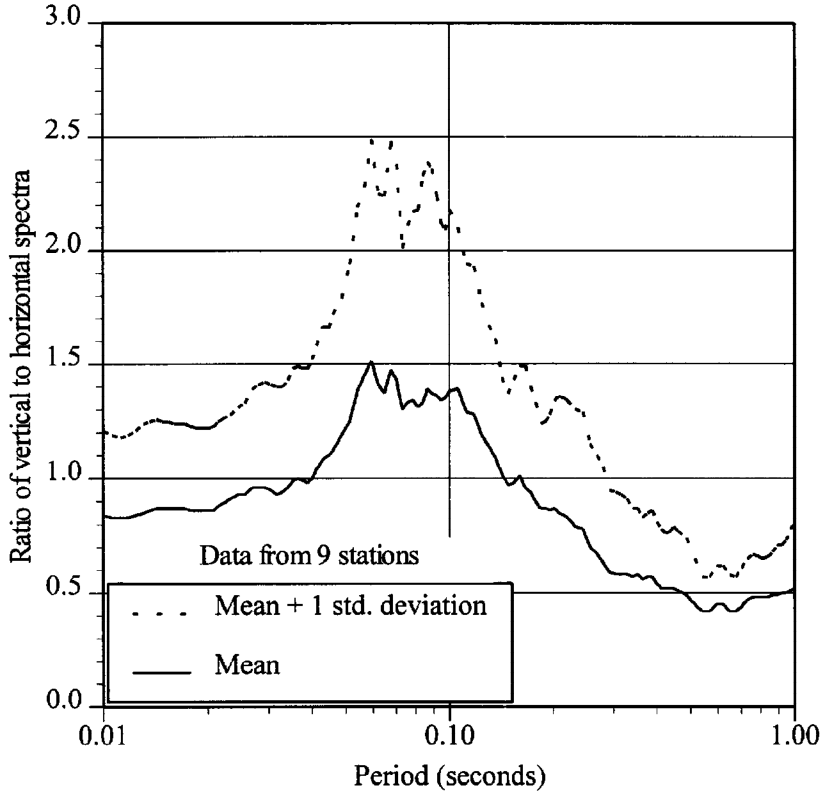

Fig. 4. Vertical to horizontal spectral ratio for distances between 5 and 10 kilometers

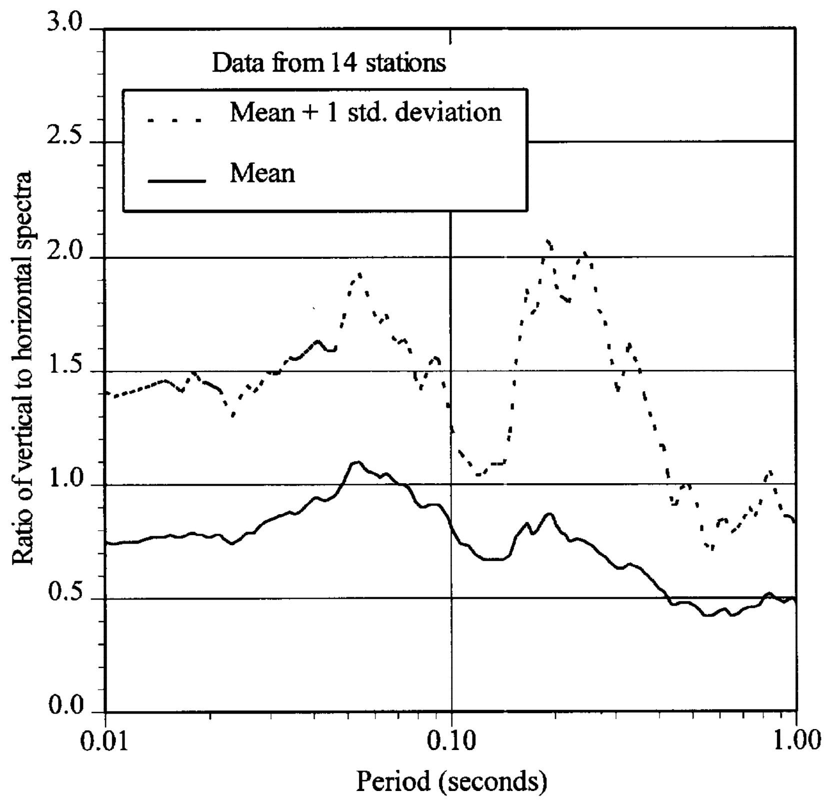

Fig. 5. Vertical to horizontal spectral ratio for distances between 10 and 20 kilometers

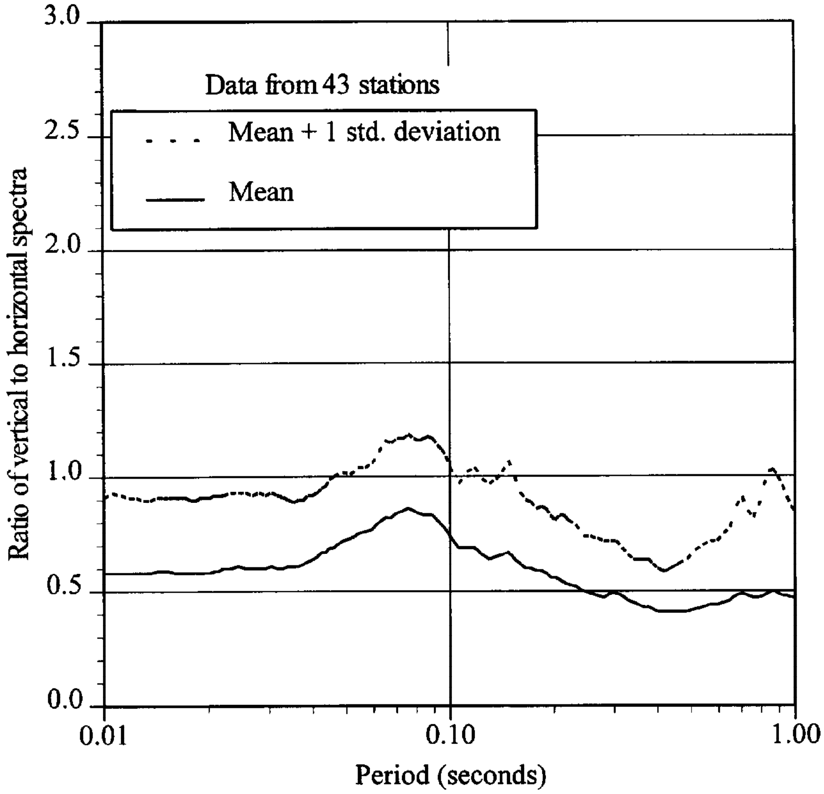

Fig. 6. Vertical to horizontal spectral ratio for distances between 20 and 40 kilometers

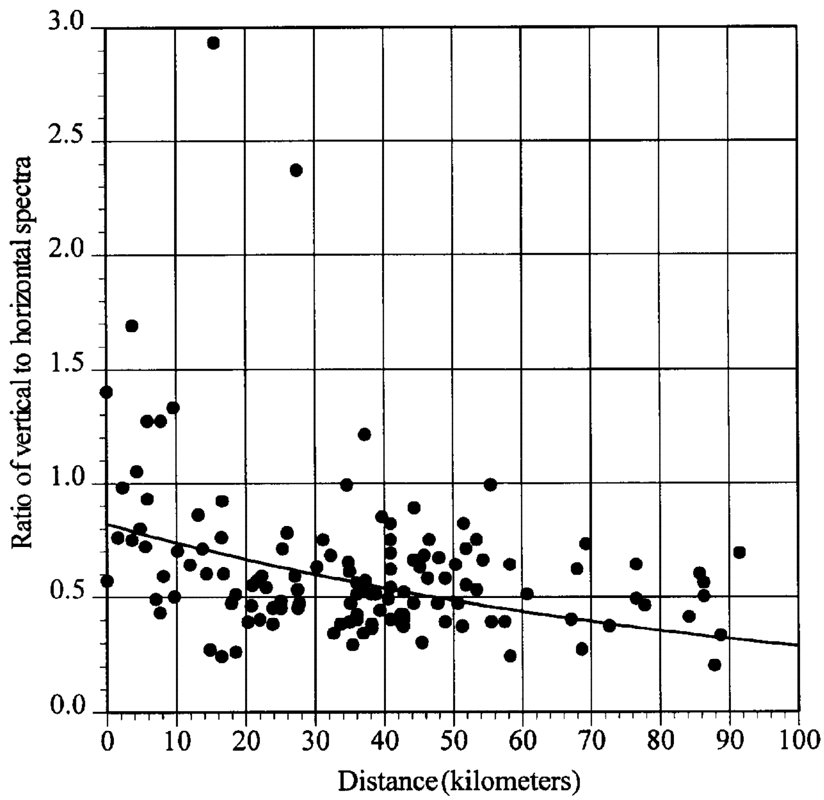

Fig. 7. Vertical to horizontal spectral ratio for period of 0.01 second

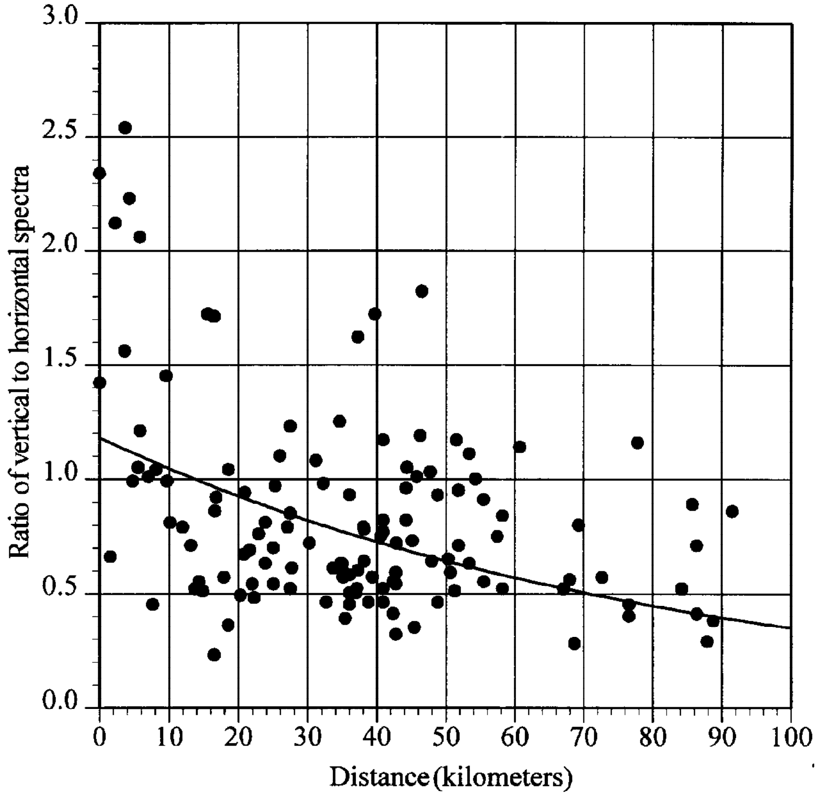

Fig. 8. Vertical to horizontal spectral ratio for period of 0.1 second

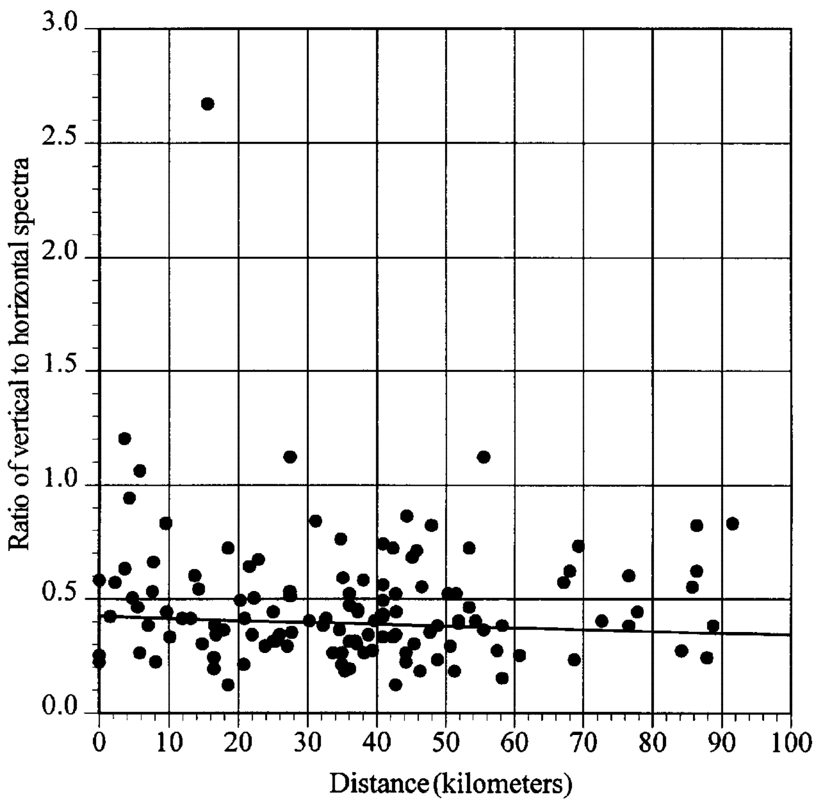

Fig. 9. Vertical to horizontal spectral ratio for period of 0.4 second

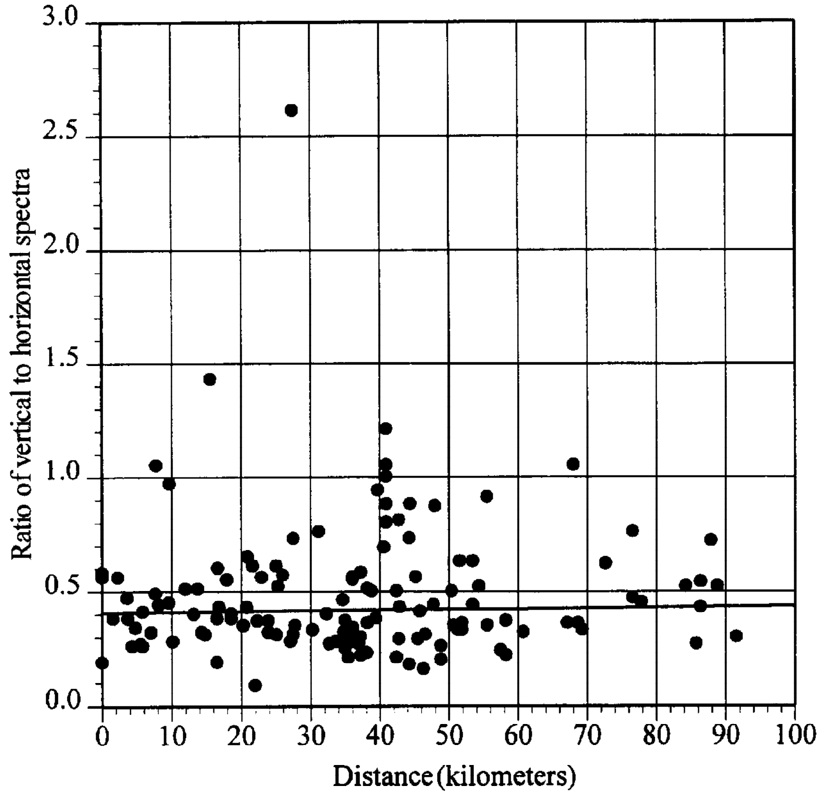

Fig.10. Vertical to horizontal spectral ratio for period of 1.0 second

greatest at periods from 0.04 to 0.08 seconds, with greater periods corresponding to greater distances from the fault.

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