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High Frequency Ground Motions by Regression and Simulation

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Several physical phenomena may contribute to control the amount of high frequency energy in the spectrum of strong ground motions. Preliminary reports on our considerations on these phenomena are reported in Anderson et al, (2000b, 2001). These phenomena include the total amount of geological slip on the fault causing the earthquake, the slip rate (or repeat time) of earthquakes on the fault, dynamics of fault rupture, lithology of the fault zone, whether the fault is in an extensional or compressional environment, and geometrical factors including whether or not the rupture reaches the surface. In this extended abstract, we present examples where several of these phenomena may be isolated and thus seem to play a role. These considerations are particularly relevant when considering the significance of ground motions from three large earthquakes that are well-recorded on strong motion accelerographs, for which the peak accelerations were surprisingly low. The first was the Michoacan, Mexico earthquake of Sept. 19, 1985 ($M_w=8.0$), where peak accelerations at four stations on rock directly above the fault had peak accelerations of 13-17 percent of gravity (Figure 1). The second is the Kocaeli, Turkey, earthquake of August 17, 1999 ($M_w=7.6$), where stations on rock within ~ 10 km of the fault recorded peak accelerations of 23-40 percent of gravity, a factor of two below predictions (Figure 2). The third is the ChiChi, Taiwan, earthquake of September 21, 1999, where peak accelerations at numerous sites with uncertain conditions were generally a factor of two smaller than regression models (Figure 3). These may represent the three best cases of near-fault strong ground motions from earthquakes with magnitudes over 7.5 on major, highly active faults. The low peak accelerations represent the fact that the amplitudes of the high-frequency end of the seismic spectrum are depleted, compared to extrapolations from smaller-magnitude earthquakes.

The low values in the Turkish events, compared with Landers (Figure 2) may be correlated with greater total slip on the North Anatolian fault (Figure 4). Wesnousky (1986) shows that faults with greater total slip have a smoother fault trace at the surface. It is reasonable that such smoothness could extend to depth also, and that a smoother fault would generate less high frequency energy. Alternatively, the low values in the Turkish events could be correlated with larger geological slip rates on the North Anatolian fault (Figure 5). Anderson et al (1996) found that faults with higher slip rates tend to have a lower static stress drop which, if correlated with lower dynamic stresses, could generate less high frequency energy.

The low values in Taiwan compared to the Kern County earthquake may result from softer lithology. At least near the surface, the Chulengpu fault is a bedding plane fault in a relatively soft shale layer. In contrast, the White Wolf fault occurs in granite. The softer material may result in less high frequency energy generation.

The low values in Mexico may result from characteristics of fault dynamics. In Figure 6, the stress drop parameter used in the composite source model of Yu (1994) and Zeng et al (1994) is shown for several large Guerrero earthquakes. Assuming these events are all on the main subduction thrust, the lithology, total slip, and slip rates are common for all events, and the main remaining variable would be rupture dynamics.

All of these correlations are admittedly anecdotal. More work needs to be done by looking at more earthquakes in order to determine which if any of these trends continues to be supported. Other physical phenomena also may differ from one of these events to another. In summary, many factors affect high frequencies, and much more data is needed before we can conclude that we understand the general case. Before we attribute differences in high frequencies to one effect, we need to consider other potential factors.

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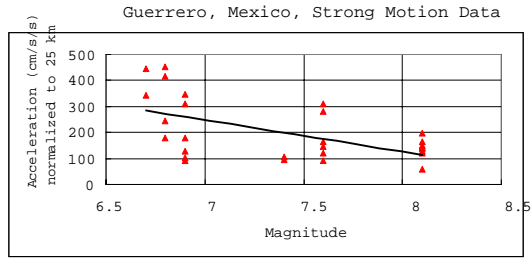
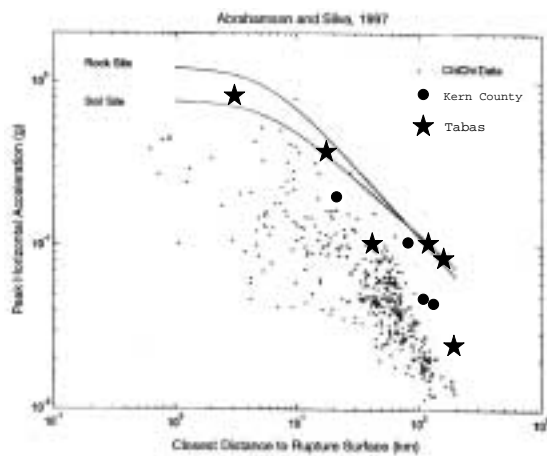


Figure 1. Peak accelerations recorded in Guerrero, Mexico, on the Guerrero accelerograph network from several earthquakes.



Peak accelerations recorded in the ChiChi, Taiwan, earthquake of 1999, the Tabas, Iran earthquake of 1978, and the Kern County, California, USA, earthquake of 1952 (from Anderson et al, 2000).

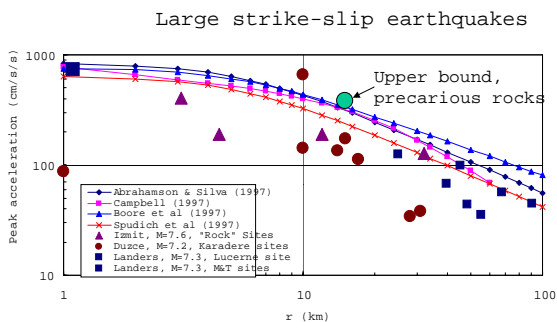


Figure 3. Peak accelerations recorded on rock sites in the 1992 Landers, California, earthquake and the two large Turkish earthquakes of 1999.

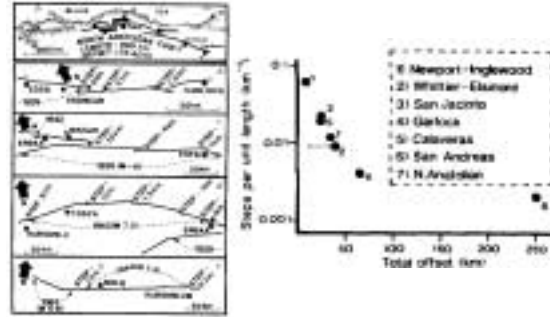


Figure 4. Relationship of irregularities of surface trace of strike-slip faults and the total offset of the fault over geological time (Wesnousky, 1986).

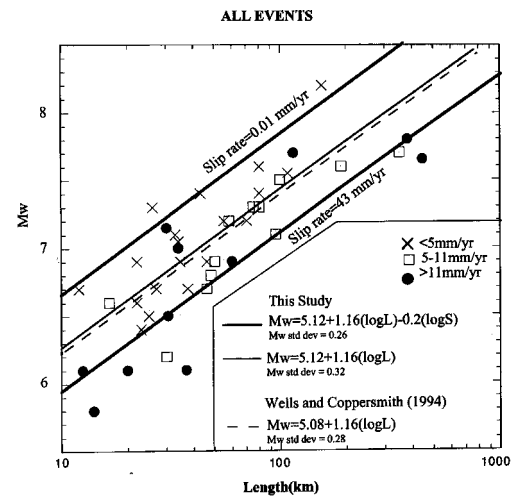


Figure 5. Relationship between length of fault rupture and magnitude of the resultant earthquake, showing dependence on the average geological slip rate (from Anderson et al, 1996).

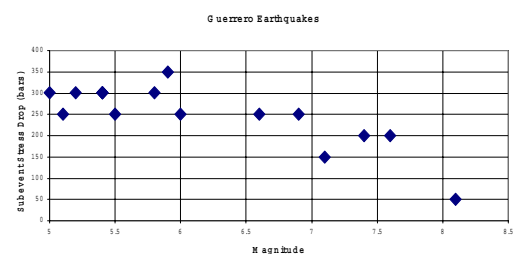


Figure 6. Subevent stress drop in the composite source model for several earthquakes recorded in Guerrero, Mexico (Johnson, 1998).