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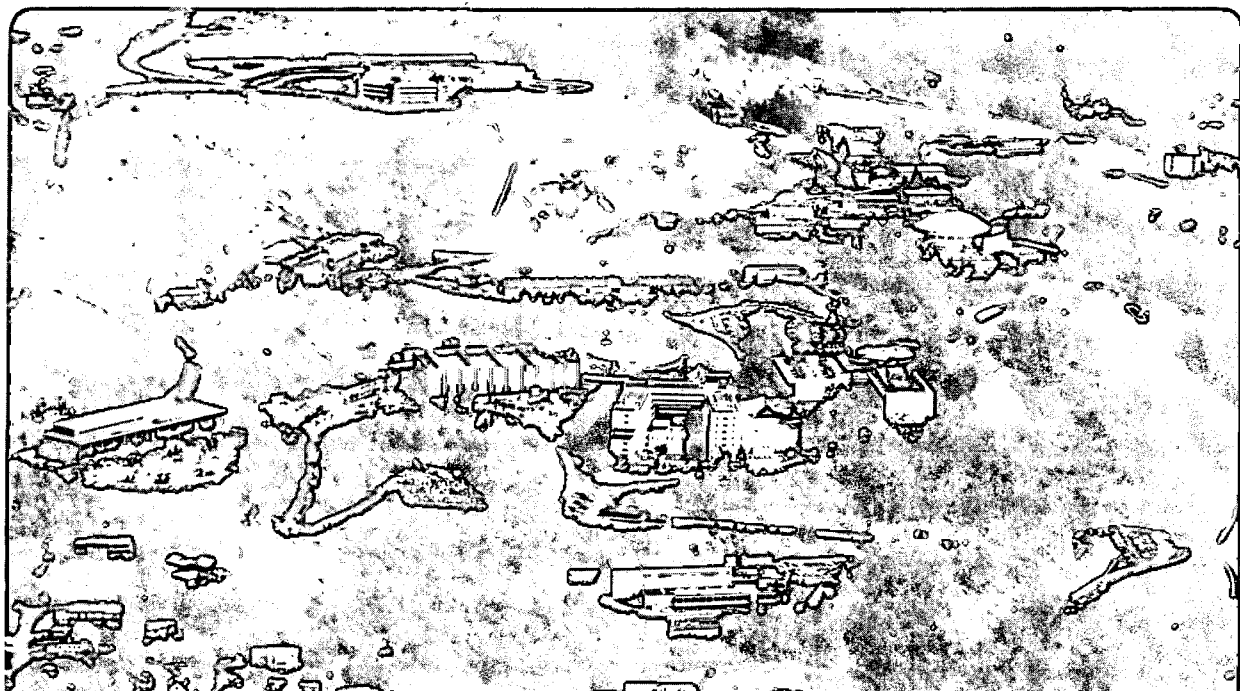
STRONG SEISMIC GROUND MOTION FOR DESIGN PURPOSES
AT THE LAWRENCE BERKELEY LABORATORY

B.A. Bolt

July 1979

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STRONG SEISMIC GROUND MOTION FOR DESIGN PURPOSES
AT THE LAWRENCE BERKELEY LABORATORY

By

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University of California, Berkeley

July 10, 1979

for

Engineering and Technical
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STRONG SEISMIC GROUND MOTION FOR DESIGN PURPOSES
AT THE LAWRENCE BERKELEY LABORATORY

Bruce A. Bolt, Seismographic Station, UCB

1. Purpose

This work is in response to a request from Lawrence Berkeley Laboratory to provide a design earthquake ground motion for the LBL site. The prescribed earthquakes are for use for equipment design and for determining the response of other structures to earthquakes.

As requested, the required ground motions correspond to what has been called "a maximum credible earthquake" or, in other words, the strongest shaking in the range of engineering interest, which is physically feasible at LBL, given local earthquake sources and geological conditions. The task does not involve stating ground motions for various probabilities of occurrence in specified time intervals.

For a number of reasons, but specially the close proximity to the Hayward Fault and the steep topography of the site, considerable judgment is needed to synthesize appropriate accelerograms and other related ground motions. Most routine estimates of this kind follow simple methodologies which simply provide a "peak acceleration" as a scale factor for a response spectrum or time history obtained under as similar circumstances as possible. Unfortunately, no strong motion record has been obtained within a few kilometers of a major fault rupture such as occurred on the Hayward Fault in 1868. There is reason to believe that in the very near field of the source the ground motion will possess special characteristics (Bolt, 1972; 1978) which cannot be accounted for by using an accelerogram recorded at a distance and adopting a high frequency peak as a scaling parameter.

The accelerogram finally synthesized (Figure 1) was supplied to Mr. Don Eagling on February 15, 1979, and used, under the name BOLTQUAKE in tests of shaking on the proposed HVEM foundation block (Godden, 1979).

2. Hayward Fault Earthquake Parameters

LBL is within a kilometer of the active Hayward Fault zone. The most intense shaking of the site would no doubt come from a major rupture of the Hayward Fault.

In historical times, two large earthquakes have been reported centered on the Hayward Fault. The first, on June 10, 1836, was reported associated with "fissures" on what is now called the Hayward Fault. Strong shaking with damage occurred as far away as Monterey. The second earthquake, on October 21, 1868, has been described in some detail (Lawson, 1908). The Hayward Fault ruptured at least from Berkeley to near Mission San Jose, a distance of 20 to 30 miles. There was considerable damage in San Jose, Hayward, Oakland, and San Francisco.

Estimation of the size of this earthquake, which we can take as nearly the maximum credible earthquake for the LBL studies, depends upon six main items of evidence: fault rupture length about 40 km, fault offset less than 80 cm, felt duration (not bracketed) about 40 secs, no tsunami, maximum intensity IX, extent of felt area (no reports north of Chico or south of Monterey). Based upon these observations, the local magnitude of the earthquake was almost certainly between $6\frac{3}{4}$ and $7\frac{1}{4}$. I would favor a value near magnitude 7.0 for 1868 and $7\frac{1}{4}$ for 1836.

In setting earthquake parameters for the construction of ground motions at LBL, it is therefore appropriate to use values consistent with the above two sources. We therefore consider waves being produced by a right-lateral strike-slip dislocation of the Hayward Fault at depths of from zero to 15 km.

The earthquake generated is taken to have a magnitude of between 6-3/4 and 7-1/4.

3. Synthesis of Hayward Fault Time Histories

Based upon the requirements of the last section, earthquake ground motions (horizontal component) were constructed that satisfied simultaneously a number of criteria.

1. A peak ground acceleration at frequencies less than 10 Hz of about 0.7g.
2. A peak ground velocity of about 100 cm/sec.
3. A peak displacement associated with the seismic waves (i.e., not "static" displacements such as landslides) of about 50 cms.
4. A bracketed duration of acceleration above 0.05g at frequencies less than 10 Hz of 20 to 30 secs.
5. An interval between the P and S wave onsets of about 5 secs, corresponding to a focal distance of 25 kms.
6. A longer period pulse following the S wave arrival that models the "fling" of the fault rebound as the rupture goes by the site.
7. A pseudo-velocity spectrum (2 per cent damping) that resembles in shape and level similar spectra obtained by combining seismic ground motions from many sources (Housner and Jennings, 1964).

These criteria represent a magnitude 6-3/4 to 7-1/4 earthquake in the vicinity of Berkeley produced by rupture of the Hayward Fault. The values in 1, 2, 3, and 4 above are extrapolations from available strong motion records obtained for the largest earthquakes elsewhere ($M \leq 7.2$) nearest to their fault sources.

The Pacoima strong motion in the 1971 San Fernando earthquake is one of the components of this assessment, with allowance for the different mechanisms involved (thrust faulting in 1971 compared to strike-slip on the Hayward Fault) and the effect of topography. (The Pacoima site was the top of a ridge while LBL is on the side of the hill - see Smith, 1975.)

The acceleration, velocity, and displacement records were built up by first drawing general envelopes with the required shape, amplitudes, and duration. Then 20 term Fourier series were used to represent the wave motion within these envelopes. The coefficients of the sine and cosine terms were varied in order to obtain allowable spectra for frequencies from 8 to 0.5 Hz and phase relations that modelled the P and S onsets, the fling pulse, and the decaying coda. Finally, additional higher frequency motion was superimposed to produce a more realistic "looking" accelerogram (i.e., one with a more continuous energy distribution through all frequencies of concern).

From the suite of records thus obtained, the records reproduced in Figure 1 were selected as meeting the criteria 1 to 7. It should be mentioned that, as is well-known, the high frequency peak of acceleration can be changed by 10 per cent or so without significantly changing the spectral curves or the overall energy.

4. Results

The ground motions for LBL constructed for a Hayward Fault earthquake, shown in Figure 1, were supplied as a card deck to LBL in February 1979. The peak acceleration (horizontal shaking) is 0.70g. The peak velocity is 90 cm/sec and the peak displacement is 54 cm.

Various spectra of engineering interest were also computed for damping of 2, 5, 10, and 20 per cent. Figures 2-4 show the displacement, velocity, and acceleration response spectra and Figure 5 shows the pseudo-velocity spectrum.

These representations were compared with various published time-histories and spectra. In general the generated motions are quite consistent with spectral energy and duration of shaking that have been observed elsewhere. In addition, the method of construction, based on general seismological theory of mechanisms, makes it very likely that the synthetic ground motions predict closely shaking that would be actually recorded on the weathered rock at the LBL site in a repetition of the 1868 earthquake.

It should be noted that the time-histories represent horizontal ground motions. The vertical component of shaking would be rather different in detailed appearance (the absence of "fling") with lower peak amplitudes but richer in higher frequencies. The maximum vertical component amplitude would probably be no more than 0.4g at frequencies equal to or less than 10 Hz.

5. References

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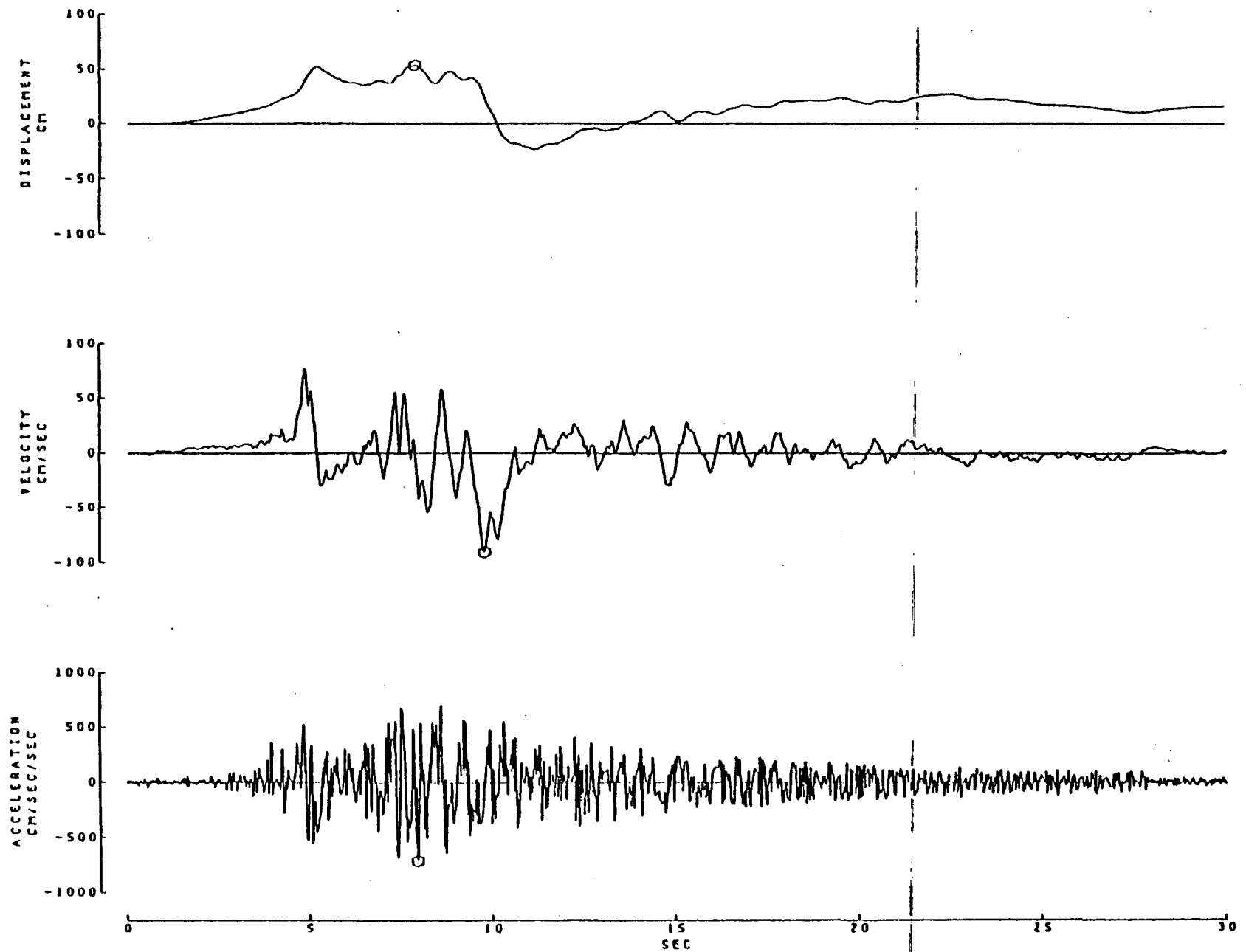


FIGURE 1. Hayward fault seismic ground motion (horizontal component). Time histories of displacement, velocity and acceleration.

DISPLACEMENT RESPONSE SPECTRUM

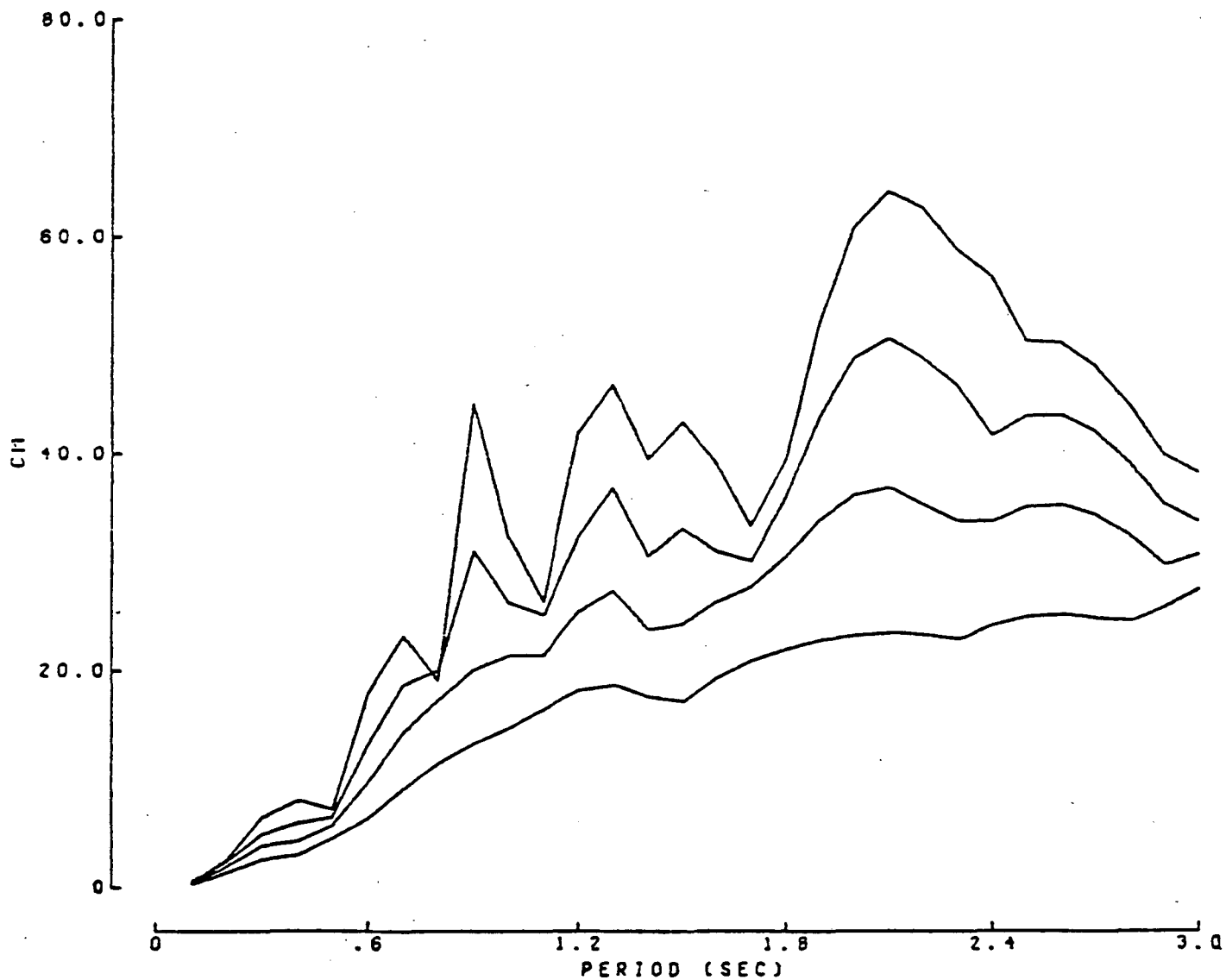


FIGURE 2. Hayward fault seismic ground motion (horizontal component). Displacement response spectrum (from top: 2, 5, 10 and 20 per cent damping).

VELOCITY RESPONSE SPECTRUM

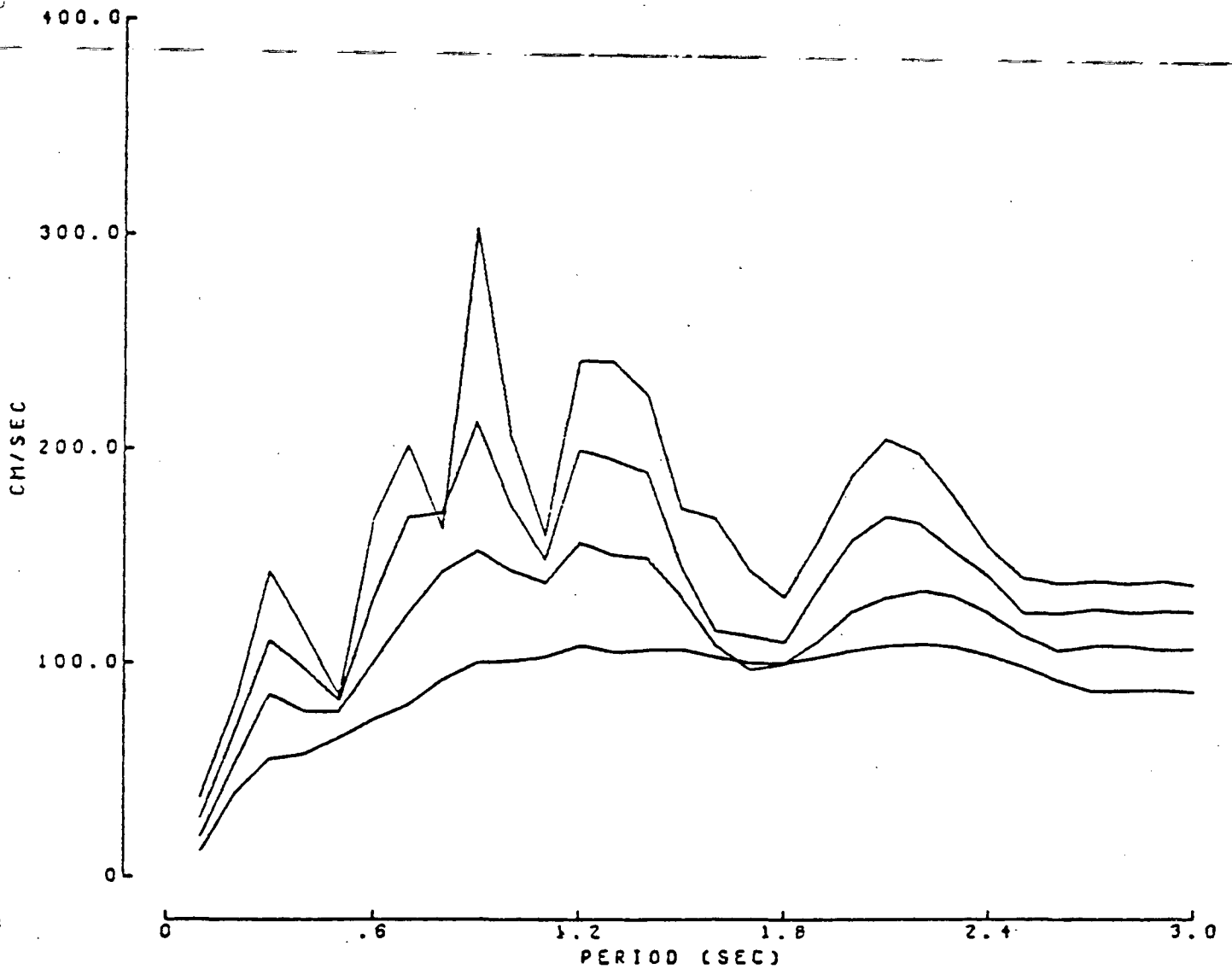


FIGURE 3. Hayward fault seismic ground motion (horizontal component). Velocity response spectrum (from top: 2, 5, 10 and 20 per cent damping).

ACCELERATION RESPONSE SPECTRUM

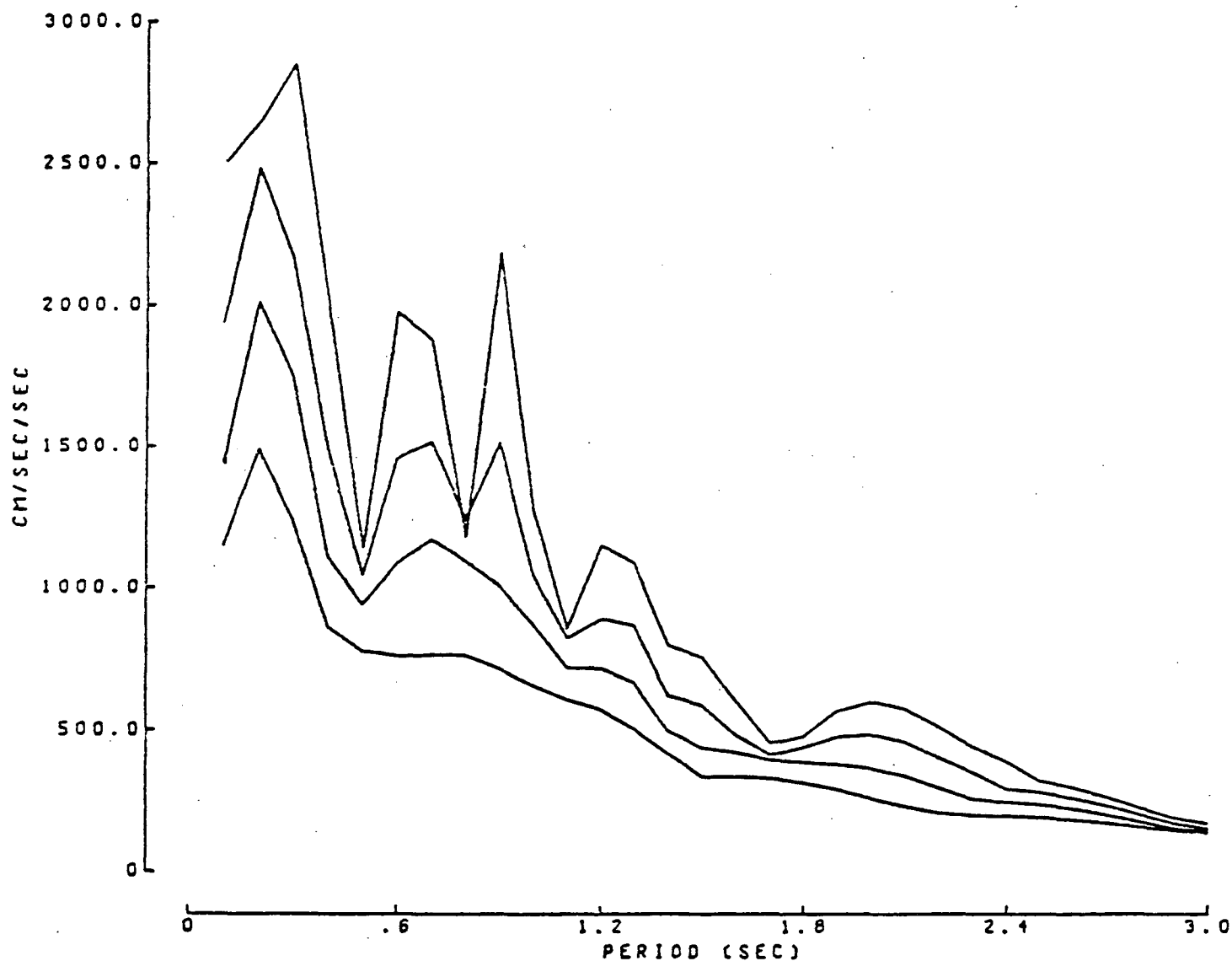


FIGURE 4. Hayward fault seismic ground motion (horizontal component). Acceleration response spectrum (from top: 2, 5, 10 and 20 per cent damping).

PSEUDO-VELOCITY SPECTRUM

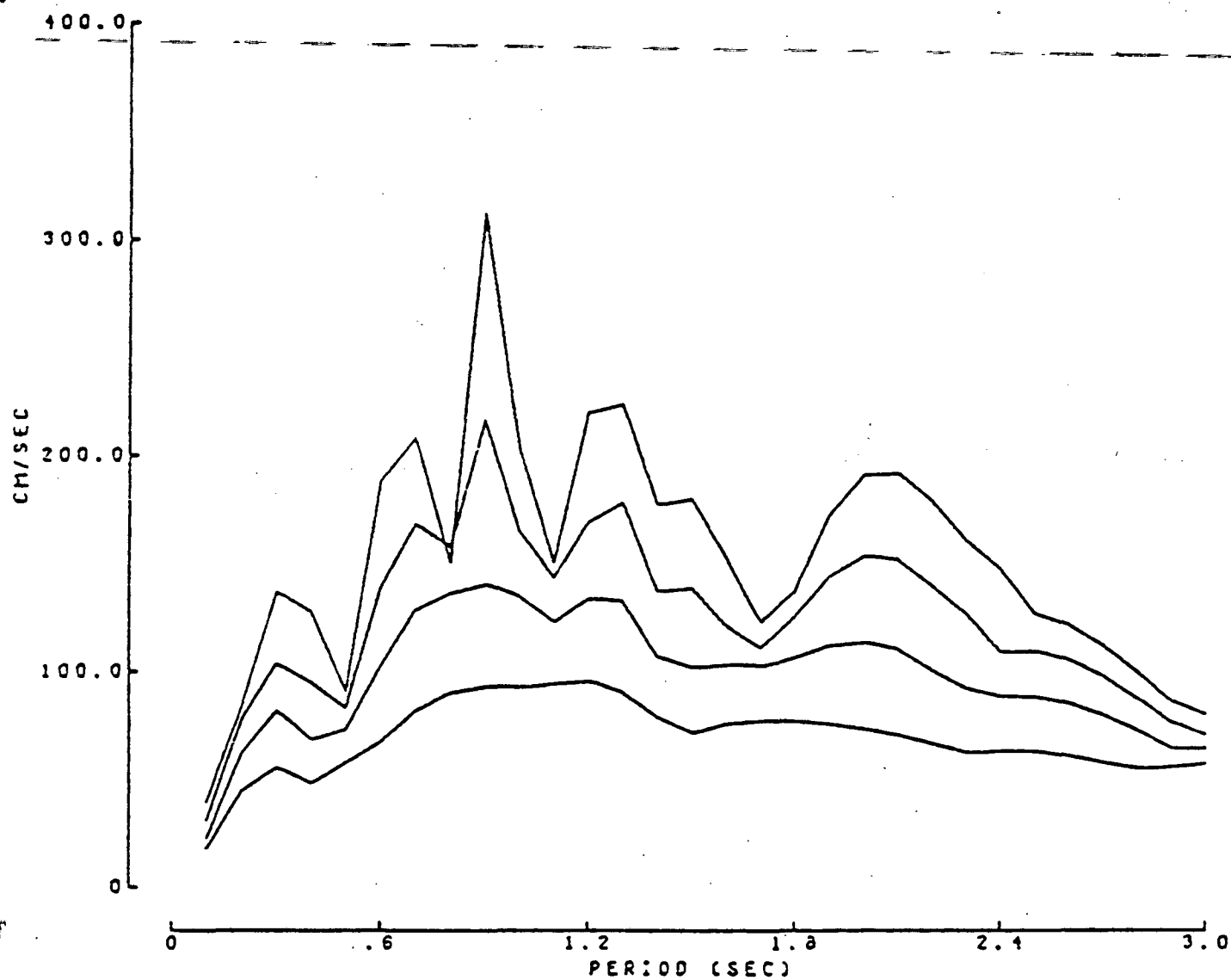


FIGURE 5. Hayward fault seismic ground motion (horizontal component). Pseudo-velocity spectrum (from top: 2, 5, 10 and 20 per cent damping).

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