

PROCESSING OF 9WCEE STRONG MOTION  
WORKSHOP TEST RECORDS BY CSMIP

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Five test records of the Second Workshop on Processing Strong Motion Records were processed by the California Strong Motion Instrumentation Program (CSMIP). Although the records may not be similar in noise characteristics and other aspects to the records which CSMIP normally processes from its 500 station network, standard processing was used for the purposes of the workshop. The CSMIP post-digitization processing is similar in many respects to that first used by the California Institute of Technology (Trifunac and Lee, 1973). The primary difference involves the selection of filter frequencies through analysis of the signal-to-noise ratio (SNR) and the noise spectrum of the digitizing system. In addition, attempts have been made to standardize procedures so that the large number of records recorded by the CSMIP network can be processed and distributed to users in a consistent manner. In general, filter selections are made conservatively, since distributing data with significant noise contamination is judged worse, for an average data user, than distributing data in which some signal has been lost in ensuring that most of the noise has been removed.

STANDARD CSMIP POST-DIGITIZATION PROCESSING

The CSMIP post-digitization processing of strong motion records has four principal steps:

Step 1. Baseline Correction and Correction for Instrument Response. The raw acceleration data are interpolated to obtain exactly 200 points/second (100 Hz Nyquist frequency). These data are then corrected for instrument response using a simple finite-difference operator. Following instrument correction, a high-frequency filter with a corner frequency at 23 Hz and a termination frequency at 25 Hz is applied. The data are then decimated to 50 points/second (25 Hz Nyquist), the standard sampling rate in which the data are finally distributed to CSMIP data users. The instrument correction is performed prior to decimation to improve the high-frequency accuracy of the instrument correction procedure (Shakal and Ragsdale, 1984).

The acceleration data computed are then high-pass filtered using an initial low-frequency filter set at 0.05 to 0.07 Hz (periods beyond about 16 seconds are filtered out). This is the standard maximum bandwidth used in CSMIP processing. Velocity and displacement are obtained by integrating the acceleration and filtered using the same low-frequency filter. To prevent introducing spurious long-period energy through aliasing, an Ormsby filter rather than a running mean filter is used prior to the decimation associated with the long-period filtering (Shakal and Ragsdale, 1984).

Step 2. Computation of Response Spectra. The pseudo-velocity (PSV) response spectra for periods from 0.04 to 15 seconds and damping values of 0, 2, 5, 10 and 20% are calculated from the accelerations obtained in Step 1 and plotted from 0.04 to 15 seconds (the maximum bandwidth) for use in filter selection.

Step 3. The filtering of Step 1 is repeated, but with a range of low-frequency filters selected by studying the signal-to-noise ratio of the record. The long-period intersection of the PSV spectrum obtained in Step 2 and the CSMIP system average noise spectrum (Shakal and Ragsdale, 1984) is used to indicate the long-period limit of useful information in the record. The final value of the filter corner to be used is selected after studying the resulting suite of displacement plots, comparing them to one another and to displacement plots computed from noise records. Present CSMIP procedure is to choose a filter frequency at which the signal-to-noise ratio (SNR) is 3 or greater, depending on the record. (In general, the filter used is an Ormsby filter; the width of the filter ramp is set to be a factor of two in frequency, for example, 0.10 to 0.20 Hz, 0.25 to 0.50, etc.).

Step 4. Final Output Preparation. The acceleration, velocity and displacement time histories obtained using the final filter are plotted for presentation in reports and saved on magnetic media. The response spectra are plotted with tripartite logarithmic scaling. Current CSMIP practice is to plot spectra only within the bandwidth of the final filter. Thus, spectral values at periods beyond the long-period filter are not plotted.

#### SPECIAL PROCESSING OF WORKSHOP TEST RECORDS

The workshop test records were processed according to standard CSMIP procedures for the most part. The most significant difference is that the noise spectra for the digitization systems and instruments, key information in the filter selection in Step 3, are not available. Less importantly, Records 2 and 5 were processed with a length of 80 seconds rather than 120 seconds because of record length limits used by CSMIP. No significant effects on the processing results are expected from this record length reduction.

Presentation. For each test record, the results are plotted in a series of three plots, denoted a, b and c. For example, Fig. 1a shows the acceleration data and the computed velocity and displacement scaled according to workshop guidelines. Fig. 1b shows the data of Fig. 1a replotted with a time range of 0 to 3 seconds, also according to guidelines. Finally, Fig. 1c shows the response spectra computed for record 1. (The limits of the plot correspond to the standard CSMIP plot, but scaling is adjusted to 5 cm/cycle, according to workshop guidelines, so that the plots can be overlaid.)

Record 1. As distributed, Record 1 has a significant zero-axis offset, visible in the plot of the original record in Fig. 1a. This was removed prior to any processing. The record was processed in the standard method, including instrument correction, except that the natural frequency was set artificially high (200 Hz) so the instrument correction would have no impact. The response spectrum appeared anomalous or noise-like beyond about 2 seconds, so a filter setting of 0.4 to 0.8 Hz was selected, filtering out periods beyond about 1.5 seconds. The computed acceleration in the expanded plot (Fig. 1b) appears ragged because of the CSMIP standard output sample rate of 50 points/second.

Record 2. The instrument natural frequency given for Record 2 (7.14 Hz) is quite low compared to that of a typical CSMIP network record. To extend the high-frequency instrument correction up to 25 Hz, as usual, is inappropriate. It was decided to terminate the high frequency calculations at twice the natural frequency, or about 14 Hz.

Record 3. This record was processed in a manner quite similar to our normal procedures. A final long period filter at 0.08 to 0.16 Hz was selected (periods longer than about 7 seconds filtered out).

Record 4. This record was processed with the same filter as Record 3, and a very similar result was obtained, but time is shifted by about 1 second.

Record 5. A long-period filter at 0.08 to 0.16 Hz (periods beyond about 7 seconds filtered out) was selected because the response spectrum appears to show a characteristic noise shape beyond about 9 seconds. This choice is made without actual knowledge of the noise characteristics of the digitization system and instrument, however.

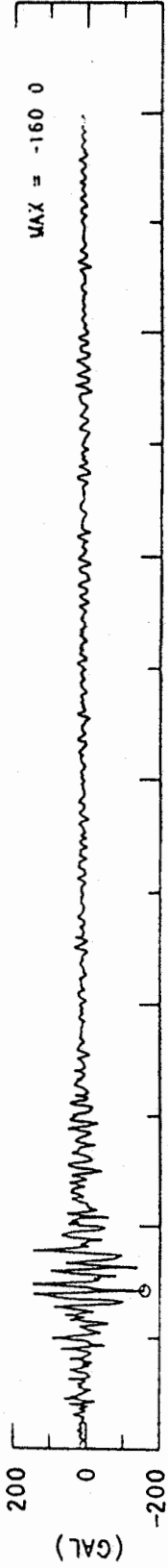
#### References

Shakal, A.F. and J.T. Ragsdale, 1984, Acceleration, velocity and displacement noise analysis for the CSMIP accelerogram digitization system, Proceedings of the 8th World Conference on Earthquake Engineering, Vol. 2, p. 111-118.

Trifunac, M.D. and V.W. Lee, 1973, Routine computer processing of strong-motion accelerograms, Earthquake Engineering Research Laboratory, Report EERL 73-03, California Institute of Technology, Pasadena.

ORIGINAL ACCELERATION

CSMIP/Shakal et al.



FILTER BAND: 40- .80 TO 23.0-25.0 HZ.

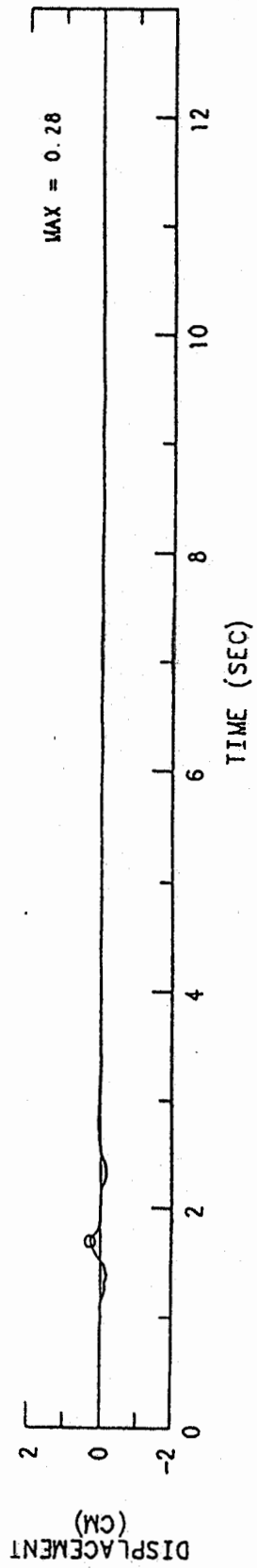
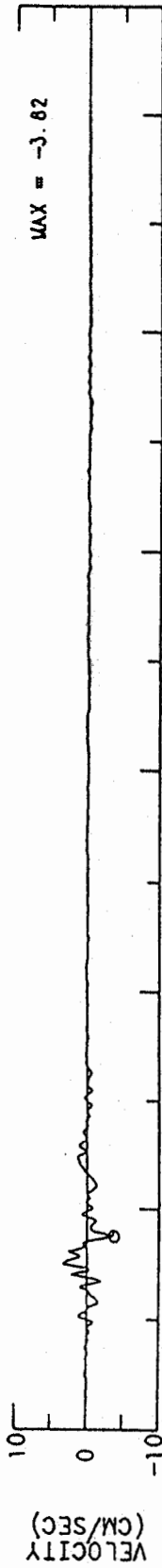
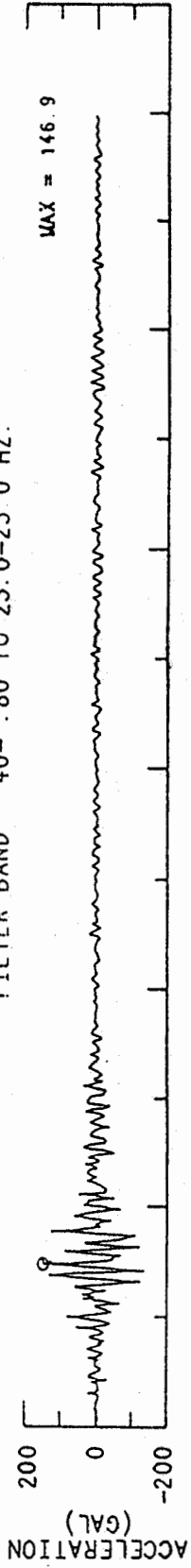
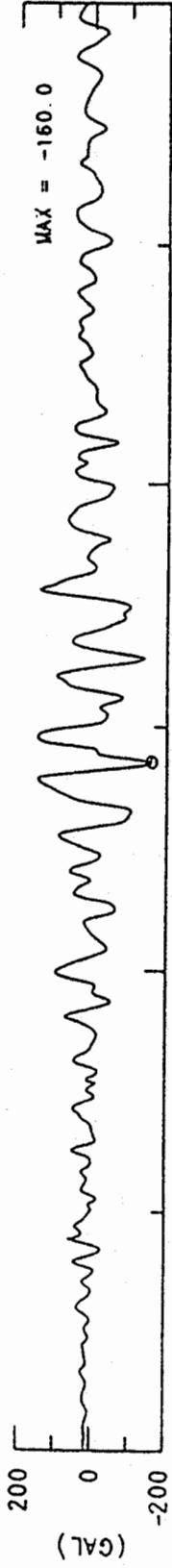


Figure 1a. Original acceleration with baseline-corrected acceleration, velocity, and displacement for Record 1.

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ORIGINAL ACCELERATION



FILTER BAND: 40- .80 TO 23.0-25.0 HZ.

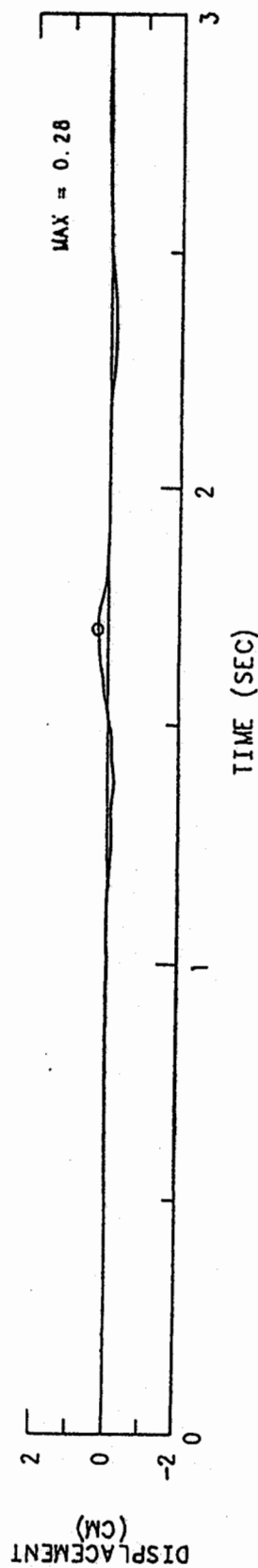
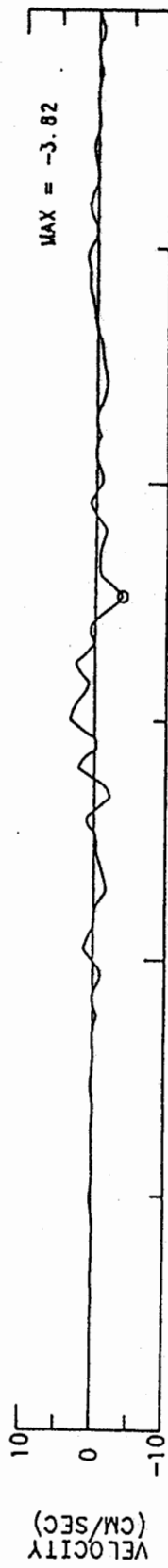
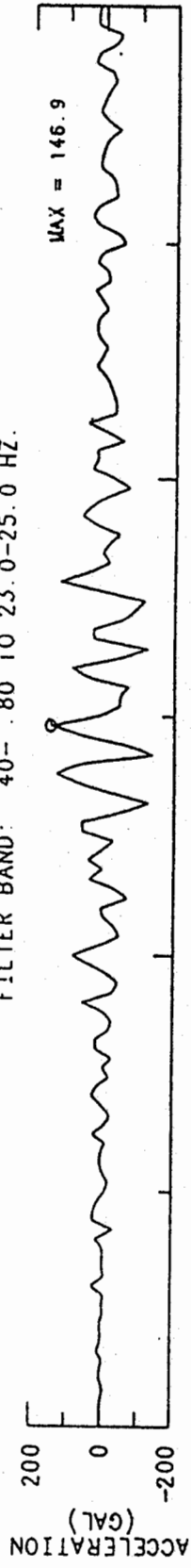


Figure 1b. Figure 1a replotted from 0 to 3 seconds.

ACCELEROGRAM BANDPASS-FILTERED WITH RAMPS AT .40-.80 TO 23.0-25.0 HZ.

— RESPONSE SPECTRA: PSV, PSA & SD  
 DAMPING VALUES: 0.2.5 %

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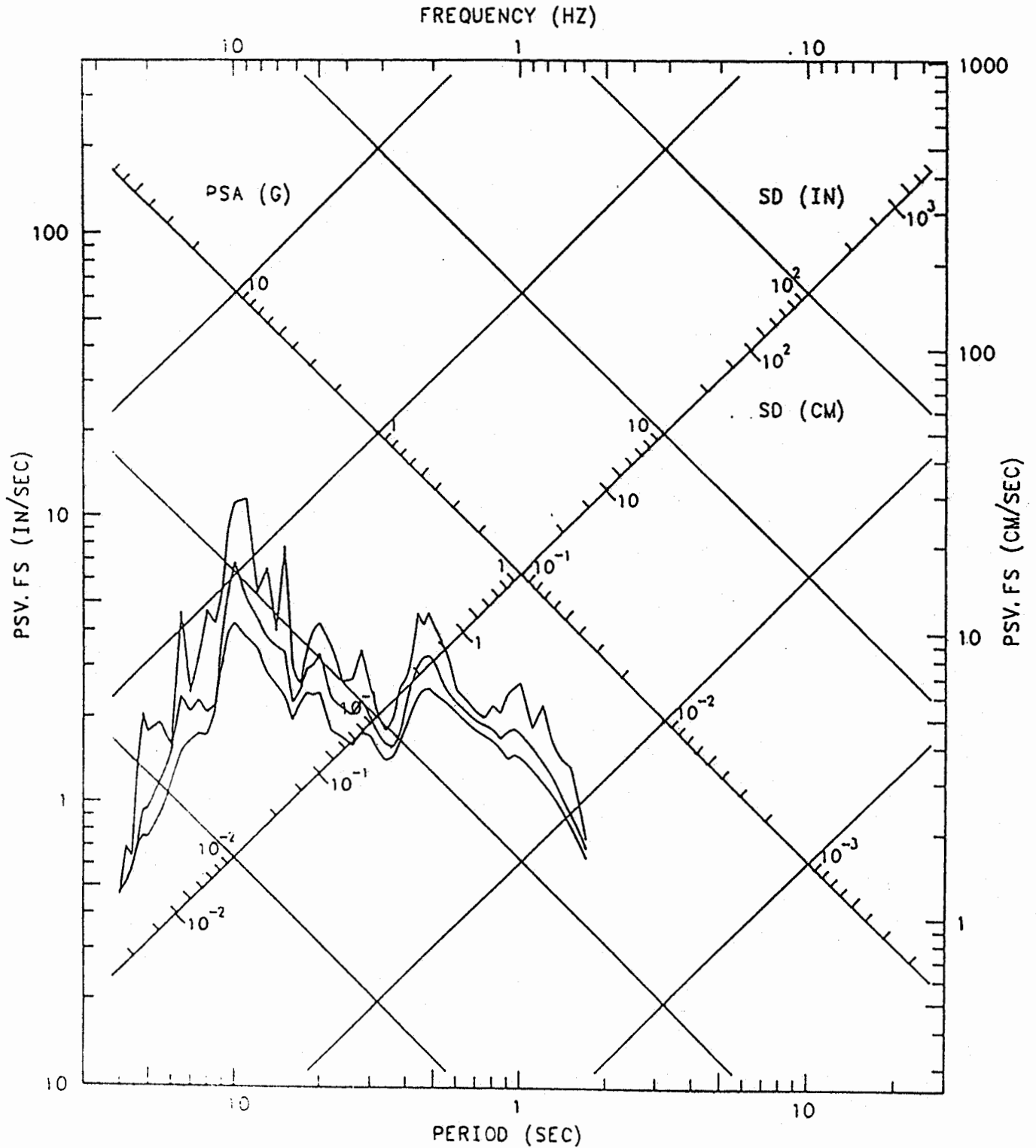
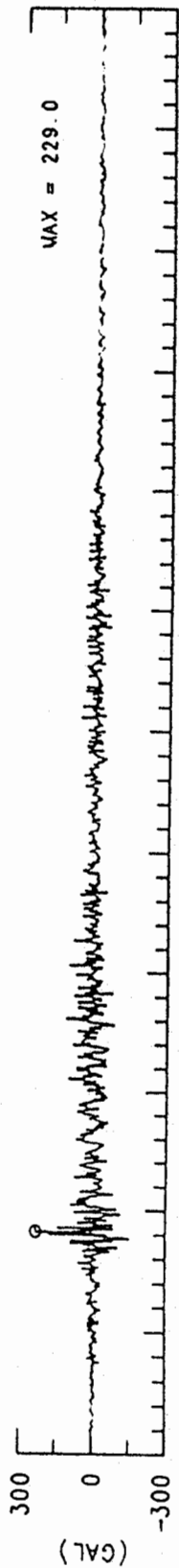


Figure 1. Response spectra for Result 1

ORIGINAL ACCELERATION



FILTER BAND: 08- .16 TO 13.0-15.0 HZ.

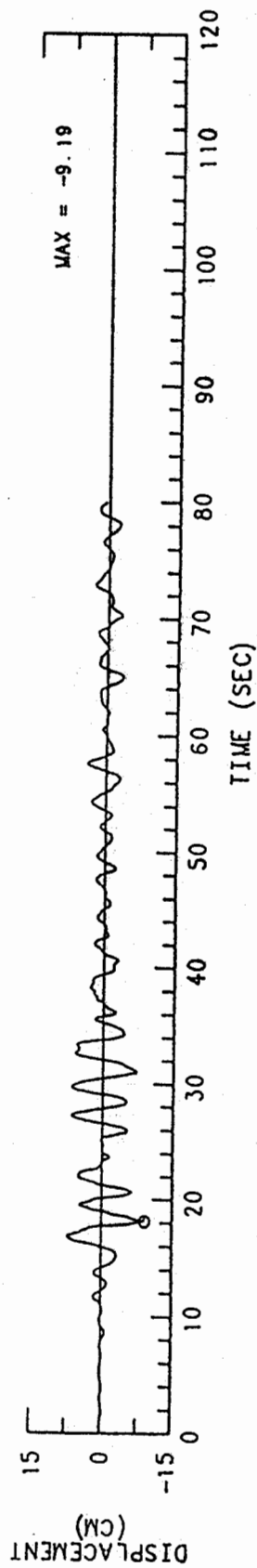
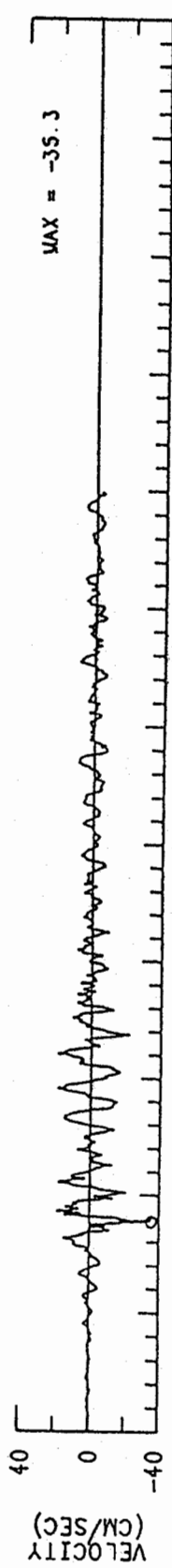
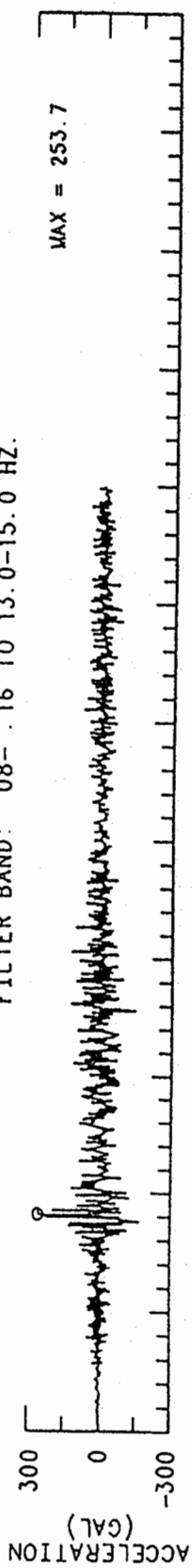
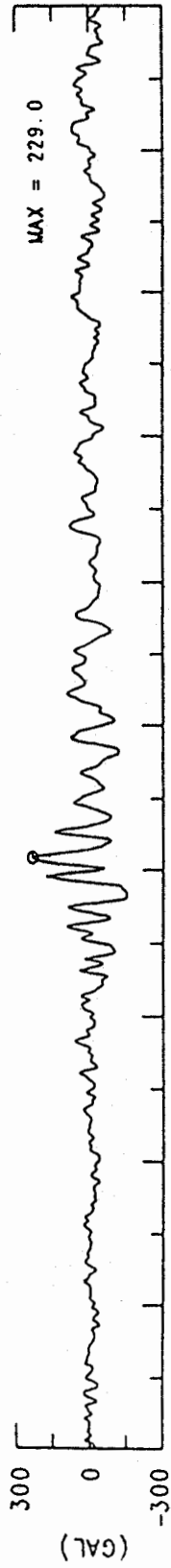


Figure 2a. Original acceleration with instrument-corrected acceleration, velocity, and displacement for Record 2.

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ORIGINAL ACCELERATION



FILTER BAND 08- .16 TO 13.0-15.0 HZ.

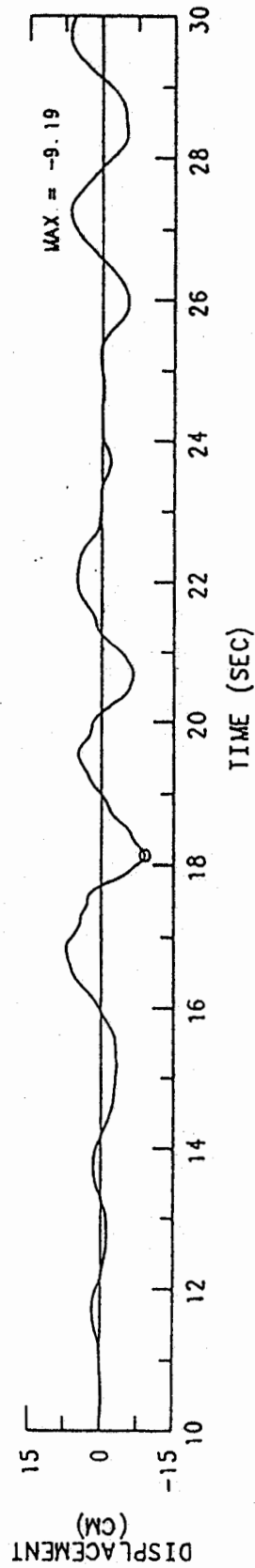
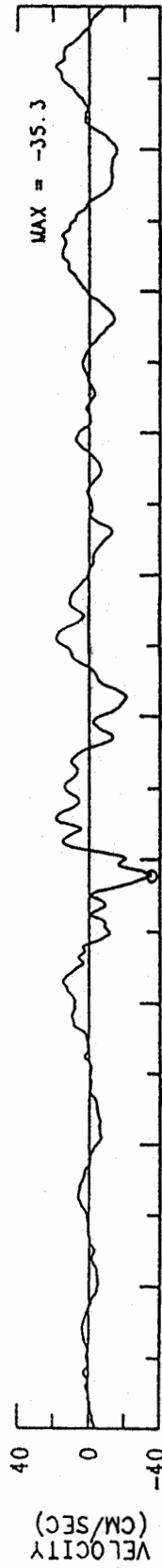
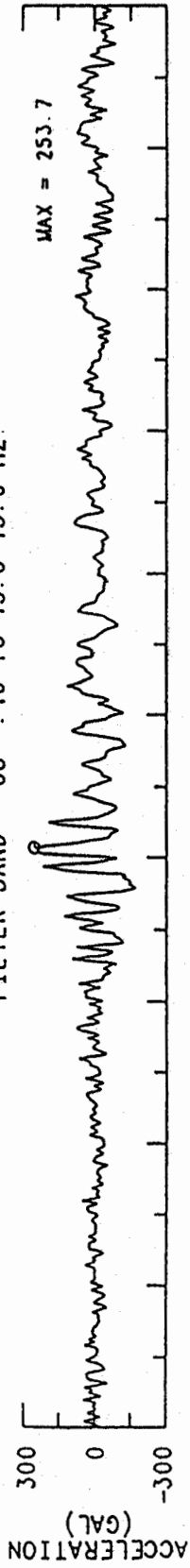


Figure 2b. Figure 2a replotted from 10 to 30 seconds.

## ACCELEROGRAM BANDPASS-FILTERED WITH RAMPS AT .08-.16 TO 13.0-15.0 HZ.

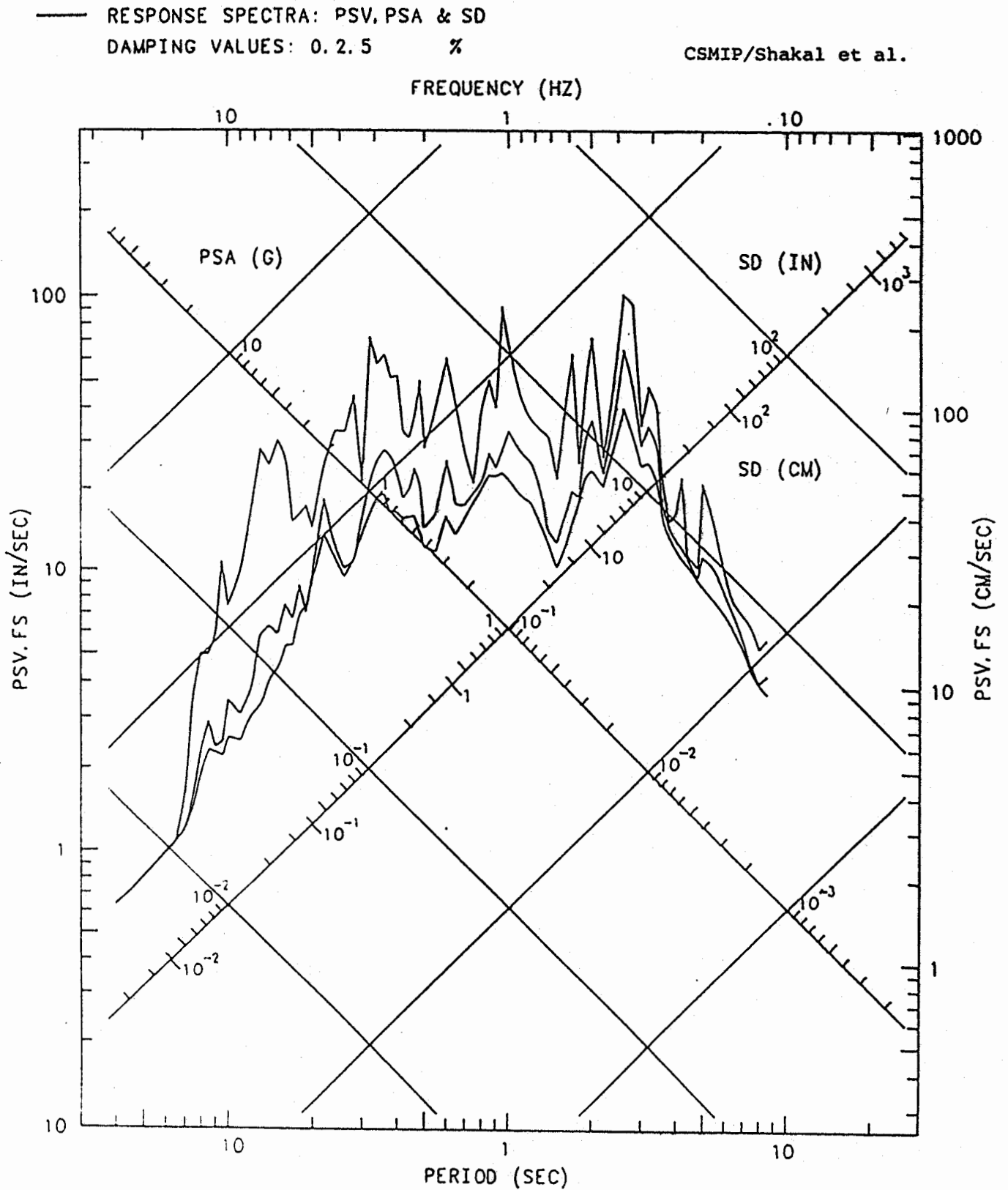
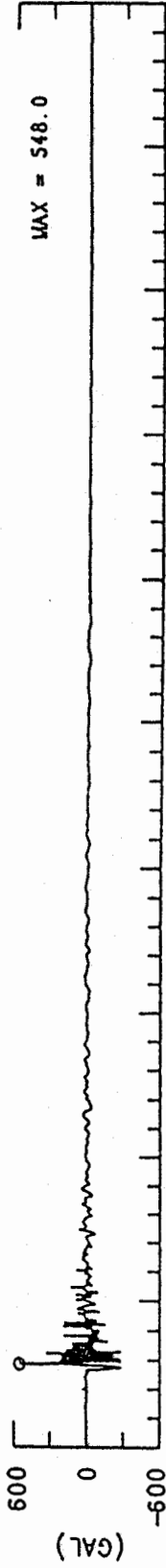


Figure 2c. Response spectra for Record 2.



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ORIGINAL ACCELERATION



FILTER BAND: 10- .20 TO 23.0-25.0 HZ.

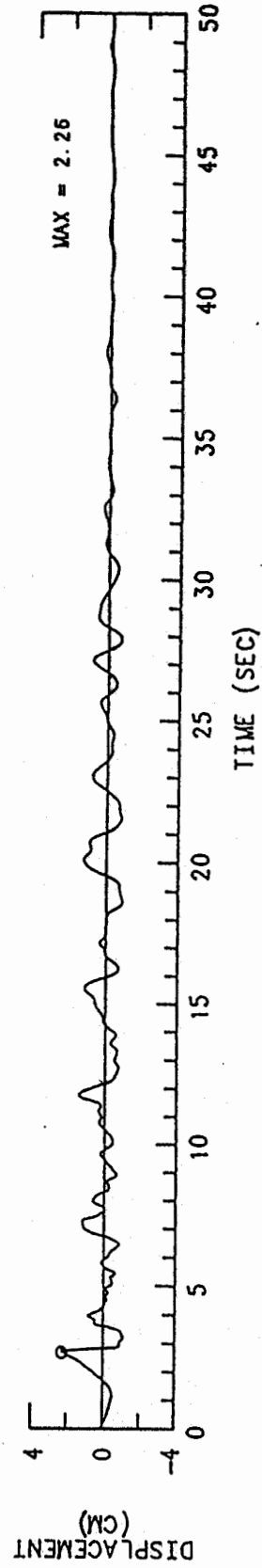
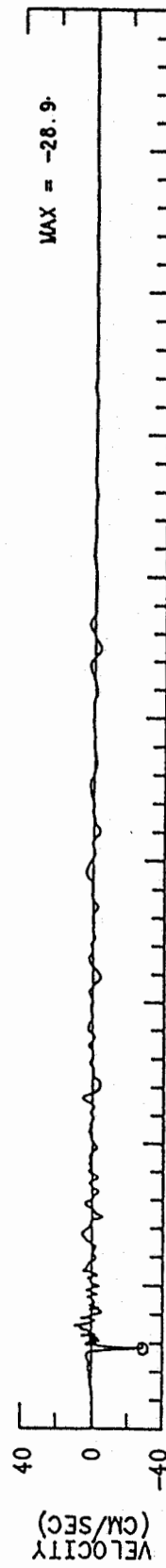
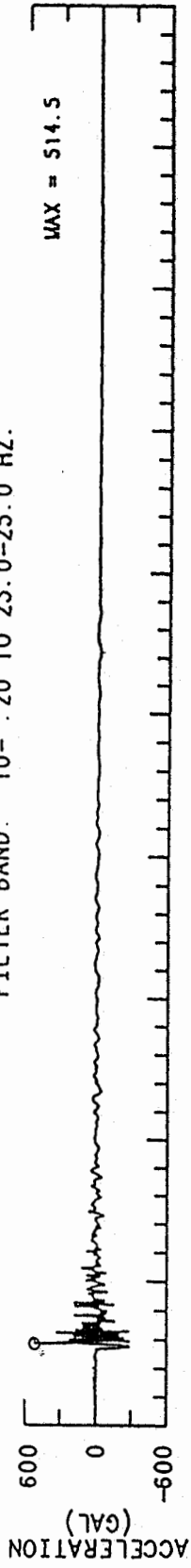


Figure 3a. Original acceleration with instrument-corrected acceleration, velocity, and displacement for Record 3.

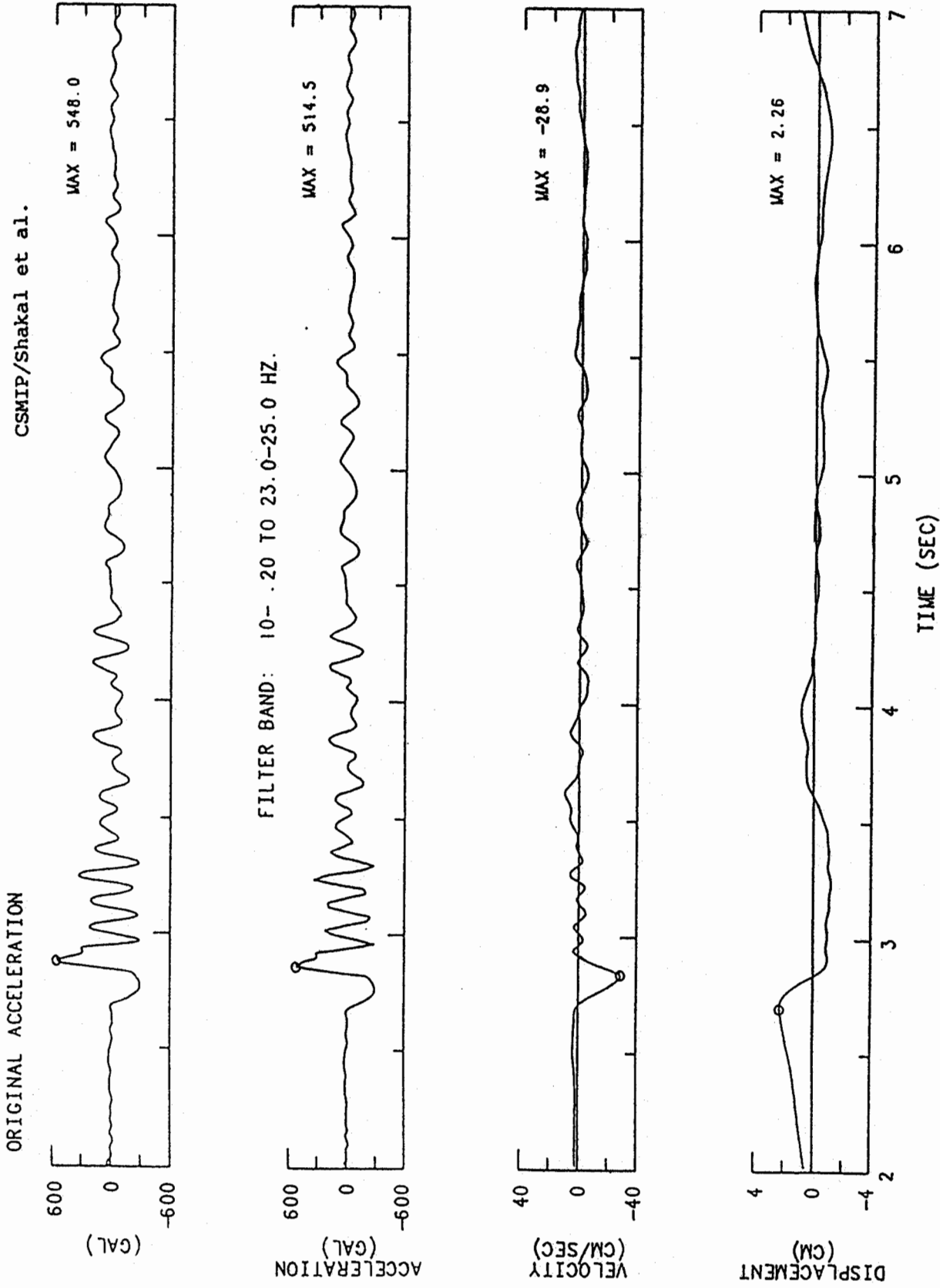


Figure 3b. Figure 3a replotted from 2 to 7 seconds.

ACCELEROGRAM BANDPASS-FILTERED WITH RAMPS AT .10-.20 TO 23.0-25.0 HZ.

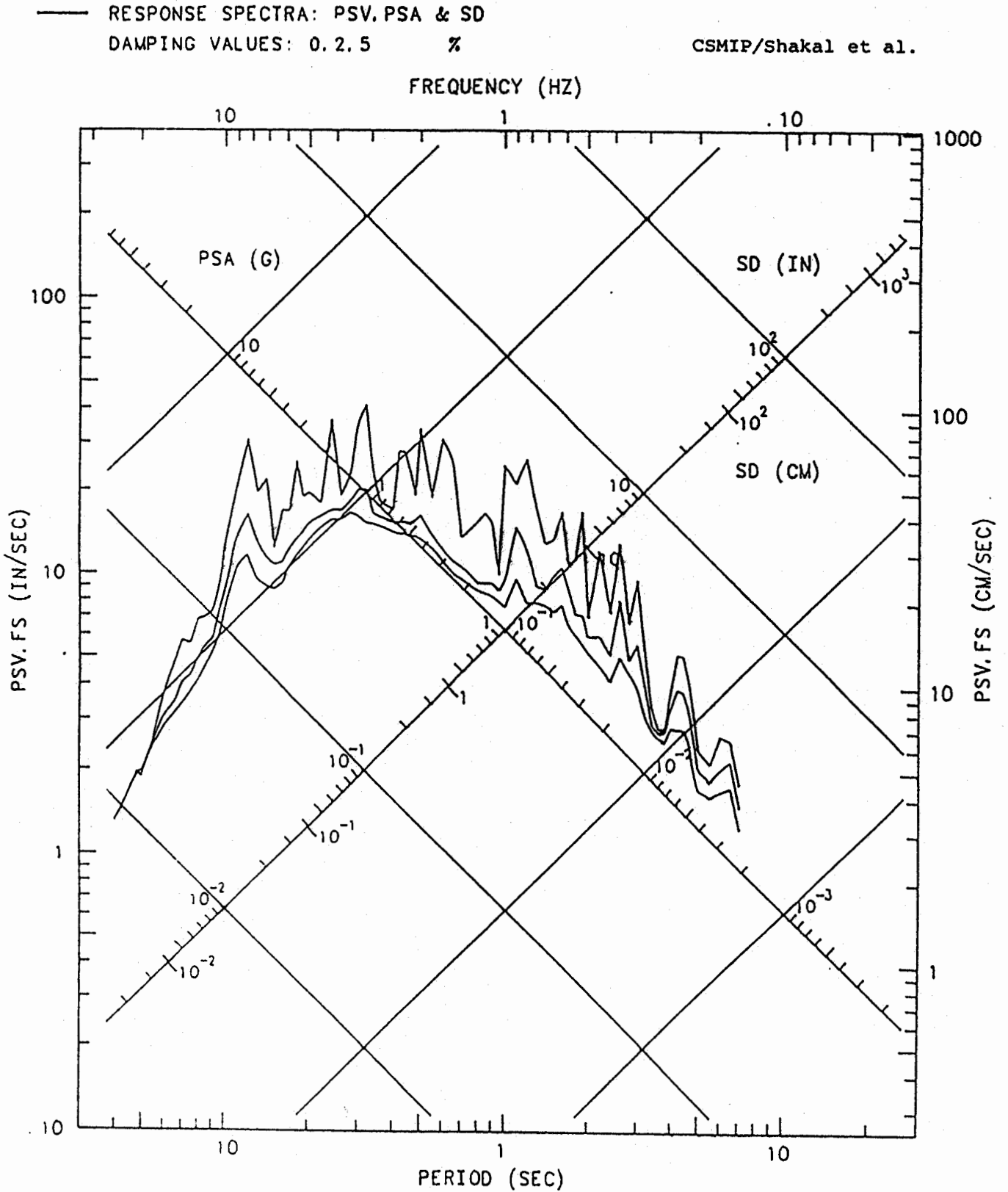
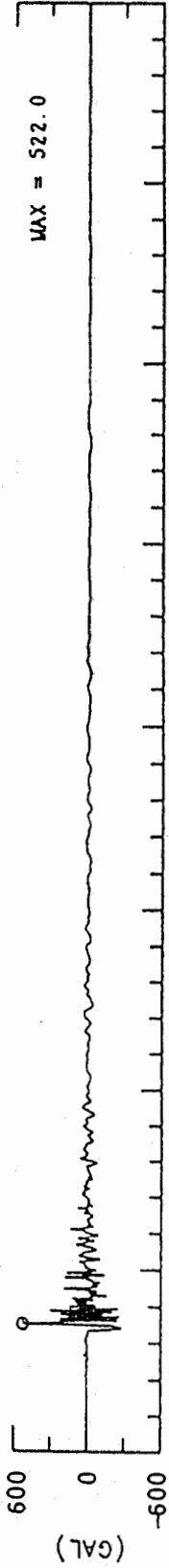


Figure 3c. Response spectra for Record 3.

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ORIGINAL ACCELERATION



FILTER BAND: 10- .20 TO 23.0-25.0 HZ.

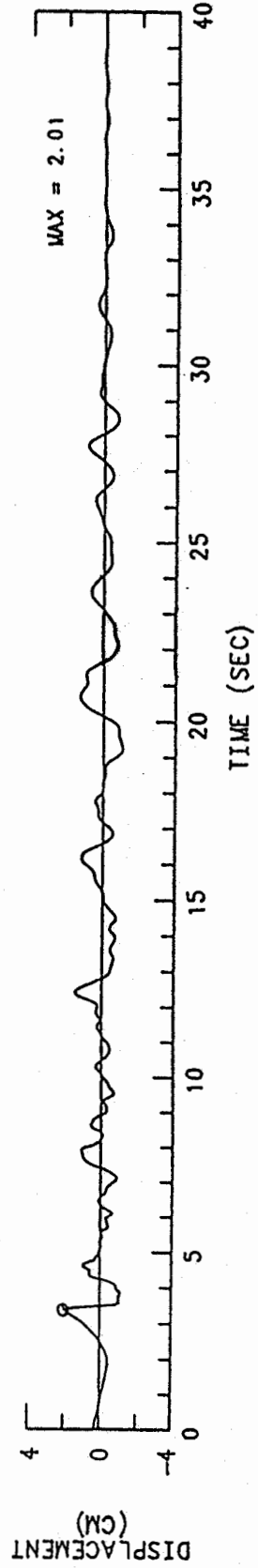
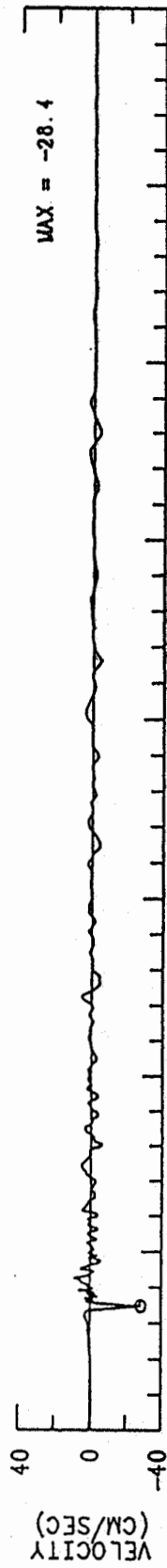
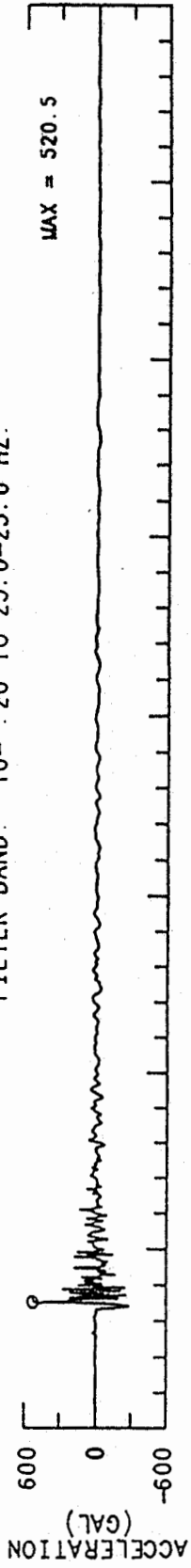
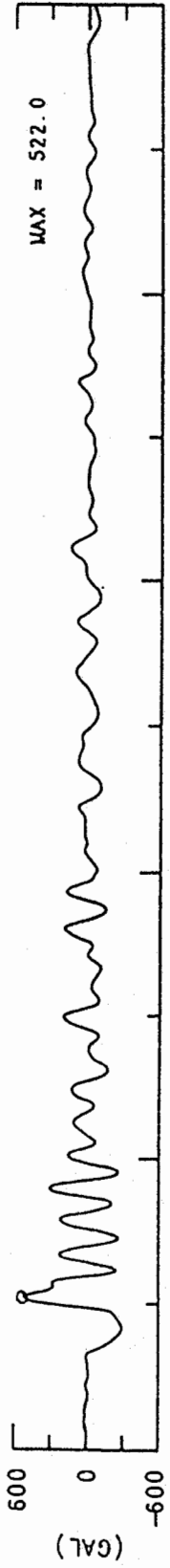


Figure 4a. Original acceleration with instrument-corrected acceleration, velocity, and displacement for Record 4.

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ORIGINAL ACCELERATION



FILTER BAND: 10- .20 TO 23.0-25.0 HZ.

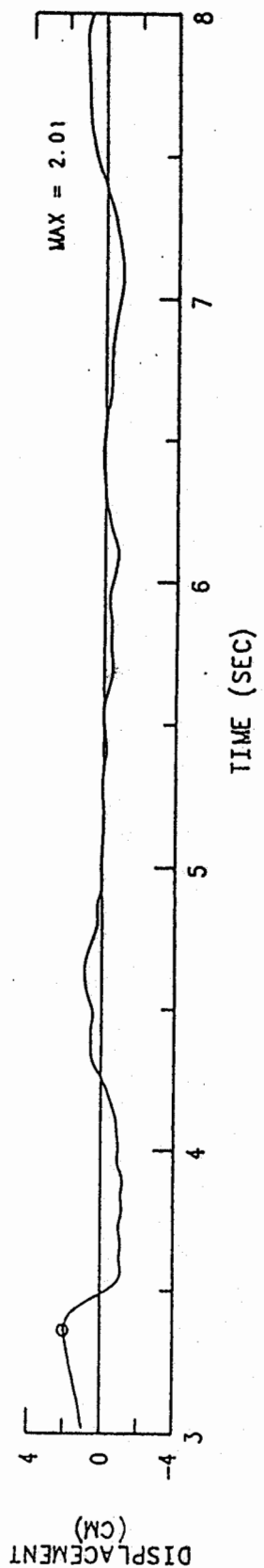
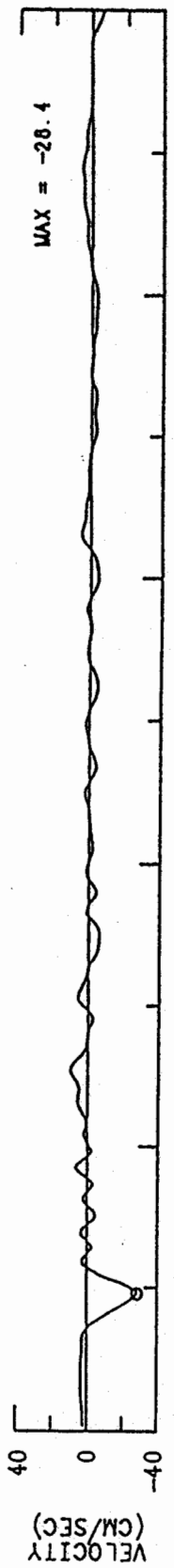
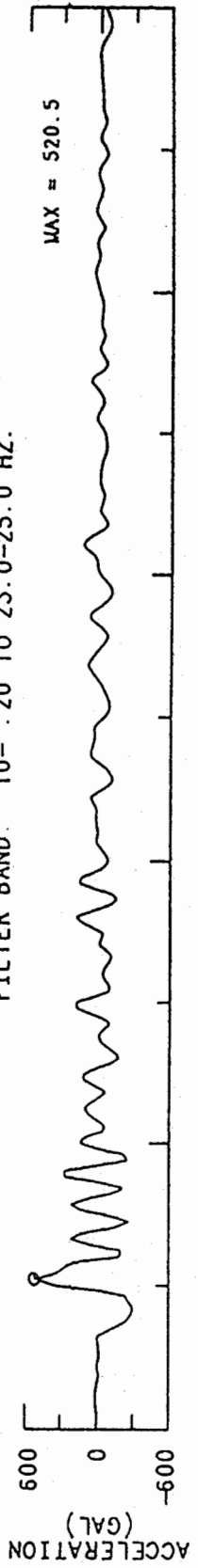


Figure 4b. Figure 4a replotted from 3 to 8 seconds.

ACCELEROGRAM BANDPASS-FILTERED WITH RAMPS AT .10-.20 TO 23.0-25.0 HZ.

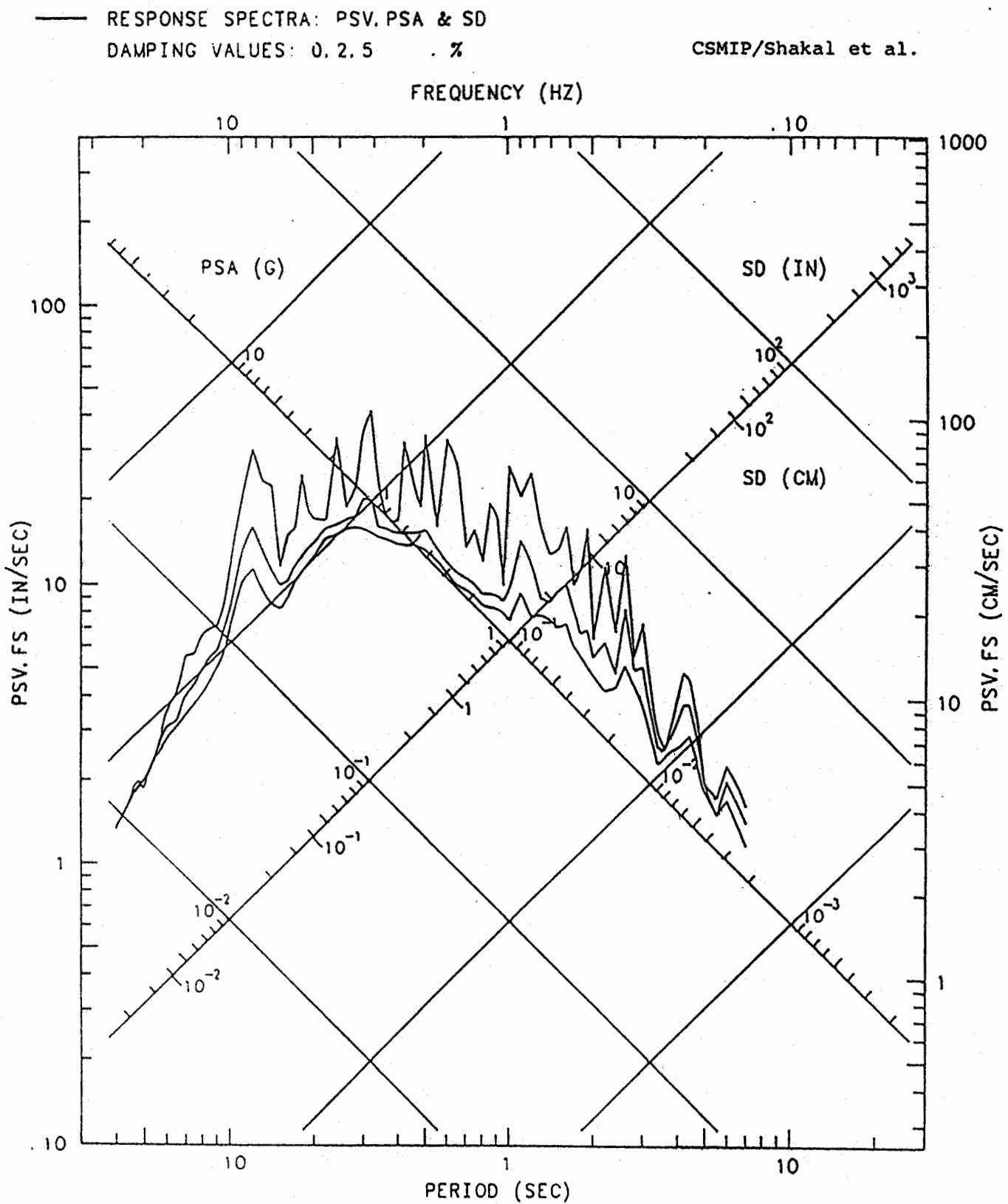
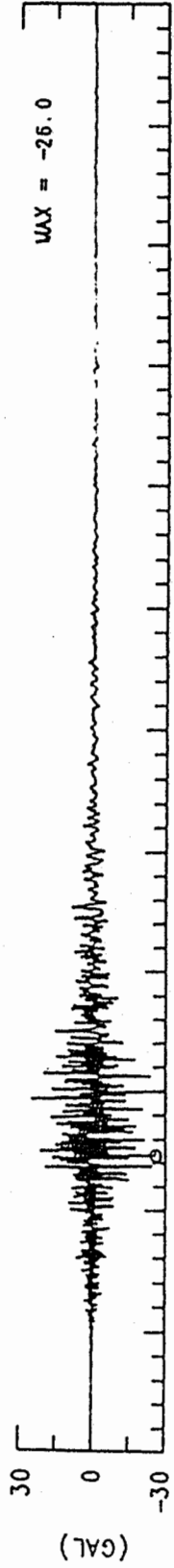


Figure 4c. Response spectra for Record 4.

ORIGINAL ACCELERATION



FILTER BAND: 08- .16 TO 23.0-25.0 HZ.

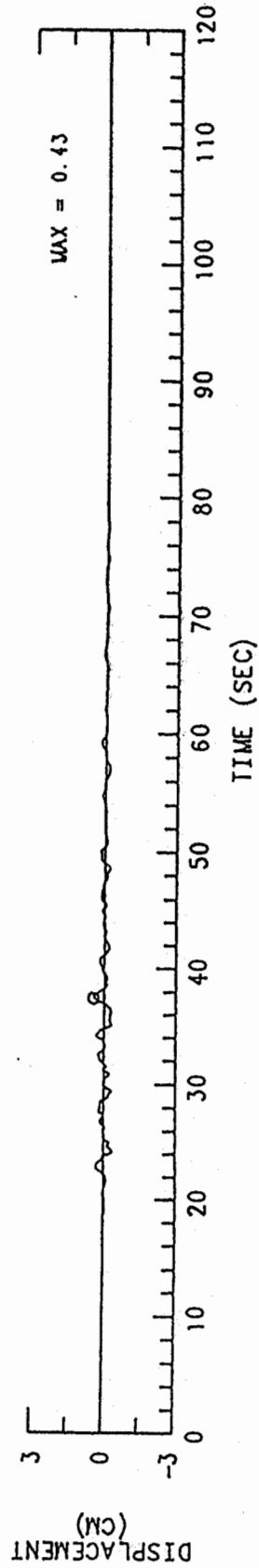
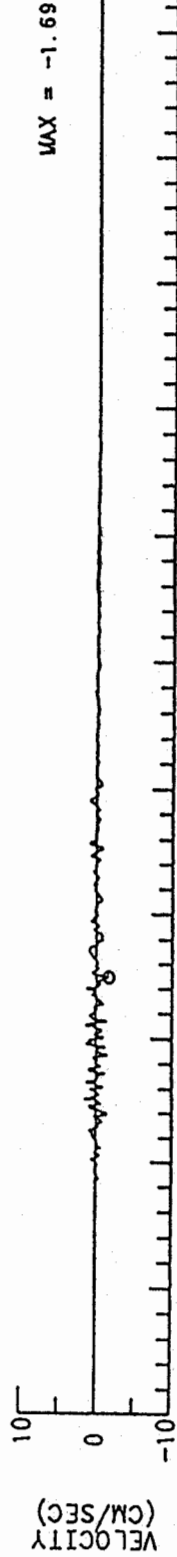
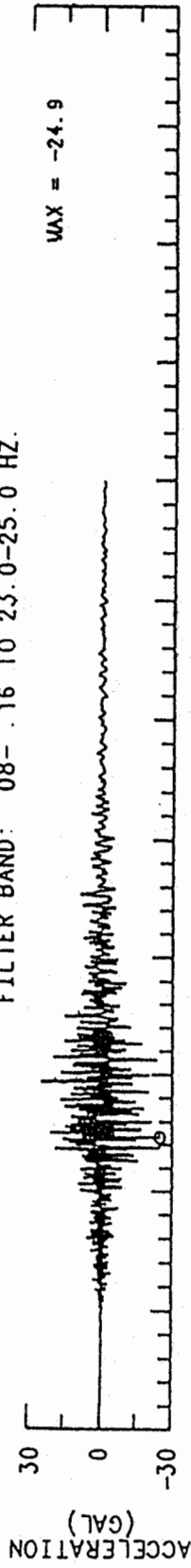
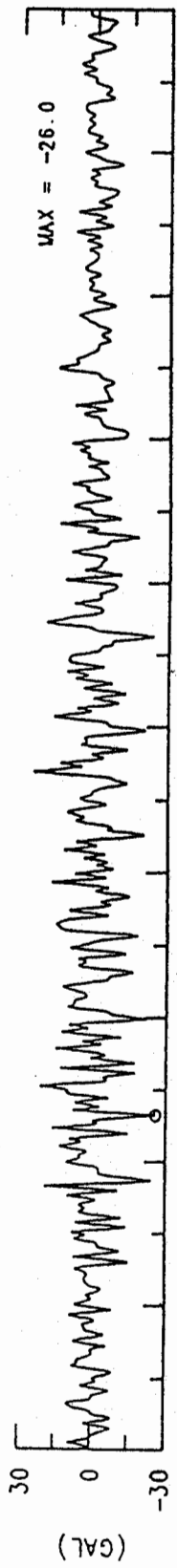


Figure 5a. Original acceleration with instrument-corrected acceleration, velocity, and displacement for Record 5.

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ORIGINAL ACCELERATION



FILTER BAND: 08- .16 TO 23.0-25.0 HZ.

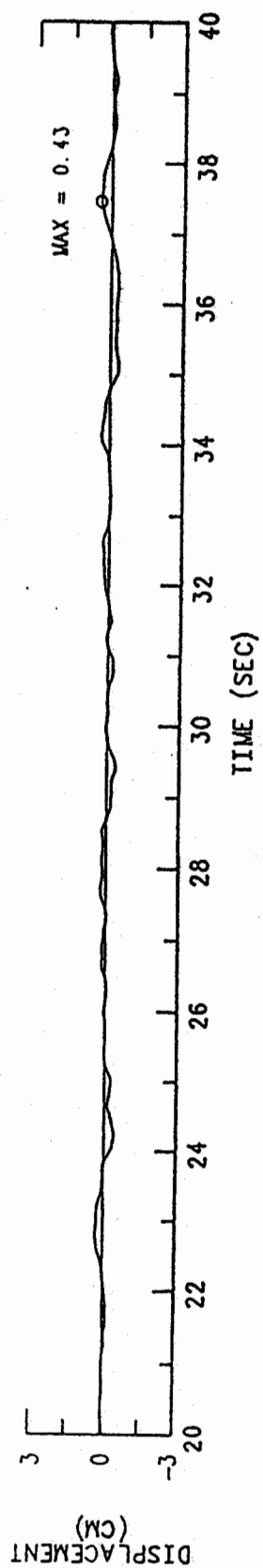
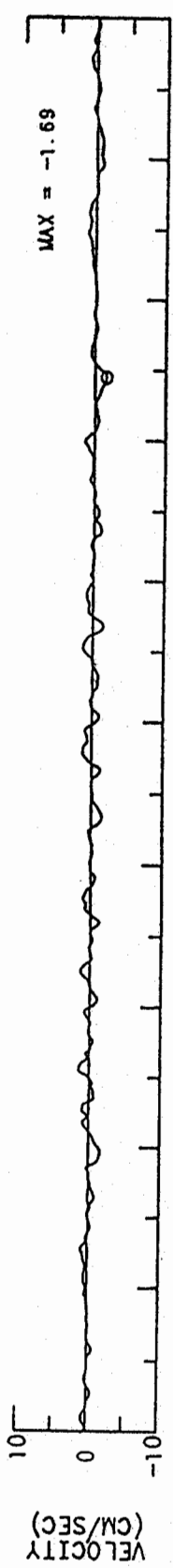
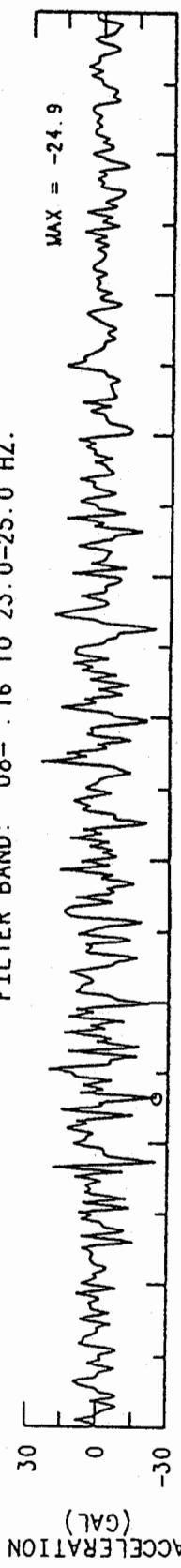


Figure 5b. Figure 5a replotted from 20 to 40 seconds.



ACCELEROGRAM BANDPASS-FILTERED WITH RAMPS AT .08-.16 TO 23.0-25.0 HZ.

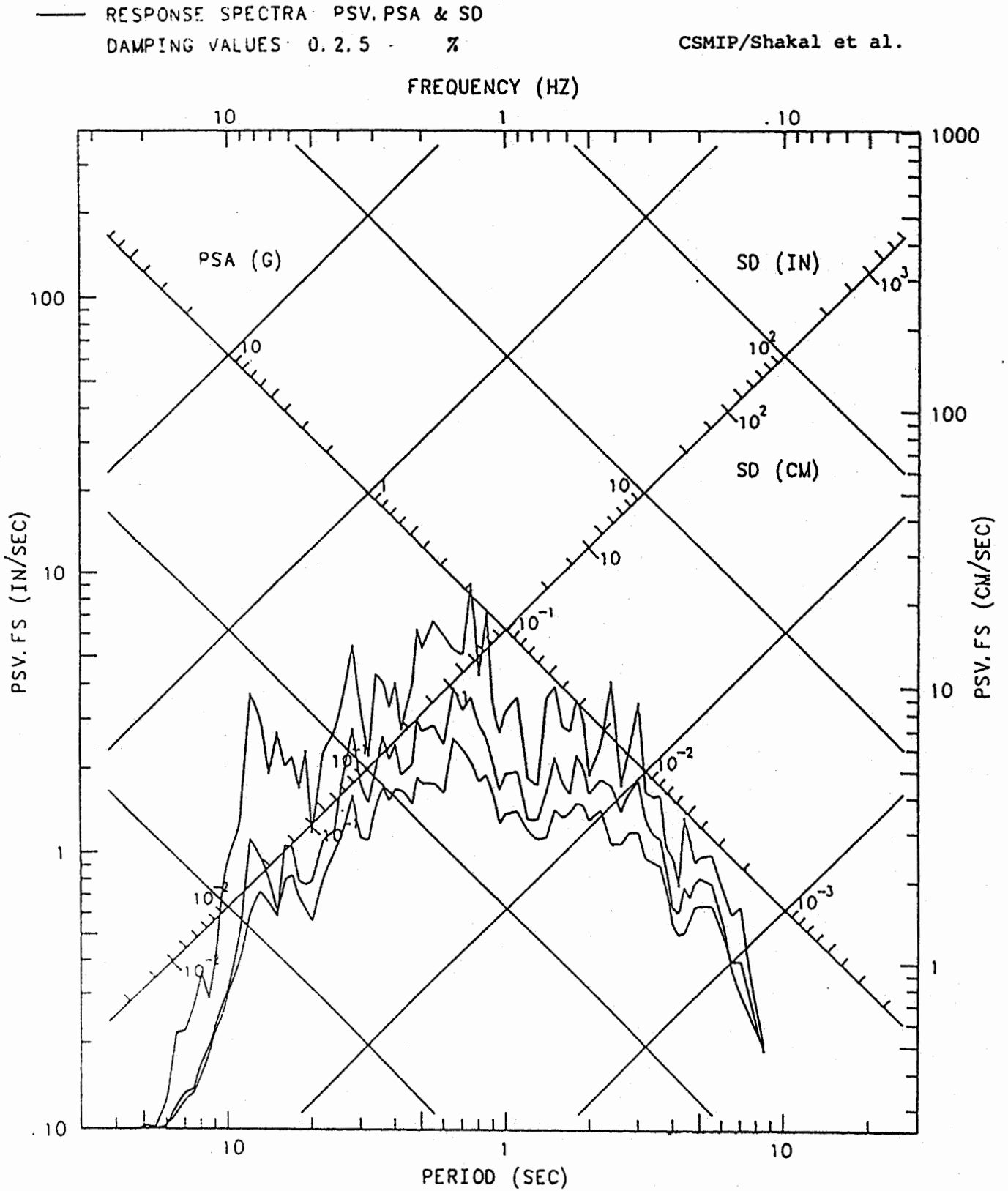


Figure 5c. Response spectra for Record 5.