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SURFACE RECORDINGS OF PAI PHASE II EXPLOSIVE TESTS

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During the week of 15 February 1982, S-CUBED participated in Phase II of the sequence of explosive tests in salt carried out by Physics Applications, Incorporated (PAI). Our role in these tests was to monitor the seismic ground motions at distances from 1 to 16 kilometers and to determine the dependence of peak velocity, signal shape, and spectral components on range, azimuth, and explosion type. The tests consisted of two Nitromethane explosions with yields

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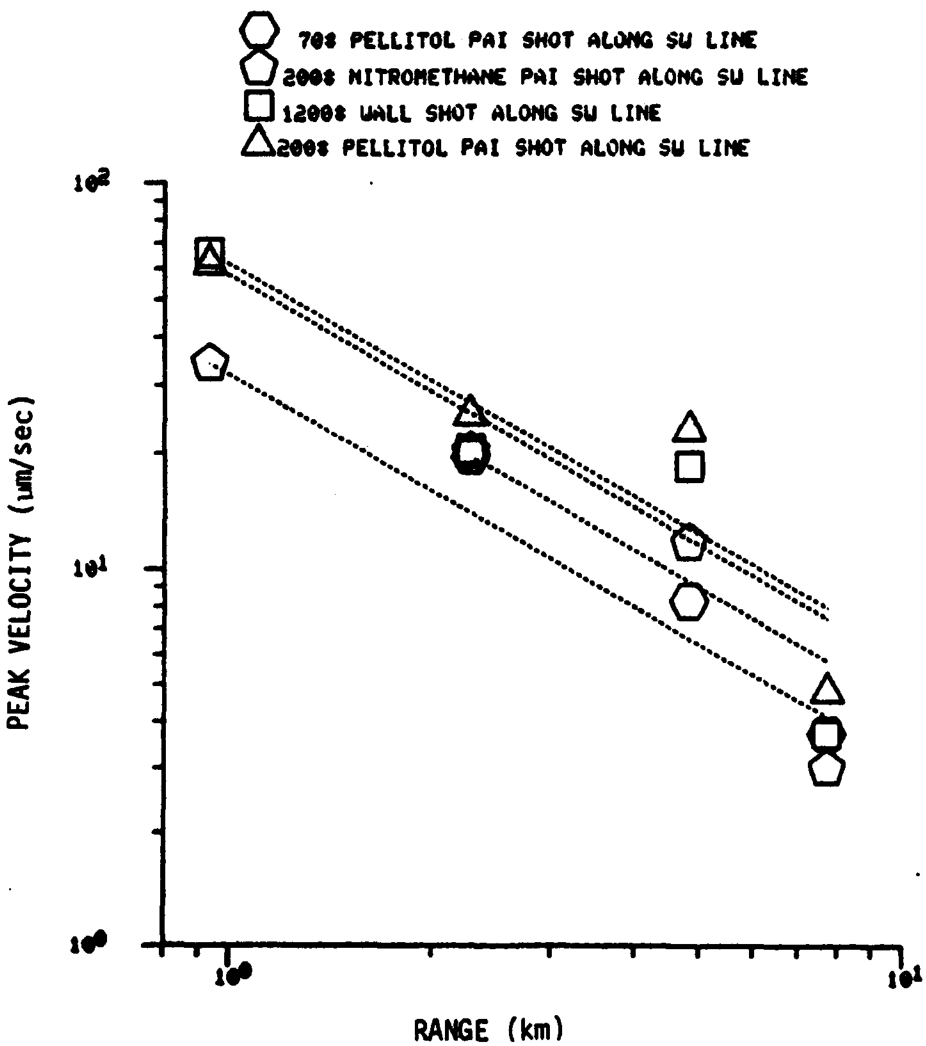
20. ABSTRACT (continued)

200 and 70 pounds and one Pellitol explosion at 200 pounds. These shots, along with a mining blast, were monitored along two azimuths 100 degrees apart at ranges from 1 to 16 kilometers. This report describes our data acquisition procedures and offers preliminary analyses of the data.

The results may be summarized in the figure below which shows peak velocities as functions of range for the explosions that were monitored. The 70 pound shot has been scaled to 200 pounds.



The dotted lines are at a slope of r^{-1} commencing at the closest data point for each event.

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I. INTRODUCTION AND SUMMARY

During the week of 15 February, 1982, S-CUBED participated in Phase II of the sequence of explosive tests in salt carried out by Physics Applications, Incorporated (PAI). Our role in these tests was to monitor the seismic ground motions at distances from 1 to 16 kilometers and to determine the dependence of peak velocity, signal shape and spectral components on range, azimuth and explosion type. The tests consisted of two Nitromethane explosions with yields 200 and 70 pounds and one Pellitol explosion at 200 pounds. These shots, along with a mining blast, were monitored along two azimuths 100 degrees apart at ranges from 1 to 16 kilometers. This report describes our data acquisition procedures and offers preliminary analyses of the data.

We find that although there is variability between events, the peak velocities decay roughly at r^{-1} and for the PAI shots scale proportional to yield. The peak velocities are about the same along both azimuths for the PAI shots but are very different for the mining blast. The shapes of the seismograms due to the various events vary considerably.

II. EXPERIMENTAL PROCEDURES

2.1 SITE DESCRIPTIONS AND POSITIONS

The explosive tests were conducted in the Morton Salt Mine about 0.5 km south of the town of Grand Saline, Texas (population 5000) which is in turn about 100 km east of Dallas. The area is used primarily for agriculture. The major sources of cultural noise were the mine, the town, two major highways (US 80 or I 20), a heavily used railroad (running east-west through town), and farming activity. However, the effects of cultural noise were minimized by conducting the tests between 1:00 and 2:00 a.m. after mining activities had ceased. The area is characterized by very gently rolling hills with loose soil. In each case, the seismometer was buried about two feet deep.

Figure 1 shows the station positions relative to the explosions. The origin is approximate since we have not yet received from PAI the exact positions of the shots within the mine complex. The stations are labeled according to whether they are in the southwestern or southeastern quadrant (SW or SE) and to the nominal range (R1, R2, etc.). For each shot, a minimum of six recordings were made (see Section III for schedule).

2.2 INSTRUMENTATION

Since ground motions were to be recorded at sites at least one kilometer apart, autonomous Sprengnether sensor/recorder systems were deployed. S-6000 transducers were used for this project. These are three-component seismometers whose response to ground velocity is flat above two Hertz. Upon amplification, the sensitivity to ground motion at ten Hertz ranges from 130 V/m/sec to 130 V/μm/sec. The amplified signals were recorded on DR-100 digital cassette recorders sampling at 100/second. To prevent aliasing, the units also included 25 Hertz low-pass filters. The system response is shown in Figure 2.

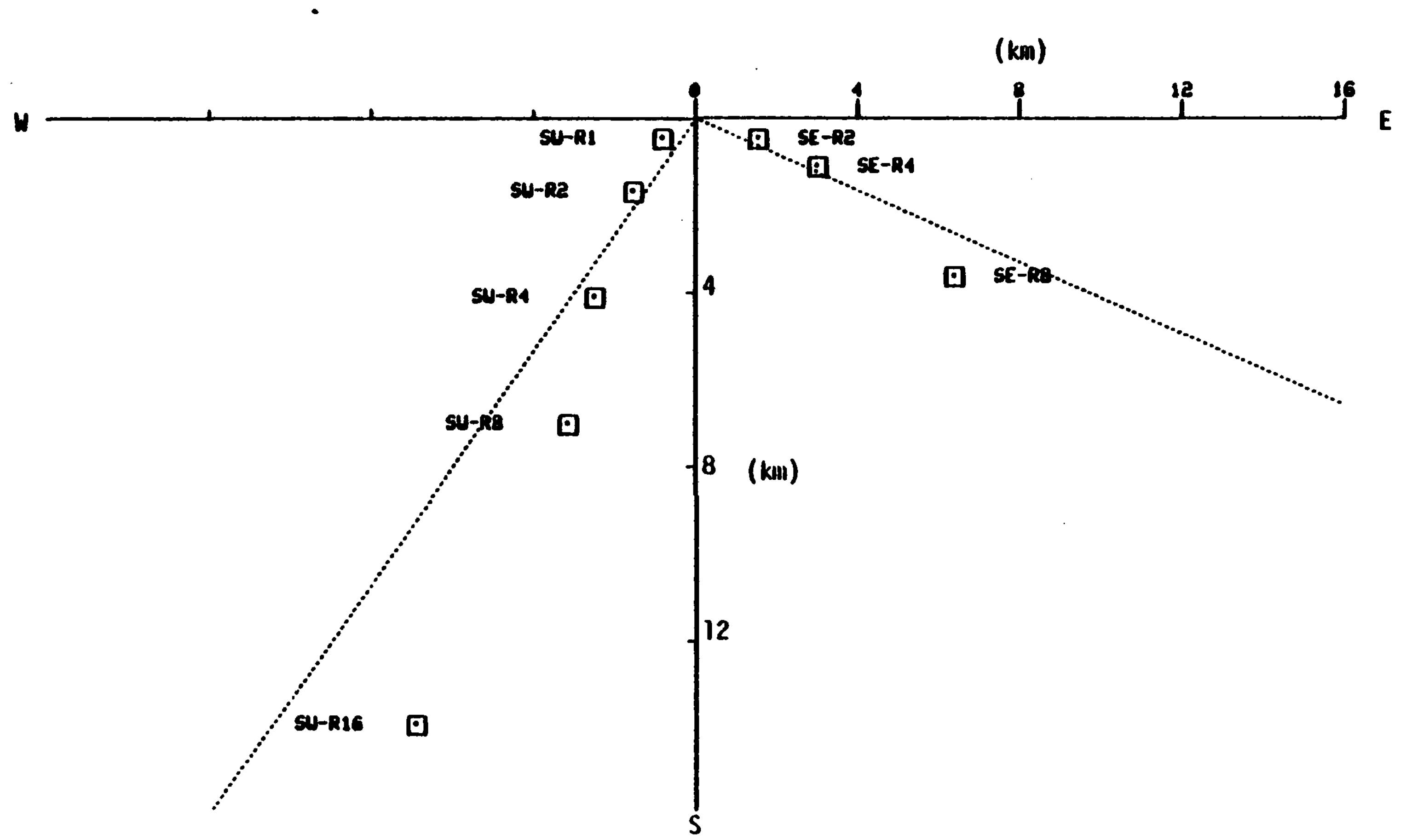

Figure 1. A map view of the recording sites relative to the shot point are shown. The dotted lines are the average azimuths along the SW or SE directions.

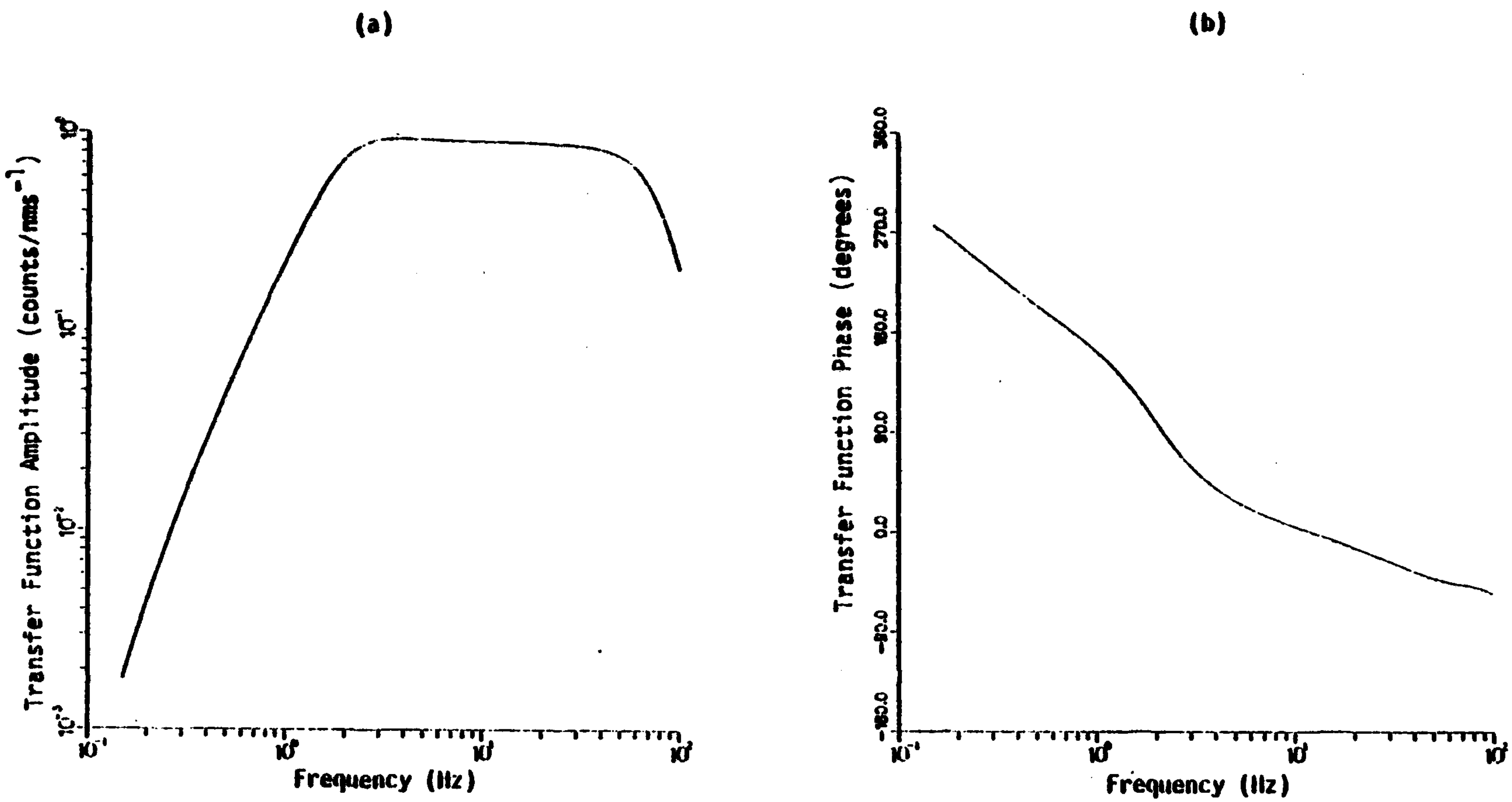

Figure 2. Seismic system transfer function for 90 dB gain: (a) amplitude response and (b) phase response.

The majority of the recorders were triggered from external timing units in which the pre-arranged shot times were set. Two recorders were triggered manually by an operator at the site to ensure that at least two recordings were made should the timed triggers fail. The recorders were synchronized to WWVB using a True Time NBS receiver/decoder. Shot time was obtained by PAI by simultaneously recording the WWV tone and their detonator pulse. The time of the mining blasts (wall shots) was predicted by measuring the rate of burning of the miners' fuse and refined afterward by comparing with the travel time curves from PAI shots.

2.3 RECORDING SCHEDULE

Table 1 shows the shot schedule and indicates the recordings that were made. Our initial layout concentrated on the southwest line where five stations were operating. One station on the other line at two km range was installed. The signals from Wall Shot 1 and PAI Shot 1 at station SW-R16 were below the background noise on the records (made using a cassette playback unit and a chart recorder); so we moved the apparatus to SE-R4. An additional station at SE-R8 was installed after equipment damaged by air freight handlers was repaired.

We attempted to record two additional nights of normal mine blasting activity (wall shots), but did not do so due to a holiday at the mine (of which we were not aware), a shipment of bad batteries, and initial difficulties in predicting the detonation time of the wall shots. A wall shot scheduled after PAI Shot 3 was detonated later than prescribed and did not fall into our recording window.

The instrument at SW-R1 triggered late for the wall shot. The recording at SW-R2 of PAI Shot 3, while still usable, is compromised by noise in the analog-to-digital converter during that shot.

Table 1

SHOT SCHEDULE

	SW-R1	SW-R2	SW-R4	SW-R8	SW-R16	SE-R2	SE-R4	SE-R8
PAI SHOT 1 200# NITROMETHANE 2/18/82, 0115	√	√	√	√	√	√		
WALL SHOT 1 1200# 2/18/82, 0130	√	√	√	√	√	√		
PAI SHOT 2 200# PELLITOL 2/19/82, 0100	√	√	√	√		√	√	√
PAI SHOT 3 70# NITROMETHANE 2/19/82, 0115		√	√	√		√	√	√

* A (√) indicates a recording was made.

III. PRELIMINARY RESULTS

Figures 3 through 8 are reduced travel time plots (reducing velocity = 3.2 km/sec) for the linear arrays described above. The peak velocity (obtained from the system gain at 10 Hz) and the start time relative to shot time are shown next to each trace. Each trace is scaled so that the peak value has the same height on the plot.

Along the southwest path, the first motions are sharp at the two closest ranges but become emergent at the farther ranges (Figures 3, 4, and 5). The emergent phase at SW-R4 has apparent lower frequency content and seems to be slightly delayed relative to reduced travel time. The dominant frequency in the first half second or so is around 20 Hertz. A lower frequency phase of frequency about 4 Hertz is apparent at later times, especially at SW-R1 and SW-R2. This is presumably a surface wave, but its amplitude relative to the initial body waves does not increase with range, as propogation in plane-layered elastic material predicts.

The dependence of peak amplitude on range is not a simple power law along either line and, in fact, varies from event to event. On the average, the peak velocity along the southwest line decays at a rate of about r^{-1} (Figure 9).

The seismograms from several shots are compared at SW-R1, SW-R2 and SE-R2 in Figures 10 through 12. For these comparisons, all traces are plotted on the same scale. The seismograms for PAI Shots 1 and 2 (Nitromethane and Pellitol) are similar, but there are differences in the interference patterns. For example, the first large low frequency peaks do not occur at the same time. More important is the disparity in amplitudes for most of the seismograms (recall that the traces are plotted on the same scale) with only the first motions having about the same peak velocity. The Wall Shot, with six times greater yield, generated about the same size signals as PAI Shots 1 and 2 (presumably due to cratering on the Wall Shot). At SW-R2 (Figure 11), the signals from PAI Shots 1 and 2 are

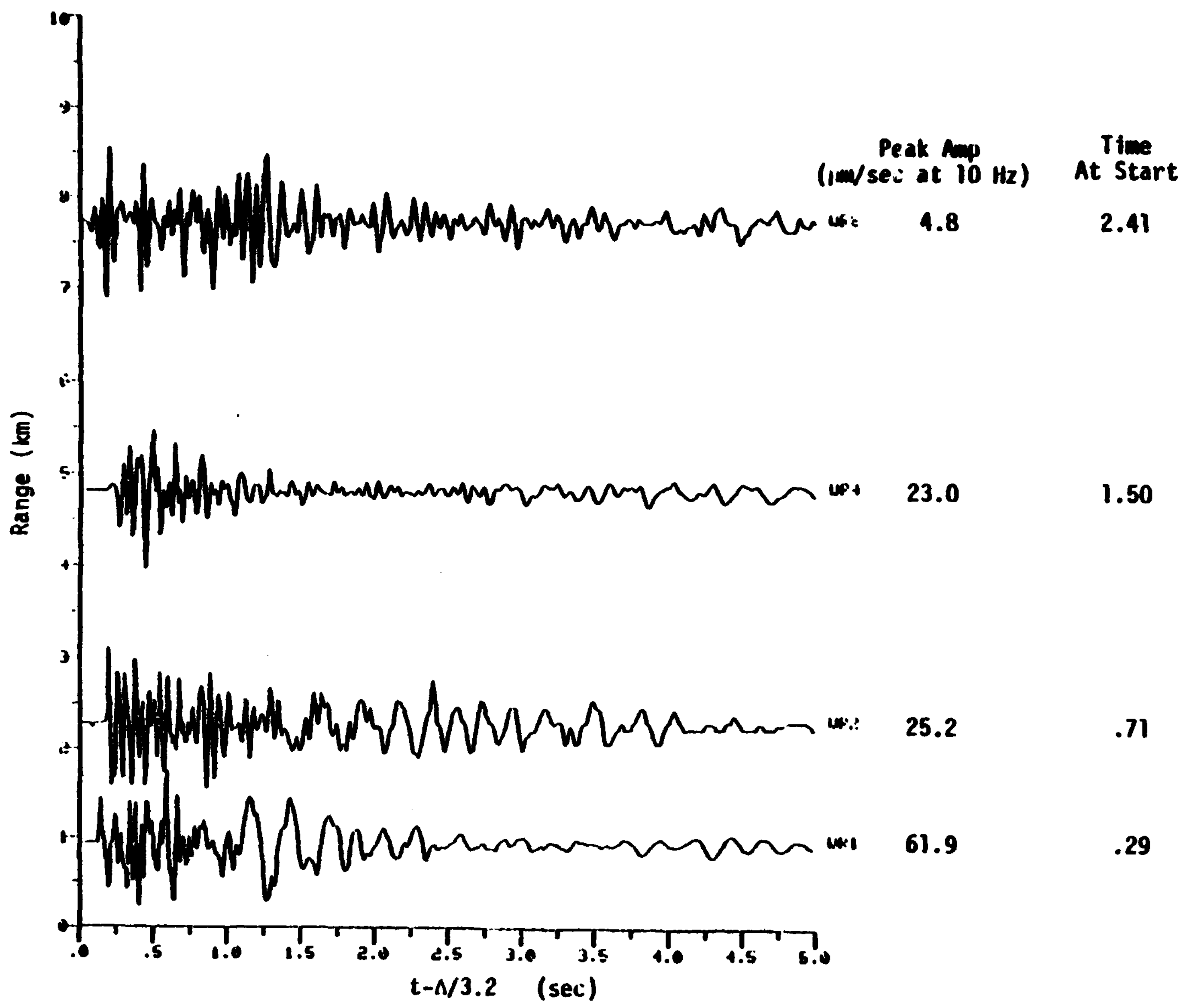

Figure 3. Recordings of PAI Shot 1 along Southwest line.

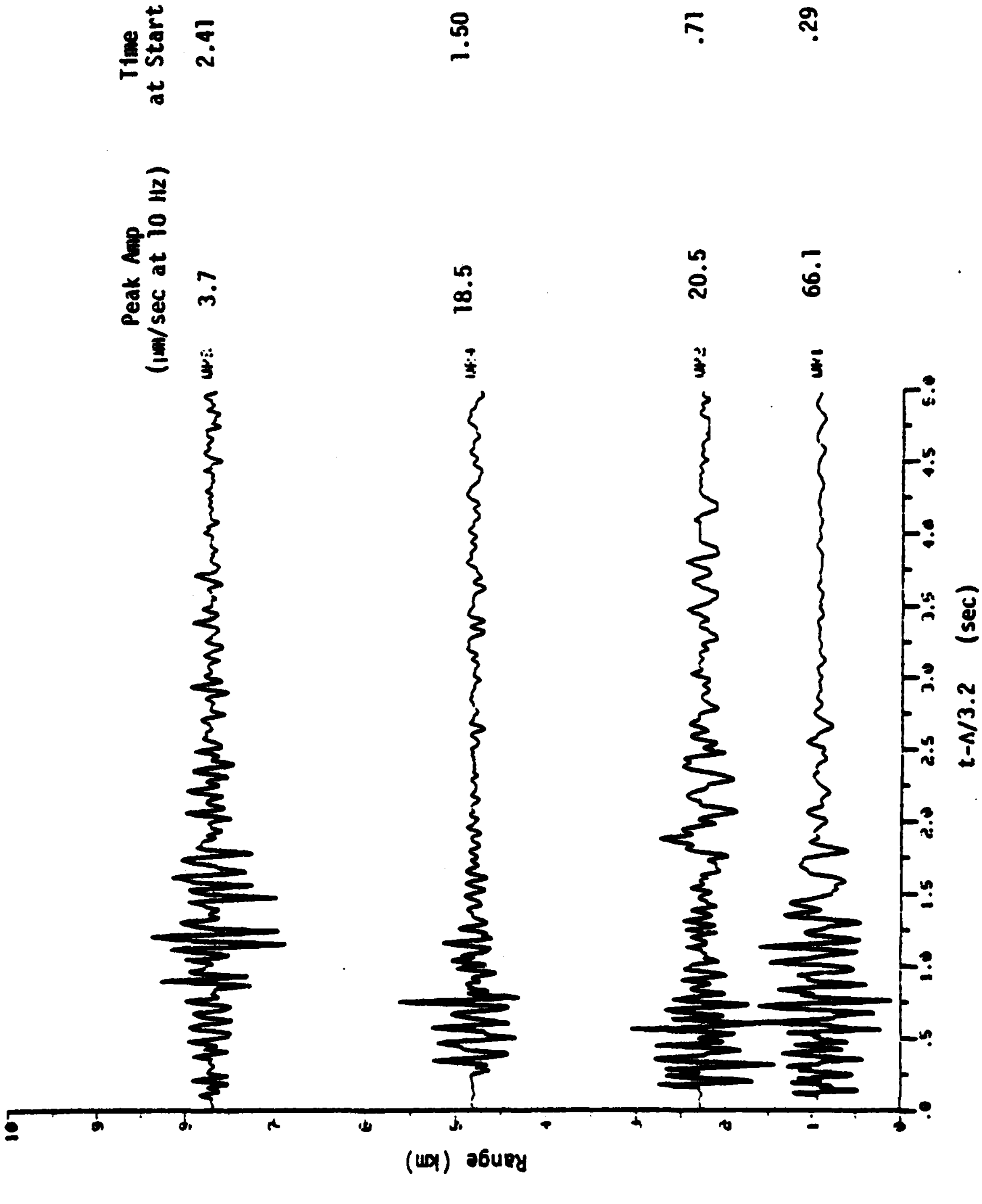

Figure 4. Recordings of Wall Shot along Southwest line.

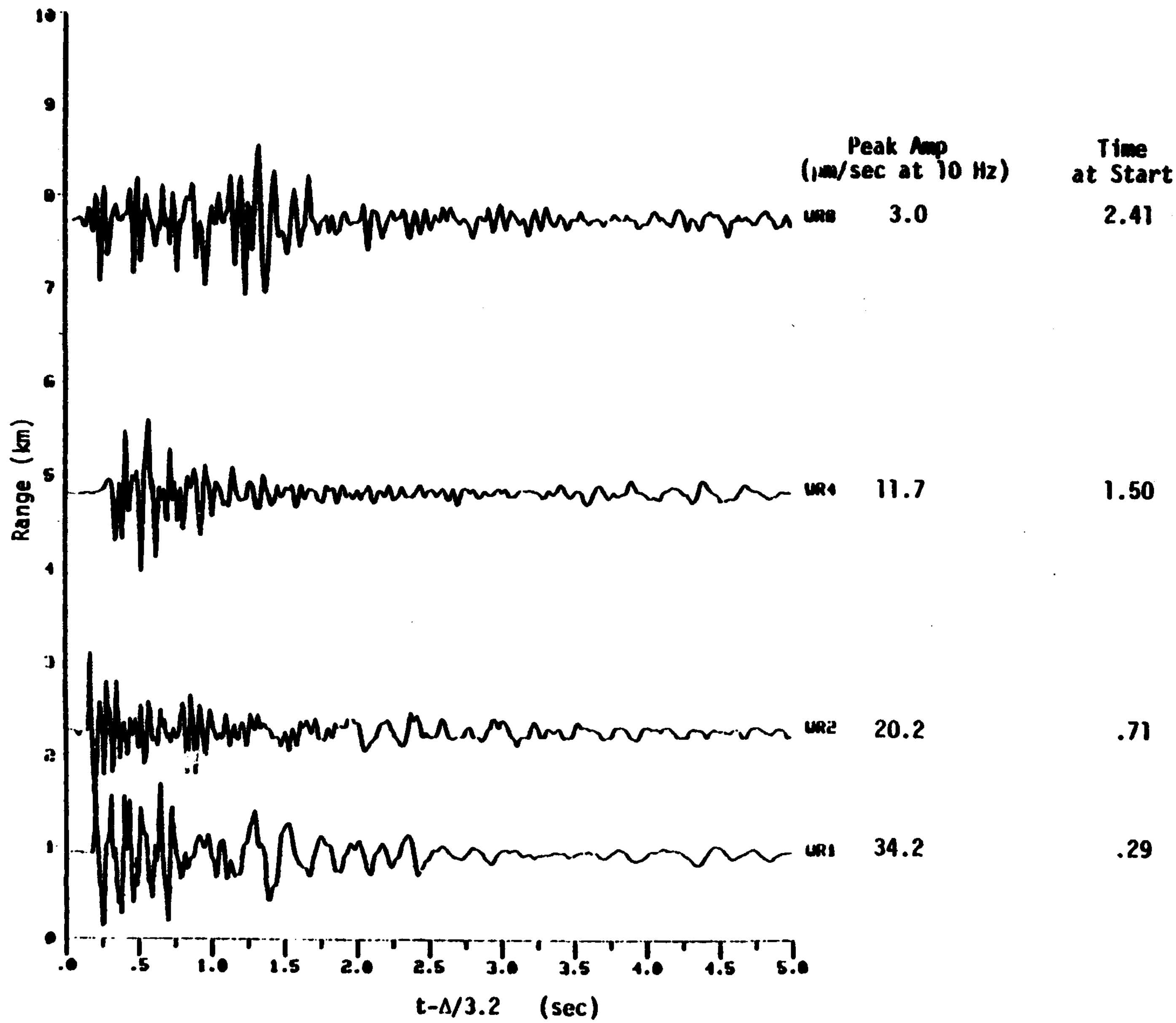

Figure 5. Recordings of PAI Shot 2 along Southwest line.

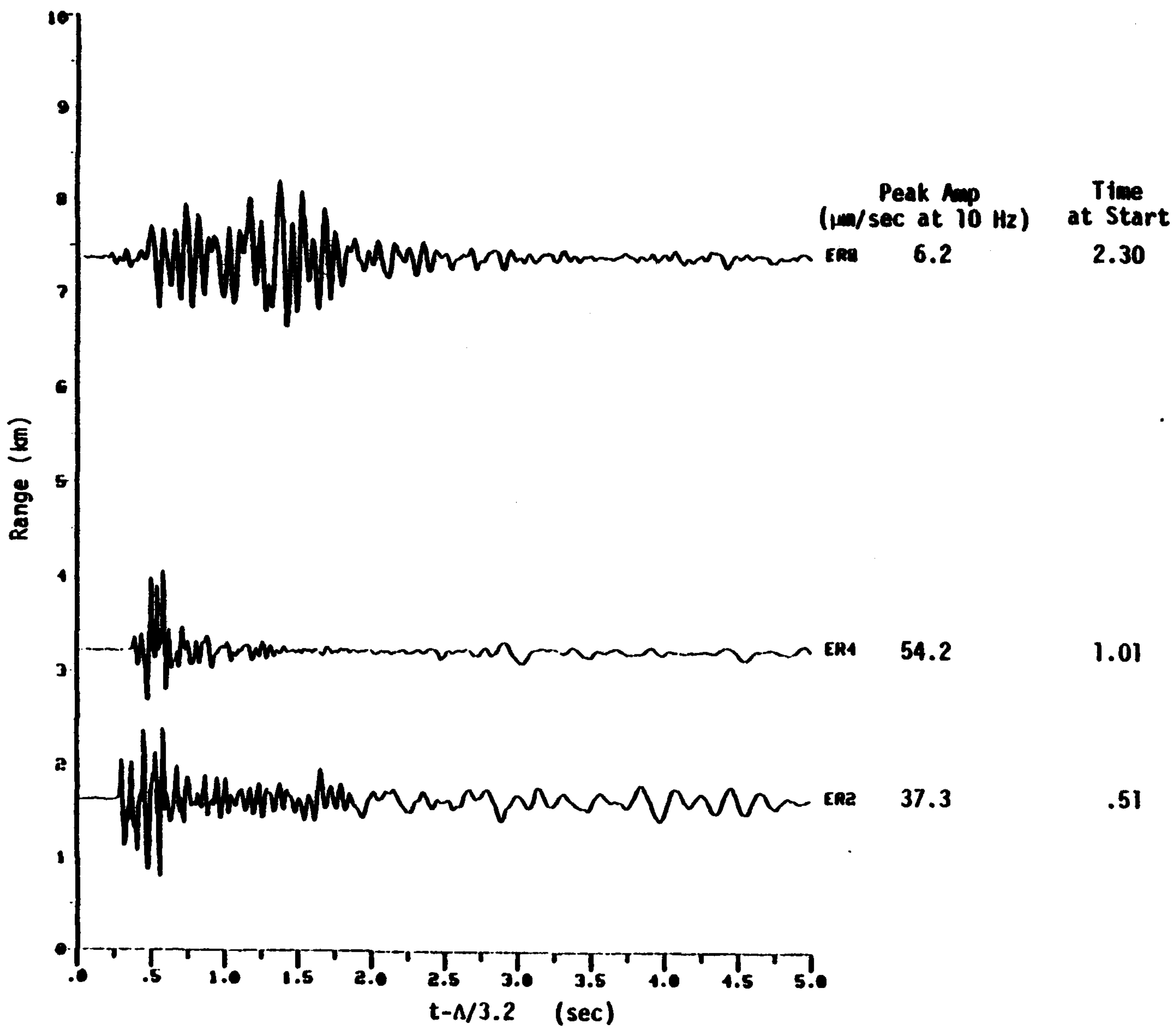

Figure 6. Recordings of PAI Shot 2 along Southeast line.

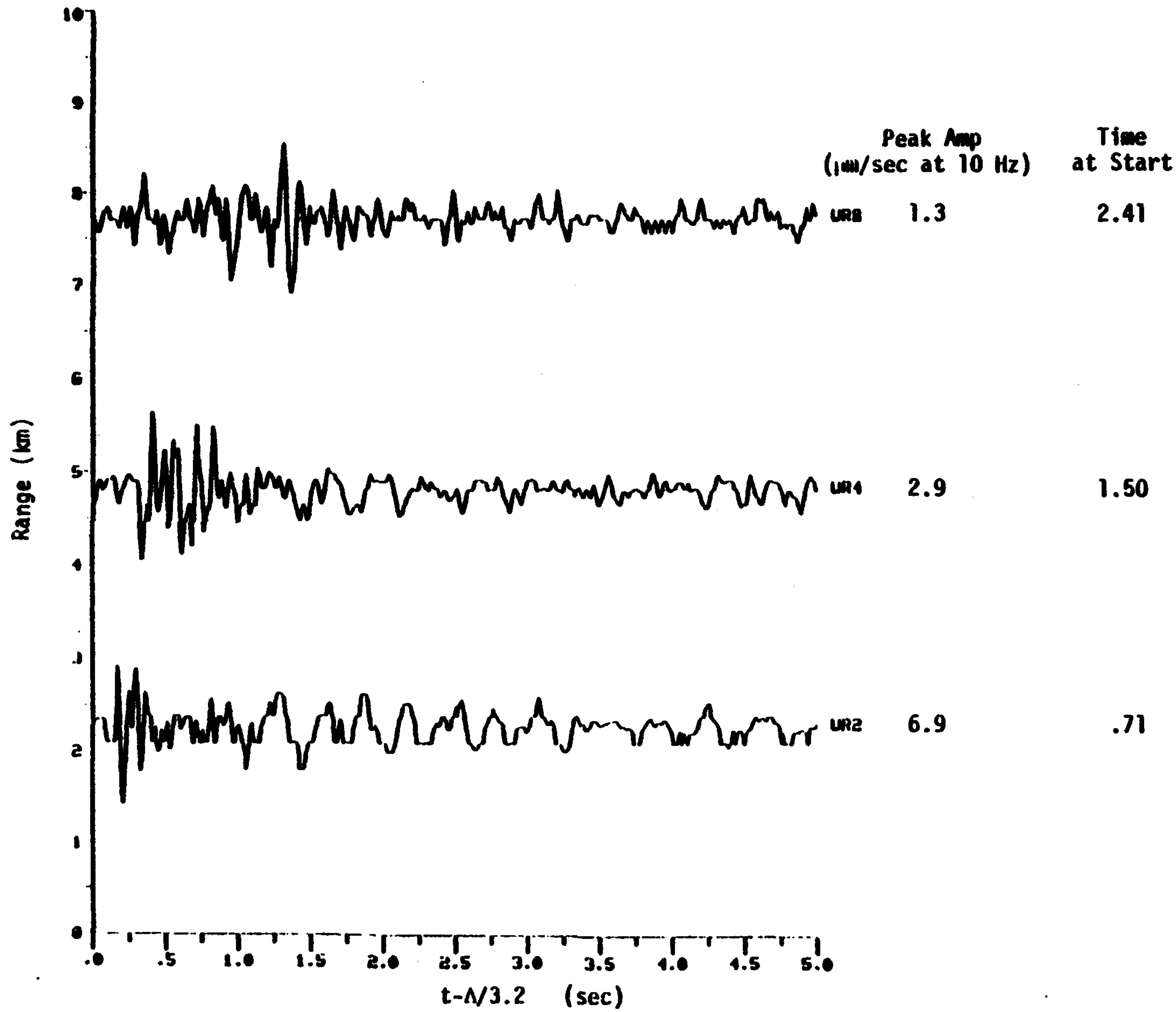

Figure 7. Recordings of PAI Shot 3 along Southwest line.

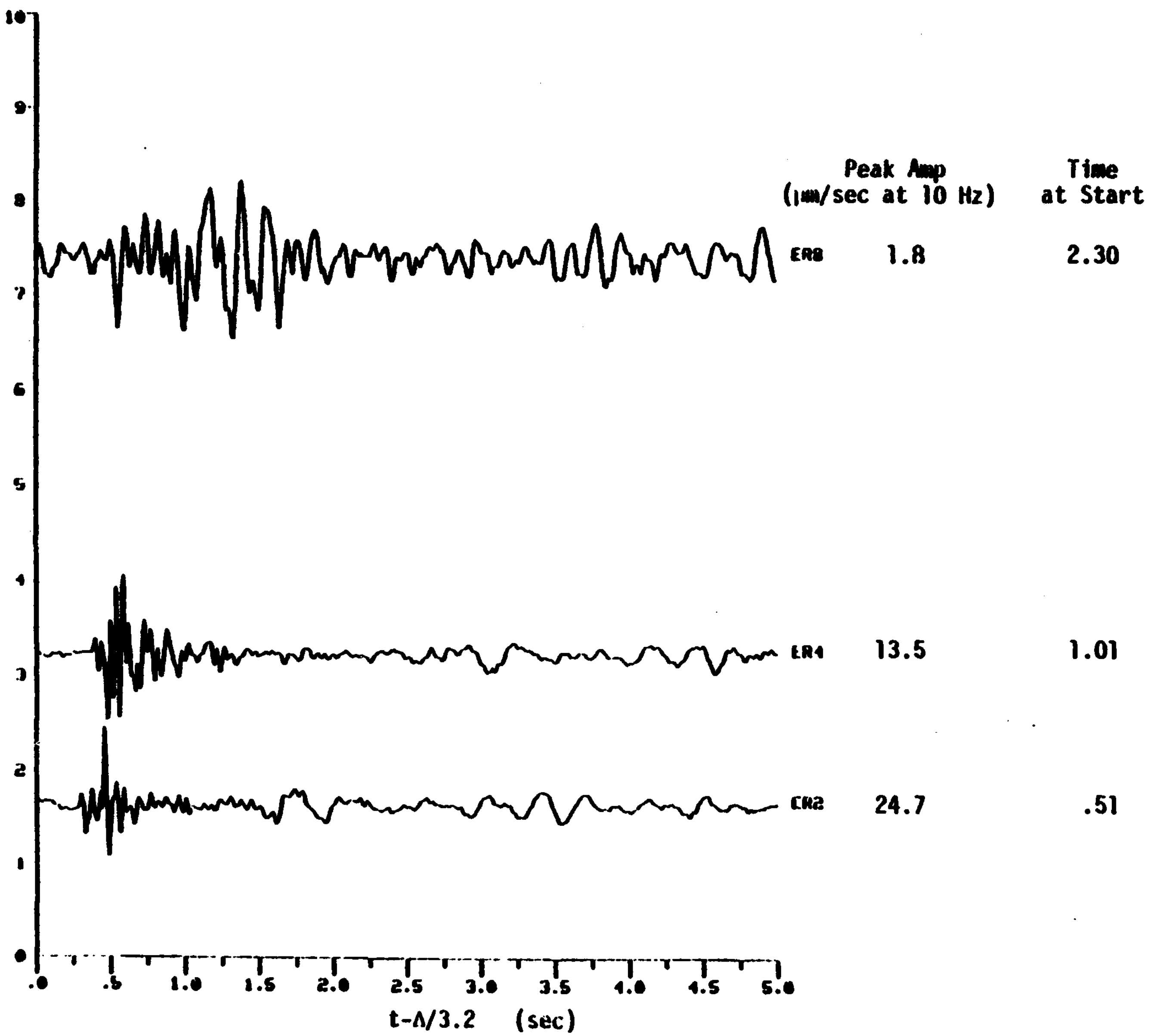

Figure 8. Recordings of PAI Shot 3 along Southeast line.

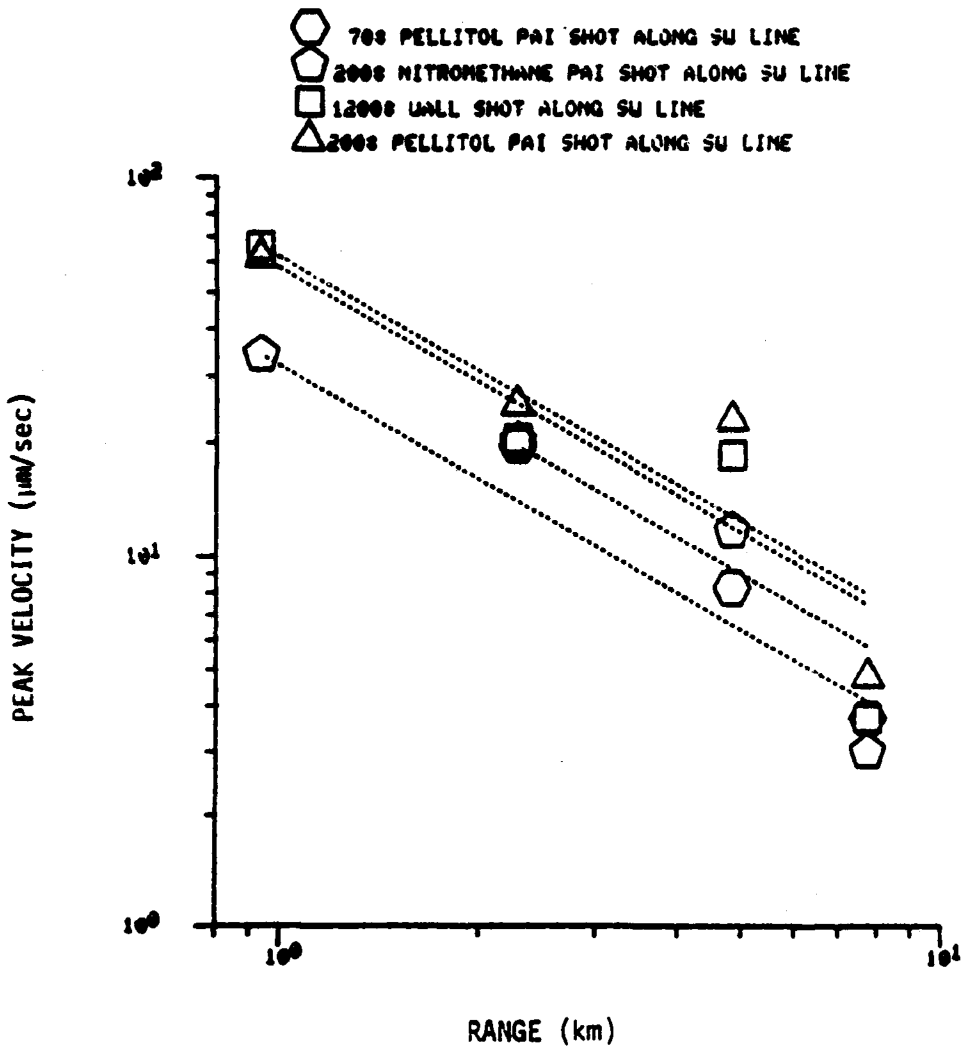

Figure 9. Peak velocity is plotted versus range. The 70 pound shot has been scaled to 200 pounds (scale factor 2.86). The dotted lines are at slopes of r^{-1} commencing at the closest range for each event.

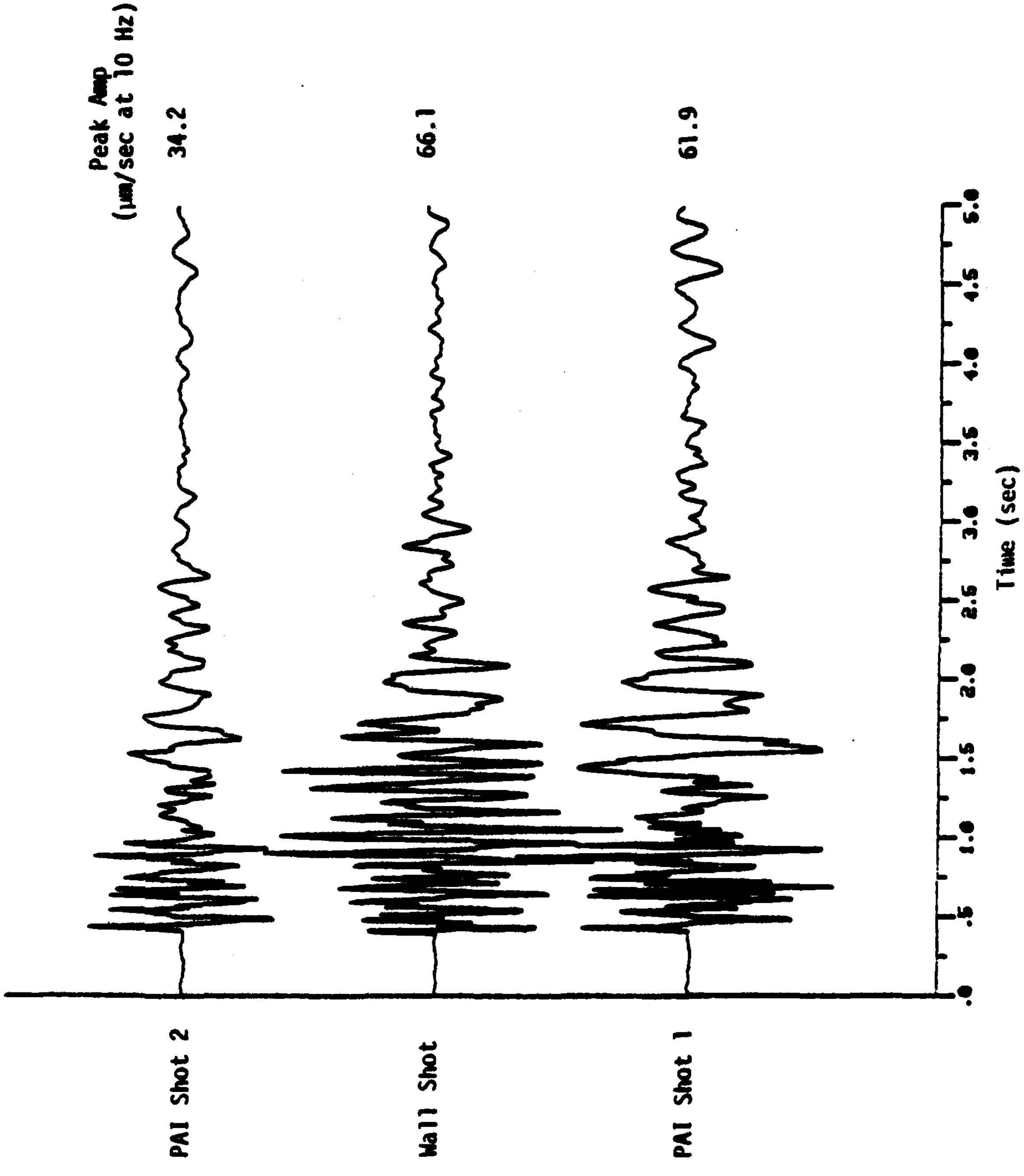

Figure 10. Recordings of three events at station SW-R1.

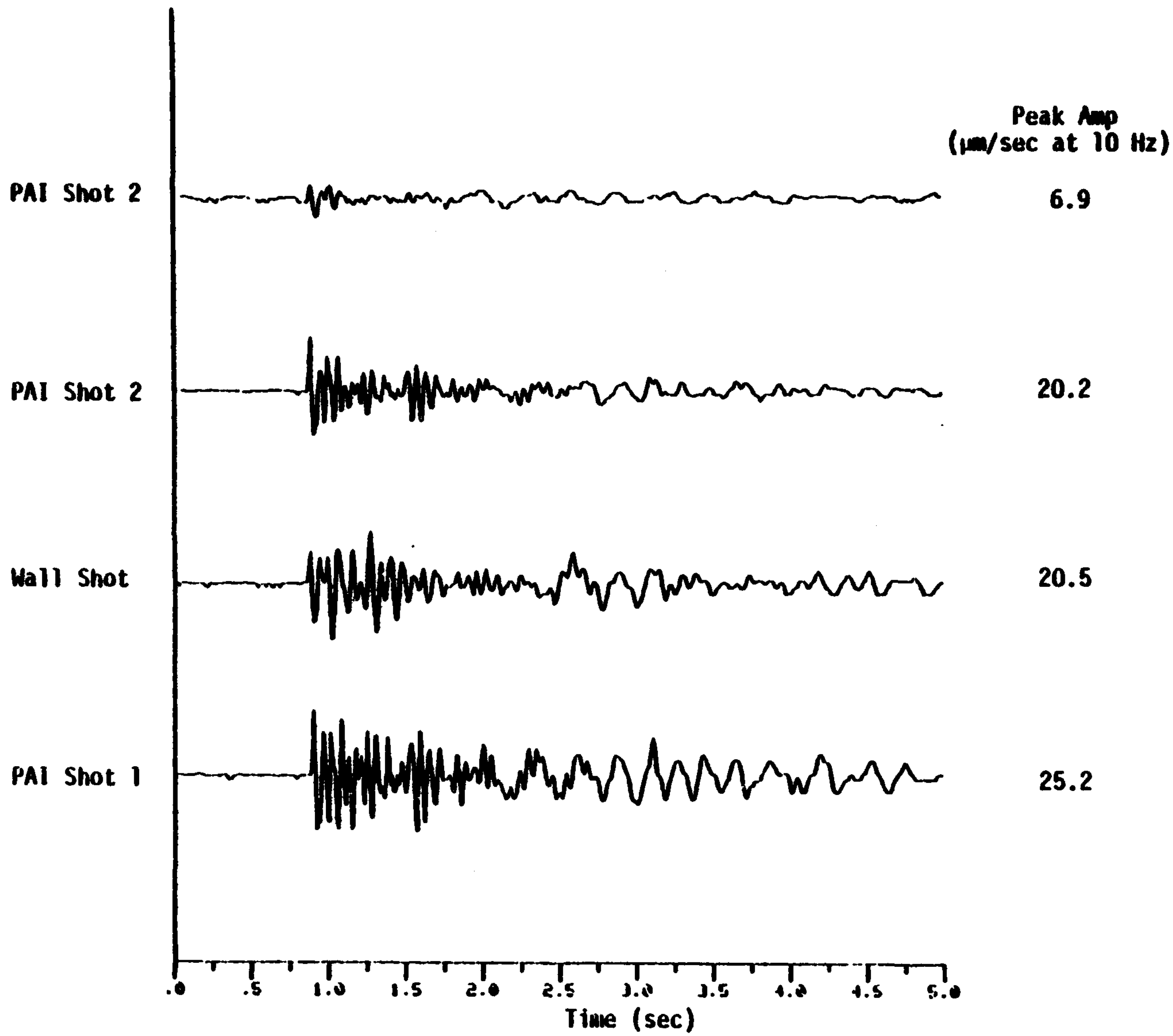

Figure 11. Recordings of four events at station SW-R2.

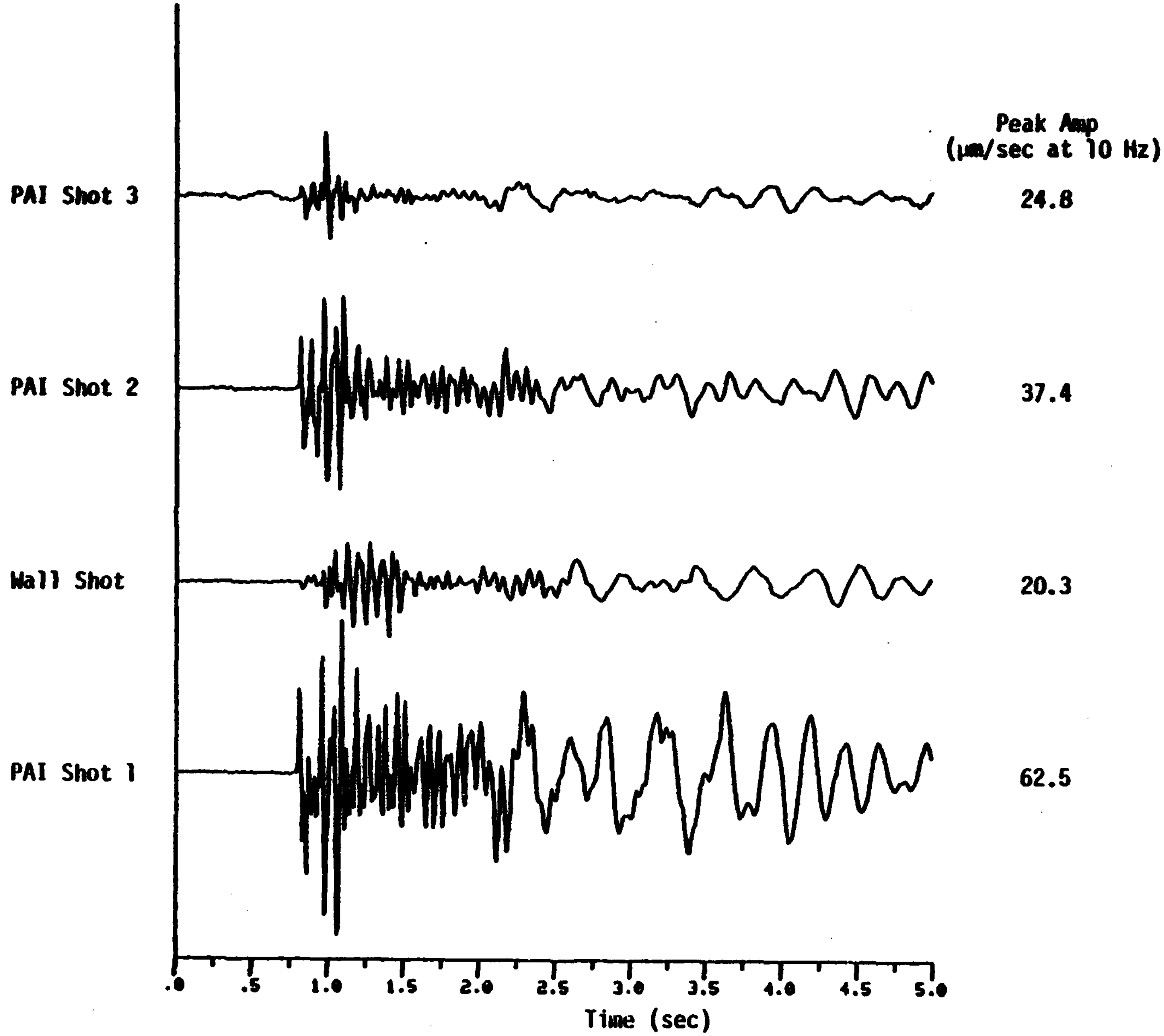

Figure 12. Recordings of four events at station SE-R2.

more coherent. A secondary high frequency packet at about 1.5 seconds is in phase. The peak velocities for PAI Shots 1 and 3 scale within 30 percent of the ratio of the explosive yields.

Although seismograms from the Wall Shot are rather similar to PAI Shots 1 and 2 at the southwest stations R1 and R2, they are quite dissimilar along the other azimuth at SE-R2. Evidently, radiation from the Wall Shot is strongly azimuthally dependent. Also, the ground motions from PAI Shot 1 are roughly twice the size of PAI Shot 2 as is the case at SW-R1.

IV. PLANNED FUTURE ANALYSIS

Further analysis will focus primarily on the frequency domain where we will study the behavior of spectral components as functions of the explosive type, range, and azimuth. The analyses will be made using standard Fourier transform methods as well as narrow-band filter methods. We will also compute signal-to-noise ratios over the band of interest.