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U.S. GEOLOGICAL SURVEY

Seismic velocities and geologic logs from borehole measurements at seven strong-motion stations that recorded the 1989 Loma Prieta, California, earthquake

by

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INTRODUCTION

The Loma Prieta earthquake of October 17, 1989 (1704 PST) was recorded at 131 strong-motion stations located through-out the San Francisco Bay area (Maley et al., 1989, Shakal, et al., 1989). This data set has enormous value for engineering and seismological studies regarding earthquake ground motions. Using damage to man-made structures from the 1906 San Francisco earthquake, Lawson (1908) recognized that ground-motion intensity could be correlated with differences in local site geology. In order to quantify the effect of local geology (e.g., Borcherdt, 1970; Borcherdt and Gibbs, 1976) on ground motions from the 1989 earthquake, detailed geologic and geophysical data are needed. To plan the acquisition of these data a meeting was held on July 6, 1990 at the USGS in Menlo Park, California. Eighteen scientists and engineers representing thirteen institutions attended the meeting to coordinate drilling and data aquisition plans at strong-motion stations.

This is the third of a planned series of four reports (Gibbs et al., 1992, 1993) detailing the results of borehole measurements at strong-motion stations recording significant ground motions during the 1989 Loma Prieta earthquake. This report contains the results of the field effort by the USGS for the following seven boreholes located near strong-motion stations operated by the U.S. Geological Survey (Figure 1).

1. Beach Park Boulevard (Foster City)
2. Fremont
3. Hayward City Hall
4. Larkspur Ferry
5. Pacific Park Plaza (Emeryville)
6. Stanford Linear Accelerator (SLAC)
7. Sunnyvale Colton Avenue

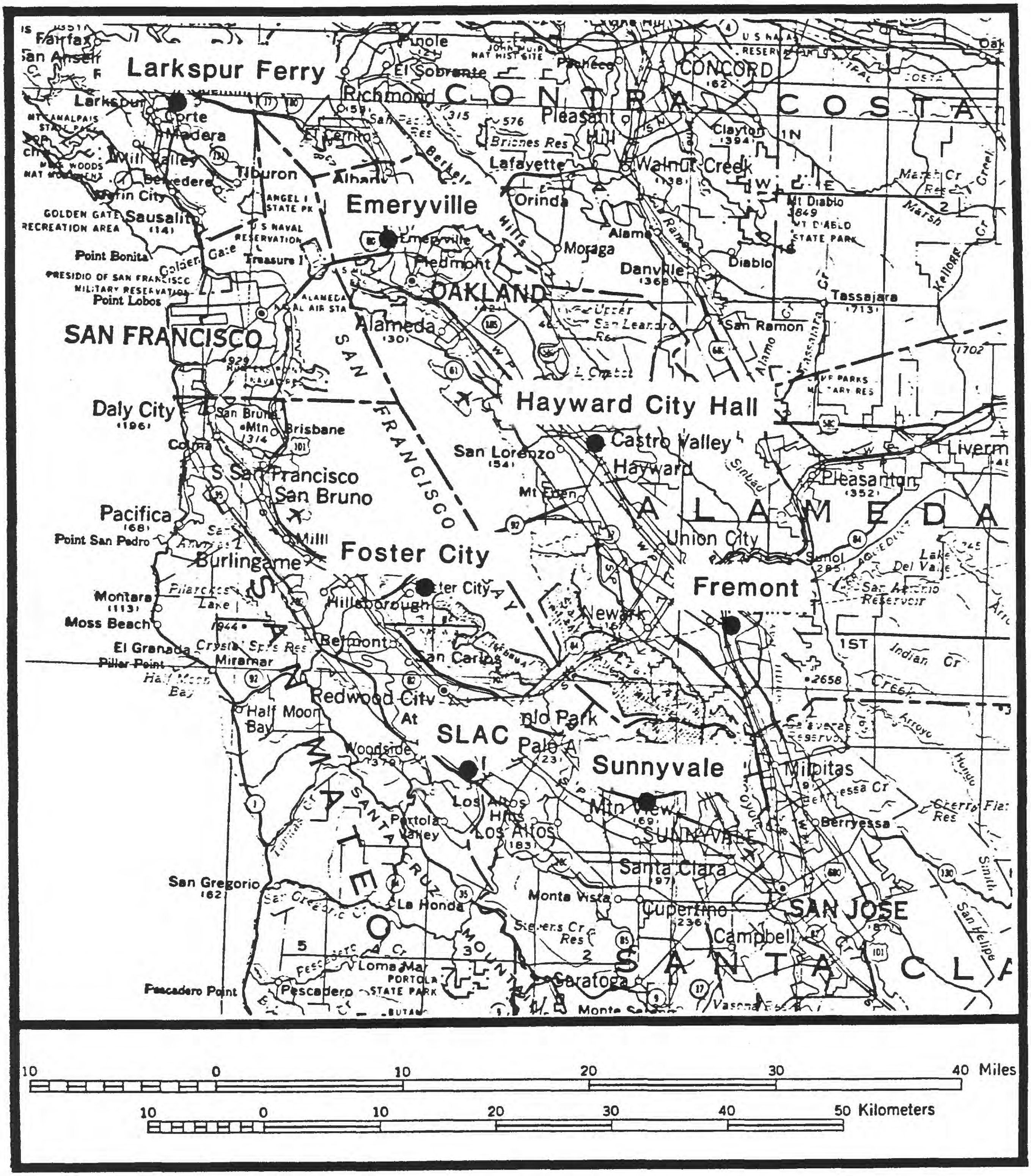

Figure 1. Regional map showing the locations of boreholes (solid circles) included in this report.

FIELD MEASUREMENTS

Drilling and Sampling Procedures

Boreholes were located as close as possible to the accelerograph stations that recorded the strong-motion from the Loma Prieta Earthquake. In the case of Beach Park Boulevard (Foster City) and Stanford Linear Accelerator (SLAC) the closest available drill site was located approximately 200 meters from the strong-motion instrument. Fremont and Sunnyvale Colton Avenue boreholes were drilled approximately 100 meters from the instrument location. Hayward City Hall borehole was located approximately 30 meters from the accelerograph station and Pacific Park Plaza (Emeryville) and Larkspur Ferry boreholes were within 10 meters of the accelerograph station.

At each site a hole approximately 6 to 10 inches in diameter was drilled using rotary-wash drilling with bentonite mud. For purposes of economy, samples were not taken in any of the boreholes.

The borings at all stations in this report were cased with 3-inch inside-diameter, class 200, polyvinyl-chloride pipe capped at the bottom.

The annular space around the casing was tremie grouted by pumping a water-cement-bentonite mixture through a 1-inch steel pipe inserted next to the casing. This provides good coupling between the casing and the wall of the borehole, and provides a sanitary seal preventing contamination of ground water. Grouting was done in stages of about 50-60 meters to prevent collapse of the casing.

Geologic Logs

Geologic logs are based on descriptions of drill cuttings, samples, reaction of the drill rig, and inspection of nearby outcrops. Sediment samples are described using the field techniques of the Soil Conservation Service (1951). Descriptions include sediment texture, color, and the amount and size of coarse fragments. Texture refers to the relative proportions of clay, silt, and sand particles less than 2 millimeters in diameter. This is determined visually and by feel without using laboratory tests. As such, this system is easier to use in the field than other classification systems. The dominant color of the sediment and prominent mottles are determined from the Munsell soil color charts.

Descriptions of rock samples include rock name, weathering condition, color, grain size, hardness, and fracture spacing. Classifications of rock hardness and fracture spacing are those used by Ellen et al., (1972) in describing hillside materials in San Mateo County, California.

Most information needed for describing relatively well-sorted soils and such properties of rock as lithology, color, and hardness are readily obtained from cuttings. Inspection of samples and nearby outcrops is necessary for determining the nature of poorly-sorted materials and fracture spacing. Reaction of the drill rig is useful in determining approximate sediment texture and in determining degree of fracturing because the rate of penetration in rock is highest for very closely fractured and crushed materials and drilling roughness generally is at a maximum in closely to moderately fractured rock. In-situ consistency of soil is determined largely from standard penetration measurements and rate of drill penetration.

Travel-time Data

Shear waves* were generated at the ground surface by an air-powered horizontal hammer (Liu, et al., 1988) striking anvils attached to the ends of a 2.3-meter-long aluminum channel. The hammer can be driven in both horizontal directions to generate positive and negative shear pulses. The switch that determines zero time is a piezo-electric sensor attached to the shear source. The source is offset from the borehole to prevent the direct arrival from traveling down the grout next to the casing. The source offset is 2 to 5 meters depending on the depth of the borehole. Shallow holes (30 meters or less) are generally offset 2 meters, while boreholes deeper than approximately 100 meters are offset 5 meters. Travel times are corrected (for slant offset) to vertical by the cosine of the angle of ray incidence.

P-waves are made by striking a steel plate with a sledge hammer at the same intervals described above. The recorder is triggered by the sledge hammer making electrical contact with the steel plate.

Measurements are made by lowering a single three-component geophone into the borehole and clamping it to the casing-wall with an electrically-actuated lever arm. A second

* In this report shear-wave(s) and S-wave are used interchangeably as well as compressional-wave and P-wave.

three-component geophone is placed at the surface approximately 30 centimeters from the shear source and is used as a check of the zero time determined by the triggering of the recorder by the contact switch. All recordings for this group of stations were made at 2.5 meter intervals. The data are recorded on magnetic tape cassettes in digital form on a twelve-channel recording system.

DATA INTERPRETATION and PROCESSING

The flow-chart, Figure 2, describes the processing and interpretation procedures. The magnetic tape cassette contains 18 recorded traces from each depth. These include data from the surface three component geophone and the downhole three-component geophone. There are a total of 6 traces for each source type (positive horizontal, negative horizontal, and vertical). As mentioned previously, the surface geophone is used only to check timing.

The orientation of the downhole geophone cannot be controlled when moving from one depth to the next, so that horizontal components are not generally oriented parallel and perpendicular to the source. This causes slight phase shifts, timing differences and amplitude variations. To minimize these effects, when timing shear-wave arrivals, the horizontal components are combined (rotated) to obtain a single component of motion. The direction of motion is determined by maximizing the integral square amplitude within a time interval containing the shear wave (Boatwright et al., 1986). Rotated traces are plotted on a 20-inch computer monitor and the first shear-wave arrival is timed for each of the horizontal rotated traces. Two arrival times are obtained from picks of the first S-wave arrival from oppositely directed horizontal impacts. Timing of the arrivals is done to one millisecond precision. The two time-picks are not always identical, due to interfering waves obscuring the first shear-arrival, slight phase shifts, or amplitude differences. If the time difference is greater than about 5 milliseconds a mistake in phase correlation (perhaps due to a reversed trace, noise etc.) can be suspected and a repick may be necessary. The two picks are averaged for velocity determinations. On clear traces one-millisecond picking accuracy can be maintained; however, because of lower signal-to-noise ratios and interfering waves in the deeper sections of the boreholes, this accuracy cannot always be achieved. In the inversion for shear-velocity the arrivals are weighted by the inverse of an assigned normalized variance. A normalized standard deviation of 1 was assigned to the

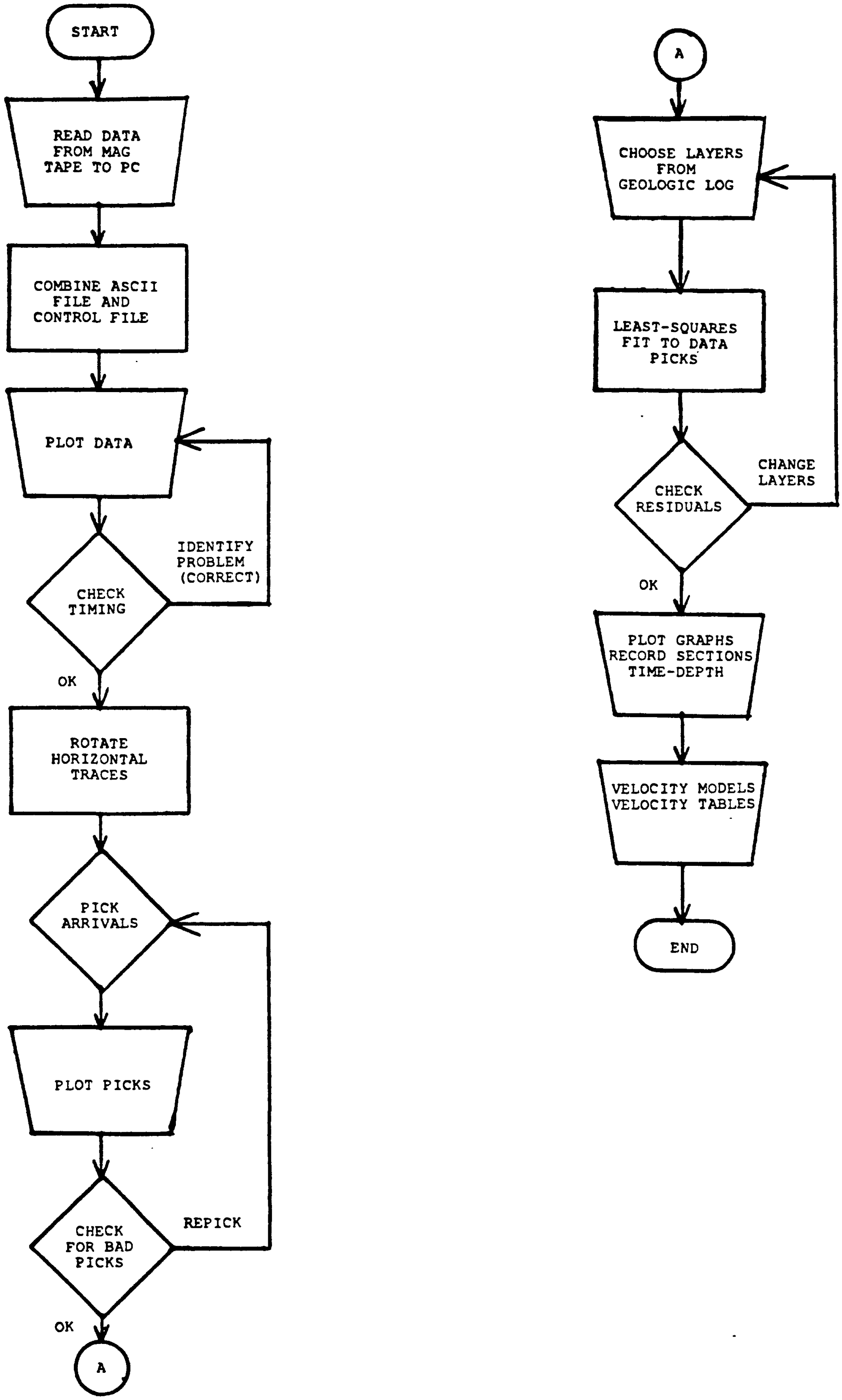

Figure 2. Flow-chart outlining the data processing and interpretation steps.

accurate picks and values ranging up to 5 were assigned to the others.

For determining the final velocity model there are a number of ways to proceed. In our earilier work (e.g., Gibbs et al., 1975) we determined the initial layer boundaries from the travel time plots by eye and then added or subtracted layers based on geologic boundaries consistent with the data. We also required at least three data points in each layer. This requirement limited the velocity determination to layers greater than 7.5 meters in thickness. The problem with this proceedure is that a mismatch (overlap or underlap) of the line segments sometimes occurred at the intersections of the layers, resulting in a discontinuous travel time curve. To address this problem we are now using a least-squares program (LFIT, Press et al., 1992) that fits the travel time data with line segments hinged at each selected layer boundary from the surface (forced through zero) to the bottom data point. Initial layer boundaries are chosen from the geologic log and are adjusted, if necessary, to reduce residuals and for consistency with the data. The S-wave travel time data are analyzed first; layer boundaries are initially the same for the P-wave model, and are then adjusted, if necessary, by adding a layer for the water table or reducing the number of layers. The velocity plots (e.g., Figure 13) show upper and lower bounds which approximate 68% confidence limits. These bounds are not symmetrical because they are based on the standard deviation of the slope of the least-squares line fit to the travel time plots (the inverse of the velocity).

SUMMARY OF RESULTS

S-wave velocities

Figure 3 summarizes S-wave velocities at three sites; Beach Park Boulevard (Foster City), Pacific Park Plaza (Emeryville), and Larkspur Ferry. These sites have varied thicknesses of soft bay mud near the surface with S-velocities less than 110 meters/second. Pacific Park Plaza has the thinnest mud section (3 meters), followed by Larkspur Ferry (14 meters) and Beach Park Boulevard (21 meters). Beach Park Boulevard has a low velocity layer at the surface because no artificial fill has been added; Pacific Park Plaza and Larkspur Ferry sites have artificial fill overlaying bay mud resulting in initial velocities of 279 amd 353 meters/second, respectively. The S-velocities below the mud are due to varying, of the textures (grain size), the compaction, and the cementation of the sediments, this

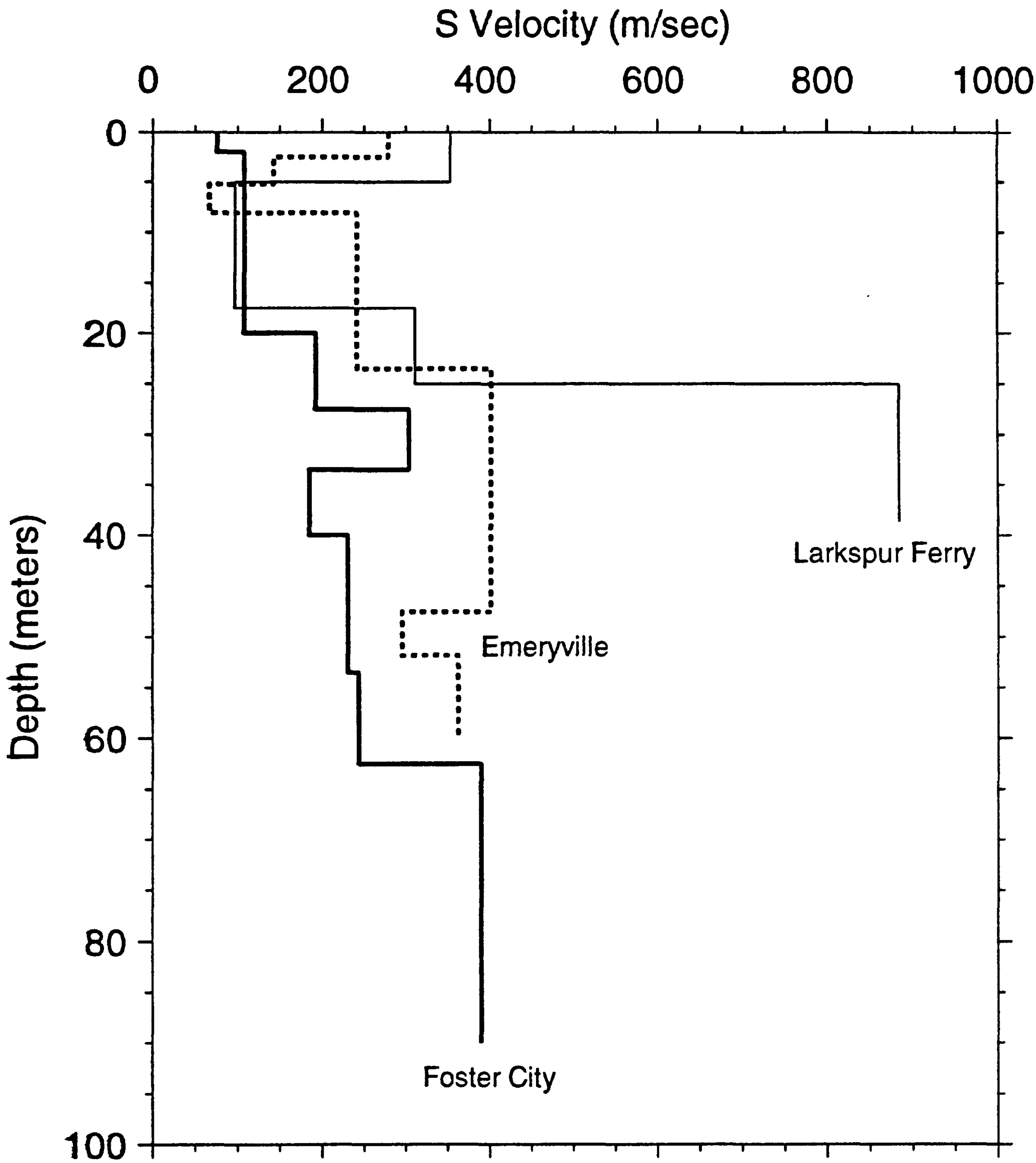

Figure 3. S-wave velocity models superimposed for comparison. The three sites shown have Holocene Bay Mud deposits near the surface and are located close to the margin of San Francisco Bay.

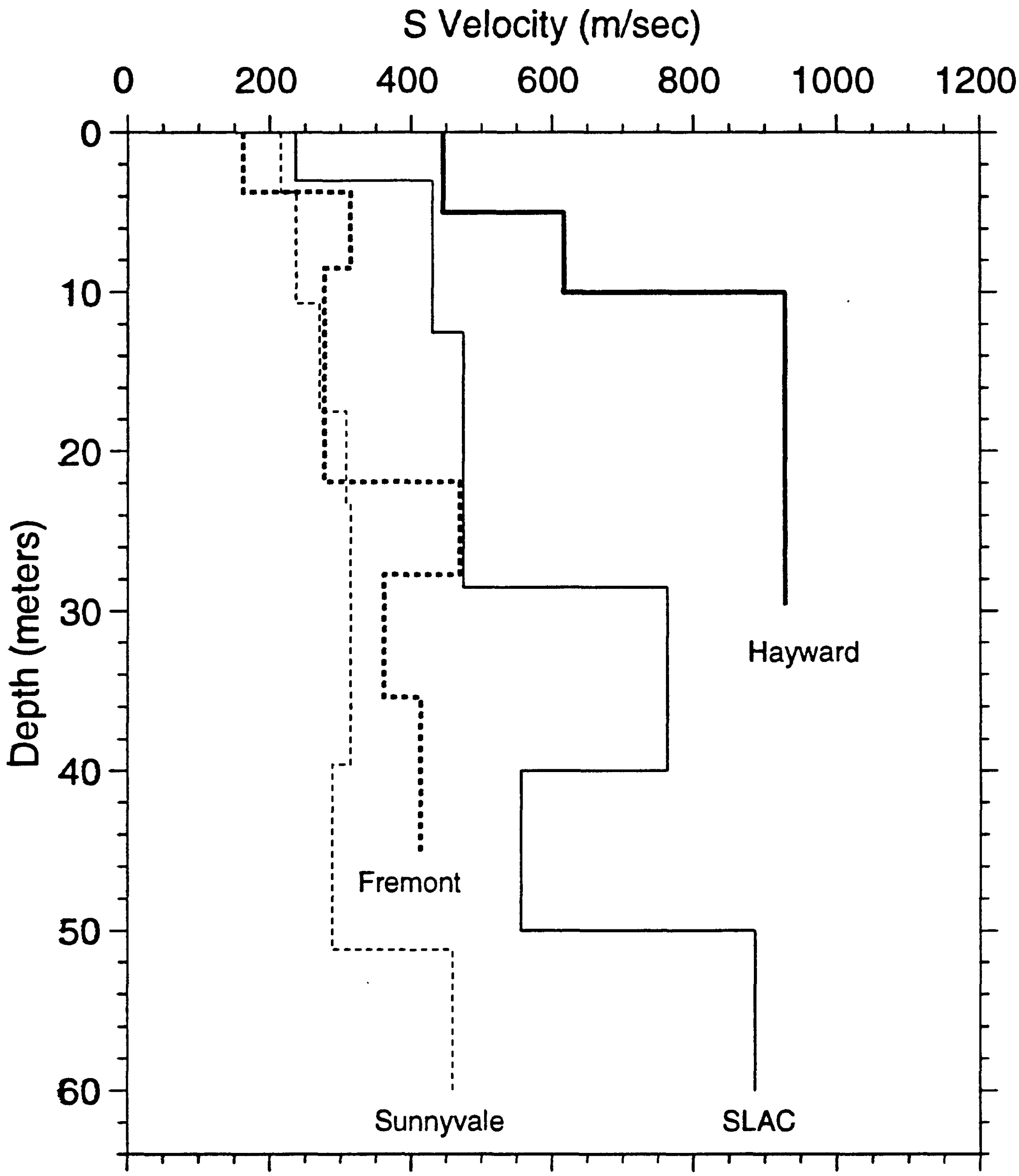

Figure 4. S-wave velocity models superimposed for comparison. In general, these four sites do not have Holocene Bay Mud deposits and and as a result have higher S-wave velocities in the uppers sections of the borehole.

variation is typical of much of the near-surface geology close to San Francisco Bay.

Figure 4 shows the summaries of S-velocities at four sites; Hayward City Hall, Fremont, SLAC and Sunnyvale Colton Avenue. Fremont and Sunnyvale Colton Avenue, located on the flatlands of the valley, have similiar velocities. The S-velocities are higher at SLAC which is farther from San Francisco Bay and in the foothills of the Santa Cruz Mountains. Higher velocities are encountered at the Hayward City Hall site which is underlain by weathered rock (617 meters/second) and by fresh rock (928 meters/second) below 10 meters depth.

P-wave velocities

Figures 5 and 6 summarizes the P-wave velocities at three sites near the margins of San Francisco Bay and at four sites farther inland, respectively. There is a poorer correlation between P-wave velocity and lithology than S-wave velocity and lithology because P-wave velocity is strongly affected by degree of saturation. Note that even though saturated, the P-wave velocities measured in the bay mud are less than the velocity of P-waves in water ($\approx$ 1500 meters/second). The explanation for this may be that the presence of trapped gas (Brandt, 1960) has reduced the P-wave velocity (e.g. air, methane from decaying organic matter).

The appendix lists the detailed results, organized alphabetically by borehole. Figures and tables for each site are arranged in the following order:

1. location map
2. geologic log
3. record sections
4. time-depth graph
5. velocity profiles
6. velocity tables

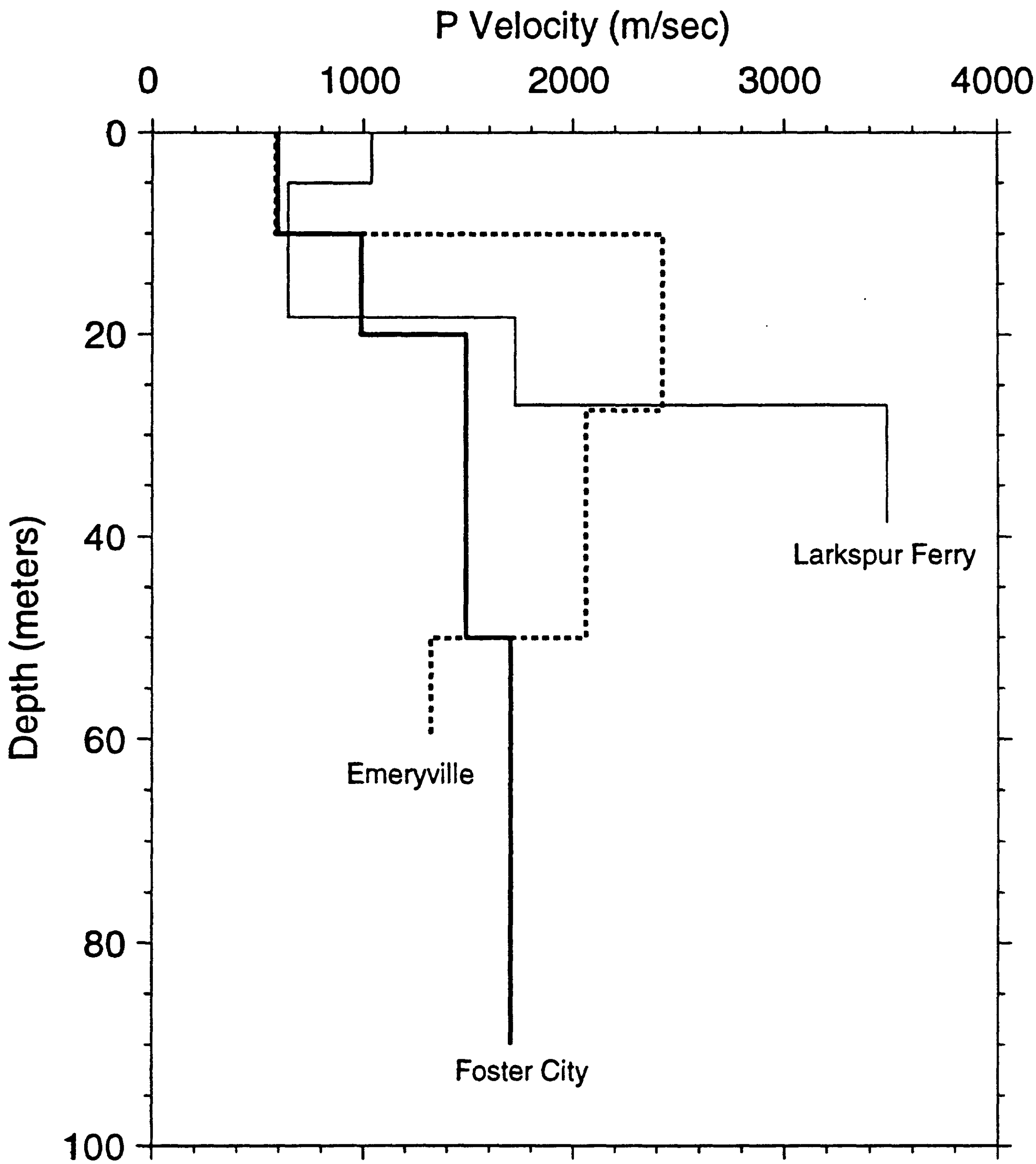

Figure 5. P-wave velocity models superimposed for comparison.

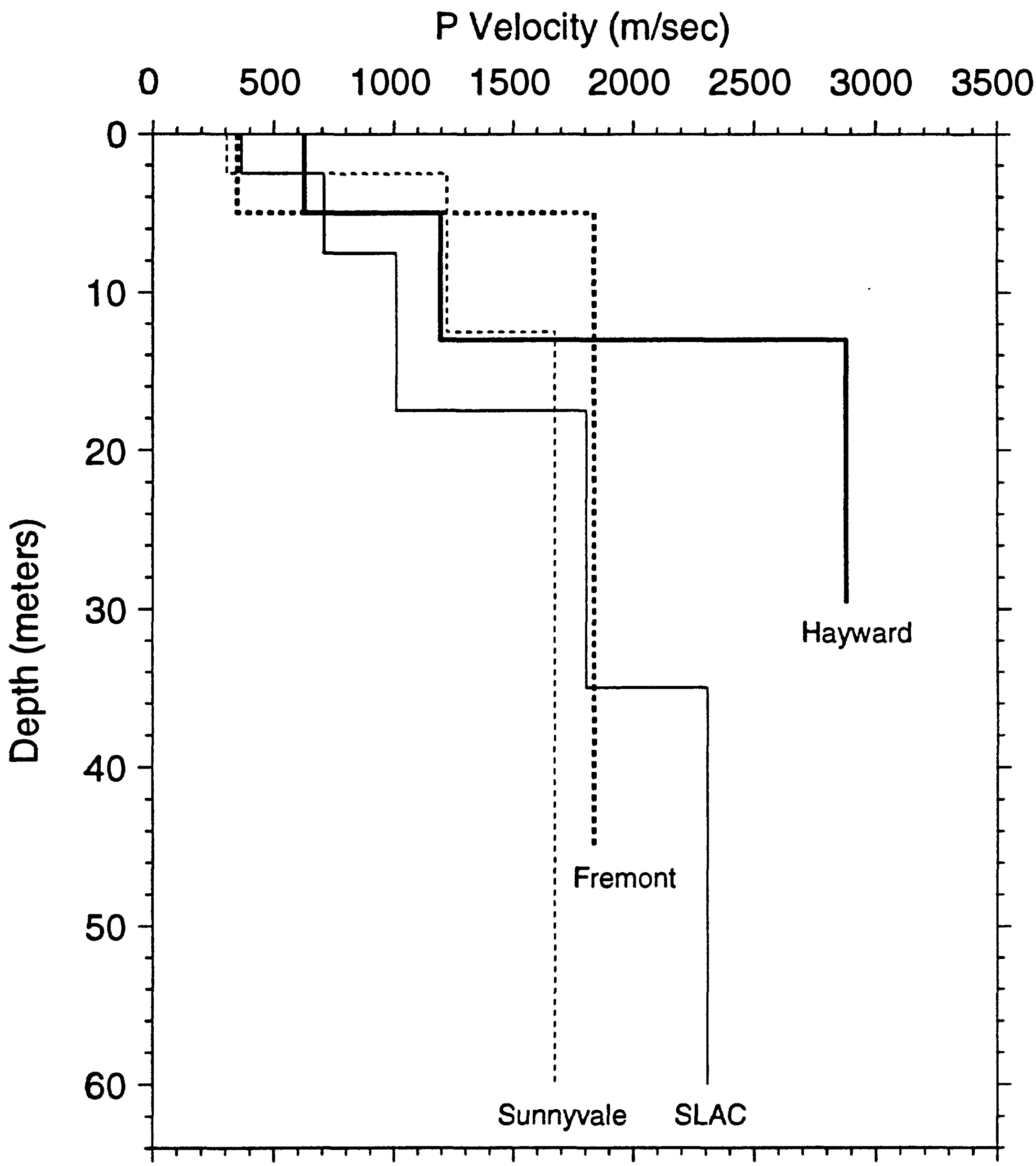

Figure 6. P -wave velocity models superimposed for comparison.

ACKNOWLEDGMENTS

We wish to thank Mr. Robert Westerlund of the *USGS* for building the electrically actuated clamp for the borehole geophone and Dr. Hsi-Ping Liu of the *USGS* for designing the shear-wave generator. In addition, we were assisted in the field by Mr. Michael Carter, and Miss Aina Fox of the *USGS.*

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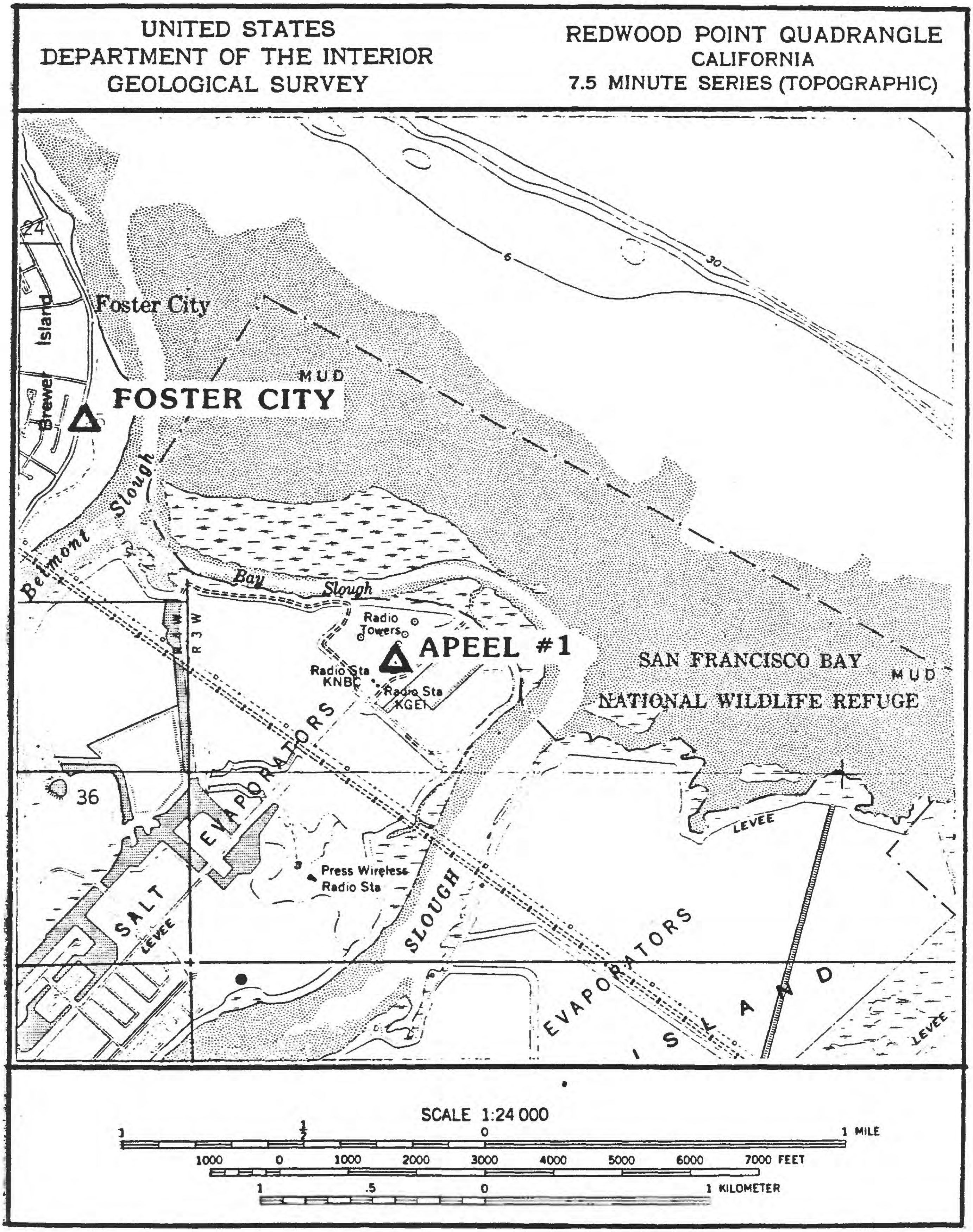


Figure 7. Site location map for the borehole at Beach Park Boulevard (Foster City) and APEEL #1 (not in this report). The borehole at Beach Park Boulevard is located approximately 300 meters from the strong-motion recorder.

Definitions of terms used for descriptions of sedimentary deposits and bedrock materials

Rock hardness: response to hand and geologic hammer: (Ellen et al., 1972)

hard - hammer bounces off with solid sound
firm - hammer dents with thud, pick point dents or penetrates slightly
soft - pick points penetrates
friable material can be crumbled into individual grains by hand.

Fracture spacing: (Ellen et al., 1972)

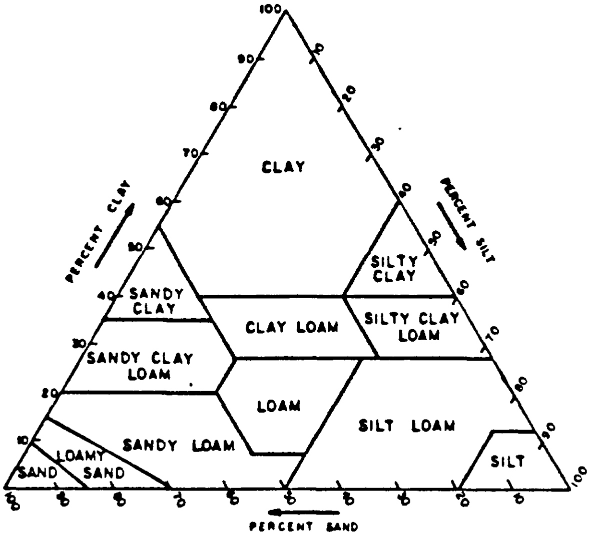
cm	in	fracture spacing
0-1	0-1/2	v. close
1-5	1/2-2	close
5-30	2-12	moderate
30-100	12-36	wide
>100	>36	v. wide

Weathering:
Fresh: no visible signs of weathering
Slight: no visible decomposition of minerals, slight discoloration
Moderate: slight decomposition of minerals and disintegration of rock, deep and thorough discoloration
Deep: extensive decomposition of minerals and complete disintegration of rock but original structure is preserved.

Relative density of sand and consistency of clay is correlated with penetration resistance: (Terzaghi and Peck, 1948)

blows/ft.	relative density	blows/ft.	consistency
0-4	v. loose	<2	v. soft
4-10	loose	2-4	soft
10-30	medium	4-8	medium
30-50	dense	8-15	stiff
>50	v. dense	15-30	v. stiff
		>30	hard

Texture: the relative proportions of clay, silt, and sand below 2mm. Proportions of larger particles are indicated by modifiers of textural class names. Determination is made in the field mainly by feeling the moist soil (Soil Survey, Staff, 1951).



Color: Standard Munsell color names are given for the dominant color of the moist soil and for prominent mottles.

Types of samples

SP - Standard Penetration 1 + 3/8 in in ID sampler)
S - Thin-wall push sampler
O - Osterberg fixed-piston sampler
P - Pitcher Barrel sampler
CH - California Penetration (2 in ID sampler)
DC - Diamond Core

Figure 8. Explanation of geologic logs.

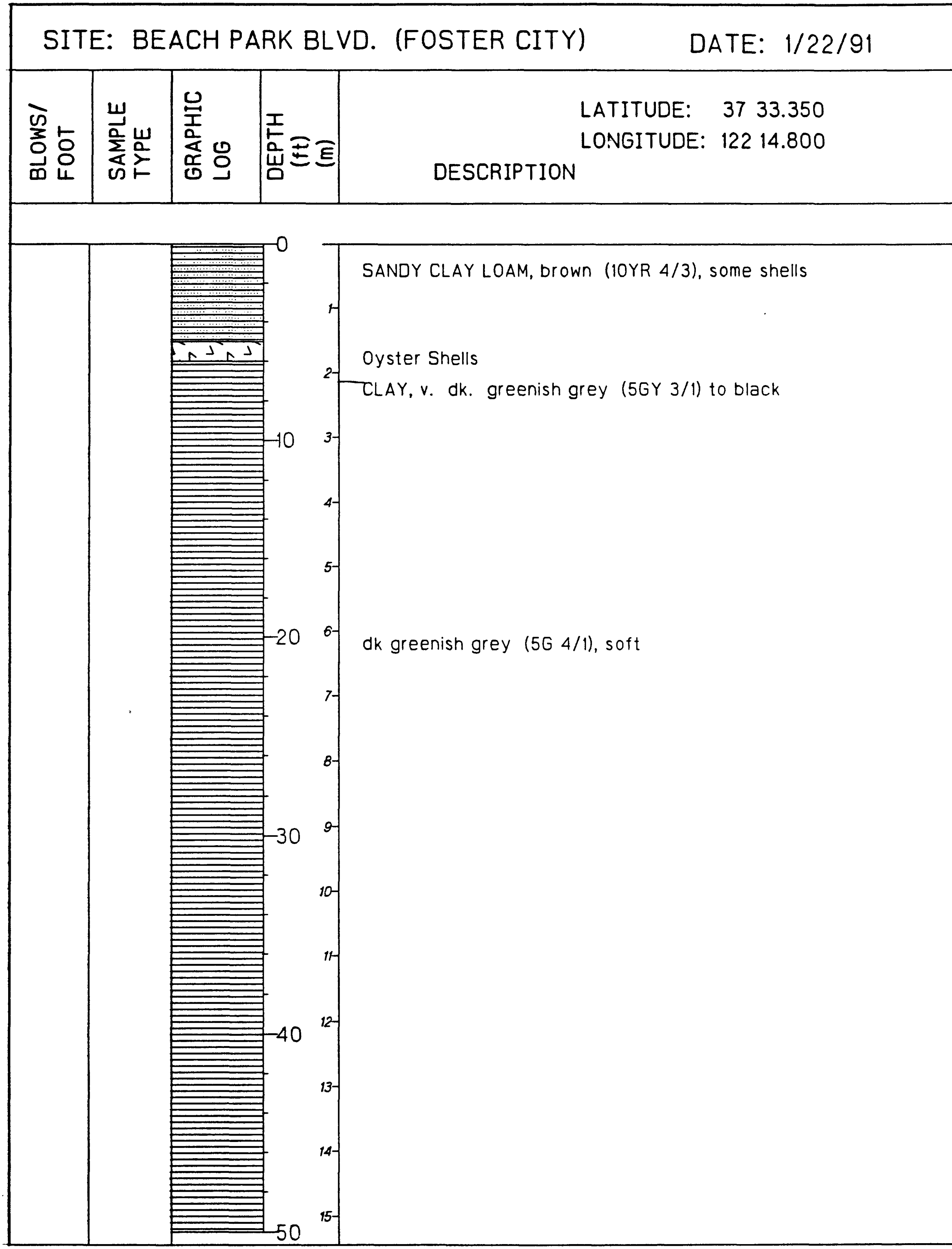


Figure 9. Geologic log of Beach Park Boulevard (Foster City) borehole.

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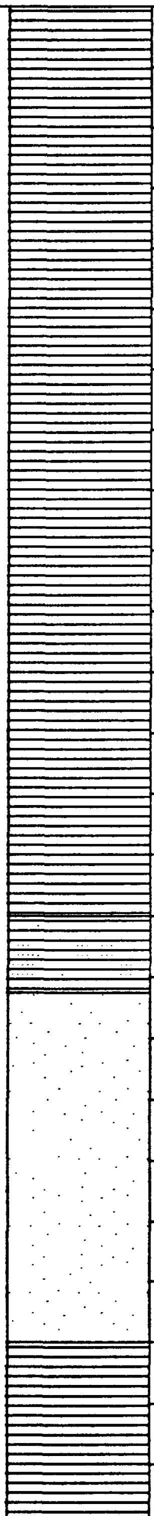
SITE: BEACH PARK BLVD. (FOSTER CITY) DATE: 1/22/91

LATITUDE: 37 33.350
LONGITUDE: 122 14.800



BLOWS/ FOOT	SAMPLE TYPE	GRAPHIC LOG	DEPTH (ft)	DEPTH (m)	DESCRIPTION
			50		
				16	
				17	
				18	
			60		
				19	
				20	stiffer
				21	
			70		
				22	
				23	
				24	
			80		
					SILTY CLAY LOAM, dk greyish brown (2.5 Y 1/2)
				25	
					SAND, brown, fine to medium grained (well sorted)
				26	
				27	
			90		some fine gravel
				28	SAND, black (5Y 2.5/2), very coarse
				29	CLAY, greenish grey (5G 5/1), stiff
				30	
			100		

Figure 9. (Continued).

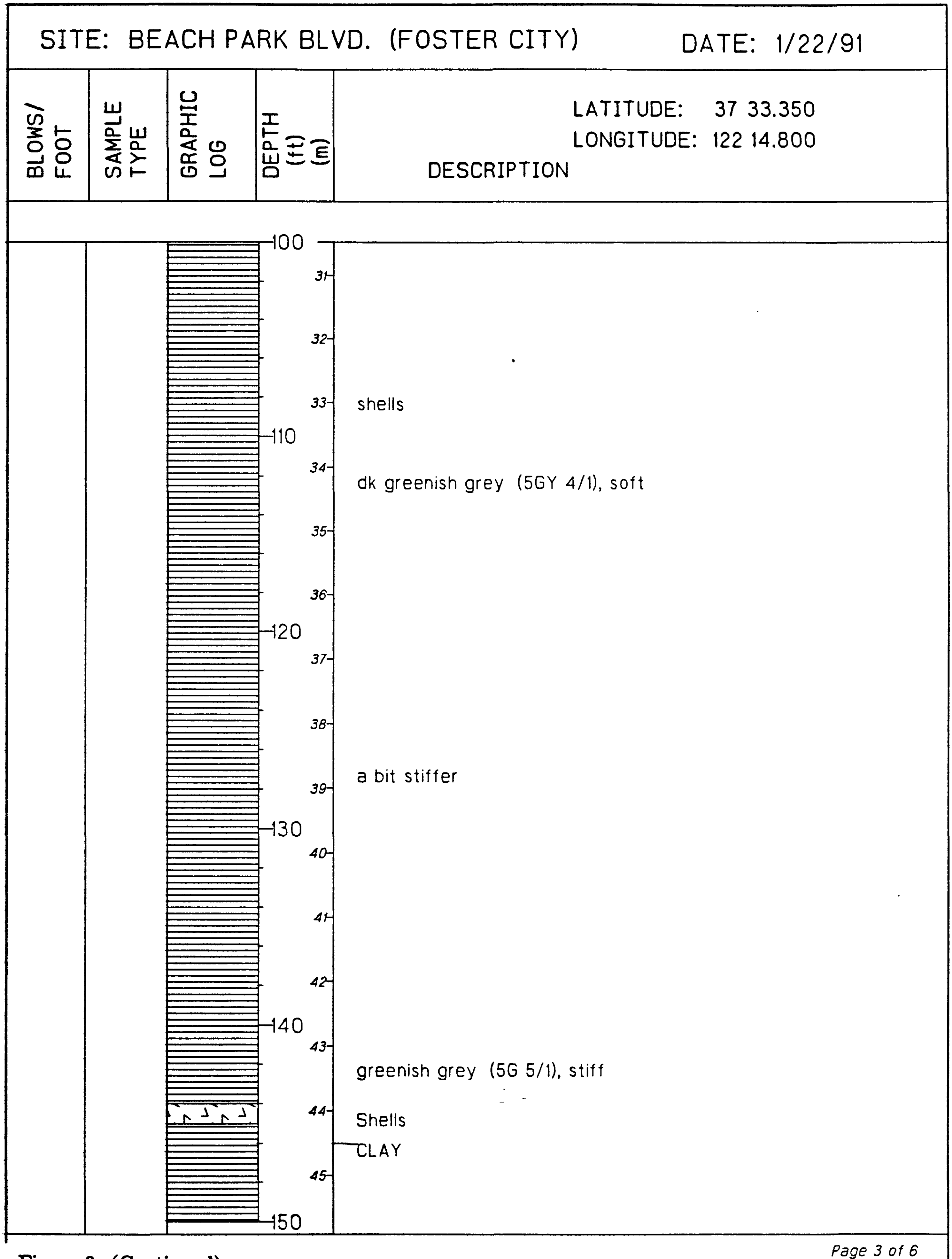
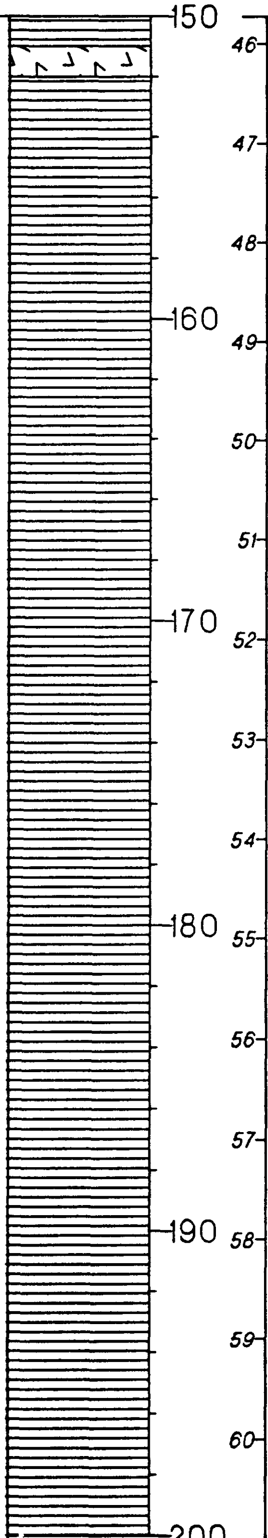


Figure 9. (Continued).

SITE: BEACH PARK BLVD. (FOSTER CITY) DATE: 1/22/91

BLOWS/ FOOT	SAMPLE TYPE	GRAPHIC LOG	DEPTH (ft) (m)	DESCRIPTION

LATITUDE: 37 33.350
LONGITUDE: 122 14.800



Shells

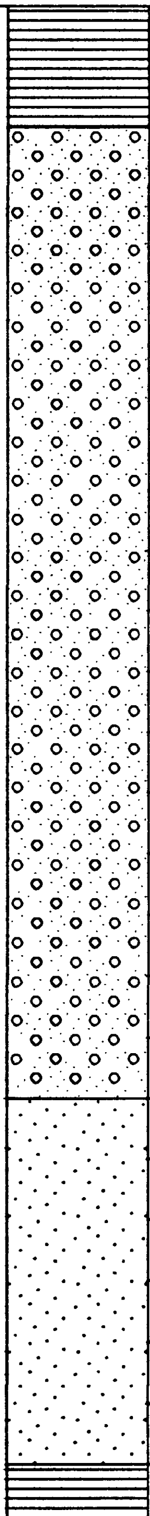
CLAY

v. dk. greenish grey (5GY 3/1), stiff

Figure 9. (Continued).

SITE: BEACH PARK BLVD. (FOSTER CITY) DATE: 1/22/91

LATITUDE: 37 33.350
LONGITUDE: 122 14.800



BLOWS/ FOOT	SAMPLE TYPE	GRAPHIC LOG	DEPTH (ft)	(m)	DESCRIPTION
			200	61	
				62	
					GRAVELLY SAND, v. dk. greenish grey
				63	
			210	64	
				65	
				66	
			220	67	
				68	
				69	
			230	70	
				71	
				72	
					SAND
			240	73	
				74	
				75	
				76	SILTY CLAY, olive grey (5Y 4/2), stiff
			250		

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Figure 9. (Continued).

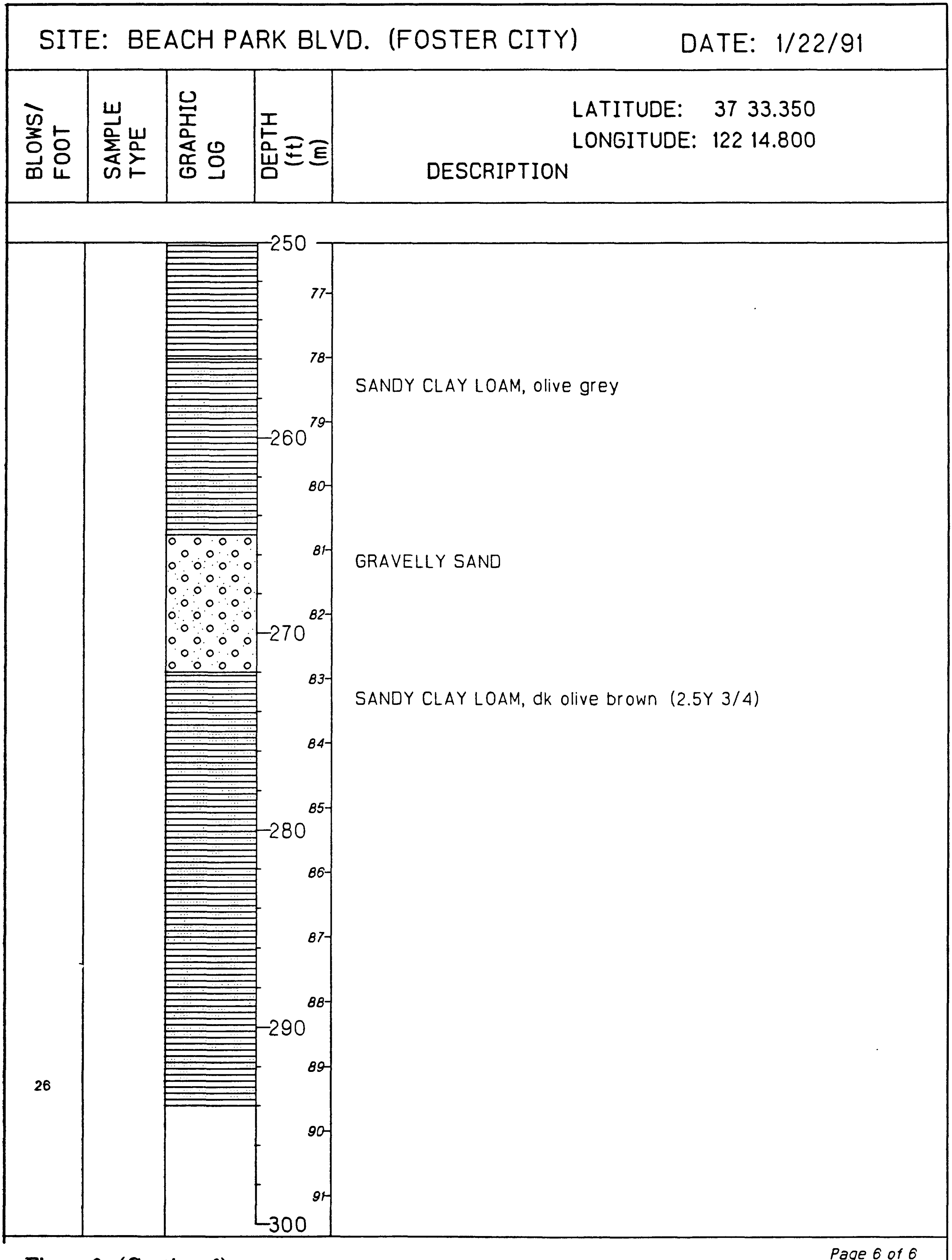
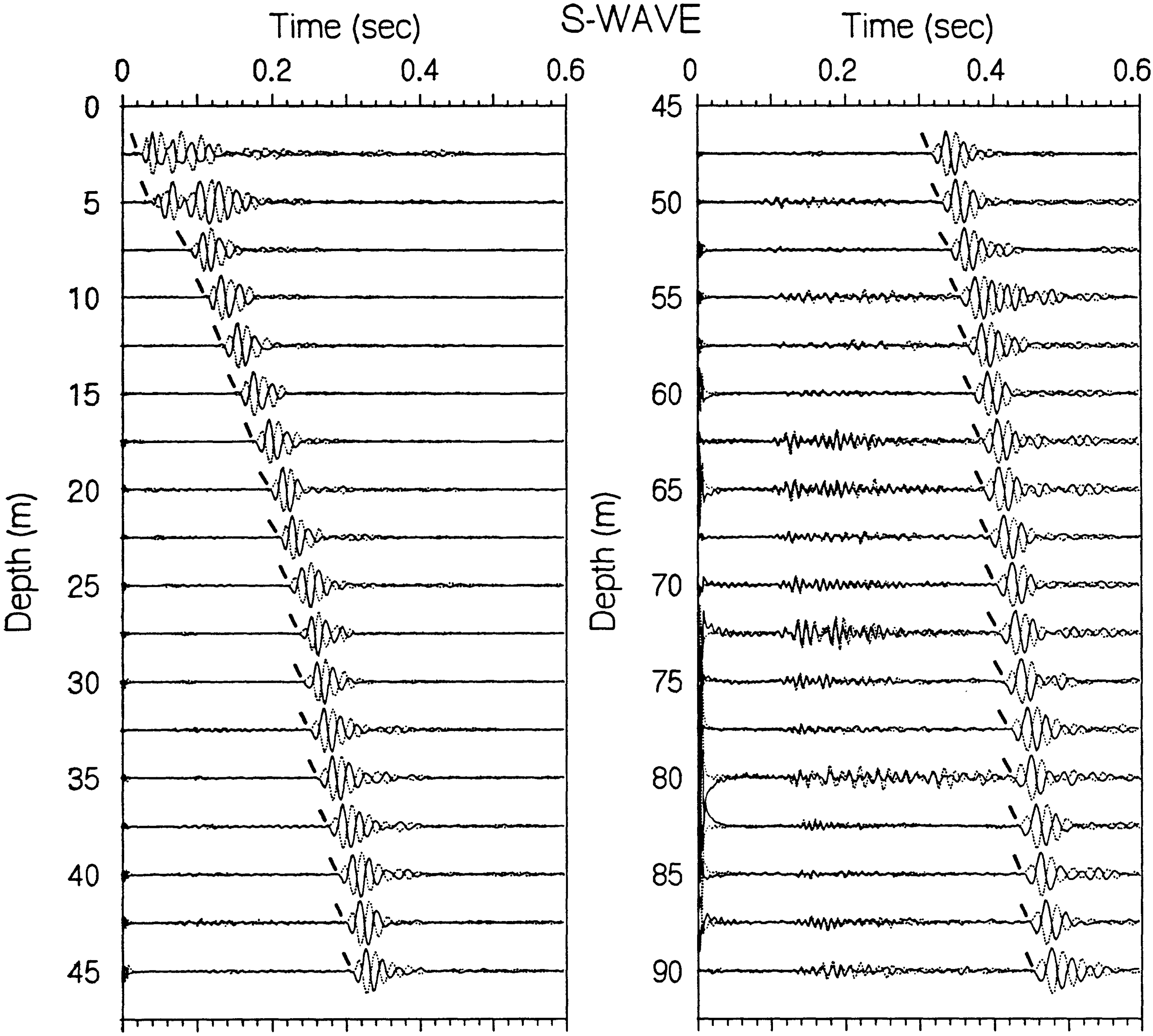


Figure 9. (Continued).



Beach Park Boulevard
(Foster City)

Figure 10. Record section of S-waves from impacts in opposite horizontal directions superimposed for indentification of S-wave onset. Approximate S-wave picks are shown by the accent marks.

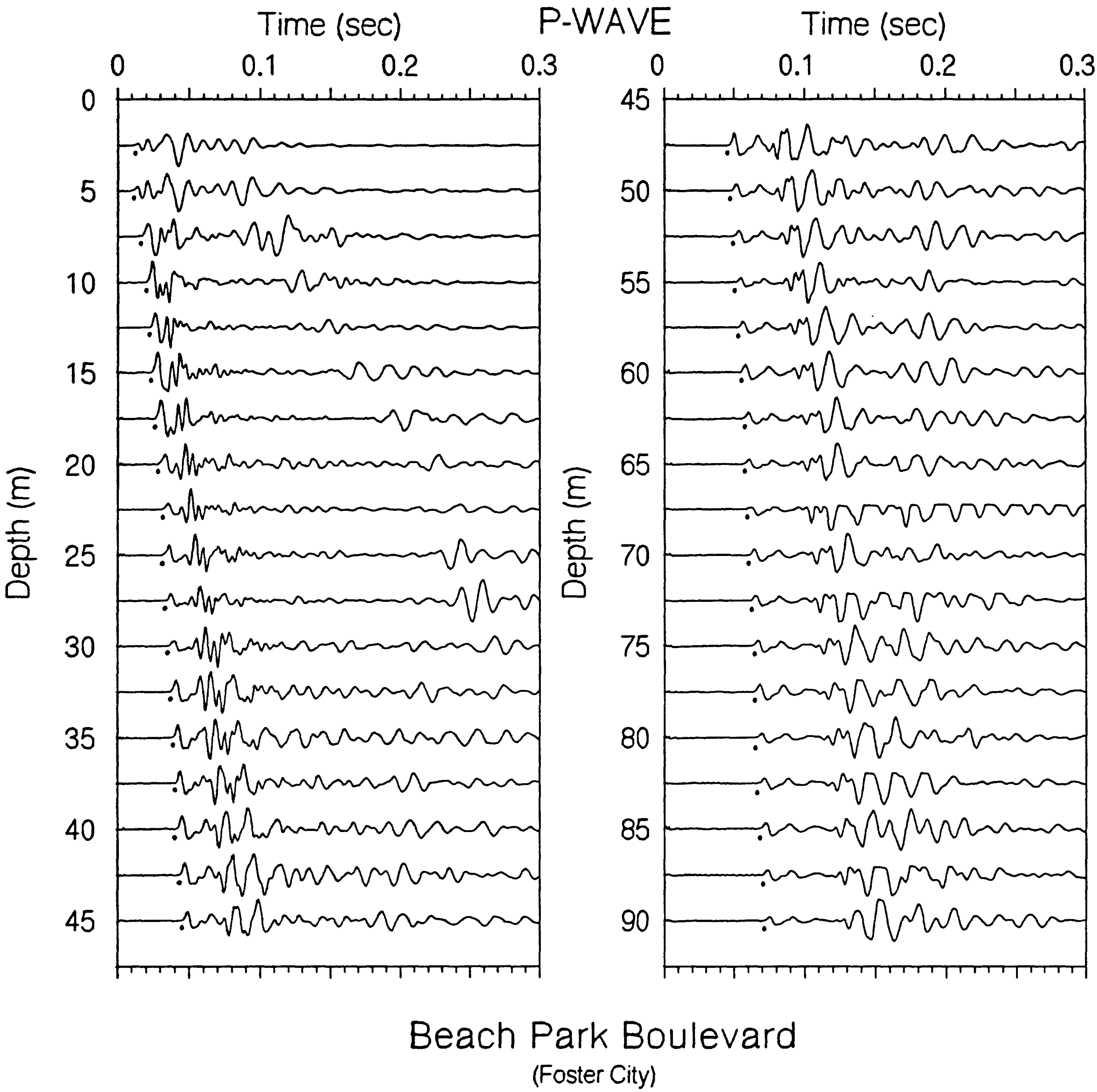


Figure 11. Vertical component record section. P-wave arrivals are shown by the solid circles.

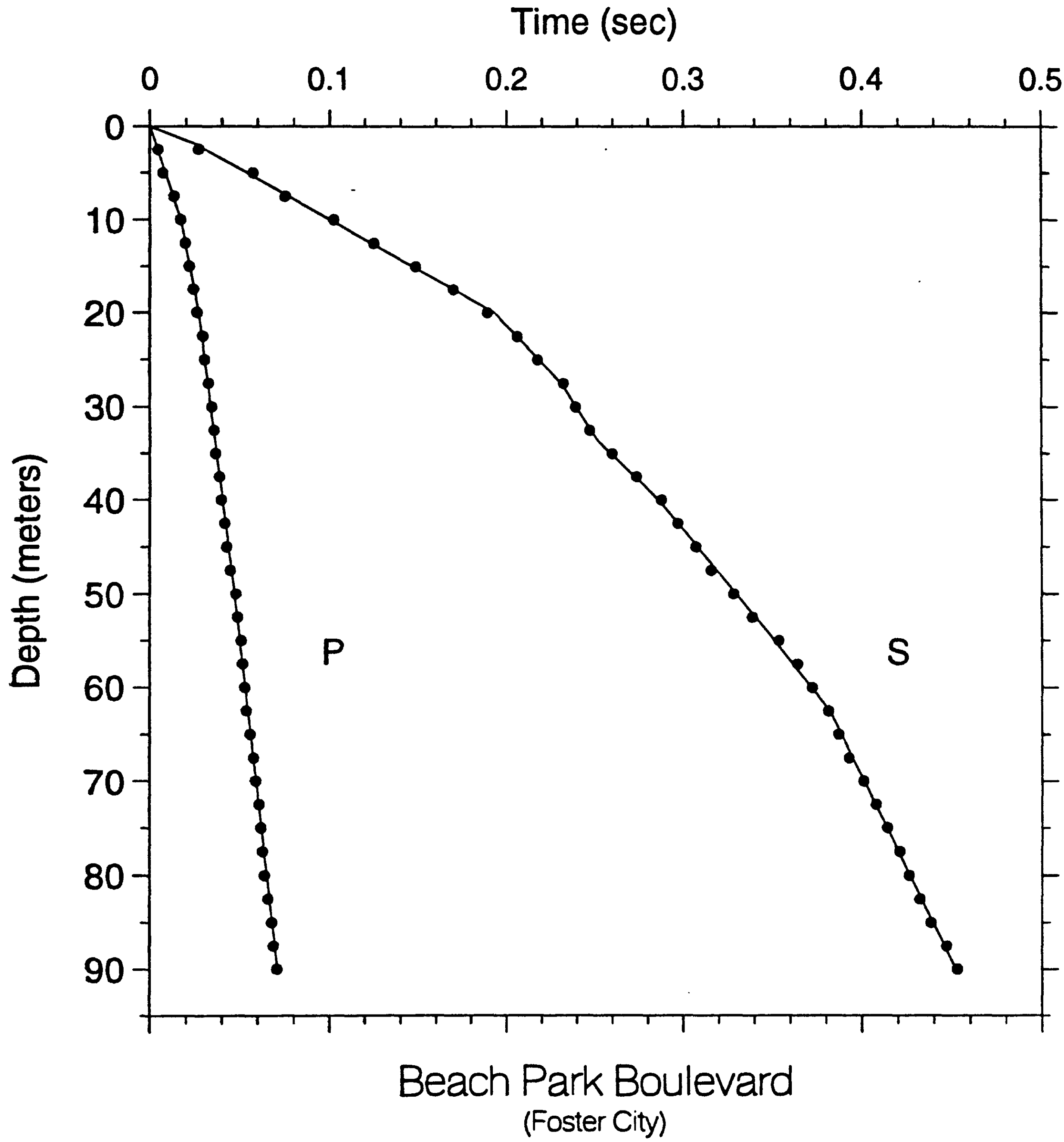


Figure 12. Time-depth graph of P-wave and S-wave picks. Line segments show the hinged-least-squares fit to the data points.

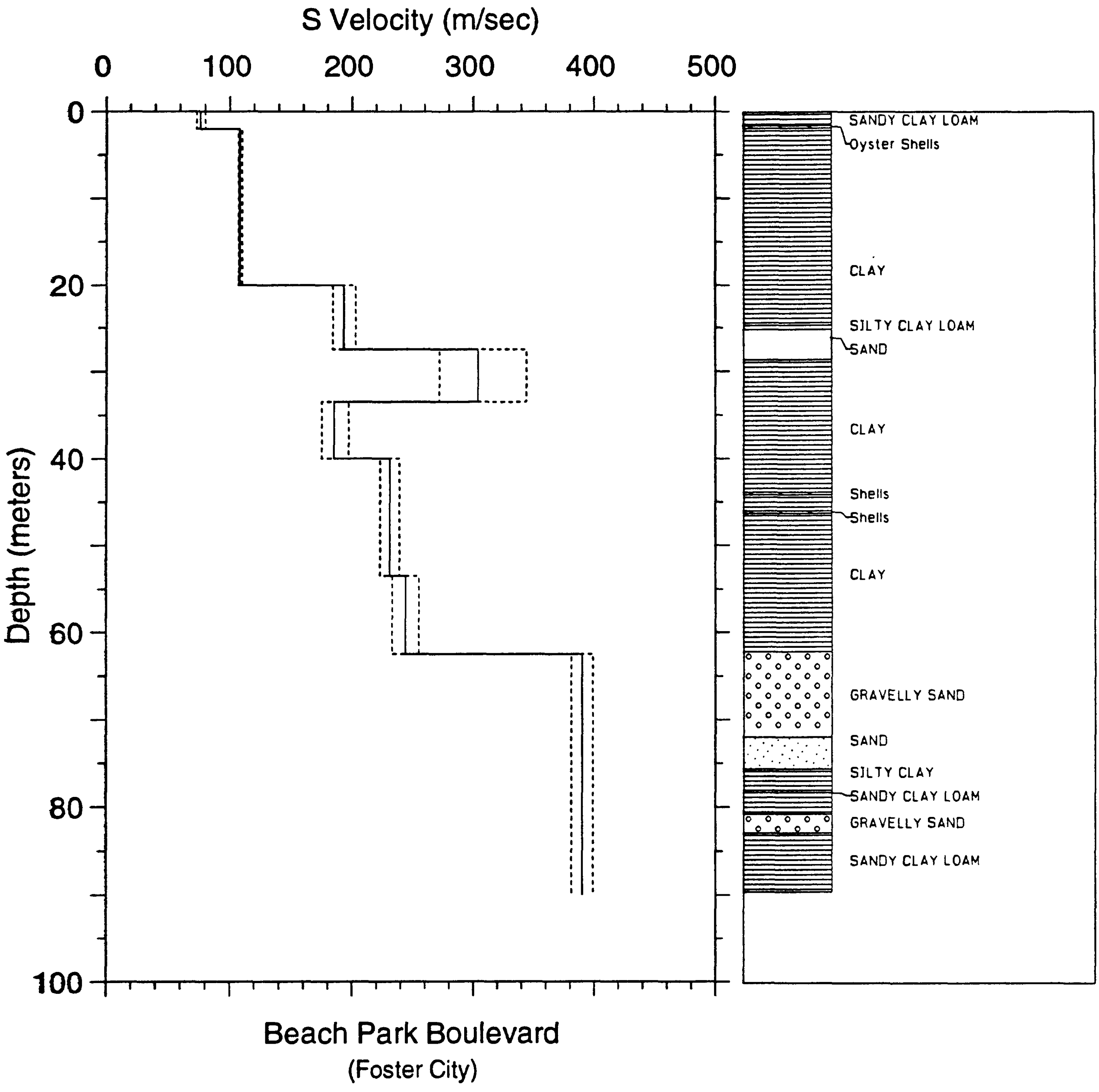


Figure 13. S-wave velocity profiles with dashed lines representing plus and minus one standard deviation. Simplified geologic log is shown for correlation with velocities.

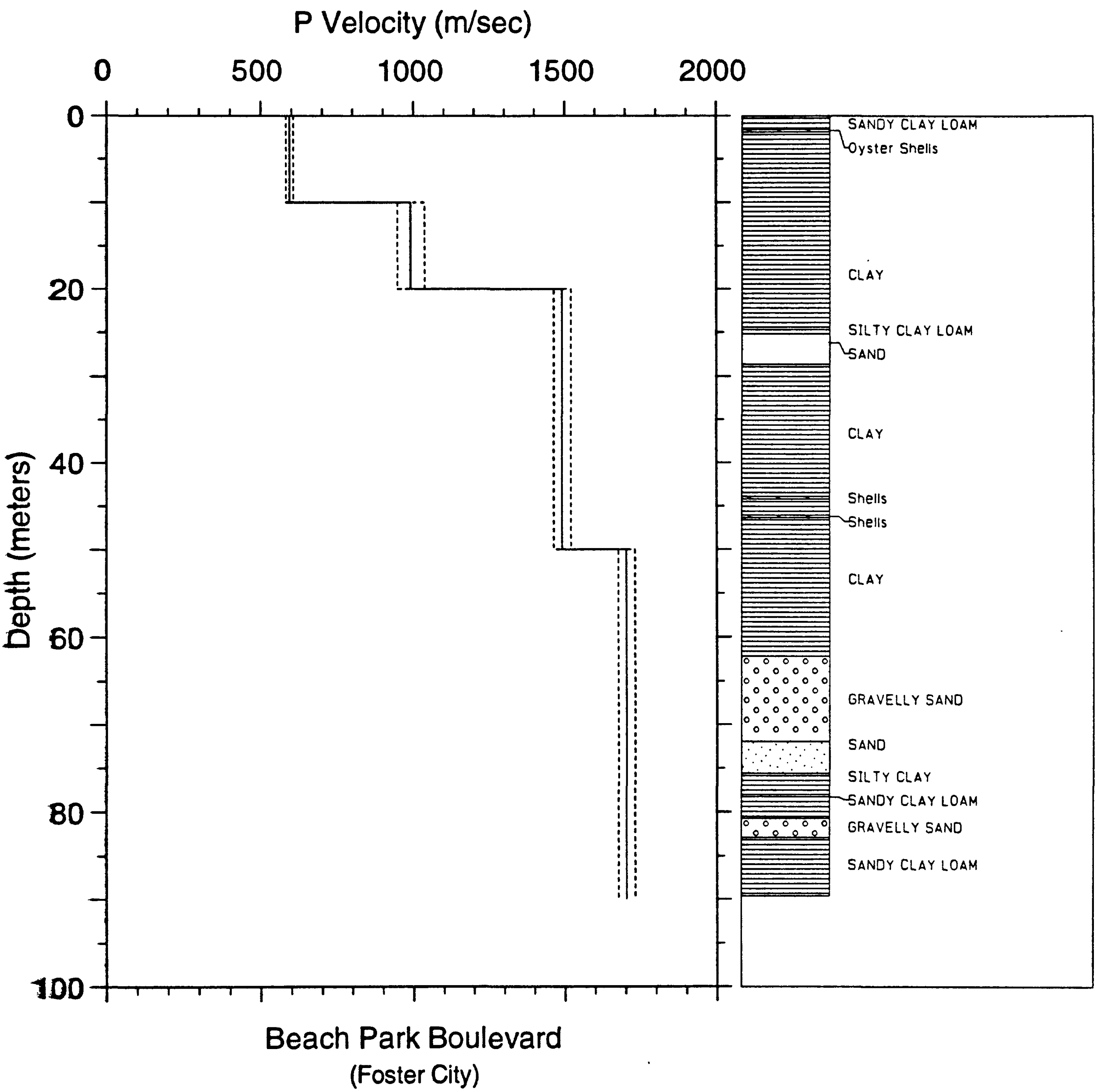


Figure 14. P-wave velocity profiles with dashed lines representing plus and minus one standard deviation. Simplified geologic log is shown for correlation with velocities.

TABLE 1. S-wave arrival times and velocity summaries for Beach Park Boulevard (Foster City) site.

d(m)	d(ft)	t(sec)	sig	rsdl/sig
2.5	8.2	.0270	1	-4.0
5.0	16.4	.0573	1	3.2
7.5	24.6	.0753	1	-1.9
10.0	32.8	.1024	1	2.2
12.5	41.0	.1249	1	1.6
15.0	49.2	.1485	1	2.1
17.5	57.4	.1697	1	.2
20.0	65.6	.1892	1	-3.4
22.5	73.8	.2060	1	.4
25.0	82.0	.2177	1	-.8
27.5	90.2	.2322	1	.8
30.0	98.4	.2392	1	-.5
32.5	106.6	.2471	1	-.8
35.0	114.8	.2599	1	.6
37.5	123.0	.2736	1	.9
40.0	131.2	.2878	1	1.6
42.5	139.4	.2970	1	-.1
45.0	147.6	.3071	1	-.8
47.5	155.8	.3158	1	-2.9
50.0	164.0	.3284	1	-1.2
52.5	172.2	.3390	1	-1.4
55.0	180.4	.3536	1	2.7
57.5	188.6	.3641	1	2.9
60.0	196.9	.3722	1	.8
62.5	205.1	.3813	1	-.4
65.0	213.3	.3869	1	-1.2
67.5	221.5	.3929	1	-1.6
70.0	229.7	.4010	1	.1
72.5	237.9	.4080	1	.6
75.0	246.1	.4141	1	.3
77.5	254.3	.4211	1	.9
80.0	262.5	.4262	1	-.4
82.5	270.7	.4322	1	-.8
85.0	278.9	.4382	1	-1.2
87.5	287.1	.4468	1	.9
90.0	295.3	.4528	1	.5

dtb(m)	dtb(ft)	ttb(s)	v(m/s)	vl(m/s)	vu(m/s)	v(ft/s)	vl(ft/s)	vu(ft/s)
.0	.0	.000	76	73	80	249	238	261
2.0	6.6	.026	76	73	80	249	238	261
20.0	65.6	.193	108	107	110	355	351	359
27.5	90.2	.231	193	184	203	634	604	667
33.5	109.9	.251	304	272	344	998	893	1130
40.0	131.2	.286	185	175	197	608	573	648
53.5	175.5	.345	231	223	239	757	733	783
62.5	205.1	.382	244	233	255	799	766	835
90.0	295.3	.452	390	381	399	1278	1250	1308

Explanation:

d(m) = depth in meters
d(ft) = depth in feet
t(sec) = arrival time in seconds (S-wave arrival times are the average of picks from traces obtained from hammer blows differing in direction by 180°)
sig = sigma, standard deviation normalized to the standard deviation of best picks
rsdl/sig = least-squares residual divided by sigma
dtb(m) = depth to bottom of layer in meters
dtb(ft) = depth to bottom of layer in feet
ttb(s) = arrival time in seconds to bottom of layer
v(m/s) = velocity in meters per second
vl(m/s) = lower limit of velocity in meters per second *
vu(m/s) = upper limit of velocity in meters per second
v(ft/s) = velocity in feet per second
vl(ft/s) = lower limit of velocity in feet per second
vu(ft/s) = upper limit of velocity in feet per second

* see text for explanation of velocity limits

TABLE 2. P-wave arrival times and velocity summaries for Beach Park Boulevard (Foster City) site.

d(m)	d(ft)	t(sec)	sig	rsdl/sig
2.5	8.2	.0045	1	.3
5.0	16.4	.0071	1	-1.3
7.5	24.6	.0133	1	.7
10.0	32.8	.0170	1	.2
12.5	41.0	.0195	1	.1
15.0	49.2	.0218	1	-.1
17.5	57.4	.0240	1	-.4
20.0	65.6	.0262	1	-.8
22.5	73.8	.0293	1	.7
25.0	82.0	.0304	1	.1
27.5	90.2	.0325	1	.5
30.0	98.4	.0345	1	.8
32.5	106.6	.0356	1	.3
35.0	114.8	.0366	1	-.4
37.5	123.0	.0387	1	.0
40.0	131.2	.0397	1	-.7
42.5	139.4	.0417	1	-.3
45.0	147.6	.0427	1	-1.0
47.5	155.8	.0448	1	-.6
50.0	164.0	.0478	1	.7
52.5	172.2	.0488	1	.3
55.0	180.4	.0508	1	.8
57.5	188.6	.0518	1	.3
60.0	196.9	.0528	1	-.1
62.5	205.1	.0538	1	-.6
65.0	213.3	.0558	1	-.1
67.5	221.5	.0578	1	.5
70.0	229.7	.0589	1	.1
72.5	237.9	.0609	1	.6
75.0	246.1	.0619	1	.2
77.5	254.3	.0629	1	-.3
80.0	262.5	.0639	1	-.8
82.5	270.7	.0659	1	-.3
85.0	278.9	.0679	1	.3
87.5	287.1	.0689	1	-.2
90.0	295.3	.0709	1	.3

dtb(m)	dtb(ft)	ttb(s)	v(m/s)	vl(m/s)	vu(m/s)	v(ft/s)	vl(ft/s)	vu(ft/s)
.0	.0	.000	594	582	606	1947	1908	1988
10.0	32.8	.017	594	582	606	1947	1908	1988
20.0	65.6	.027	990	947	1037	3248	3105	3403
50.0	164.0	.047	1491	1464	1520	4893	4803	4986
90.0	295.3	.071	1703	1676	1731	5586	5498	5678

Explanation:
- d(m) = depth in meters
- d(ft) = depth in feet
- t(sec) = arrival time in seconds (S-wave arrival times are the average of picks from traces obtained from hammer blows differing in direction by 180°)
- sig = sigma, standard deviation normalized to the standard deviation of best picks
- rsdl/sig = least-squares residual divided by sigma
- dtb(m) = depth to bottom of layer in meters
- dtb(ft) = depth to bottom of layer in feet
- ttb(s) = arrival time in seconds to bottom of layer
- v(m/s) = velocity in meters per second
- vl(m/s) = lower limit of velocity in meters per second *
- vu(m/s) = upper limit of velocity in meters per second
- v(ft/s) = velocity in feet per second
- vl(ft/s) = lower limit of velocity in feet per second
- vu(ft/s) = upper limit of velocity in feet per second

* see text for explanation of velocity limits

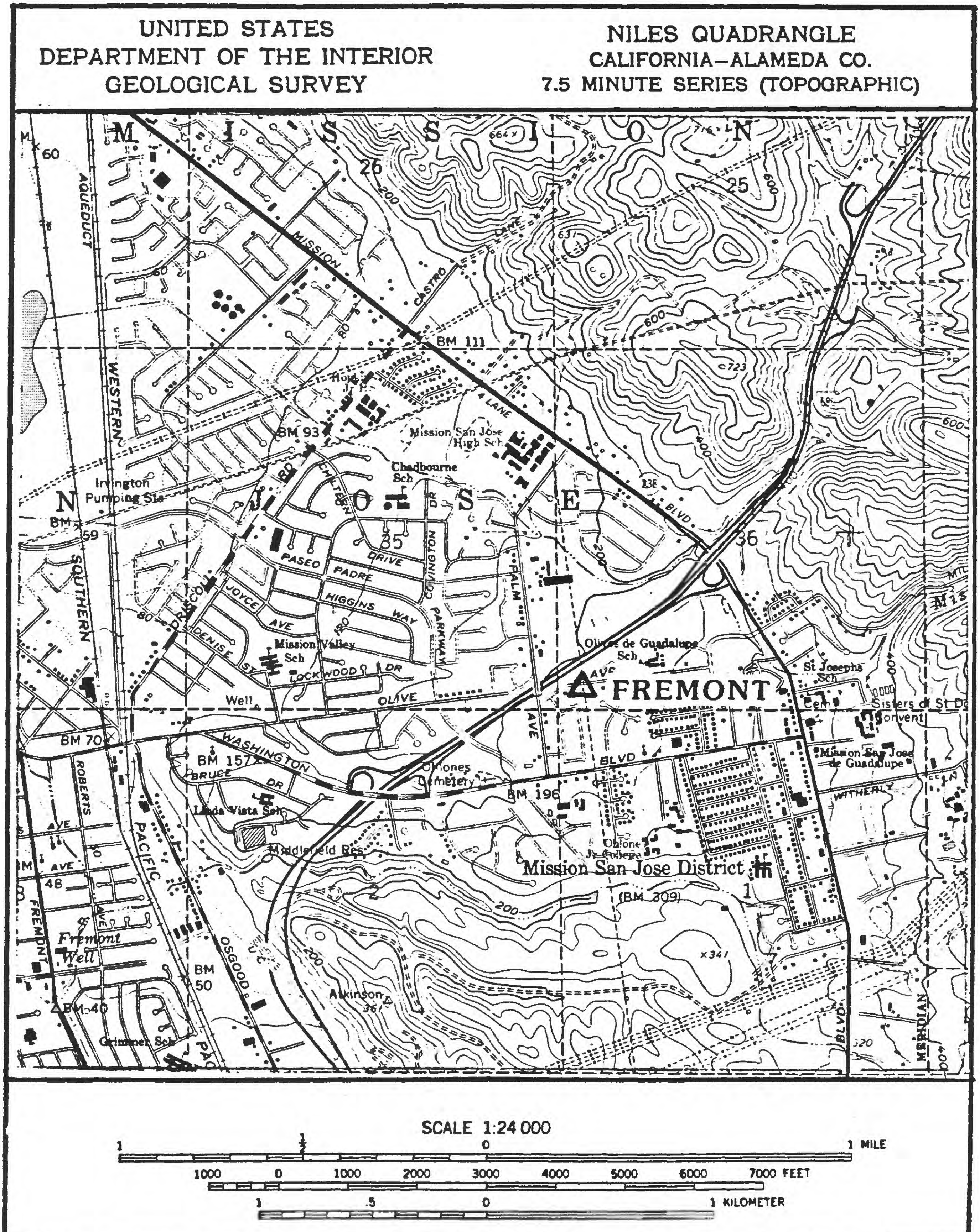


Figure 15. Site location map for Fremont borehole.

Definitions of terms used for descriptions of sedimentary deposits and bedrock materials

Rock hardness: response to hand and geologic hammer: (Ellen et al., 1972)

hard - hammer bounces off with solid sound
firm - hammer dents with thud, pick point dents or penetrates slightly
soft - pick points penetrates
friable material can be crumbled into individual grains by hand.

Fracture spacing: (Ellen et al., 1972)

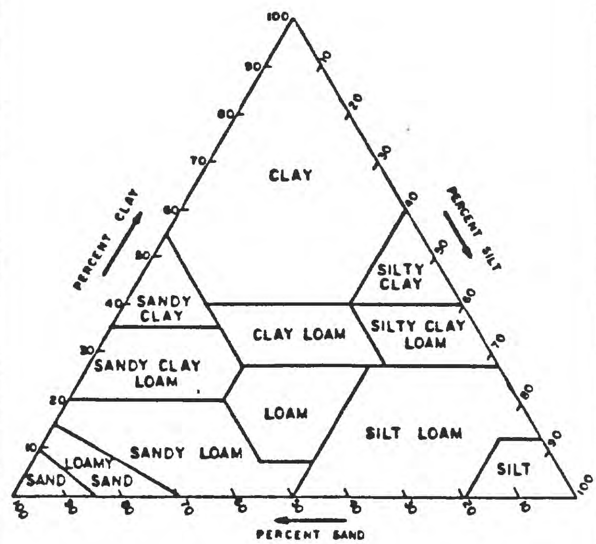
cm	in	fracture spacing
0-1	0-1/2	v. close
1-5	1/2-2	close
5-30	2-12	moderate
30-100	12-36	wide
>100	>36	v. wide

Weathering:
Fresh: no visible signs of weathering
Slight: no visible decomposition of minerals, slight discoloration
Moderate: slight decomposition of minerals and disintegration of rock, deep and thorough discoloration
Deep: extensive decomposition of minerals and complete disintegration of rock but original structure is preserved.

Relative density of sand and consistency of clay is correlated with penetration resistance: (Terzaghi and Peck, 1948)

blows/ft.	relative density	blows/ft.	consistency
0-4	v. loose	<2	v. soft
4-10	loose	2-4	soft
10-30	medium	4-8	medium
30-50	dense	8-15	stiff
>50	v. dense	15-30	v. stiff
		>30	hard

Texture: the relative proportions of clay, silt, and sand below 2mm. Proportions of larger particles are indicated by modifiers of textural class names. Determination is made in the field mainly by feeling the moist soil (Soil Survey, Staff, 1951).



Color: Standard Munsell color names are given for the dominant color of the moist soil and for prominent mottles.

Types of samples

SP - Standard Penetration 1+3/8 in in ID sampler)
S - Thin-wall push sampler
O - Osterberg fixed-piston sampler
P - Pitcher Barrel sampler
CH - California Penetration (2 in ID sampler)
DC - Diamond Core

Figure 16. Explanation of geologic log.

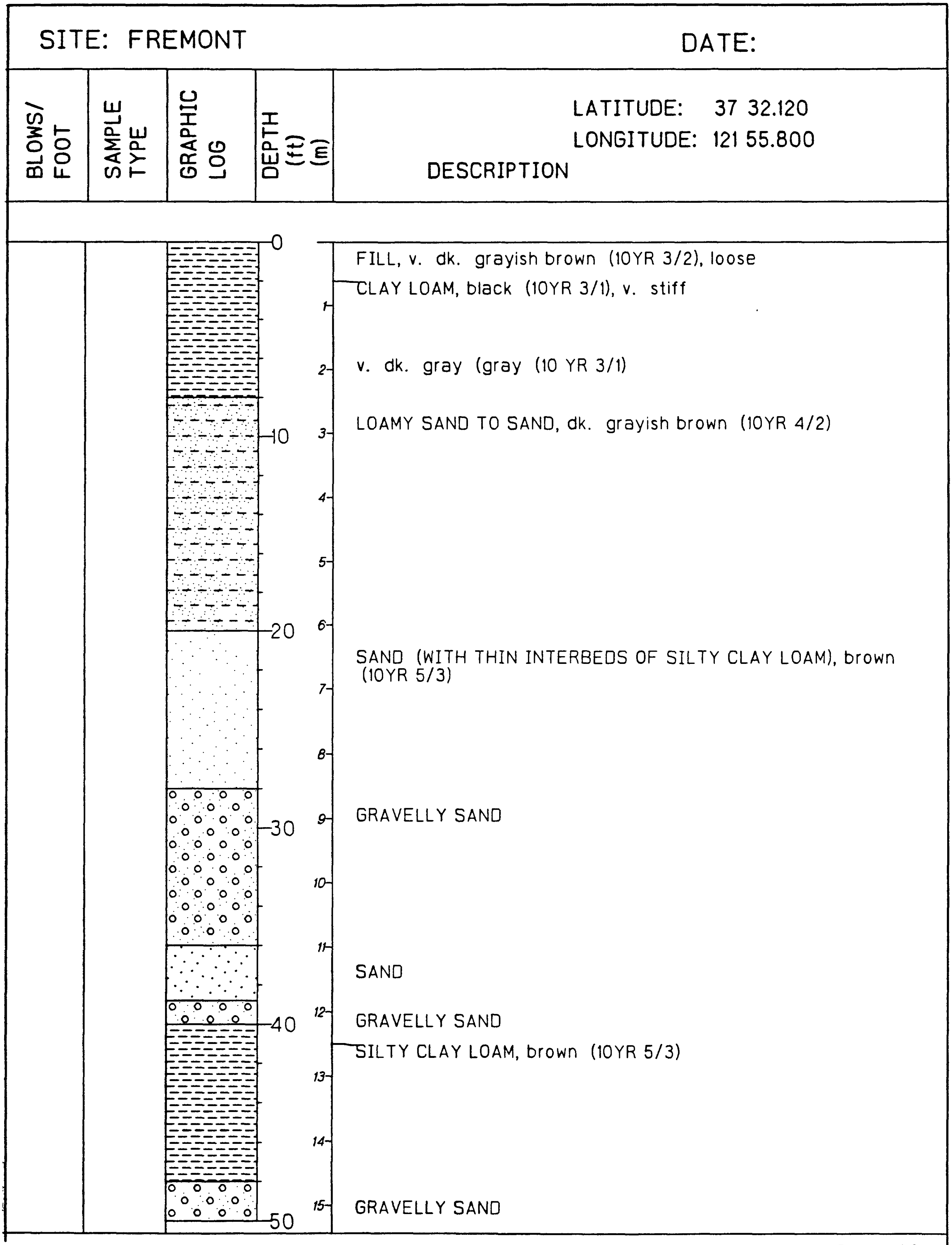
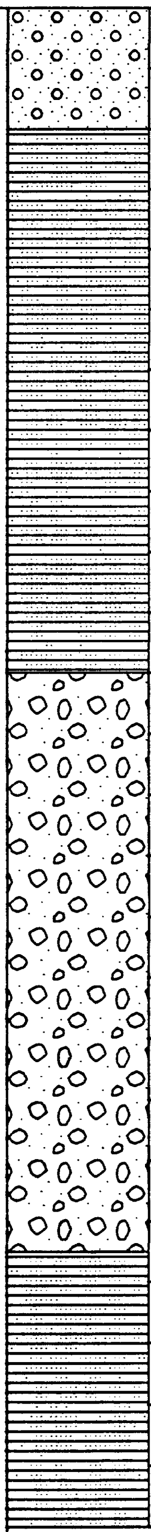


Figure 17. Geologic log of Fremont borehole.

SITE: FREMONT

DATE:

BLOWS/ FOOT	SAMPLE TYPE	GRAPHIC LOG	DEPTH (ft) (m)	DESCRIPTION LATITUDE: 37 32.120 LONGITUDE: 121 55.800



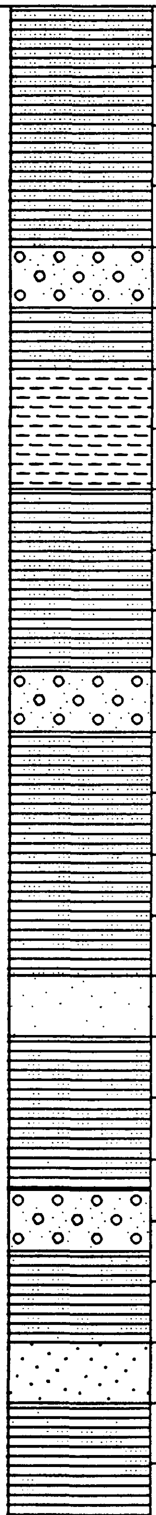
Depth (ft)	Depth (m)	Description
50		
	16	
	17	LOAM, brown (10YR 5/3)
	18	
60		
	19	
	20	
	21	
70		
	22	GRAVELLY SAND
	23	
	24	SANDY GRAVEL
80		
	25	
	26	
	27	
90		
	28	LOAM TO SILTY CLAY LOAM, yellowish brown (10YR 5/4)
	29	
	30	
100		

Figure 17. (Continued).

SITE: FREMONT

DATE:

LATITUDE: 37 32.120
LONGITUDE: 121 55.800



BLOWS/ FOOT	SAMPLE TYPE	GRAPHIC LOG	DEPTH (ft)	DEPTH (m)	DESCRIPTION
			100		
				31	
				32	
				33	
					GRAVELLY SAND
			110		
				34	LOAM, brown
					SILTY LOAM TO SILTY CLAY LOAM, stiffer
				35	
					LOAM, pale brown (10YR 6/3), v. stiff
				36	
			120		
				37	
					GRAVELLY SAND
				38	LOAM, pale brown (10YR 6/3), v. stiff
				39	
			130		
				40	
					SAND
				41	LOAM, yellowish brown (10YR 5/4)
				42	SANDY CLAY LOAM
			140		
				43	
					SANDY CLAY LOAM, yellowish brown (10YR 5/4), v. stiff
				44	SAND, poorly sorted
				45	LOAM
			150		

Figure 17. (Continued).

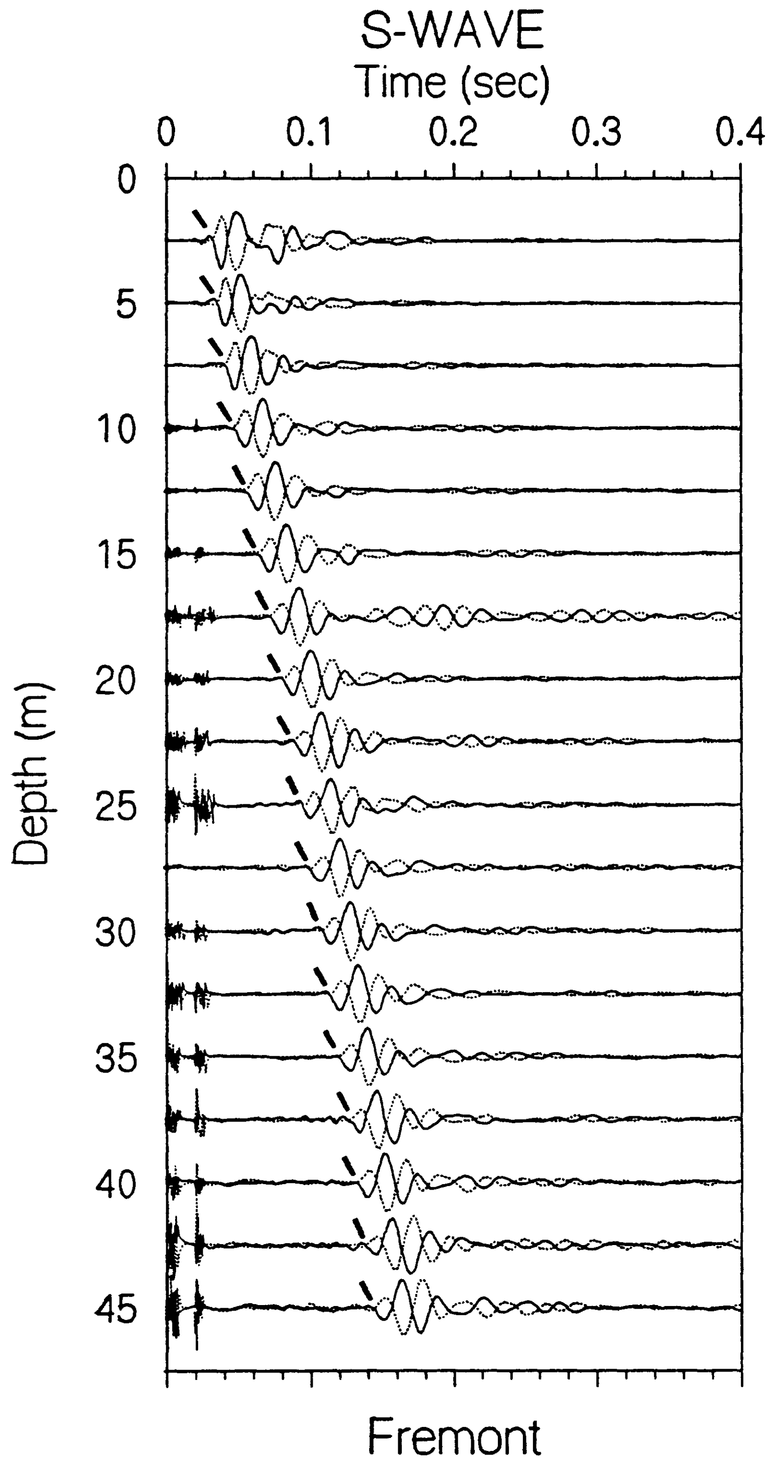


Figure 18. Horizontal-component record section (from horizontal impacts in opposite directions) superimposed for identification of S-wave arrivals. Approximate S-wave picks are shown by the accent marks.

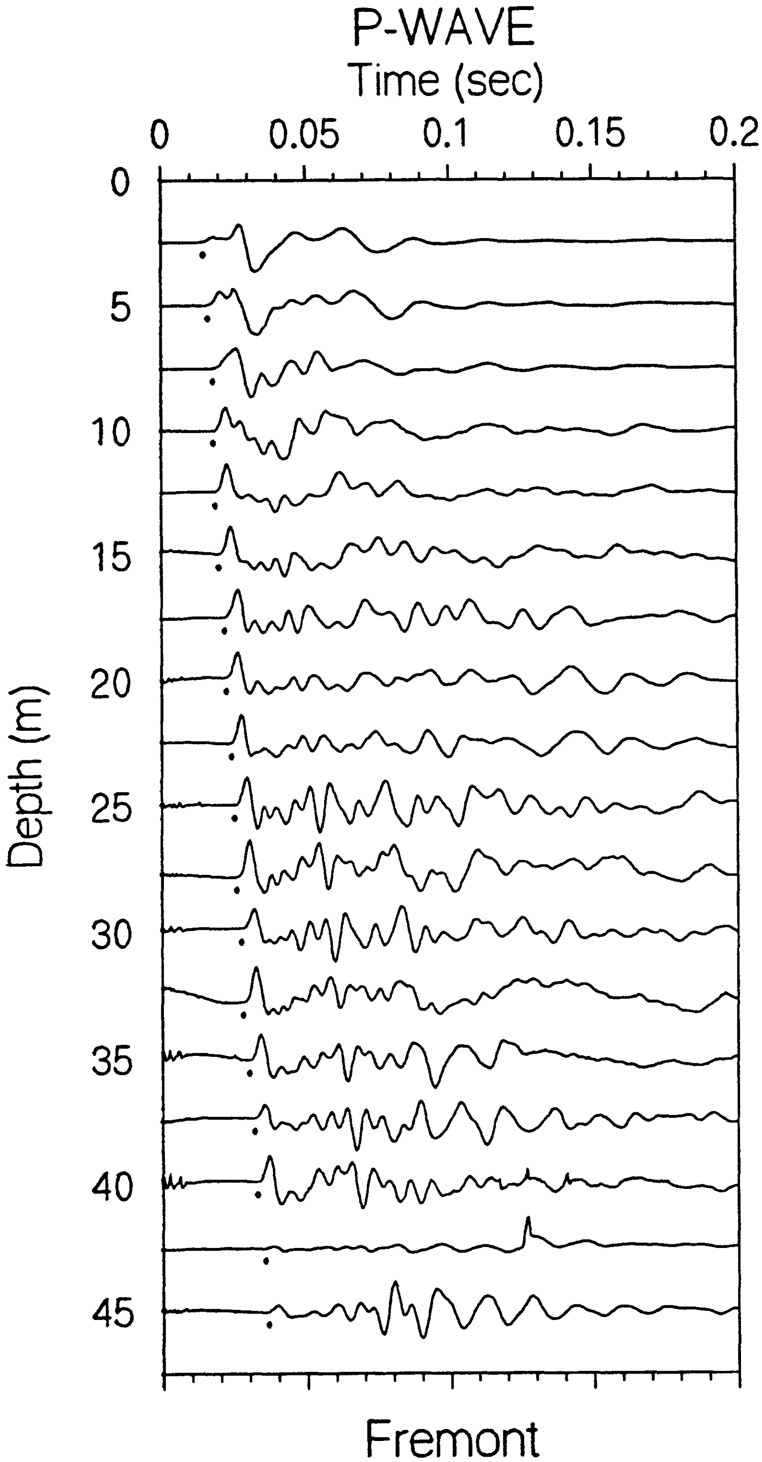


Figure 19. Vertical-component record section. P-waves are shown by the solid circles.

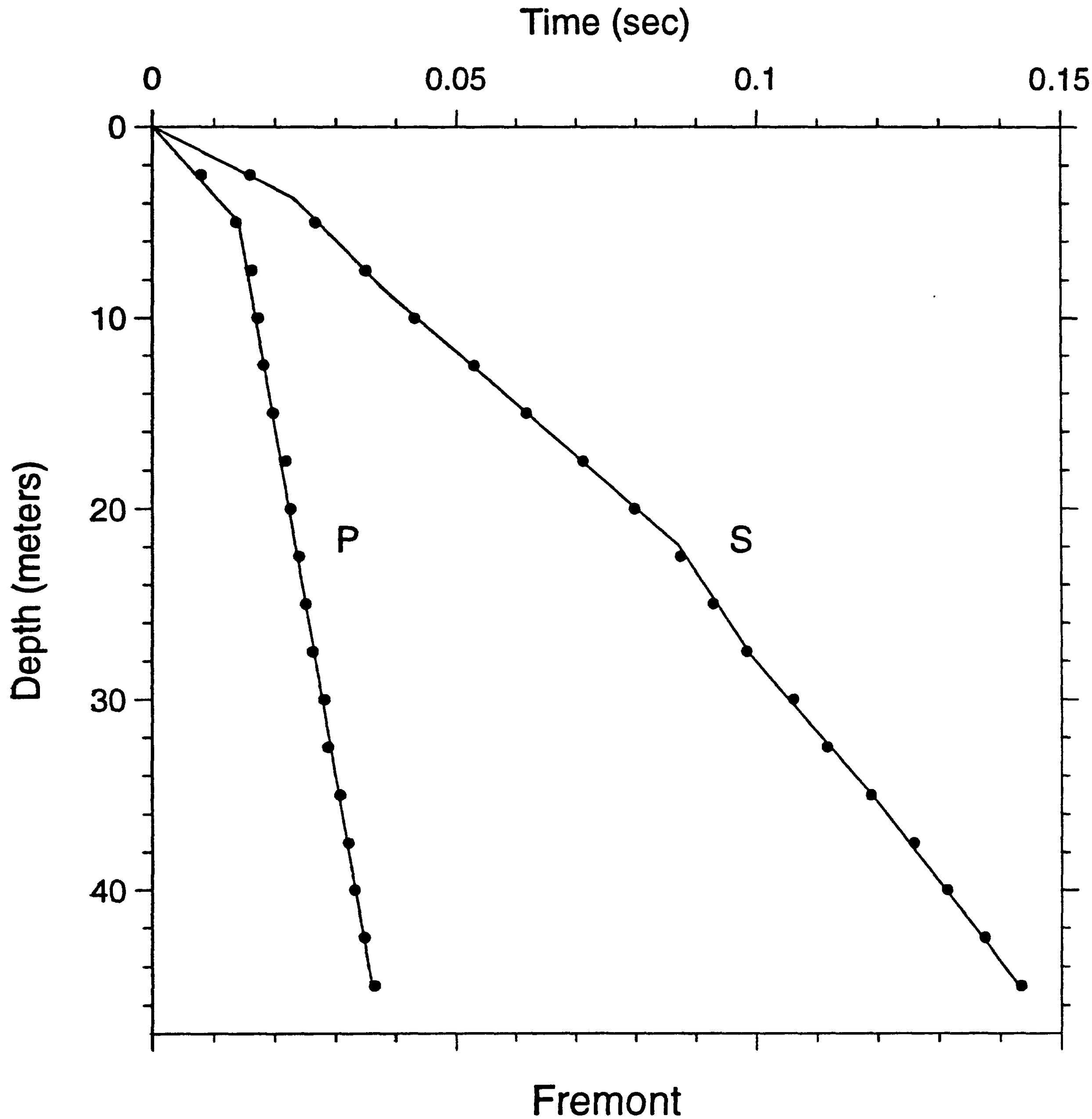


Figure 20. Time-depth graph of P-wave and S-wave picks. Line segments show the hinged-least-squares fit to the data points.

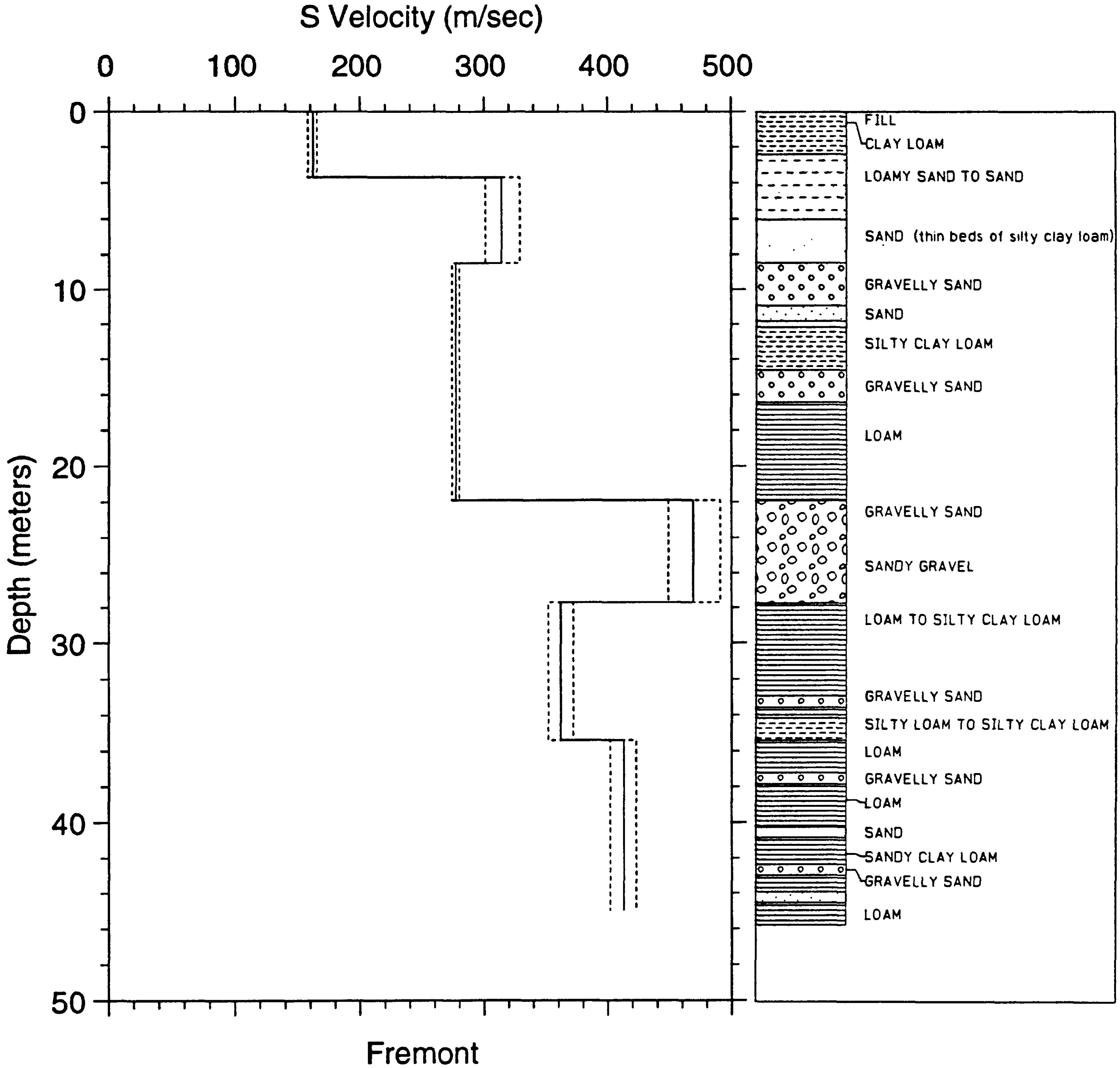


Figure 21. S-wave velocity profiles with dashed lines representing plus and minus one standard deviation. Simplified geologic log is shown for correlation with velocities.

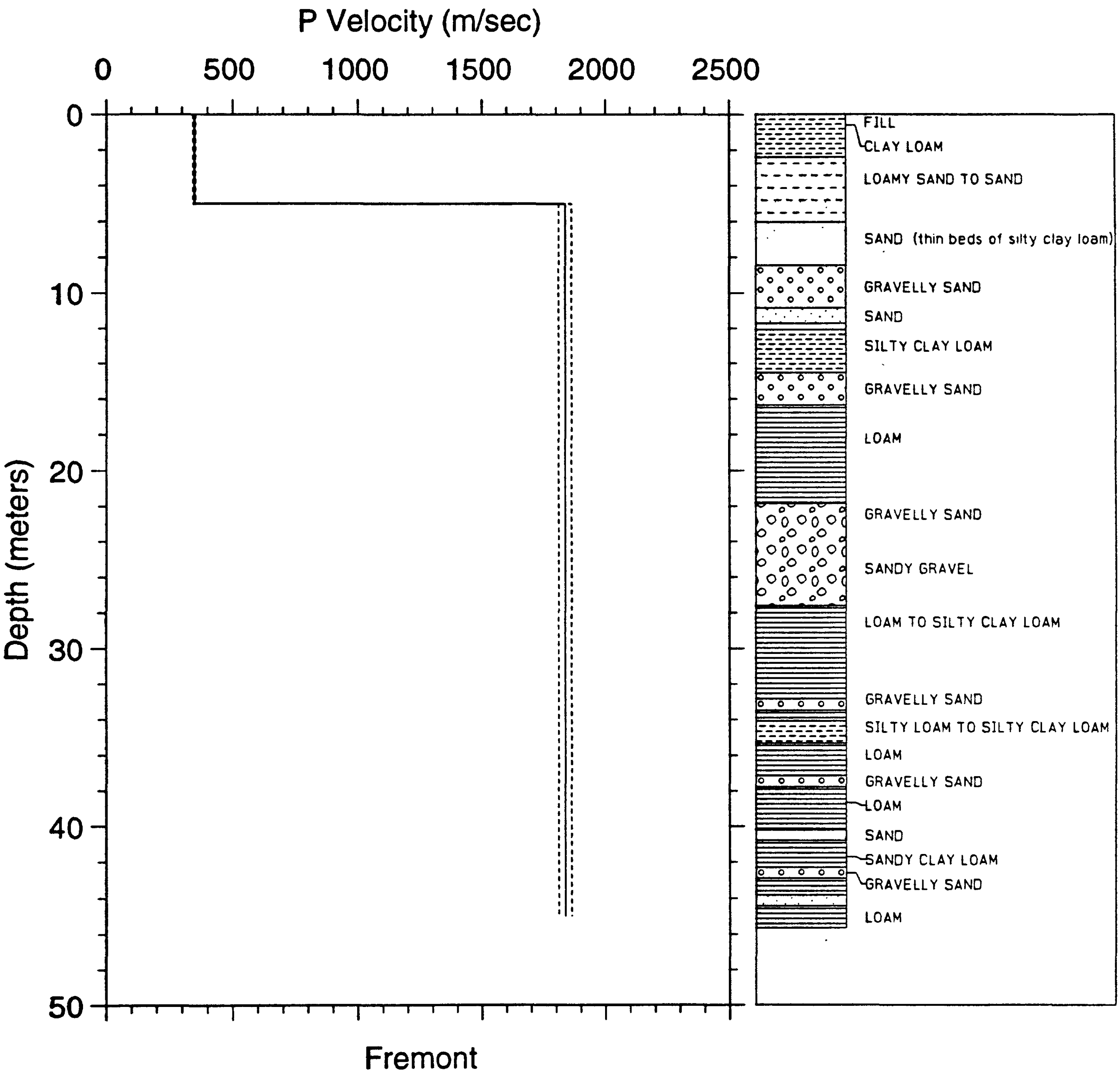


Figure 22. P-wave velocity profiles with dashed lines representing plus and minus one standard deviation. Simplified geologic log is shown for correlation with velocities.

TABLE 3. S-wave arrival times and velocity summaries for Fremont site.

d(m)	d(ft)	t(sec)	sig	rsdl/sig
2.5	8.2	.0159	1	.4
5.0	16.4	.0266	1	-.4
7.5	24.6	.0350	1	.0
10.0	32.8	.0431	1	-.5
12.5	41.0	.0530	1	.4
15.0	49.2	.0617	1	.1
17.5	57.4	.0712	1	.5
20.0	65.6	.0798	1	.1
22.5	73.8	.0874	1	-.4
25.0	82.0	.0928	1	-.4
27.5	90.2	.0984	1	-.1
30.0	98.4	.1061	1	.8
32.5	106.6	.1116	1	-.6
35.0	114.8	.1188	1	-.3
37.5	123.0	.1259	1	.6
40.0	131.2	.1313	1	-.1
42.5	139.4	.1374	1	.0
45.0	147.6	.1434	1	-.1

dtb(m)	dtb(ft)	ttb(s)	v(m/s)	vl(m/s)	vu(m/s)	v(ft/s)	vl(ft/s)	vu(ft/s)
.0	.0	.000	162	158	165	531	519	542
3.7	12.1	.023	162	158	165	531	519	542
8.5	27.9	.038	314	301	329	1031	987	1079
21.9	71.9	.087	277	274	280	908	898	919
27.7	90.9	.099	469	449	491	1538	1472	1610
35.4	116.1	.120	362	352	372	1186	1155	1219
45.0	147.6	.143	413	402	423	1354	1320	1389

Explanation:
- d(m) = depth in meters
- d(ft) = depth in feet
- t(sec) = arrival time in seconds (S-wave arrival times are the average of picks from traces obtained from hammer blows differing in direction by 180°)
- sig = sigma, standard deviation normalized to the standard deviation of best picks
- rsdl/sig = least-squares residual divided by sigma
- dtb(m) = depth to bottom of layer in meters
- dtb(ft) = depth to bottom of layer in feet
- ttb(s) = arrival time in seconds to bottom of layer
- v(m/s) = velocity in meters per second
- vl(m/s) = lower limit of velocity in meters per second *
- vu(m/s) = upper limit of velocity in meters per second
- v(ft/s) = velocity in feet per second
- vl(ft/s) = lower limit of velocity in feet per second
- vu(ft/s) = upper limit of velocity in feet per second

* see text for explanation of velocity limits

TABLE 4. P-wave arrival times and velocity summaries for Fremont site.

d(m)	d(ft)	t(sec)	sig	rsdl/sig
2.5	8.2	.0079	1	.7
5.0	16.4	.0136	1	-.8
7.5	24.6	.0162	1	.5
10.0	32.8	.0173	1	.2
12.5	41.0	.0181	1	-.4
15.0	49.2	.0197	1	-.1
17.5	57.4	.0218	1	.6
20.0	65.6	.0226	1	.1
22.5	73.8	.0240	1	.1
25.0	82.0	.0251	1	-.2
27.5	90.2	.0263	1	-.3
30.0	98.4	.0282	1	.2
32.5	106.6	.0288	1	-.6
35.0	114.8	.0308	1	.1
37.5	123.0	.0322	1	.1
40.0	131.2	.0332	1	-.2
42.5	139.4	.0348	1	.0
45.0	147.6	.0365	1	.3

dtb(m)	dtb(ft)	ttb(s)	v(m/s)	vl(m/s)	vu(m/s)	v(ft/s)	vl(ft/s)	vu(ft/s)
.0	.0	.000	348	343	352	1141	1127	1155
5.0	16.4	.014	348	343	352	1141	1127	1155
45.0	147.6	.036	1837	1811	1863	6026	5941	6113

Explanation:
- d(m) = depth in meters
- d(ft) = depth in feet
- t(sec) = arrival time in seconds (S-wave arrival times are the average of picks from traces obtained from hammer blows differing in direction by 180°)
- sig = sigma, standard deviation normalized to the standard deviation of best picks
- rsdl/sig = least-squares residual divided by sigma
- dtb(m) = depth to bottom of layer in meters
- dtb(ft) = depth to bottom of layer in feet
- ttb(s) = arrival time in seconds to bottom of layer
- v(m/s) = velocity in meters per second
- vl(m/s) = lower limit of velocity in meters per second *
- vu(m/s) = upper limit of velocity in meters per second
- v(ft/s) = velocity in feet per second
- vl(ft/s) = lower limit of velocity in feet per second
- vu(ft/s) = upper limit of velocity in feet per second

* see text for explanation of velocity limits

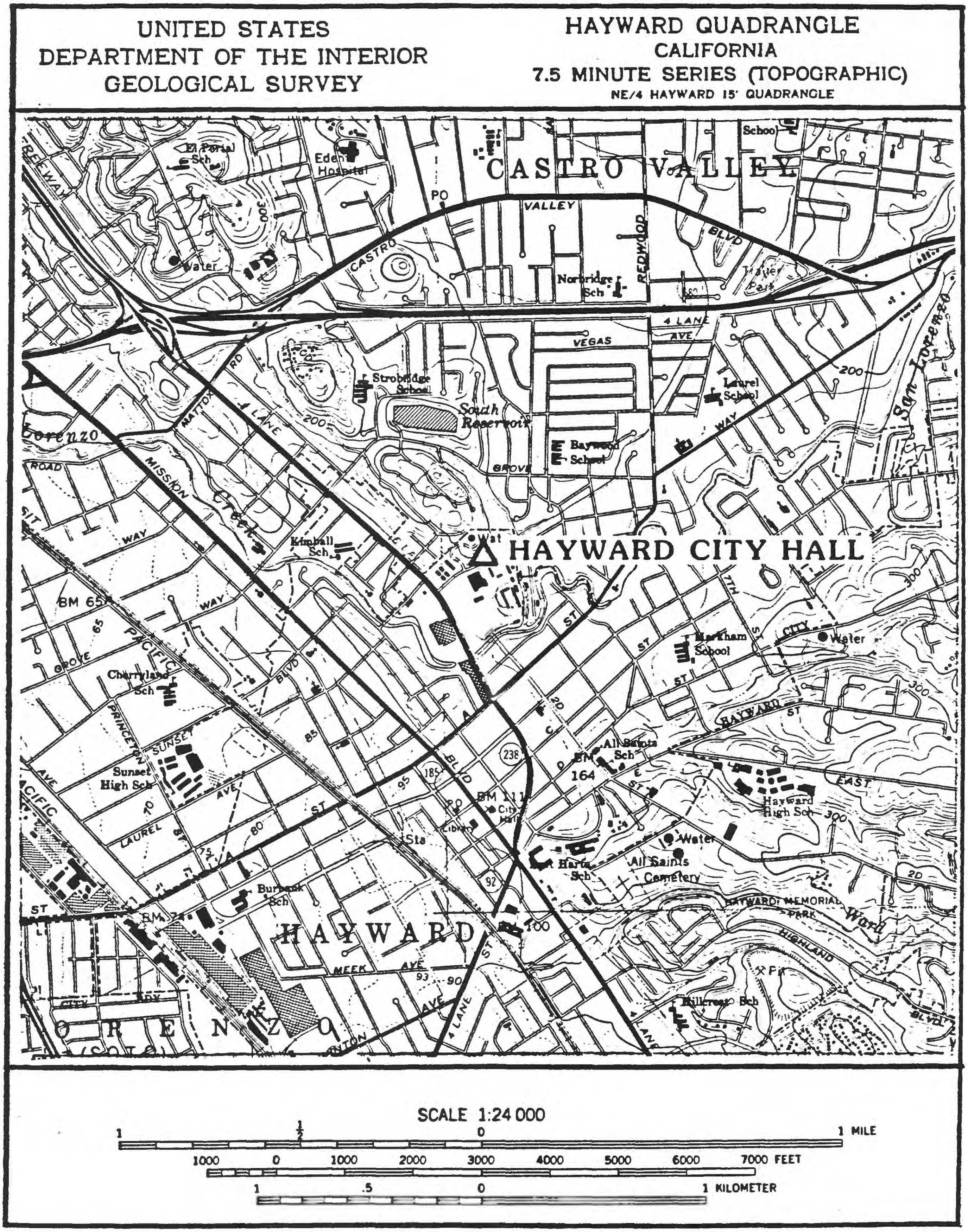


Figure 23. Location map for Hayward City Hall borehole. The borehole is located approximatelly 100 meters from the strong-motion accelerograph.

Definitions of terms used for descriptions of sedimentary deposits and bedrock materials

Rock hardness: response to hand and geologic hammer: (Ellen et al., 1972)

hard - hammer bounces off with solid sound
firm - hammer dents with thud, pick point dents or penetrates slightly
soft - pick points penetrates
friable material can be crumbled into individual grains by hand.

Fracture spacing: (Ellen et al., 1972)

cm	in	fracture spacing
0-1	0-1/2	v. close
1-5	1/2-2	close
5-30	2-12	moderate
30-100	12-36	wide
>100	>36	v. wide

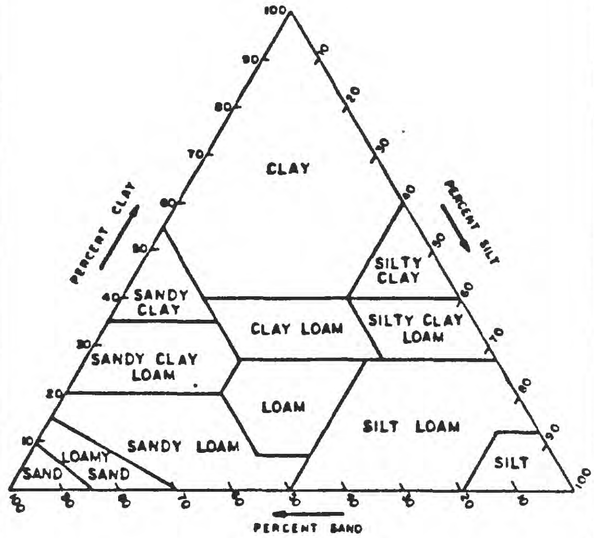
Weathering:

Fresh: no visible signs of weathering
Slight: no visible decomposition of minerals, slight discoloration
Moderate: slight decomposition of minerals and disintegration of rock, deep and thorough discoloration
Deep: extensive decomposition of minerals and complete disintegration of rock but original structure is preserved.

Relative density of sand and consistency of clay is correlated with penetration resistance: (Terzaghi and Peck, 1948)

blows/ft.	relative density	blows/ft.	consistency
0-4	v. loose	<2	v. soft
4-10	loose	2-4	soft
10-30	medium	4-8	medium
30-50	dense	8-15	stiff
>50	v. dense	15-30	v. stiff
		>30	hard

Texture: the relative proportions of clay, silt, and sand below 2mm. Proportions of larger particles are indicated by modifiers of textural class names. Determination is made in the field mainly by feeling the moist soil (Soil Survey, Staff, 1951).



Color: Standard Munsell color names are given for the dominant color of the moist soil and for prominent mottles.

Types of samples

SP - Standard Penetration 1 + 3/8 in in ID sampler)
S - Thin-wall push sampler
O - Osterberg fixed-piston sampler
P - Pitcher Barrel sampler
CH - California Penetration (2 in ID sampler)
DC - Diamond Core

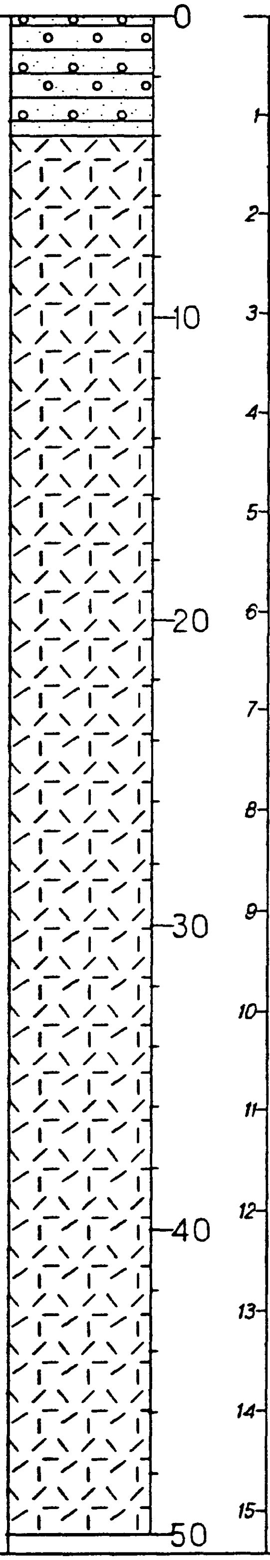
Figure 24. Explanation of geologic log.

SITE: HAYWARD CITY HALL

DATE: 2/5/91

LATITUDE: 37 40.858
LONGITUDE: 122 04.870

BLOWS/ FOOT	SAMPLE TYPE	GRAPHIC LOG	DEPTH (ft) (m)	DESCRIPTION



97

GRAVELLY SANDY LOAM, dk brown (10YR 3/3)

RHYOLITE, yellowish brown (10YR 5/6), deeply weathered

hard

softer, v. closely sheared

hard, moderately fractured, yellowish brown (10YR 5/6) to dk yellowish brown (10YR 4/4)

Figure 25. Geologic log of Hayward City Hall borehole.

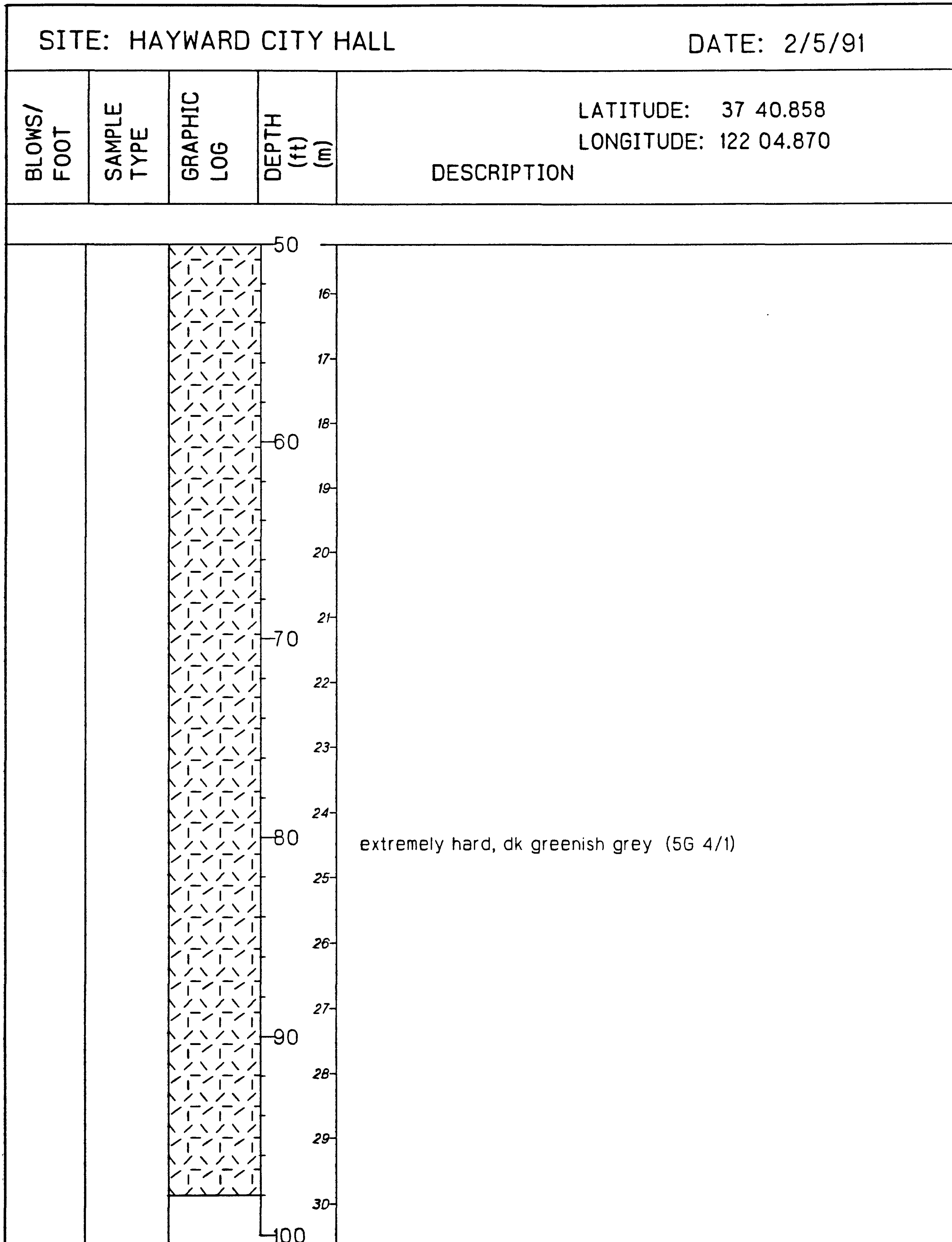


Figure 25. (Continued).

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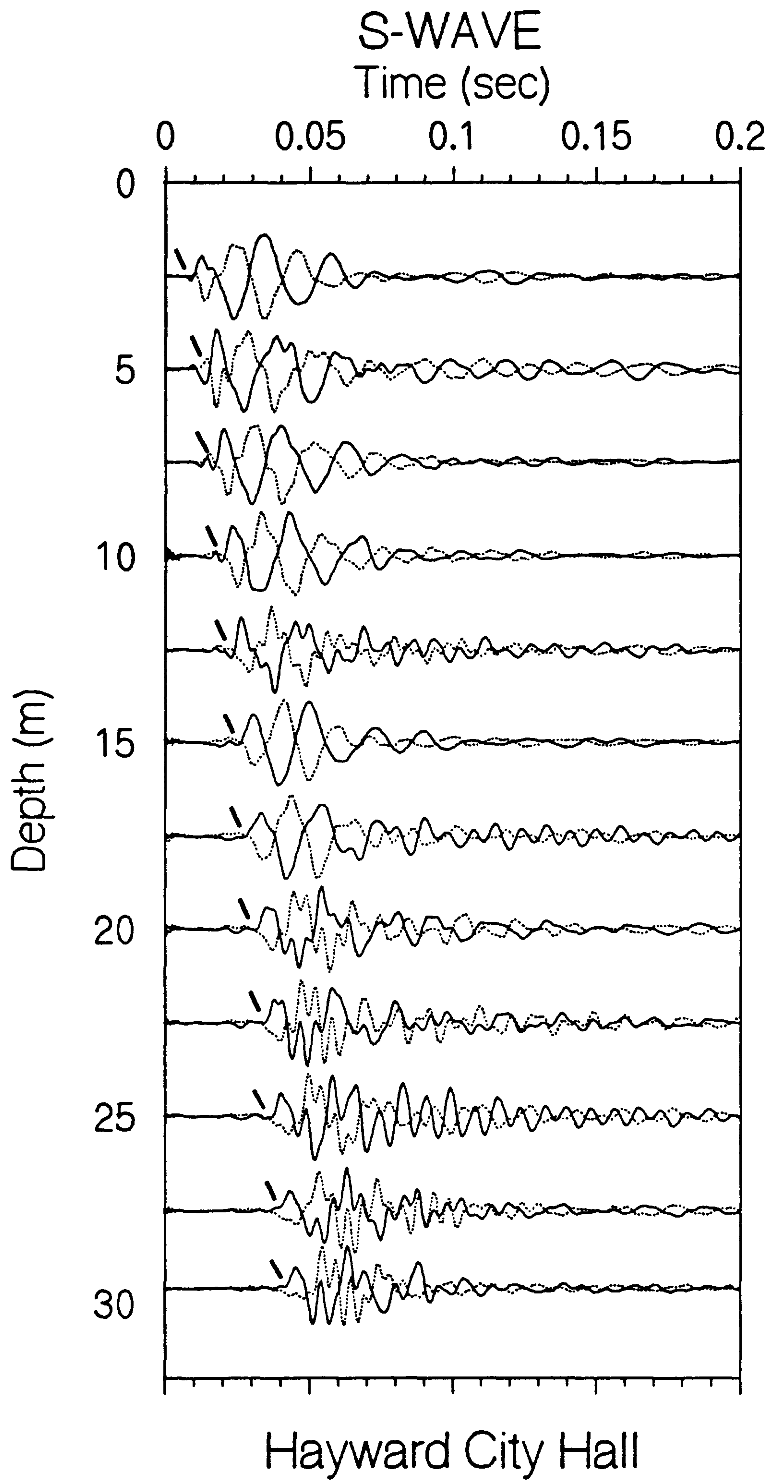


Figure 26. Horizontal-component record section (from horizontal impacts in opposite directions) superimposed for identification of S-wave onset. Approximate S-wave picks are indicated by the accent marks.

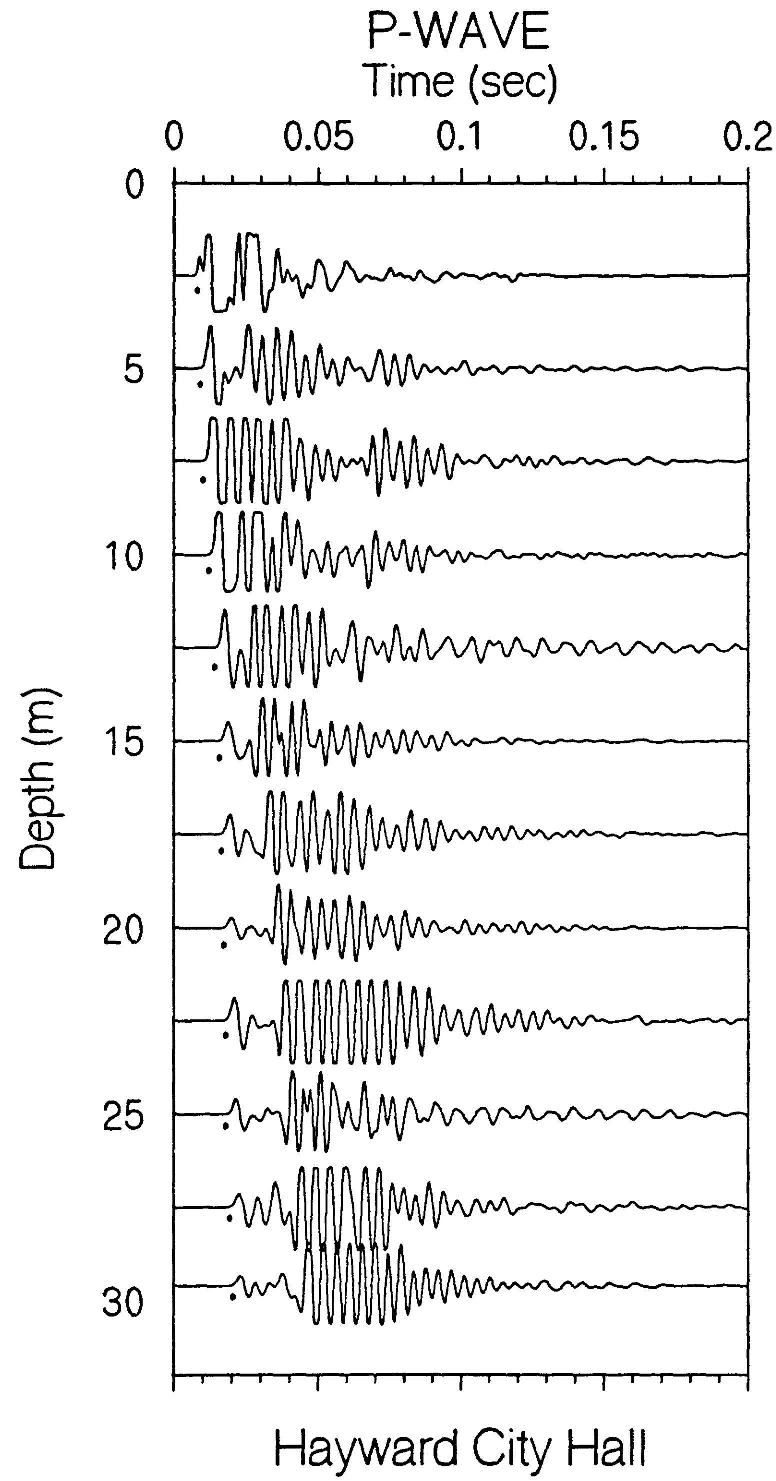


Figure 27. P-wave record section. Approximate P-wave picks are shown by the dots.

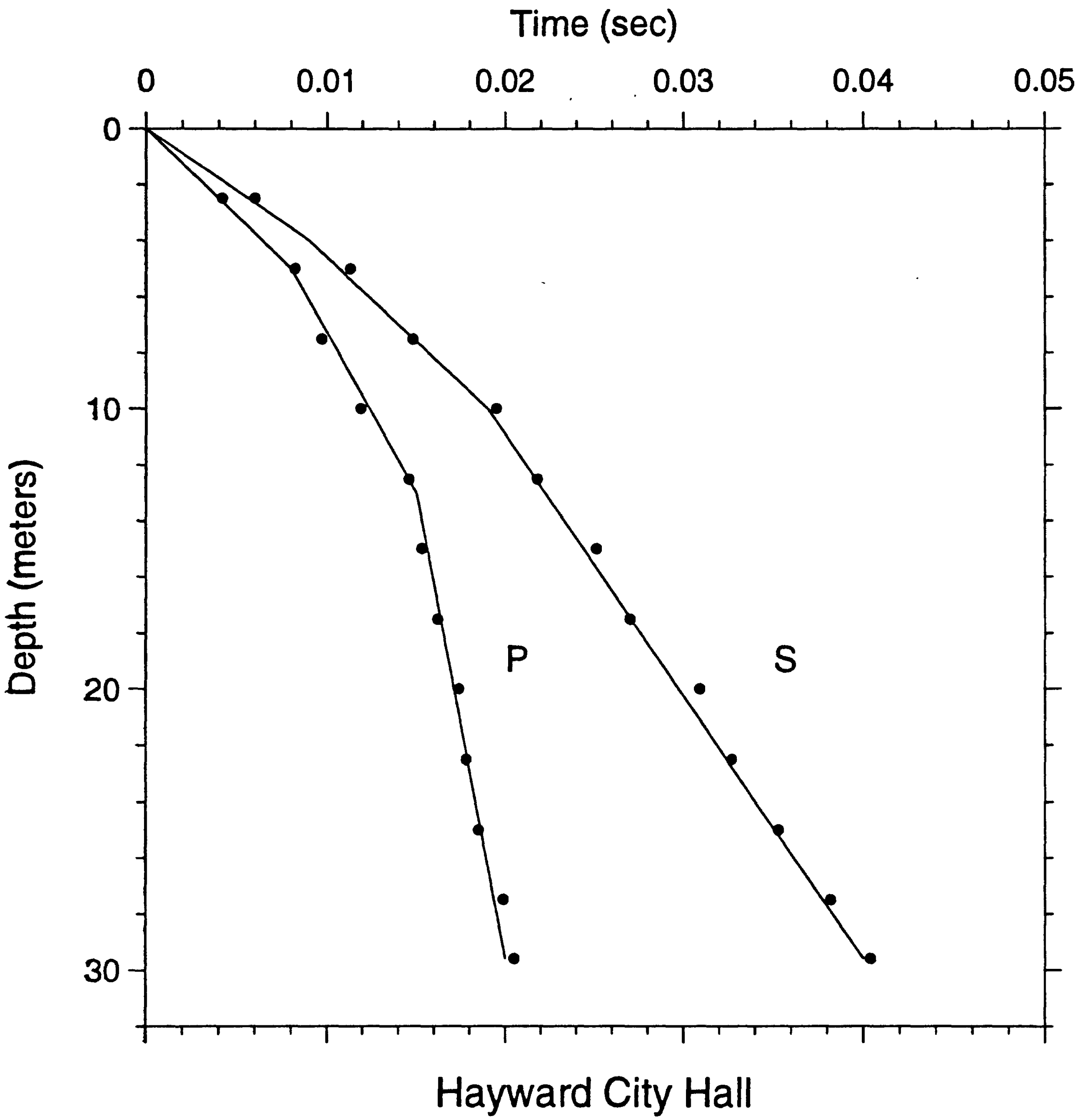


Figure 28. Time-depth graph of P-wave and S-wave picks. Line segments show the hing-least-squares fit to the data.

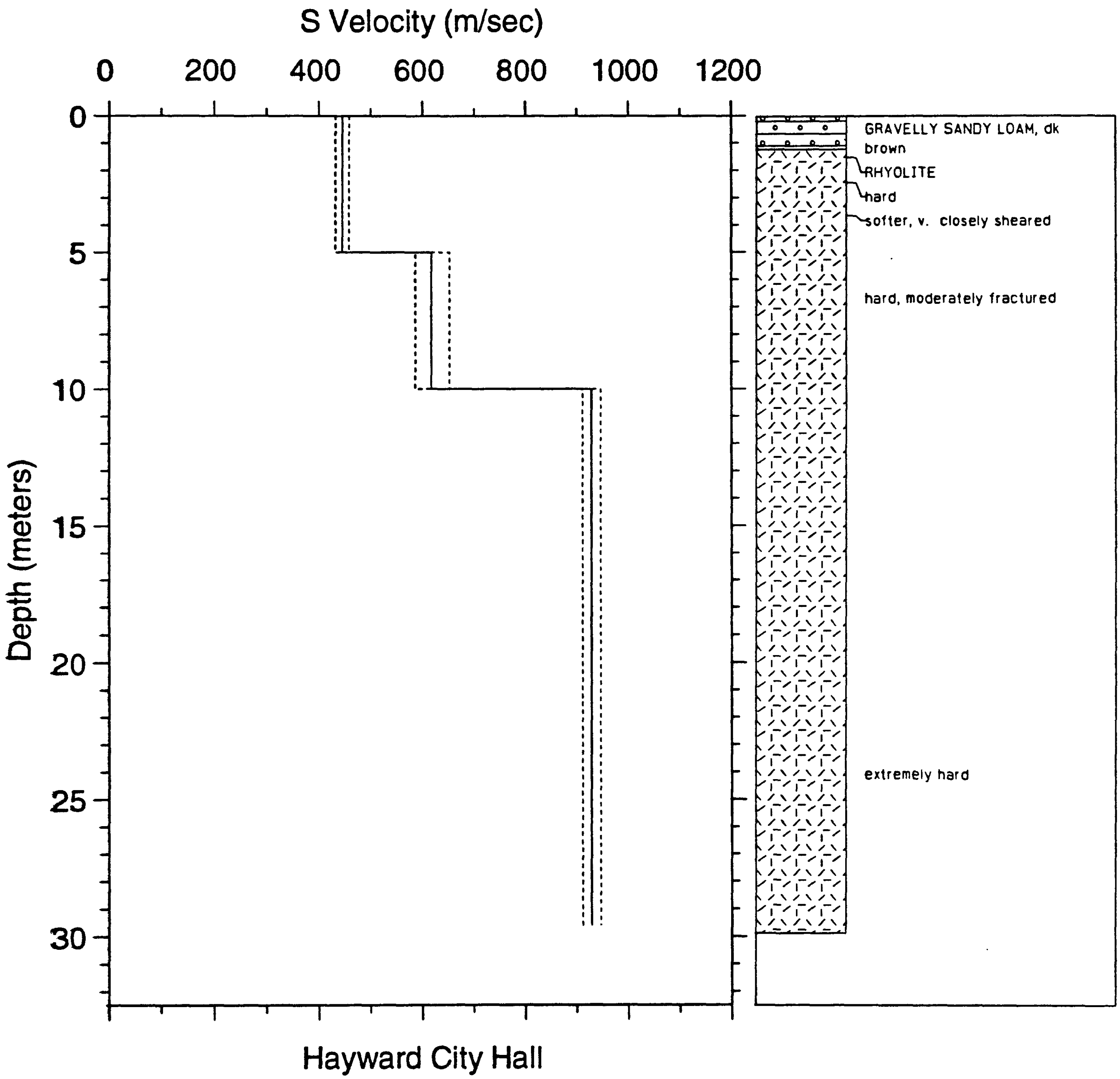


Figure 29. S-wave velocity profiles with dashed lines representing plus and minus one standard deviation. Simplified geologic log is shown for correlation with velocities.

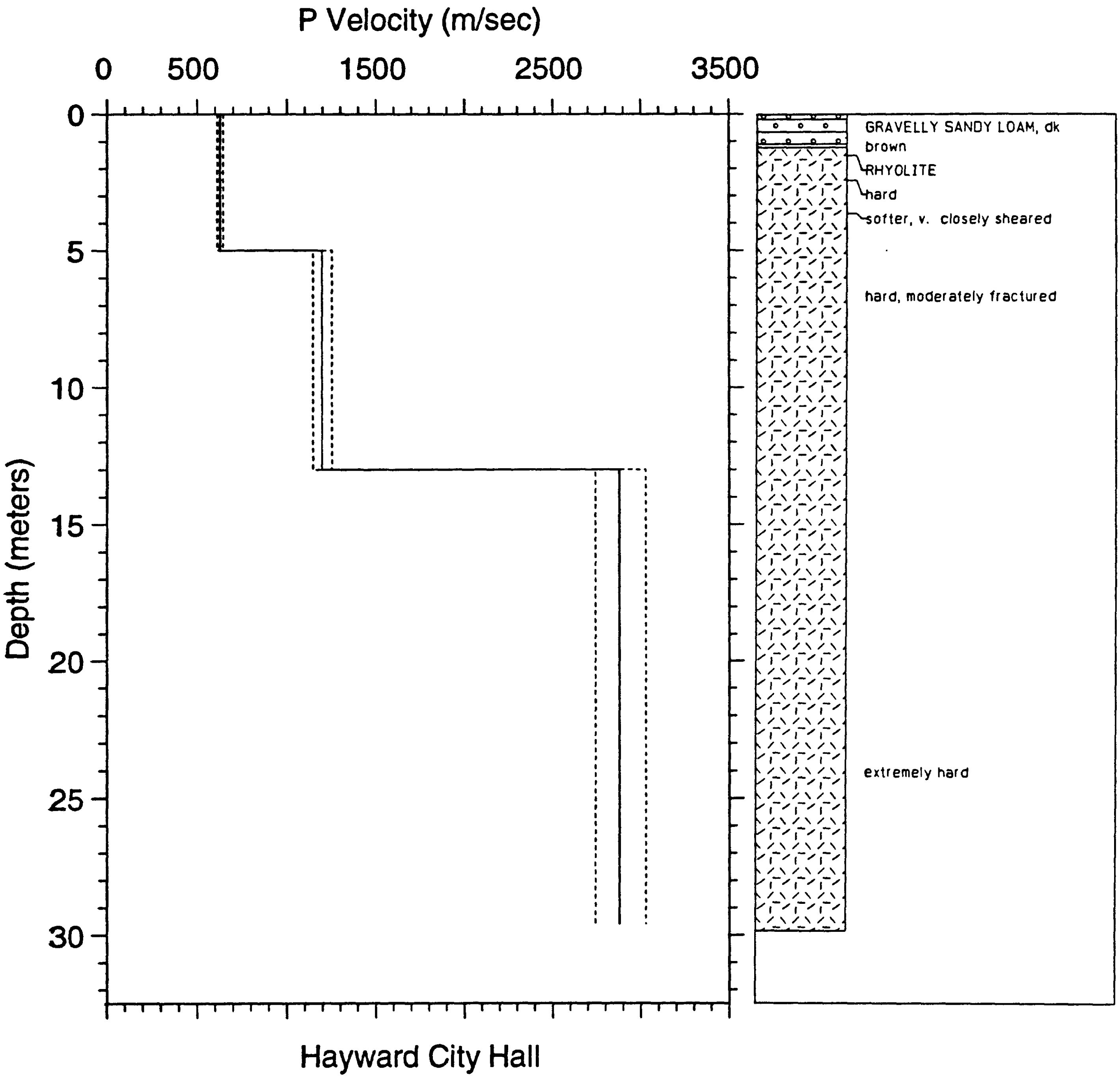


Figure 30. P-wave velocity profiles with dashed lines representing plus and minus one standard deviation. Simplified geologic log is shown for correlation with velocities.

TABLE 5. S-wave arrival times and velocity summaries for Hayward City Hall site.

d(m)	d(ft)	t(sec)	sig	rsdl/sig
2.5	8.2	.0060	1	.4
5.0	16.4	.0113	1	.1
7.5	24.6	.0148	1	-.5
10.0	32.8	.0195	1	.2
12.5	41.0	.0218	1	-.2
15.0	49.2	.0251	1	.4
17.5	57.4	.0270	1	-.4
20.0	65.6	.0309	1	.8
22.5	73.8	.0327	1	-.1
25.0	82.0	.0353	1	-.2
27.5	90.2	.0382	1	.0
29.6	97.1	.0404	1	-.1

dtb(m)	dtb(ft)	ttb(s)	v(m/s)	vl(m/s)	vu(m/s)	v(ft/s)	vl(ft/s)	vu(ft/s)
.0	.0	.000	445	432	458	1459	1417	1503
5.0	16.4	.011	445	432	458	1459	1417	1503
10.0	32.8	.019	617	586	652	2024	1922	2138
29.6	97.1	.040	928	911	946	3045	2988	3104

Explanation:

d(m) = depth in meters
d(ft) = depth in feet
t(sec) = arrival time in seconds (S-wave arrival times are the average of picks from traces obtained from hammer blows differing in direction by 180°)
sig = sigma, standard deviation normalized to the standard deviation of best picks
rsdl/sig = least-squares residual divided by sigma
dtb(m) = depth to bottom of layer in meters
dtb(ft) = depth to bottom of layer in feet
ttb(s) = arrival time in seconds to bottom of layer
v(m/s) = velocity in meters per second
vl(m/s) = lower limit of velocity in meters per second *
vu(m/s) = upper limit of velocity in meters per second
v(ft/s) = velocity in feet per second
vl(ft/s) = lower limit of velocity in feet per second
vu(ft/s) = upper limit of velocity in feet per second

* see text for explanation of velocity limits

TABLE 6. P-wave arrival times and velocity summaries for Hayward City Hall site.

d(m)	d(ft)	t(sec)	sig	rsdl/sig
2.5	8.2	.0042	1	.2
5.0	16.4	.0082	1	.2
7.5	24.6	.0097	1	-.4
10.0	32.8	.0119	1	-.3
12.5	41.0	.0146	1	.3
15.0	49.2	.0153	1	-.1
17.5	57.4	.0162	1	.0
20.0	65.6	.0174	1	.3
22.5	73.8	.0178	1	-.2
25.0	82.0	.0185	1	-.3
27.5	90.2	.0199	1	.2
29.6	97.1	.0205	1	.1

dtb(m)	dtb(ft)	ttb(s)	v(m/s)	vl(m/s)	vu(m/s)	v(ft/s)	vl(ft/s)	vu(ft/s)
.0	.0	.000	627	611	644	2056	2004	2112
5.0	16.4	.008	627	611	644	2056	2004	2112
13.0	42.7	.015	1195	1145	1251	3922	3756	4103
29.6	97.1	.020	2878	2743	3028	9444	8998	9936

Explanation:
d(m) = depth in meters
d(ft) = depth in feet
t(sec) = arrival time in seconds (S-wave arrival times are the average of picks from traces obtained from hammer blows differing in direction by 180°)
sig = sigma, standard deviation normalized to the standard deviation of best picks
rsdl/sig = least-squares residual divided by sigma
dtb(m) = depth to bottom of layer in meters
dtb(ft) = depth to bottom of layer in feet
ttb(s) = arrival time in seconds to bottom of layer
v(m/s) = velocity in meters per second
vl(m/s) = lower limit of velocity in meters per second *
vu(m/s) = upper limit of velocity in meters per second
v(ft/s) = velocity in feet per second
vl(ft/s) = lower limit of velocity in feet per second
vu(ft/s) = upper limit of velocity in feet per second
* see text for explanation of velocity limits

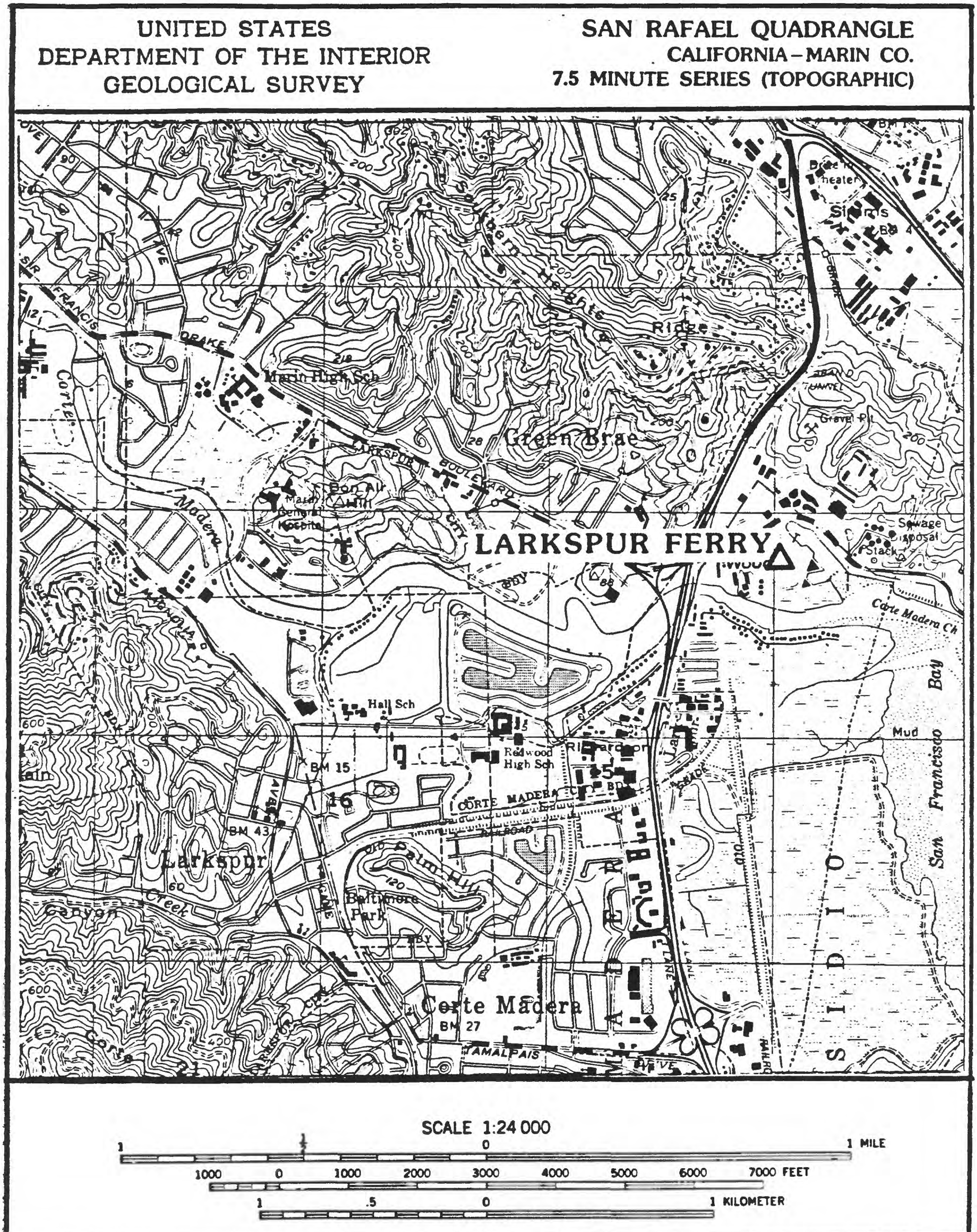


Figure 31. Location map for Larkspur Ferry borehole. The strong-motion accelerograph is located within 10 meters of the borehole.

Definitions of terms used for descriptions of sedimentary deposits and bedrock materials

Rock hardness: response to hand and geologic hammer: (Ellen et al., 1972)

hard - hammer bounces off with solid sound
firm - hammer dents with thud, pick point dents or penetrates slightly
soft - pick points penetrates
friable material can be crumbled into individual grains by hand.

Fracture spacing: (Ellen et al., 1972)

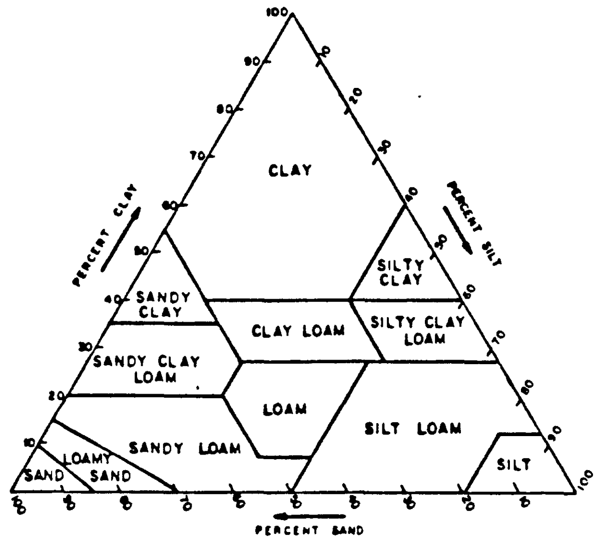
cm	in	fracture spacing
0-1	0-1/2	v. close
1-5	1/2-2	close
5-30	2-12	moderate
30-100	12-36	wide
>100	>36	v. wide

Weathering:
Fresh: no visible signs of weathering
Slight: no visible decomposition of minerals, slight discoloration
Moderate: slight decomposition of minerals and disintegration of rock, deep and thorough discoloration
Deep: extensive decomposition of minerals and complete disintegration of rock but original structure is preserved.

Relative density of sand and consistency of clay is correlated with penetration resistance: (Terzaghi and Peck, 1948)

blows/ft.	relative density	blows/ft.	consistency
0-4	v. loose	<2	v. soft
4-10	loose	2-4	soft
10-30	medium	4-8	medium
30-50	dense	8-15	stiff
>50	v. dense	15-30	v. stiff
		>30	hard

Texture: the relative proportions of clay, silt, and sand below 2mm. Proportions of larger particles are indicated by modifiers of textural class names. Determination is made in the field mainly by feeling the moist soil (Soil Survey, Staff, 1951).



Color: Standard Munsell color names are given for the dominant color of the moist soil and for prominent mottles.

Types of samples

SP - Standard Penetration 1+3/8 in in ID sampler)
S - Thin-wall push sampler
O - Osterberg fixed-piston sampler
P - Pitcher Barrel sampler
CH - California Penetration (2 in ID sampler)
DC - Diamond Core

Figure 32. Explanation of geologic log.

SITE: LARKSPUR FERRY

DATE:

LATITUDE: 37 56.685
LONGITUDE: 122 30.628

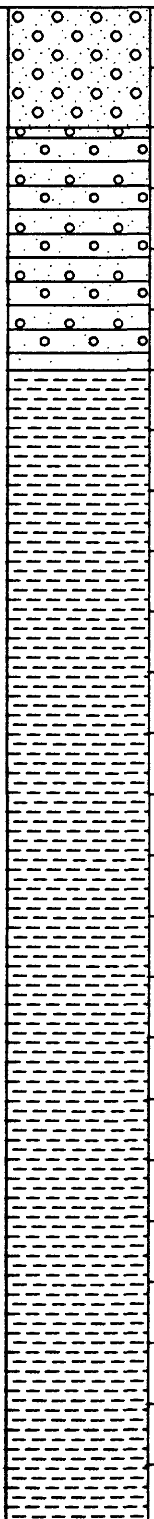
BLOWS/ FOOT	SAMPLE TYPE	GRAPHIC LOG	DEPTH (ft) (m)	DESCRIPTION
			0	GRAVELLY SAND, v. dk. gray (5Y 3/1), poorly sorted (fill)
			1	
				GRAVELLY SANDY LOAM
			2	
			3, 10	
			4	SILTY CLAY, v. dk. gray (5Y 3/1) soft, shelly
			5	
			6, 20	
			7	
			8	
			9, 30	
			10	
			11	
			12, 40	
			13	
			14	
			15, 50	

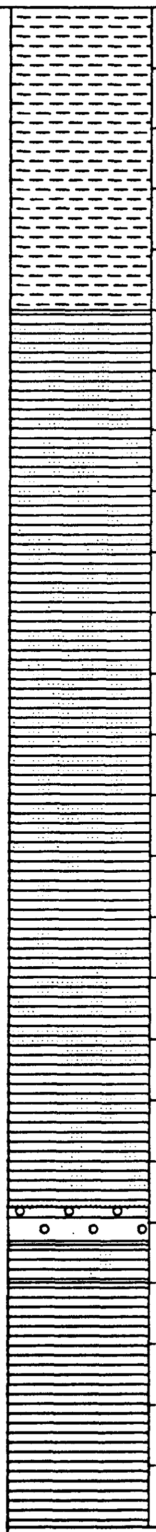
Figure 33. Geologic log of Larkspur Ferry borehole.

Page 1 of 3

SITE: LARKSPUR FERRY

DATE:

BLOWS/ FOOT	SAMPLE TYPE	GRAPHIC LOG	DEPTH (ft) (m)	DESCRIPTION LATITUDE: 37 56.685 LONGITUDE: 122 30.628



Depth (ft): 50, 60, 70, 80, 90, 100

Depth (m): 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30

SANDY CLAY LOAM, dk. grayish brown (10YR 4/2), some gravel

dk. brown (10YR 3/3)

FINE SANDY CLAY, brownish yellow (10YR 4/6) to yellowish brown (10YR 5/4), stiff

COARSE SANDY CLAY, dk. yellowish brown (10YR 4/4)

GRAVELLY SANDY LOAM

SANDY LOAM, dense

SHALE (with occasional SANDSTONE interbeds), shale is black, sandstone is v. dk. gray, v. hard

Figure 33 (Continued).

SITE: LARKSPUR FERRY

DATE:

BLOWS/ FOOT	SAMPLE TYPE	GRAPHIC LOG	DEPTH (ft) (m)	DESCRIPTION

LATITUDE: 37 56.685
LONGITUDE: 122 30.628

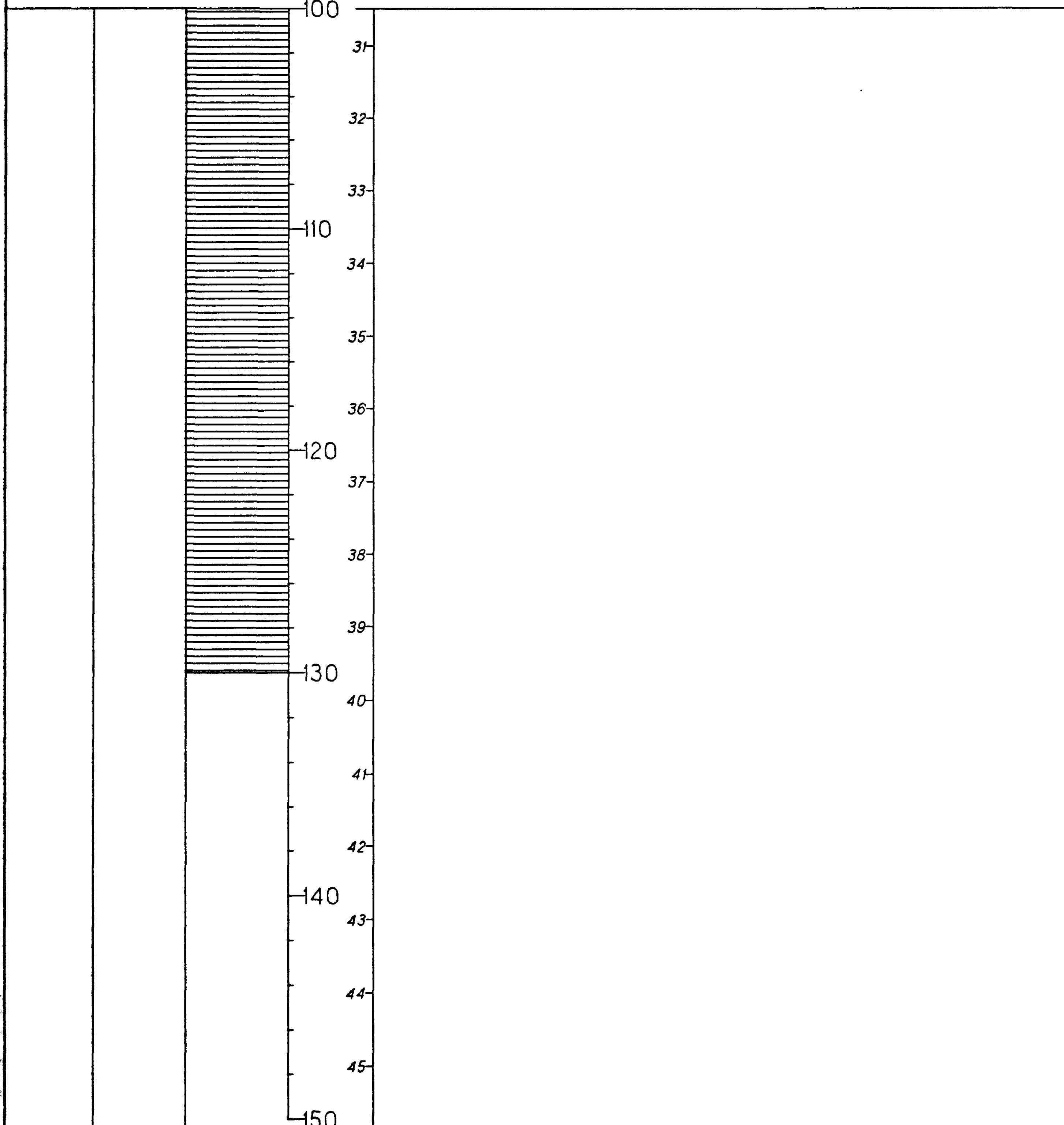


Figure 33 (Continued).

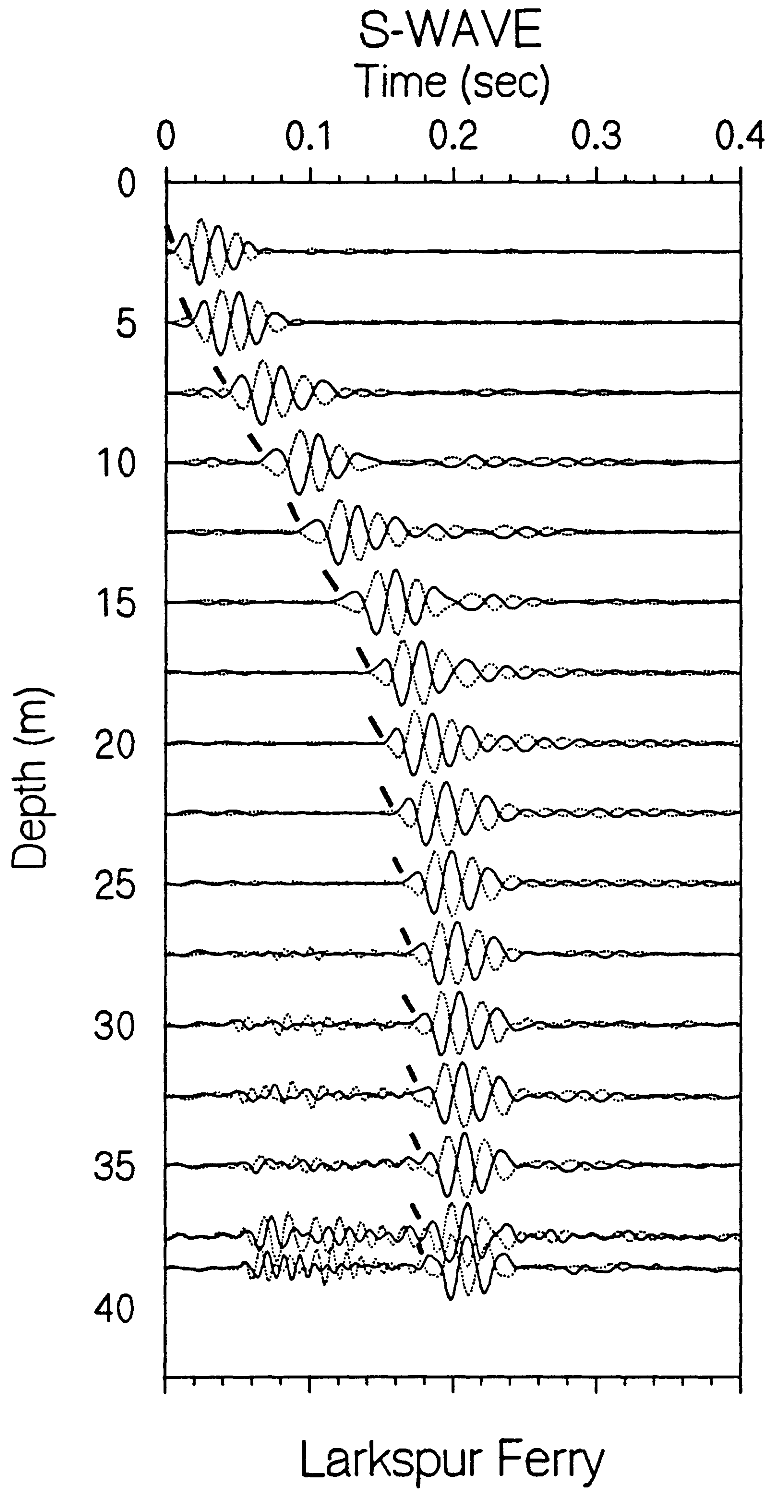


Figure 34. Horizontal-component record section (from horizontal impacts in opposite directions) superimposed for identification of S-wave onset. Approximate S-wave picks are indicated by the accent marks.

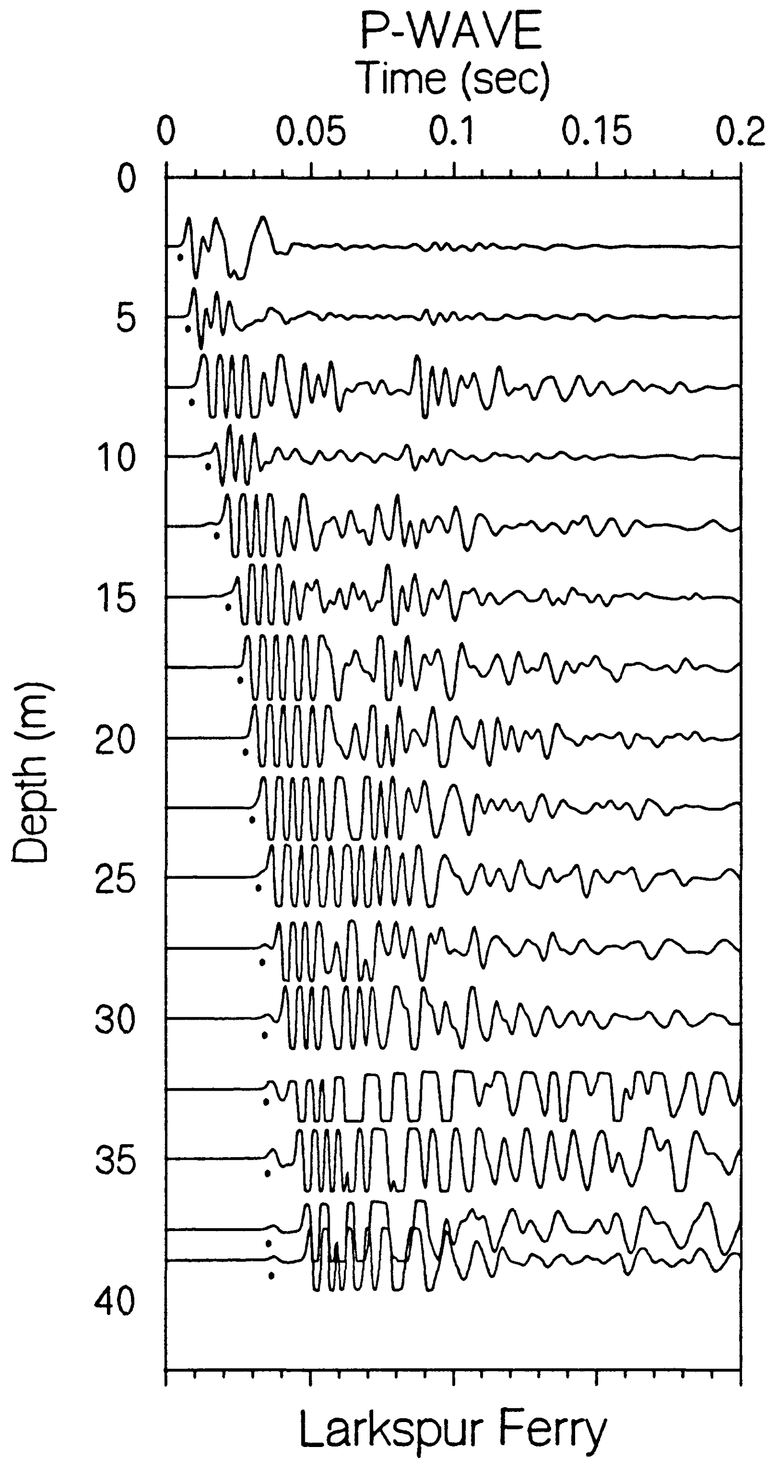


Figure 35. Vertical-component record section. P-wave arrivals are shown by the solid circles.

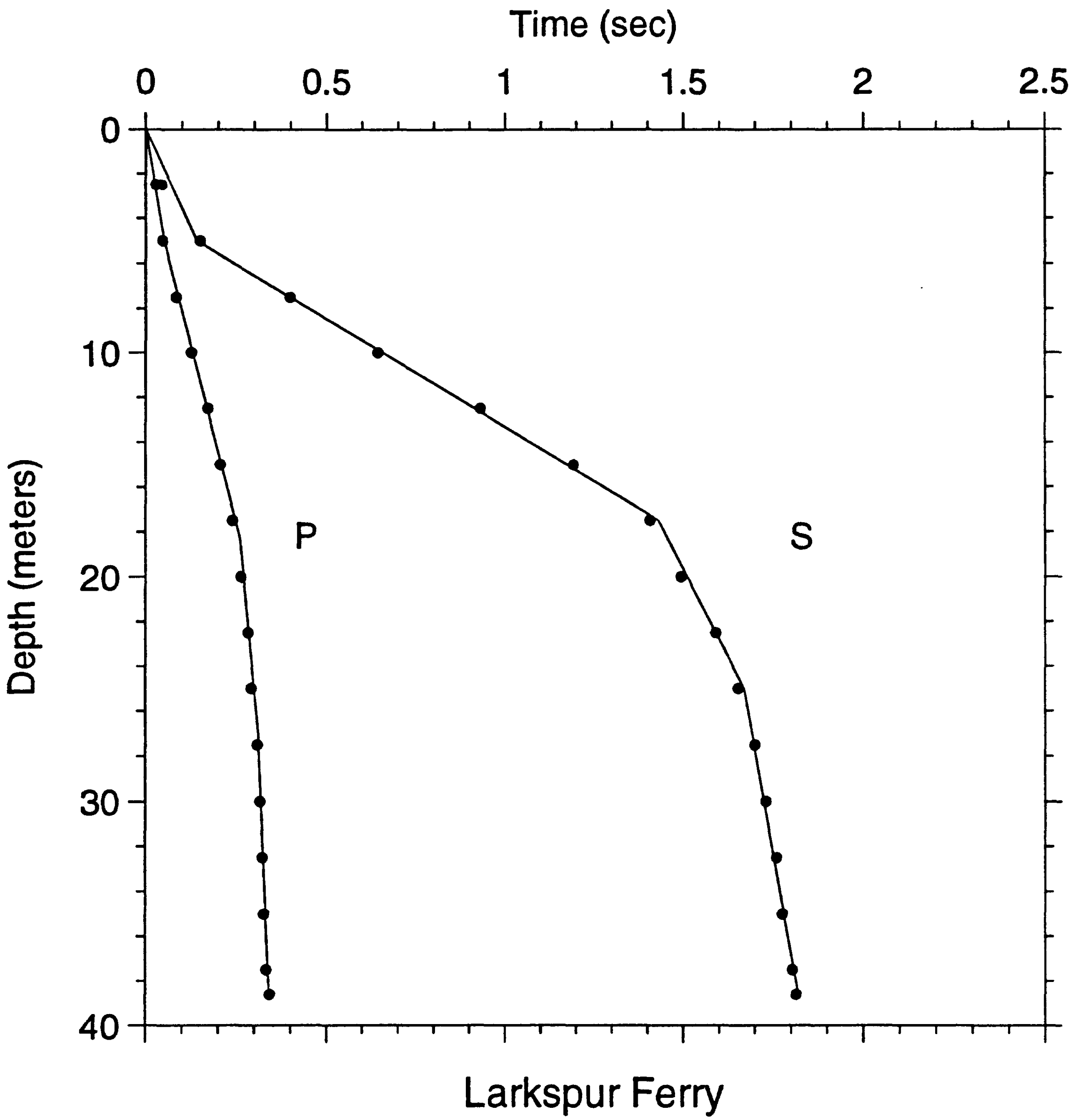


Figure 36. Time-depth graph of P-wave and S-wave picks. Line segments show the hinged-least-squares fit to the data points.

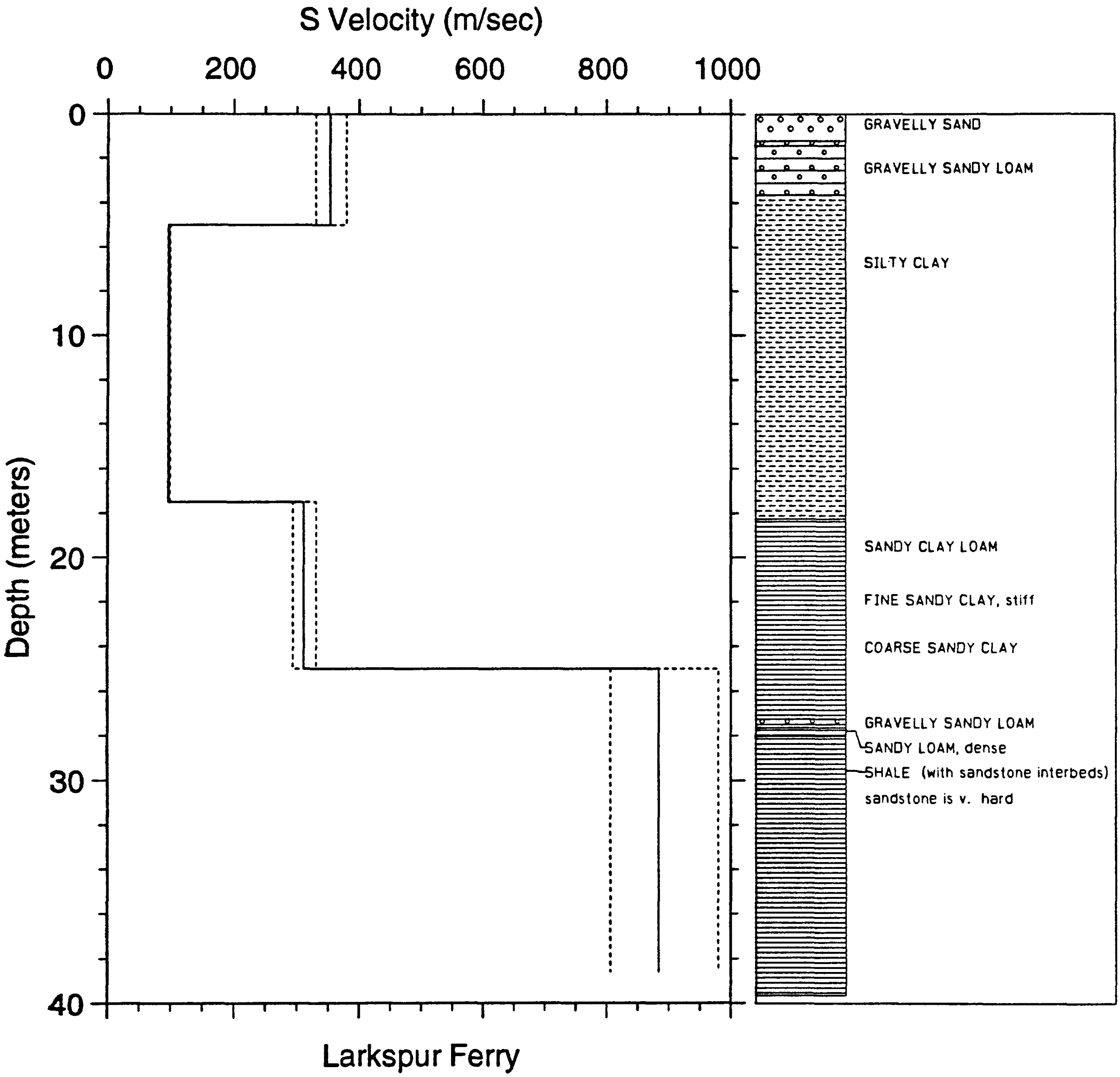


Figure 37. S-wave velocity profiles with dashed lines representing plus and minus one standard deviation. Simplified geologic log is shown for correlation with velocities.

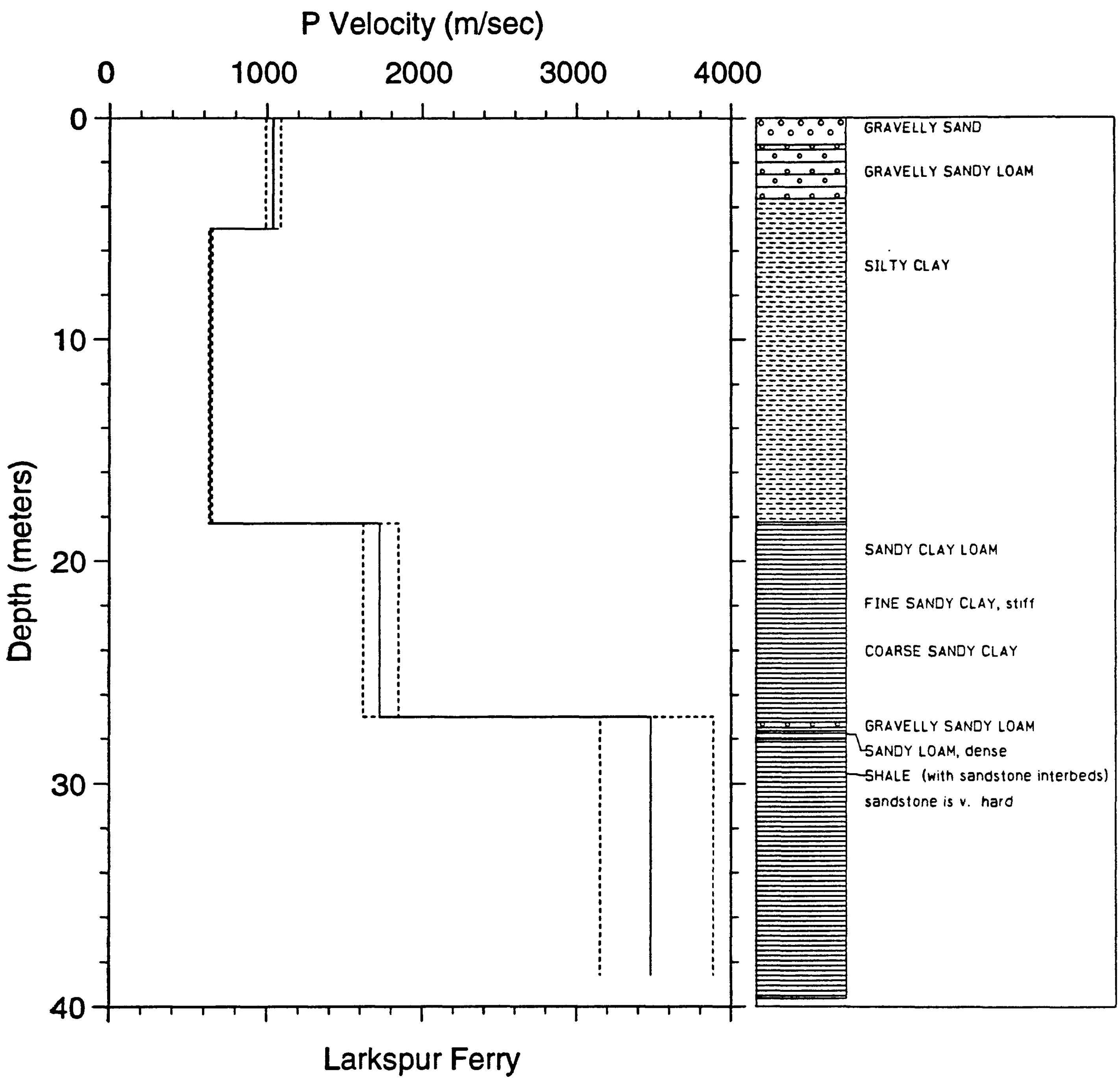


Figure 38. P-wave velocity profiles with dashed lines representing plus and minus one standard deviation. Simplified geologic log is shown for correlation with velocities.

TABLE 7. S-wave arrival times and velocity summaries for Larkspur Ferry site.

d(m)	d(ft)	t(sec)	sig	rsdl/sig
2.5	8.2	.0045	1	-2.6
5.0	16.4	.0149	1	.7
7.5	24.6	.0399	1	.1
10.0	32.8	.0644	1	-1.1
12.5	41.0	.0930	1	1.8
15.0	49.2	.1192	1	2.3
17.5	57.4	.1407	1	-1.8
20.0	65.6	.1493	1	-1.3
22.5	73.8	.1590	1	.4
25.0	82.0	.1654	1	-1.2
27.5	90.2	.1700	1	.6
30.0	98.4	.1731	1	.8
32.5	106.6	.1761	1	1.0
35.0	114.8	.1777	1	-.2
37.5	123.0	.1804	1	-.3
38.6	126.6	.1815	1	-.5

dtb(m)	dtb(ft)	ttb(s)	v(m/s)	vl(m/s)	vu(m/s)	v(ft/s)	vl(ft/s)	vu(ft/s)
.0	.0	.000	353	330	379	1157	1081	1245
5.0	16.4	.014	353	330	379	1157	1081	1245
17.5	57.4	.143	97	96	99	320	316	323
25.0	82.0	.167	311	294	331	1022	964	1087
38.6	126.6	.182	884	806	980	2902	2644	3216

Explanation:
- d(m) = depth in meters
- d(ft) = depth in feet
- t(sec) = arrival time in seconds (S-wave arrival times are the average of picks from traces obtained from hammer blows differing in direction by 180°)
- sig = sigma, standard deviation normalized to the standard deviation of best picks
- rsdl/sig = least-squares residual divided by sigma
- dtb(m) = depth to bottom of layer in meters
- dtb(ft) = depth to bottom of layer in feet
- ttb(s) = arrival time in seconds to bottom of layer
- v(m/s) = velocity in meters per second
- vl(m/s) = lower limit of velocity in meters per second *
- vu(m/s) = upper limit of velocity in meters per second
- v(ft/s) = velocity in feet per second
- vl(ft/s) = lower limit of velocity in feet per second
- vu(ft/s) = upper limit of velocity in feet per second

* see text for explanation of velocity limits

TABLE 8. P-wave arrival times and velocity summaries for Larkspur Ferry site.

d(m)	d(ft)	t(sec)	sig	rsdl/sig
2.5	8.2	.0028	1	.4
5.0	16.4	.0046	1	-.2
7.5	24.6	.0084	1	-.3
10.0	32.8	.0126	1	.0
12.5	41.0	.0171	1	.6
15.0	49.2	.0206	1	.2
17.5	57.4	.0240	1	-.3
20.0	65.6	.0263	1	-.3
22.5	73.8	.0283	1	.3
25.0	82.0	.0292	1	-.3
27.5	90.2	.0308	1	.0
30.0	98.4	.0316	1	.1
32.5	106.6	.0323	1	.1
35.0	114.8	.0327	1	-.2
37.5	123.0	.0333	1	-.3
38.6	126.6	.0343	1	.4

dtb(m)	dtb(ft)	ttb(s)	v(m/s)	vl(m/s)	vu(m/s)	v(ft/s)	vl(ft/s)	vu(ft/s)
.0	.0	.000	1039	994	1088	3408	3260	3570
5.0	16.4	.005	1039	994	1088	3408	3260	3570
18.3	60.0	.026	641	630	652	2103	2068	2139
27.0	88.6	.031	1724	1618	1846	5657	5307	6056
38.6	126.6	.034	3480	3152	3884	11418	10342	12742

Explanation:
- d(m) = depth in meters
- d(ft) = depth in feet
- t(sec) = arrival time in seconds (S-wave arrival times are the average of picks from traces obtained from hammer blows differing in direction by 180°)
- sig = sigma, standard deviation normalized to the standard deviation of best picks
- rsdl/sig = least-squares residual divided by sigma
- dtb(m) = depth to bottom of layer in meters
- dtb(ft) = depth to bottom of layer in feet
- ttb(s) = arrival time in seconds to bottom of layer
- v(m/s) = velocity in meters per second
- vl(m/s) = lower limit of velocity in meters per second *
- vu(m/s) = upper limit of velocity in meters per second
- v(ft/s) = velocity in feet per second
- vl(ft/s) = lower limit of velocity in feet per second
- vu(ft/s) = upper limit of velocity in feet per second

* see text for explanation of velocity limits

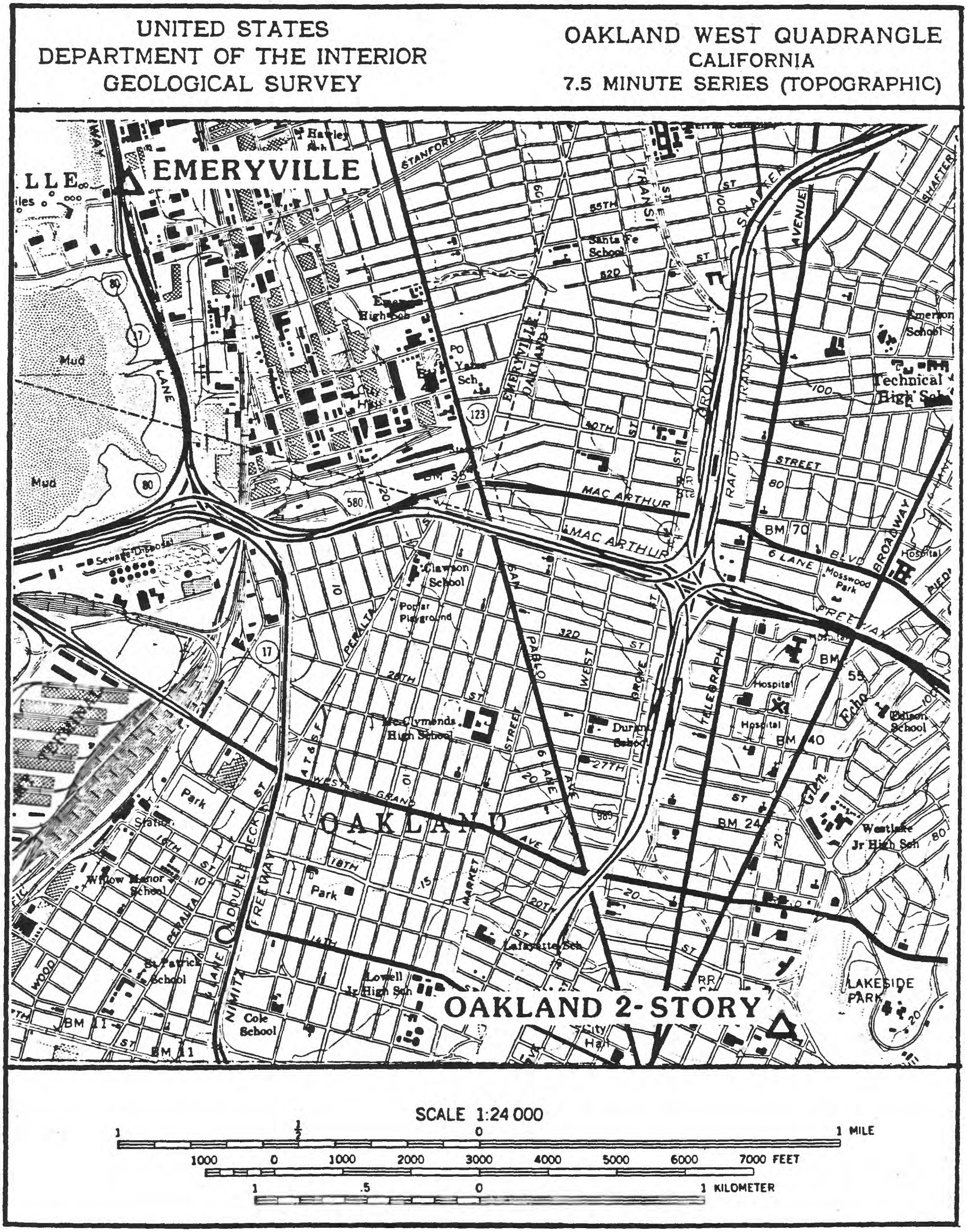


Figure 39. Site location map for Pacific Park Plaza (Emeryville) and Oakland 2-Story (not in this report). The strong-motion accelerograph is located approximately 10 meters from the borehole.

Definitions of terms used for descriptions of sedimentary deposits and bedrock materials

Rock hardness: response to hand and geologic hammer: (Ellen et al., 1972)

hard - hammer bounces off with solid sound
firm - hammer dents with thud, pick point dents or penetrates slightly
soft - pick points penetrates
friable material can be crumbled into individual grains by hand.

Fracture spacing: (Ellen et al., 1972)

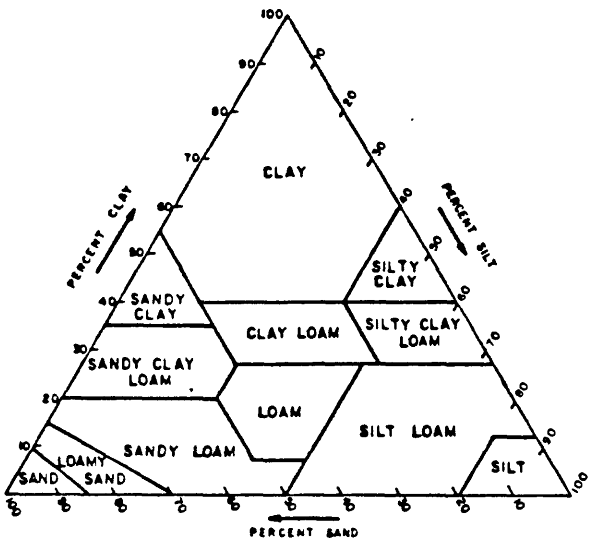
cm	in	fracture spacing
0-1	0-1/2	v. close
1-5	1/2-2	close
5-30	2-12	moderate
30-100	12-36	wide
>100	>36	v. wide

Weathering:
Fresh: no visible signs of weathering
Slight: no visible decomposition of minerals, slight discoloration
Moderate: slight decomposition of minerals and disintegration of rock, deep and thorough discoloration
Deep: extensive decomposition of minerals and complete disintegration of rock but original structure is preserved.

Relative density of sand and consistency of clay is correlated with penetration resistance: (Terzaghi and Peck, 1948)

blows/ft.	relative density	blows/ft.	consistency
0-4	v. loose	<2	v. soft
4-10	loose	2-4	soft
10-30	medium	4-8	medium
30-50	dense	8-15	stiff
>50	v. dense	15-30	v. stiff
		>30	hard

Texture: the relative proportions of clay, silt, and sand below 2mm. Proportions of larger particles are indicated by modifiers of textural class names. Determination is made in the field mainly by feeling the moist soil (Soil Survey, Staff, 1951).



Color: Standard Munsell color names are given for the dominant color of the moist soil and for prominent mottles.

Types of samples

SP - Standard Penetration 1+3/8 in in ID sampler)
S - Thin-wall push sampler
O - Osterberg fixed-piston sampler
P - Pitcher Barrel sampler
CH - California Penetration (2 in ID sampler)
DC - Diamond Core

Figure 40. Explanation of geologic logs.

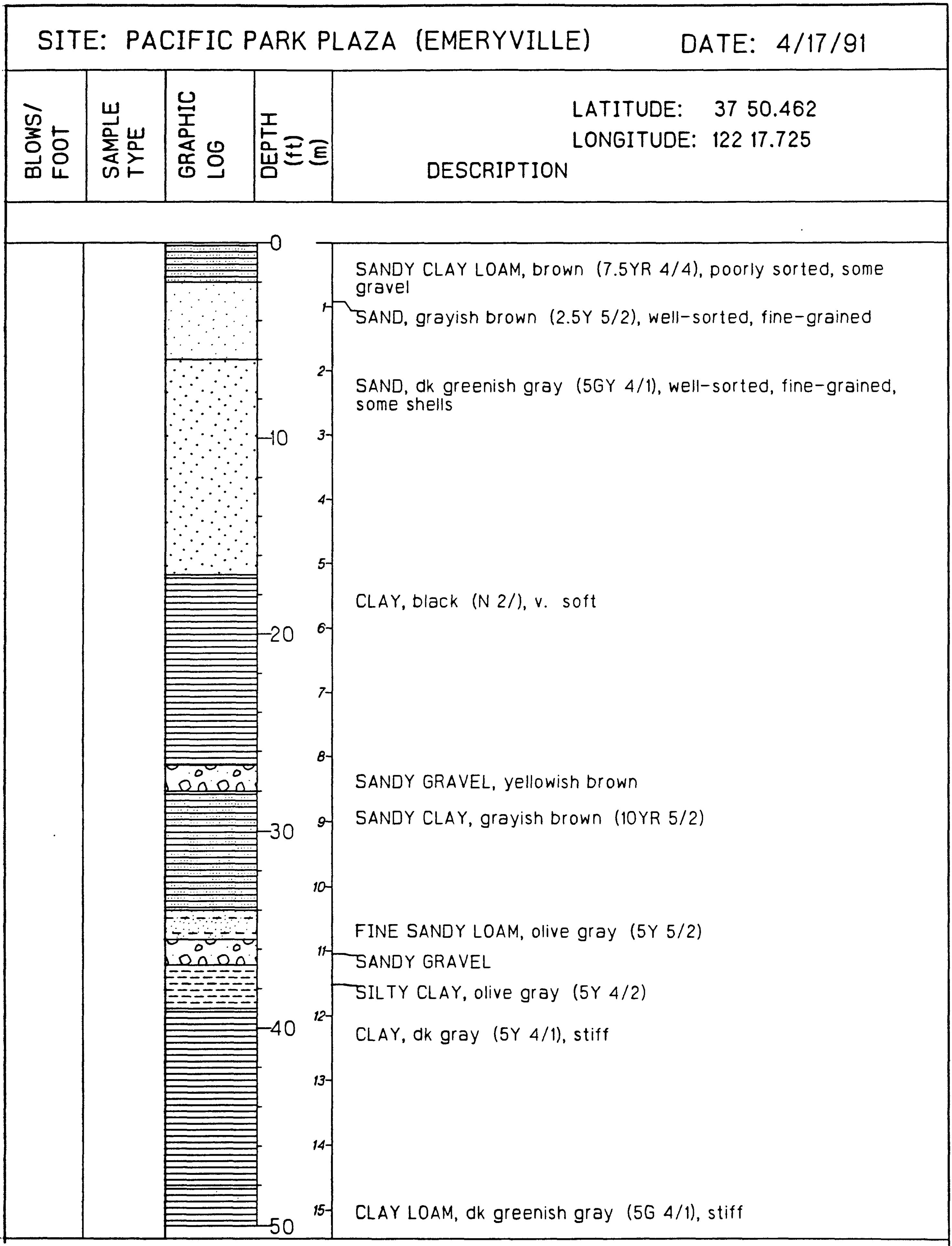


Figure 41. Geologic log of Pacific Park Plaza (Emeryville) borehole.

SITE: PACIFIC PARK PLAZA (EMERYVILLE) DATE: 4/17/91

LATITUDE: 37 50.462
LONGITUDE: 122 17.725

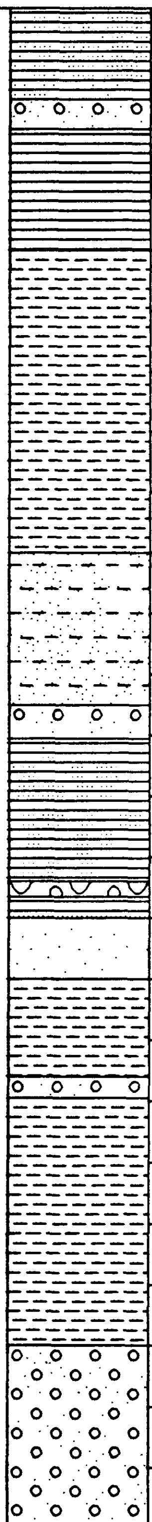
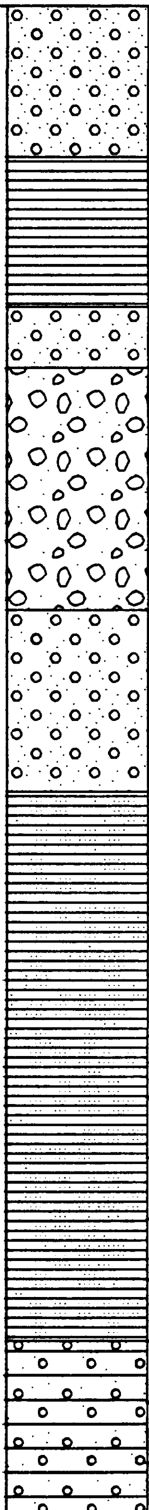
BLOWS/ FOOT	SAMPLE TYPE	GRAPHIC LOG	DEPTH (ft)	(m)	DESCRIPTION
			50		
				16	GRAVELLY SAND
				17	CLAY, olive brown (2.5Y 4/4), v. stiff
					softer, dk greenish gray
				18	
			60		
				19	SILTY CLAY, v.dk. greenish gray (5G 3/1), stiff
				20	
				21	SANDY LOAM, brown (10YR 4/3), some fine gravel, dense
			70		
				22	GRAVELLY SAND
				23	SANDY CLAY LOAM, brown (10YR 4/3), poorly sorted
				24	GRAVEL
			80		SAND
				25	SILTY CLAY LOAM, yellowish brown (10YR 5/6), v. stiff
				26	GRAVELLY SAND
					brown (10YR 5/6) to pale brown (10YR 6/3)
				27	
			90		
				28	
				29	GRAVELLY SAND, dk. yellowish brown, mostly v. fine-grained sandstone
				30	
			100		

Figure 41. (Continued).

SITE: PACIFIC PARK PLAZA (EMERYVILLE) DATE: 4/17/91

LATITUDE: 37 50.462
LONGITUDE: 122 17.725

BLOWS/ FOOT	SAMPLE TYPE	GRAPHIC LOG	DEPTH (ft)	DEPTH (m)	DESCRIPTION
			100		
				31	
				32	CLAY LOAM, grayish brown (2.5Y 5/2), stiffer
				33	
			110		
				34	GRAVELLY SAND
					SANDY GRAVEL
				35	
				36	
			120		
				37	GRAVELLY SAND
				38	
				39	SANDY CLAY LOAM, light olive brown (2.5Y 5/4), v. stiff
			130		
				40	
				41	
					lt. brownish gray (2.5Y 6/2), some gravel
				42	
			140		lt. olive brown (2.5Y 5/4)
				43	
				44	GRAVELLY SANDY LOAM
				45	
			150		

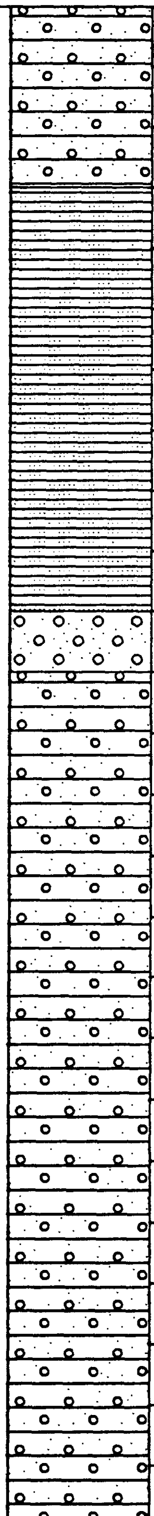
Page 3 of 4

Figure 41. (Continued).

SITE: PACIFIC PARK PLAZA (EMERYVILLE) DATE: 4/17/91

BLOWS/ FOOT	SAMPLE TYPE	GRAPHIC LOG	DEPTH (ft) (m)	DESCRIPTION

LATITUDE: 37 50.462
LONGITUDE: 122 17.725



DEPTH (ft)	DEPTH (m)	DESCRIPTION
150		
	46	
	47	
	48	SANDY CLAY LOAM
160		
	49	
	50	
	51	
170		
	52	GRAVELLY SAND
		SANDY LOAM, v. coarse
	53	
	54	
180		
	55	
	56	
	57	
190		
	58	
	59	
	60	
200		

Figure 41. (Continued).

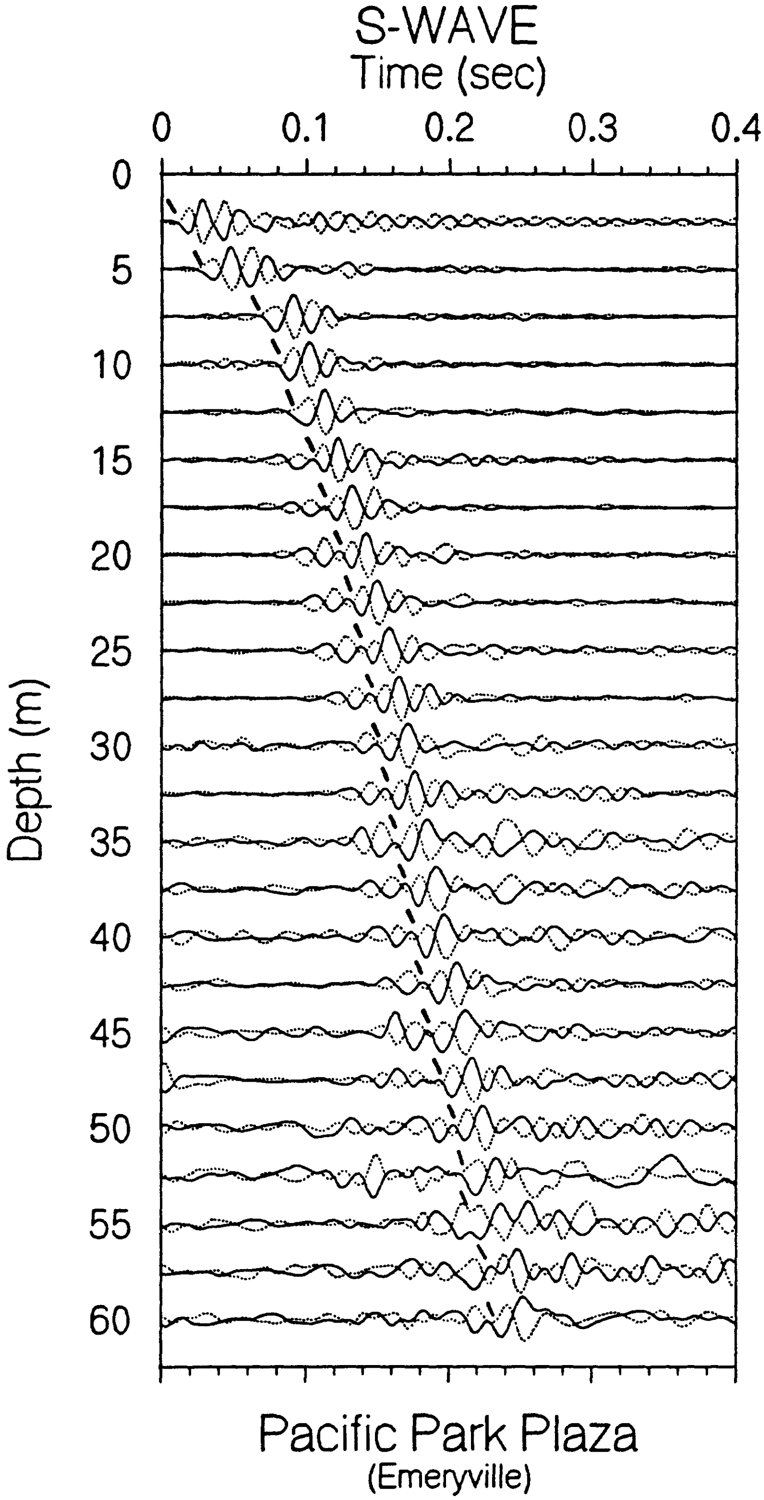


Figure 42. Horizontal-component record section (from horizontal impacts in opposite directions) superimposed for identification of S-wave onset. Approximate S-wave picks are indicated by the accent marks.

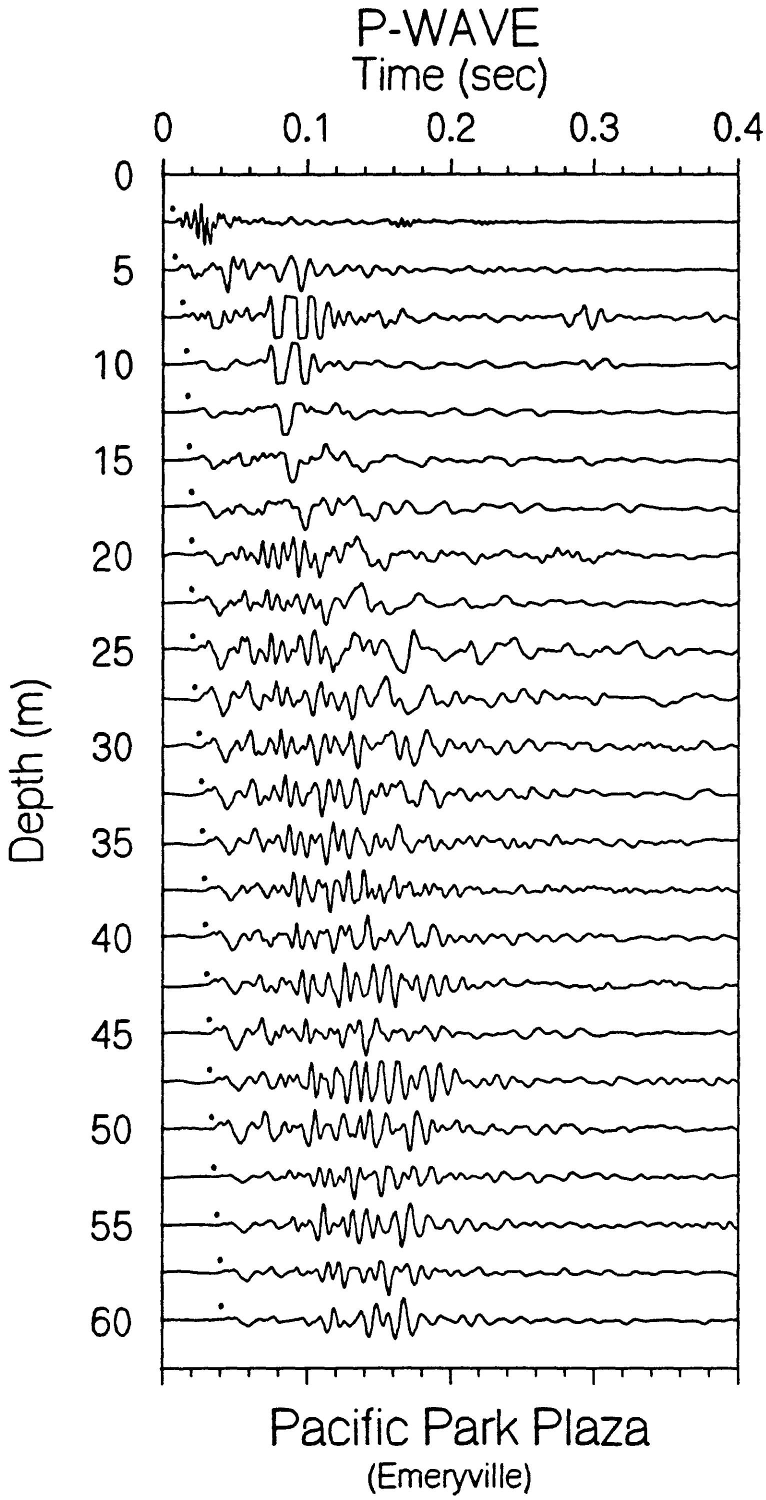


Figure 43. Vertical-component record section. P-wave arrivals are shown by the solid circles.

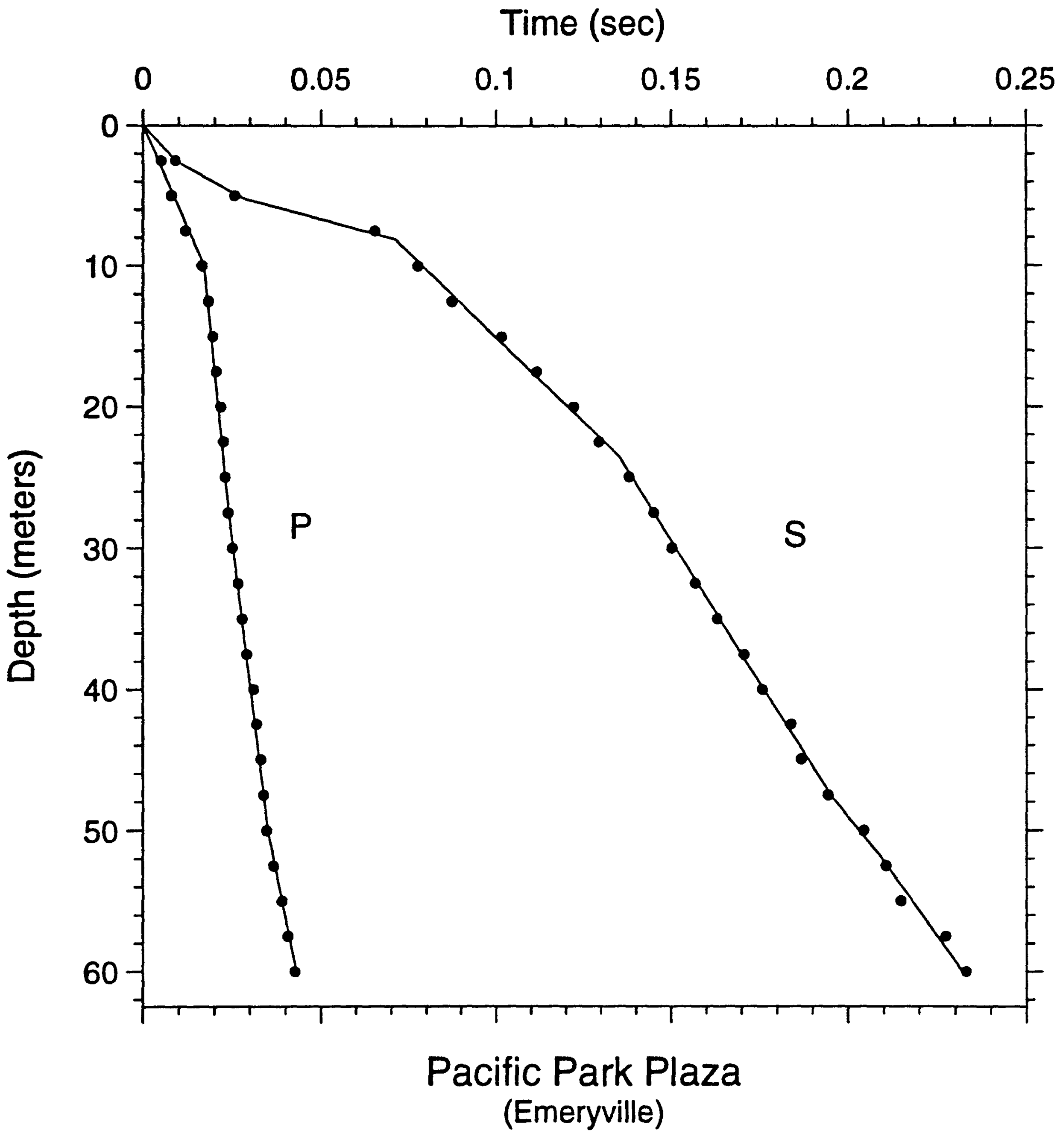


Figure 44. Time-depth graph of P-wave and S-wave picks. Line segments show the hinged-least-squares fit to the data points.

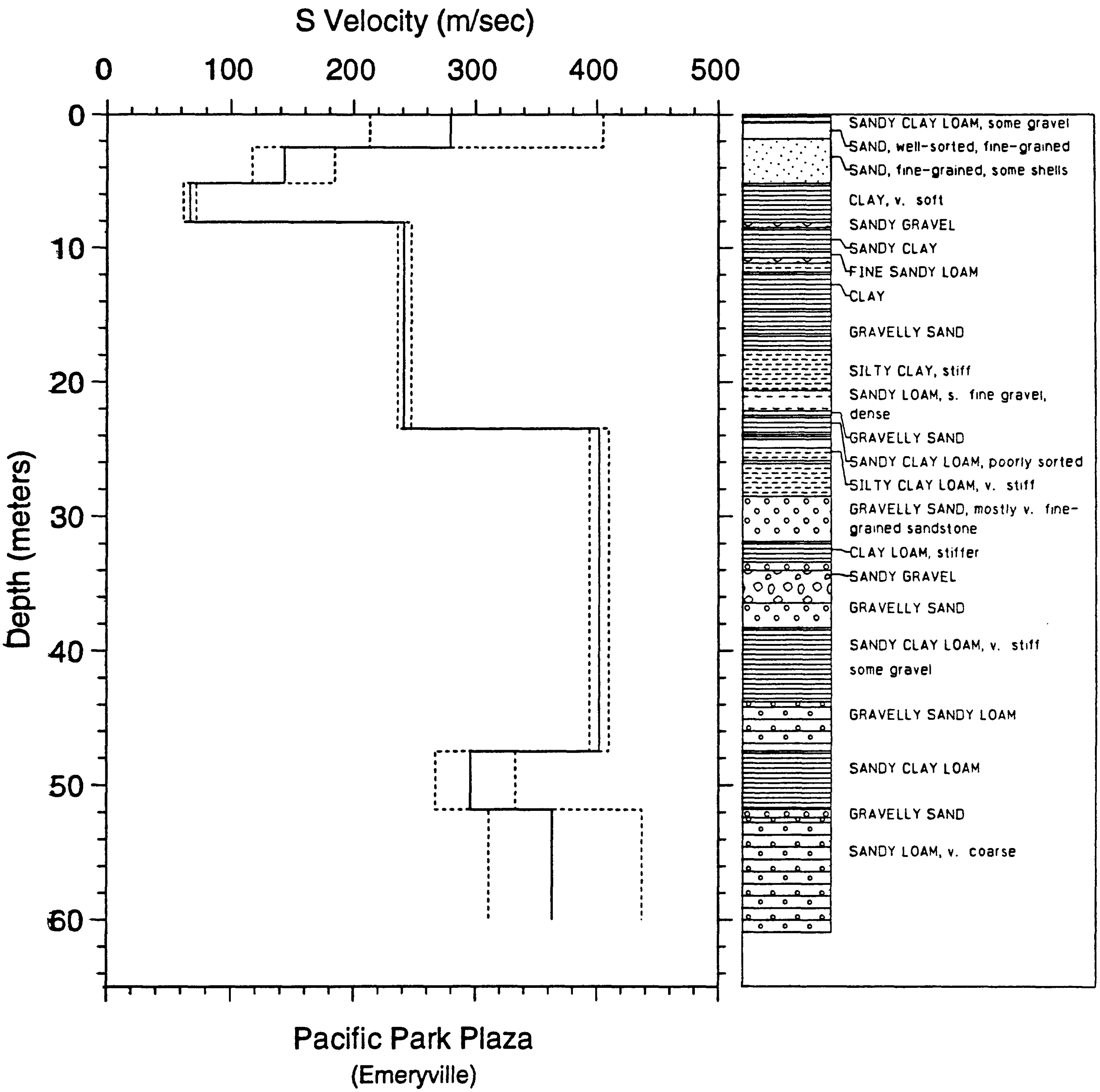
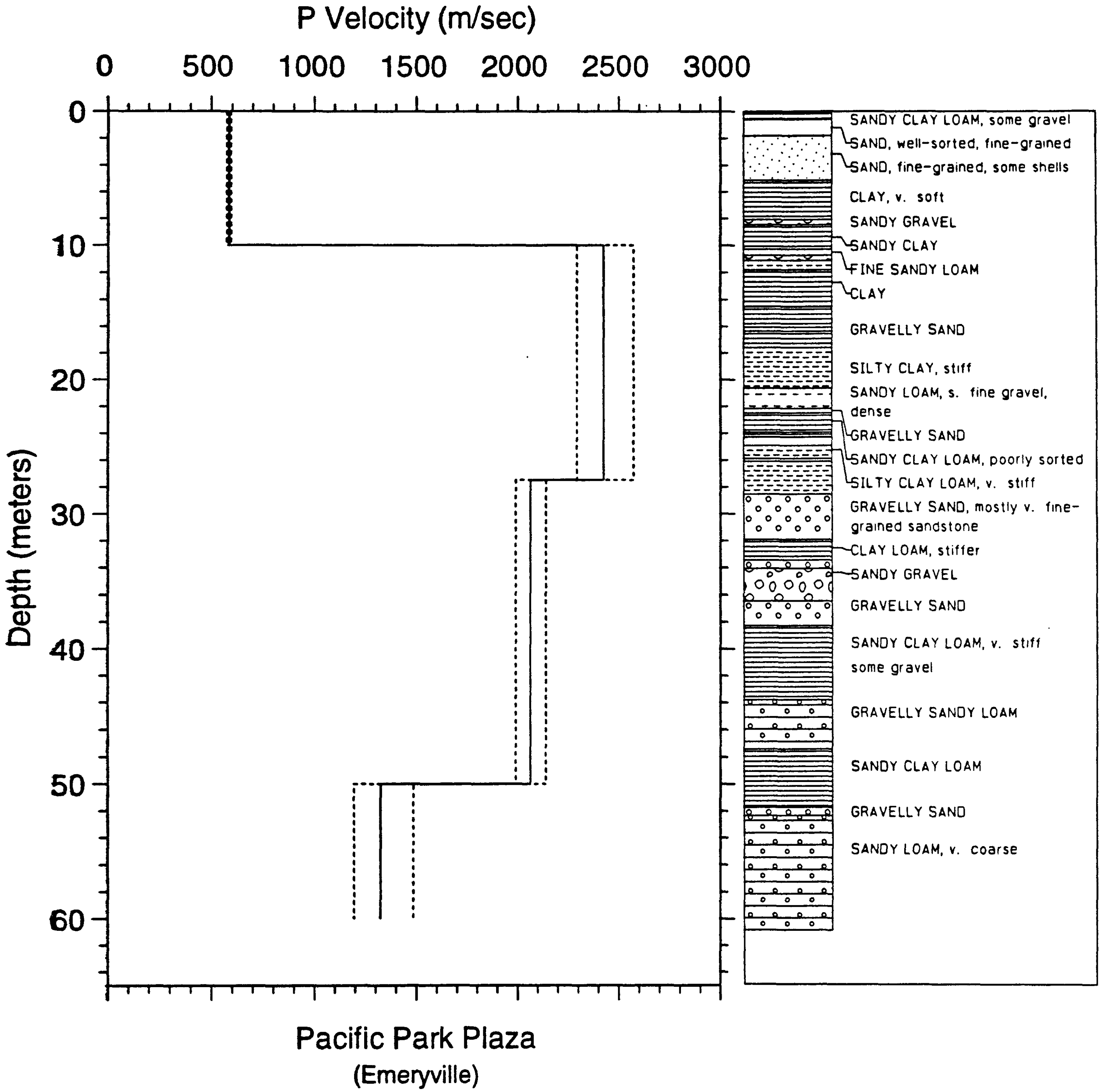


Figure 45. S-wave velocity profiles with dashed lines representing plus and minus one standard deviation. Simplified geologic log is shown for correlation with velocities.



Pacific Park Plaza
(Emeryville)

Figure 46. P-wave velocity profiles with dashed lines representing plus and minus one standard deviation. Simplified geologic log is shown for correlation with velocities.

TABLE 9. S-wave arrival times and velocity summaries for Pacific Park Plaza site.

d(m)	d(ft)	t(sec)	sig	rsdl/sig
2.5	8.2	.0090	2	.0
5.0	16.4	.0257	2	-.4
7.5	24.6	.0653	2	1.6
10.0	32.8	.0776	1	-1.3
12.5	41.0	.0873	1	-2.0
15.0	49.2	.1016	1	1.9
17.5	57.4	.1116	1	1.5
20.0	65.6	.1222	1	1.8
22.5	73.8	.1294	1	-1.4
25.0	82.0	.1380	1	-.7
27.5	90.2	.1451	1	.2
30.0	98.4	.1502	1	-.9
32.5	106.6	.1569	1	-.4
35.0	114.8	.1632	1	-.4
37.5	123.0	.1707	1	.9
40.0	131.2	.1759	1	-.1
42.5	139.4	.1839	1	1.7
45.0	147.6	.1868	1	-1.6
47.5	155.8	.1944	1	-.3
50.0	164.0	.2044	1	1.3
52.5	172.2	.2107	1	-.4
55.0	180.4	.2149	2	-1.5
57.5	188.6	.2273	3	.8
60.0	196.9	.2331	3	.4

dtb(m)	dtb(ft)	ttb(s)	v(m/s)	vl(m/s)	vu(m/s)	v(ft/s)	vl(ft/s)	vu(ft/s)
.0	.0	.000	279	213	405	917	699	1330
2.5	8.2	.009	279	213	405	917	699	1330
5.2	17.1	.028	143	117	184	470	384	604
8.1	26.6	.071	67	62	72	220	205	238
23.5	77.1	.135	241	236	247	791	773	809
47.5	155.8	.195	402	394	410	1319	1293	1346
51.8	169.9	.209	296	267	333	972	876	1092
60.0	196.9	.232	363	311	437	1191	1019	1433

Explanation:

d(m) = depth in meters
d(ft) = depth in feet
t(sec) = arrival time in seconds (S-wave arrival times are the average of picks from traces obtained from hammer blows differing in direction by 180°)
sig = sigma, standard deviation normalized to the standard deviation of best picks
rsdl/sig = least-squares residual divided by sigma
dtb(m) = depth to bottom of layer in meters
dtb(ft) = depth to bottom of layer in feet
ttb(s) = arrival time in seconds to bottom of layer
v(m/s) = velocity in meters per second
vl(m/s) = lower limit of velocity in meters per second *
vu(m/s) = upper limit of velocity in meters per second
v(ft/s) = velocity in feet per second
vl(ft/s) = lower limit of velocity in feet per second
vu(ft/s) = upper limit of velocity in feet per second
* see text for explanation of velocity limits

TABLE 10. P-wave arrival times and velocity summaries for Pacific Park Plaza site.

d(m)	d(ft)	t(sec)	sig	rsdl/sig
2.5	8.2	.0051	1	.8
5.0	16.4	.0079	1	-.7
7.5	24.6	.0119	1	-.9
10.0	32.8	.0165	4	-.2
12.5	41.0	.0183	1	.1
15.0	49.2	.0196	1	.4
17.5	57.4	.0205	1	.3
20.0	65.6	.0218	1	.6
22.5	73.8	.0226	1	.3
25.0	82.0	.0230	1	-.3
27.5	90.2	.0239	1	-.4
30.0	98.4	.0251	1	-.5
32.5	106.6	.0267	1	-.1
35.0	114.8	.0279	1	-.1
37.5	123.0	.0291	1	-.1
40.0	131.2	.0311	1	.7
42.5	139.4	.0319	1	.3
45.0	147.6	.0331	1	.3
47.5	155.8	.0339	1	-.1
50.0	164.0	.0347	1	-.5
52.5	172.2	.0367	4	-.1
55.0	180.4	.0391	1	.1
57.5	188.6	.0407	3	-.1
60.0	196.9	.0427	3	.0

dtb(m)	dtb(ft)	ttb(s)	v(m/s)	vl(m/s)	vu(m/s)	v(ft/s)	vl(ft/s)	vu(ft/s)
.0	.0	.000	584	574	594	1916	1884	1949
10.0	32.8	.017	584	574	594	1916	1884	1949
27.5	90.2	.024	2424	2292	2572	7954	7521	8439
50.0	164.0	.035	2062	1991	2140	6767	6531	7020
60.0	196.9	.043	1324	1194	1485	4343	3917	4873

Explanation:
- d(m) = depth in meters
- d(ft) = depth in feet
- t(sec) = arrival time in seconds (S-wave arrival times are the average of picks from traces obtained from hammer blows differing in direction by 180°)
- sig = sigma, standard deviation normalized to the standard deviation of best picks
- rsdl/sig = least-squares residual divided by sigma
- dtb(m) = depth to bottom of layer in meters
- dtb(ft) = depth to bottom of layer in feet
- ttb(s) = arrival time in seconds to bottom of la; er
- v(m/s) = velocity in meters per second
- vl(m/s) = lower limit of velocity in meters per second *
- vu(m/s) = upper limit of velocity in meters per second
- v(ft/s) = velocity in feet per second
- vl(ft/s) = lower limit of velocity in feet per second
- vu(ft/s) = upper limit of velocity in feet per second

* see text for explanation of velocity limits

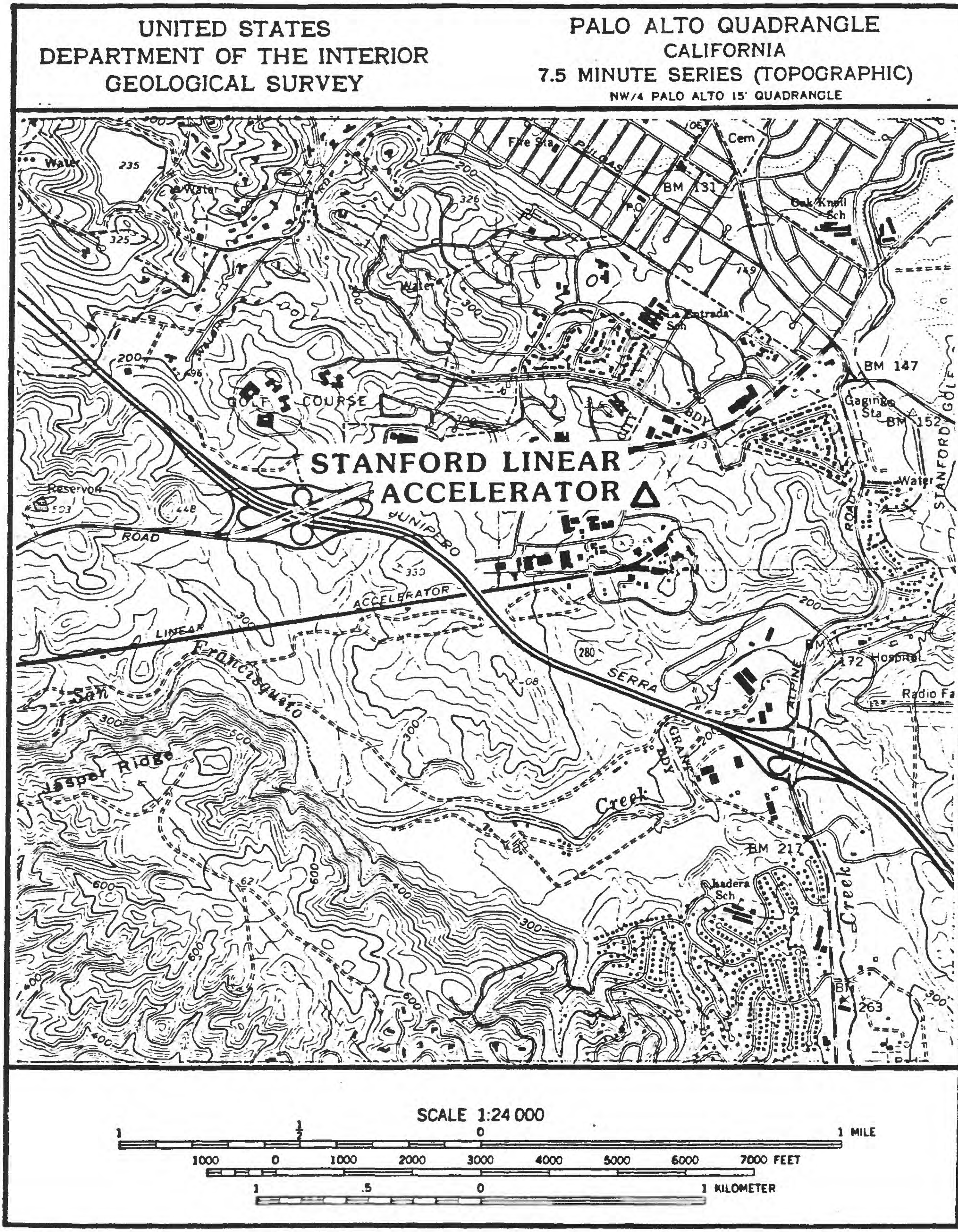


Figure 47. Location map for Stanford Linear Accelerator (SLAC) borehole. The borehole is located approximately 300 meters from the strong-motion recorder.

Definitions of terms used for descriptions of sedimentary deposits and bedrock materials

Rock hardness: response to hand and geologic hammer: (Ellen et al., 1972)

hard - hammer bounces off with solid sound
firm - hammer dents with thud, pick point dents or penetrates slightly
soft - pick points penetrates
friable material can be crumbled into individual grains by hand.

Fracture spacing: (Ellen et al., 1972)

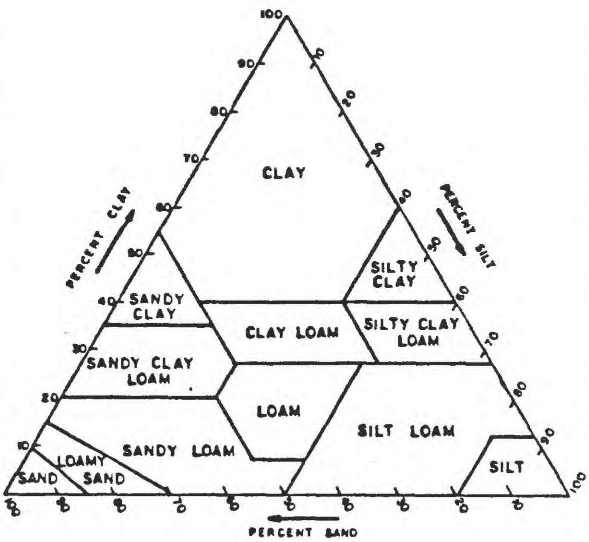
cm	in	fracture spacing
0-1	0-1/2	v. close
1-5	1/2-2	close
5-30	2-12	moderate
30-100	12-36	wide
>100	>36	v. wide

Weathering:
Fresh: no visible signs of weathering
Slight: no visible decomposition of minerals, slight discoloration
Moderate: slight decomposition of minerals and disintegration of rock, deep and thorough discoloration
Deep: extensive decomposition of minerals and complete disintegration of rock but original structure is preserved.

Relative density of sand and consistency of clay is correlated with penetration resistance: (Terzaghi and Peck, 1948)

blows/ft.	relative density	blows/ft.	consistency
0-4	v. loose	<2	v. soft
4-10	loose	2-4	soft
10-30	medium	4-8	medium
30-50	dense	8-15	stiff
>50	v. dense	15-30	v. stiff
		>30	hard

Texture: the relative proportions of clay, silt, and sand below 2mm. Proportions of larger particles are indicated by modifiers of textural class names. Determination is made in the field mainly by feeling the moist soil (Soil Survey, Staff, 1951).



Color: Standard Munsell color names are given for the dominant color of the moist soil and for prominent mottles.

Types of samples

SP - Standard Penetration 1 + 3/8 in in ID sampler)
S - Thin-wall push sampler
O - Osterberg fixed-piston sampler
P - Pitcher Barrel sampler
CH - California Penetration (2 in ID sampler)
DC - Diamond Core

Figure 48. Explanation of geologic log.

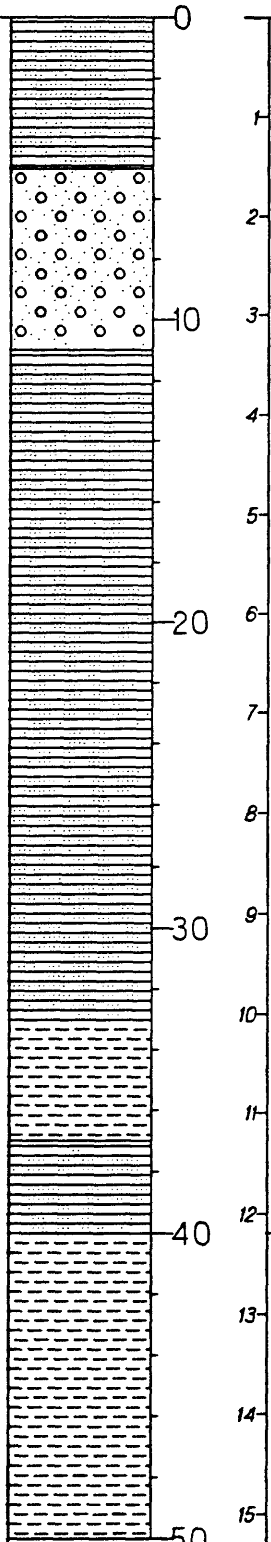
SITE: SLAC

DATE: 4/9/91

BLOWS/ FOOT	SAMPLE TYPE	GRAPHIC LOG	DEPTH (ft) (m)	DESCRIPTION

LATITUDE: 37 25.175

LONGITUDE: 122 12.050



SANDY CLAY LOAM, v. dk. grayish brown (10YR 3/2)

SANDY GRAVEL, poorly sorted

SANDY CLAY LOAM, strong brown (7.5YR 5/8) to brownish yellow (10YR 6/6), firm

and strong brown (7.5YR 5/8)

grayish brown (10YR 5/2)

CLAY LOAM, v. dk. gray (5Y 3/1), firm

SANDY CLAY LOAM TO SANDY LOAM, lt. olive gray (5Y 6/2) to lt. gray (5Y 6/1)

SILTSTONE, mottled dk. gray and yellowish brown, firm v. dk.gray (N 3/)

Figure 49. Geologic log of SLAC borehole.

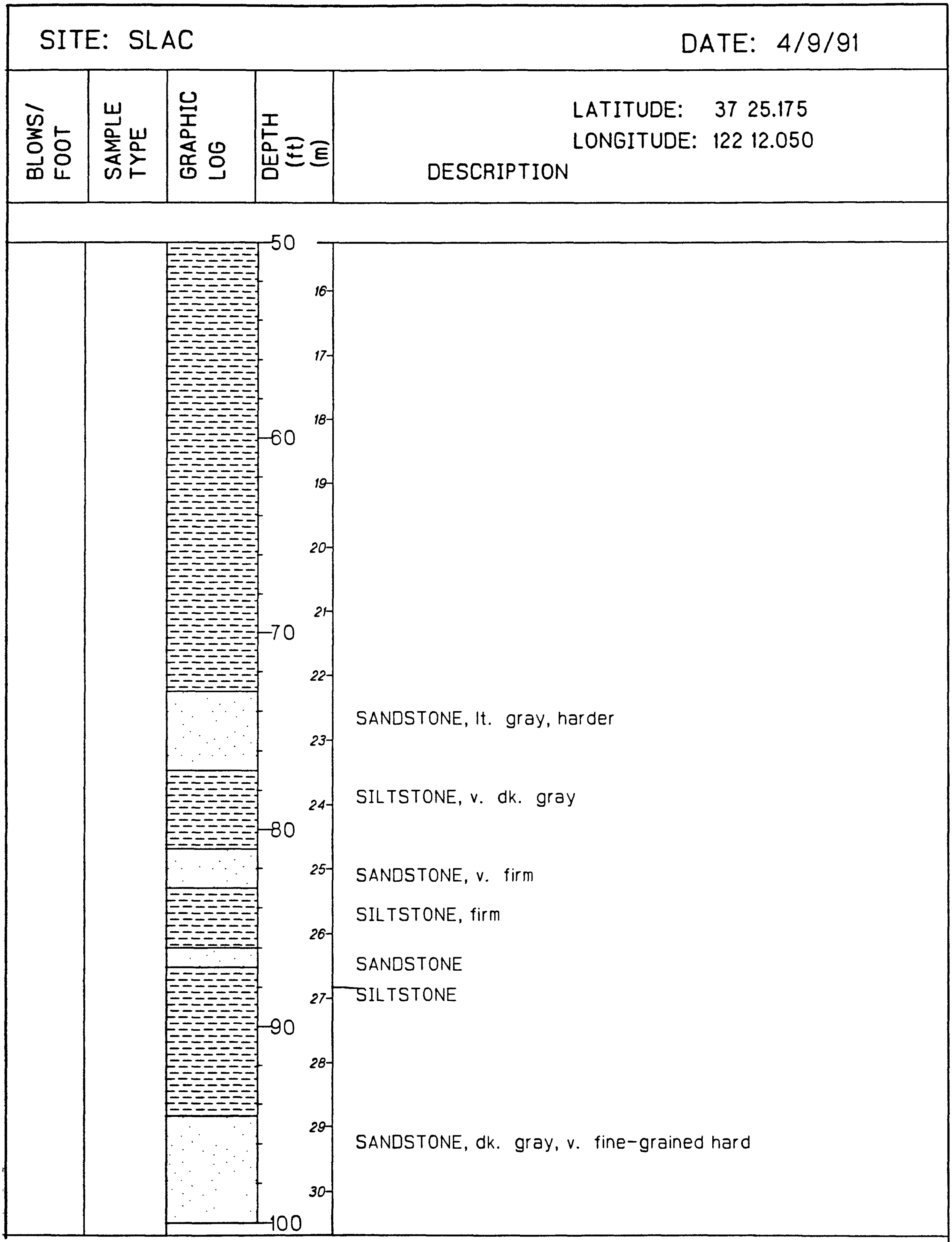


Figure 49. (Continued).

SITE: SLAC

DATE: 4/9/91

LATITUDE: 37 25.175
LONGITUDE: 122 12.050

BLOWS/ FOOT	SAMPLE TYPE	GRAPHIC LOG	DEPTH (ft)	DEPTH (m)	DESCRIPTION
			100		
				31	SILTSTONE, firm
					SANDSTONE, v. fine-grained, v. firm to hard
				32	
				33	
			110		
				34	dk. gray, v. firm
				35	gray (N 5/), hard
				36	
			120		
				37	
				38	
					SILTSTONE, v. firm
				39	
			130		
				40	SANDSTONE, dk. gray, v. fine-grained, v. firm to hard
				41	hard, close to moderately fractured
				42	
			140		
				43	
				44	
				45	
			150		

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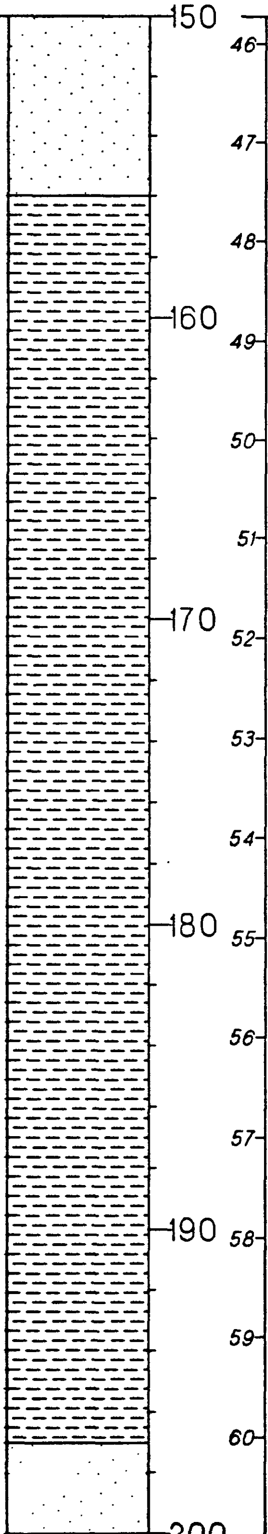
Figure 49. (Continued).

SITE: SLAC

DATE: 4/9/91

LATITUDE: 37 25.175
LONGITUDE: 122 12.050

BLOWS/ FOOT	SAMPLE TYPE	GRAPHIC LOG	DEPTH (ft) (m)	DESCRIPTION



SILTSTONE, v. firm

SANDSTONE, fine-grained, hard

Page 4 of 4

Figure 49. (Continued).

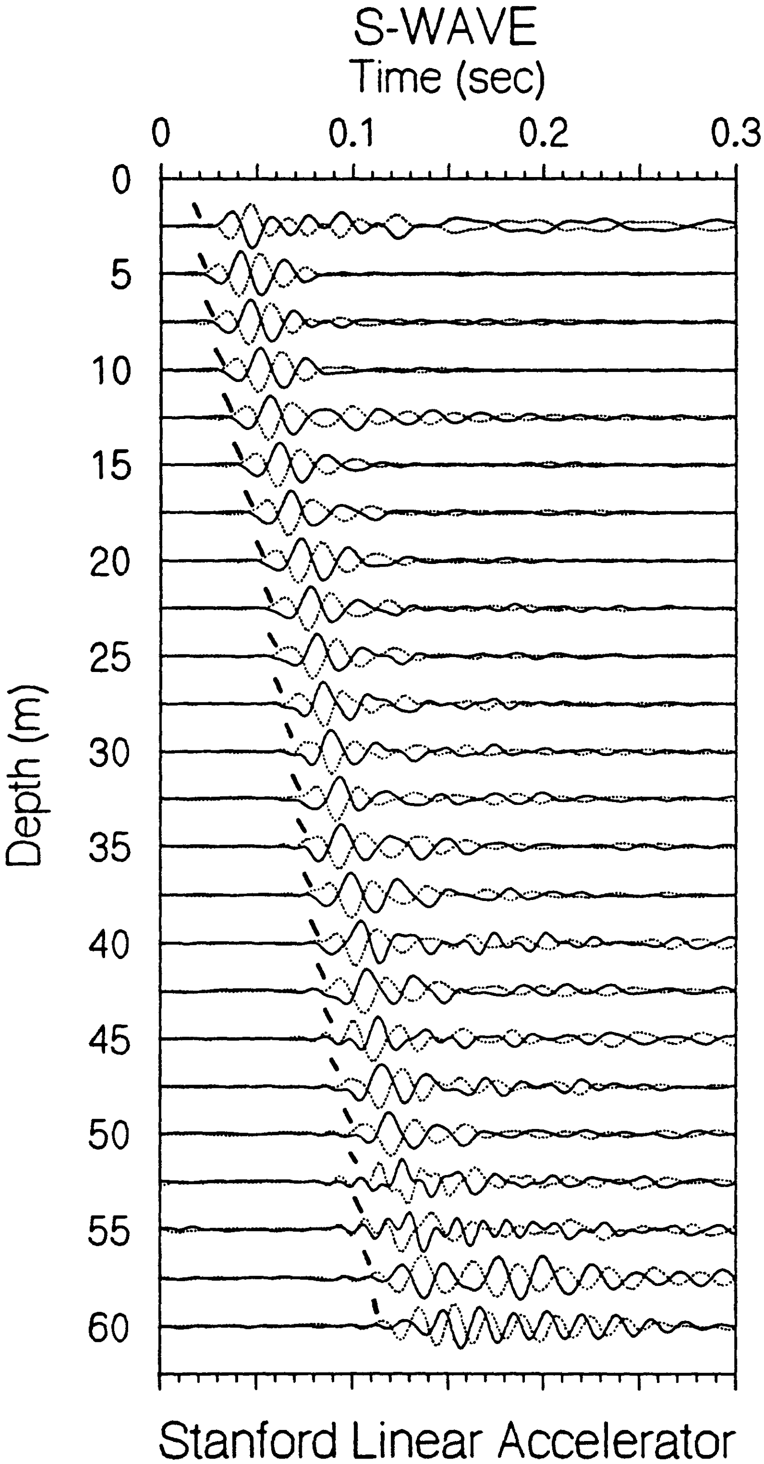


Figure 50. Horizontal-component record section (from horizontal impacts in opposite directions) superimposed for identification of S-wave onset. Approximate S-wave picks are indicated by the accent marks.

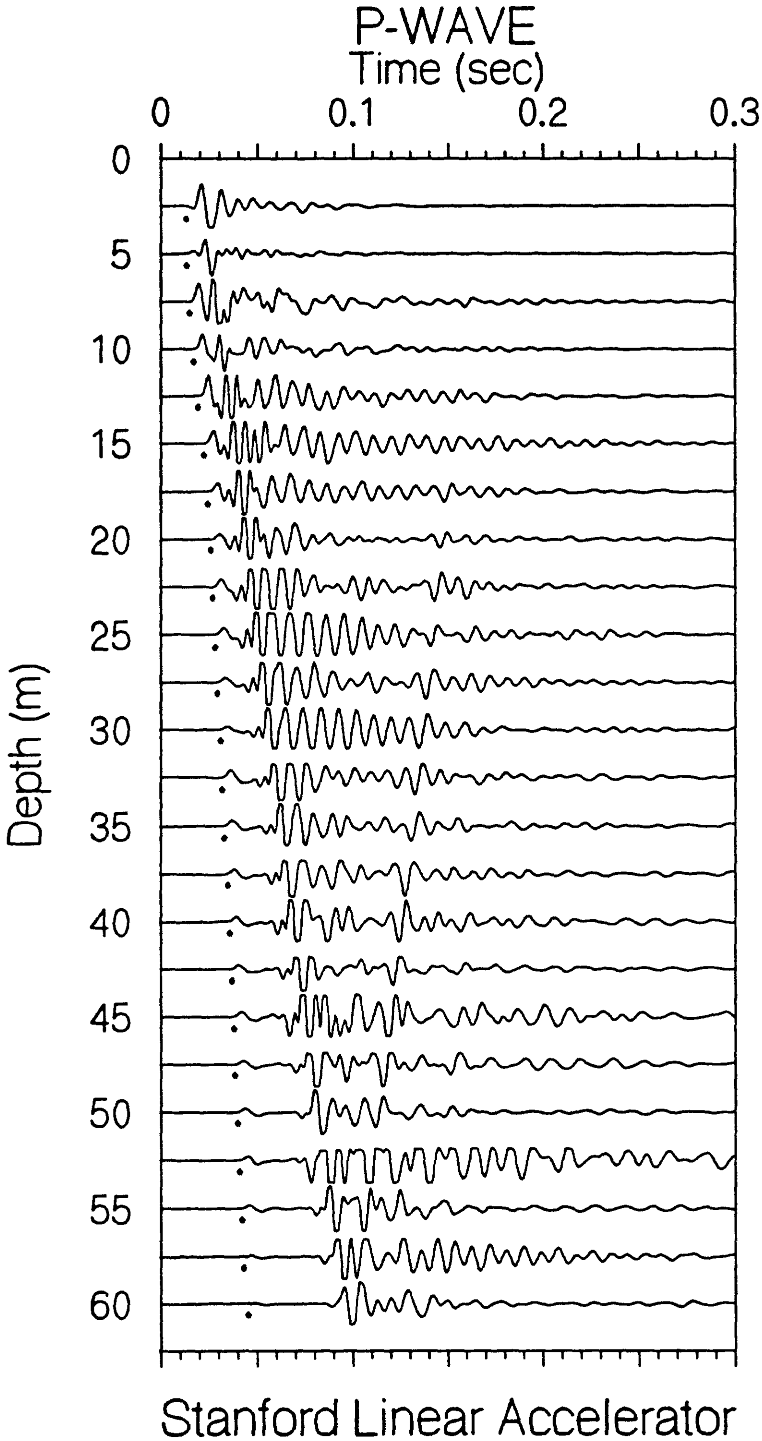


Figure 51. Vertical-component record section. P-wave arrivals are shown by the solid circles.

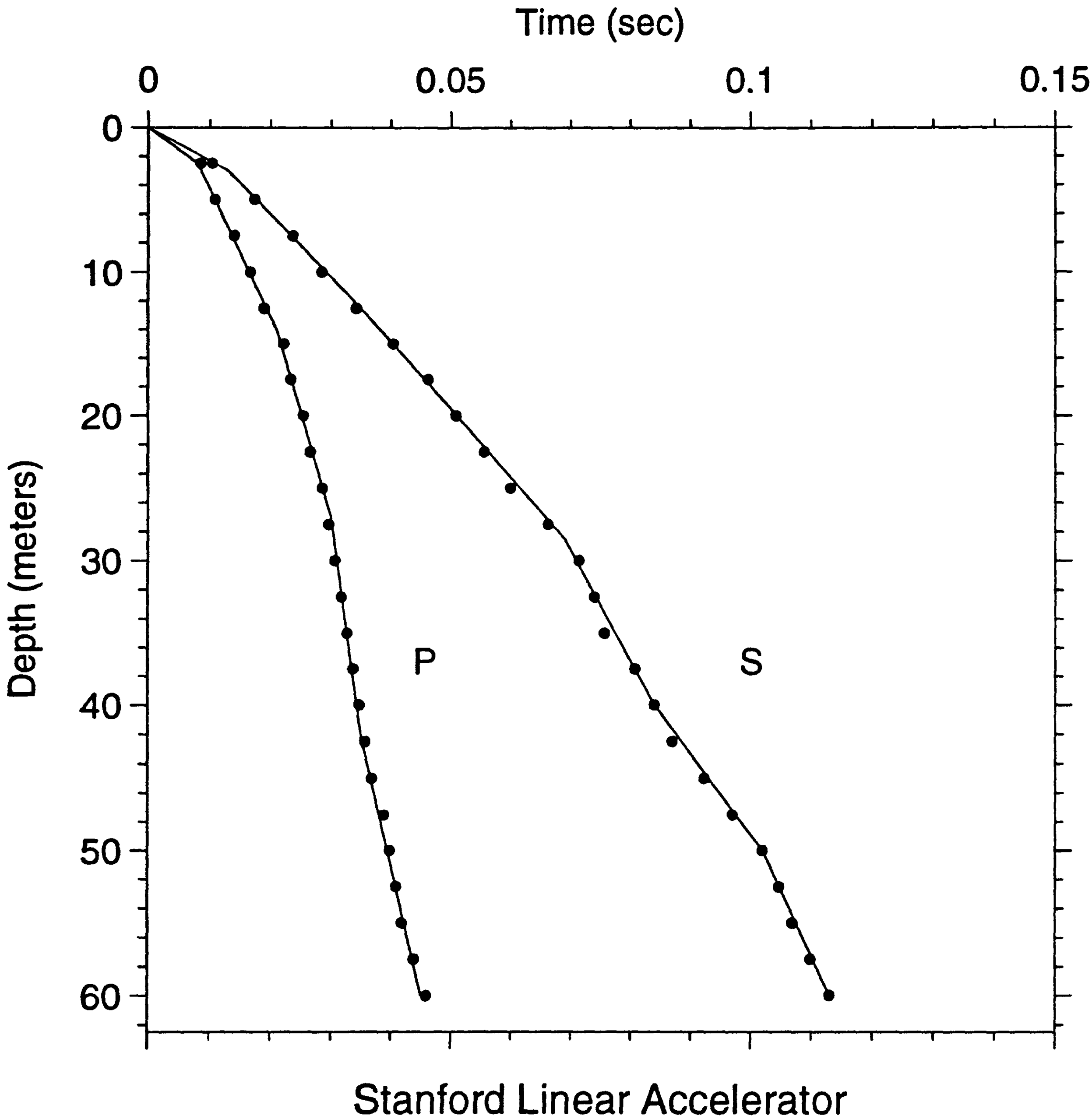


Figure 52. Time-depth graph of P-wave and S-wave picks. Line segments show the hinged-least-squares fit to the data points.

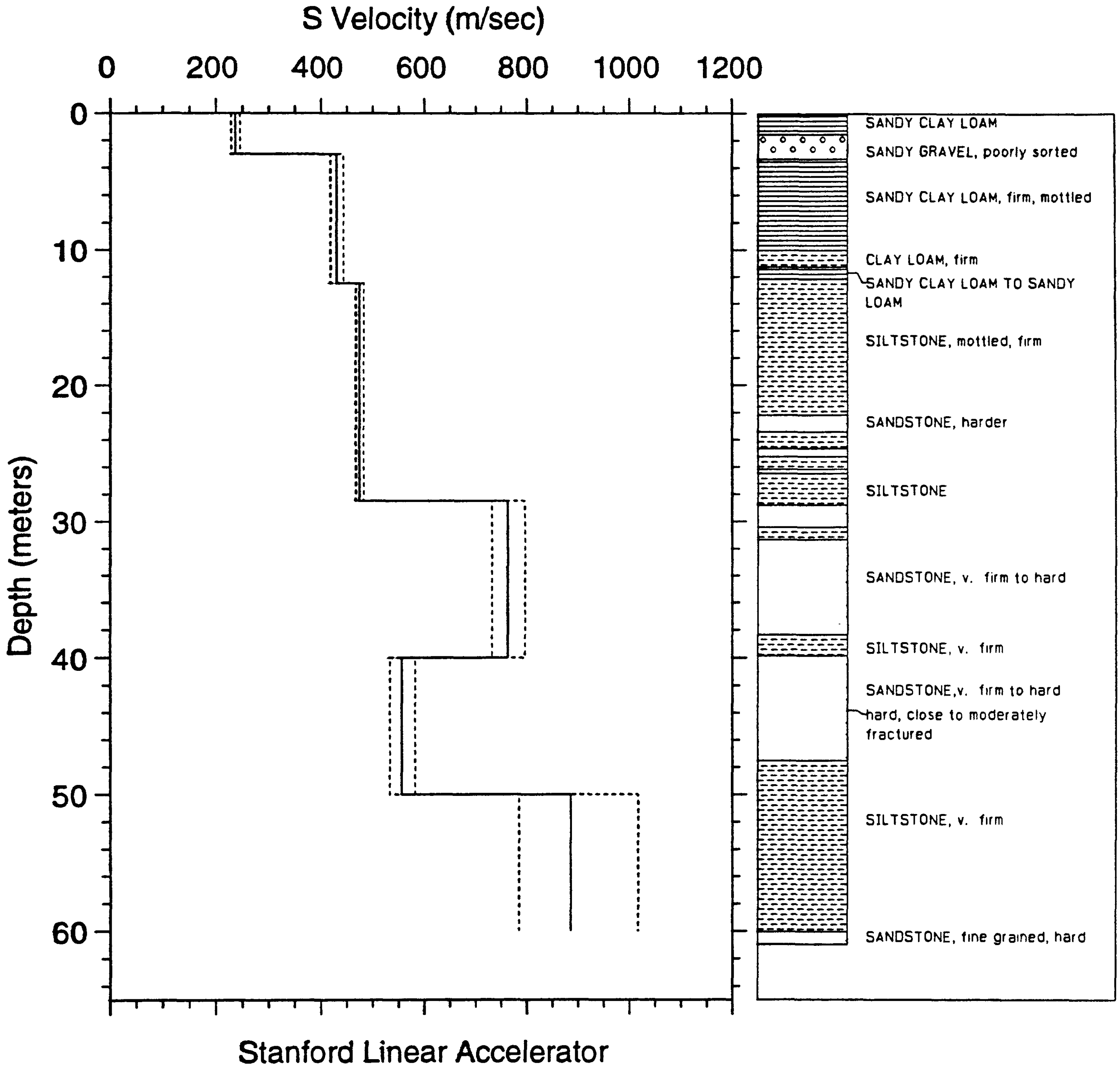


Figure 53. S-wave velocity profiles with dashed lines representing plus and minus one standard deviation. Simplified geologic log is shown for correlation with velocities.

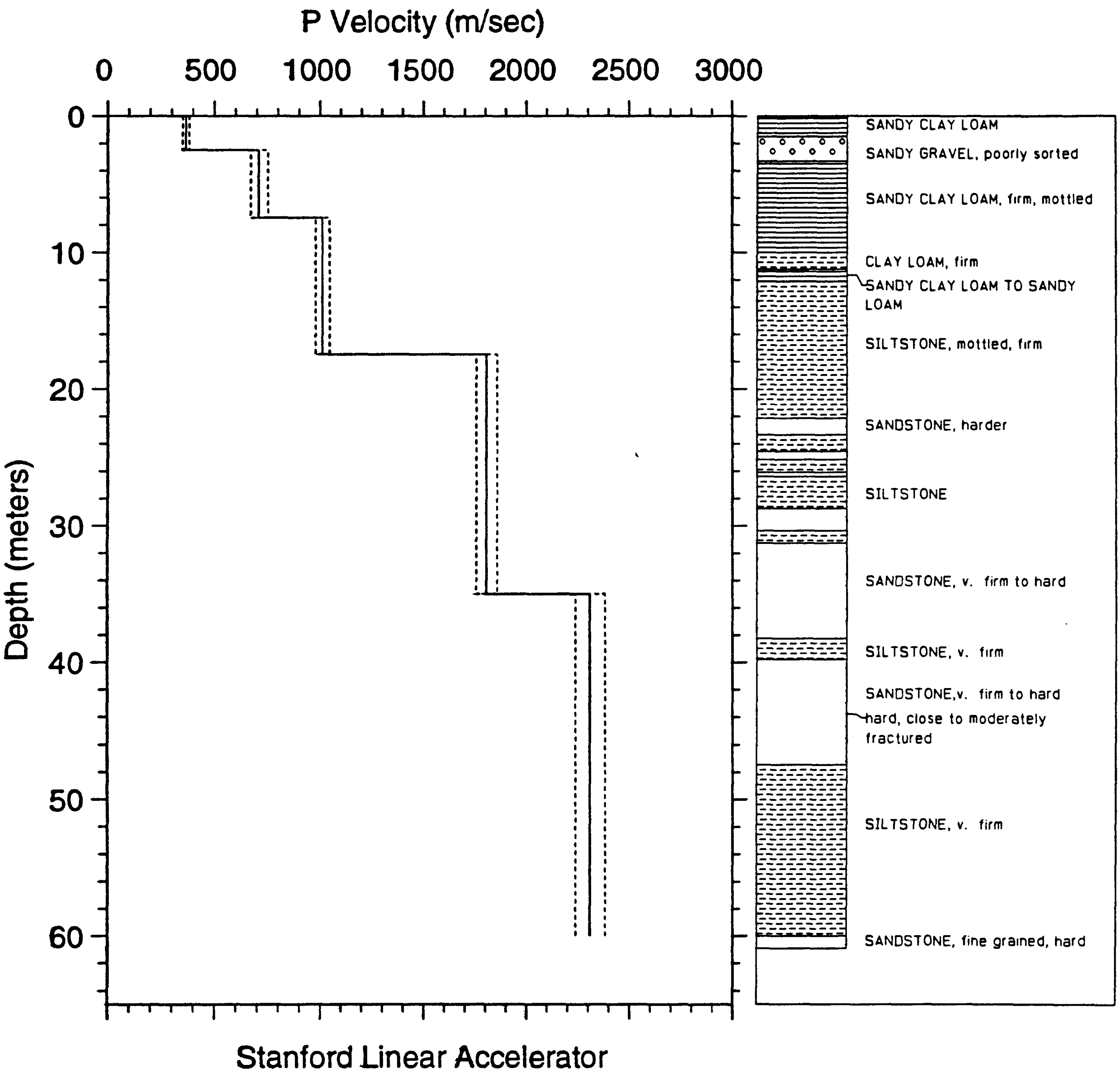


Figure 54. P-wave velocity profiles with dashed lines representing plus and minus one standard deviation. Simplified geologic log is shown for correlation with velocities.

TABLE 11. S-wave arrival times and velocity summaries for SLAC site.

d(m)	d(ft)	t(sec)	sig	rsdl/sig
2.5	8.2	.0104	1	-.2
5.0	16.4	.0174	1	.0
7.5	24.6	.0237	1	.5
10.0	32.8	.0285	1	-.5
12.5	41.0	.0343	1	-.5
15.0	49.2	.0404	1	.3
17.5	57.4	.0462	1	.8
20.0	65.6	.0509	1	.3
22.5	73.8	.0556	1	-.3
25.0	82.0	.0600	1	-1.2
27.5	90.2	.0663	1	-.1
30.0	98.4	.0714	1	.9
32.5	106.6	.0740	1	.2
35.0	114.8	.0757	2	-.9
37.5	123.0	.0808	1	.5
40.0	131.2	.0840	2	.3
42.5	139.4	.0870	2	-.7
45.0	147.6	.0923	4	-.1
47.5	155.8	.0970	1	-.1
50.0	164.0	.1020	2	.3
52.5	172.2	.1047	3	.1
55.0	180.4	.1069	4	-.1
57.5	188.6	.1099	3	-.1
60.0	196.9	.1130	3	.0

dtb(m)	dtb(ft)	ttb(s)	v(m/s)	vl(m/s)	vu(m/s)	v(ft/s)	vl(ft/s)	vu(ft/s)
.0	.0	.000	236	228	245	774	747	803
3.0	9.8	.013	236	228	245	774	747	803
12.5	41.0	.035	430	418	443	1411	1371	1452
28.5	93.5	.069	474	467	482	1556	1532	1582
40.0	131.2	.084	763	732	797	2504	2402	2616
50.0	164.0	.102	556	533	582	1824	1748	1908
60.0	196.9	.113	886	785	1017	2908	2576	3337

Explanation:
- d(m) = depth in meters
- d(ft) = depth in feet
- t(sec) = arrival time in seconds (S-wave arrival times are the average of picks from traces obtained from hammer blows differing in direction by 180°)
- sig = sigma, standard deviation normalized to the standard deviation of best picks
- rsdl/sig = least-squares residual divided by sigma
- dtb(m) = depth to bottom of layer in meters
- dtb(ft) = depth to bottom of layer in feet
- ttb(s) = arrival time in seconds to bottom of layer
- v(m/s) = velocity in meters per second
- vl(m/s) = lower limit of velocity in meters per second *
- vu(m/s) = upper limit of velocity in meters per second
- v(ft/s) = velocity in feet per second
- vl(ft/s) = lower limit of velocity in feet per second
- vu(ft/s) = upper limit of velocity in feet per second

* see text for explanation of velocity limits

TABLE 12. P-wave arrival times and velocity summaries for SLAC site.

d(m)	d(ft)	t(sec)	sig	rsdl/sig
2.5	8.2	.0068	1	-.1
5.0	16.4	.0105	1	.1
7.5	24.6	.0138	1	-.1
10.0	32.8	.0162	1	-.2
12.5	41.0	.0191	1	.2
15.0	49.2	.0217	1	.4
17.5	57.4	.0243	1	.5
20.0	65.6	.0250	1	-.2
22.5	73.8	.0260	1	-.6
25.0	82.0	.0275	1	-.5
27.5	90.2	.0291	1	-.3
30.0	98.4	.0312	1	.5
32.5	106.6	.0322	1	.1
35.0	114.8	.0334	1	-.1
37.5	123.0	.0349	1	.3
40.0	131.2	.0358	1	.1
42.5	139.4	.0367	1	-.1
45.0	147.6	.0380	1	.2
47.5	155.8	.0389	1	.0
50.0	164.0	.0398	1	-.2
52.5	172.2	.0410	1	-.1
55.0	180.4	.0419	1	-.3
57.5	188.6	.0440	2	.4
60.0	196.9	.0458	3	.5

dtb(m)	dtb(ft)	ttb(s)	v(m/s)	vl(m/s)	vu(m/s)	v(ft/s)	vl(ft/s)	vu(ft/s)
.0	.0	.000	365	350	381	1196	1147	1250
2.5	8.2	.007	365	350	381	1196	1147	1250
7.5	24.6	.014	708	670	751	2323	2197	2464
17.5	57.4	.024	1011	978	1045	3315	3210	3429
35.0	114.8	.034	1805	1756	1857	5921	5760	6092
60.0	196.9	.044	2308	2238	2382	7571	7342	7816

Explanation:
d(m) = depth in meters
d(ft) = depth in feet
t(sec) = arrival time in seconds (S-wave arrival times are the average of picks from traces obtained from hammer blows differing in direction by 180°)
sig = sigma, standard deviation normalized to the standard deviation of best picks
rsdl/sig = least-squares residual divided by sigma
dtb(m) = depth to bottom of layer in meters
dtb(ft) = depth to bottom of layer in feet
ttb(s) = arrival time in seconds to bottom of layer
v(m/s) = velocity in meters per second
vl(m/s) = lower limit of velocity in meters per second *
vu(m/s) = upper limit of velocity in meters per second
v(ft/s) = velocity in feet per second
vl(ft/s) = lower limit of velocity in feet per second
vu(ft/s) = upper limit of velocity in feet per second
* see text for explanation of velocity limits

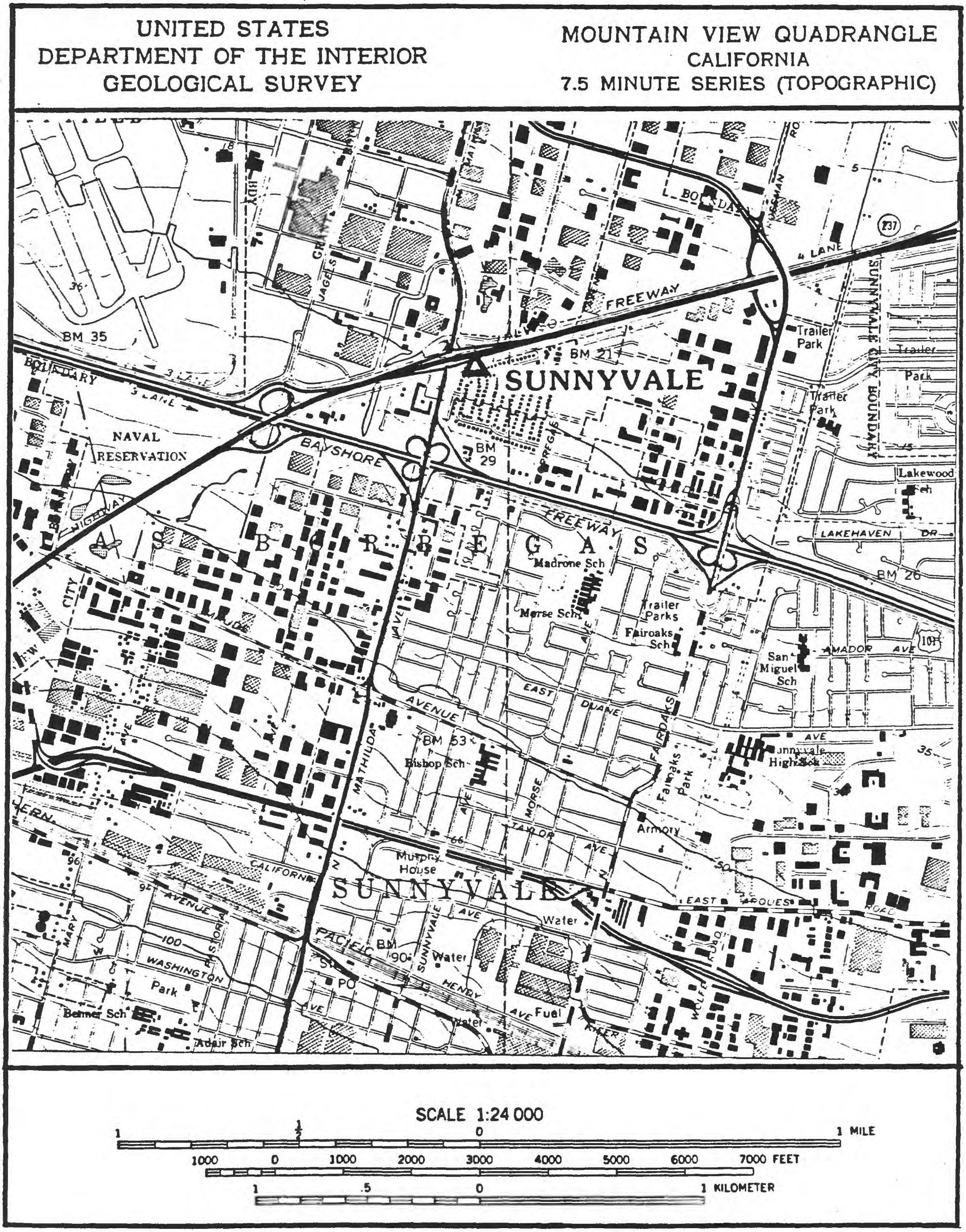


Figure 55. Site location map for Sunnyvale Colton Avenue borehole. The borehole is located approximately 100 meters from the strong-motion recorder.

Rock hardness: response to hand and geologic hammer: (Ellen et al., 1972)

hard - hammer bounces off with solid sound
firm - hammer dents with thud, pick point dents or penetrates slightly
soft - pick points penetrates
friable material can be crumbled into individual grains by hand.

Fracture spacing: (Ellen et al., 1972)

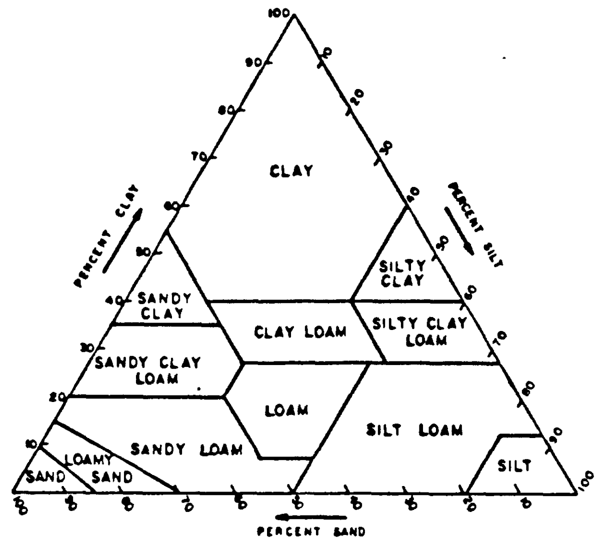
cm	in	fracture spacing
0-1	0-1/2	v. close
1-5	1/2-2	close
5-30	2-12	moderate
30-100	12-36	wide
>100	>36	v. wide

Weathering:
Fresh: no visible signs of weathering
Slight: no visible decomposition of minerals, slight discoloration
Moderate: slight decomposition of minerals and disintegration of rock, deep and thorough discoloration
Deep: extensive decomposition of minerals and complete disintegration of rock but original structure is preserved.

Relative density of sand and consistency of clay is correlated with penetration resistance: (Terzaghi and Peck, 1948)

blows/ft.	relative density	blows/ft.	consistency
0-4	v. loose	<2	v. soft
4-10	loose	2-4	soft
10-30	medium	4-8	medium
30-50	dense	8-15	stiff
>50	v. dense	15-30	v. stiff
		>30	hard

Texture: the relative proportions of clay, silt, and sand below 2mm. Proportions of larger particles are indicated by modifiers of textural class names. Determination is made in the field mainly by feeling the moist soil (Soil Survey, Staff, 1951).



Color: Standard Munsell color names are given for the dominant color of the moist soil and for prominent mottles.

Types of samples

SP - Standard Penetration 1+3/8 in in ID sampler)
S - Thin-wall push sampler
O - Osterberg fixed-piston sampler
P - Pitcher Barrel sampler
CH - California Penetration (2 in ID sampler)
DC - Diamond Core

Figure 56. Explanation of geologic log.

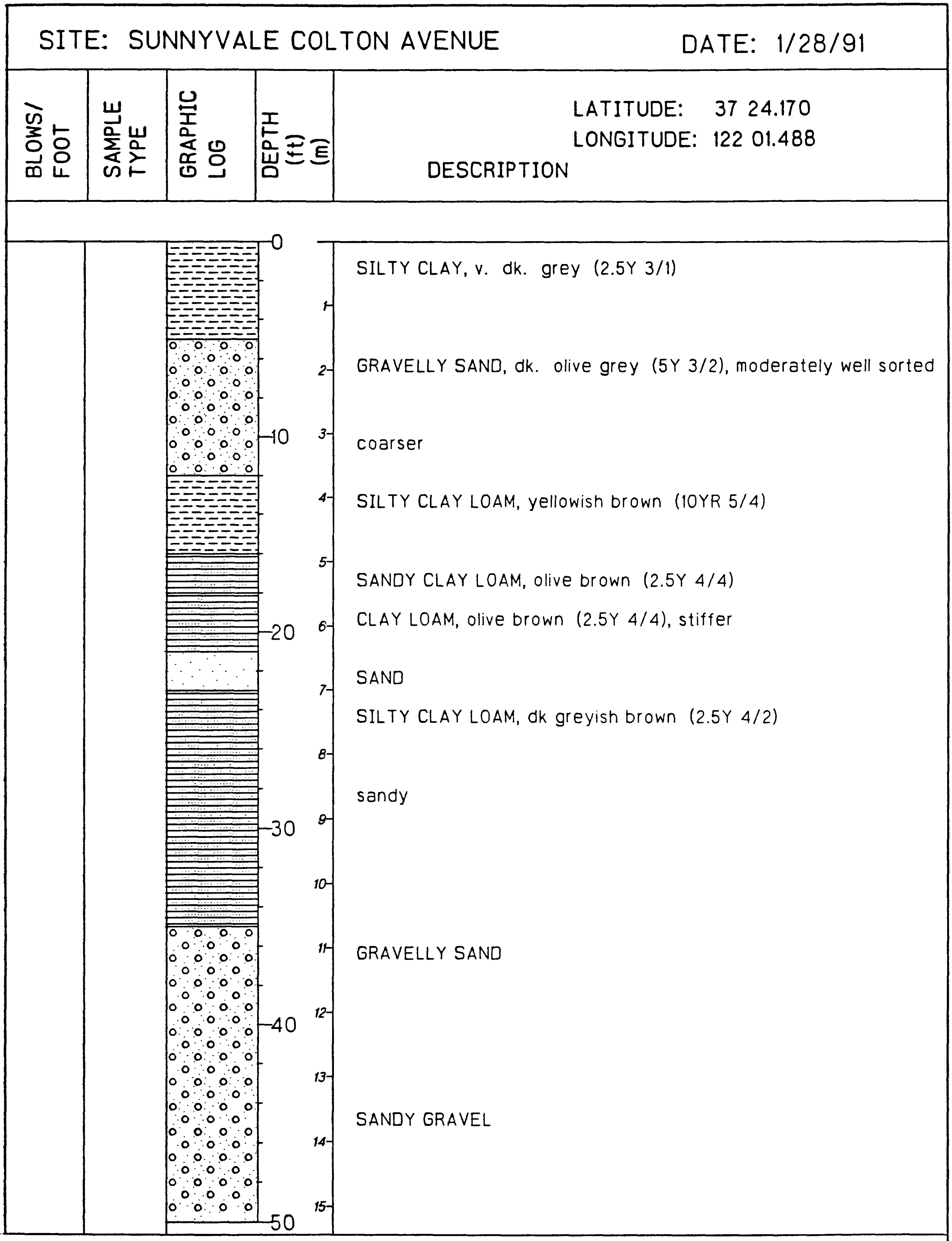


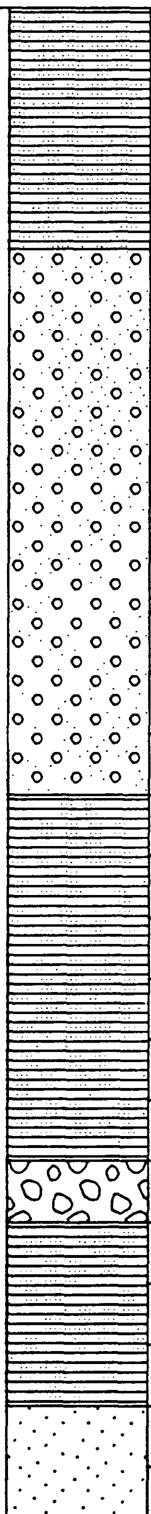
Figure 57. Geologic log of the Sunnyvale Colton Avenue borehole.

SITE: SUNNYVALE COLTON AVENUE

DATE: 1/28/91

LATITUDE: 37 24.170

LONGITUDE: 122 01.488

BLOWS/ FOOT	SAMPLE TYPE	GRAPHIC LOG	DEPTH (ft)	DEPTH (m)	DESCRIPTION
			50		CLAY LOAM TO SANDY CLAY LOAM, brown (10YR 5/3), stiffer
				16	
				17	
				18	GRAVELLY SAND
			60		
				19	
				20	
				21	
			70		
				22	
				23	CLAY LOAM, v. stiff
				24	
			80		
				25	
				26	
				27	GRAVEL
			90		SANDY CLAY LOAM
				28	
					sandier
				29	
					SAND, moderately well sorted, some fine gravel
				30	
			100		

Page 2 of 4

Figure 57. (Continued).

SITE: SUNNYVALE COLTON AVENUE

DATE: 1/28/91

LATITUDE: 37 24.170
LONGITUDE: 122 01.488

BLOWS/ FOOT	SAMPLE TYPE	GRAPHIC LOG	DEPTH (ft)	DEPTH (m)	DESCRIPTION
			100		
				31	SILTY CLAY TO CLAY LOAM, olive gray (5Y 4/2)
				32	SAND
				33	
			110		
				34	SILTY CLAY,olive gray, v. stiff
				35	GRAVELLY SAND
					SILTY CLAY
				36	
			120		
				37	SAND
				38	
				39	
			130		
				40	SILTY LOAM TO SILTY CLAY LOAM, dk greenish grey (5GY 4/1), stiff
				41	
				42	
			140		v. stiff
				43	
				44	
				45	
			150		

Figure 57. (Continued).

SITE: SUNNYVALE COLTON AVENUE

DATE: 1/28/91

LATITUDE: 37 24.170
LONGITUDE: 122 01.488

BLOWS/ FOOT	SAMPLE TYPE	GRAPHIC LOG	DEPTH (ft) (m)	DESCRIPTION
				somewhat sandy
				GRAVELLY SAND, light yellowish brown (2.5Y 6/4) clay matrix, v. dk greyish brown (2.5Y 4/2) v. coarse sand
				SANDY GRAVEL
				INTERBEDDED SAND AND CLAY LOAM

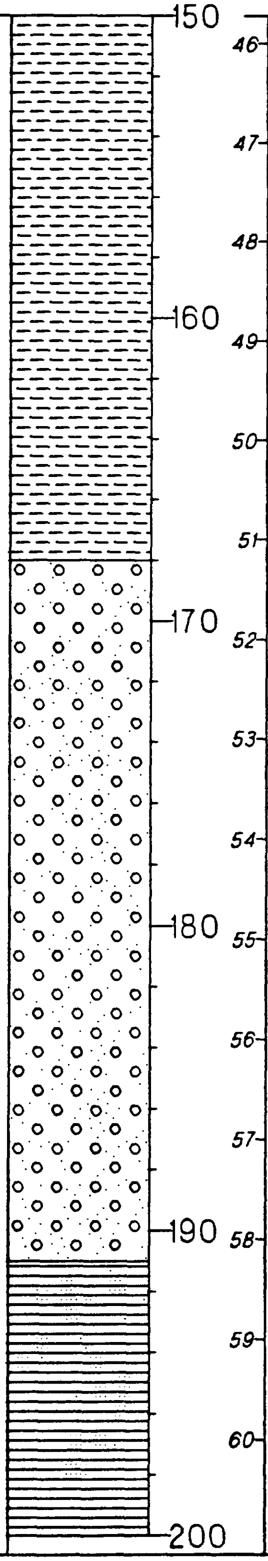


Figure 57. (Continued).

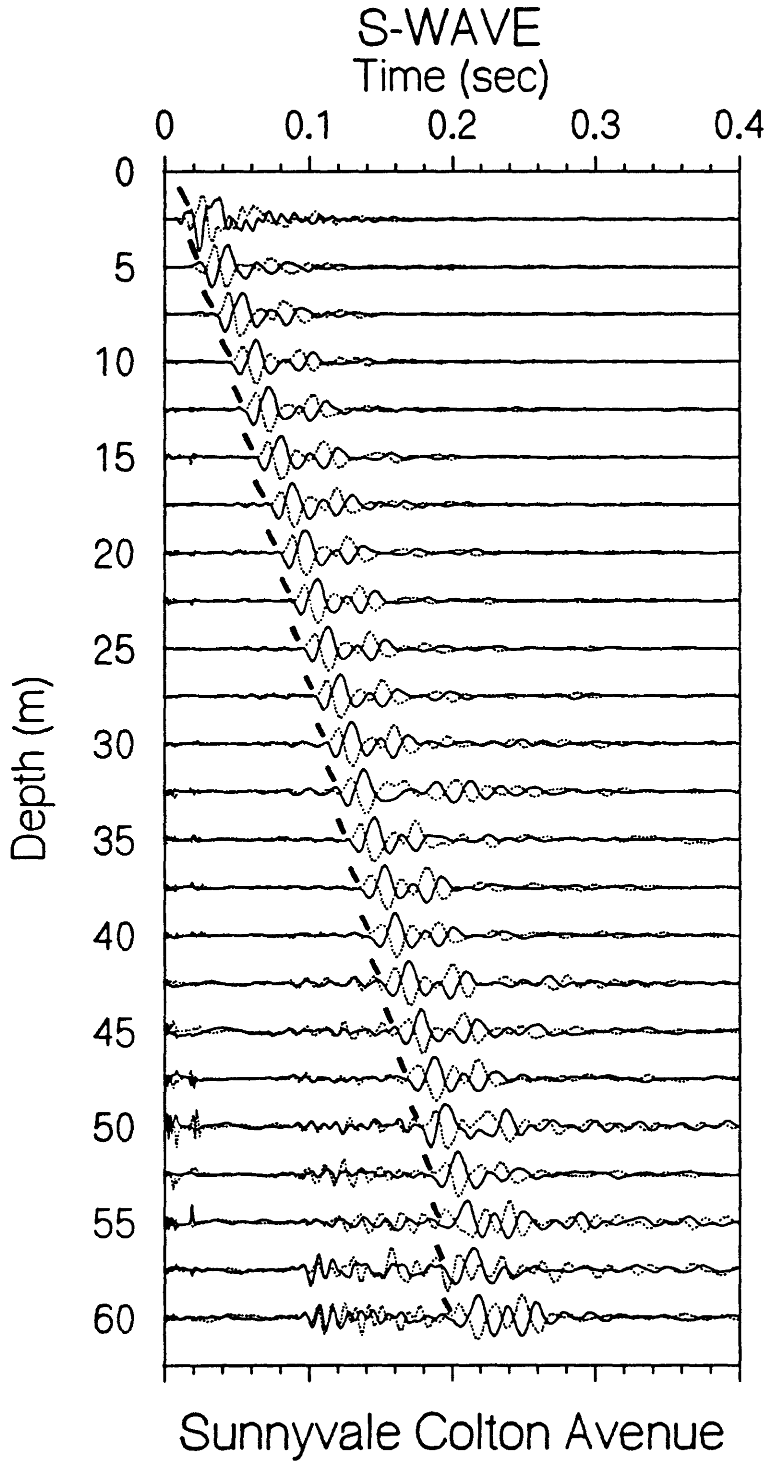


Figure 58. Horizontal-component record section (from horizontal impacts in opposite directions) superimposed for identification of S-wave onset. Approximate S-wave picks are indicated by the accent marks.

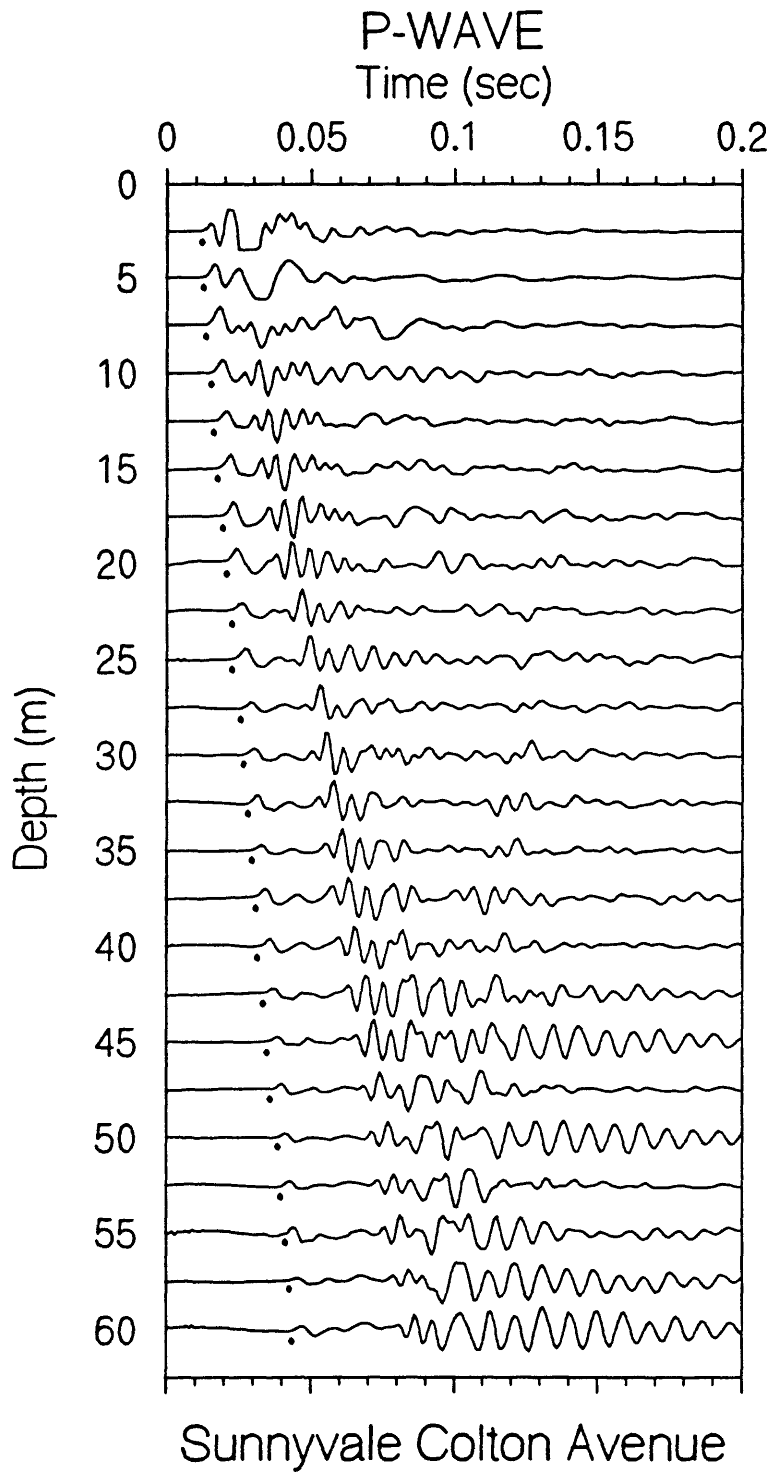


Figure 59. Vertical-component record section. P-wave arrivals are shown by the solid circles.

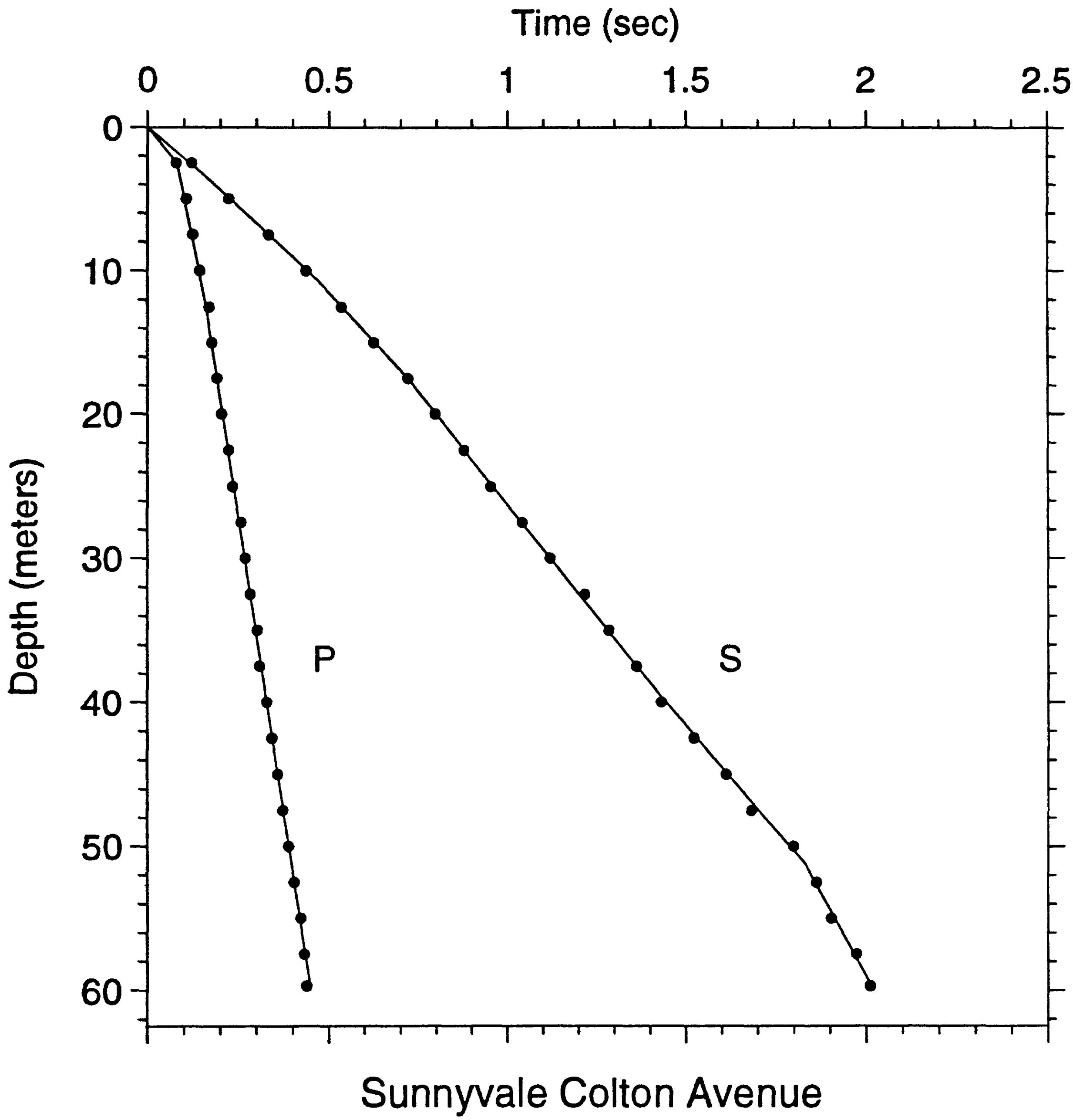


Figure 60. Time-depth graph of P-wave and S-wave picks. Line segments show the hinged-least-squares fit to the data points.

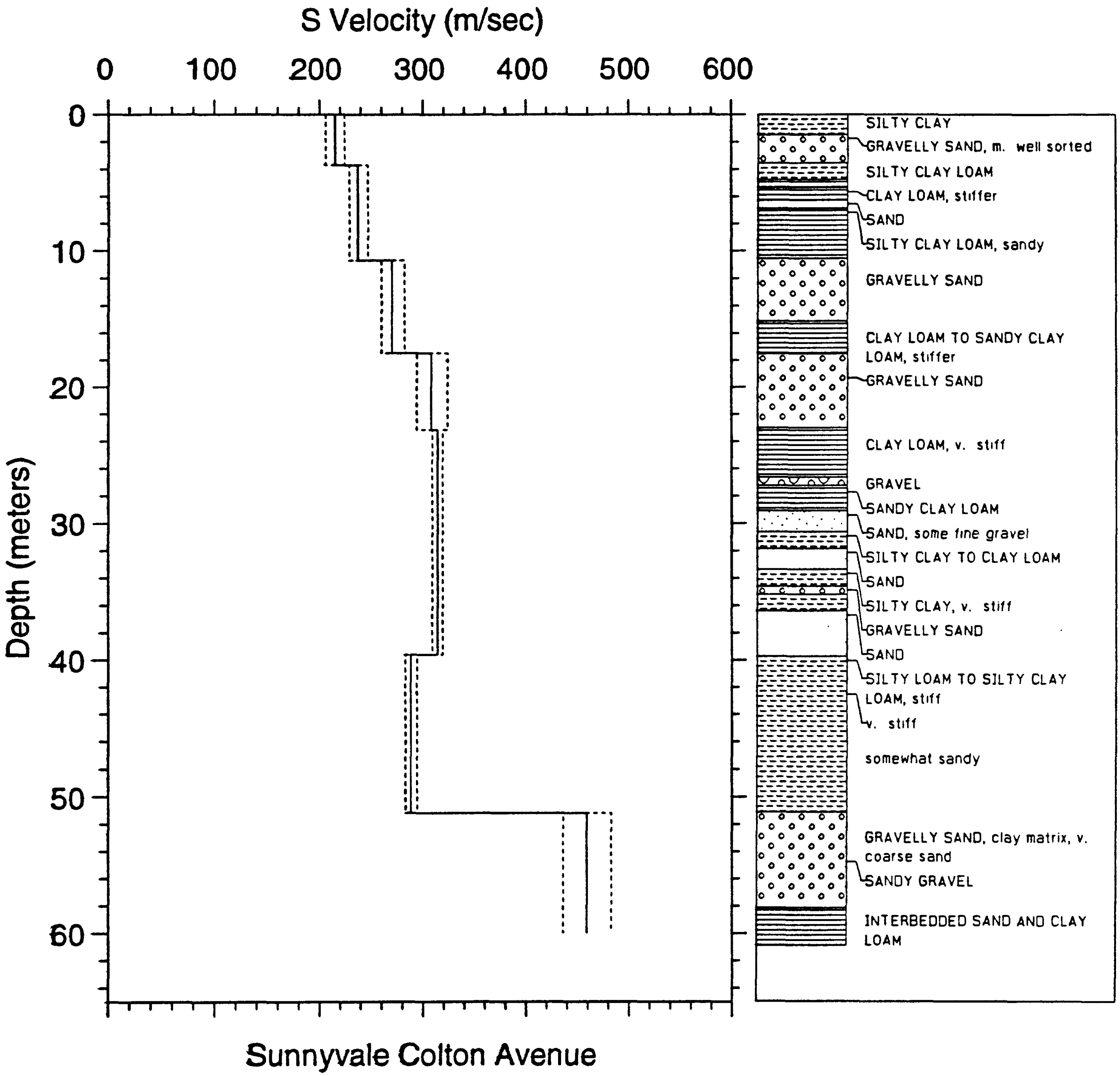


Figure 61. S-wave velocity profiles with dashed lines representing plus and minus one standard deviation. Simplified geologic log is shown for correlation with velocities.

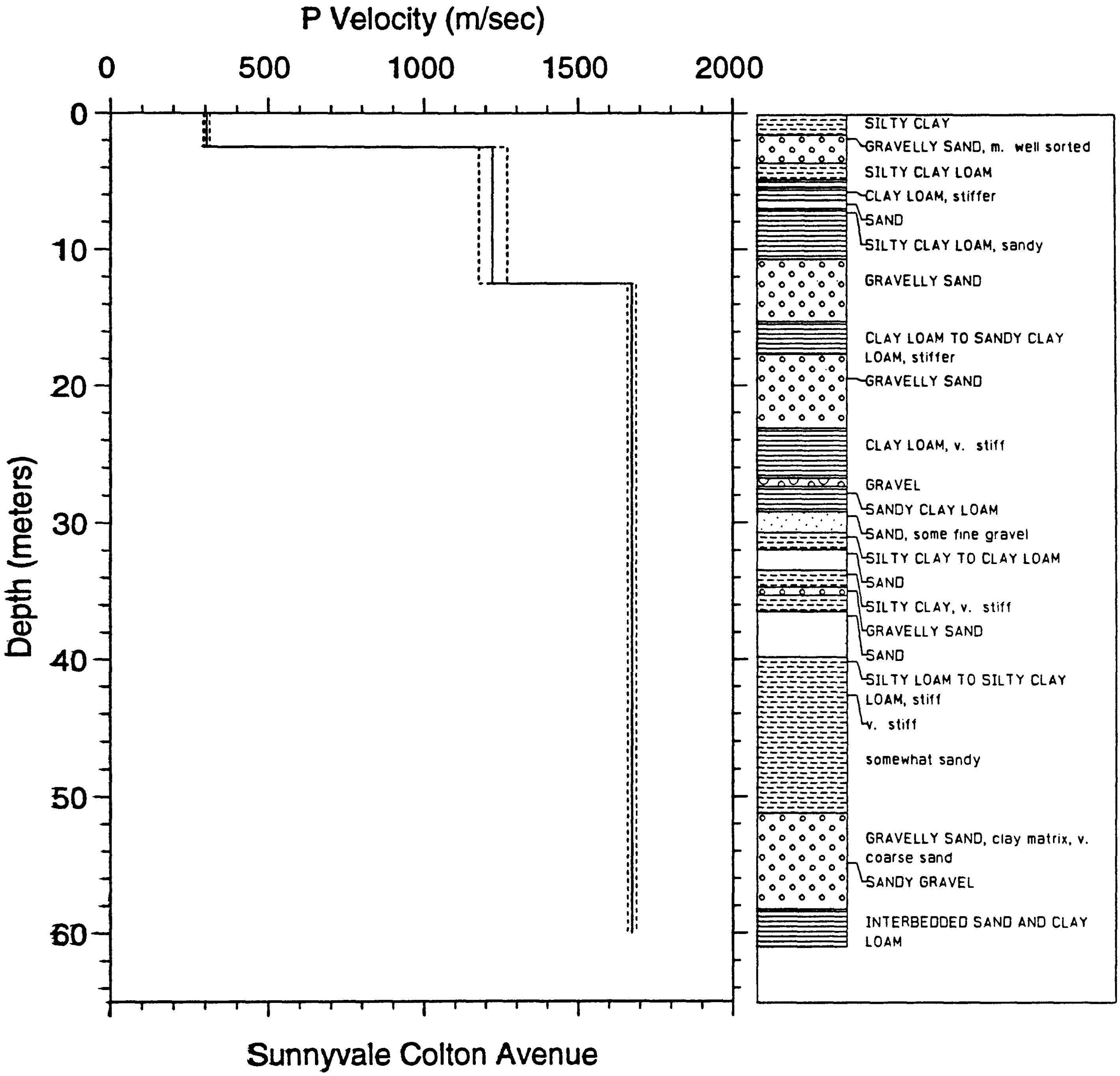


Figure 62. P-wave velocity profiles with dashed lines representing plus and minus one standard deviation. Simplified geologic log is shown for correlation with velocities.

TABLE 13. S-wave arrival times and velocity summaries for Sunnyvale Colton Avenue site.

d(m)	d(ft)	t(sec)	sig	rsdl/sig
2.5	8.2	.0121	1	.5
5.0	16.4	.0223	1	-.4
7.5	24.6	.0333	1	.1
10.0	32.8	.0437	1	-.1
12.5	41.0	.0535	1	.1
15.0	49.2	.0626	1	.0
17.5	57.4	.0720	1	.1
20.0	65.6	.0797	1	-.3
22.5	73.8	.0878	1	-.3
25.0	82.0	.0953	1	-.8
27.5	90.2	.1042	1	.2
30.0	98.4	.1120	1	.0
32.5	106.6	.1217	1	1.7
35.0	114.8	.1285	1	.6
37.5	123.0	.1362	1	.3
40.0	131.2	.1432	1	-.8
42.5	139.4	.1522	1	-.5
45.0	147.6	.1612	1	-.1
47.5	155.8	.1683	1	-1.7
50.0	164.0	.1799	1	1.2
52.5	172.2	.1863	1	.6
55.0	180.4	.1903	1	-.8
57.5	188.6	.1973	1	.7
59.7	195.9	.2011	1	-.3

dtb(m)	dtb(ft)	ttb(s)	v(m/s)	vl(m/s)	vu(m/s)	v(ft/s)	vl(ft/s)	vu(ft/s)
.0	.0	.000	215	206	224	704	675	736
3.7	12.1	.017	215	206	224	704	675	736
10.7	35.1	.047	237	229	247	779	750	811
17.5	57.4	.072	270	260	282	887	852	925
23.2	76.1	.090	308	294	324	1011	965	1062
39.6	129.9	.143	314	309	319	1030	1014	1046
51.2	168.0	.183	288	283	294	946	927	965
60.0	196.9	.202	459	436	483	1505	1432	1586

Explanation:
d(m) = depth in meters
d(ft) = depth in feet
t(sec) = arrival time in seconds (S-wave arrival times are the average of picks from traces obtained from hammer blows differing in direction by 180°)
sig = sigma, standard deviation normalized to the standard deviation of best picks
rsdl/sig = least-squares residual divided by sigma
dtb(m) = depth to bottom of layer in meters
dtb(ft) = depth to bottom of layer in feet
ttb(s) = arrival time in seconds to bottom of layer
v(m/s) = velocity in meters per second
vl(m/s) = lower limit of velocity in meters per second *
vu(m/s) = upper limit of velocity in meters per second
v(ft/s) = velocity in feet per second
vl(ft/s) = lower limit of velocity in feet per second
vu(ft/s) = upper limit of velocity in feet per second
* see text for explanation of velocity limits

TABLE 14. P-wave arrival times and velocity summaries for Sunnyvale Colton Avenue site.

d(m)	d(ft)	t(sec)	sig	rsdl/sig
2.5	8.2	.0079	1	-.3
5.0	16.4	.0106	1	.3
7.5	24.6	.0124	1	.1
10.0	32.8	.0144	1	.0
12.5	41.0	.0169	1	.5
15.0	49.2	.0177	1	-.2
17.5	57.4	.0191	1	-.3
20.0	65.6	.0204	1	-.5
22.5	73.8	.0224	1	.0
25.0	82.0	.0234	1	-.5
27.5	90.2	.0258	1	.4
30.0	98.4	.0269	1	.0
32.5	106.6	.0283	1	.0
35.0	114.8	.0303	1	.5
37.5	123.0	.0309	1	-.4
40.0	131.2	.0329	1	.1
42.5	139.4	.0343	1	.0
45.0	147.6	.0359	1	.1
47.5	155.8	.0373	1	.0
50.0	164.0	.0389	1	.1
52.5	172.2	.0405	1	.2
55.0	180.4	.0423	1	.5
57.5	188.6	.0433	1	.0
59.7	195.9	.0439	1	-.7

dtb(m)	dtb(ft)	ttb(s)	v(m/s)	vl(m/s)	vu(m/s)	v(ft/s)	vl(ft/s)	vu(ft/s)
.0	.0	.000	304	295	314	999	969	1030
2.5	8.2	.008	304	295	314	999	969	1030
12.5	41.0	.016	1222	1177	1270	4009	3862	4167
60.0	196.9	.045	1674	1660	1688	5491	5445	5538

Explanation:
- d(m) = depth in meters
- d(ft) = depth in feet
- t(sec) = arrival time in seconds (S-wave arrival times are the average of picks from traces obtained from hammer blows differing in direction by 180°)
- sig = sigma, standard deviation normalized to the standard deviation of best picks
- rsdl/sig = least-squares residual divided by sigma
- dtb(m) = depth to bottom of layer in meters
- dtb(ft) = depth to bottom of layer in feet
- ttb(s) = arrival time in seconds to bottom of layer
- v(m/s) = velocity in meters per second
- vl(m/s) = lower limit of velocity in meters per second *
- vu(m/s) = upper limit of velocity in meters per second
- v(ft/s) = velocity in feet per second
- vl(ft/s) = lower limit of velocity in feet per second
- vu(ft/s) = upper limit of velocity in feet per second

* see text for explanation of velocity limits