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SEISMIC VELOCITIES AND GEOLOGIC LOGS FROM BOREHOLE MEASUREMENTS AT SEVEN STRONG-MOTION STATIONS THAT RECORDED THE 1989 LOMA PRIETA EARTHQUAKE

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Seismic velocities and geologic logs from borehole measurements at seven strong-motion stations that recorded the Loma Prieta 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 shaking-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 (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 scientist and engineers representing thirteen institutions attended the meeting to coordinate drilling and data aquisition plans at strong-motion stations. The USGS agreed to participate in geologic and geophysical data collection at sites drilled by other agencies.

This report contains the results of the field effort by the USGS for the following eight boreholes (Figure 1).

1. Alameda Naval Air Station
2. Gilroy #2 (EPRI)
3. Gilroy #2 (USGS)
4. Outer Harbor Wharf
5. San Francisco International Airport
6. Treasure Island
7. Veterans Hospital - Palo Alto
8. Yerba Buena Island

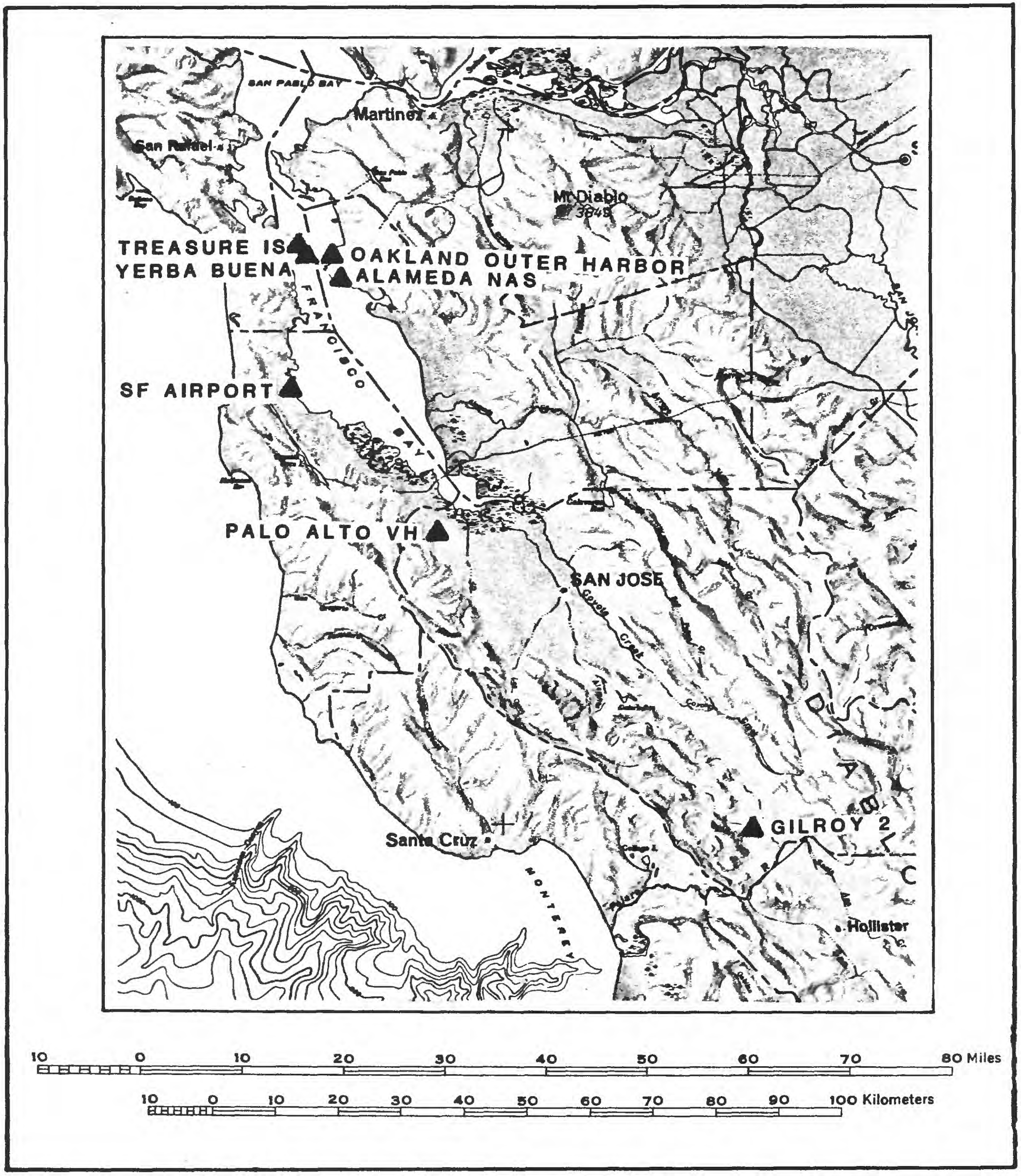

Figure 1. Generalized map showing the locations of boreholes (triangles) included in this report.

FIELD MEASUREMENTS

Drilling and Sampling Procedures

Drill sites in this study were chosen in order to provide detailed geologic, geophysical and geotechnical data at several "deep soil" sites and at two rock-soil site pairs, namely Yerba Buena Island (rock)– Treasure Island ("soft soil") and Gilroy #1 (rock)– Gilroy #2 ("stiff soil"). Gilroy #1 has been previouly investigated (Fumal et al., 1982) and is not included in this report. At each site a pilot hole approximately 5 inches in diameter was drilled for sampling purposes using rotary wash drilling with bentonite mud. At most sites this pilot hole penetrated about 15 meters into bedrock. At Gilroy #2 (USGS) and at Alameda Naval Air Station drilling was stopped about 1 to 2 meters into rock. At San Francisco International Airport, drilling was stopped 5 meters into rock because the bit twisted off.

"Undisturbed" samples were taken inside Shelby tubes (3-inch outside diameter) using either a push sampler, a fixed piston (Osterberg) sampler, or a Pitcher barrel, depending on the stiffness of the sediment. These samples were allowed to drain of free water and sealed with wax plugs and endcaps. Standard penetration tests were carried out in sandy sediments above 30 meters in accordance with ASTM Standards D1586. Below 30 meters, penetration samples were taken with a 340 lb. hammer and 2-inch inside diameter sampler. Rock cores (NX-size) were taken at Palo Alto Veterans Hospital, Oakland Outer Harbor Wharf and Yerba Buena Island. "Undisturbed" samples collected at Alameda Naval Air Station were taken by Dr. Kyle Rollins of Bringham Young University for testing. All samples taken at Palo Alto Veterans Hospital went to Woodward-Clyde Consultants for analysis. Portions of penetrometer samples obtained at Treasure Island, Oakland Outer Harbor Wharf and San Francisco International Airport were sent to Professor I.M. Idriss at the University of California at Davis. All other "undisturbed" samples went to Professor Kenneth Stoke of the University of Texas at Austin for testing.

After completion of the pilot holes, the holes were reamed to 8 or 10 inches depending on the size of the casing installed. Gilroy #2 (USGS), Alameda Naval Air Station and Palo Alto Veterans Hospital were cased with 4-inch inside diameter, class 200, polyvinyl-chloride pipe capped at the bottom. The other sites were cased with 5-inch inside diameter polyvinyl-chloride pipe.

The annular space around the casing was tremie grouted by pumping a water-cement-bentonite mixture through a 1-inch steel pipe installed 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. The California Division of Mines and Geology plans to install a strong-motion instrument package at the bottom of each 5-inch hole to supplement surface recordings.

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.

Site Geology

The very near-surface geology at four of the sites, Alameda Naval Air Station, Oakland Outer Harbor Wharf, Treasure Island and San Francisco International Airport is similar, consisting of 1 to 13.5 meters of artificial fill overlying 1 to 15.5 meters of soft Holocene Bay mud. At the first three of these sites, these deposits are underlain by 55- to 130-meter thick sections of stiff Pleistocene Bay mud and clayey or sandy alluvial deposits. At San Francisco Airport, however, the Pleistocene Bay mud is only about 3 meters thick and the deposits underlying the Holocene Bay mud are almost entirely dense marine and continental sand.

The near surface geology at the two "stiff soil" sites, Palo Alto Veterans Hospital and Gilroy #2 is quite dissimilar. Palo Alto Veterans Hospital is underlain by about 4 meters of Late Pleistocene alluvium overlying 128 meters of poorly sorted alluvium of the Santa Clara Formation. Gilroy #2 is underlain by 13 meters of Holocene alluvium, 8 meters of late Pleistocene alluvium and 18 meters of Pleistocene lacustrine deposits overlying poorly sorted alluvium of the Santa Clara Formation. The Santa Clara Formation at Gilroy #2 is generally coarser-grained than that at Palo Alto Veterans Hospital.

Three deep holes have been drilled at Gilroy #2; we present results in this report for two of them. During Fall 1979, the USGS drilled a 182 meter deep hole at Gilroy #2. This hole bottomed 2 meters into hard sandstone, probably graywacke of the Franciscan assemblage similar to that underlying Gilroy #1. This hole was located about 100 meters northeast of the strong-motion recorder. No sampling was attempted in this hole. The Electric Power Research Institute funded a second deep hole (EPRI #1) during Fall 1990. This hole, located about 60 meters northeast of the strong-motion recorder, penetrated about 8 meters of firm sandstone of the Miocene Monterey Formation and 7 meters of sheared serpentinite. A third deep hole (EPRI #2) was drilled during fall 1991 in order to further investigate the bedrock. This hole, about 4 meters north of EPRI #1, penetrated 14 meters of siltstone, 11.5 meters of serpentinite and 50.5 meters of sheared to closely fractured shale and siltstone of the Franciscan assemblage. The serpentinite and sheared shale may be part of a fault zone named the Carnadero Fault by Dibblee and Brabb (1978). The geologic log from EPRI #2 is included for reference but at this time (March 1992) the USGS has not logged EPRI #2 for velocity data.

The strong-motion instrument on Yerba Buena Island is located in a small building at the top of the cliffs on the southwest corner of the island. This building is founded on slightly weathered to fresh, moderately to widely fractured sandstone and minor shale of the Franciscan assemblage. Because of landscaping, the borehole is located about 160 meters north of the strong-motion instrument. This hole penetrated about 15 meters of deeply to moderately weathered sandstone. The fresh rock below 15 meters was largely very closely to closely fractured shale with some sandstone, and may be more characteristic of the material beneath the strong-motion recorder than is the weathered rock near the surface at the borehole site.

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 three-component geophone into the borehole and clamping it to the casing with an electrically actuated lever arm. A second three-component geophone is placed at the surface approximately 10 centimeters from the shear source and is used as a check of the switch triggering the recorder for zero time. Depending

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

on geologic information, measurements are repeated at 2.5 or 5.0 meter intervals. The 2.5 meter spacing is used when the layering of the sediments is thin (under 10 meters) and generally from the surface to 30 meters depth.

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 proceedures. 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: 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 positive and negative shear-wave arrivals. 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. The arrivals are weighted by the inverse of an assigned normalized variance. A normalized standard deviation of 1 was assigned to the accurate picks and values ranging up to 5 were assigned

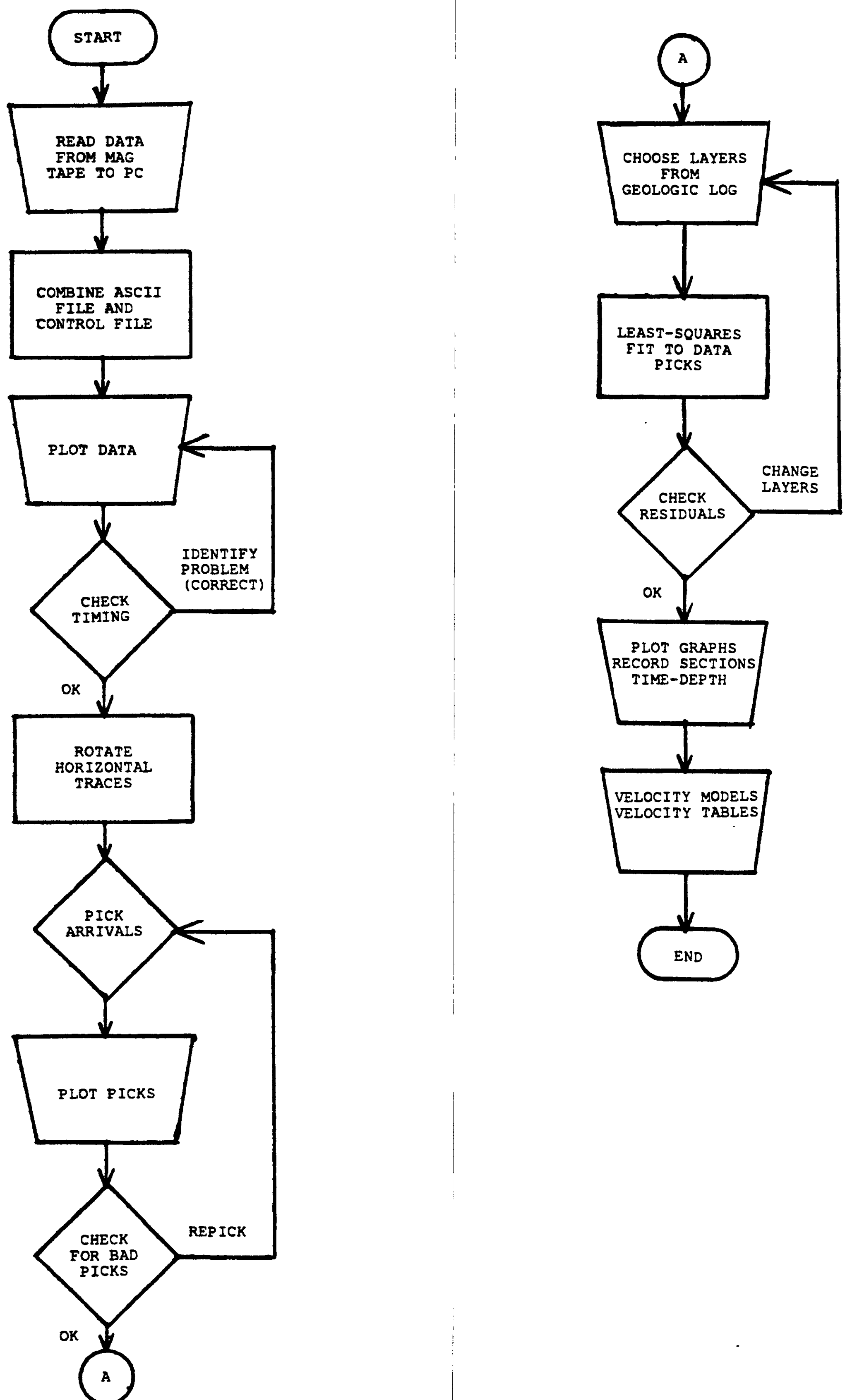

Figure 2. Flow-chart outlining the data processing and interpretation steps.

to the others.

For determining the final velocity model there are a number of ways to proceed. In previous reports (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 (Press et al., 1986) 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 23) 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 shear-wave velocities obtained at the five sites in the San Francisco - Oakland area, four with thick sections of sedimentary deposits including Holocene bay mud and one rock site at Yerba Buena Island. Velocities measured in the present and previous investigations (Gibbs et al., 1976, 1977) suggest a linear increase in shear-wave velocity in Holocene bay mud with increasing thickness of overlying fill. The previous studies indicated shear-wave velocities of 100 meters/second or less for Holocene bay mud overlain by about 1 meter of fill and 145 meters/second for mud overlain by 7 meters of fill. Values obtained for bay mud in the study are: San Francisco Airport shear-wave velocity = 100 meters/second, with 2 meters of fill, Alameda Naval Air Station shear-wave velocity

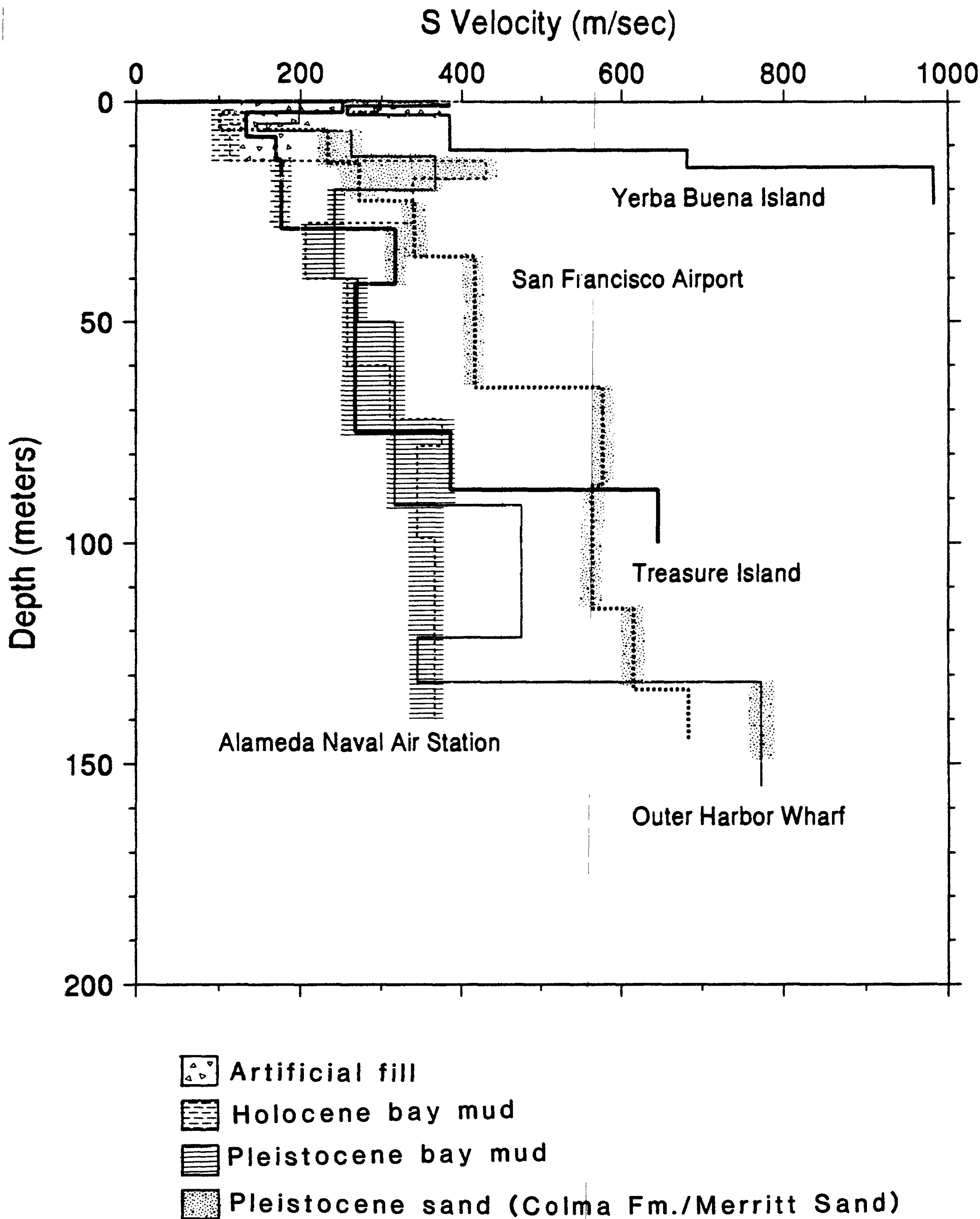

Figure 3. S-wave velocity models superimposed for comparison. The velocity below 15 meters at Yerba Buena Island is determined in fresh rock of the Franciscan assemblage. Velocities were not obtained in fresh Franciscan rock at the other sites. Shading indicates the geologic materials penetrated by the boreholes.

= 114 meters/second with 5 meters of fill, and Treasure Island shear-wave velocity = 177 meters/second with 13 meters of fill. Well determined velocities obtained for artificial fill ranged from 135 to 250 meter/second.

Sedimentary deposits below 20 meters at Oakland Outer Harbor Wharf and about 30 meters at Treasure Island and Alameda Naval Air Station are predominantly Pleistocene estuarine clay, and the velocity profiles at these sites are very similar. Shear wave velocities obtained in the Pleistocene bay mud range from 200 meters/second at 27.5 meters to 365 meters/second at 140 meters. In contrast to the sites with large thicknesses of Pleistocene bay mud (Alameda Naval Air Station, Oakland Outer Harbor Wharf and Treasure Island) sediments below 6.5 meters at San Francisco Airport are largely dense sands of the Colma Formation. Shear-wave velocities in these deposits are significantly higher than the Pleistocene clay at all depths, ranging from 260 meters/second at 6.5 meters to 770 meters/second at 150 meters.

Unfortunately, we were unable to measure shear-wave velocity in unweathered rock at either Treasure Island or Oakland Outer Harbor Wharf due to poor transmission of energy across the sediment-bedrock interface and wave interference that obscured the shear wave arrivals. The value at Treasure Island (645 meters/second) is an average value for an interval containing both weathered and fresh rock. At Oakland Outer Harbor Wharf only one or two reliable measurements were obtained in rock so an average value was calculated for the sediments and rock below 131.5 meters. This should not be taken as indicating there is no velocity contrast at the sediment-rock interface, only that we were unable to resolve the contrast with our data.

As noted earlier, the rock encountered in the borehole at Yerba Buena Island has a much thicker weathered zone and is more closely fractured than the rock underlying the strong-motion instrument site. Consequently, the velocities measured in the borehole are significantly lower than the expected values for the rock at the instrument site.

Figure 4 summarizes the shear-wave velocities obtained at Palo Alto Veterans Hospital and Gilroy #2. Because interfering waves obscured the shear wave arrivals, we were unable to measure shear-wave velocity below 70 meters in the Gilroy #2 EPRI hole. The USGS Gilroy #2 borehole was drilled in 1979, when a preliminary velocity logging was done with

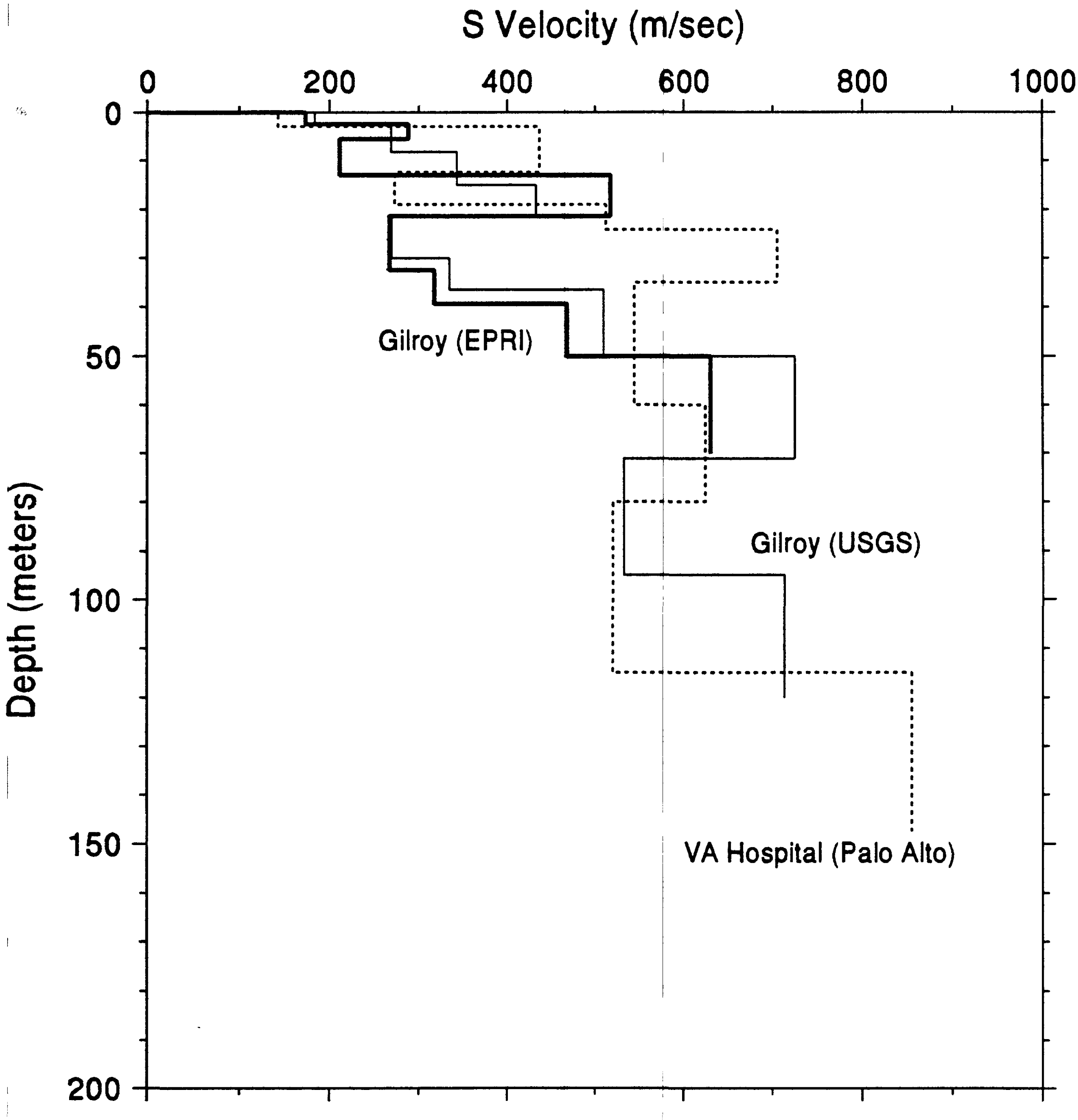

Figure 4. S-wave velocity models superimposed for comparison. The boreholes at Gilroy #2 (EPRI) and Gilroy#2 (USGS) are approximately 50 meters apart and show some minor differences in velocity perhaps due to small variations in sediment thickness and to different mixtures of fine and coarse grained sediments.

measurements made at 20-meter intervals (Joyner, et al., 1981). When it was relogged in 1989 the casing was blocked at 120 meters (Gibbs, 1992). At Gilroy #2, the sedimentary deposits from about 21 to 40 meters consist of late Pleistocene lacustrine clay. Velocities in these deposits (270 to 335 meters/second) are slightly higher than those obtained for Pleistocene bay mud at these depths. Below these deposits and below about 4 meters at Palo Alto Veterans Hospital are poorly sorted fluvial and alluvial fan deposits of the Plio-Pleistocene Santa Clara Formation. Shear-wave velocities in these deposits range from 260 to 980 meters/second. The higher velocities correlate with higher percentages of gravel or a greater degree of cementation (Fumal 1978) in the lower parts of the deposits.

P-wave velocities

Figures 5 and 6 summarize compressional-wave velocities at the five northern sites and the two southern sites 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 Holocene bay mud are less than the velocity of P-waves in water ($\approx$ 1500 meters/second). The explanation for this may be 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

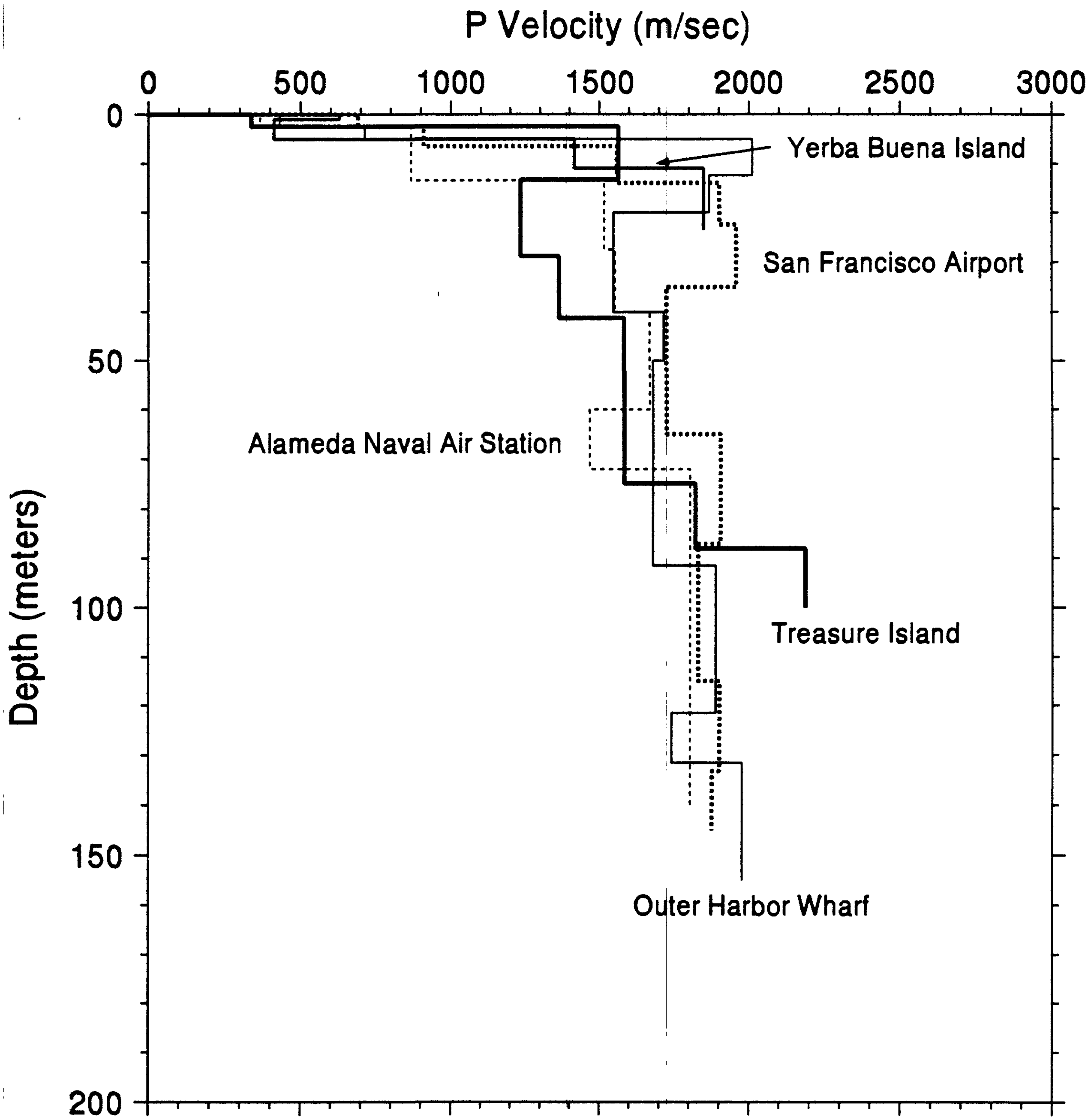

Figure 5. P-wave velocity models superimposed for comparison.

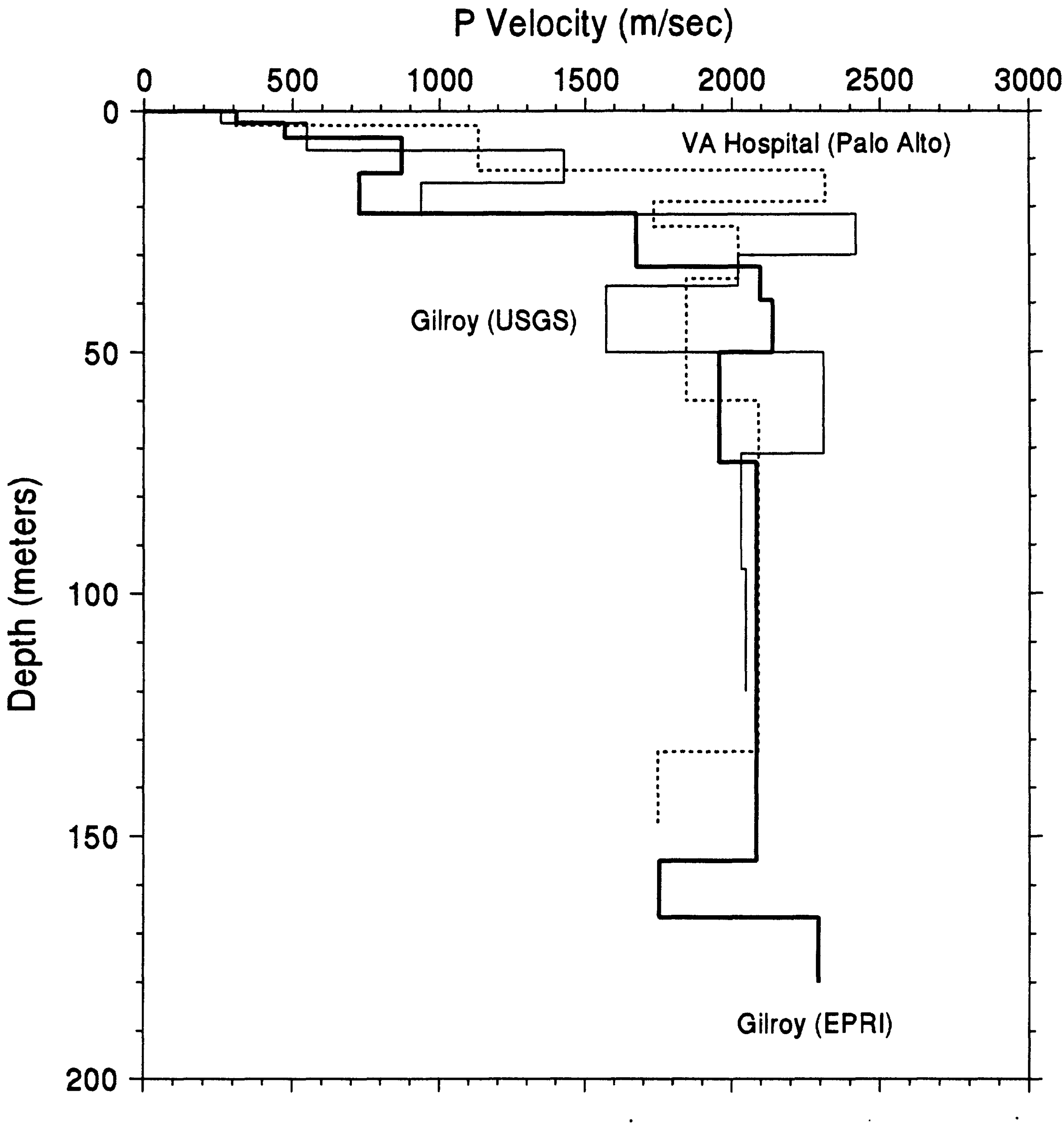

Figure 6. P -wave velocity models superimposed for comparison.

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Woodward-Clyde Consultants directed the drilling of all boreholes except the 1979 borehole at Gilroy, under contract with EPRI and the U.S. Veterans Administration. Drilling was arranged and coordinated by Dr. Joseph Sun and Mr. Peter Solberg under the direction of Dr. Lelio H. Mejia of *Woodward-Clyde Consultants.*

Pitcher Drilling Company, Palo Alto, Ca drilled all borings under contract with *Woodward-Clyde Consultants* except for the 1979 borehole.

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The analysis of the data was facilitated by the graphics software of Scherbaum and Johnson (1990) and CoHort Software.

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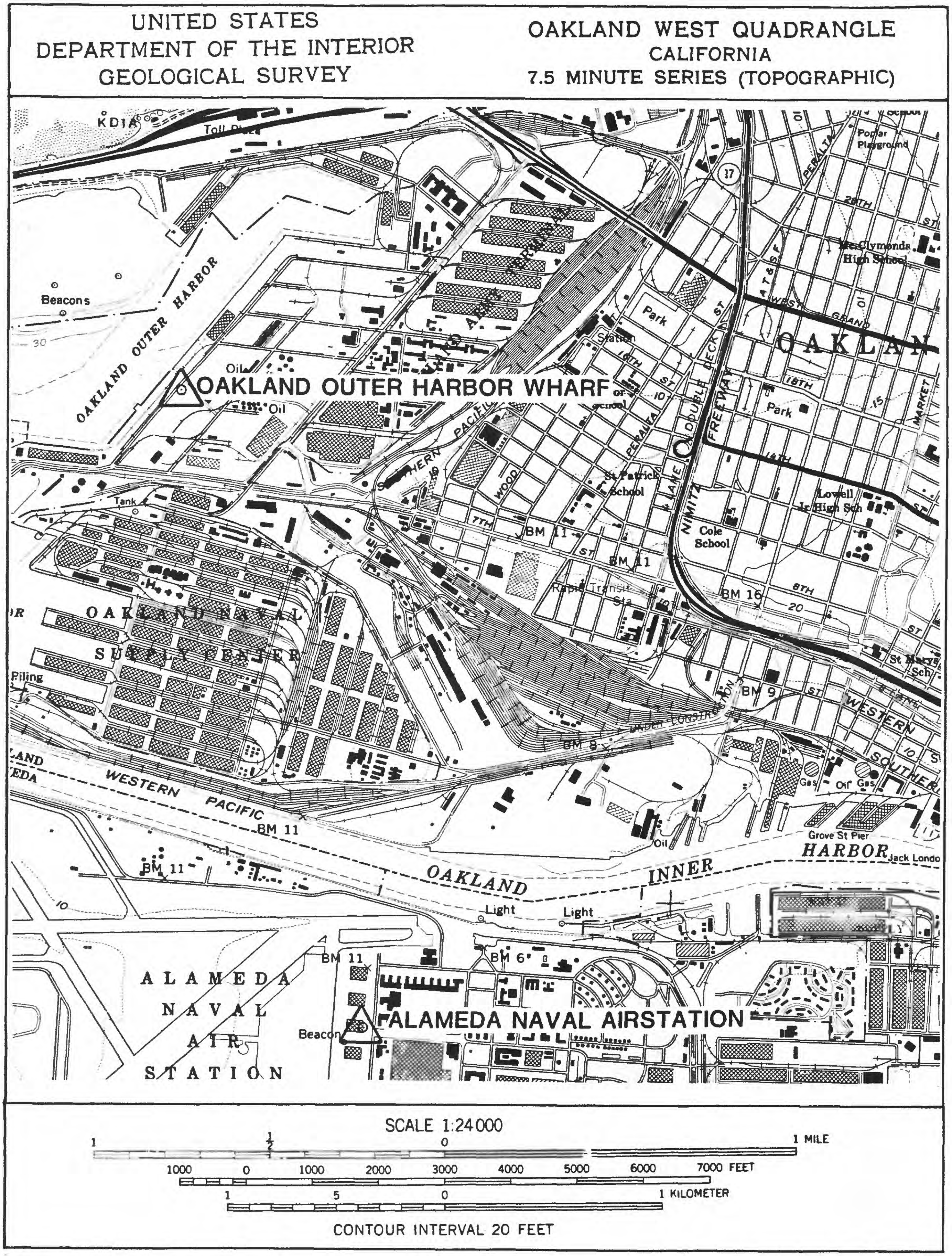


Figure 7. Site location map for borehole at Alameda Naval Air Station and Oakland Outer Harbor Wharf. The borehole is located within 15 meters of the strong motion recorder.

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)

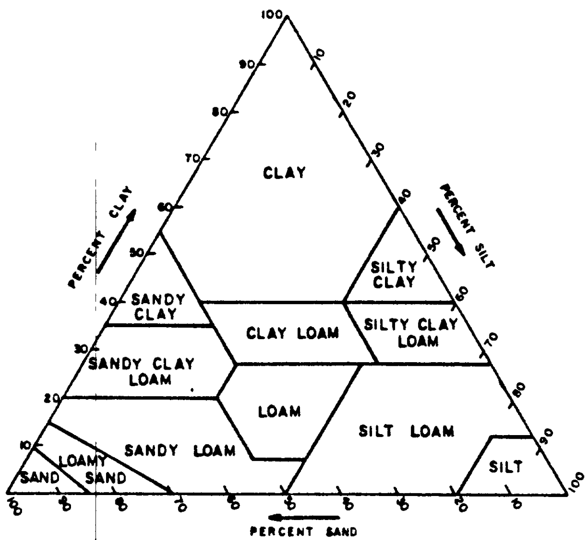
cm	in	fracture spacing
0-1	0-1/2	v. close
1-5	1/2-2	close
5-30	2-12	moderate
30-100	12-36	wide
>100	>36	v. wide

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 8. Explanation of geologic logs.

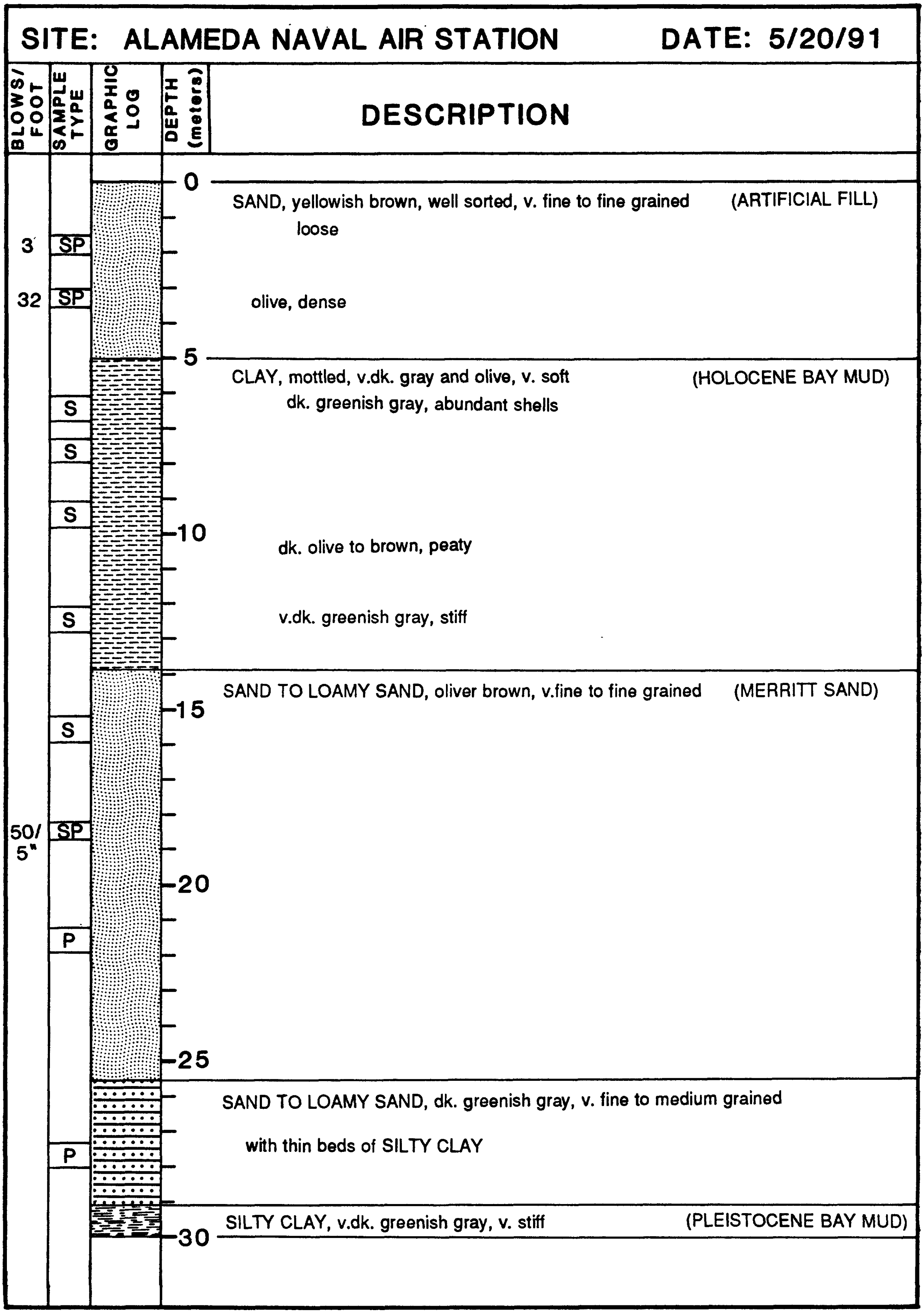


Figure 9. Geologic log for Alameda Naval Air Station borehole.

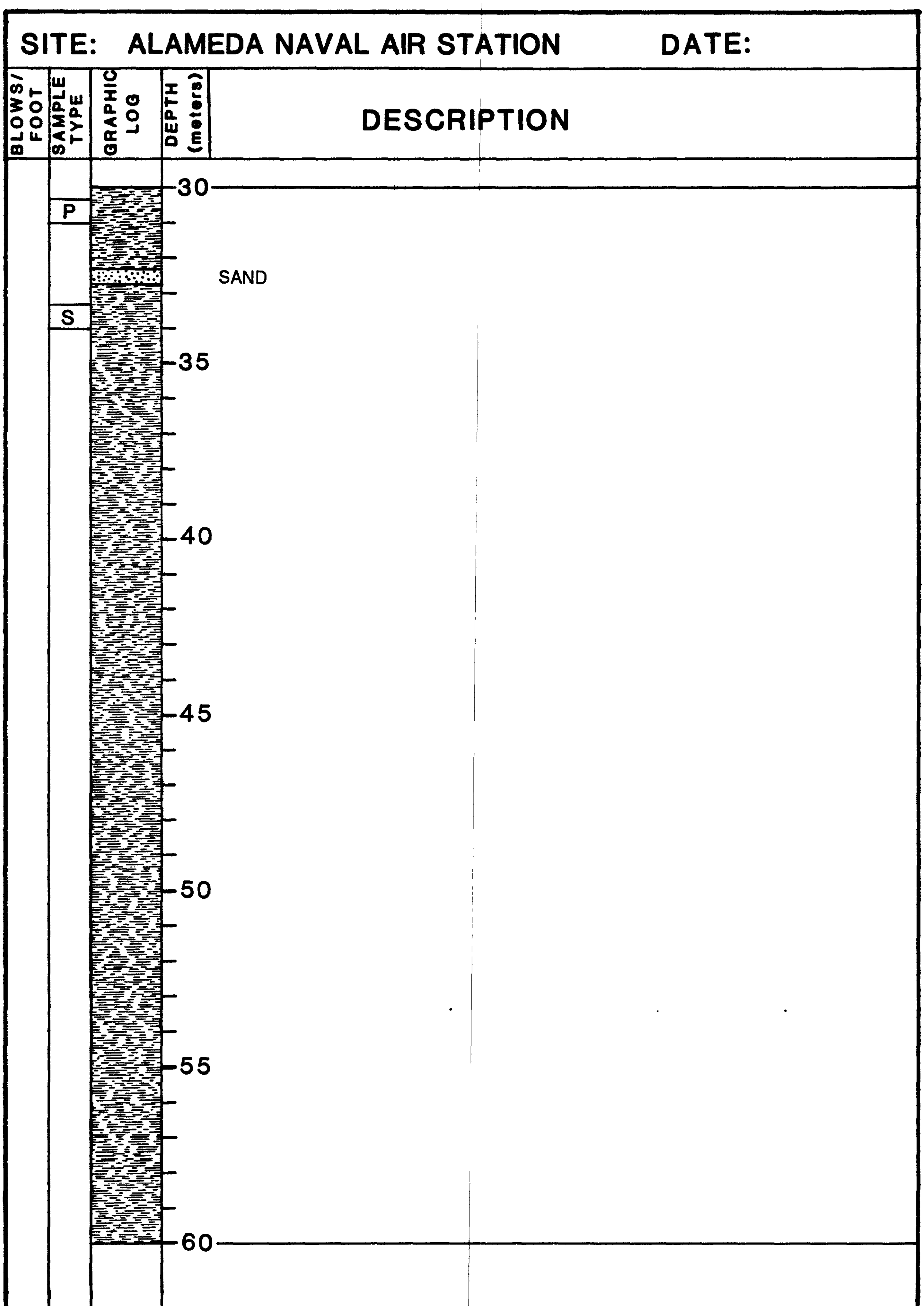


Figure 9. (Continued).

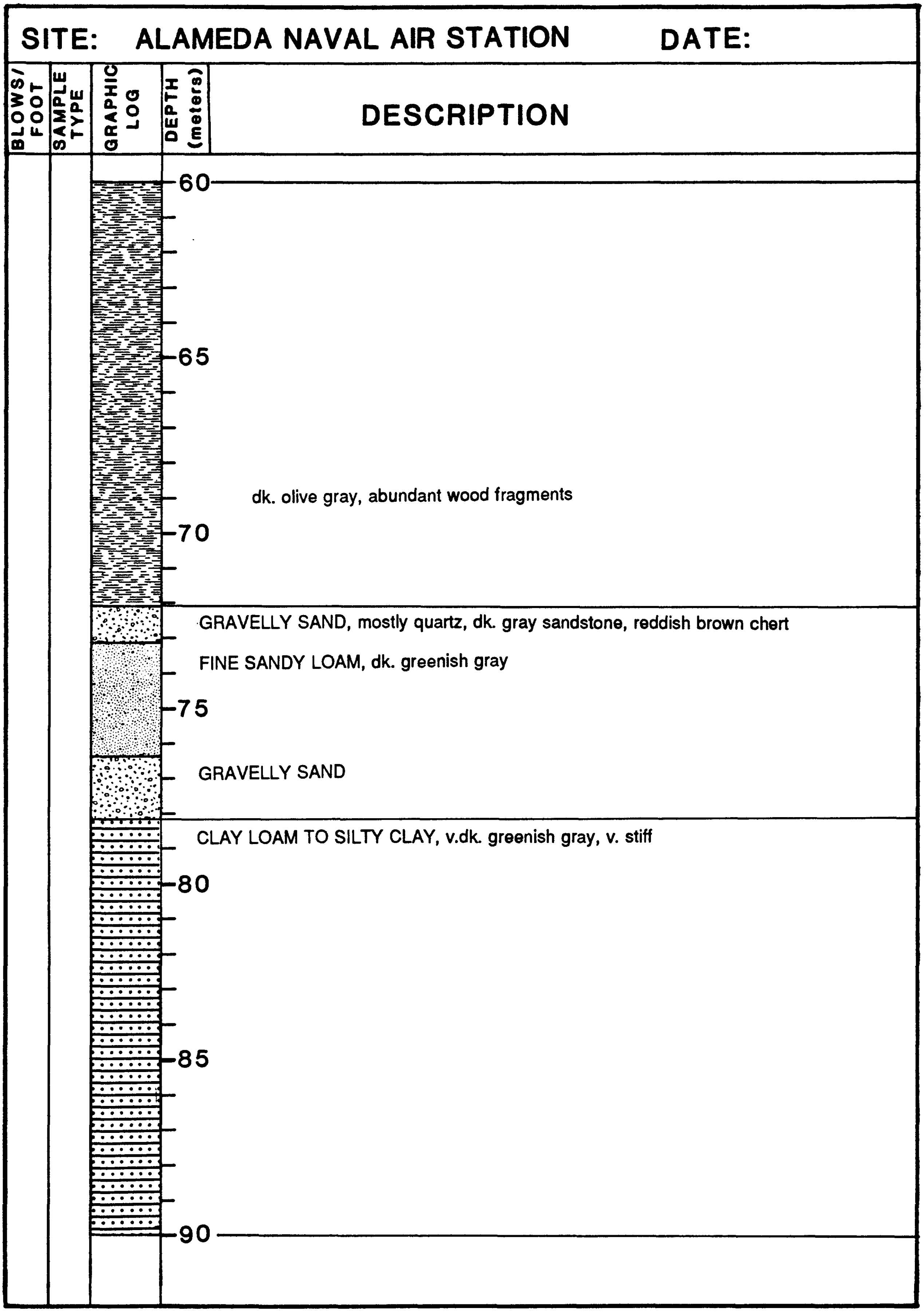


Figure 9. (Continued).

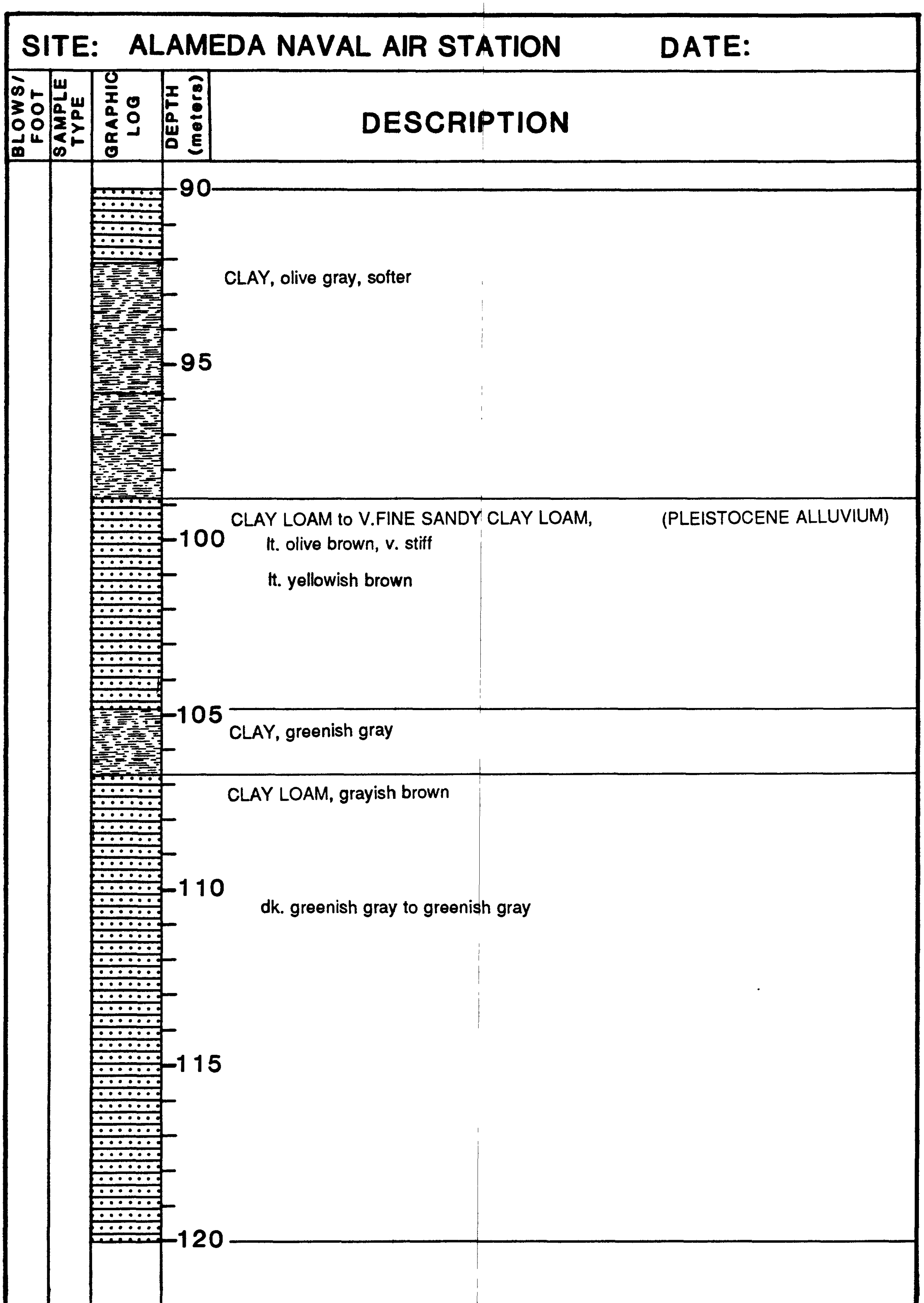


Figure 9. (Continued).

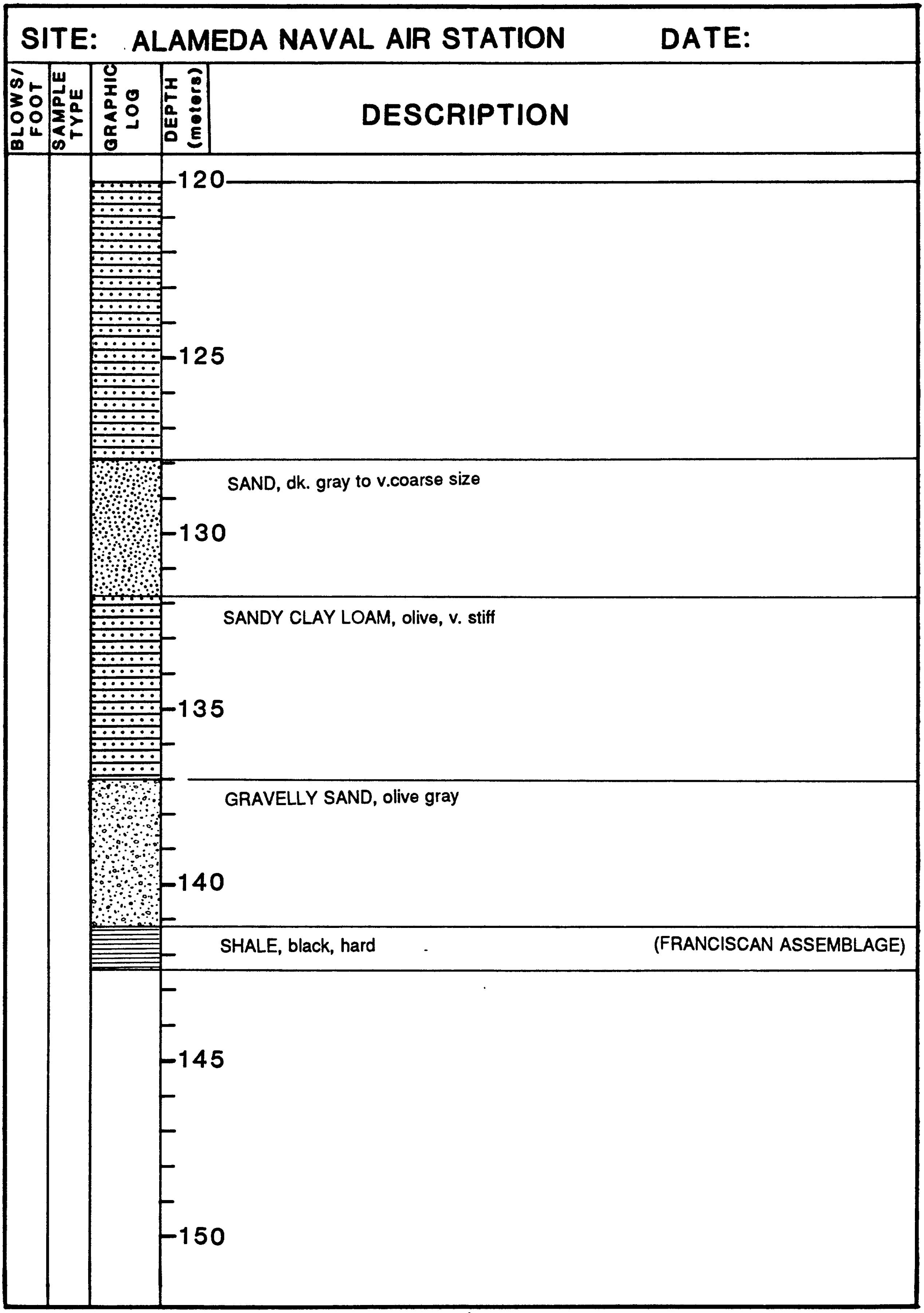


Figure 9. (Continued).

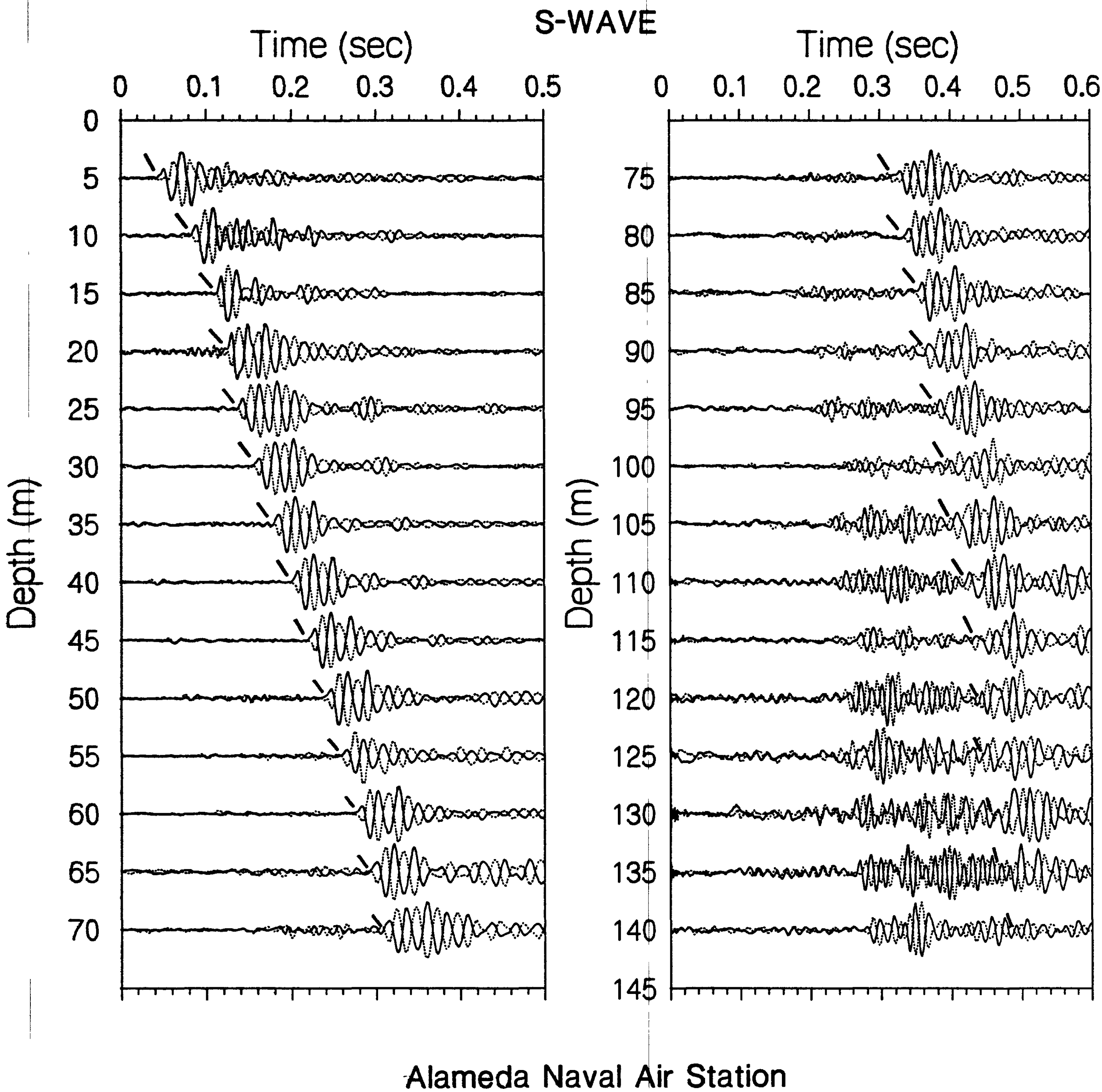


Figure 10. Horizontal-component record section from impacts in opposite horizontal directions superimposed for identification of shear arrivals. S-wave arrivals are shown by the accent marks. An early arriving wave-train starts to build in amplitude at about 100 meters and continues to the bottom of the borehole; it is probably a tube wave traveling in the fluid-filled borehole. Identification of S-wave arrivals below 100 meters, although slightly lower in frequency than the earlier arriving energy, is less certain due to interference by the early arriving wave.

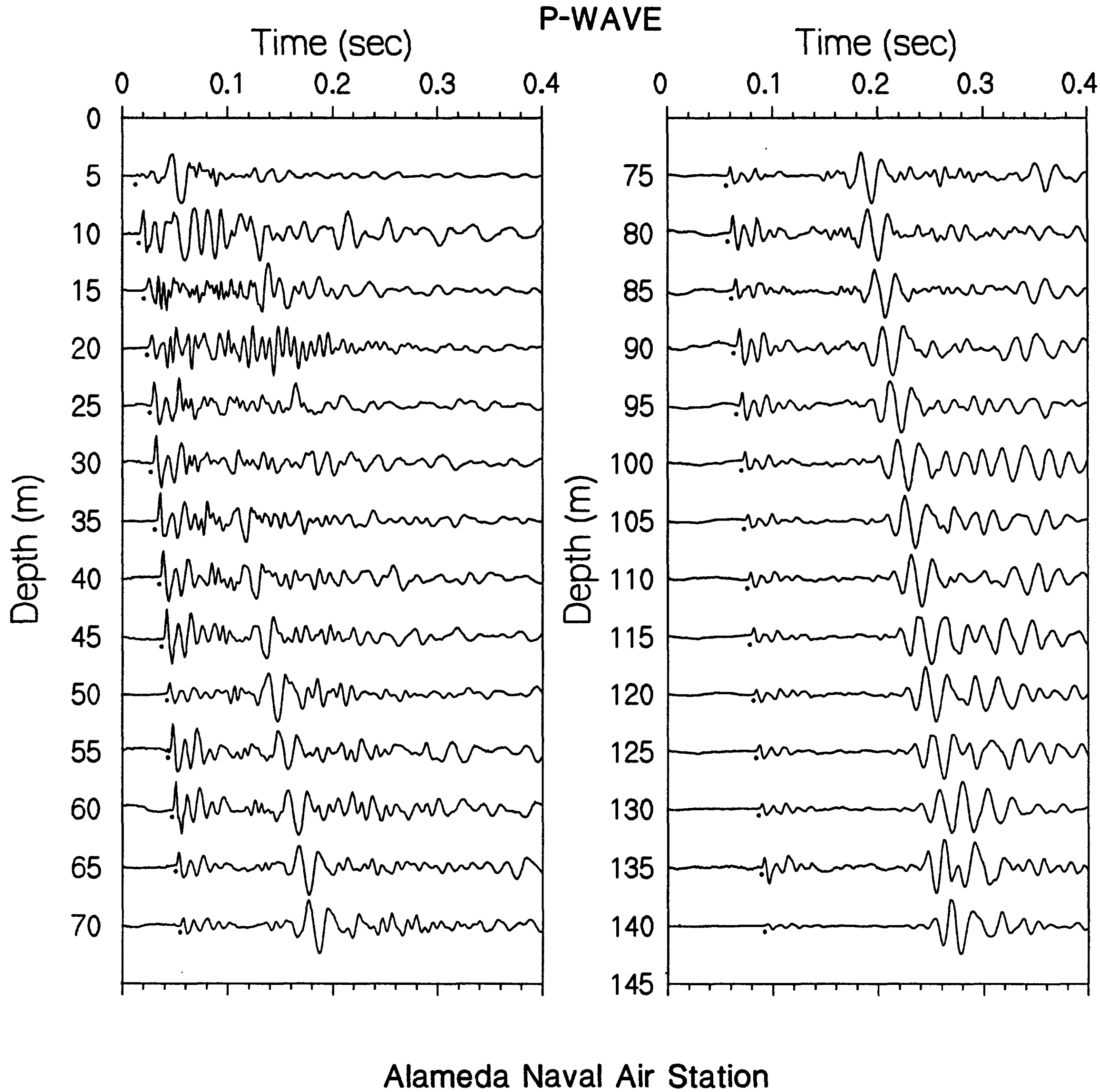


Figure 11. Vertical component record section. P-wave arrivals are shown by the solid circles.

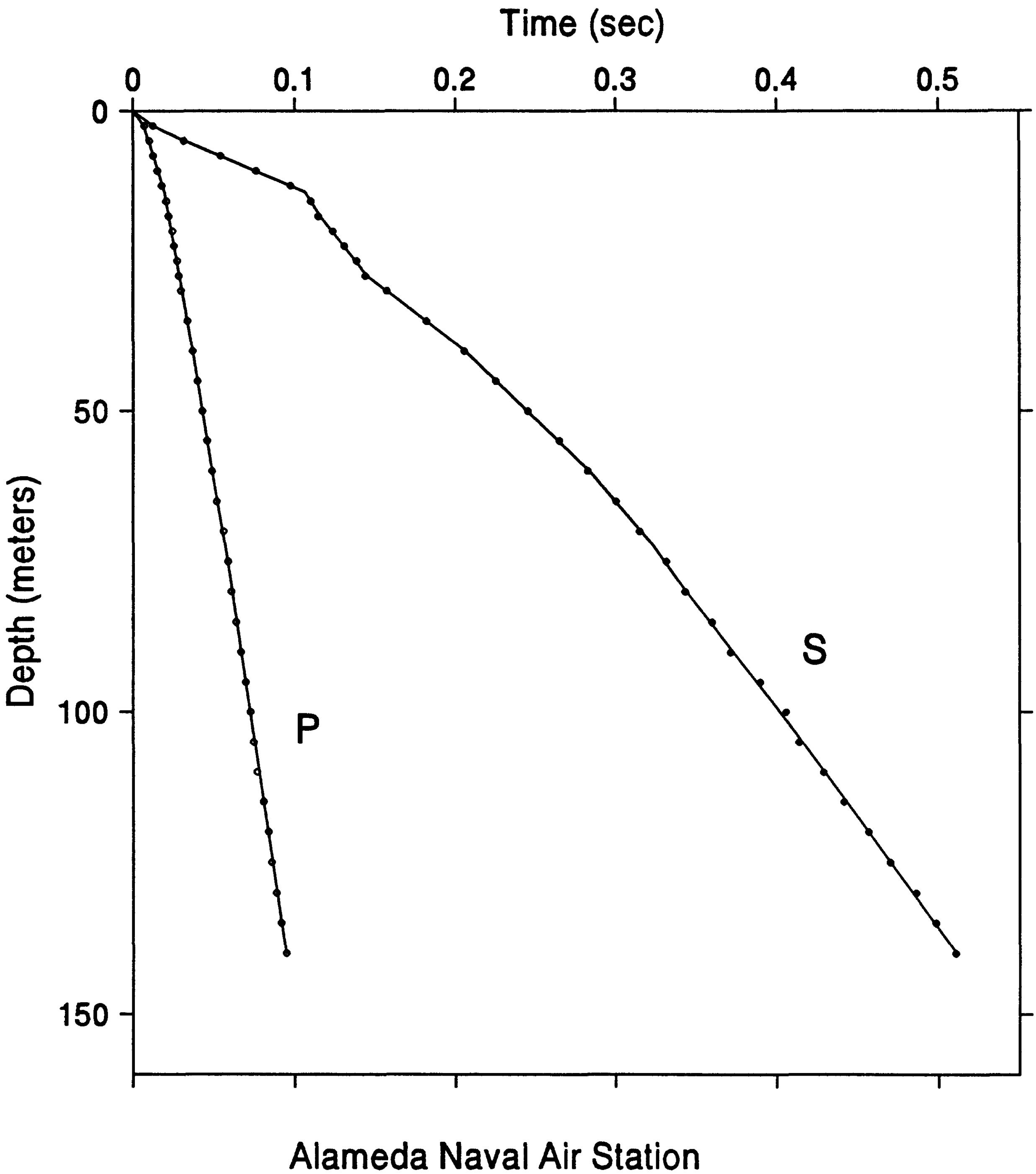


Figure 12. Time-depth graph of P-wave and S-wave picks. Line segments show the hinged-least-squares fit to the data points.

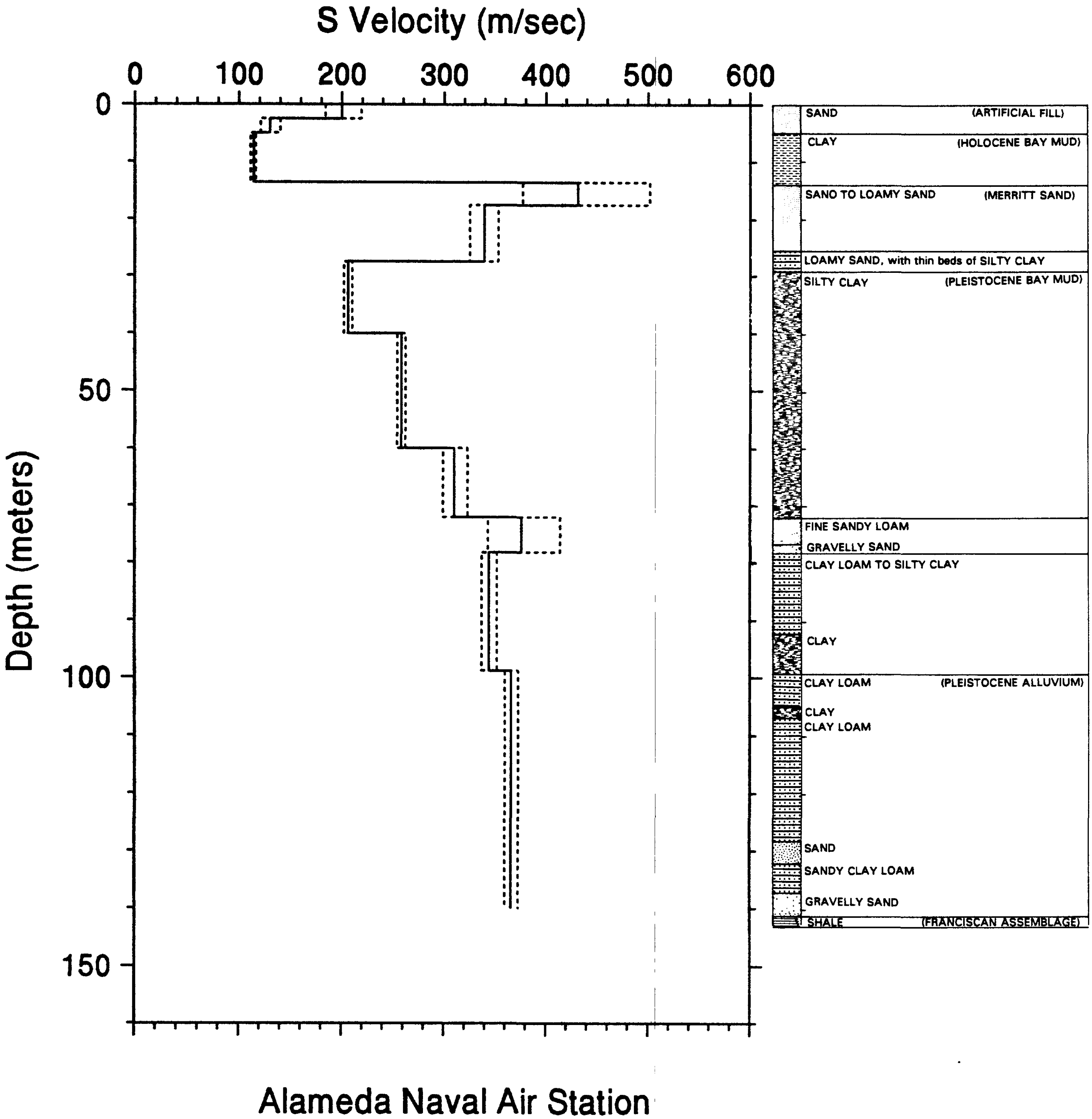


Figure 13. S-wave velocity profiles with dashed lines representing plus and minus one standard deviation. The statistics are done on the slope (reciprocal velocity) so that some of the limits will not appear symmetrical. Simplified geologic log is shown for correlation with velocities.

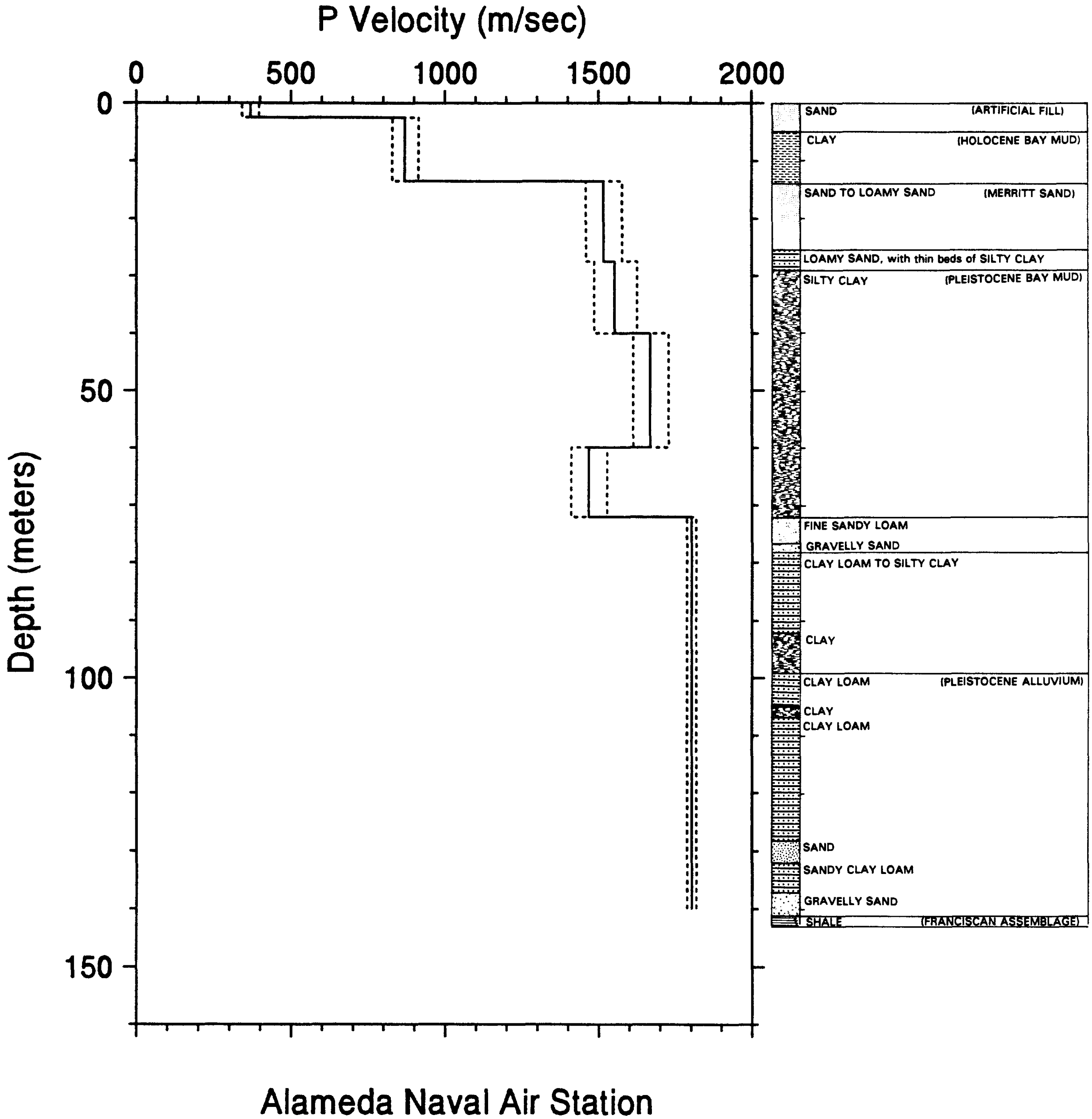


Figure 14. P-wave velocity profiles with dashed lines representing plus and minus one standard deviation. The statistics are done on the slope (reciprocal velocity) so that some of the limits will not appear symmetrical. Simplified geologic log is shown for correlation with velocities.

TABLE 1. S-wave arrival times and velocity summaries for Alameda Naval Air Station.

d(m)	d(ft)	t(sec)	sig	rsdl/sig
2.5	8.2	.0125	1	.0
5.0	16.4	.0315	1	-.3
7.5	24.6	.0541	1	.3
10.0	32.8	.0760	1	.2
12.5	41.0	.0975	1	-.2
15.0	49.2	.1100	1	.0
17.5	57.4	.1149	1	-.9
20.0	65.6	.1237	1	.5
22.5	73.8	.1313	1	.7
25.0	82.0	.1388	1	.8
27.5	90.2	.1441	1	-1.2
30.0	98.4	.1574	1	-.1
35.0	114.8	.1822	1	.5
40.0	131.2	.2054	1	-.6
45.0	147.6	.2251	1	-.2
50.0	164.0	.2453	1	.6
55.0	180.4	.2649	1	.8
60.0	196.9	.2825	1	-1.0
65.0	213.3	.3001	1	.5
70.0	229.7	.3147	1	-1.0
75.0	246.1	.3313	1	1.2
80.0	262.5	.3428	1	-1.1
85.0	278.9	.3594	1	1.0
90.0	295.3	.3714	1	-1.5
95.0	311.7	.3895	1	2.1
100.0	328.1	.4055	2	1.9
105.0	344.5	.4135	1	-1.9
110.0	360.9	.4286	1	-.4
115.0	377.3	.4411	2	-.8
120.0	393.7	.4566	2	.1
125.0	410.1	.4701	2	.1
130.0	426.5	.4861	2	1.2
135.0	442.9	.4982	3	.3
140.0	459.3	.5102	3	-.2

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	200	184	219	656	603	719
2.5	8.2	.012	200	184	219	656	603	719
5.0	16.4	.032	130	121	140	425	396	459
13.5	44.3	.107	114	111	116	373	366	381
17.5	57.4	.116	431	377	502	1413	1237	1647
27.5	90.2	.145	339	325	353	1112	1068	1159
40.0	131.2	.206	206	202	210	676	664	689
60.0	196.9	.283	258	254	262	847	833	861
72.0	236.2	.322	310	299	323	1018	980	1059
78.2	256.6	.339	376	343	414	1232	1127	1359
98.8	324.1	.398	344	337	352	1130	1104	1156
140.0	459.3	.511	366	360	373	1202	1181	1224

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 Alameda Naval Air Station.

d(m)	d(ft)	t(sec)	sig	rsdl/sig
2.5	8.2	.0072	2	.2
5.0	16.4	.0099	2	.1
7.5	24.6	.0125	2	.0
10.0	32.8	.0152	1	-.2
12.5	41.0	.0176	1	-.7
15.0	49.2	.0209	1	.5
17.5	57.4	.0221	1	.0
20.0	65.6	.0243	1	.6
22.5	73.8	.0254	1	.0
25.0	82.0	.0275	1	.5
27.5	90.2	.0285	1	-.2
30.0	98.4	.0296	1	-.7
35.0	114.8	.0337	1	.2
40.0	131.2	.0367	1	.0
45.0	147.6	.0398	1	.1
50.0	164.0	.0428	1	.1
55.0	180.4	.0458	1	.1
60.0	196.9	.0488	1	.1
65.0	213.3	.0518	1	-.3
70.0	229.7	.0559	1	.3
75.0	246.1	.0589	1	.3
80.0	262.5	.0609	1	-.5
85.0	278.9	.0639	1	-.2
90.0	295.3	.0669	1	.0
95.0	311.7	.0699	1	.2
100.0	328.1	.0729	1	.4
105.0	344.5	.0749	1	-.3
110.0	360.9	.0769	2	-.5
115.0	377.3	.0809	1	.1
120.0	393.7	.0839	1	.4
125.0	410.1	.0859	1	-.4
130.0	426.5	.0889	1	-.2
135.0	442.9	.0919	1	.0
140.0	459.3	.0949	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	368	342	397	1207	1123	1303
2.5	8.2	.007	368	342	397	1207	1123	1303
13.5	44.3	.019	869	829	913	2851	2719	2997
27.5	90.2	.029	1516	1459	1577	4973	4786	5175
40.0	131.2	.037	1552	1485	1625	5092	4873	5331
60.0	196.9	.049	1668	1613	1727	5472	5291	5665
72.0	236.2	.057	1467	1410	1528	4812	4625	5014
140.0	459.3	.095	1803	1788	1818	5915	5868	5963

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

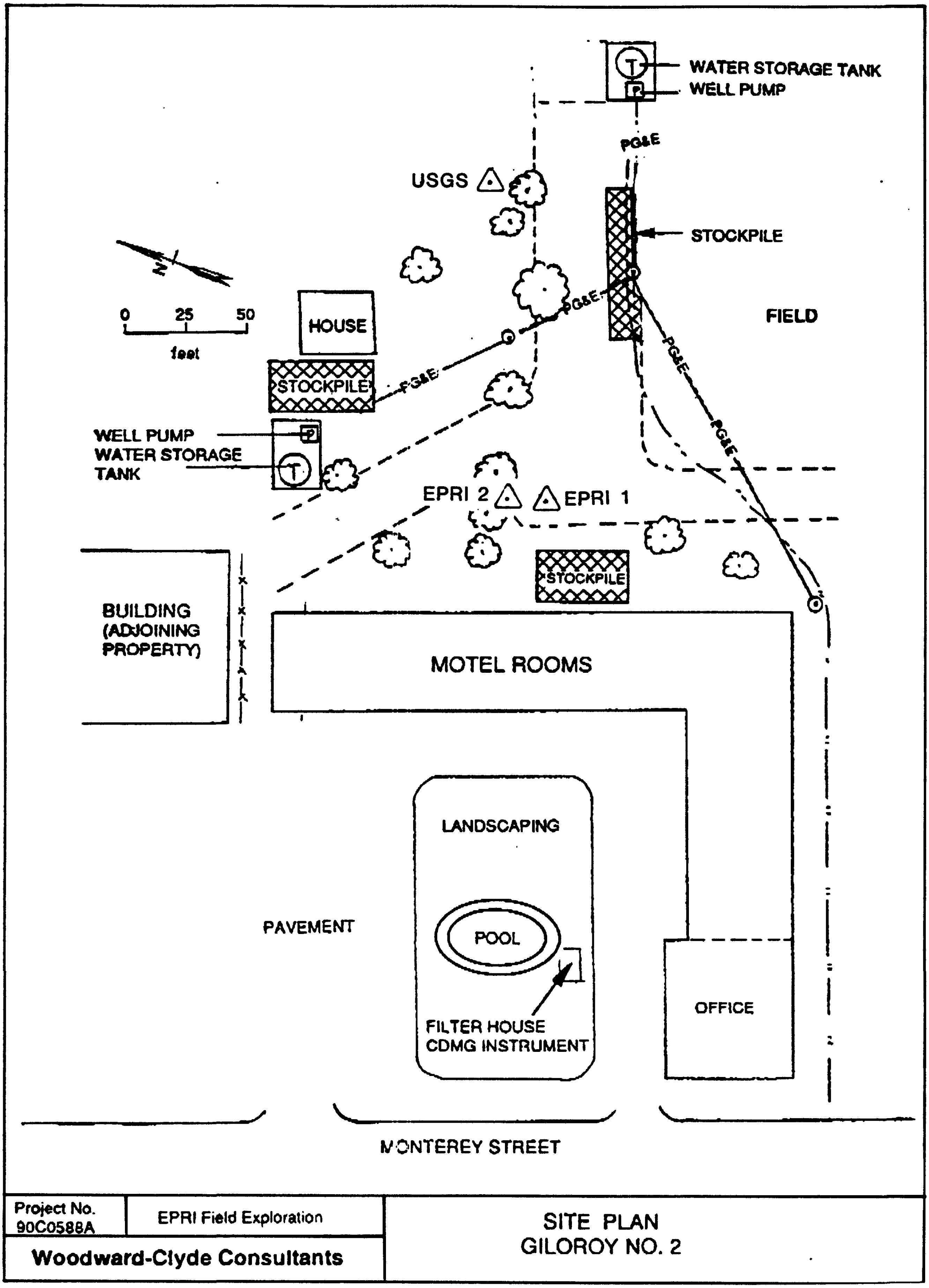


Figure 15. Detailed site location of Gilroy #2. Notice the location of EPRI and USGS boreholes relative to strong-motion recorder.

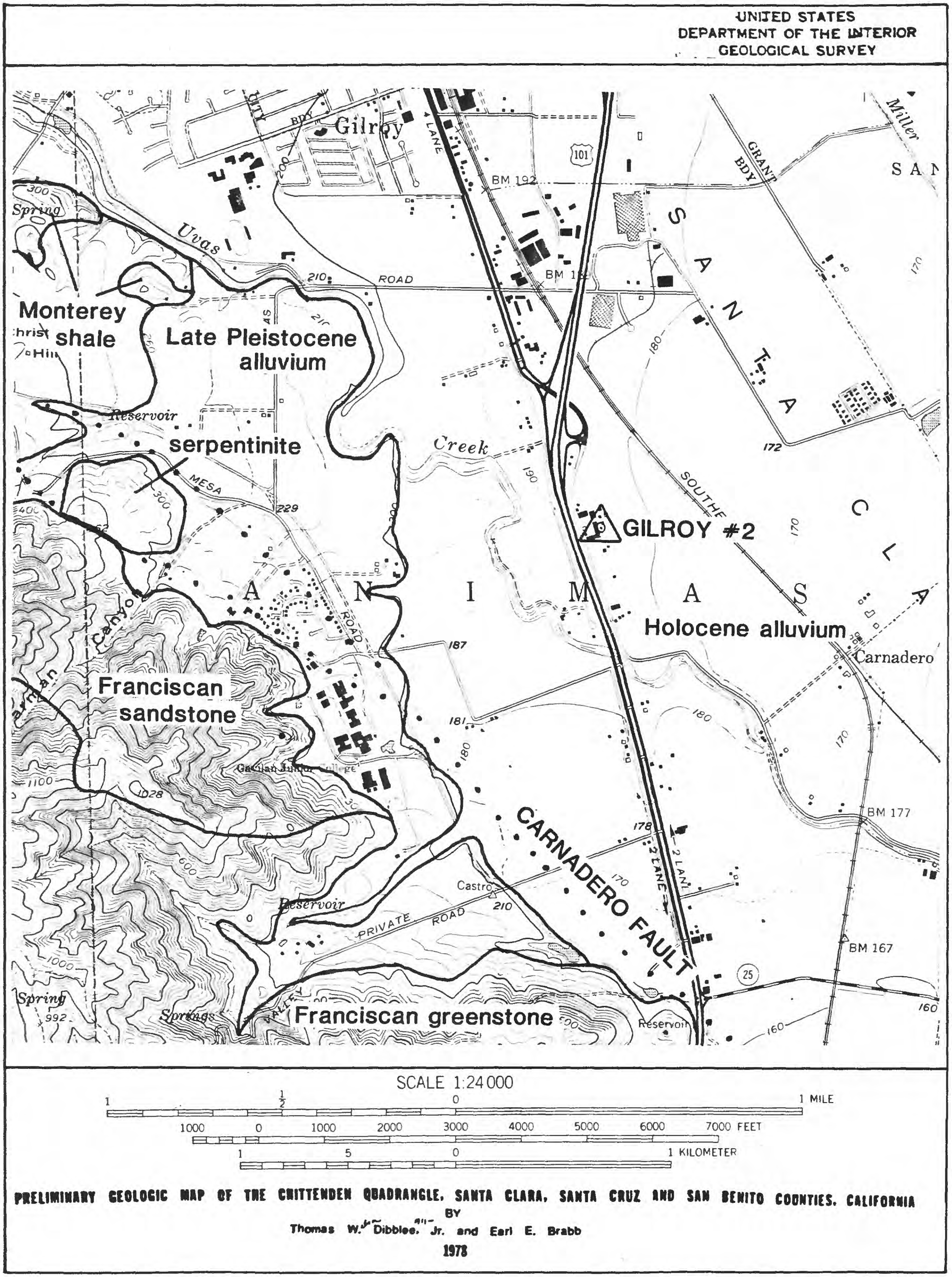


Figure 16. Site location map for Gilroy #2.

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)

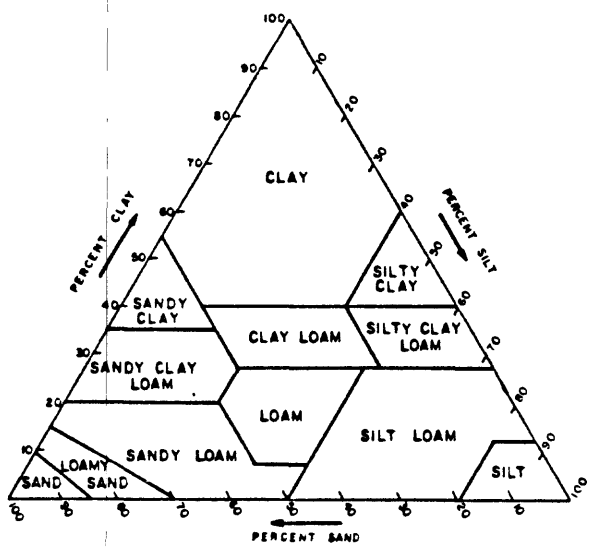
cm	in	fracture spacing
0-1	0-1/2	v. close
1-5	1/2-2	close
5-30	2-12	moderate
30-100	12-36	wide
>100	>36	v. wide

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 17. Explanation of geologic log for Gilroy #2 (EPRI #1).

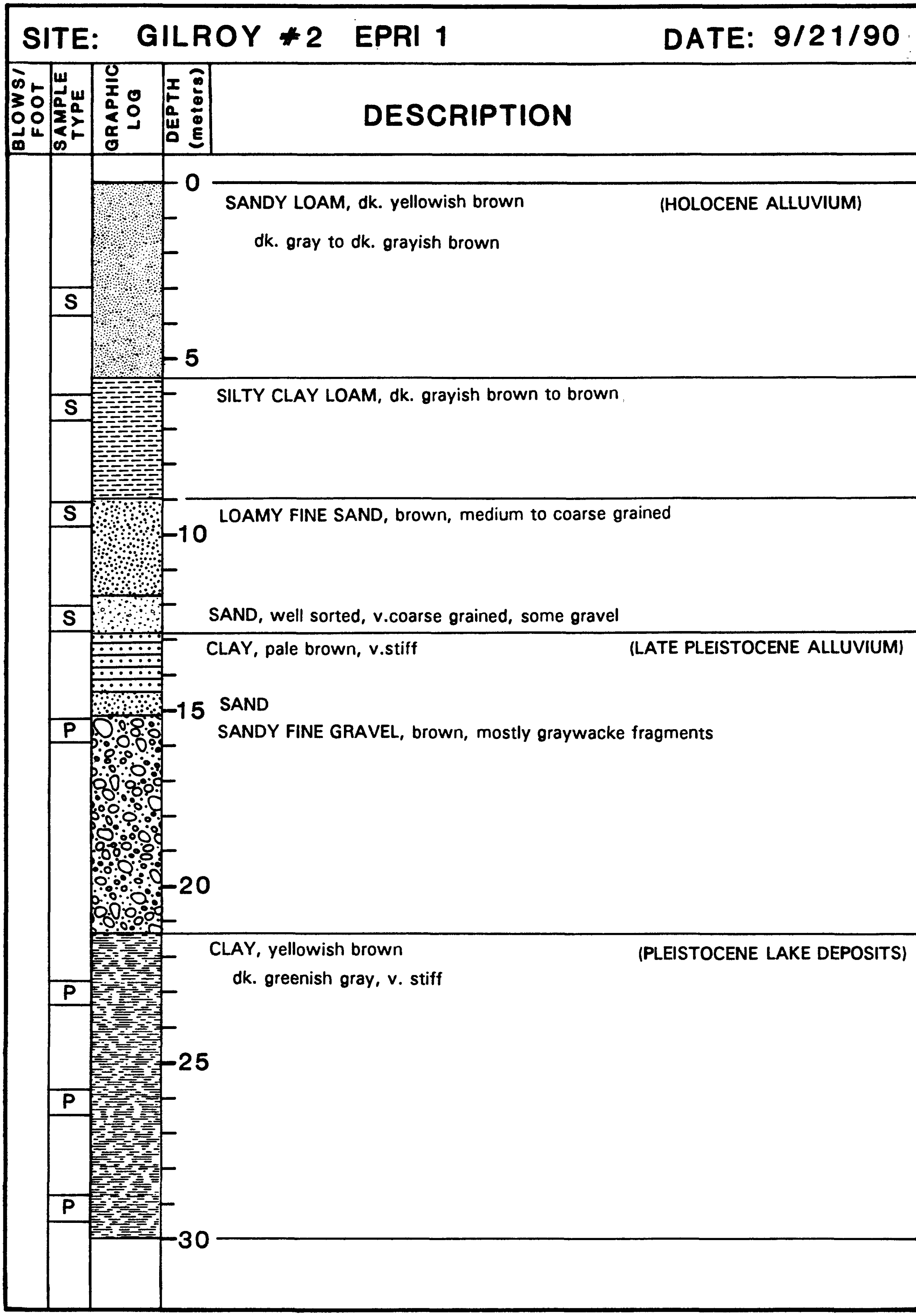


Figure 18. Geologic log for Gilroy #2 (EPRI #1).

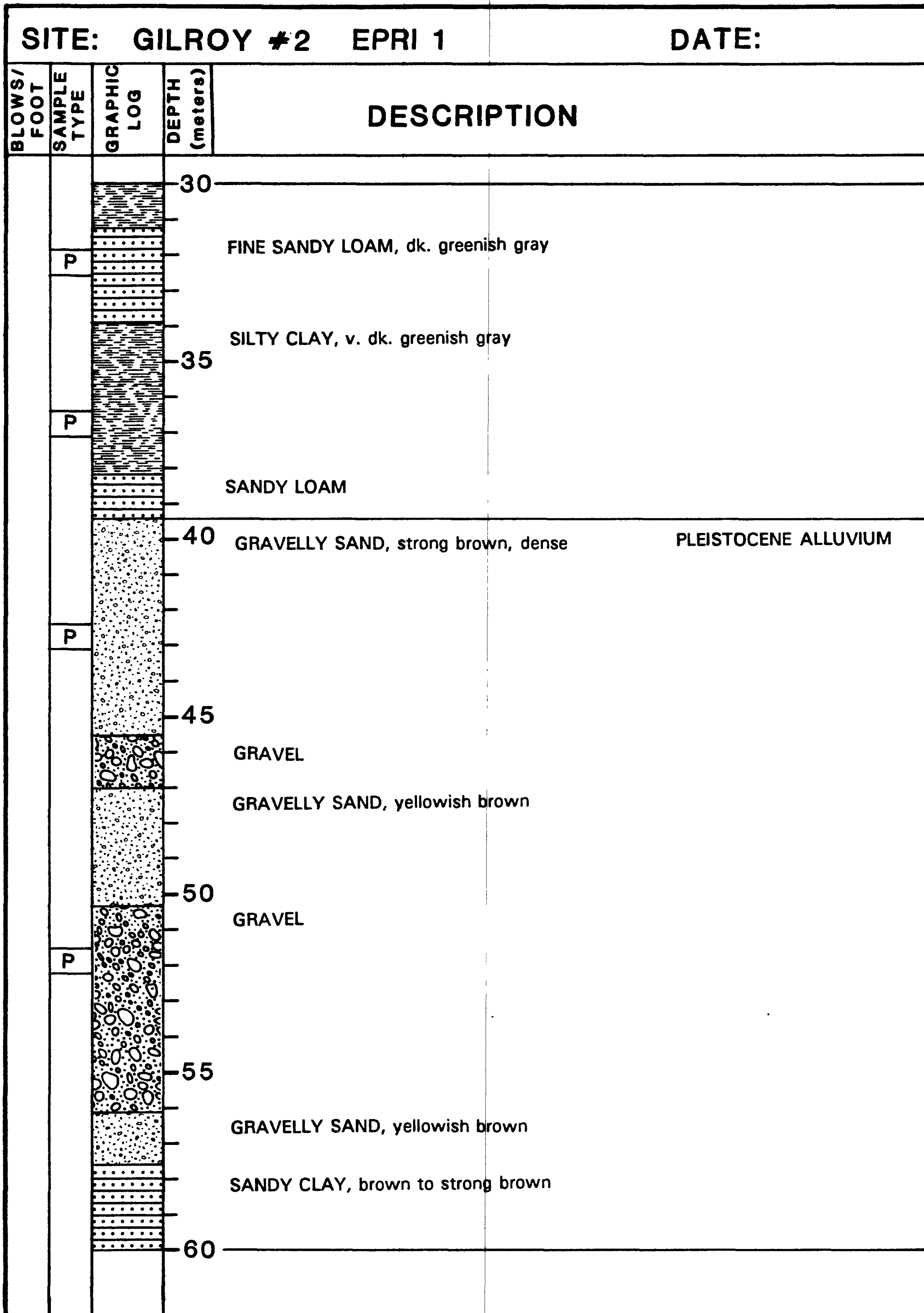


Figure 18. (Continued).

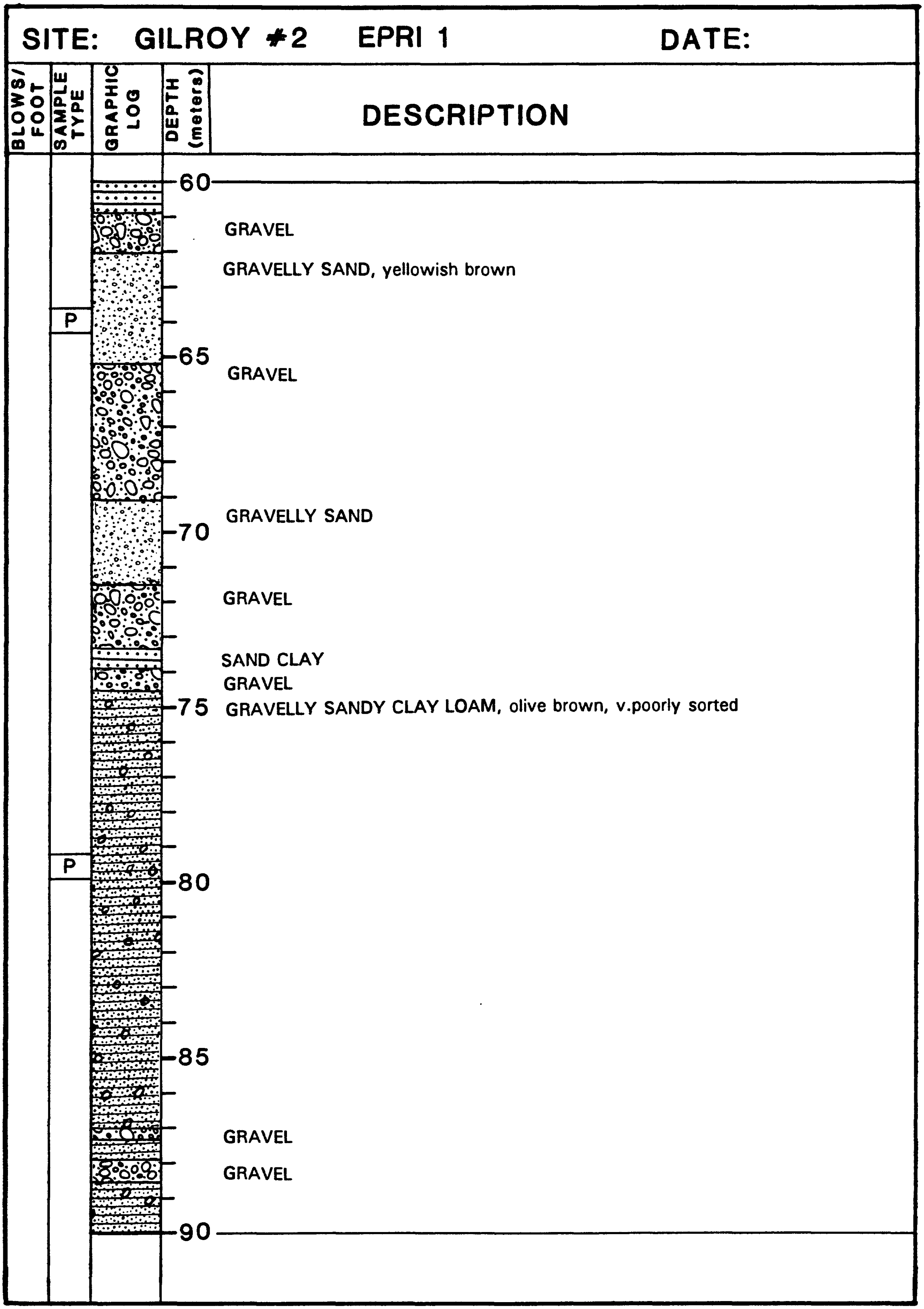


Figure 18. (Continued).

SITE: GILROY #2 EPRI 1 **DATE:**

BLOWS/ FOOT	SAMPLE TYPE	GRAPHIC LOG	DEPTH (meters)	DESCRIPTION
	P		90	GRAVEL, dk. yellowish brown, v.poorly sorted, texture of matrix is SANDY CLAY LOAM
				SANDY CLAY LOAM
				GRAVEL
			95	SANDY CLAY LOAM
			100	
			105	SANDY CLAY, strong brown
	DH			SANDY CLAY, occasional thin lenses of gravel
			110	
	DH		115	SANDY CLAY LOAM, v. dense, v. poorly sorted
				GRAVEL
				SANDY CLAY
				GRAVELLY SANDY CLAY LOAM, brown, v. dense
			120	

Figure 18. (Continued).

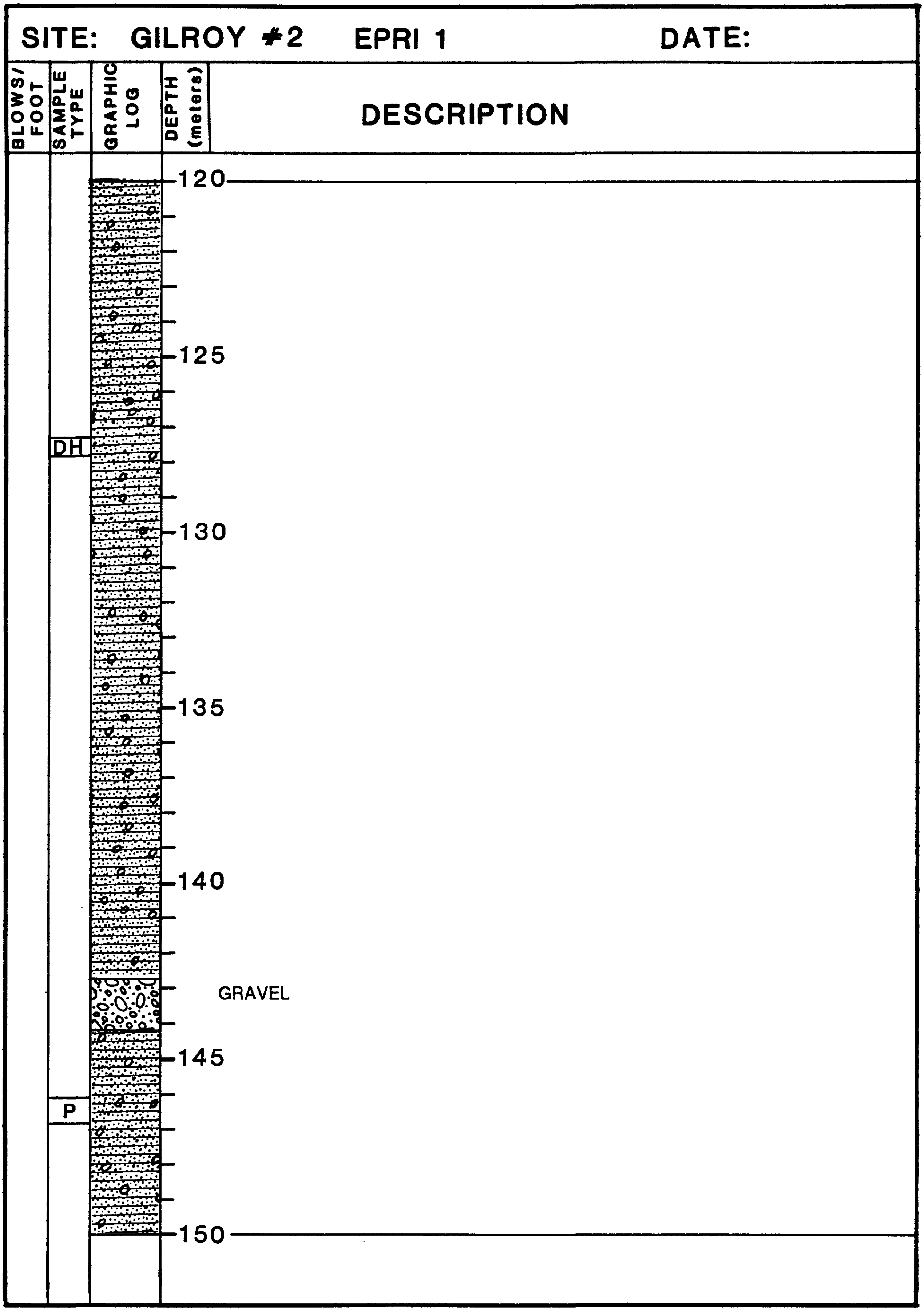


Figure 18. (Continued).

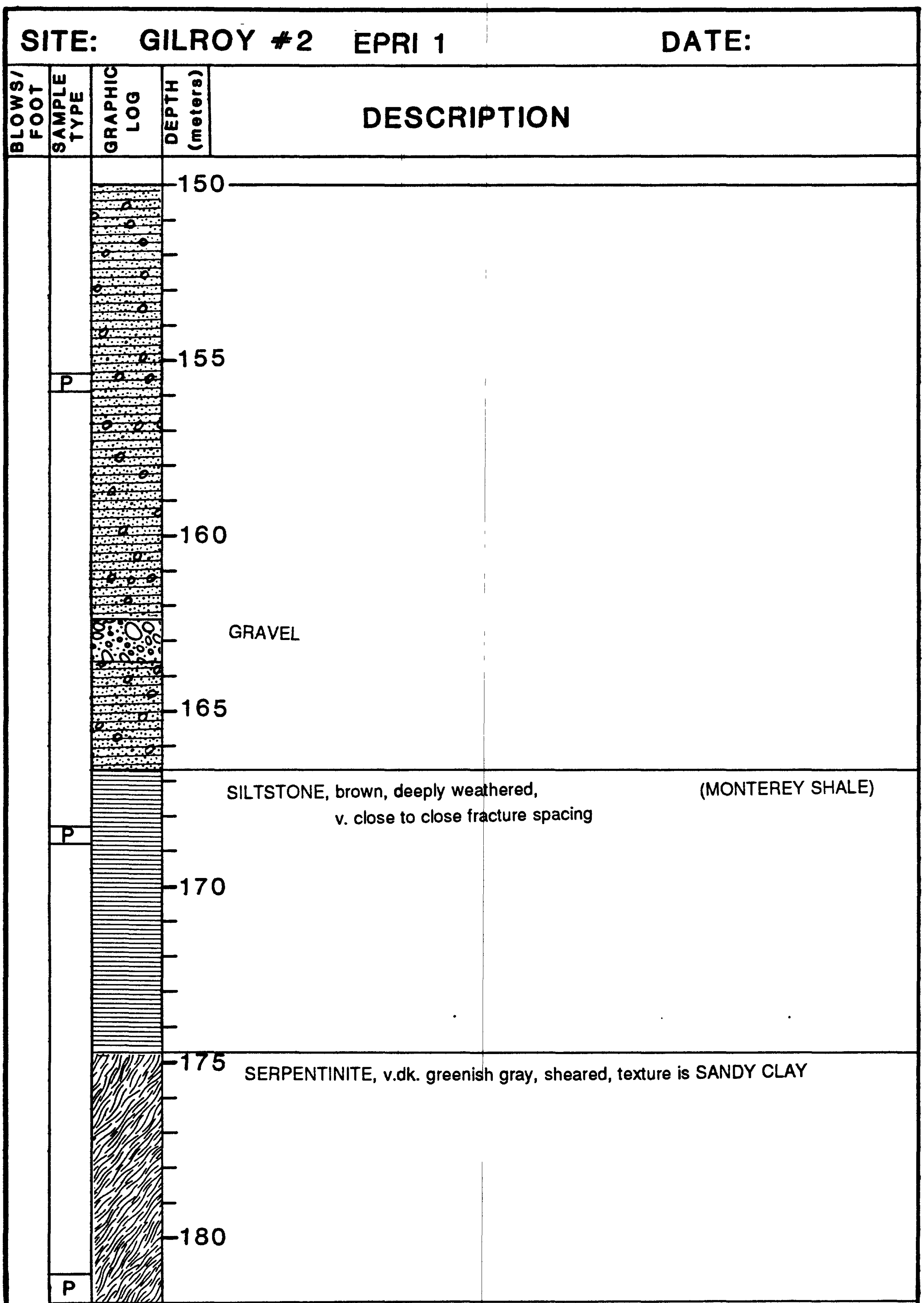


Figure 18. (Continued).

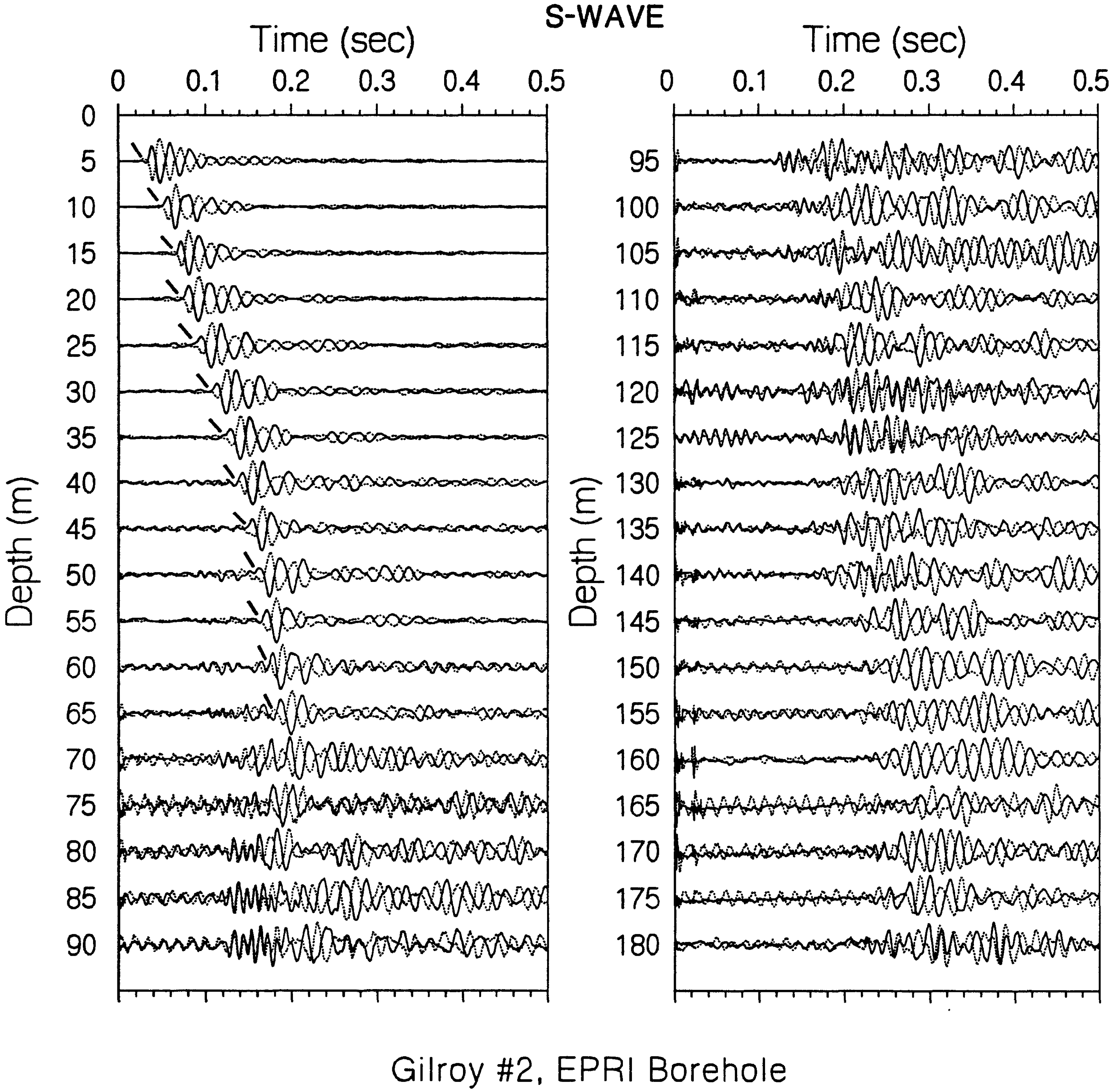


Figure 19. Horizontal-component record section from impacts in opposite horizontal directions superimposed for identification of shear arrivals. S-wave arrivals are shown by the accent marks. An early arriving wave-train starts to build in amplitude at about 70 meters and continues to the bottom of the borehole. Interference to S-wave arrivals below 70 meters made picks too uncertain for velocity determinations .

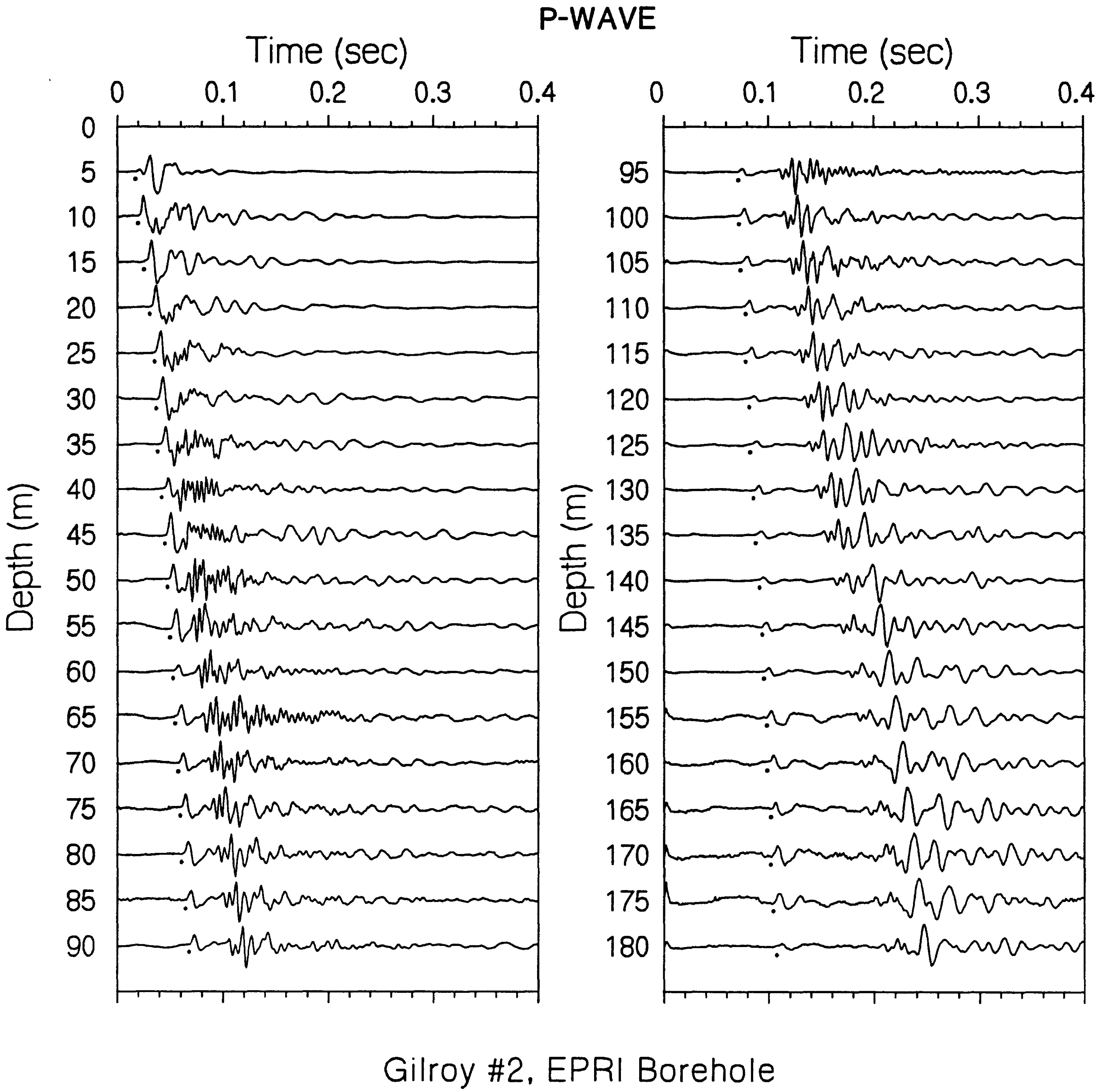


Figure 20. Vertical-component record section. P-waves are shown by the solid circles.

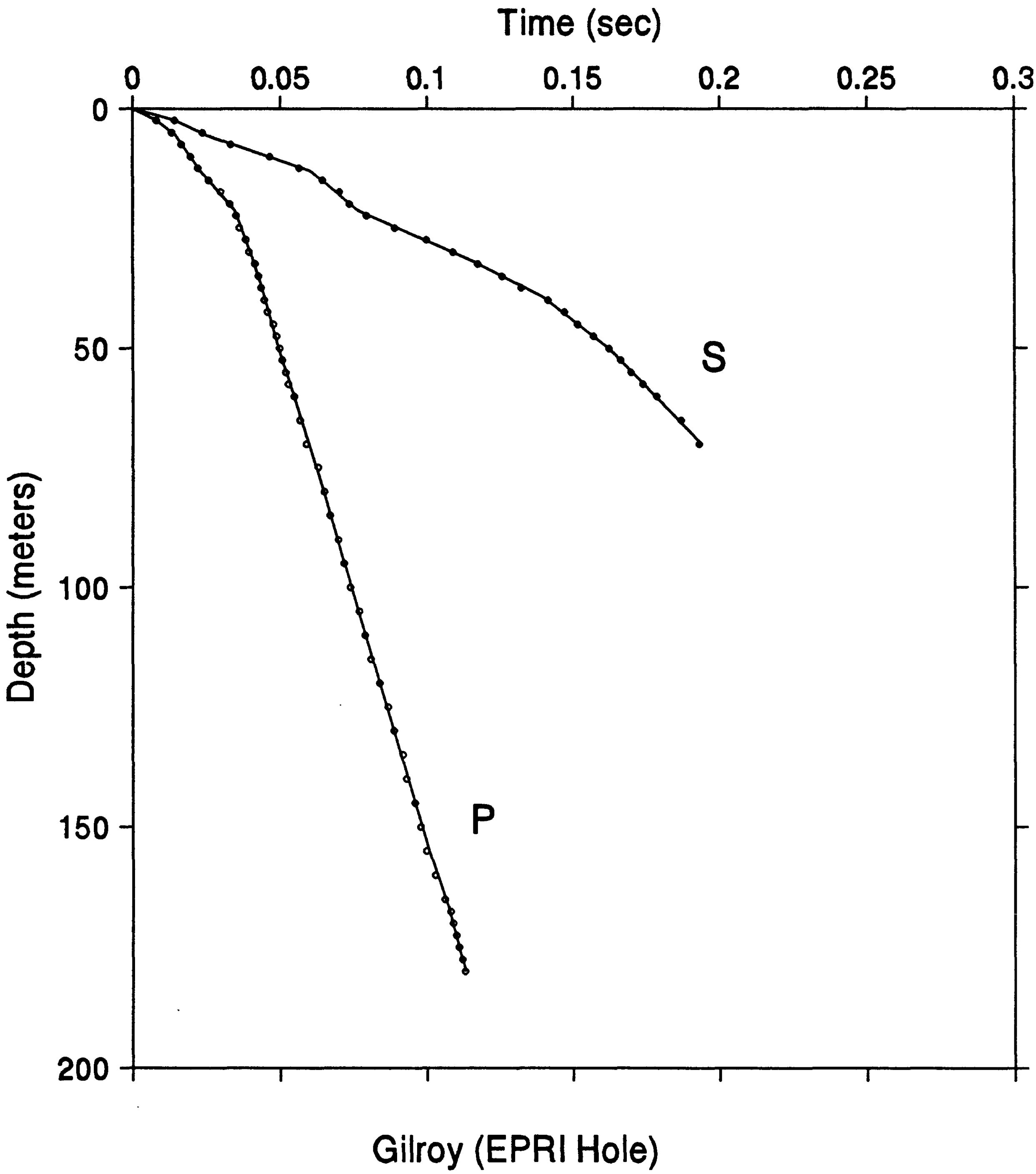


Figure 21. Time-depth graph of P-wave and S-wave picks. Line segments show the hinged-least-squares fit to the data points.

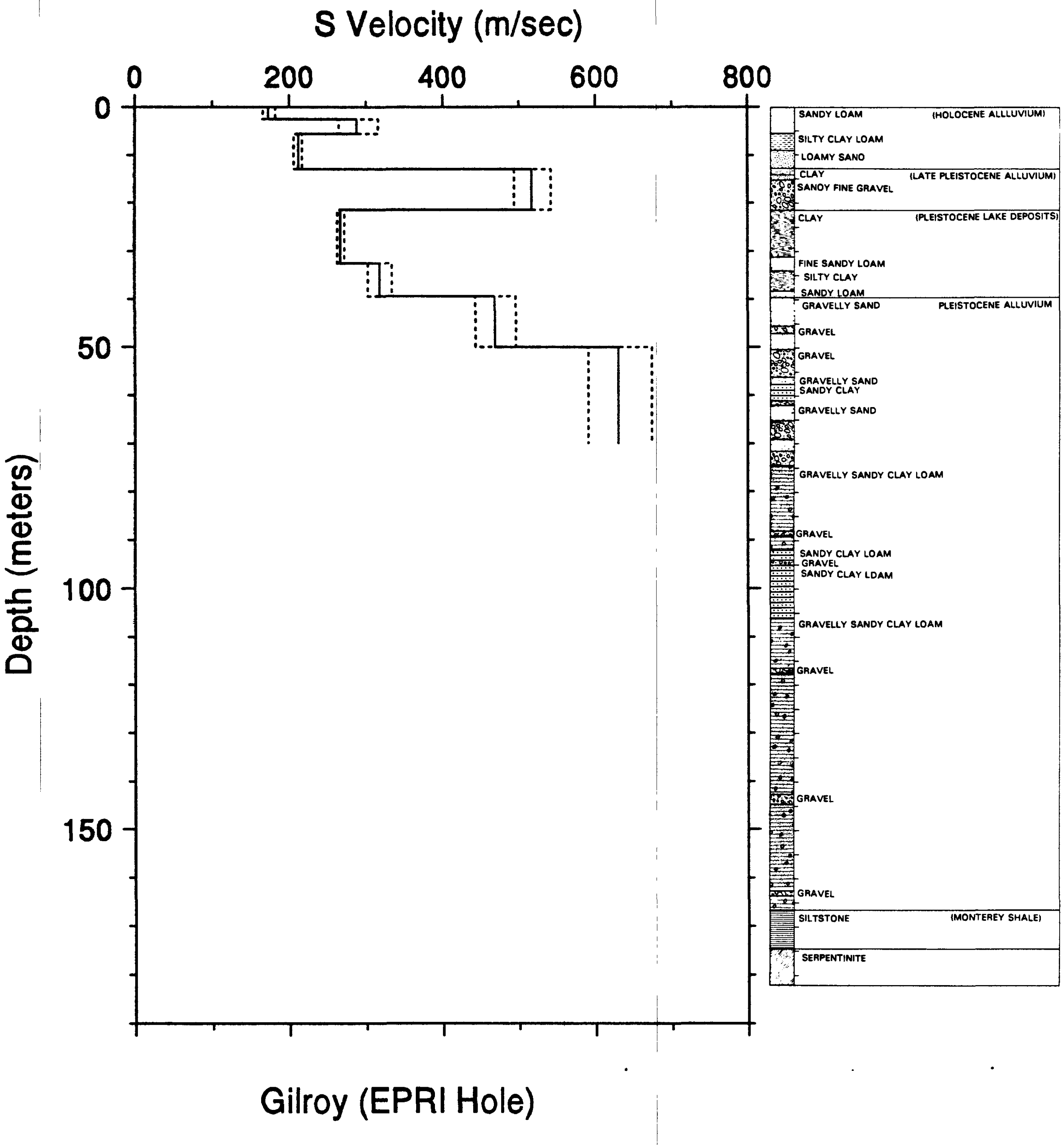


Figure 22. S-wave velocity profiles with dashed lines representing plus and minus one standard deviation. The statistics are done on the slope (reciprocal velocity) so that some of the limits will not appear symmetrical. Simplified geologic log is shown for correlation with velocities.

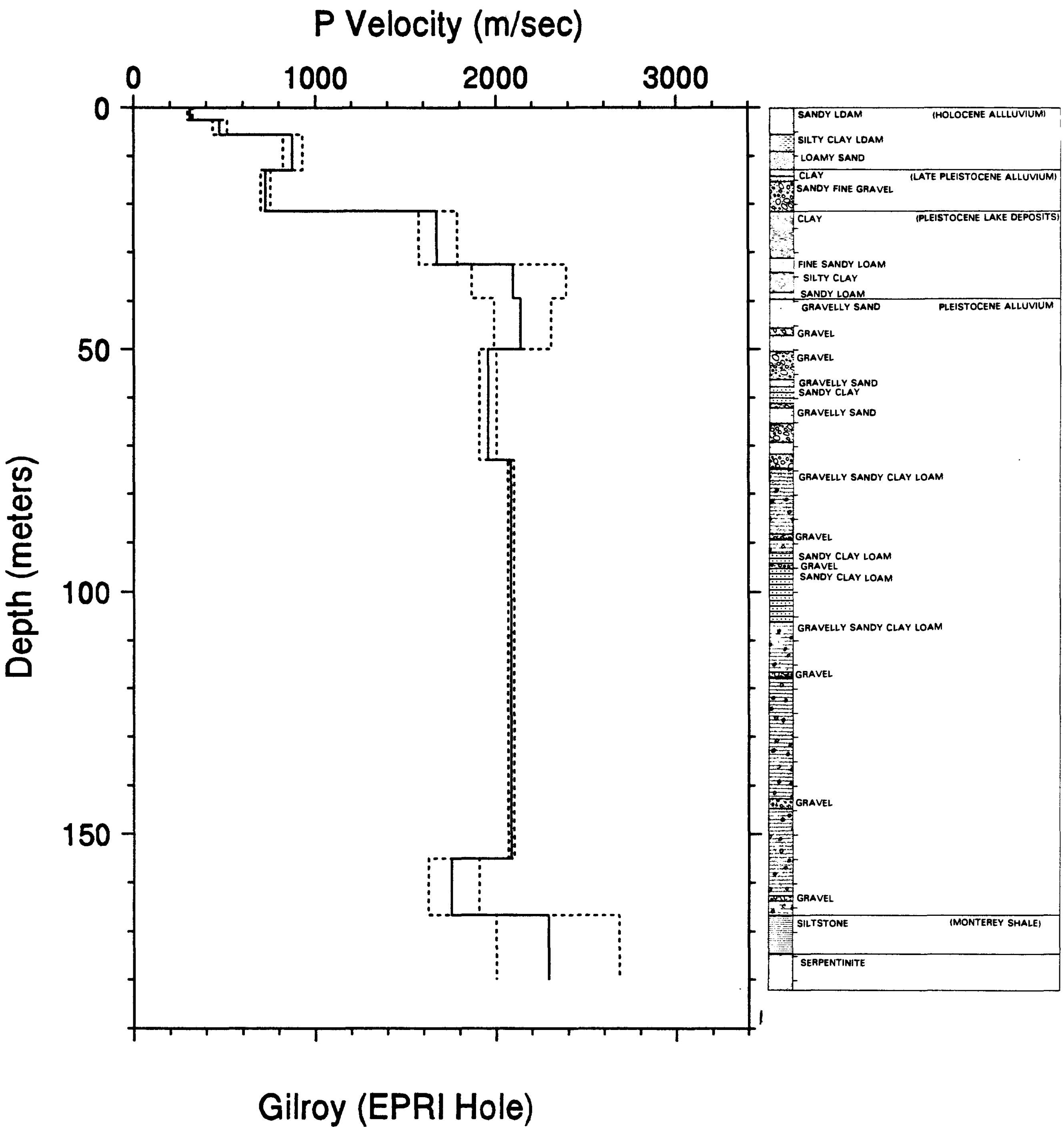


Figure 23. P-wave velocity profiles with dashed lines representing plus and minus one standard deviation. The statistics are done on the slope of the line segments (reciprocal velocity) so that some of the limits will not appear symmetrical. Simplified geologic log is shown for correlation with velocities.

TABLE 3. S-wave arrival times and velocity summaries for Gilroy #2 (EPRI #1).

d(m)	d(ft)	t(sec)	sig	rsdl/sig
2.5	8.2	.0143	1	-.1
5.0	16.4	.0237	1	.6
7.5	24.6	.0333	1	-.8
10.0	32.8	.0465	1	.5
12.5	41.0	.0566	1	-1.2
15.0	49.2	.0645	1	.5
17.5	57.4	.0702	1	1.3
20.0	65.6	.0738	1	.1
22.5	73.8	.0795	1	-1.0
25.0	82.0	.0892	1	-.7
27.5	90.2	.0999	1	.7
30.0	98.4	.1090	1	.5
32.5	106.6	.1176	1	-.3
35.0	114.8	.1257	1	-.1
37.5	123.0	.1323	2	-.7
40.0	131.2	.1414	2	.3
42.5	139.4	.1470	2	.4
45.0	147.6	.1516	2	.0
47.5	155.8	.1571	2	.1
50.0	164.0	.1622	2	.0
52.5	172.2	.1662	2	.0
55.0	180.4	.1698	2	-.2
57.5	188.6	.1738	2	-.2
60.0	196.9	.1784	2	.1
65.0	213.3	.1869	3	.3
70.0	229.7	.1930	5	-.2

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	173	166	182	569	544	596
2.5	8.2	.014	173	166	182	569	544	596
5.6	18.4	.025	288	265	316	946	869	1038
13.0	42.7	.060	212	206	217	694	677	712
21.4	70.2	.076	517	494	542	1697	1621	1780
32.5	106.6	.118	267	263	272	878	862	893
39.4	129.3	.140	318	303	334	1042	993	1095
50.0	164.0	.162	468	443	496	1536	1453	1629
70.0	229.7	.194	630	591	674	2066	1938	2213

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 Gilroy #2 (EPRI #1).

d(m)	d(ft)	t(sec)	sig	rsdl/sig
2.5	8.2	.0080	1	.0
5.0	16.4	.0134	1	.1
7.5	24.6	.0166	1	-.1
10.0	32.8	.0197	1	.1
12.5	41.0	.0223	1	-.2
15.0	49.2	.0256	1	-.2
17.5	57.4	.0298	1	.5
20.0	65.6	.0330	1	.3
22.5	73.8	.0351	1	-.2
25.0	82.0	.0363	1	-.5
27.5	90.2	.0384	1	.1
30.0	98.4	.0395	1	-.3
32.5	106.6	.0415	1	.2
35.0	114.8	.0426	1	.1
37.5	123.0	.0436	1	.0
40.0	131.2	.0447	1	-.1
42.5	139.4	.0457	1	-.3
45.0	147.6	.0477	1	.5
47.5	155.8	.0487	1	.4
50.0	164.0	.0498	1	.3
52.5	172.2	.0508	1	.0
55.0	180.4	.0518	1	-.3
57.5	188.6	.0528	1	-.6
60.0	196.9	.0548	1	.2
65.0	213.3	.0568	1	-.4
70.0	229.7	.0589	1	-.8
75.0	246.1	.0629	1	.7
80.0	262.5	.0649	1	.3
85.0	278.9	.0669	1	-.1
90.0	295.3	.0699	1	.5
95.0	311.7	.0719	1	.1
100.0	328.1	.0739	1	-.3
105.0	344.5	.0769	1	.3
110.0	360.9	.0789	1	-.1
115.0	377.3	.0809	1	-.5
120.0	393.7	.0839	1	.1
125.0	410.1	.0869	1	.7
130.0	426.5	.0889	1	.3
135.0	442.9	.0919	1	.9
140.0	459.3	.0929	1	-.6
145.0	475.7	.0959	1	.0
150.0	492.1	.0979	1	-.4
155.0	508.5	.0999	2	-.4
160.0	524.9	.1029	2	-.3
165.0	541.3	.1060	2	-.2
167.5	549.5	.1080	2	.2
170.0	557.7	.1090	2	.1
172.5	565.9	.1100	2	.1
175.0	574.1	.1110	2	.0
177.5	582.3	.1120	2	.0
180.0	590.6	.1130	2	-.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	312	298	327	1023	976	1074
2.5	8.2	.008	312	298	327	1023	976	1074
5.6	18.4	.015	474	437	517	1554	1432	1697
13.0	42.7	.023	872	822	929	2862	2697	3048
21.4	70.2	.035	725	699	754	2380	2293	2474
32.5	106.6	.041	1673	1573	1787	5488	5159	5863
39.4	129.3	.045	2095	1865	2391	6874	6118	7844
50.0	164.0	.050	2137	1991	2307	7013	6532	7570
73.0	239.5	.061	1955	1908	2003	6413	6261	6572
155.0	508.5	.101	2083	2067	2099	6833	6781	6886
166.7	546.9	.107	1752	1623	1905	5749	5324	6248
180.0	590.6	.113	2291	2000	2682	7517	6562	8799

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

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)

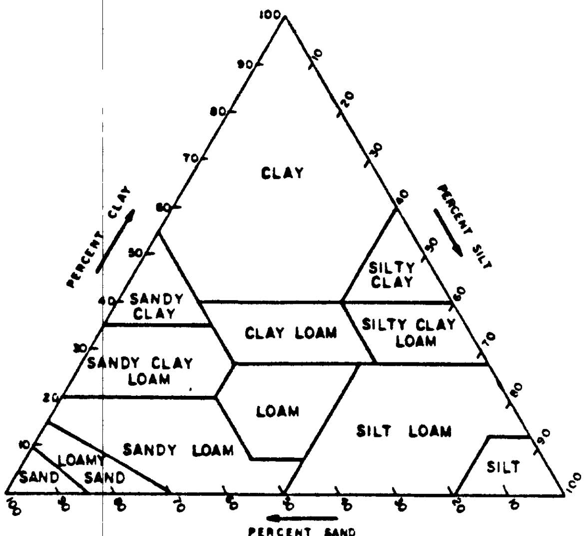
cm	in	fracture spacing
0-1	0-1/2	v. close
1-5	1/2-2	close
5-30	2-12	moderate
30-100	12-36	wide
>100	>36	v. wide

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.

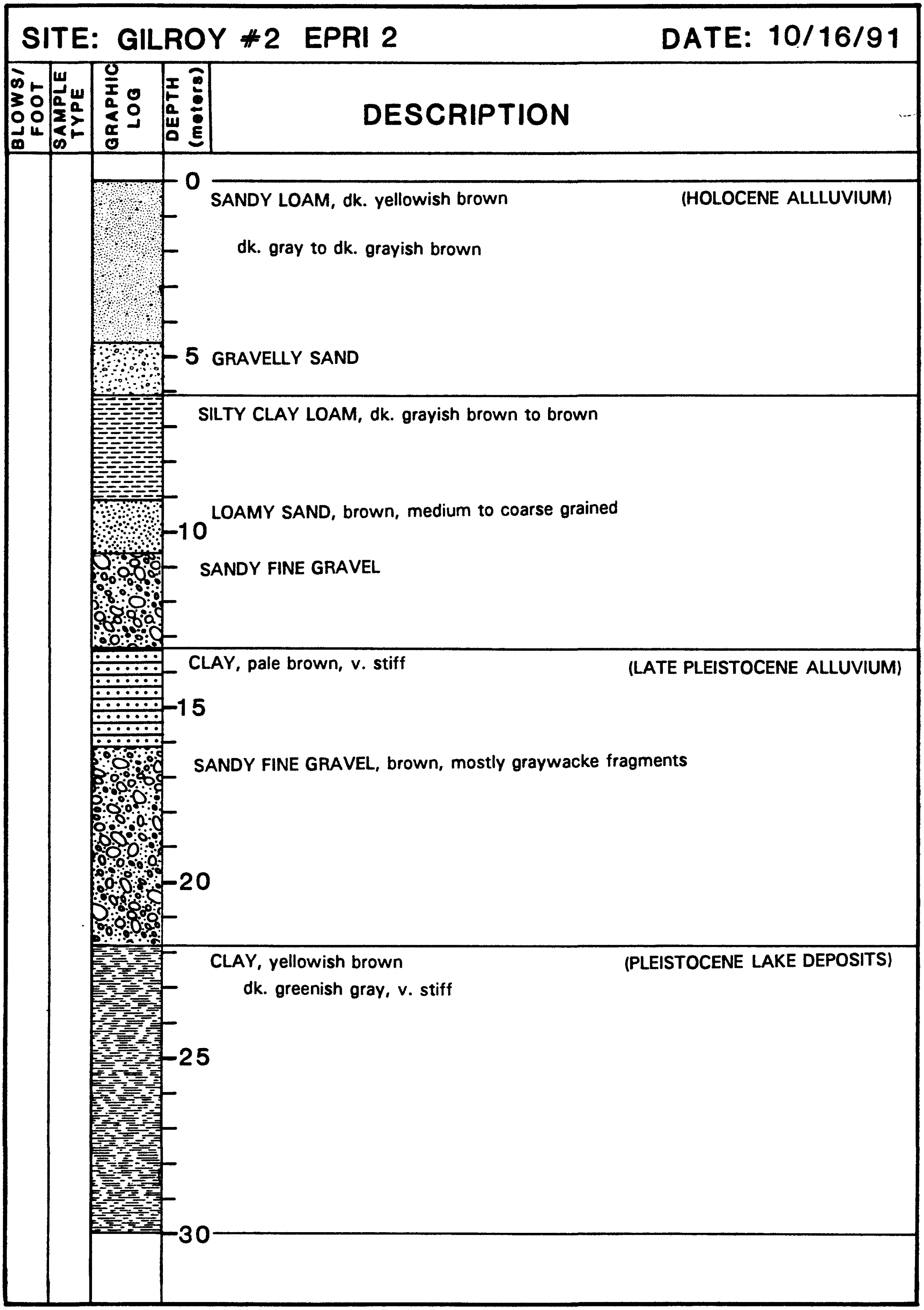


Figure 25. Geologic log for Gilroy #2 (EPRI #2).

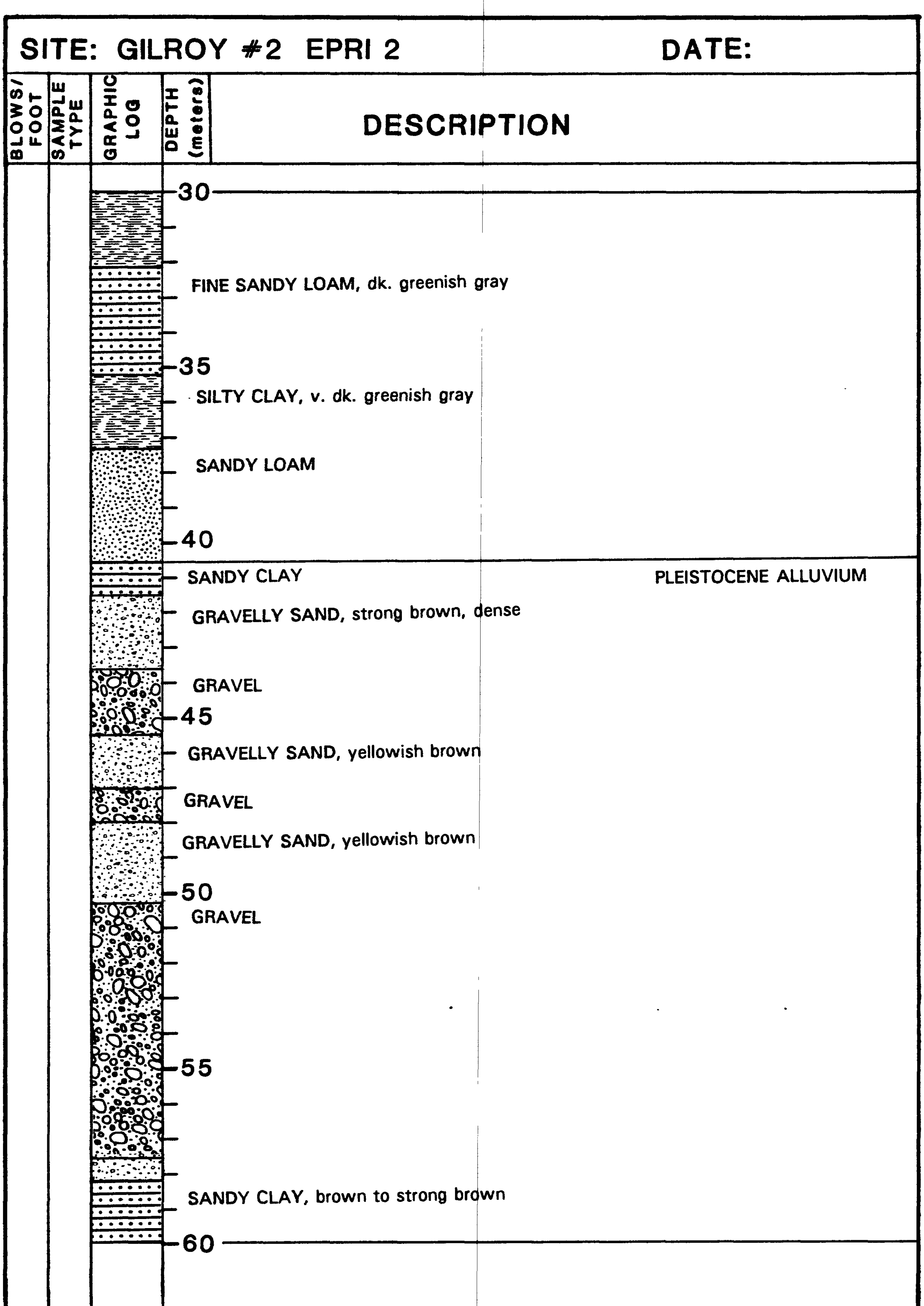


Figure 25. (Continued).

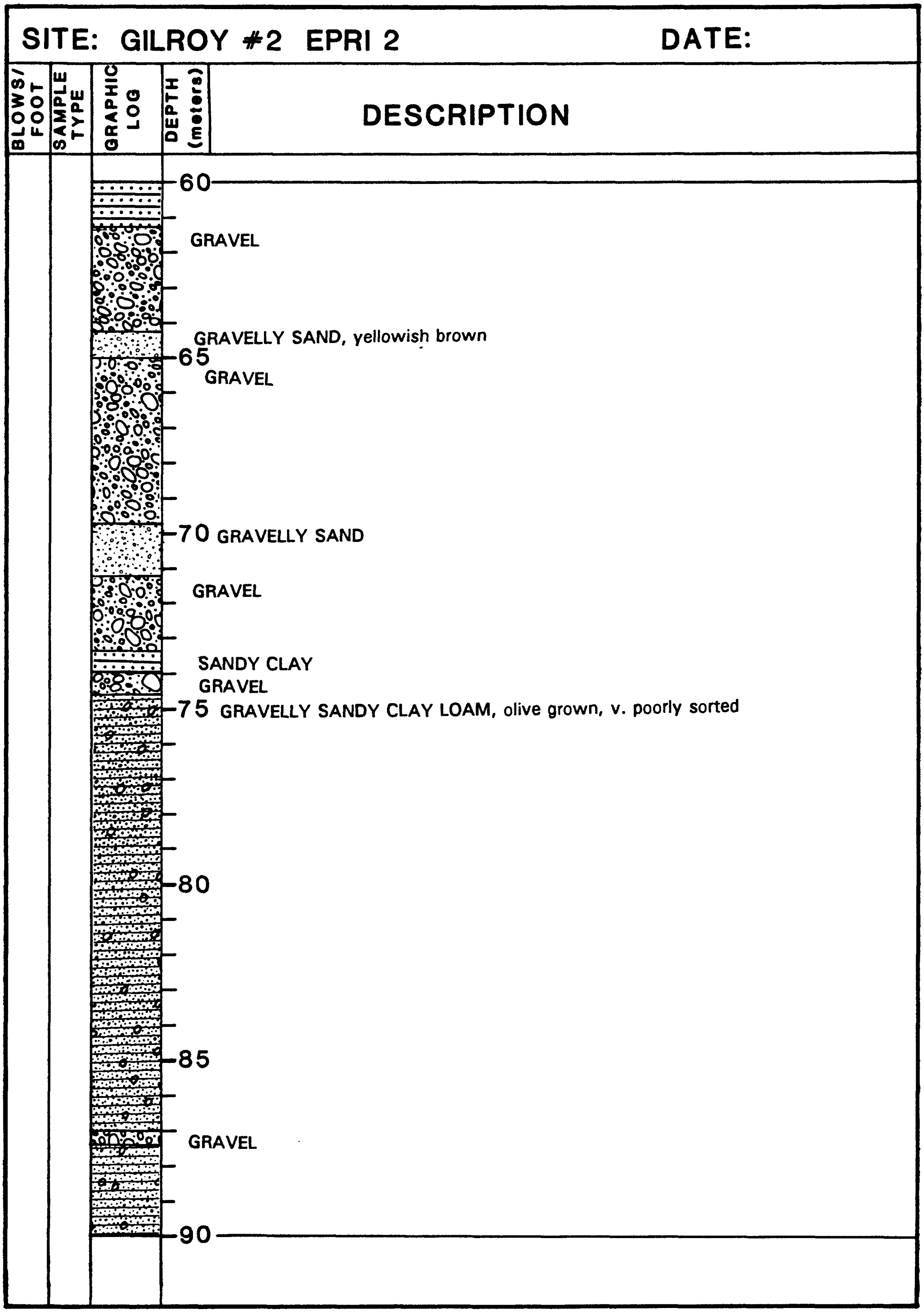


Figure 25. (Continued).

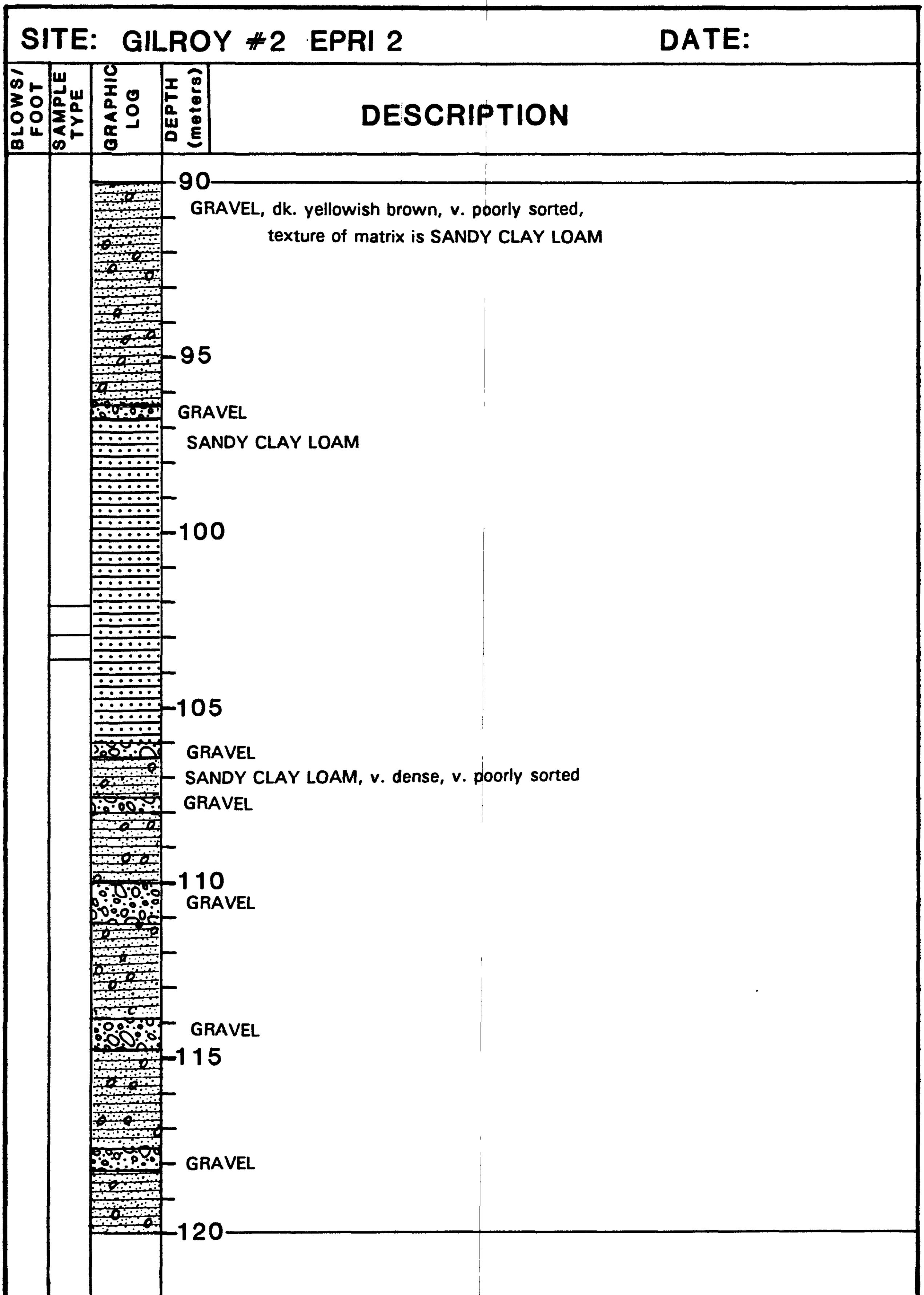


Figure 25. (Continued).

SITE: GILROY #2 EPRI 2 DATE:

BLOWS/ FOOT	SAMPLE TYPE	GRAPHIC LOG	DEPTH (meters)	DESCRIPTION
			120	GRAVELLY SANDY CLAY LOAM, brown, v. dense
			125	
			130	
			135	GRAVEL
			140	
			145	
			150	

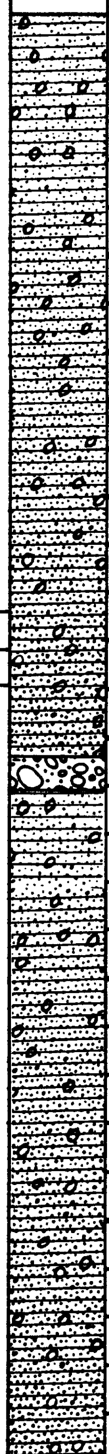


Figure 25. (Continued).

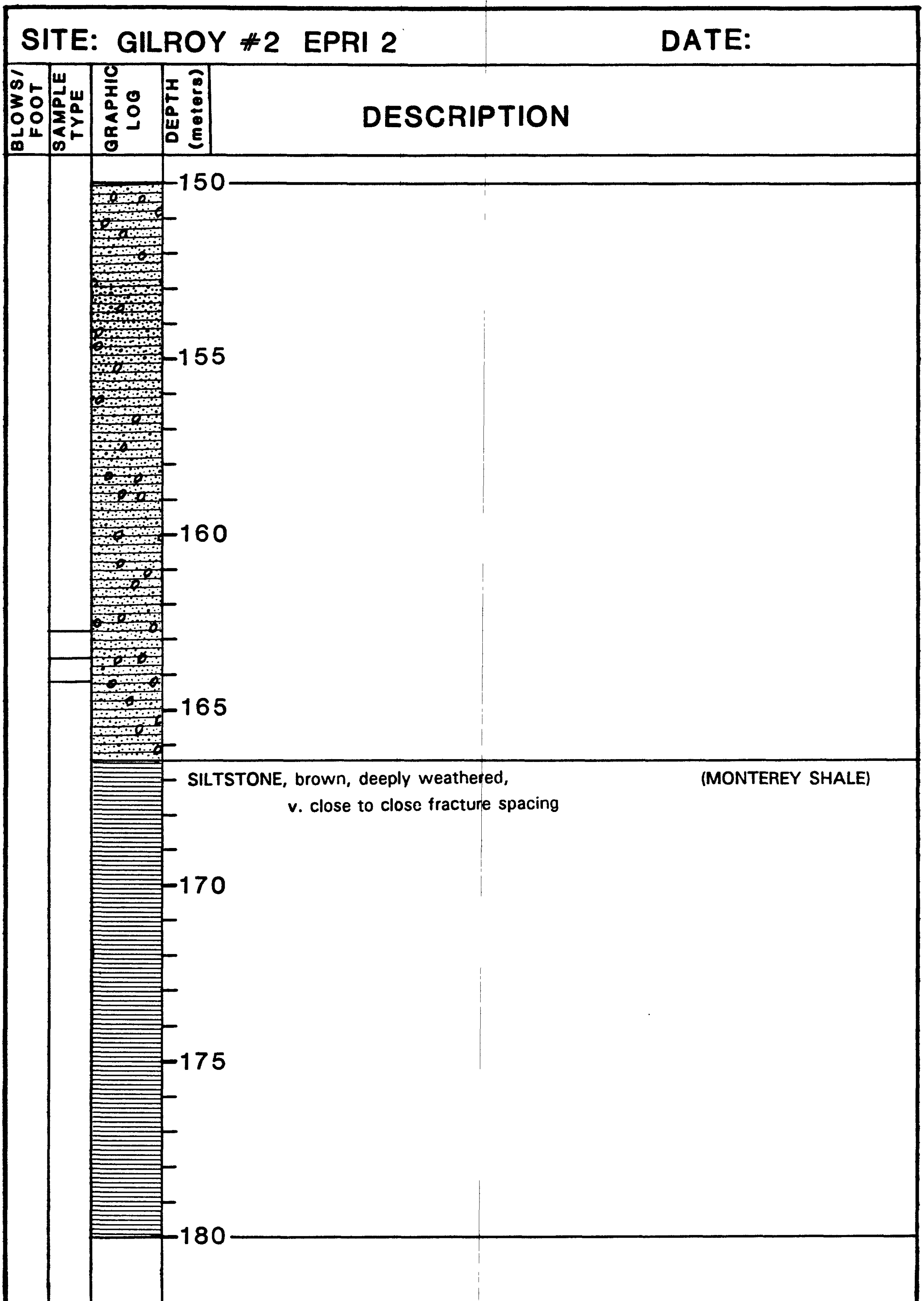


Figure 25. (Continued).

SITE: GILROY #2 EPRI 2				DATE:
BLOWS/ FOOT	SAMPLE TYPE	GRAPHIC LOG	DEPTH (meters)	DESCRIPTION
			180	
				SERPENTINITE, v. dk. greenish gray, sheared, texture is SANDY CLAY Some hard, closely fractured blocks
			185	
			190	
				SHALE, gray, sheared to v. closely fractured
			195	
			200	
			205	
			210	

Figure 25. (Continued).

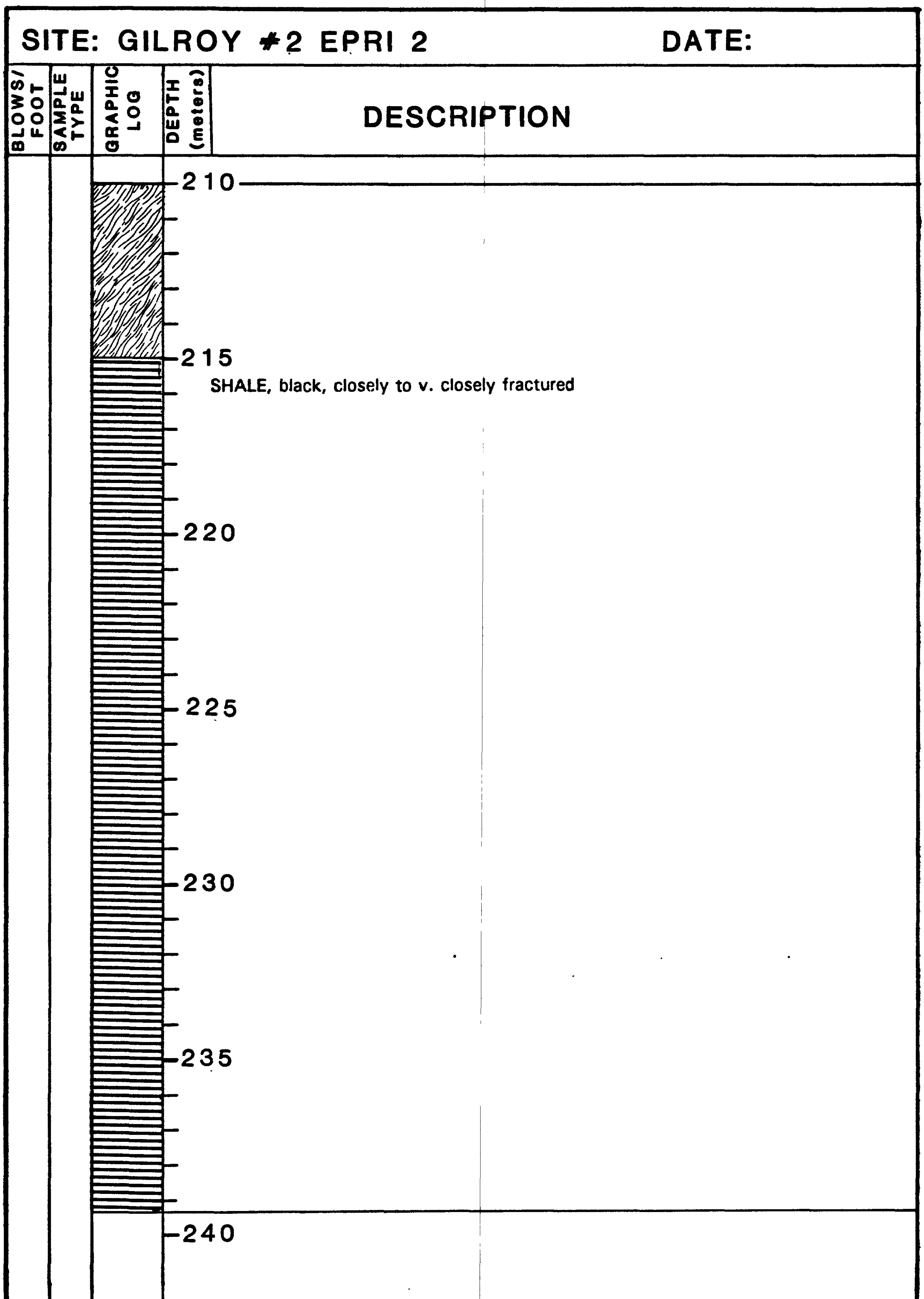


Figure 25. (Continued).

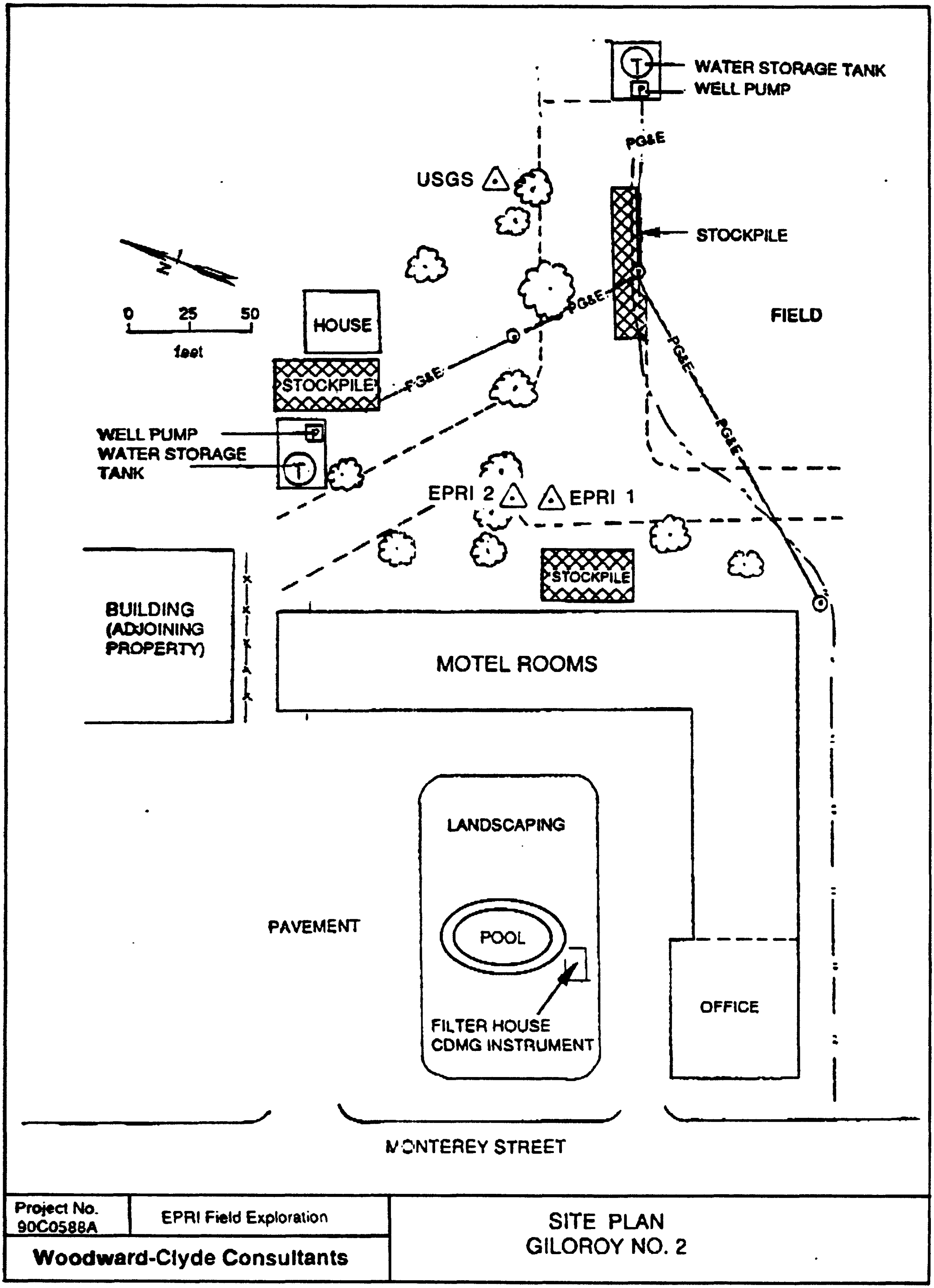


Figure 26. Detailed map showing location of Gilroy #2 (USGS) relative to strong-motion instrument.

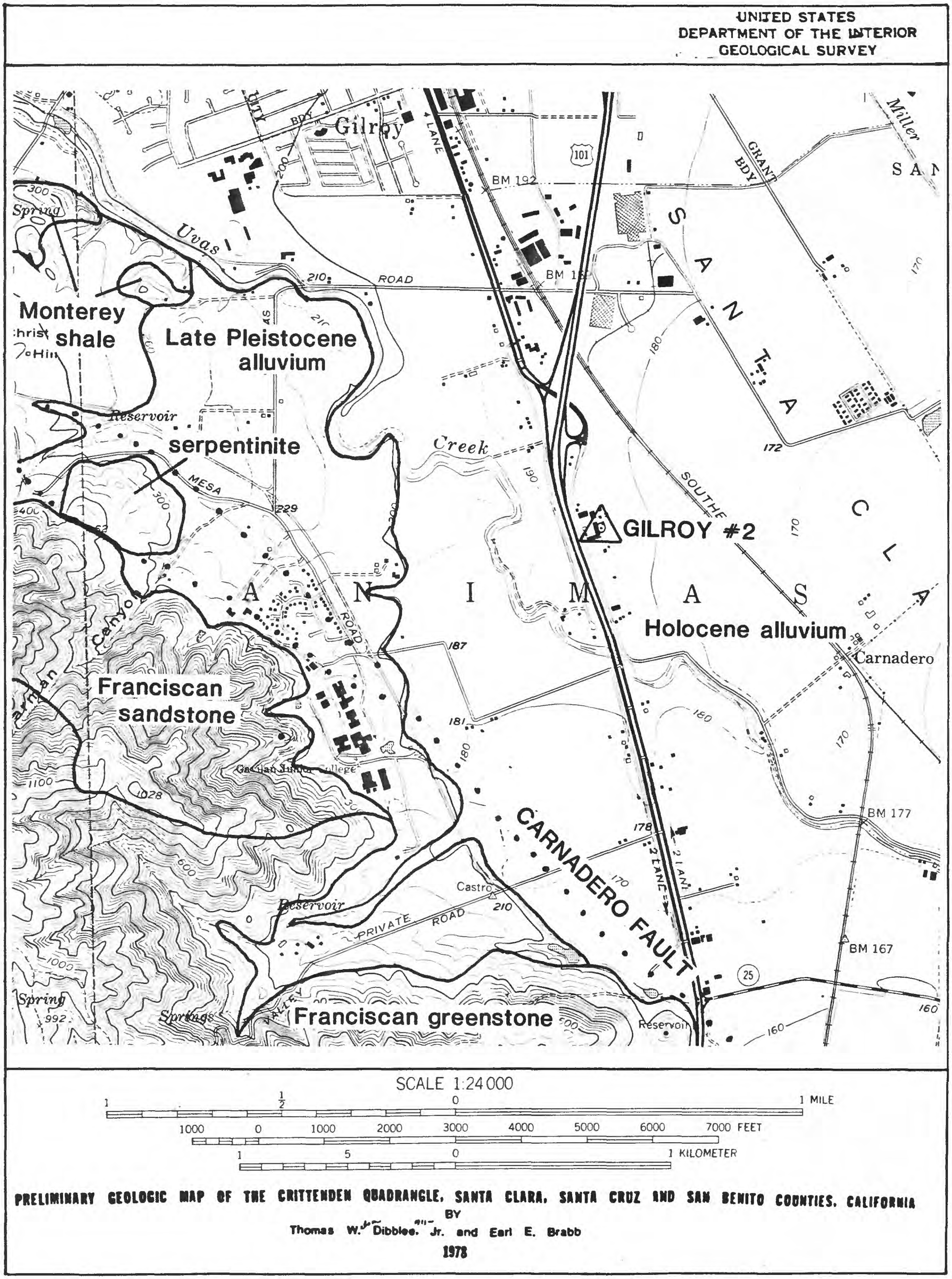


Figure 27. Site location map for Gilroy #2 (USGS).

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)

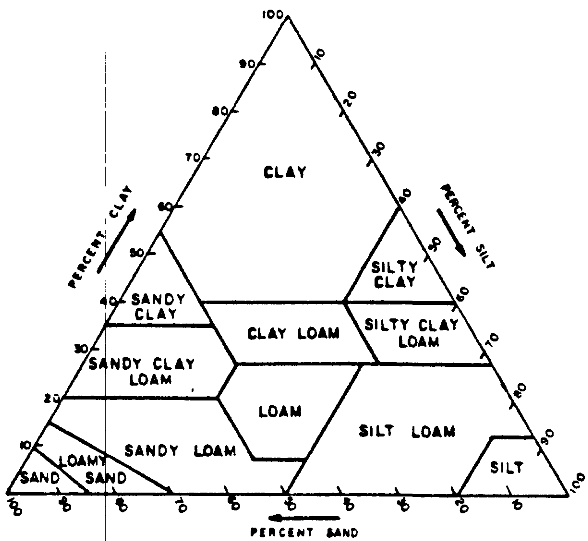
cm	in	fracture spacing
0-1	0-1/2	v. close
1-5	1/2-2	close
5-30	2-12	moderate
30-100	12-36	wide
>100	>36	v. wide

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 28. Explanation of geologic logs.

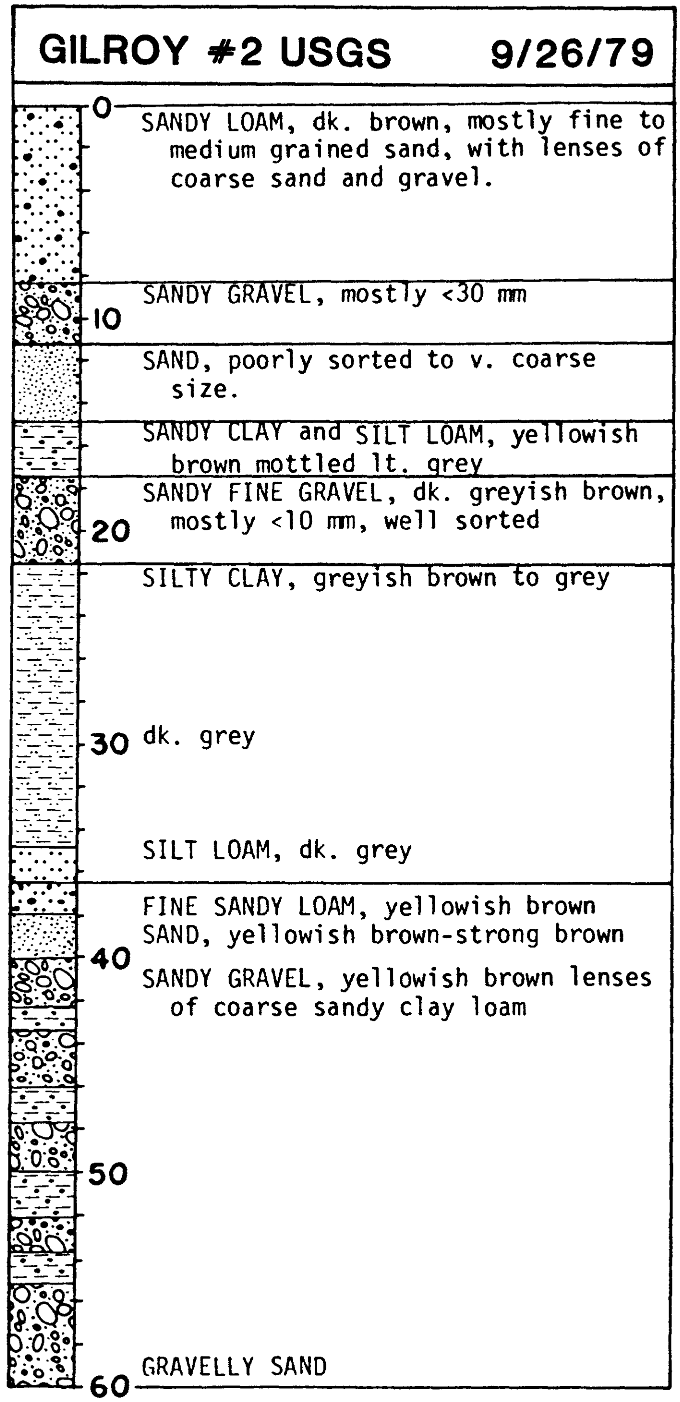


Figure 29. Geologic log of Gilroy #2 (USGS) borehole.

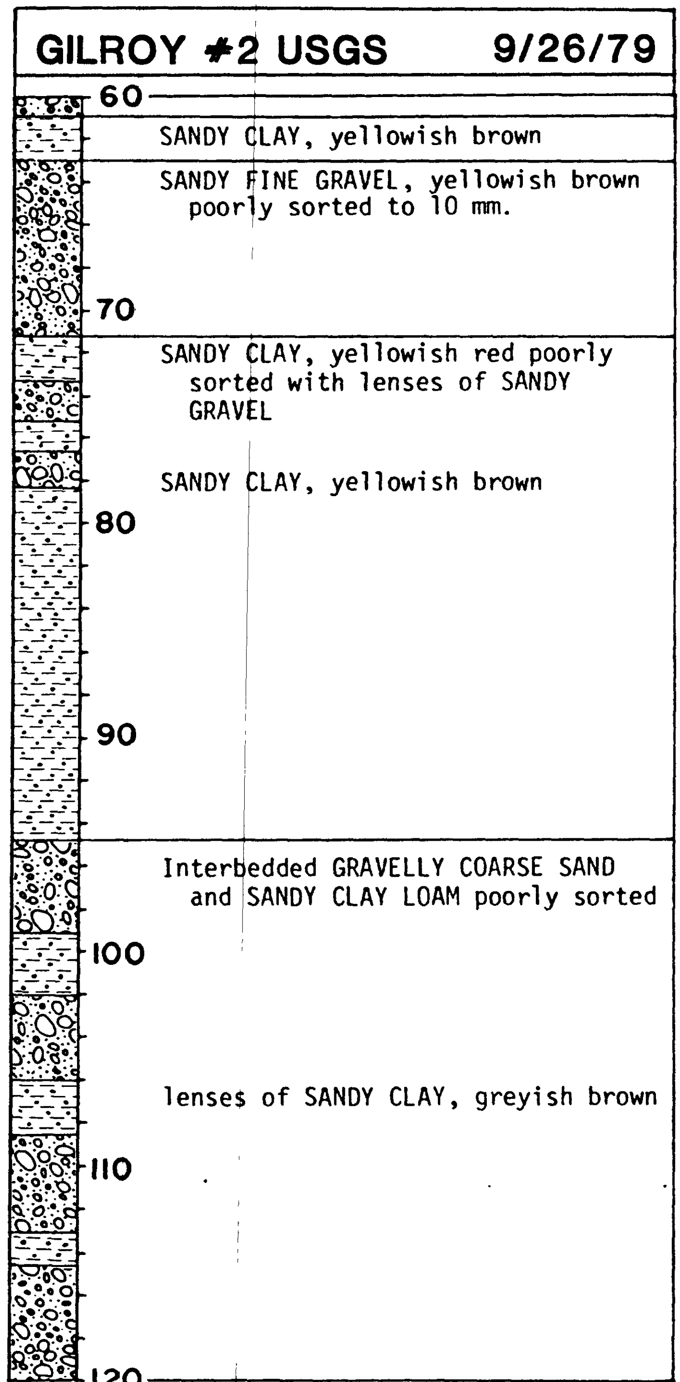


Figure 29. (Continued).

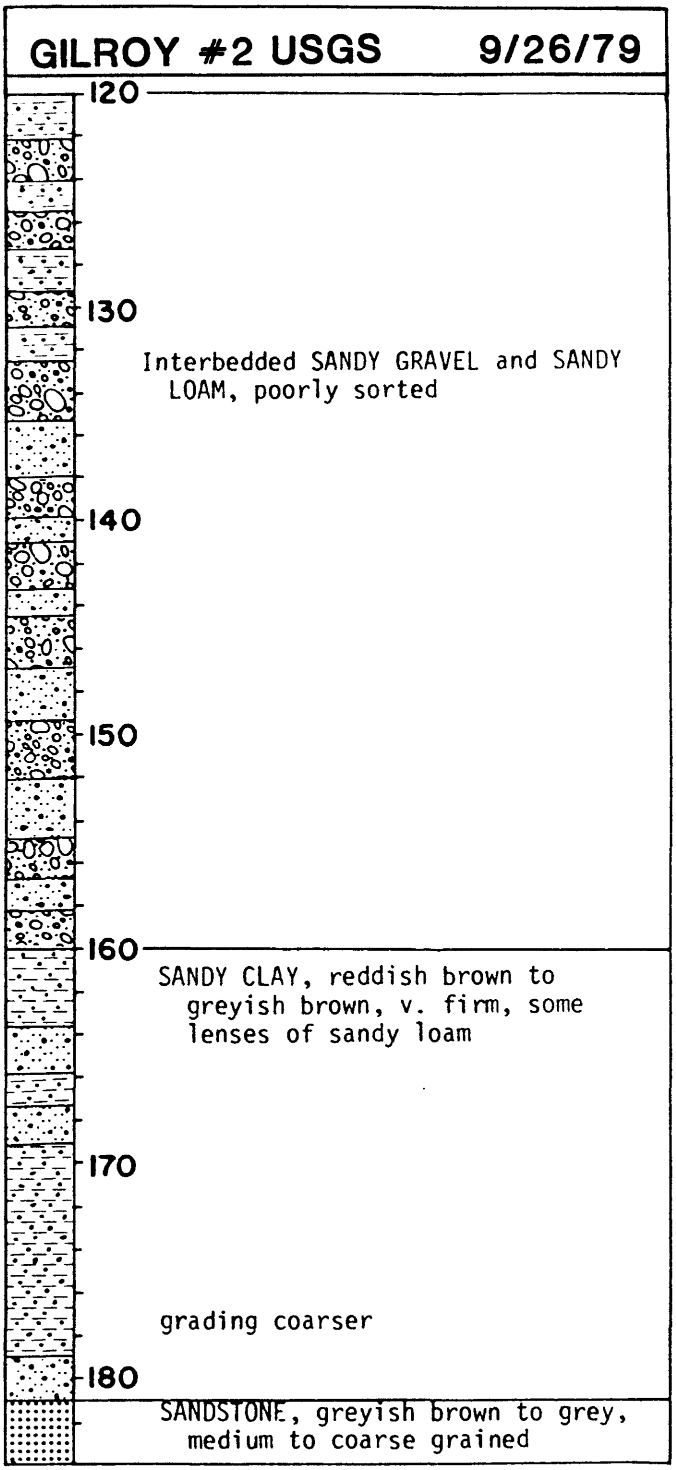


Figure 29. (Continued).

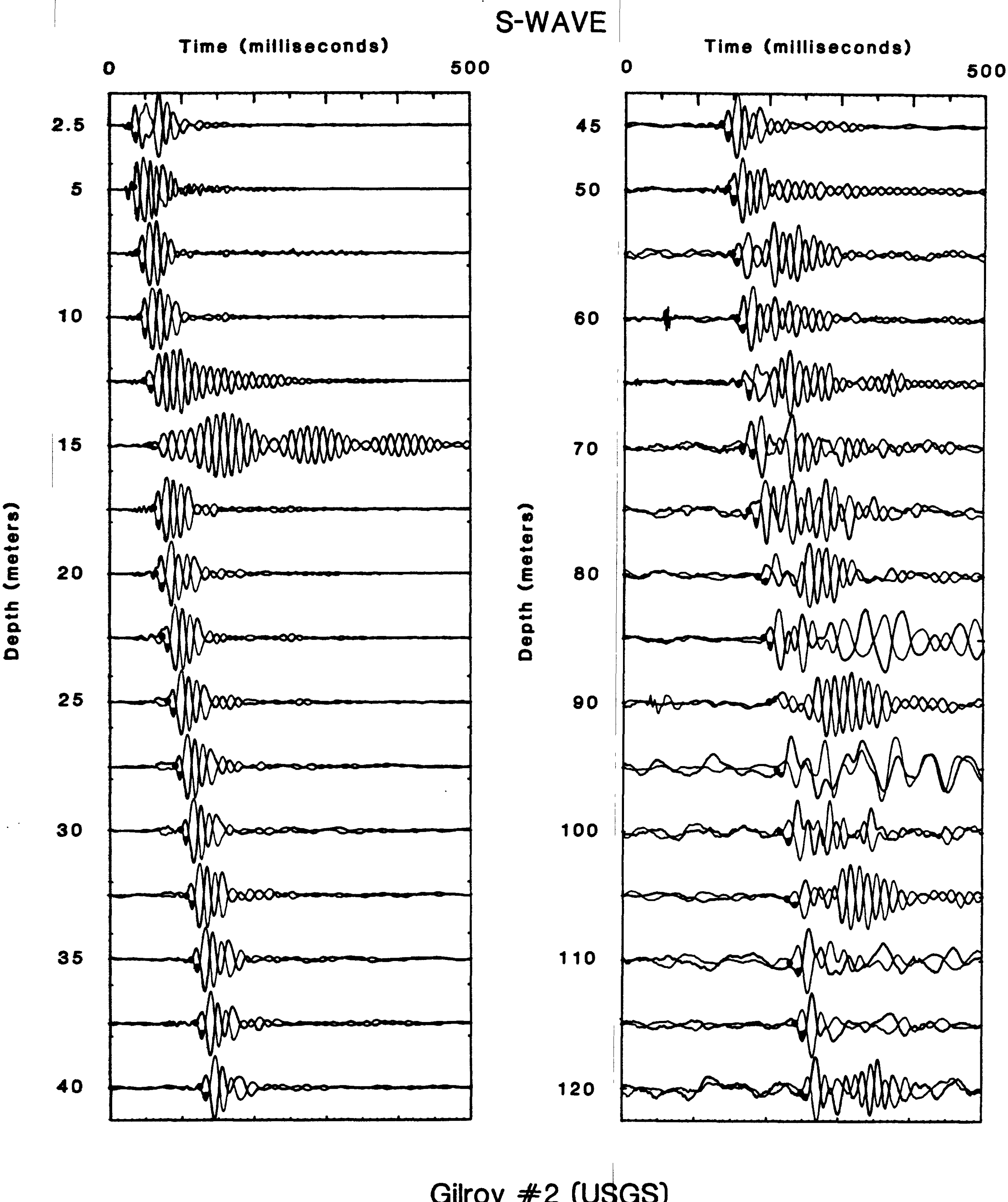


Figure 30. Horizontal-component record section from impacts in opposite horizontal directions superimposed for identification of shear arrivals. Two set of picks are shown, S wave onset (solid circles) and first trough (filled). S-wave onset picks are used for velocity determinations.

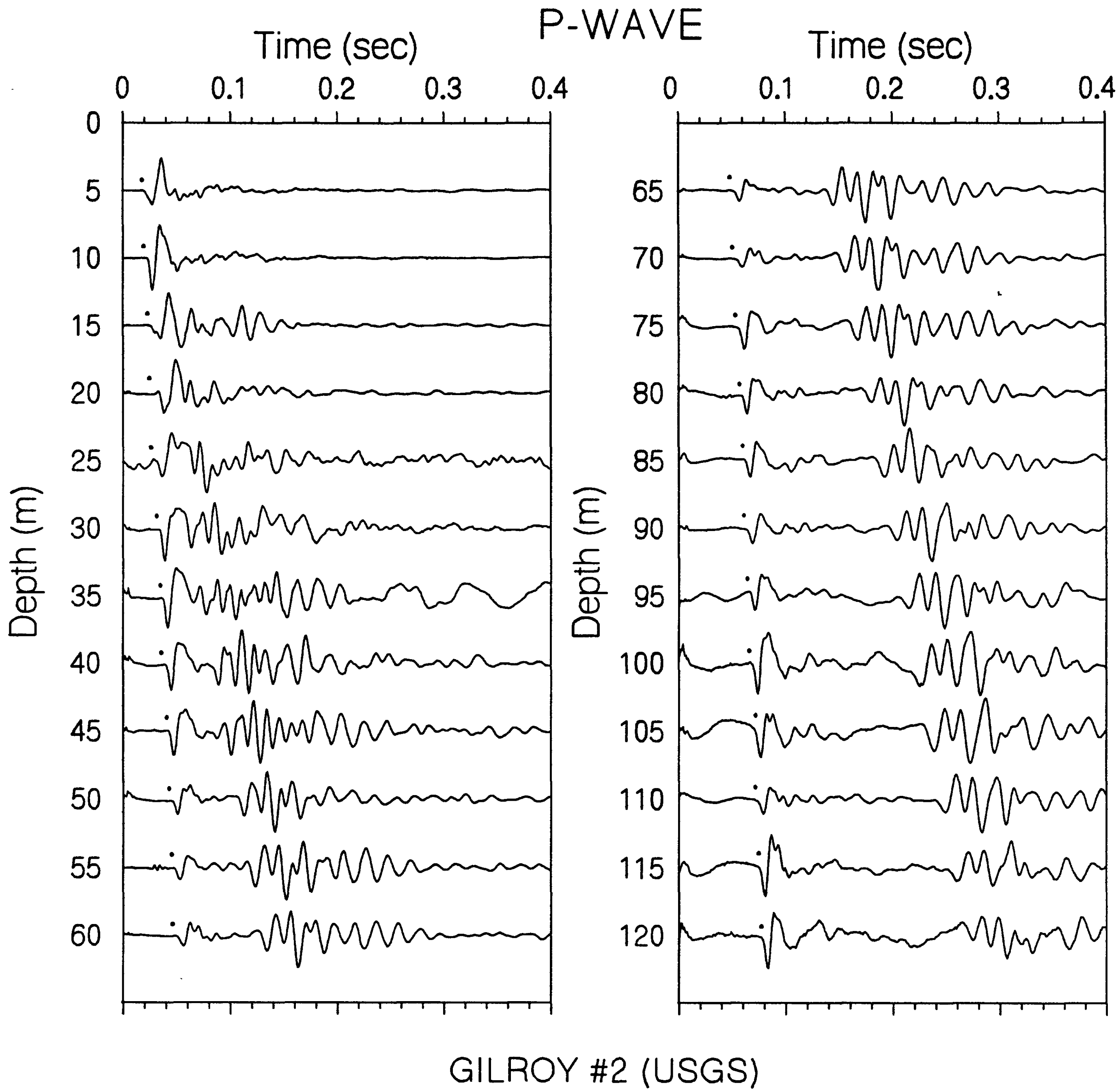


Figure 31. Vertical-component record section. P-wave arrivals are shown by the solid circles. Intermediate traces at 2.5 meter intervals are excluded for clarity.

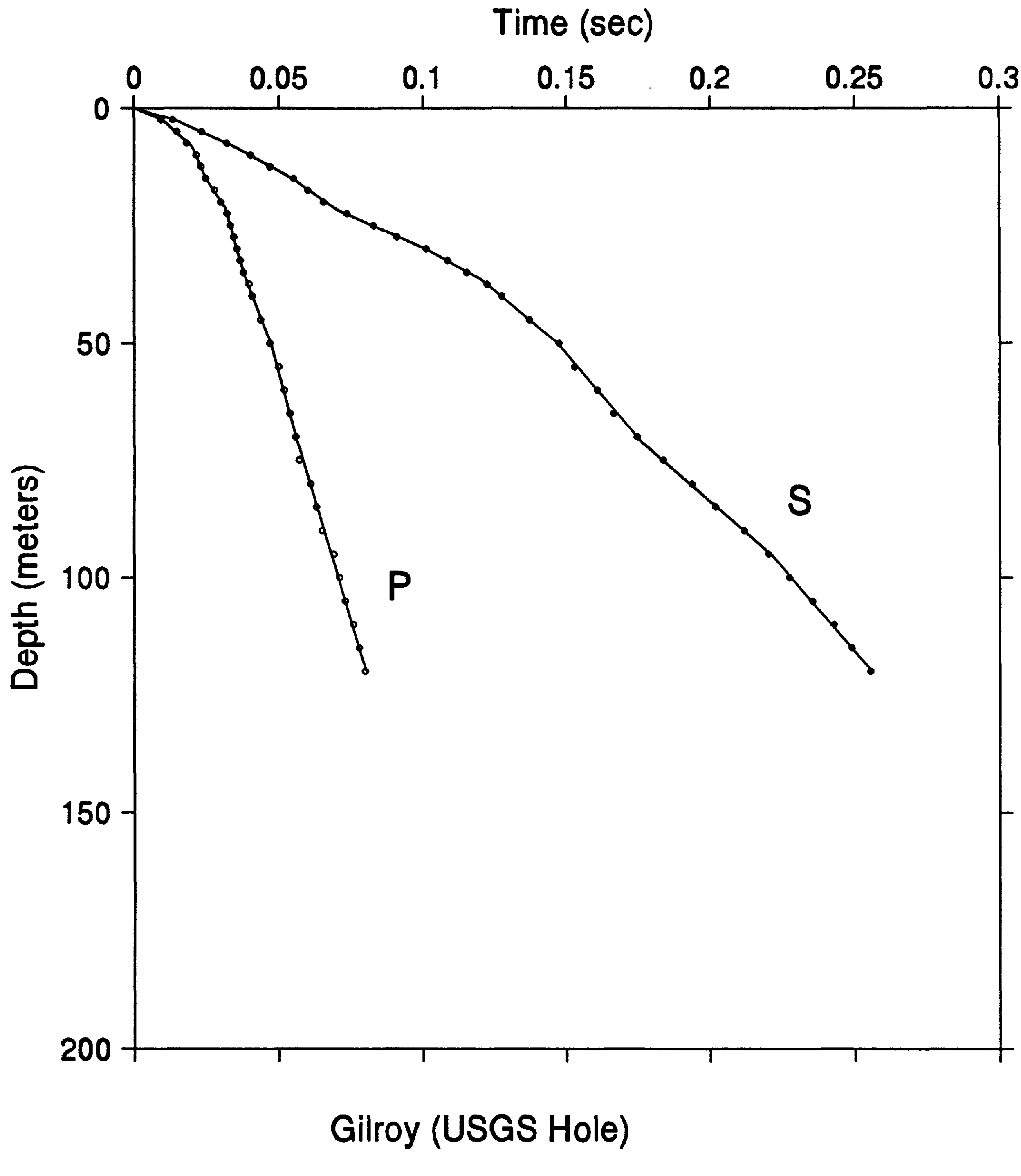


Figure 32. Time-depth graph of P-wave and S-wave picks. Line segments show the hinged-least-squares fit to the data points.

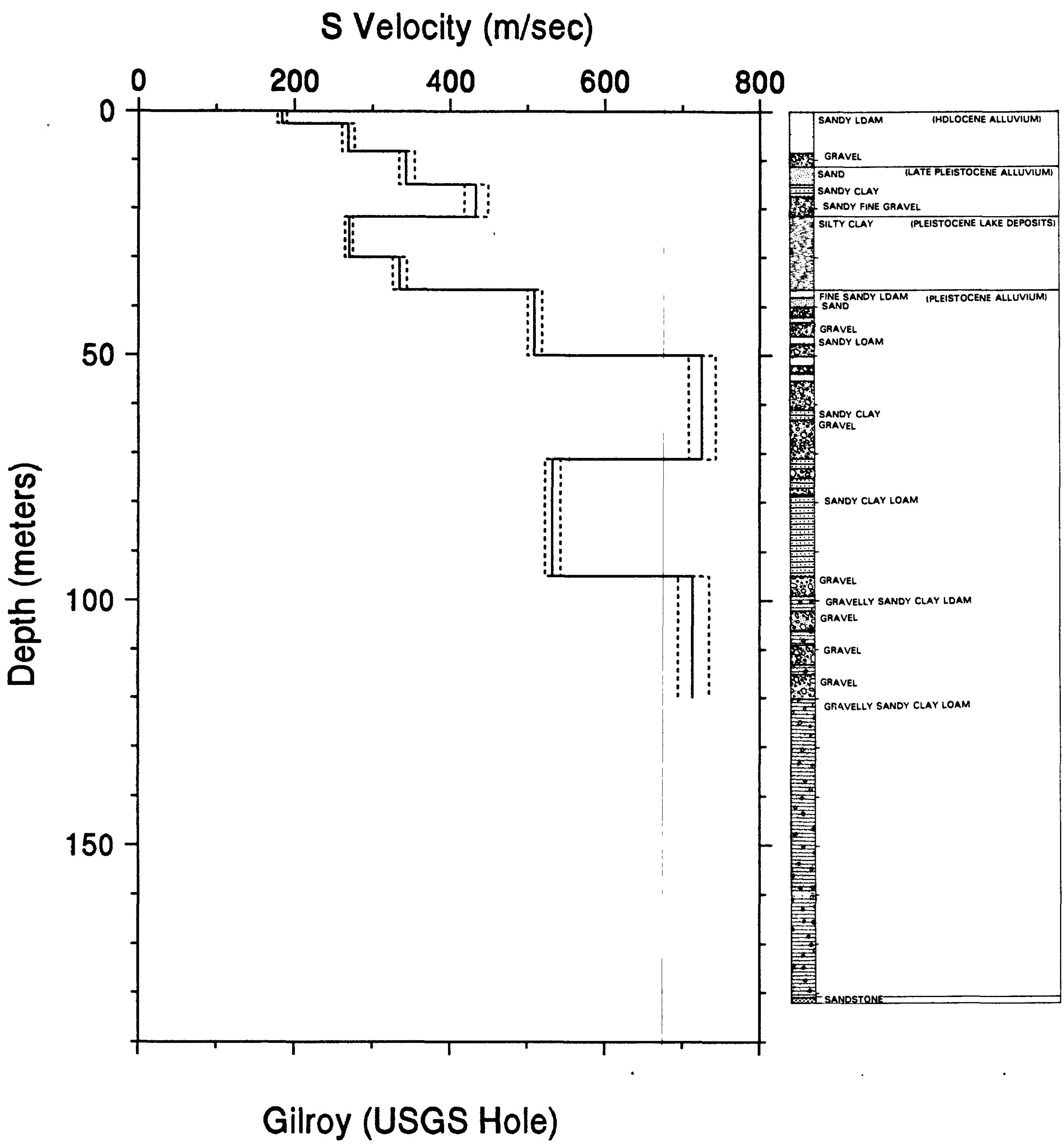
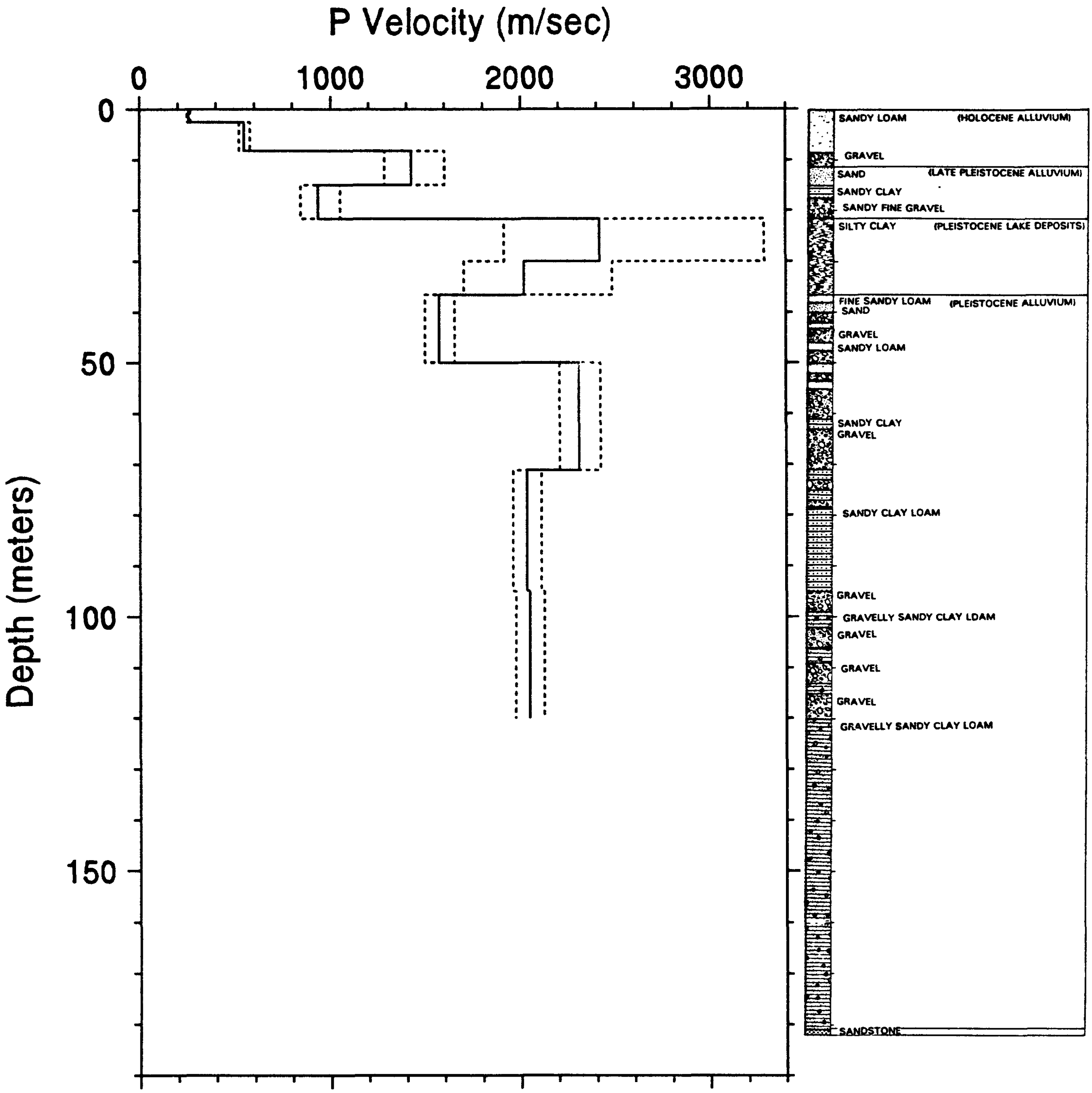


Figure 33. S-wave velocity profiles with dashed lines representing plus and minus one standard deviation. The statistics are done on the slope (reciprocal velocity) so that some of the limits will not appear symmetrical. Simplified geologic log is shown for correlation with velocities.



Gilroy (USGS Hole)

Figure 34. P-wave velocity profiles with dashed lines representing plus and minus one standard deviation. The statistics are done on the slope (reciprocal velocity) so that some of the limits will not appear symmetrical. Simplified geologic log is shown for correlation with velocities.

TABLE 5. S-wave arrival times and velocity summaries for Gilroy #2 (USGS).

d(m)	d(ft)	t(sec)	sig	rsdl/sig
2.5	8.2	.0134	1	-.2
5.0	16.4	.0233	1	.4
7.5	24.6	.0320	1	-.2
10.0	32.8	.0402	1	.2
12.5	41.0	.0469	1	-.4
15.0	49.2	.0551	1	.5
17.5	57.4	.0601	1	-.3
20.0	65.6	.0655	1	-.6
22.5	73.8	.0737	1	.5
25.0	82.0	.0829	1	.5
27.5	90.2	.0910	1	-.7
30.0	98.4	.1011	1	.2
32.5	106.6	.1087	1	.3
35.0	114.8	.1153	1	-.6
37.5	123.0	.1224	1	.1
40.0	131.2	.1275	1	.3
45.0	147.6	.1371	1	.1
50.0	164.0	.1473	1	.5
55.0	180.4	.1529	1	-.8
60.0	196.9	.1609	1	.3
65.0	213.3	.1665	2	-.5
70.0	229.7	.1746	2	.1
75.0	246.1	.1836	2	.2
80.0	262.5	.1936	2	.5
85.0	278.9	.2017	2	-.2
90.0	295.3	.2117	2	.2
95.0	311.7	.2202	2	-.3
100.0	328.1	.2272	2	-.3
105.0	344.5	.2352	2	.2
110.0	360.9	.2427	2	.4
115.0	377.3	.2488	2	.0
120.0	393.7	.2553	2	-.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	184	178	190	603	585	622
2.5	8.2	.014	184	178	190	603	585	622
8.2	26.9	.035	269	261	277	883	857	910
15.0	49.2	.055	343	334	354	1127	1094	1161
21.6	70.9	.070	433	418	449	1421	1371	1475
30.0	98.4	.101	270	265	275	886	870	902
36.5	119.8	.120	335	326	344	1099	1070	1128
50.0	164.0	.147	509	500	519	1671	1640	1704
71.2	233.6	.176	725	708	743	2379	2323	2438
95.0	311.7	.221	532	523	543	1747	1714	1780
120.0	393.7	.256	713	694	734	2340	2277	2407

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 Gilroy #2 (USGS).

d(m)	d(ft)	t(sec)	sig	rsdl/sig
2.5	8.2	.0094	1	-.3
5.0	16.4	.0148	1	.6
7.5	24.6	.0183	1	-.5
10.0	32.8	.0215	1	.2
12.5	41.0	.0232	1	.1
15.0	49.2	.0247	1	-.1
17.5	57.4	.0279	5	.1
20.0	65.6	.0301	5	.0
22.5	73.8	.0322	2	.0
25.0	82.0	.0333	2	.0
27.5	90.2	.0344	2	.0
30.0	98.4	.0355	2	.1
32.5	106.6	.0366	1	.0
35.0	114.8	.0376	1	-.2
37.5	123.0	.0396	1	.4
40.0	131.2	.0407	1	-.1
45.0	147.6	.0437	1	-.3
50.0	164.0	.0468	1	-.4
55.0	180.4	.0498	1	.5
60.0	196.9	.0518	1	.3
65.0	213.3	.0538	1	.1
70.0	229.7	.0559	1	.1
75.0	246.1	.0569	2	-.7
80.0	262.5	.0609	1	.2
85.0	278.9	.0629	1	-.3
90.0	295.3	.0649	1	-.7
95.0	311.7	.0689	2	.4
100.0	328.1	.0709	1	.4
105.0	344.5	.0729	1	-.1
110.0	360.9	.0759	1	.5
115.0	377.3	.0779	1	.1
120.0	393.7	.0799	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	259	250	268	849	820	880
2.5	8.2	.010	259	250	268	849	820	880
8.2	26.9	.020	548	522	577	1798	1712	1894
15.0	49.2	.025	1426	1285	1601	4677	4217	5251
21.6	70.9	.032	936	844	1051	3072	2771	3448
30.0	98.4	.035	2417	1912	3285	7930	6273	10777
36.5	119.8	.039	2019	1702	2482	6624	5583	8143
50.0	164.0	.047	1570	1497	1652	5152	4910	5419
71.2	233.6	.056	2308	2205	2422	7573	7234	7946
95.0	311.7	.068	2031	1959	2109	6663	6426	6918
120.0	393.7	.080	2046	1974	2124	6714	6477	6970

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

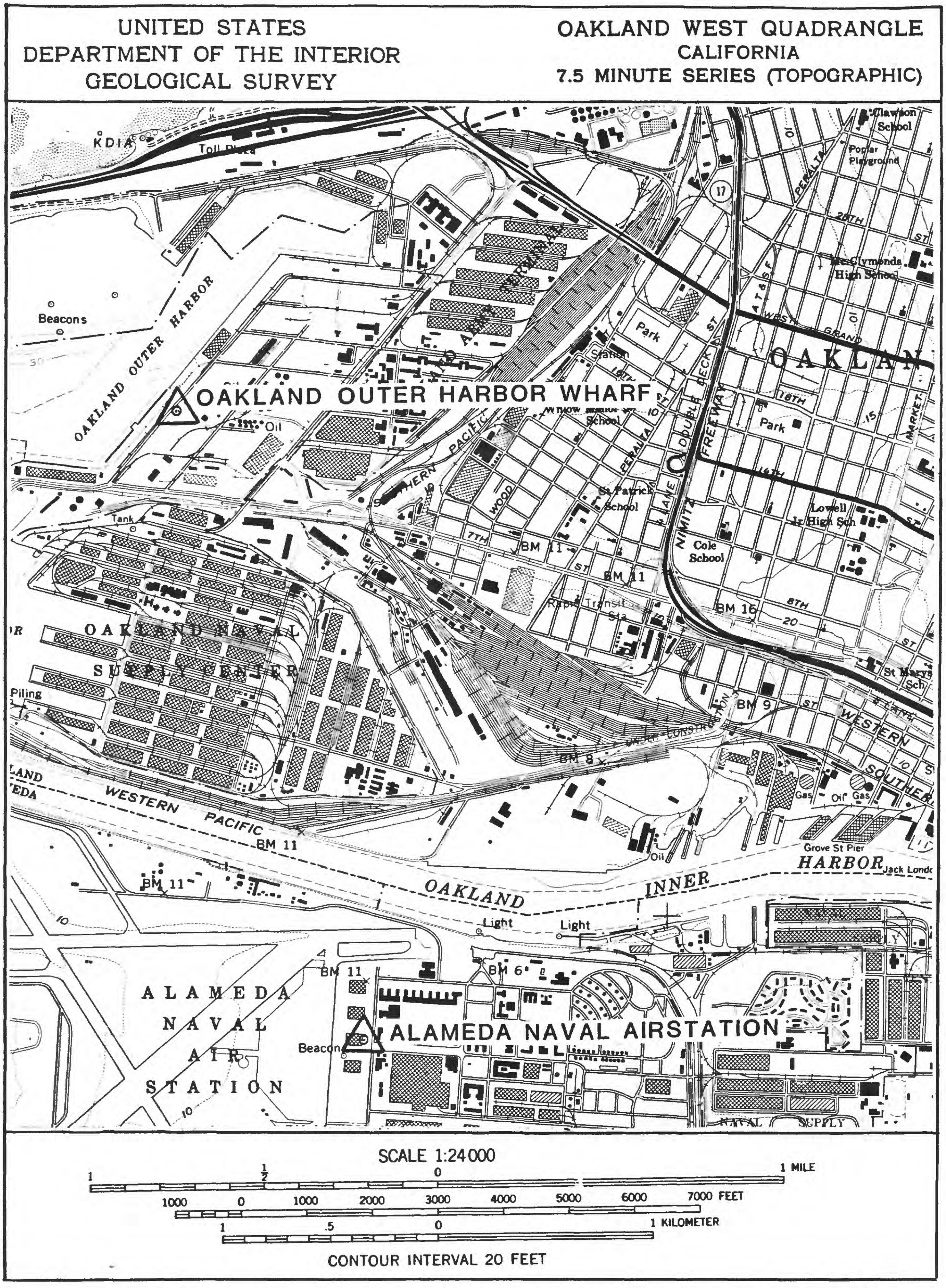


Figure 35. Site location map for Oakland Outer Harbor Wharf (this is the same as Figure 7). The borehole is within 15 meters of the strong-motion recorder.

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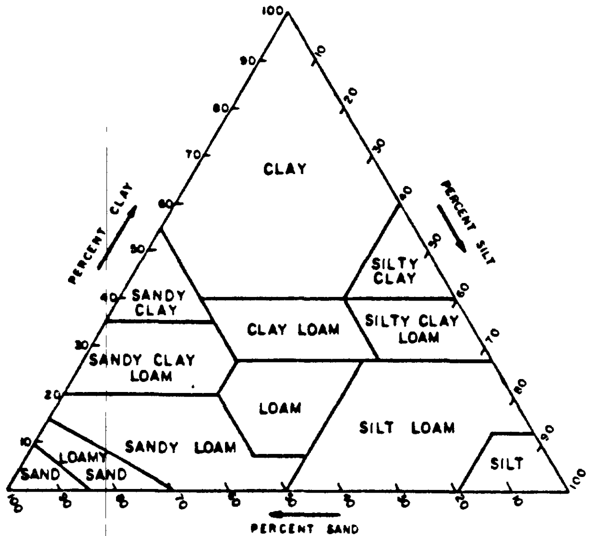
Relative density of sand and consistency of clay is correlated with penetration resistance: (Terzaghi and Peck, 1948)

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 36. Explanation of geologic logs.

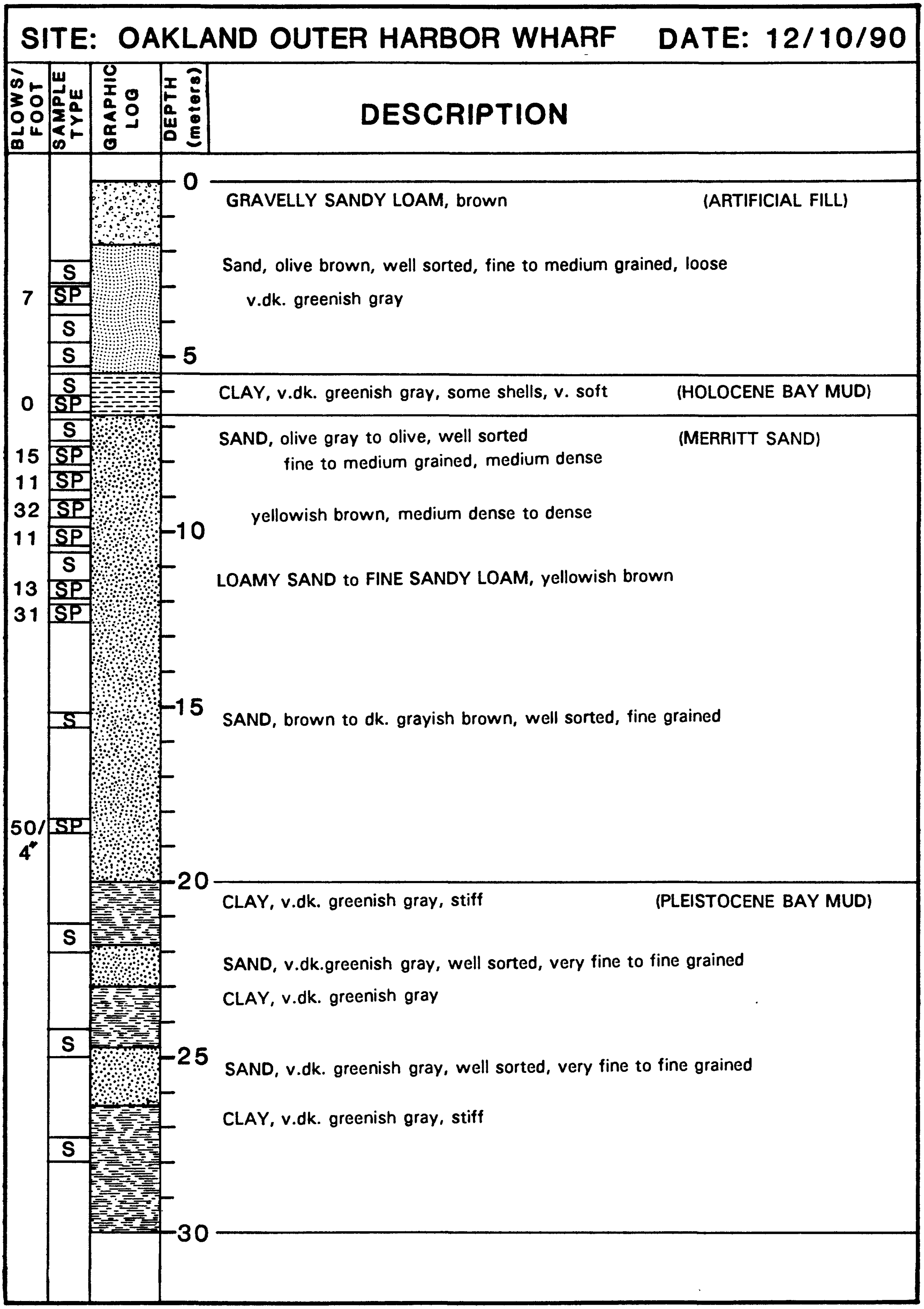


Figure 37. Geologic log for Oakland Outer Harbor Wharf.

SITE: OAKLAND OUTER HARBOR WHARF DATE:

BLOWS/ FOOT	SAMPLE TYPE	GRAPHIC LOG	DEPTH (meters)	DESCRIPTION
			30	
0	SP			
	S			
			35	
	S		40	
				SAND, v.dk. greenish gray
			45	
	S			
			50	GRAVELLY SAND, v. dense
				CLAY to SANDY CLAY LOAM, v.dk. greenish gray
	S			
			55	
			60	

Figure 37. (Continued).

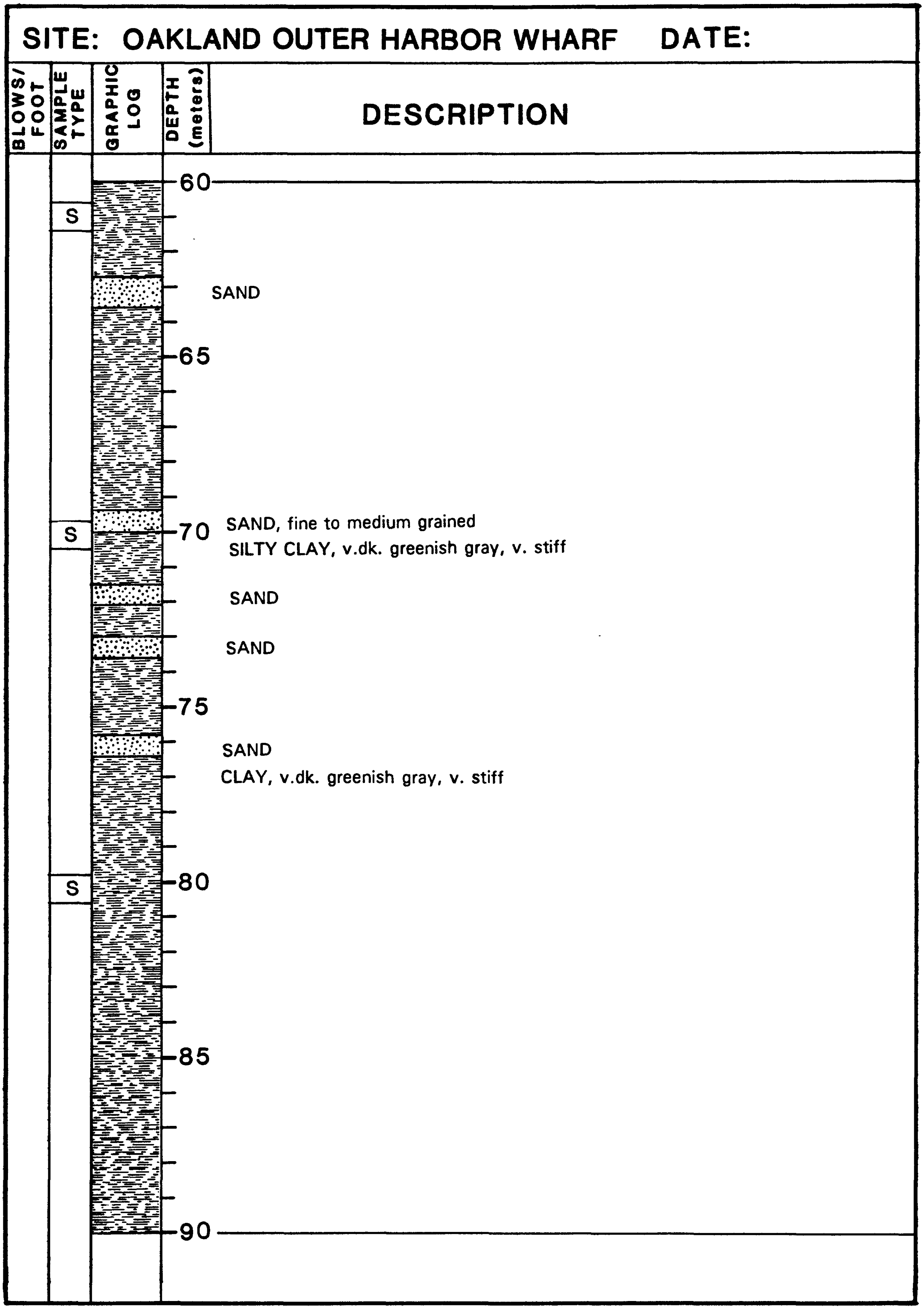


Figure 37. (Continued).

SITE: OAKLAND OUTER HARBOR WHARF DATE:

BLOWS/FOOT	SAMPLE TYPE	DEPTH (meters)	DESCRIPTION
		90	
	S		SAND, dk. greenish gray, v. fine to fine grained, v. dense
		95	
			SANDY CLAY LOAM, yellowish brown
			GRAVEL, pale brown to brown, siliceous shale fragments
			CLAY, dk. grayish brown, hard
		100	dk. greenish gray
			FINE GRAVELLY SANDY LOAM, brown, v. noorly sorted, [illegible] pale brown siliceous shale, dense
	P	105	
			SILTY CLAY, olive gray
		110	
			LOAMY SAND to SAND, brownish yellow, some fine gravel
		115	
			CLAY, dk. greenish gray, mottled greenish gray
	P		
		120	

Figure 37. (Continued).

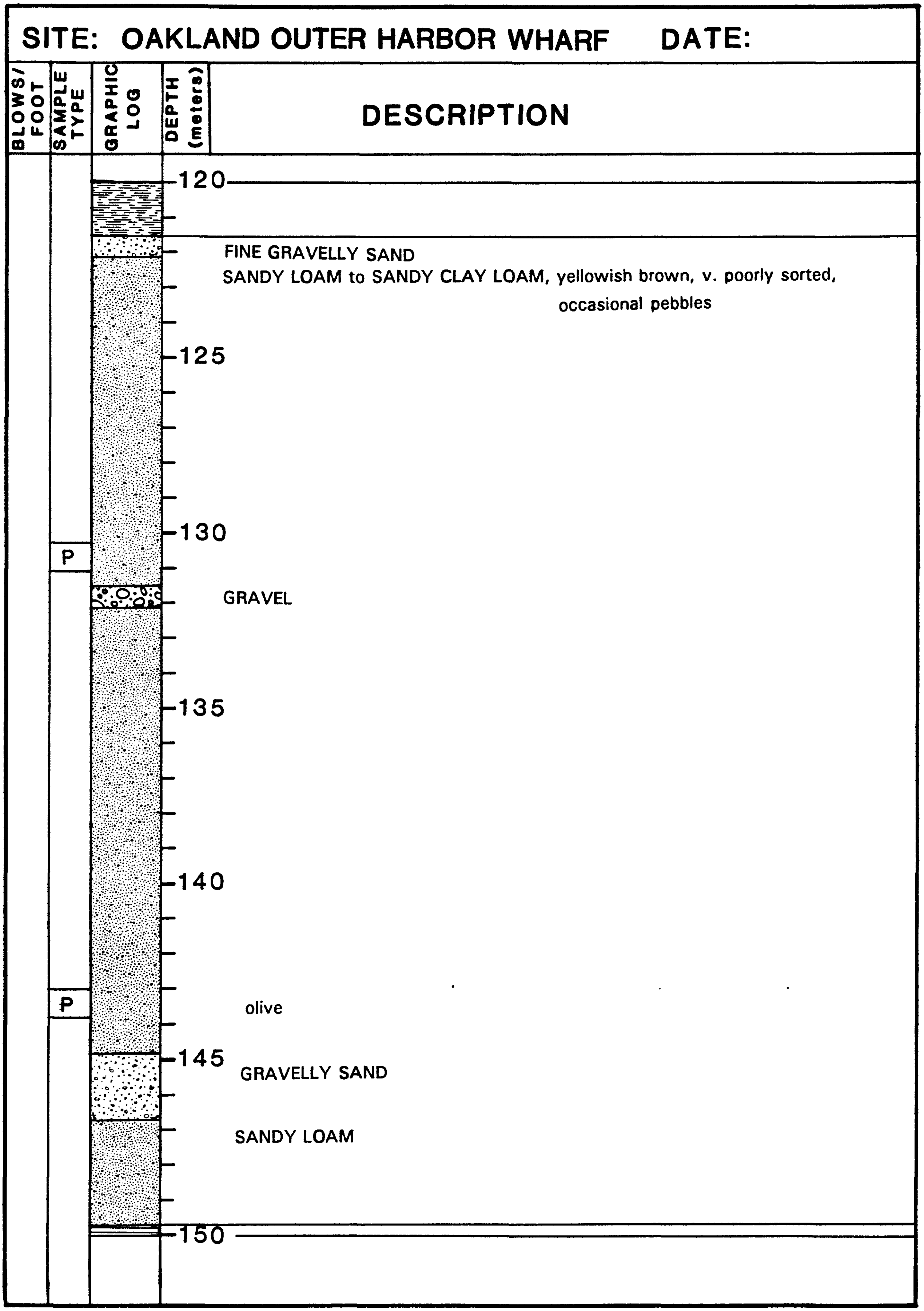


Figure 37. (Continued).

SITE: OAKLAND OUTER HARBOR WHARF **DATE:**

BLOWS/ FOOT	SAMPLE TYPE	GRAPHIC LOG	DEPTH (meters)	DESCRIPTION
			150	SHALE, dk. grayish brown, moderatley weathered (FRANCISCAN ASSEMBLAGE) black, fresh
			155	SANDSTONE, dk. gray, hard, some black SHALE
			160	
			165	
	DC			
			170	
			175	
			180	

Figure 37. (Continued).

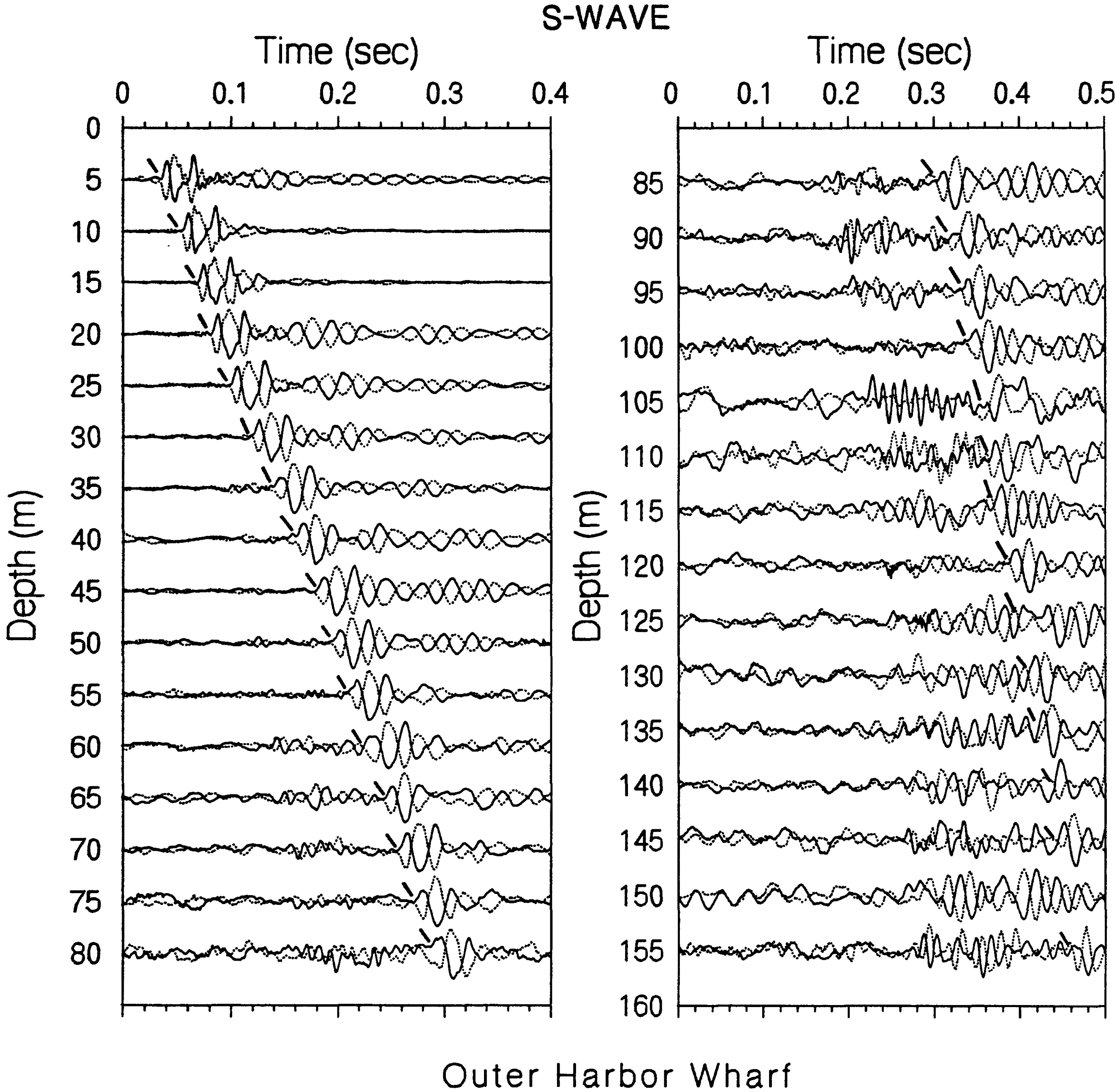


Figure 38. Horizontal-component record section from impacts in opposite horizontal directions superimposed for identification of shear arrivals. S-wave arrivals are shown by the accent marks.

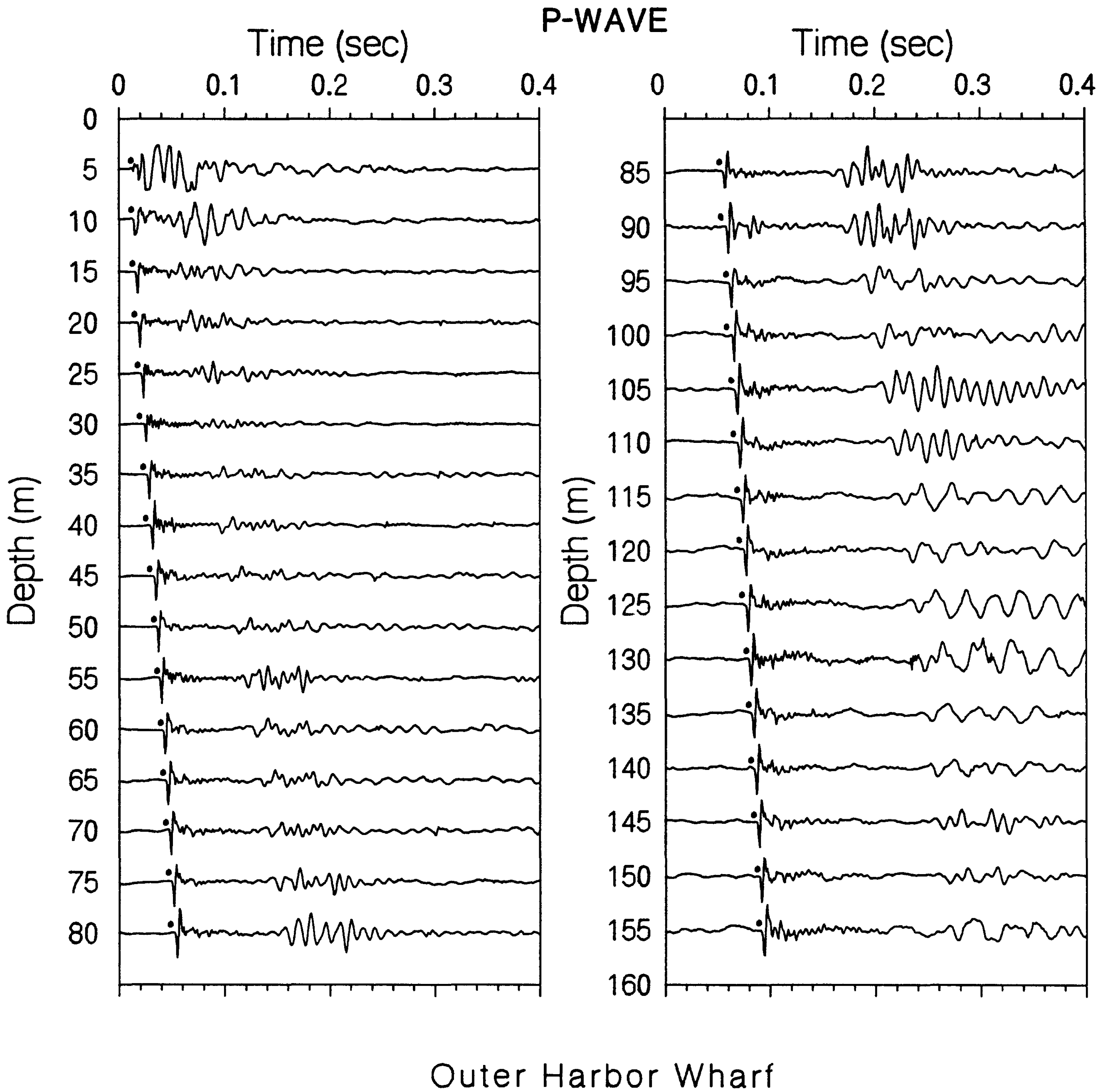
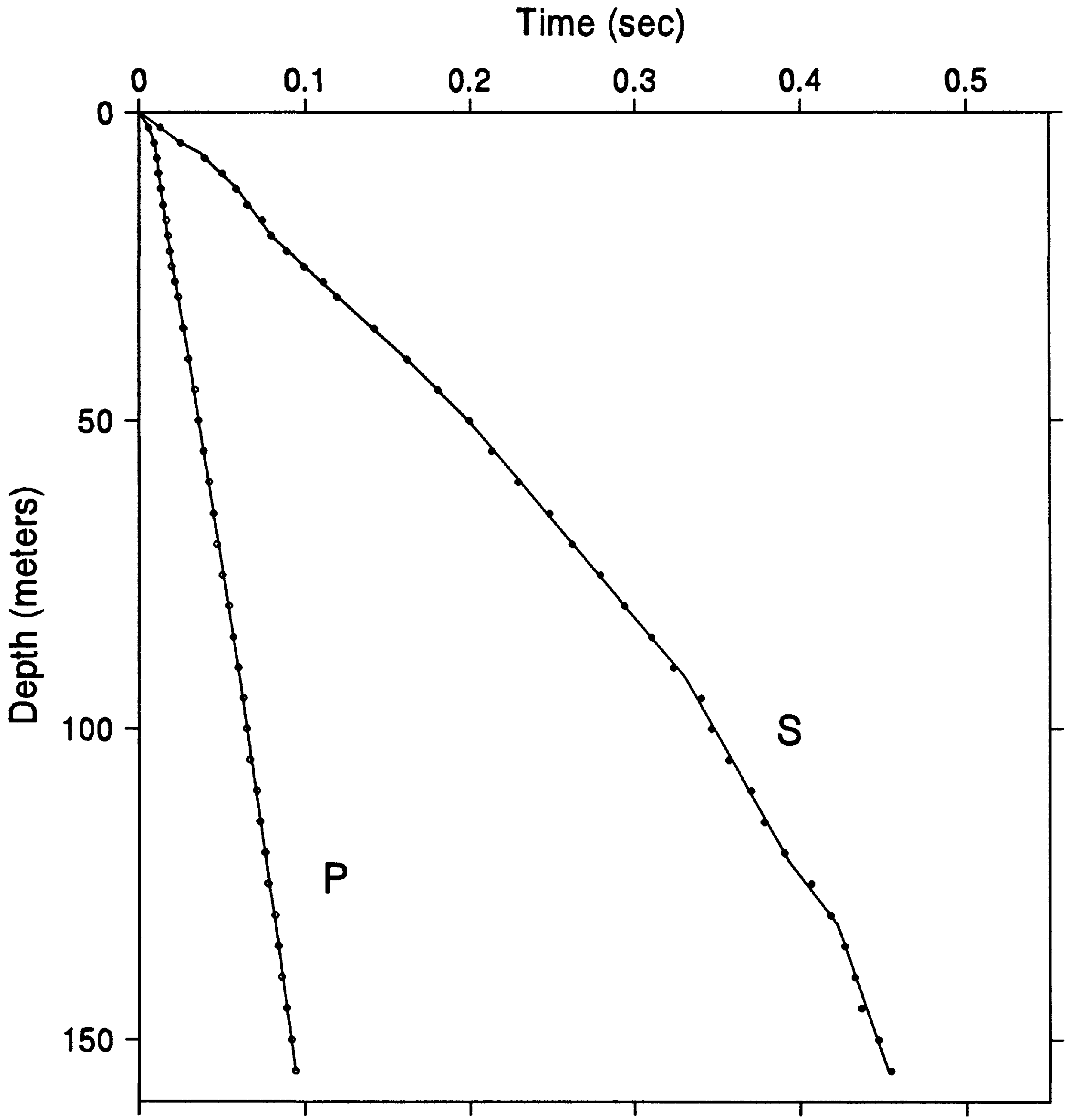
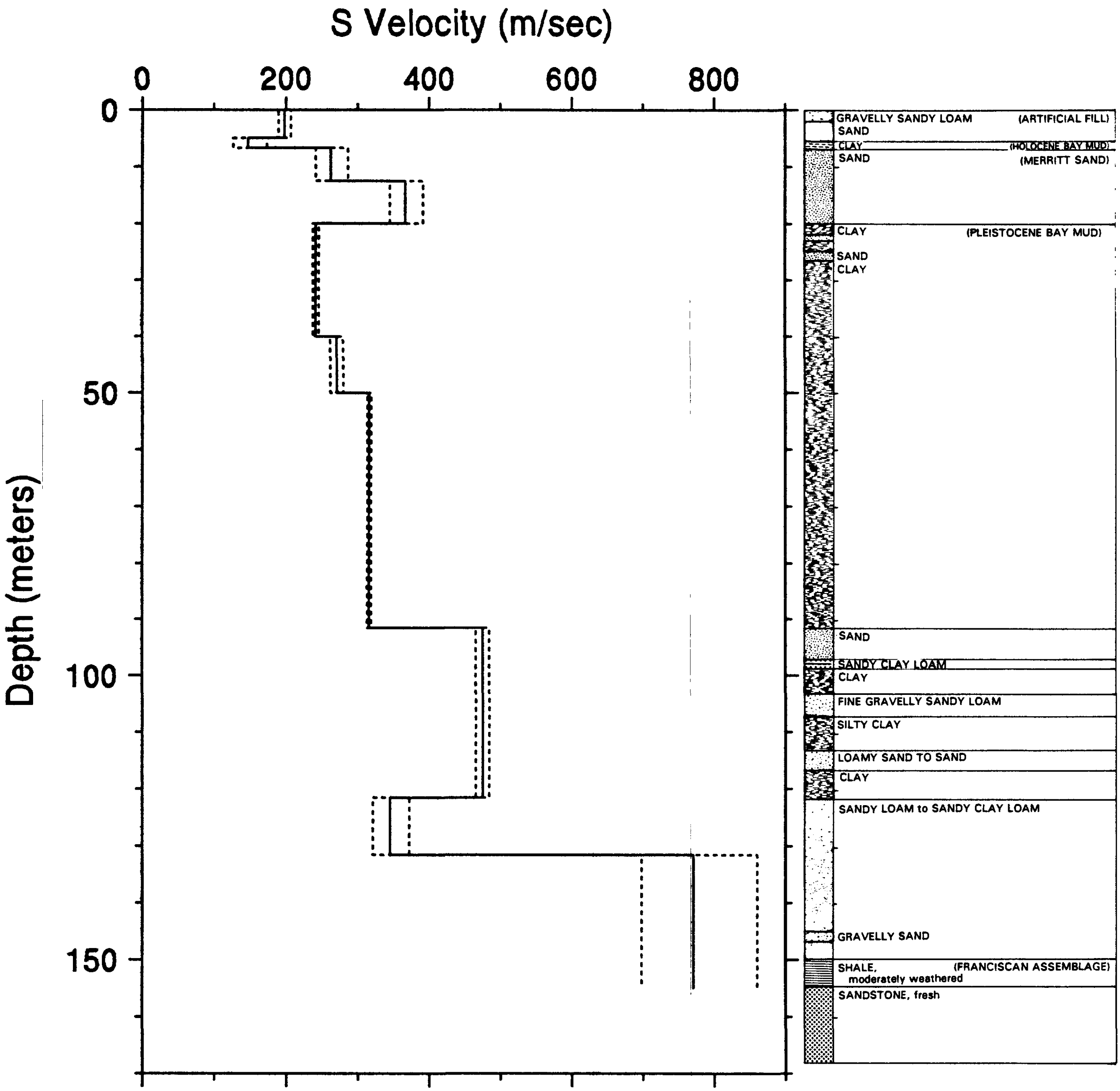


Figure 39. Vertical-component record section. P-wave arrivals are shown by the solid circles.



Outer Harbor Wharf

Figure 40. Time-depth graph of P-wave and S-wave picks. Line segments show the hinged-least-squares fit to the data points.



Oakland Outer Harbor Wharf

Figure 41. S-wave velocity profiles with dashed lines representing plus and minus one standard deviation. The statistics are done on the slope (reciprocal velocity) so that some of the limits will not appear symmetrical. Simplified geologic log is shown for correlation with velocities.

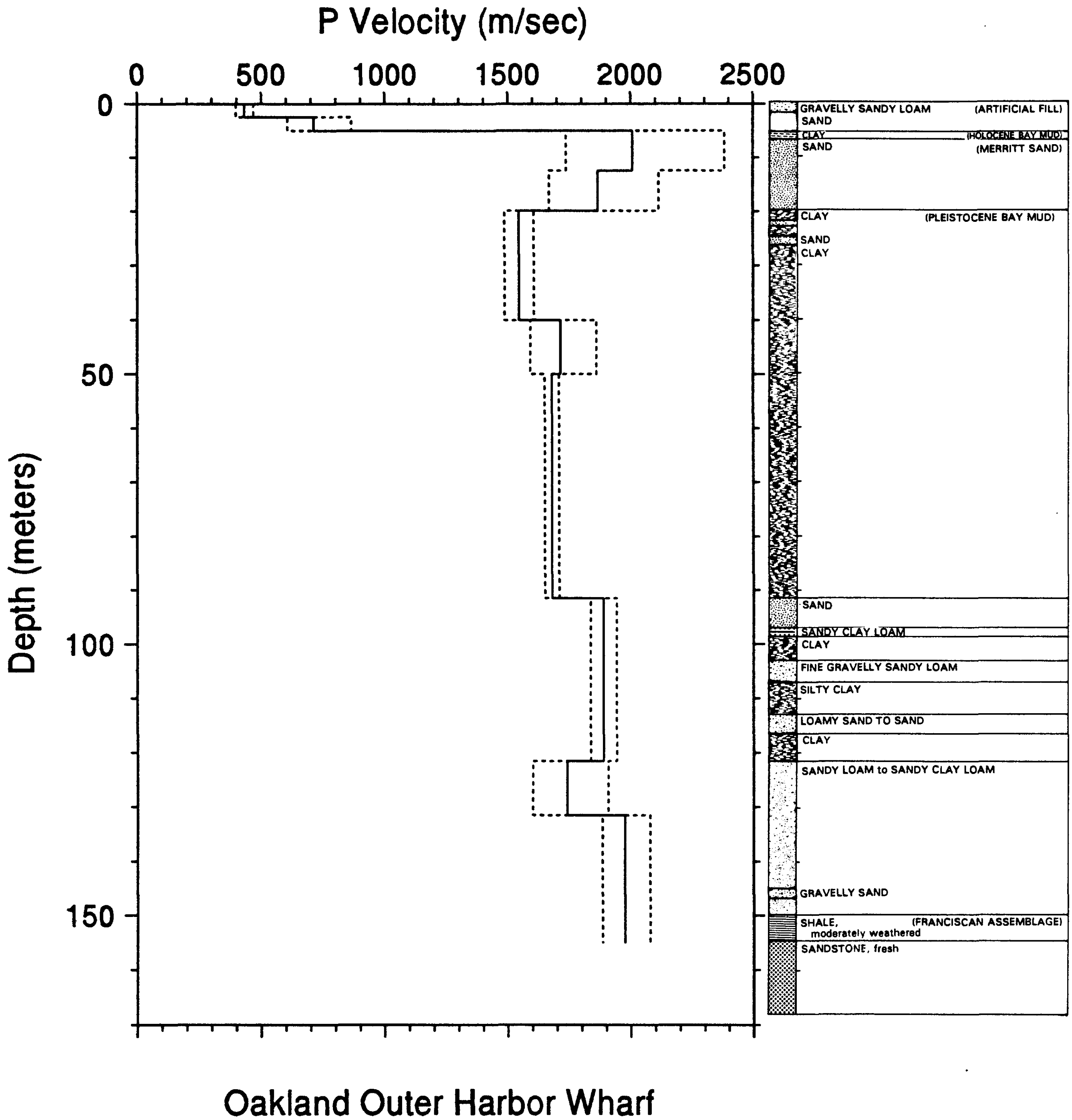


Figure 42. P-wave velocity profiles with dashed lines representing plus and minus one standard deviation. The statistics are done on the slope (reciprocal velocity) so that some of the limits will not appear symmetrical. Simplified geologic log is shown for correlation with velocities.

TABLE 7. S-wave arrival times and velocity summaries for Oakland Outer Harbor Wharf.

d(m)	d(ft)	t(sec)	sig	rsdl/sig
2.5	8.2	.0129	1	.3
5.0	16.4	.0251	1	-.1
7.5	24.6	.0395	1	-.4
10.0	32.8	.0501	1	.7
12.5	41.0	.0585	1	-.4
15.0	49.2	.0650	1	-.7
17.5	57.4	.0740	1	1.5
20.0	65.6	.0795	1	.2
22.5	73.8	.0888	1	-.9
25.0	82.0	.0995	1	-.5
27.5	90.2	.1112	1	.9
30.0	98.4	.1194	1	-1.2
35.0	114.8	.1421	1	.9
40.0	131.2	.1617	1	-.2
45.0	147.6	.1804	1	.0
50.0	164.0	.1995	1	.7
55.0	180.4	.2131	1	-1.5
60.0	196.9	.2292	1	-1.2
65.0	213.3	.2483	1	2.1
70.0	229.7	.2618	1	-.2
75.0	246.1	.2789	1	1.1
80.0	262.5	.2934	1	-.2
85.0	278.9	.3100	1	.6
90.0	295.3	.3230	1	-2.2
95.0	311.7	.3400	1	2.7
100.0	328.1	.3461	1	-1.8
105.0	344.5	.3566	2	-.9
110.0	360.9	.3701	1	1.2
115.0	377.3	.3781	1	-1.4
120.0	393.7	.3902	1	.2
125.0	410.1	.4067	2	1.7
130.0	426.5	.4182	2	.2
135.0	442.9	.4267	2	.0
140.0	459.3	.4327	2	-.2
145.0	475.7	.4367	2	-1.5
150.0	492.1	.4468	3	.2
155.0	508.5	.4543	2	.8

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	198	190	207	650	622	680
5.0	16.4	.025	198	190	207	650	622	680
6.7	22.0	.037	147	127	173	482	418	569
12.5	41.0	.059	263	242	287	862	795	943
20.0	65.6	.079	367	345	392	1203	1131	1286
40.0	131.2	.162	242	238	246	795	782	808
50.0	164.0	.199	271	262	280	888	860	918
91.5	300.2	.330	316	314	319	1038	1029	1047
121.5	398.6	.393	475	465	484	1557	1527	1589
131.5	431.4	.422	345	321	372	1132	1055	1220
155.0	508.5	.453	771	698	860	2529	2291	2823

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 Oakland Outer Harbor Wharf.

d(m)	d(ft)	t(sec)	sig	rsdl/sig
2.5	8.2	.0058	1	.0
5.0	16.4	.0092	1	-.1
7.5	24.6	.0108	1	.3
10.0	32.8	.0116	1	-.2
12.5	41.0	.0130	1	.0
15.0	49.2	.0142	1	-.2
17.5	57.4	.0163	1	.6
20.0	65.6	.0175	1	.4
22.5	73.8	.0185	1	-.2
25.0	82.0	.0196	1	-.7
27.5	90.2	.0216	1	-.3
30.0	98.4	.0237	1	.2
35.0	114.8	.0267	1	-.1
40.0	131.2	.0298	1	-.2
45.0	147.6	.0338	1	.9
50.0	164.0	.0358	1	.0
55.0	180.4	.0388	1	.0
60.0	196.9	.0419	1	.1
65.0	213.3	.0449	1	.2
70.0	229.7	.0469	1	-.8
75.0	246.1	.0499	1	-.8
80.0	262.5	.0539	1	.2
85.0	278.9	.0569	1	.2
90.0	295.3	.0599	1	.3
95.0	311.7	.0629	1	.5
100.0	328.1	.0649	1	-.1
105.0	344.5	.0669	1	-.8
110.0	360.9	.0709	1	.6
115.0	377.3	.0729	1	-.1
120.0	393.7	.0759	1	.3
125.0	410.1	.0779	1	-.5
130.0	426.5	.0819	1	.6
135.0	442.9	.0839	1	.0
140.0	459.3	.0859	1	-.6
145.0	475.7	.0889	1	-.1
150.0	492.1	.0919	1	.4
155.0	508.5	.0940	1	.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	431	398	470	1414	1307	1541
2.5	8.2	.006	431	398	470	1414	1307	1541
5.0	16.4	.009	713	607	866	2341	1990	2842
12.5	41.0	.013	2010	1738	2382	6594	5703	7816
20.0	65.6	.017	1867	1670	2116	6124	5478	6943
40.0	131.2	.030	1546	1488	1608	5072	4884	5277
50.0	164.0	.036	1716	1592	1861	5631	5224	6106
91.5	300.2	.061	1680	1651	1709	5510	5417	5606
121.5	398.6	.076	1888	1836	1943	6196	6025	6376
131.5	431.4	.082	1741	1601	1908	5712	5251	6261
155.0	508.5	.094	1976	1885	2077	6484	6183	6815

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

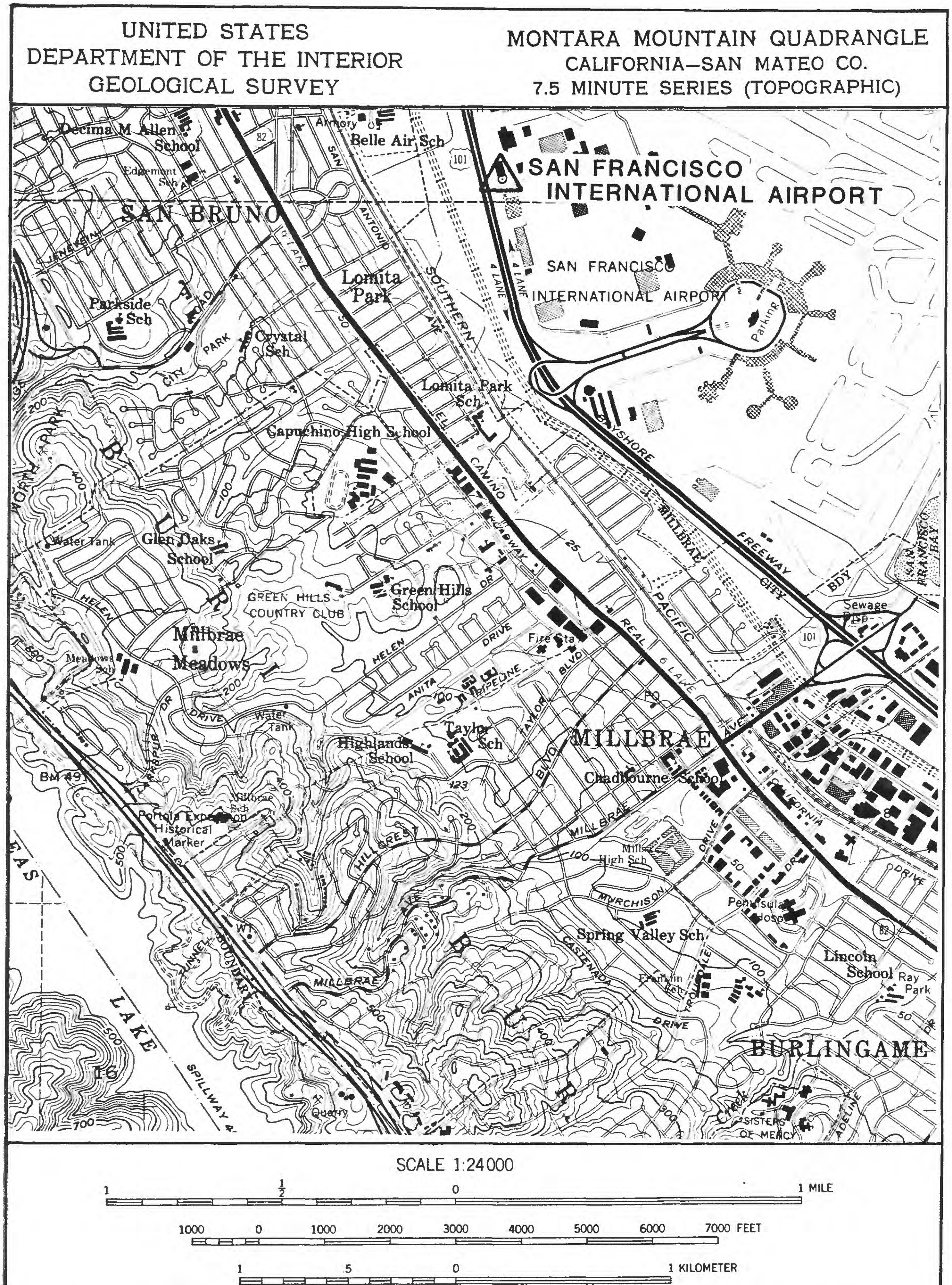


Figure 43. Location map for San Francisco International Airport. The borehole is located within 15 meters of the strong-motion recorder.

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)

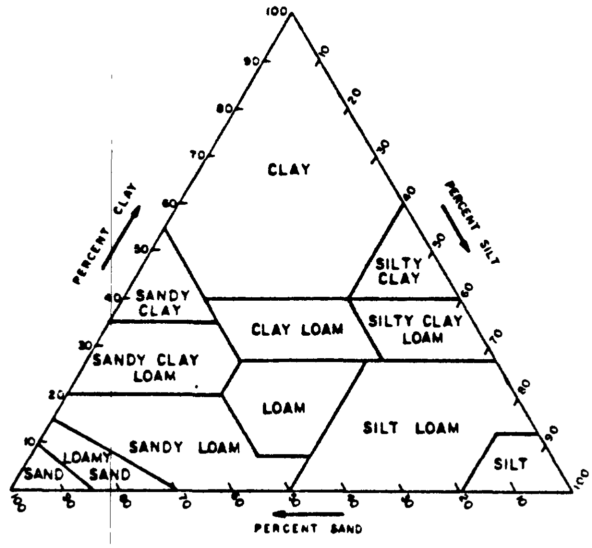
cm	in	fracture spacing
0-1	0-1/2	v. close
1-5	1/2-2	close
5-30	2-12	moderate
30-100	12-36	wide
>100	>36	v. wide

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 44. Explanation of geologic log.

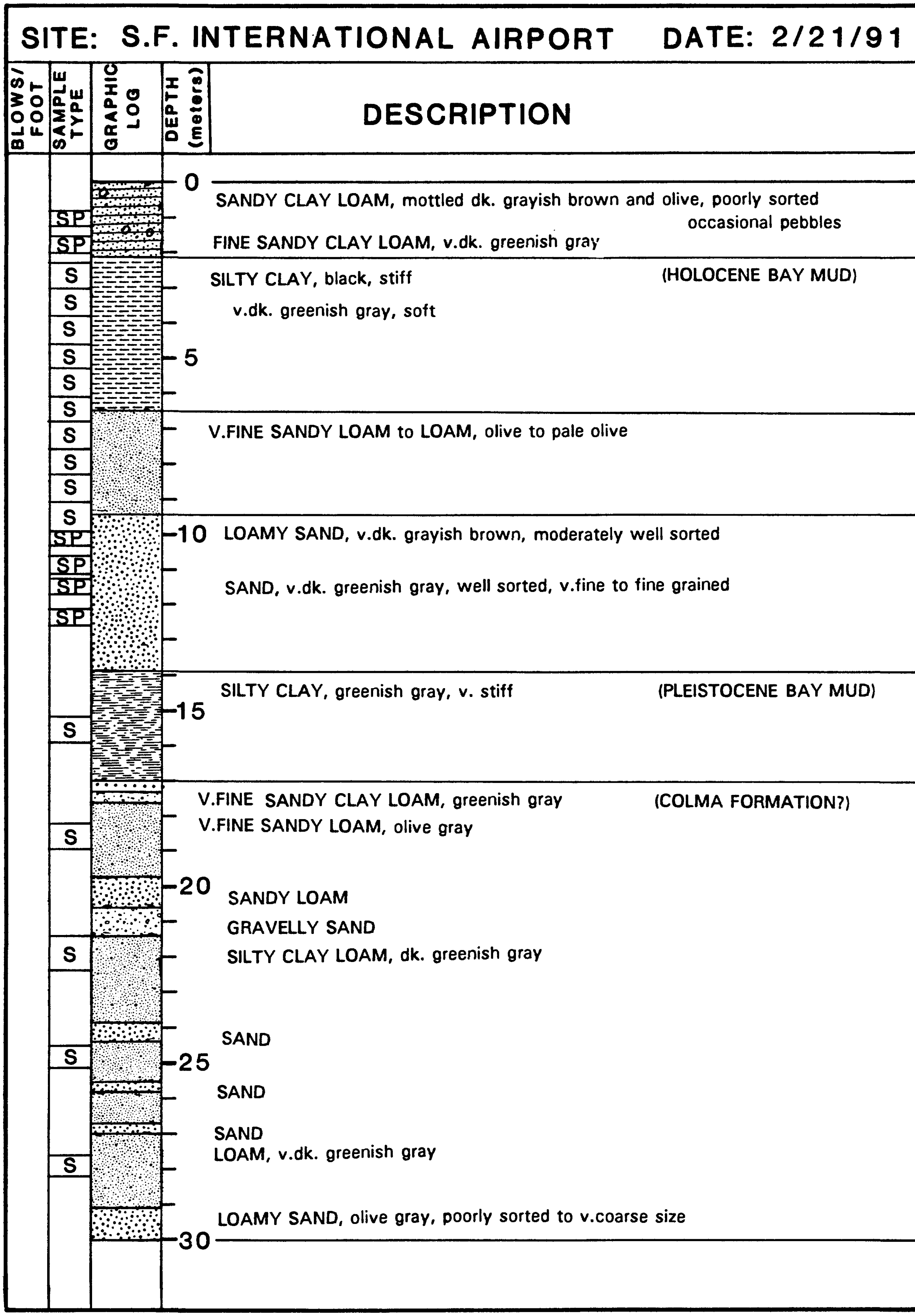


Figure 45. Geologic log for San Francisco International Airport.

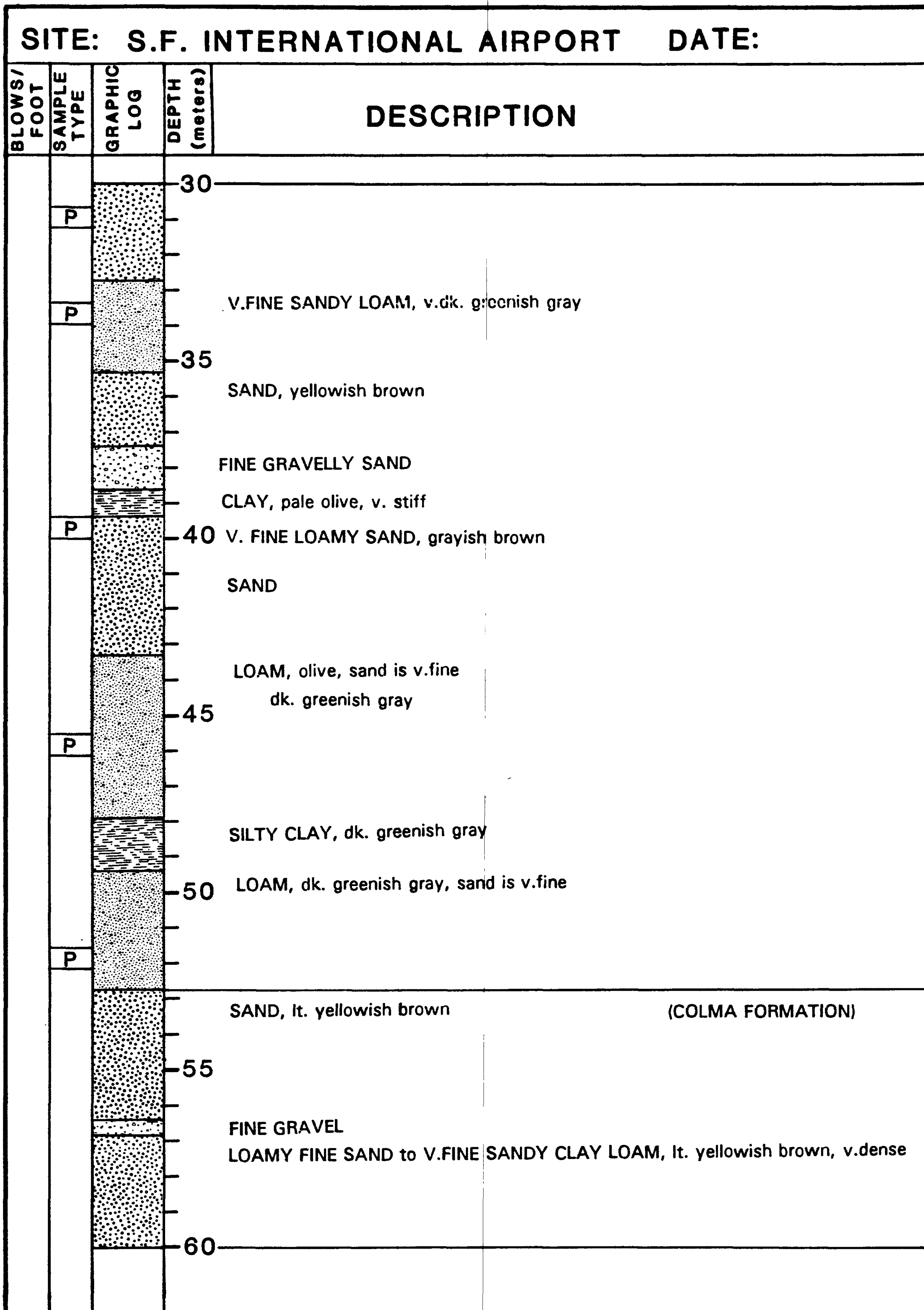


Figure 45. (Continued).

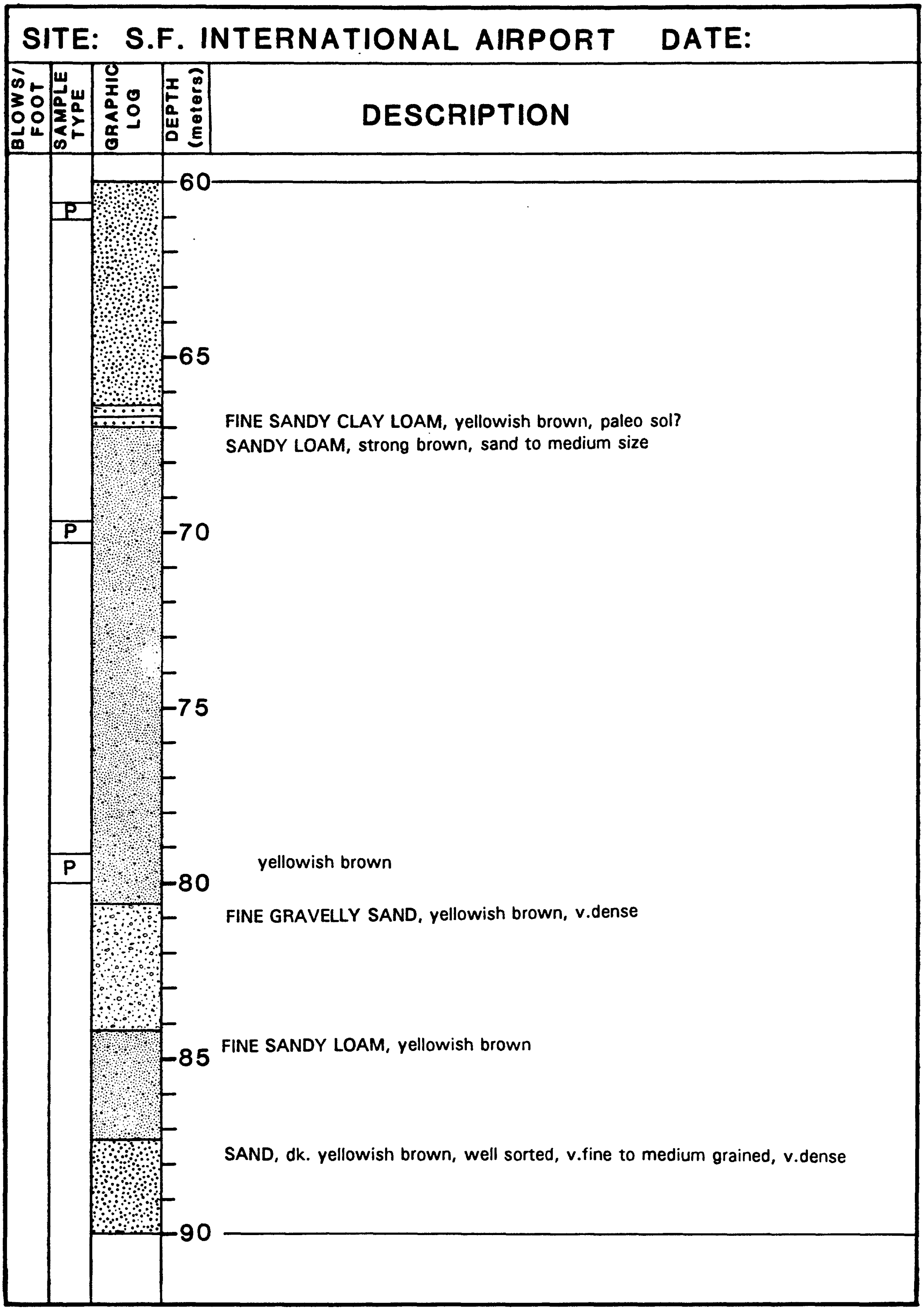


Figure 45. (Continued).

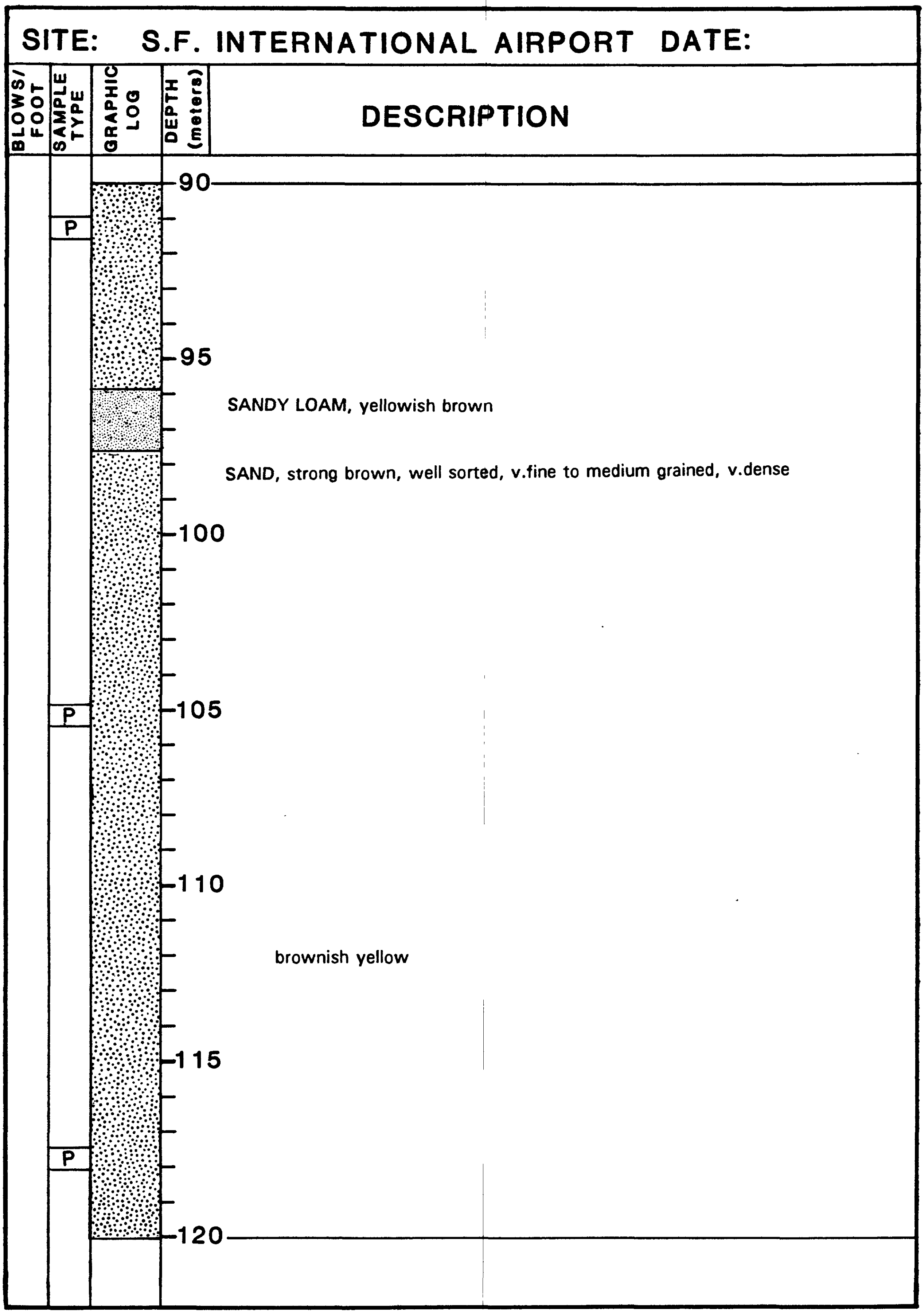


Figure 45. (Continued).

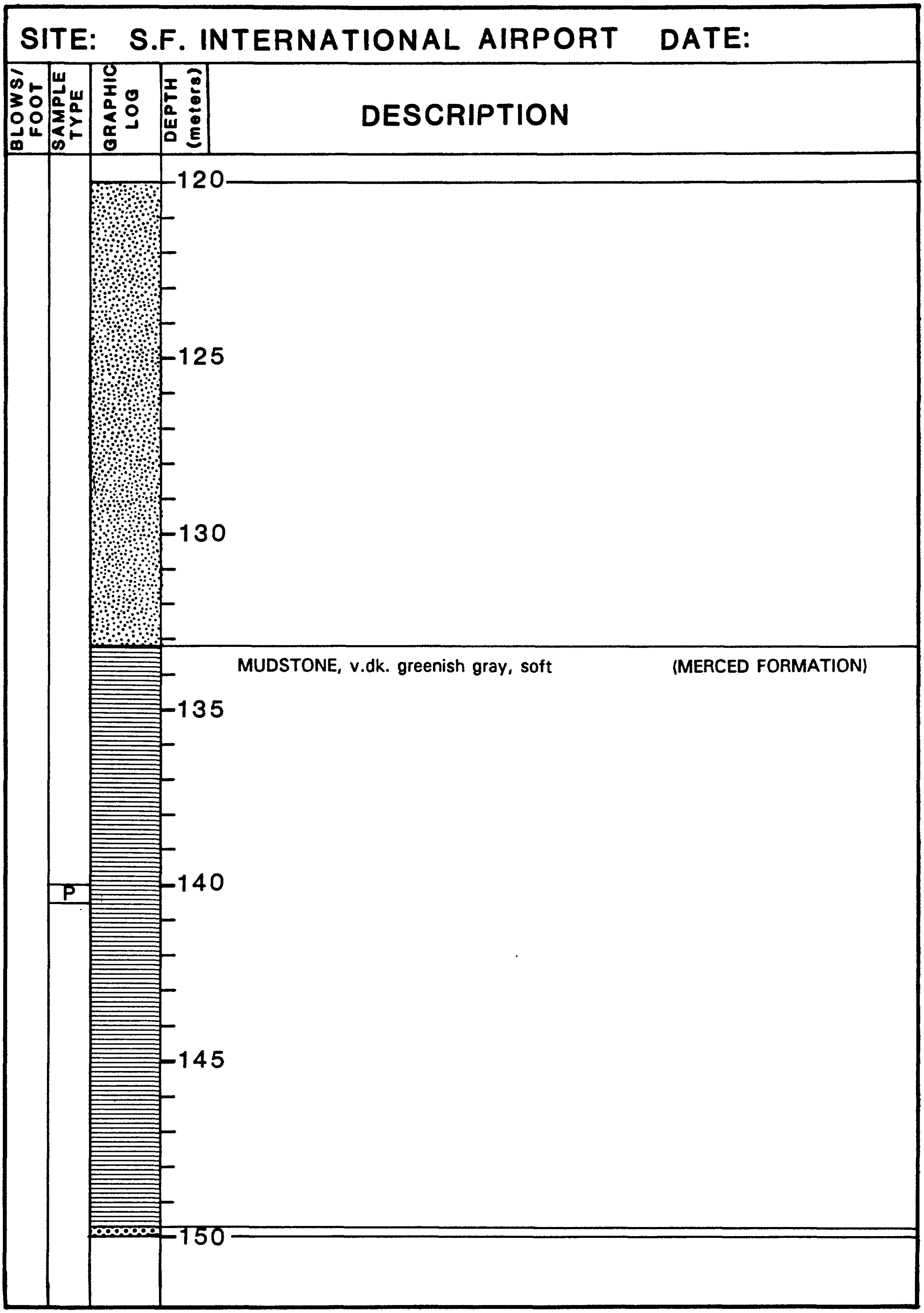


Figure 45. (Continued).

SITE: S.F. INTERNATIONAL AIRPORT DATE:

BLOWS/ FOOT	SAMPLE TYPE	GRAPHIC LOG	DEPTH (meters)	DESCRIPTION
			150	SANDSTONE, lt. gray to medium gray, fresh, hard (FRANCISCAN ASSEMBLAGE)
			155	
			160	
			165	
			170	
			175	
			180	

Figure 45. (Continued).

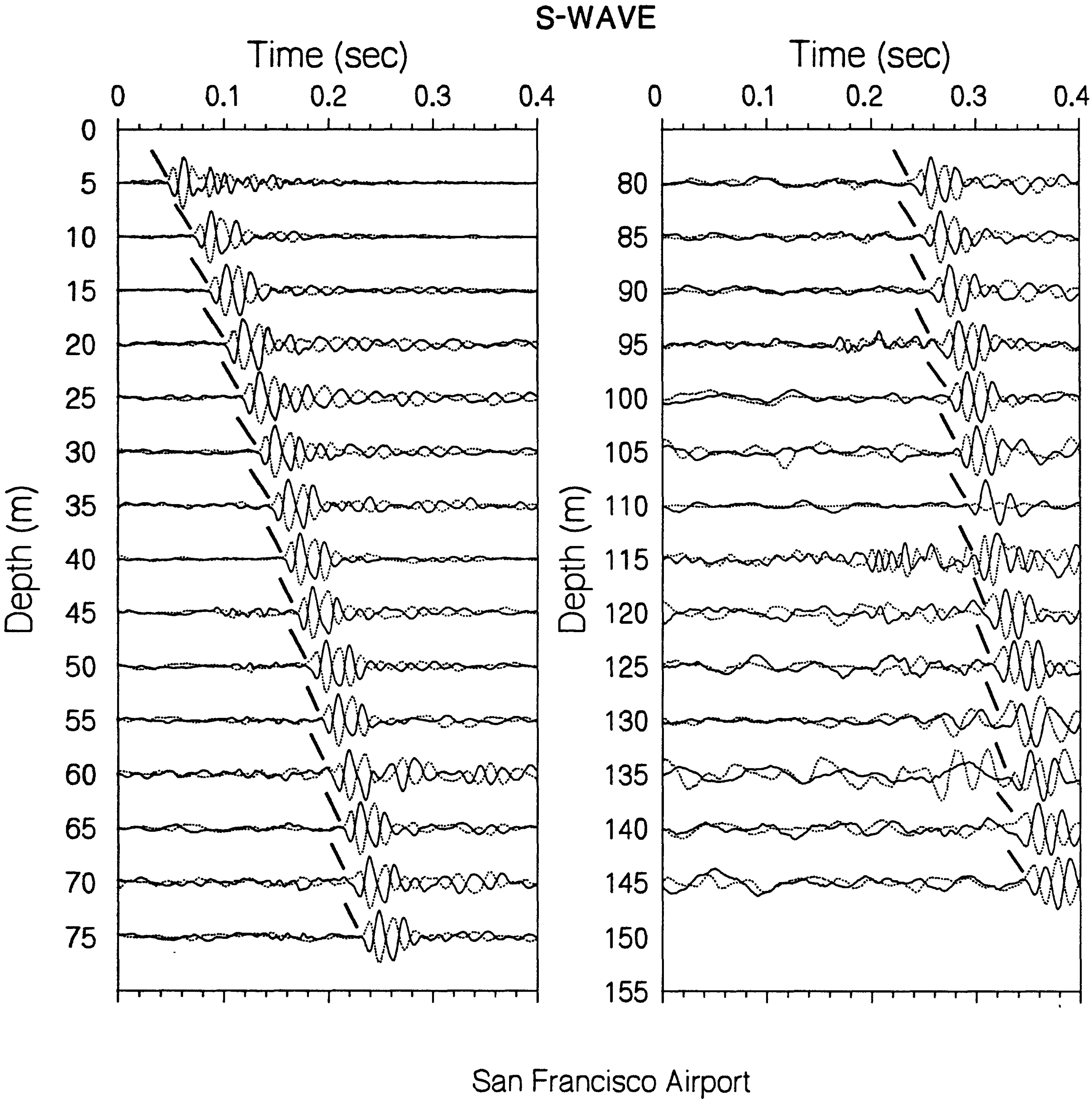


Figure 46. Horizontal-component record section from impacts in opposite horizontal directions superimposed for identification of shear arrivals. S-wave arrivals are shown by the accent marks.

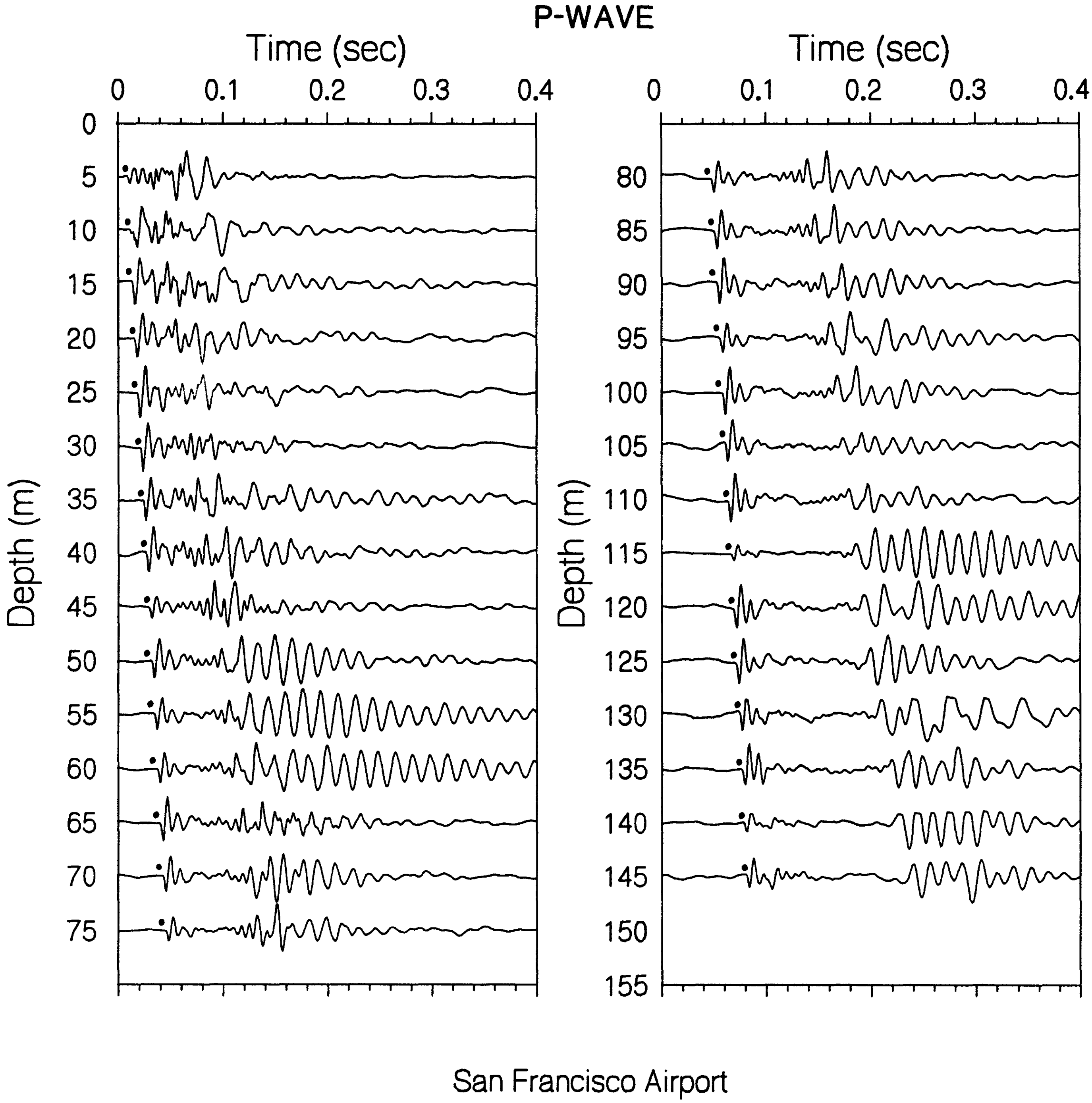


Figure 47. Vertical-component record section. P-wave arrivals are shown by the solid circles.

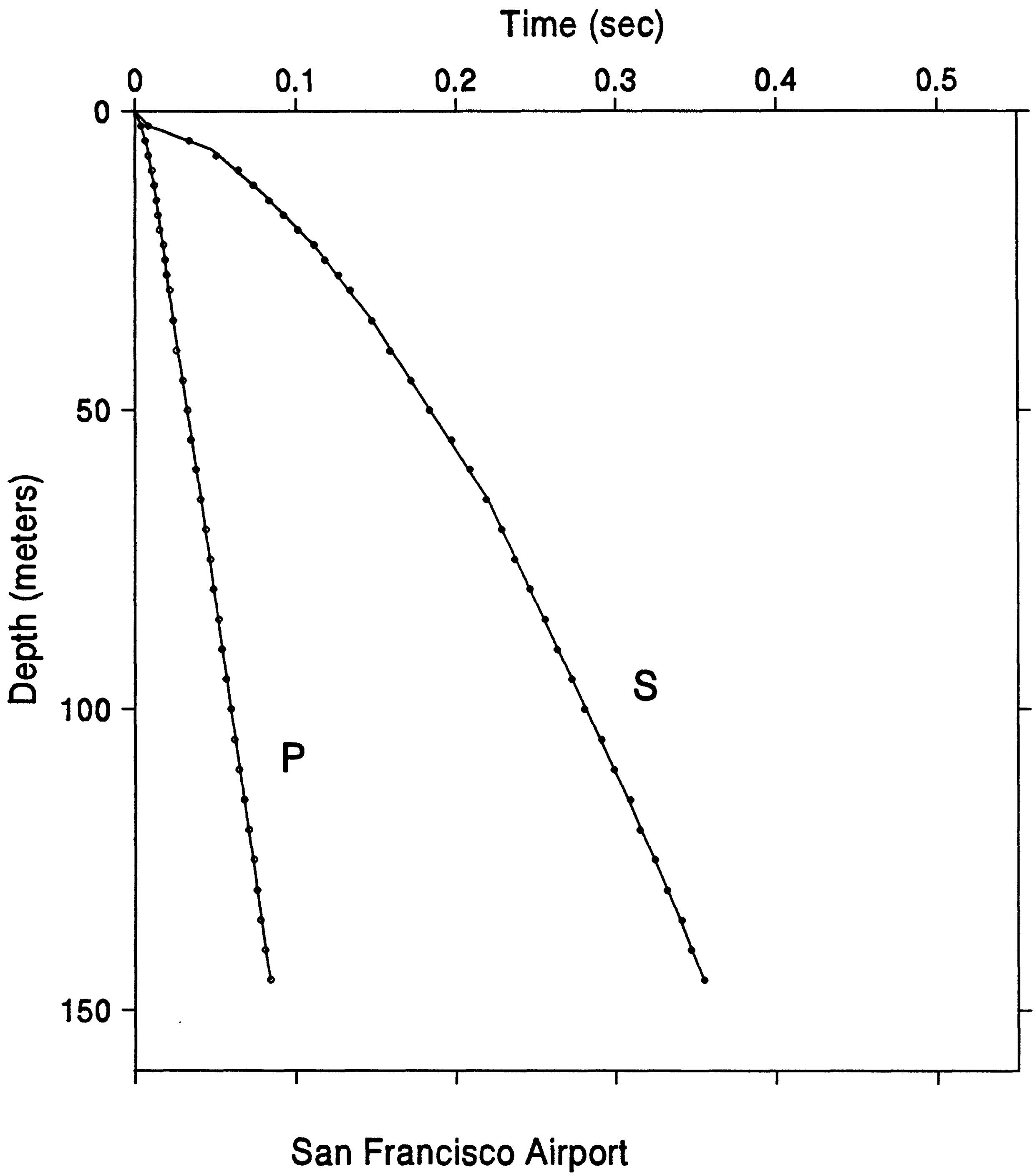


Figure 48. Time-depth graph of P-wave and S-wave picks. Line segments show the hinged-least-squares fit to the data points.

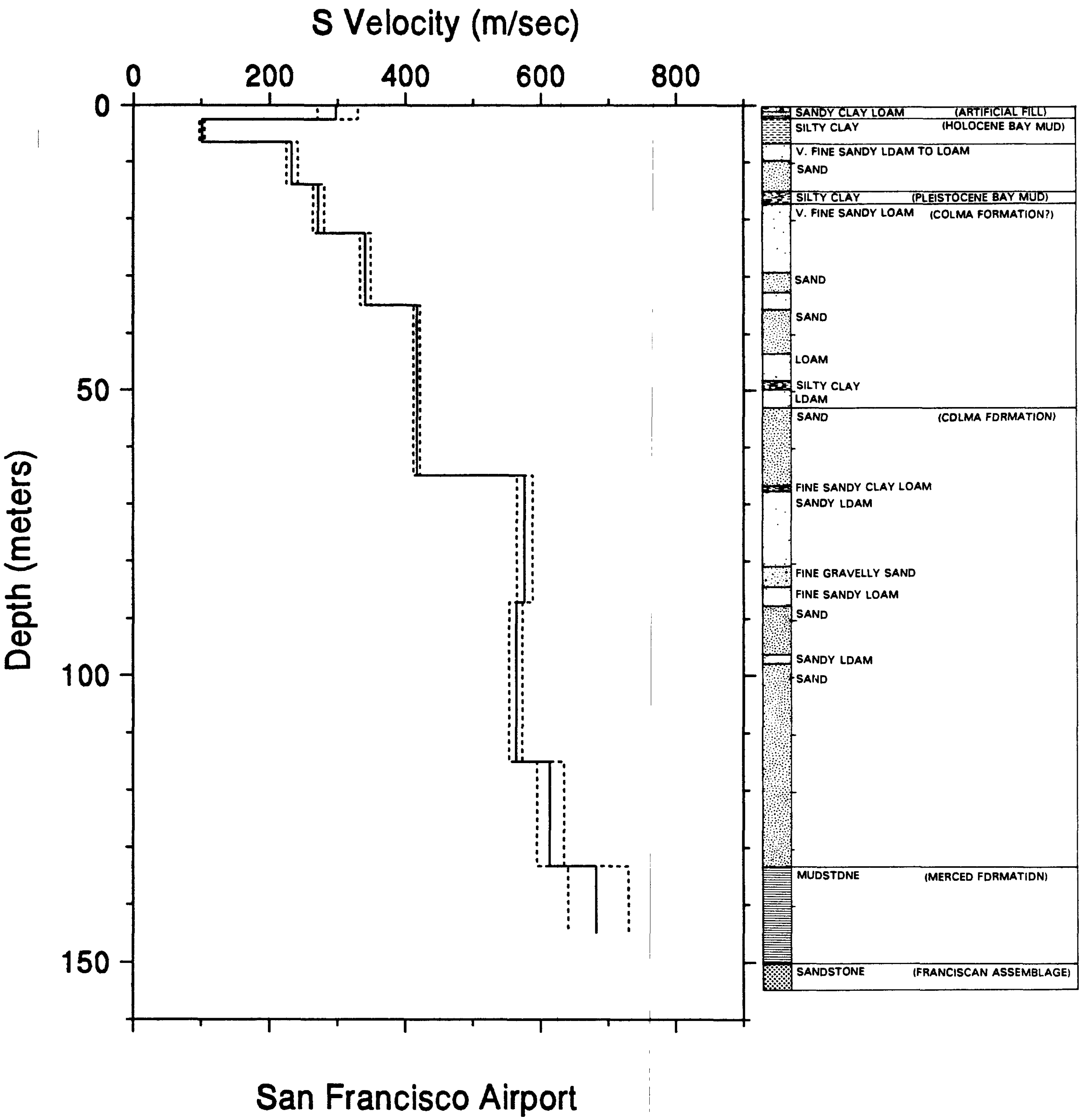
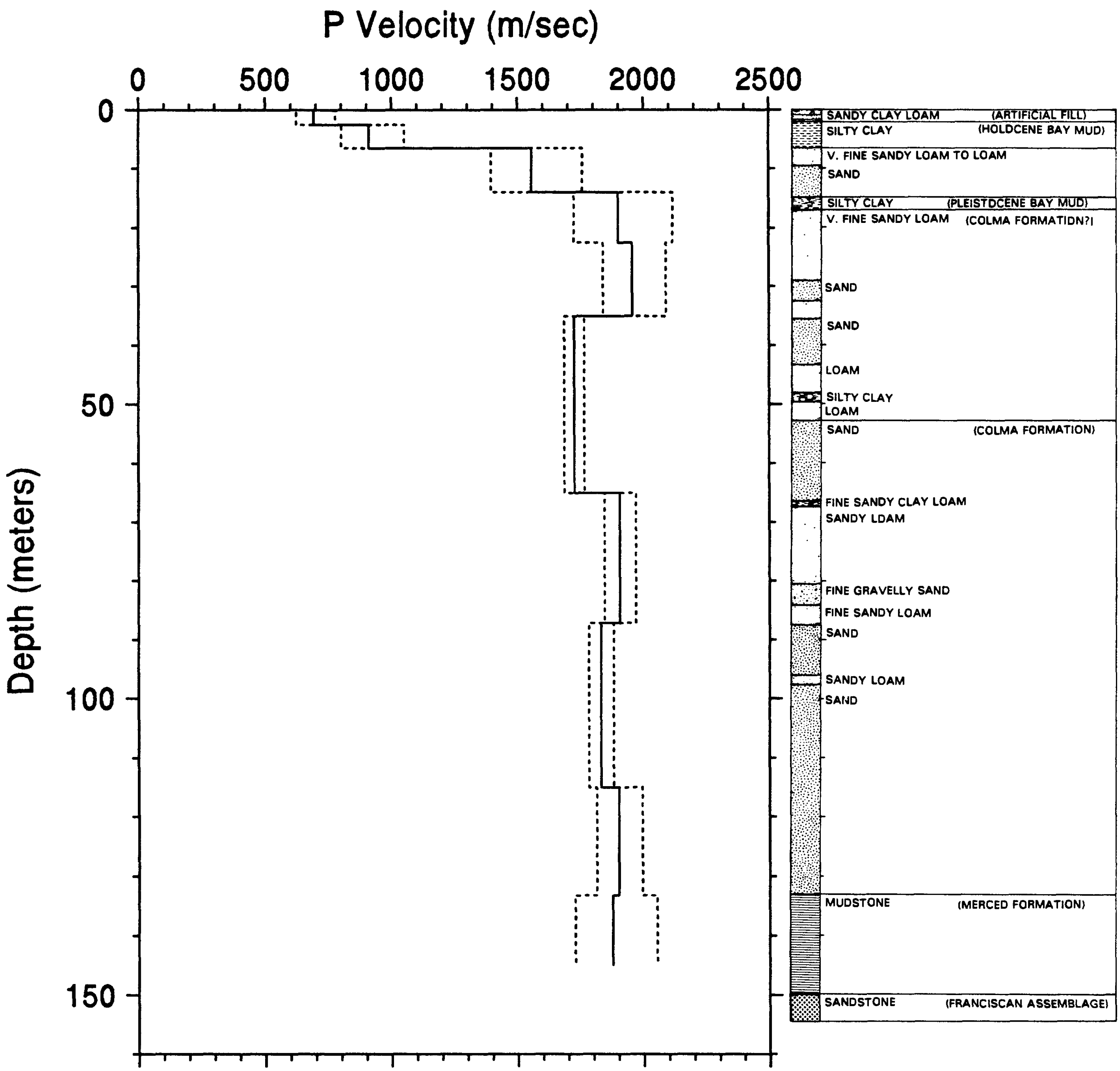


Figure 49. S-wave velocity profiles with dashed lines representing plus and minus one standard deviation. The statistics are done on the slope (reciprocal velocity) so that some of the limits will not appear symmetrical. Simplified geologic log is shown for correlation with velocities.



San Francisco Airport

Figure 50. P-wave velocity profiles with dashed lines representing plus and minus one standard deviation. The statistics are done on the slope (reciprocal velocity) so that some of the limits will not appear symmetrical. Simplified geologic log is shown for correlation with velocities.

TABLE 9. S-wave arrival times and velocity summaries for San Francisco International Airport.

d(m)	d(ft)	t(sec)	sig	rsdl/sig
2.5	8.2	.0082	1	-.2
5.0	16.4	.0336	1	.5
7.5	24.6	.0508	1	-1.4
10.0	32.8	.0644	1	1.5
12.5	41.0	.0738	1	.2
15.0	49.2	.0835	1	-.2
17.5	57.4	.0923	1	-.6
20.0	65.6	.1014	1	-.7
22.5	73.8	.1113	1	.1
25.0	82.0	.1182	1	-.4
27.5	90.2	.1269	1	1.0
30.0	98.4	.1341	1	.9
35.0	114.8	.1475	1	-.4
40.0	131.2	.1588	1	-1.1
45.0	147.6	.1719	1	.0
50.0	164.0	.1836	1	-.3
55.0	180.4	.1972	1	1.3
60.0	196.9	.2088	1	.9
65.0	213.3	.2189	1	-1.0
70.0	229.7	.2284	1	-.1
75.0	246.1	.2365	1	-.7
80.0	262.5	.2460	1	.1
85.0	278.9	.2556	1	1.0
90.0	295.3	.2631	1	-.3
95.0	311.7	.2721	1	-.1
100.0	328.1	.2801	1	-1.0
105.0	344.5	.2907	1	.7
110.0	360.9	.2987	1	-.1
115.0	377.3	.3087	1	1.0
120.0	393.7	.3147	1	-1.2
125.0	410.1	.3242	1	.2
130.0	426.5	.3318	1	-.3
135.0	442.9	.3408	1	.8
140.0	459.3	.3468	1	-.5
145.0	475.7	.3548	1	.2

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	298	271	330	977	889	1084
2.5	8.2	.008	298	271	330	977	889	1084
6.5	21.3	.048	101	98	105	332	322	343
14.0	45.9	.080	233	225	242	766	739	794
22.5	73.8	.111	272	264	281	893	867	921
35.0	114.8	.148	341	333	349	1119	1093	1145
65.0	213.3	.220	417	412	422	1368	1352	1384
87.2	286.1	.258	576	565	588	1890	1852	1930
115.0	377.3	.308	564	554	573	1849	1818	1881
133.2	437.0	.337	614	595	635	2015	1953	2082
145.0	475.7	.355	682	641	730	2239	2102	2395

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

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TABLE 10. P-wave arrival times and velocity summaries for San Francisco International Airport.

d(m)	d(ft)	t(sec)	sig	rsdl/sig
2.5	8.2	.0036	1	.0
5.0	16.4	.0064	1	.0
7.5	24.6	.0083	1	-.4
10.0	32.8	.0107	1	.4
12.5	41.0	.0121	1	.2
15.0	49.2	.0133	1	-.1
17.5	57.4	.0144	1	-.3
20.0	65.6	.0155	1	-.5
22.5	73.8	.0176	1	.3
25.0	82.0	.0186	1	.0
27.5	90.2	.0197	1	-.2
30.0	98.4	.0217	1	.6
35.0	114.8	.0238	1	.1
40.0	131.2	.0258	1	-.8
45.0	147.6	.0298	1	.3
50.0	164.0	.0328	1	.4
55.0	180.4	.0349	1	-.4
60.0	196.9	.0379	1	-.3
65.0	213.3	.0409	1	-.2
70.0	229.7	.0439	1	.2
75.0	246.1	.0469	1	.6
80.0	262.5	.0489	1	-.1
85.0	278.9	.0519	1	.3
90.0	295.3	.0539	1	-.4
95.0	311.7	.0569	1	-.1
100.0	328.1	.0599	1	.2
105.0	344.5	.0619	1	-.6
110.0	360.9	.0649	1	-.3
115.0	377.3	.0679	1	.0
120.0	393.7	.0709	1	.4
125.0	410.1	.0739	1	.7
130.0	426.5	.0759	1	.1
135.0	442.9	.0779	1	-.6
140.0	459.3	.0809	1	-.2
145.0	475.7	.0840	1	.2

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	692	623	777	2269	2044	2551
2.5	8.2	.004	692	623	777	2269	2044	2551
6.5	21.3	.008	910	802	1052	2985	2630	3450
14.0	45.9	.013	1557	1396	1760	5108	4581	5773
22.5	73.8	.017	1901	1725	2117	6238	5661	6945
35.0	114.8	.024	1958	1840	2091	6423	6038	6862
65.0	213.3	.041	1725	1686	1765	5658	5530	5792
87.2	286.1	.053	1905	1844	1969	6249	6050	6461
115.0	377.3	.068	1831	1783	1881	6007	5851	6172
133.2	437.0	.077	1900	1814	1995	6235	5952	6546
145.0	475.7	.084	1875	1727	2052	6153	5665	6732

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

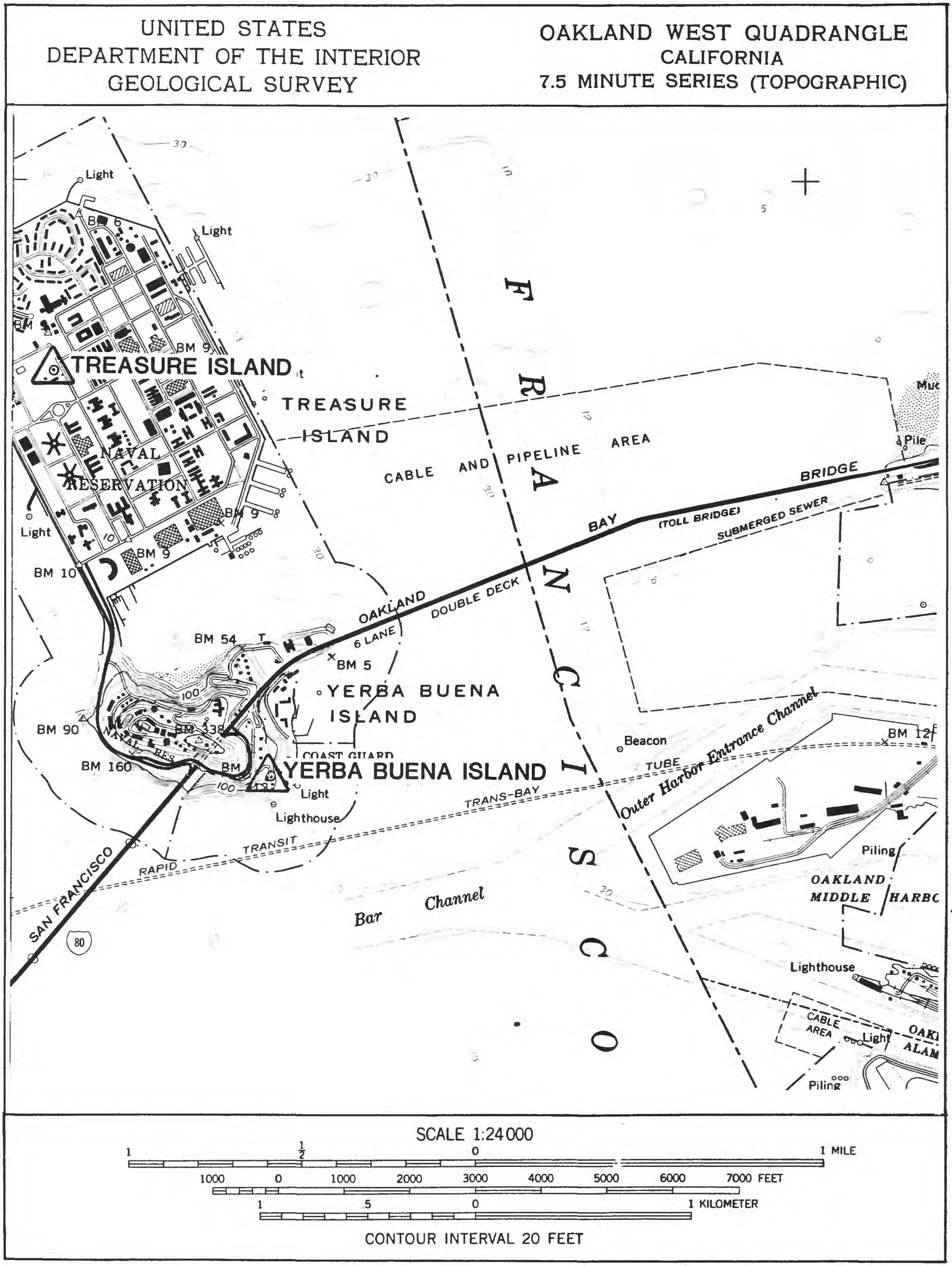


Figure 51. Site location map for Treasure Island and Yerba Buena Island. For Treasure Island, the borehole is located within 15 meters of the strong-motion recorder.

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)

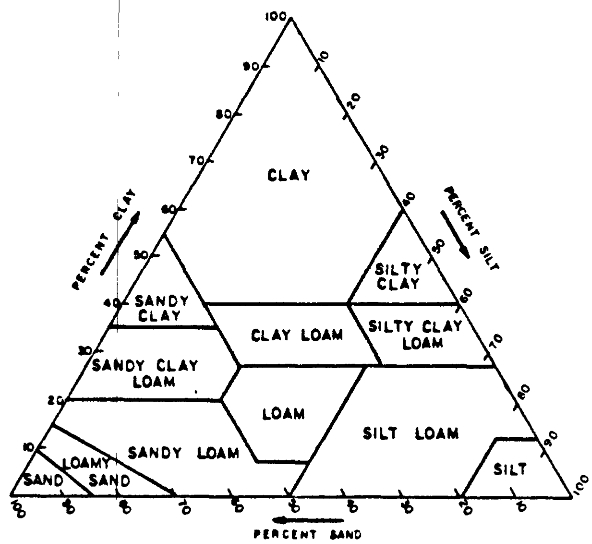
cm	in	fracture spacing
0-1	0-1/2	v. close
1-5	1/2-2	close
5-30	2-12	moderate
30-100	12-36	wide
>100	>36	v. wide

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 52. Explanation of geologic log.

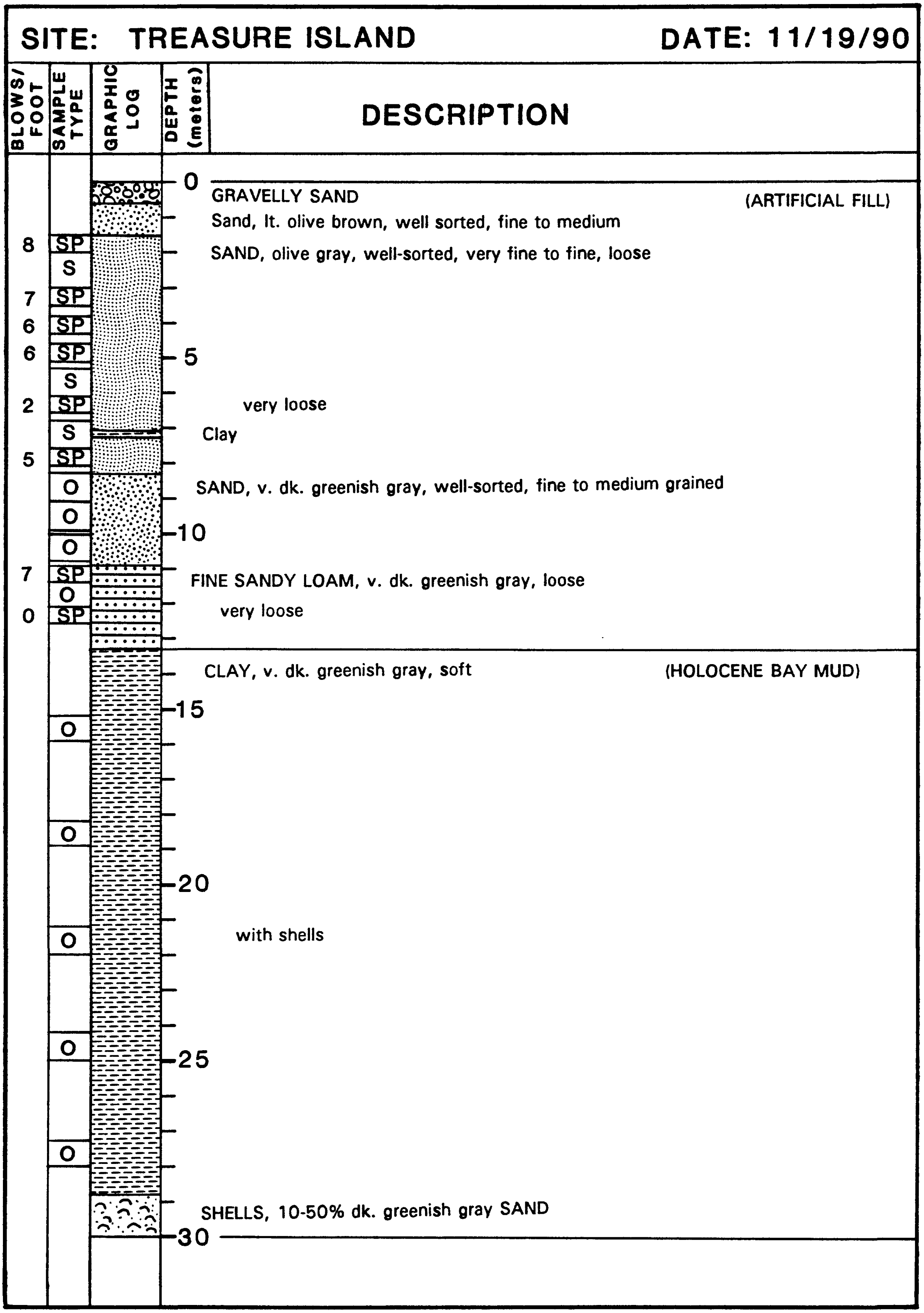


Figure 53. Geologic log for Treasure Island.

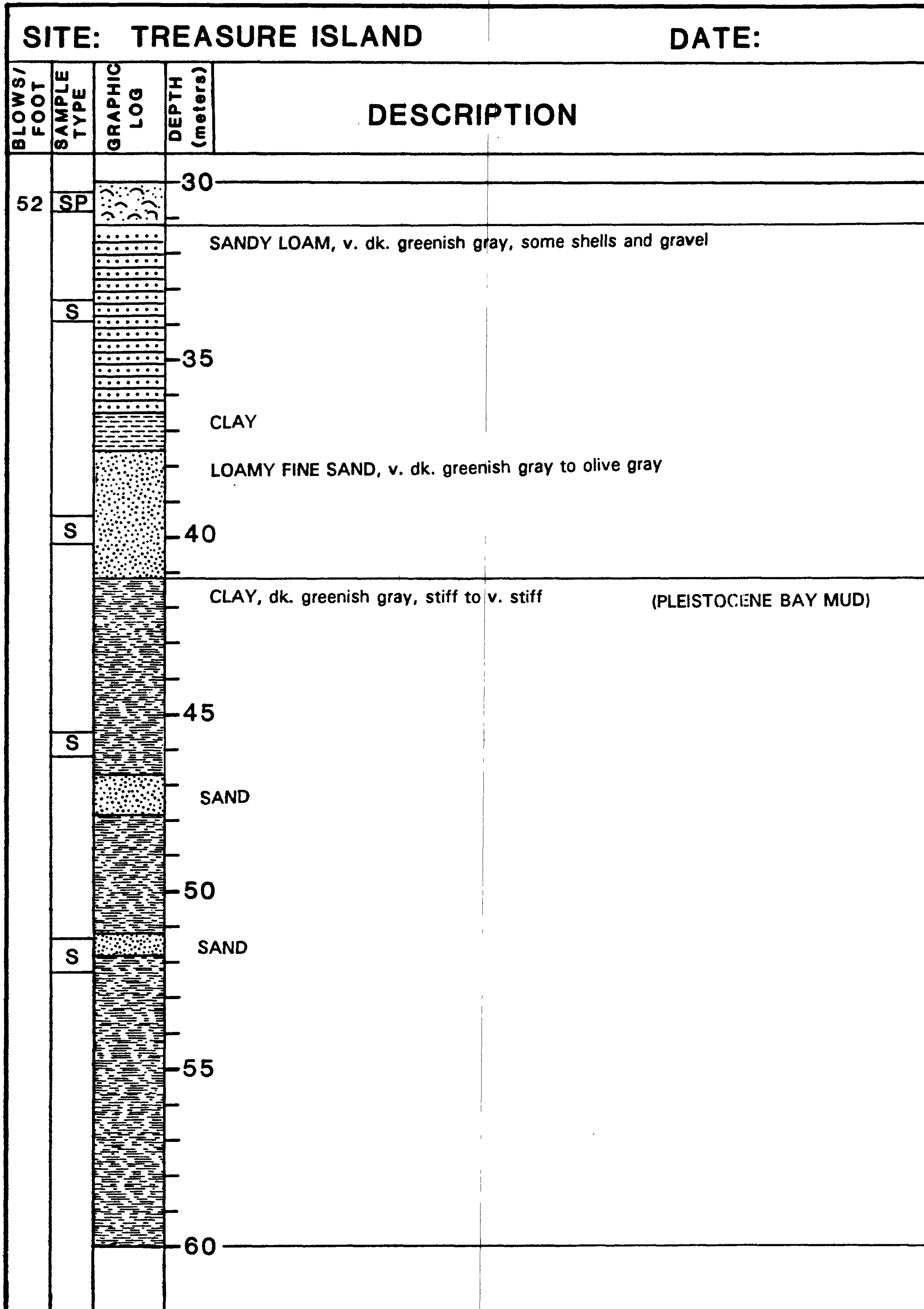


Figure 53. (Continued).

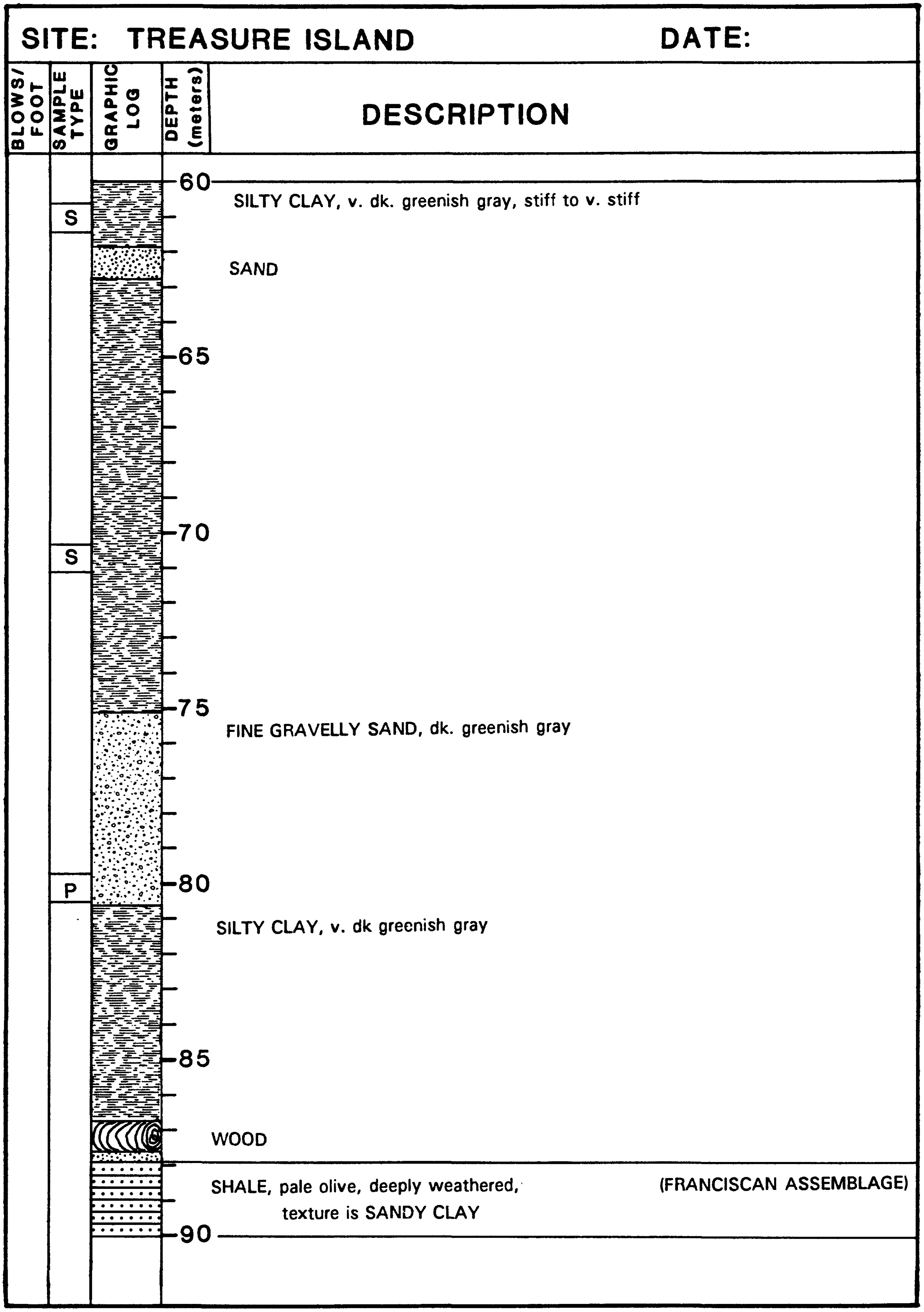


Figure 53. (Continued).

SITE: TREASURE ISLAND **DATE:**

BLOWS/ FOOT	SAMPLE TYPE	GRAPHIC LOG	DEPTH (meters)	DESCRIPTION
			90	
				SHALE, lt. greenish gray to dk. brownish gray, firm
	P			black, hard, v. closely fractured, fresh
			95	SANDSTONE, dk. gray, fine-grained
				SHALE
				SANDSTONE, dk. gray, fine-grained
			100	
			105	
			110	
			115	
			120	

Figure 53. (Continued).

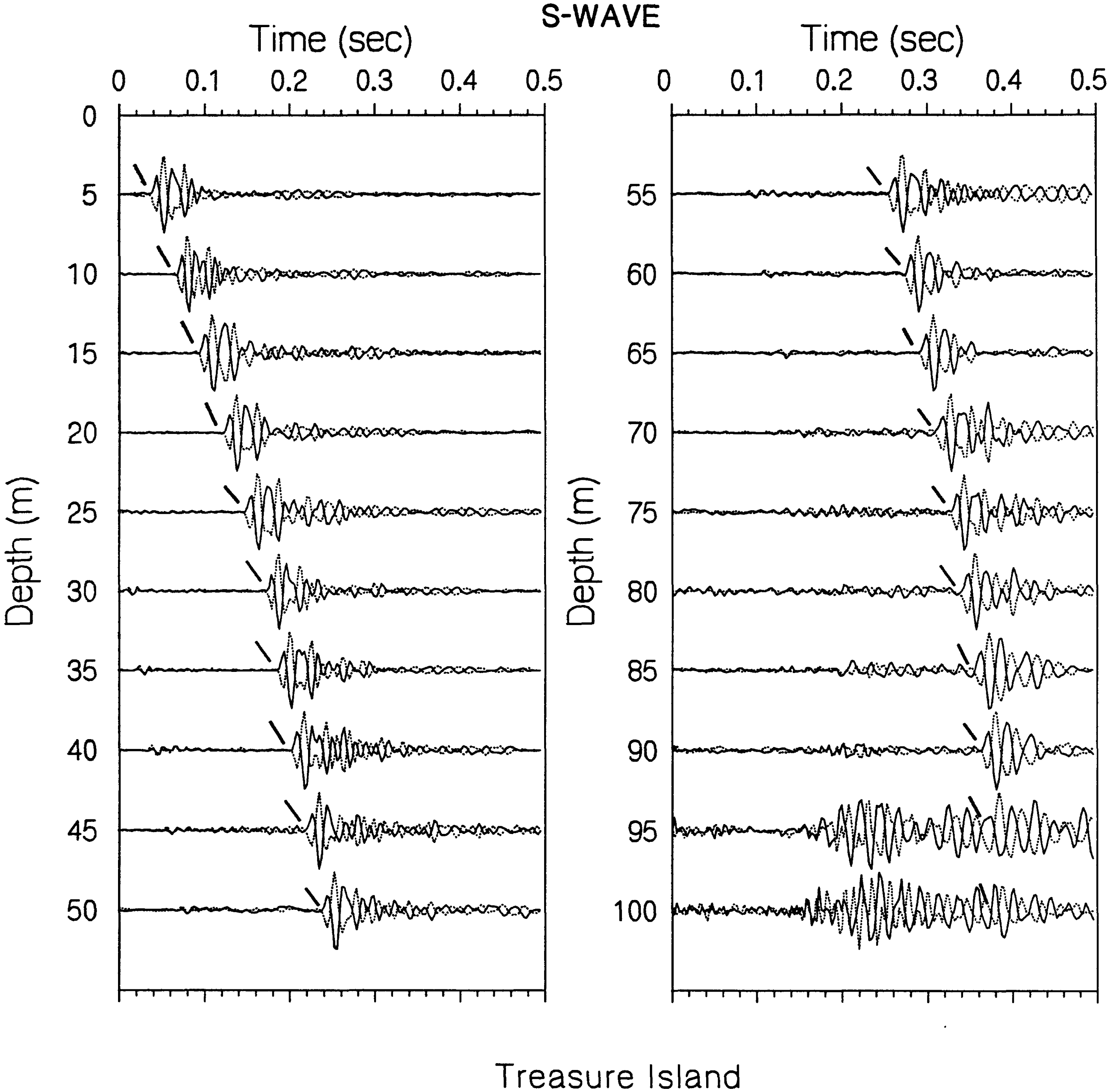


Figure 54. Horizontal-component record section from impacts in opposite horizontal directions superimposed for identification of shear arrivals. S-wave arrivals are shown by the accent marks.

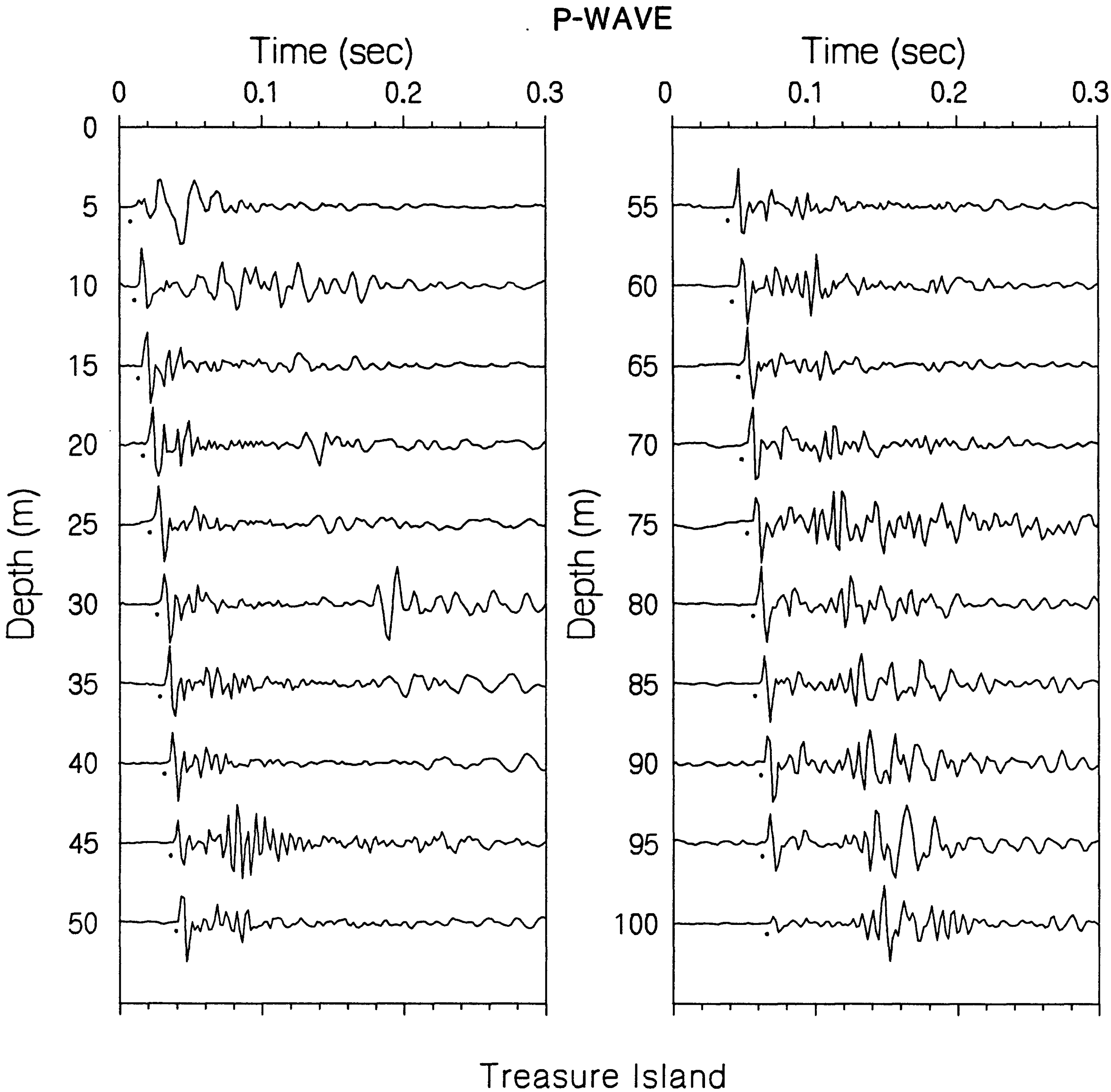


Figure 55. Vertical-component record section. P-wave arrivals are shown by the solid circles.

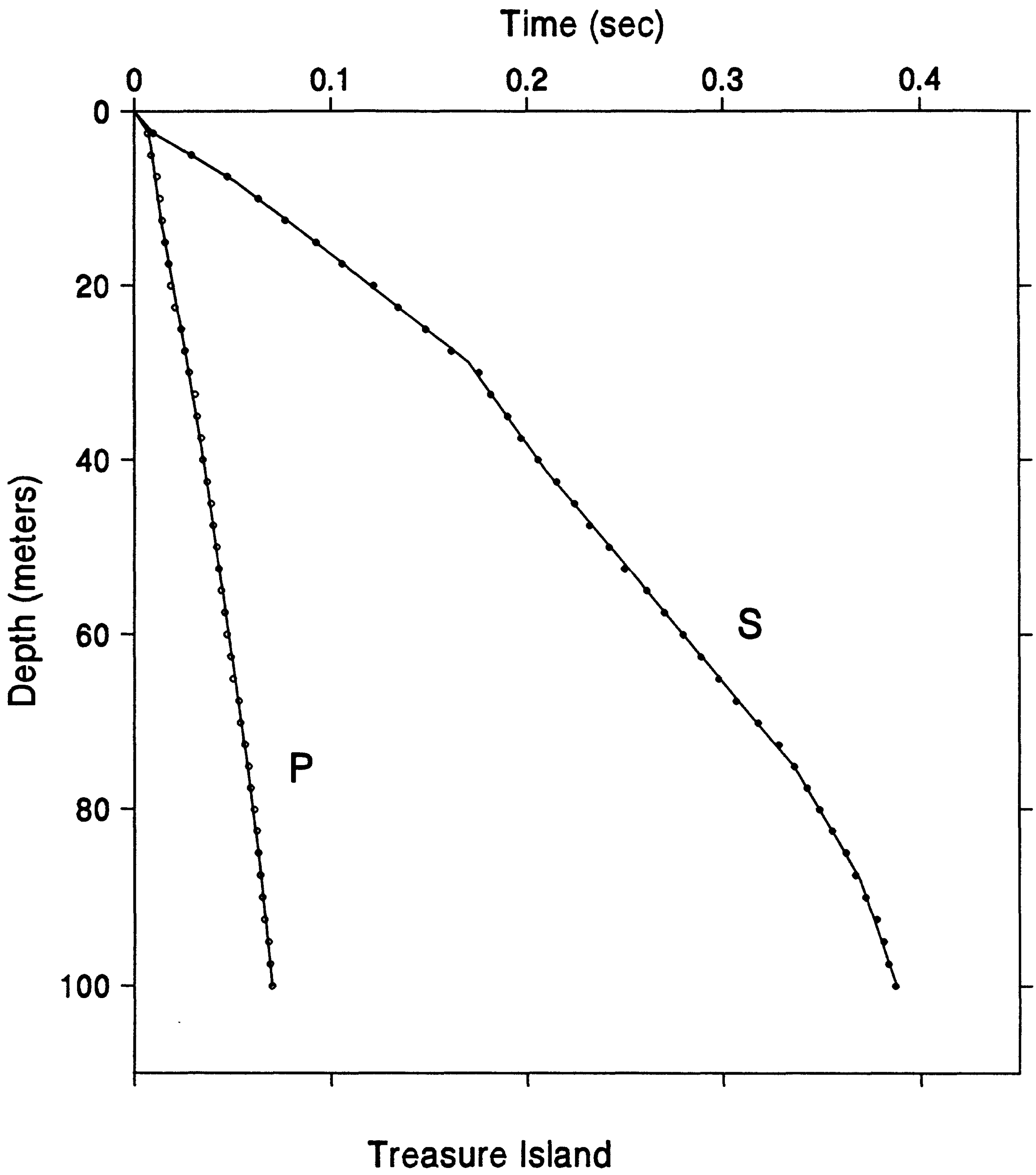


Figure 56. Time-depth graph of P-wave and S-wave picks. Line segments show the hinged-least-squares fit to the data points.

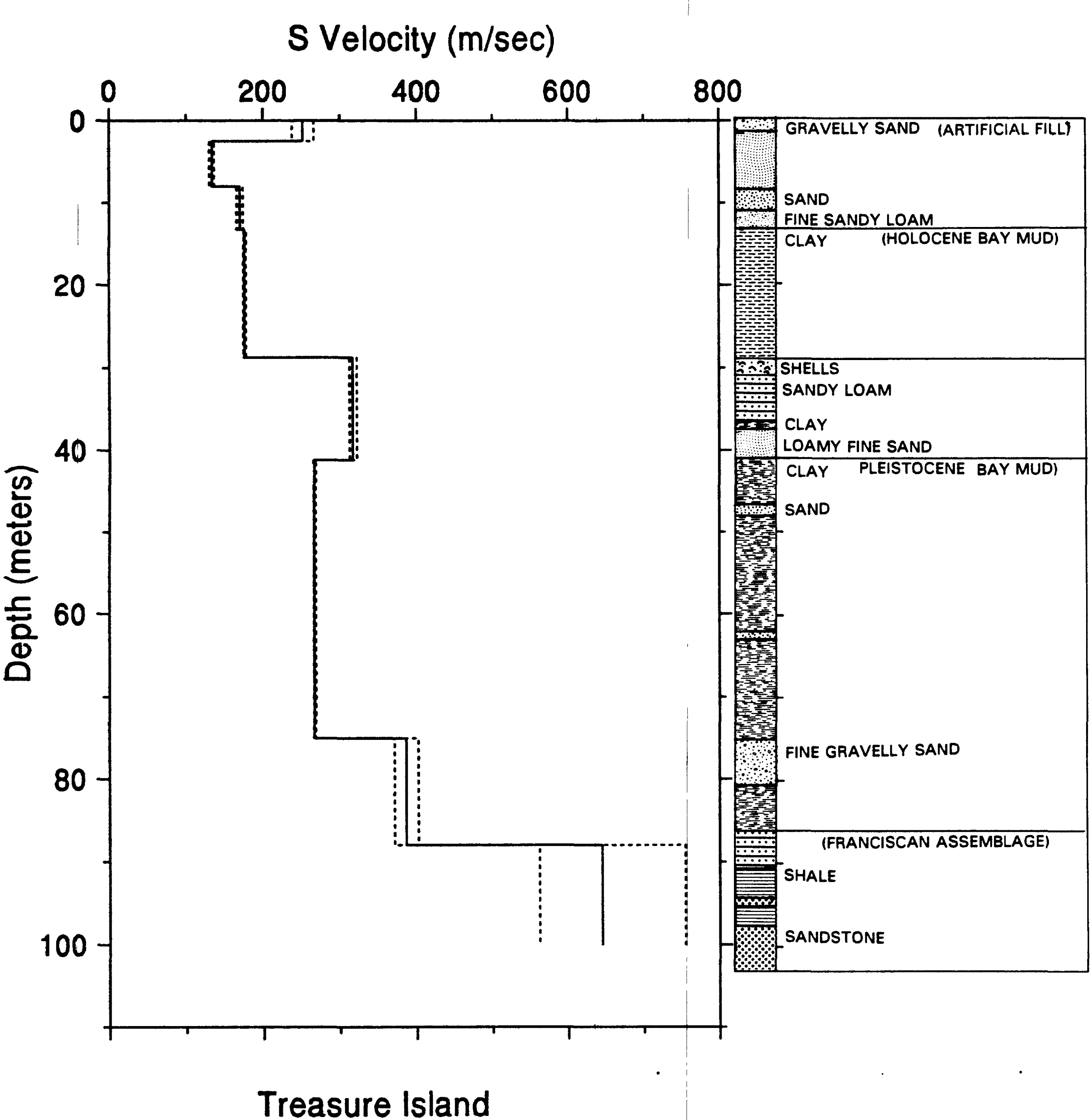


Figure 57. S-wave velocity profiles with dashed lines representing plus and minus one standard deviation. The statistics are done on the slope (reciprocal velocity) so that some of the limits will not appear symmetrical. Simplified geologic log is shown for correlation with velocities.

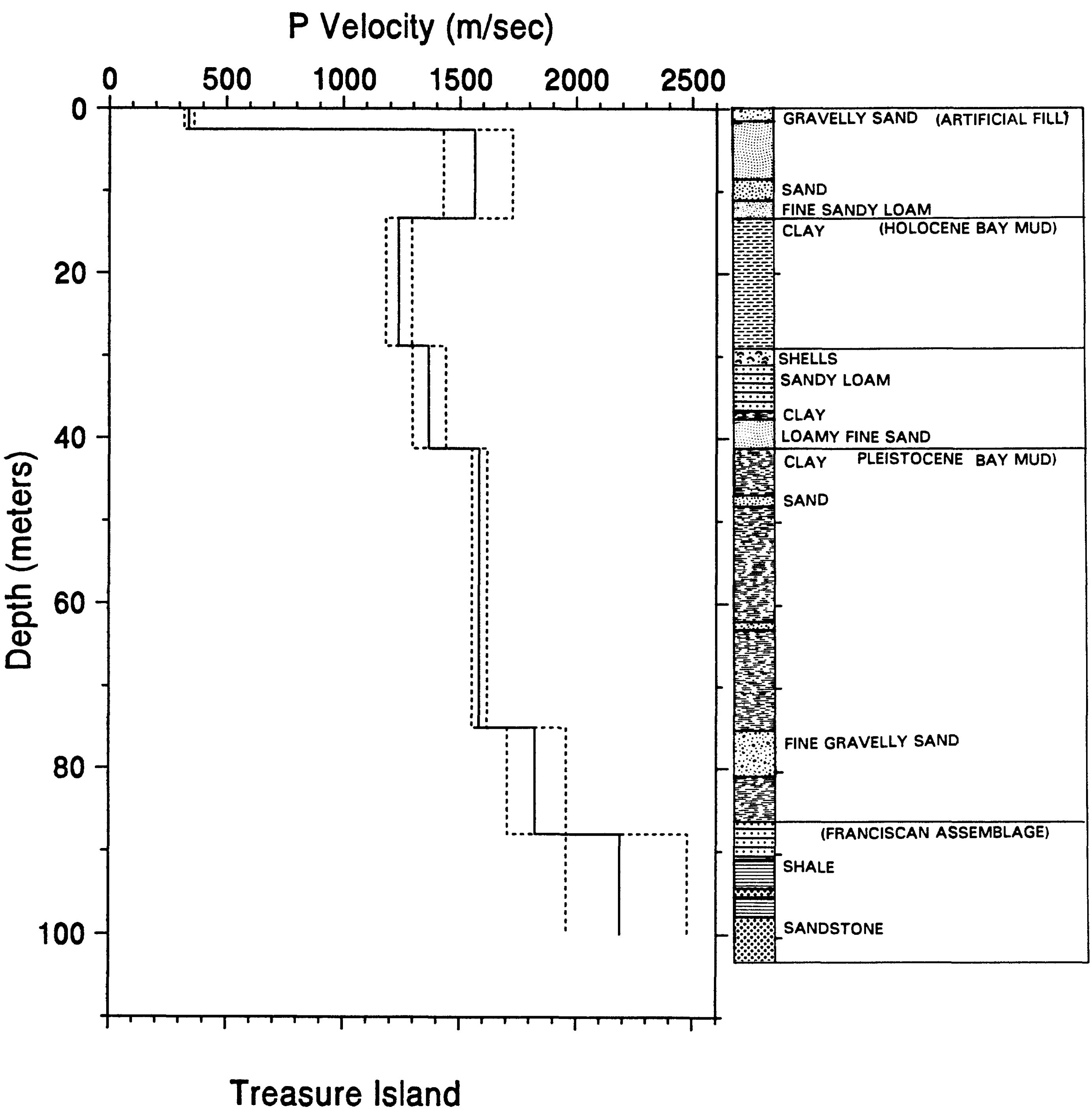


Figure 58. P-wave velocity profiles with dashed lines representing plus and minus one standard deviation. The statistics are done on the slope (reciprocal velocity) so that some of the limits will not appear symmetrical. Simplified geologic log is shown for correlation with velocities.

TABLE 11. S-wave arrival times and velocity summaries for Treasure Island.

d(m)	d(ft)	t(sec)	sig	rsdl/sig
2.5	8.2	.0098	1	-.1
5.0	16.4	.0289	1	.3
7.5	24.6	.0472	1	-.1
10.0	32.8	.0631	1	.2
12.5	41.0	.0767	1	-.9
15.0	49.2	.0923	1	.4
17.5	57.4	.1058	1	-.3
20.0	65.6	.1216	1	1.4
22.5	73.8	.1344	1	.0
25.0	82.0	.1481	1	-.5
27.5	90.2	.1613	1	-1.4
30.0	98.4	.1754	1	1.5
32.5	106.6	.1816	1	-.2
35.0	114.8	.1898	1	.2
37.5	123.0	.1969	1	-.6
40.0	131.2	.2055	1	.1
42.5	139.4	.2150	1	1.0
45.0	147.6	.2241	1	.7
47.5	155.8	.2317	1	-1.0
50.0	164.0	.2417	2	-.2
52.5	172.2	.2498	2	-.8
55.0	180.4	.2608	2	.0
57.5	188.6	.2698	2	-.2
60.0	196.9	.2794	2	-.1
62.5	205.1	.2884	2	-.2
65.0	213.3	.2974	2	-.4
67.5	221.5	.3065	2	-.5
70.0	229.7	.3175	2	.3
72.5	237.9	.3280	2	.9
75.0	246.1	.3360	2	.2
77.5	254.3	.3425	2	.2
80.0	262.5	.3486	2	.0
82.5	270.7	.3551	3	.0
85.0	278.9	.3621	3	.2
87.5	287.1	.3671	3	-.3
90.0	295.3	.3721	3	-.1
92.5	303.5	.3776	5	.3
95.0	311.7	.3812	5	.2
97.5	319.9	.3837	5	-.1
100.0	328.1	.3872	5	-.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	252	238	267	826	781	877
2.5	8.2	.010	252	238	267	826	781	877
8.0	26.2	.051	134	131	137	438	429	448
13.3	43.6	.082	170	166	174	557	544	571
28.8	94.5	.170	176	175	178	579	575	583
41.2	135.2	.209	317	313	322	1041	1027	1056
75.0	246.1	.336	267	266	269	877	872	882
88.0	288.7	.369	386	371	402	1266	1218	1320
100.0	328.1	.388	645	562	755	2115	1845	2477

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 Treasure Island.

d(m)	d(ft)	t(sec)	sig	rsdl/sig
2.5	8.2	.0069	1	-.5
5.0	16.4	.0086	1	-.4
7.5	24.6	.0115	1	.9
10.0	32.8	.0130	1	.8
12.5	41.0	.0143	1	.5
15.0	49.2	.0155	1	-.2
17.5	57.4	.0175	1	-.2
20.0	65.6	.0186	1	-1.1
22.5	73.8	.0207	1	-1.0
25.0	82.0	.0237	1	-.1
27.5	90.2	.0257	1	-.1
30.0	98.4	.0278	1	.1
32.5	106.6	.0308	1	1.2
35.0	114.8	.0318	1	.4
37.5	123.0	.0338	1	.6
40.0	131.2	.0348	1	-.2
42.5	139.4	.0368	1	.1
45.0	147.6	.0388	1	.5
47.5	155.8	.0399	1	.0
50.0	164.0	.0419	1	.4
52.5	172.2	.0429	1	-.2
55.0	180.4	.0439	1	-.7
57.5	188.6	.0459	1	-.3
60.0	196.9	.0469	1	-.9
62.5	205.1	.0489	1	-.5
65.0	213.3	.0499	1	-1.1
67.5	221.5	.0529	1	.4
70.0	229.7	.0539	1	-.2
72.5	237.9	.0559	1	.2
75.0	246.1	.0579	1	.6
77.5	254.3	.0589	1	.3
80.0	262.5	.0609	1	.9
82.5	270.7	.0619	1	.5
85.0	278.9	.0629	1	.1
87.5	287.1	.0639	1	-.2
90.0	295.3	.0649	1	-.4
92.5	303.5	.0659	1	-.6
95.0	311.7	.0679	1	.3
97.5	319.9	.0689	1	.1
100.0	328.1	.0699	1	.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	339	319	361	1111	1047	1183
2.5	8.2	.007	339	319	361	1111	1047	1183
13.3	43.6	.014	1562	1428	1725	5126	4684	5659
28.8	94.5	.027	1236	1182	1294	4054	3879	4245
41.2	135.2	.036	1365	1297	1440	4477	4254	4725
75.0	246.1	.057	1583	1551	1617	5195	5088	5306
88.0	288.7	.064	1822	1704	1956	5976	5592	6417
100.0	328.1	.070	2187	1957	2477	7174	6421	8127

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

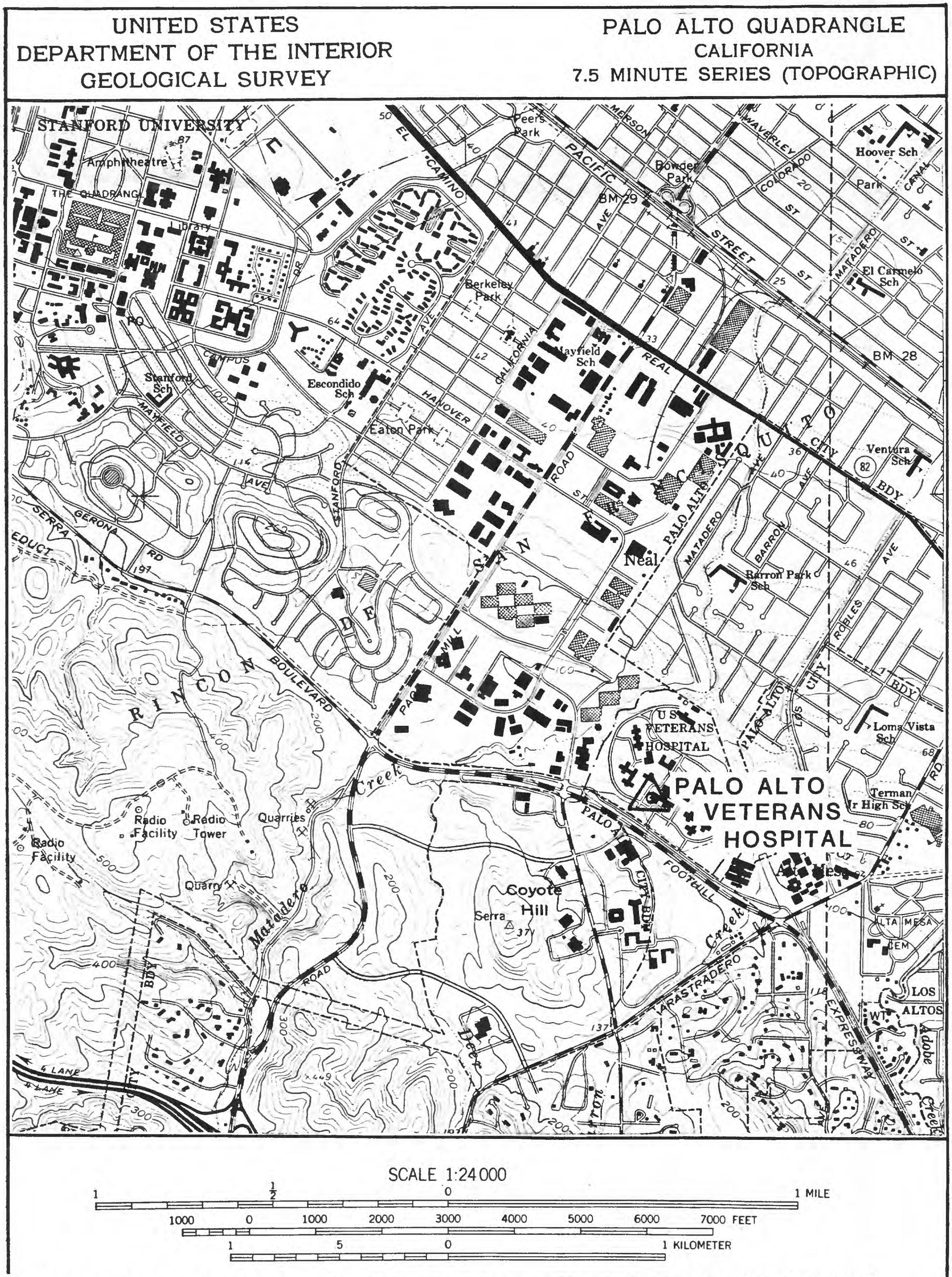


Figure 59. Site location map for Palo Alto Veterans Hospital. The borehole is located within 15 meters of the strong-motion recorder.

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)

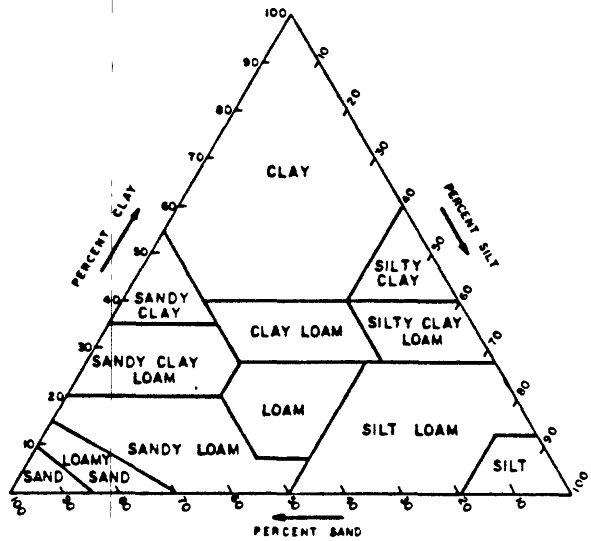
cm	in	fracture spacing
0-1	0-1/2	v. close
1-5	1/2-2	close
5-30	2-12	moderate
30-100	12-36	wide
>100	>36	v. wide

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 60. Explanation of geologic log.

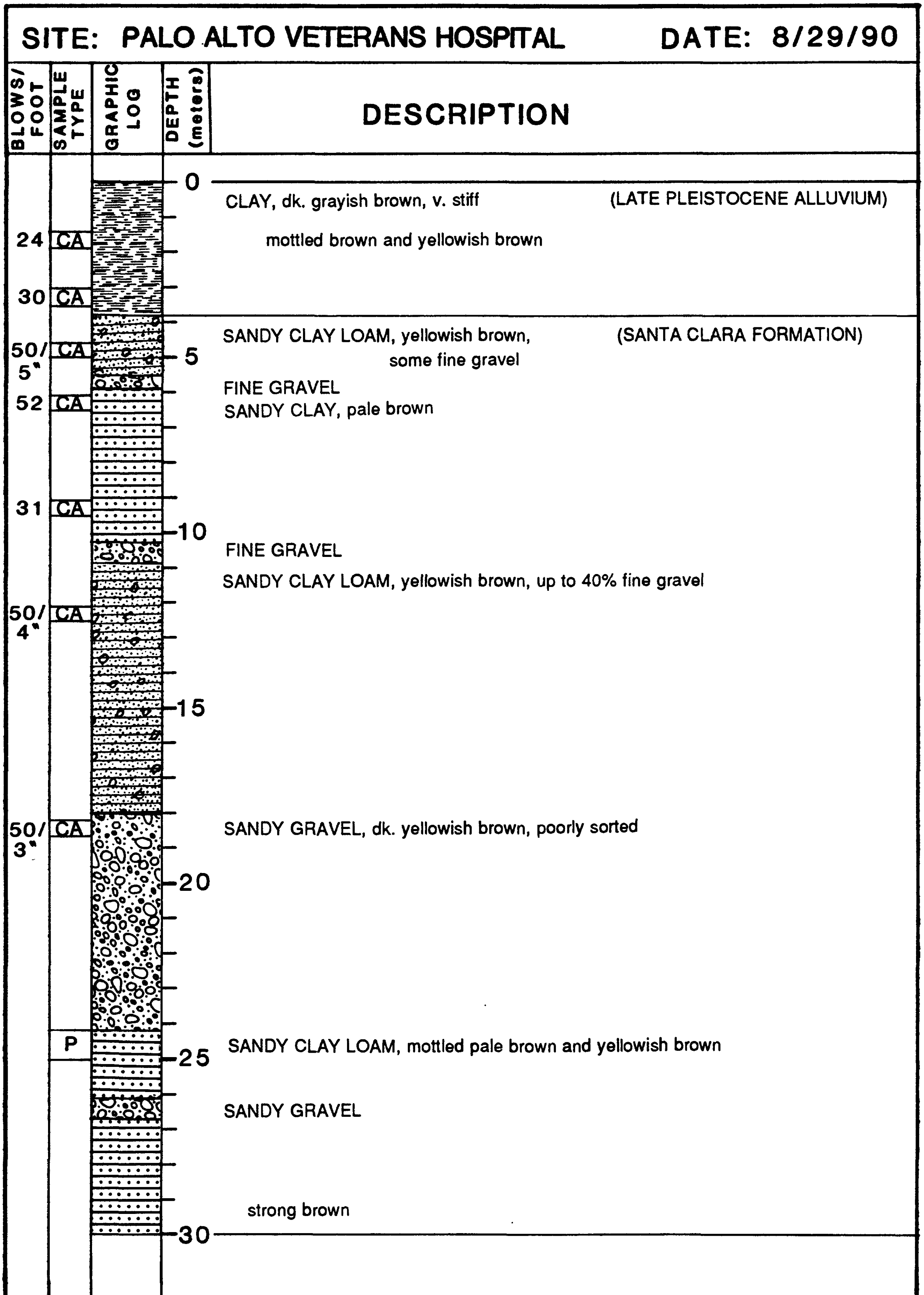
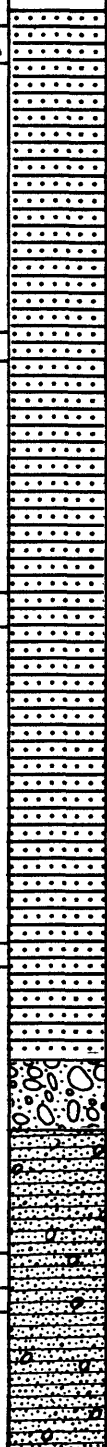


Figure 61. Geologic log for Palo Alto Veterans Hospital.

SITE: PALO ALTO VETERANS HOSPITAL DATE:



BLOWS/ FOOT	SAMPLE TYPE	GRAPHIC LOG	DEPTH (meters)	DESCRIPTION
			30	
73	CA			
				yellowish brown
			35	
100	CA			strong brown
			40	
	P			yellowish brown
			45	
54	CA			LOAM to SILTY CLAY LOAM, yellowish brown
			50	
				FINE GRAVEL
				SANDY CLAY LOAM, poorly sorted, 10-20% fine gravel
			55	
	P			
	CA			
			60	

Figure 61. (Continued).

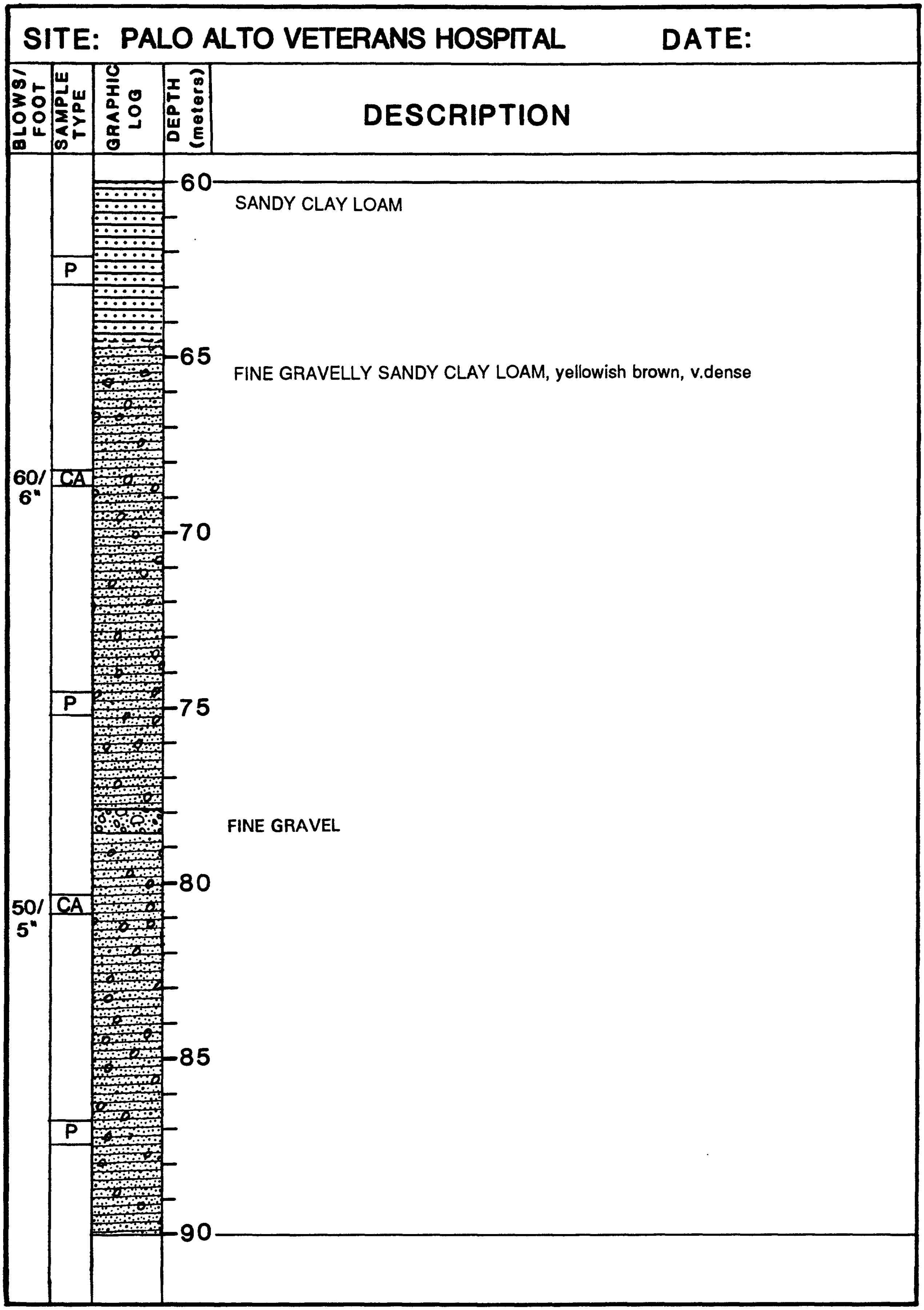


Figure 61. (Continued).

SITE: PALO ALTO VETERANS HOSPITAL DATE:

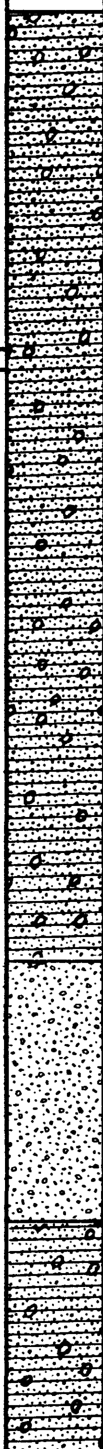
BLOWS/ FOOT	SAMPLE TYPE	GRAPHIC LOG	DEPTH (meters)	DESCRIPTION
			90	
			95	
50/ 4"	CA			
			100	
			105	
			110	GRAVELLY SAND
			115	SANDY CLAY LOAM, strong brown
			120	

Figure 61. (Continued).

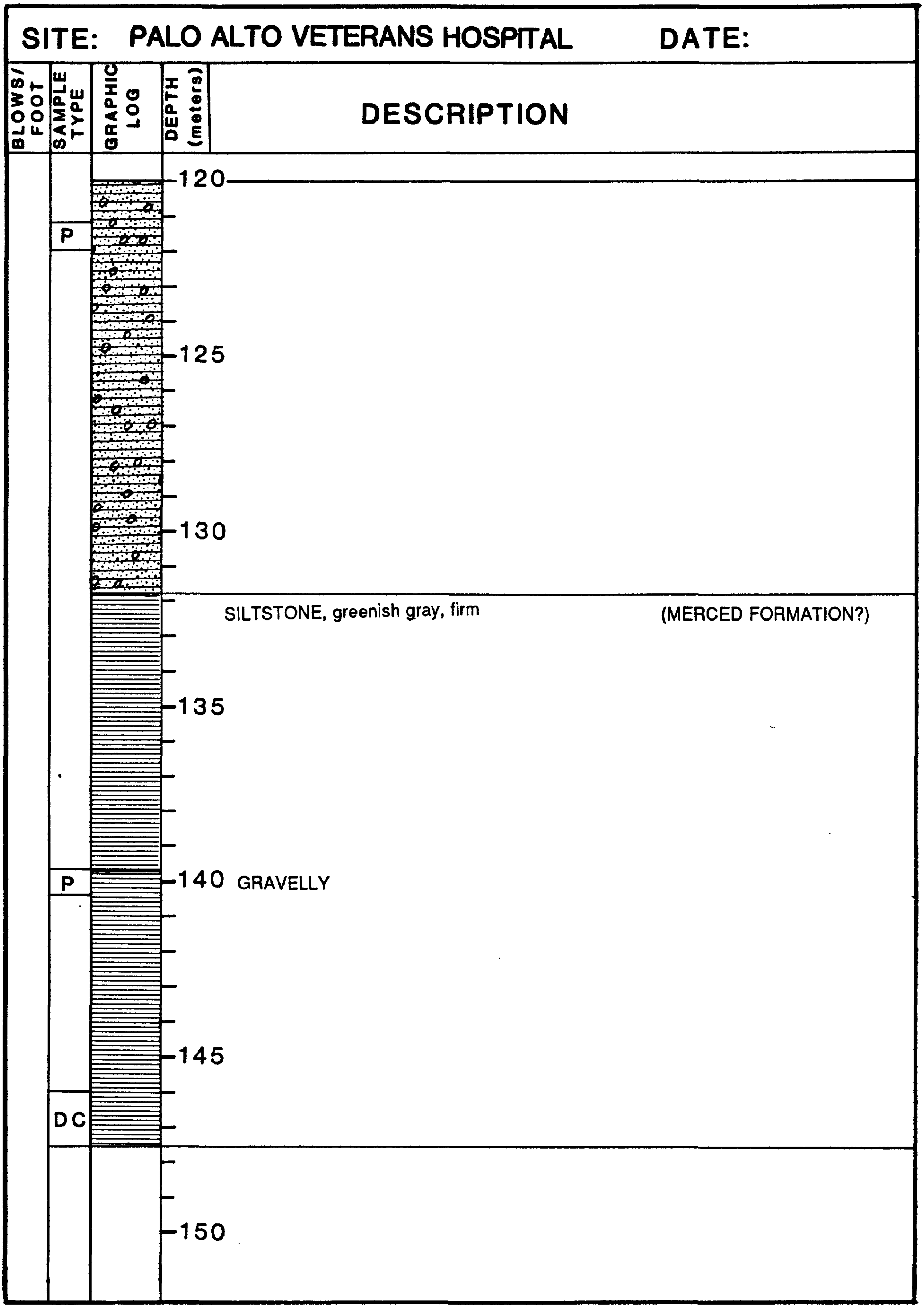


Figure 61. (Continued).

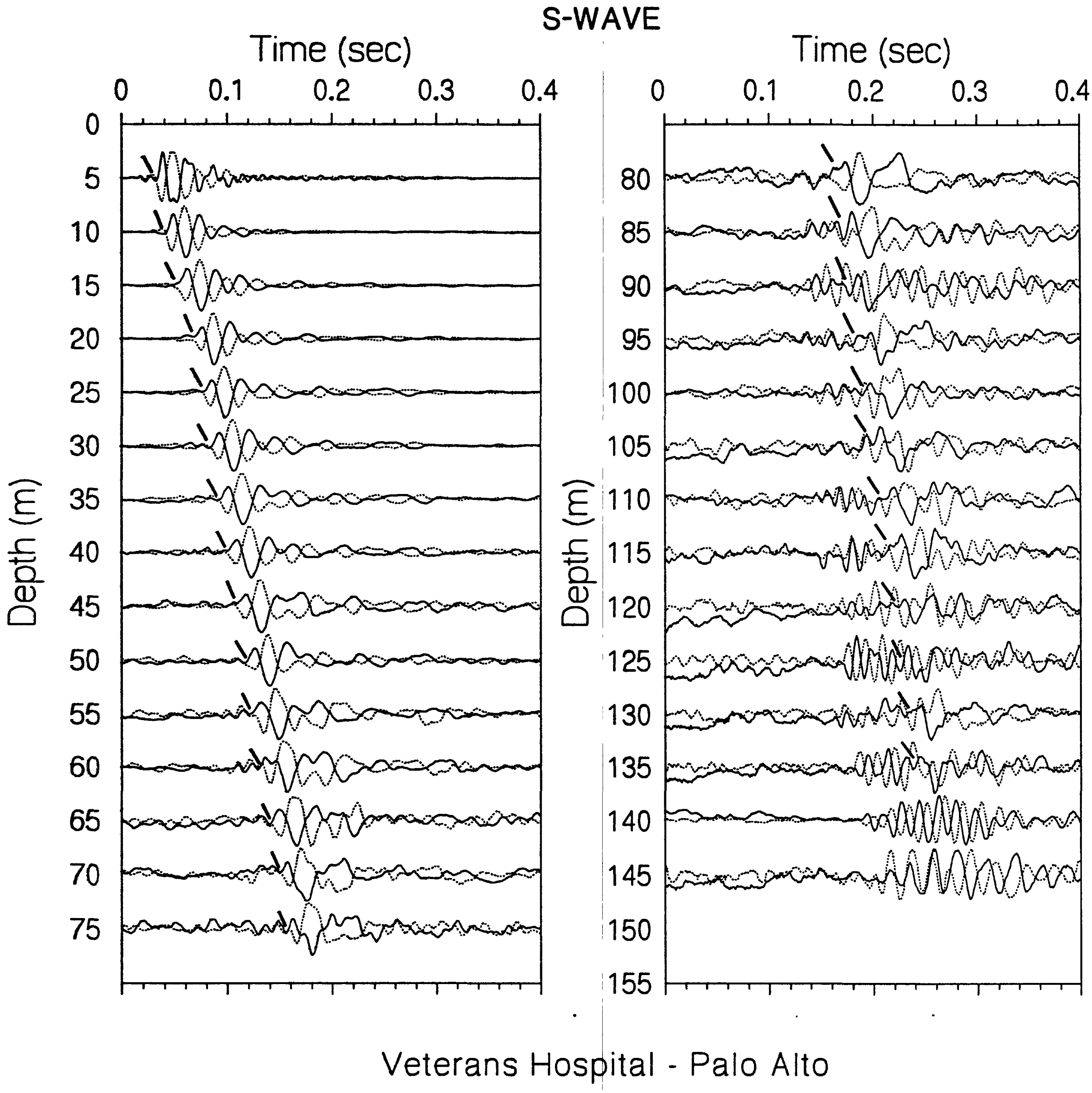


Figure 62. Horizontal-component record section from impacts in opposite horizontal directions superimposed for identification of shear arrivals. S-wave arrivals are shown by the accent marks.

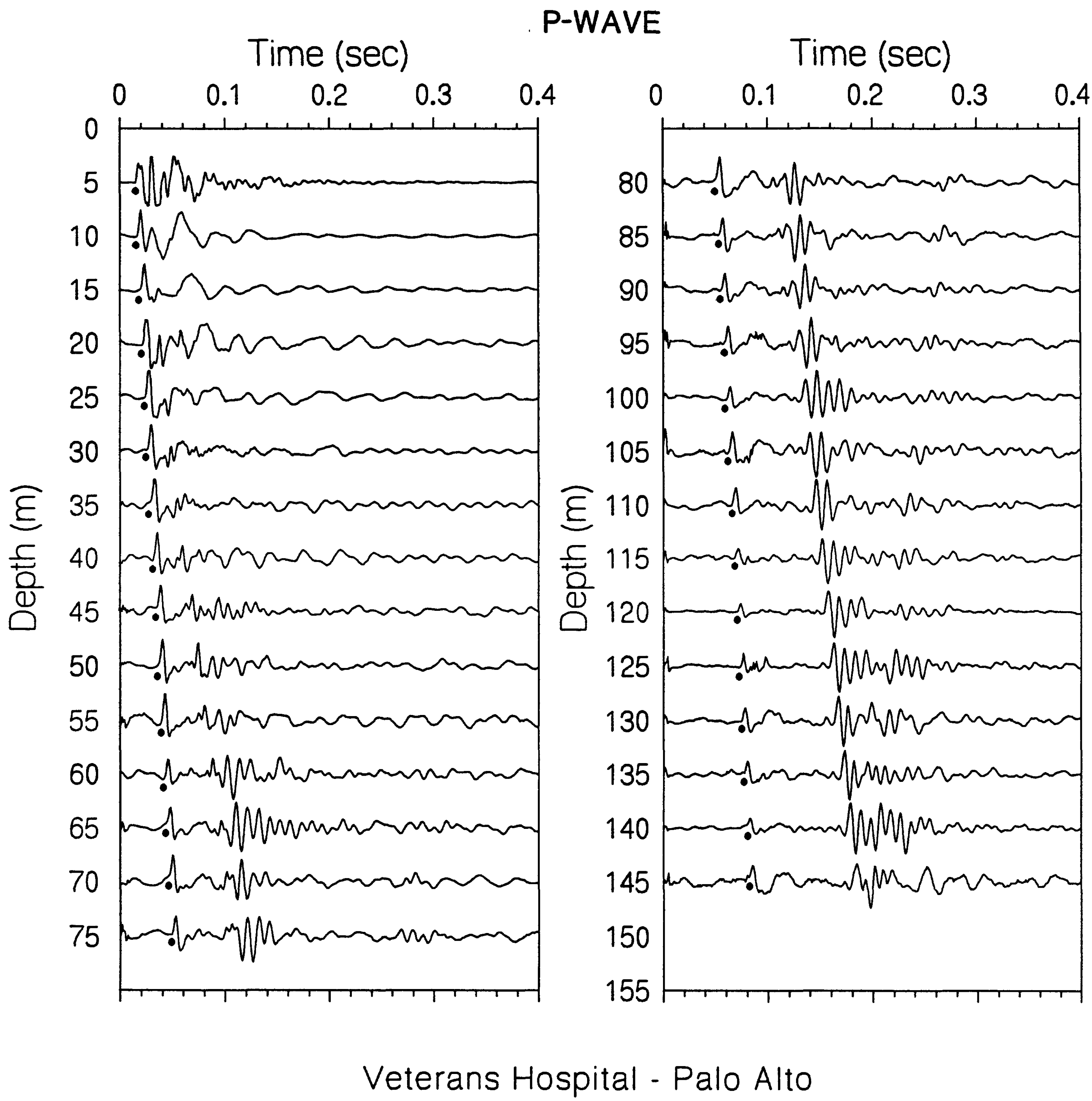


Figure 63. Vertical-component record section. P-wave arrivals are shown by the solid circles.

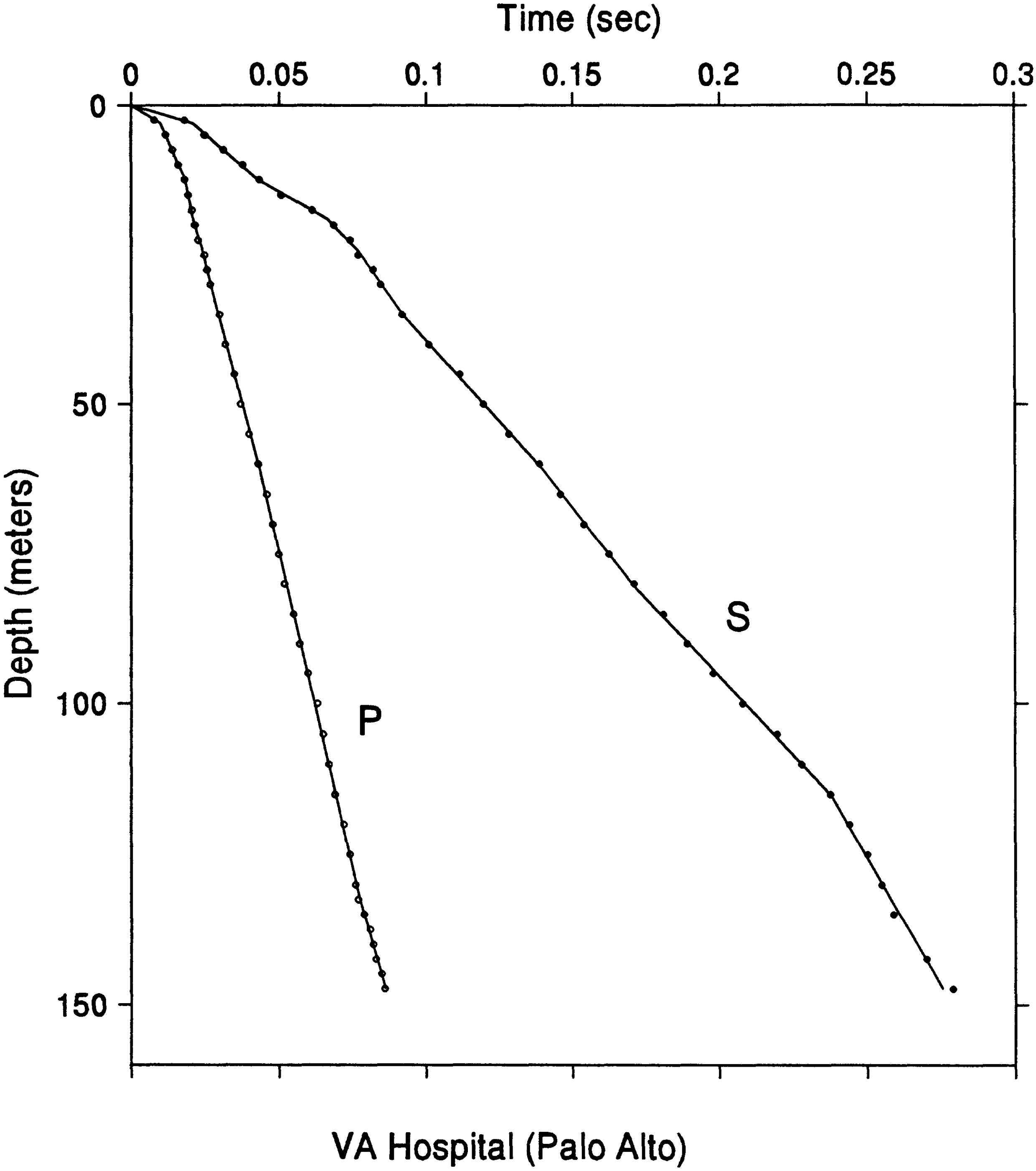


Figure 64. Time-depth graph of P-wave and S-wave picks. Line segments show the hinged-least-squares fit to the data points.

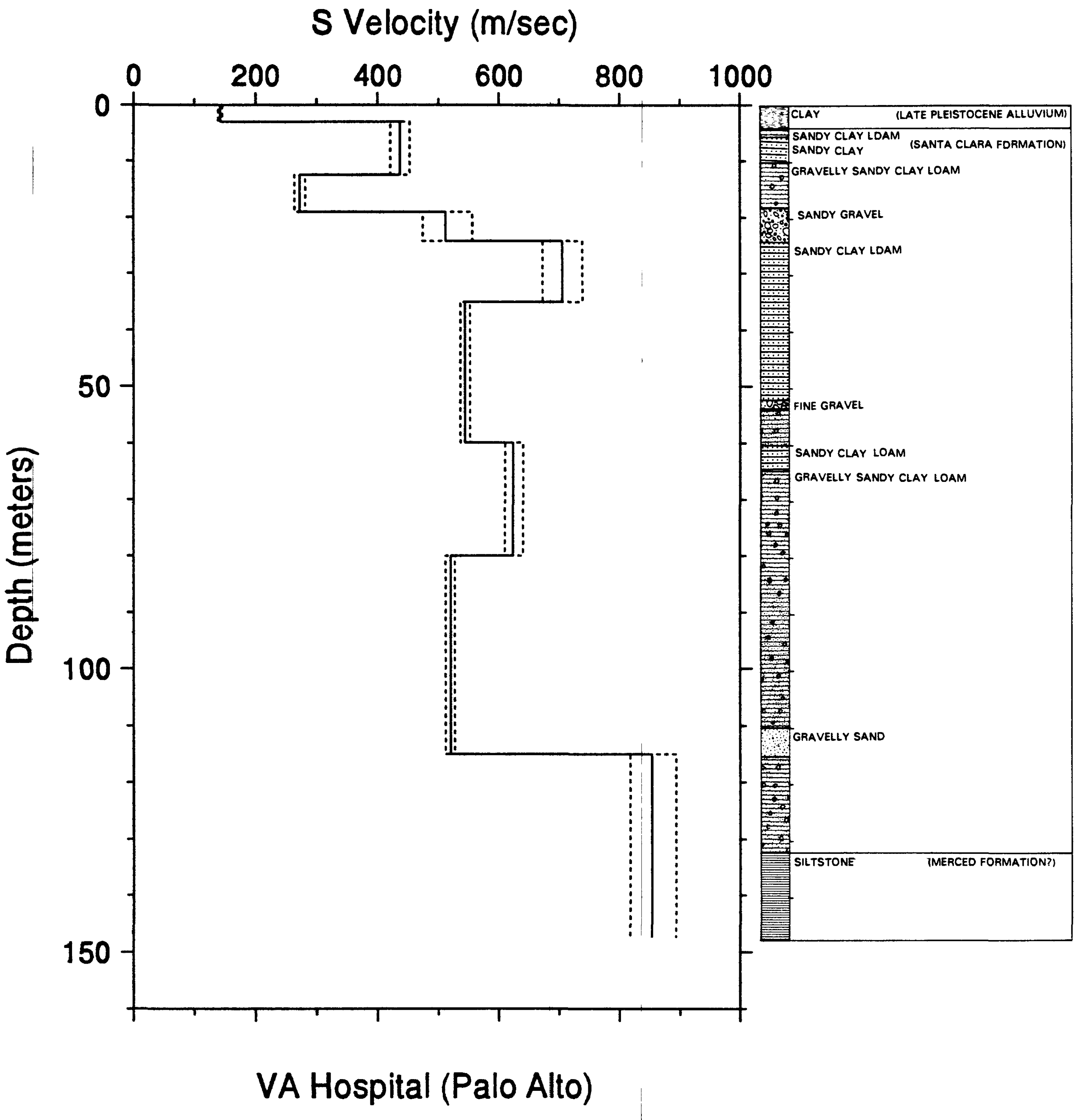


Figure 65. S-wave velocity profiles with dashed lines representing plus and minus one standard deviation. The statistics are done on the slope (reciprocal velocity) so that some of the limits will not appear symmetrical. Simplified geologic log is shown for correlation with velocities.

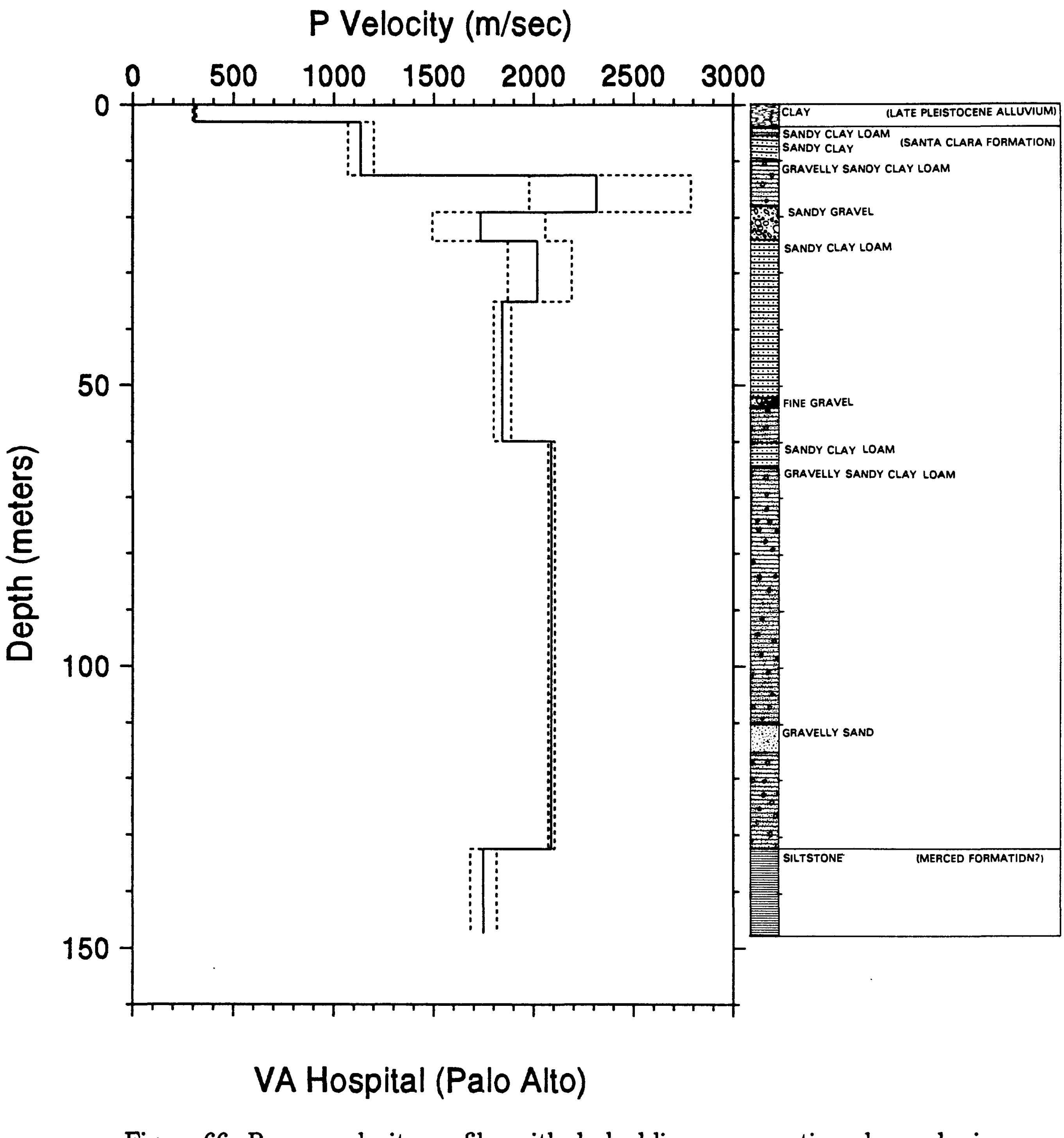


Figure 66. P-wave velocity profiles with dashed lines representing plus and minus one standard deviation. The statistics are done on the slope (reciprocal velocity) so that some of the limits will not appear symmetrical. Simplified geologic log is shown for correlation with velocities.

TABLE 13. S-wave arrival times and velocity summaries for Palo Alto Veterans Hospital.

d(m)	d(ft)	t(sec)	sig	rsdl/sig
2.5	8.2	.0180	1	.5
5.0	16.4	.0250	1	-.6
7.5	24.6	.0313	1	-.1
10.0	32.8	.0376	1	.5
12.5	41.0	.0433	1	.5
15.0	49.2	.0507	1	-1.3
17.5	57.4	.0614	1	.3
20.0	65.6	.0686	1	.0
22.5	73.8	.0743	1	.8
25.0	82.0	.0770	1	-.9
27.5	90.2	.0821	1	.6
30.0	98.4	.0847	1	-.3
35.0	114.8	.0919	1	-.2
40.0	131.2	.1010	1	-.3
45.0	147.6	.1116	1	1.1
50.0	164.0	.1196	1	-.1
55.0	180.4	.1282	1	-.7
60.0	196.9	.1387	1	.6
65.0	213.3	.1457	1	-.4
70.0	229.7	.1537	1	-.4
75.0	246.1	.1623	1	.2
80.0	262.5	.1708	2	.3
85.0	278.9	.1808	2	.5
90.0	295.3	.1888	2	-.3
95.0	311.7	.1978	2	-.6
100.0	328.1	.2078	2	-.4
105.0	344.5	.2193	2	.5
110.0	360.9	.2278	2	.0
115.0	377.3	.2374	2	.0
120.0	393.7	.2439	2	.3
125.0	410.1	.2499	2	.4
130.0	426.5	.2549	2	-.1
135.0	442.9	.2589	2	-1.0
142.5	467.5	.2699	4	.1
147.4	483.6	.2789	4	.9

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	143	139	146	468	456	480
3.0	9.8	.021	143	139	146	468	456	480
12.5	41.0	.043	437	421	453	1432	1381	1487
19.0	62.3	.067	273	264	282	895	866	926
24.2	79.4	.077	512	474	556	1680	1556	1825
35.0	114.8	.092	705	673	739	2313	2210	2426
60.0	196.9	.138	544	536	552	1785	1759	1811
80.0	262.5	.170	624	610	640	2048	2000	2099
115.0	377.3	.237	520	512	527	1705	1681	1730
147.4	483.6	.275	854	818	894	2802	2683	2932

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

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TABLE 14. P-wave arrival times and velocity summaries for Palo Alto Veterans Hospital.

d(m)	d(ft)	t(sec)	sig	rsdl/sig
2.5	8.2	.0079	1	-.3
5.0	16.4	.0117	1	.1
7.5	24.6	.0141	1	.3
10.0	32.8	.0158	1	-.2
12.5	41.0	.0181	1	-.1
15.0	49.2	.0193	1	.0
17.5	57.4	.0205	1	.1
20.0	65.6	.0216	1	.0
22.5	73.8	.0226	1	-.4
25.0	82.0	.0247	1	.3
27.5	90.2	.0257	1	.1
30.0	98.4	.0268	1	-.1
35.0	114.8	.0298	1	.4
40.0	131.2	.0318	1	-.3
45.0	147.6	.0349	1	.1
50.0	164.0	.0369	1	-.6
55.0	180.4	.0399	1	-.3
60.0	196.9	.0429	1	.0
65.0	213.3	.0459	1	.6
70.0	229.7	.0479	1	.2
75.0	246.1	.0499	1	-.2
80.0	262.5	.0519	1	-.6
85.0	278.9	.0549	1	.0
90.0	295.3	.0569	1	-.4
95.0	311.7	.0599	1	.2
100.0	328.1	.0629	1	.8
105.0	344.5	.0650	1	.5
110.0	360.9	.0670	1	.1
115.0	377.3	.0690	1	-.2
120.0	393.7	.0720	1	.4
125.0	410.1	.0740	1	.0
130.0	426.5	.0760	1	-.4
132.5	434.7	.0770	1	-.6
135.0	442.9	.0790	1	-.1
137.5	451.1	.0810	1	.5
140.0	459.3	.0820	1	.1
142.5	467.5	.0830	1	-.3
145.0	475.7	.0850	1	.2
147.4	483.6	.0860	1	-.2

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	306	297	316	1004	973	1037
3.0	9.8	.010	306	297	316	1004	973	1037
12.5	41.0	.018	1132	1071	1201	3715	3514	3939
19.0	62.3	.021	2314	1978	2787	7592	6489	9145
24.2	79.4	.024	1732	1494	2059	5681	4901	6757
35.0	114.8	.029	2019	1872	2190	6623	6143	7184
60.0	196.9	.043	1843	1800	1888	6047	5905	6195
132.5	434.7	.078	2089	2073	2105	6854	6802	6906
147.4	483.6	.086	1747	1684	1815	5732	5525	5955

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

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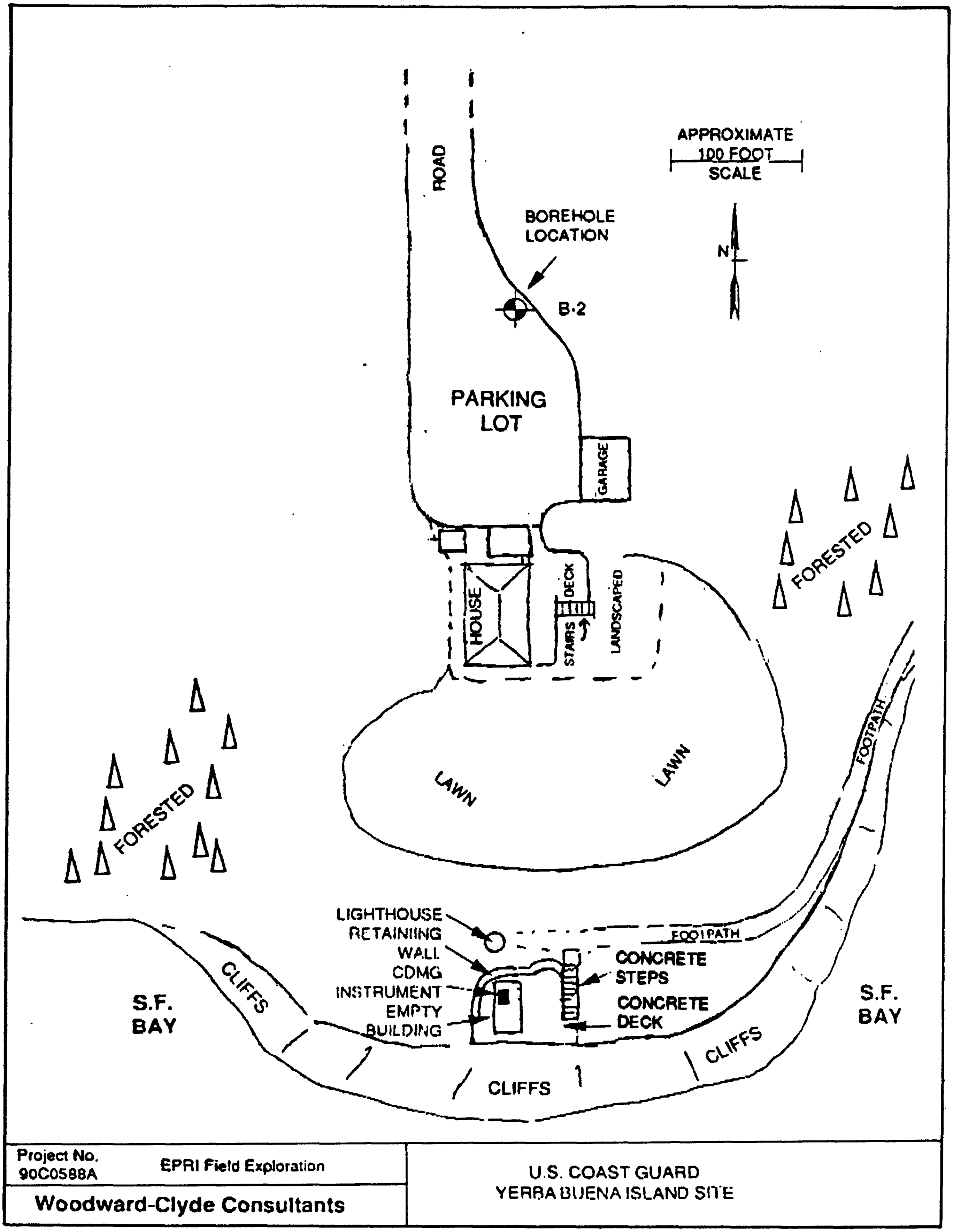


Figure 67. Detailed map showing location of the borehole relative to the strong-motion recorder.

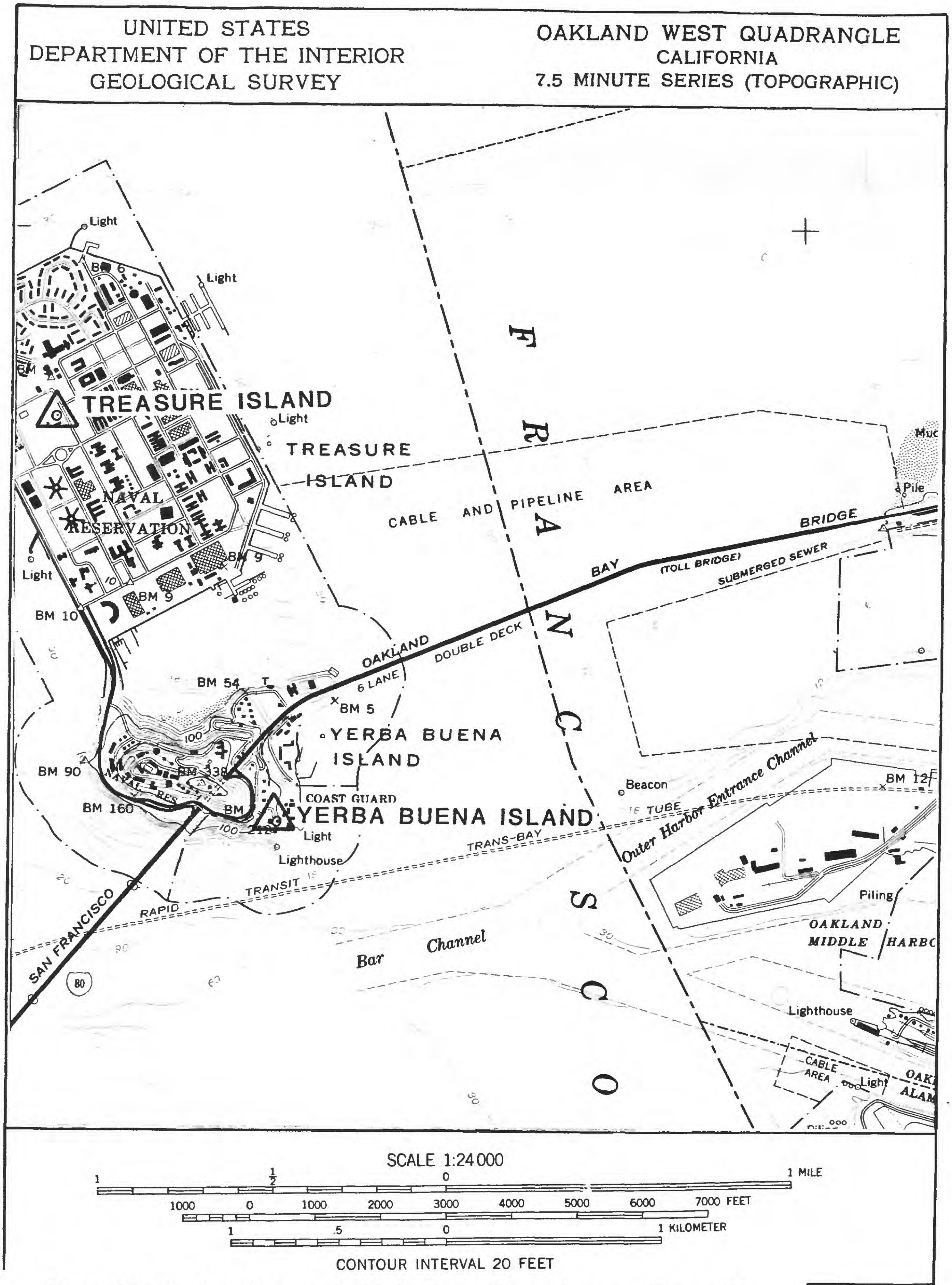


Figure 68. Site location map for Yerba Buena Island (same as Figure 49).

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)

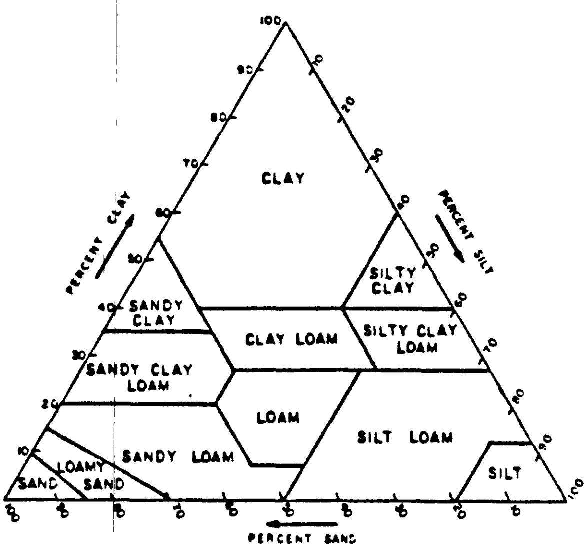
cm	in	fracture spacing
0-1	0-1/2	v. close
1-5	1/2-2	close
5-30	2-12	moderate
30-100	12-36	wide
>100	>36	v. wide

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 69. Explanation of geologic log.

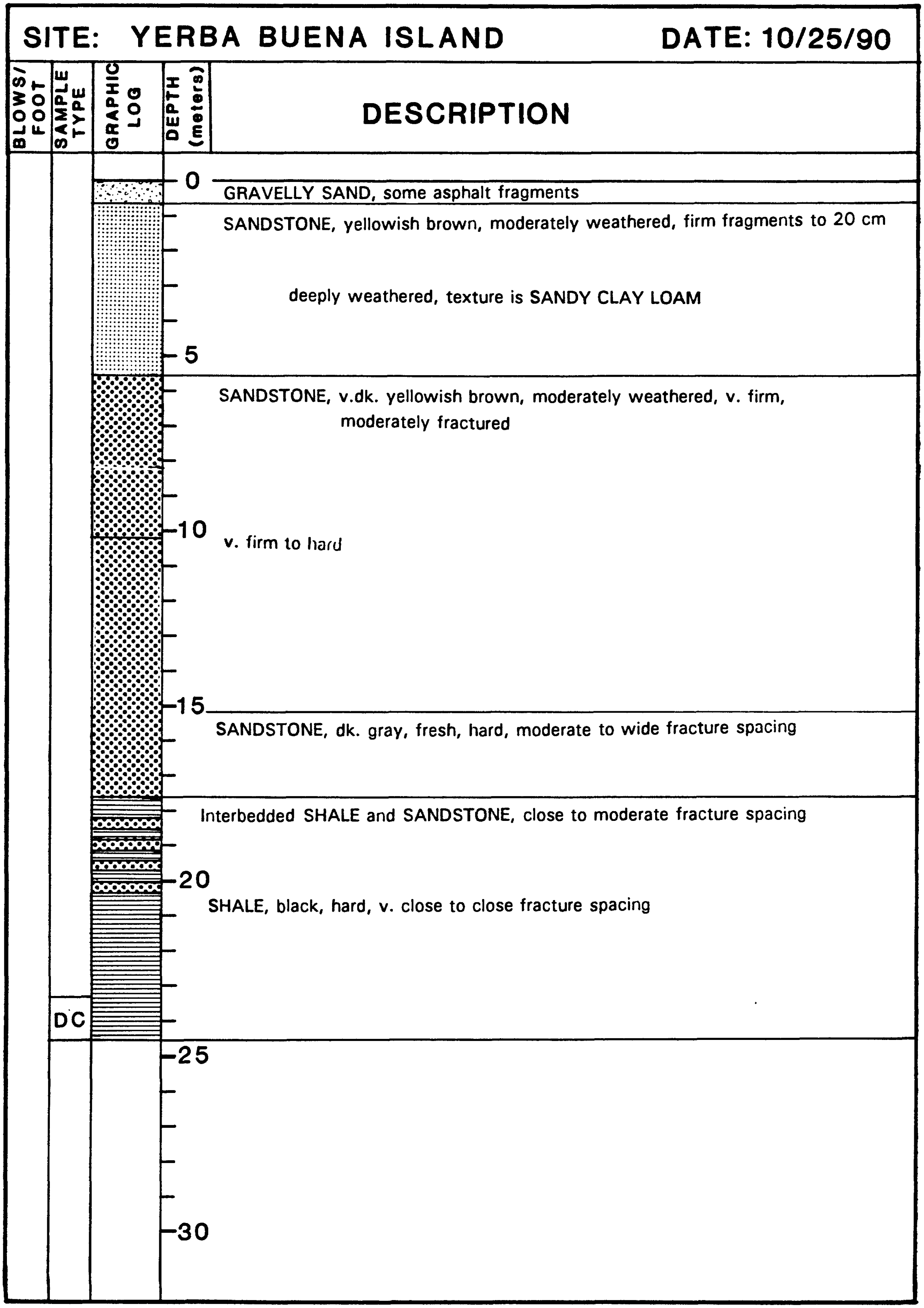


Figure 70. Geologic log for Yerba Buena Island.

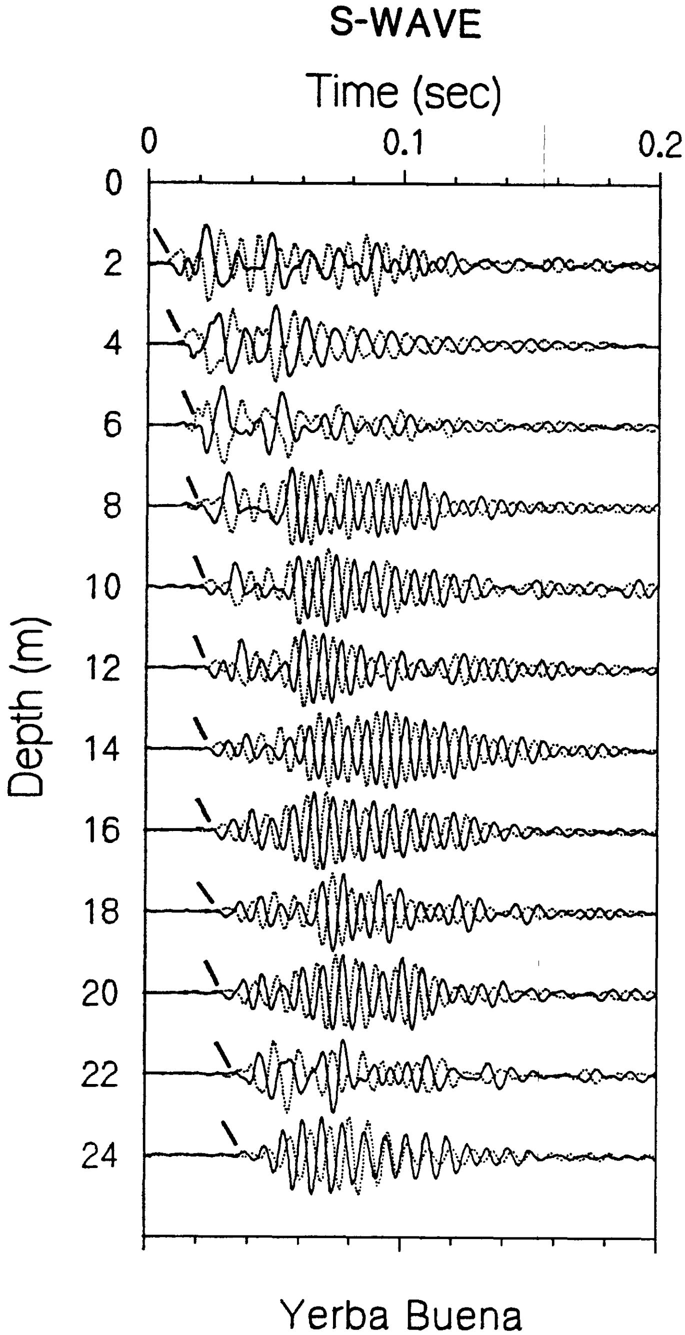


Figure 71. Horizontal-component record section from impacts in opposite horizontal directions superimposed for identification of shear arrivals. S-wave arrivals are shown by the accent marks.

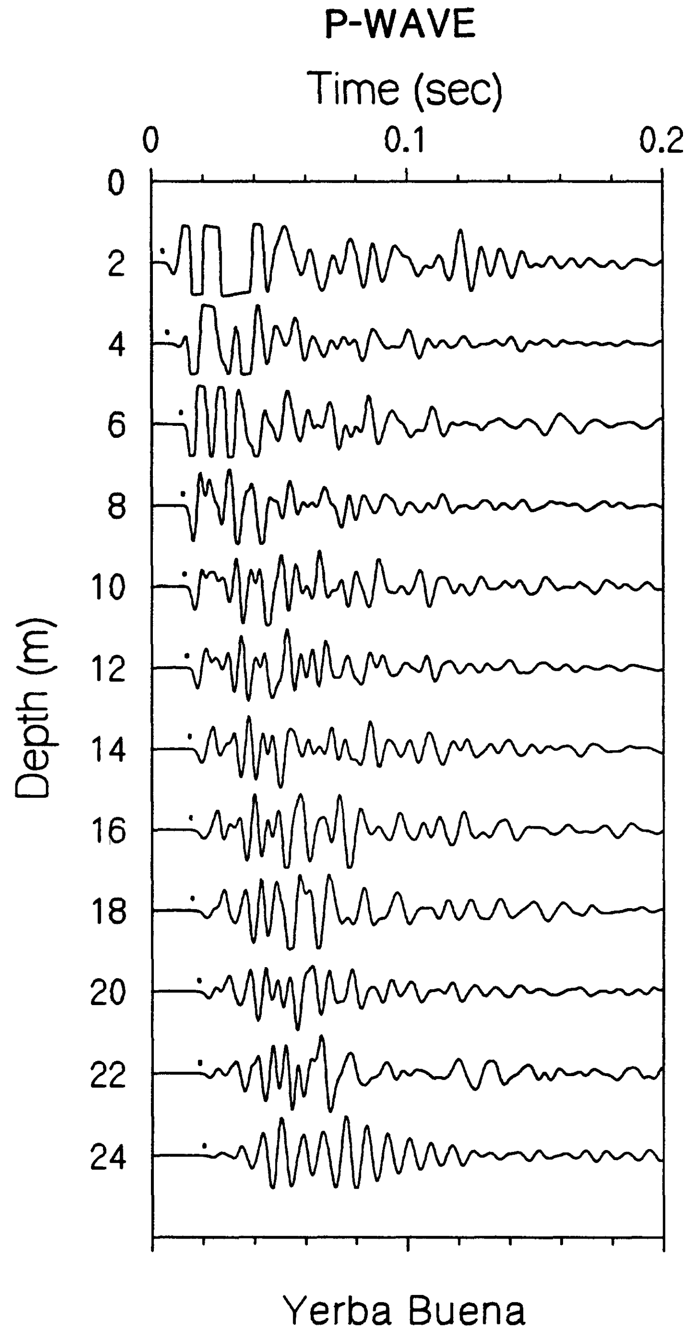


Figure 72. Vertical-component record section. P-wave arrivals are shown by the solid circles.

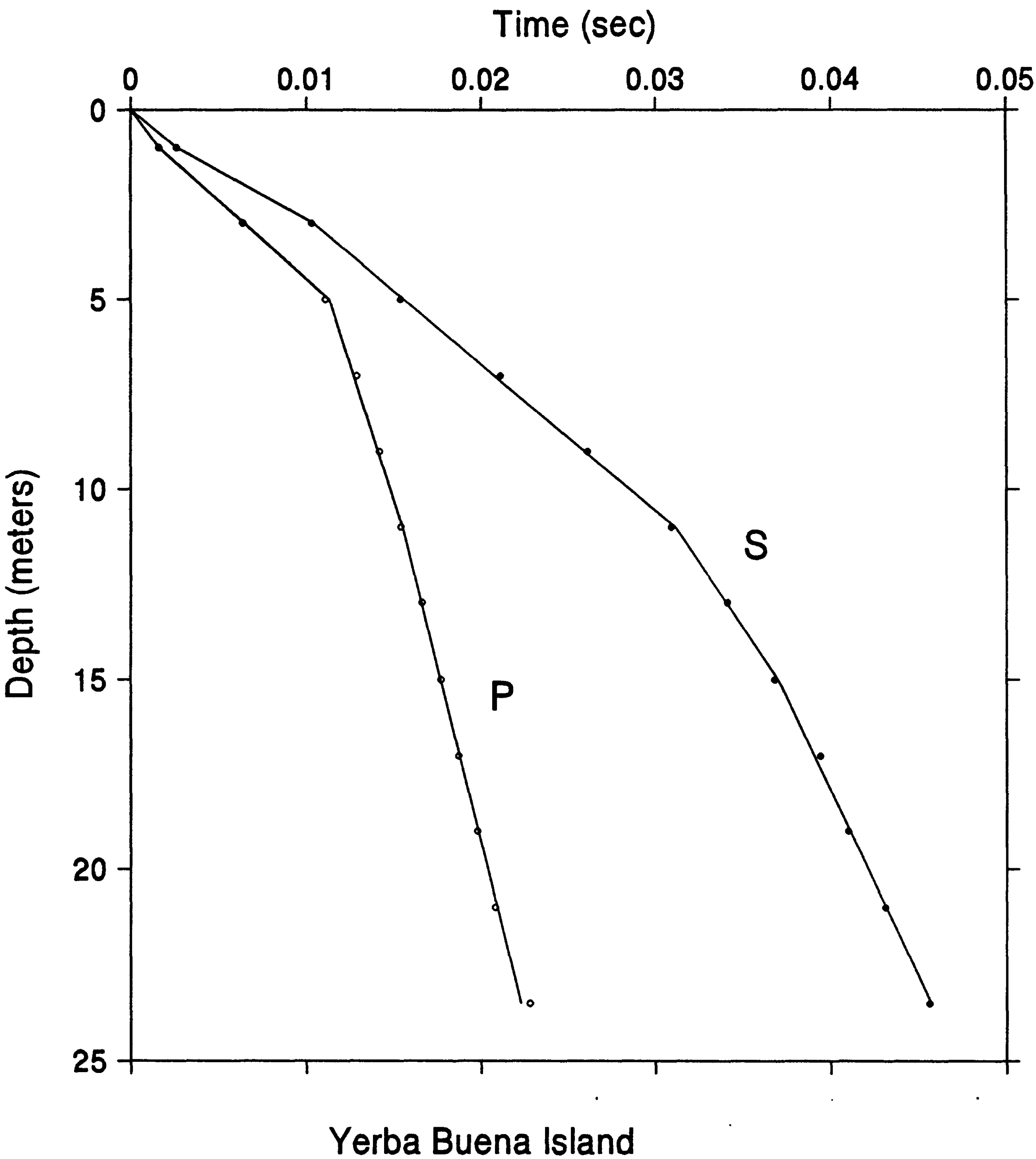


Figure 73. Time-depth graph of P-wave and S-wave picks. Line segments show the hinged-least-squares fit to the data points.

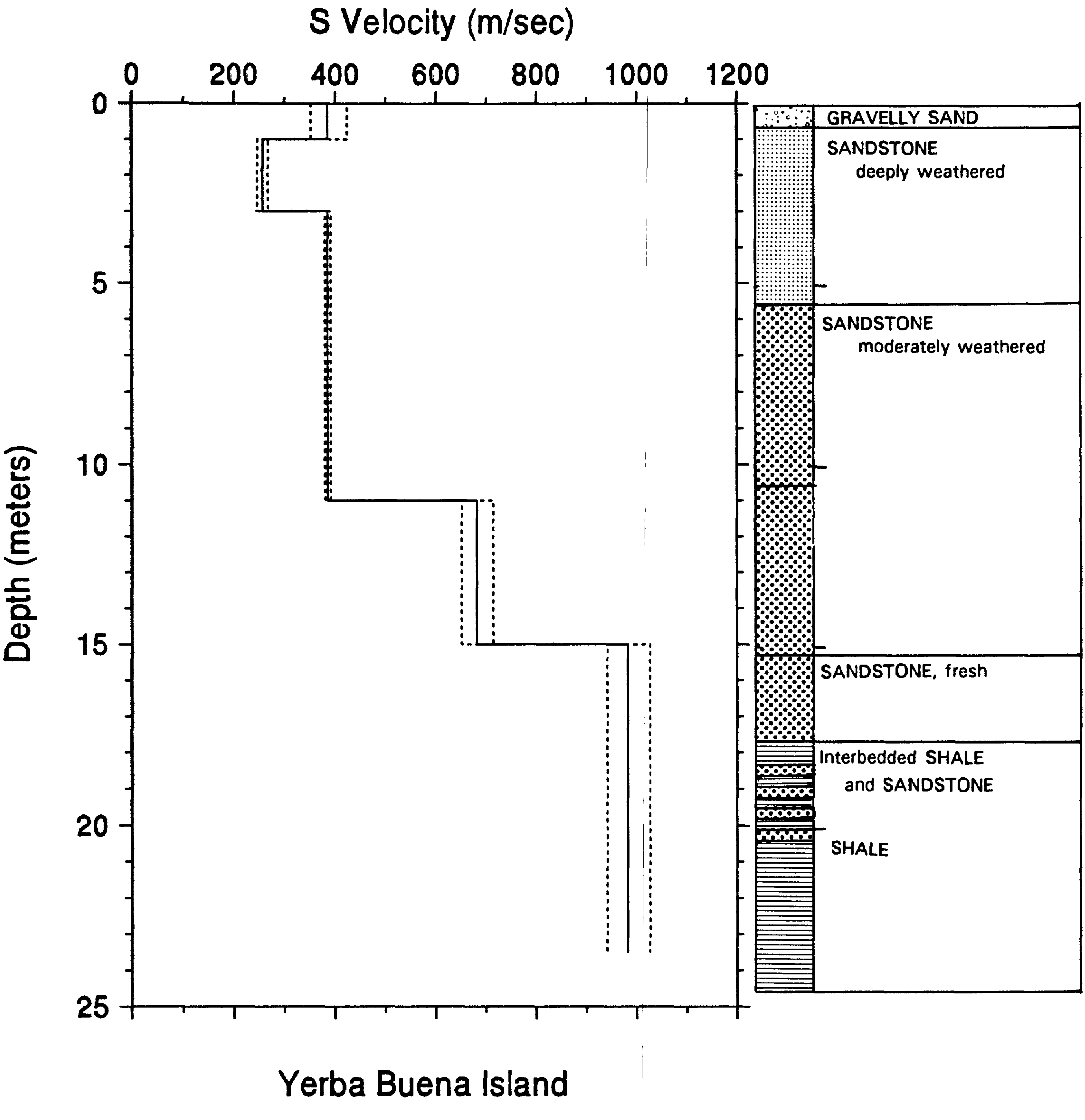


Figure 74. S-wave velocity profiles with dashed lines representing plus and minus one standard deviation. The statistics are done on the slope (reciprocal velocity) so that some of the limits will not appear symmetrical. Simplified geologic log is shown for correlation with velocities.

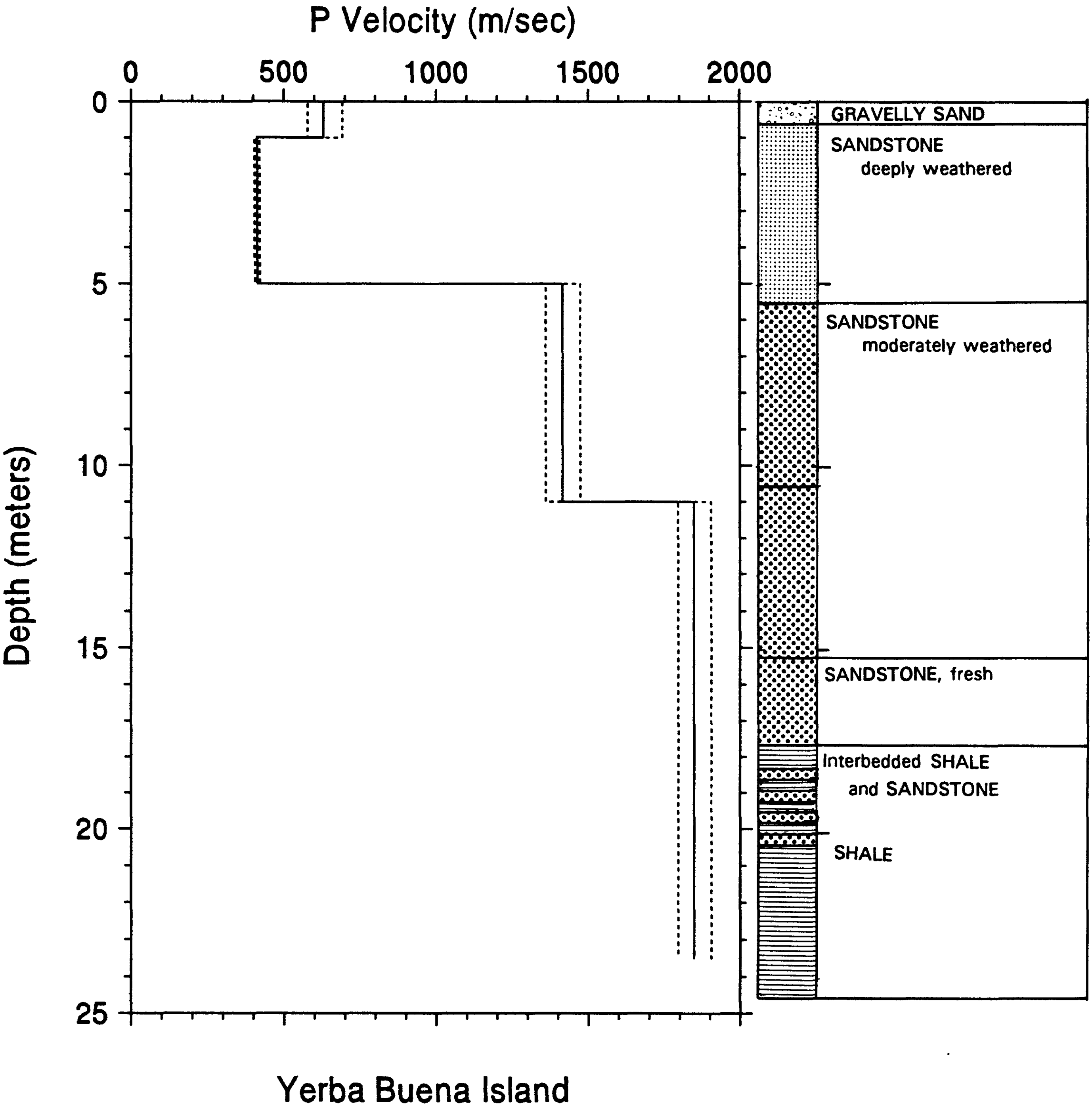


Figure 75. P-wave velocity profiles with dashed lines representing plus and minus one standard deviation. The statistics are done on the slope (reciprocal velocity) so that some of the limits will not appear symmetrical. Simplified geologic log is shown for correlation with velocities.

TABLE 15. S-wave arrival times and velocity summaries for Yerba Buena Island.

d(m)	d(ft)	t(sec)	sig	rsdl/sig
1.0	3.3	.0026	1	.0
3.0	9.8	.0103	1	-.1
5.0	16.4	.0154	1	-.2
7.0	23.0	.0211	1	.3
9.0	29.5	.0261	1	.1
11.0	36.1	.0309	1	-.2
13.0	42.7	.0341	1	.0
15.0	49.2	.0368	1	-.2
17.0	55.8	.0394	1	.3
19.0	62.3	.0410	1	-.1
21.0	68.9	.0431	1	.0
23.5	77.1	.0456	2	.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	385	352	424	1262	1155	1391
1.0	3.3	.003	385	352	424	1262	1155	1391
3.0	9.8	.010	257	247	268	844	812	878
11.0	36.1	.031	385	380	391	1264	1246	1282
15.0	49.2	.037	681	651	714	2235	2137	2342
23.5	77.1	.046	982	941	1027	3221	3086	3369

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 16. P-wave arrival times and velocity summaries for Yerba Buena Island.

d(m)	d(ft)	t(sec)	sig	rsdl/sig
1.0	3.3	.0016	1	.0
3.0	9.8	.0064	1	.0
5.0	16.4	.0111	1	-.2
7.0	23.0	.0129	1	.2
9.0	29.5	.0142	1	.1
11.0	36.1	.0154	1	-.1
13.0	42.7	.0166	1	.0
15.0	49.2	.0177	1	.0
17.0	55.8	.0187	1	-.1
19.0	62.3	.0198	1	.0
21.0	68.9	.0208	1	-.1
23.5	77.1	.0228	2	.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	630	579	691	2068	1901	2267
1.0	3.3	.002	630	579	691	2068	1901	2267
5.0	16.4	.011	413	405	422	1356	1328	1384
11.0	36.1	.016	1415	1361	1474	4643	4465	4836
23.5	77.1	.022	1848	1796	1904	6064	5892	6246

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