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

by

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INTRODUCTION

The Loma Prieta earthquake of October 17, 1989 (1704 PST) was recorded at 131 strong-motion stations located through-out the San Francisco Bay area (Maley et al., 1989, Shakal, et al., 1989). This data set has enormous value for engineering and seismological studies regarding earthquake ground motions. Using damage to man-made structures from the 1906 San Francisco earthquake, Wood (in Lawson, chairman,1908) recognized that ground-motion intensity could be correlated with differences in local site geology. In order to quantify the effect of local geology (e.g., Borcherdt, 1970; Borcherdt and Gibbs, 1976; Borcherdt and Glassmoyer, 1992) on ground motions from the 1989 earthquake, detailed geologic and geophysical data are needed. To plan the acquisition of these data a meeting was held on July 6, 1990 at the USGS in Menlo Park, California. Eighteen scientists and engineers representing thirteen institutions attended the meeting to coordinate drilling and data aquisition plans at strong-motion stations.

This is the forth in a series of four reports (Gibbs et al., 1992, 1993, 1994) detailing the results of borehole measurements at strong-motion stations recording significant ground motions during the 1989 Loma Prieta earthquake. This report contains the results of the field effort by the USGS for the following seven boreholes located near strong-motion stations operated by the U.S. Geological Survey (Figure 1).

1. Anderson Dam (downstream)
2. Calaveras Reservoir
3. Callens Ranch
4. Hollister Airport
5. Sunol Fire Station
6. Williams Ranch
7. Webb Ranch

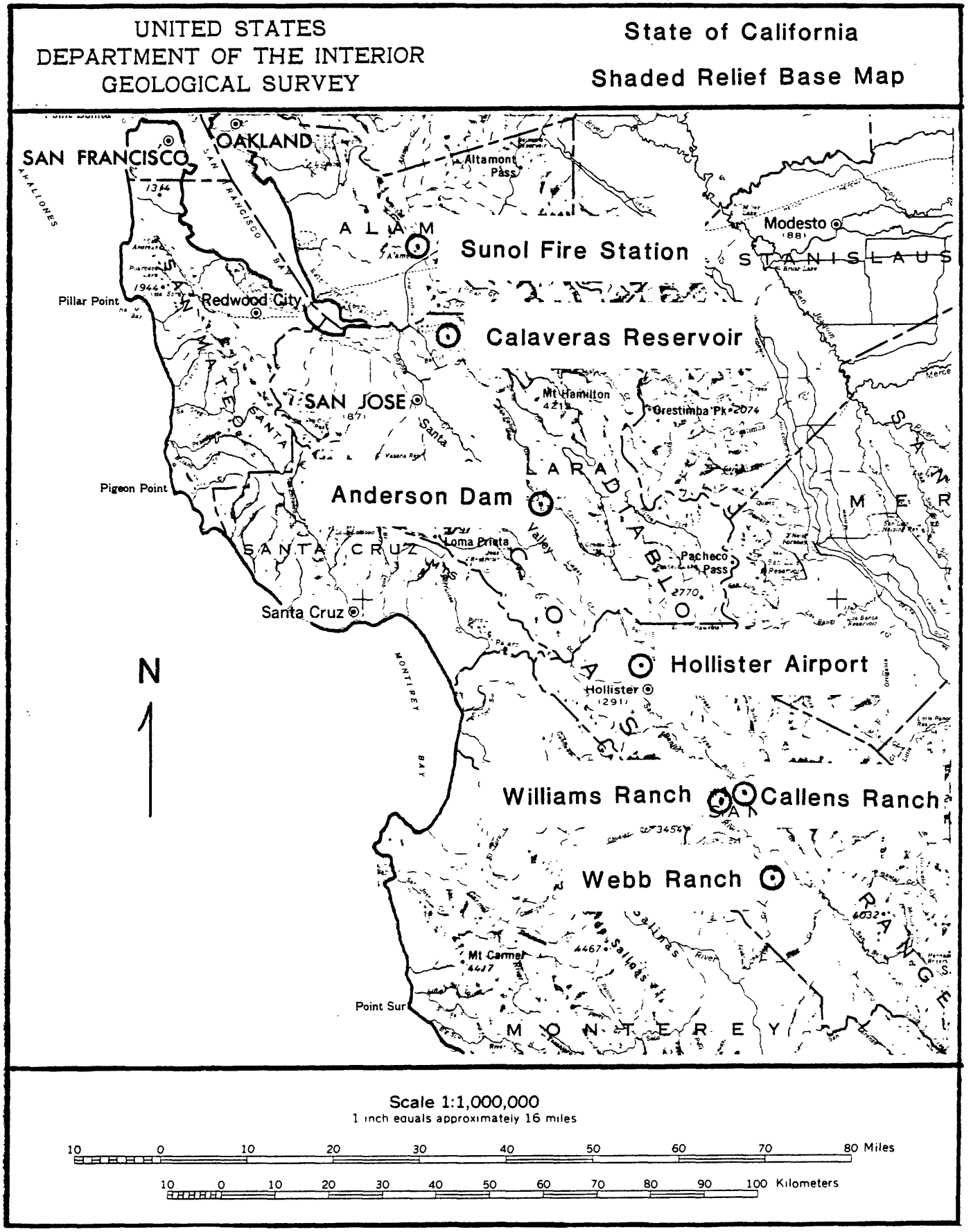

Figure 1. Regional map showing the locations of boreholes (center of circles) included in this report.

FIELD MEASUREMENTS

Drilling and Sampling Procedures

Boreholes were located as close as possible to the accelerograph stations that recorded the strong-motion from the Loma Prieta Earthquake. In the case of Anderson Dam, Calaveras Reservoir, Sunol Fire Station, and Webb Ranch the boreholes were drilled approximately 30 meters from the strong-motion instrument. Callens Ranch and Hollister Airport borehole were located within 20 meters of the instrument and Williams Ranch borehole was within 10 meters of the strong-motion accelerograph.

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

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

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

Geologic Logs

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

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

California.

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

S- and P-wave Data

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

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

Measurements are made by lowering a single three-component geophone into the borehole and clamping it to the casing-wall with an electrically-actuated lever arm. A second three-component geophone is placed at the surface approximately 30 centimeters from the shear source and is used as a check of the zero time determined by the triggering of the

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

recorder by the contact switch. After the measurement at the bottom of the borehole all measurements for this group of stations were made at 2.5 meter intervals. The data are recorded on magnetic tape cassettes in digital form on a twelve-channel recording system.

DATA INTERPRETATION and PROCESSING

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

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

For determining the final velocity model there are a number of ways to proceed. In

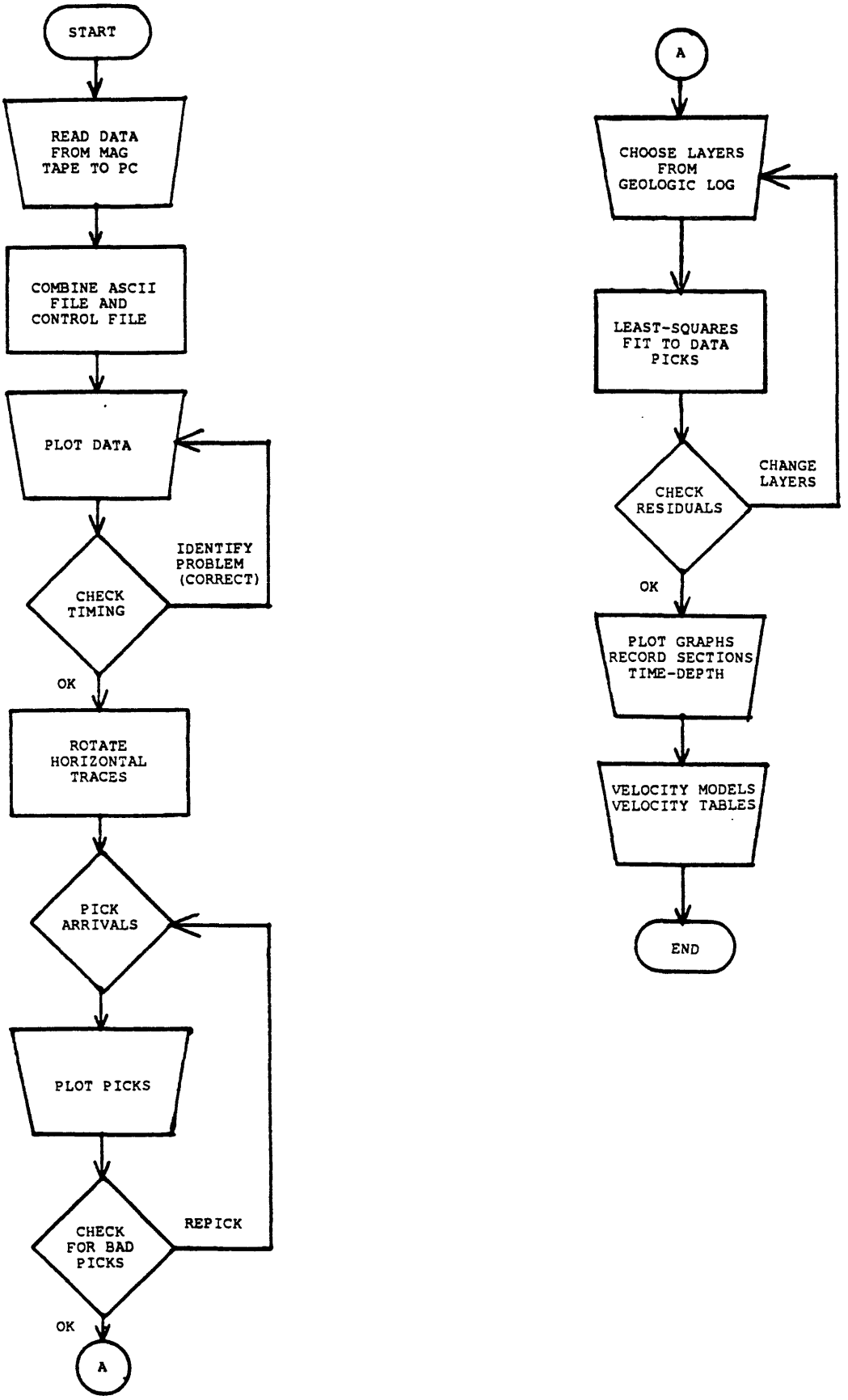

Figure 2. Flow-chart outlining the data processing and interpretation steps.

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

SUMMARY OF RESULTS

S-wave velocities

Figure 3 summarizes S-wave velocities at four sites Anderson Dam, Calaveras Reservoir, Callens Ranch, and Sunol Fire Station. In general, the upper sections at Calaveras Reservoir, Callens Ranch and Sunol Fire Station have similar velocities in thin layering with varing amounts of sand-clay-loam. Anderson Dam has a slightly higher velocity from the surface to 2.5 and then below that a higher velocity layer (543 m/s gravely-sandy-loam) to 25.6 meters and a lower velocity (386 m/s mudstone) to the bottom of the borehole at 36.2 meters. The higher velocities at Anderson Dam (543 m/s), Calaveras Reservoir (728 m/s), Callens Ranch (1098 m/s), and Sunol Fire Station (934 m/s) are the result of decreased amounts of sand, increased gravel and cementation. The increase in texture (grain size) has been correlated with increasing S-wave velocity (e.g. Fumal, 1978). The average velocity to 35 meters (measurement at this depth in all seven boreholes) is 473 m/s, 501

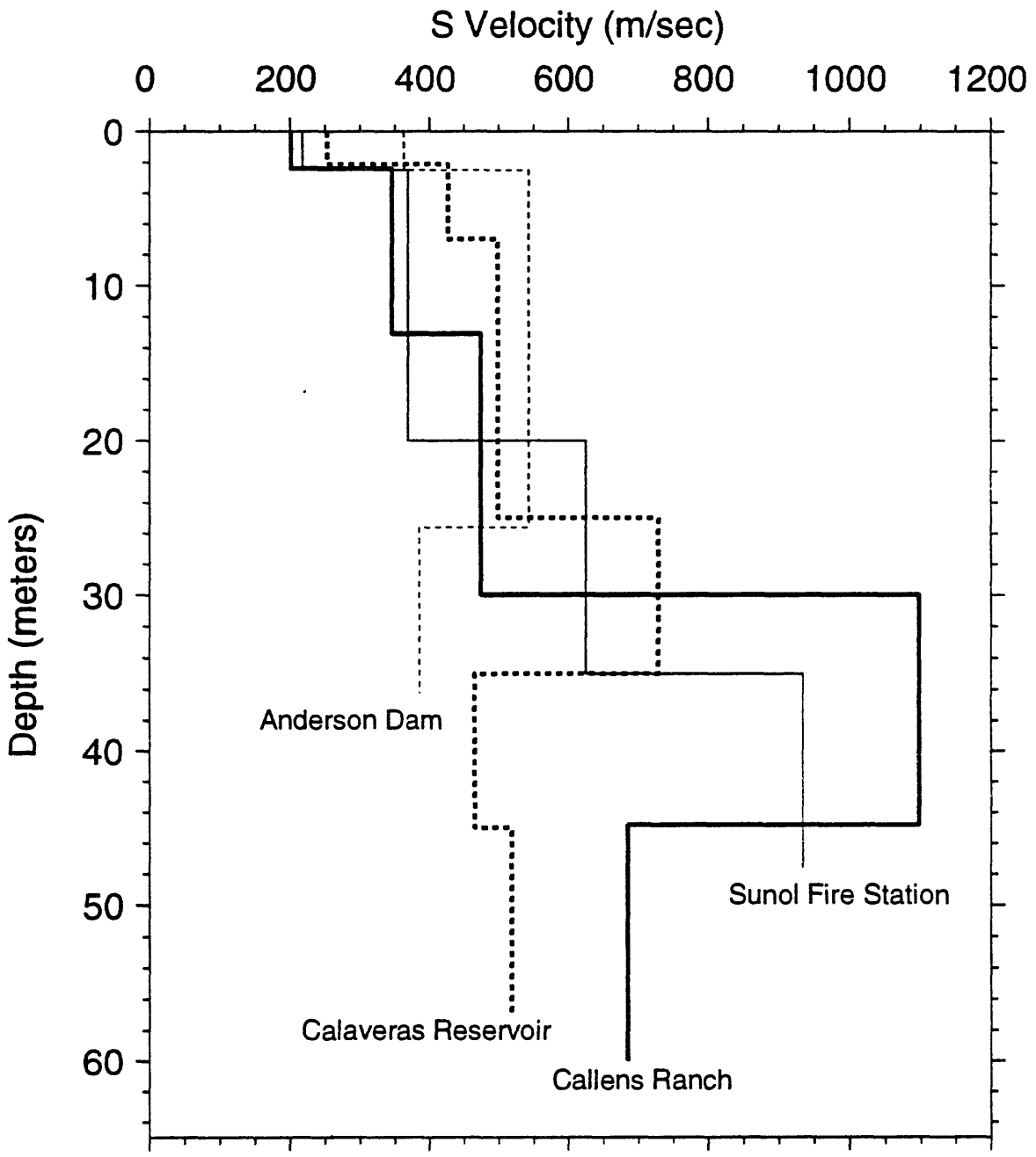

Figure 3. S-wave velocity models superimposed for comparison. The four sites shown here have higher average velocities in the upper sections of the borehole than those of Figure 4. Probably due to increased gravel content in the upper sections of the borehole.

m/s, 419 m/s, and 419 m/s for Anderson Dam, Calaveras Reservoir, Callens Ranch, and Sunol Fire Station, respectively.

Figure 4 summarizes the S-wave velocities at Hollister Airport, Webb Ranch, and Williams Ranch. The lithology of this group, in general, has less gravel content in the layering and therefore have lower average velocities than those of Figure 3. The average velocity to 35 meters is 223 m/s, 323 m/s, and 327 m/s for Hollister Airport, Webb Ranch, and Williams Ranch, respectively.

P-wave velocities

Figures 5 and 6 summarize the P-wave velocities at the seven sites of this report. There is a poorer correlation between P-wave velocity and lithology than between S-wave velocity and lithology because P-wave velocity is strongly affected by degree of saturation. The saturation level (water table) in unconsolidated sediments is sometimes indicated by an increase in P-wave velocity to near 1500 m/s. This is not always true as trapped gas (e.g. the presence of air, methane from decaying organic matter) can reduce the P-wave velocity below 1500 m/s even when the formation is saturated (Brandt, 1960).

APPENDIX

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

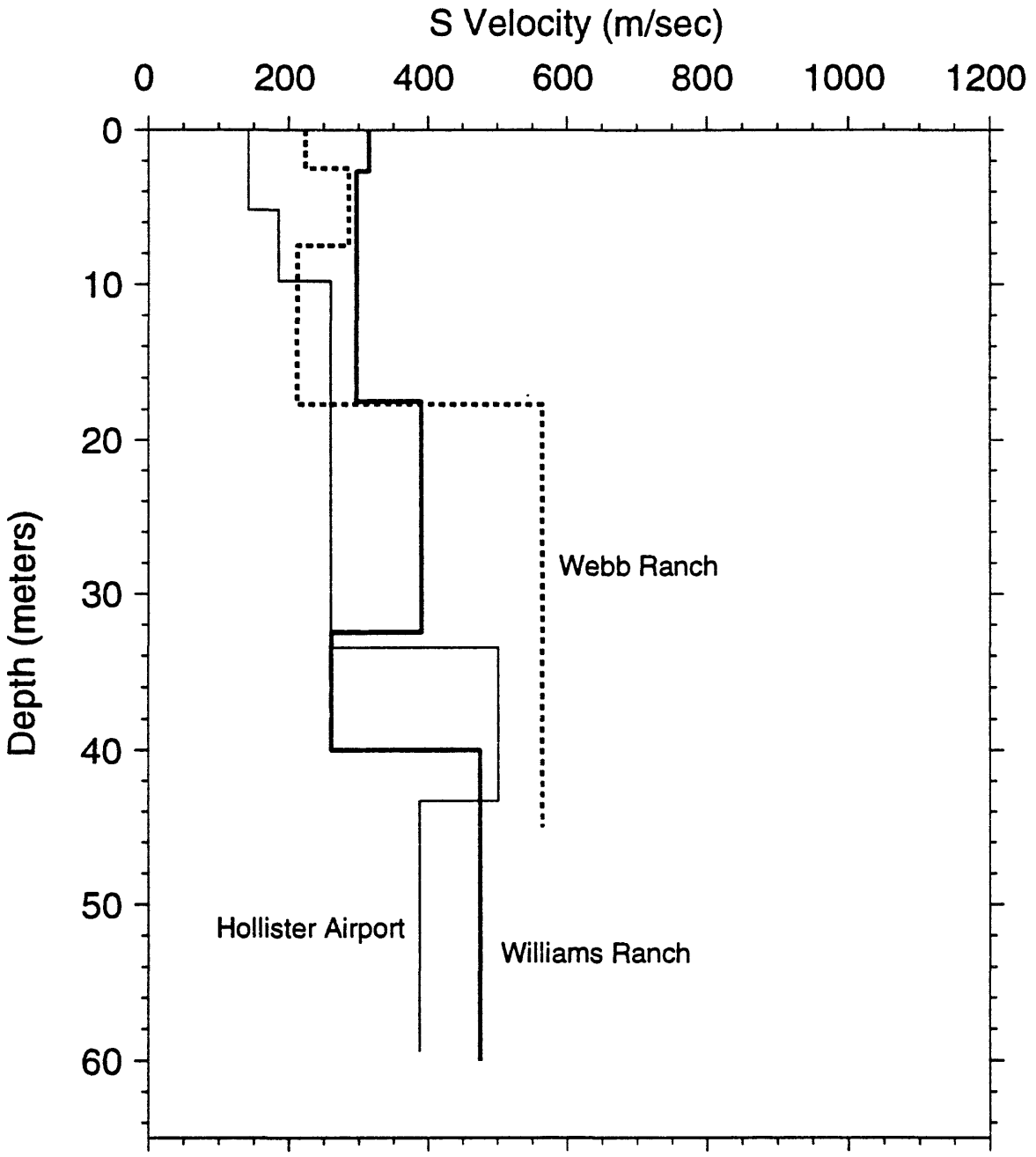

Figure 4. S-wave velocity models superimposed for comparison. In general, these three sites do not have as much gravel as those of Figure 3 and as a result have lower S-wave velocities in the uppers sections of the borehole.

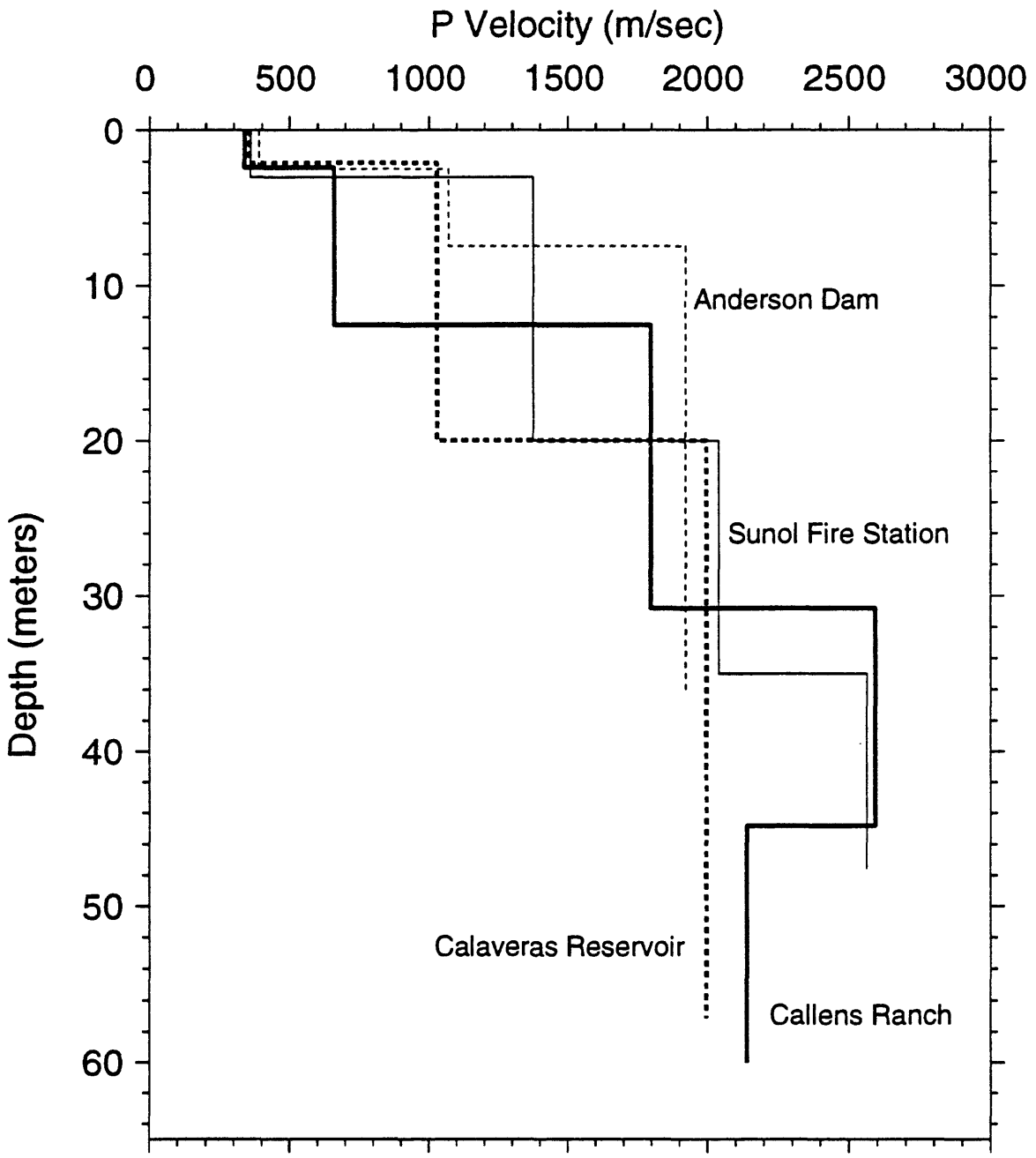

Figure 5. P-wave velocity models superimposed for comparison.

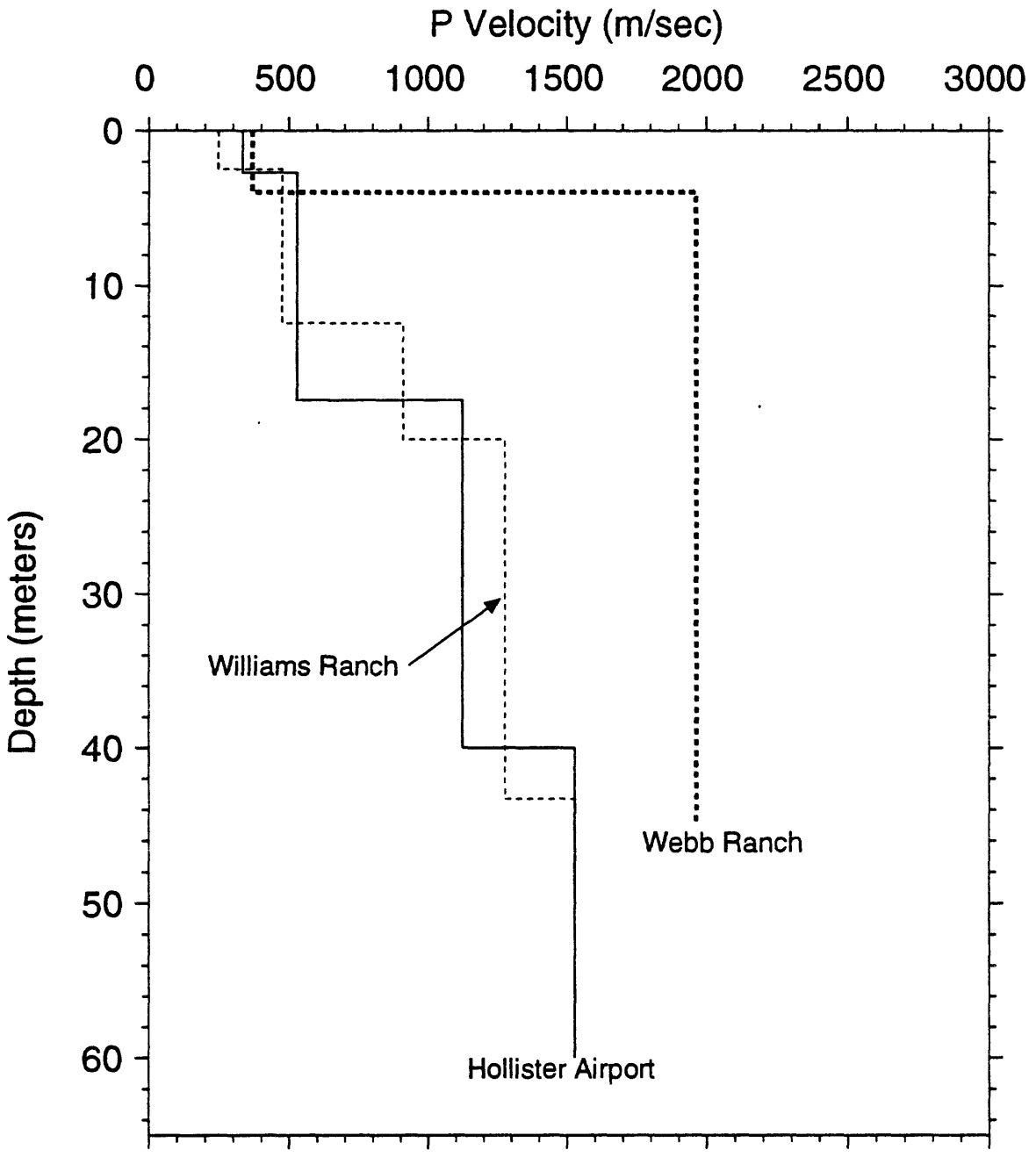

Figure 6. P -wave velocity models superimposed for comparison.

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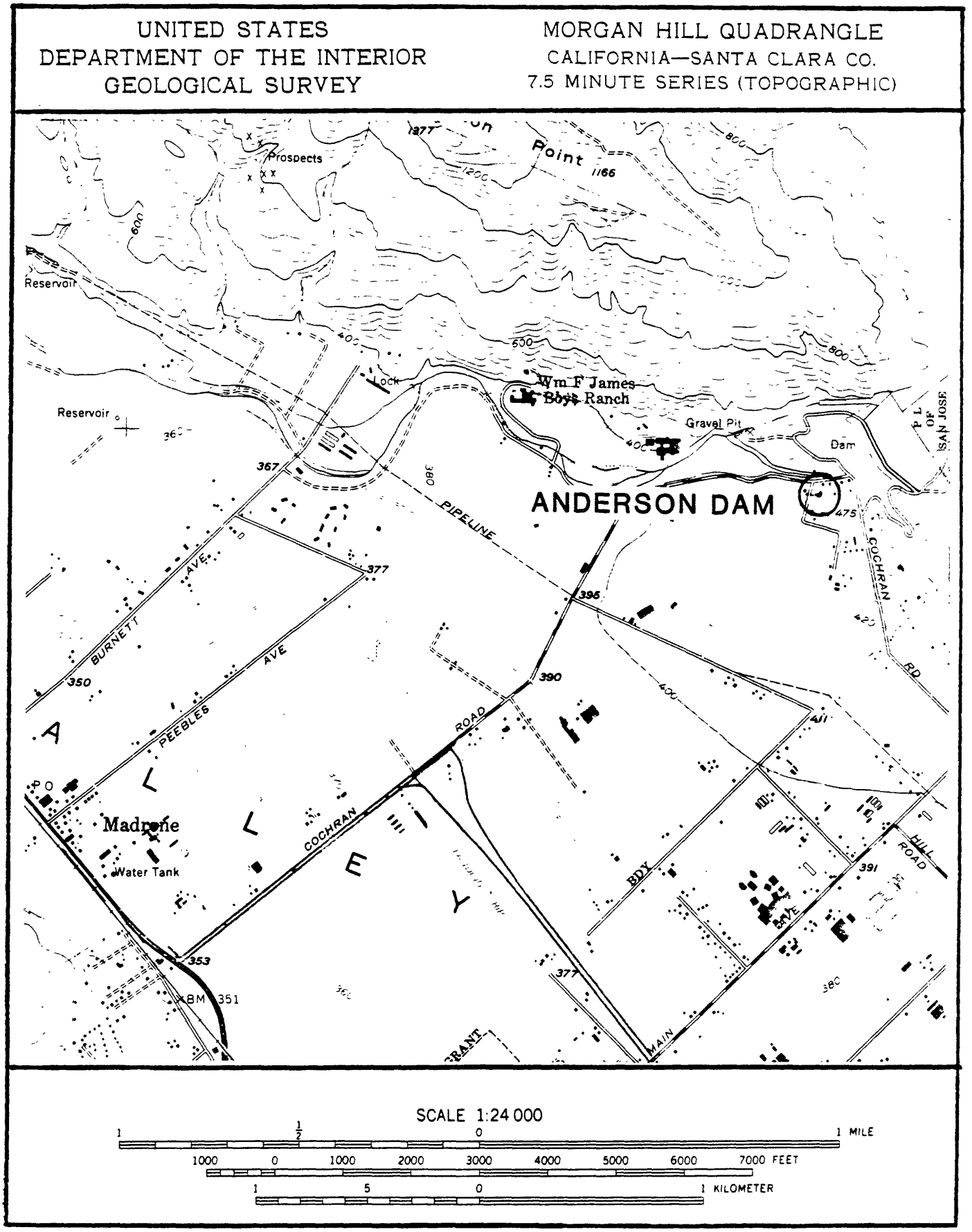


Figure 7. Site location map for the borehole at Anderson Dam (downstream) The borehole at Anderson Dam is located approximately 30 meters from the strong-motion recorder.

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

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

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

Fracture spacing: (Ellen et al., 1972)

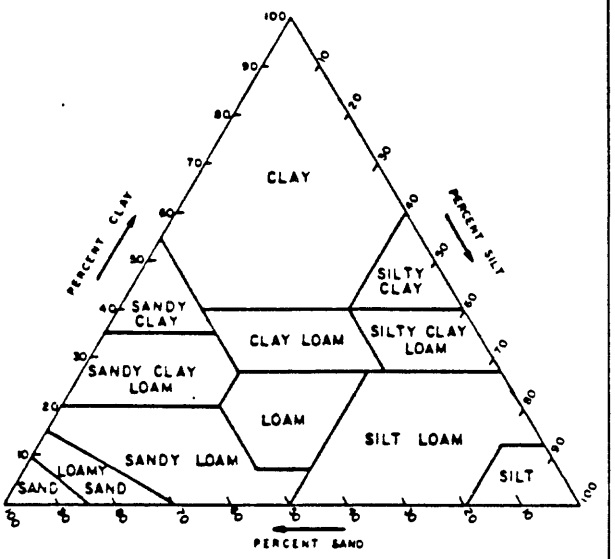
cm	in	fracture spacing
0-1	0-1/2	v. close
1-5	1/2-2	close
5-30	2-12	moderate
30-100	12-36	wide
>100	>36	v. wide

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

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

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

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



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

Types of samples

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

Figure 8. Explanation of geologic logs.

SITE: ANDERSON DAM DOWNSTREAM DATE: 2-14-91

LATITUDE: 37 09.845
LONGITUDE: 121 37.888

BLOWS/ FOOT	SAMPLE TYPE	GRAPHIC LOG	DEPTH (ft) (m)	DESCRIPTION
			0	
			1	GRAVELLLY SANDY LOAM, dk. brown (10YR 3/3)
			2	SANDY CLAY LOAM, fine gravelly
			10 3	GRAVEL, v. dk. grayish brown (10YR 3/2), moderately well sorted
			4	GRAVELLY SANDY LOAM, brown (10YR 4/3), poorly sorted
			5	
			20 6	GRAVELLY SANDY CLAY LOAM, poorly sorted, v. dense
			7	
			8	
			30 9	
			10	
			11	
			40 12	GRAVELLY SANDY LOAM
			13	olive brown (2.5Y 4/4)
			14	
			50 15	
			16	
			17	
			60 18	olive (5Y 4/3), v. dense, v. poorly sorted
			19	
			20	
			70 21	
			22	
			23	
			80 24	dk. grayish brown (2.5Y 4/2), poorly sorted
			25	
			26	
			27	MUDSTONE, olive (5Y 4/3), firm
			90 28	yellowish brown (10YR 3/4)
			29	
			30	
			100 31	
			32	
			33	
			110 34	
			35	
			36	
			120	

Figure 9. Geologic log of Anderson Dam borehole.

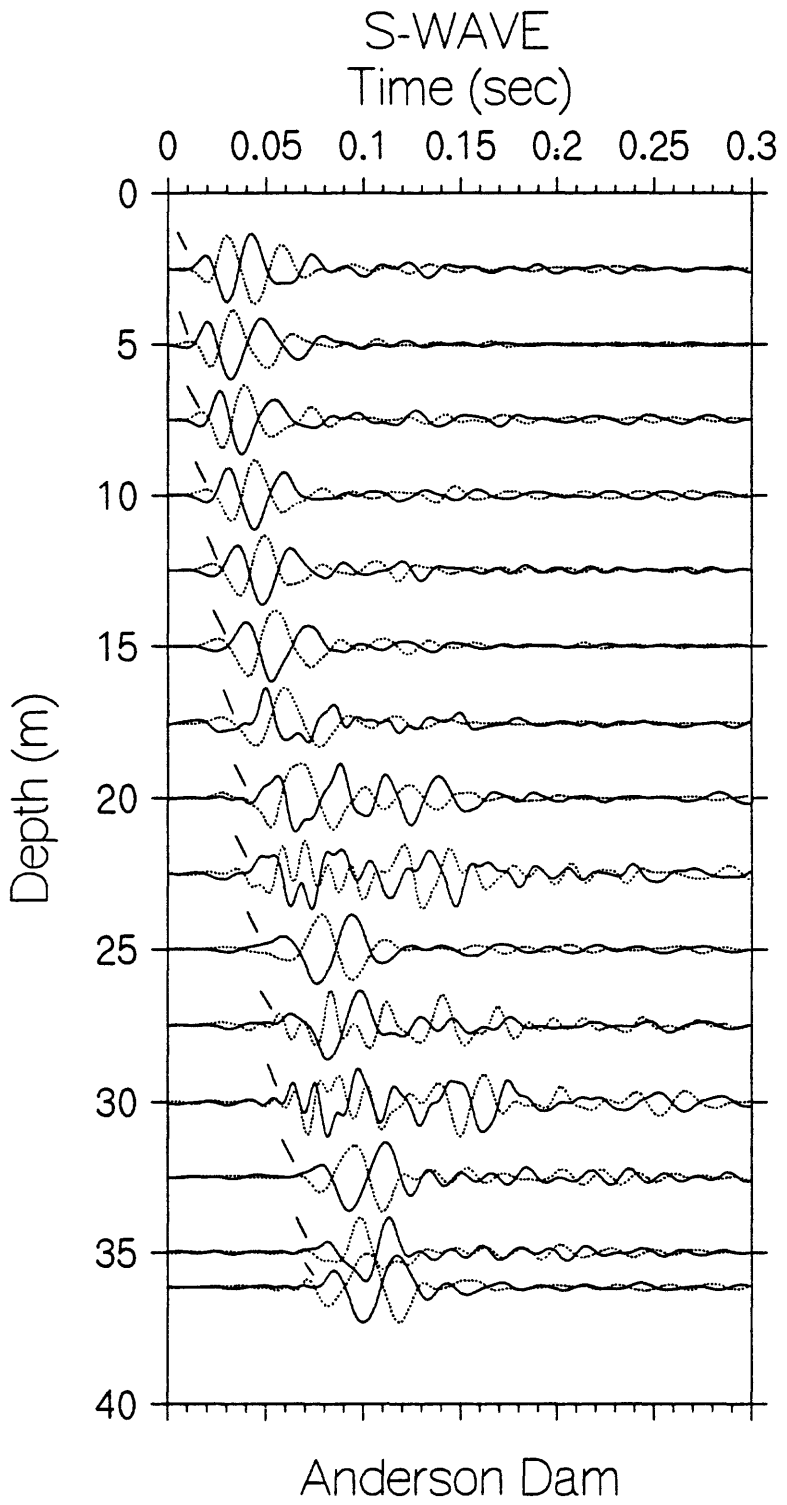


Figure 10. Record section of S-waves from impacts in opposite horizontal directions superimposed for indentification of S-wave onset. Approximate S-wave picks are shown by the accent marks.

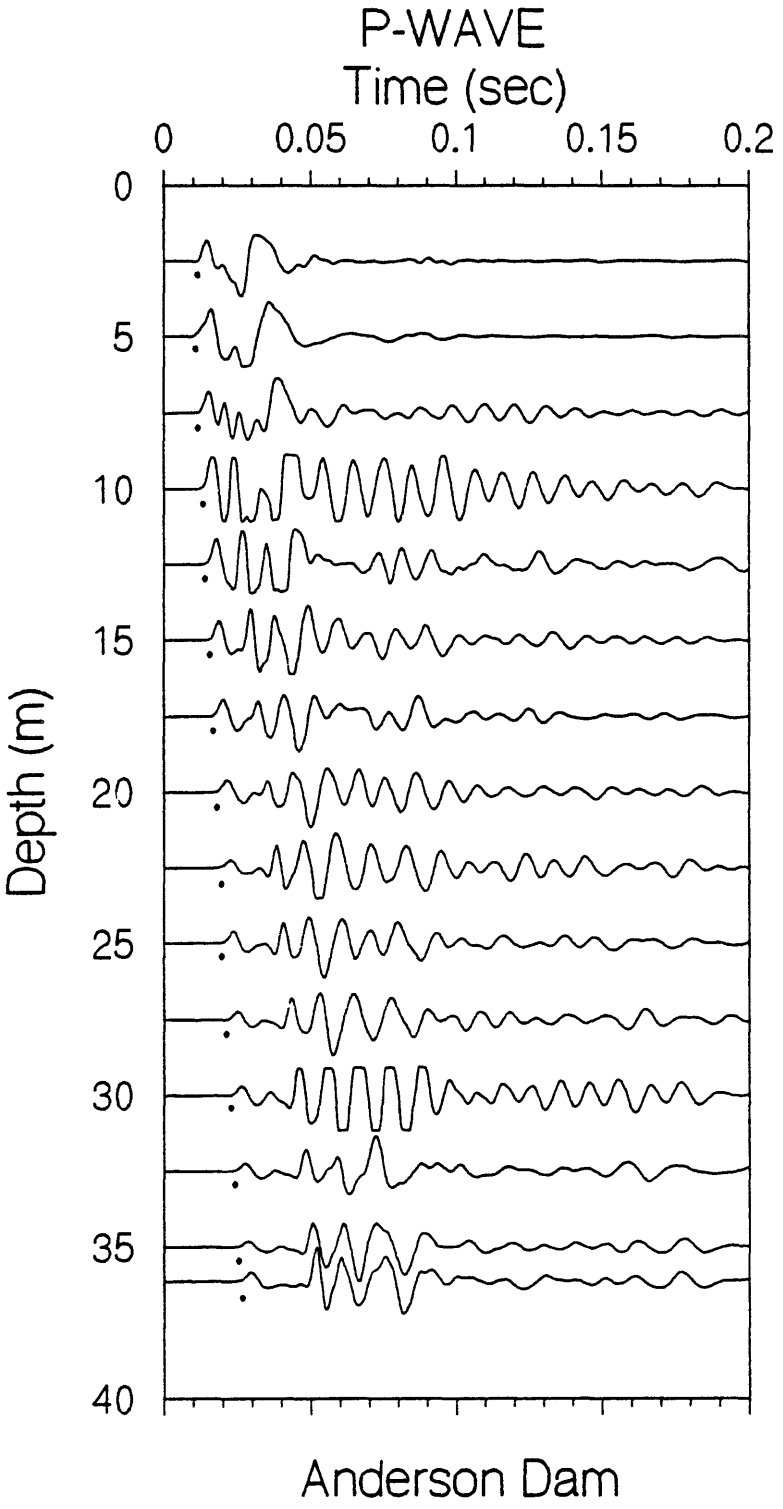


Figure 11. Vertical component record section. P-wave arrivals are shown by the solid circles.

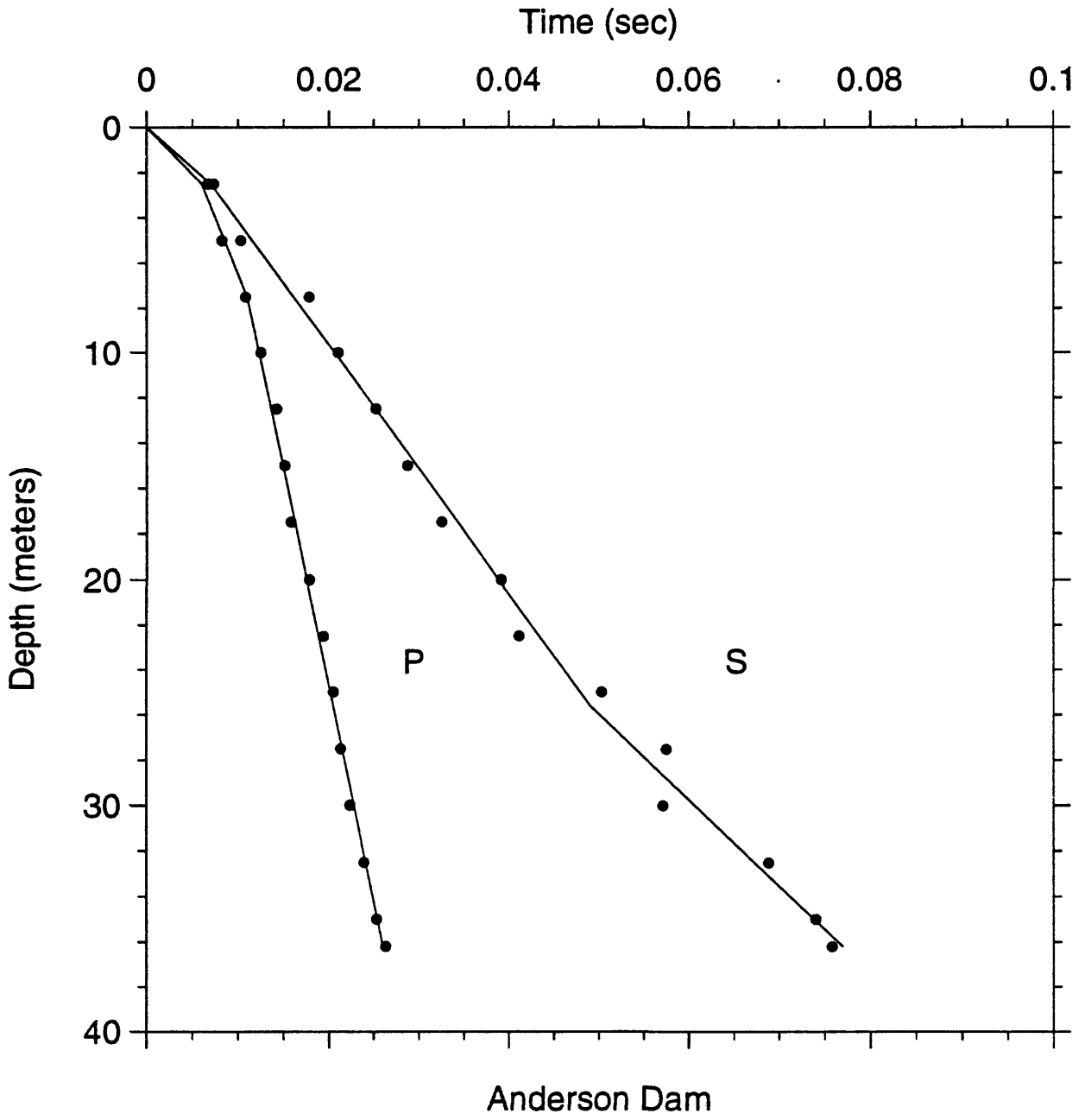


Figure 12. Time-depth graph of P-wave and S-wave picks. Line segments show the hinged-least-squares fit to the data points.

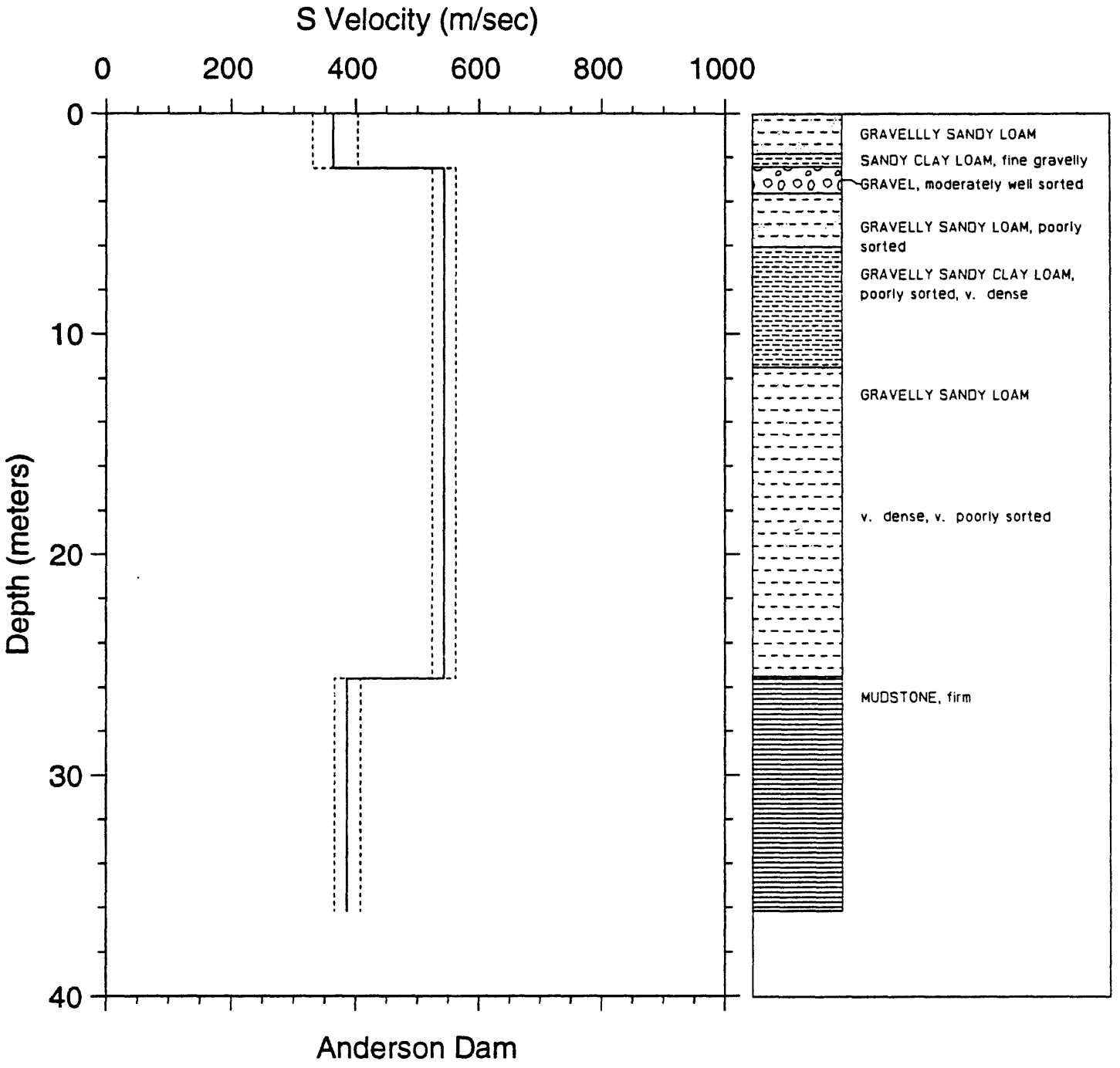


Figure 13. S-wave velocity profiles with dashed lines representing plus and minus one standard deviation. Simplified geologic log is shown for correlation with velocities.

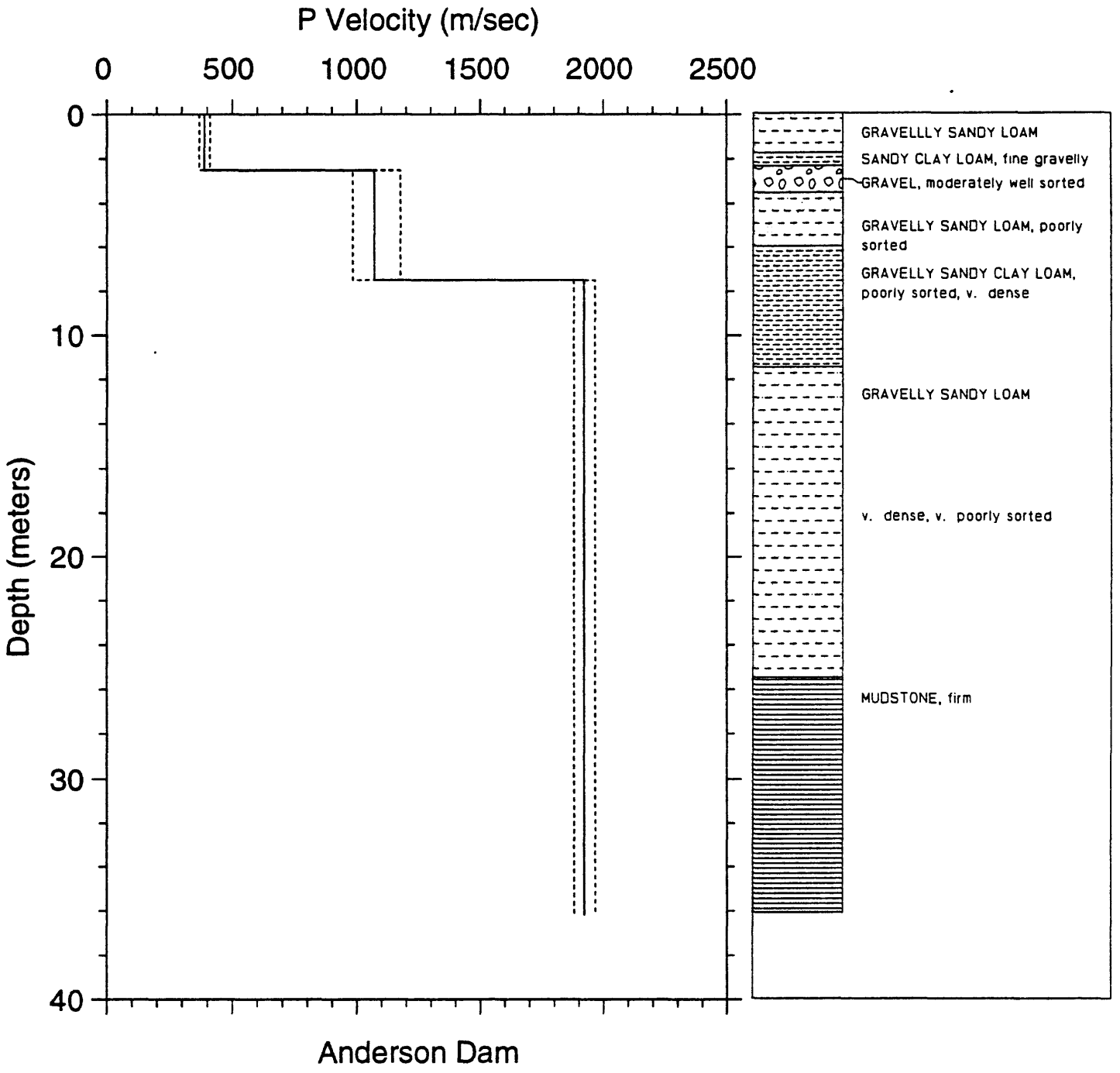


Figure 14. P-wave velocity profiles with dashed lines representing plus and minus one standard deviation. Simplified geologic log is shown for correlation with velocities.

TABLE 1. S-wave arrival times and velocity summaries for Anderson Dam (downstream).

d(m)	d(ft)	t(sec)	sig	rsdl/sig	dtb(m)	dtb(ft)	ttb(s)	v(m/s)	vl(m/s)	vu(m/s)	v(ft/s)	vl(ft/s)	vu(ft/s)
2.5	8.2	.0073	1	.4	.0	.0	.000	363	330	403	1190	1083	1321
5.0	16.4	.0103	1	-1.2	2.5	8.2	.007	363	330	403	1190	1083	1321
7.5	24.6	.0178	1	1.7	25.6	84.0	.049	543	524	562	1780	1721	1843
10.0	32.8	.0210	1	.3	36.2	118.8	.077	386	366	408	1265	1199	1338
12.5	41.0	.0252	1	-.1									
15.0	49.2	.0287	1	-1.2									
17.5	57.4	.0325	2	-1.0									
20.0	65.6	.0391	2	.0									
22.5	73.8	.0411	3	-1.1									
25.0	82.0	.0503	2	1.0									
27.5	90.2	.0575	2	1.6									
30.0	98.4	.0571	3	-1.3									
32.5	106.6	.0688	2	1.0									
35.0	114.8	.0740	1	.2									
36.2	118.8	.0758	2	-.8									

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 Anderson Dam (downstream).

d(m)	d(ft)	t(sec)	sig	rsdl/sig	dtb(m)	dtb(ft)	ttb(s)	v(m/s)	vl(m/s)	vu(m/s)	v(ft/s)	vl(ft/s)	vu(ft/s)
2.5	8.2	.0067	1	.3	.0	.0	.000	389	369	412	1277	1211	1350
5.0	16.4	.0082	1	-.6	2.5	8.2	.006	389	369	412	1277	1211	1350
7.5	24.6	.0108	1	-.3	7.5	24.6	.011	1071	983	1177	3515	3224	3862
10.0	32.8	.0125	1	.1	36.2	118.8	.026	1922	1881	1966	6307	6171	6449
12.5	41.0	.0142	1	.5									
15.0	49.2	.0151	1	.1									
17.5	57.4	.0158	1	-.5									
20.0	65.6	.0178	1	.2									
22.5	73.8	.0194	1	.5									
25.0	82.0	.0205	1	.3									
27.5	90.2	.0213	1	-.2									
30.0	98.4	.0223	1	-.5									
32.5	106.6	.0239	1	-.2									
35.0	114.8	.0253	1	-.1									
36.2	118.8	.0263	1	.3									

Explanation:

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

* see text for explanation of velocity limits

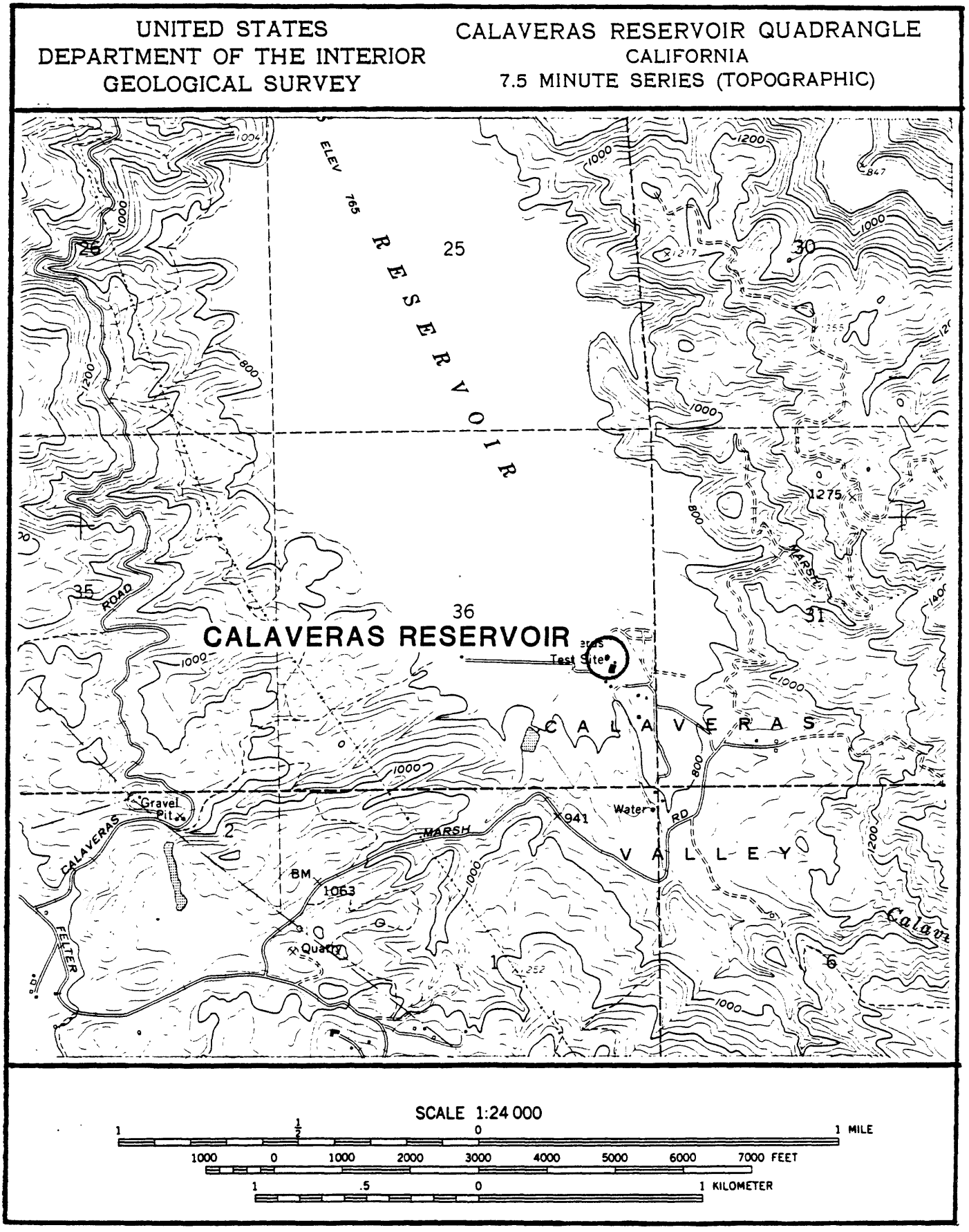


Figure 15. Site location map for Calaveras Reservoir borehole.

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

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

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

Fracture spacing: (Ellen et al., 1972)

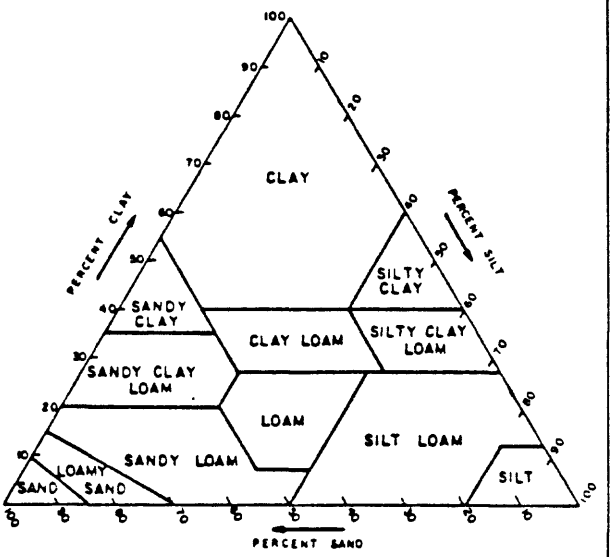
cm	in	fracture spacing
0-1	0-1/2	v. close
1-5	1/2-2	close
5-30	2-12	moderate
30-100	12-36	wide
>100	>36	v. wide

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

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

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

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



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

Types of samples

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

Figure 16. Explanation of geologic log.

SITE: CALAVERAS RESERVOIR DATE: 1-30-91

BLOWS/ FOOT	SAMPLE TYPE	GRAPHIC LOG	DEPTH (ft) (m)	LATITUDE: 37 27.175 LONGITUDE: 121 48.405 DESCRIPTION
			0	
			1	FINE GRAVELLLY SANDY LOAM, dk. brown (10YR 3/3), poorly sorted
			2	harder
			10	
			3	
			4	
			5	SANDY GRAVEL, v. hard
			20	
			6	
			7	SANDY CLAY LOAM, brown (10YR 3/3)
			8	GRAVELLY SANDY CLAY LOAM, v. poorly sorted
			30	
			9	
			10	SANDY GRAVEL
			11	
			12	GRAVELLY SAND
			40	
			13	FINE GRAVELLY SAND, poorly sorted
			14	SANDY LOAM, v. dense
			15	
			50	
			16	
			17	GRAVELLY SAND
			18	SANDY LOAM, v. dense
			60	
			19	
			20	GRAVELLY SAND
			21	SANDY GRAVEL
			70	
			22	SANDY LOAM, some gravel
			23	
			24	
			80	
			25	
			26	SANDY GRAVEL
			27	
			90	
			28	
			29	
			30	
			100	

Page 1 of 2

Figure 17. Geologic log of Calaveras Reservoir borehole.

SITE: CALAVERAS RESERVOIR DATE: 1-30-91

LATITUDE: 37 27.175
LONGITUDE: 121 48.405

BLOWS/ FOOT	SAMPLE TYPE	GRAPHIC LOG	DEPTH (ft) (m)	DESCRIPTION
			100 31	
				SANDY GRAVEL
			110 34	
			120 37	SANDY CLAY LOAM, olive (5Y 4/3), v. dense
			130 40	GRAVELLLY SANDY LOAM, poorly sorted
				SANDY CLAY LOAM, some gravel, (5G 2/1), dk. greenish gray
			140 43	rocky
			150 46	
				SANDY GRAVEL, olive brown (2.5Y 4/4) to dk. grayish brown (2.5Y 4/2), poorly sorted
			160 49	
				SANDY LOAM, olive (5Y 4/3)
			170 52	
			180 55	GRAVELLY SANDY LOAM
				v. hard
			190 58	
			200	

Figure 17. (Continued).

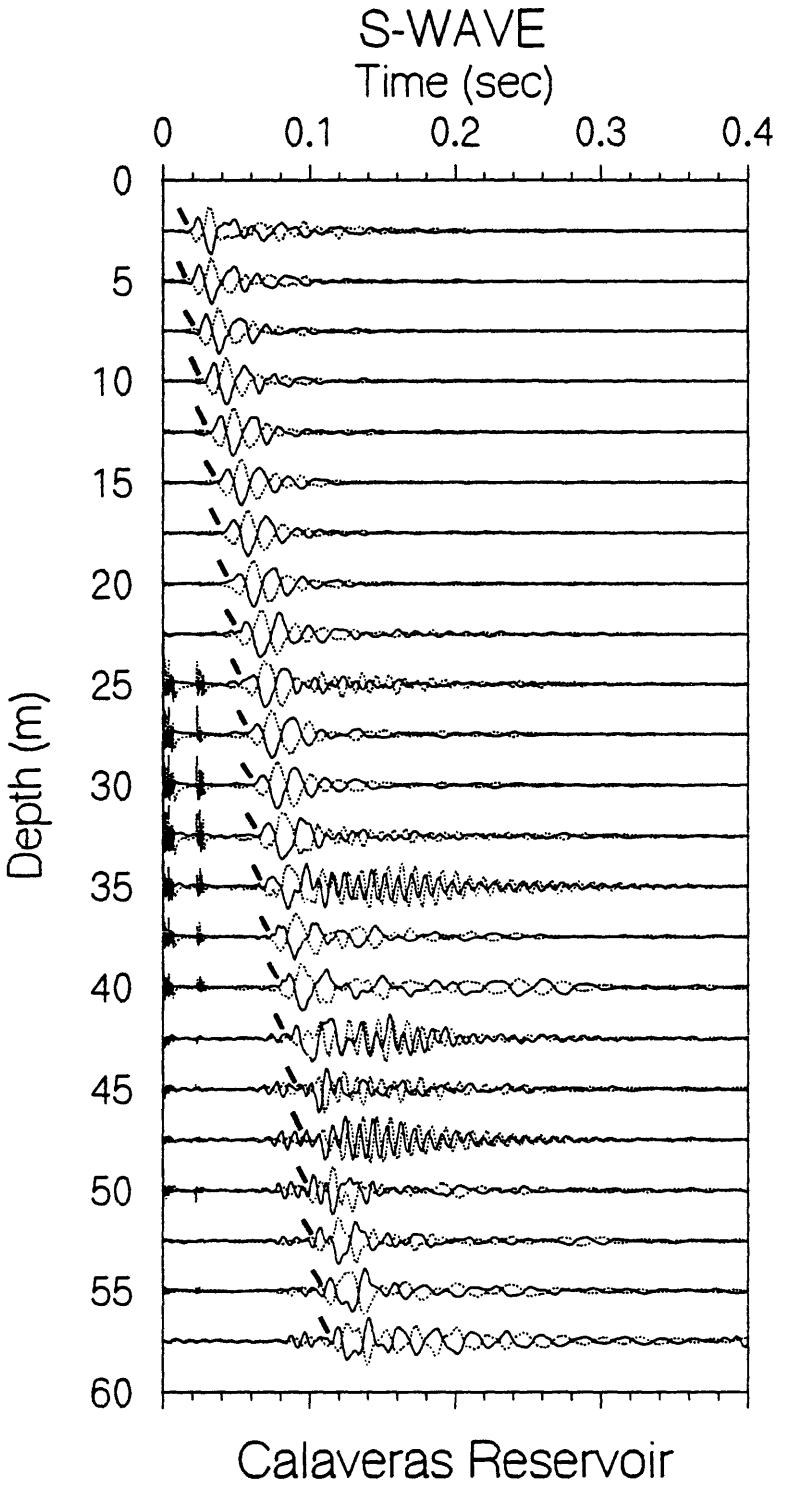


Figure 18. Horizontal-component record section (from horizontal impacts in opposite directions) superimposed for identification of S-wave arrivals. Approximate S-wave picks are shown by the accent marks.

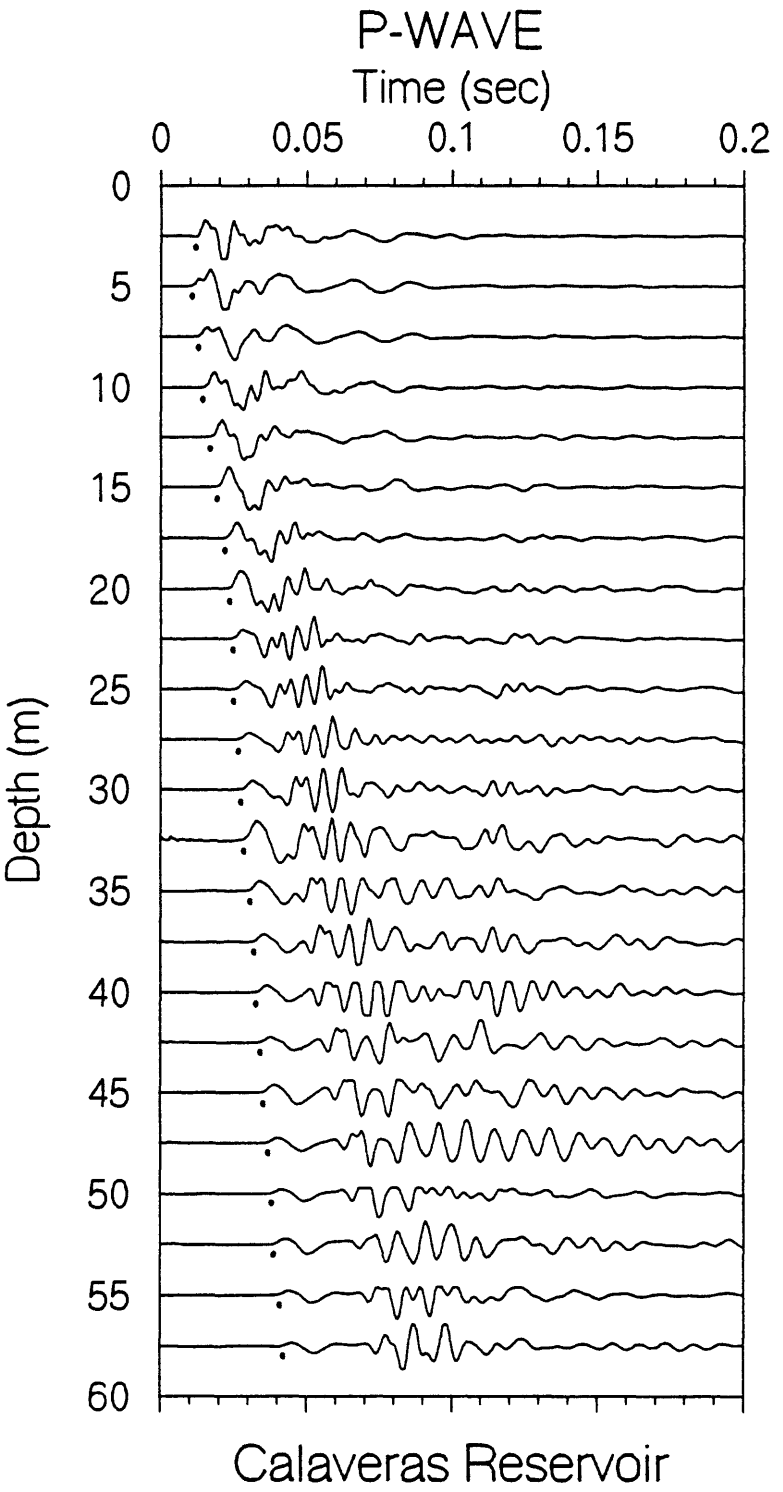


Figure 19. Vertical-component record section. Approximate P-wave picks are shown by the solid circles.

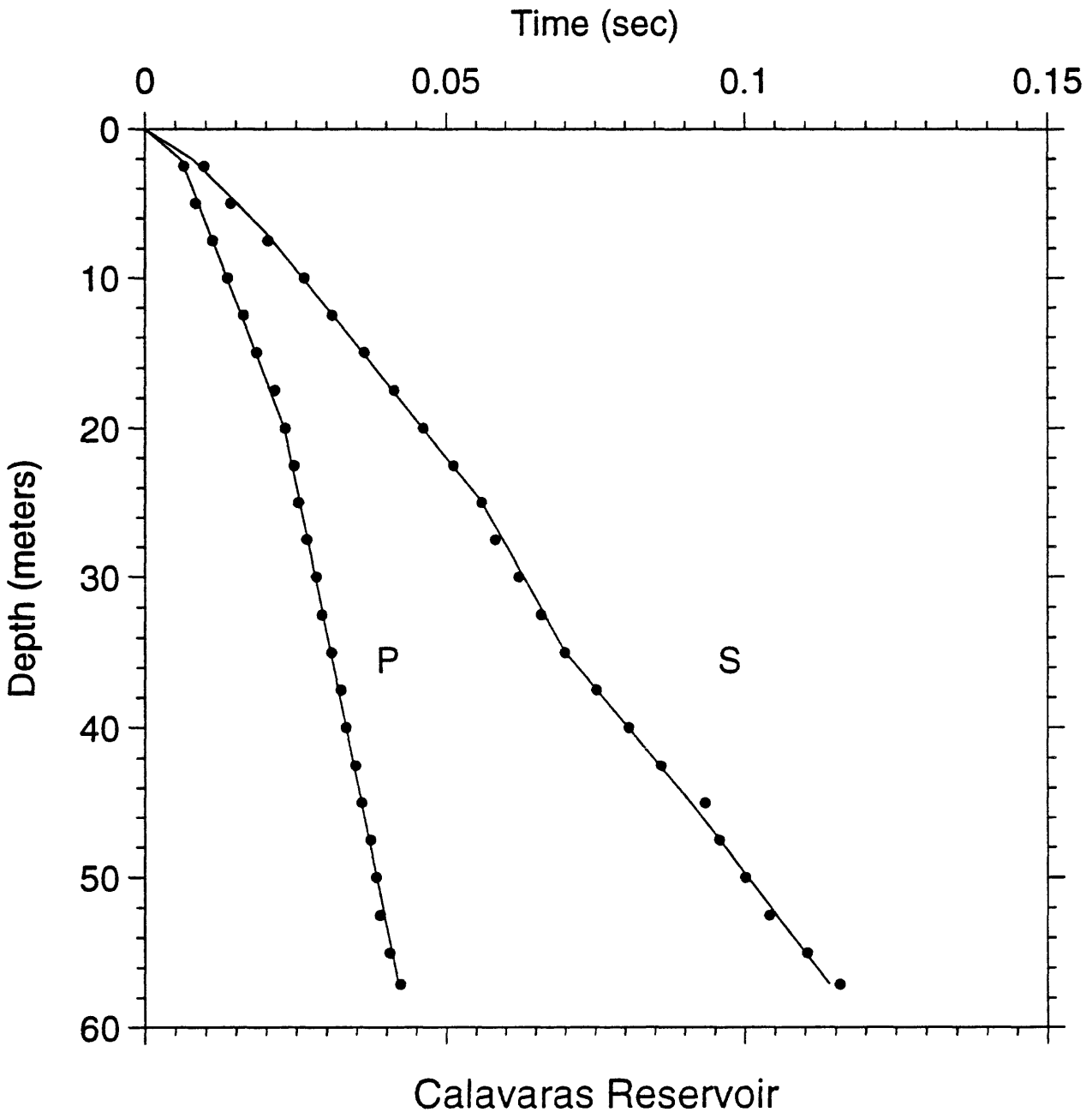


Figure 20. Time-depth graph of P-wave and S-wave picks. Line segments show the hinged-least-squares fit to the data points.

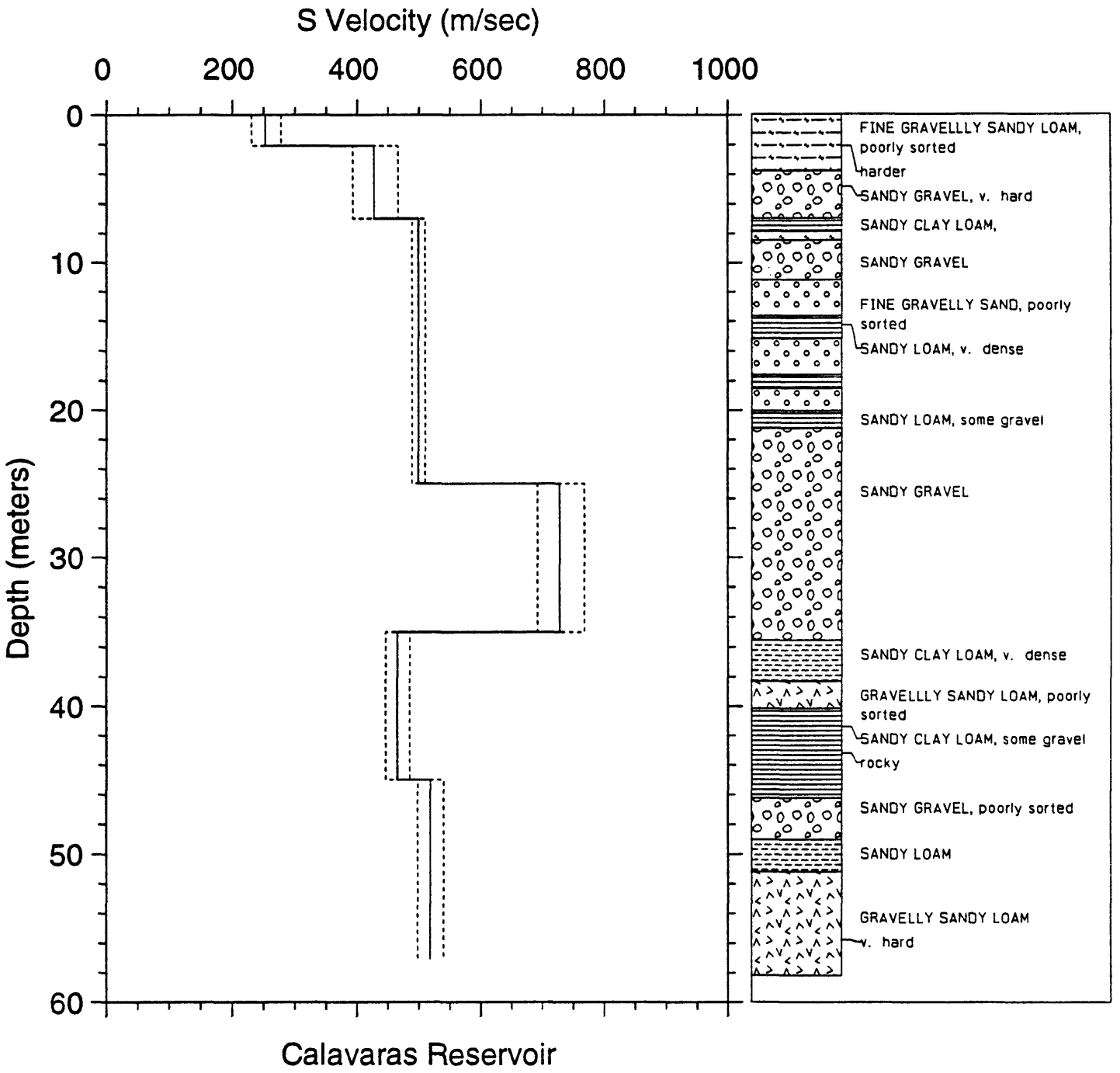


Figure 21. S-wave velocity profiles with dashed lines representing plus and minus one standard deviation. Simplified geologic log is shown for correlation with velocities.

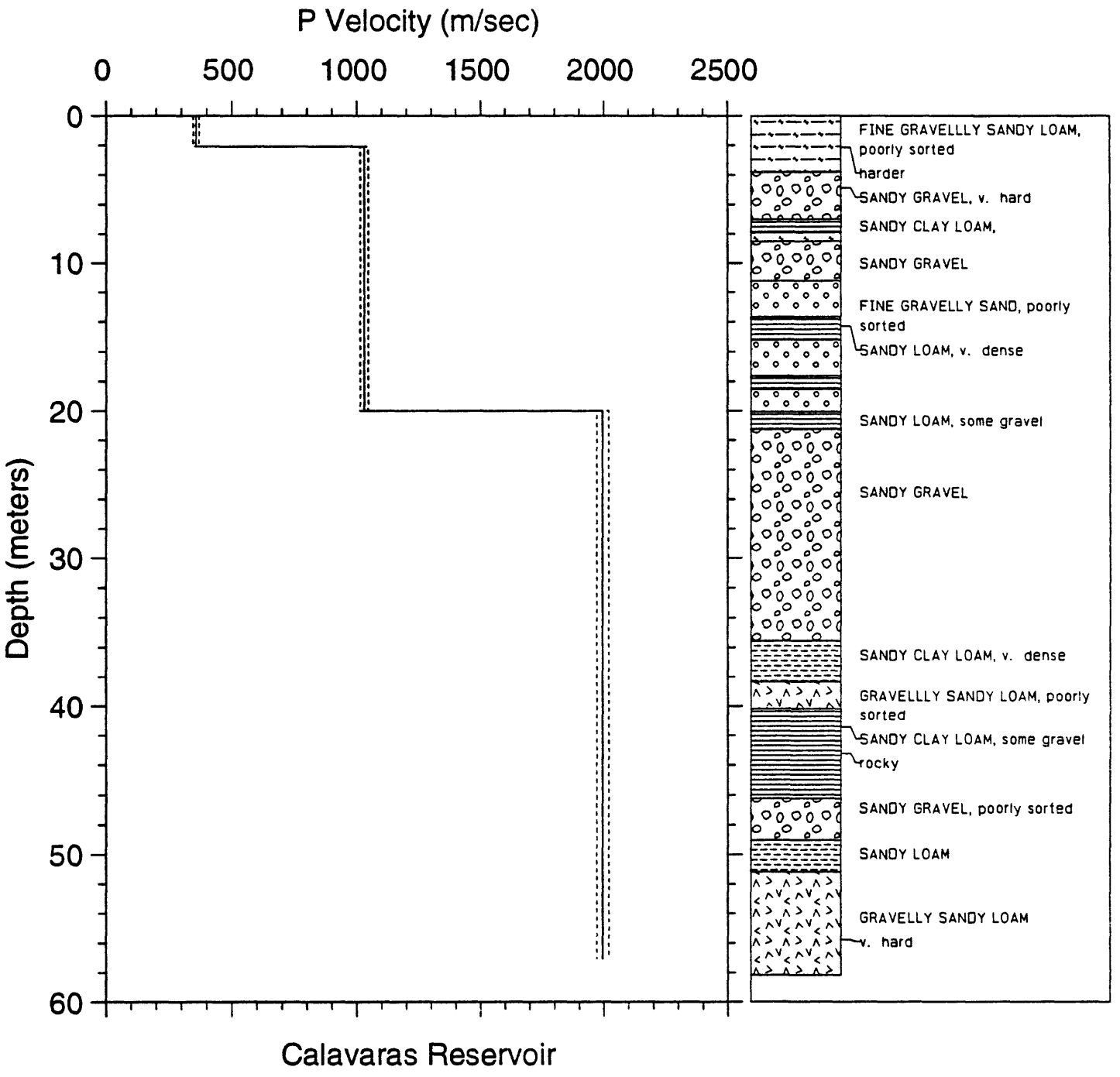


Figure 22. P-wave velocity profiles with dashed lines representing plus and minus one standard deviation. Simplified geologic log is shown for correlation with velocities.

TABLE 3. S-wave arrival times and velocity summaries for Calaveras Reservoir.

d(m)	d(ft)	t(sec)	sig	rsdl/sig	dtb(m)	dtb(ft)	ttb(s)	v(m/s)	vl(m/s)	vu(m/s)	v(ft/s)	vl(ft/s)	vu(ft/s)
2.5	8.2	.0097	1	.4	.0	.0	.000	253	231	278	829	759	913
5.0	16.4	.0141	1	-1.0	2.1	6.9	.008	253	231	278	829	759	913
7.5	24.6	.0203	1	-.5	7.0	23.0	.020	427	393	466	1399	1290	1529
10.0	32.8	.0263	1	.5	25.0	82.0	.056	499	489	510	1638	1605	1673
12.5	41.0	.0309	1	.1	35.0	114.8	.070	728	692	768	2390	2272	2521
15.0	49.2	.0363	1	.5	45.0	147.6	.091	465	446	485	1525	1464	1592
17.5	57.4	.0413	1	.5	57.1	187.3	.114	518	498	540	1700	1633	1772
20.0	65.6	.0461	1	.3									
22.5	73.8	.0512	1	.4									
25.0	82.0	.0559	1	.1									
27.5	90.2	.0582	1	-1.1									
30.0	98.4	.0622	1	-.5									
32.5	106.6	.0659	1	-.2									
35.0	114.8	.0699	1	.3									
37.5	123.0	.0752	1	.2									
40.0	131.2	.0806	1	.3									
42.5	139.4	.0860	1	.3									
45.0	147.6	.0934	2	1.2									
47.5	155.8	.0957	2	-.1									
50.0	164.0	.1001	1	-.6									
52.5	172.2	.1041	1	-1.5									
55.0	180.4	.1103	1	-.1									
57.1	187.3	.1157	1	1.3									

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 Calaveras Reservoir.

d(m)	d(ft)	t(sec)	sig	rsdl/sig	dtb(m)	dtb(ft)	ttb(s)	v(m/s)	vl(m/s)	vu(m/s)	v(ft/s)	vl(ft/s)	vu(ft/s)
2.5	8.2	.0064	1	.1	.0	.0	.000	357	346	370	1173	1134	1214
5.0	16.4	.0083	1	-.4	2.1	6.9	.006	357	346	370	1173	1134	1214
7.5	24.6	.0111	1	.0	20.0	65.6	.023	1030	1014	1046	3380	3328	3433
10.0	32.8	.0136	1	.1	57.1	187.3	.042	1995	1971	2020	6546	6465	6629
12.5	41.0	.0162	1	.2									
15.0	49.2	.0184	1	.0									
17.5	57.4	.0214	1	.6									
20.0	65.6	.0231	1	-.2									
22.5	73.8	.0246	1	.1									
25.0	82.0	.0253	1	-.5									
27.5	90.2	.0267	1	-.3									
30.0	98.4	.0283	1	.0									
32.5	106.6	.0292	1	-.3									
35.0	114.8	.0308	1	.0									
37.5	123.0	.0324	1	.4									
40.0	131.2	.0332	1	-.1									
42.5	139.4	.0348	1	.3									
45.0	147.6	.0359	1	.1									
47.5	155.8	.0373	1	.3									
50.0	164.0	.0383	1	.0									
52.5	172.2	.0389	1	-.6									
55.0	180.4	.0405	1	-.3									
57.1	187.3	.0423	1	.5									

Explanation:

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

* see text for explanation of velocity limits

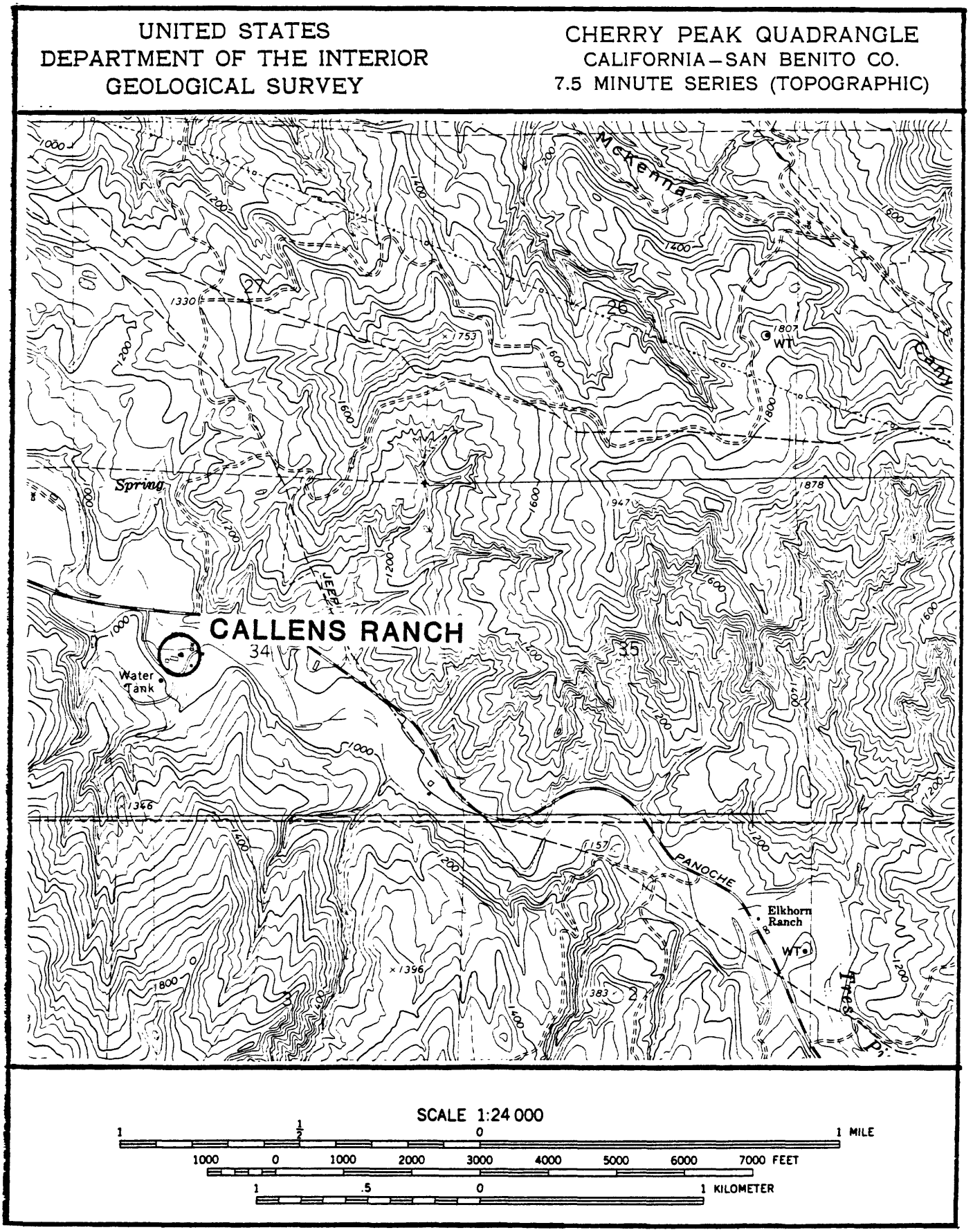


Figure 23. Location map for Callens Ranch borehole. The borehole is located approximatelly 20 meters from the strong-motion accelerograph.

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

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

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

Fracture spacing: (Ellen et al., 1972)

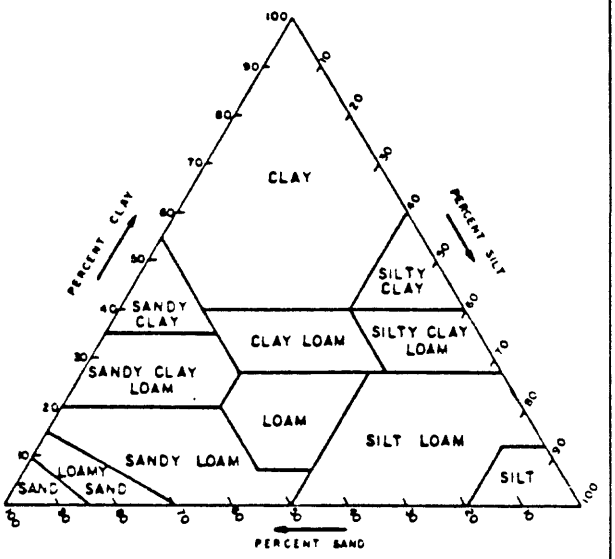
cm	in	fracture spacing
0-1	0-1/2	v. close
1-5	1/2-2	close
5-30	2-12	moderate
30-100	12-36	wide
>100	>36	v. wide

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

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

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

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



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

Types of samples

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

Figure 24. Explanation of geologic log.

SITE: CALLENS RANCH

DATE: 3-19-91

LATITUDE: 36 40.390
LONGITUDE: 121 11.725

BLOWS/ FOOT	SAMPLE TYPE	GRAPHIC LOG	DEPTH (ft) (m)	DESCRIPTION
			0 1	SANDY CLAY LOAM, dk. grayish brown (2.5Y 4/2)
			2	
			10 3	GRAVELLY SANDY LOAM, poorly sorted
			4	
			5	LOAM-SAND, sand is v. fine to v. coarse size
			20 6	
			7	
			8	SAND, with thin lenses of gravel
			30 9	GRAVELLY v. coarse SAND, grayish brown
			10	
			11	
			40 12	SANDY GRAVEL
				GRAVEL, coarse
			13	SILTY CLAY, olive (5Y 5/3)
			14	olive brown (2.5Y 4/4)
			50 15	
			16	SILTY CLAY LOAM to SILT LOAM, v. dk. greenish gray (5GY 3/1)
			17	
			18	stiff
			60 19	SILTY CLAY, v. dk. greenish gray (5GY 3/1), v. stiff
			20	
			21	
			70 22	
			23	
			24	
			80 25	
			26	
			27	
			90 28	
			29	
			30	
			100	

Figure 25. Geologic log of Callens Ranch borehole.

SITE: CALLENS RANCH

DATE: 3-19-91

LATITUDE: 36 40.390
LONGITUDE: 121 11.725

BLOWS/ FOOT	SAMPLE TYPE	GRAPHIC LOG	DEPTH (ft) (m)	DESCRIPTION
			100 31	
			32	GRAVEL, dk. greenish gray to grayish green, weakly to moderately cemented
			110 33	
			34	
			35	SANDY GRAVEL, cemented
			36	GRAVEL, with thin beds of clay
			120 37	SILTY CLAY
			38	SANDY GRAVEL, cemented
			39	
			130 40	
			41	
			42	
			140 43	
			44	
			45	
			150 46	MUDSTONE, firm (texture is silty clay)
			47	
			48	
			160 49	
			50	
			51	SILTY CLAY, dk. greenish gray (5BG 4/1), softer
			170 52	
			53	
			54	
			180 55	
			56	
			57	
			190 58	
			59	SILTY CLAY LOAM, dk. gray (5Y 4/1)
			60	
			200	

Figure 25. (Continued).

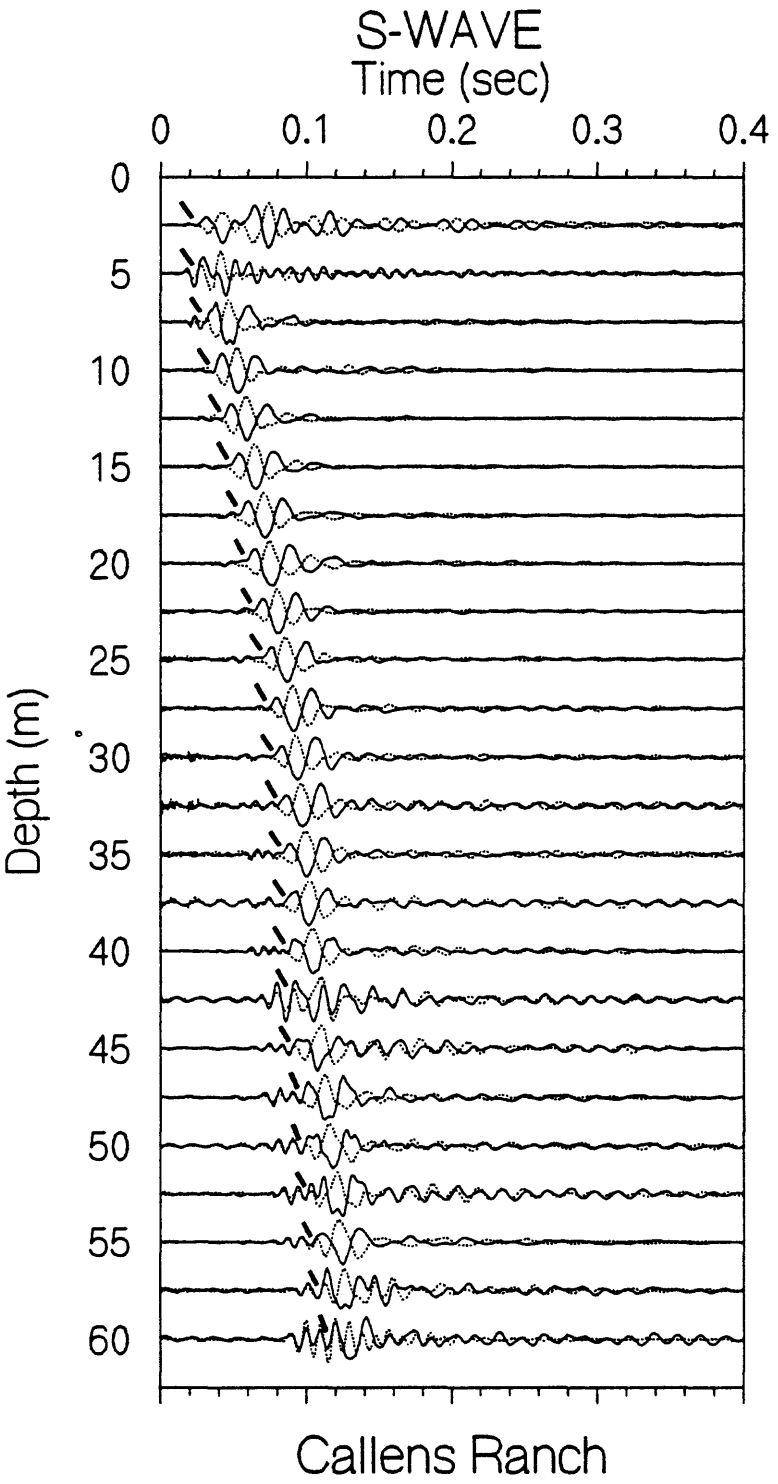


Figure 26. Horizontal-component record section (from horizontal impacts in opposite directions) superimposed for identification of S-wave onset. Approximate S-wave picks are indicated by the accent marks.

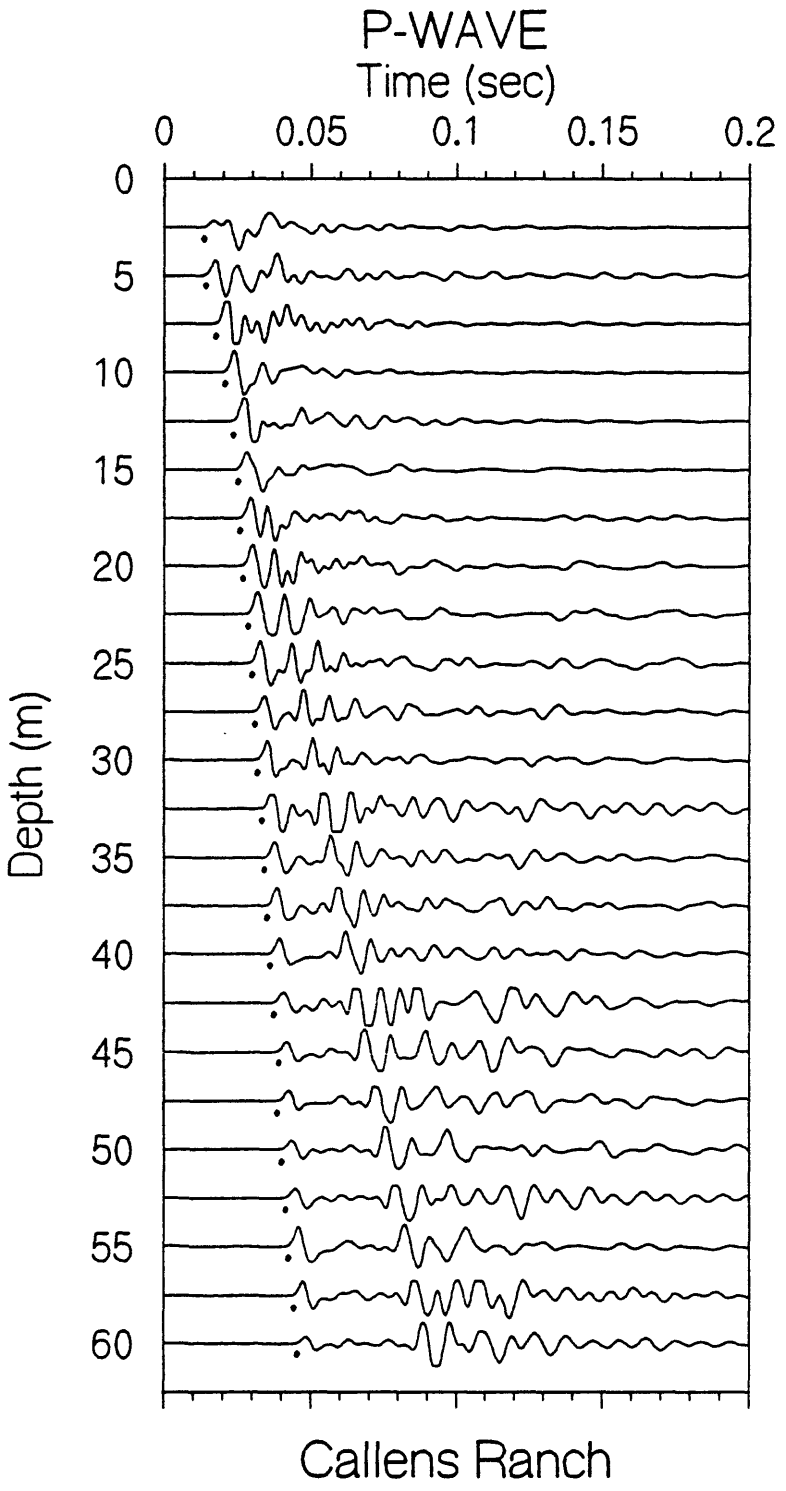


Figure 27. P-wave record section. Approximate P-wave picks are shown by the dots.

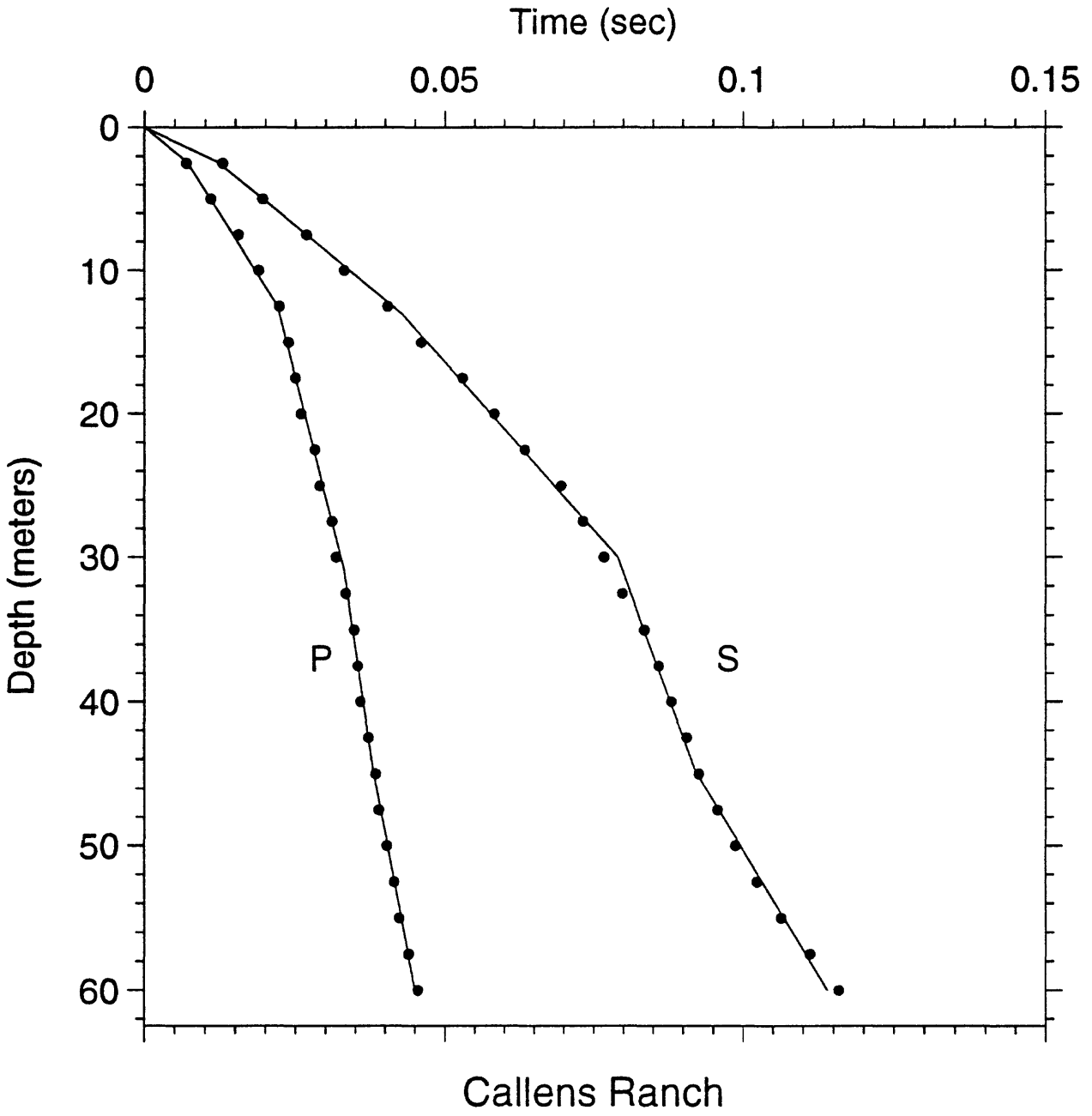


Figure 28. Time-depth graph of P-wave and S-wave picks. Line segments show the hing-least-squares fit to the data.

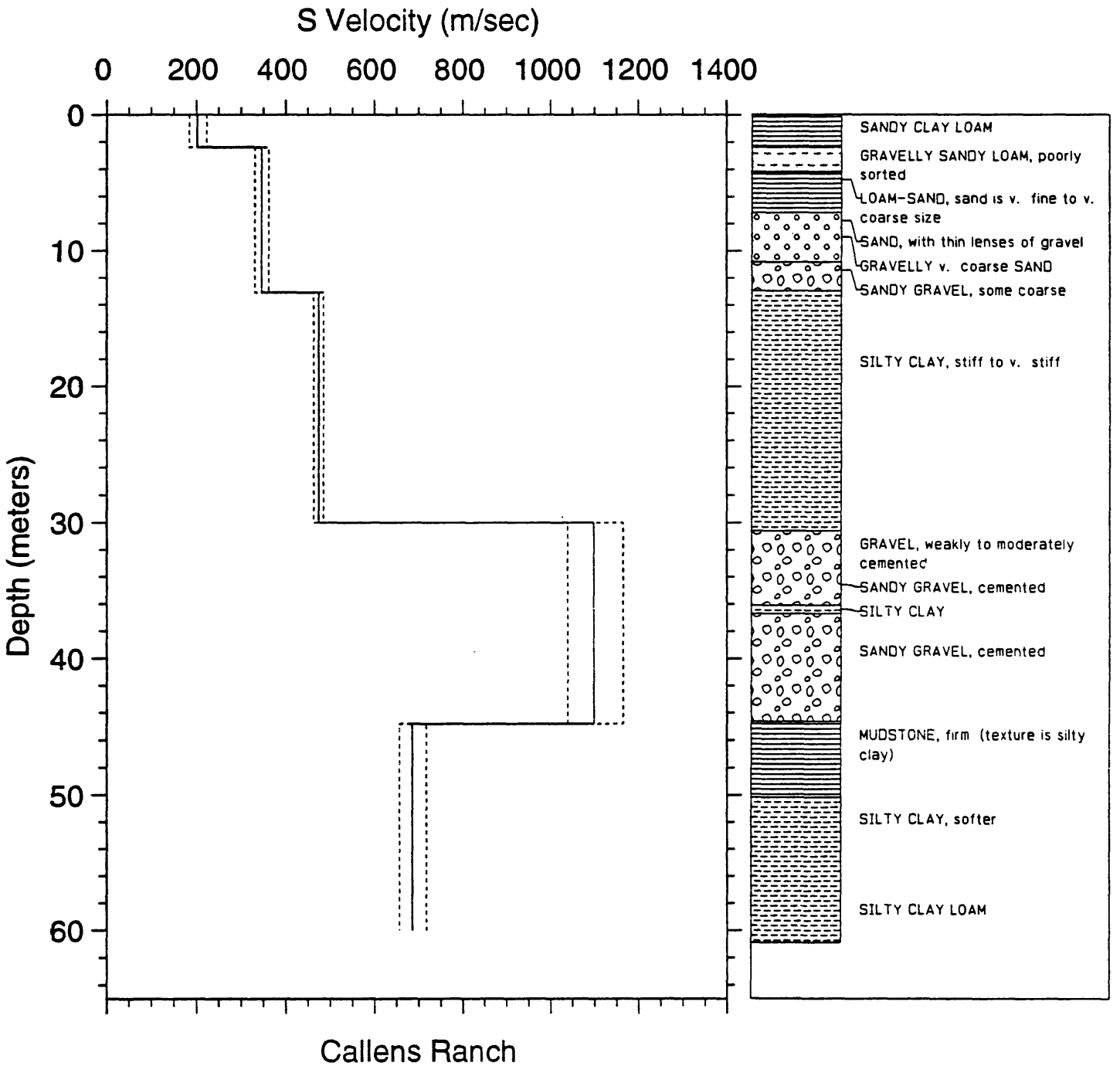


Figure 29. S-wave velocity profiles with dashed lines representing plus and minus one standard deviation. Simplified geologic log is shown for correlation with velocities.

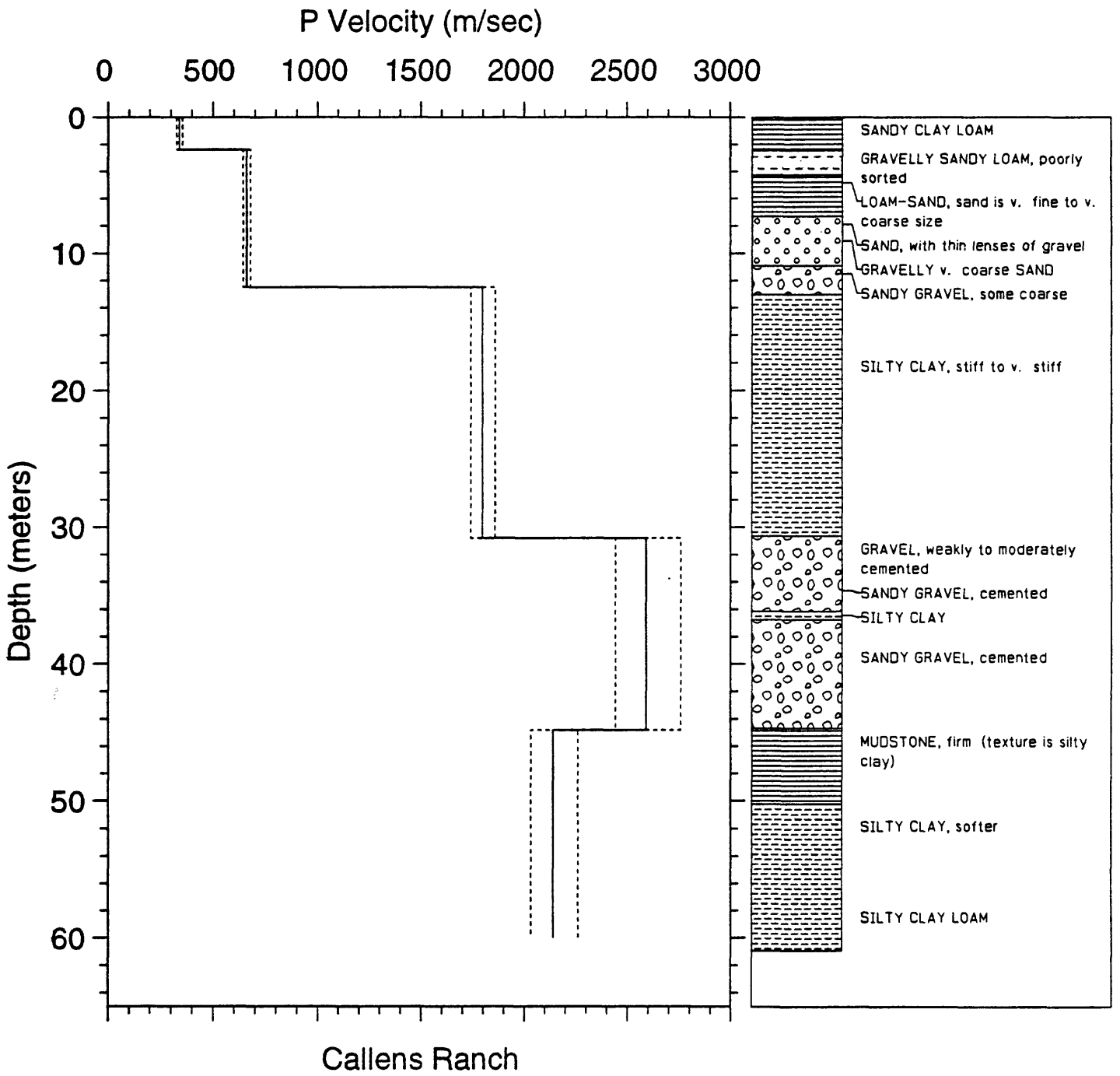


Figure 30. P-wave velocity profiles with dashed lines representing plus and minus one standard deviation. Simplified geologic log is shown for correlation with velocities.

TABLE 5. S-wave arrival times and velocity summaries for Callens Ranch site.

d(m)	d(ft)	t(sec)	sig	rsdl/sig	dtb(m)	dtb(ft)	ttb(s)	v(m/s)	vl(m/s)	vu(m/s)	v(ft/s)	vl(ft/s)	vu(ft/s)
2.5	8.2	.0129	2	.4	.0	.0	.000	202	184	223	661	605	730
5.0	16.4	.0195	2	.0	2.4	7.9	.012	202	184	223	661	605	730
7.5	24.6	.0268	1	.1	13.1	43.0	.043	346	331	362	1134	1085	1188
10.0	32.8	.0331	1	-.8	30.0	98.4	.079	474	463	485	1554	1519	1590
12.5	41.0	.0404	1	-.7	44.8	147.0	.092	1098	1039	1165	3604	3408	3823
15.0	49.2	.0460	1	-.9	60.0	196.9	.114	685	656	717	2248	2152	2352
17.5	57.4	.0530	1	.9									
20.0	65.6	.0583	1	.9									
22.5	73.8	.0634	1	.7									
25.0	82.0	.0695	1	1.5									
27.5	90.2	.0732	1	-.1									
30.0	98.4	.0767	1	-1.8									
32.5	106.6	.0798	1	-1.0									
35.0	114.8	.0835	1	.4									
37.5	123.0	.0859	1	.5									
40.0	131.2	.0880	1	.4									
42.5	139.4	.0906	1	.7									
45.0	147.6	.0926	1	.3									
47.5	155.8	.0957	1	-.2									
50.0	164.0	.0987	1	-.9									
52.5	172.2	.1023	1	-.9									
55.0	180.4	.1063	1	-.6									
57.5	188.6	.1111	1	.6									
60.0	196.9	.1159	2	1.1									

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 Callens Ranch site.

d(m)	d(ft)	t(sec)	sig	rsdl/sig	dtb(m)	dtb(ft)	ttb(s)	v(m/s)	vl(m/s)	vu(m/s)	v(ft/s)	vl(ft/s)	vu(ft/s)
2.5	8.2	.0069	1	-.3	.0	.0	.000	339	326	354	1112	1068	1161
5.0	16.4	.0109	1	-.1	2.4	7.9	.007	339	326	354	1112	1068	1161
7.5	24.6	.0155	1	.7	12.5	41.0	.022	660	643	678	2164	2108	2223
10.0	32.8	.0189	1	.3	30.8	101.0	.033	1797	1740	1859	5897	5708	6099
12.5	41.0	.0223	1	-.1	44.8	147.0	.038	2592	2444	2759	8504	8018	9052
15.0	49.2	.0238	1	.0	60.0	196.9	.045	2140	2032	2261	7022	6665	7419
17.5	57.4	.0250	1	-.2									
20.0	65.6	.0259	1	-.7									
22.5	73.8	.0282	1	.2									
25.0	82.0	.0290	1	-.3									
27.5	90.2	.0311	1	.4									
30.0	98.4	.0317	1	-.4									
32.5	106.6	.0333	1	.1									
35.0	114.8	.0348	1	.6									
37.5	123.0	.0354	1	.2									
40.0	131.2	.0358	1	-.3									
42.5	139.4	.0372	1	.1									
45.0	147.6	.0384	1	.3									
47.5	155.8	.0389	1	-.3									
50.0	164.0	.0403	1	-.1									
52.5	172.2	.0415	1	-.1									
55.0	180.4	.0423	1	-.4									
57.5	188.6	.0439	1	.0									
60.0	196.9	.0455	1	.4									

Explanation:

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

* see text for explanation of velocity limits

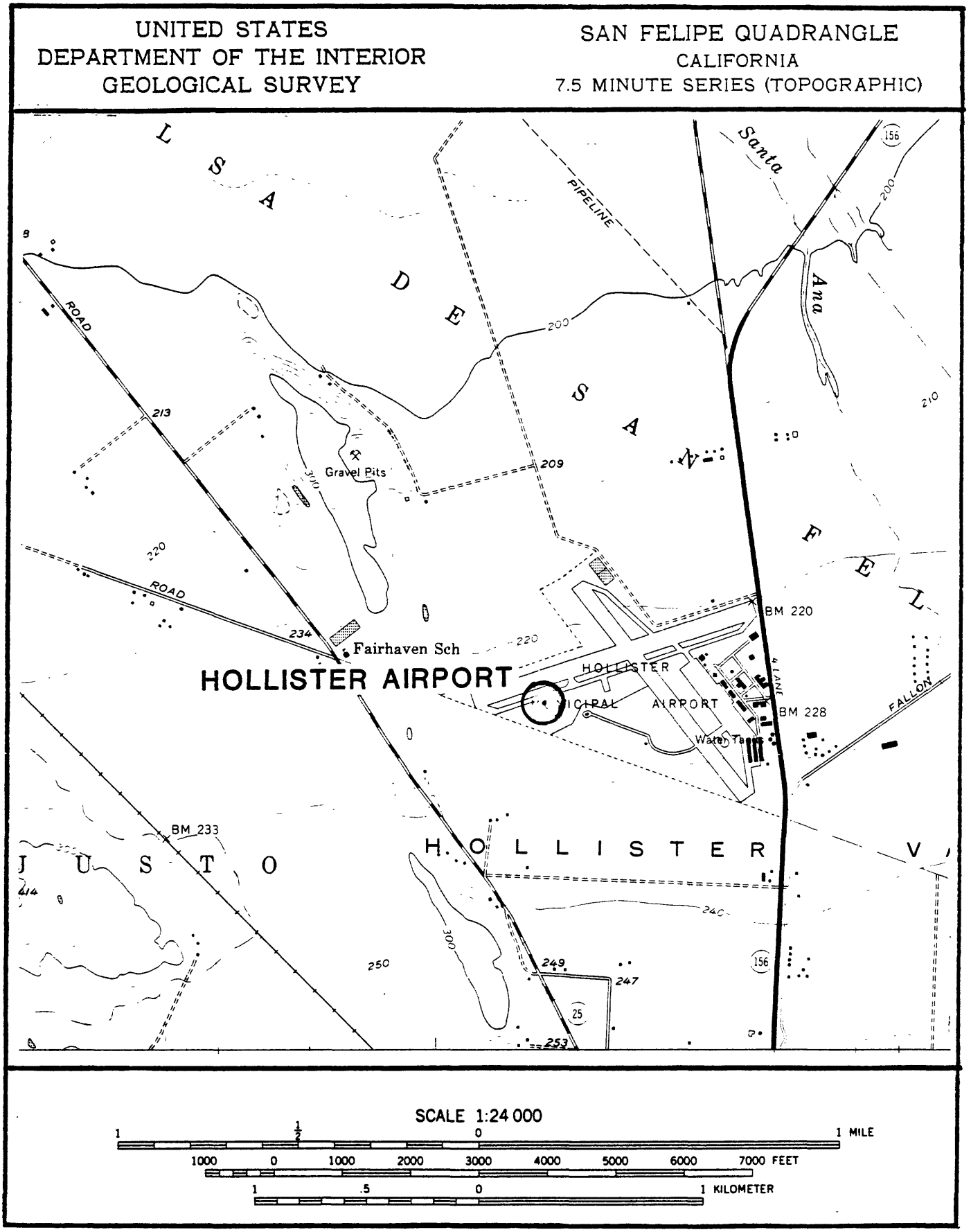


Figure 31. Location map for Hollister Airport borehole. The strong-motion accelerograph is located within 20 meters of the borehole.

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

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

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

Fracture spacing: (Ellen et al., 1972)

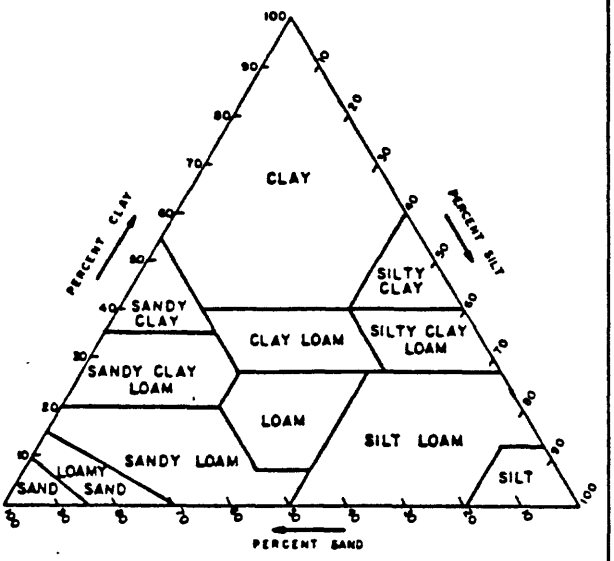
cm	in	fracture spacing
0-1	0-1/2	v. close
1-5	1/2-2	close
5-30	2-12	moderate
30-100	12-36	wide
>100	>36	v. wide

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

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

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

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



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

Types of samples

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

Figure 32. Explanation of geologic log.

SITE: HOLLISTER AIRPORT

DATE: 3-25-91

LATITUDE: 36 53.350
LONGITUDE: 121 24.675

BLOWS/ FOOT	SAMPLE TYPE	GRAPHIC LOG	DEPTH (ft) (m)	DESCRIPTION
			0	
			1	CLAY, black (2.5Y 2.5/1)
			2	dk. grayish brown (2.5Y 4/2)
			3	dk. olive grown (2.5Y 3/4)
			4	SAND
			5	CLAY
			6	LOAMY SAND
			7	SILTLY CLAY, olive brown (2.5Y 4/4), stiff
			8	
			9	
			10	SAND, to v. coarse size, moderately well sorted
			11	fine gravely sand
			12	SAND, to v. coarse size
			13	
			14	
			15	fine gravely sand
			16	SAND, to v. coarse size
			17	
			18	
			19	CLAY, v. dk. greenish gray, (5GY 3/1), v. stiff
			20	mottled olive brown (2.5Y 4/4)
			21	
			22	
			23	
			24	
			25	
			26	
			27	
			28	brown (10YR 4/3)
			29	SAND
			30	CLAY, brown (10YR 5/4) to lt. yellowish brown (10YR 6/4), v. stiff

10 20 30 40 50 60 70 80 90 100

Figure 33. Geologic log of Hollister Airport borehole. **50**

SITE: HOLLISTER AIRPORT DATE: 3-25-91

LATITUDE: 36 53.350
LONGITUDE: 121 24.675

BLOWS/ FOOT	SAMPLE TYPE	GRAPHIC LOG	DEPTH (ft) (m)	DESCRIPTION
			100 31	CLAY, brown (10YR 5/4) to lt. yellowish brown (10YR 6/4), v. stiff
			32	
			33	
			110 34	SANDY CLAY, lt. yellowish brown (10YR 6/4)
			35	GRAVELLY SAND, v. dense
			36	
			120 37	SANDY GRAVEL, hard
			38	
			39	
			130 40	
			41	
			42	
			140 43	
			44	SILTY CLAY LOAM, grayish brown (2.5Y 5/2)
			45	GRAVELLY SAND
			150 46	
			47	SANDY CLAY LOAM, grayish brown (2.5Y 5/2)
			48	
			160 49	SANDY GRAVEL
			50	SANDY CLAY LOAM
			51	GRAVELLY SAND
			170 52	SANDY GRAVEL
			53	GRAVELLLY SAND
			54	SANDY CLAY LOAM, denser
			180 55	SAND
			56	SILT LOAM, olive gray (5Y 4/2), denser
			57	
			190 58	
			59	
			60	
			200	GRAVELLY SAND

Figure 33 (Continued).

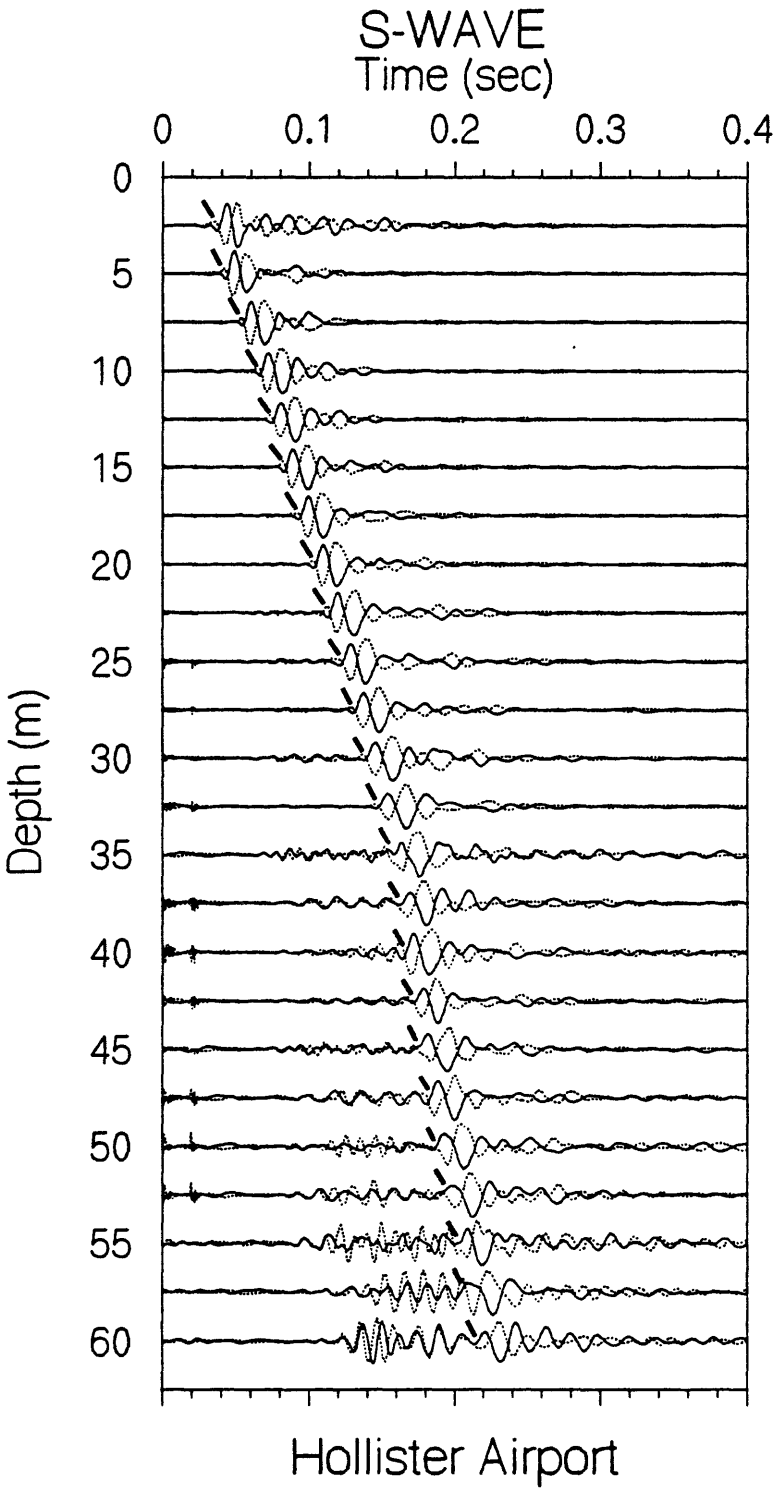


Figure 34. Horizontal-component record section (from horizontal impacts in opposite directions) superimposed for identification of S-wave onset. Approximate S-wave picks are indicated by the accent marks.

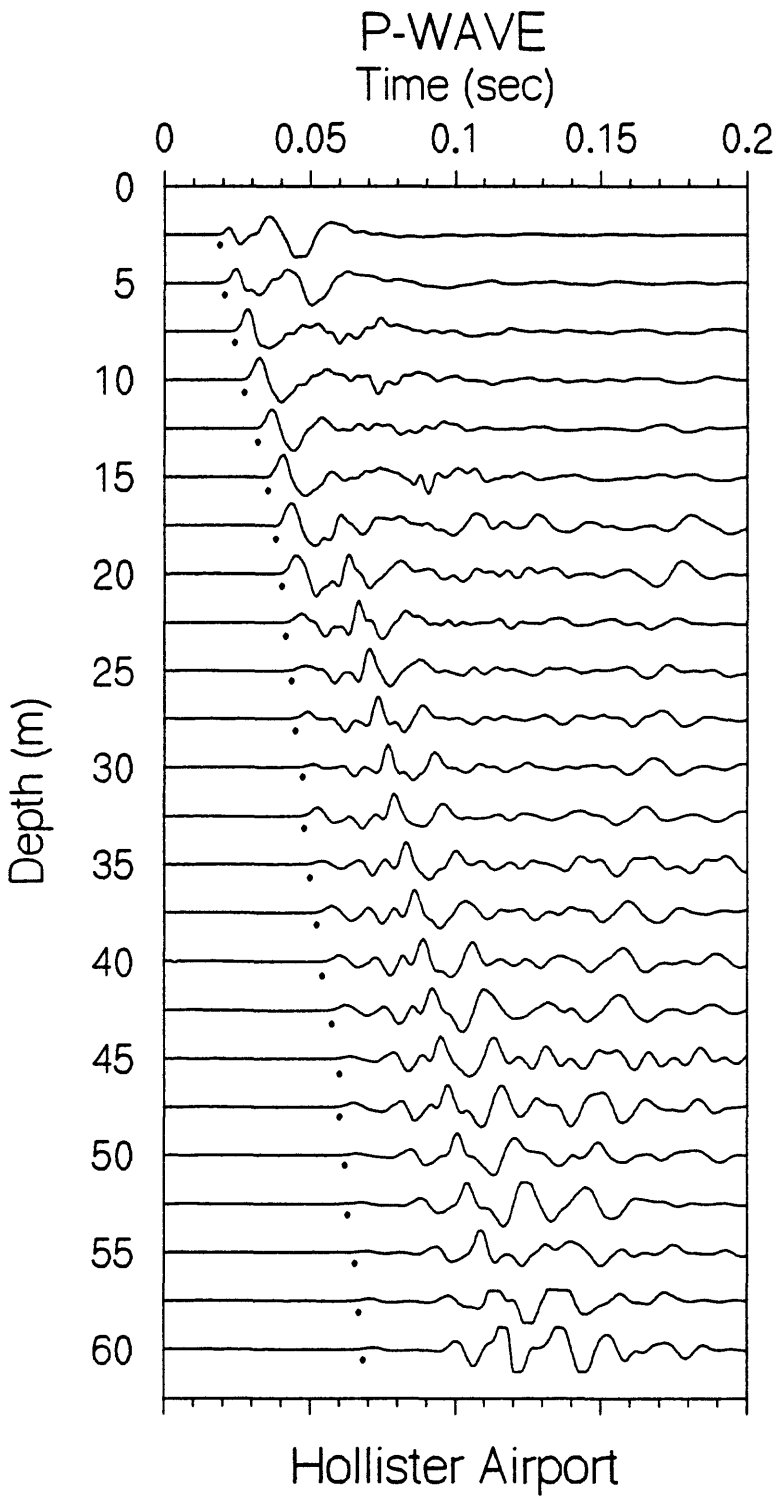


Figure 35. Vertical-component record section. Approximate P-wave picks are shown by the solid circles.

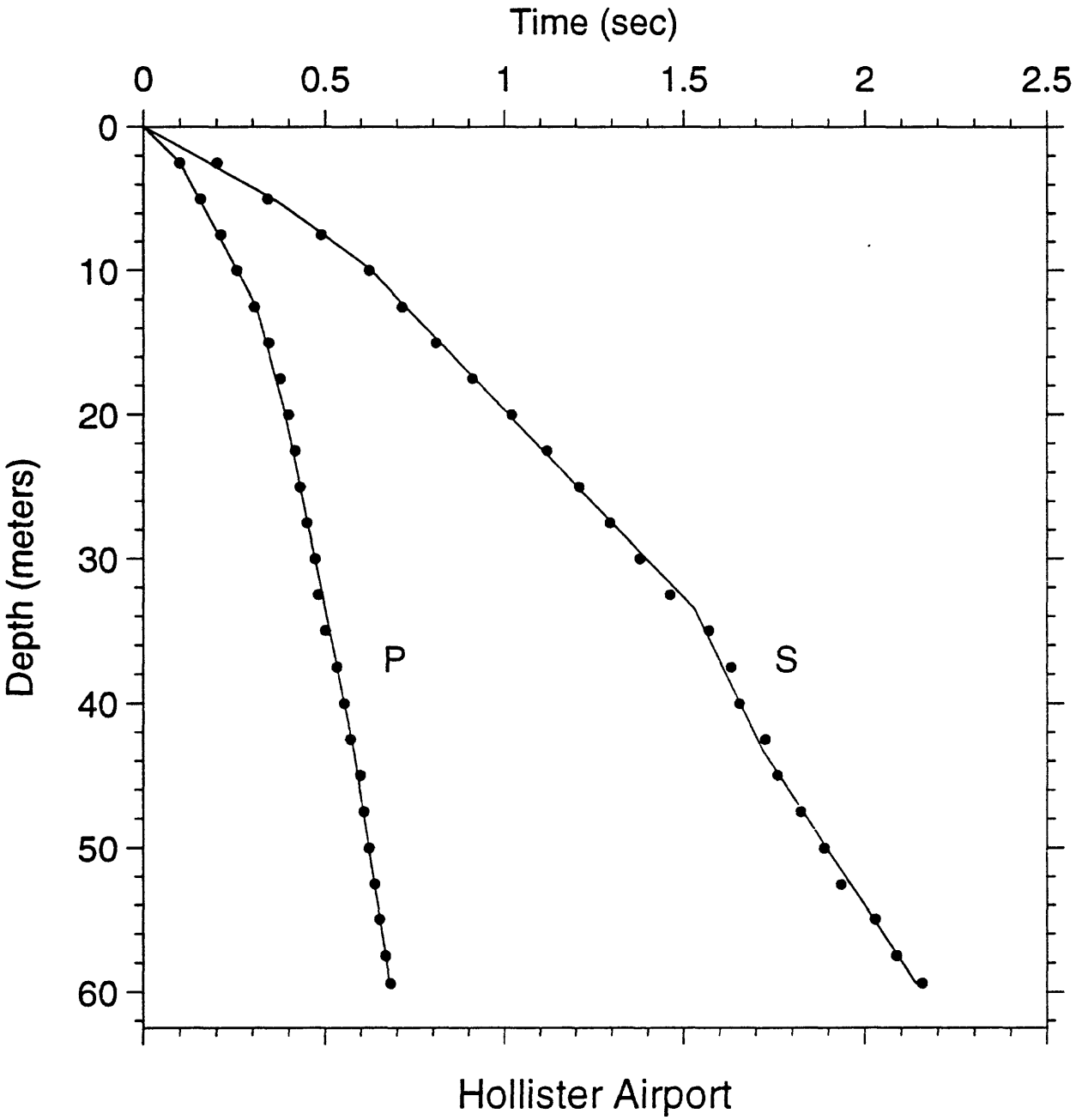


Figure 36. Time-depth graph of P-wave and S-wave picks. Line segments show the hinged-least-squares fit to the data points.

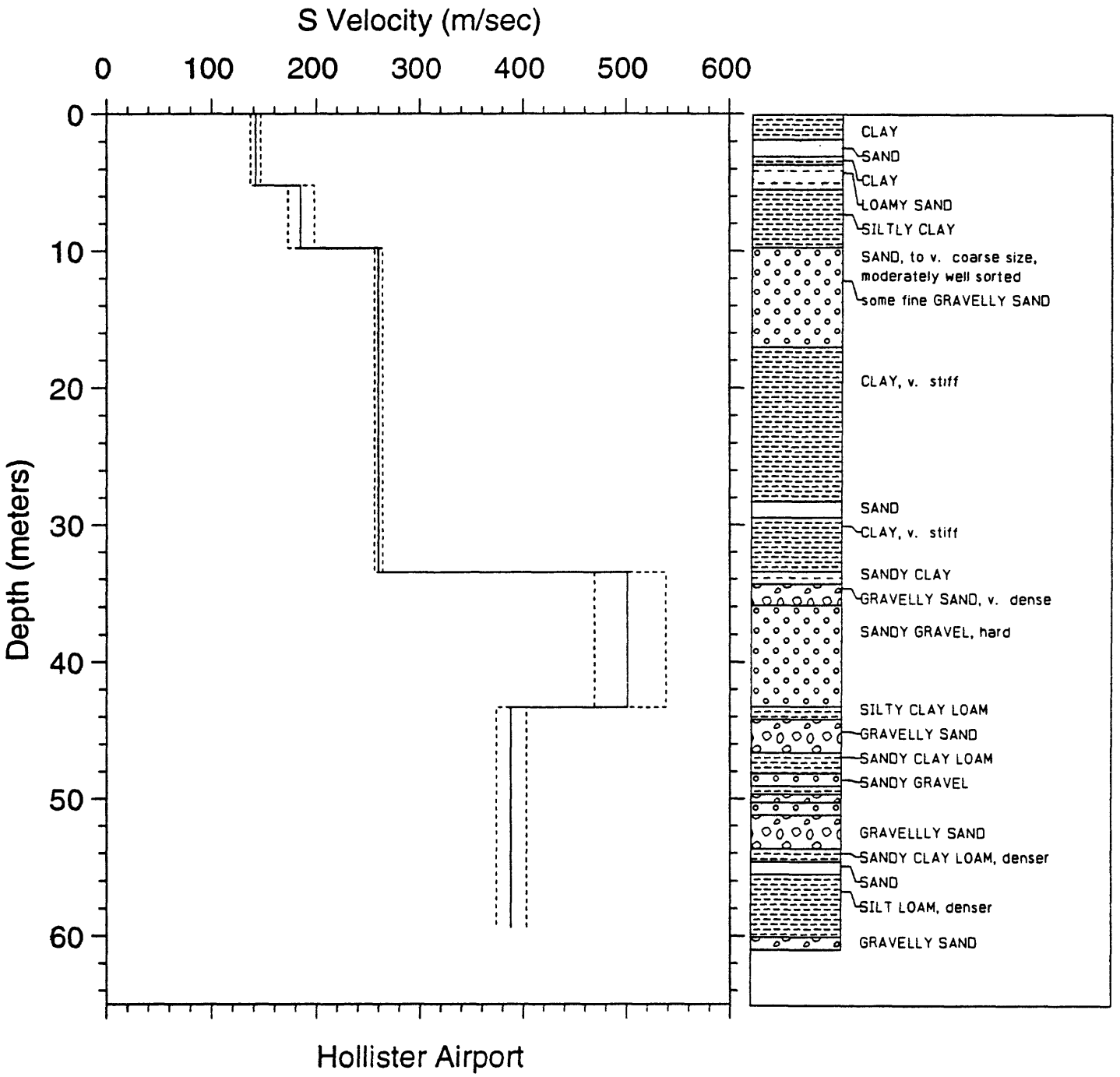


Figure 37. S-wave velocity profiles with dashed lines representing plus and minus one standard deviation. Simplified geologic log is shown for correlation with velocities.

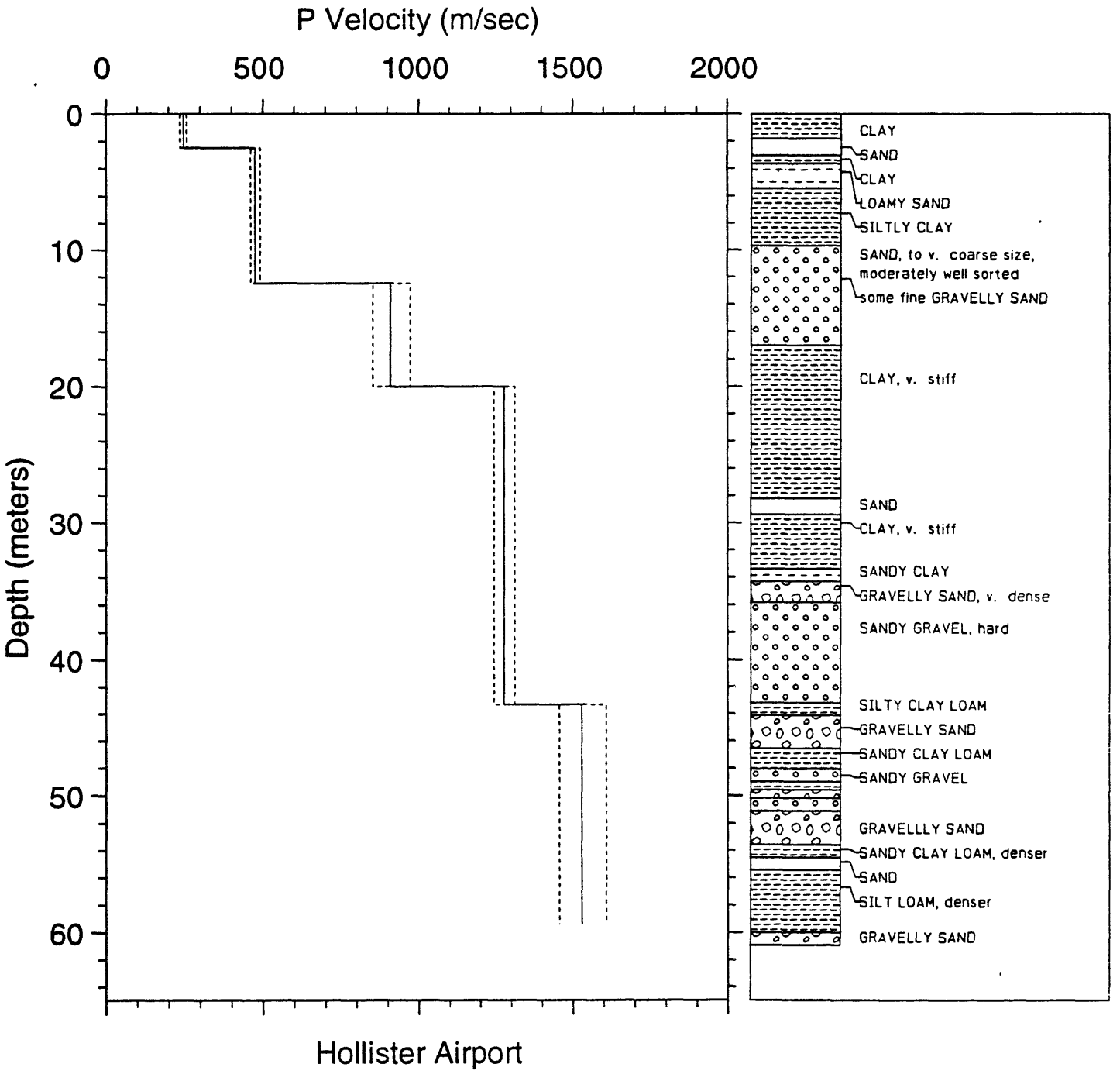


Figure 38. P-wave velocity profiles with dashed lines representing plus and minus one standard deviation. Simplified geologic log is shown for correlation with velocities.

TABLE 7. S-wave arrival times and velocity summaries for Hollister Airport site.

d(m)	d(ft)	t(sec)	sig	rsdl/sig	dtb(m)	dtb(ft)	ttb(s)	v(m/s)	vl(m/s)	vu(m/s)	v(ft/s)	vl(ft/s)	vu(ft/s)
2.5	8.2	.0201	1	2.5	.0	.0	.000	142	137	147	465	449	483
5.0	16.4	.0341	1	-1.1	5.2	17.1	.037	142	137	147	465	449	483
7.5	24.6	.0489	1	-.2	9.8	32.2	.062	185	173	198	607	569	651
10.0	32.8	.0622	1	-.1	33.5	109.9	.153	260	256	264	852	839	866
12.5	41.0	.0714	1	-.5	43.3	142.1	.172	501	469	538	1645	1539	1766
15.0	49.2	.0808	1	-.7	59.4	194.9	.214	388	374	403	1273	1227	1323
17.5	57.4	.0910	1	-.2									
20.0	65.6	.1020	1	1.2									
22.5	73.8	.1119	1	1.5									
25.0	82.0	.1209	1	.9									
27.5	90.2	.1294	1	-.3									
30.0	98.4	.1378	1	-1.5									
32.5	106.6	.1461	1	-2.8									
35.0	114.8	.1570	1	1.3									
37.5	123.0	.1631	1	2.4									
40.0	131.2	.1654	1	-.3									
42.5	139.4	.1726	1	1.9									
45.0	147.6	.1759	1	-.8									
47.5	155.8	.1824	1	-.7									
50.0	164.0	.1888	1	-.8									
52.5	172.2	.1934	1	-2.6									
55.0	180.4	.2029	1	.5									
57.5	188.6	.2087	1	-.2									
59.4	194.9	.2157	1	1.9									

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 Hollister Airport site.

d(m)	d(ft)	t(sec)	sig	rsdl/sig	dtb(m)	dtb(ft)	ttb(s)	v(m/s)	vl(m/s)	vu(m/s)	v(ft/s)	vl(ft/s)	vu(ft/s)
2.5	8.2	.0098	1	-.3	.0	.0	.000	247	236	258	809	775	846
5.0	16.4	.0156	1	.2	2.5	8.2	.010	247	236	258	809	775	846
7.5	24.6	.0212	1	.5	12.5	41.0	.031	475	460	491	1559	1510	1611
10.0	32.8	.0256	1	-.3	20.0	65.6	.039	909	853	973	2983	2800	3191
12.5	41.0	.0305	1	-.7	43.3	142.1	.058	1277	1244	1312	4190	4081	4305
15.0	49.2	.0344	1	.5	59.4	194.9	.068	1528	1456	1608	5014	4776	5276
17.5	57.4	.0376	1	.9									
20.0	65.6	.0398	1	.4									
22.5	73.8	.0417	1	.3									
25.0	82.0	.0431	1	-.3									
27.5	90.2	.0449	1	-.4									
30.0	98.4	.0472	1	-.1									
32.5	106.6	.0480	1	-1.2									
35.0	114.8	.0501	1	-1.1									
37.5	123.0	.0533	1	.2									
40.0	131.2	.0553	1	.2									
42.5	139.4	.0571	1	.0									
45.0	147.6	.0598	1	1.0									
47.5	155.8	.0608	1	.4									
50.0	164.0	.0622	1	.1									
52.5	172.2	.0638	2	.0									
55.0	180.4	.0652	1	-.1									
57.5	188.6	.0668	1	-.2									
59.4	194.9	.0682	1	.0									

Explanation:

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

* see text for explanation of velocity limits

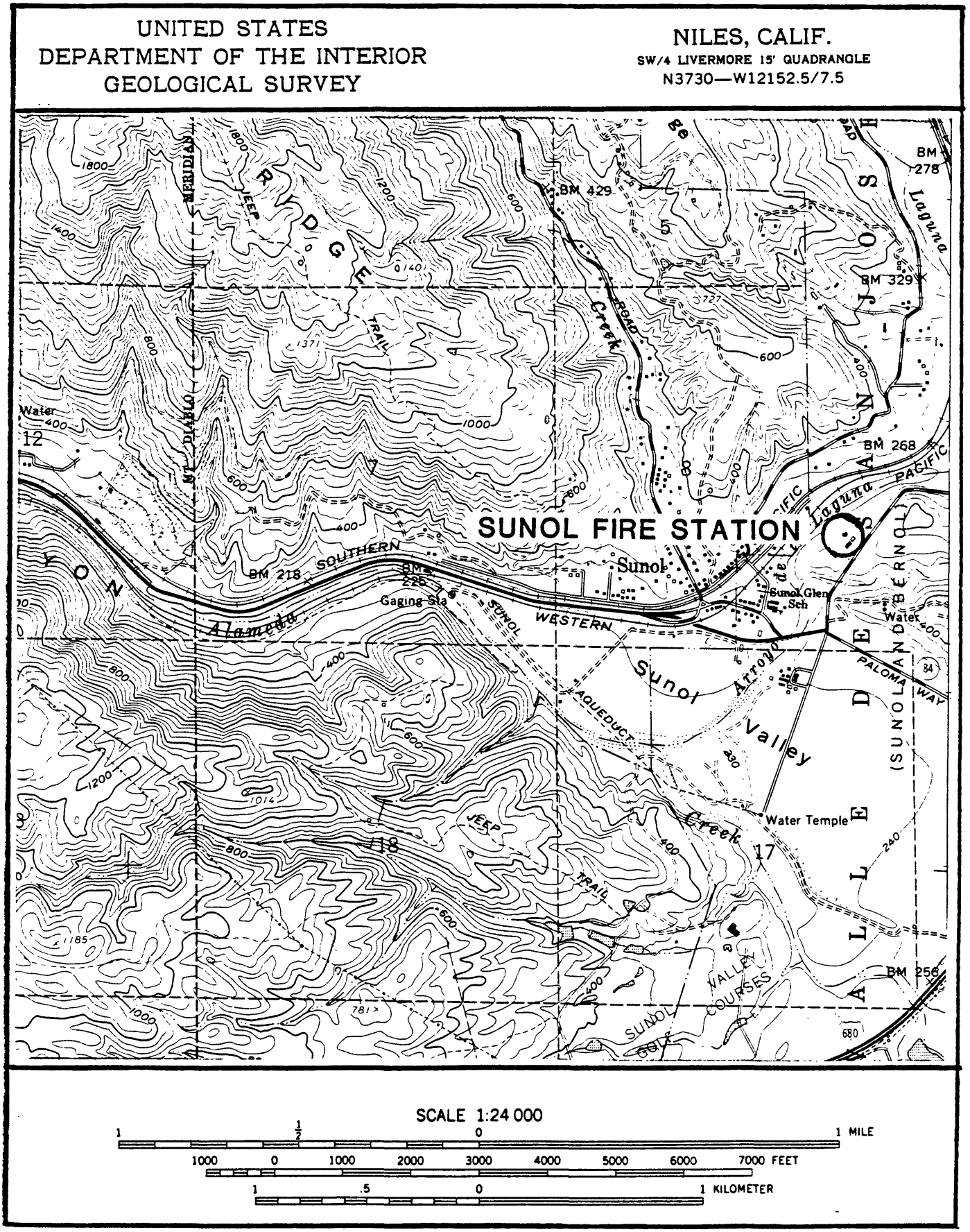


Figure 39. Site location map for Sunol Fire Station borehole. The strong-motion accelerograph is located approximately 30 meters from the borehole.

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

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

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

Fracture spacing: (Ellen et al., 1972)

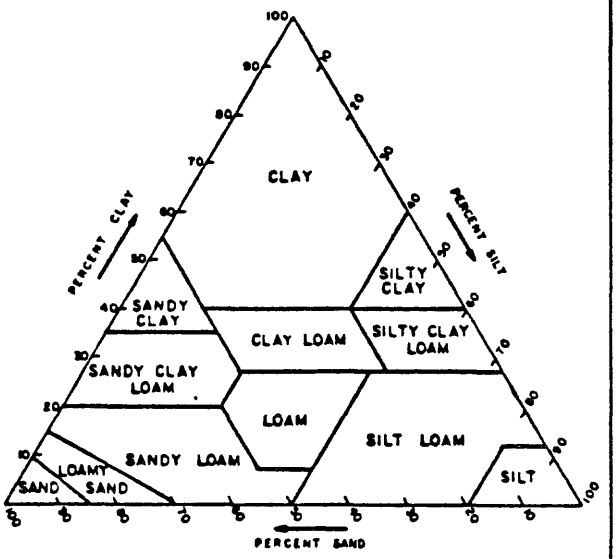
cm	in	fracture spacing
0-1	0-1/2	v. close
1-5	1/2-2	close
5-30	2-12	moderate
30-100	12-36	wide
>100	>36	v. wide

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

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

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

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



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

Types of samples

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

Figure 40. Explanation of geologic logs.

SITE: SUNOL FIRE STATION

DATE: 2-1-91

LATITUDE: 37 35.812
LONGITUDE: 121 52.812

BLOWS/ FOOT	SAMPLE TYPE	GRAPHIC LOG	DEPTH (ft) (m)	DESCRIPTION
			0	GRAVELLY LOAMY SAND, brown (10YR 3/3)
			10	SANDY CLAY LOAM, yellowish brown (10YR 5/4)
				SANDY CLAY LOAM, grayish brown, (25Y 5/2), some gravel
			20	SANDY CLAY LOAM, lt. olive brown (2.5Y 5/4)
				GRAVELLY SAND
			30	CLAY LOAM, yellowish brown (10YR 5/4), v. stiff
				CLAY, brown (10YR 4/3), v. stiff
			40	CLAY, olive mottled, greenish gray (5G 5/1)
				SAND
			50	FINE GRAVELLY SAND, dk. greenish gray, mottled olive brown (2.5Y 4/6), poorly sorted
			60	
			70	
			80	
			90	
				SANDY GRAVEL, dk. greenish gray, (5G 4/1), poorly sorted, v. dense
			100	
			110	
			120	
			130	
			140	
			150	
			160	

Page 1 of 1

Figure 41. Geologic log of Sunol Fire Station borehole.

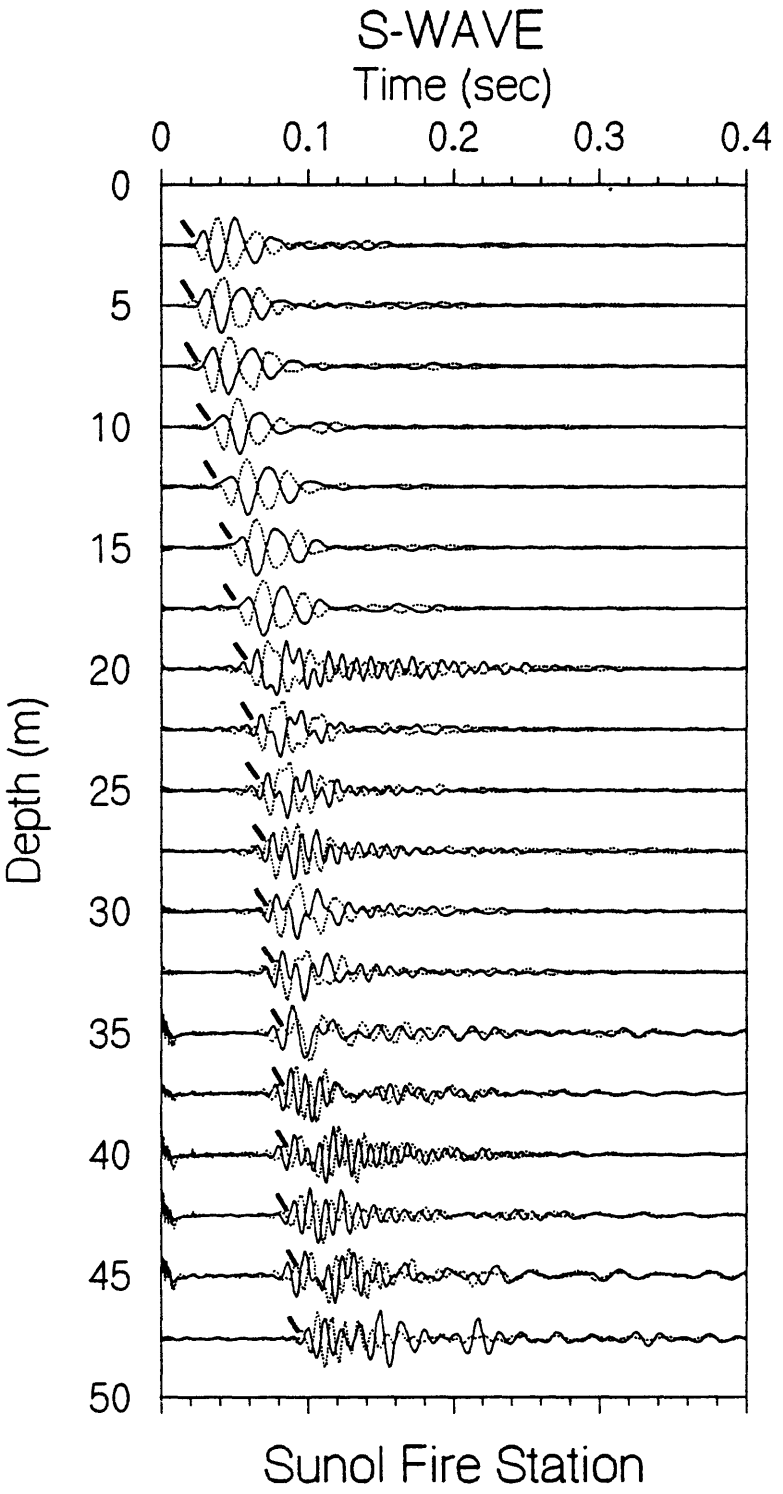


Figure 42. Horizontal-component record section (from horizontal impacts in opposite directions) superimposed for identification of S-wave onset. Approximate S-wave picks are indicated by the accent marks.

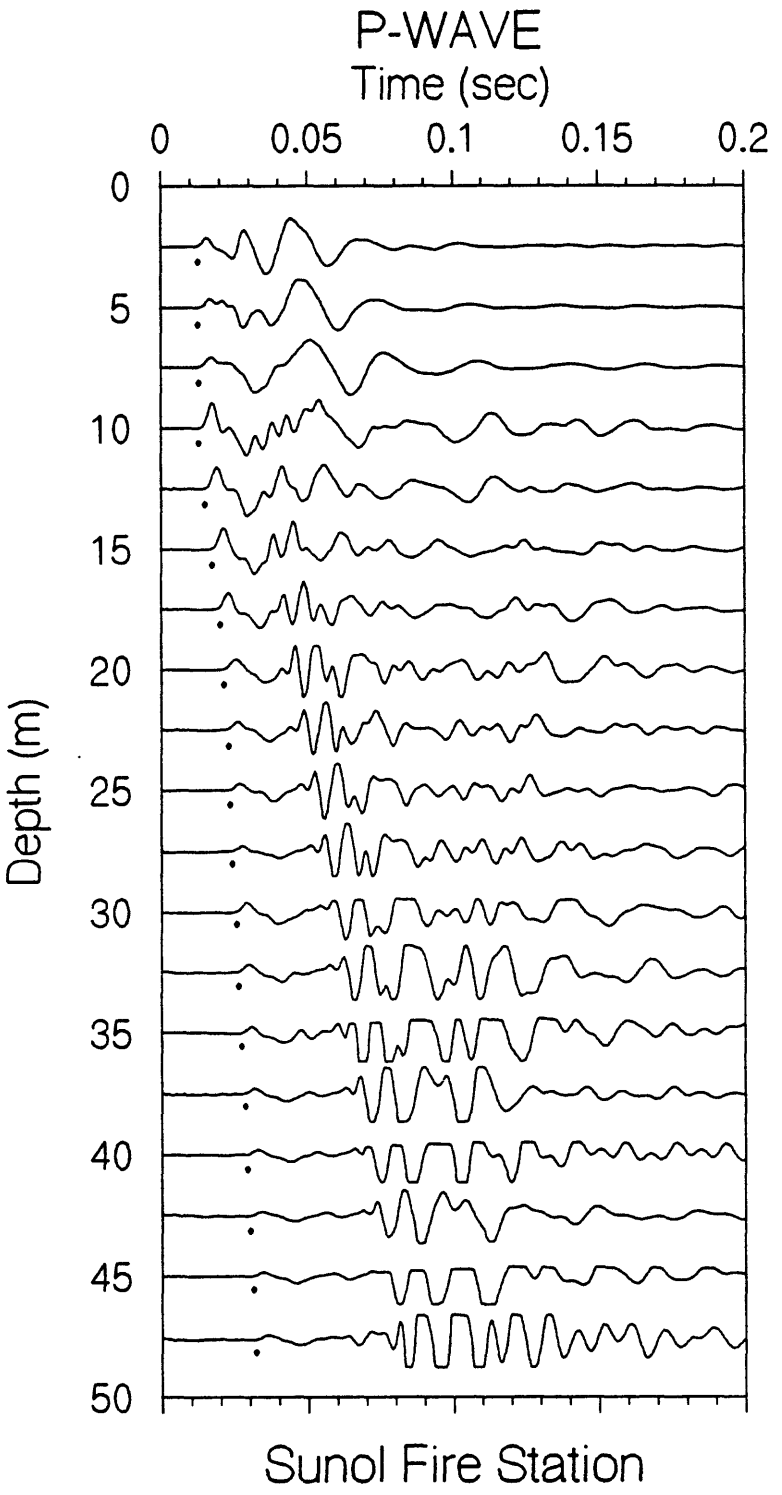


Figure 43. Vertical-component record section. P-wave arrivals are shown by the solid circles.

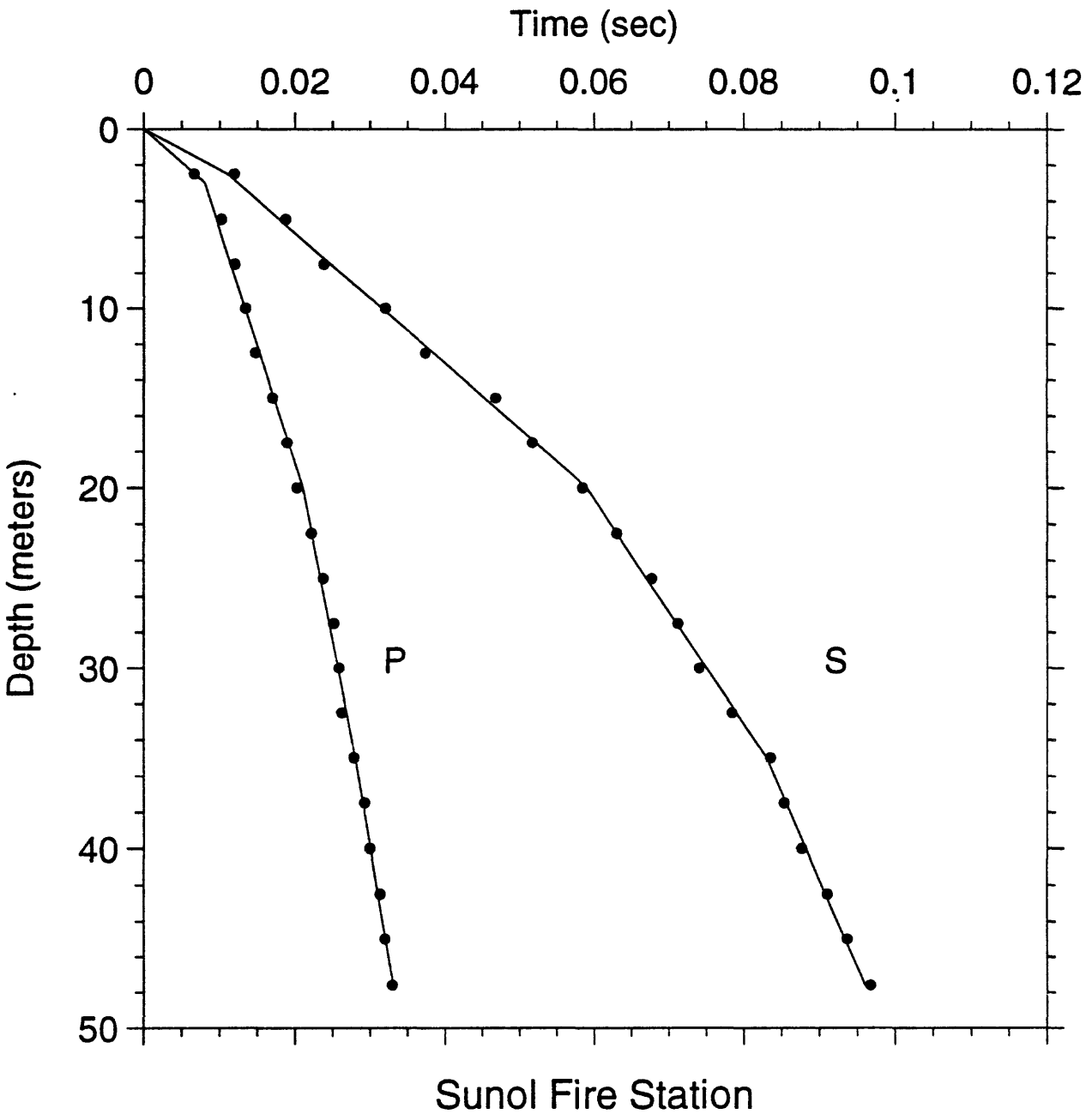


Figure 44. Time-depth graph of P-wave and S-wave picks. Line segments show the hinged-least-squares fit to the data points.

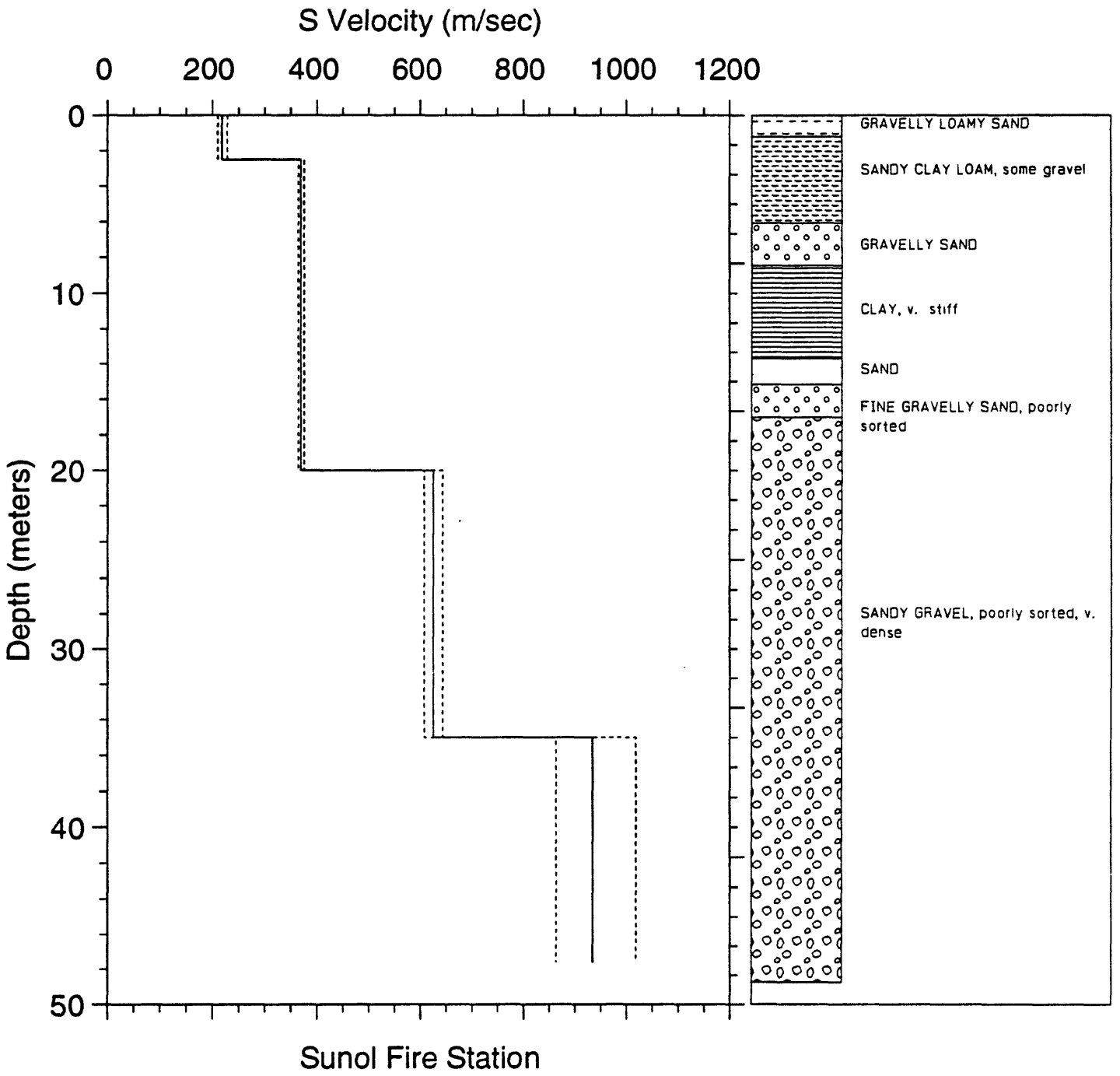


Figure 45. S-wave velocity profiles with dashed lines representing plus and minus one standard deviation. Simplified geologic log is shown for correlation with velocities.

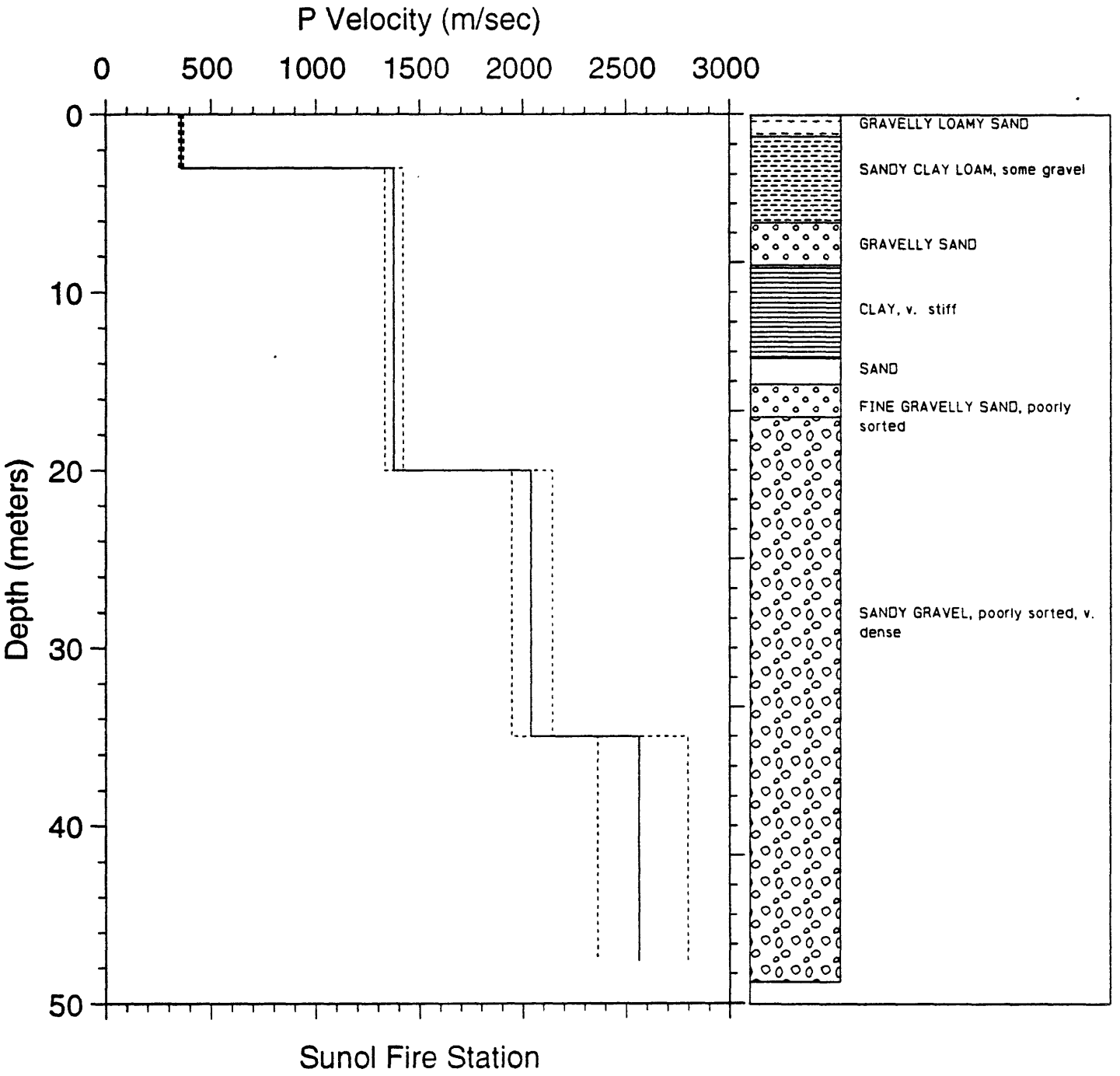


Figure 46. P-wave velocity profiles with dashed lines representing plus and minus one standard deviation. Simplified geologic log is shown for correlation with velocities.

TABLE 9. S-wave arrival times and velocity summaries for Sunol Fire Station borehole.

d(m)	d(ft)	t(sec)	sig	rsdl/sig	dtb(m)	dtb(ft)	ttb(s)	v(m/s)	vl(m/s)	vu(m/s)	v(ft/s)	vl(ft/s)	vu(ft/s)
2.5	8.2	.0119	1	.4	.0	.0	.000	218	210	228	716	688	747
5.0	16.4	.0187	1	.5	2.5	8.2	.011	218	210	228	716	688	747
7.5	24.6	.0238	1	-1.2	20.0	65.6	.059	369	364	375	1212	1194	1230
10.0	32.8	.0320	1	.2	35.0	114.8	.083	625	607	643	2050	1993	2110
12.5	41.0	.0373	1	-1.2	47.6	156.2	.096	934	863	1018	3063	2830	3339
15.0	49.2	.0468	1	1.5									
17.5	57.4	.0517	1	-.4									
20.0	65.6	.0584	1	-.4									
22.5	73.8	.0630	1	.2									
25.0	82.0	.0677	1	.9									
27.5	90.2	.0712	1	.4									
30.0	98.4	.0740	1	-.8									
32.5	106.6	.0784	1	-.4									
35.0	114.8	.0835	1	.7									
37.5	123.0	.0853	2	-.1									
40.0	131.2	.0876	2	-.4									
42.5	139.4	.0910	2	.1									
45.0	147.6	.0936	2	.0									
47.6	156.2	.0967	2	.2									

Explanation:

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

* see text for explanation of velocity limits

TABLE 10. P-wave arrival times and velocity summaries for Sunol Fire Station borehole.

d(m)	d(ft)	t(sec)	sig	rsdl/sig	dtb(m)	dtb(ft)	ttb(s)	v(m/s)	vl(m/s)	vu(m/s)	v(ft/s)	vl(ft/s)	vu(ft/s)
2.5	8.2	.0066	1	-.4	.0	.0	.000	359	348	371	1177	1141	1216
5.0	16.4	.0102	1	.4	3.0	9.8	.008	359	348	371	1177	1141	1216
7.5	24.6	.0120	1	.4	20.0	65.6	.021	1375	1333	1421	4512	4372	4661
10.0	32.8	.0134	1	.0	35.0	114.8	.028	2040	1946	2143	6692	6386	7029
12.5	41.0	.0147	1	-.6	47.6	156.2	.033	2562	2362	2798	8405	7749	9181
15.0	49.2	.0170	1	-.1									
17.5	57.4	.0189	1	.0									
20.0	65.6	.0202	1	-.5									
22.5	73.8	.0221	1	.2									
25.0	82.0	.0237	1	.5									
27.5	90.2	.0251	1	.7									
30.0	98.4	.0258	1	.2									
32.5	106.6	.0262	1	-.6									
35.0	114.8	.0278	1	-.3									
37.5	123.0	.0292	1	.1									
40.0	131.2	.0299	1	-.1									
42.5	139.4	.0313	1	.3									
45.0	147.6	.0319	1	-.1									
47.6	156.2	.0329	1	-.1									

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

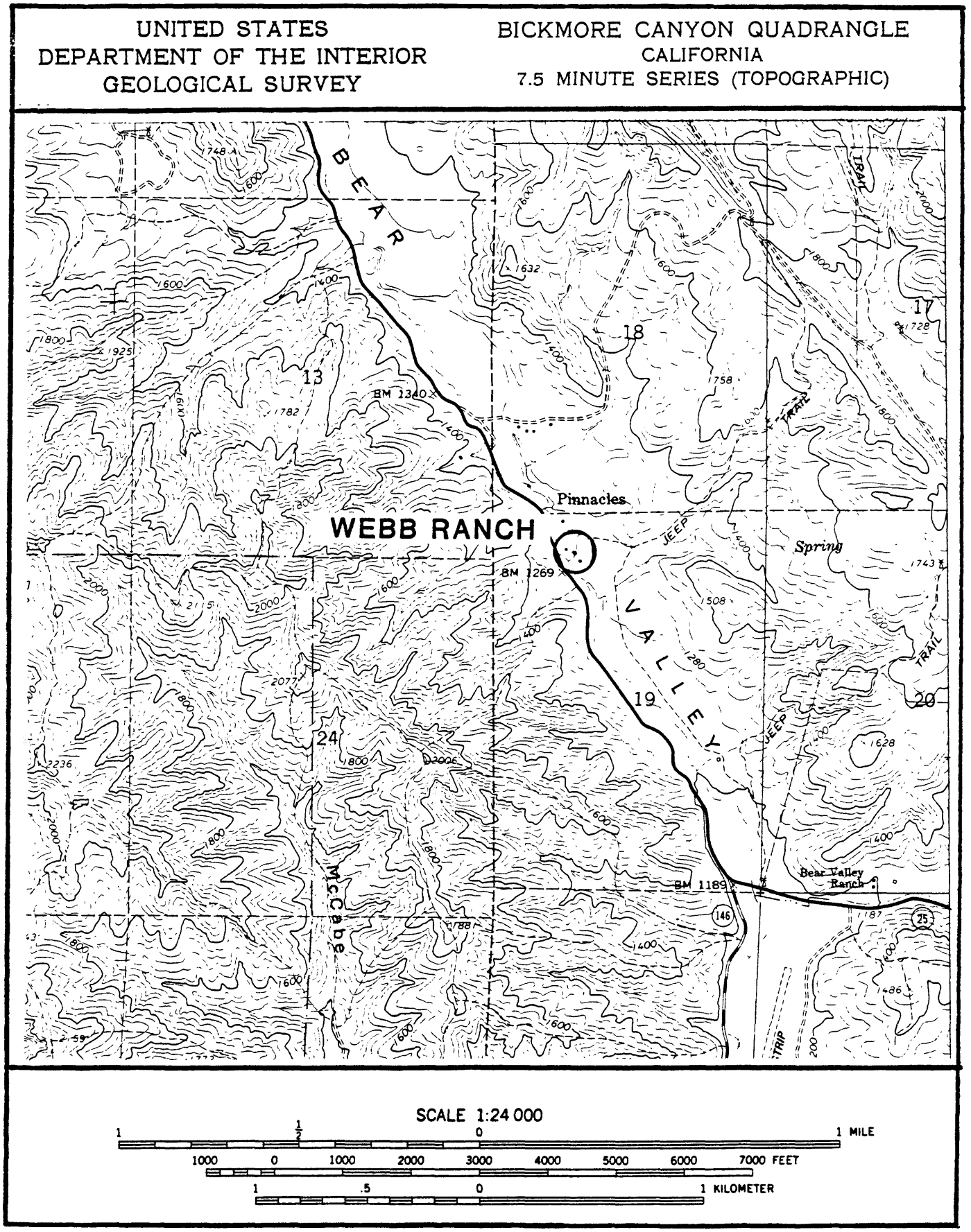


Figure 47. Location map for Webb Ranch borehole. The borehole is located approximately 30 meters from the strong-motion recorder.

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

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

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

Fracture spacing: (Ellen et al., 1972)

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

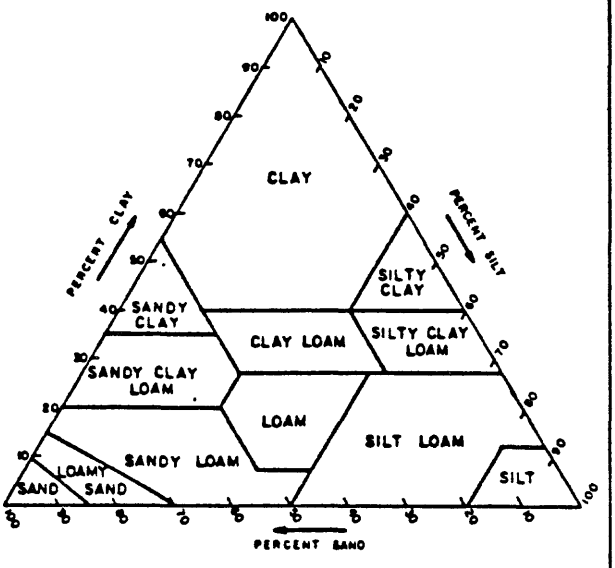
Weathering:

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

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

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

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



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

Types of samples

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

Figure 48. Explanation of geologic log.

SITE: WEBB RANCH

DATE: 3-14-91

LATITUDE: 36 31.880
LONGITUDE: 121 08.618

BLOWS/ FOOT	SAMPLE TYPE	GRAPHIC LOG	DEPTH (ft) (m)	DESCRIPTION
			0	SANDY LOAM, dk. v. fine, grayish brown (10YR 3/2), occasionally fine gravel
			10	fine GRAVEL to v. coarse SAND
			20	SANDY CLAY LOAM, dk. grayish brown (10YR 4/2)
			30	SAND, gray (N5/), v. coarse, with interbeds of dk. gray (10YR 4/1) fine SANDY CLAY LOAM
			40	fine GRAVELLY SAND
				SANDY CLAY LOAM, v. dk. gray (N3/)
			50	SAND
				SANDY GRAVEL, siliceous mudstone, quartz
			60	SAND, v. dense or SANDSTONE, soft to firm
				occasional layers of gravel
			70	MUDSTONE (?), black (5Y 2.5/2)
				SANDSTONE, gray (N6/), v. coarse grained, some gravel layers
			80	GRAVEL
			90	SANDSTONE, gray, v. coarse grained
			100	
			110	
			120	
			130	SANDSTONE, coarse grained, some firm layers, v. hard
			140	
			150	

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Figure 49. Geologic log of Webb Ranch borehole.

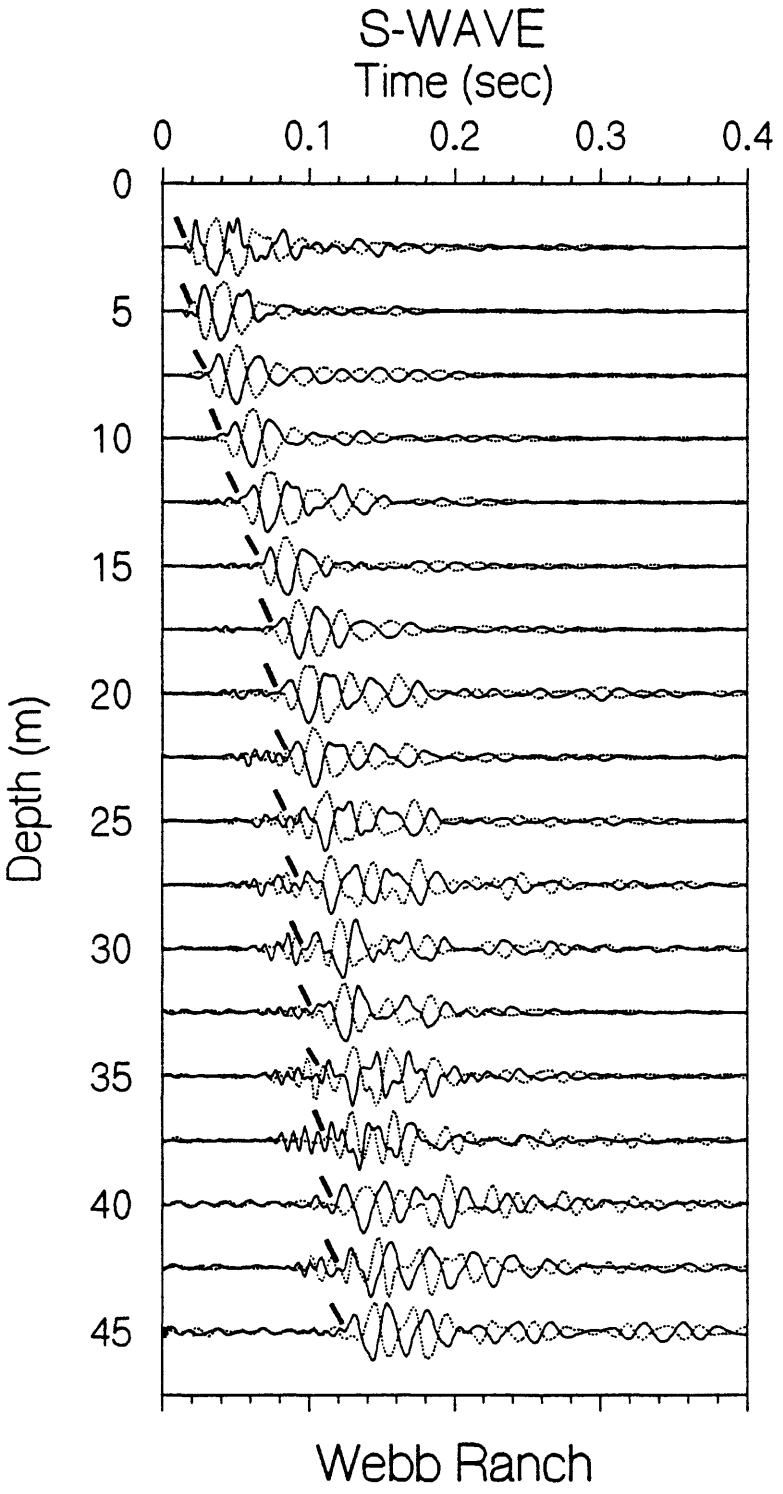


Figure 50. Horizontal-component record section (from horizontal impacts in opposite directions) superimposed for identification of S-wave onset. Approximate S-wave picks are indicated by the accent marks.

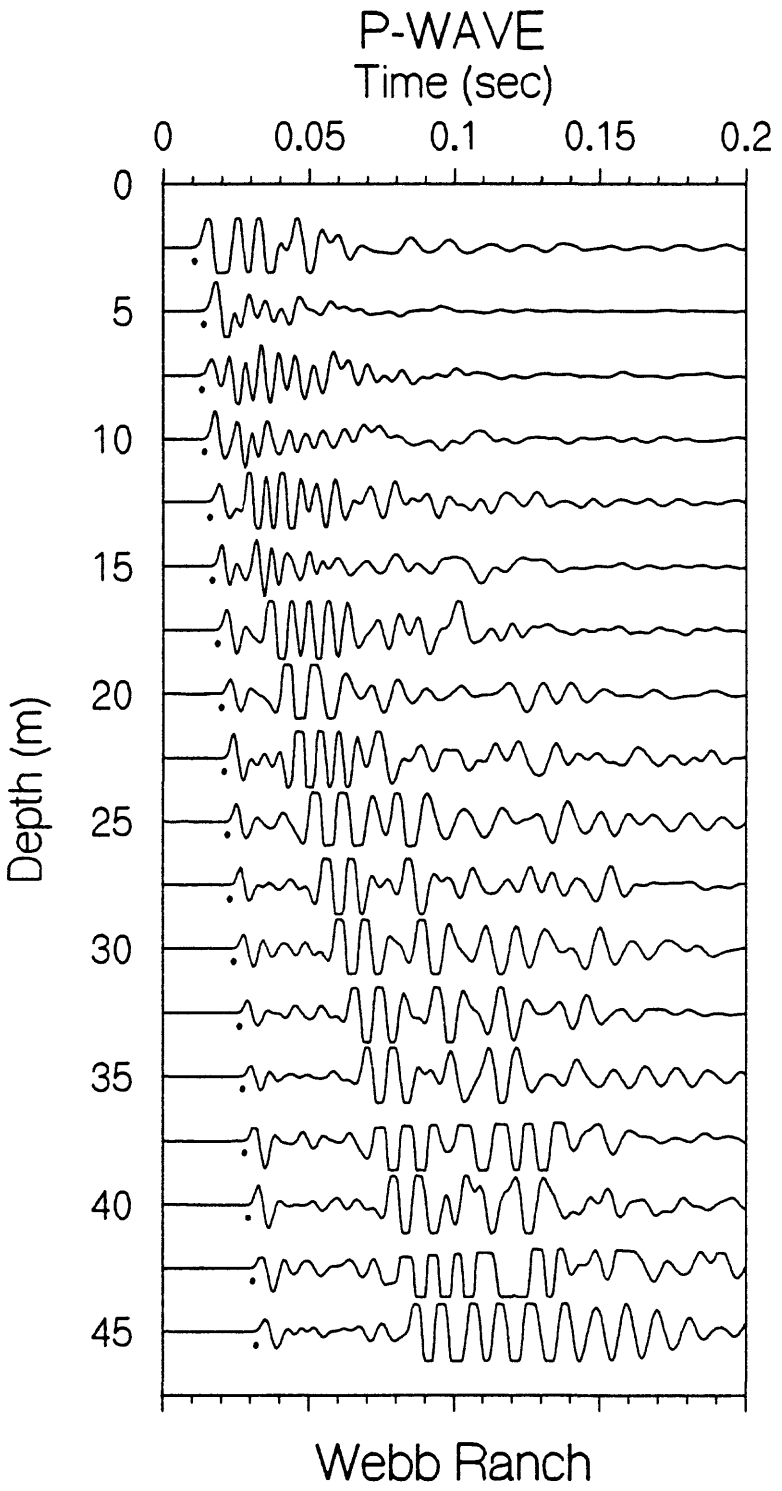


Figure 51. Vertical-component record section. P-wave arrivals are shown by the solid circles.

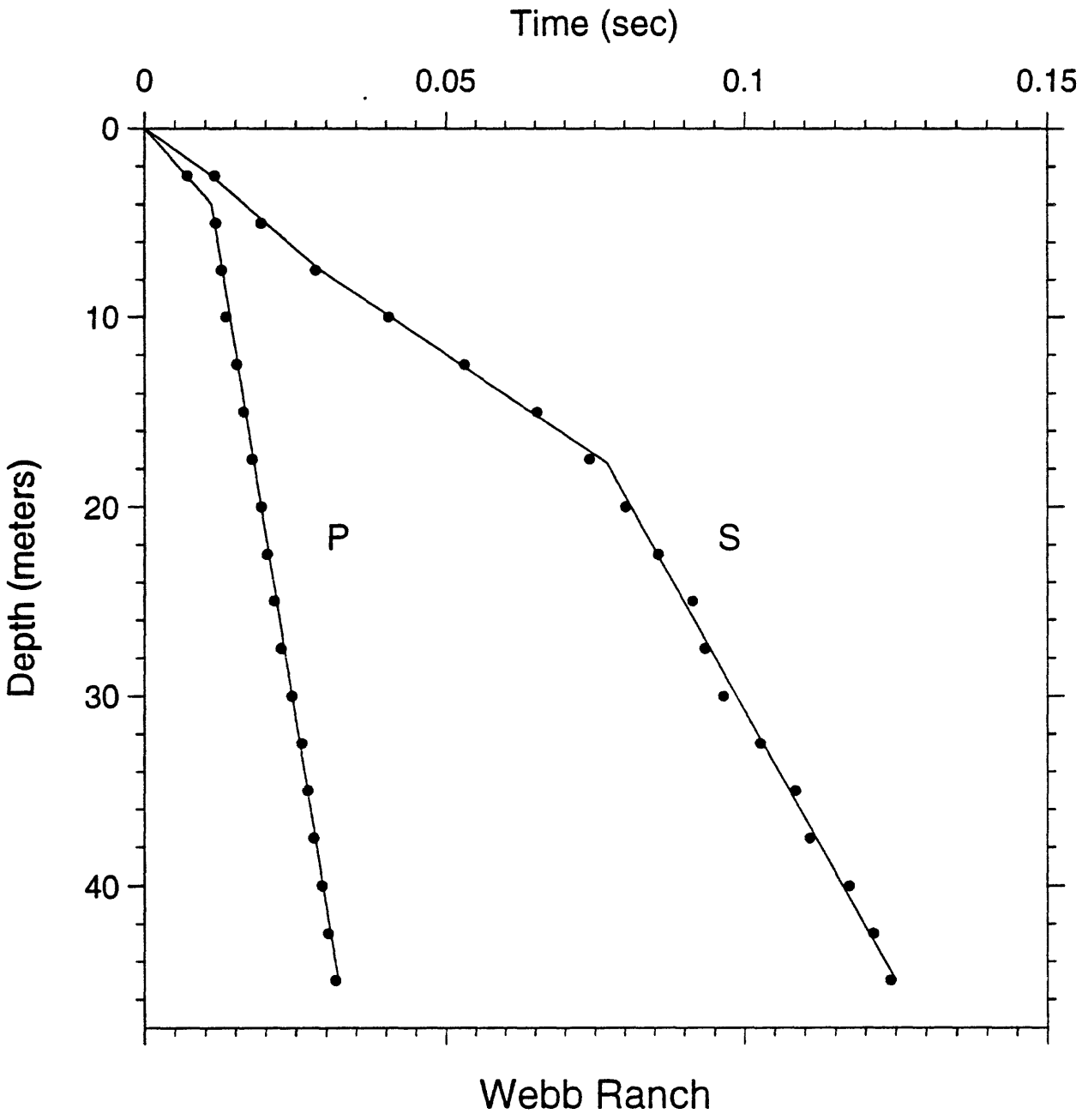


Figure 52. Time-depth graph of P-wave and S-wave picks. Line segments show the hinged-least-squares fit to the data points.

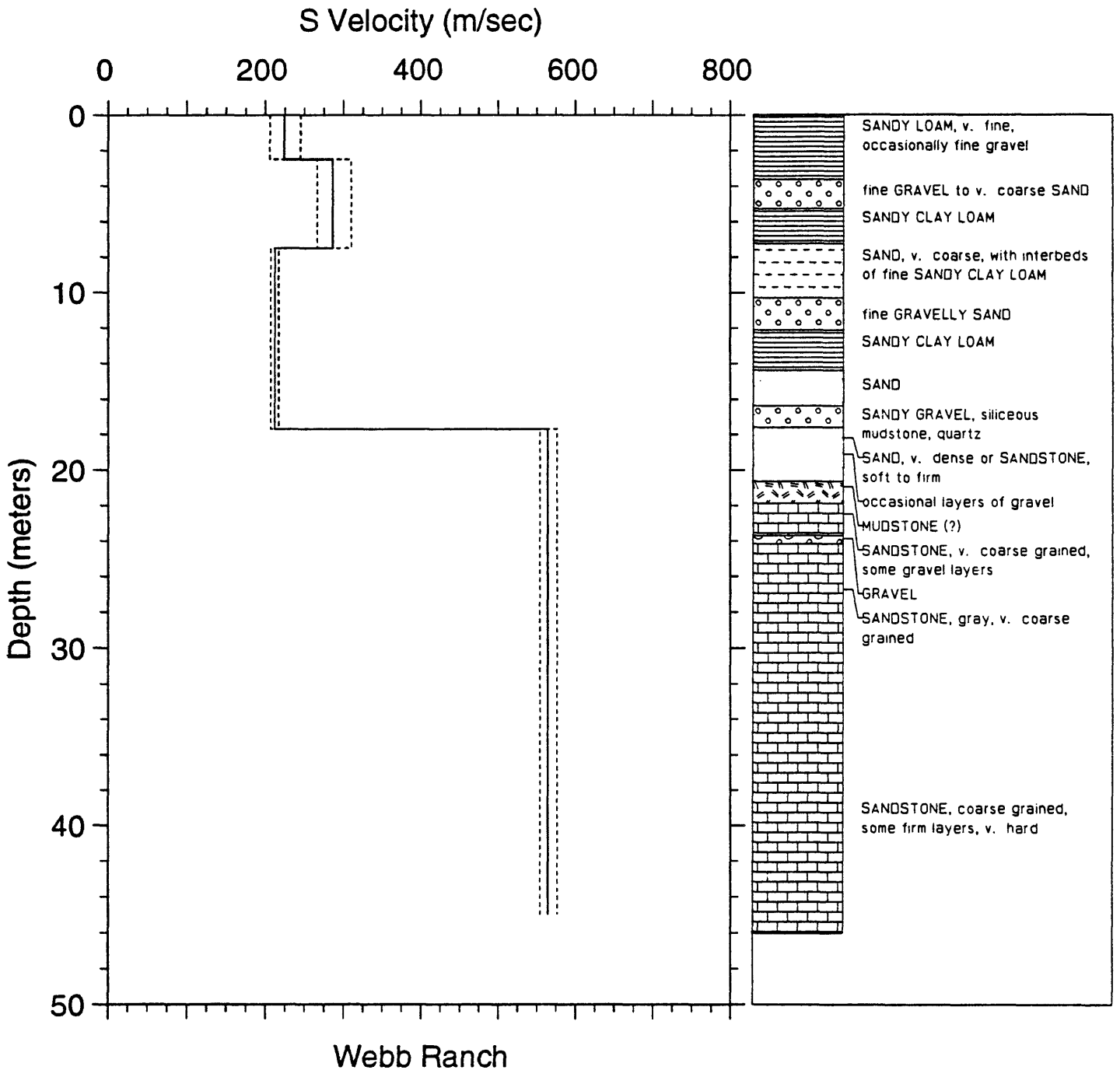


Figure 53. S-wave velocity profiles with dashed lines representing plus and minus one standard deviation. Simplified geologic log is shown for correlation with velocities.

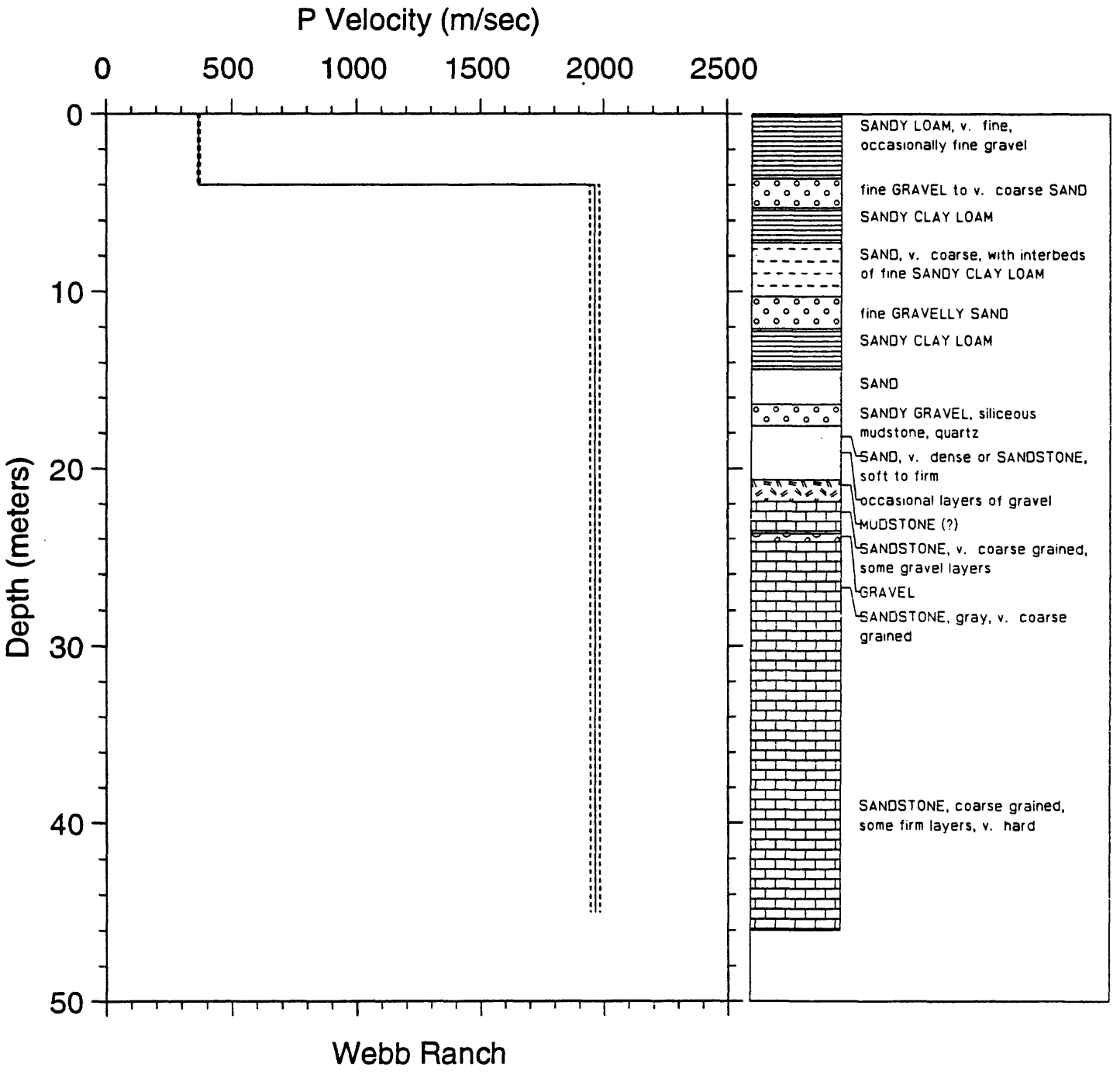


Figure 54. P-wave velocity profiles with dashed lines representing plus and minus one standard deviation. Simplified geologic log is shown for correlation with velocities.

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

d(m)	d(ft)	t(sec)	sig	rsdl/sig	dtb(m)	dtb(ft)	ttb(s)	v(m/s)	vl(m/s)	vu(m/s)	v(ft/s)	vl(ft/s)	vu(ft/s)
2.5	8.2	.0115	1	.3	.0	.0	.000	224	206	245	735	676	805
5.0	16.4	.0192	1	-.7	2.5	8.2	.011	224	206	245	735	676	805
7.5	24.6	.0282	1	-.4	7.5	24.6	.029	286	266	310	940	873	1017
10.0	32.8	.0404	1	.0	17.7	58.1	.077	212	207	217	695	681	711
12.5	41.0	.0531	1	.9	45.0	147.6	.125	564	554	576	1852	1817	1888
15.0	49.2	.0653	1	1.3									
17.5	57.4	.0741	1	-1.7									
20.0	65.6	.0801	1	-.7									
22.5	73.8	.0856	1	.4									
25.0	82.0	.0913	1	1.6									
27.5	90.2	.0934	2	-.5									
30.0	98.4	.0965	2	-1.4									
32.5	106.6	.1026	1	-.4									
35.0	114.8	.1084	1	1.0									
37.5	123.0	.1108	1	-1.0									
40.0	131.2	.1173	1	1.0									
42.5	139.4	.1213	1	.6									
45.0	147.6	.1241	1	-1.0									

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 Webb Ranch site.

d(m)	d(ft)	t(sec)	sig	rsdl/sig	dtb(m)	dtb(ft)	ttb(s)	v(m/s)	vl(m/s)	vu(m/s)	v(ft/s)	vl(ft/s)	vu(ft/s)
2.5	8.2	.0070	1	.2	.0	.0	.000	368	364	373	1209	1195	1222
5.0	16.4	.0117	1	.3	4.0	13.1	.011	368	364	373	1209	1195	1222
7.5	24.6	.0126	1	.0	45.0	147.6	.032	1963	1944	1983	6441	6378	6505
10.0	32.8	.0134	1	-.5									
12.5	41.0	.0152	1	.0									
15.0	49.2	.0163	1	-.2									
17.5	57.4	.0177	1	.0									
20.0	65.6	.0192	1	.2									
22.5	73.8	.0202	1	-.1									
25.0	82.0	.0214	1	-.2									
27.5	90.2	.0225	1	-.3									
30.0	98.4	.0243	1	.2									
32.5	106.6	.0259	1	.5									
35.0	114.8	.0269	1	.3									
37.5	123.0	.0279	1	.0									
40.0	131.2	.0293	1	.1									
42.5	139.4	.0303	1	-.2									
45.0	147.6	.0315	1	-.2									

Explanation:

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

* see text for explanation of velocity limits

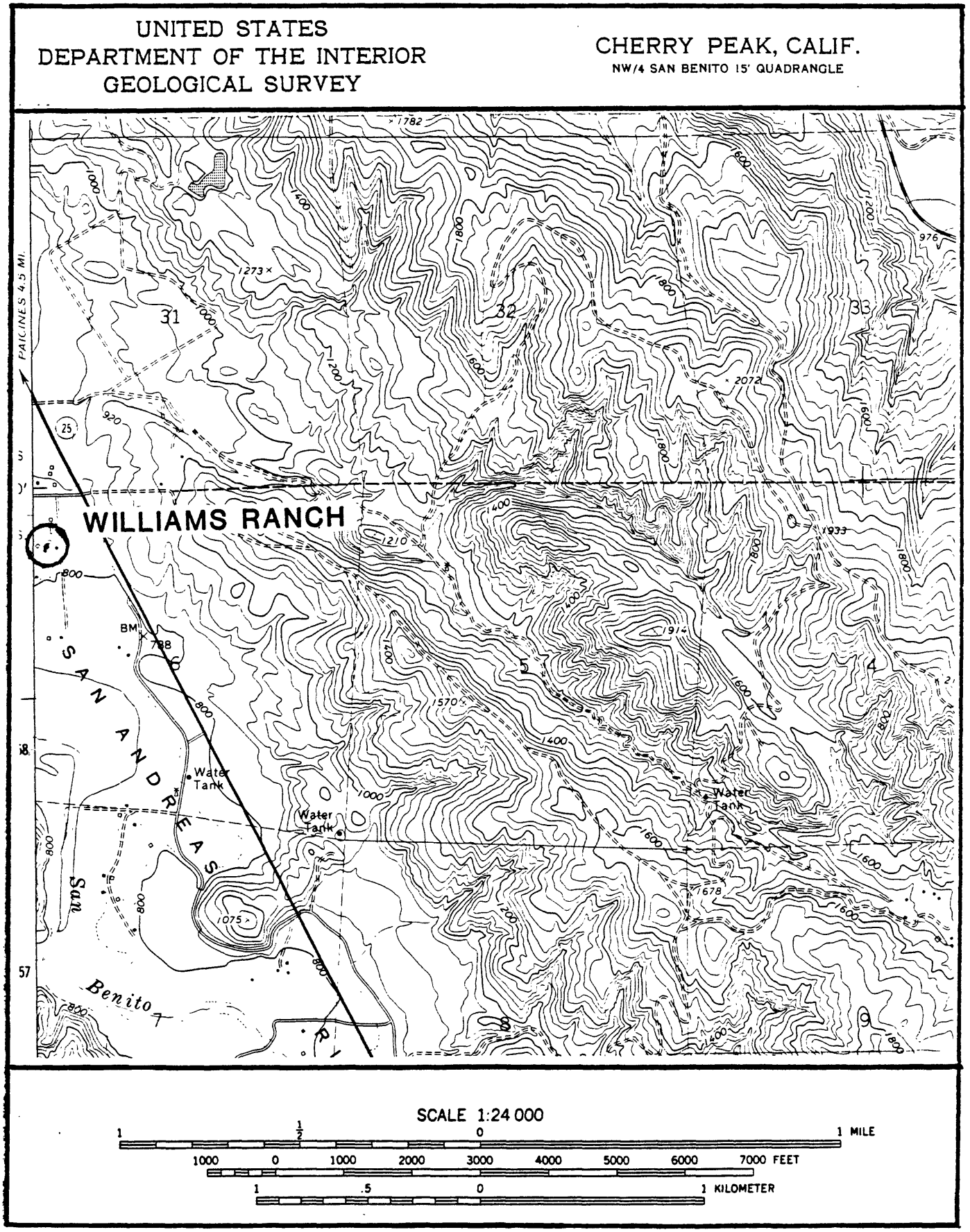


Figure 55. Site location map for Williams Ranch borehole. The borehole is located approximately 10 meters from the strong-motion recorder.

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

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

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

Fracture spacing: (Ellen et al., 1972)

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

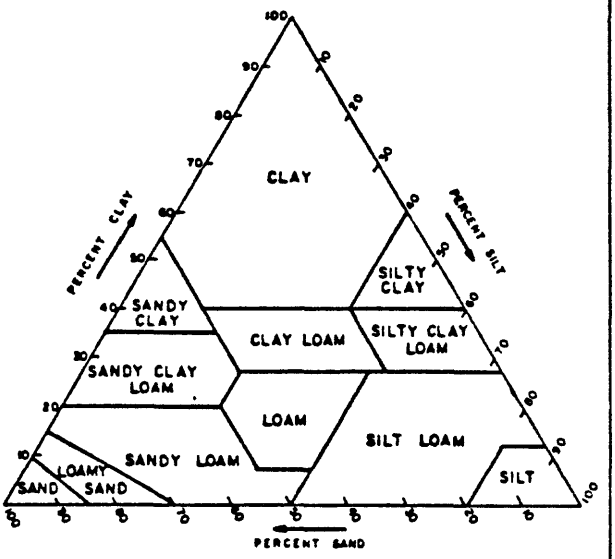
Weathering:

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

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

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

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



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

Types of samples

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

Figure 56. Explanation of geologic log.

SITE: WILLIAMS RANCH

DATE: 3-12-91

LATITUDE: 36 39.858
LONGITUDE: 121 14.962

BLOWS/ FOOT	SAMPLE TYPE	GRAPHIC LOG	DEPTH (ft) (m)	DESCRIPTION
			0	SANDY LOAM, dk. brown (10YR 3/3)
			1	COBBLY SAND
			2	GRAVEL, v. coarse
			10 3	SANDY CLAY LOAM, dk. brown (10YR 3/3)
			4	
			5	SAND, mosty fine to medium, some to v. coarse
			20 6	
			7	SANDY LOAM, v. fine to SANDY CLAY LOAM, v. fine
			8	
			30 9	
			10	SILTY CLAY LOAM, lt. olive brown (2.5Y 5/4)
			11	
			40 12	
			13	
			14	
			50 15	
			16	
			17	SAND, v. fine
			60 18	
			19	SANDY CLAY LOAM, sand to med. size, some f. gravel, (10YR 4/3)
			20	
			21	GRAVELLY SAND, fine
			70 22	
			23	SAND, to v. coarse size
			24	SANDY CLAY LOAM, brown (10YR 4/3)
			80 25	SANDY CLAY LOAM, fine, yellowish brown (10YR 5/4)
			26	
			27	
			90 28	
			29	
			30	
			100	

Figure 57. Geologic log of the Williams Ranch borehole.

SITE: WILLIAMS RANCH

DATE: 3-12-91

LATITUDE: 36 39.858
LONGITUDE: 121 14.962

BLOWS/ FOOT	SAMPLE TYPE	GRAPHIC LOG	DEPTH (ft) (m)	DESCRIPTION
			100 31	
			32	SANDY CLAY LOAM, fine, yellowish brown (10YR 5/4)
			110 33	
			34	
			35	.
			36	GRAVELLY v. course SAND
			120 37	
			38	
			39	SANDY GRAVEL, granitic
			130 40	SANDY CLAY LOAM, fine, yellowish brown (10YR 5/6)
			41	
			42	
			140 43	SAND
			44	
			45	SANDY CLAY LOAM, stiffer
			150 46	SAND
			47	SANDY CLAY LOAM, stiffer
			48	
			160 49	SAND, v. dense
			50	
			51	
			170 52	SANDY CLAY LOAM, v. dense
			53	
			54	
			180 55	
			56	SAND, coarse, v. dense
			57	
			190 58	
			59	SAND v. dense and interbedded fine SANDY CLAY LOAM, lt. olive brown (2.5Y 5/5)
			60	
			200	

Figure 57. (Continued).

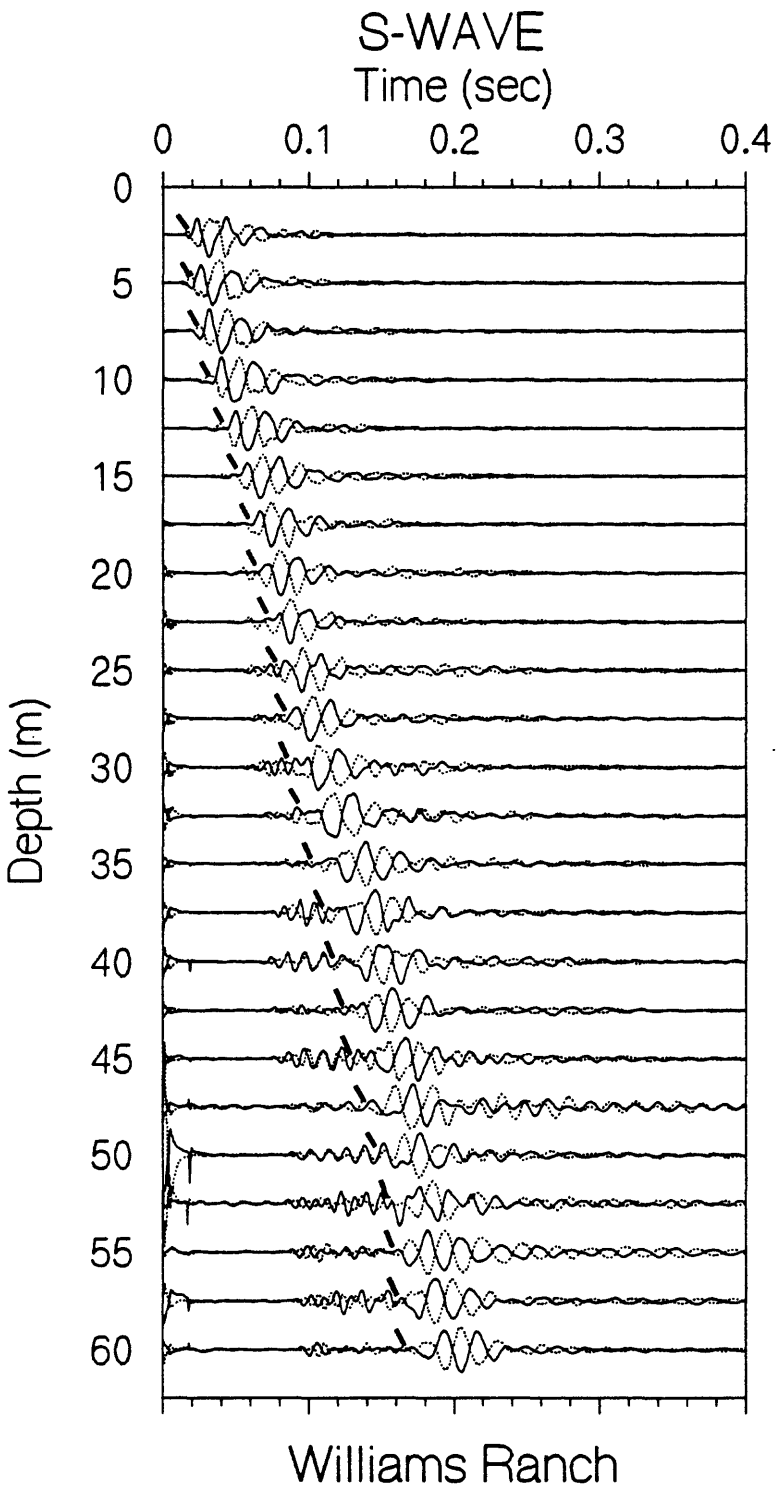


Figure 58. Horizontal-component record section (from horizontal impacts in opposite directions) superimposed for identification of S-wave onset. Approximate S-wave picks are indicated by the accent marks.

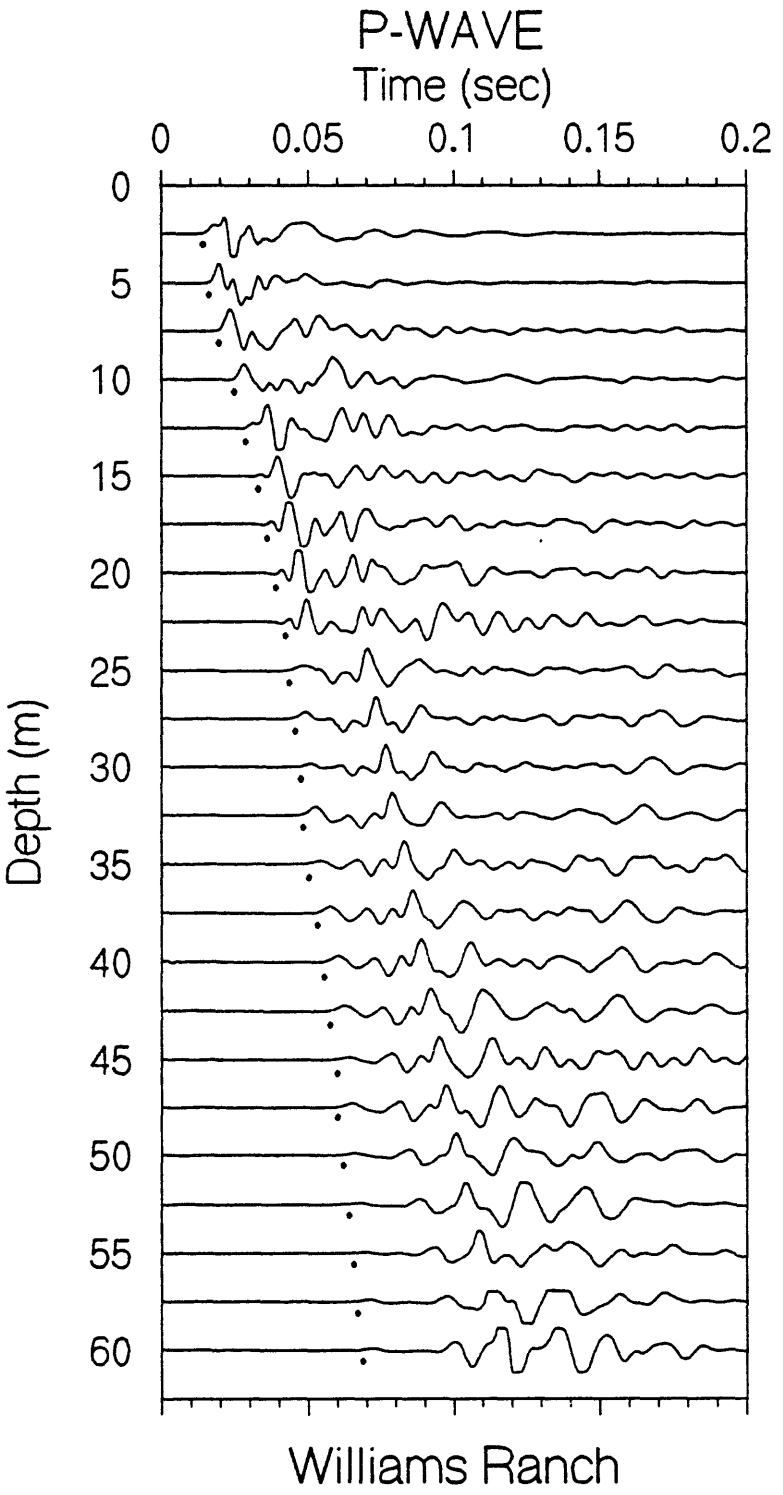


Figure 59. Vertical-component record section. P-wave arrivals are shown by the solid circles.

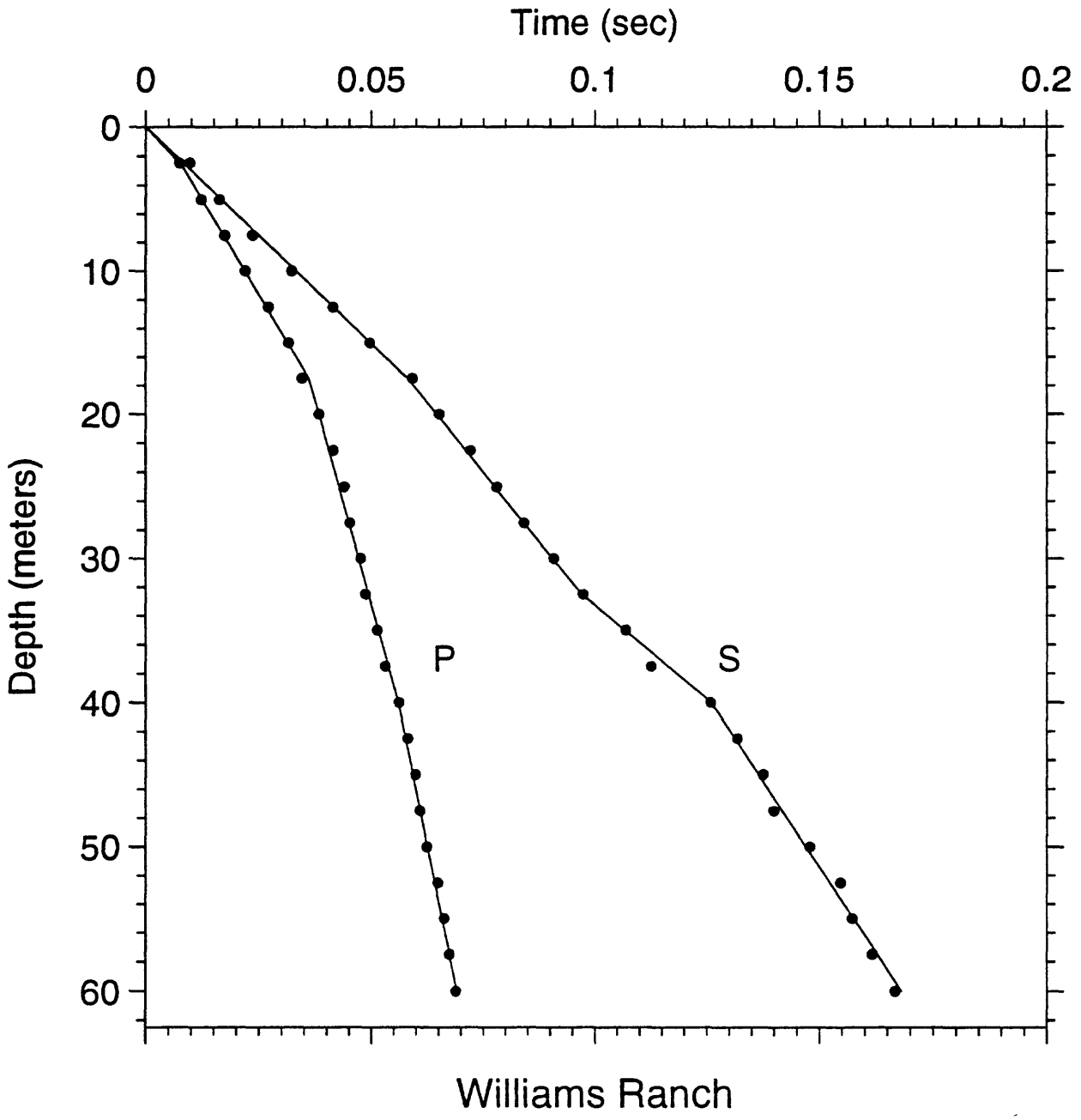


Figure 60. Time-depth graph of P-wave and S-wave picks. Line segments show the hinged-least-squares fit to the data points.

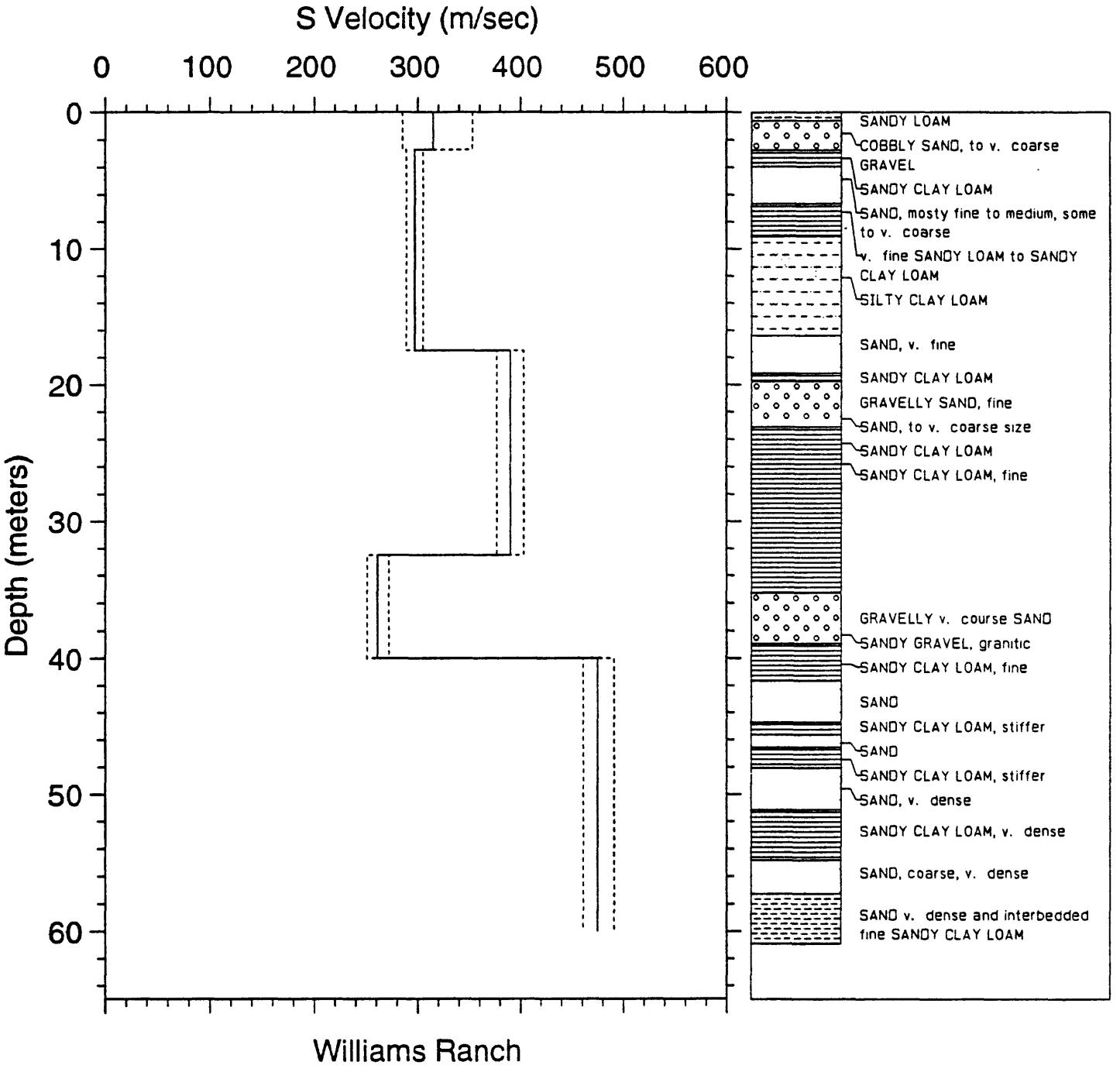


Figure 61. S-wave velocity profiles with dashed lines representing plus and minus one standard deviation. Simplified geologic log is shown for correlation with velocities.

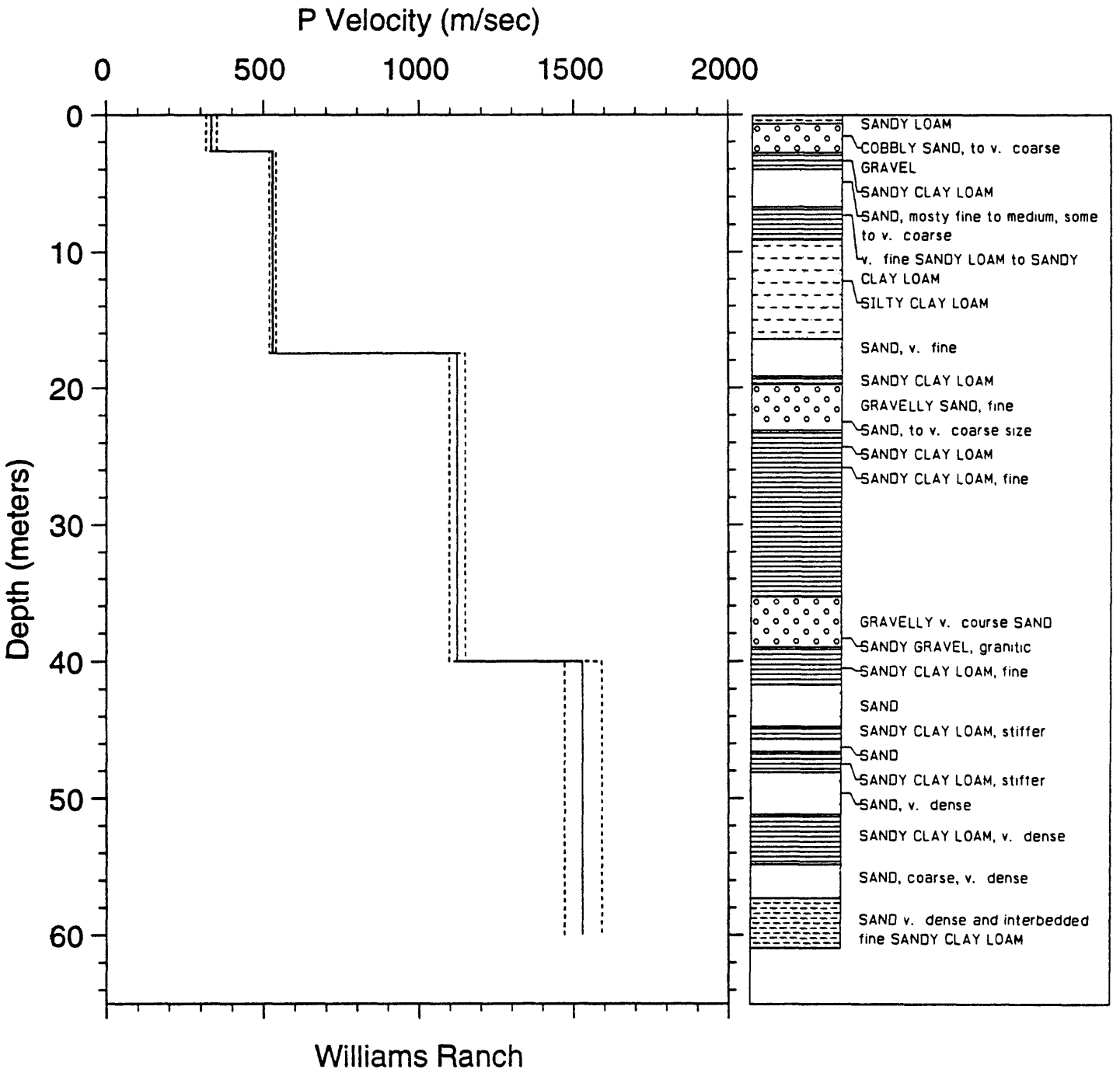


Figure 62. P-wave velocity profiles with dashed lines representing plus and minus one standard deviation. Simplified geologic log is shown for correlation with velocities.

TABLE 13. S-wave arrival times and velocity summaries for Williams Ranch site.

d(m)	d(ft)	t(sec)	sig	rsdl/sig	dtb(m)	dtb(ft)	ttb(s)	v(m/s)	vl(m/s)	vu(m/s)	v(ft/s)	vl(ft/s)	vu(ft/s)
2.5	8.2	.0097	1	1.8	.0	.0	.000	315	285	353	1034	933	1158
5.0	16.4	.0162	1	-.1	2.7	8.9	.009	315	285	353	1034	933	1158
7.5	24.6	.0235	1	-1.3	17.5	57.4	.058	297	289	305	973	947	1000
10.0	32.8	.0322	1	-1.0	32.5	106.6	.097	390	377	403	1278	1238	1321
12.5	41.0	.0413	1	-.3	40.0	131.2	.126	261	251	272	857	822	894
15.0	49.2	.0496	1	-.4	60.0	196.9	.168	475	461	491	1559	1512	1610
17.5	57.4	.0591	1	.6									
20.0	65.6	.0651	1	.2									
22.5	73.8	.0721	1	.8									
25.0	82.0	.0780	1	.3									
27.5	90.2	.0841	1	.0									
30.0	98.4	.0908	1	.2									
32.5	106.6	.0973	1	.3									
35.0	114.8	.1069	1	.4									
37.5	123.0	.1126	1	-3.5									
40.0	131.2	.1258	1	.1									
42.5	139.4	.1318	1	.8									
45.0	147.6	.1375	1	1.3									
47.5	155.8	.1399	1	-1.6									
50.0	164.0	.1479	1	1.2									
52.5	172.2	.1546	1	2.6									
55.0	180.4	.1572	1	-.1									
57.5	188.6	.1616	1	-.9									
60.0	196.9	.1666	1	-1.2									

Explanation:

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

* see text for explanation of velocity limits

TABLE 14. P-wave arrival times and velocity summaries for Williams Ranch site.

d(m)	d(ft)	t(sec)	sig	rsdl/sig
2.5	8.2	.0074	1	-.1
5.0	16.4	.0122	1	-.2
7.5	24.6	.0173	1	.1
10.0	32.8	.0219	1	.0
12.5	41.0	.0270	1	.4
15.0	49.2	.0315	1	.2
17.5	57.4	.0345	1	-1.6
20.0	65.6	.0382	1	-.1
22.5	73.8	.0414	1	.9
25.0	82.0	.0438	1	1.1
27.5	90.2	.0451	1	.1
30.0	98.4	.0476	1	.4
32.5	106.6	.0486	1	-.8
35.0	114.8	.0513	1	-.3
37.5	123.0	.0531	1	-.8
40.0	131.2	.0561	1	.0
42.5	139.4	.0581	1	.4
45.0	147.6	.0598	1	.4
47.5	155.8	.0608	1	-.2
50.0	164.0	.0624	1	-.2
52.5	172.2	.0648	1	.5
55.0	180.4	.0662	1	.3
57.5	188.6	.0674	1	-.1
60.0	196.9	.0688	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	334	318	352	1096	1045	1154
2.7	8.9	.008	334	318	352	1096	1045	1154
17.5	57.4	.036	529	519	540	1735	1701	1771
40.0	131.2	.056	1123	1098	1149	3685	3603	3771
60.0	196.9	.069	1528	1471	1591	5014	4825	5218

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