U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

COMPILATION OF 29 SONIC AND DENSITY LOGS FROM 23 OIL TEST WELLS IN WESTERN WASHINGTON STATE

By

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Open-File Report 98-249

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1998

ABSTRACT

Three-dimensional velocity models for Puget Sound provide a means for better understanding the lateral variations in strong ground motions recorded during local earthquakes in Puget Lowland. We have compiled 29 sonic and density logs from 23 oil test wells to help us determine the geometry and physical properties of the Cenozoic basins in western Washington. The maximum depths sampled by the test wells are between 0.47 and 4.04 km. These well logs sample Quaternary to Eocene sedimentary and volcanic rocks. This report presents the locations, elevations, depths, stratigraphic and other information about the oil test wells, and provides plots showing the density and sonic velocities as a function of depth for each well log. We also present two-way travel times calculated from the sonic velocities.

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INTRODUCTION

We describe sonic velocity and density log data from oil test wells being used to help develop a three-dimensional velocity model for the Puget Sound. These 3-D models will be used to calculate synthetic seismograms to help understand the lateral variations of strong ground motions in the Puget Lowland urban corridor. We present data from 29 sonic and density logs from 23 oil test wells to categorize the sonic velocities and densities of Cenozoic sedimentary basins in western Washington, primarily in Puget Lowland (Fig. 1).

The locations, elevations, and depths of the oil test wells, as well as the lease name, well number, operator, and completion year are presented in Table 1. In this table the wells are ordered by latitude from south to north. This information is taken from the Well History Control System (WHCS) One-line File, an on-line digital well-log database leased from Petroleum Information by the USGS Office of Energy Resources at Denver. Because the logs were run over a 28-year interval between 1958 and 1985, Table 1 provides information on the type of sonic and density tool used to make the log, as well as the other tools which were run simultaneously with these tools (normally caliper, spontaneous potential, and gamma-ray). Several of the sonic logs were made with older, short tools, with short spans between the source and receivers. Stratigraphic control is available for many of the wells [MacFarland, 1983; Brown and Ruth Laboratories, Inc., 1984; Johnson and others, 1996; Rau and Johnson, in press; S.Y. Johnson, written commun., 1998]. We note here that the formation picks for the Dungeness Spit #1 well (shown in Table 3 and on Figure 14) are inferred from the formation tops at the Dungeness Unit #1-54 well, located approximately 9 km to its southeast (T30N, R4W, Section 17; McFarland, 1983).

Where known (Table 2), the generalized stratigraphy encountered in the holes may be characterized as follows [MacFarland, 1983; Rau and Johnson, in press]. Tertiary sediment rocks (generally Eocene), underlie Pleistocene glacial deposits (clays, sands, and gravels), and in a few wells are in turn underlain by Eocene Crescent Formation volcanics (or other volcanics).

A map showing thickness of unconsolidated deposits (Jones, 1994) was used to help ascertain thicknesses of Pleistocene deposits at wells for which we lacked other stratigraphic information.

WELL LOG ANALYSIS

Sonic and density logs were hand digitized at non-uniform intervals between 3 and 30 m to capture the significant variations of the logs with depth for frequencies up to 2 Hz. The sampling interval was adequate to estimate linear trends in the data over these intervals. We note that our sampling interval was not intended and is not sufficiently dense for the calculation of high-frequency (say >10 Hz) synthetic seismograms. For higher-frequency synthetics, it will be necessary to redigitize the logs with a finer sampling interval.

For the sonic logs, we picked transit times (μs/ft) as a function of depth down the well. For the gamma-gamma density logs, we picked bulk density in g/cm^3 as a function of depth down the well. For the neutron density porosity logs, we converted the logged density porosity (ϕ) back to formation density (ρ_{fd}) using $\rho_{fd} = \rho_m + (\rho_f - \rho_m)\phi$, where the matrix density ρ_m = 2.65 g/cm^3, and the fluid density ρ_f = 1.0 g/cm^3 [Ellis, 1987]. All of the logs analyzed here are plotted at a scale of 30.49 m = 5 cm (100 feet = 2 inches). Depths are measured from an arbitrary reference datum, normally the Kelley Bushing (KB), located 3.65 m (12 feet) above ground level. The downhole depths reported here have not been corrected for this small upward shift. Cased intervals of the wells and sections identified on the logs as having cycle skipping problems were not digitized. In some cases data from the logs were ignored: these data were associated with washouts, thick mudcake, invasion of drill fluids or large deviations from the general trend of density and sonic values having very limited depth extent, generally less than a few tens of feet [Ellis, 1987]. The digitized sonic log data were converted from transit times to velocities (m/s) and depths from feet to meters for both the sonic and density logs. Plots showing seismic velocities and densities as a function of depth for each well are presented in Figures 2 to 28. Although we digitized all repeated passes of tools in sections of the wells, we do not show these redundant passes in Figures 2 to 28.

We have calculated two-way travel times from the sonic logs and displayed these in Figures 29 to 46. This calculation required us to extrapolate sonic velocities to the surface. In some cases, the distance over which the first measured sonic velocity was judged to be too great to extrapolate it to the surface. In these cases, we calculated two-way travel times starting at the top of the sonic log.

COMMENTS ON THE WELL LOG DATA

Although the deepest boreholes for which logs are included in this completion are more than 3.9 and 4 km deep respectively (Table 1), these deep wells were unfortunately not logged to the completed depth of the holes. The four longest sonic well logs are from the following wells (numbers in parens provide the logged intervals): Washington State #1 (300-3500 m), Socal Schroeder #1 (100-2950 m), Silvana Community #12-1 (150-2250 m), and the Socal Whidbey #1 (50-2050 m). The density logs from the same holes are generally slightly shorter. The four longest density well logs are from the following wells: Socal-Schroeder #1 (350-2950 m), Montesano 1-X (50-2100 m), Black Diamond #4-13 (200-2000 m), and Socal Whidbey #1 (300-2050 m).

The Amoco Weyerhaeuser #1-29 well was drilled and logged twice. The longest logs shown in this report are from the initial borehole; the second, shorter logs are from the first redrill. The sonic velocities measured in both wells provide comparable estimates in the overlap region (Fig. 3), however, there is a significant offset of 0.2 g/cm^3 between the densities determined at the adjacent wells (Fig. 22). The origin of this mismatch is not currently known.

We have superimposed the formation tops from Table 2 on the well logs shown in this report. Often, but by no means always, these formation changes correspond to significant changes in the sonic velocity and density, and/or in the character of these logs. In Table 3 we show average velocities and linear regressions over intervals of the boreholes corresponding to known or inferred formations. The average sonic velocities represent the inverse of the average transit times (slownesses) over the interval. In some cases, we show these averages and linear regressions for the entire log. As anticipated, average sonic velocities (generally 1450 to 2200 m/s) and densities (2.09 g/cm^3) in the Pleistocene glacial deposits are significantly lower than those of underlying Tertiary sedimentary rocks (Table 3). There is typically a general increase with depth in the sonic velocity within these Tertiary sedimentary rocks without a major change at the formation boundaries; although the low R^2 values found for most of the linear regressions indicate that there is much scatter in this trend. The top of the Crescent Formation volcanics, however, does typically represent at large (over 1 km/s) increase in sonic velocity from the overlying Tertiary sedimentary rocks (Table 3).

Similar averages and linear regressions on the density log data are shown in Table 4. The density logs typically show even less evidence for constrasts between the Tertiary sedimentary rocks. There is, however, a significant (0.17 g/cm^3) contrast between these units and the underlying Crescent Formation volcanics at the Socal Whidbey #1 well.

The density log from Socal Schroeder #1 shows an apparent reversal within the Blakeley Formation, and densities of the andesitic volcanic rocks are lower than those of the Blakeley Formation (Table 4). This reversal is not accompanied by a similar reversal in sonic velocity, which, in combination with the generally poor quality of the density log for this well, suggest that the apparent reversal in density may be an artifact.

DATA AVAILABILITY

The picks of density and seismic velocity shown in Figures 2 to 28 are available in Excel5 spreadsheets using anonymous ftp. The anonymous ftp address is: andreas.wr.usgs.gov. Change the directory (cd) to /pub/outgoing/puget. The files are named puget.sonic.xl5.bin, puget.density.xl5.bin, and puget.TT.xl5.bin, all in Mac Binary II format. Table 1 of this report in Excel5 format is also in this ftp site, labeled as Table 1.bin. Figure 1 is in Adobe Illustrator 6 format in file OFR.Fig1.

DISCUSSION

Published compilations of S-wave data for sedimentary rocks provide some guidance for typical Vp/Vs ratios in Tertiary sedimentary units. Ohta et al. [1977] published Vs and Vp in two deep holes sampling Tertiary sediments in Japan. Hamilton [1979] compiled these and similar measurements in Russia to obtain Vp/Vs ratios in the uppermost 1 km of section within Tertiary sedimentary units. Finally, Castagna et al. [1985] compiled Vs and Vp data from S-wave and P-wave logging and other measurements to obtain Vp/Vs for a variety of clastic silicate rocks. Castagna et al. [1985] suggest that Vp/Vs ratios in sandstones reach an average value near 1.7 beginning at depths of about 2 km, whereas the Vp/Vs in noncalcareous shales reach an average value of about 2 at depths near 3 km.

ACKNOWLEDGEMENTS

Zenon Valin, USGS, kindly performed a search of a digital database providing well locations and other well information. Larry Beyer, USGS, made many useful suggestions for digitizing the well log data. Sam Johnson, USGS, provided preprints of his papers on the biostratigraphy of many of the wells in Puget Sound, and reviewed an earlier version of this report. Weldon Rau and Bill Lingley, Washington Department of Natural Resources, provided stratigraphy for several of the boreholes.

This work was supported by the National Earthquake Hazards Reduction Program.

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ABBREVIATIONS USED IN TABLE 1:

BHC - Borehole Compensated Sonic Log
CNFD - Compensated Neutron Formation Density*
CFD gg - Compensated Formation Density (gamma-gamma)*
CNF (ds) - Compensated Neutron Formation Density (Dual Spaced)*
Cal. - Caliper
SP - Spontaneous Potential
GR - Gamma Ray

T3R3R - Sonic tool spacing (in feet) between transmitter (T) and receivers (R)

*All density logging tools employ the backscattered gamma-ray technique, commonly called "gamma-gamma". The different names used here are either from different vendors or from different generations (having different trademark names).

Table 1. Oil Test Well Data.

Leasename	No.	Operator	Field	Latitude	Longitude	Depth, ft	Depth, m	Elev, ft	Elev, m	Datum	T	T	R	R	S	Year	Sonic Log	Density Log	Other Logs
KERRYN BN	34-11	L B PETROLEUM	Carbonado	47.08853	-122.02711	5000	1524	1342	409	GL	N	19	E	6	34	1985	BHC 5"	FDC/CNL	Cal., GR, SP
AMOCO-WEYERHAEUSER	1-29	AMOCO PROD	Caldwell Creek	47.10136	-123.70526	13250	4040	390	119	GL	N	19	W	8	29	1985	BHC 2"	FDC/CNL	Cal., GR
BLESSING SILER	1	CARR EDWARD J	Bonney Lake	47.17198	-122.10001	7562	2305	658	201	GL	N	20	E	6	31	1962	T3R3R		SP?
WASHINGTON STATE	1	PHILLIPS PETROLEUM CO.	Lake Tapps	47.18277	-122.10367	12920	3939	625	191	GL	N	20	E	5	36	1963	T3R3R		Cal., SP
BRANDT	1	MCCROSKY A E SYNDICATE	Kummer Anticline	47.25790	-122.01697	3944	1202	657	200	KB	N	21	E	6	34	1961	T3R3R		
BRANDT	2	MCCROSKEY A E SYNDICATE	Kummer Anticline	47.25887	-122.01749	3411	1040	629	192	GL	N	21	E	6	34	1961	T3R3R		SP
BLACK DIAMOND	4-13	VOYAGER PETROLE		47.32875	-121.91422	7270	2216				N	21	E	7	4	1983		Den	
KSD	1	GEOTHERMAL RESOURCES INT'L	Kent	47.41684	-122.16891	9291	2833	438	134	GL	N	22	E	5	4	1967	BHC T3R2R		Cal., SP
SOCAL-SCHROEDER	1	STANDARD OIL OF CALIF.	Brier-Puget Sound	47.79410	-122.26332	9675	2950	366	112	GL	N	27	E	4	26	1972	BHC	CFD gg, CNFD	Cal., GR, SP
KINGSTON	1	MOBIL OIL	Wildcat	47.80862	-122.49829	8648	2637	283	86	GL	N	27	E	2	26	1972	BHC T3R2R	CFD gg	Cal., GR, SP
POPE & TALBOT	18-1	UNION OIL OF CALIF	Port Gamble	47.83406	-122.5892	4019	1225	190	58	GL	N	27	E	2	18	1972	BHC T3R3R		Cal., SP
SOCAL WHIDBEY	1	STANDARD OIL OF CALIF.	Whidbey Island	47.97520	-122.40491	6693	2041	446	136	GL	N	29	E	3	27	1972	BHC T3R2R	CFD gg	Cal., GR, SP
POPE & TALBOT	3-1	STANDARD OIL OF CALIF.	Whidbey Island	48.05327	-122.55345	4375	1334	318	97	GL	N	30	E	2	28	1962	T3R3R		Cal., SP
ENGSTROM COMMUNITY	1	STANDARD OIL OF CALIF.		48.09395	-122.58786	7353	2242				N	30	E	2	17	1958	Son		
DUNGENESS	1	STANDARD OIL OF CALIF.	Dungeness Area	48.16671	-123.13582	5105	1556	0	0	GL	N	31	W	4	24	1965	T3R3R		Cal., GR
R D MERRILL CO.	1	TEXACO INC	Pysht Area	48.19199	-124.09622	8460	2579	240	73	GL	N	31	W	11	10	1966	T3R3R		Cal., SP
SILVANA COMMUNITY	12-1	STANDARD OIL OF CALIF.	Silvana	48.19441	-122.23065	7419	2262	31	9	GL	N	31	E	4	12	1958	T3R3R		SP
MERRILL-RING	1	RUSSELL A. COBB, Jr.	Pillar Point	48.21706	-124.13037	8519	2597	155	47	GL	N	31	W	11	4	1960	T1R1R		SP
SQUALICUM	1	WASHUTA DRILLING &	Bellingham	48.77538	-122.35051	6180	1884	538	164	GL	N	38	E	4	18	1968		CFD gg	Cal.
ROSS	1	EL PASO NATURAL	Wildcat	48.77798	-122.33031	4707	1435	695	212	GL	N	38	E	4	17	1962	T3R3R		Cal., SP
STREMLER	1	CAN-AMER PETROL., LTD	Lynden	48.97983	-122.43848	8342	2543	122	37	GL	N	40	E	3	4	1962	T3R3R		Cal., SP

Table 2. Stratigraphy in oil test wells

Well Name	Formation	Depth (ft)	Depth (m)
Montesano #1-X*	Pleist. glacial		
	Top/Astoria Fm. (?)	250	76.2
	Top/Lincoln Creek Fm.	900	274.4
	Top/Humptulips Fm.	6100	1859.8
Kerryn BN #34-11 ,	Carbonado Fm.	0-4920	0-1500
Weyerhaeuser #1-29*	in Astoria (?) Fm.	1700	518.3
	Top/Lincoln Creek Fm.	3200	975.6
Blessing Siler Community #1	Puget Group?	820-7544	250-2300
Washington State #1	Pleistocene	0-850	0-259
	Top/Spiketon Fm.	7000	259
	Top/Northcraft Fm.	7650	2134
	Top/Carbonado Fm.	12920	2332
Brandt #1	Puget Group	984-4018	300-1225
Brandt #2	Puget Group	656-3444	200-1050
Black Diamond #4-13	Quaternary Alluvium	0	0
	Lower Puget Group	50	15
	Raging River Fm.		
	regressive ss facies	1500	457
	deeper water facies	4500	1372
	transgressive ss facies	5500	1677
	Basement?	6500	1982
KSD #1 ,	Renton Fm.	to 6870	to 2095
	Top/Tukwilla Fm.	6870	2095
	Top/Tiger Mountain Fm.	8700	2652
Schroeder #1*	in Pleist. glacial		
	Top/Blakeley Fm.	680	207.3
	Top/Renton Fm.	5660	1725.6
	Top/Mt. Perris volc. rx.	8000	2439.0
	Top/Puget Group	8850	2698.2
Kingston #1*	in Pleist. glacial	500	152.4
	Top/Blakeley Fm.	1720	524.4
	Top/Puget Group correlative?	3500	1067.1
	Top/Scow Bay ss	4800	1463.4
Pope & Talbot #18-1	Pleistocene	0	0

	Top/Blakeley Fm.	1328	405
	Top/Crescent Fm.	3369	1027
Soleduck #1 , □□□	Ozette Melange (Eocene and Miocene broken fm. and melange)	328-1066	100-325
Socal Whidbey #1*	in Pleist. glacial	100	30.5
	Top/Blakeley Fm.	600	182.9
	indurated ss	6000	1829.3
	Top/Crescent Fm. - Volcs.	6100	1859.8
	Top/Scow Bay ss	6500	1981.7
Pope & Talbot #3-1**	Pleistocene	0	0
	Top/Blakeley Fm. (upper part)	672	205
	Top/Blakeley Fm. (lower part)	2230	680
	Top/ss of Scow Bay/unnamed strata	3411	1040
Dungeness Unit #1-54 ,***	Pleist. glacial	0	0.0
	Top/Pleist. conglomerate	1560	476
	Top/Twin River Fm.	3282	1000.6
	Top/Crescent Fm. - Volcs.	6365	1940.5
Silvana Community #12-1*	in Pleist. glacial	520	158.5
	Top/Bulson Creek Fm.	900	274.4
	Top/Basaltic volc. rocks	7350	2240.9
Merrill-Ring #1□□□	Upper and Middle Twin River Group	to 5000	to 1524
	Middle Twin River Group	5000	1524
Squalicum Lake #1	Chuckanut Fm.	1886-5576	575-1700
Ross #1	Pleistocene	0	0
	Top/Chuckanut Fm.	843	257
Stremler #1	Chuckanut and Huntingdon Fm.	2542-7380	775-2250

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Table 3. Linear regression of sonic velocities in oil test well logs

Wellname and number	Formation Name	Depth Interval (m)	Average Velocity (km/s)	Intercept Velocity (km/s)	Velocity Gradient (km/s/km)	R^2
Kerryn BN #34-11	Carbonado Fm.	96-1481	4.36	3.83	0.84	0.32
Weyerhaeuser #1-29	All	532-1370	2.40	2.14	0.30	0.10
Weyerhaeuser #1-29 redrill	Lincoln Creek Fm.	1059-1414	2.62	3.90	-1.01	0.10
Blessing Siler #1	Puget Group?	229-2304	3.68	3.39	0.33	0.10
Washington State #1	Puget Group	303-3472	3.74	2.91	0.54	0.52
Brandt #1	Puget Group	421-1199	3.49	3.17	0.52	0.05
Brandt #2	Pleistocene	149-202	1.45			
	Puget Group?	229-1037	3.31	2.55	1.49	0.23
KSD #1	Puget Group	>2350	4.44	4.04	0.18	0.00
Socal-Schroeder #1	Pleist. deposits	0-207	1.59			
	Blakeley Fm.	207-1726	3.26	2.36	0.88	0.46
	Renton Fm.	1726-2439	3.30	5.70	-1.09	0.12
	Andesitic volc. rocks	2439-2698	3.78			
	Puget Group	>2698	3.54			
Kingston #1	Pleist. deposits	175-524	1.83	1.57	0.92	0.37
	Eocene sed. rocks	>524	2.88	2.04	0.85	0.44
Pope&Talbot #18-1	Pleistocene	0-405	N/A			
	Blakeley Fm.	405-1027	2.78	2.03	1.08	0.51
	Crescent Fm. volc.	1027-1225	4.65			
Socal-Whidbey #1	All	47-2040	2.69	1.80	1.09	0.78
	Pleist. deposits	31-183	1.71			
	Blakeley Fm.	183-1829	2.77	2.01	0.86	0.73
	Indurated Ss.	1829-1860	3.30			
	Crescent Fm. volc.	1860-1982	5.04			
	Scow Bay Ss.	>1982	4.25			
Pope&Talbot #3-1	All	165-1324	2.70	1.62	1.70	0.84
	Pleistocene	0-205	1.57			
	Blakeley Fm.	205-680	2.43	2.09	0.84	0.27
	Blakeley Fm.	>680	2.98	1.26	1.96	0.75
	Crescent Fm. volc.	>1040	3.83			
Dungeness #1	All Pleistocene?	236-850	2.28	1.97	0.70	0.09
	Pleist. deposits?	0-625	2.14	2.31	-0.28	0.01
	Pleist. conglomerates?	625-825	2.50			
	Twin River Fm.?	825-1500	2.59	1.73	0.74	0.50
	Crescent Fm.?	>1500	3.70			
R.D. Merrill #1	All	302-1829	2.50	1.94	0.61	0.54
Silvana Comm. #12-1	All	160-2255	3.04	2.38	0.62	0.47
	Pleist. deposits	159-274	2.17			
	Bulson Creek Fm.	274-2240	3.12	2.54	0.50	0.37
	Basaltic volc. rocks	>2240	4.87			
Merrill-Ring #1	All	1465-2271	2.50	-0.69	1.80	0.58
Ross #1	Pleistocene	0-257	1.92			
	Chuckanut Fm.	257-620	3.60	2.48	2.90	0.36
Stremler #1	Chuckanut and Huntingdon Fm.	765-2233	4.31	4.22	0.09	0.01

Table 4. Linear regression of densities in oil test well logs

Wellname and number	Formation Name	Depth Interval (m)	Average Density (g/cc)	Intercept Density (g/cc)	Density Gradient (g/cc)	R^2
Montesano #1-X	All	59-2112	2.16	2.04	0.10	0.44
	Astoria (?) Fm.	76-274	2.11			
	Lincoln Creek Fm.	274-1860	2.15			
	Humptulips Fm.	>1860	2.36			
Kerryn BN #34-11	Carbonado Fm.	101-1475	2.61	2.57	0.05	0.08
Weyerhaeuser #1-29	All	532-1384	2.05	2.13	-0.08	0.06
Weyerhaeuser #1-29 redrill	Lincoln Creek Fm.	1062-1417	2.28	2.71	-0.30	0.46
Black Diamond #4-13	All	205-1985	2.53	2.59	-0.06	0.07
Socal-Schroeder #1	Pleist. deposits	0-207	N/A			
	Blakeley Fm.	207-1726	2.49			
	Renton Fm.	1726-2439	2.23			
	Andesitic volc. rocks	2439-2698	2.19			
	Puget Group	>2698	2.17			
Kingston #1	Pleist. deposits	175-524	2.09	1.95	0.40	0.34
	Eocene sed. rocks	524-1550	2.29	2.07	0.20	0.43
Soleduck #1	Tertiary broken fm?	96-316	2.20	2.11	0.50	0.10
Socal-Whidbey #1	Pleist. deposits	31-183	N/A			
	Blakeley Fm.	183-1829	2.23	2.03	0.20	0.56
	Indurated Ss.	1829-1860	2.47			
	Crescent Fm. volc.	1860-1982	2.64			
	Scow Bay Ss.	>1982	2.49			
Squalicum #1	Chuckanut Fm.	610-1687	2.52	2.45	0.07	0.06

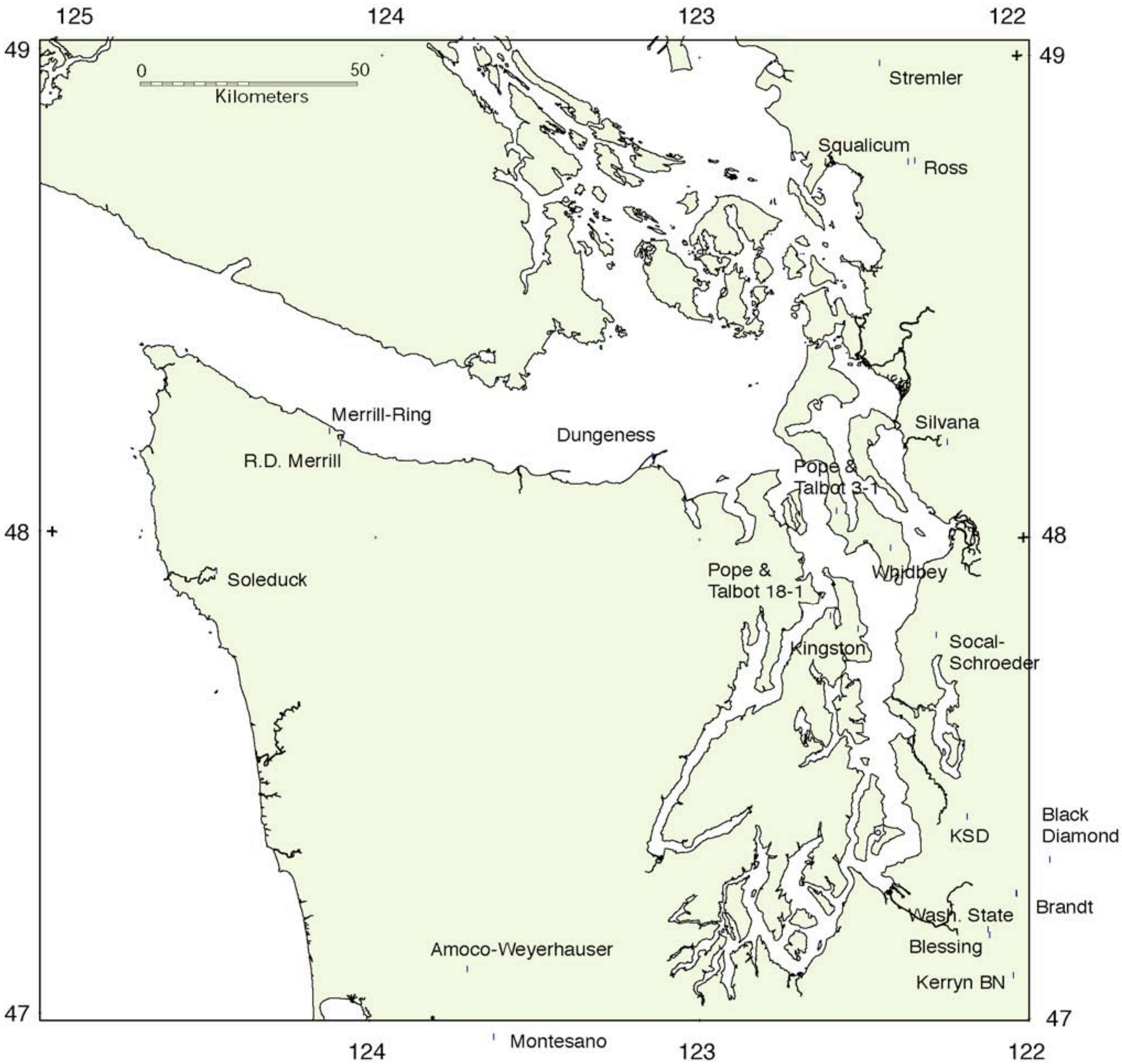


Figure 1. Map showing location of wells having logs analyzed in this report.

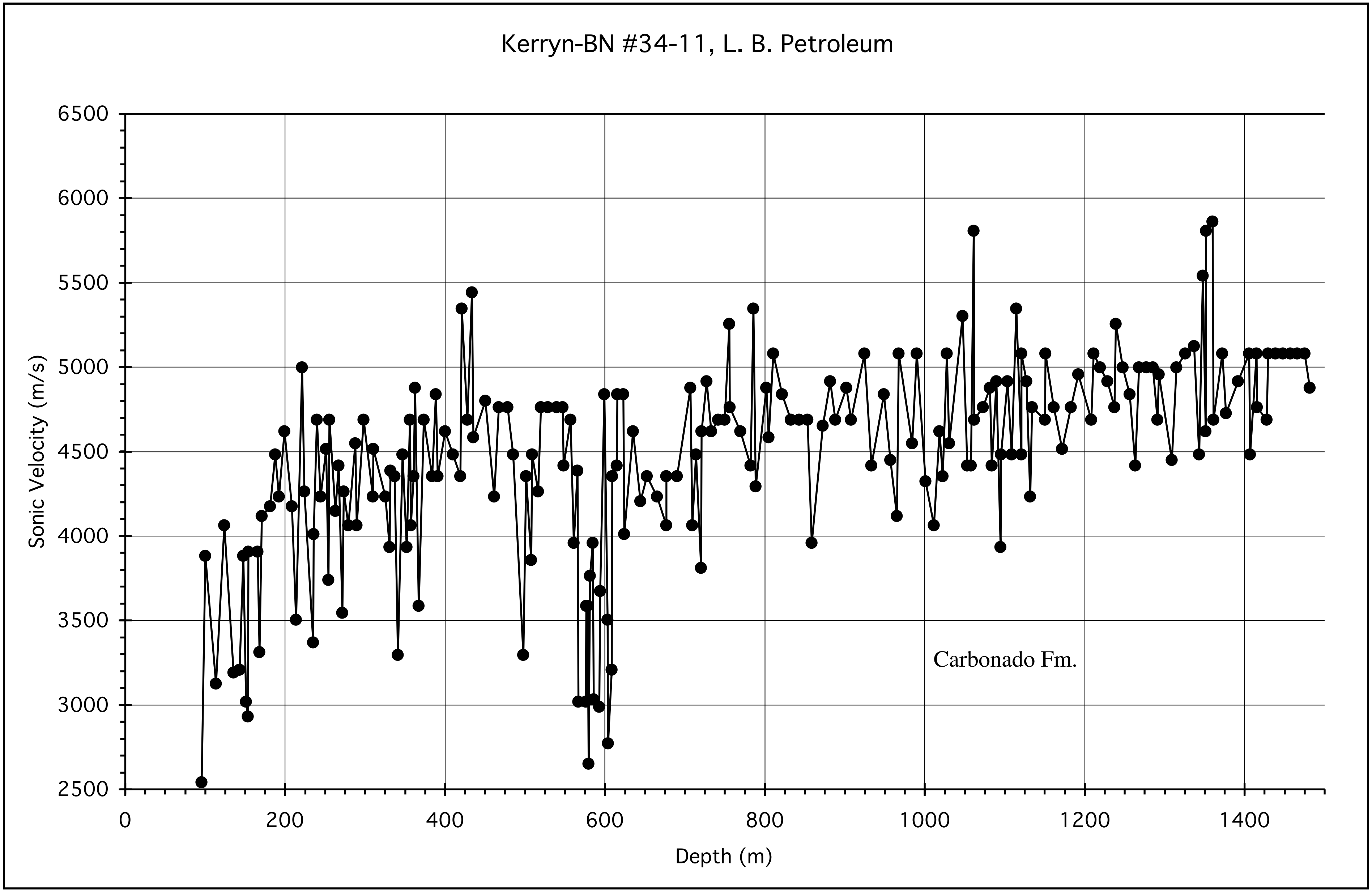
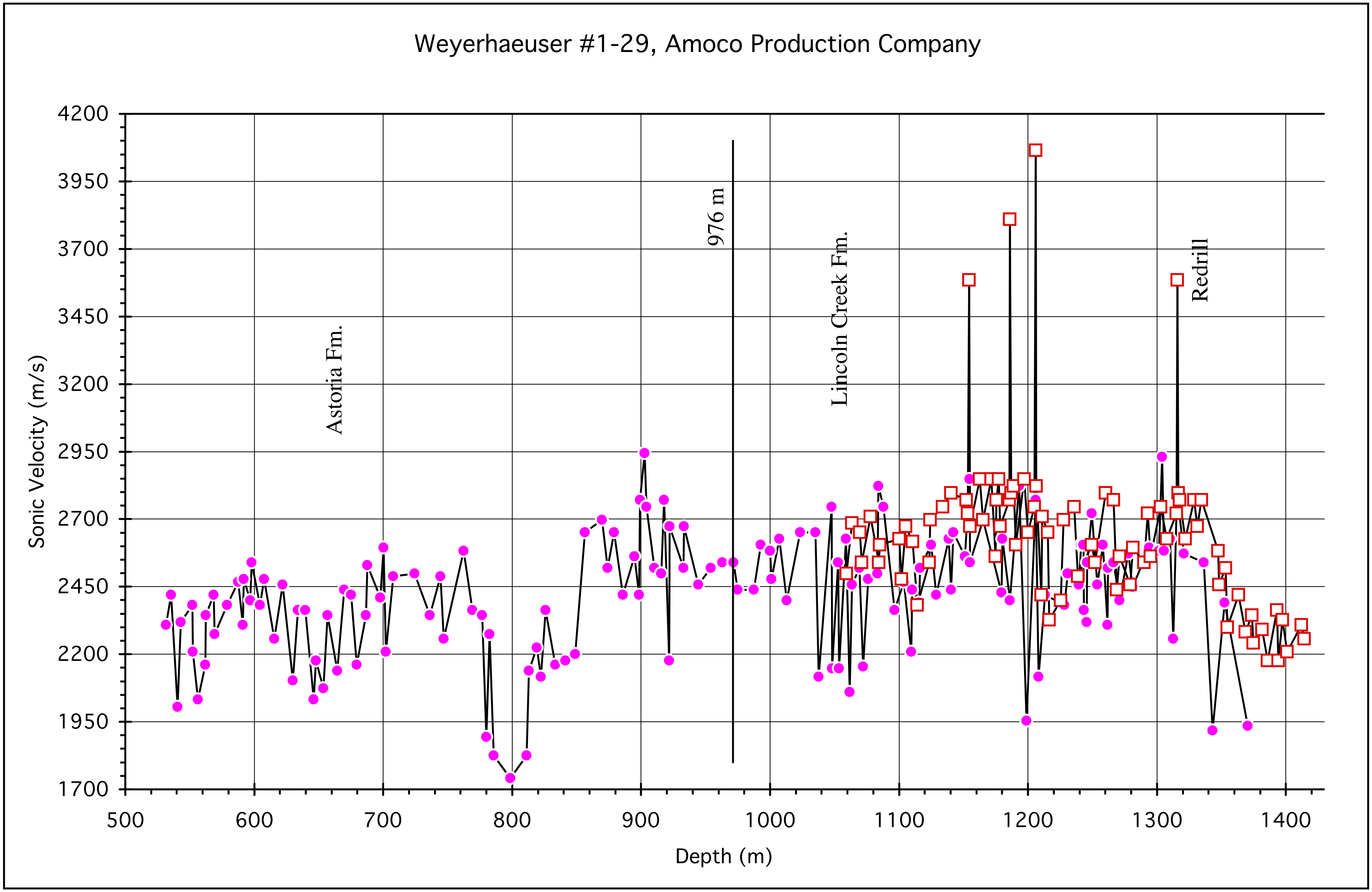

Kerryn-BN #34-11, L. B. Petroleum
Sonic Velocity (m/s)
Depth (m)
Carbonado Fm.
6500
6000
5500
5000
4500
4000
3500
3000
2500
0
200
400
600
800
1000
1200
1400

Figure 2.



Weyerhaeuser #1-29, Amoco Production Company
Sonic Velocity (m/s)
Depth (m)
4200
3950
3700
3450
3200
2950
2700
2450
2200
1950
1700
500
600
700
800
900
1000
1100
1200
1300
1400
Astoria Fm.
976 m
Lincoln Creek Fm.
Redrill

Figure 3.

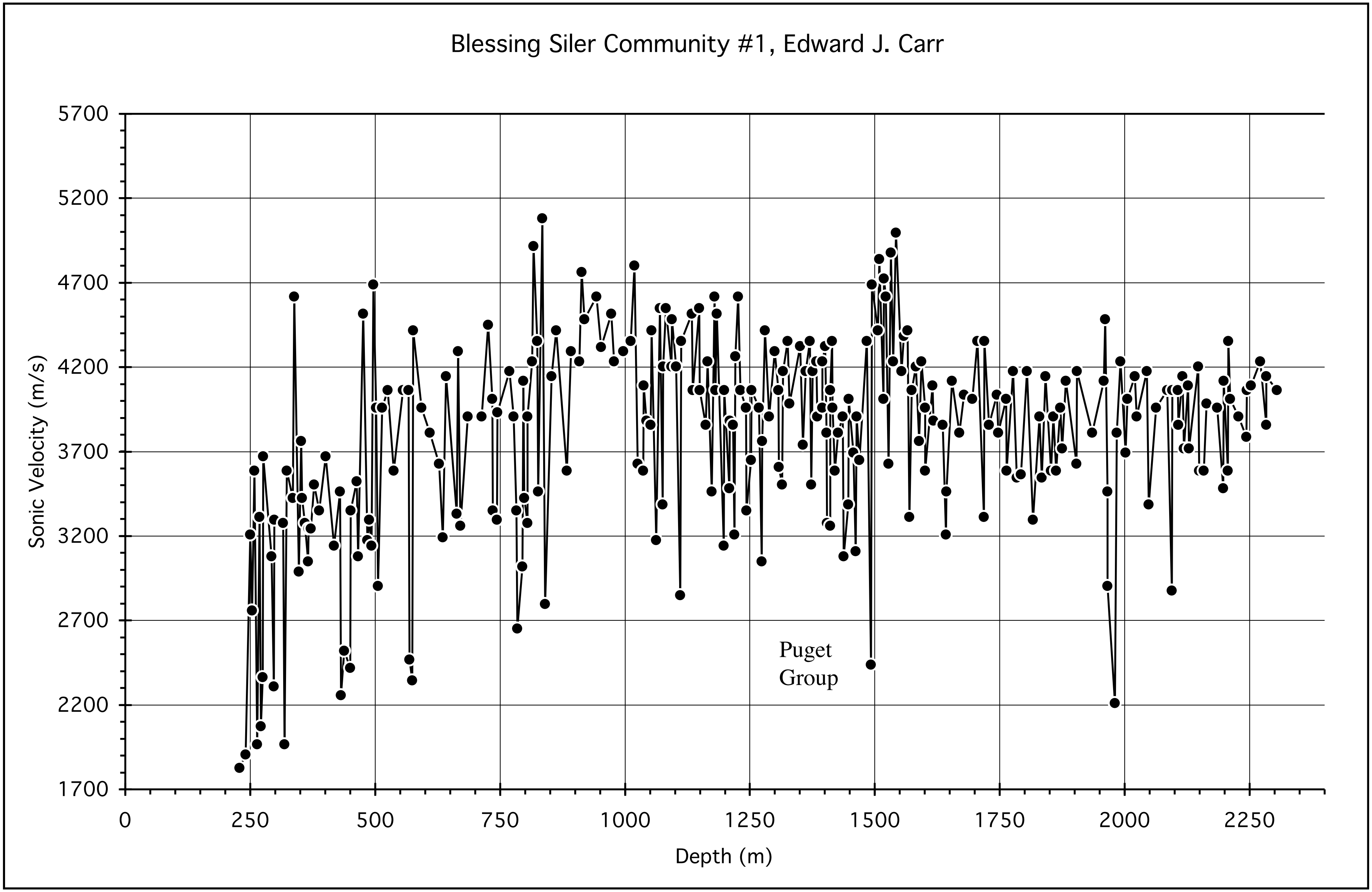
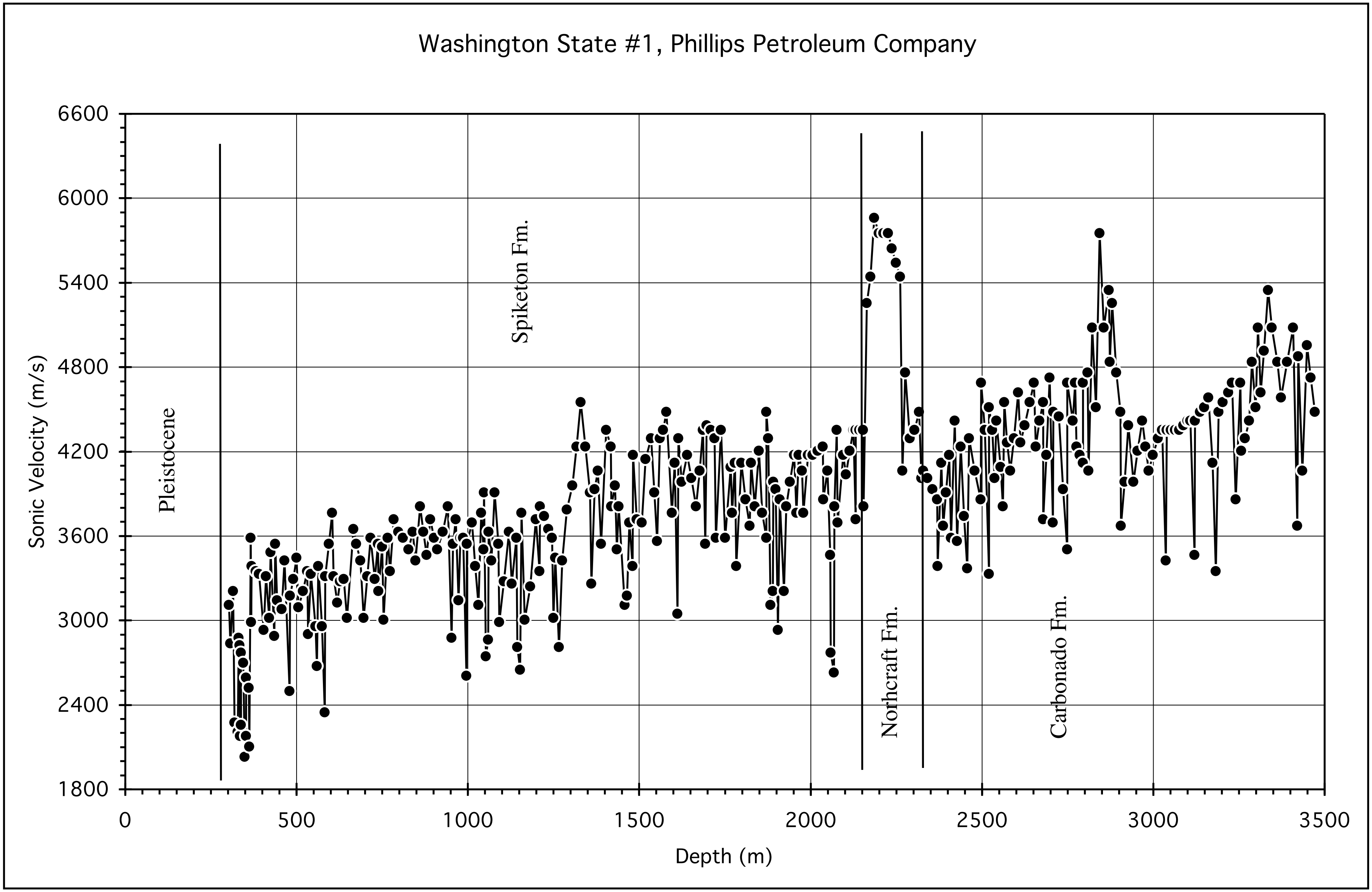
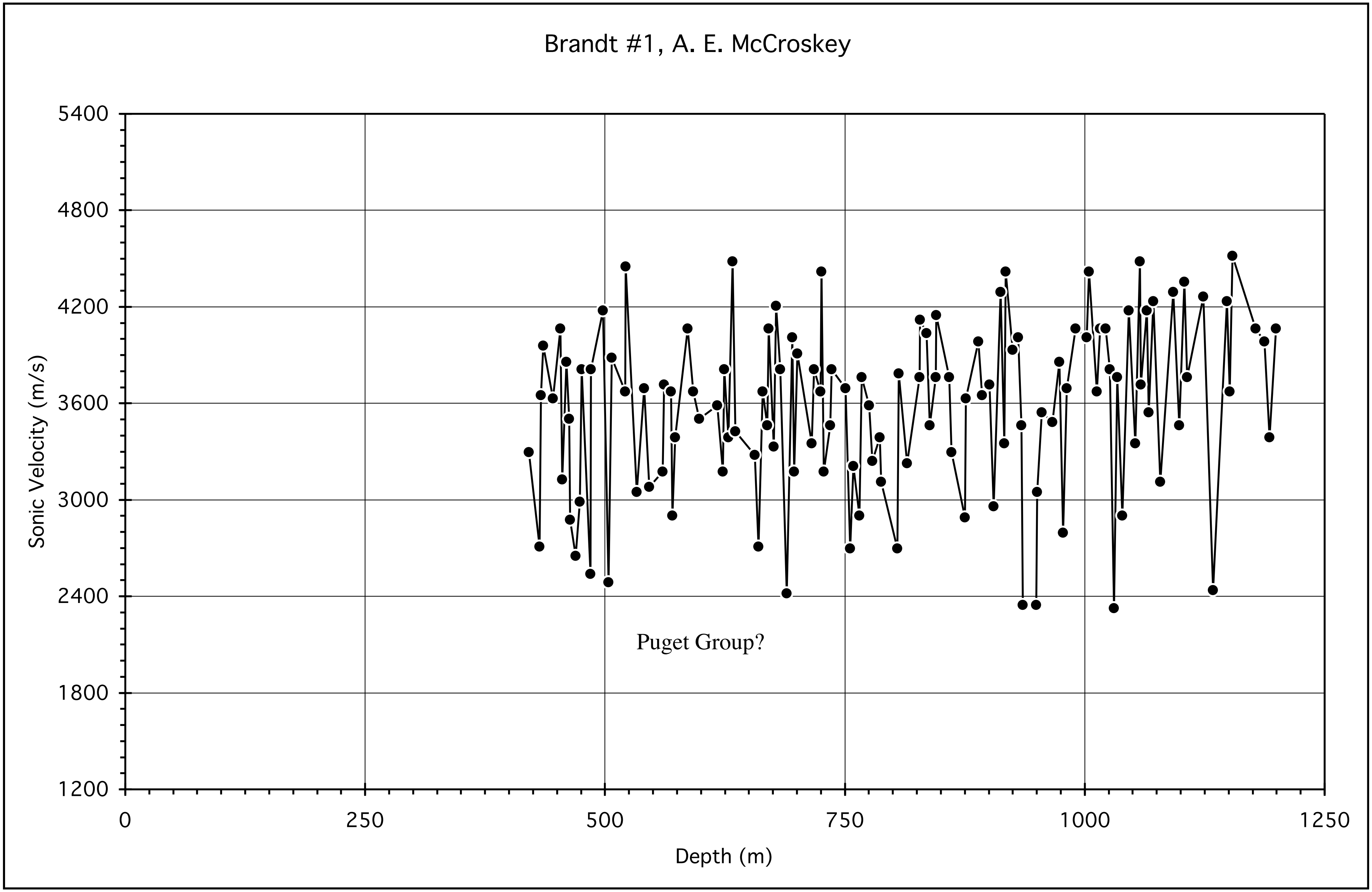

Blessing Siler Community #1, Edward J. Carr
Sonic Velocity (m/s)
5700
5200
4700
4200
3700
3200
2700
2200
1700
0
250
500
750
1000
1250
1500
1750
2000
2250
Depth (m)
Puget
Group

Figure 4.



Washington State #1, Phillips Petroleum Company
Sonic Velocity (m/s)
Depth (m)
6600
6000
5400
4800
4200
3600
3000
2400
1800
0
500
1000
1500
2000
2500
3000
3500
Pleistocene
Spiketon Fm.
Norhcraft Fm.
Carbonado Fm.

Figure 5.



Brandt #1, A. E. McCroskey
5400
4800
4200
3600
3000
2400
1800
1200
Sonic Velocity (m/s)
Puget Group?
0
250
500
750
1000
1250
Depth (m)

Figure 6.

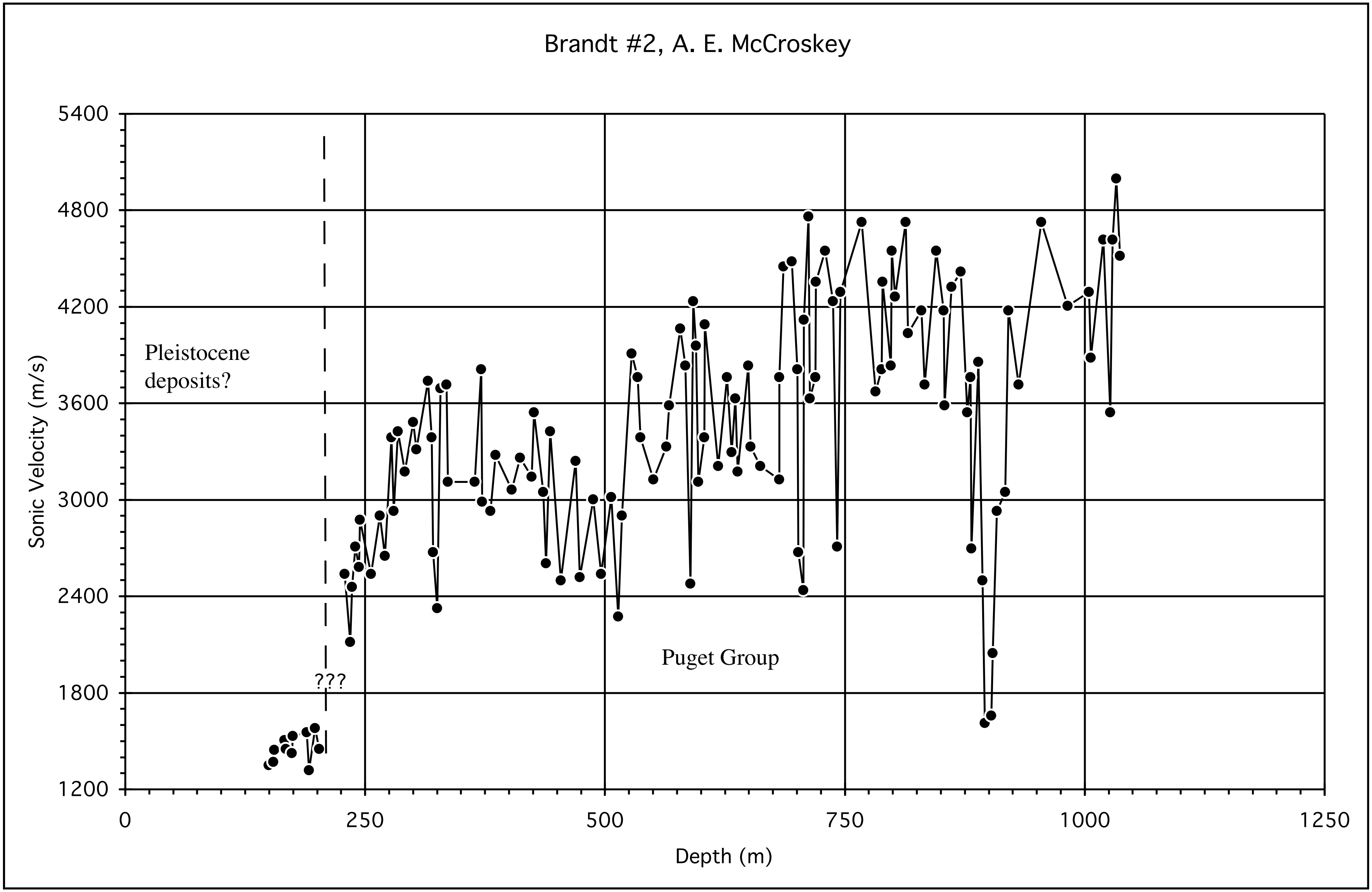

Brandt #2, A. E. McCroskey
Sonic Velocity (m/s)
Depth (m)
5400
4800
4200
3600
3000
2400
1800
1200
0
250
500
750
1000
1250
Pleistocene
deposits?
???
Puget Group

Figure 7.

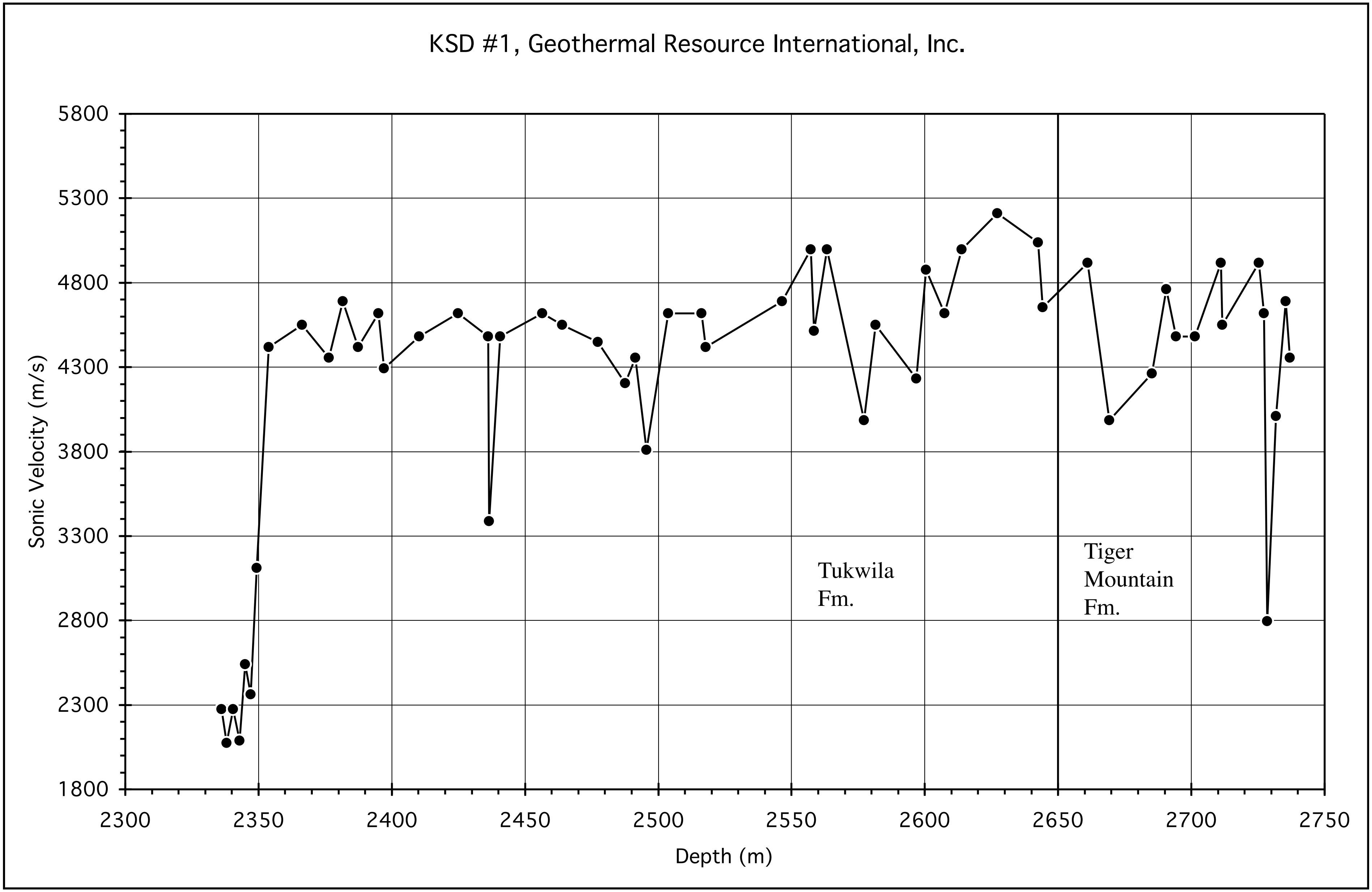
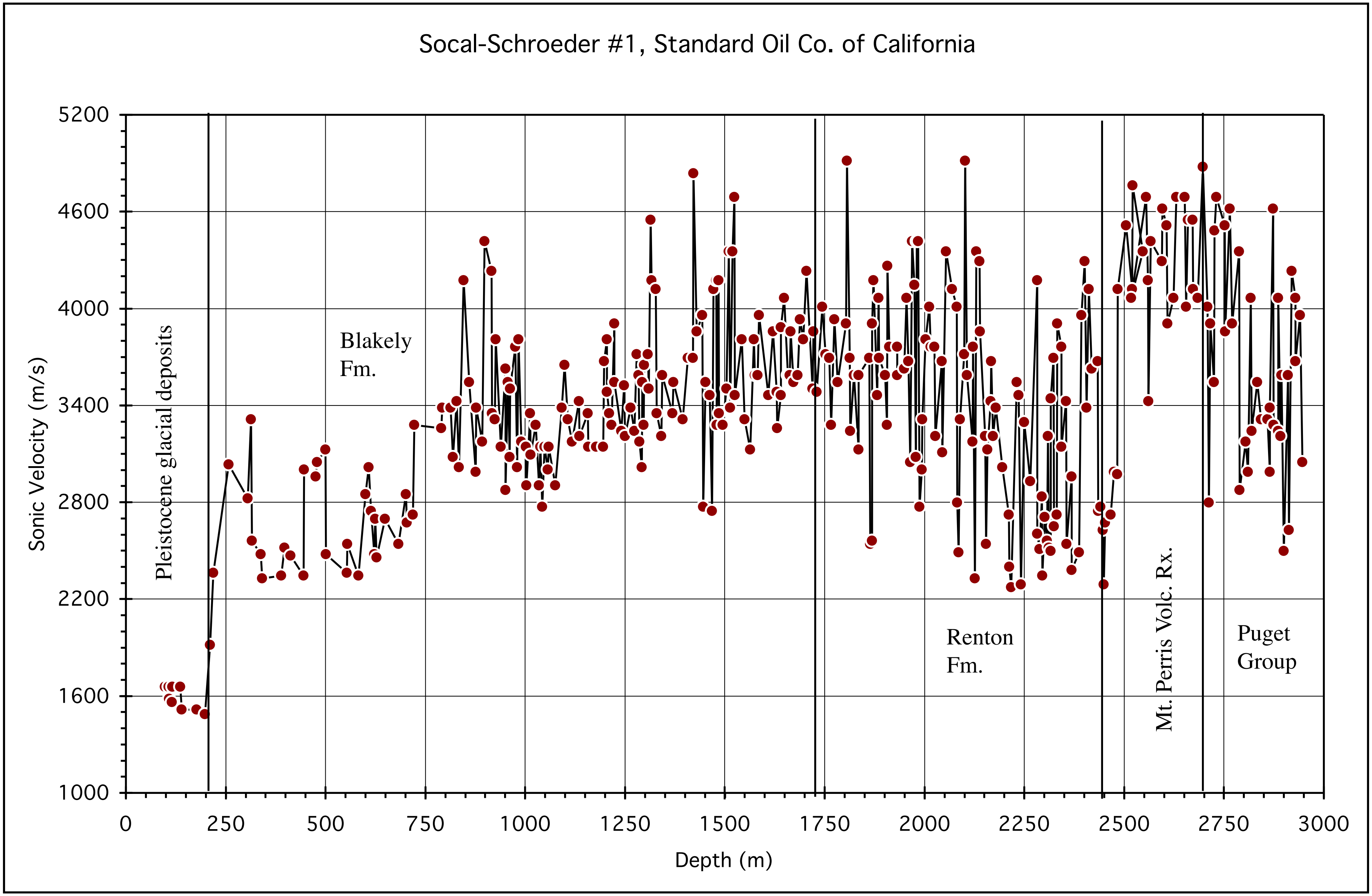

KSD #1, Geothermal Resource International, Inc.
Sonic Velocity (m/s)
Depth (m)
5800
5300
4800
4300
3800
3300
2800
2300
1800
2300
2350
2400
2450
2500
2550
2600
2650
2700
2750
Tukwila
Fm.
Tiger
Mountain
Fm.

Figure 8.



Socal-Schroeder #1, Standard Oil Co. of California
Sonic Velocity (m/s)
Depth (m)
Pleistocene glacial deposits
Blakely Fm.
Renton Fm.
Mt. Perris Volc. Rx.
Puget Group
5200
4600
4000
3400
2800
2200
1600
1000
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
2750
3000

Figure 9.

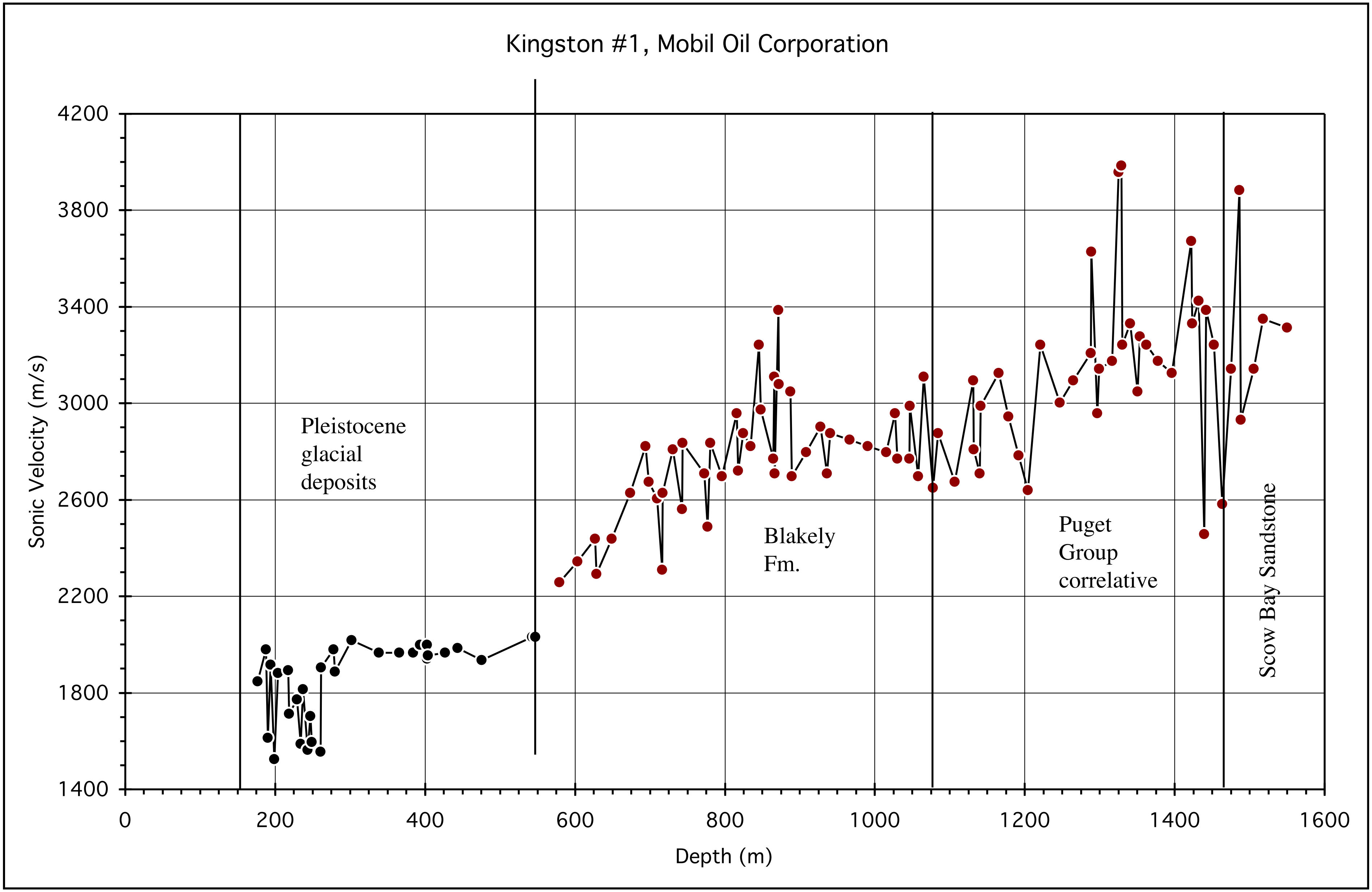
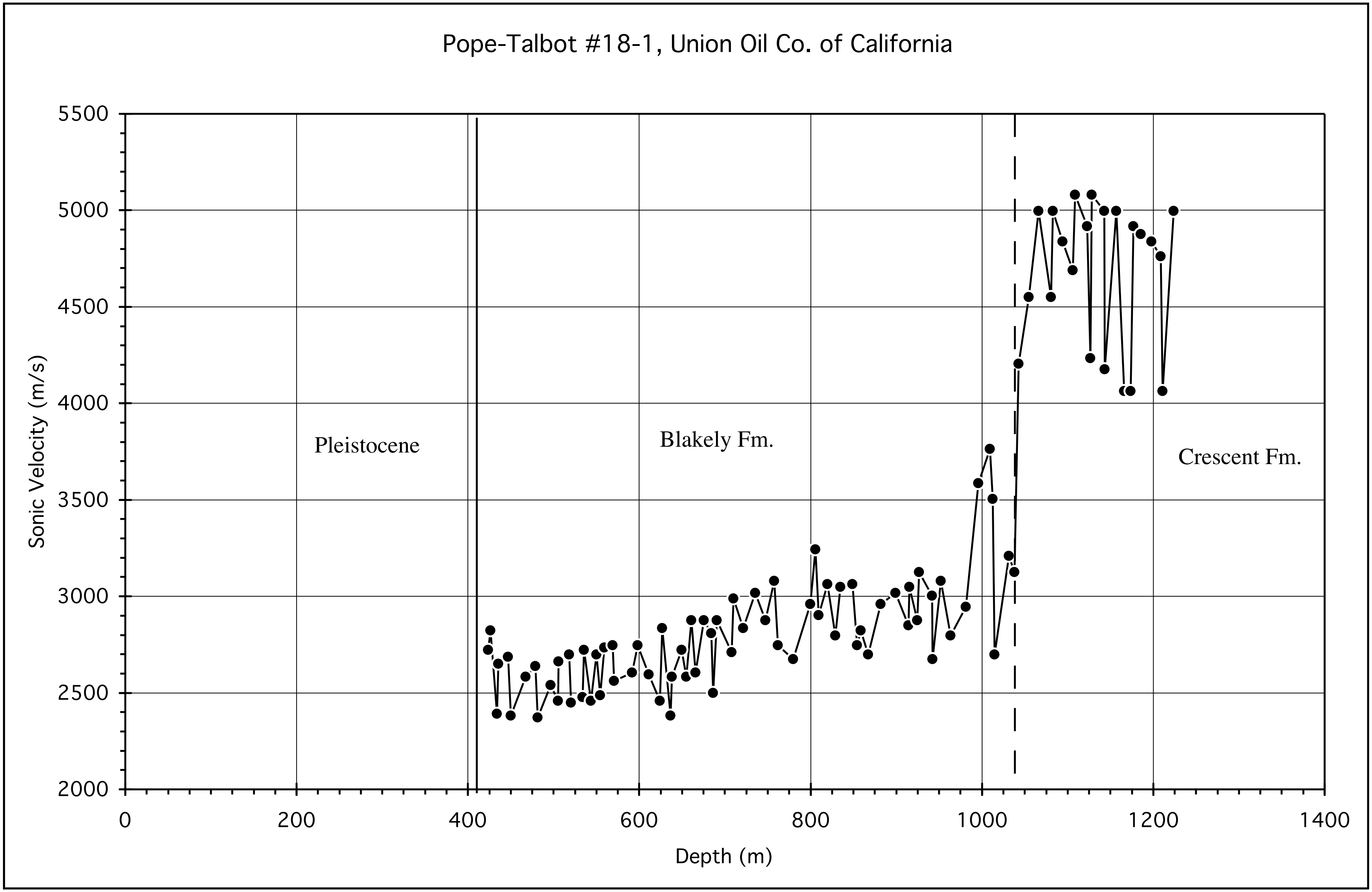
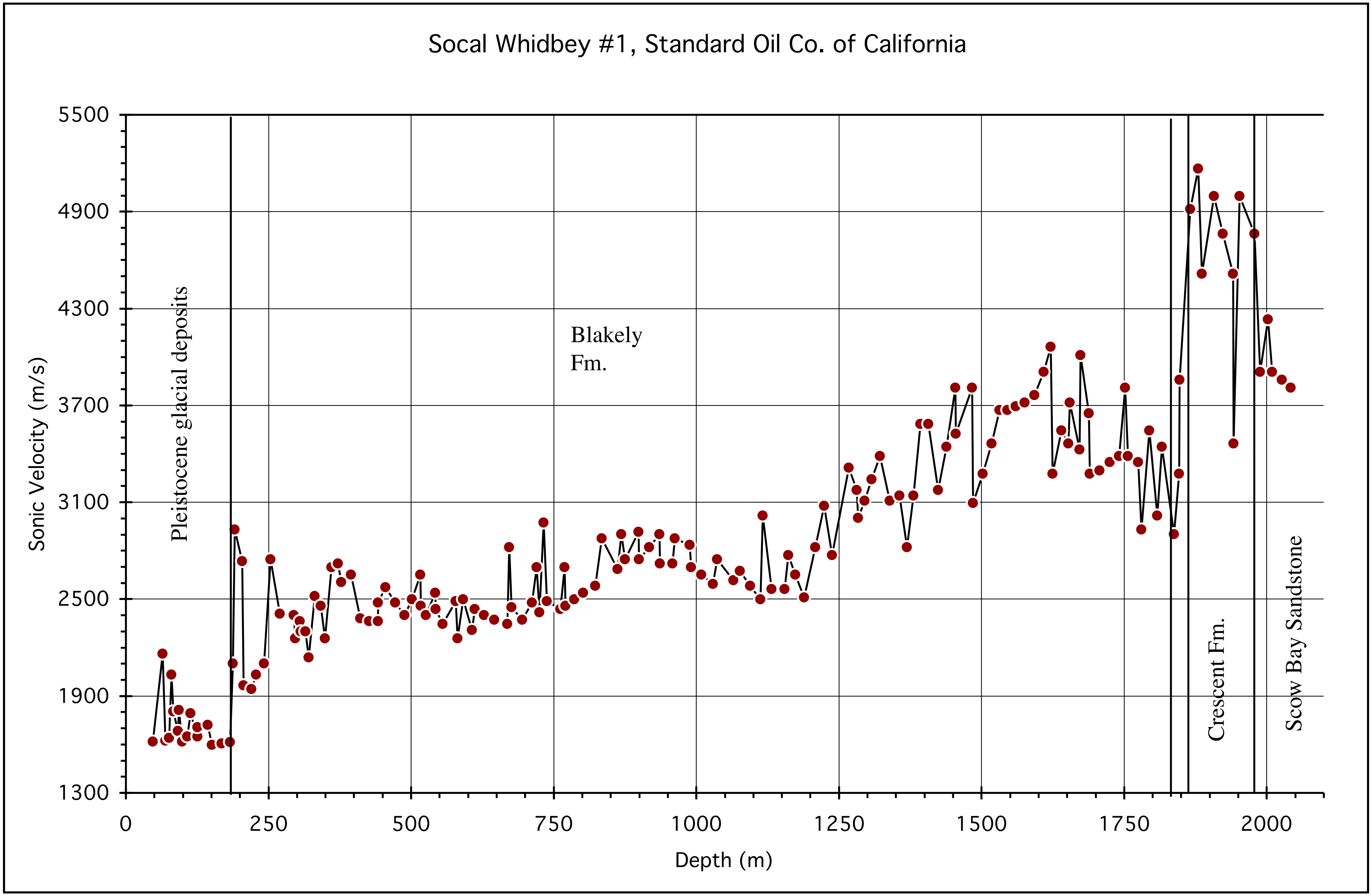

Kingston #1, Mobil Oil Corporation
Sonic Velocity (m/s)
4200
3800
3400
3000
2600
2200
1800
1400
0
200
400
600
800
1000
1200
1400
1600
Depth (m)
Pleistocene
glacial
deposits
Blakely
Fm.
Puget
Group
correlative
Scow Bay Sandstone

Figure 10.



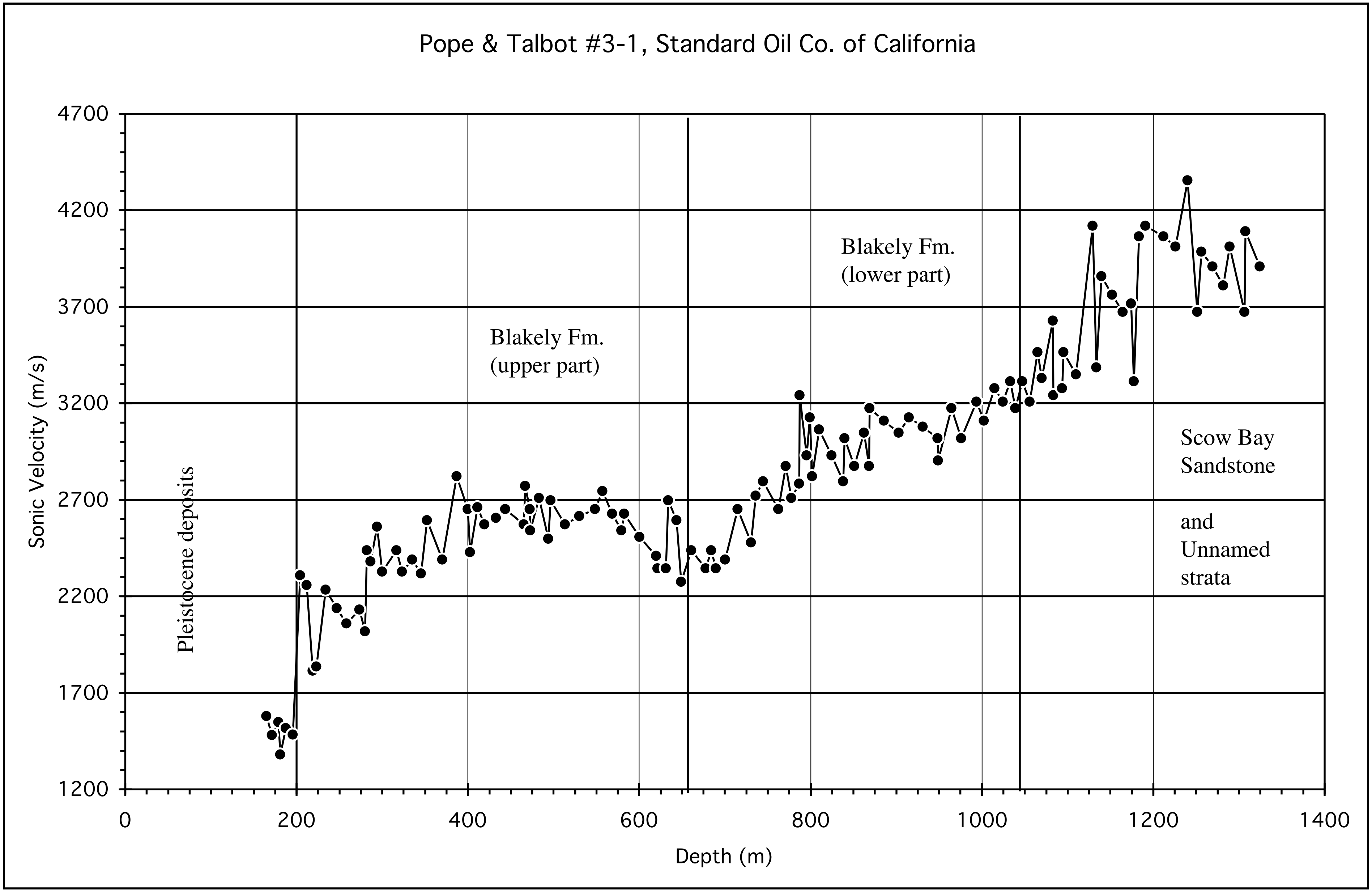
Pope-Talbot #18-1, Union Oil Co. of California
Sonic Velocity (m/s)
5500
5000
4500
4000
3500
3000
2500
2000
Pleistocene
Blakely Fm.
Crescent Fm.
0
200
400
600
800
1000
1200
1400
Depth (m)

Figure 11.



Socal Whidbey #1, Standard Oil Co. of California
Sonic Velocity (m/s)
Depth (m)
Pleistocene glacial deposits
Blakely Fm.
Crescent Fm.
Scow Bay Sandstone
5500
4900
4300
3700
3100
2500
1900
1300
0
250
500
750
1000
1250
1500
1750
2000

Figure 12.



Pope & Talbot #3-1, Standard Oil Co. of California
Sonic Velocity (m/s)
Depth (m)
4700
4200
3700
3200
2700
2200
1700
1200
0
200
400
600
800
1000
1200
1400
Pleistocene deposits
Blakely Fm. (upper part)
Blakely Fm. (lower part)
Scow Bay Sandstone
and Unnamed strata

Figure 13.

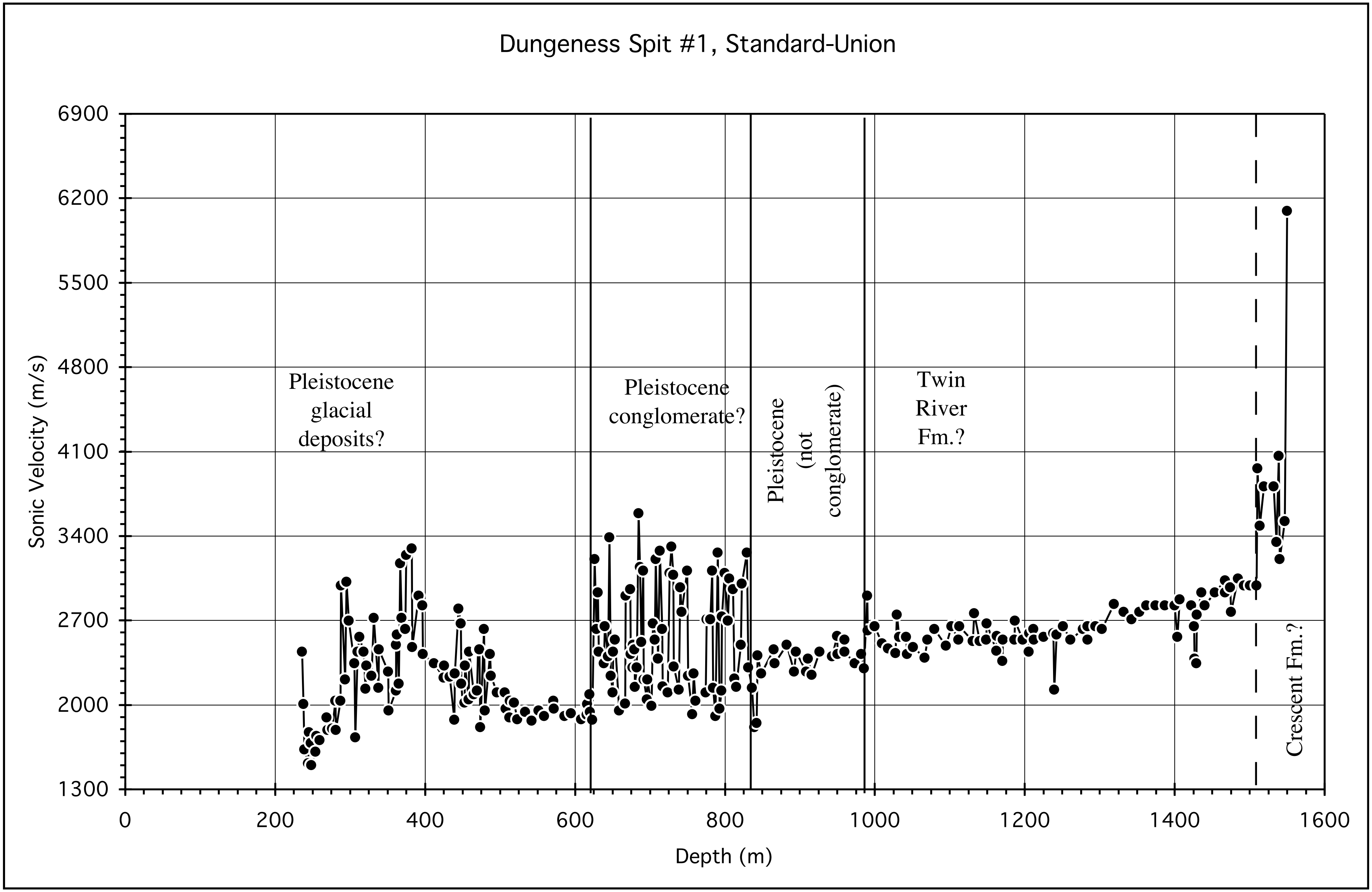

Dungeness Spit #1, Standard-Union
Sonic Velocity (m/s)
Depth (m)
Pleistocene glacial deposits?
Pleistocene conglomerate?
Pleistocene (not conglomerate)
Twin River Fm.?
Crescent Fm.?
6900
6200
5500
4800
4100
3400
2700
2000
1300
0
200
400
600
800
1000
1200
1400
1600

Figure 14.

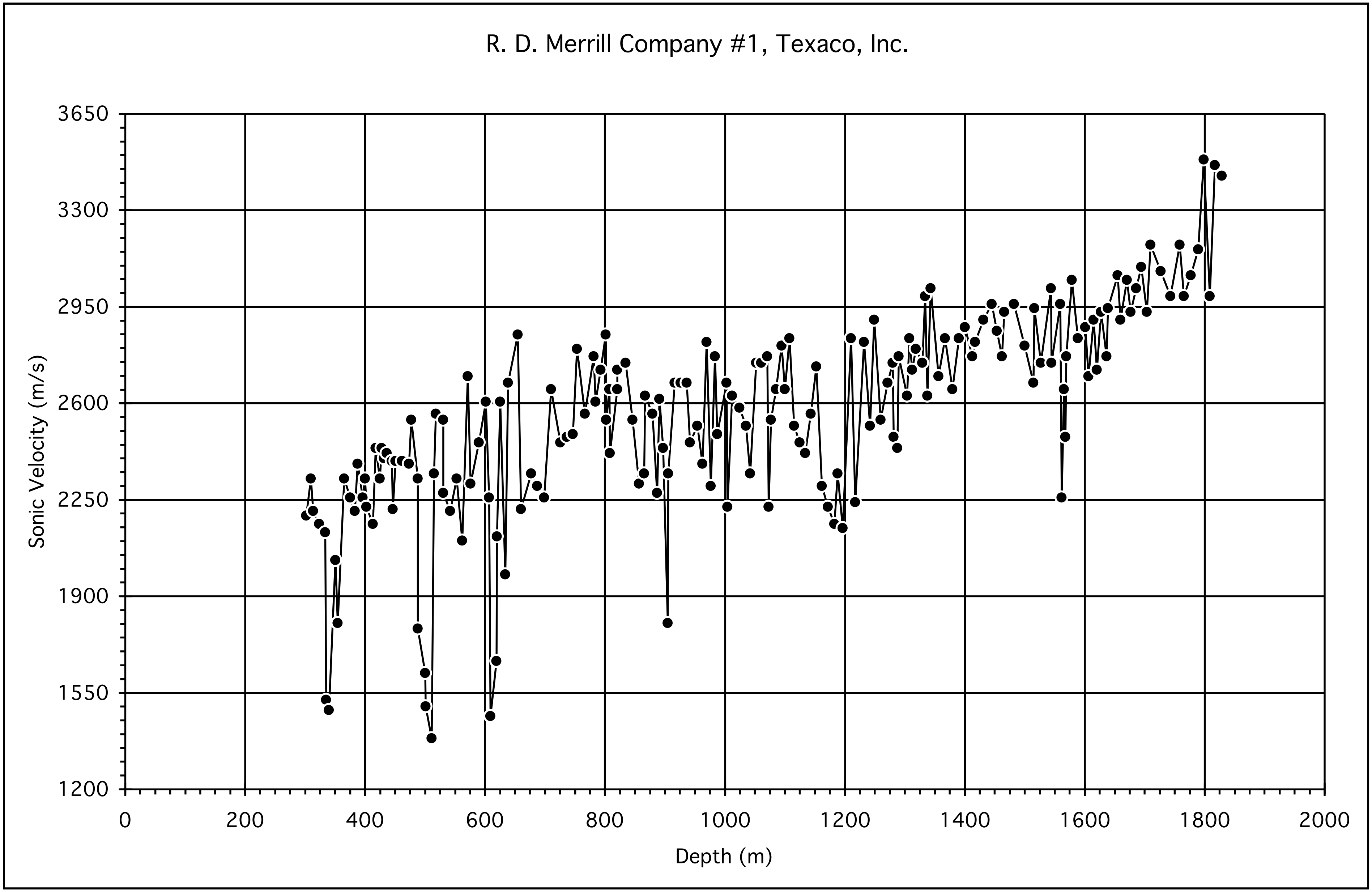
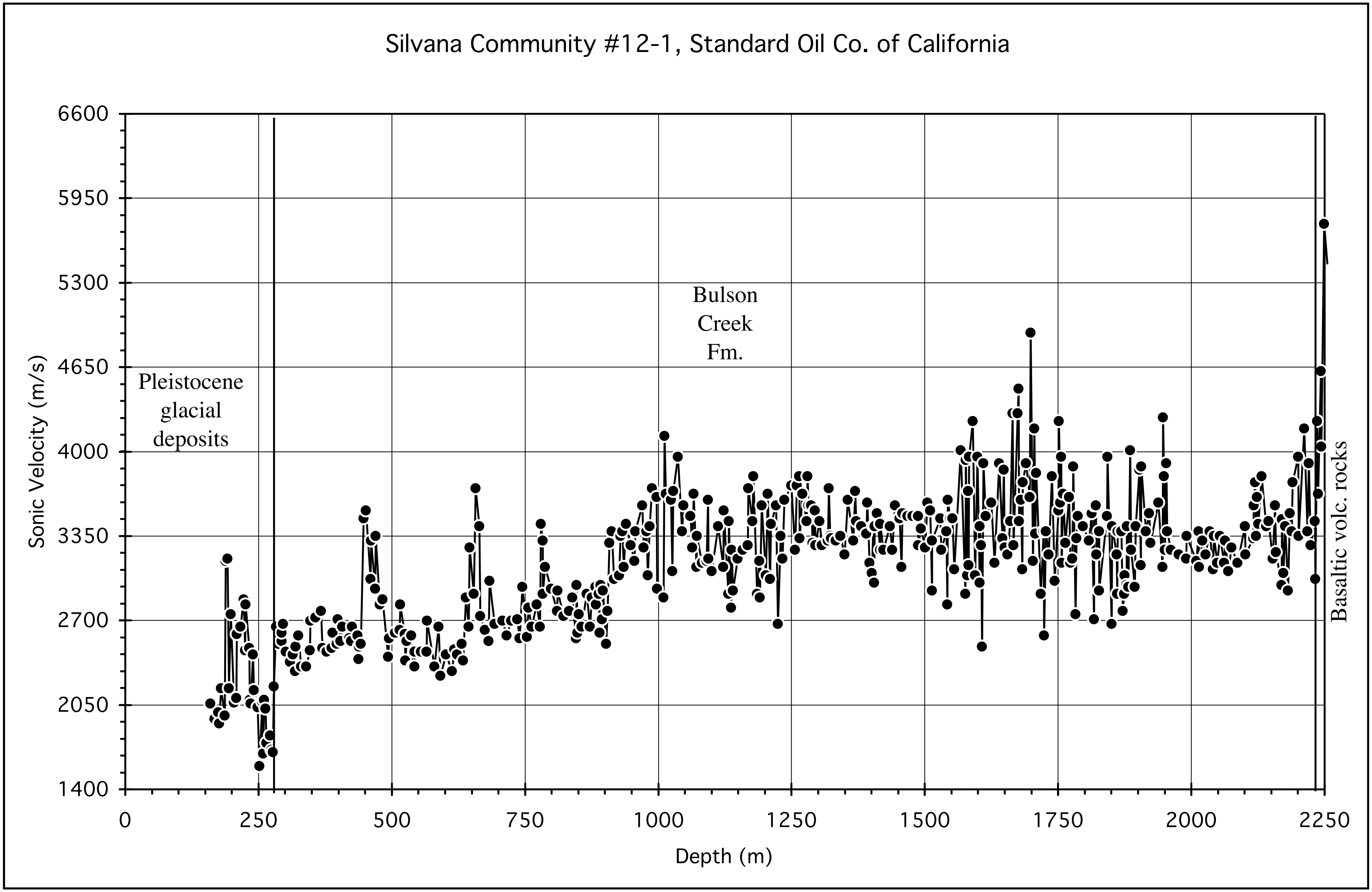

R. D. Merrill Company #1, Texaco, Inc.
Sonic Velocity (m/s)
3650
3300
2950
2600
2250
1900
1550
1200
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Depth (m)

Figure 15.



Silvana Community #12-1, Standard Oil Co. of California
Sonic Velocity (m/s)
6600
5950
5300
4650
4000
3350
2700
2050
1400
Pleistocene glacial deposits
Bulson Creek Fm.
Basaltic volc. rocks
0
250
500
750
1000
1250
1500
1750
2000
2250
Depth (m)

Figure 16.

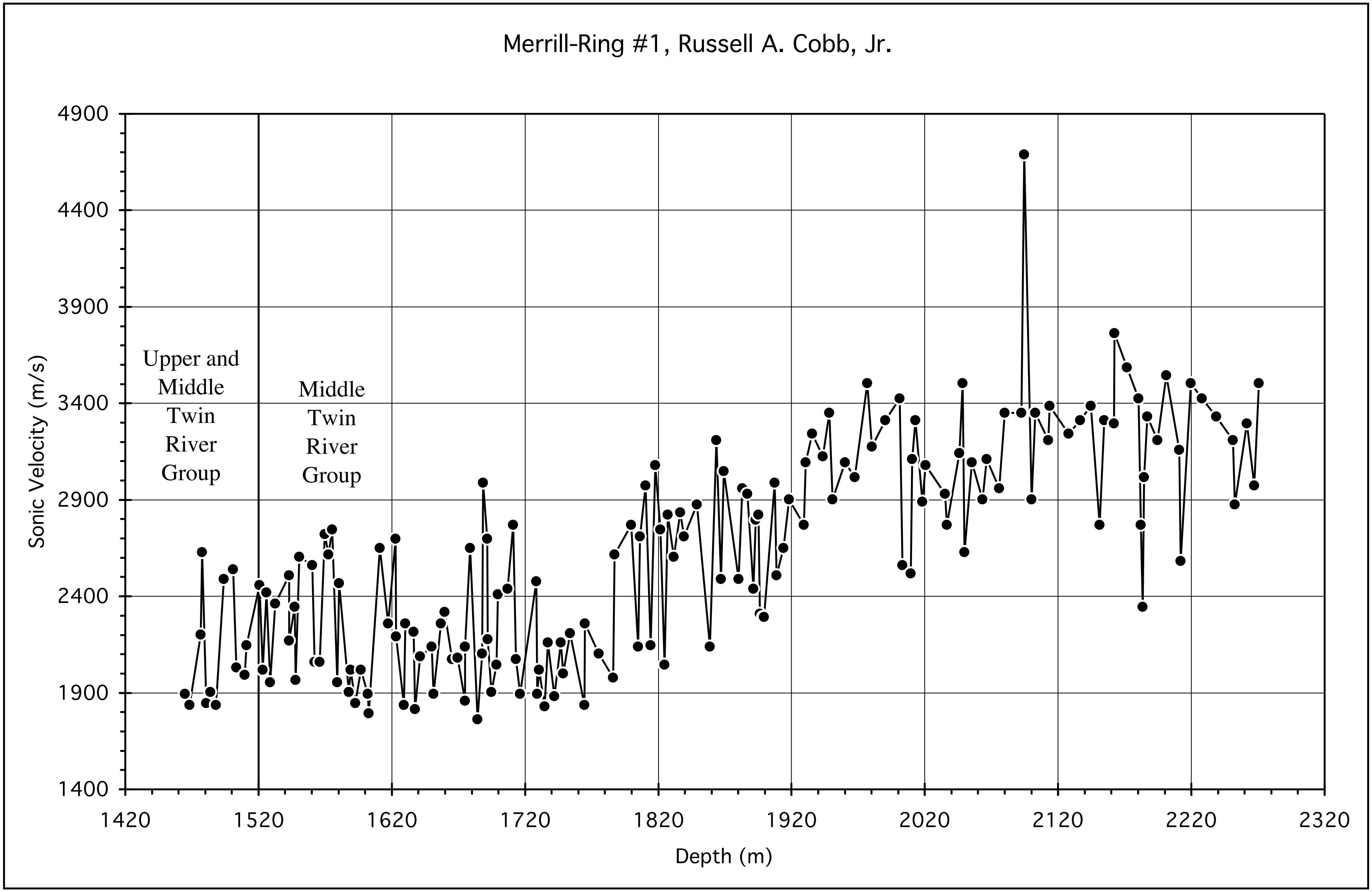
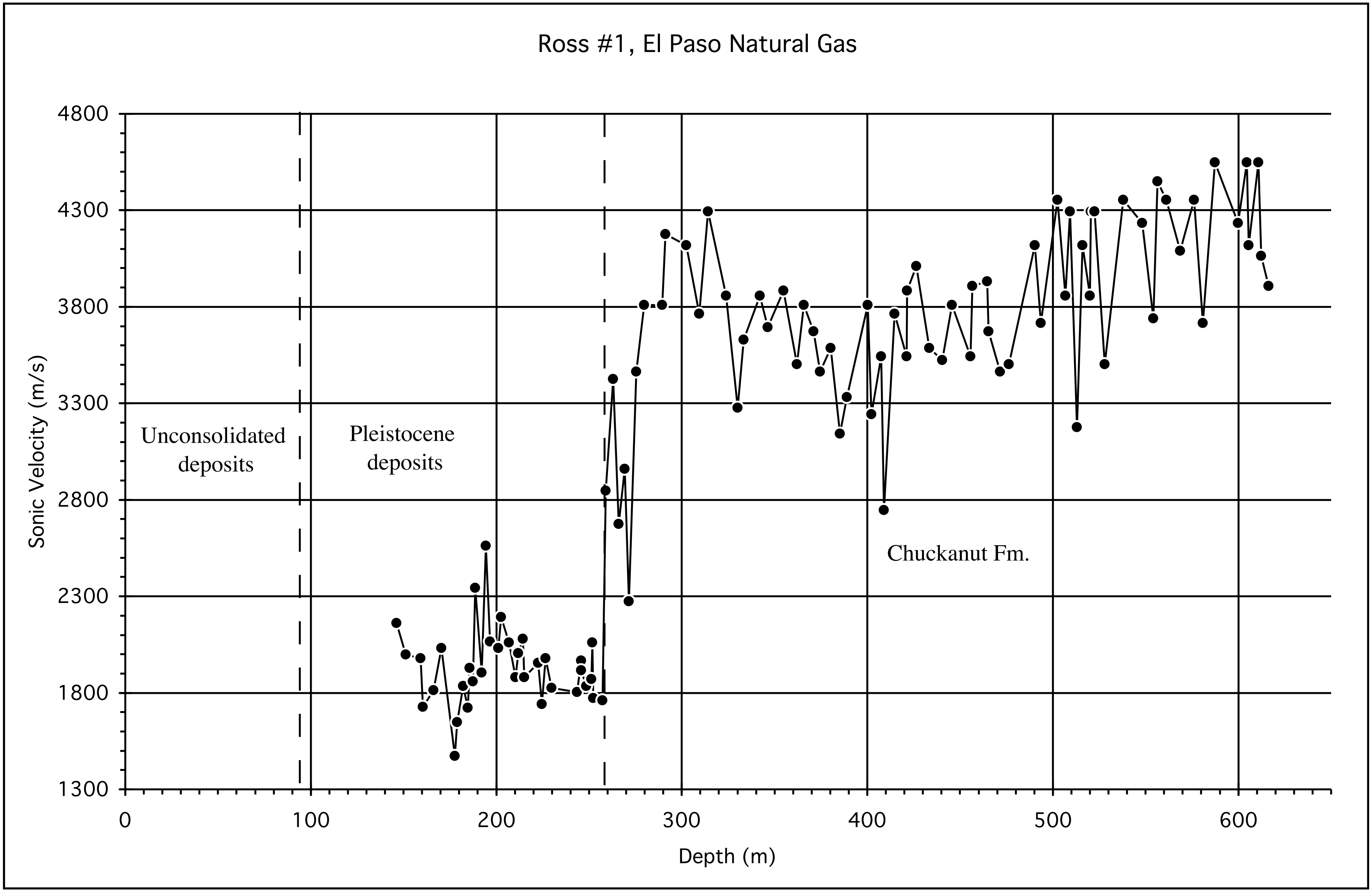

Merrill-Ring #1, Russell A. Cobb, Jr.
Sonic Velocity (m/s)
Depth (m)
4900
4400
3900
3400
2900
2400
1900
1400
1420
1520
1620
1720
1820
1920
2020
2120
2220
2320
Upper and Middle Twin River Group
Middle Twin River Group

Figure 17.



Ross #1, El Paso Natural Gas
4800
4300
3800
3300
2800
2300
1800
1300
Sonic Velocity (m/s)
Unconsolidated deposits
Pleistocene deposits
Chuckanut Fm.
0
100
200
300
400
500
600
Depth (m)

Figure 18.

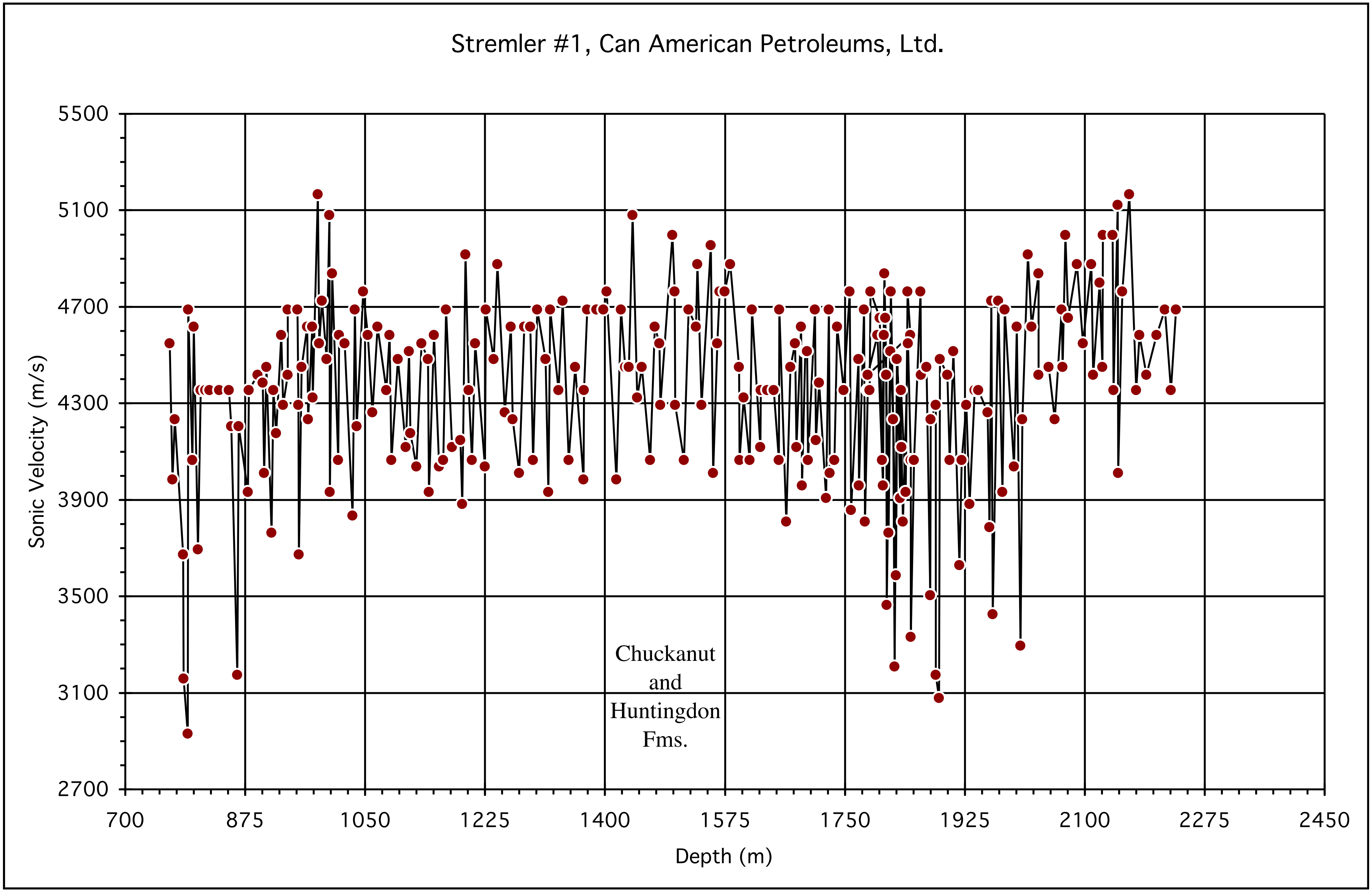

Stremler #1, Can American Petroleums, Ltd.
5500
5100
4700
4300
3900
3500
3100
2700
Sonic Velocity (m/s)
700
875
1050
1225
1400
1575
1750
1925
2100
2275
2450
Depth (m)
Chuckanut
and
Huntingdon
Fms.

Figure 19.

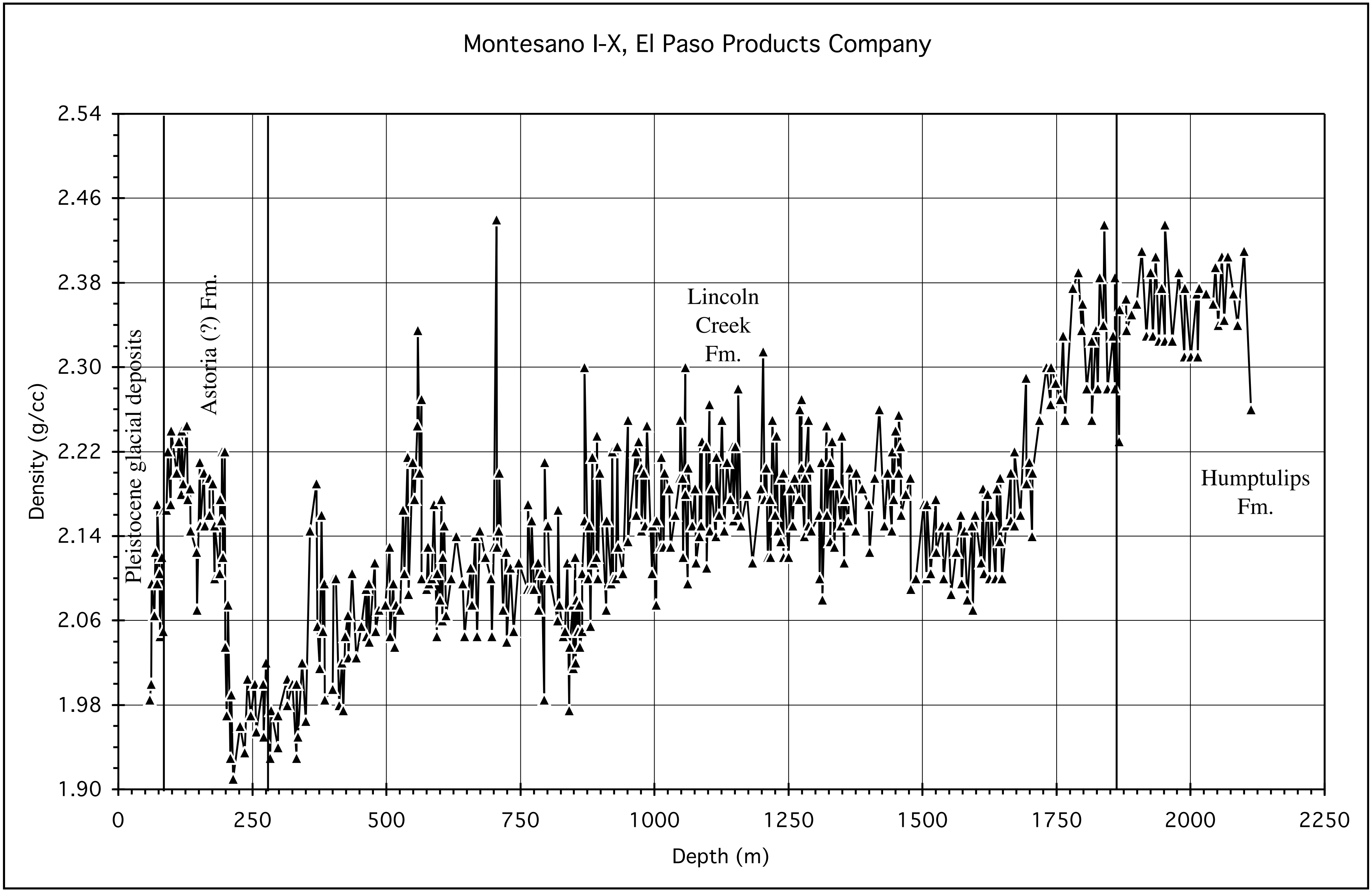

Montesano I-X, El Paso Products Company
Density (g/cc)
2.54
2.46
2.38
2.30
2.22
2.14
2.06
1.98
1.90
0
250
500
750
1000
1250
1500
1750
2000
2250
Depth (m)
Pleistocene glacial deposits
Astoria (?) Fm.
Lincoln
Creek
Fm.
Humptulips
Fm.

Figure 20.

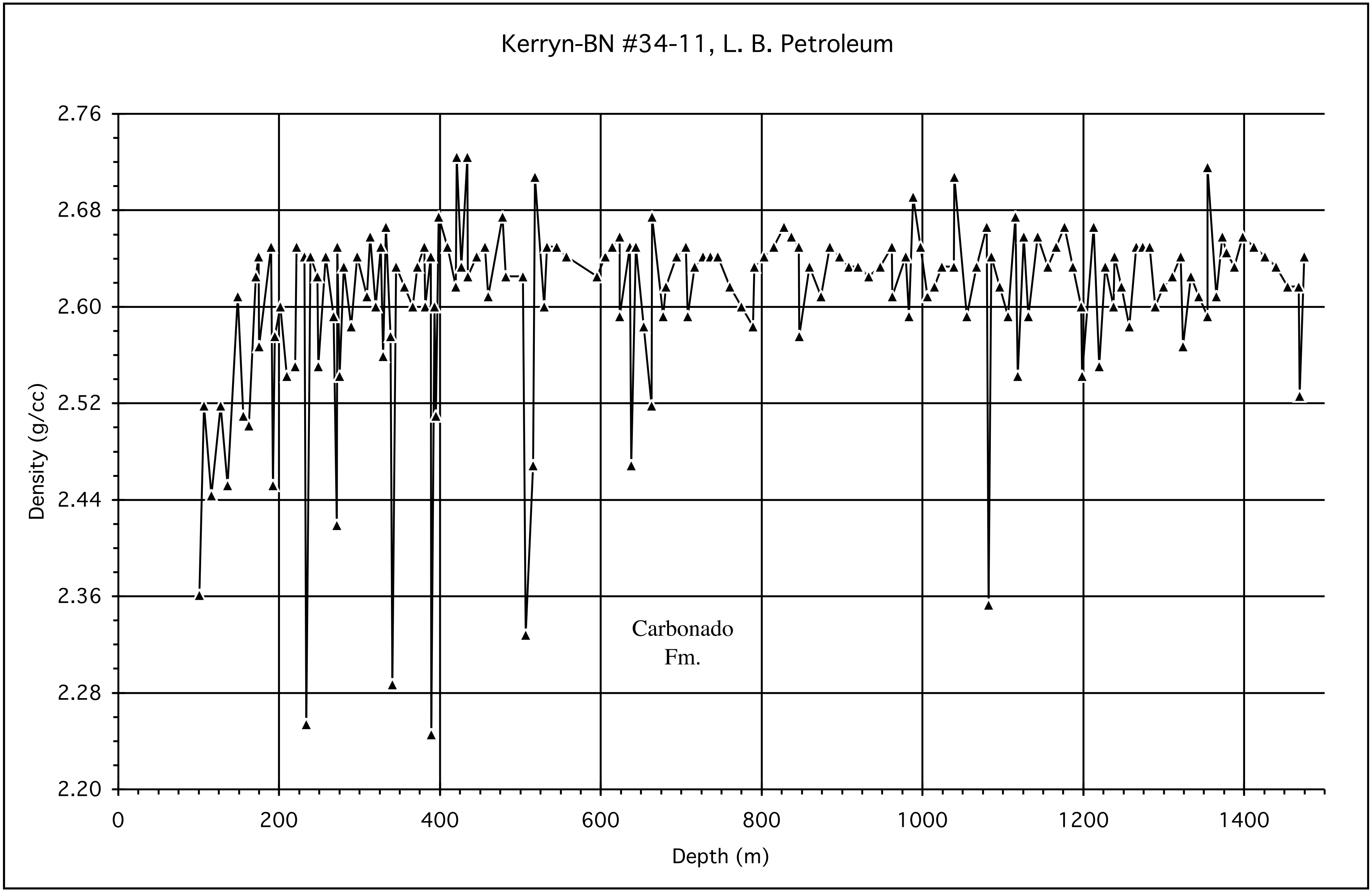

Kerryn-BN #34-11, L. B. Petroleum
Density (g/cc)
2.76
2.68
2.60
2.52
2.44
2.36
2.28
2.20
0
200
400
600
800
1000
1200
1400
Depth (m)
Carbonado
Fm.

Figure 21.

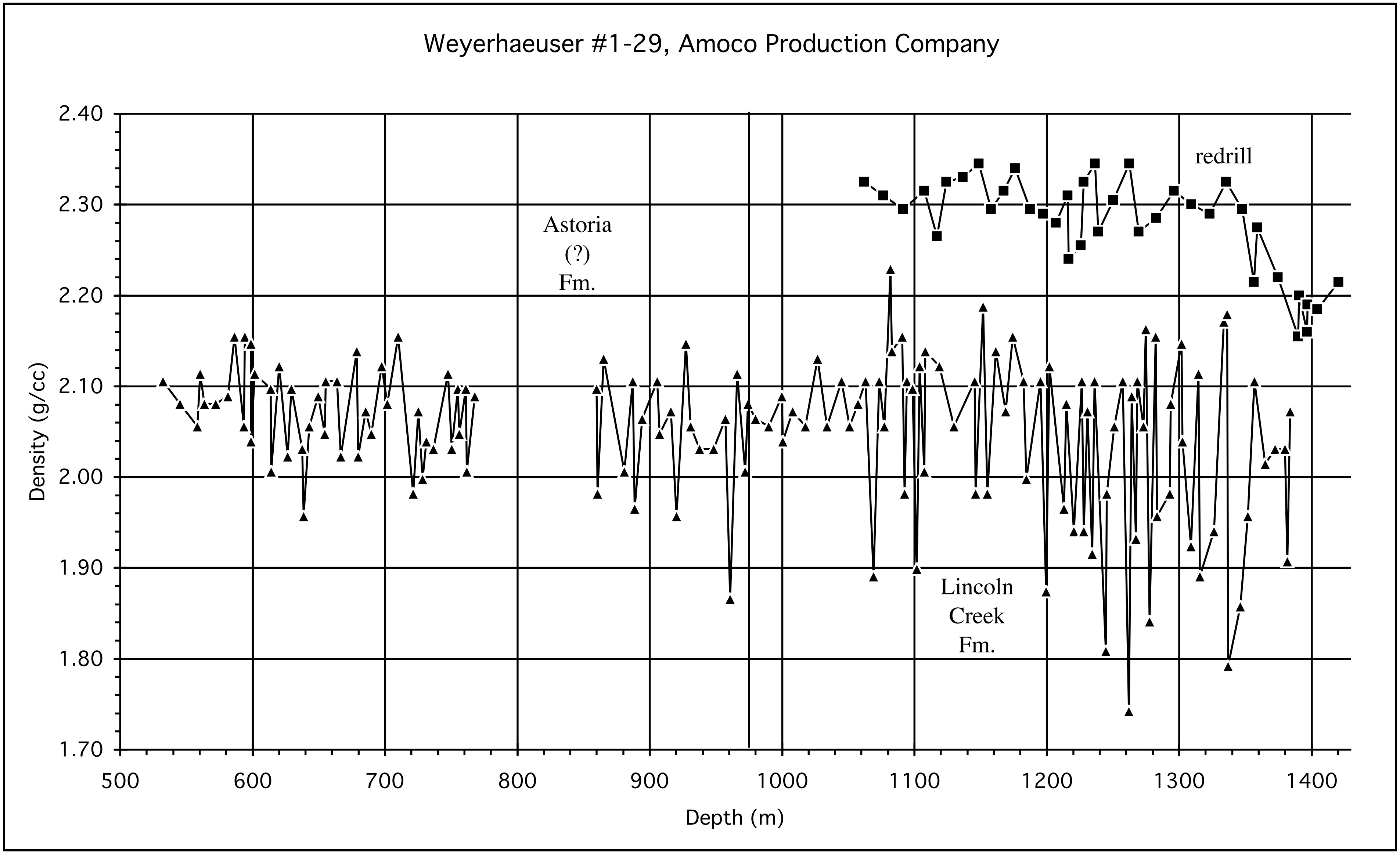
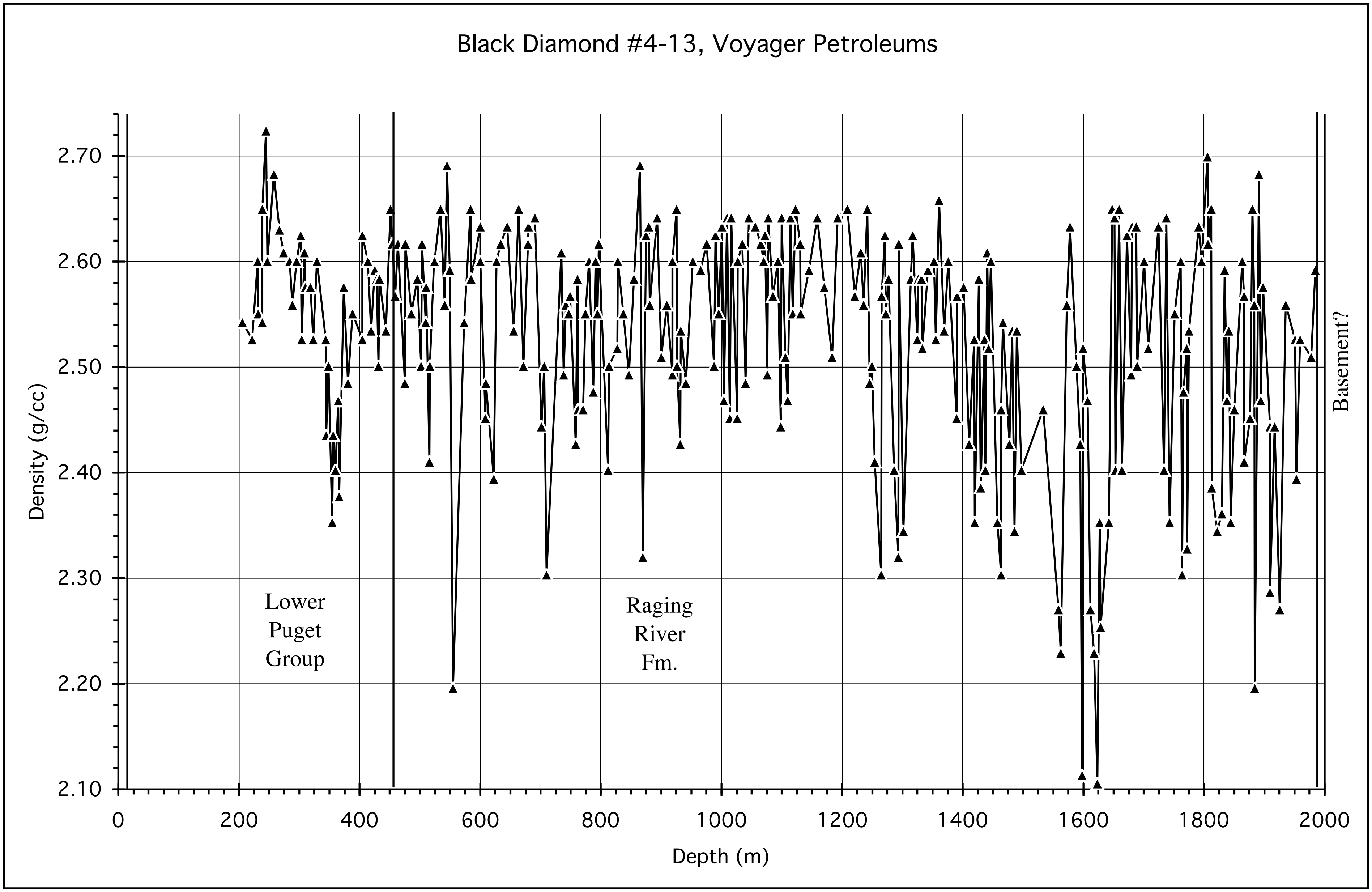

Weyerhaeuser #1-29, Amoco Production Company
Density (g/cc)
Depth (m)
2.40
2.30
2.20
2.10
2.00
1.90
1.80
1.70
500
600
700
800
900
1000
1100
1200
1300
1400
Astoria
(?)
Fm.
redrill
Lincoln
Creek
Fm.

Figure 22.



Black Diamond #4-13, Voyager Petroleums
Density (g/cc)
2.70
2.60
2.50
2.40
2.30
2.20
2.10
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Depth (m)
Lower Puget Group
Raging River Fm.
Basement?

Figure 23.

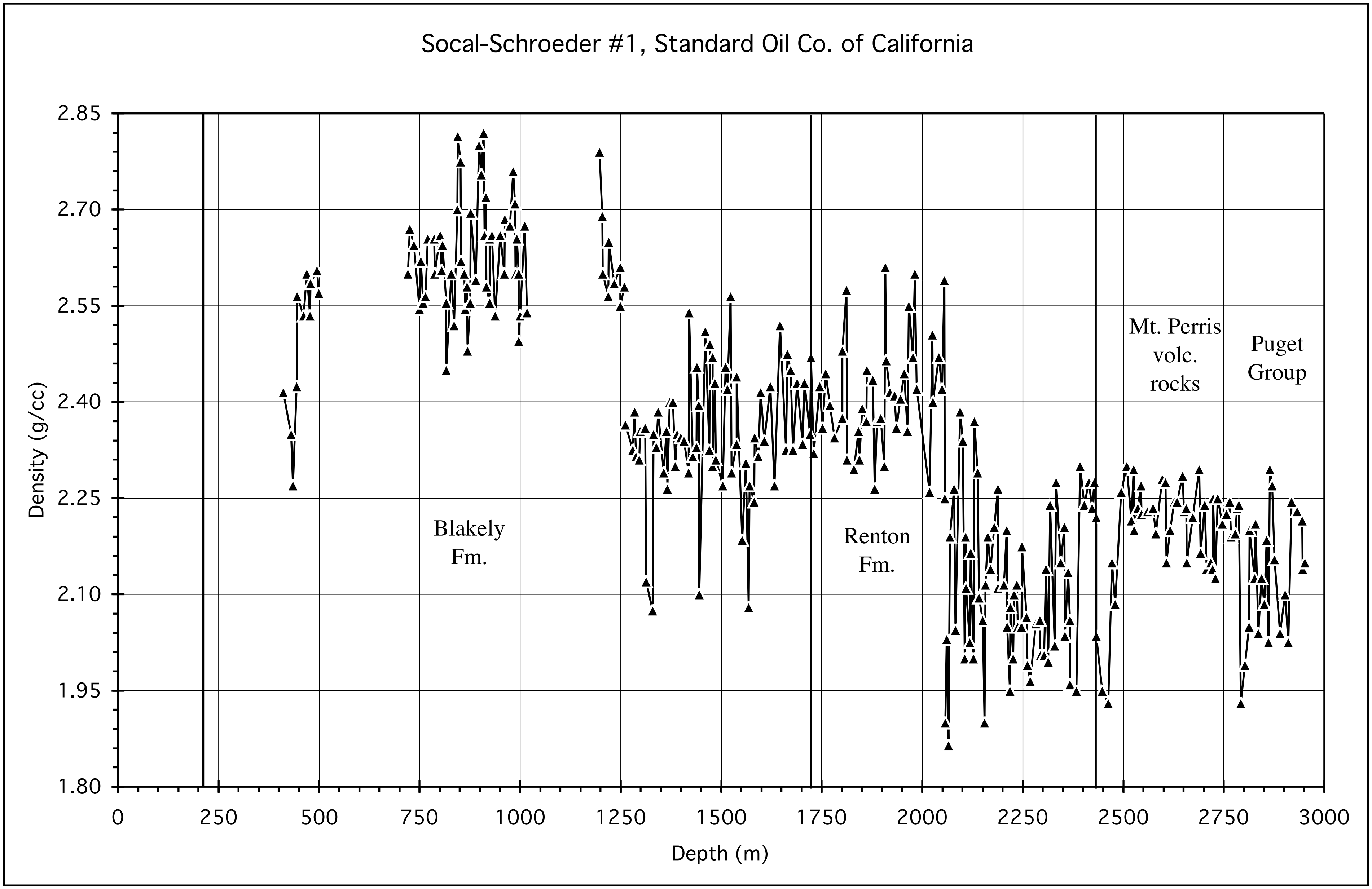
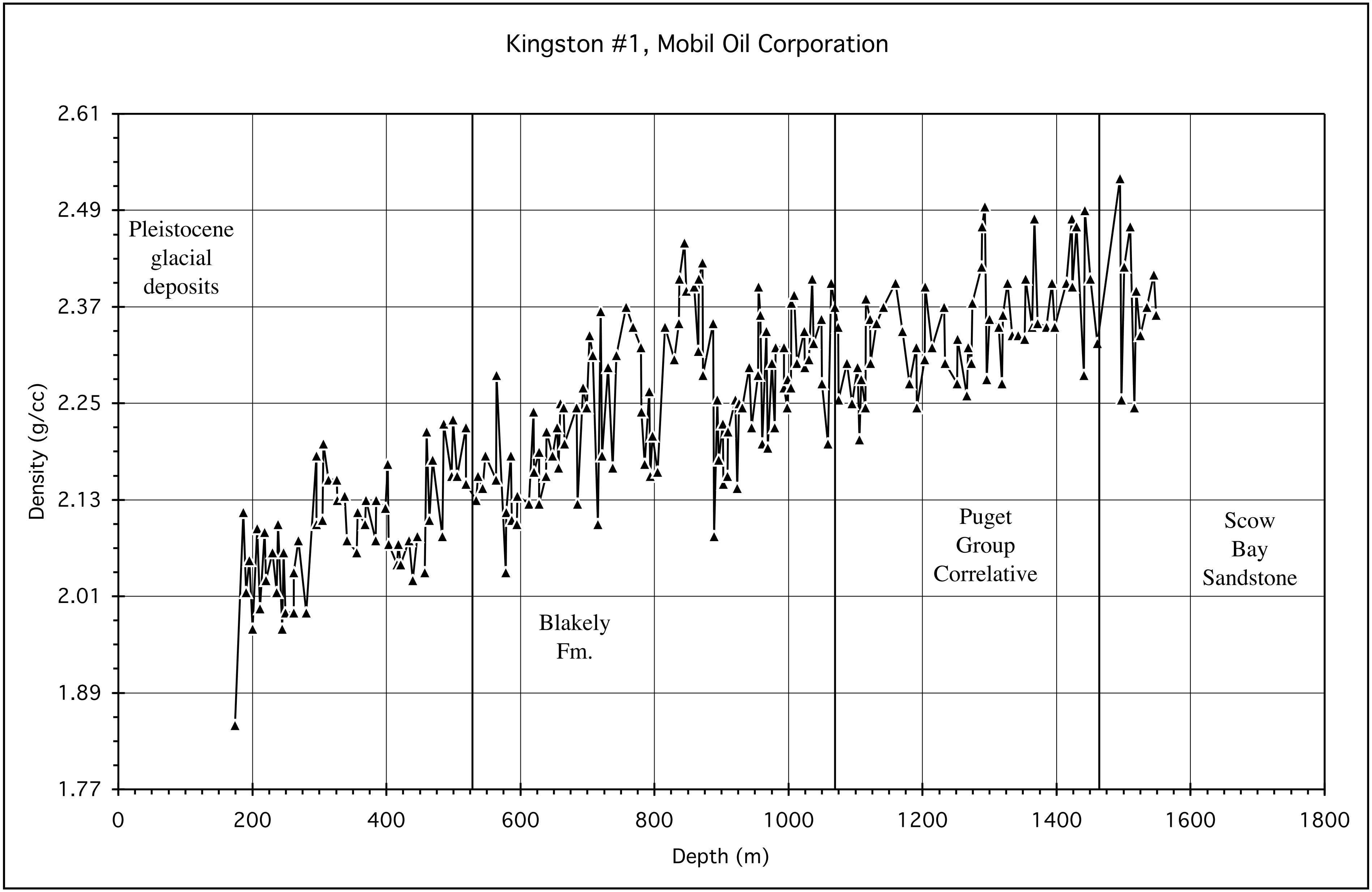

Socal-Schroeder #1, Standard Oil Co. of California
2.85
2.70
2.55
2.40
2.25
2.10
1.95
1.80
Density (g/cc)
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
2750
3000
Depth (m)
Blakely Fm.
Renton Fm.
Mt. Perris volc. rocks
Puget Group

Figure 24.



Kingston #1, Mobil Oil Corporation
Density (g/cc)
2.61
2.49
2.37
2.25
2.13
2.01
1.89
1.77
Depth (m)
0
200
400
600
800
1000
1200
1400
1600
1800
Pleistocene glacial deposits
Blakely Fm.
Puget Group Correlative
Scow Bay Sandstone

Figure 25.

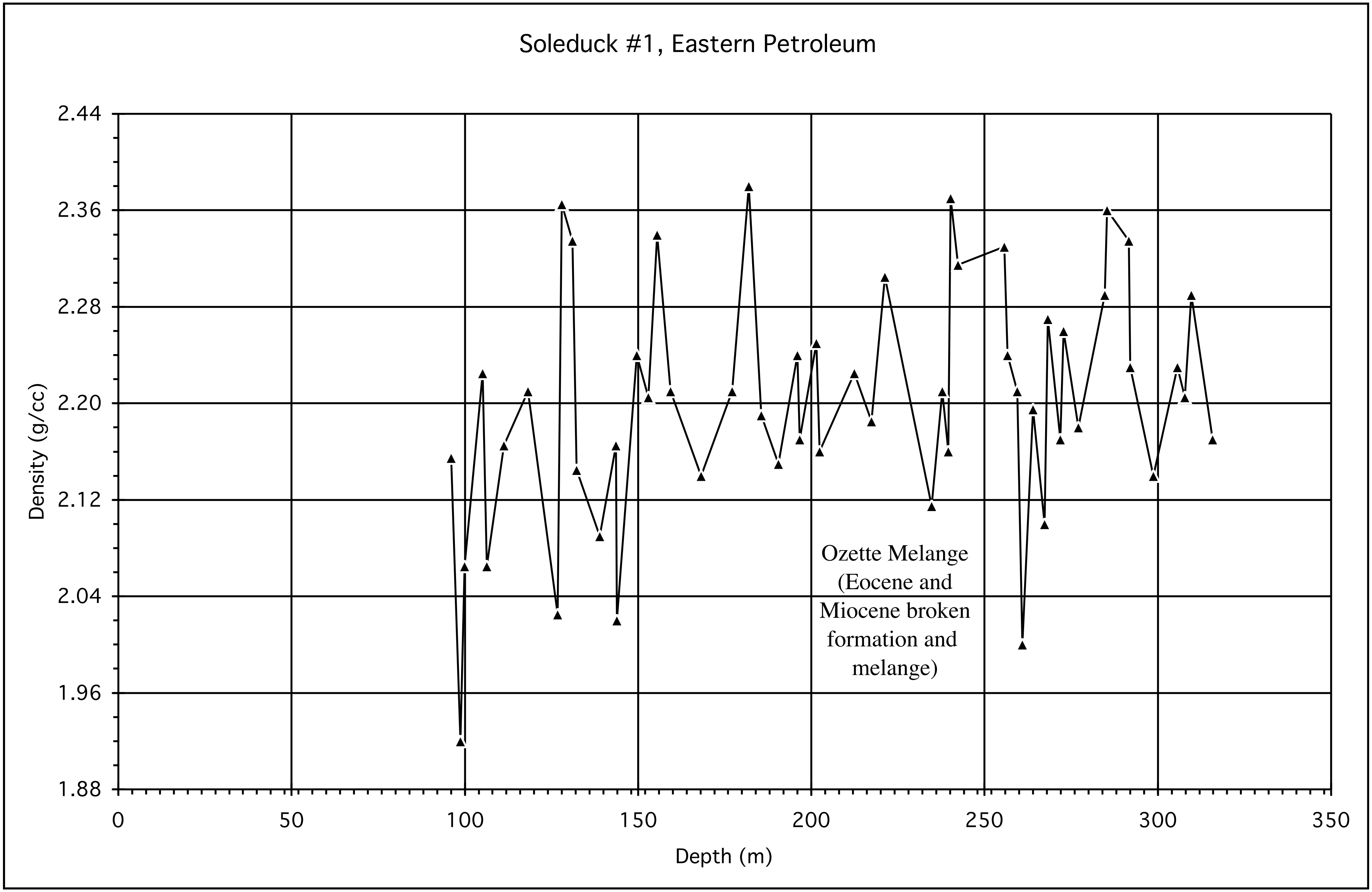
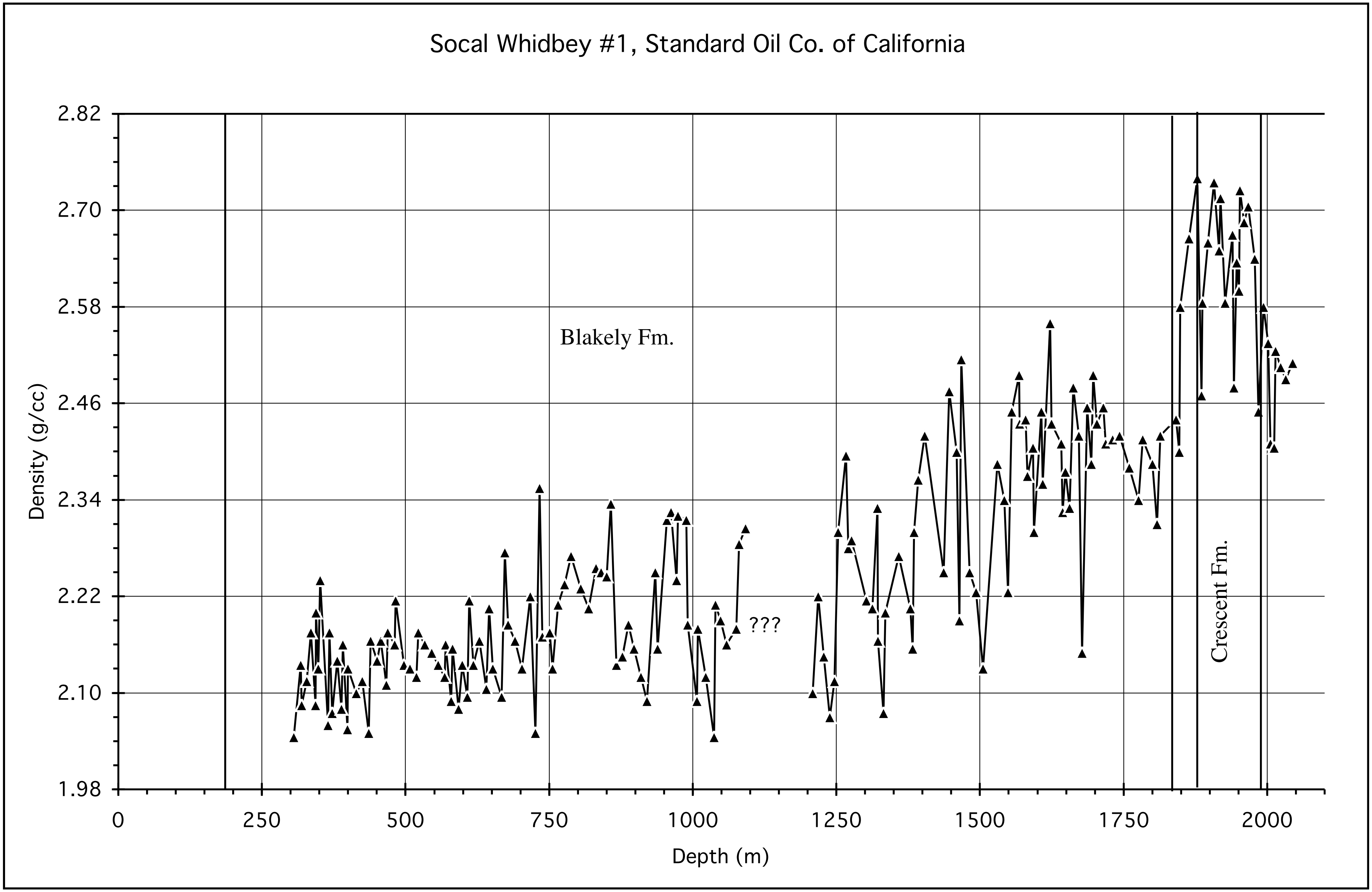

Soleduck #1, Eastern Petroleum
Density (g/cc)
2.44
2.36
2.28
2.20
2.12
2.04
1.96
1.88
0
50
100
150
200
250
300
350
Depth (m)
Ozette Melange
(Eocene and
Miocene broken
formation and
melange)

Figure 26.



Socal Whidbey #1, Standard Oil Co. of California
Blakely Fm.
Crescent Fm.
???
Density (g/cc)
2.82
2.70
2.58
2.46
2.34
2.22
2.10
1.98
0
250
500
750
1000
1250
1500
1750
2000
Depth (m)

Figure 27.

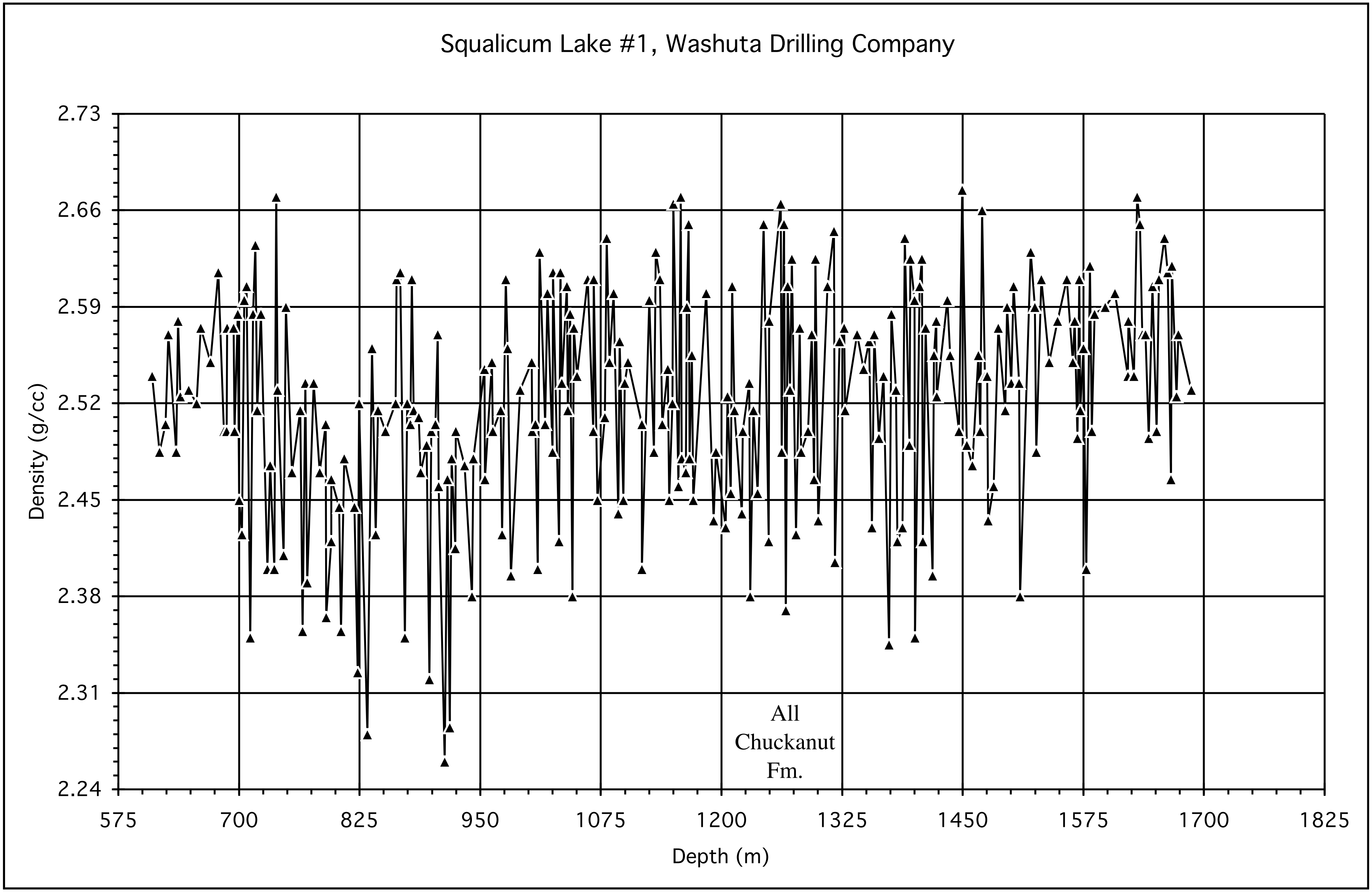

Squalicum Lake #1, Washuta Drilling Company
2.73
2.66
2.59
2.52
2.45
2.38
2.31
2.24
Density (g/cc)
575
700
825
950
1075
1200
1325
1450
1575
1700
1825
Depth (m)
All
Chuckanut
Fm.

Figure 28.

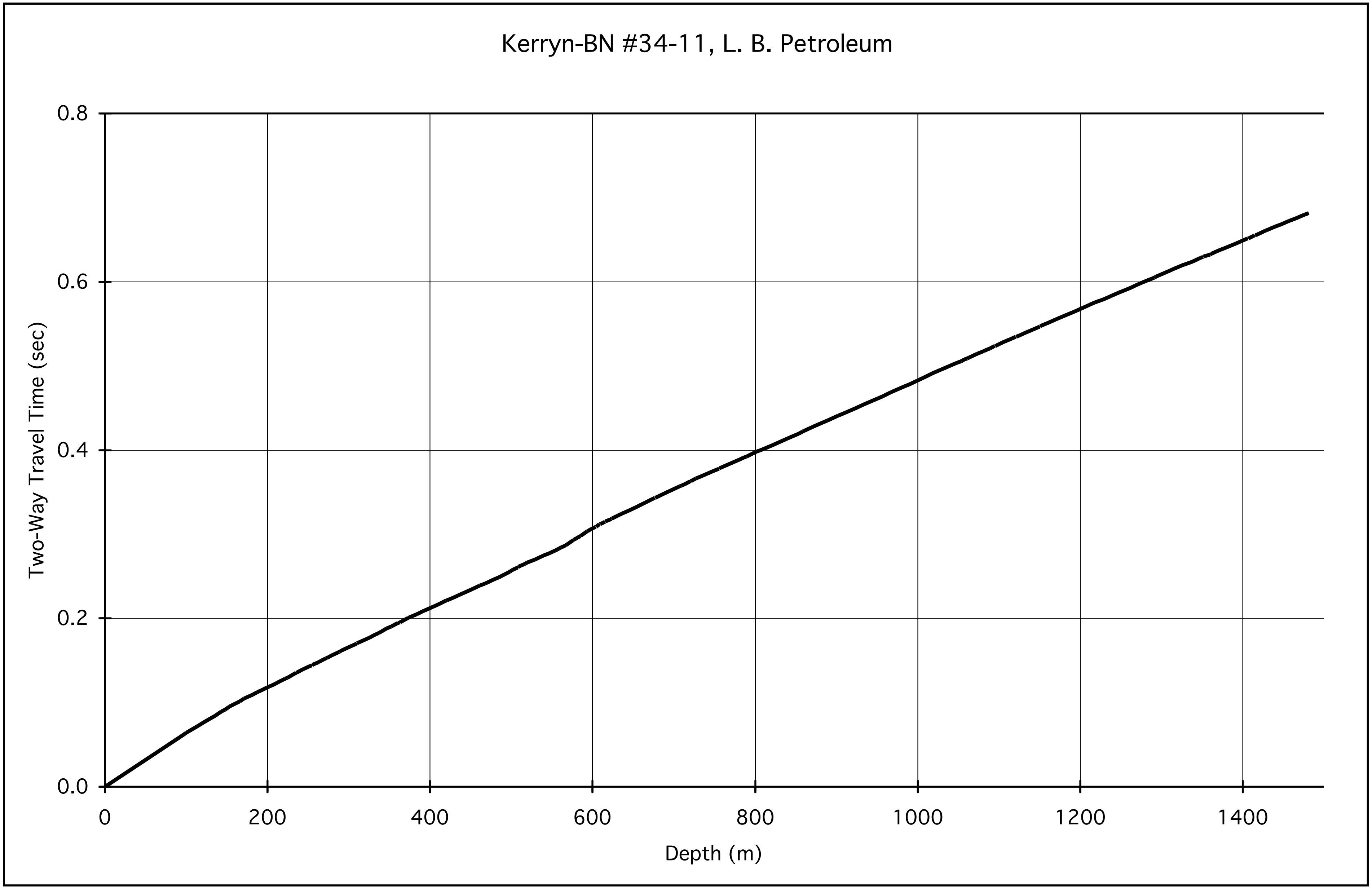

Kerryn-BN #34-11, L. B. Petroleum
Two-Way Travel Time (sec)
0.0
0.2
0.4
0.6
0.8
0
200
400
600
800
1000
1200
1400
Depth (m)

Figure 29.

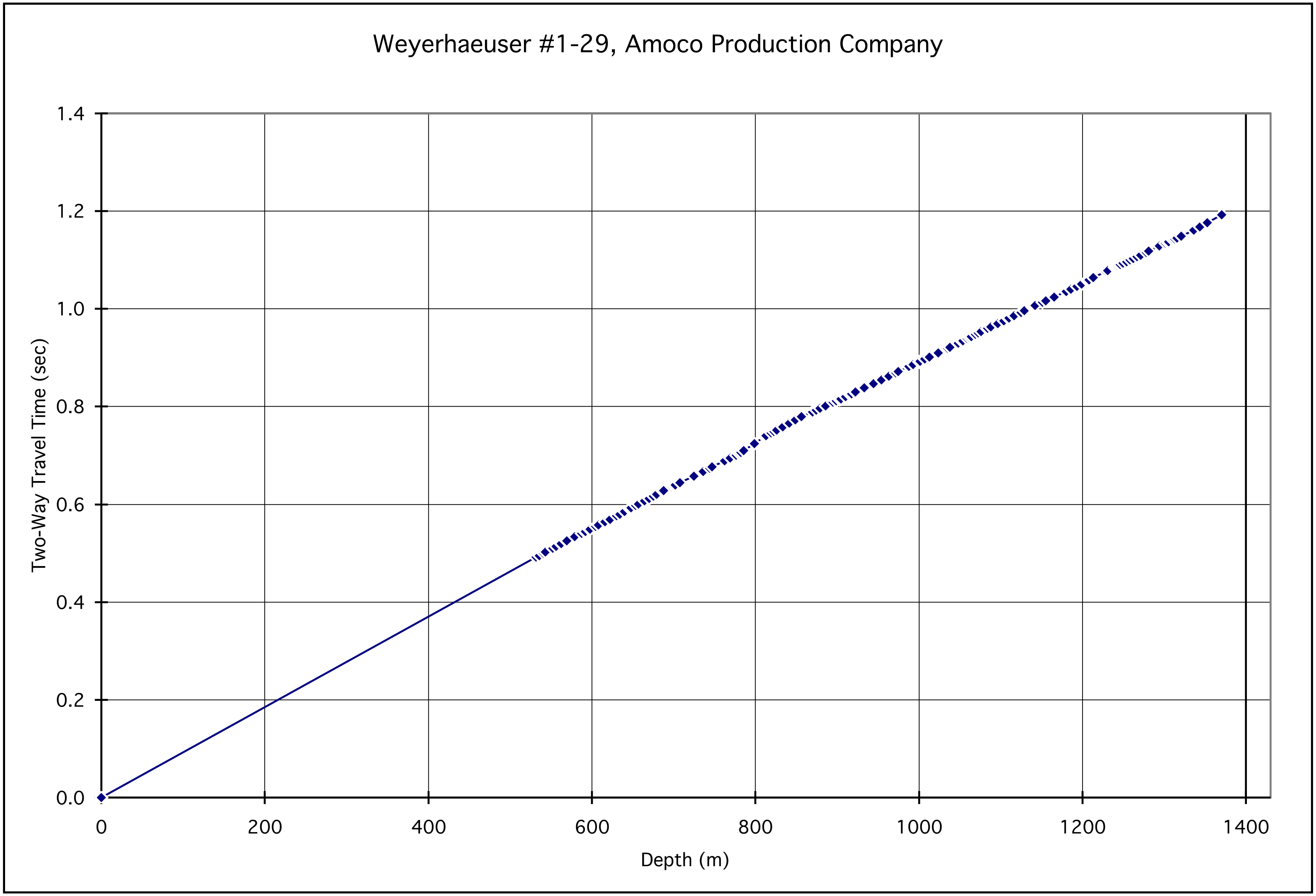

Weyerhaeuser #1-29, Amoco Production Company
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Two-Way Travel Time (sec)
0
200
400
600
800
1000
1200
1400
Depth (m)

Figure 30.

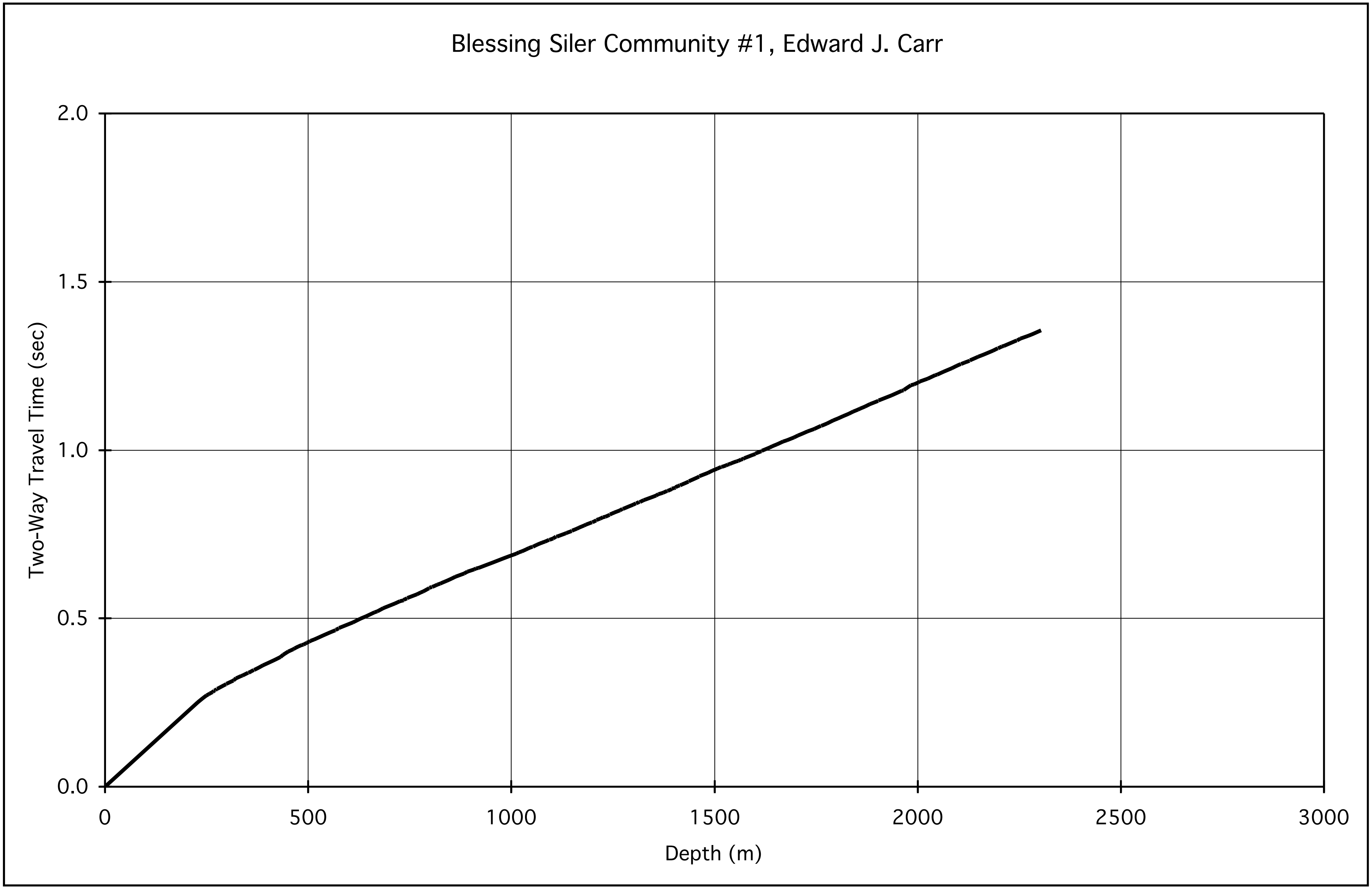

Blessing Siler Community #1, Edward J. Carr
Two-Way Travel Time (sec)
2.0
1.5
1.0
0.5
0.0
0
500
1000
1500
2000
2500
3000
Depth (m)

Figure 31.

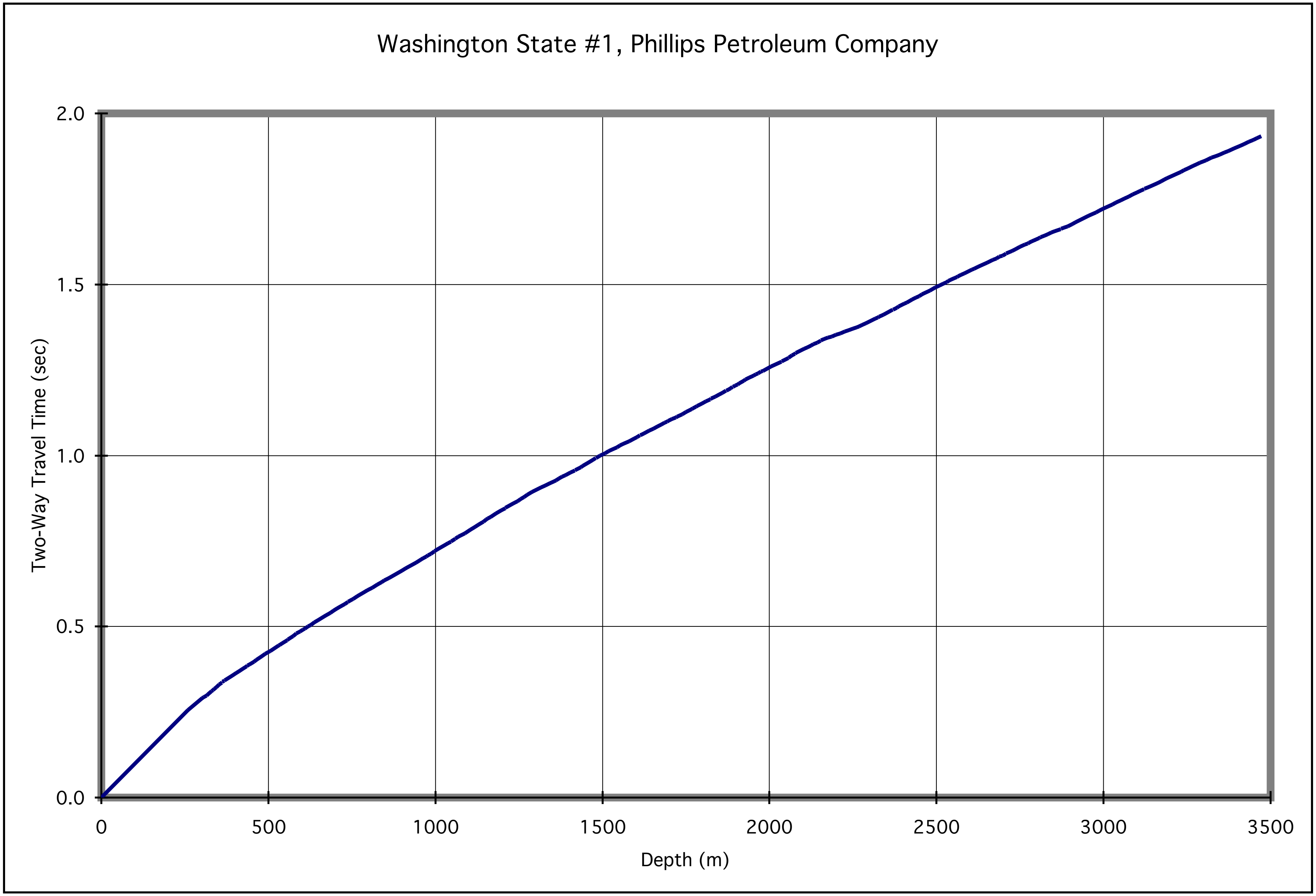

Washington State #1, Phillips Petroleum Company
2.0
1.5
1.0
0.5
0.0
Two-Way Travel Time (sec)
0
500
1000
1500
2000
2500
3000
3500
Depth (m)

Figure 32.

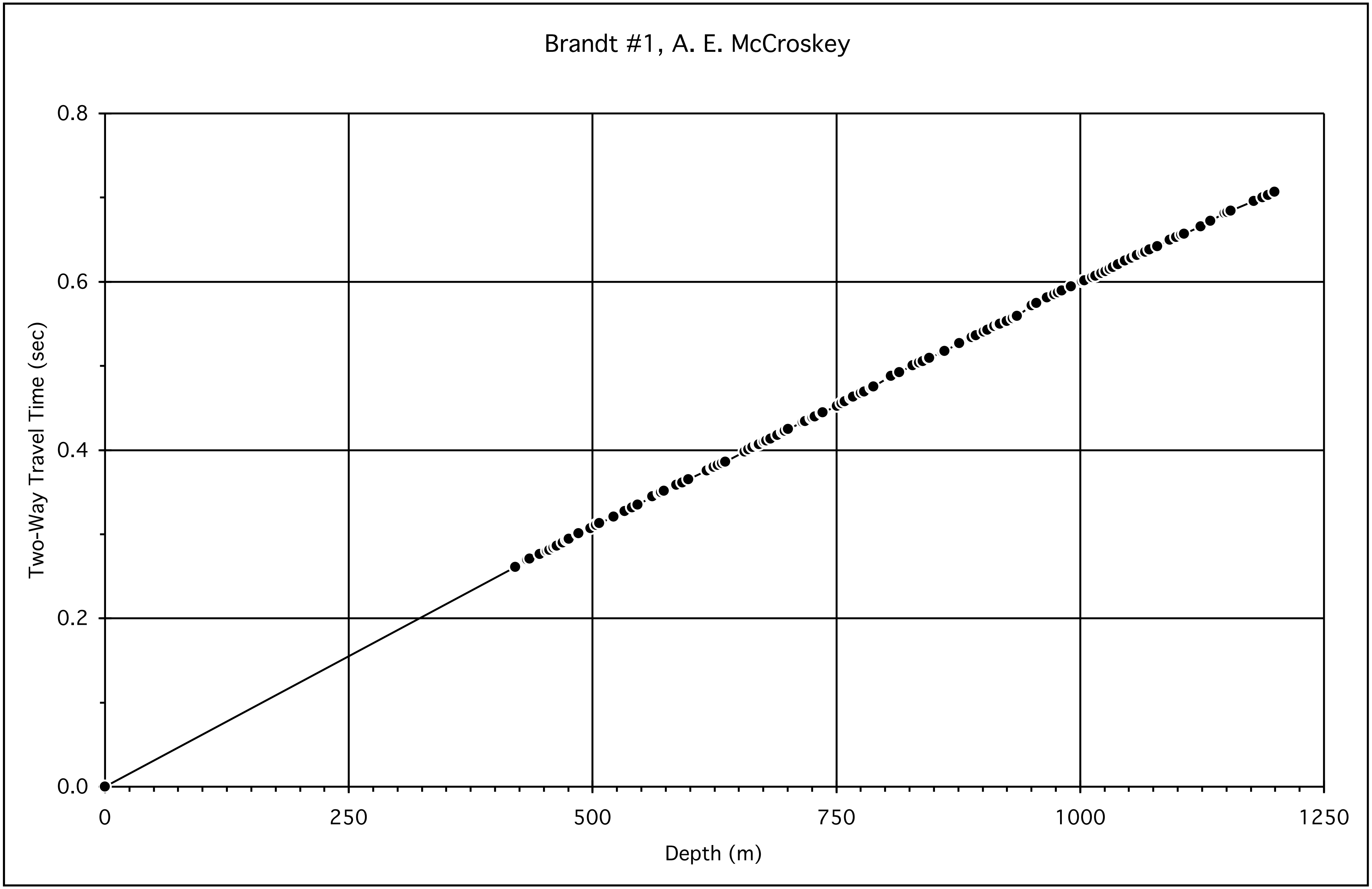

Brandt #1, A. E. McCroskey
0.8
0.6
0.4
0.2
0.0
Two-Way Travel Time (sec)
0
250
500
750
1000
1250
Depth (m)

Figure 33,

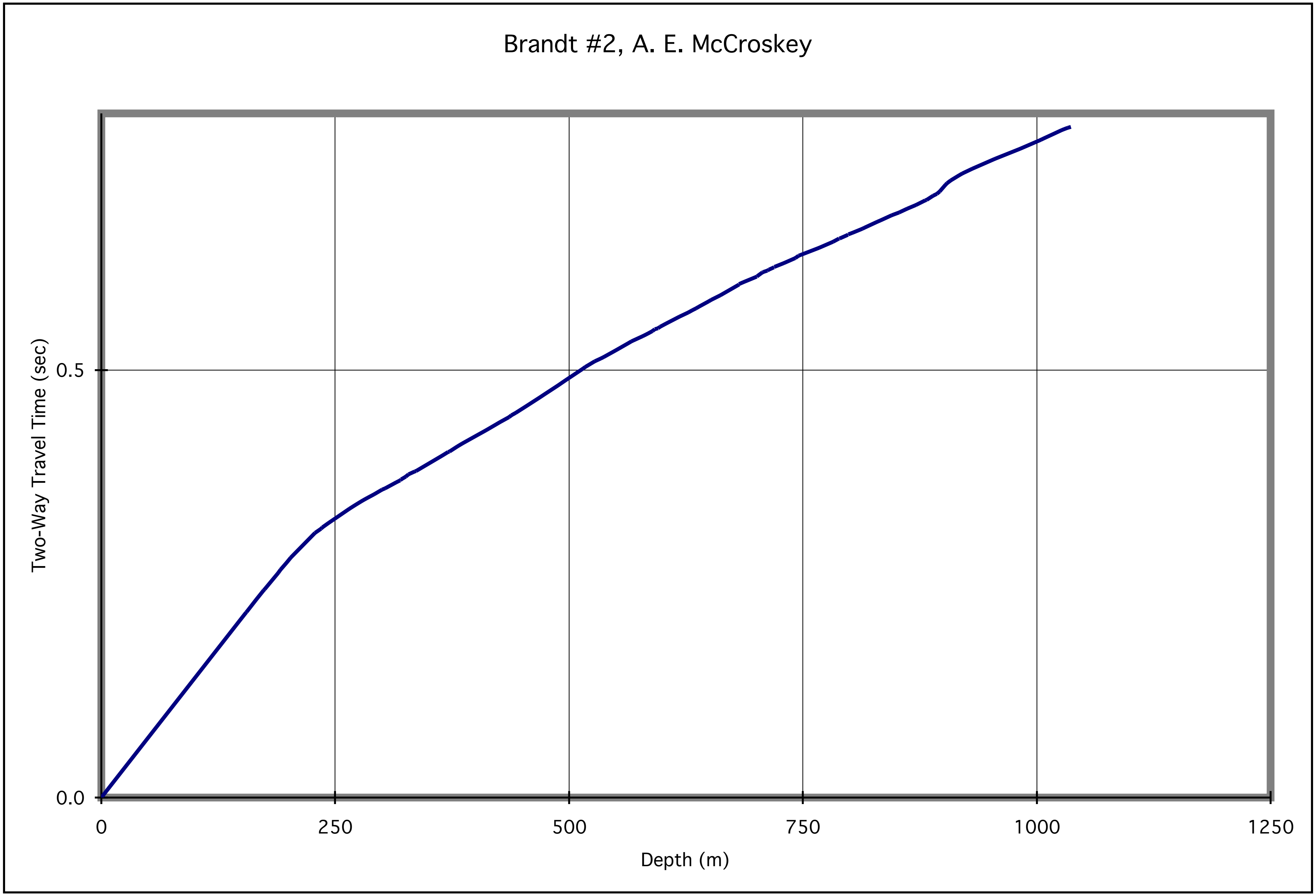

Brandt #2, A. E. McCroskey
Two-Way Travel Time (sec)
0.5
0.0
0
250
500
750
1000
1250
Depth (m)

Figure 34.

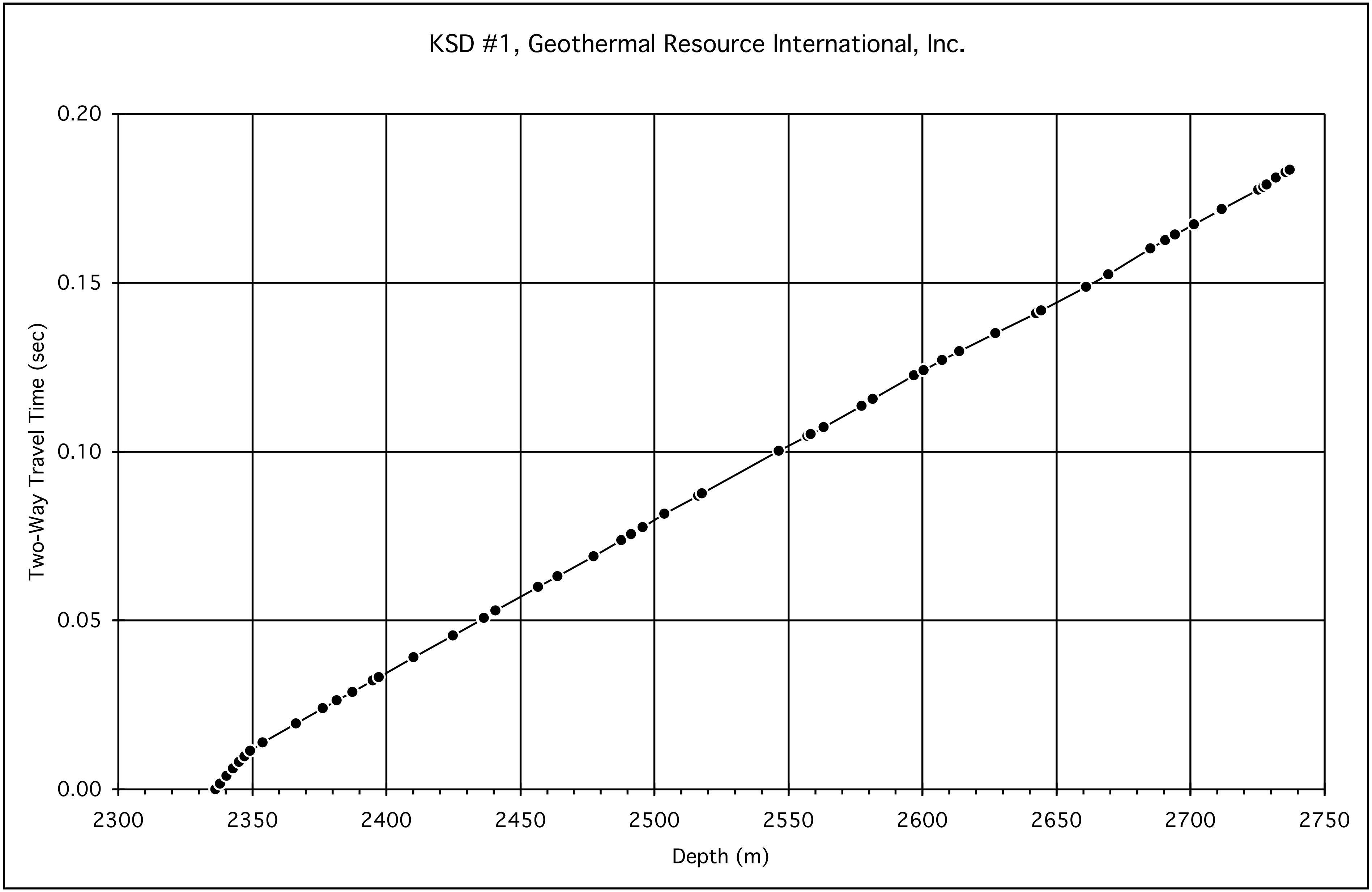

KSD #1, Geothermal Resource International, Inc.
Two-Way Travel Time (sec)
0.20
0.15
0.10
0.05
0.00
2300
2350
2400
2450
2500
2550
2600
2650
2700
2750
Depth (m)

Figure 35.

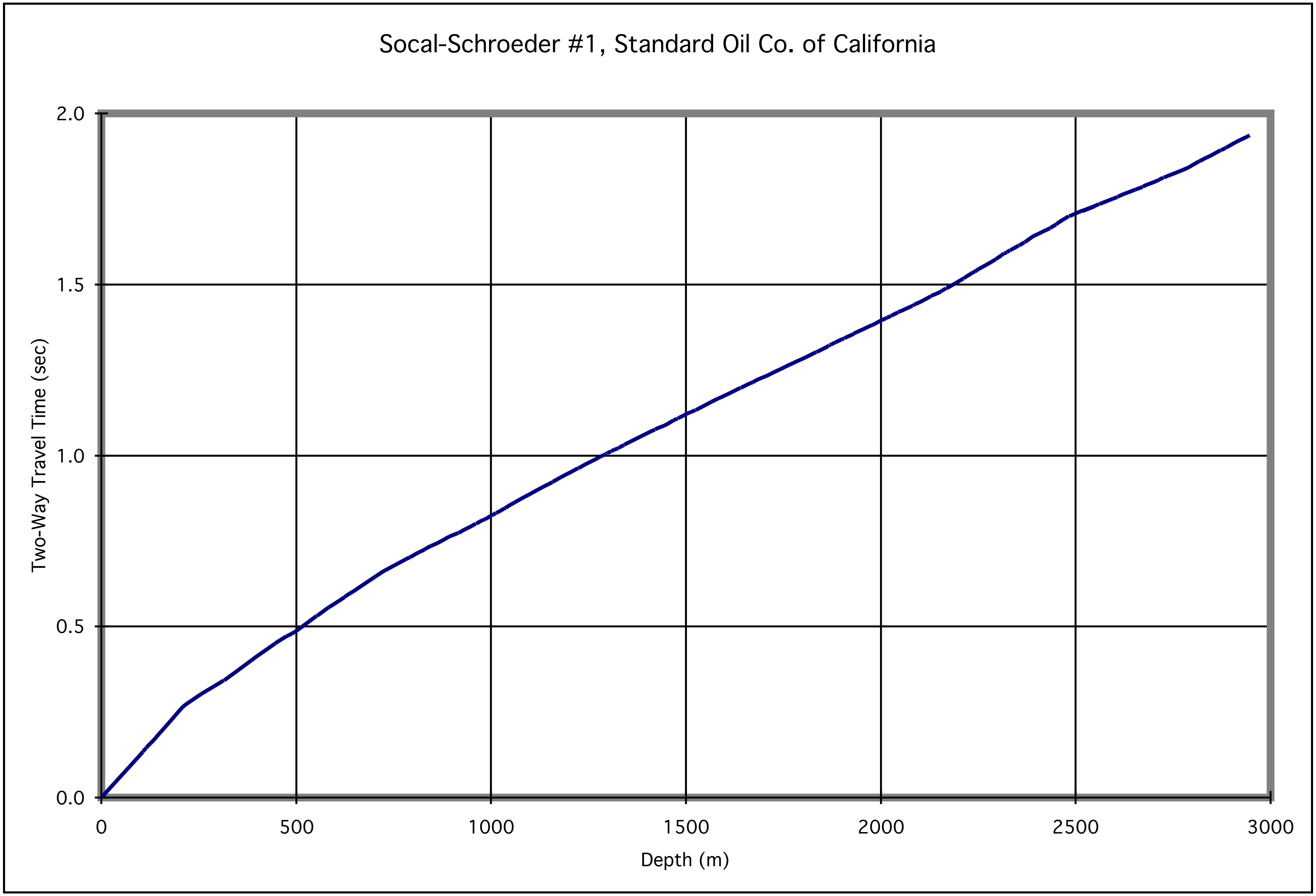

Socal-Schroeder #1, Standard Oil Co. of California
2.0
1.5
1.0
0.5
0.0
Two-Way Travel Time (sec)
0
500
1000
1500
2000
2500
3000
Depth (m)

Figure 36.

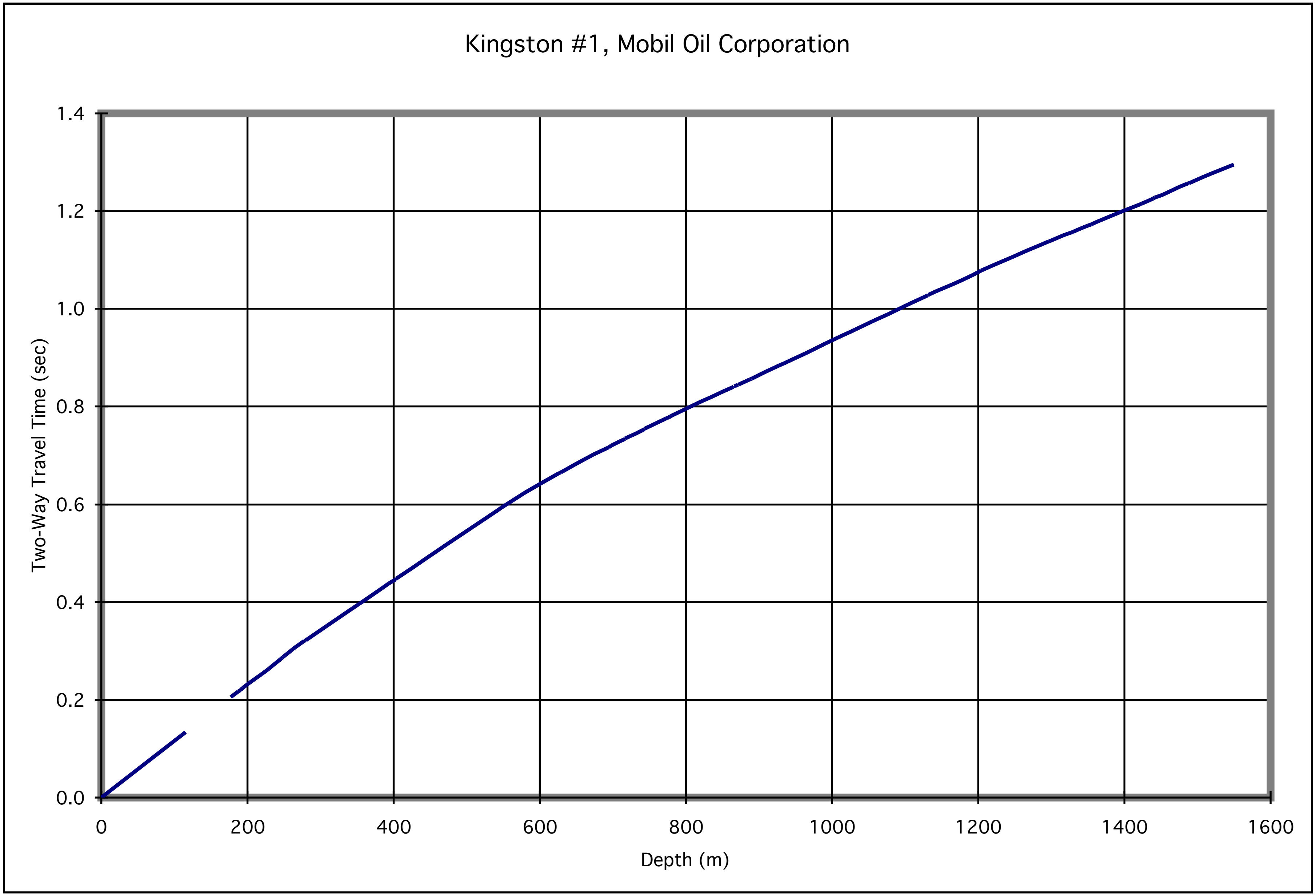

Kingston #1, Mobil Oil Corporation
Two-Way Travel Time (sec)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
0
200
400
600
800
1000
1200
1400
1600
Depth (m)

Figure 37.

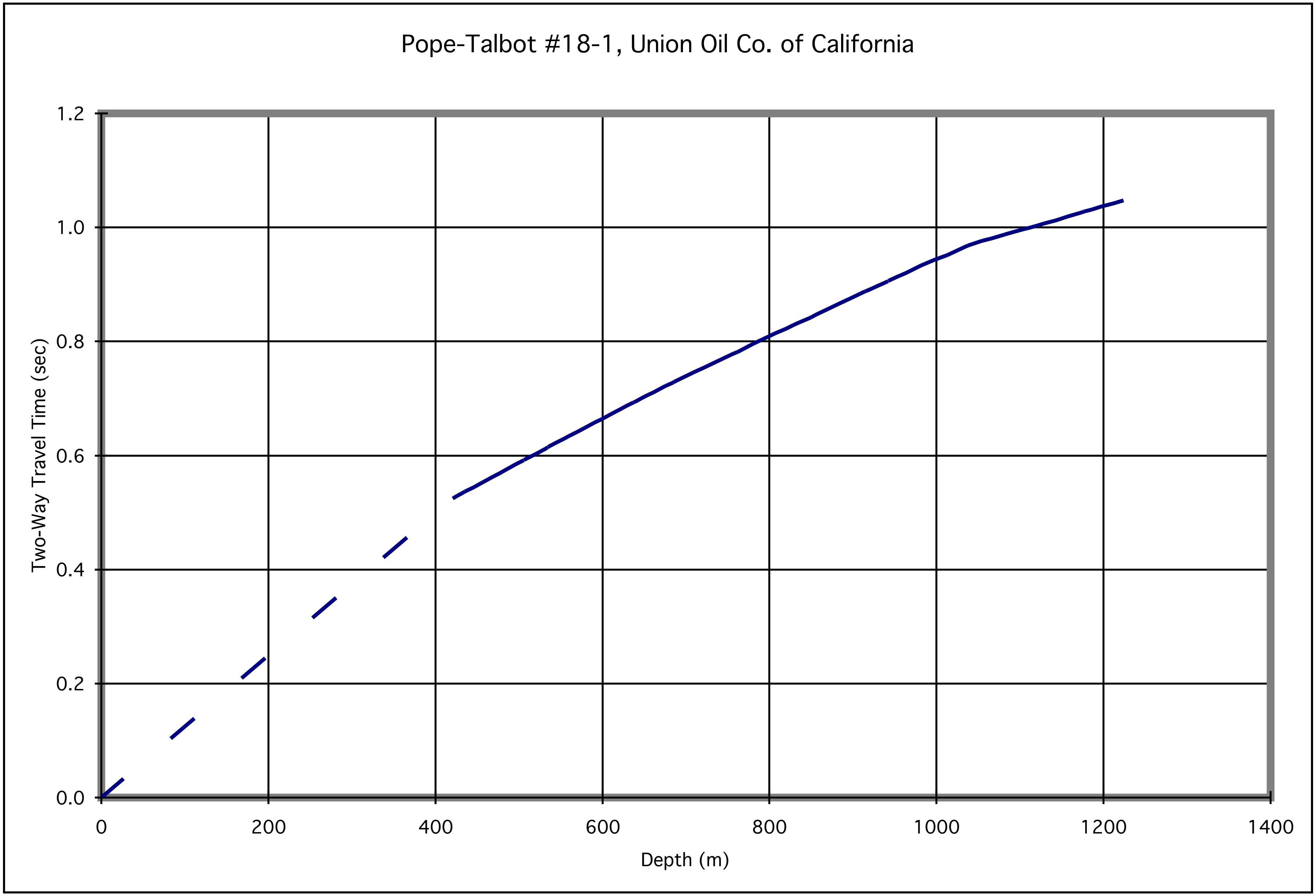

Pope-Talbot #18-1, Union Oil Co. of California
Two-Way Travel Time (sec)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
200
400
600
800
1000
1200
1400
Depth (m)

Figure 38.

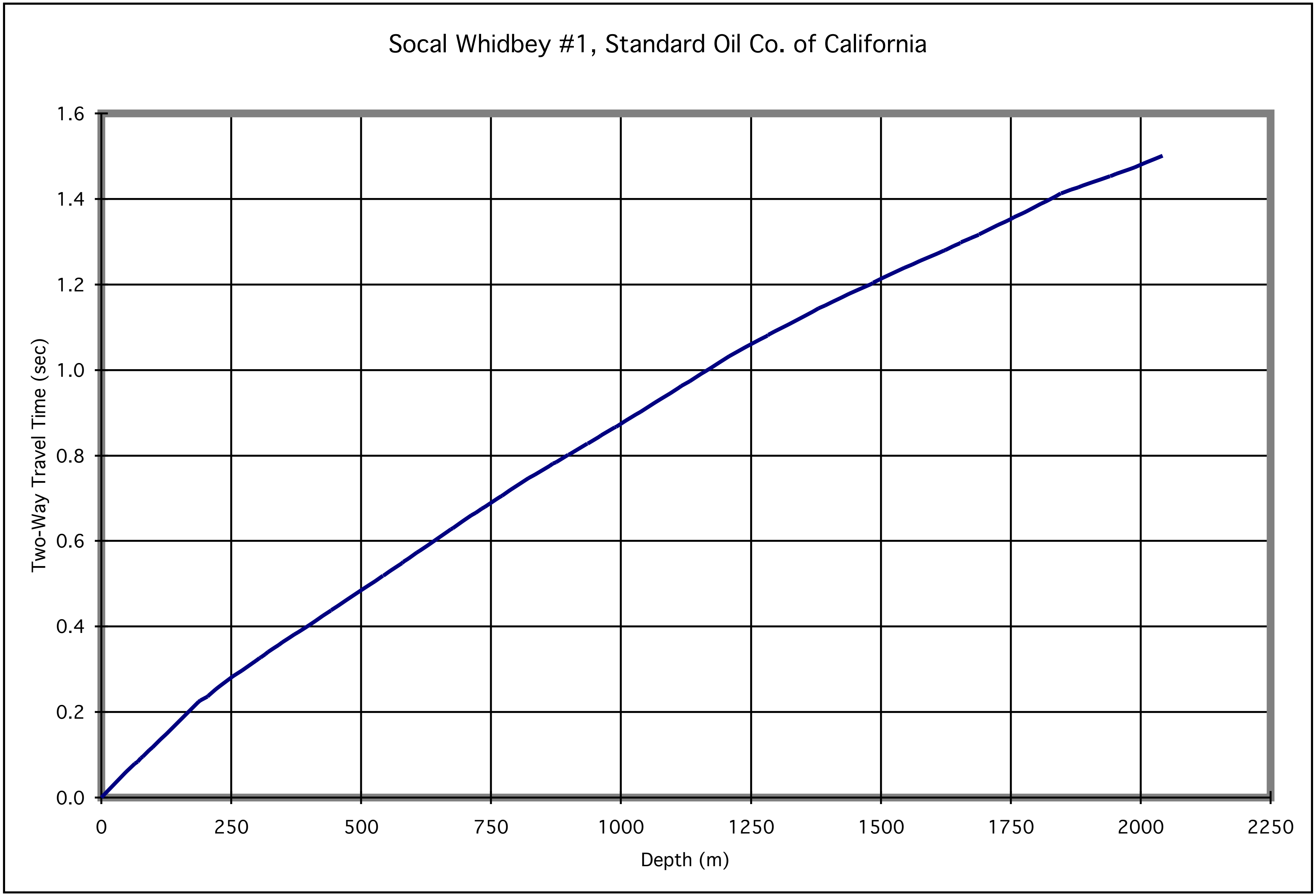

Socal Whidbey #1, Standard Oil Co. of California
Two-Way Travel Time (sec)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
250
500
750
1000
1250
1500
1750
2000
2250
Depth (m)

Figure 39.

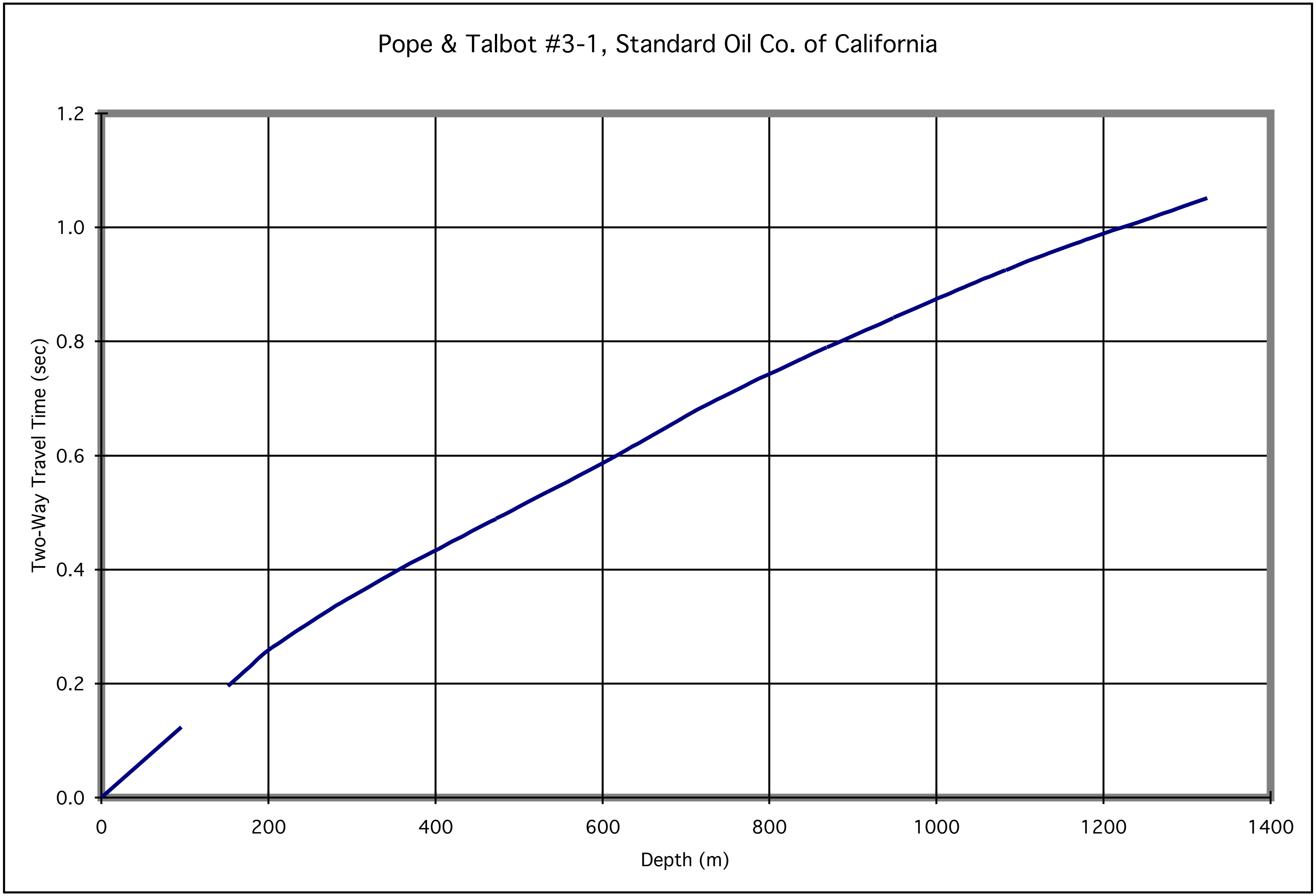
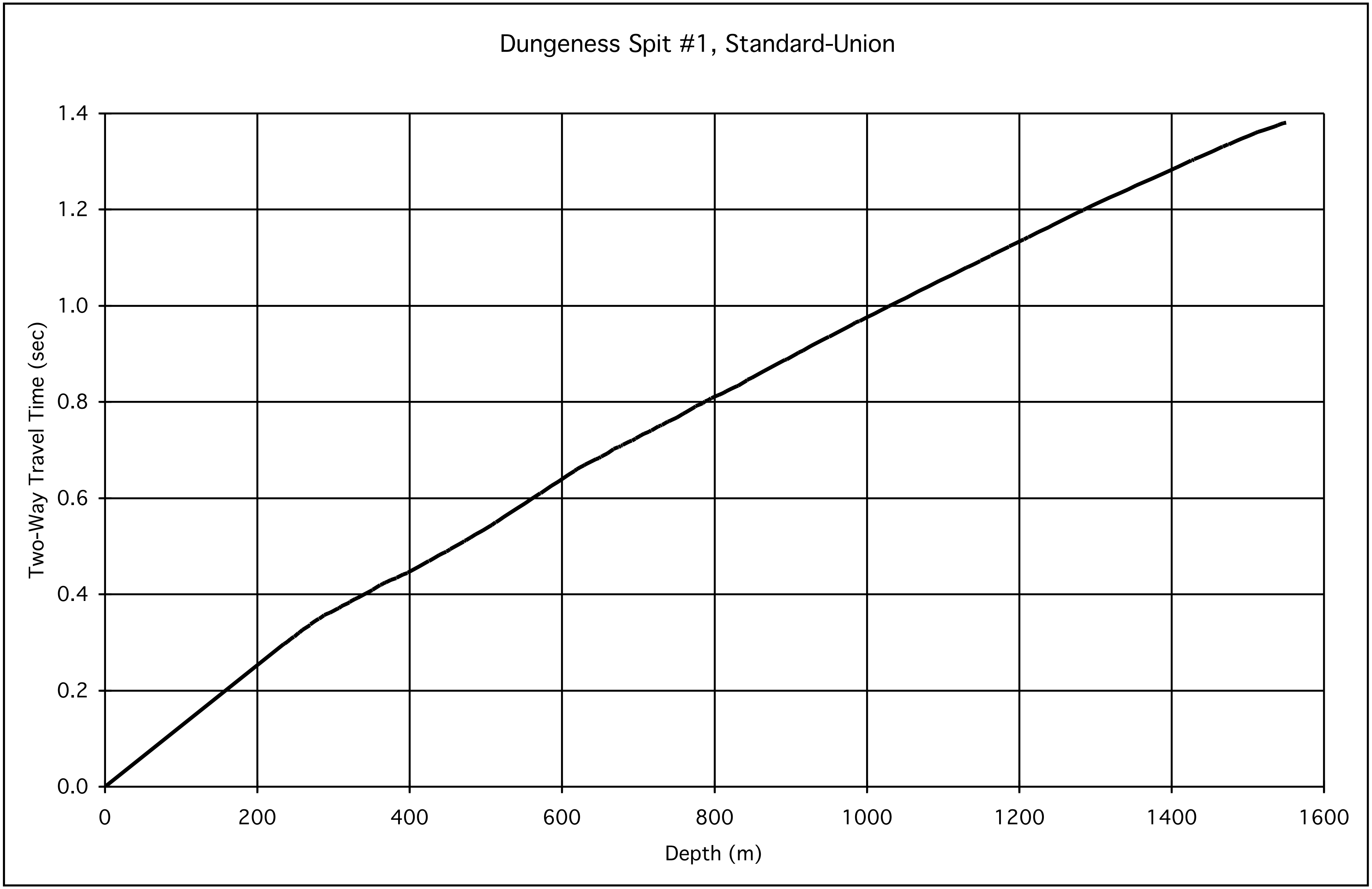

Pope & Talbot #3-1, Standard Oil Co. of California
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Two-Way Travel Time (sec)
0
200
400
600
800
1000
1200
1400
Depth (m)

Figure 40.



Dungeness Spit #1, Standard-Union
Two-Way Travel Time (sec)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
200
400
600
800
1000
1200
1400
1600
Depth (m)

Figure 41.

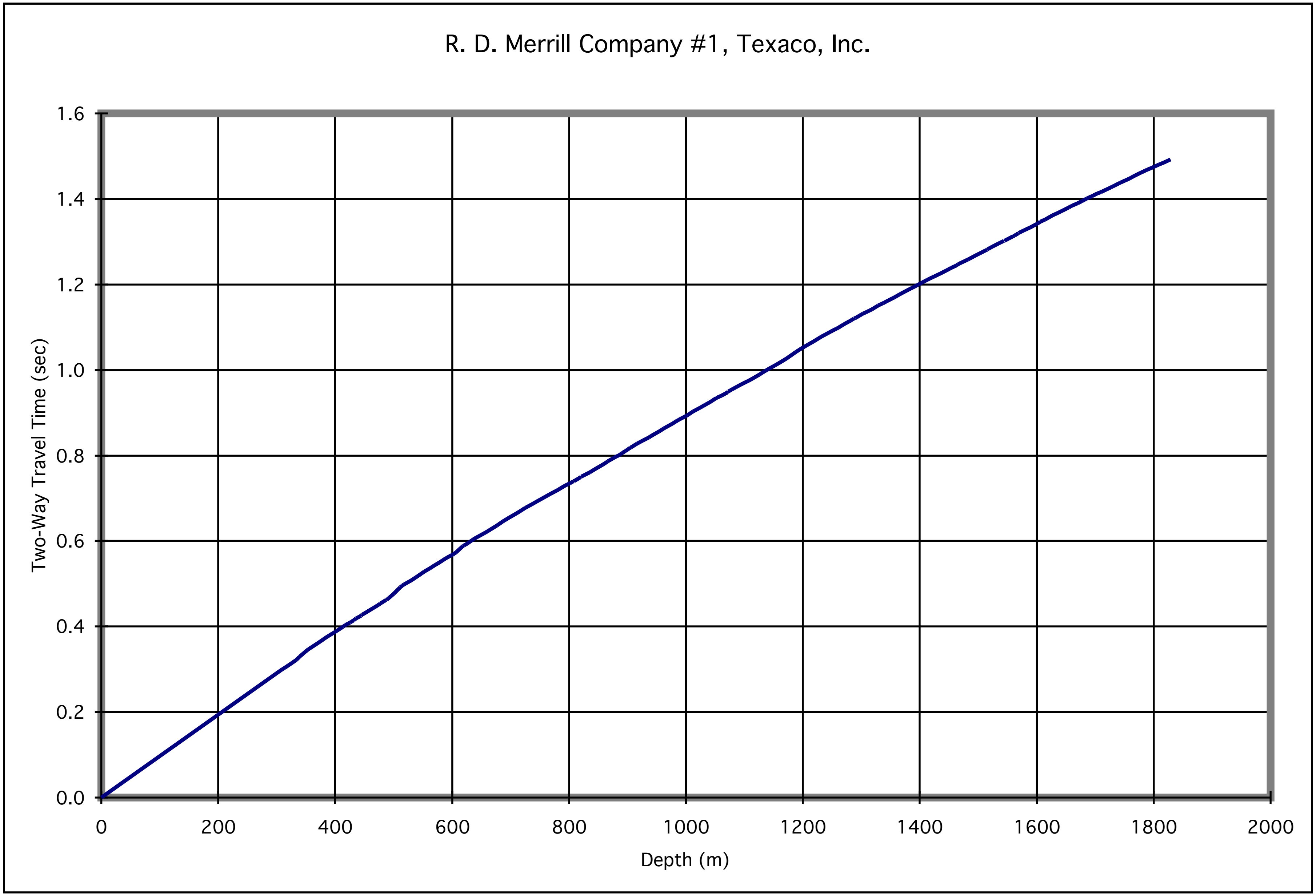

R. D. Merrill Company #1, Texaco, Inc.
Two-Way Travel Time (sec)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Depth (m)

Figure 42.

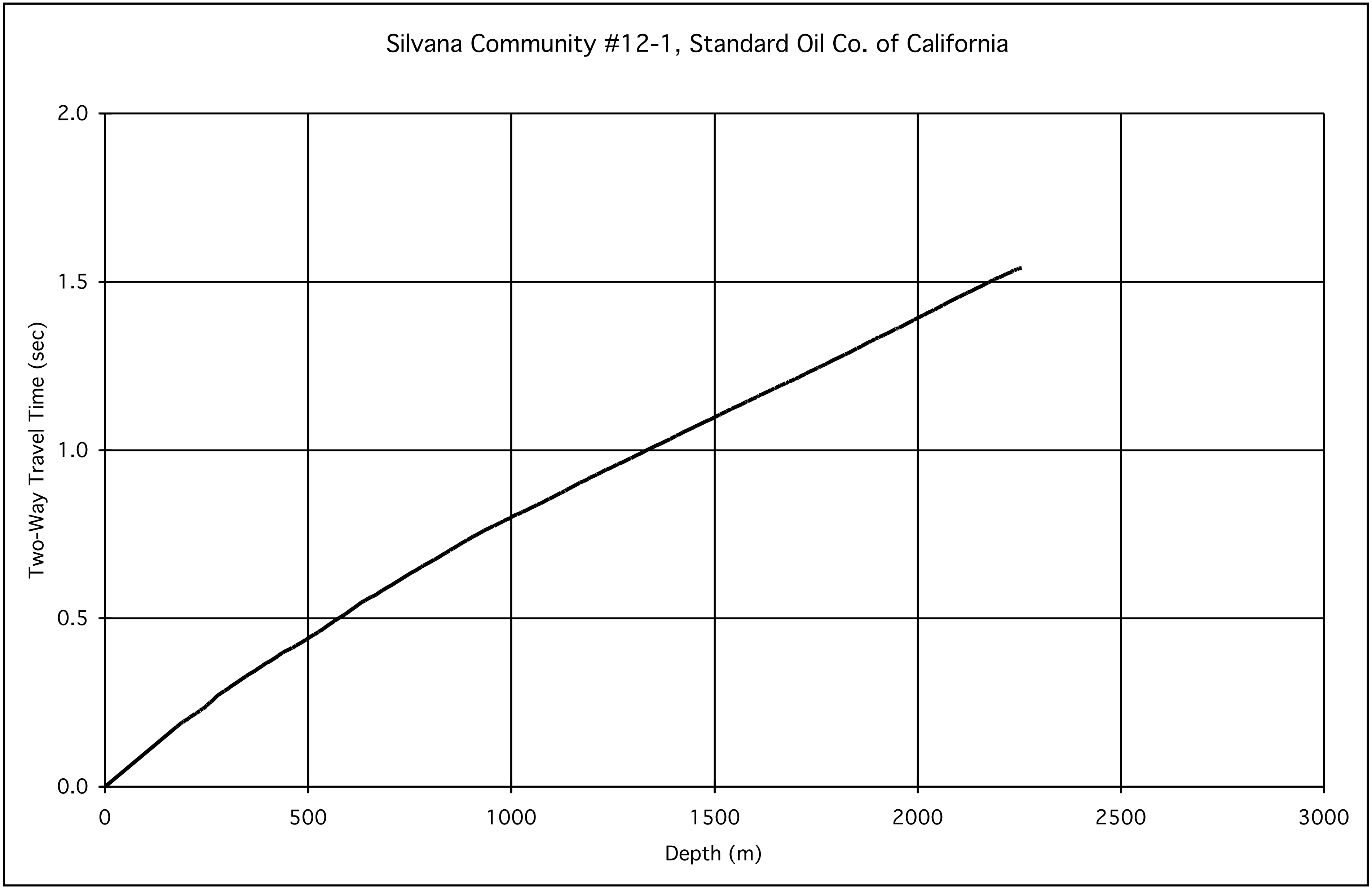

Silvana Community #12-1, Standard Oil Co. of California
Two-Way Travel Time (sec)
2.0
1.5
1.0
0.5
0.0
0
500
1000
1500
2000
2500
3000
Depth (m)

Figure 43.

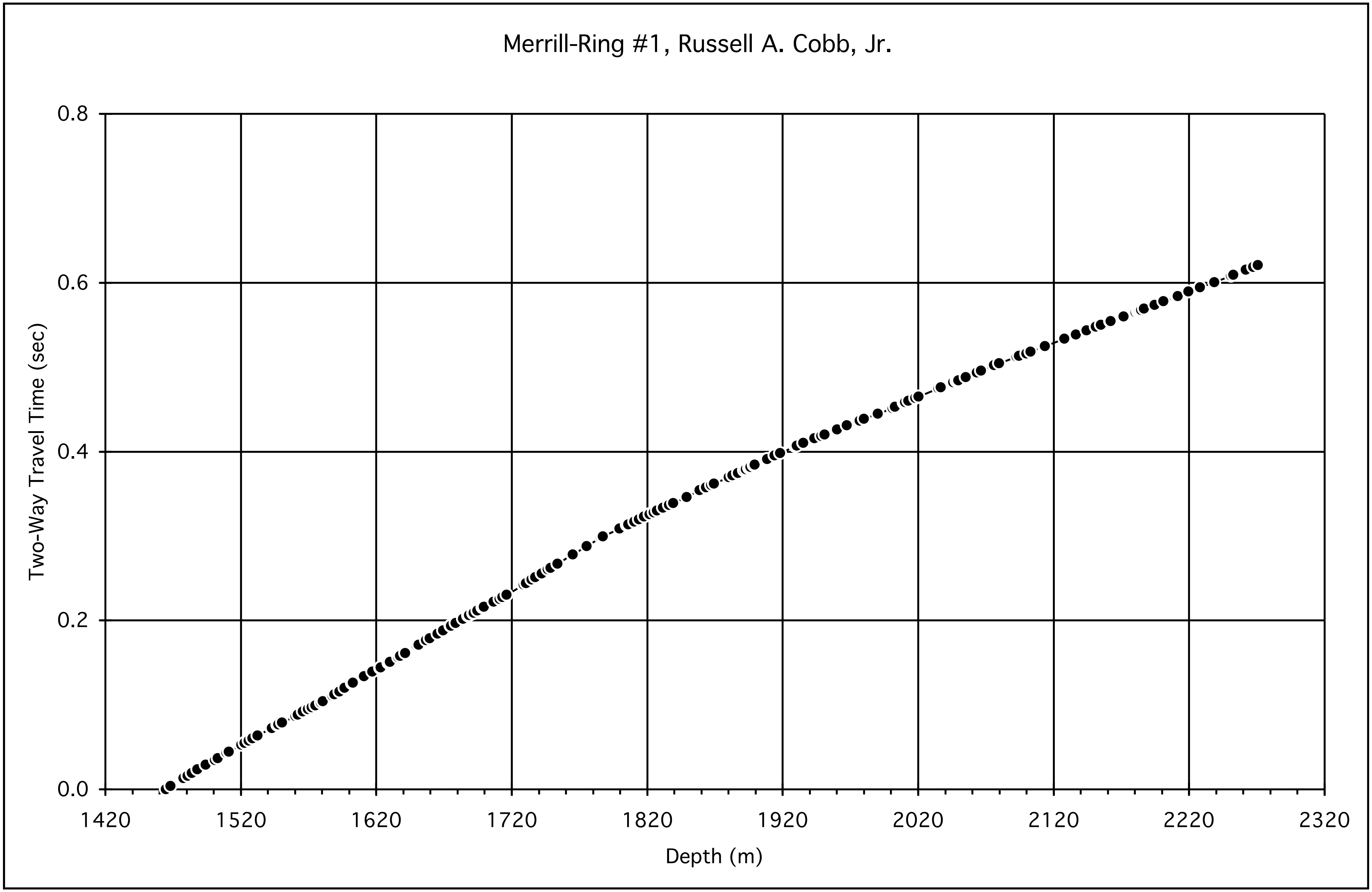
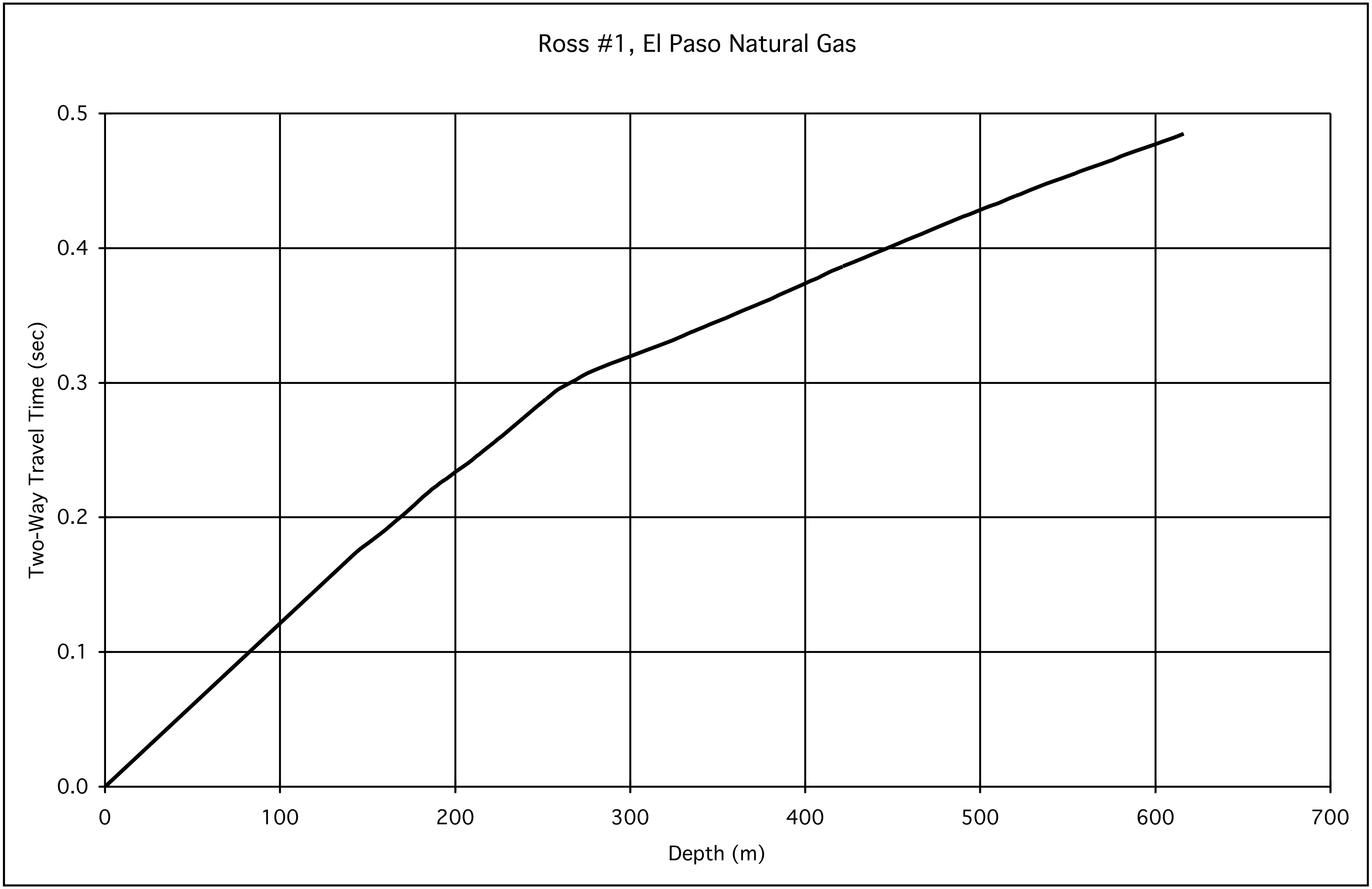

Merrill-Ring #1, Russell A. Cobb, Jr.
Two-Way Travel Time (sec)
0.0
0.2
0.4
0.6
0.8
1420
1520
1620
1720
1820
1920
2020
2120
2220
2320
Depth (m)

Figure 44.



Ross #1, El Paso Natural Gas
0.5
0.4
0.3
0.2
0.1
0.0
Two-Way Travel Time (sec)
0
100
200
300
400
500
600
700
Depth (m)

Figure 45.

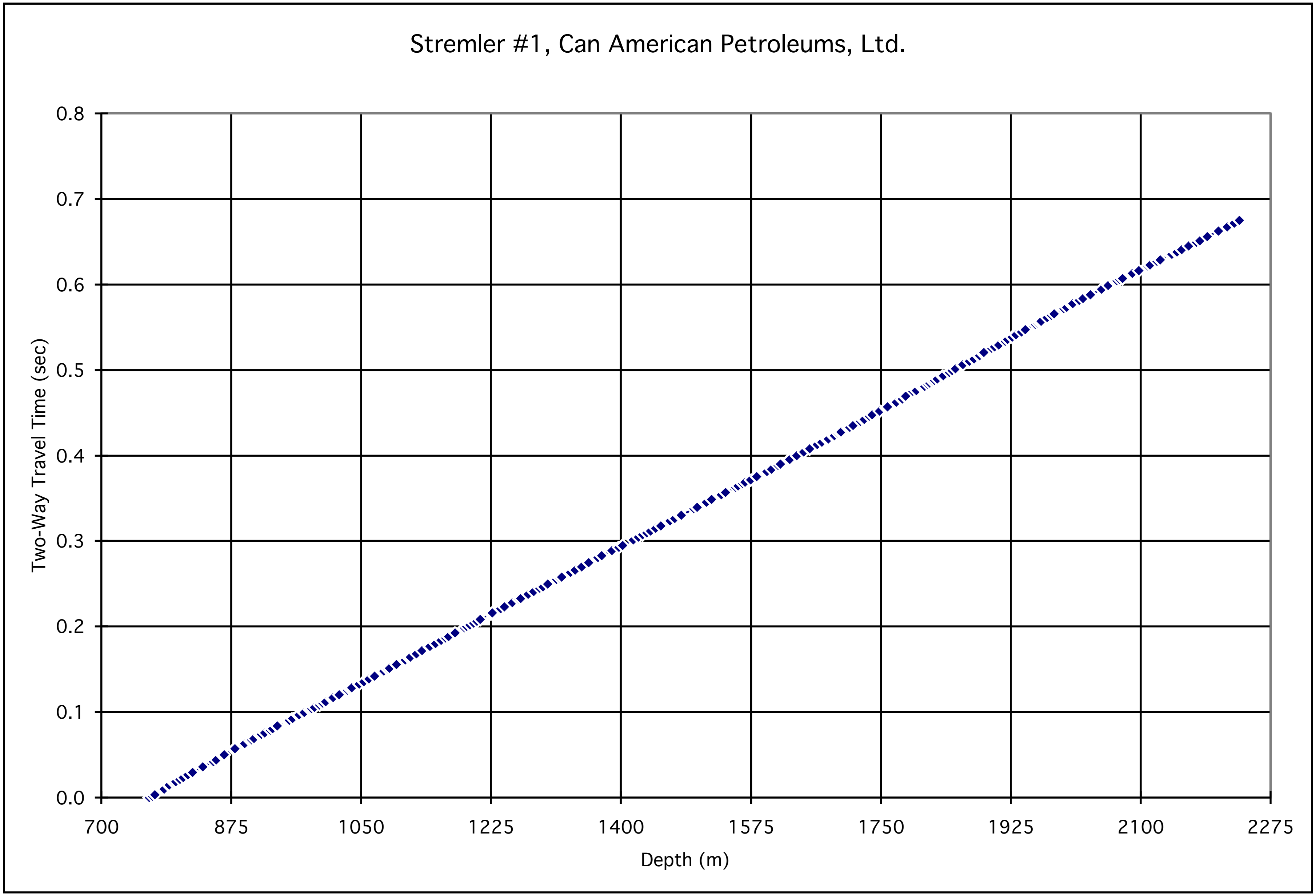

Stremler #1, Can American Petroleums, Ltd.
Two-Way Travel Time (sec)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
700
875
1050
1225
1400
1575
1750
1925
2100
2275
Depth (m)

Figure 46.