TECHNICAL REPORT NO. 63-88

DEEP WELL SITE REPORT
TERRY NO. 1 WELL, ORANGE COUNTY, FLORIDA

THE GEOTECHNICAL CORPORATION
3401 Shiloh Road
Garland, Texas

16 September 1963

CONTENTS

ILLUSTRATIONS

ILLUSTRATIONS, Continued

ILLUSTRATIONS, Continued

DEEP WELL SITE REPORT
TERRY NO. 1 WELL, ORANGE COUNTY, FLORIDA

ABSTRACT

The Terry No. 1 Deep Well in Orange County, Florida, has been prepared for use in a deep-well measurement program. The history and geology of the well are given. The deep well and surface instrumentation is described, typical recorded events are illustrated, and results of analysis of records are described.

DEEP WELL SITE REPORT
TERRY NO. 1 WELL, ORANGE COUNTY, FLORIDA

1. GEOLOGY AND HISTORY OF THE TERRY NO. 1 DEEP WELL

1.1 INTRODUCTION

The Terry No. 1 well was prepared for use in a deep-well measurement program as part of tasks 1h (1) and 1h (2) of the Statement of Work of Contract AF 33(600)-43369, Project VT/1139, Phase III.

1.2 WELL HISTORY

The well is situated in the north-central part of Orange County, Florida, about 15 miles southeast of the city of Orlando (see map, figure 1). It was originally drilled by Warren Petroleum Corporation as an exploratory test for oil and gas and was plugged and abandoned as a dry hole on September 13, 1955.

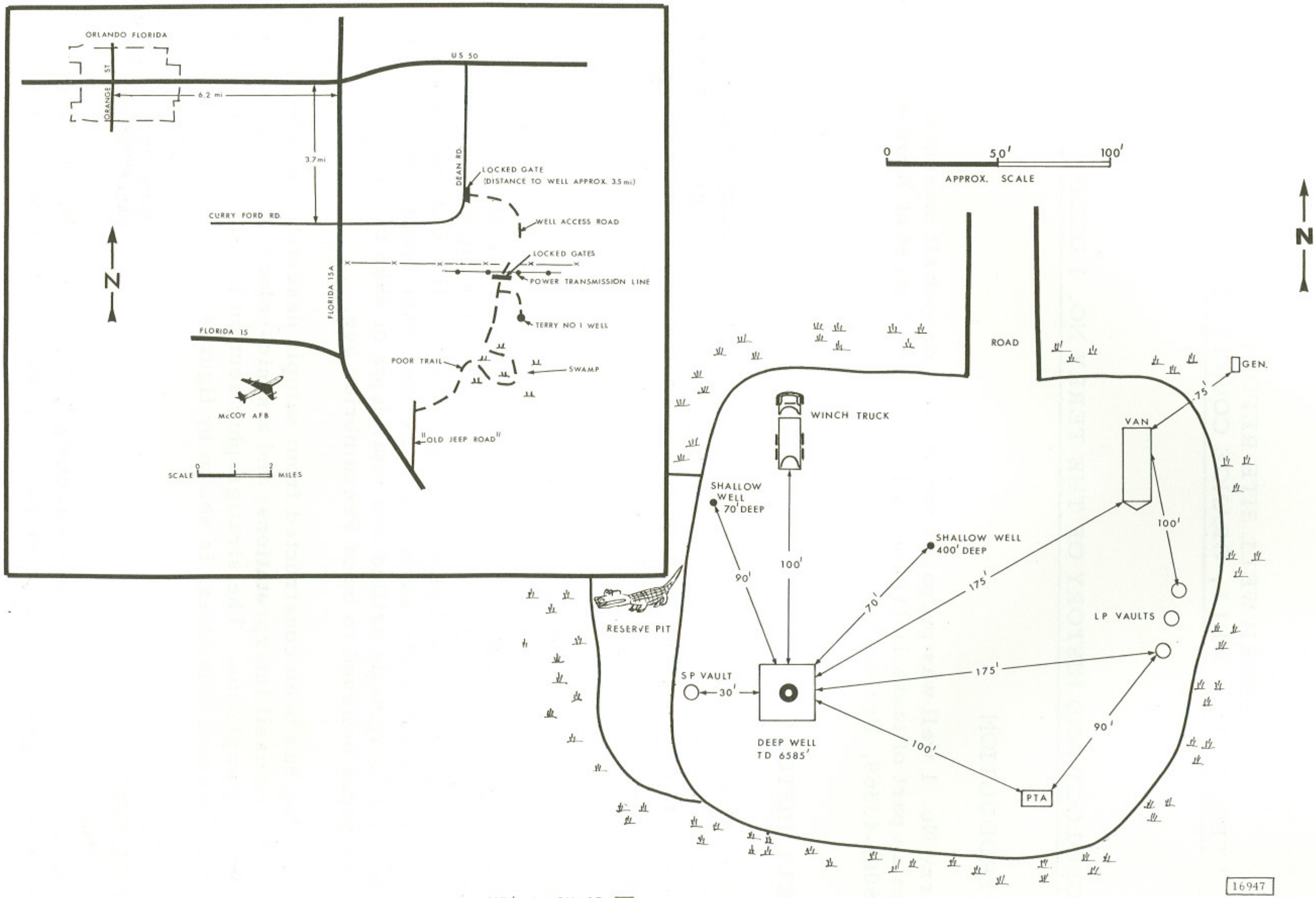
1.3 GEOLOGY OF THE AREA

Located in the east-central part of the Florida Peninsula, about 40 miles inland from the Atlantic coastline, the well is structurally situated on the southeast flank of the Ocala Uplift (see figures 2 and 3). Unconsolidated Quaternary sediments at the surface overlie the Ocala limestone of Eocene age. The well, originally drilled to a total depth of 6585 ft, is bottomed in crystalline rocks believed to be of Precambrian age.

A lithologic log has been constructed from sample descriptions, electrical logs, and microfossil interpretations; and a sonic-velocity log was conducted during well recompletion. The stratigraphic section penetrated, together with related interval velocities, is shown by figures 4 and 5.

1.4 WELL PREPARATION

Recompletion of the well as The Geotechnical Corporation No. 1 Terry was effected 24 April 1963. It was cleaned out to the original total depth of



VT/1139 PHASE III
TERRY NO.1 DEEP WELL
ORANGE COUNTY, FLORIDA
81° 13' 17" W
28° 28' 01" N

Figure 1. Site map, Terry No. 1

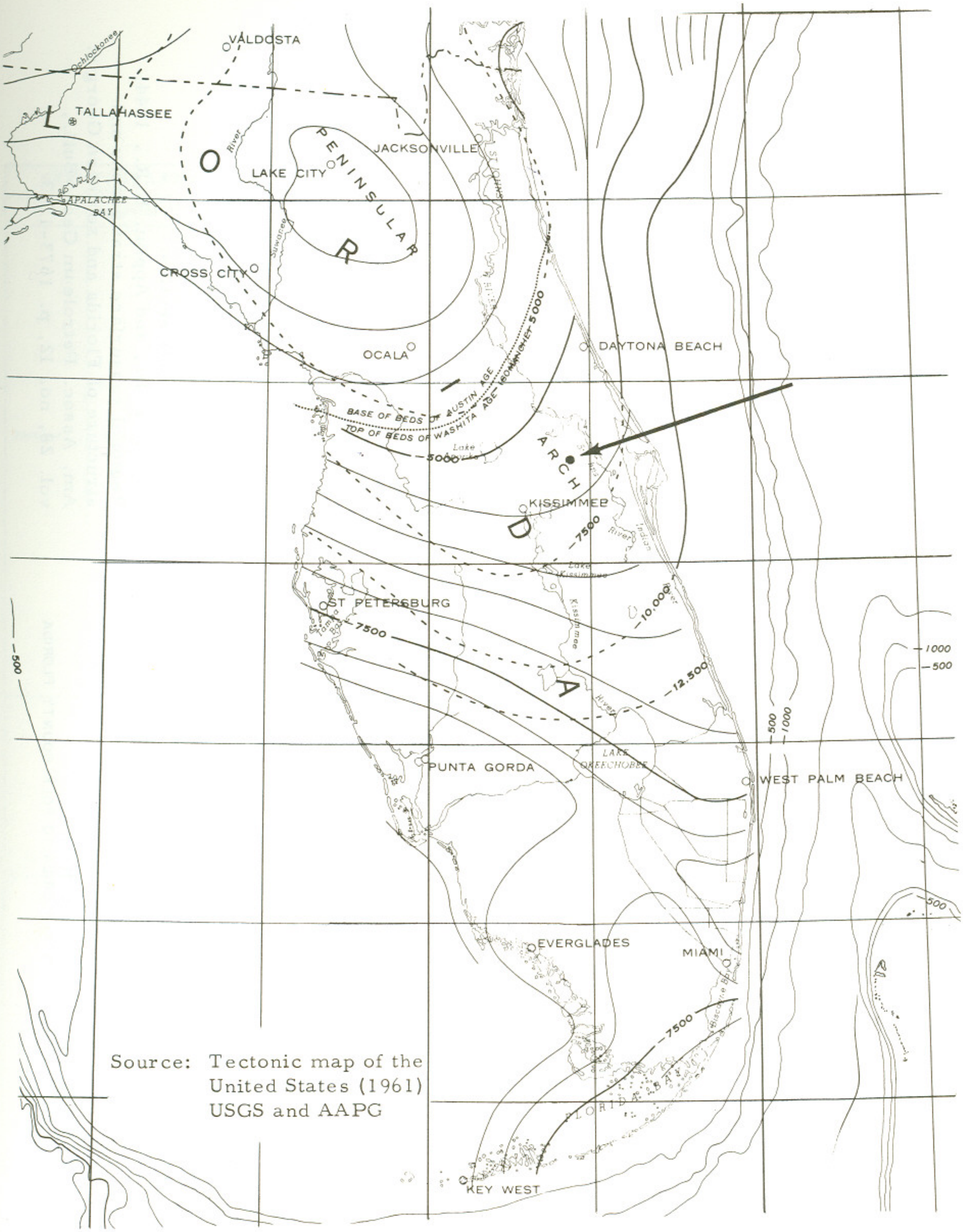
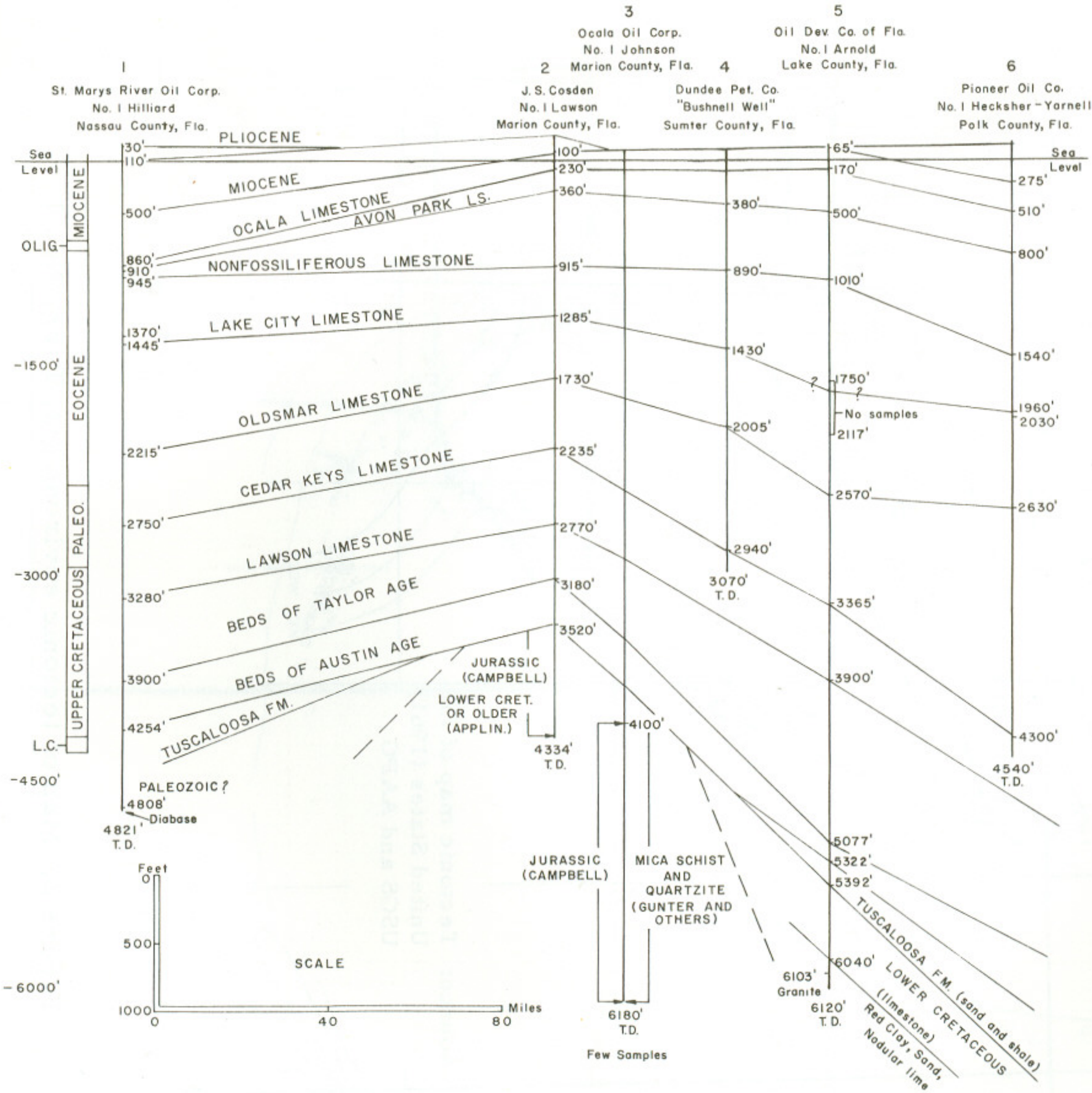
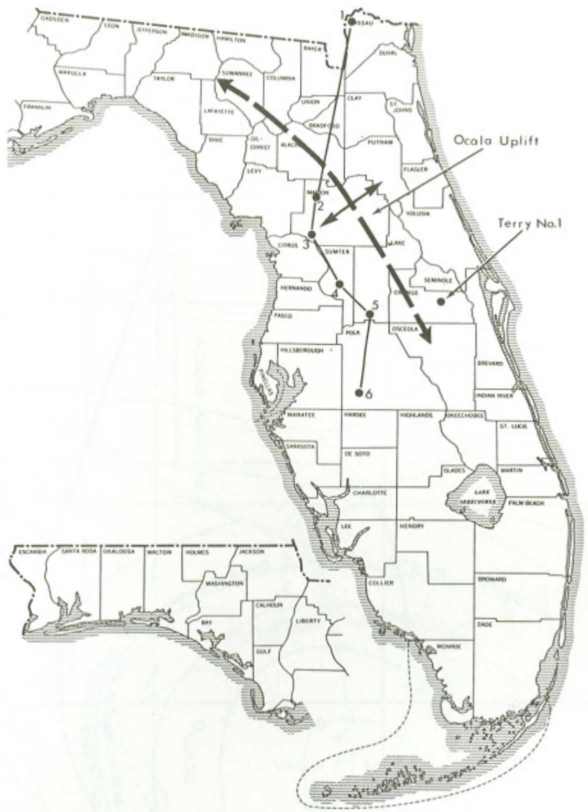


Figure 2. Map of tectonic environment, Terry No. 1



NORTH - SOUTH CROSS SECTION
THROUGH WELLS FROM NASSAU COUNTY FLORIDA TO POLK COUNTY FLORIDA



Source of cross section:
Applin, P. L., and Applin, E. R., 1944,
Regional subsurface stratigraphy and
structure of Florida and southern Georgia:
Am. Assoc. Petroleum Geol. Bull.,
vol. 28, no. 12, p. 1673-1753

Figure 3. Geologic cross section, Ocala uplift

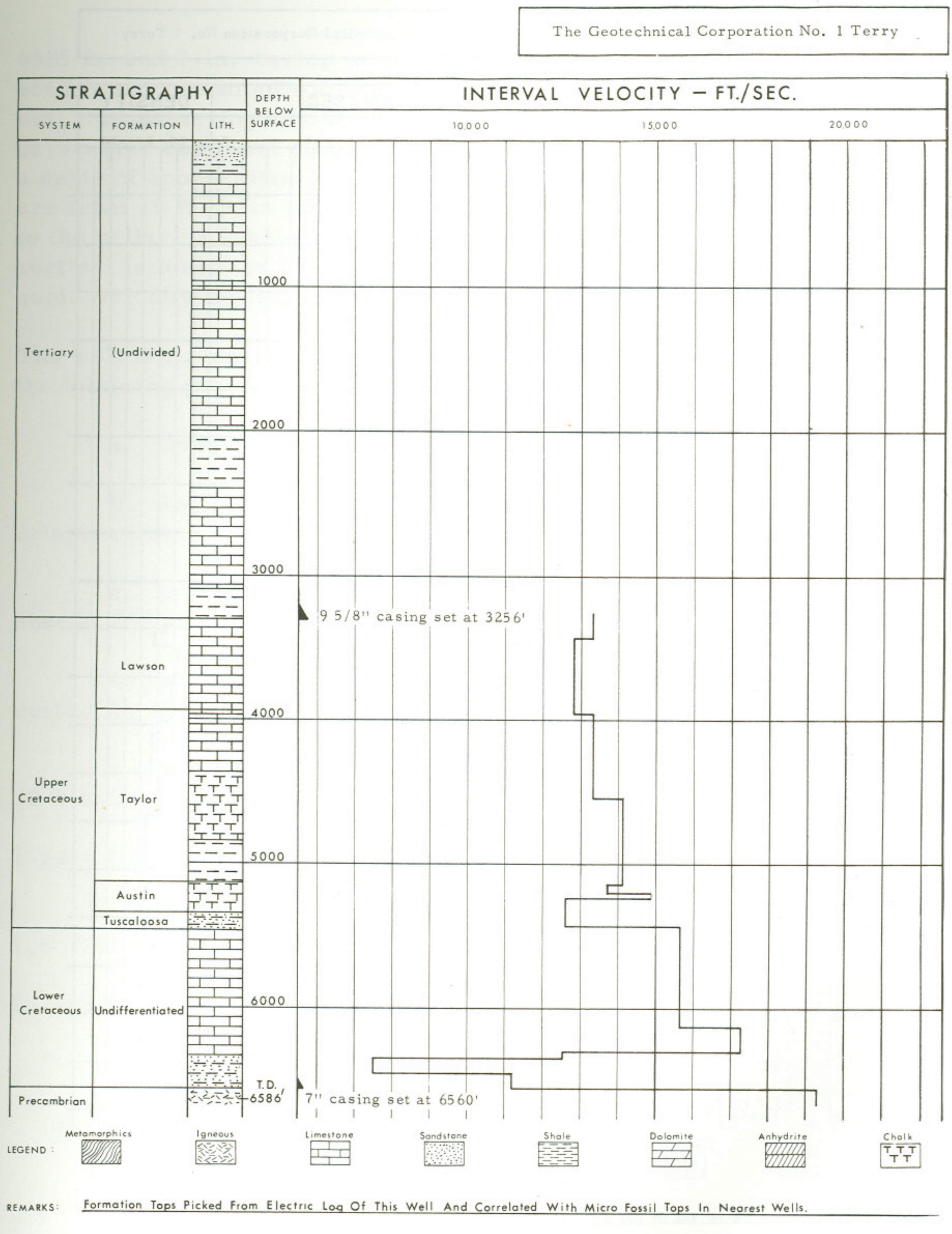


Figure 4. Stratigraphy and velocities, Terry No. 1

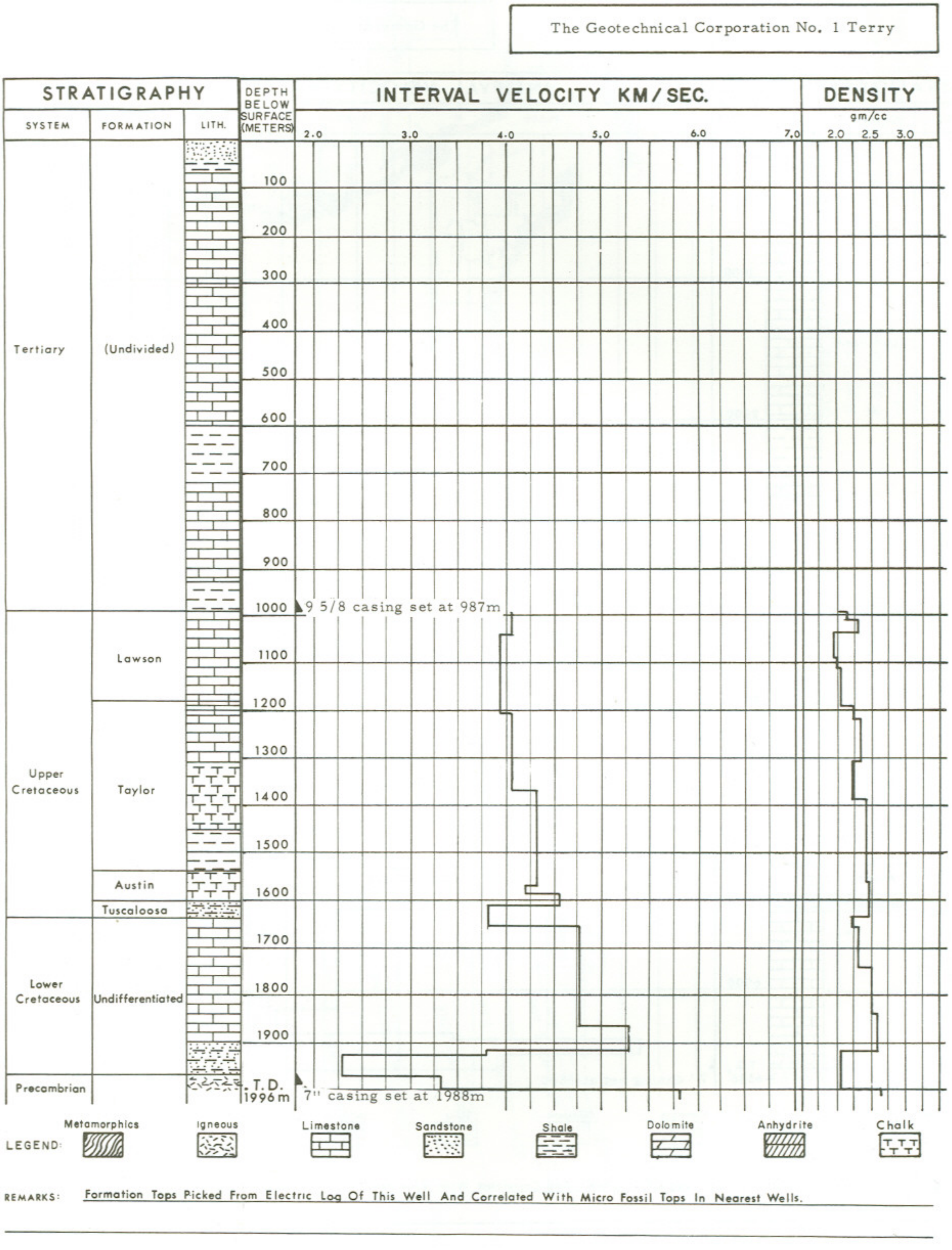


Figure 5. Stratigraphy and velocities (metric), Terry No. 1

6585 ft, and 7-in. casing was set below the top of the basement complex at 6560 ft and cemented with 680 sacks of cement. The casing plug was drilled out, thus achieving an operating environment of 25 ft of uncased hole in the crystalline basement complex. The top of the cement behind the casing is at a depth of approximately 3100 ft. (See figure 6.) All footage measurements are from 16 ft above permanent datum, which is the bradenhead flange located in the cellar, 3 ft below ground level. Maximum deviation of the hole from vertical is less than 5°. Maximum bottom hole temperature observed during sonic-velocity logging operations is 152° F.

The well is so completed that a seismometer may be optionally operated at the following positions.

a. On the bottom at 6585 ft in basement complex;

b. Anywhere in the 25 ft of open-hole penetration of the basement complex from 6585 ft to 6560 ft;

c. In the cased hole in the basement complex by locking in the casing shoe at 6560 ft;

d. In the cased hole at the approximate Lower Cretaceous/basement contact by locking in the casing float collar at 6549 ft; and

e. At any desired depth up the cased hole at intervals of approximately 30 ft at the casing collars.

Figure 7 shows the completed well site.

1.5 GENERAL

Detailed information on the site location and facilities is given in appendix 1.

2. MEASUREMENT PROGRAM AT THE TERRY NO. 1 DEEP WELL

2.1 INTRODUCTION

Measurements were made with surface instruments and with a deep-well seismometer operated at various depths in the well. The surface

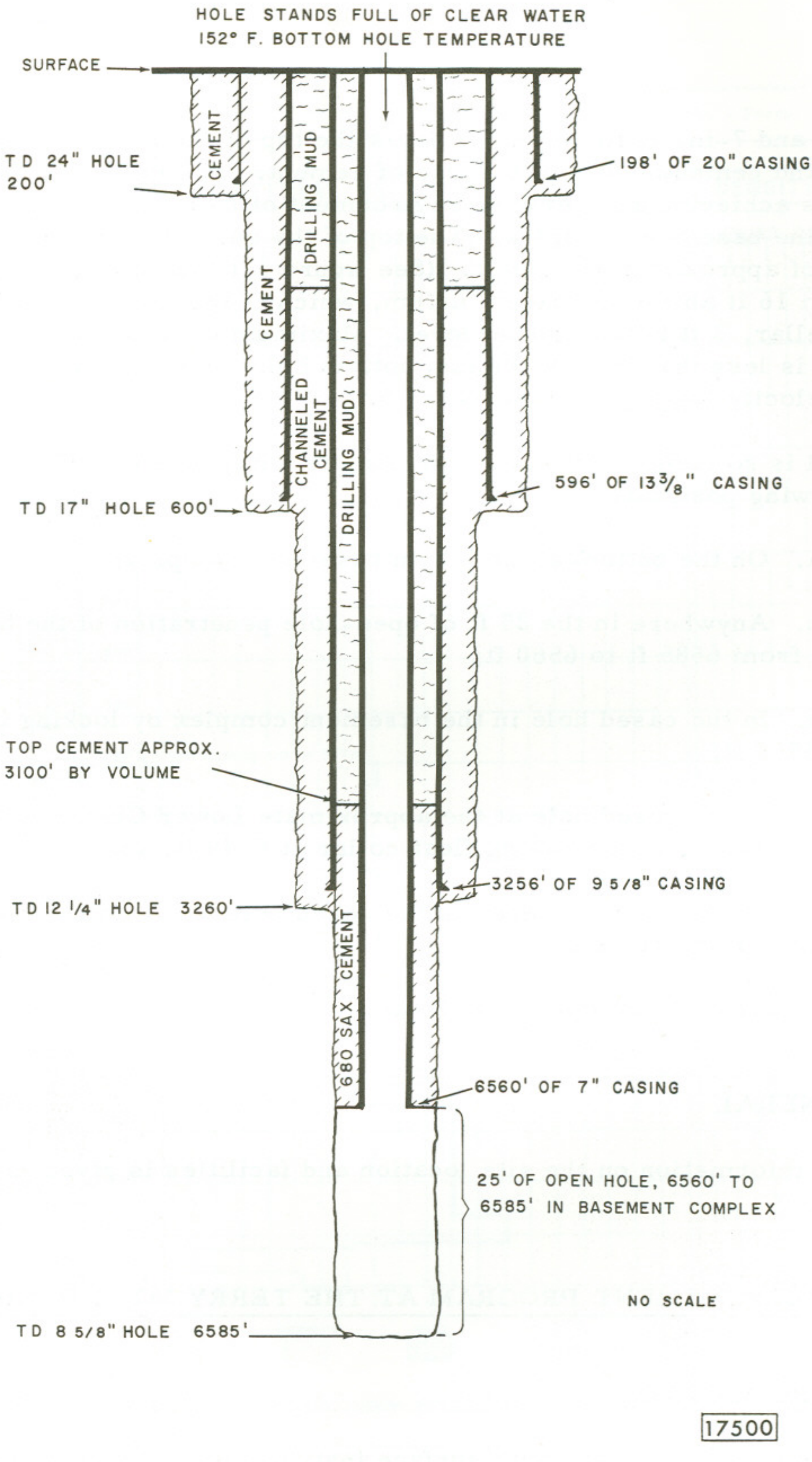


Figure 6. Casing diagram, Terry No. 1

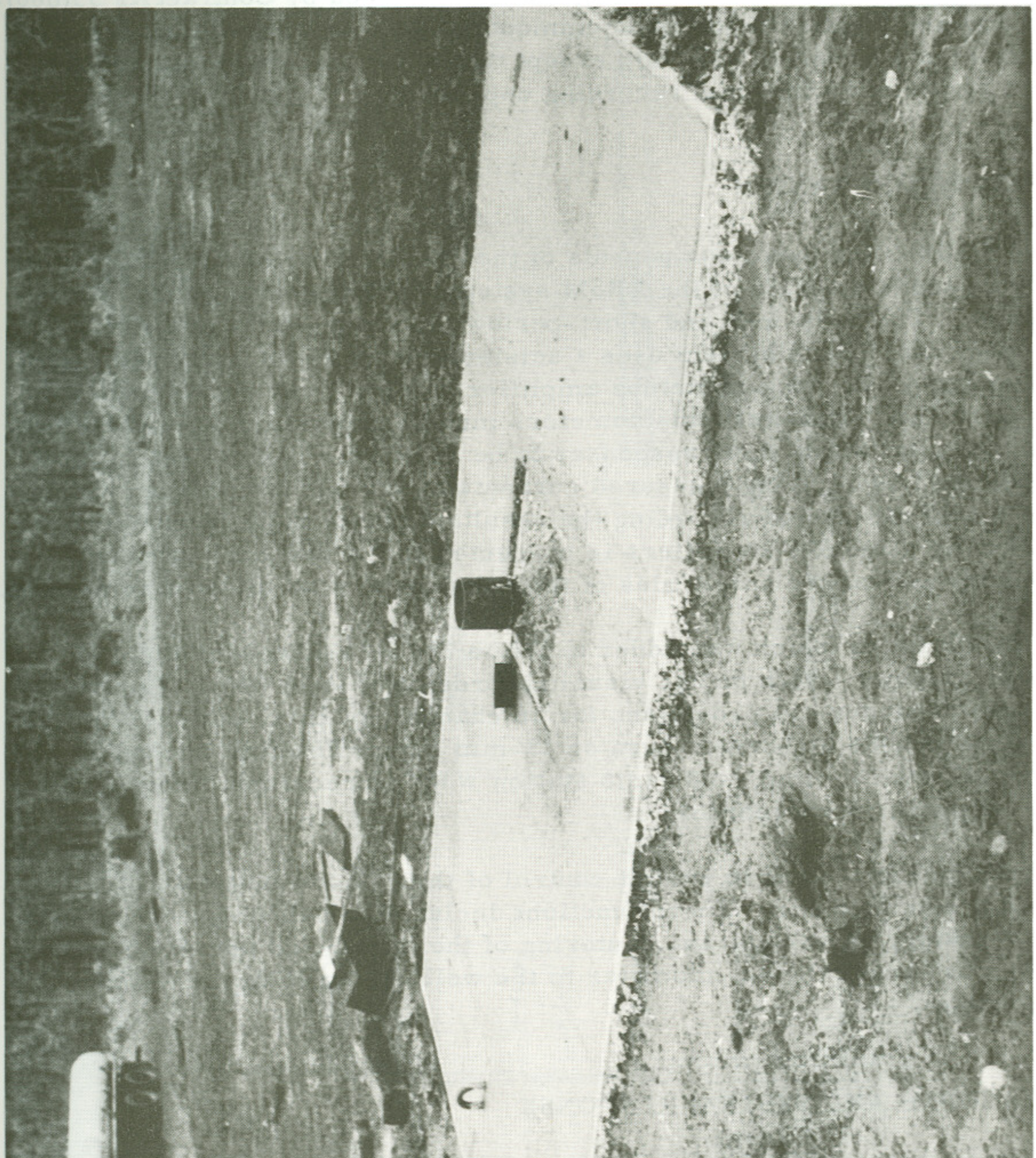


Figure 7. Completed well site, Terry No. 1

instrumentation consisted of a recording van and associated equipment, short-period and long-period seismometers, and phototube amplifiers. The recording van and surface instruments were provided by Contract AF 33(600)-41694 and are identical with the equipment used in the Long-Range Seismic Measurements Program (LRSM), except that a film recorder was added to the van to provide additional recording capability.

2.2 INSTRUMENTATION

Figure 8 shows the basic components of the deep-well seismograph. Figure 9 shows a block diagram of the LRSM system, including long-period instrumentation. The deep-well and short-period surface systems are similar in their response. Each system uses a seismometer with an undamped natural frequency of 1 cps and a phototube amplifier using a 5 cps galvanometer. The surface and deep-well seismometers include provisions for remote calibration, thus allowing their responses to be verified. The calibration is accomplished by applying measured currents at various frequencies to the internal calibrators and recording the resultant output of the system. The output of the phototube amplifiers is connected to the recorders through attenuators so that the amplitudes of the records may be adjusted as desired.

The film recorder which was added to the van is a 16-channel automatic processing device which makes visual records on 16-mm film. The magnetic tape recorder has provisions for 16 channels of data, and the Mark II recorders provide 4 channels each on 35-mm film. The film recorders also record station time, and radio station WWV is recorded on one channel of the magnetic tape recorder.

A control device is used to permit control of the various functions of the deep-well seismometer. These functions include the calibration mentioned above, locking, unlocking, and centering of the mass, and operation of a hole lock to secure the seismometer to the well casing at any selected casing collar.

2.3 RECORDS AND SYSTEM RESPONSE

Figures 10 and 11 show events recorded in the well. Figures 12 and 13 show the response of the seismographs to steady-state calibration frequencies.

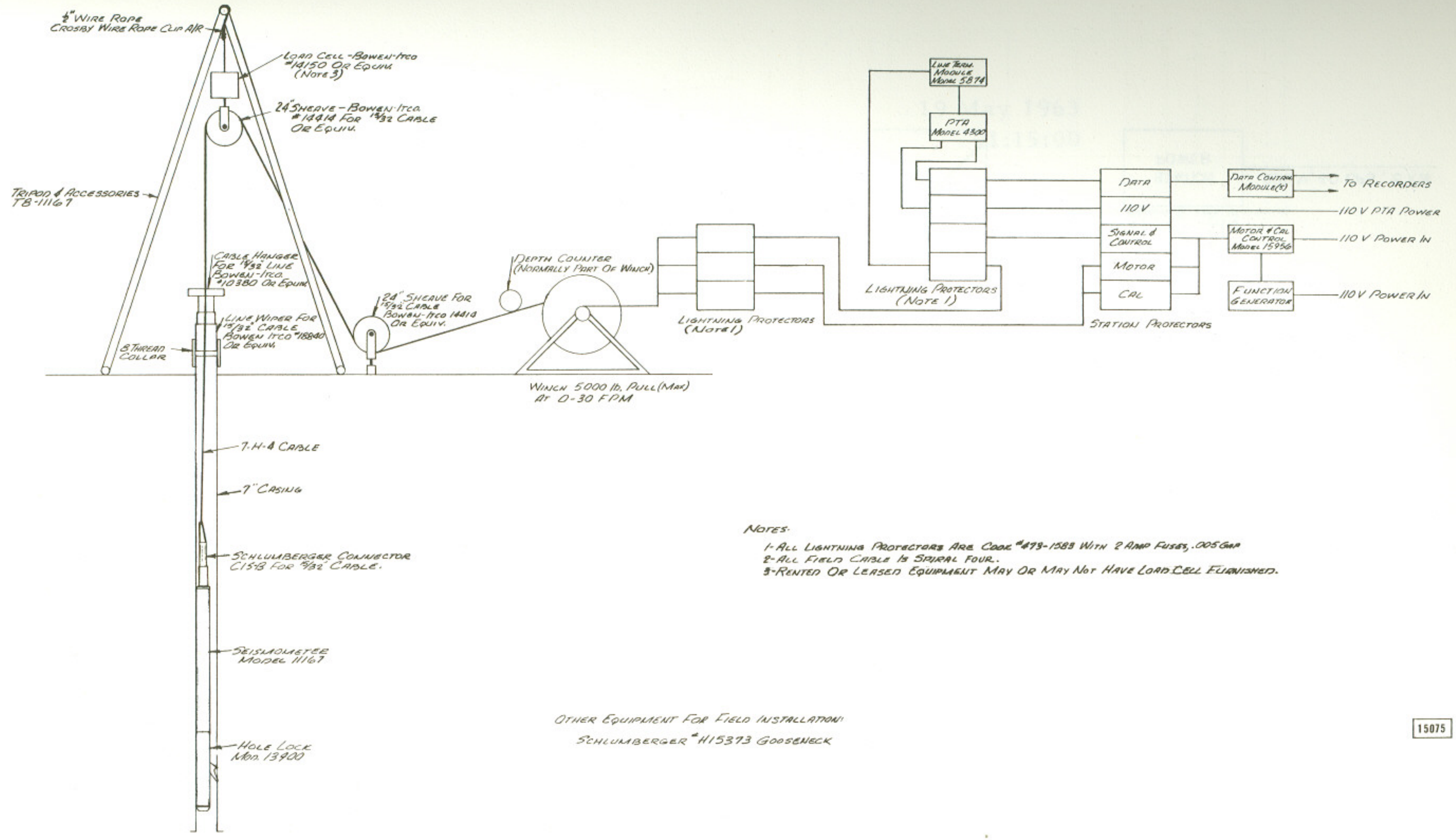


Figure 8. Deep-well Seismograph System, Model 15075

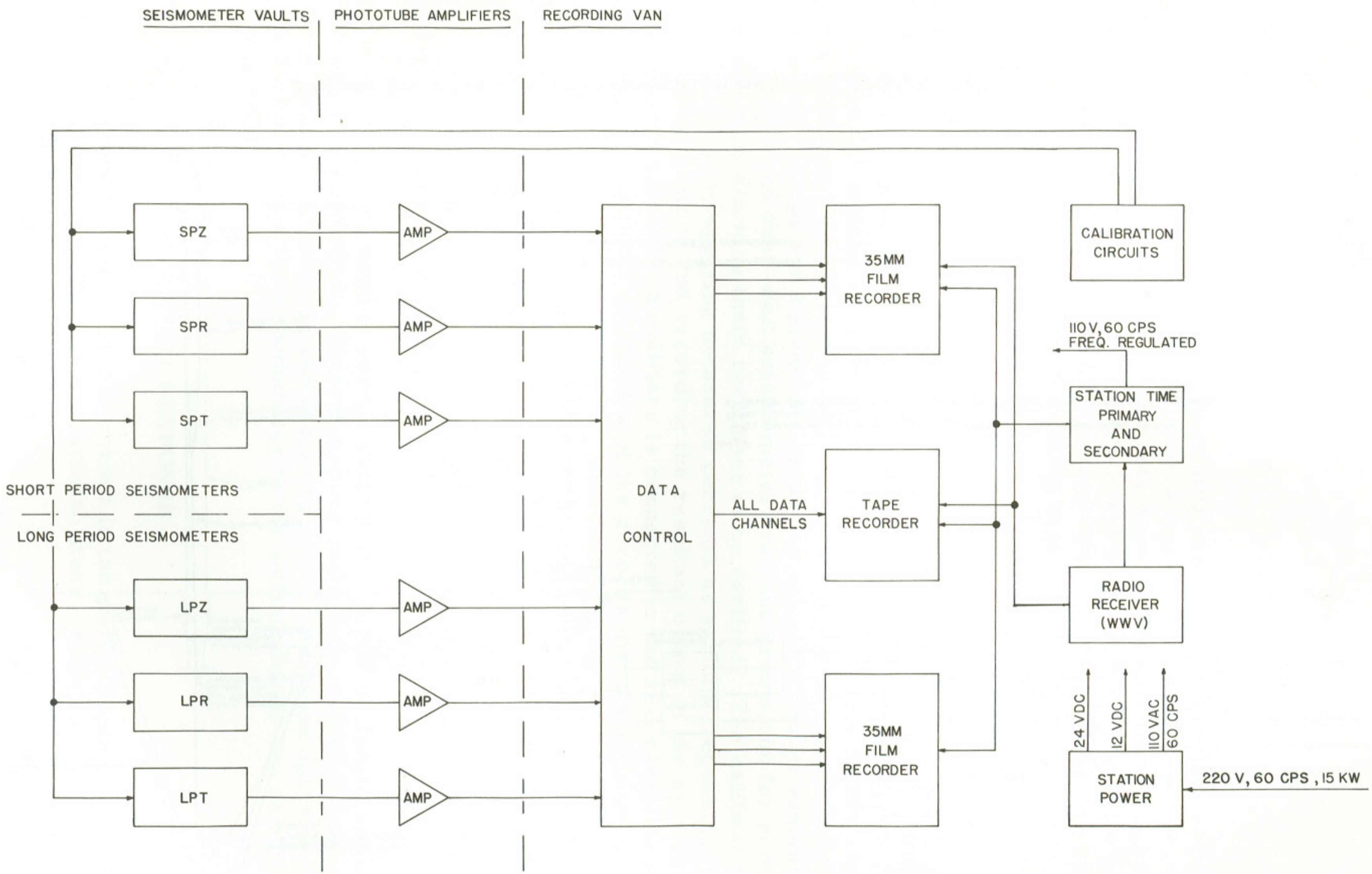


Figure 9. Simplified block diagram of the LRSM seismograph system

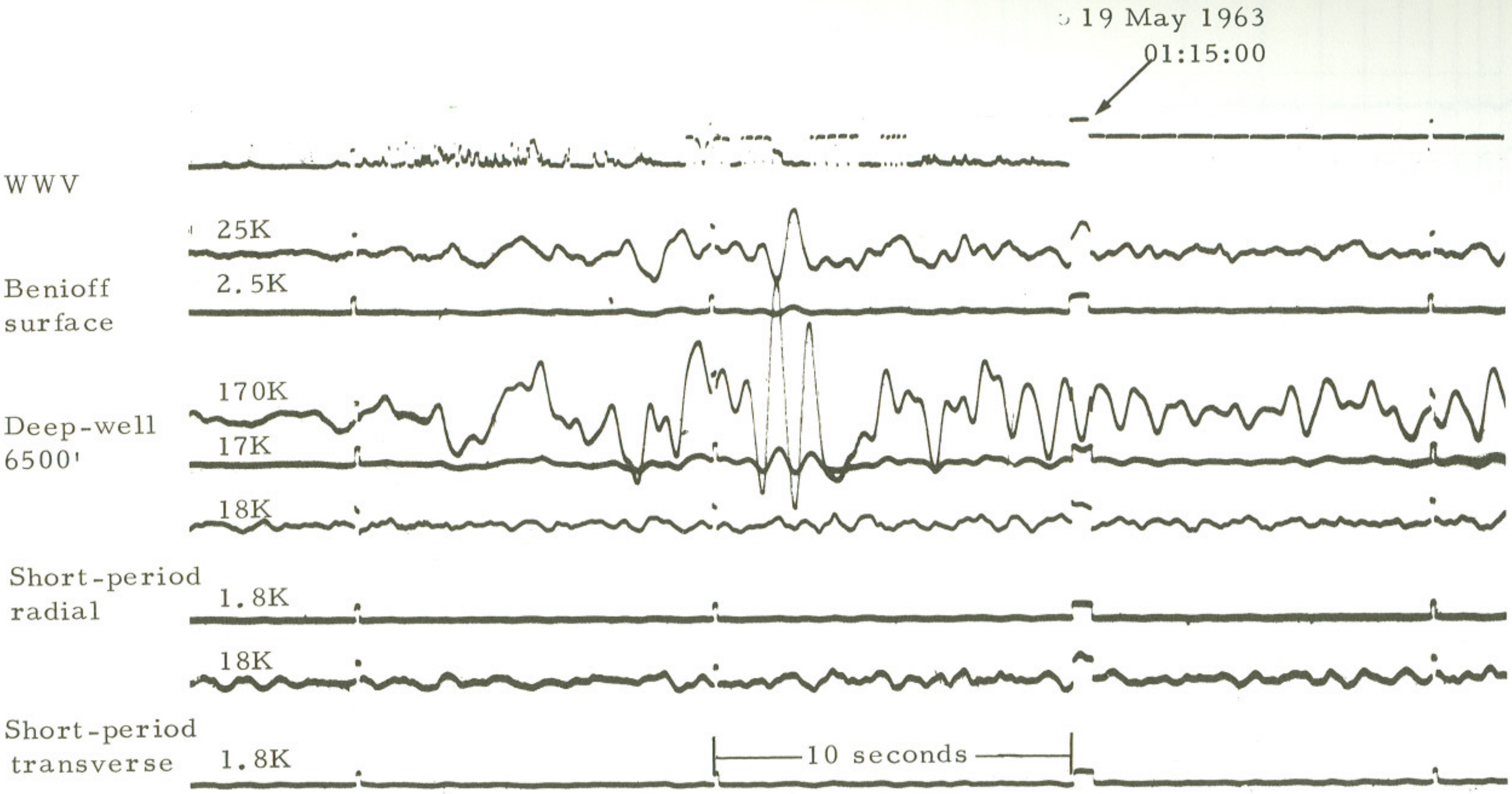


Figure 10. Develocorder record of small Benioff, deep-well, short-period radial, and short-period transverse seismometers at Orlando, Florida. Magnification at 1 cps, X10 view. Event from coast of southern Chile, Δ approximately 78°, depth about 33 km, m = 6.5.

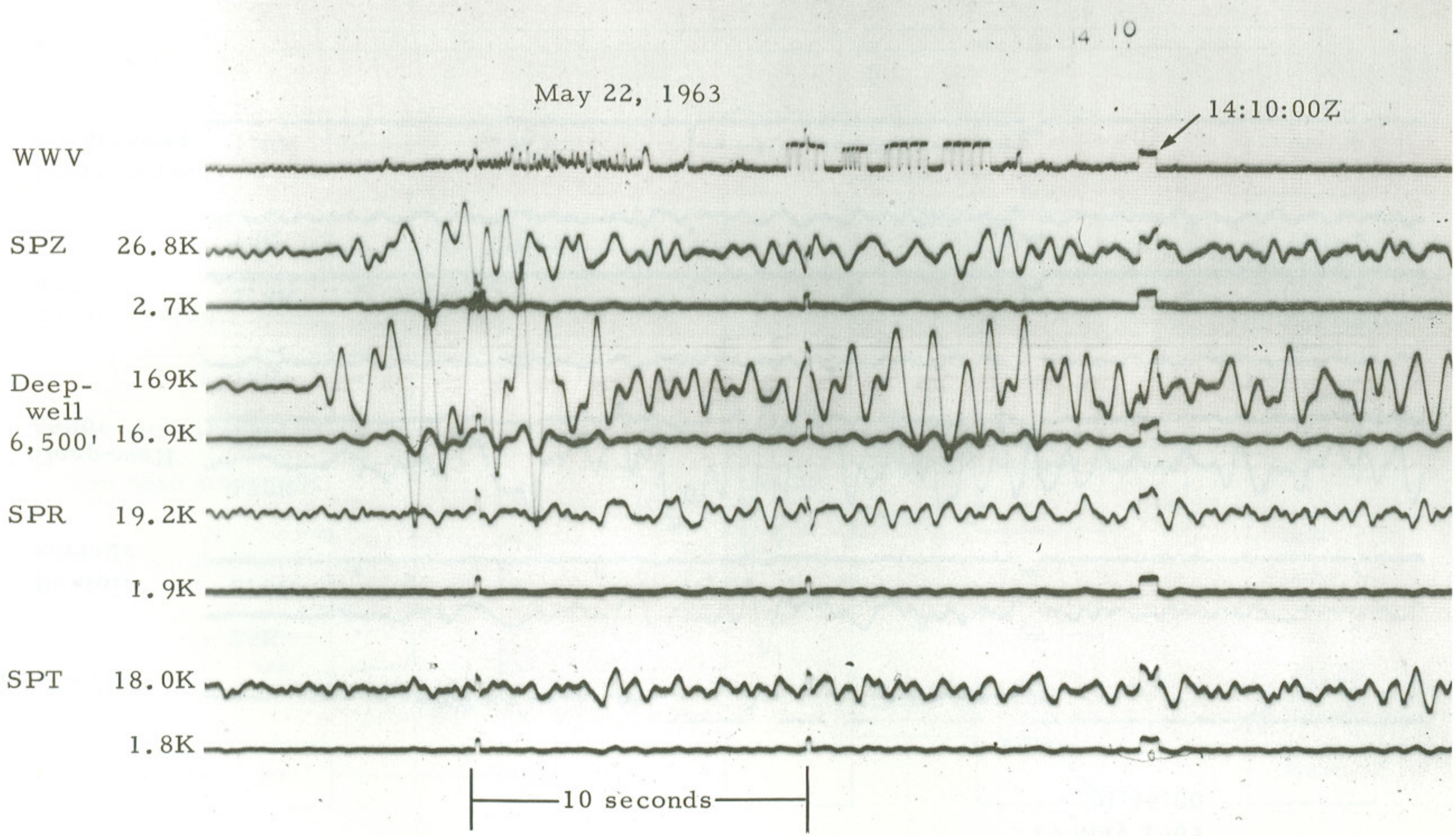


Figure 11. Develocorder record of small Benioff, deep-well and horizontal Benioff seismometers at Orlando, Florida. Magnification at 1 cps, X10 view.

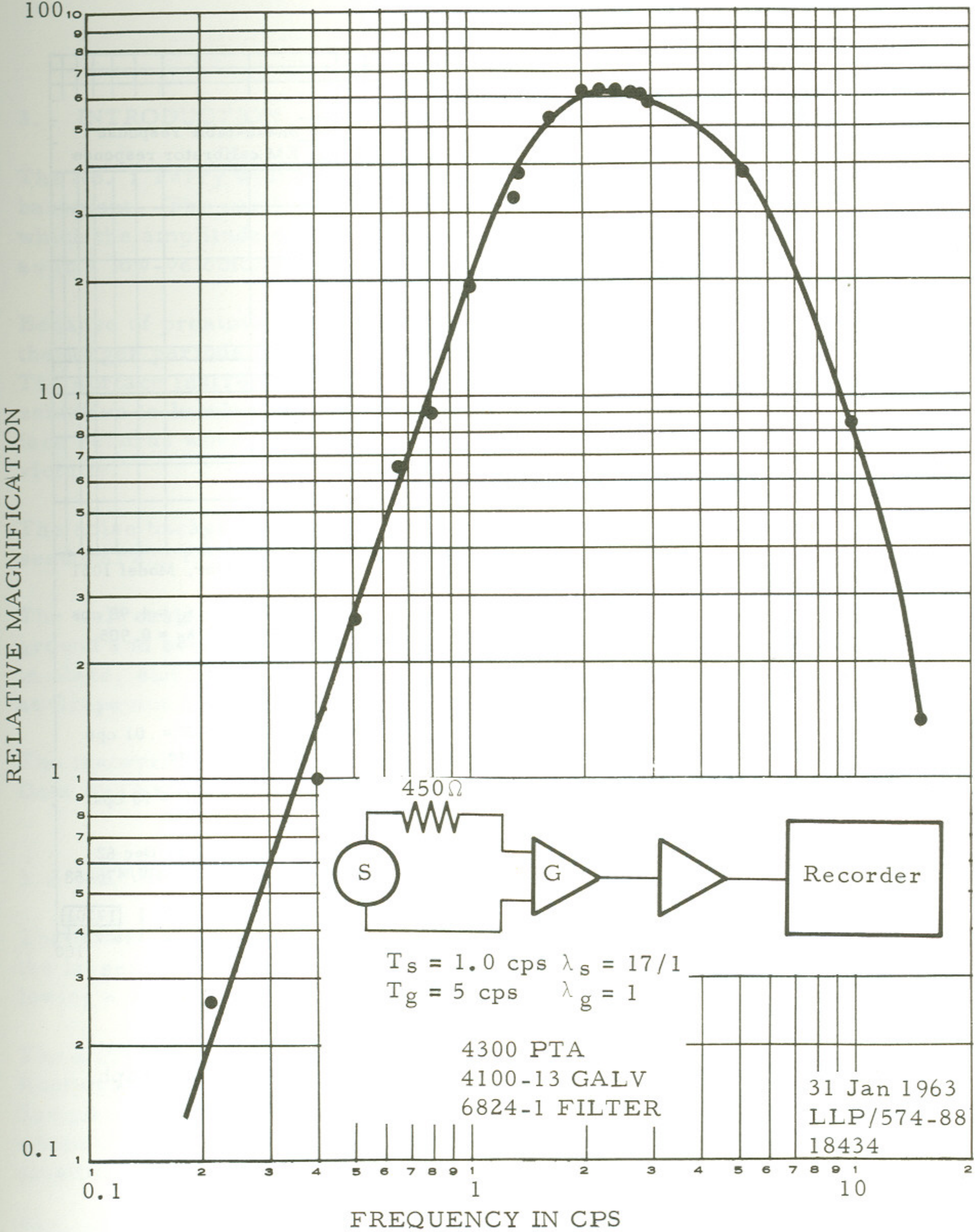


Figure 12. Frequency response of deep-well seismograph

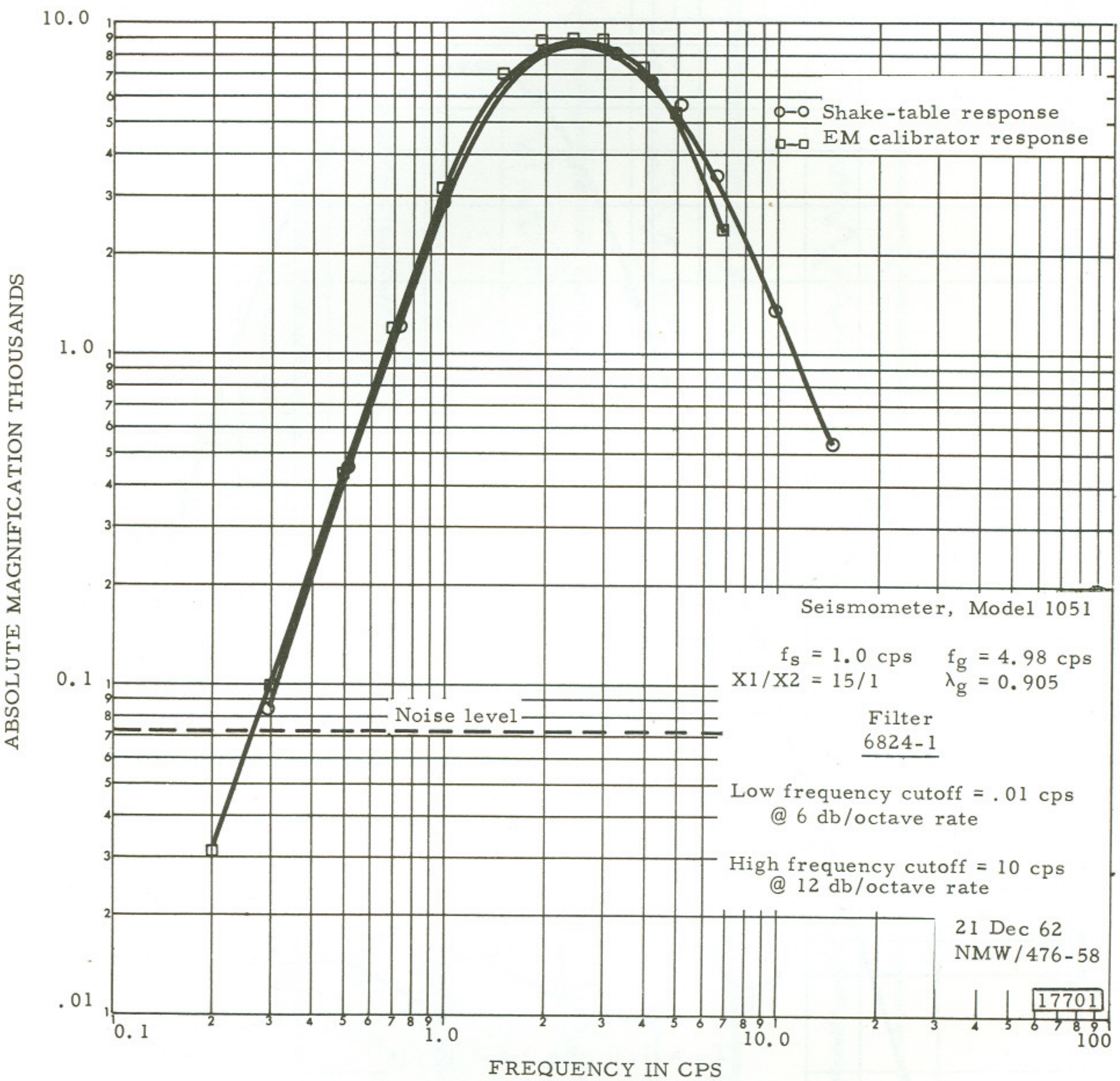


Figure 13. Frequency response of the short-period seismograph, from shake-table and electromagnetic calibrator tests

3. DATA ANALYSIS

3.1 INTRODUCTION

The No. 1 Terry well reaches a total depth of 6585 ft and penetrates the basement. The section is composed mainly of high-velocity limestones, in which the amplitude of surface waves is not expected to decrease as rapidly as in a low-velocity section.

Because of proximity to the ocean, the noise background is rather large for the longer periods (0.8 to 1.5 sec) in the passband of interest (0.3 to 1.5 sec). The surface instruments are located on unconsolidated material which is very sensitive to local vibrations; high frequency noise predominates on the surface records when the wind is blowing or when cultural activity is high in the vicinity.

The noise background at the site is abnormally variable, probably due to seasonal and diurnal changes in the sources responsible for the noise.

The well casing is cemented from 3100 ft to the bottom, and coupling between ground and seismometer is good. Above 3100 ft, the casing is not cemented in place, and coupling may be poor as was demonstrated during experiments at Grapevine, Texas.

The theoretical results included in the data analysis were obtained from the Data Analysis and Technique Development Center in Alexandria, Virginia.

3.2 METHOD OF MEASURING NOISE

The noise distribution curves given in the report were obtained by measuring the largest noise amplitude present in the 10-sec interval immediately following a 5-min mark.

The amplitudes were not corrected for instrument response, and the magnifications at 1 cps were used to obtain the millimicron ($m\mu$) values given. Samples were taken during times when the cultural activity in the vicinity was minimum; 100 samples were taken at each depth. All measurements of amplitude were peak-to-peak.

This method of measuring the noise essentially defines the detection capability of the site. The results are given as "probability of occurrence" curves which determine the probability that a noise pulse of the same amplitude as a signal will occur at approximately the same time. The slope of the curve gives a measure of the variability of the noise amplitudes.

The periods of the pulses measured are also plotted to allow a comparison of the periods predominant at each depth.

The method has the advantage of ease of measurement and gives consistent, reproducible results by visual analysis; however, it should not be taken as a substitute for spectral analysis of the noise.

The probability of occurrence curves give a good picture of the decrease in noise level in the deep well without making any attempt to distinguish between the decay of the different frequencies which occur in the noise.

3.3 NOISE ANALYSIS

Figures 14 through 21 show the probability of occurrence and the frequency distribution curves for the different depths at which the deep-well seismometer was operated at Orlando, Florida.

The surface noise is extremely variable, mainly due to the variability in the cultural high-frequency (0.3 to 0.5 sec) noise; however, from the deep-well results it can be seen that the longer period (0.8 to 1.5 sec) noise is also rather variable. Changes of as much as 25% in average noise amplitude have been observed in 24 hours.

With one seismometer in the deep well, measurements can be obtained at only one depth at a time, and the variability in the results cannot be avoided. Noise measurements were made at times when the high-frequency noise at the surface was at a minimum to facilitate the measurement of the longer periods which govern the improvement possible at depth.

Figure 22 shows a plot of the 50% probability of occurrence level at each depth together with the P wave velocity section in the well. There appears to be no simple relationship between the velocities in the well and the decrease of the noise with depth.

Figure 23 shows the noise-amplitude attenuation with depth of Rayleigh waves compared to the theoretical results for the fundamental at 0.5, 1.0, and 2.0 sec and first higher mode waves at 1.0 sec. The theoretical results given

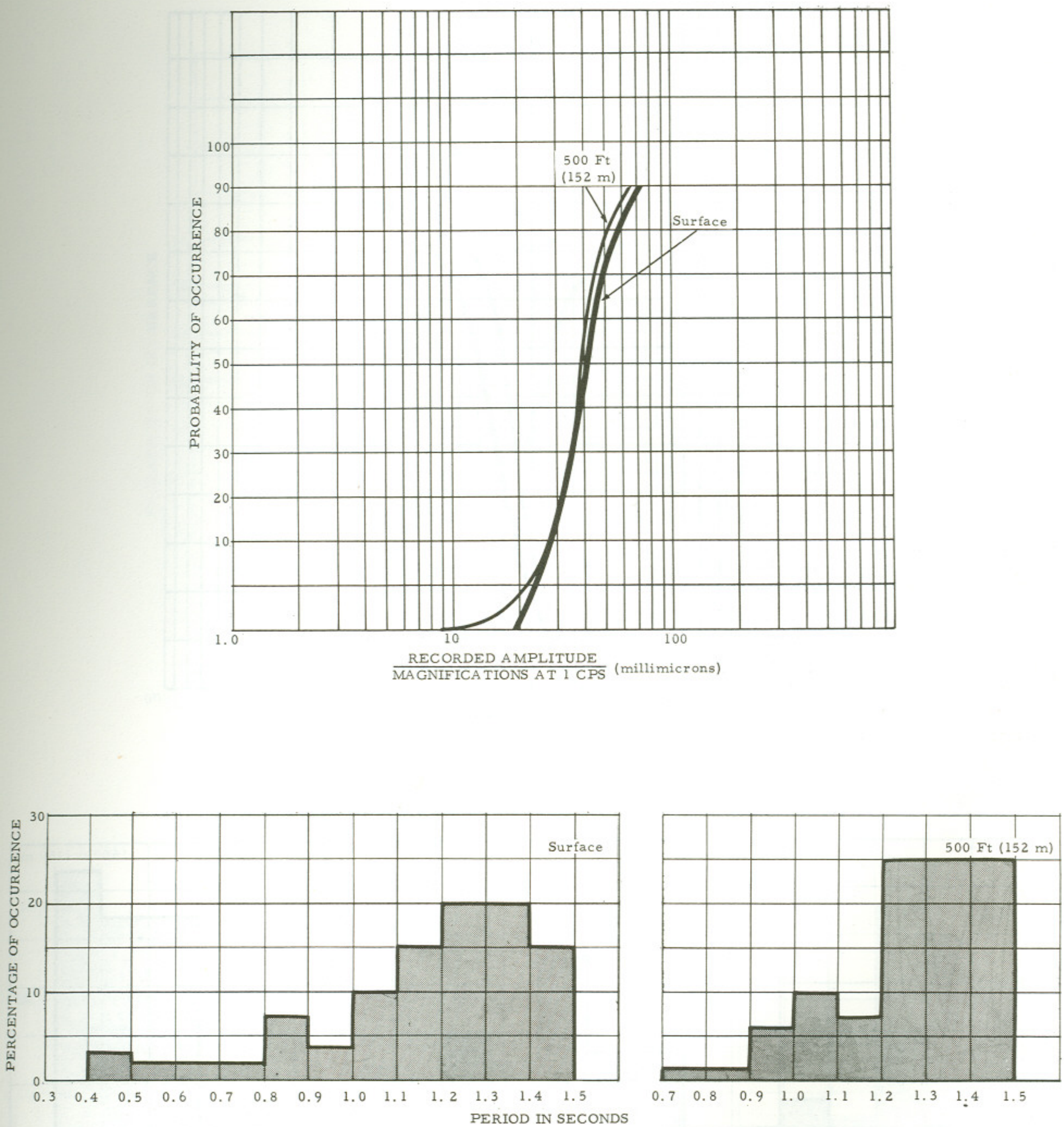
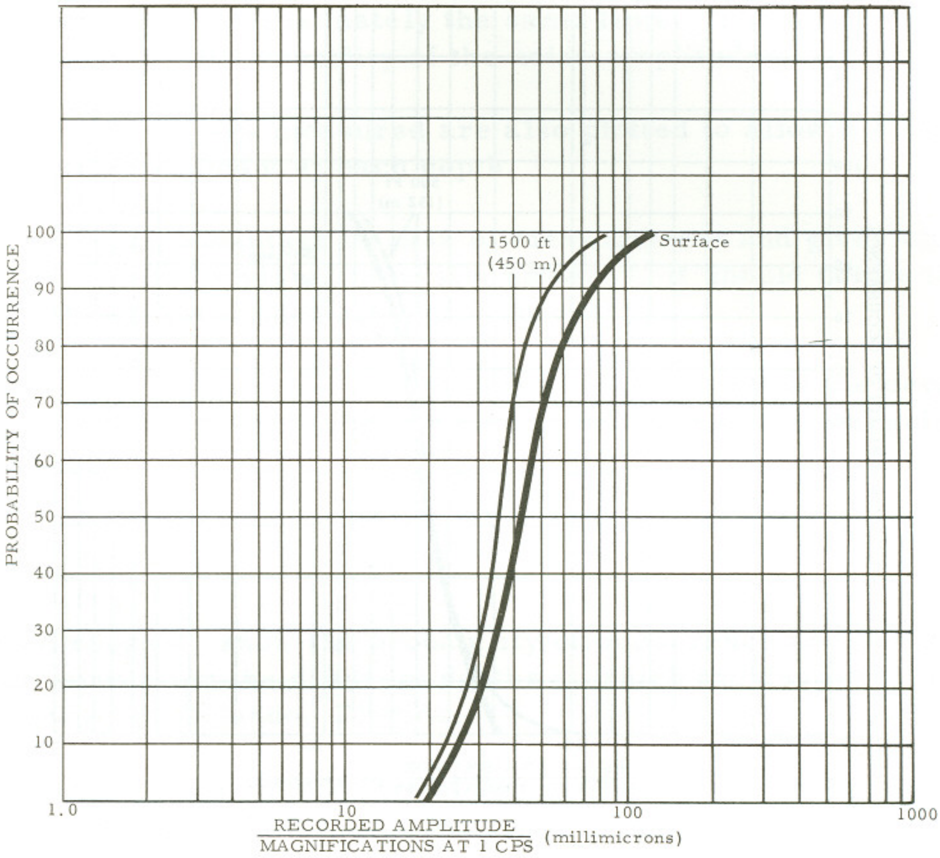


Figure 14. Distribution curves and histograms for the 0.3- to 1.5-sec noise at the surface and at 500 ft (152 m) in the deep well, Orlando, Florida



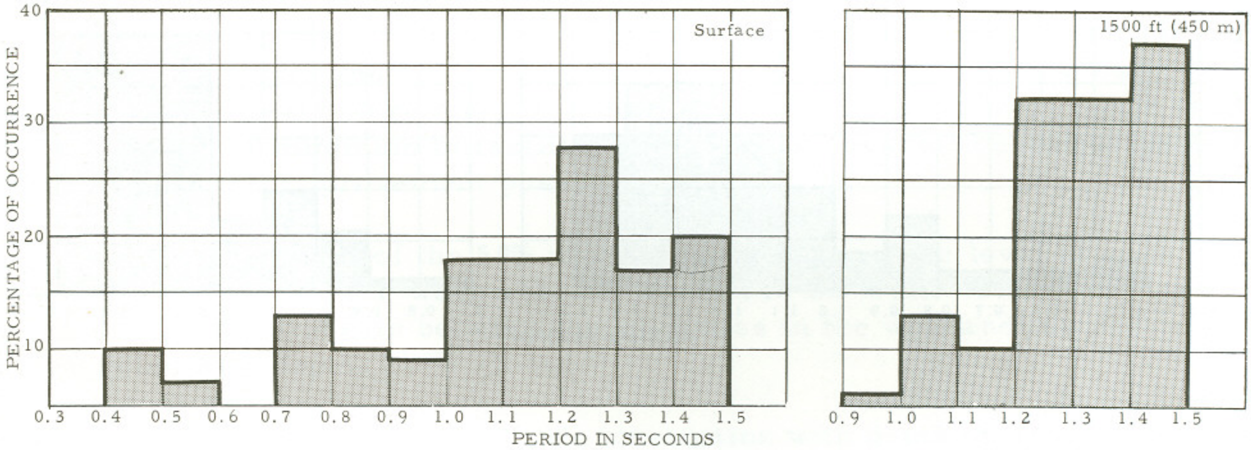
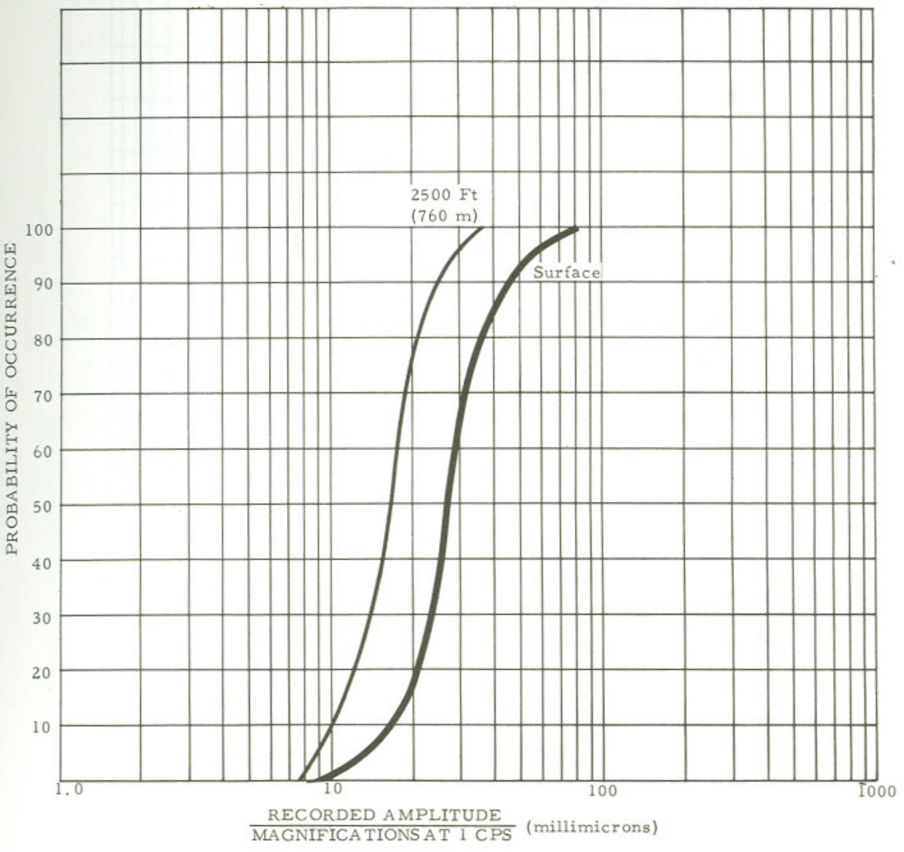


Figure 15. Distribution curves and histograms for the 0.3- to 1.5-sec noise at the surface and at 1500 ft (450 m) in the deep well, Orlando, Florida



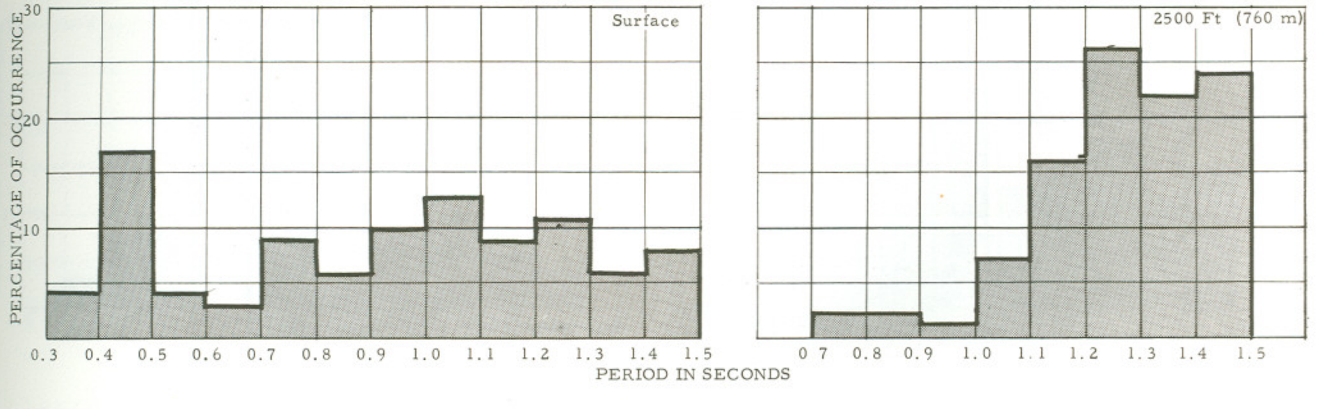
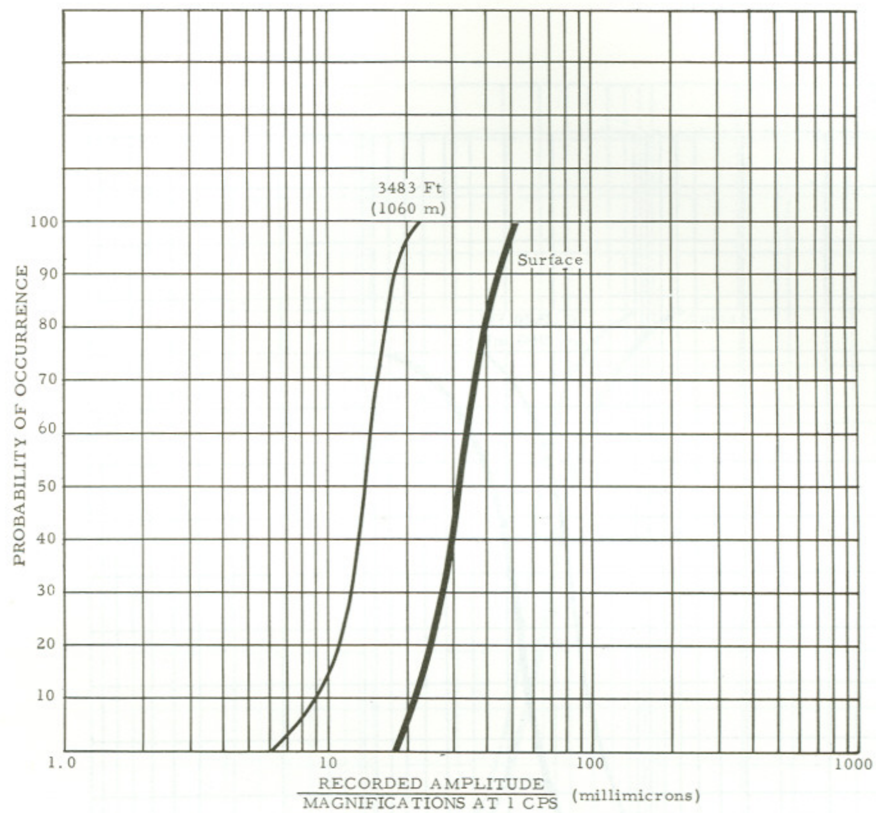


Figure 16. Distribution curves and histograms for the 0.3- to 1.5-sec noise at the surface and at 2500 ft (760 m) in the deep well, Orlando, Florida



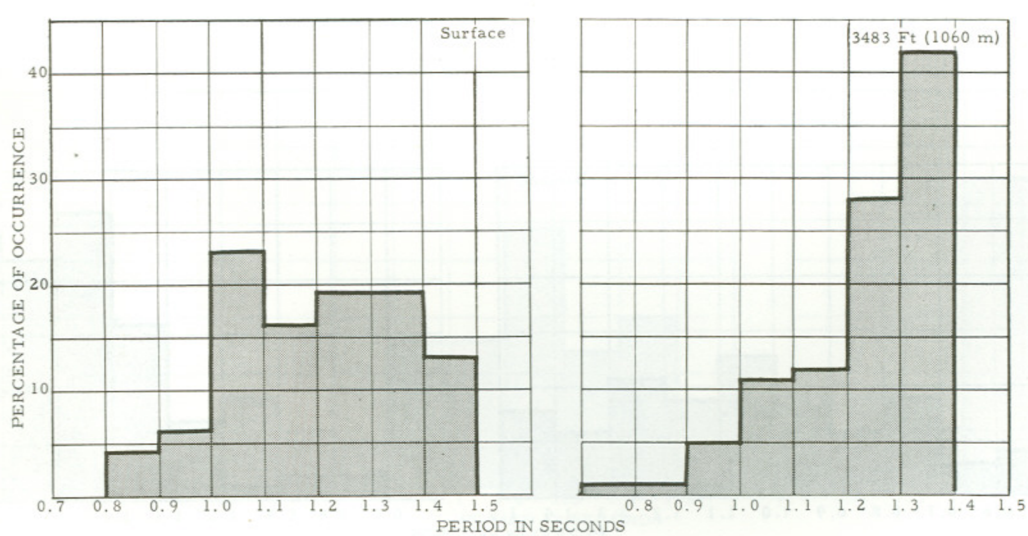


Figure 17. Distribution curves and histograms for the 0.3- to 1.5-sec noise at the surface and at 3483 ft (1060 m) in the deep well, Orlando, Florida

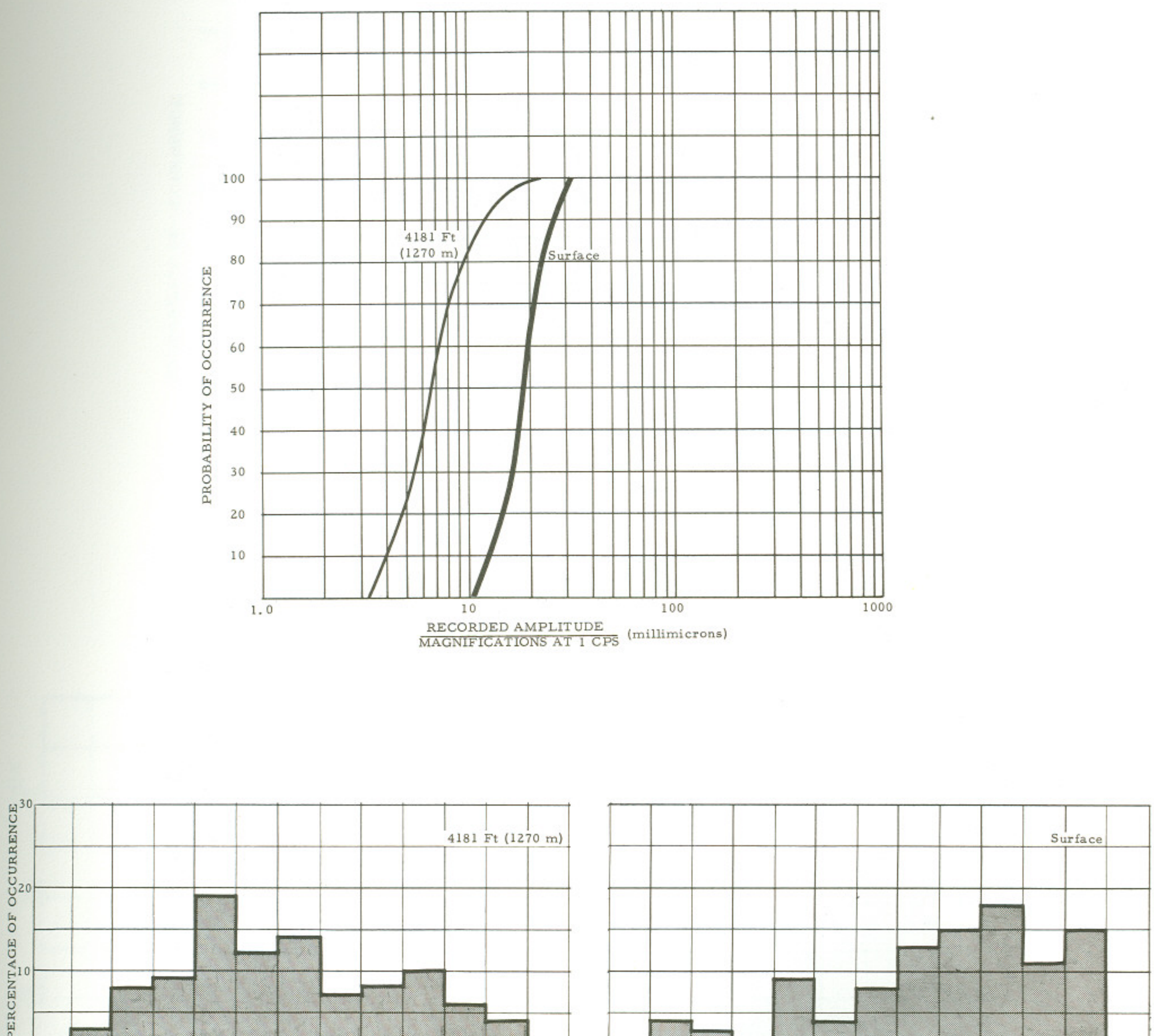
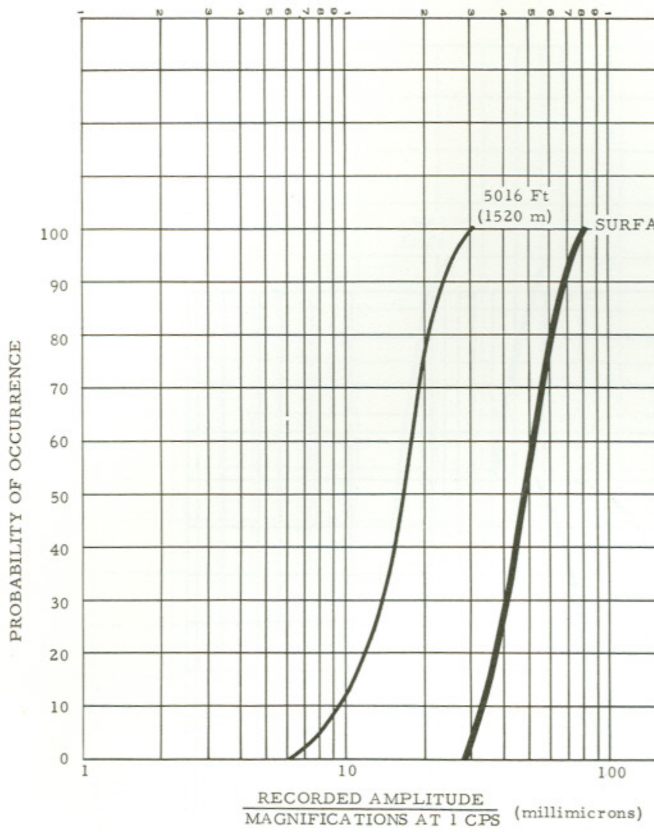


Figure 18. Distribution curves and histograms for the 0.3- to 1.5-sec noise at the surface and at 4181 ft (1270 m) in the deep well, Orlando, Florida



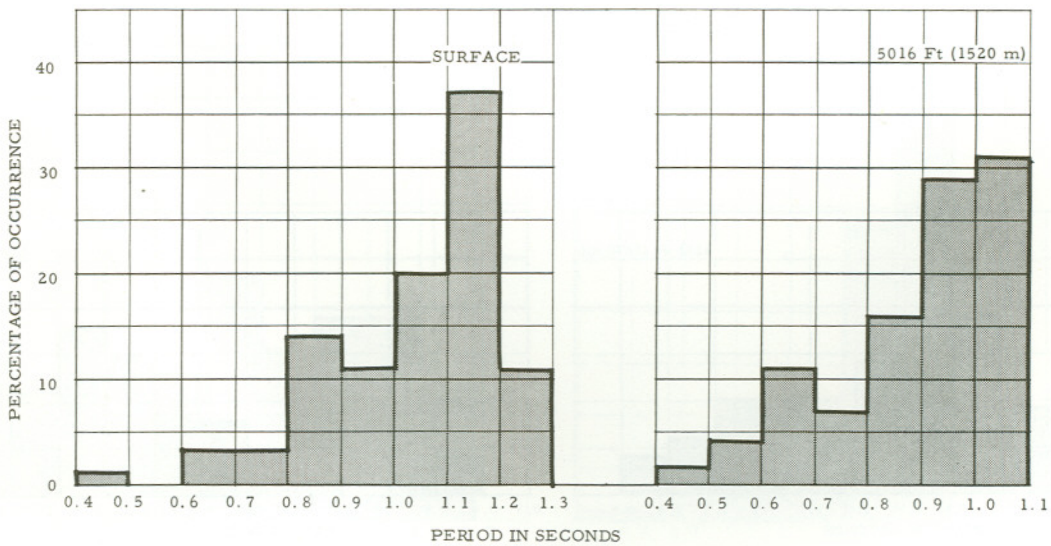
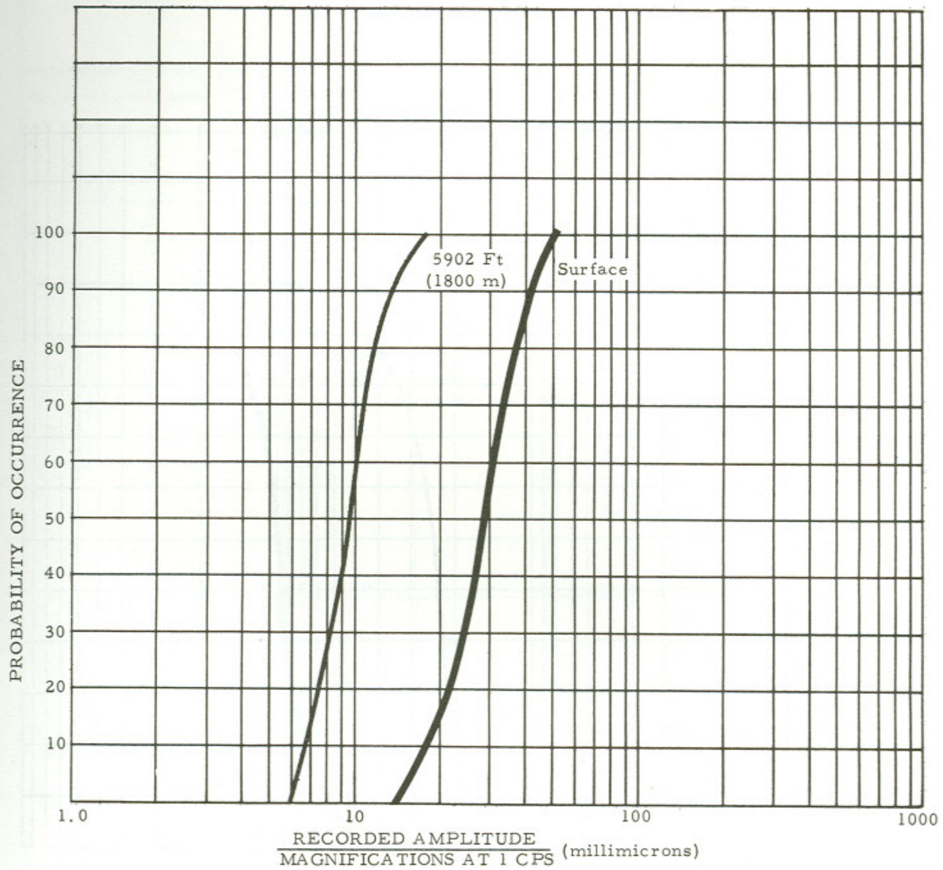


Figure 19. Distribution curves and histograms of the 0.3- to 1.5-sec noise at the surface and at 5016 ft (1520 m) in the deep well, Orlando, Florida



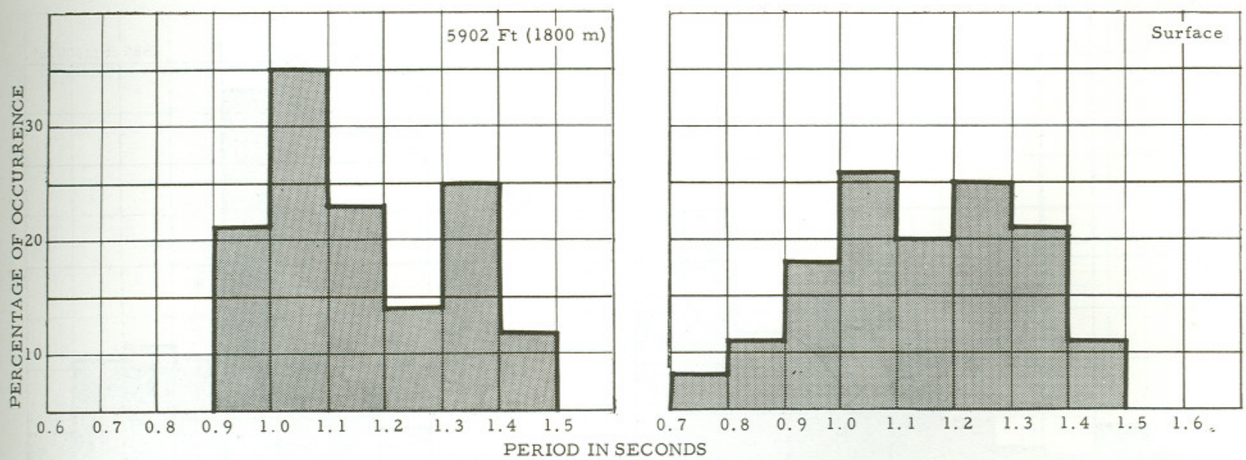
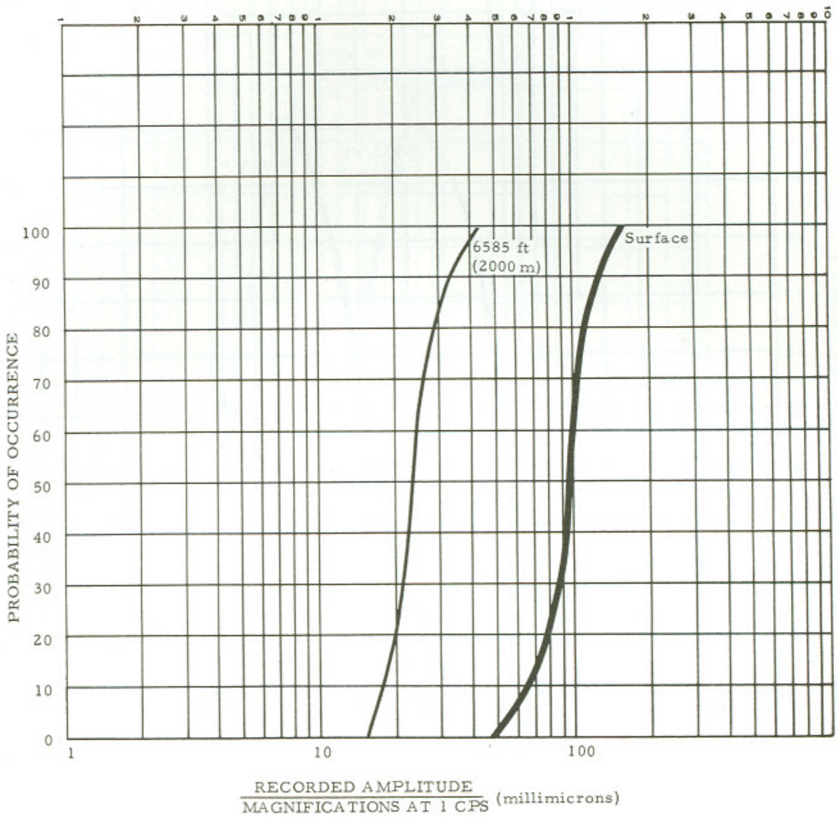


Figure 20. Distribution curves and histograms for the 0.3- to 1.5-sec noise at the surface and at 5902 ft (1800 m) in the deep well, Orlando, Florida



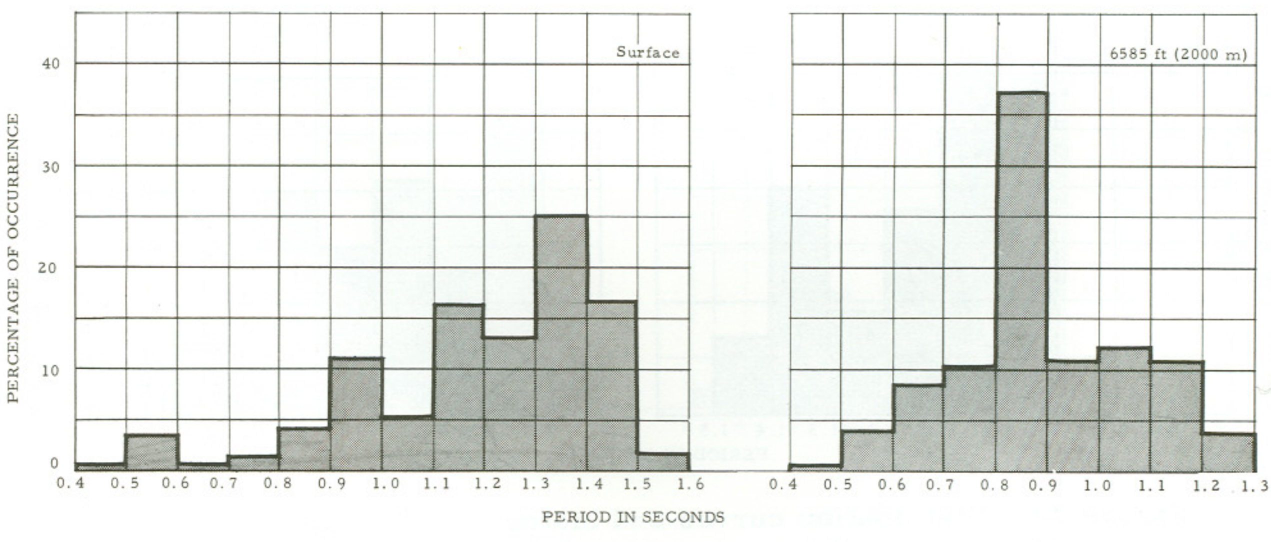


Figure 21. Distribution curves and histograms of the 0.3- to 1.5-sec noise at the surface and at 6585 ft (2000 m) in the deep well, Orlando, Florida

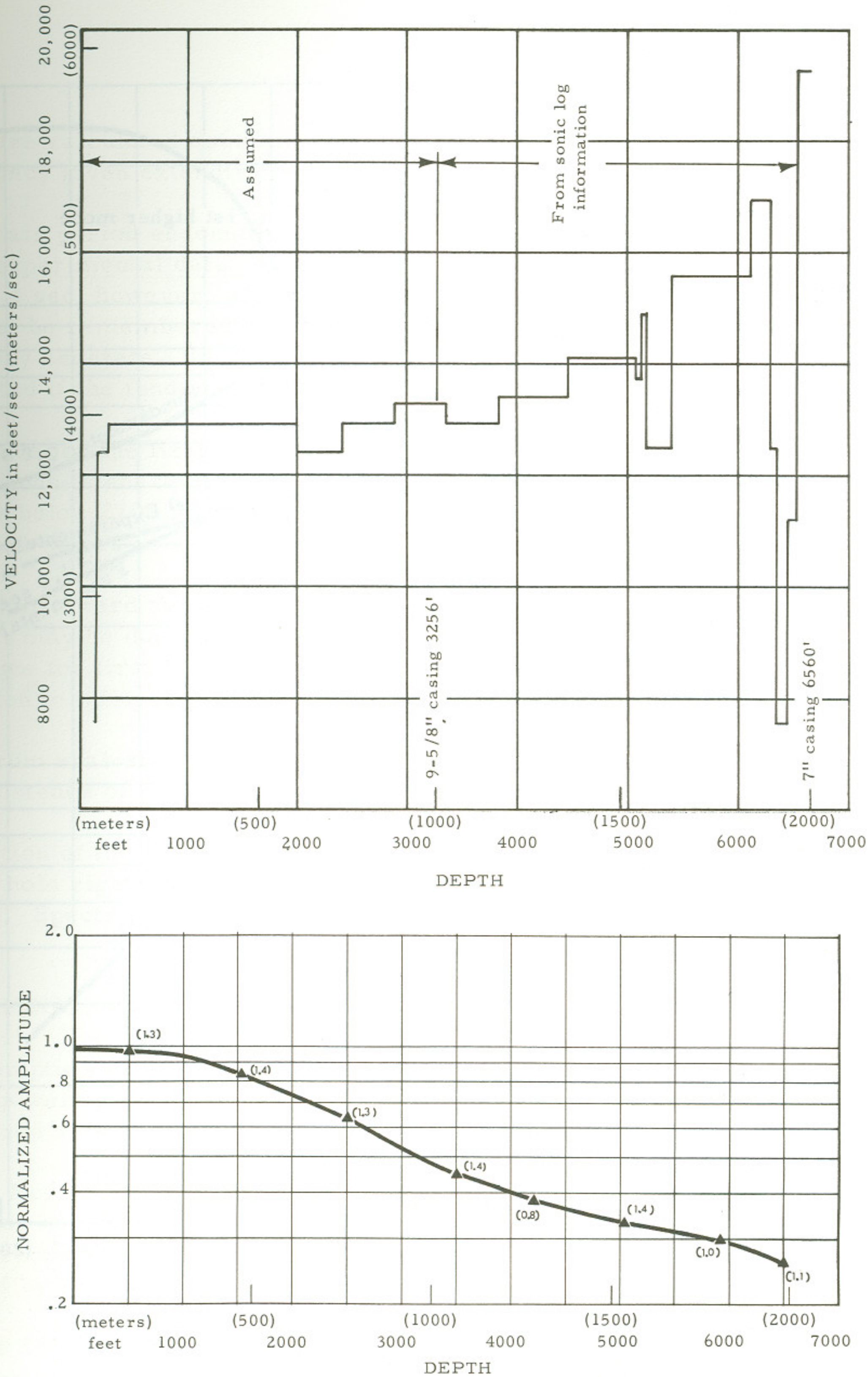


Figure 22. Depth versus P-wave velocity, and depth versus noise amplitude, Orlando, Florida

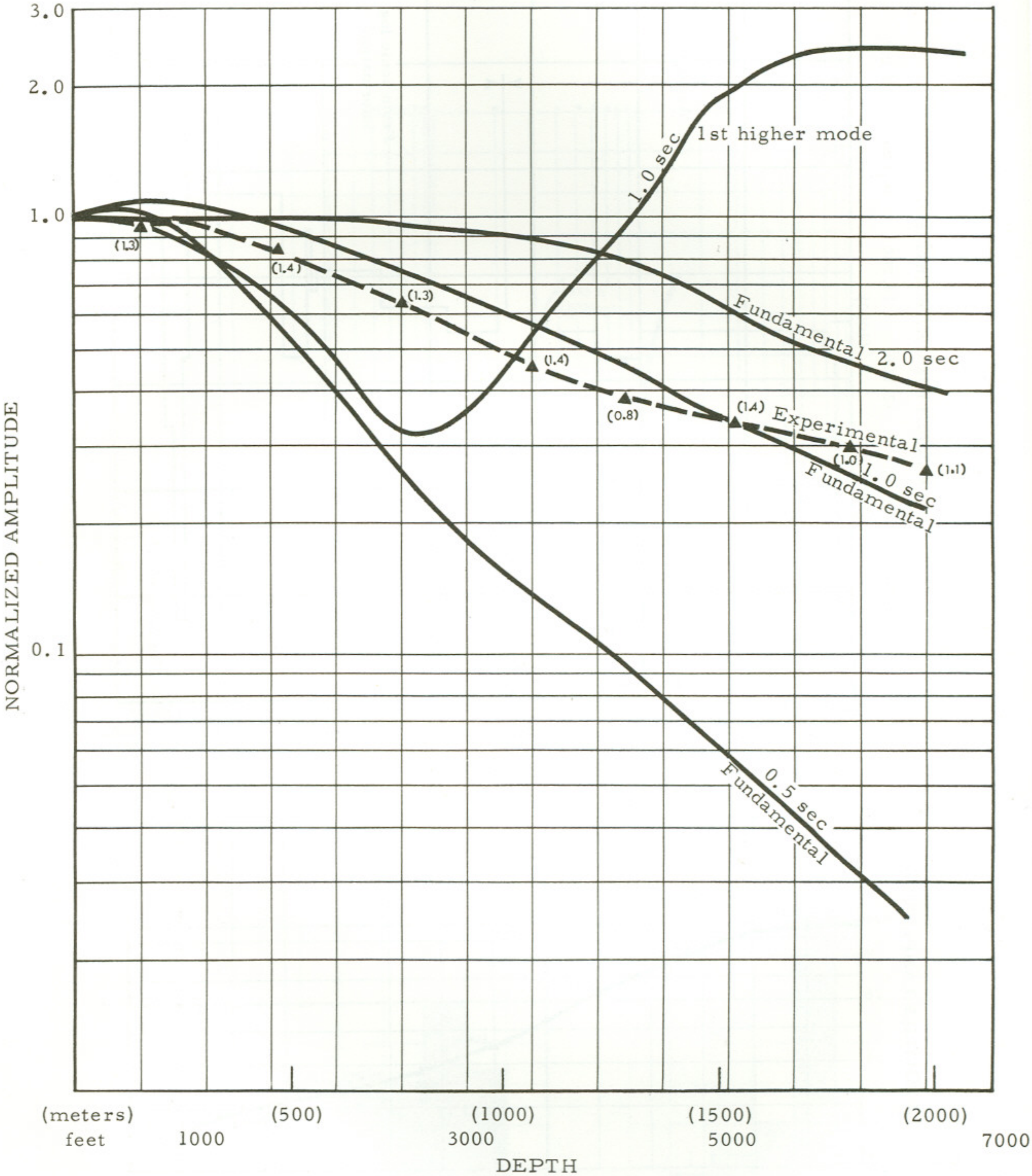


Figure 23. Plot of the theoretical Rayleigh wave amplitude decay with depth together with the experimental results obtained. Predominant noise period in parenthesis

here are calculated assuming a Ricker pulse with a center frequency at the frequency given extending over approximately one octave.

The main period encountered in the noise at various depths is given beside each experimental data point. In general, the predominant periods are 1.3 and 1.4 sec; however, at several depths shorter periods are predominant. It must be remembered that measurement of the noise by visual means is not very accurate. In general, the noise decays approximately as would be expected if the fundamental mode Rayleigh wave predominated in the noise.

Evidence for the first higher mode can sometimes be found in the noise. This mode is characterized by a 180° phase shift between the surface and depths below 2700 ft. A noise sample with suspected first higher mode Rayleigh waves is shown in figure 24.

The shift toward the shorter periods with depth that is evident at 5902 and 6585 ft may be due to the presence of first higher mode noise. However, evidence for first higher mode noise at Orlando of sufficient amplitude and duration to influence the results is not available at present.

Spectrum analysis of the records may provide an answer to the problem of the existence of higher modes at this site.

Operation of the deep-well seismometer in the open hole at bottom and in the cased hole right above the bottom did not reveal any difference in the noise levels. Spectrum analyses may show differences.

3.4 SIGNAL ANALYSIS

In attempting to determine the signal-to-noise improvement obtained at depth in deep wells, the decrease of P-wave signal amplitude with depth must be examined as well as the decrease in the noise amplitude.

At the No. 1 Terry well, 44 teleseismic signals of sufficient amplitude to be used for analysis were obtained. The amplitudes of the P waves were measured from the first cycle at both surface and at depth to avoid the interference caused by the surface reflection in the deep well.

Figure 25 shows the decrease in signal amplitude with depth. The points were obtained by averaging over all the events received at each depth.

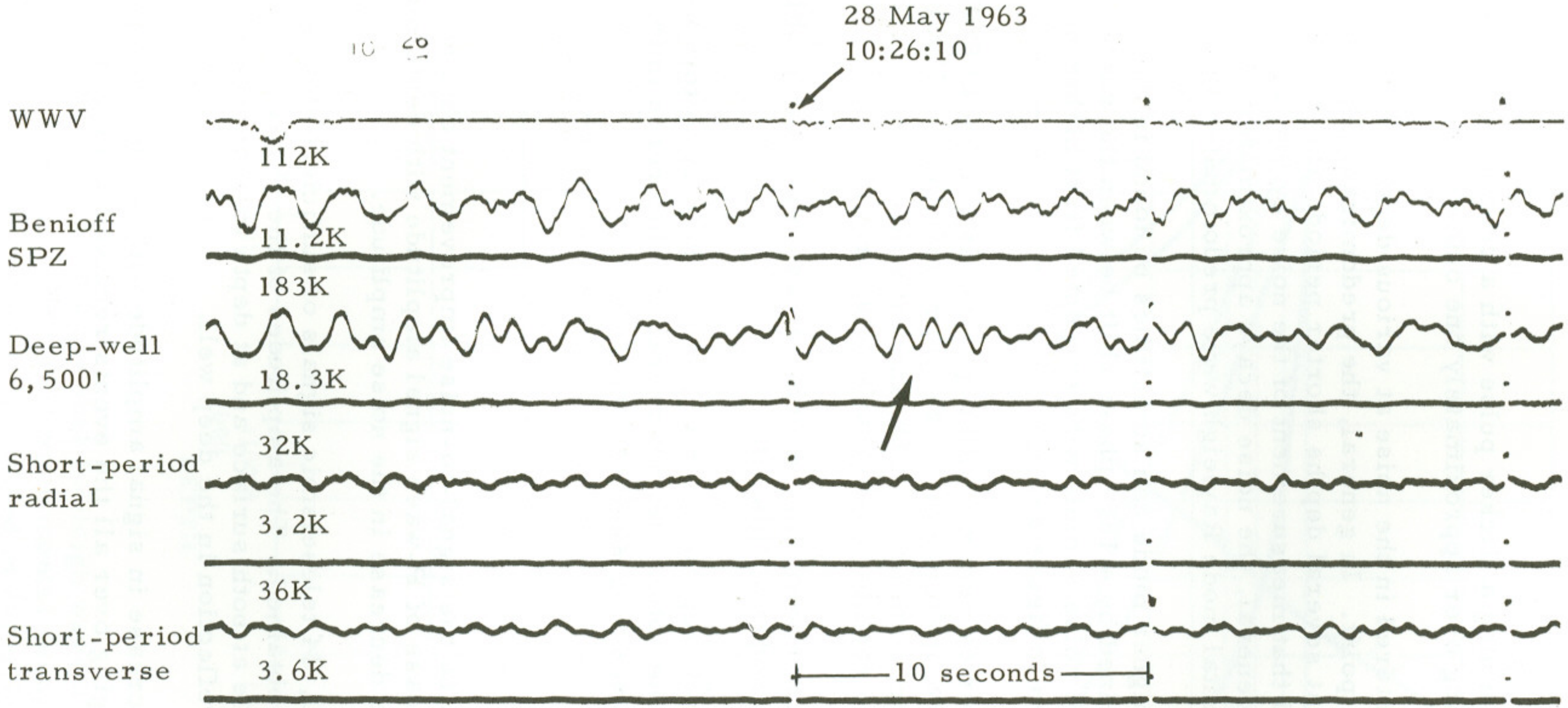


Figure 24. Develocorder record of small Benioff and deep-well seismometers at Orlando, Florida. Magnification at 1 cps (X10 enlargement). Noise sample showing first higher mode Rayleigh wave microseisms

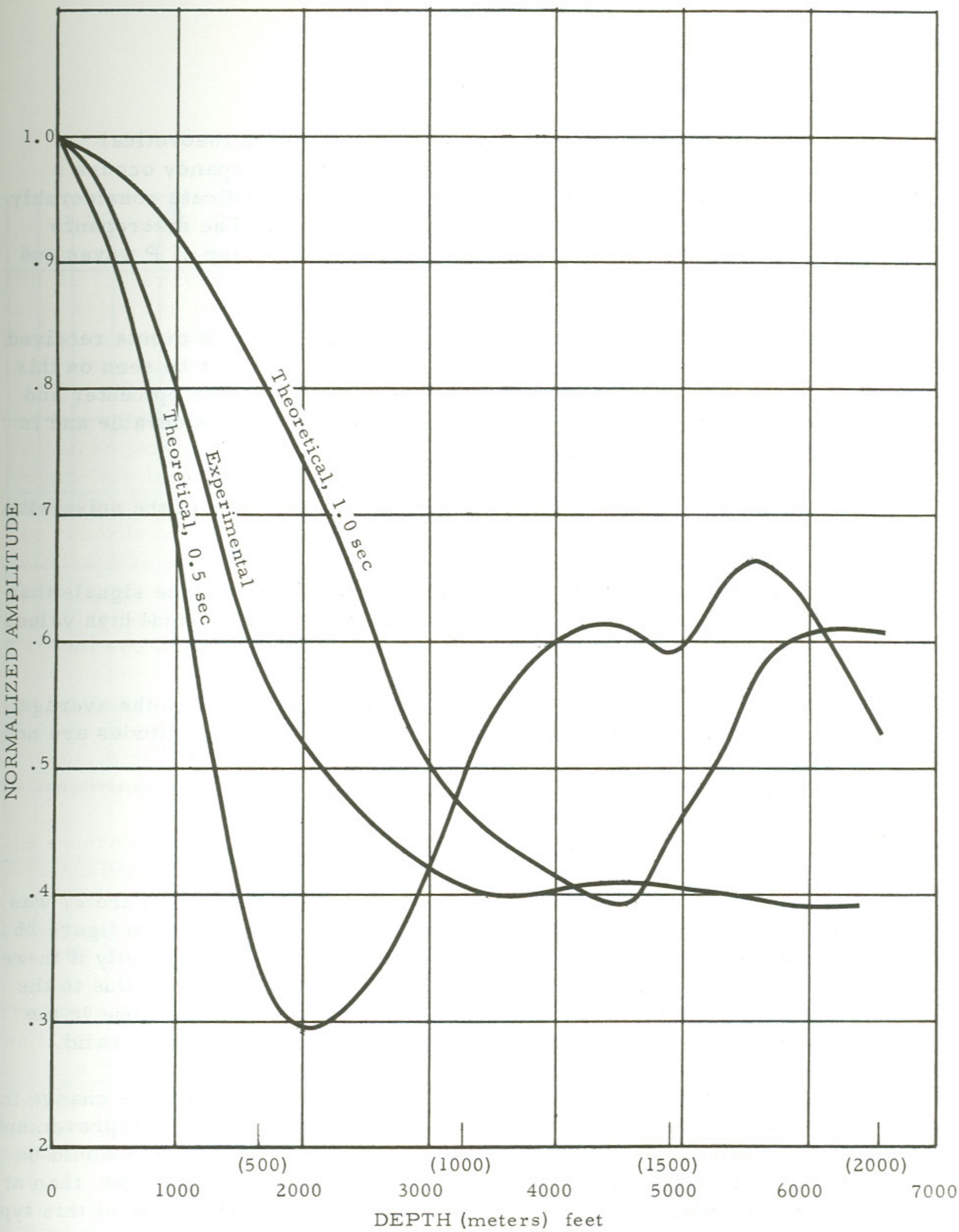


Figure 25. Theoretical amplitude of P waves with depth compared to the experimental results. The theory assumes a Ricker wavelet. Orlando, Florida

The experimental results agree reasonably well with the theoretical predictions as can be seen in figure 25. The main discrepancy occurs between 5000 and 6000 ft where the theoretical results indicate considerably larger amplitude than actually encountered in the well. The discrepancy may be explained by the difference between the actual shape of P waves and the Ricker pulse which the theory assumes.

Figure 26 shows the deep well-to-surface amplitude ratio of events received at 6,585 ft plotted against distance to the epicenter. As can be seen on this plot, there is no obvious relationship between distance to the epicenter and amplitude at 6,585 ft. The scatter of the data points is considerable and is probably due to one of the following:

a. Changes in amplitude caused by the interference of the noise with the signal;

b. The unconsolidated surface layer which may enhance signals that fall close to its natural period of vibration, thus giving abnormal high values of ground motion.

The few extremely large events received agree fairly well with the average, as can be seen on figure 26. For these events, the noise amplitudes are not large enough to appreciably distort the signal amplitude.

3.5 SIGNAL-TO-NOISE RATIOS

The increase in the signal-to-noise ratios with depth shown in figure 27 was obtained by dividing (point-by-point) the signal amplitude shown in figure 25 by noise amplitudes shown in figure 23. This technique is valid only if there is no major change in frequency content of the noise with depth. Due to the small change in frequency content below 1500 ft, the relative change in the signal-to-noise ratio between the different depths below 1500 ft is valid.

Between the surface and the depths below 1500 ft, the considerable change in frequency content of the noise indicates that the signal-to-noise improvement is frequency-dependent. For example, a signal of 0.5-sec period would be more clearly visible at depth, due to the lack of noise of this period, than at the surface where noise of this period is present. Considerations of this type indicate that for visual examination, the signal-to-noise improvement is larger than indicated in figure 27 for signals of periods below 1.0 sec.

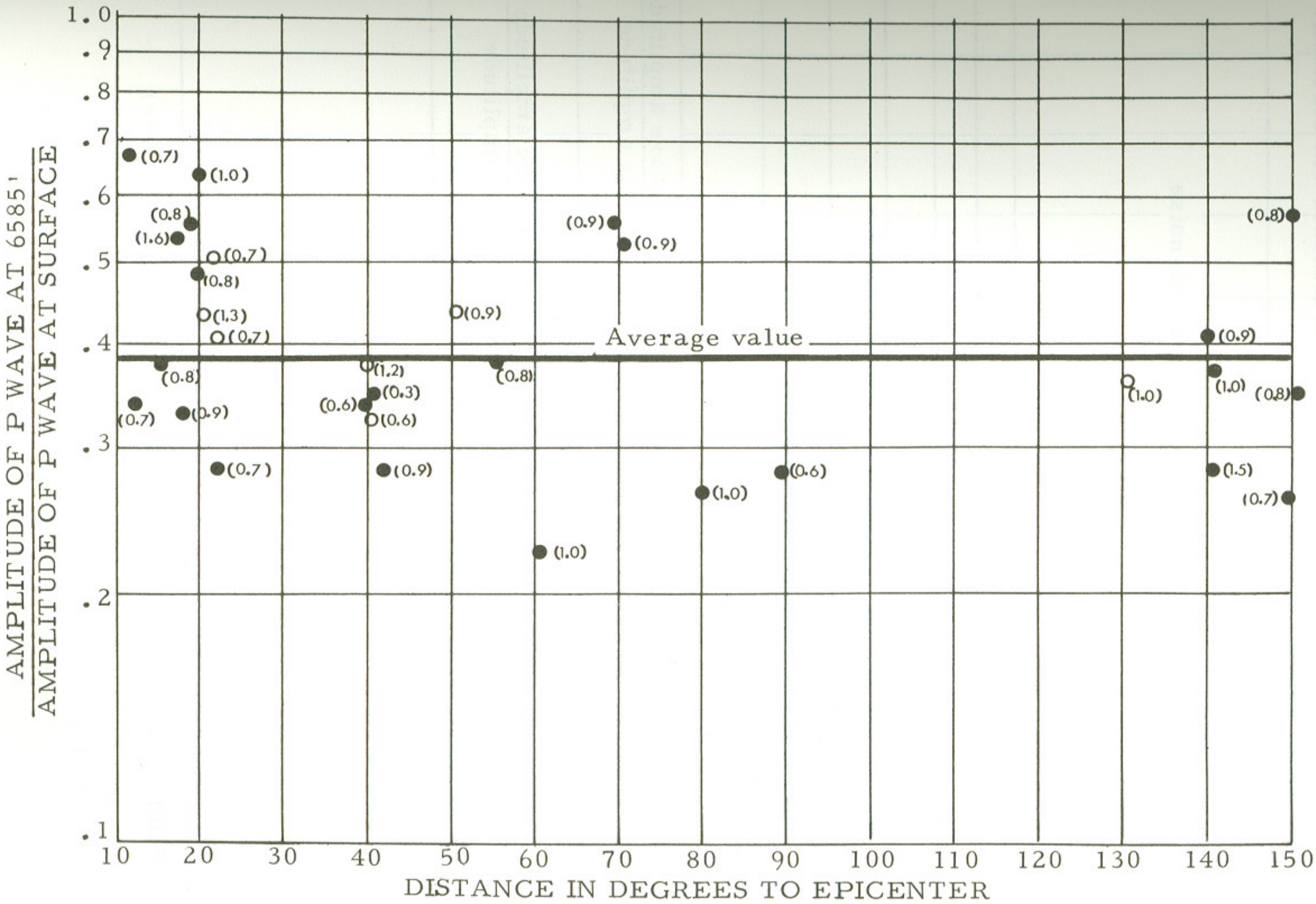


Figure 26. Plot of P-wave amplitude ratio against distance in degrees to epicenter. O indicates an event of amplitude greater than 150 mμ at the surface. Period of the signal is given in parenthesis. Orlando, Florida

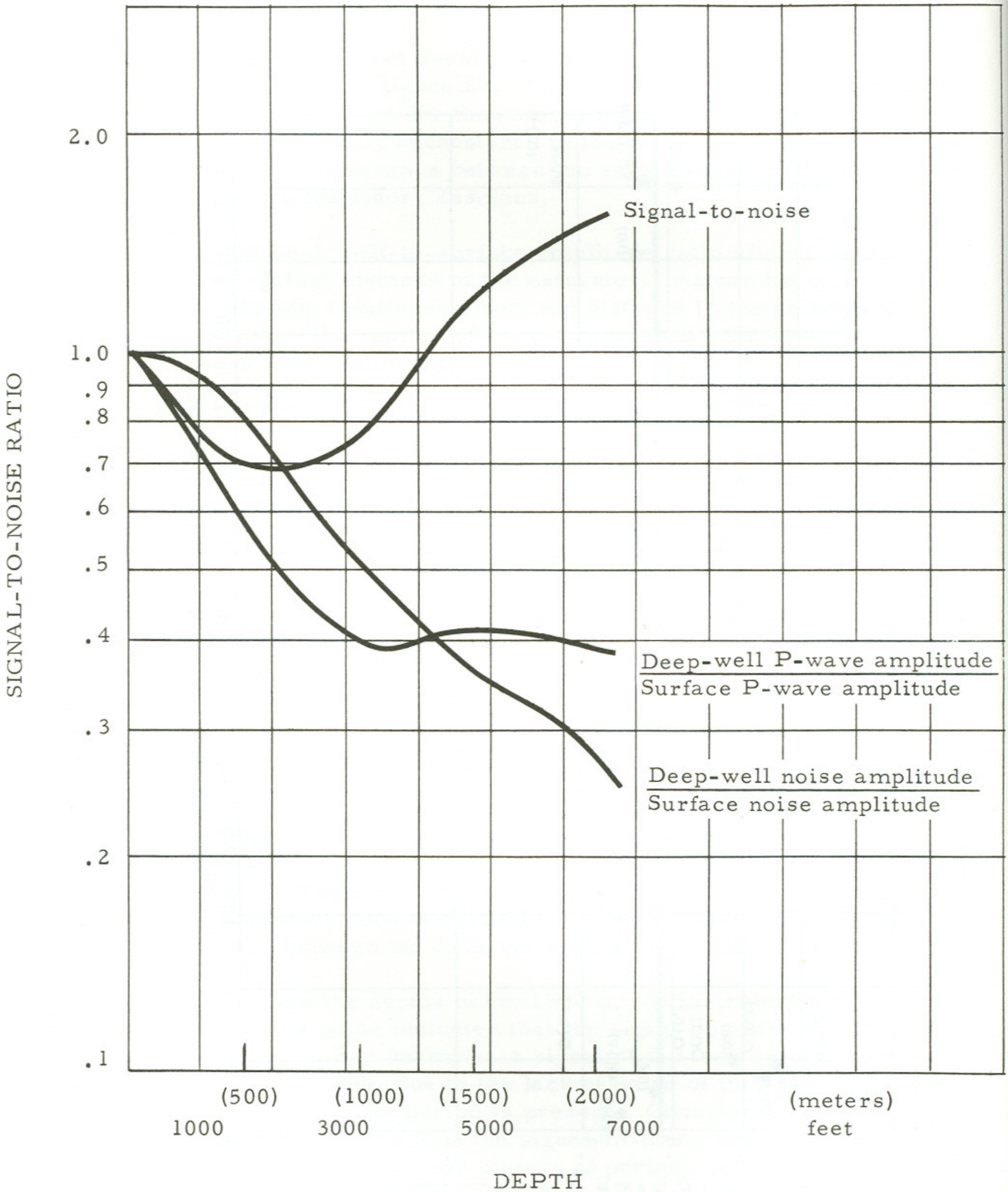


Figure 27. Signal-to-noise ratio versus depth, Orlando, Florida

Figures 28 and 29 show two events of completely different periods which illustrate the considerations discussed above.

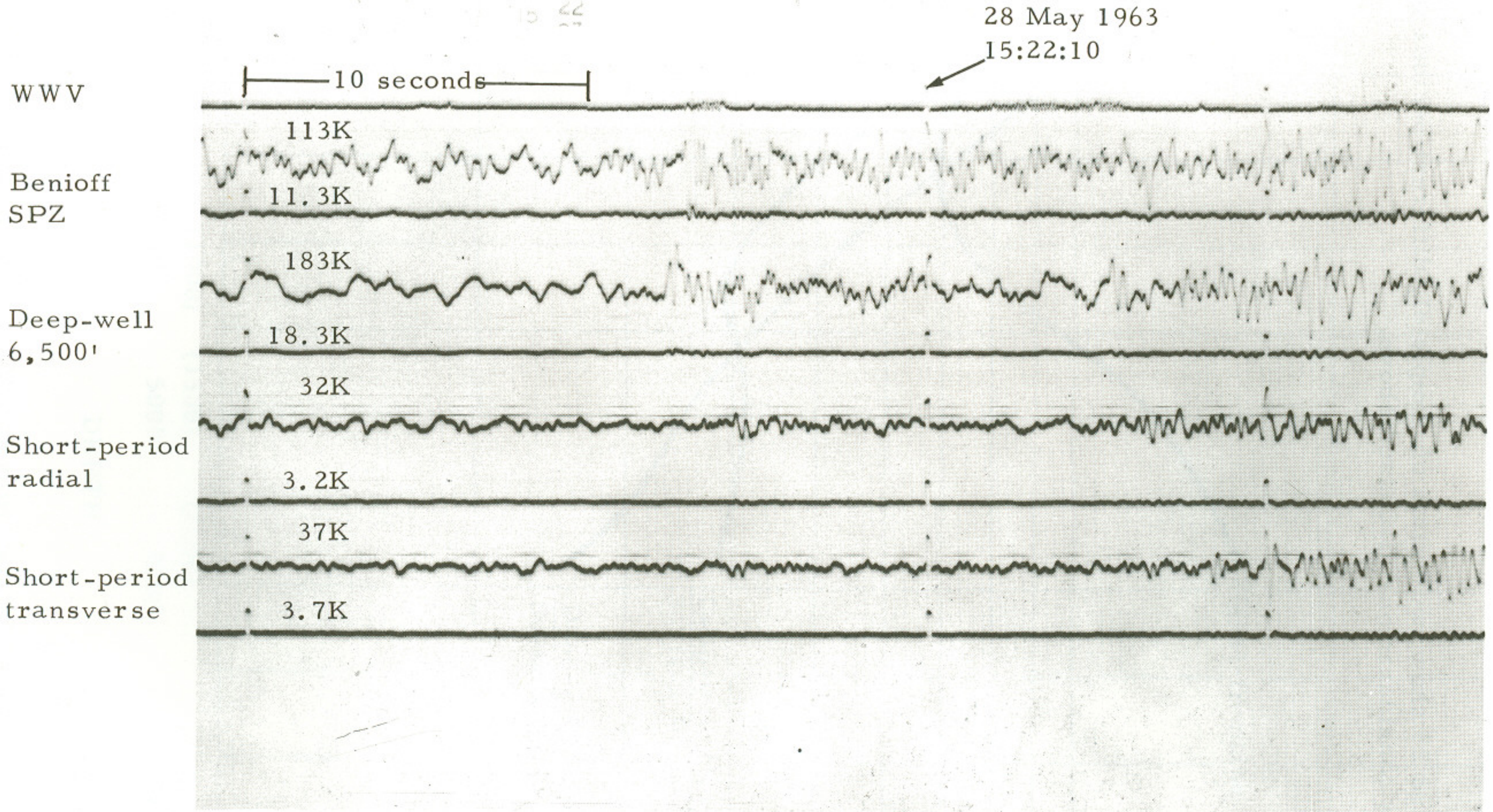


Figure 28. Develocorder record of small Benioff and deep-well seismometers at Orlando, Florida. Magnification at 1 cps (X10 enlargement).

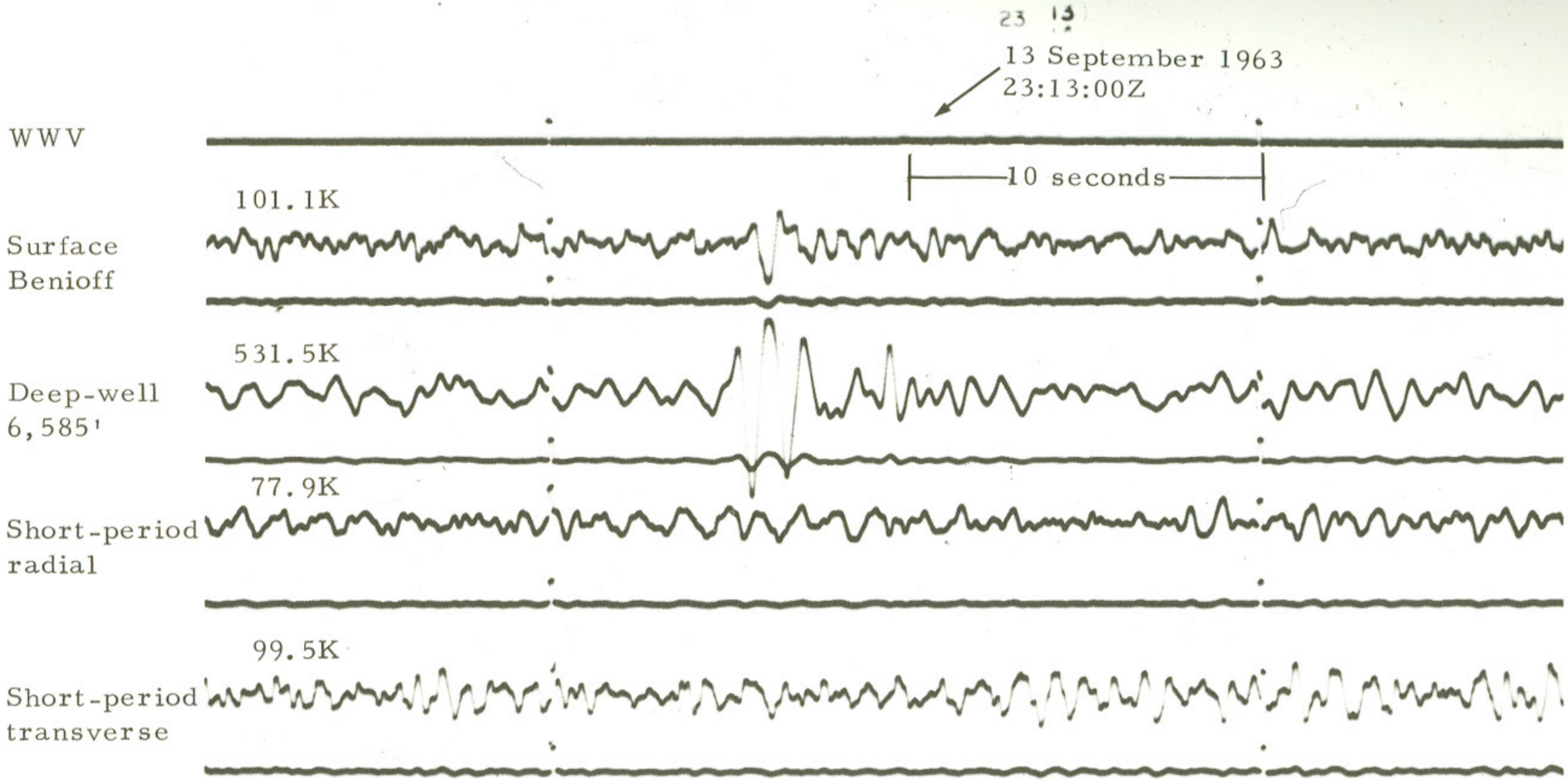


Figure 29. Develocorder record of small surface Benioff and deep-well seismometers at Orlando, Florida. Magnification at 1 cps (X10 enlargement).

APPENDIX 1 to TECHNICAL REPORT NO. 63-88

TERRY NO. 1 DEEP WELL SITE DATA

TERRY NO. 1 DEEP WELL SITE DATA

Location:	C SW/4 SE/4 Sec 21, Twp 23s, Rg 31E Orange County, Florida, 15 miles southeast of Orlando
Latitude:	28° 28' 01" N
Longitude:	81° 13' 17" W
Topo sheet:	Orlando NH 17-11
Elevation:	78' K.B. 65' G.L.
Lease:	Dated 1 April 1963 from Conway Land, Inc., covering 10 acres, for a period of one year.
Surface easements:	(a) Terry Cattle Co., Inc. (b) Culsman Corporation and Canlando Corporation (c) Anzac of Florida, Inc.
Access:	All weather roads to site
Power:	About 3.5 miles at Dean Road - no service at site
Telephone:	About 3.5 miles at Dean Road - no service at site
Site facilities:	(a) Previously existing well approximately 70 ft deep, cased, no overhead facility, located 90 ft from deep well. (b) Previously existing well approximately 400 ft deep, cased, no overhead facility, located 70 ft from deep well. (c) Concrete pad around deep well.

Cultural noise sources: (a) Dean Road, carrying light traffic, about 3-1/2 miles distant.

(b) City of Orlando activity about 8 miles distant.

(c) Cape Canaveral complex about 50 miles distant.