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APPLICATION OF A VIDEO PULSE RADAR SYSTEM TO DETECT TUNNELS AT THE CURTIS SCHOOL YARD IN TRUMBULL COUNTY, OHIO

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Video Pulse radar systems are used to detect underground features at the Curtis School yard in Trumbull County, Ohio. Measured results and their interpretation are given. The results are correlated with a map based on drill hole data and local history.

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I. INTRODUCTION

The purpose of this report is to present data taken using the video pulse radar systems at the Curtis School yard site in Trumbull County, Ohio. This school yard was developed by leveling the ground over the abandoned Curtis mines. In the winter of 1978, we were notified by geologist Professor Ann Harris of Youngstown State University that subsidence had caused a hole to appear in the center of the school yard. We believed this site to be a reasonable geometry to test our equipment and at that time we had no idea of what was actually underground. We did expect the tunnels to be at relatively shallow depths. Radar measurements were made on three separate trips. Subsequent to our first two trips to the site, the yard was drilled at a number of spots on a 25 foot square grid pattern. Some additional drill holes were dug for more localized data. Measurements on the third trip were made after the drill holes had been completed. The first trip was made in February 1978 just after a very deep snowstorm. Professor Harris had arranged with local officials to remove the snow from the yard. Measurements on the second trip were taken in the spring under much more pleasant weather conditions and on the third trip in October of 1978.

Professor Harris has contributed substantially to this part of our research program. Indeed, without her, there is no way that these measurements could be completed. Moreover, her unceasing study of the local coal mine structures has been of immense value. She should be an essential part in any future studies in the geometries of the coal mine structures in this area.

Before proceeding with the discussion of our results let us first call attention to the fact that our radars have specifically been designed first to detect shallow utilities and later to detect tunnels. We observe that a large room would be detectable only from measurements taken near the edges. After examining some of the results taken at this site, Professor Harris made the suggestion that we had a good coal detector. We were very likely seeing the region near the discontinuity where mining had stopped. Indeed, the development of radar systems to detect coal layers is a very worthwhile goal and has a good chance for success.

II. VIDEO PULSE RADAR SYSTEMS

The radars used in this site are in the class we have designated as High Frequency Window (HFW) Radars[1]. These would operate in a frequency band where tunnel resonances would be observed since we generally used 150 ps and 6 ns pulsers. As we shall see, most of the projected underground structures will have dimensions in the proper range for such resonances. The most essential feature of this system is the antenna. Various antennas used are discussed in detail by Wald[2], and by Davis and Peters[3]. All antennas are of the crossed linear dipole configuration and are designed only to see targets that are in some way nonsymmetrical with respect to the symmetry axis of the antenna system. This is of great value in seeking tunnels since this configuration would avoid clutter that would be caused by scattering from layers parallel to the antenna.

The antennas used include a Terrascan Antenna[4], a Modified Terrascan Antenna[2], a Short Box Antenna, and a Long Box Antenna[2,5]. The reader is referred to the other reports in this series for a more detailed description of these antennas.

The receiver used was a Tektronix Sampling Oscilloscope. The data were recorded through a digital system and could be displayed using an <u>INTEL MDS 800</u> micro computer. It could also be plotted on hard copy using a digital plotter. Data were stored on Floppy disks and could be used at the ElectroScience Laboratory for further data processing.

Curtis School Test Site

Figure 1 shows the geometry of the Curtis School yard using the school as a reference. The drill hole pattern is superimposed on this map. Figure 2 shows the drill hole results insofar as the presence of coal or of a void is concerned. The actual drilling logs are given in Appendix I. Figure 3 was provided by Professor Harris with the following description: "I hope this diagram (Figure 3) will help you. The size and distribution of the rooms are nothing but a wild guess, but it was the only logical pattern that I could come up with. I am pretty positive about the railroad tunnel, the mule room and the main entry to the ravine and the horseback in the northeast corner of the playground. On the second sheet (Figure 2) I just marked the voids and coal, perhaps you can come up with a more logical pattern. The 25' drilling pattern wasn't close enough." Appendix II contains results of measurements taken over the drill hole sites before they were drilled. A tentative interpretation of these results prepared by Izadian and Schrote is also given in this appendix.

Results of First Trip

On the first trip to the Curtis School yard, the ground was surveyed using the conventional Terrascan system. An unusually large set of echoes were obtained in the region of the gridded site shown in Figure 1. The grid was designated in a letter-number combination in one foot intervals, starting with the most southwest point. Increasing numbers indicate motion to the north in feet and increasing letters indicate motion to the east in increments of one foot. Figure 4 shows a compilation of the raw data waveforms recorded over the region, A through K and 1 through 19. A standard Terrascan antenna and a 150 picosecond pulse were used. The contours plotted over the grid map shown in Figure 5 represent a first attempt to summarize where the largest signals were occurring. The numbers plotted are derived from the peak to peak signal amplitudes measured at delays of 30 to 40 nanoseconds.

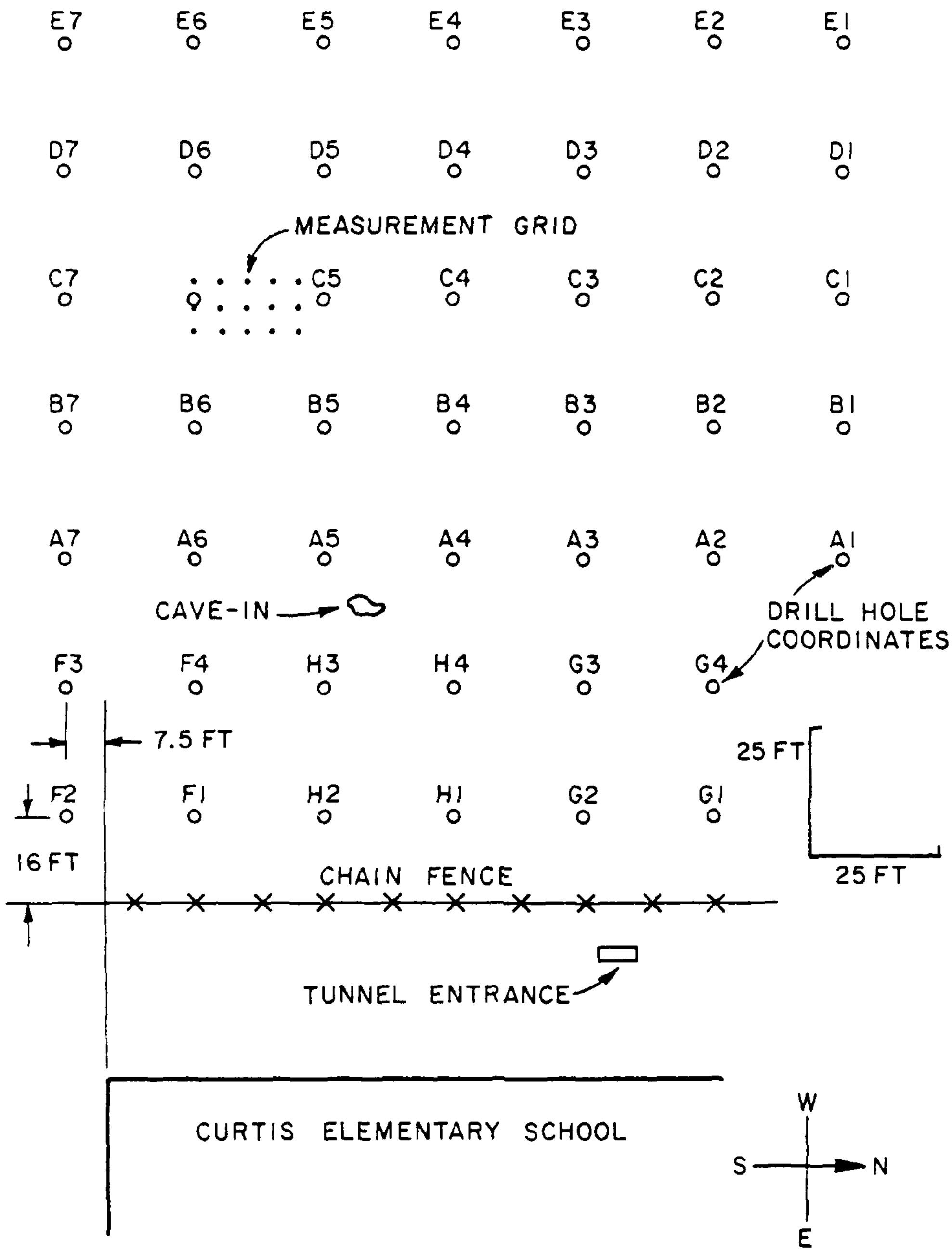


Figure 1. Curtis School yard surface features.

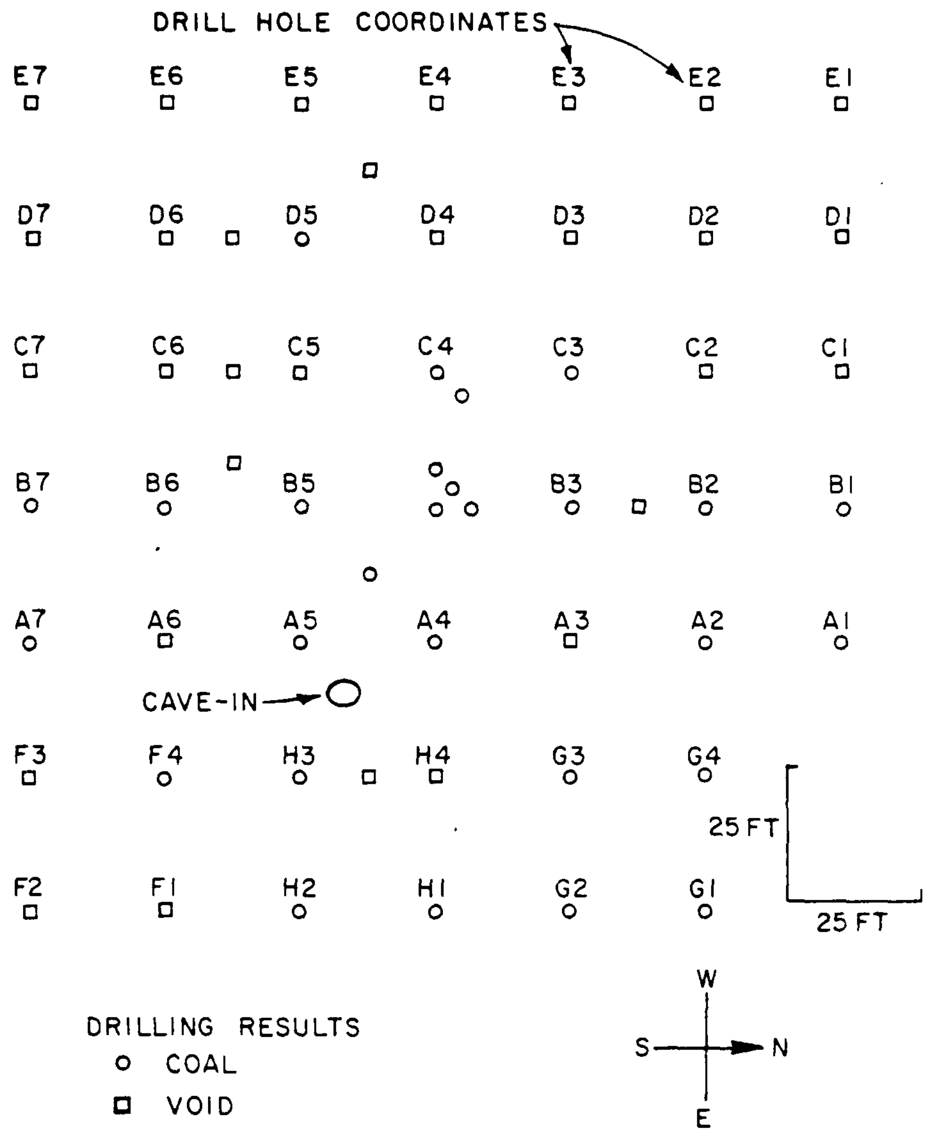


Figure 2. Curtis School drilling results.

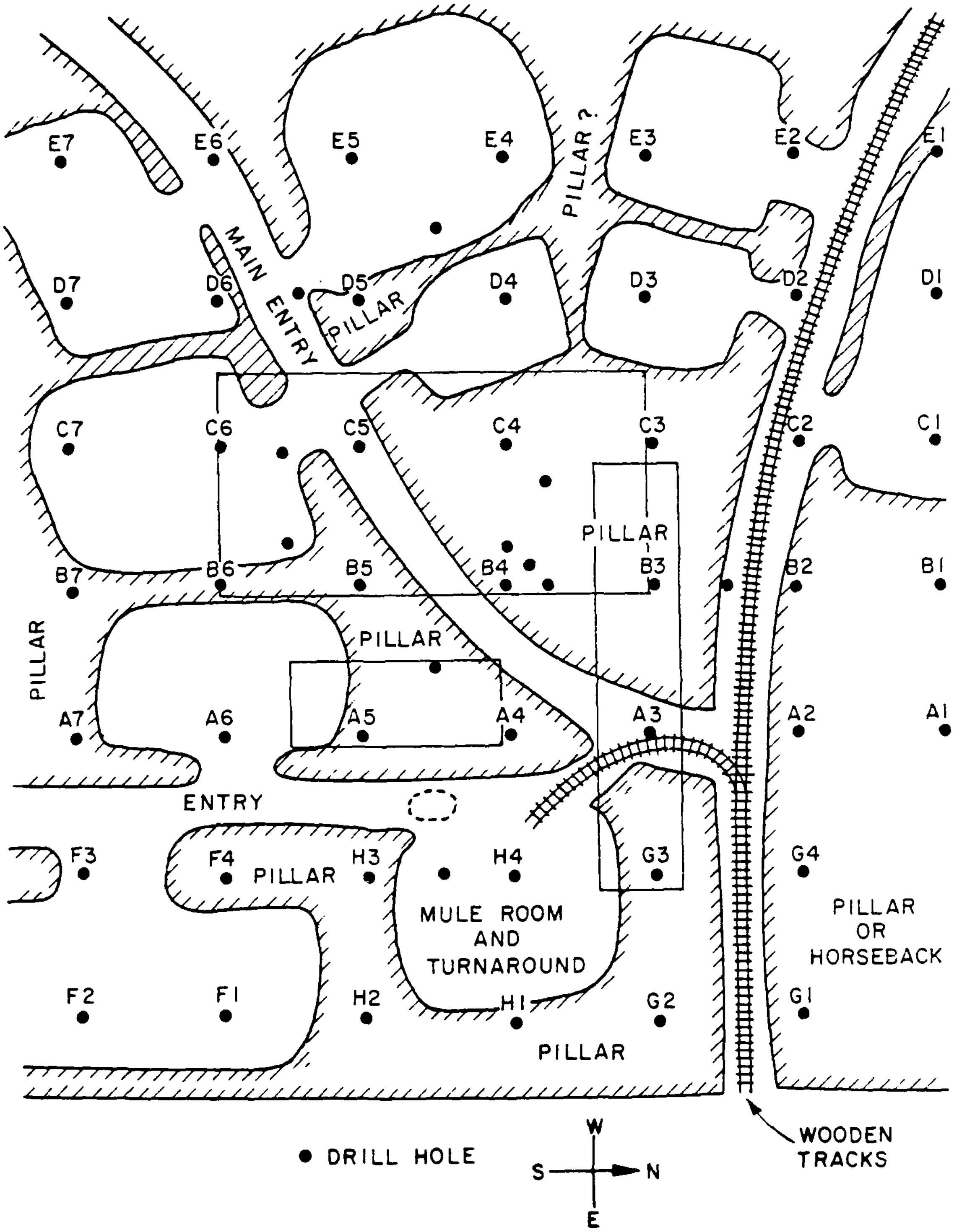
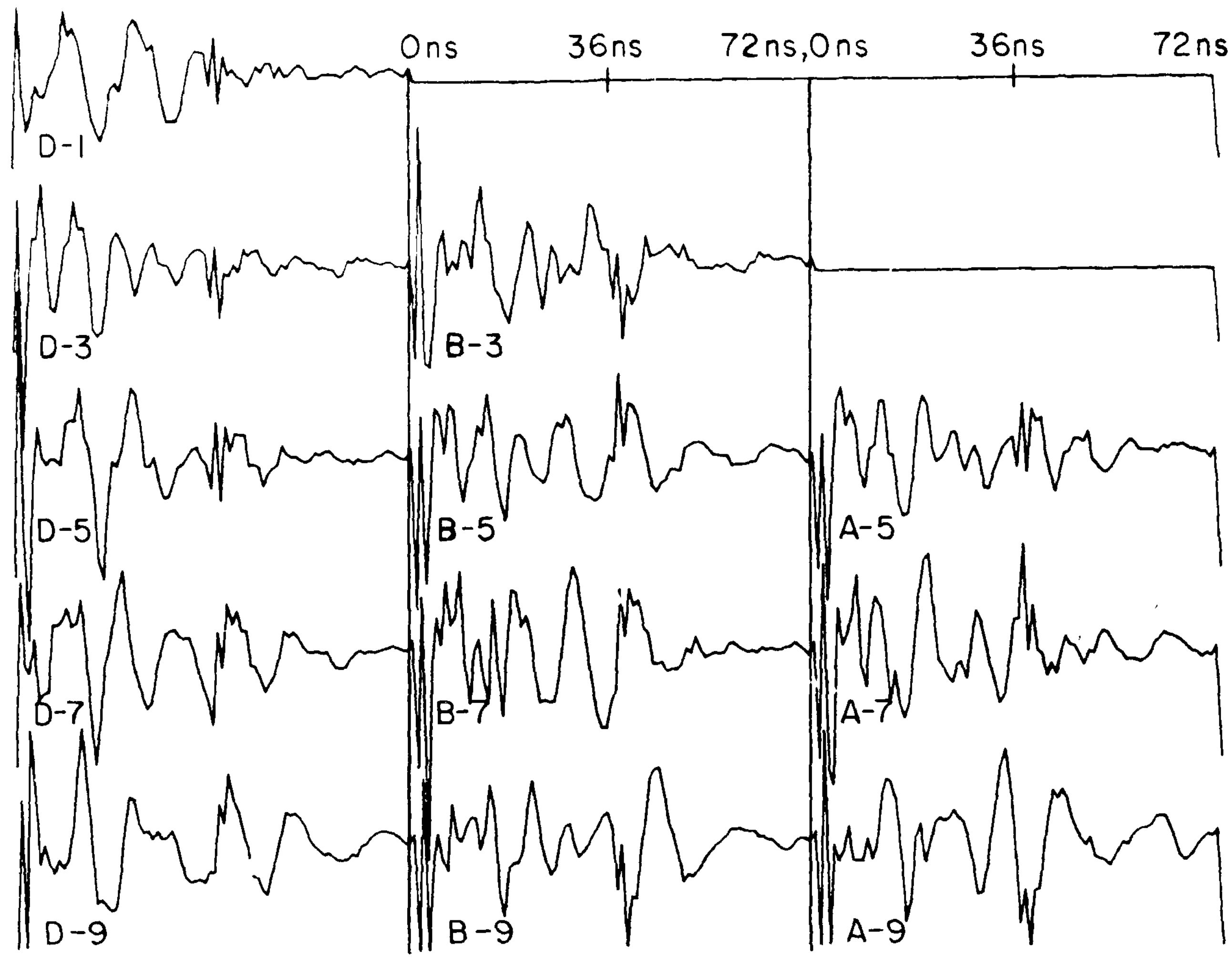


Figure 3. Possible underground features at Curtis School based on drilling results and local history.



(a)

Figure 4. Raw waveforms from measurement grid, A through K, 1 through 19. (Terrascan antenna).

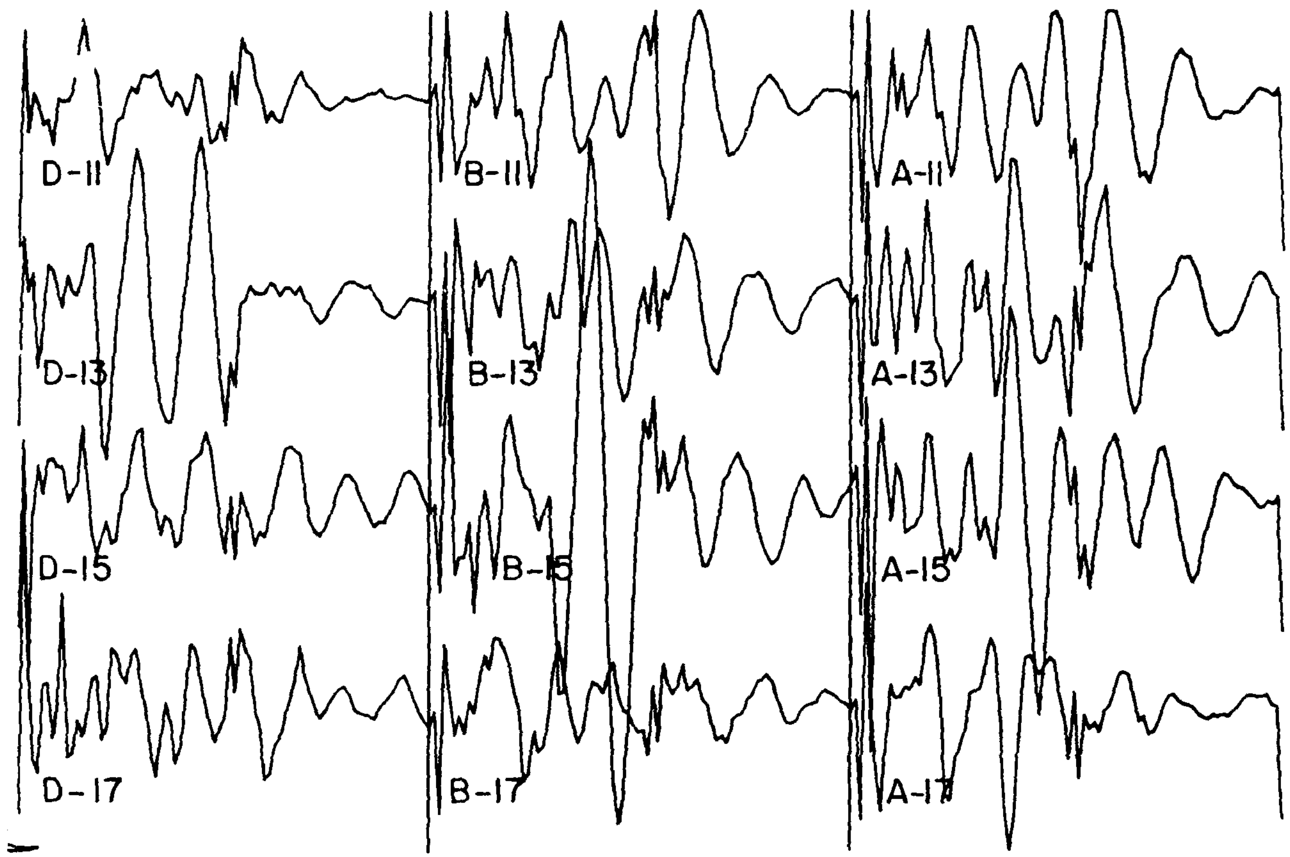


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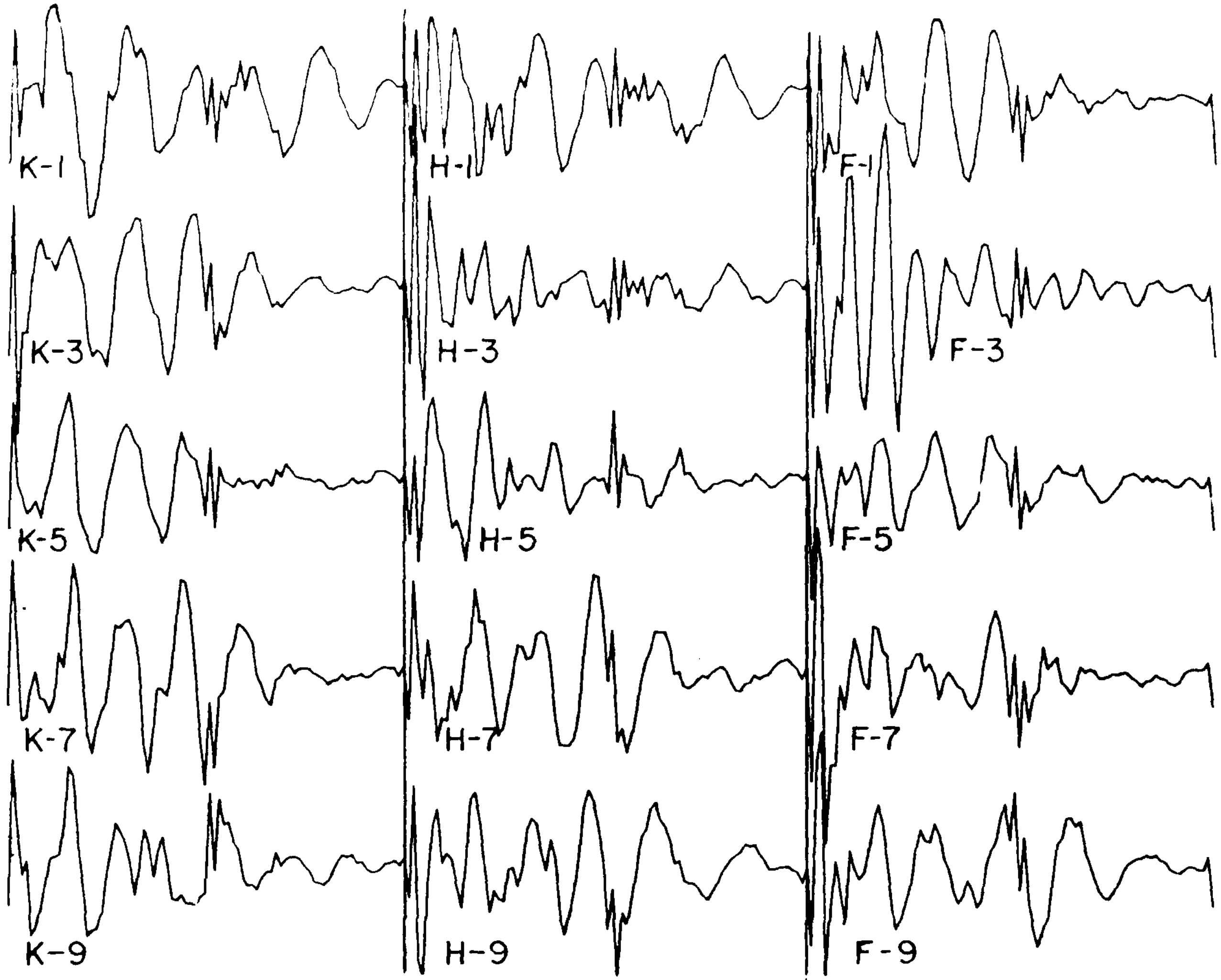
Figure 4. Continued.



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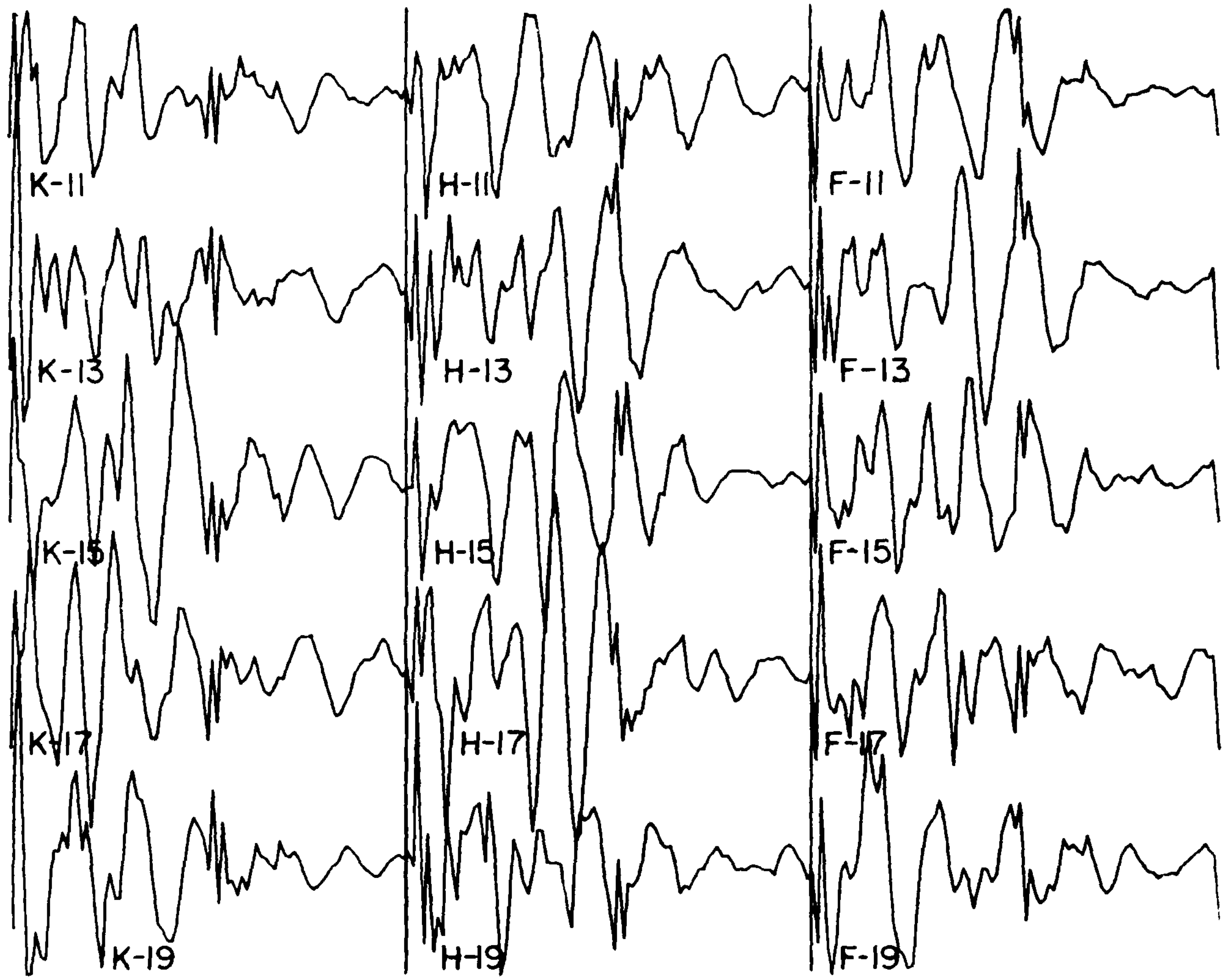


(d)

Figure 4. Continued.

This contour plot displays a region of very strong signals which is roughly co-linear with the tunnel entrance, the hole (see Figure 1), and a ravine up the hill off the playground. Noting that grid position E-i is equivalent to drill hole C-6, Professor Harris' sketch (Figure 3) shows the suspected main entry coinciding with the strong signal contours of Figure 5.

Subsequently a more sophisticated mapping system was initiated by Davis and carried to completion by Stapp[6]. This is a grey level plotting process in which the darkness of the plot is an indication of signal level. Plots have been made both of plan views and depth vs a horizontal displacement of the antenna.

For the plan views this process involves choosing a small time interval in the raw data waveforms and computing an R.M.S. effective amplitude for this signal region. At the chosen delay (depth) these figures of merit are derived for each waveform in the measurement grid. These numbers are then used to form 'plan view' intensity plots displaying x versus y travel information, at a given depth.

Figure 6 shows one of these plots of the same grid map data for a depth range of 59 to 78 nanoseconds. Stapp[6] shows a series of these plots at various depths. The linear object in the upper right corner encompasses the largest signals of the plot. The strikingly linear edges suggest that this may be the floor of a tunnel in that plots for shallower depths (such as Figure 5) show that there are strong radar returns above this tunnel 'floor' but they meander about. It was felt that this was possibly caused by the presence of a room or by erosion. Part of this area has subsequently been evacuated between log positions C-6, C-7, D-6 and D-7 and found to be filled with loose material and large boulders apparently washed into the tunnel over the years. A deeper plot for the range 69 to 88 nanoseconds showed that relative signal strength falls off rapidly beyond 69 nanoseconds. No tunnel-like features are evident beyond this depth. The drilling log for position C-5 finds a void from 8 feet to 12 feet.

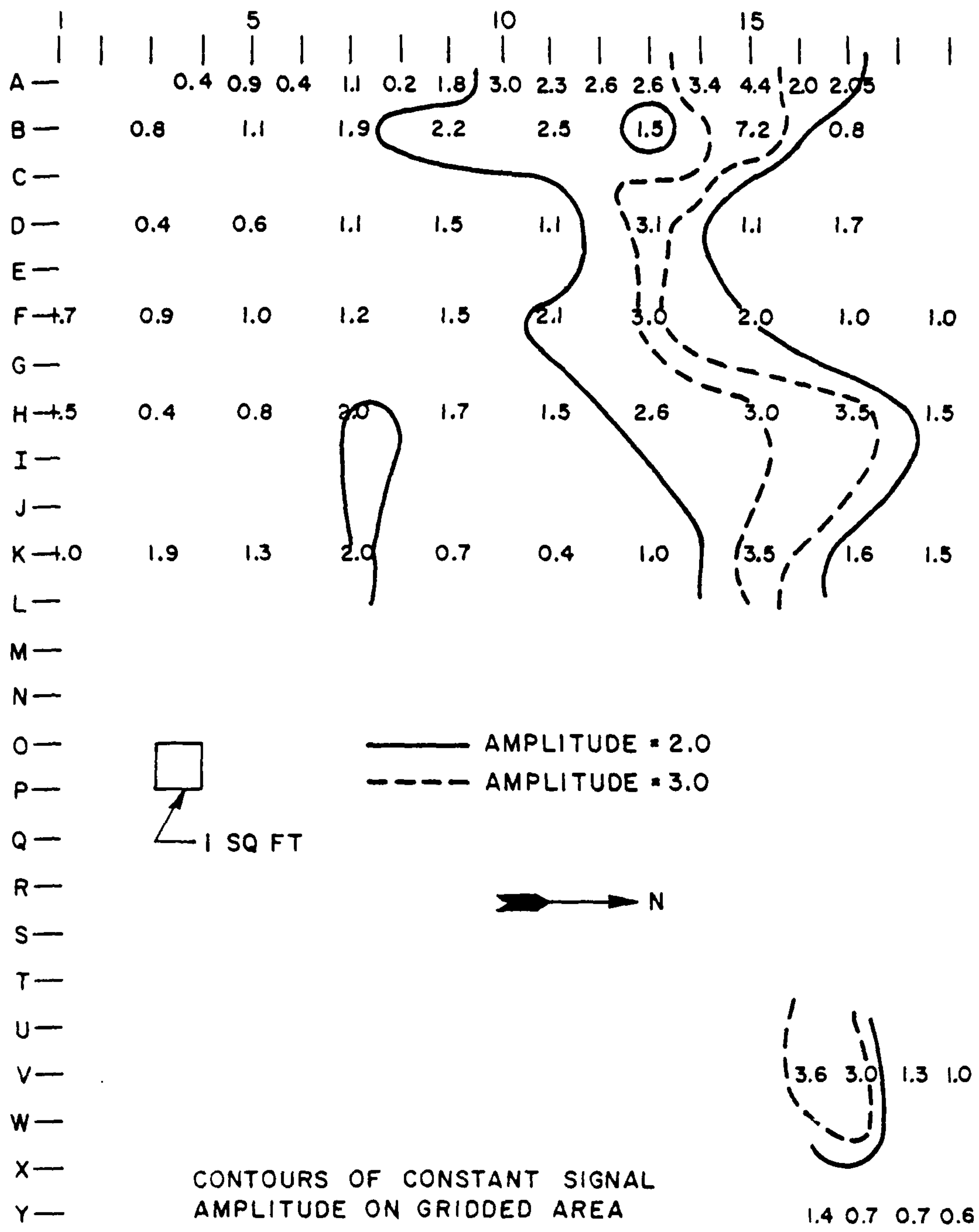


Figure 5. Contours of constant signal amplitude over Curtis School gridded area.

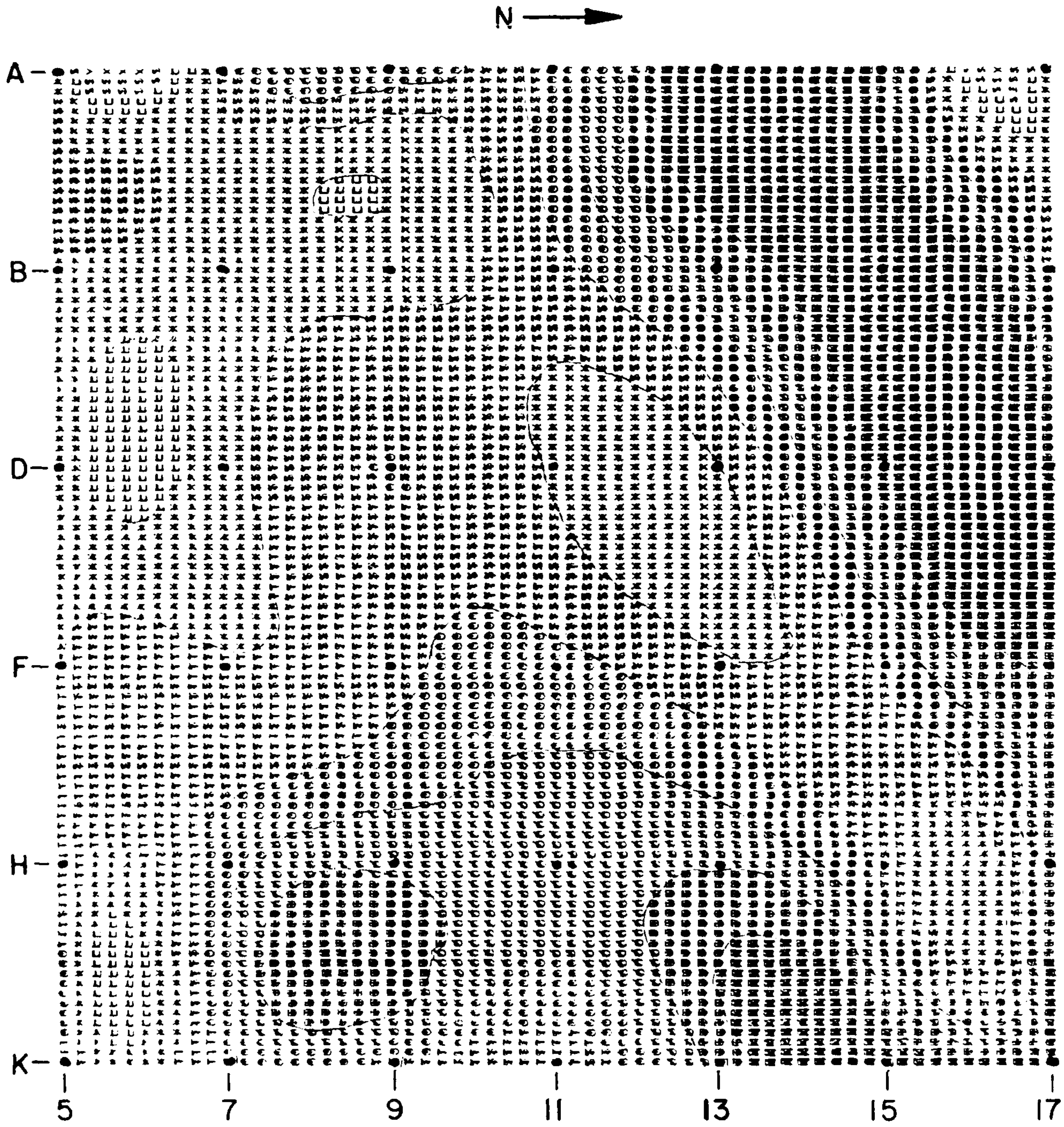


Figure 6. Plan view of gridded area for depth range of 59 to 78 nanoseconds. Strongest signals are darkest.

The large raw waveform features which are evidenced by the contour and intensity plots are clearly visible in Figure 4 in the coordinate range 13-17 at depths of 30 through 65 nanoseconds.

Second Trip

The second trip had several intended goals. The first was to repeat a path over the local grid indicated in Figure 1. These measurements showed the results were repeatable even under drastic changes in weather conditions. The second was to search the playground with the Terrascan and locate any other sources of large signals and finally to map the entire ground using a mobile shallow mapping radar system being developed for EPRI[7]. A computer printed map resulting from measurements using this system is shown in Figure 7. Three separate portions of the area were mapped, the results from which have been pieced together in Figure 7. These three areas are indicated also in Figure 3 by the rectangular blocks. This approach was necessary because of the presence of a fence which had been erected around the area of the cave-in for safety purposes. During mapping the computer was programmed to record waveforms at one foot intervals. Two passes were taken along each line, the polarization of the antenna being rotated by 45 degrees between the two. Traverse lines were spaced five feet apart. In the figure, the area at the north end of the playground was traversed in an east-west direction; the other two areas were traversed in a north-south direction.

For presentation purposes the two polarizations are printed in adjacent columns. They thus apply to the same traverse line which may be considered as being midway between them. The next pair of columns is for the traverse line five feet away and so on. Each received waveform was examined over the time interval between 52 and 83 nanoseconds, corresponding to a depth from 10.6 to 17 feet assuming a value of permittivity equal to 6. The AC peak value for each waveform was found within

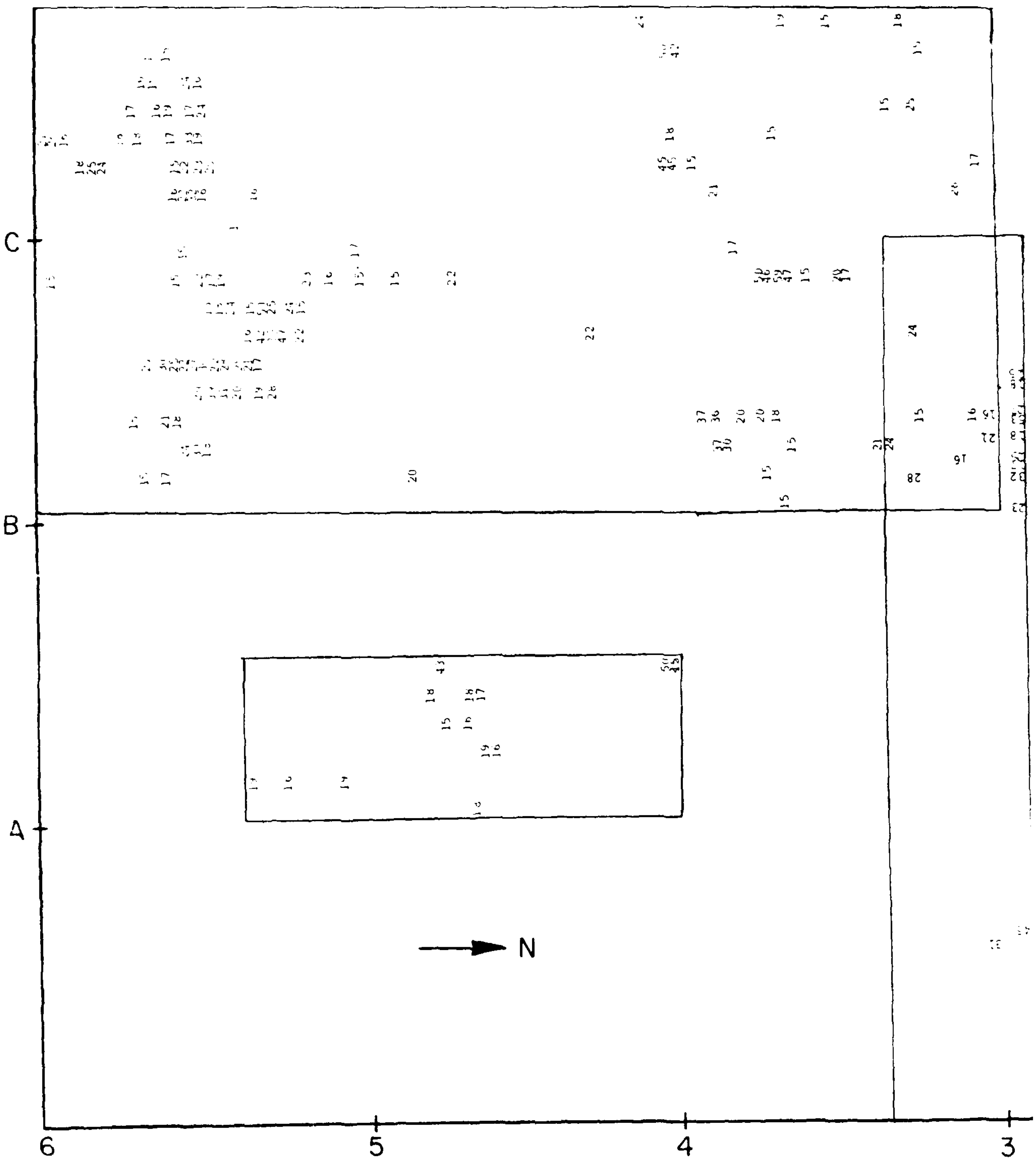


Figure 7. Early EPRI system signal amplitude map for depth range 10.7 to 17 feet.

this range window. A threshold of 15 voltage units was selected and Figure 7 displays only those values which were 15 units or greater.

Looking at this map, we see that the system acquired very large signals in the measurement grid we had mapped earlier (see Figures 5 and 6) which was in the block bounded by drillers coordinates C-5, C-6, D-6, and D-5.

Another source of relatively large echoes was discovered extending from B-6 to C-5. This could be the entrance to one of the rooms shown in Figure 3. We also observe that the map of Figure 7 shows echoes in the grid B-4, B-3 to C-4, C-3. Drilling indicated only coal in these areas but it could be that these areas bordered on an excavation of some type, particularly in view of the well known pillar robbing that occurred in these mines during the depression. Observe that Professor Harris' map (Figure 3) is based on the drill hole results.

Third Trip

For this trip a carefully selected set of measurements were made. These were selected based on the drill hole data. In particular, efforts were made to cross regions where there was change from coal to void or void to coal. One such path is taken from 2.5' south of B-5 to 2.5' south of C-5. These numbers and letters are those associated with the drill holes. These measurements were made with the long box antenna and the 6 nanosecond pulser. Figure 8 shows the complete set of data with time and voltage scales indicated in the inset. The position to the west in feet along this traverse is indicated adjacent to each waveform. Waveform BC:1 corresponds to 2.5' south of B-5; waveform BC:27 corresponds to 2.5' south of C-5. There are in this single pattern set a number of interesting features. First, the beginning of waveform BC:2 is unusually smooth. There is however a negative peak appearing in waveform BC:2 that occurs 22.5 nanoseconds after the waveform starts which moves outward and decays in successive waveforms. This indicates

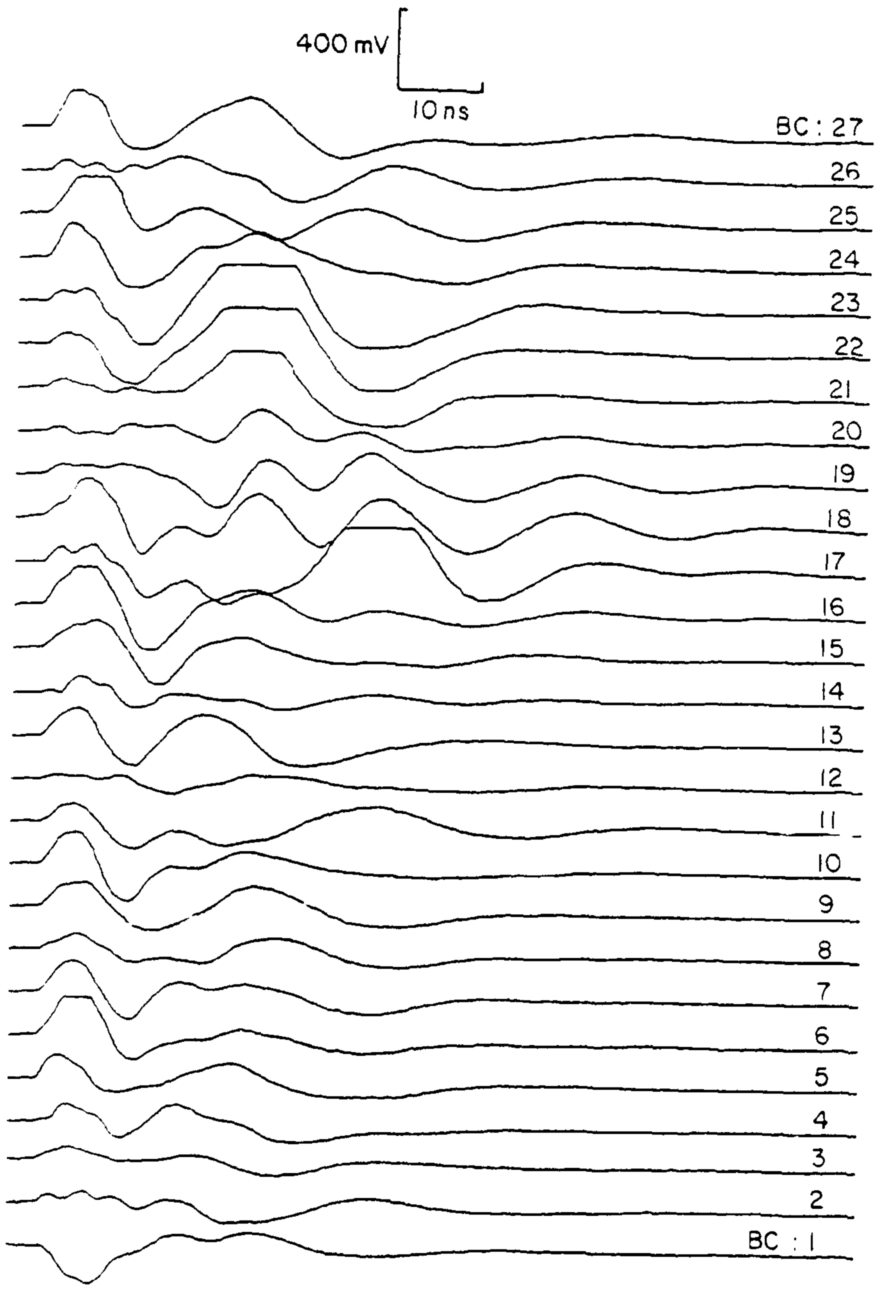


Figure 8. Antenna traverse from 2.5 ft. south of B-5 (BC:1) to 2.5 ft. south of C-5 (BC:27). Long Box Antenna.

the presence of a rather weak buried scatterer at a depth of the order of 4.5' (assuming ϵ_r=6). Perhaps the most important feature in these waveforms occurs in waveform BC:17. There is a large peak at about 37 nanoseconds from the onset of the signal. This corresponds to a depth of 7.5' (again assuming ϵ_r=6). This is particularly interesting in that it could not possibly be caused by multiple reflections on the antenna since the signal that preceeds it is relatively weak. It is followed by a negative peak about 13 nanoseconds later (at 50 ns). If this should represent crossing from a region where the coal has not been mined (BC:16) to one where it has been removed (a void, BC:17) then this second reflection would be from the bottom. If the feature in waveform BC:17 is indeed from such a discontinuity, the theory of diffraction would indicate that it would have a distinct pattern in space, thus as the probe moves from void to coal, the returned signal would decay more rapidly than would be normally expected from a point scatterer. The later lobe structure seen in the waveforms of BC:17, 18 and 19 (around 48 nanoseconds) seem to be closest to the origin in waveform BC:18 indicating that this position is closest to the discontinuity. The dominant frequency in these waveforms is approximately 40 MHz, obtained by finding $f = \frac{1}{T}$ where T is an approximation to the period of these peaks. There is another large discontinuity occurring around waveform BC:22 at about 24 nanoseconds. This also appears to be beyond the region where the first antenna multiple reflections would appear and we would conclude this is caused by some shallow scatterer. A nearby test drill showed loose rock from 3.6' to 8' with void from 8' to 12.2'. Another showed a void from 3.2-5.5'. Apparently the eroded roof of the tunnel or room is around 3-8 feet. Now examining these echoes in the light of the map of Figure 3, the result from waveform BC:17 is seen to be in agreement with Professor Harris' suggested position of the entry shaft.

One can make a number of hypotheses from this data; however, it would be more profitable to further process the data to remove the antenna resonances. Such a scheme has recently been developed and it is expected that data interpretation will be greatly improved. It is intended that we will pursue this depending on availability of further support.

Next we consider a path running from south to north from a point positioned 13' east of C-6 to 12' east of C-5. This is designated as the BCC data set (Figure 9). In this case the modified Terrascan antenna was used in the radar and again the 6 nanosecond pulser was used. Waveform BCC:22 in this set should correspond to waveform BC:13 in the set just discussed (Figure 8) exclusive of the multiple reflected pulses on the antenna structure (different antennas) and indeed the patterns are quite similar.

In this BCC data set one's attention is directed to waveforms BCC:16-19. The large feature in BCC:18 seems to be nearest to the origin. Its first major peak is at about 18 nanoseconds and it is too large to be accounted for simply by reflection from the end of the antenna. It becomes very fascinating when one examines the drillers log for the position 17' east and 13' north of position C-6. There is a void at a depth of 3.2'. This corresponds to a time of the order of 15 nanoseconds and agrees with the strong lobes observed in the waveform designated as BCC:14. The resonant frequency in this waveform appears to be about 100 MHz. The resonant frequency for 2.5' void is about 120 MHz. It is also interesting to observe that Professor Harris' map postulates that an edge to a room exists at about the position where these peaks occur.

The data set of Figure 9 was used to form a grey scale plot of the depth versus antenna position variety. The features previously discussed can be observed in this cross-sectional plot (Figure 10). The major feature of interest is the set of dark hyperbolic shapes centered around antenna position BCC:18. This was where we suspected the edge of the room to be. From position BCC:15 through BCC:11, a dark feature is evident which becomes weaker as it approaches the surface.

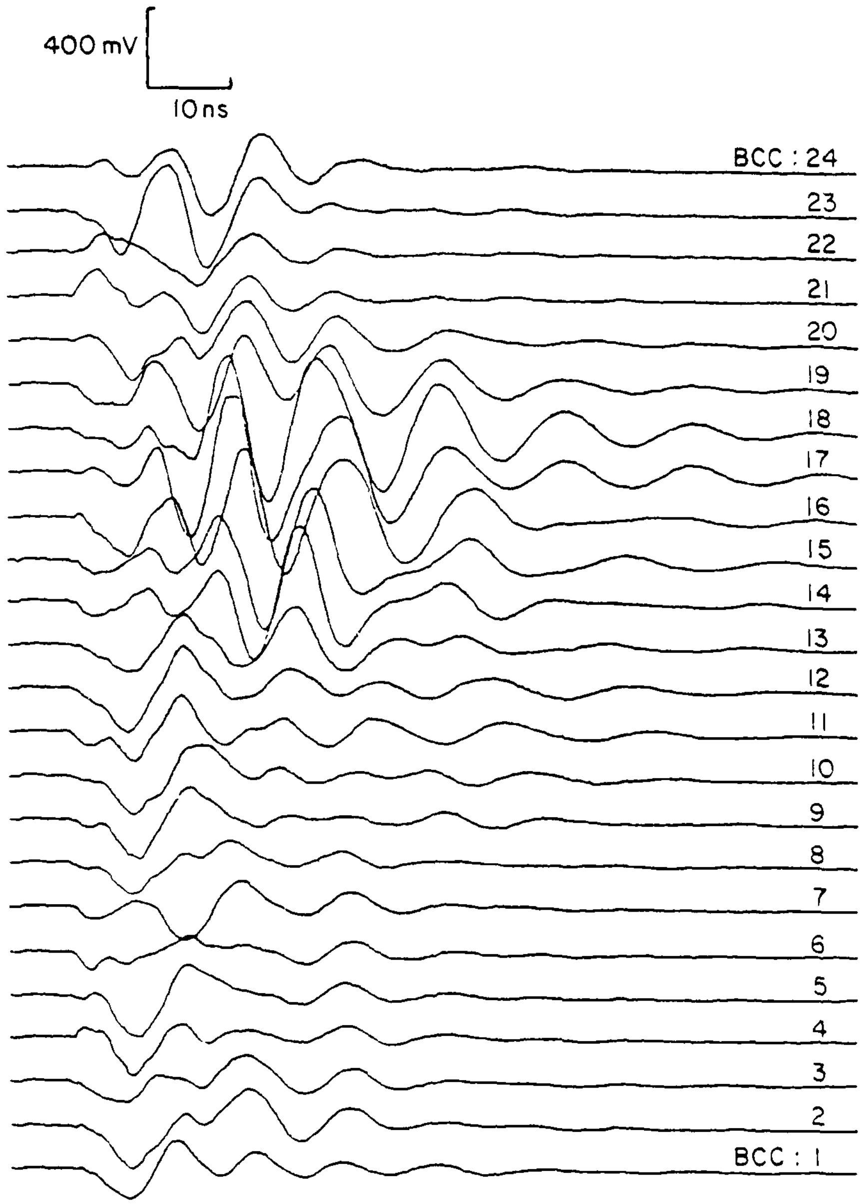


Figure 9. Antenna traverse from 13 ft. east of C-6 (BCC:1) to 12 ft. east of C-5 (BCC:24). Modified Terrascan antenna.

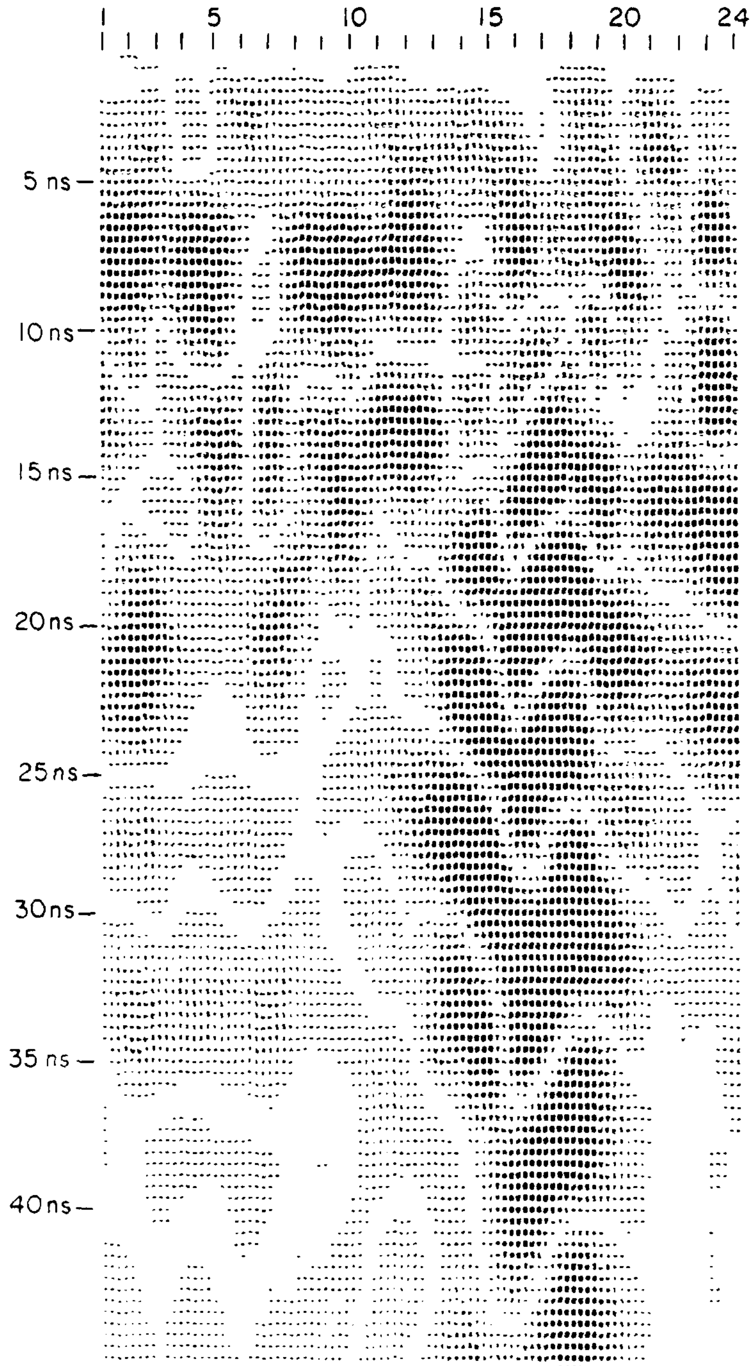


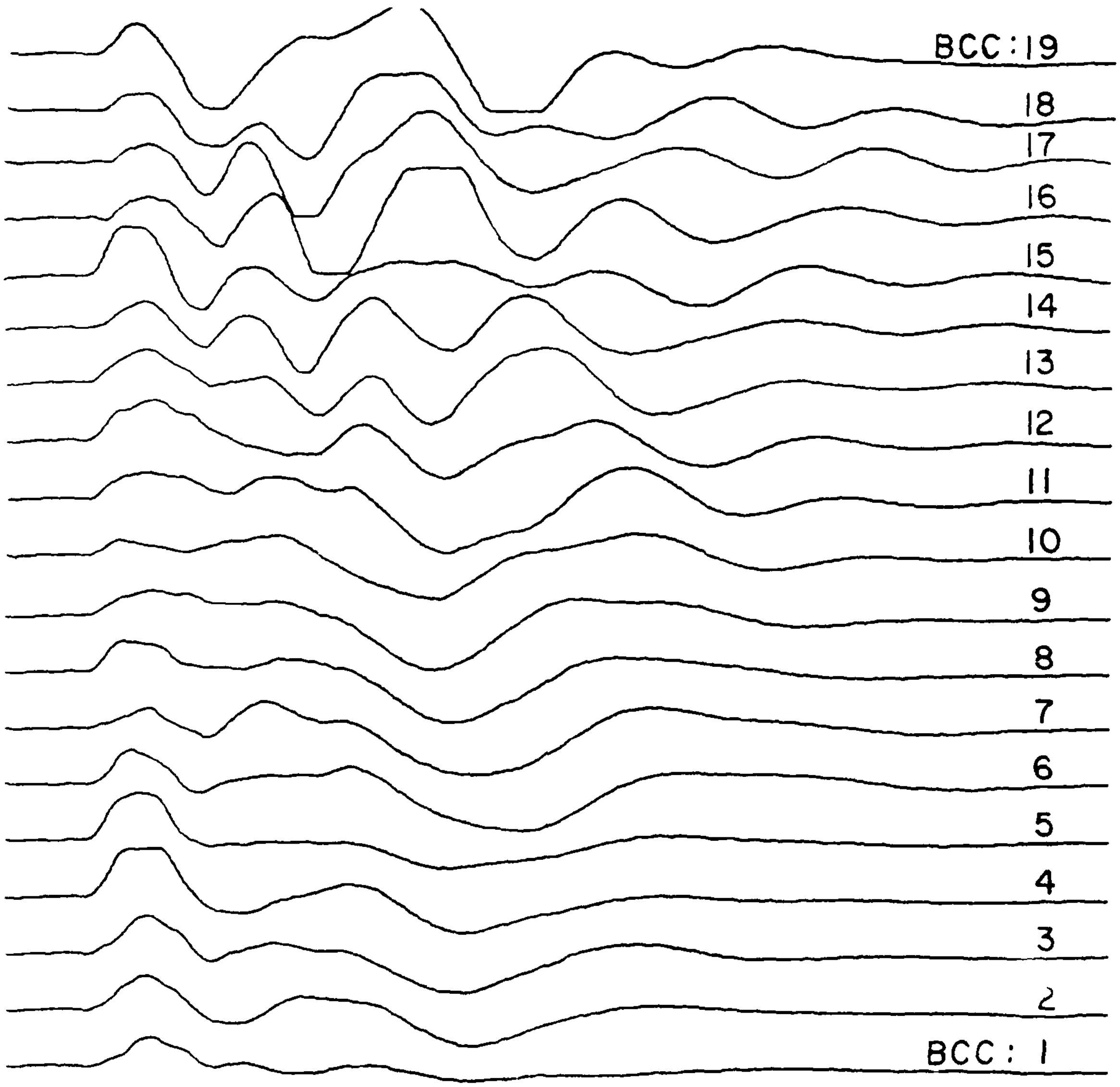
Figure 10. Depth versus antenna position from BCC traverse. Modified Terrascan antenna.

This is hypothesized to be an echo from the eroded ceiling of the void, which might curve upward from position BCC:15, leveling off by position BCC:11. (The radar is a cross polarized system which receives no response from a planar layer, so when the ceiling has leveled off no return is received.)

This BCC pattern set has also been repeated using the long box antenna (Figure 11). The measured patterns in the common region are strikingly similar thus discounting any possibility that these lobes are caused by any multiple reflection on the antenna. Waveforms recorded using the long box antenna were taken for an additional 13' to the north (BCC:23 to 36). A very large lobe structure becomes apparent in these waveforms and they coincide in position with Professor Harris' postulate for the position of the entry shaft. The period of this structure however has increased to about 30 nanoseconds and thus the resonant frequency to about 33 MHz corresponding a tunnel dimension of the order of 6 feet.

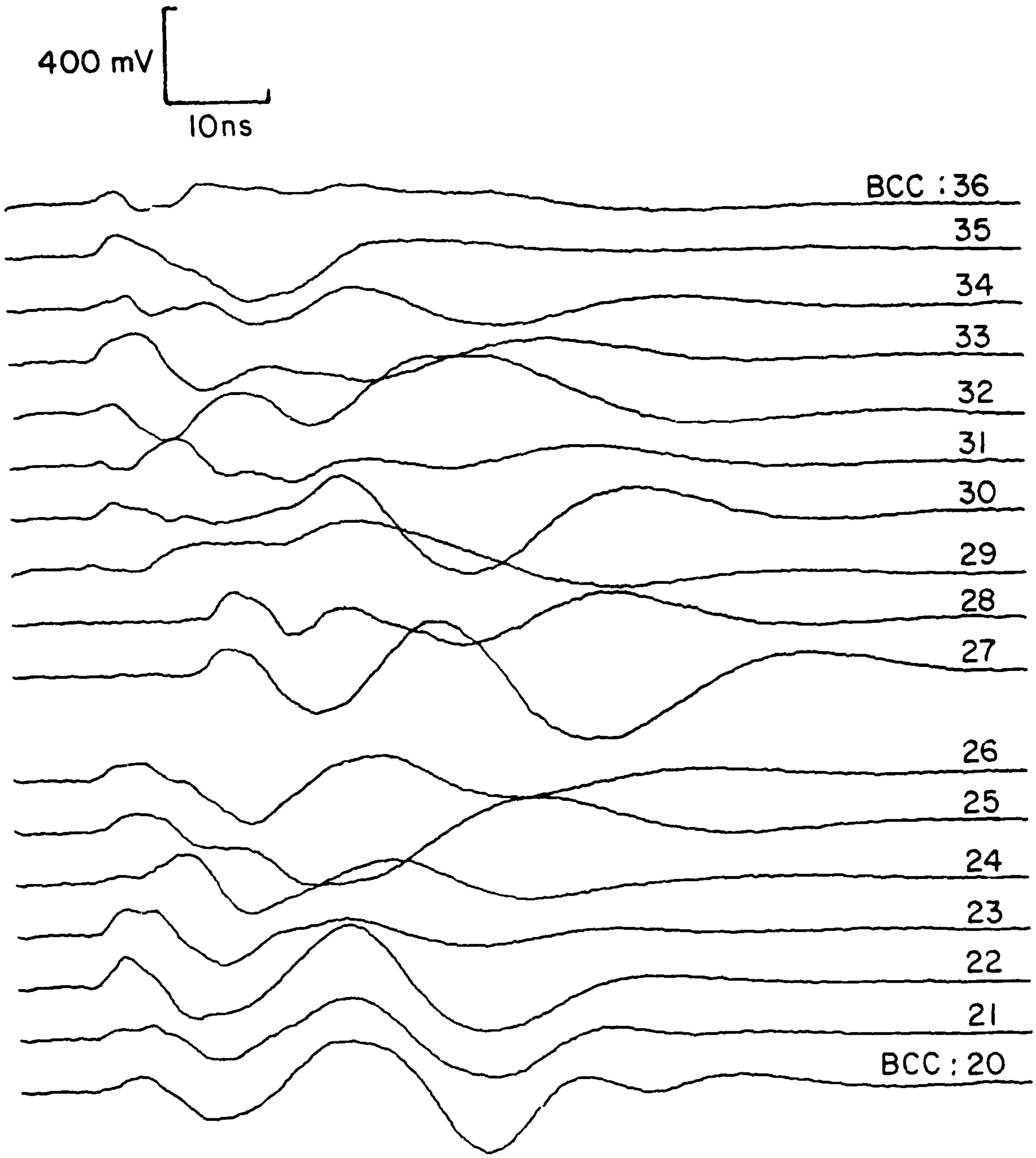
The next set of waveforms to be discussed were taken in one foot increments from position C-3 to D-3 (Figure 12). The obvious goal here was to determine if the wall to the room (see Professor Harris' map) could be fixed. This is postulated to occur at about position CD:12. There seems to be a fascinating reversal of polarity at about position CD:17 (5' west of the postulated wall position). This is probably the position of the wall. One of the problems that seemed to plague these measurements is that often around a drill hole there was a large early signal. This appears quite distinctly in this last data set. Yet we observe quite similar behavior in the results shown in Appendix II. These measurements (Appendix) were made before the holes were drilled, using a short antenna, 150 picoseconds pulser and a 20 nanosecond per division setting on the sampling oscilloscope.

Next consider a path starting at a point 12.5' west of A-2 and going south 28' in increments of a foot (Figure 13). Let us designate this as path ABB. Looking at the map of Figure 3 it is seen that this



(a)

Figure 11. Antenna traverse from 13 ft. east of C-6 (BCC:1) north 35 ft. (BCC:36). Long Box Antenna.



(b)

Figure 11. Continued.

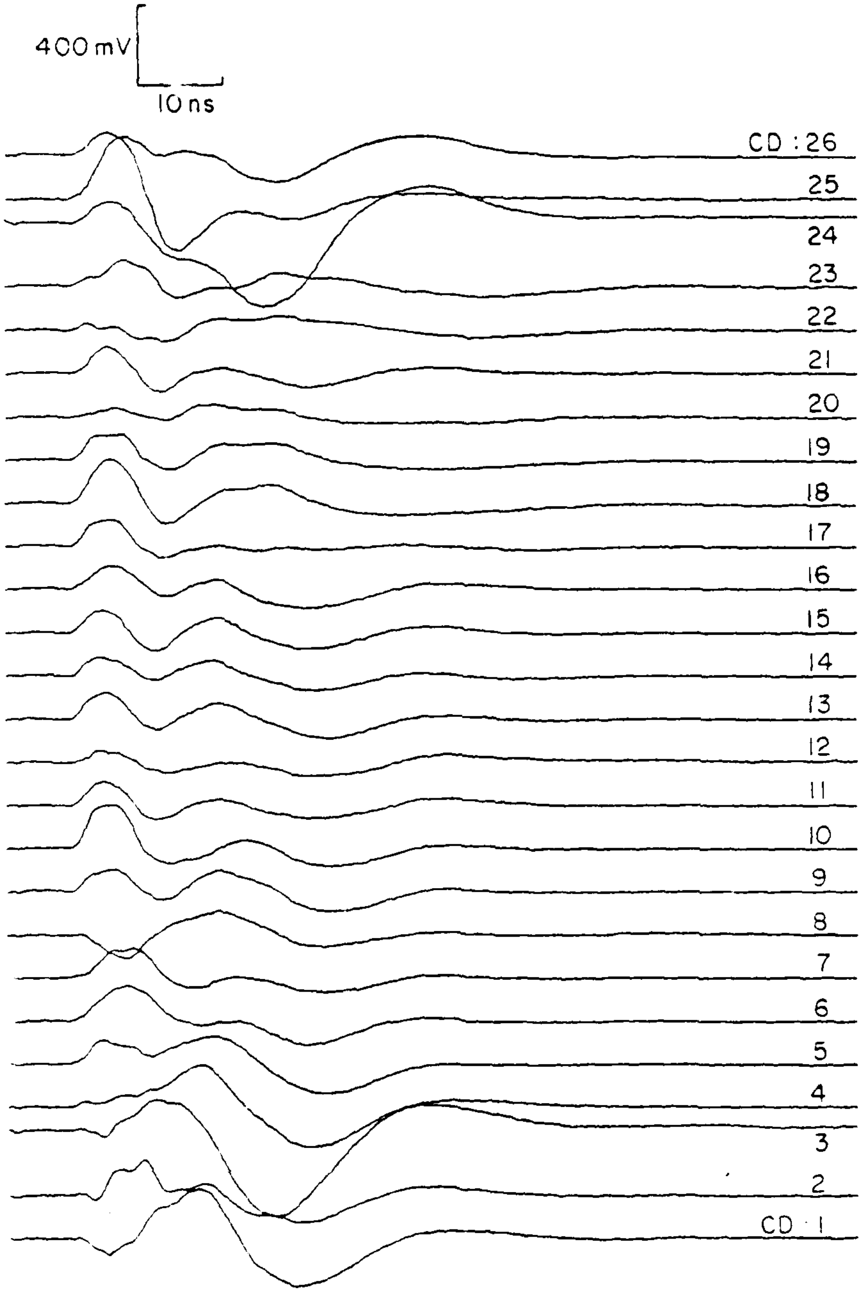


Figure 12. Antenna traverse from C-3 (CD:1) to D-3 (CD:26). Long Box Antenna.

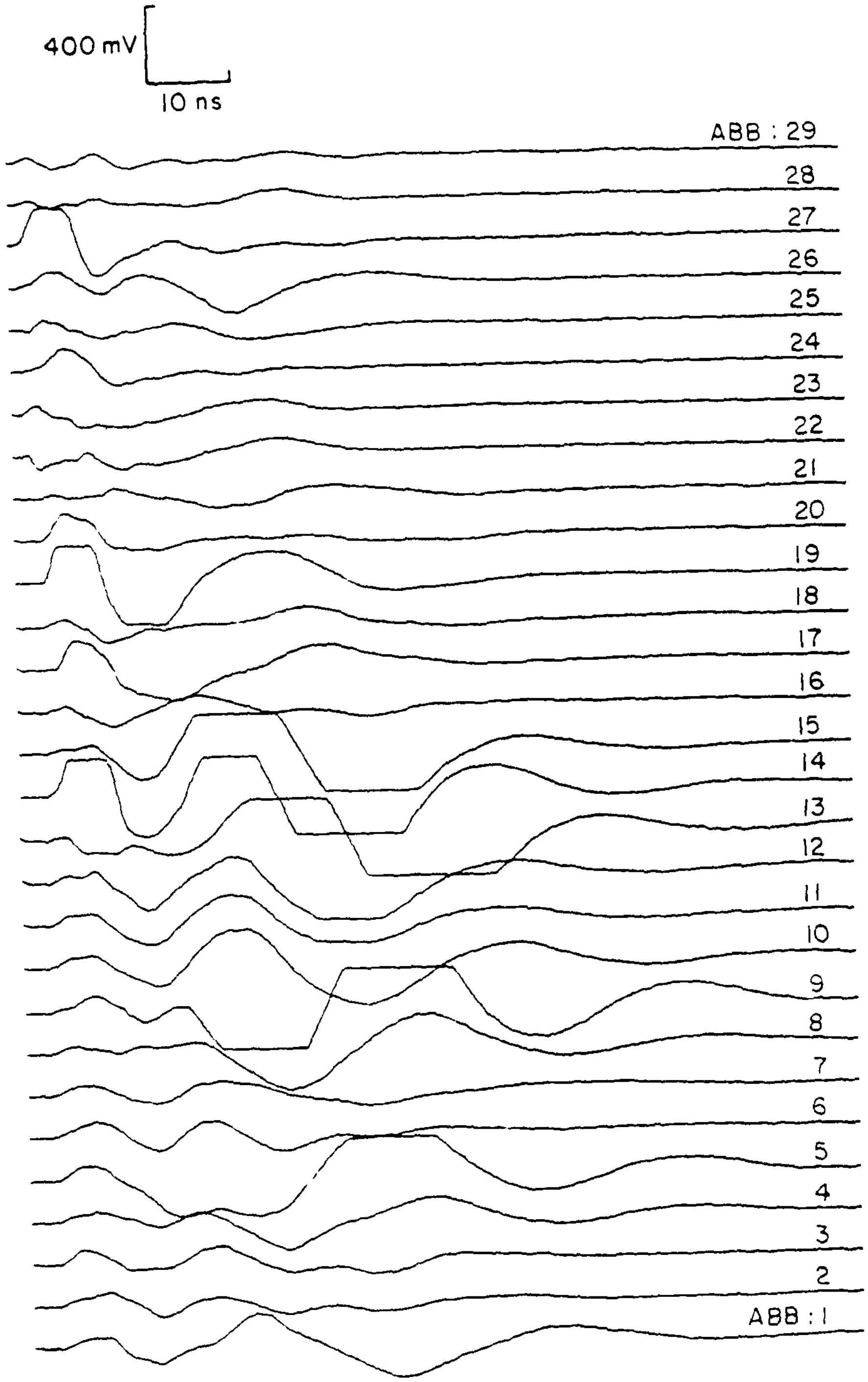


Figure 13. Antenna traverse from 12.5 ft. west of A-2 (ABB:1). South 28 ft. (ABB:29), Long Box Antenna.

should cross the shaft which originally contained the rails (believed to be wooden). It is interesting that our first major feature of interest is at position ABB:4 or 5 which seems to disappear in ABB:6 and 7, reoccurs in ABB:8-9, reverses polarity and arrives at a slightly earlier time and disappears finally at position ABB:16. The minimum arrival time appears to be at position ABB:11 or 12. This could lead us to infer that the tunnel is on the order of 9' wide. However, there is an asphalt gravel discontinuity that is oriented in an east-west direction at position ABB:14. The strong reflections occurring in waveforms ABB:13, 14 and 15 could be caused by this discontinuity.

The next path is taken from 2' East of C-2 to the north in increments of one foot. Measurements were taken with the modified Terrascan antenna (Figure 14), the short box antenna (Figure 15), and the long box antenna (Figure 16). From Professor Harris' map, this does not appear to be an extremely interesting area and indeed looking at the plots of Figure 14, this seems to be the case. There appears to be some activity at position CC:10 for both short antennas and this may imply that the lip of the entrance to a void is being approached. Oddly, both short antennas show a peculiar waveform behavior at positions CC:1, 2 and 3 near the beginning of each waveform.

The next traverse is from G-4 to G-8 and then to H-4 (Figure 17). These patterns are taken with the long box antenna. From the map, it is seen this takes the radar from the pillar (or horseback) again across the tunnel with the tracks and finally over the mule room (or turnaround). The first obvious step is to compare this set of patterns with the previous set over the tunnel with tract (ABB, Figure 13). The first three waveforms are quite similar. Waveforms G4:4-7 are very quiet whereas waveforms about five in the ABB set show strong reflections. Waveforms G4:8,9 are similar to waveforms ABB:10-13. We see reflections where edges of this tunnel are suspected. To accurately delineate the tunnel walls would require obtaining data in a grid along the direction of the tunnel walls.

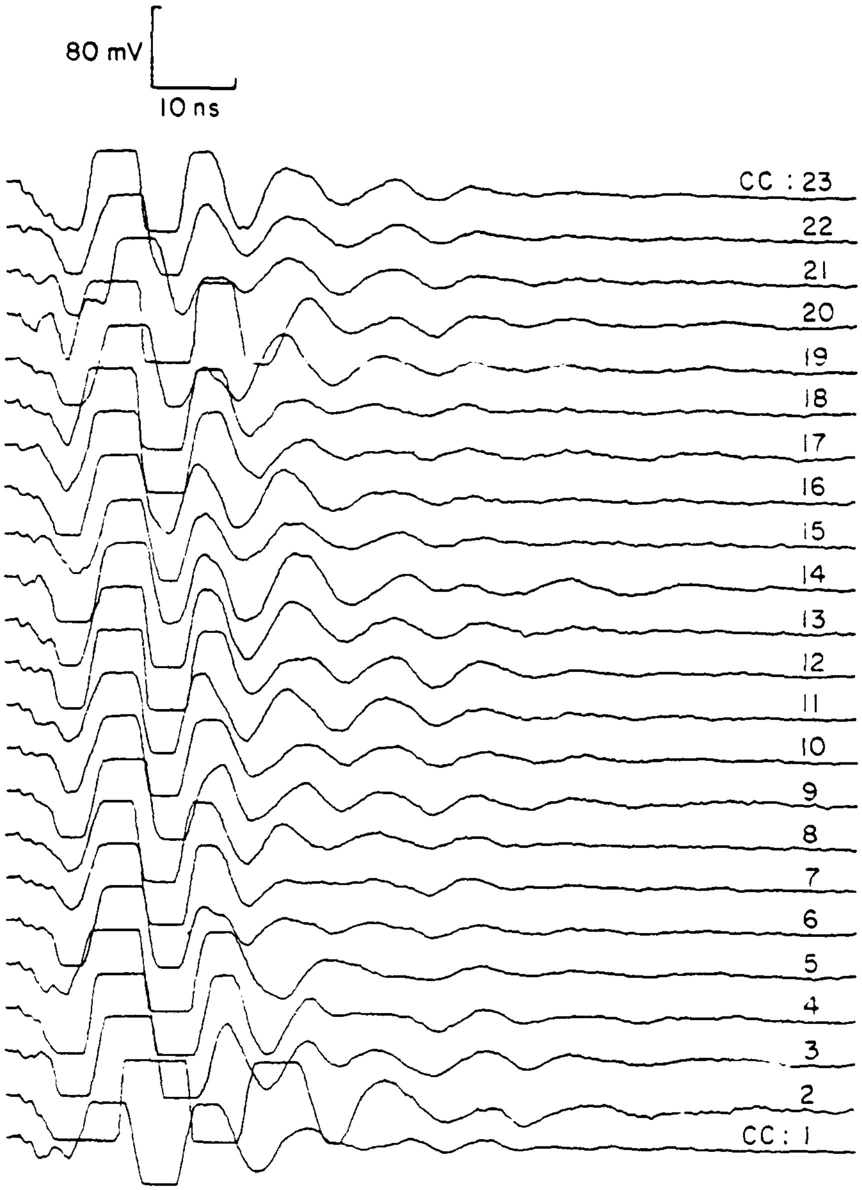


Figure 14. Antenna traverse from 2 ft. east of C-2 (CC:1) north 22 ft. (CC:23). Modified Terrascan Antenna.

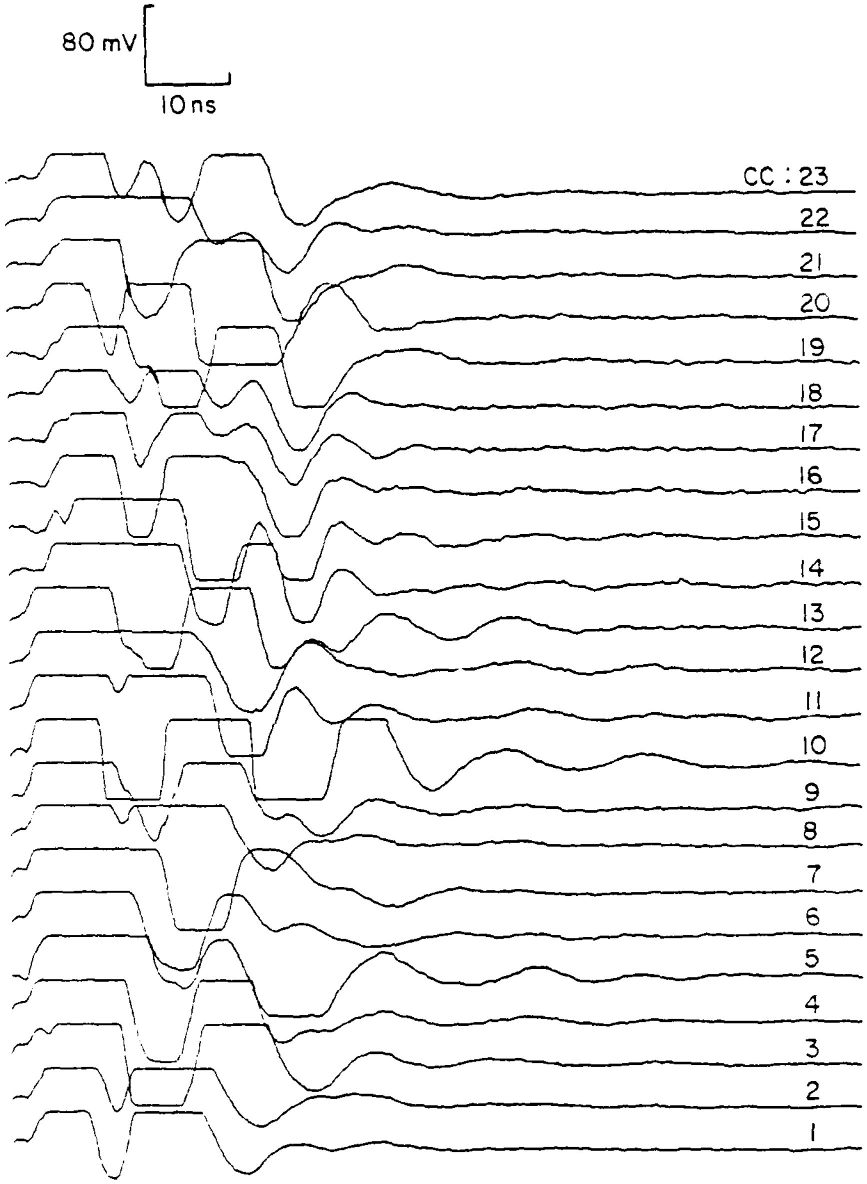


Figure 15. Antenna traverse from 2 ft. east of C-2 (CC:1) north 22 ft. (CC:23). Short Box Antenna.

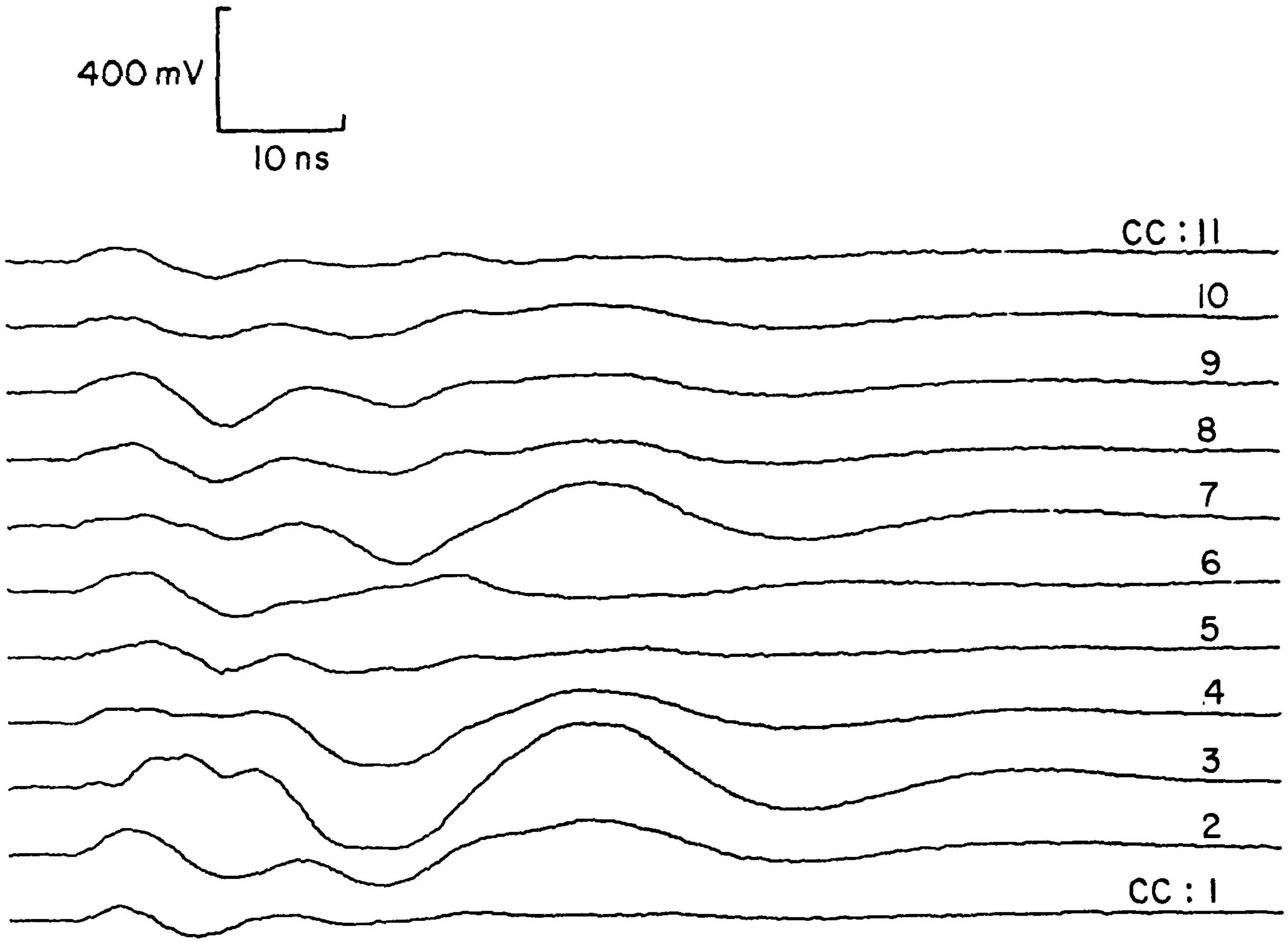
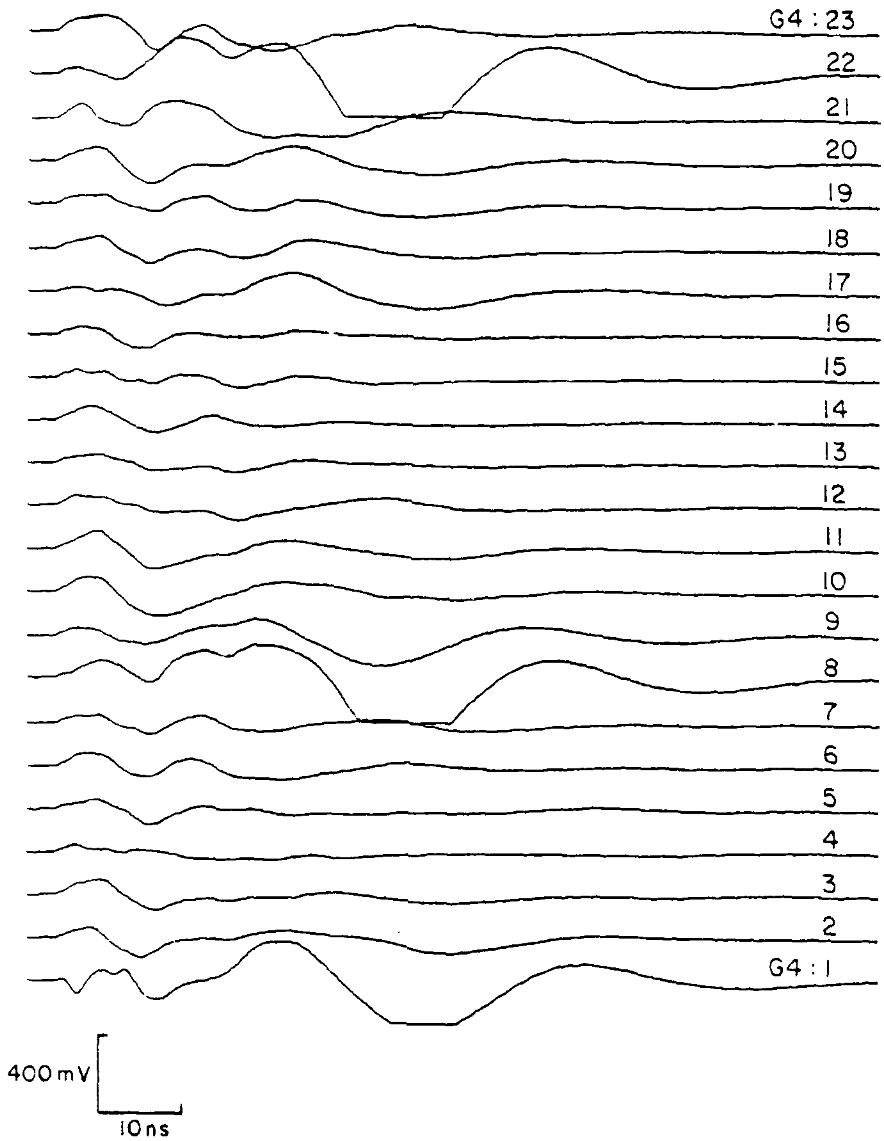
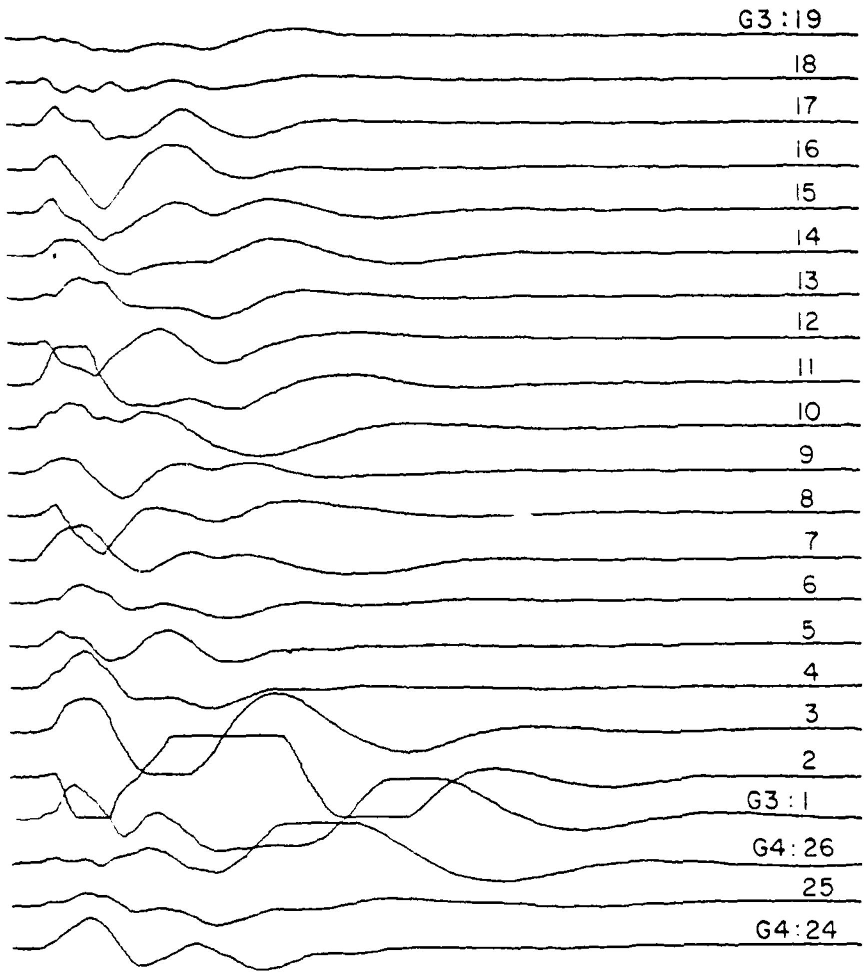


Figure 16. Antenna traverse from 2 ft east of C-2 (CC:1) north 10 ft (CC:11). Long Box Antenna.



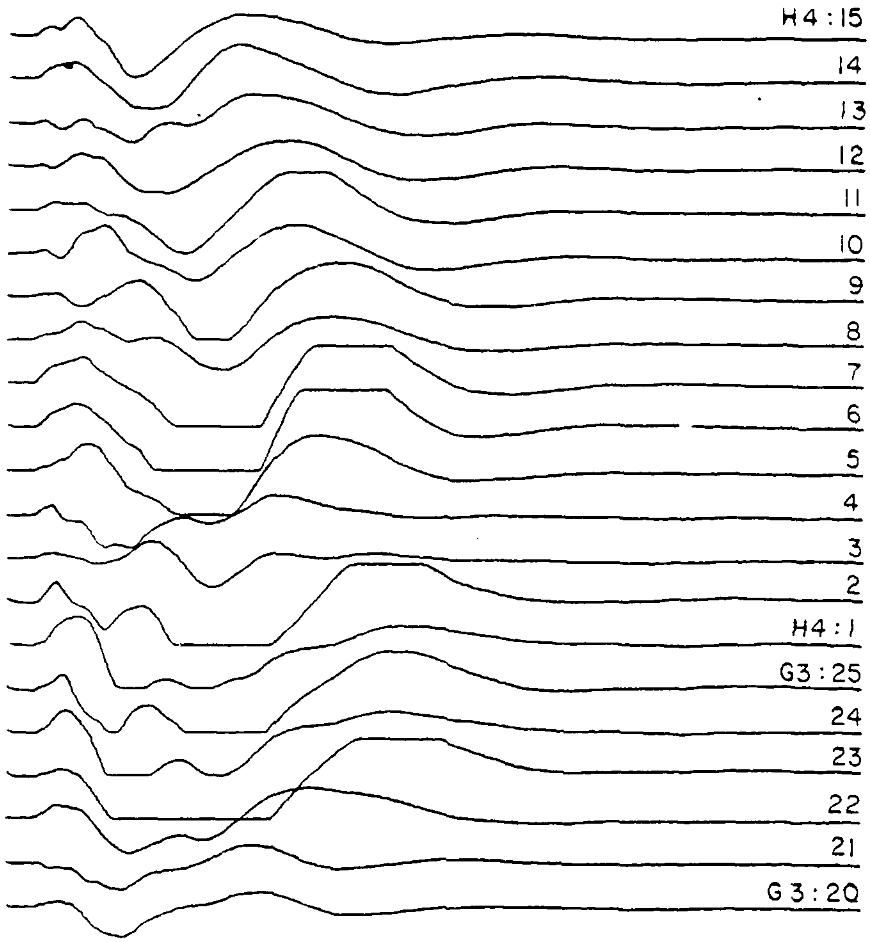
(a)

Figure 17. Antenna traverse from G-4 (G4:1) south 26 ft. to G-3 (G3:1) south 25 ft. in H-4 (H4:1) south 14 ft. (H4:15). Long Box Antenna.



(b)

Figure 17. Continued.



(c)

Figure 17. Continued.

The waveforms for positions G4:10-20 also seem to show no features of interest except perhaps at G4:17. This is in direct contrast to the data set of ABB (Figure 13). This is the region where the asphalt discontinuity exists. There is a feature at position G4:22 that looks like that obtained at G4:8. If this delineated the tracked tunnel it would be 14' wide. This is questionable. One must wonder if possible cave-ins have obscured the data. This trajectory now carries the radar from G3 to H4 and over the mule room. The coordinate numbering starts over at G3. However, again there seems to be very little activity in the radar plots. If one is concerned that the drill holes have changed the water flow pattern and can not be considered to be valid data then position G4:1, 2 and 24 and G3:1 must be discounted when there is a very large initial reflection. The data from G3 to H4 would fix the mule room wall at position G3:14, since waveform G3:14 has the lobe structure occurring at the earliest time. This peak occurs at 27 nanoseconds and is in agreement with the depth to the mule room obtained from drilling.

Proceeding now from H4 in one foot increments to the south, there is evidently a lobe structure moving consistently to an earlier time in successive waveforms. For example, the last positive peak has moved from about 40 nanoseconds beyond the starting part of the waveform at position H4:2 and moves to 23 nanoseconds at position H4:14. This feature seems to be caused from something moving steadily nearer to the surface. This last waveform is about 14' east of the cave-in that appeared in the schoolyard. The depth derived from the waveform feature is in agreement with the depth of a void at the nearby drill hole.

Finally, a set of waveforms is added as the antenna is moved from position H4:5 diagonally to the southwest (Figure 18). These patterns were taken with the antenna over extremely rough ground but again there seems to be an approaching feature that is very near the surface similar to that in the H4 waveform set. The last waveform, 5' west of H4:13, is 7' east of the cave-in.

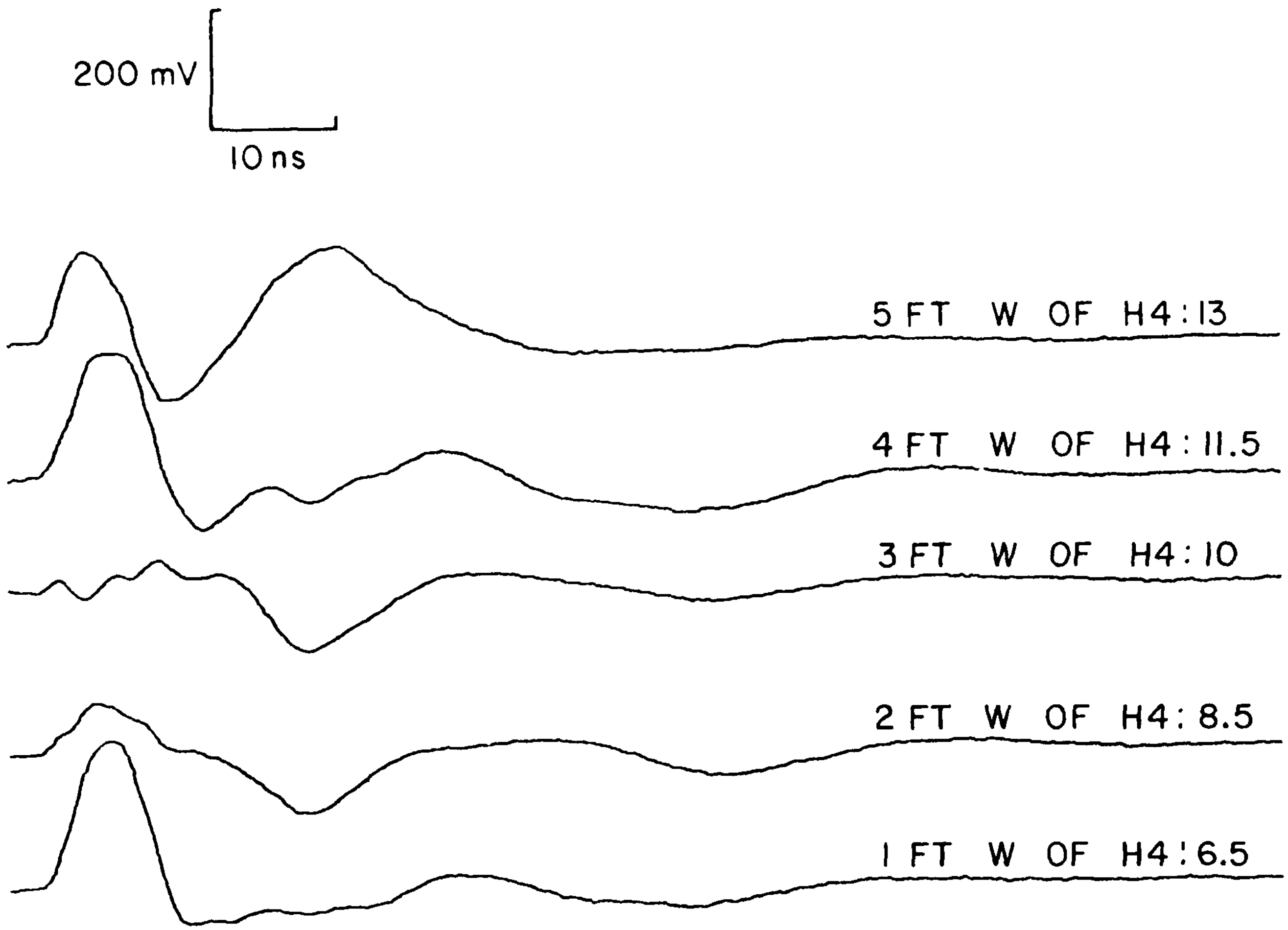


Figure 18. Antenna traverse southwest from H4:4 as noted. Long Box Antenna.

III. CONCLUSIONS

This report contains data obtained using video pulse radars at a site above an abandoned coal mine region. Underground voids occurred at depths generally of the order of 3 to 12 feet. The radar systems seem to be most adept at locating the demarcation line between regions where coal has and has not been mined. The system most sensitive to these structures consisted of the 6 nanosecond pulser and possibly the Long Box Antenna. This may be merely a conjecture since the Modified Terrascan Antenna, at least at one location, gave equally good performance. However, the Long Box Antenna gave a response everywhere one was expected.

REFERENCES

References 1, 2, 3, 5, and 6 were prepared by The Ohio State University ElectroScience Laboratory, Department of Electrical Engineering under Contract DAAG53-76-C-0179 for US Army Mobility Equipment Research and Development Command, Ft. Belvoir, Virginia.

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7. R. Caldecott, A. Terzuoli, J. Hall. "An Advanced Prototype System for Locating and Mapping Underground Obstacles," Report 784652-2, January 1979, The Ohio State University ElectroScience Laboratory, Department of Electrical Engineering; prepared under Contract RP7856-1 for Electric Power Research Institute, Inc.

APPENDIX I
CURTIS SCHOOL DRILLING LOGS

This appendix contains copies of the actual drilling logs made in a 25 foot square grid pattern at the Curtis School yard (see Figure 1 in main body of report).

Abbreviations and Notation:

SS: Sand Stone

Lost water: The drill bit is kept clear of debris by a continuous flow of water. This debris is pumped to the surface where it is examined to compile the drill logs. When the drill bit encounters a void or a cavity, the water flows into the void and does not return to the surface. A notation of "lost water" means that a cavity of some sort was encountered. When the drill bit reenters solid material, the water is again able to be pumped to the surface.

Chatter: When broken rock is encountered the drilling rig will vibrate up and down. This is described as drill chatter.

FIELD BORING LOG

Project Code | Project Identification: TRUODNR CURTIS SCHOOL (Co, Rt, Sec No)

Station: E6 + | Offset | Order Code

Crew: GORDON | Date: 6-15-78

Equipment: MOBILE 33

Surface Elev | Water Elev

Depth Feet	Field Number	Description
0.0		
1.5		SANDSTONE
		CHATTER
5		WEATHERED FERUGINOUS SS COARSE
	6.0	GRAY SS
	7.0	FERUGINOUS SS FINE
	8.8	ROOF SHALE
10		
11.8		LOST WATER
12.8		
15		VOID
18.2		BOTTOM
25		
30		

Use reverse side of this sheet for additional notes.

Form TE-133

FIELD BORING LOG

Project Code | Project Identification: TRUODNR CURTIS SCHOOL (Co, Rt, Sec No)

Station: E5 + | Offset | Order Code

Crew: GORDON | Date: 6-15-78

LOGGED BY PROF. HAE | Equipment: MOBILE

Surface Elev | Water Elev

Depth Feet	Field Number	Description
0.0		SANDY CLAY SOIL
	2.5	
	4.5	THIN-BEDDED SS
5	5.0	CHATTER COMPOSITION OF SS
	6.3	LOST WATER CHANGED
		COLLAPSED ROCK IN VOID
		CLATTER
	8.7	HEAVY CLATTER
10		
	12.5	VOID FILLED W/COLLAPSED RX
		PROBABLY TUNNEL OR ROOM
15		
	17.8	BOTTOM
20	20.0	FIRE CLAY
25		
30		

Use reverse side of this sheet for additional notes.

Form TE-133

FIELD BORING LOG

Project Code ____ Project Identification ____

Station ____ + ____ Offset ____ Co., Rt., Sec. No. ____ Order Code ____

12.5'N-12.5H of A5 Date 6-22-78

GORDON ____ Equipment MOBILE B33

Surface Elev ____ Water Elev ____

Depth Feet	Field Number	Description
0.0-0.5		SOD
2.0		CHATTER SANDSTONE
6		
[illegible]		COAL
10		
[illegible]		Bottom UNDERCLAY
15		
20		
25		
30		

Use reverse side of this sheet for additional notes.

Form TF-133

FIELD BORING LOG

Project Code | Project Identification: TRUODNR CURTIS SCHool (Co., Rt., Sec No)

Station: E4 + | Offset | Order Code

Crew: GORDON | Date: 6-15-78

Equipment: MOBILE 33

Surface Elev. | Water Elev.

Depth Feet	Field Number	Description
0.0-		
3.0		SAND STONE
5		
9.6 / 10		LOST WATER
11.5		VOID
		CAVE IN BROKEN ROCK
15		
18.0		Bottom
		CLAY
20		
25		
30		

Use reverse side of this sheet for additional notes.

Form TE-133

FIELD BORING LOG

Project Code | Project Identification: FRV ODNR CURTIS SCHOOL (Co., Rt., Sec No)

Station: D4 + | Offset | Order Code

Crew: GORDON | Date: 6-15-78

Equipment: MOBILE 33

Surface Elev. | Water Elev.

Depth Feet	Field Number	Description
0.0-		
		THIN BEDDED SAND STONE
		DRILL CHATTERED to GRAY
		SAND STONE
5		DRILL CHATTER HEAVY @ 6'
8.0		GRAY SAND STONE
9.0		LOST WATER FOR SECONDS THEN RETURN
10		SAND STONE W/ ROOF SHALE
10.5		LOST WATER VOID, OPEN to 13.5'
		DROPPED FREE ROD
13.5		
15		Bottom DRILL PRESSURE 600#
		FIRE CLAY
17.0		SAND STONE
20		
25		
30		

Use reverse side of this sheet for additional notes.

Form TE-133

FIELD BORING LOG

Project Code | Project Identification: TRUDONR CURTIS SCHOOL

Station: E6 | Offset | Order Code

Crew: GORDON | Date: 6-15-78

Equipment: MOBILE 33

Surface Elev. | Water Elev.

Depth Feet	Field Number	Description
0.0		
1.5		SANDSTONE
		CHATTER
		WEATHERED FERUGINOUS SS COARSE
	6.0	GRAY SS
	7.0	FERUGINOUS SS FINE
	8.8	ROOF SHALE
11.8		LOST WATER
12.8		
		VOID
19.2		Bottom

Use reverse side of this sheet for additional notes

Form TE 133

FIELD BORING LOG

Project Code | Project Identification: TRUDONR CURTIS SCHOOL

Station: E5+ | Offset | Order Code

Crew: GORDON | Date: 6-15-78

Logged By: PROF. HART | Equipment: MOBILE

Surface Elev. | Water Elev.

Depth Feet	Field Number	Description
0.0		SANDY CLAY SOIL
	2.5	THIN-BEDDED SS
	4.5	
	5.0	CHATTER COMPOSITION OF SS
	6.3	LOST WATER CHANGED
		COLLAPSED ROCK IN VOID
		CLATTER
	8.7	HEAVY CLATTER
	12.5	VOID FILLED W/ COLLAPSED RX
		PROBABLY TUNNEL OR ROOM
	17.8	Bottom
	20.0	FIRE CLAY

Use reverse side of this sheet for additional notes

Form TE-133

FIELD BORING LOG

Project Code: | Project Identification: C-1
Station: + . | Offset | Co., Rt., Sec. No. | Order Code
Crew: Gordon | Date: 5-31-78 6-1-78
Equipment: Mobil 33 449002
Surface Elev | Water Elev.

Depth Feet	Field Number	Description
0.0	6"	Crack top
	2	Silty Sandy Soil
		Thin Bedded Ss
5	4.5	Thin Bedded Ss
		Rock void 6-6.5
	7	
10		Ss
	11.5	
		11.5 Lost Water
		From 9.5' Drilled in Broken Rx
15		Void or soft material
		to 15'
		From 15-20' Appears to be weathered Ss
20		Rock More Firm at 20'
		Bottom of Hole
25		
30		

Use reverse side of this sheet for additional notes.

Form TE-133

FIELD BORING LOG

Project Code: | Project Identification: D-1
Station: + . | Offset | Co., Rt., Sec. No. | Order Code
Crew: | Date: 6-1-78
Equipment: Mobil 33 449002
Surface Elev | Water Elev.

Depth Feet	Field Number	Description
0.0		0.5 rd
	2	Br. Silt Clay w/ Stone Frag
	4	Thin bedded Ss
5		
	7	Thin Bedded Ss
10	10	Firm Rock Broken
		Drill Bouncing
	12.5	Lost Water
	13.5	Void
15		
	17	Bottom
20		
25		
30		

Use reverse side of this sheet for additional notes.

Form TE-133

FIELD BORING LOG

Project Code: | Project Identification: E-1 | Trv DDNR
Station: + . | Offset | Co., Rt., Sec. No. | Order Code
Crew: Joe Gordon | Date: 6-5-78
Equipment: 449007 mobile 33
Surface Elev | Water Elev.

Depth Feet	Field Number	Description
0.0		
		Washout Br. Sandy Silt Clay
5		
		Thin bedded Ss
		Heavy Drill Chatter
10		Chatter
		Lost water at 12' Return at 12.5
		Lost water at 13' Drill chatter
		Roof Cave in
15		14.8 Void
	18	Drilling in Soft material
20	20.5	Bottom
		Firm Material
25		
30		

Use reverse side of this sheet for additional notes.

Form TE-133

FIELD BORING LOG

Project Code | Project Identification: TRV ODNR CURTIS SCHOOL (Co, Rt, Sec No)

Station: A3 + | Offset | Order Code

Crew: GORDON | Date: 6-7-78

Equipment: MOBILE 33

Surface Elev. | Water Elev.

Depth Feet	Field Number	Description
0.0		
		THIN BEDDED SAND STONE
5		SANDSTONE WITH COAL LENSES
7.8		LOST WATER-VOID
10		
12.0		
13.0		WEATHERED (SOFT)
13.5		FIRM Bottom
15		
20		
25		
30		

Use reverse side of this sheet for additional notes.

Form TE-133

FIELD BORING LOG

Project Code | Project Identification: TRV ODNR CURTIS SCHOOL (Co, Rt, Sec No)

Station: B3 + | Offset | Order Code

Crew: GORDON | Date: 6-7-78

Equipment: MOBILE 33

Surface Elev. | Water Elev.

Depth Feet	Field Number	Description
0.0		
		BR. SILT CLAY W/ SANDSTONE FRAGS.
5		
7.0		DRILL CHATTER
7.5		COAL
10		COAL
12.0		
12.5		GRAY FIRE CLAY 12.0 to 12.5
15		
20		
25		
30		

Use reverse side of this sheet for additional notes.

Form TE-133

FIELD BORING LOG

Project Code | Project Identification: TRV ODNR CURTIS SCHOOL (Co, Rt, Sec No)

Station: C3 + | Offset | Order Code

Crew: GORDON | Date: 6-7-78

Equipment: MOBILE 33

Surface Elev. | Water Elev.

Depth Feet	Field Number	Description
0.0		
		BR. SILT CLAY W/ STONE FRAGS.
5		DRILL CHATTER
		ROOF SHALE
6.2		WATER BLACK @ 6.2
10		COAL
12.2		
13.0		GRAY FIRE CLAY
15		
20		
25		
30		

Use reverse side of this sheet for additional notes.

Form TE-133

FIELD BORING LOG

Project Code — Project Identification

Co, Rt, Sec No

Station B4 + , Offset — Order Code

Crew 7' WEST — Date 6-8-78

GORDON — Equipment MOBILE 33

Surface Elev — Water Elev.

Depth Feet	Field Number	Description
0.0-		
		BR. SILT CLAY W/ SANDSTONE FRAGS
5		THIN BEDDED SANDSTONE
6.2		COAL
10		
11.8		
12.5		GRAY FIRE CLAY
15		
20		
25		
30		

Use reverse side of this sheet for additional notes.

Form TE-133

FIELD BORING LOG

Project Code — Project Identification TKV OONR CURTIS SCHOOL

Co, Rt, Sec No

Station 84 + , Offset — Order Code

Crew 4' NORTH WEST — Date 6-7-78

GORDON — Equipment MOBILE 33

Surface Elev — Water Elev.

Depth Feet	Field Number	Description
0.0-		
		BR. SILT CLAY W/ STONE FRAGS
5		COAL
10		
12.0		
15		
20		
25		
30		

Use reverse side of this sheet for additional notes.

Form TE-133

FIELD BORING LOG

Project Code: [ ] Project Identification: TRV ODNR CURTIS SCHOOL
Station: C 7 Offset: Order Code:
Crew: GORDAN Date: 6-14-78
Equipment: MOBILE 33
Surface Elev: Water Elev:

Depth Feet	Field Number	Description
0.0		THIN BEDDED SS.
3		Lost WATER AT 3' BROKEN ROCK DRILL CHATTER
		DRILL CHATTER IN CAVE IN
11.5		BOTTOM
14.0		FIRE CLAY SS

Use reverse side of this sheet for additional notes

Form TE 133

FIELD BORING LOG

Project Code: [ ] Project Identification: TRV ODNR CURTIS SCHOOL
Station: C 7 Offset: Order Code:
Crew: GORDON Date: 6-14-78
Equipment: MOBILE 33
Surface Elev: Water Elev:

Depth Feet	Field Number	Description
0.0		SOD
		THIN BEDDED SANDSTONE
		DRILL CHATTER 6' SANDSTONE
6.4		LOST WATER
8.5		HEAVY CHATTER BROKEN ROOF
		VOID
11.0		
11.5		FIRE CLAY BOTTOM

Use reverse side of this sheet for additional notes

Form TE 133

FIELD BORING LOG

Project Code: [ ] Project Identification: TRV ODNR CURTIS SCHOOL
Station: C 6 Offset: Order Code:
Crew: 3 NE GORDON Date: 6-14-78
Equipment: MOBILE 33
Surface Elev: Water Elev:

Depth Feet	Field Number	Description
0.0		
		THIN BEDDED SANDSTONE
		SAND STONE W/ CML SEAM
5.0		LOST WATER RETURNED IN 30 SECONDS DRILL CHATTER
9.0		VOID LOST WATER
11.0		DRILLING IN FALLEN ROCK
18.2		Bottom
		THIS VOID AT 8' I BELIEVE IS CAVE IN MINE TUNNEL AT 11'

Use reverse side of this sheet for additional notes

Form TE 133

FIELD BORING LOG

Project Code | Project Identification: TRV ODNR CURTIS SCHOOL (Co., Rt., Sec No.)

Station: 03 + | Offset | Order Code

Crew: GORDON | Date: 6-7-78

Equipment: MOBILE 33

Surface Elev. | Water Elev.

Depth Feet	Field Number	Description
0.0		BR. SILT CLAY W/ SAND STONE FRAGS
7.5		DRILL CHATTER SAND STONE W/ CRACKS WATER LOSS AT INTERVALS & RETURNS
10.5		10.5 WATER GRAY
11.0		11' VOID
		DRILLING IN WEATHERED MATERIAL
16.5		FIRM @ 16.5 CLAY IN ROLLER BIT

Use reverse side of this sheet for additional notes.

Form TE-133

FIELD BORING LOG

Project Code | Project Identification: TRV ODNR CURTIS SCHOOL (Co., Rt., Sec No.)

Station: E3 + | Offset | Order Code

Crew: GORDON | Date: 6-7-78

Equipment: MOBILE 33

Surface Elev. | Water Elev.

Depth Feet	Field Number	Description
0.0		BR. SILT CLAY W/ SANDSTONE FRAGS
		THIN BEDDED SAND STONE SANDSTONE
8.7		LOST WATER BROKEN ROCK (CHATTER)
14.5		14.5' VOID
19.0		19.0'
20.0		FIRE CLAY 20.0'

Use reverse side of this sheet for additional notes.

Form TE-133

FIELD BORING LOG

Project Code | Project Identification: TRV ODNR CURTIS SCHOOL (Co., Rt., Sec No.)

Station: 84 + | Offset | Order Code

Crew: 7' NORTH GORDON | Date: 6-7-78

Equipment: MOBILE 33

Surface Elev. | Water Elev.

Depth Feet	Field Number	Description
0.0		BR. SILT CLAY W/ STONE
6.2		COAL 6.2'
		COAL
12.9		
13.3		GRAY CLAY

Use reverse side of this sheet for additional notes.

Form TE-133

FIELD BORING LOG

Project Code | Project Identification: TRU ODNR CURTIS SCHOOL

Station: C5+ | Offset | Order Code

Crew: GORDON | Date: 6-14-78

Equipment: MOBILE 33

Surface Elev | Water Elev

Depth Feet	Field Number	Description
0.0		
3.6		DRILL CHATTER LOST WATER
5		DRILLING IN FALLEN ROCK BROKEN
10		VOID
12.7		Bottom
13.5		FIRECLAY
15		
20		
25		
30		

Use reverse side of this sheet for additional notes

Form TE 133

FIELD BORING LOG

Project Code | Project Identification: TRU ODNR CURTIS SCHOOL

Station: C4+ | Offset | Order Code

Crew: GORDON | Date: 6-8-78 - 6-13-78

Equipment: MOBILE

Surface Elev | Water Elev

Depth Feet	Field Number	Description
0.0		BR. SILT CLAY W/ STONE FRAGS THIN BEDDED SANDSTONE
5		THIN BEDDED SANDSTONE, HEAVY DRILL CHATTER
7.5		7.5 COAL
10		
12.0		
12.5		FIRE CLAY
15		
20		
25		
30		

Use reverse side of this sheet for additional notes

Form TE 133

FIELD BORING LOG

Project Code | Project Identification: TRU ODNR CURTIS SCHOOL

Station: B5+ | Offset | Order Code

Crew: GORDON | Date: 6-13-78

Equipment: MOBILE 37

Surface Elev | Water Elev

Depth Feet	Field Number	Description
0.0		THIN BEDDED SANDSTONE
5		
5.8		5.8 COAL
10		
11.8		11.8
12.5		FIRE CLAY
15		
20		
25		
30		

Use reverse side of this sheet for additional notes

Form TE 133

FIELD BORING LOG

Project Code
Project Identification: TRV ODNR CURTIS SCHOOL
Station: 05 + | Offset | Order Code
Crew: GORDON
Date: 6-14-78
Equipment: MOBILE 33
Surface Elev | Water Elev

Depth Feet	Field Number	Description
0.0		
		THIN BEDDED SANDSTONE DRILL CHATTER - SAND STONE
5		
6.5	6.8	TRACES OF ROOF SHALE LOST WATER (6.8) CHATTER
	7	VOID (8')
10		WATER CAME BACK
		COAL INTERFINGERED W/SS LOST WATER AGAIN
15		
17		BOTTOM
20		
25		
30		

Use reverse side of this sheet for additional notes

Form TE 133

FIELD BORING LOG

Project Code
Project Identification: TRV ODNR CURTIS SCHOOL
Station: 06 + | Offset | Order Code
Crew: 12'N GORDON
Date: 6-14-78
Equipment: MOBILE 33
Surface Elev | Water Elev

Depth Feet	Field Number	Description
0.0		
		THIN BEDDED SANDSTONE
5		SAND STONE
7.0		ROOF SHALE DRILL CHATTER
8.0		LOST WATER
		VOID
10		
12.0		BOTTOM
		FIRE CLAY
14.0		SAND STONE
15		
20		
25		
30		

Use reverse side of this sheet for additional notes

Form TE 133

FIELD BORING LOG

Project Code
Project Identification: TRV ODNR CURTIS SCHOOL
Station: 06 + | Offset | Order Code
Crew: GORDON
Date: 6-14-78
Equipment: MOBILE 33
Surface Elev | Water Elev

Depth Feet	Field Number	Description
0.0		
		THIN BEDDED SANDSTONE
5		
6.6		HEAVY DRILL CHATTER ROOF SHALE
7.3		LOST WATER
		VOID
10		
12.5		BOTTOM
		FIRE CLAY
15		
20		
25		
30		

Use reverse side of this sheet for additional notes

Form TE 133

FIELD BORING LOG

Project Code ____ Project Identification ____

Station ____ + ____ Offset ____ Co., Rt., Sec. No. ____ Order Code ____

Crew ____ Date ____

Equipment ____

Surface Elev ____ Water Elev ____

Depth Feet	Field Number	Description
0.0		
5		
10		
		E-7 E-6 E-5 E-4 E-3 E-2 E-1
15		D-7 D-6 D-5 D-4 D-3 D-2 D-1
		C-7 C-6 C-5 C-4 C-3 C-2 C-1
		B-7 B-6 B-5 B-4 B-3 B-2 B-1
20		A-7 A-6 A-5 A-4 Hole A-3 A-2 A-1
		F-3 F-4 H-3 H-4 G-3 G-4
25		F-2 F-1 H-2 H-1 G-2 G-1
		mine Exit
30		

Use reverse side of this sheet for additional notes.

Form TE-133

FIELD BORING LOG

Project Code ____ Project Identification A-1

Station ____ + ____ Offset ____ Co., Rt., Sec. No. ____ Order Code ____

Crew ____ Date 5-31-78

Equipment Mobile 33 440002

Surface Elev ____ Water Elev ____

Depth Feet	Field Number	Description
0.0	0.5	Grass Top
		Silty Sandy Soil
5	5	Weathered Bedrock
	7.8	Thin Bedded SS
		Coal 9' 11 9.2"
10		
15		
20		
25		
30		

Use reverse side of this sheet for additional notes.

Form TE-133

FIELD BORING LOG

Project Code ____ Project Identification A1

Station ____ + ____ Offset ____ Co., Rt., Sec. No. ____ Order Code ____

Crew ____ Date 5-31-78

Equipment Mobile 33 750002

Surface Elev ____ Water Elev ____

Depth Feet	Field Number	Description
0.0	1.5	Grass Top
		Silty Sandy Soil
5	4.5	Weathered SS - Thin-bedded
	7	
10	11	Coal 11-12"
	12.5	Sharon SS w/ Fossils
15		
		Cored from 11 - 14.5
20		Butt of SS removed
25		
30		

Use reverse side of this sheet for additional notes.

Form TE-133

FIELD BORING LOG

Project Code | Project Identification: B-2 TRU OONR | Co, Ri, Sec No

Station | Offset | Order Code

Crew ____ Date 6-6-78 Equipment 4490007 mobile 32

Surface Elev ____ Water Elev ____

Depth Feet	Field Number	Description
0.0		Thin black top
		Br. Sandy Silt Clay Washout
5		
10	9.5	Coal @ 9.5 ((Coal 3.2'))
	12.7	Bottom of Coal
15		
20		
25		
30		

Use reverse side of this sheet for additional notes.

Form TE-133

FIELD BORING LOG

Project Code | Project Identification: A 2 TRU OONR | Co, Ri, Sec No

Station | Offset | Order Code

Crew ____ Date 6-6-78 Equipment 4490002 mobile 32

Surface Elev ____ Water Elev ____

Depth Feet	Field Number	Description
0.0		
		Br. Sandy Silt Clay Washout
5		
10		Coal @ 10
	13.5	13.5 Bottom
15		
20		
25		
30		

Use reverse side of this sheet for additional notes.

Form TE-133

FIELD BORING LOG

Project Code | Project Identification: G-4 TRU OONR | Co, Ri, Sec No

Station | Offset | Order Code

Crew ____ Date 6-6-78 Equipment 4490002 Mobile 32

Surface Elev ____ Water Elev ____

Depth Feet	Field Number	Description
0.0		
		Br. Sandy Silt Clay Washout
5		
		Drill chalk
10		GRAY CLAY WASHOUT
	11.5	11.5 Coal 1' Coal
	12.5	Bottom
15		
20		
25		
30		

Use reverse side of this sheet for additional notes.

Form TE-133

FIELD BORING LOG

Project Code | Project Identification: G-1 TRU-ODNR (Co., Rt., Sec. No.)

Station | Offset | Order Code

Crew | Date 6-6-78 | Equipment 449003 mobile 33

Surface Elev | Water Elev

Depth Feet	Field Number	Description
0.0		Thin blacktop
		Brown Silty Sandy Clay
7.5		Coal at 7.5' Coal 3.5' Thick
11.0		Bottom at 11.0

Use reverse side of this sheet for additional notes.

Gordon

Form TE-133

FIELD BORING LOG

Project Code | Project Identification: G-2 TRU-ODNR (Co., Rt., Sec. No.)

Station | Offset | Order Code

Crew | Date 6-6-78 | Equipment 449002 mobile 33

Surface Elev | Water Elev

Depth Feet	Field Number	Description
0.0		Thin blacktop
		Brown silty sandy clay
11.0		Thin coal lenses in sandstone
13.0		Bottom

Use reverse side of this sheet for additional notes.

Form TE-133

FIELD BORING LOG

Project Code | Project Identification: TRU. ODNR CURTIS SCHOOL (Co., Rt., Sec. No.)

Station G3+ | Offset | Order Code

Crew GORDON | Date 6-7-78 | Equipment MOBILE 33

Surface Elev | Water Elev

Depth Feet	Field Number	Description
0.0		BR. SILT CLAY W/ SAND STONE FRAGS.
9.0		SAND STONE W/ THIN COAL LENSES
11.5		SAND STONE LOST PART OF WATER
16.5		

Use reverse side of this sheet for additional notes.

Form TE-133

FIELD BORING LOG

Project Code:
Project Identification: TRU ODNR CURTIS SCHool
Co., Rt., Sec No.
Station: B6 +
Offset:
Order Code:
Crew: GORDON
Date: 6-13-78
Equipment: MOBILE 33
Surface Elev:
Water Elev:

Depth Feet	Field Number	Description
0.0		BR. SILT CLAY W/ S.S. FRAGS
4.5		THIN BEDDED S.S.
6.5		SAND STONE W/ THIN COAL SEAMS
13.0		DRILL CHATTER ROCK MORE FIRM
15		
20		
25		
30		

Use reverse side of this sheet for additional notes

Form TE 133

FIELD BORING LOG

Project Code:
Project Identification: TRU ODNR CURTIS SCHOOL
Co., Rt., Sec No.
Station:
Offset:
Order Code:
Crew: GORDON
Date: 6-13-78
Equipment: T.A.
Surface Elev:
Water Elev:

Depth Feet	Field Number	Description
0.0		
		THIN BEDDED SANDSTONE
5		HEAVY DRILL CHATTER @ 5'
6.5		SAND STONE
10		COAL
11.3		LOST WATER @ 11.3
13.0		BOTTOM
15		COULD HAVE BEEN DRILLING IN PILLAR. DRILL BIT BROKE INTO OPEN
20		
25		
30		

Use reverse side of this sheet for additional notes

Form TE 133

FIELD BORING LOG

Project Code:
Project Identification: TRU ODNR CURTIS SCHool
Co., Rt., Sec No.
Station:
Offset:
Order Code:
Crew: 6' N. E. STAKE C4
Date: 6-13-78
Equipment: MOBILE 33
Surface Elev:
Water Elev:

Depth Feet	Field Number	Description
0.0		BR. SILT CLAY W/ SAND STONE FRAGS
5		THIN BEDDED SAND STONE
6.2		6.2
10		COAL
		BOTTOM
14.7		FIRE CLAY TO SANDSTONE
20		
25		
30		

Use reverse side of this sheet for additional notes

Form TE 133

FIELD BORING LOG

Project Code | Project Identification: TRV ODNR CURTIS SCHOOL (Co., Rt., Sec. No.)

Station: E 7 + | Offset | Order Code

Crew | Date 6-19-78 | 2' Higher than mT

Equipment MOBILE 33

Surface Elev | Water Elev

Depth Feet	Field Number	Description
0.0		SANDY SILTY CLAY SOIL
2.0		CHATTER / SS BROKEN
3.7		CHATTER
5.2		LOST WATER
8.7		SS - BROKEN
9.4		VOID
15.3		BOTTOM

Use reverse side of this sheet for additional notes

Form TE 133

FIELD BORING LOG

Project Code | Project Identification: TRV ODNRCURTIS SCHOOL (Co., Rt., Sec. No.)

Station: A 4 + | Offset | Order Code

Crew GORDON | Date 6-20-78

Equipment MOBILE B 33

Surface Elev | Water Elev

Depth Feet	Field Number	Description
0.0		SOD
		BR. SANDY SILT CLAY W/ STONE FRAGS
2.7		SAND STONE CHATTER
		THIN BEDDED SS.
		CHATTER
		SAND STONE
7.2		COAL
13.0		Bottom
		FIRE CLAY

Use reverse side of this sheet for additional notes

Form TE 133

FIELD BORING LOG

Project Code | Project Identification: TRV ODNR CURTIS SCHOOL (Co., Rt., Sec. No.)

Station: A 5 + | Offset | Order Code

Crew GORDON | Date 6-20-78

Equipment MOBILE B 33

Surface Elev | Water Elev

Depth Feet	Field Number	Description
0.0		SOD
		BR. SANDY SILT CLAY W/ STONE FRAGS
5.5		THIN BEDDED SAND STONE
7.5		COAL
12.2		Bottom

Use reverse side of this sheet for additional notes

Form TE 133

FIELD BORING LOG

Project Code ☐☐☐☐ Project Identification: TRV ODNR CURTIS SCHOOL (Co., Rt., Sec. No.)

Station: A 7 + | Offset | Order Code

Crew: GORDON Date: 6-20-78

Equipment: MOBILE B33

Surface Elev. ____ Water Elev. ____

Depth Feet	Field Number	Description
0.0-0.5		SOD
		BR. SANDY SILTCLAY W/ SAND STONE FRAGMENTS
4.0		THIN BEDDED SAND STONE
7.0		COAL
10		
12.5		Bottom (FIRE CLAY 12.5-12?)
15		
20		
25		
30		

Use reverse side of this sheet for additional notes.

Form TE-33

FIELD BORING LOG

Project Code ☐☐☐☐ Project Identification: TRV ODNR CURTIS SCHOOL (Co., Rt., Sec. No.)

Station: A 6 + | Offset | Order Code

Crew: GORDON Date: 6-20-78

Equipment: MOBILE B33

Surface Elev. ____ Water Elev. ____

Depth Feet	Field Number	Description
0.0-0.5		SOD
		BR. SANDY SILT CLAY W/ SAND STONE FRAGS.
5		THIN BEDDED SAND STONE (SHATTER)
8		VOID AT 8'
10		
11		LOST WATER AT 11'
13.9		BOTTOM WATER RETURN
15		
20		
25		
30		

Use reverse side of this sheet for additional notes.

Form TE-133

FIELD BORING LOG

Project Code ☐☐☐☐ Project Identification: TRV ODNR CURTIS SCHOOL (Co., Rt., Sec. No.)

Station: H 4 + | Offset | Order Code

Crew: GORDON Date: 6-20-78

Equipment: MOBILE B33

Surface Elev. ____ Water Elev. ____

Depth Feet	Field Number	Description
0.0-0.5		SOD
		BR. SILTCLAY W/ S.S. FRAGS
5		THIN BEDDED SANDSTONE
6.9		VOID LOST WATER
8.0		WATER RETURN W/ COAL
10		
10.9 / 11		LOST WATER / WATER RETURN
13.5		Bottom FIRECLAY
15		
20		
25		
30		

Use reverse side of this sheet for additional notes.

Form TE-133

FIELD BORING LOG

Project Code ____ Project Identification TRU ODNR CURTIS SCHOOL

Station H 4 + Offset ____ Order Code ____

Crew 13.5' SOUTH GORDON Date 6-20-78 Equipment MOBILE B 33

Surface Elev ____ Water Elev ____

Depth Feet	Field Number	Description
0.0		THIN SOIL LAYER BROKEN ROCK
	3.0	SOME LARGE FRAGMENTS
		SS
5	5.0	LOST WATER
	5.7	
10		VOID - DRILL WENT DOWN FREE
	14.0	BOTTOM
15	14.8	UNDERCLAY
20		
25		
30		

Use reverse side of this sheet for additional notes.

Form TE-133

FIELD BORING LOG

Project Code ____ Project Identification TRU ODNR CURTIS SCHOOL

Station H 3 + — Offset ____ Order Code ____

Crew GORDON Date 6-20-78 Equipment MOBILE B33

Surface Elev ____ Water Elev ____

Depth Feet	Field Number	Description
0.0		SOD
	3.0	BR. SILT CLAY W/ S.S. FRAGS. THINBEDDEDSAND STONE
5		
	7.0	COAL
10		
15	14.6	BOTTOM
20		
25		
30		

Use reverse side of this sheet for additional notes.

Form TE-133

FIELD BORING LOG

Project Code ____ Project Identification TRU ODNR CURTIS SCHOOL

Station F 4 + Offset ____ Order Code ____

Crew GORDON Date 6-20-78 Equipment MOBILE 33

Surface Elev ____ Water Elev ____

Depth Feet	Field Number	Description
0.0		SANDY SILTY SOIL
		SOFT SS
5	6.8	COAL
10		
	13.7	UNDER CLAY
15	15.4	BOTTOM SS
20		
25		
30		

Use reverse side of this sheet for additional notes.

Form TE-133

FIELD BORING LOG

Project Code | Project Identification: TRU ODNR - CURTIS SCHOOL (Co., Rt., Sec No)

Station: F3 + | Offset | Order Code

Crew: GORDON | Date: 6-20-78

Equipment: MOBILE 33

Surface Elev | Water Elev

Depth Feet	Field Number	Description
0.0-0.5		SOD
		BR. SANDY SILT CLAY W/ SS. FRECS.
3.7 / 4.1		ROCK COLLAPSE TO 4.7 VOIDS
		CHATTER
6.8		VOID
8.8		COAL
13.2		UNDERCLAY SS

Use reverse side of this sheet for additional notes.

Form TE 133

FIELD BORING LOG

Project Code | Project Identification: TRU ODNR CURTIS SCHOOL (Co., Rt., Sec No)

Station: H1 + | Offset | Order Code

Crew: GORDON | Date: 6-20-78

Equipment: MOBILE B33

Surface Elev | Water Elev

Depth Feet	Field Number	Description
0.0 / 0.5		SOD
		SANDY SILT CLAY
1.5		BROKEN SAND STONE
5		THIN BEDDED SANDSTONE
6.0		REFUSE WHICH FILLED TUNNEL - GOB
		SOFT BLACK MATERIAL
12.0		6" COAL
		UNDERCLAY
15		BOTTOM
		SS.
		NO WATER LOSS

Use reverse side of this sheet for additional notes.

Form TE-133

FIELD BORING LOG

Project Code | Project Identification: TRU-ODNR CURTIS SCHOOL (Co., Rt., Sec No)

Station: H2 + | Offset | Order Code

Crew: GORDON | Date: 6-20-78

Equipment: MOBILE 33

Surface Elev | Water Elev

Depth Feet	Field Number	Description
0.0-		SOD
		SANDY SILTY CLAY SOIL
4.5		SS. COARSE
		FERRISENOUS SS
9.7		COAL
11.6		SS
12.2		BOTTOM

Use reverse side of this sheet for additional notes

Form TE-133

FIELD BORING LOG

Project Identification: TRU ODNR CURTIS SCHOOL

Station: F I

Crew: GORDON

Date: 6-21-79

Equipment: MOBILE B 33

Surface Elev ____ Water Elev ____

Depth Feet	Field Number	Description
0.5		SOD.
		BR. SANDY SILT CLAY W/SS FRAGS.
4.4		MATERIAL SOFT, REFUSE IN TUNNEL (GOR)
		NO WATER LOSS
10.6		THIN COAL SEAM to FIRECLAY
		Bottom
15		
20		
25		
30		

Use reverse side of this sheet for additional notes.

Form TE 133

FIELD BORING LOG

Project Identification: TRU ODNR CURTIS SCHOOL

Station: C 2

Crew: GORDON

Date: 6-21-78

Equipment: MOBILE B 33

Surface Elev ____ Water Elev ____

Depth Feet	Field Number	Description
0.0		SOD
0.5		
4.2		SAND STONE
5.5		
7.4		VOID NO WATER LOSS
		CHATTER SANDSTONE
9.2		
10.0		CARBONACEOUS SS
11.4	DRILL	UNDERCLAY
12.2	DRIVE	DRIVE SAMPLE 11.4 to 12.2 Blows $\frac{85}{23}$ $\frac{63}{37}$
15		
20		
25		
30		

Use reverse side of this sheet for additional notes.

Form TE 133

FIELD BORING LOG

Project Code ____ Project Identification: TRV ODNR - CURTIS SCHOOL

Station: C1 Offset ____ Order Code ____

Crew: GORDON, 34' E 20' S of ET (W)

Date: 6-21-78

Equipment: MOBILE 33

Surface Elev ____ Water Elev ____

Depth Feet	Field Number	Description
0.0		
2.5		SANDY SILTY CLAY
		SS
4.0		CHATTER
		THIN-BEDDED SS
		MASSIVE SS
		HEAVY CHATTER
10		
		WEATHERED SS - BROKEN
13.5		LOST WATER
15		
		VOID
19.0		BOTTOM
20		
		RAVINE HAS ALREADY COLLAPSED 3' & HAS BEEN SLOWLY SUBSIDING OVER THE YEARS
25		
30		

Use reverse side of this sheet for additional notes.

Form TE 133

FIELD BORING LOG

Project Code ____ Project Identification: TRV ODNR CURTIS SCHOOL

Co., Rt., Sec. No.

Station ____ + ____ Offset ____ Order Code ____

Crew 12.5' W-13 S N of R9 — GORDON ?

Date 6-22-78

Equipment MOBILE B33

Surface Elev ____ Water Elev ____

Depth Feet	Field Number	Description
0.0		
		BR SANDY SILT CLAY
2.9		SAND STONE
5		SAND STONE CHATTER
6.1		GRAY SAND STONE
		FERRIGENOUS SS
7.5		LOST WATER CAME BACK, LOST AGAIN
		BROKEN SS
10.2		WATER CAME BACK - GRAY COLOR
		COAL CHIPS
12.1		VOID
15		
16.7		UNDERCLAY
20		
25		
30		

Use reverse side of this sheet for additional notes.

Form TE-133

FIELD BORING LOG

Young

Project Code ____ Project Identification: TRV ODNR CURTIS SCHOOL

Co., Rt., Sec. No.

Station ____ + ____ Offset ____ Order Code ____

Crew ITE, 13' N of CL — GORDON

Date 6-22-78

Equipment MOBILE B33

Surface Elev ____ Water Elev ____

Depth Feet	Field Number	Description
0.0		SOD
0.5		BR. SILT CLAY W/ STONE FRAGS
2.2		LOST WATER IN BROKEN COLLAPSED SANDSTONE
3.2		VOID
5.5		SLIGHT RISISTANCE
		WEATHERED MATERIAL
10		
		BOTTOM
11.5		UNDERCLAY
15		
20		
25		
30		

Use reverse side of this sheet for additional notes.

Form TE-133

FIELD BORING LOG

Young

Project Code ____ Project Identification: TRV ODNR CURTIS SCHOOL

Co., Rt., Sec. No.

Station ____ + ____ Offset ____ Order Code ____

Crew 12.0' N. Rt. SOGS 12.5'

Date 6-22-78

Equipment MOBILE B33

Surface Elev ____ Water Elev ____

Depth Feet	Field Number	Description
0.0		SOD
		BR. SANDY SILT CLAY
3.2		VERY SOFT MAT'L AT 3.2
		SLIGHT RISISTANCE
5		LOST WATER VOID
		INTERMITTENT WATER RETURN
10		
11.0		BOTTOM
		UNDERCLAY
15		
20		
25		
30		

Use reverse side of this sheet for additional notes.

Form TE-133

FIELD BORING LOG

Project Code: __ Project Identification: E-2 Trv C ODvR

Co, Rt, Sec No

Station __ + __ Offset __ Order Code __

Crew __ Date 6-6-78 Mobil 33

Equipment __

Surface Elev __ Water Elev __

Depth Feet	Field Number	Description
0.0		Water Br
5		Thin-bedded SS
	7.0	Drill Chatter
10		
		Broken Rock
	13.3	Lost Water Void 13.3
15		Drilling in Fallen
	19.0	Soft Material 19'
20	19.0	Bottom 19'
25		
30		

Use reverse side of this sheet for additional notes.

Form TE-133

FIELD BORING LOG

Project Code: __ Project Identification: D-2 Trv Co ODNR

Co, Rt, Sec No

Station __ + __ Offset __ Order Code __

Crew __ Date 6-6-78 Mobil 33

Equipment 6-6-78

Surface Elev __ Water Elev __

Depth Feet	Field Number	Description
0.0		Br Silt-clay Washout
5	4.0	Thin-bedded SS
	7.0	Thin Bedded SS
		Chatter
10		Heavy Drill Chatter (Gray Br)
	12.8	Lost water
15		Void 12.8
		Drilling in fallen roof
	18.0	Bottom
20		
25		
30		

Water Br — Gray

Use reverse side of this sheet for additional notes.

Form TE-133

FIELD BORING LOG

Project Code: __ Project Identification: C-2 Trv ODNR

Co, Rt, Sec No

Station __ + __ Offset __ Order Code __

Crew __ Date 6-6-78 Mobil 33

Equipment __

Surface Elev __ Water Elev __

Depth Feet	Field Number	Description
0.0		Thin bedded
		Br Sandy Silt Clay Washout
5		Thin-Bedded SS
		Lost Water 7' Broken Rock
10	11.0	Void 11
15		
		Soft Material
20	20.5	Bottom
25		
30		

Use reverse side of this sheet for additional notes.

Form TE-133

APPENDIX II
COMPARISON OF DRILLING RESULTS AND RADAR DATA

by

Mark Schrote and Jamal Izadian

From drilling logs obtained at the Curtis School yard in Youngstown, Ohio, we were able to determine the type of earth layers present and their thickness. Knowing the type of layer, an estimate was made of the dielectric constant. From the dielectric constant and the thickness of the layer, we were above to calculate the time delay between when an impulse is sent and when the signal from a reflecting discontinuity (the bottom of the layer) is received. We then looked at the measured radar waveforms at the expected return times in order to identify any characteristic waveshape associated with the boundary.

First we constructed a quick reference chart from the drilling log results (Table A1). The chart includes the location, the type of earth layer, the thickness of the layer, the dielectric constant, and the calculated signal time delay. Next the waveforms which were obtained with the Terrascan unit were multiplied by a sliding gain factor. The gain factor was a gain of one at zero time to a gain of five at 200 ns. We then partitioned the waveforms into areas which corresponded to the different earth layers. See Figures A1 through A16.

In most cases, where we determined that a boundary existed, a feature was apparent in the waveform. There were a few cases where the waveforms implied that a boundary existed, however from the survey results, we determined that no boundary existed. In some cases, we found distinct similarities between waveforms for identical boundaries that were recorded in the same area. But for identical boundaries that were not in the same area, the waveforms were not at a l alike.

Some attempts were made to line up waveforms which were expected to be similar because of the similarity of their corresponding earth layers. In some cases this did reveal some signatures which were alike. For example, locations E2 and E3 had quite similar earth layers both in the types of the layers and in their thicknesses. If E2 and E3 are superimposed, it will show that the waveforms are quite similar. This suggests the possibility of being able to determine what is beneath the ground by inspecting the waveform.

Some problems that we encountered were as follows:

1. The antenna balun reflection often interrupted the waveform at points which caused confusion as to what the real signal was like. This reflection occurs at 36 nanosecond intervals.

2. The dielectric constant was often difficult to determine -- either we were not quite sure what type of earth layer we were dealing with or there was a mixture of earth layers.

3. Since the antenna is a crossed dipole, it is not sensitive to horizontal plane surfaces. Hence, the boundaries must have roughness in order to be visible in the waveforms.

Test Station	Depth	Ground description	Dielec. const.	Distance on graph inch	Signal and chart interpretation
A_3	0.0	Thin bedded-Sand Stone	6.3	0.0	
	5'	Sand Stone with coal	6.0	1.0	
	7.8	Void	1.0	1.55	
	12	Weathered soft	2.7	1.89	
	13	Firm bottom S.S.	6	2.02	
B_3	0.0	Silt clay w/ S.S. frags	4.0	0.0	
	7	Broken S.S.	5.0	1.12	
	7.5	Coal	5?	1.21	
	12	Fire clay	3.3	2.01	
	12.5	Sand Stone	6.0	2.11	
B_4	0.0	Silt clay w/ S.S. frags	4.0	0.0	
	5	Sand Stone	6.0	.80	
	6.2	Coal	5.0?	1.04	
	11	Fire clay	3.3	1.89	
B_5	0.0	Sand Stone	6.0	0.0	
	5.8	Coal	5.0?	1.14	
	11.8	Fire clay	4.0	2.21	
	12.5	Sand Stone	6.0	2.31	
B_6	0.0	Silt clay w/S.S. frags	4.0	0.0	
	4.5	Sand Stone	6.0	.72	
	6.5	Sand Stone w/thin coal seams	5.5?	1.11	
	12.0	Drill chatter or S.S.	6.0	2.14	

C_3	0.0	Silt clay w/ S.S. frags	4.0	0.0	The area (5-6.2) does not make any sense because ($39=\epsilon_r$)
	5	Roof shale	4?	.80	
	6.2	Coal	5.0?	.99	
	12.2	Fire clay	3.3	2.07	
	13.0	Sand Stone	6.0	2.18	
C_4	0.0	Silt clay w/S.S. frags	4.0	0.0	
	3	Sand Stone	6.0	.48	
	7.5	Coal	5?	1.35	
	12	Fire clay	3.3	2.17	
C_5	0.0	Drill chatter	6	0.0	
	3.6	Falling rock	5	.71	
	8	Void	1.0	1.43	
	12.3	Fire clay	3.3	1.84	
D_1	0.0 w/S.S.	Silt clay frags	4.0	0.0	
	2	Sand Stone	6.3	.32	
	10	Broken S.S.	5.0	1.93	
	13.5	Void	1.0	2.55	
	17	Bottom	6	2.83	
D_2	0.0	Clay soil	3.3	0.0	
	4	Sand Stone	6.3	.58	
	7	Broke rocks	5	1.18	
	13.8	Void	1	2.40	
	18	Bottom	6	2.74	
D_3	0.0	Silt clay and S.S.	4.0	0.0	
	7.5	S.S. w/cracks	6.0	1.20	
	11	Void	1.0	1.89	
	16.5	Firm clay	3.0	2.33	
D_4	0.0	Sand Stone	6.3	0.0	
	8.1	Grey S.S.	6.3	1.63	
	9	Sand Stone	6.3	1.81	
	10.5	Void	1.0	2.11	
	15	Fire clay	3.3	2.47	
	17	Sand Stone	6	2.76	

D_5	00	Thin bedded Sand Stone	6.3	0.0	
	6.5	Traces of roof shale	4?	1.31	
	6.8	Chatter	4.7	1.35	
	8	Void	1.0	1.56	
	13	Coal and Sand stone	6.0	1.96	
	14	Void	1.0	2.16	
	17	Bottom		2.40	
E_1	0.0	Sandy clay soil	3.0	0.0	
	6	Sand Stone	6.0	.83	
	14.5	Void	1.0	2.50	
	18	Soft material	2.7	2.78	
	20.5	Firm clay	3.0	3.11	
E_2	0.0	Thin bedded S.S.	6.3	0.0	Almost well defined boundaries, similar to E_3
	7	Broken rocks	5	1.41	
	13.3	Void	1.0	2.53	
	19	Soft material	2.7	2.99	
E_3	0.0	Silt clay w/S.S. Frags.	4.0	0.0	Well defined boundaries
	6	Sand STone	6	.06	
	8.7	Broken rock	5	1.49	
	14.5	Void	1.0	2.53	
	19	Fire clay	3.3	2.89	
E_4	0.0	Sand stone	6.3	0.0	
	9.6	Void	1.0	1.93	
	17.6	Clay	3.3	2.57	
E_5	0	Sandy clay soil	3.00	0.0	
	2.5	Thin bedded Sand Stone	6.0	.35	
	4.5	Chatter composition of S.S.	4.7	.74	
	8.7	Heavy chatter	1.5	1.47	
	12.5	Filled with collapsed RX probably tunnel or room	1.0	1.84	
	17.8	Bottom fire clay	3.3	2.27	

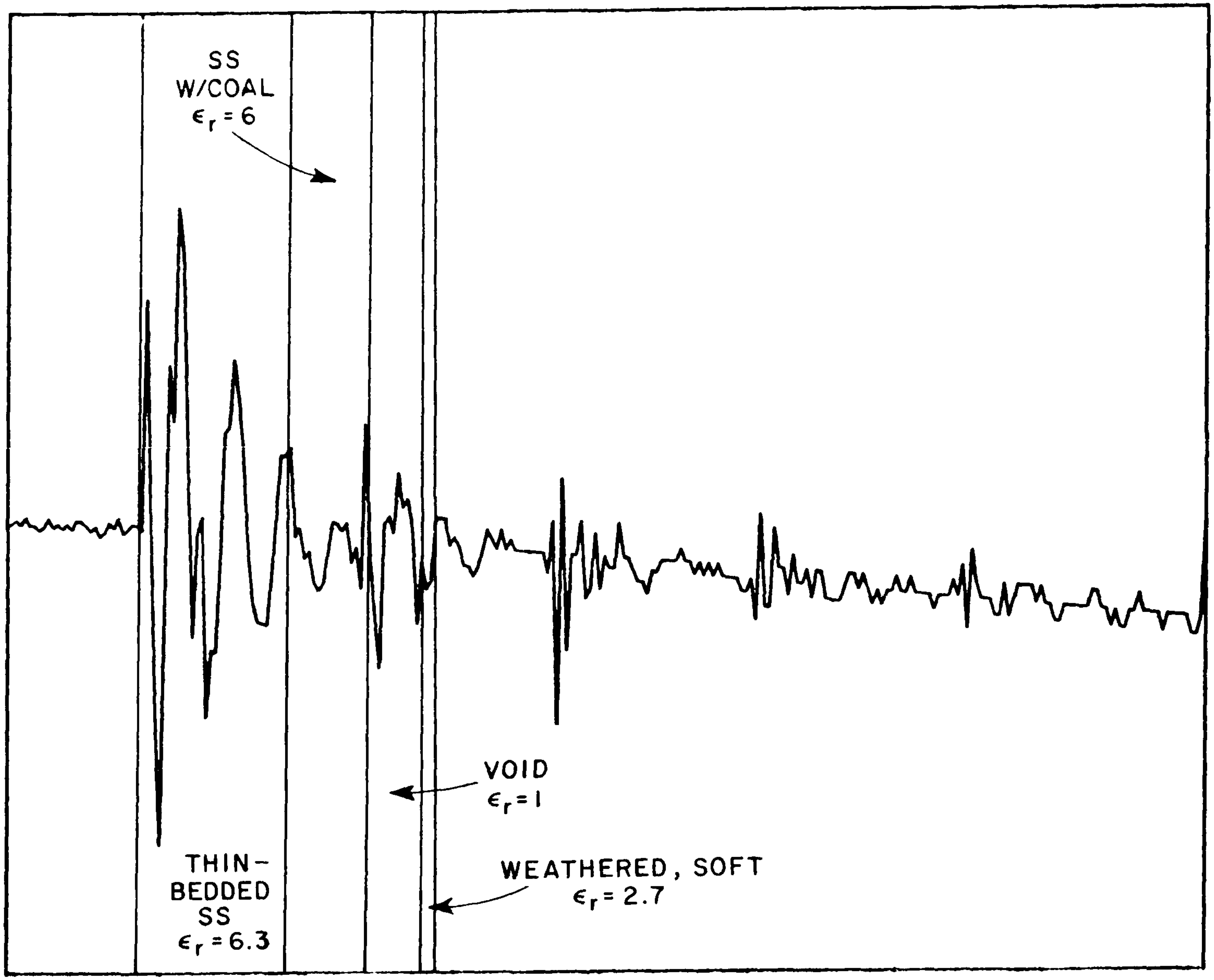

Figure A1. Waveform at drill coordinate A-3.

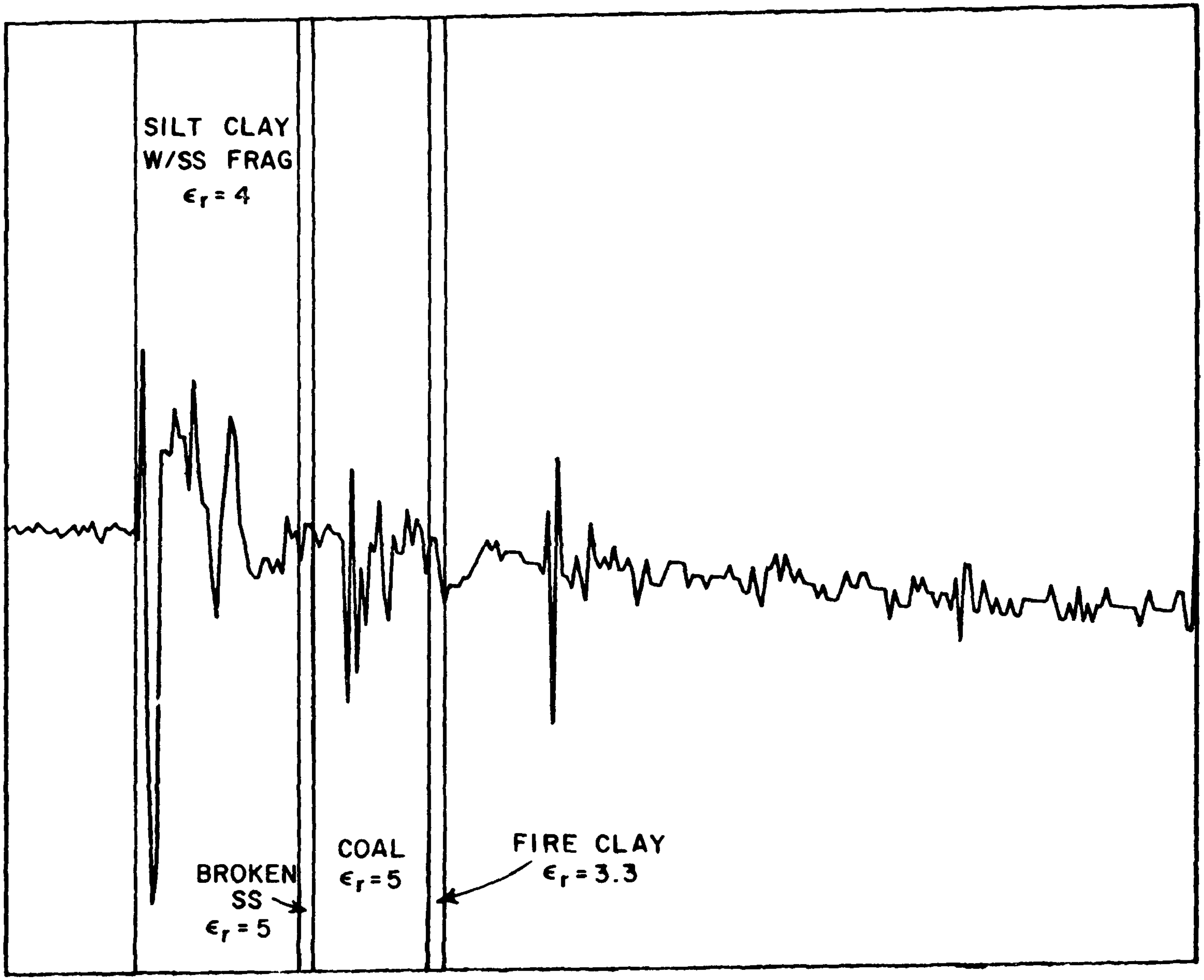

Figure A2. Waveform at drill coordinate B-3.

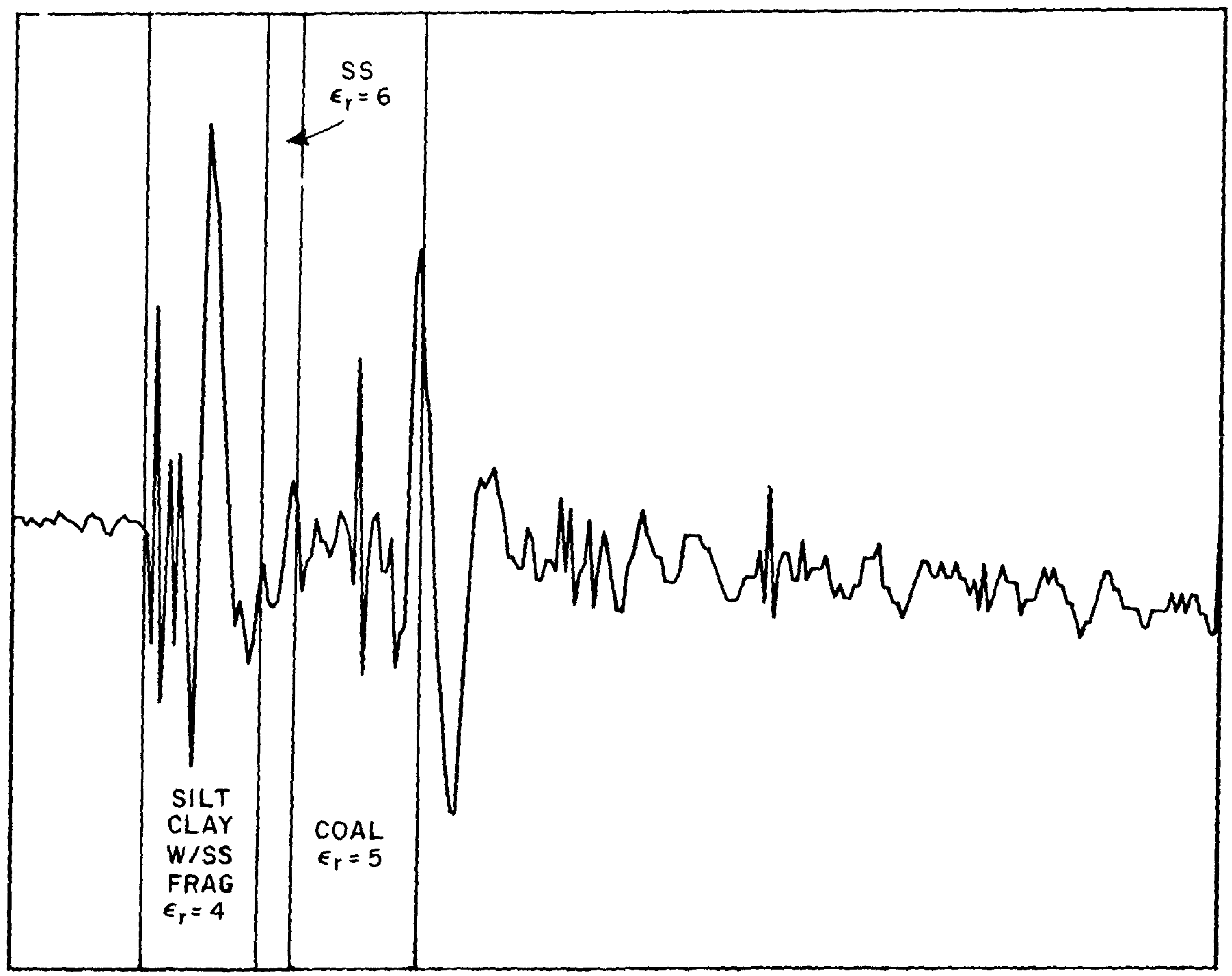

Figure A3. Waveform at drill coordinate B-4.

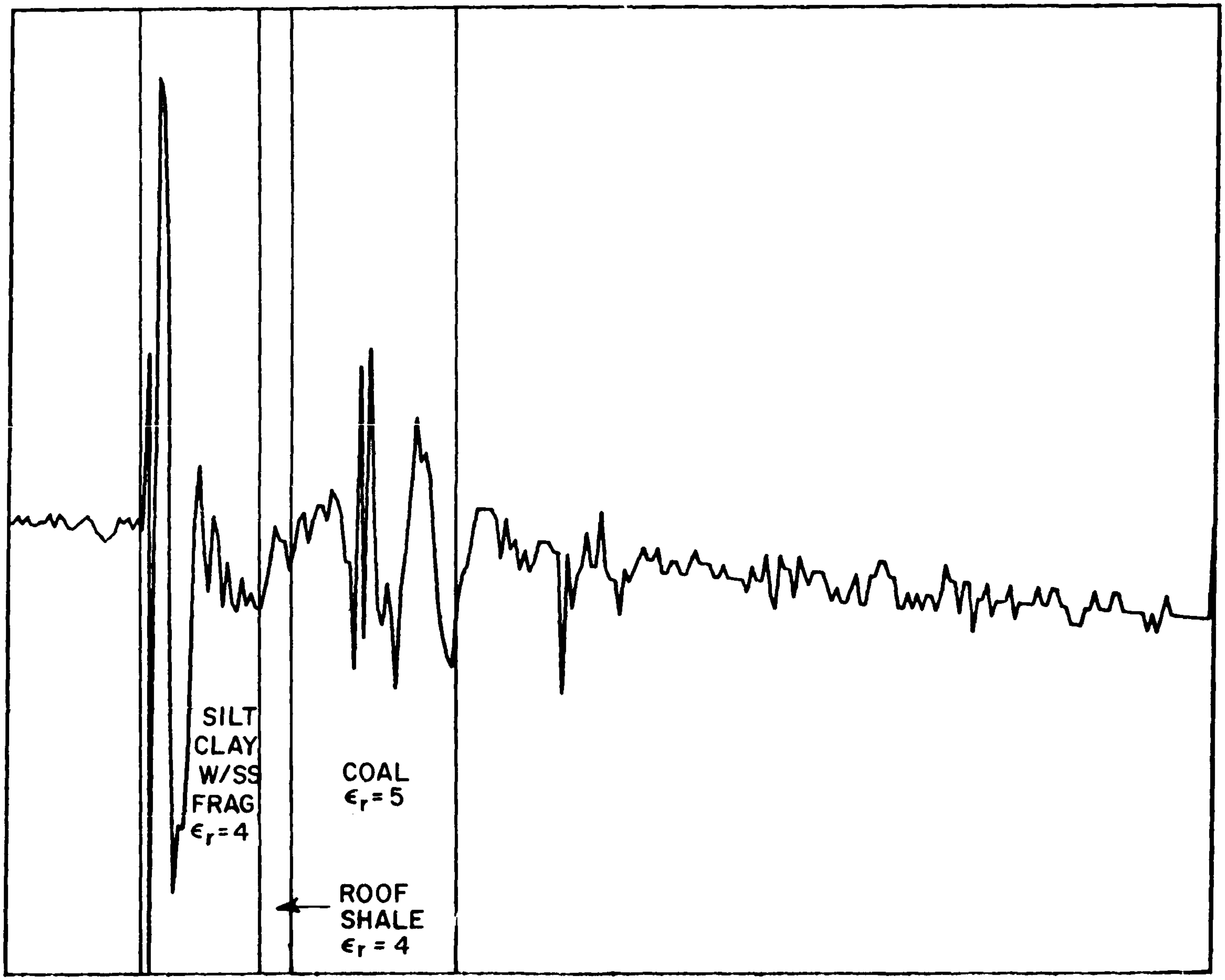

Figure A4. Waveform at drill coordinate C-3.

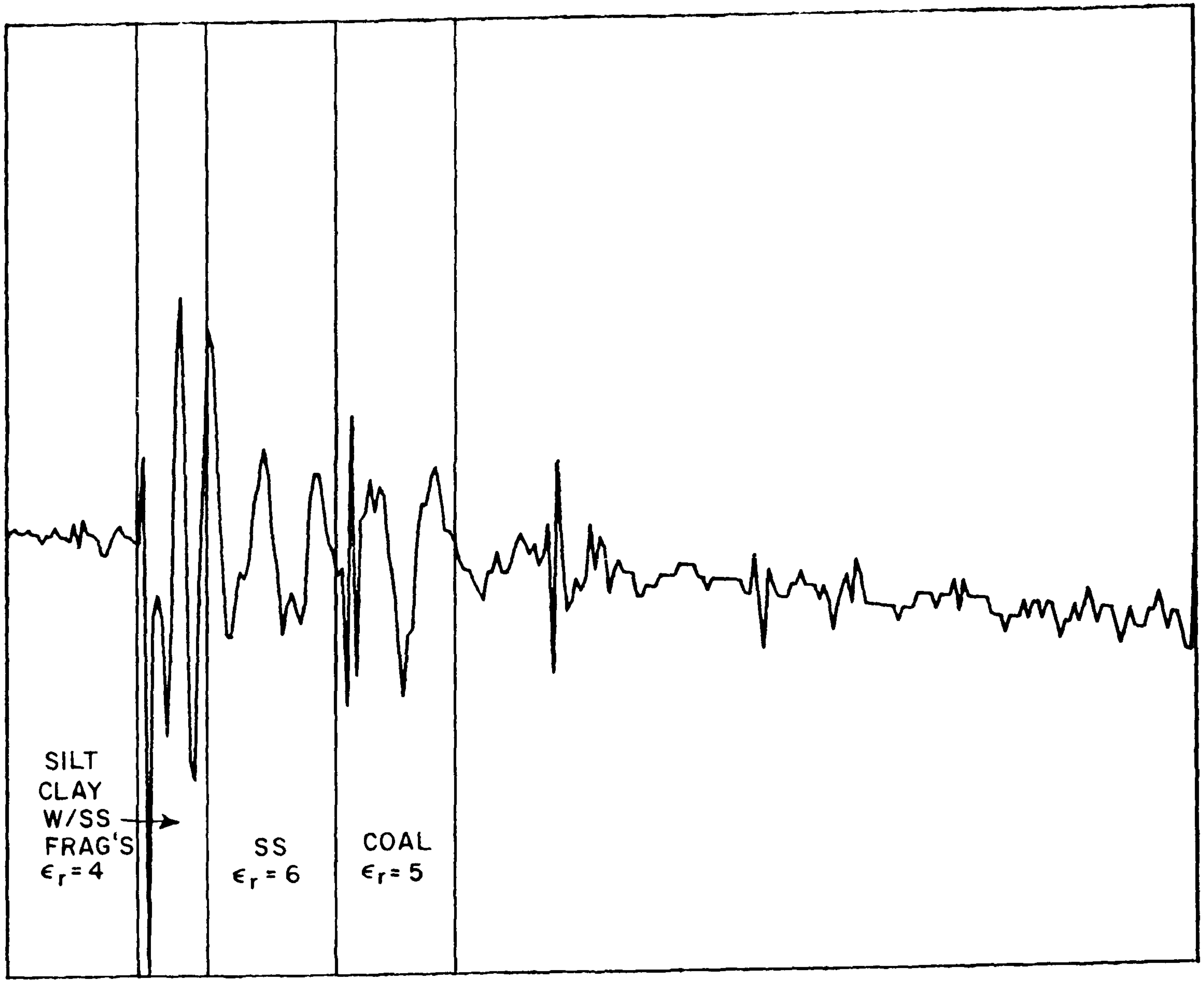

Figure A5. Waveform at drill coordinate C-4.

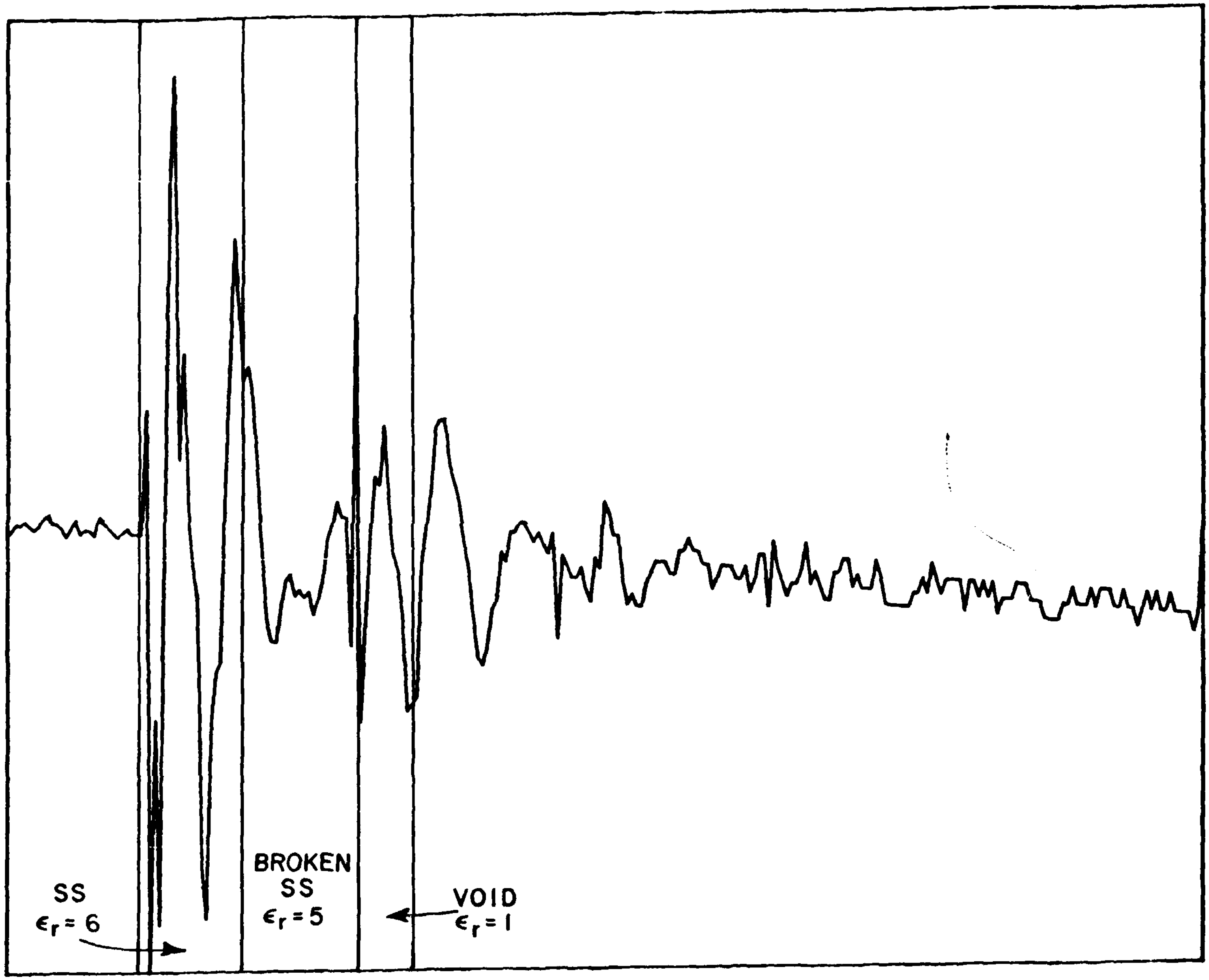

Figure A6. Waveform at drill coordinate C-5.

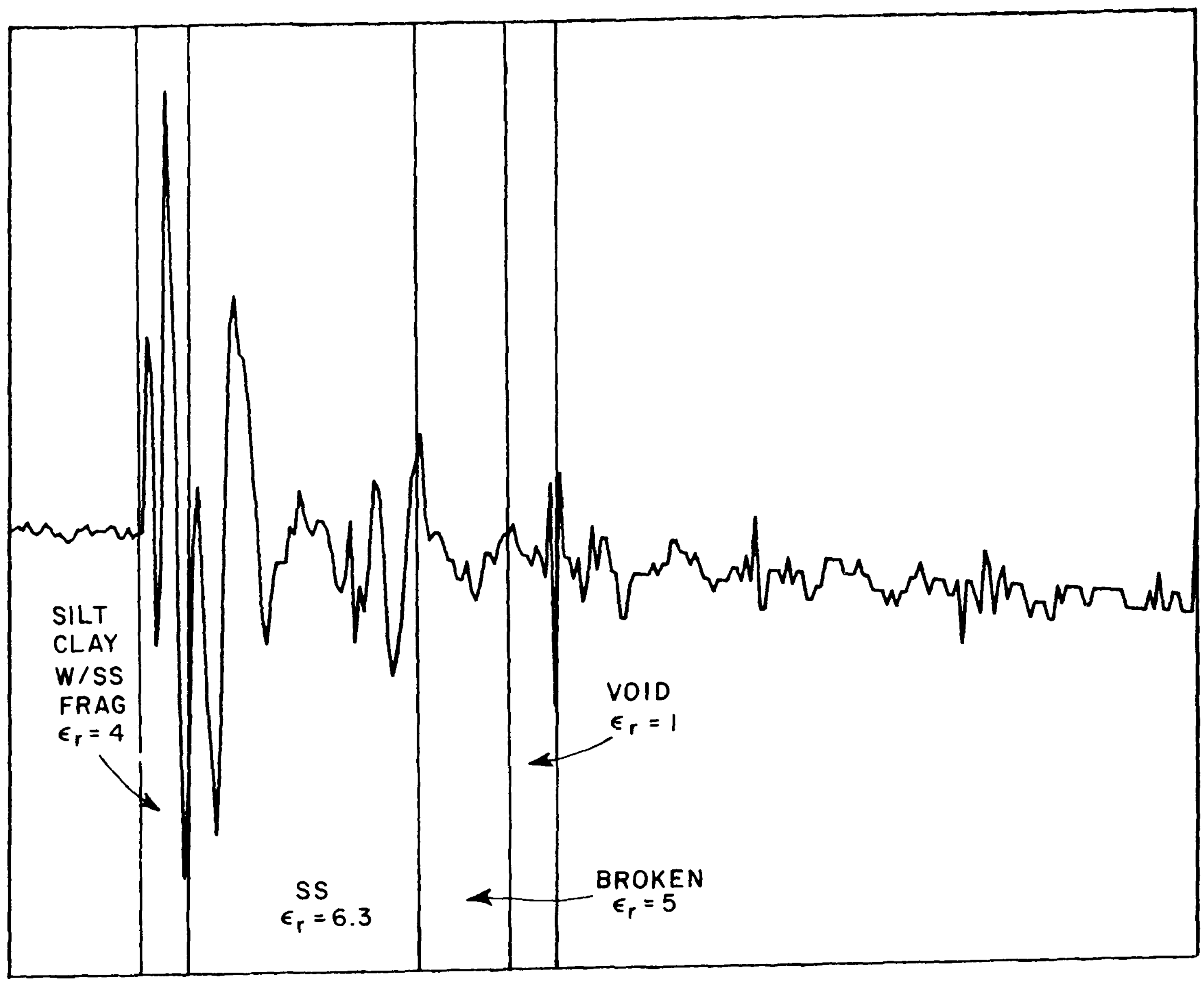

Figure A7. Waveform at drill coordinate D-1.

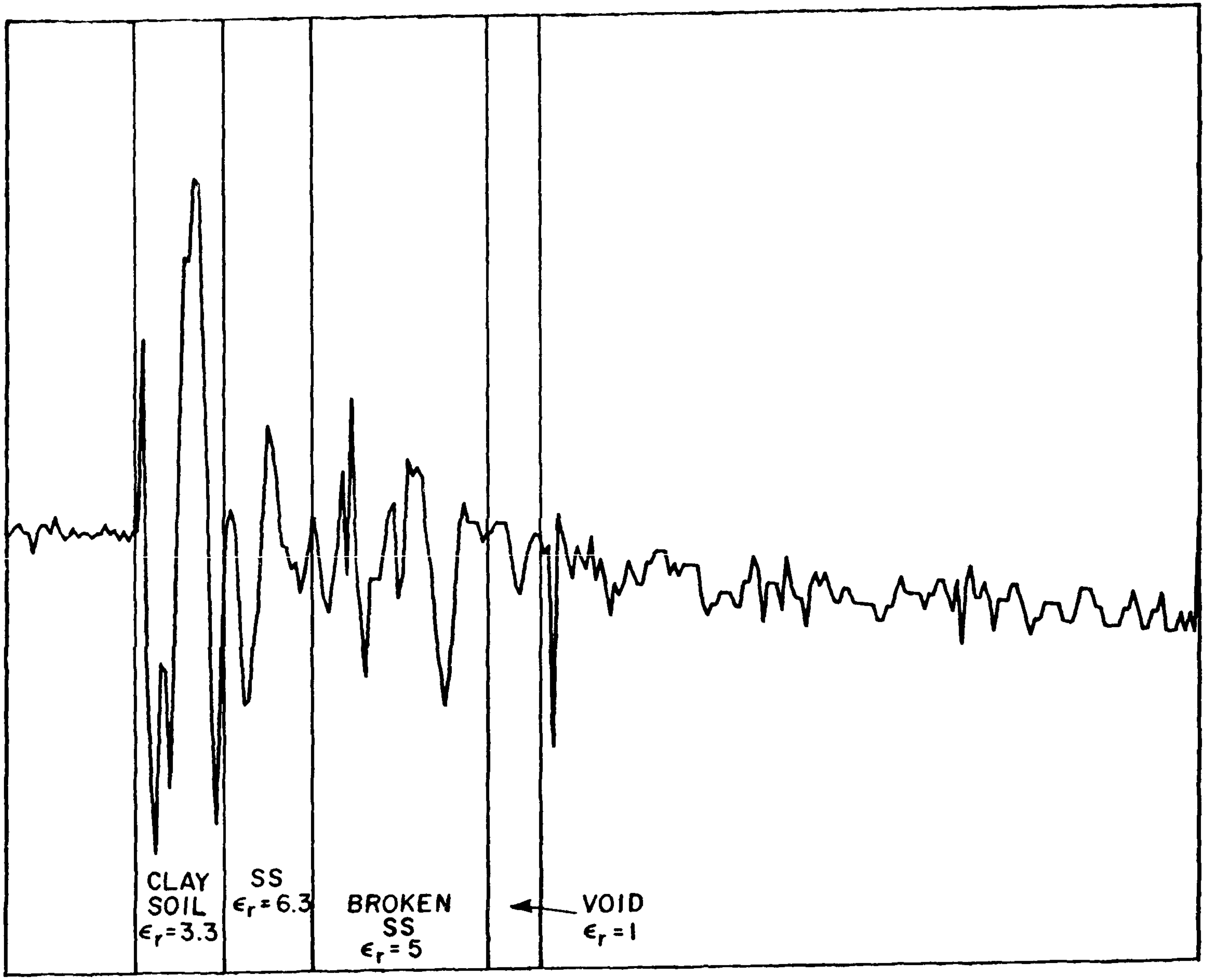

Figure A8. Waveform at drill coordinate D-2.

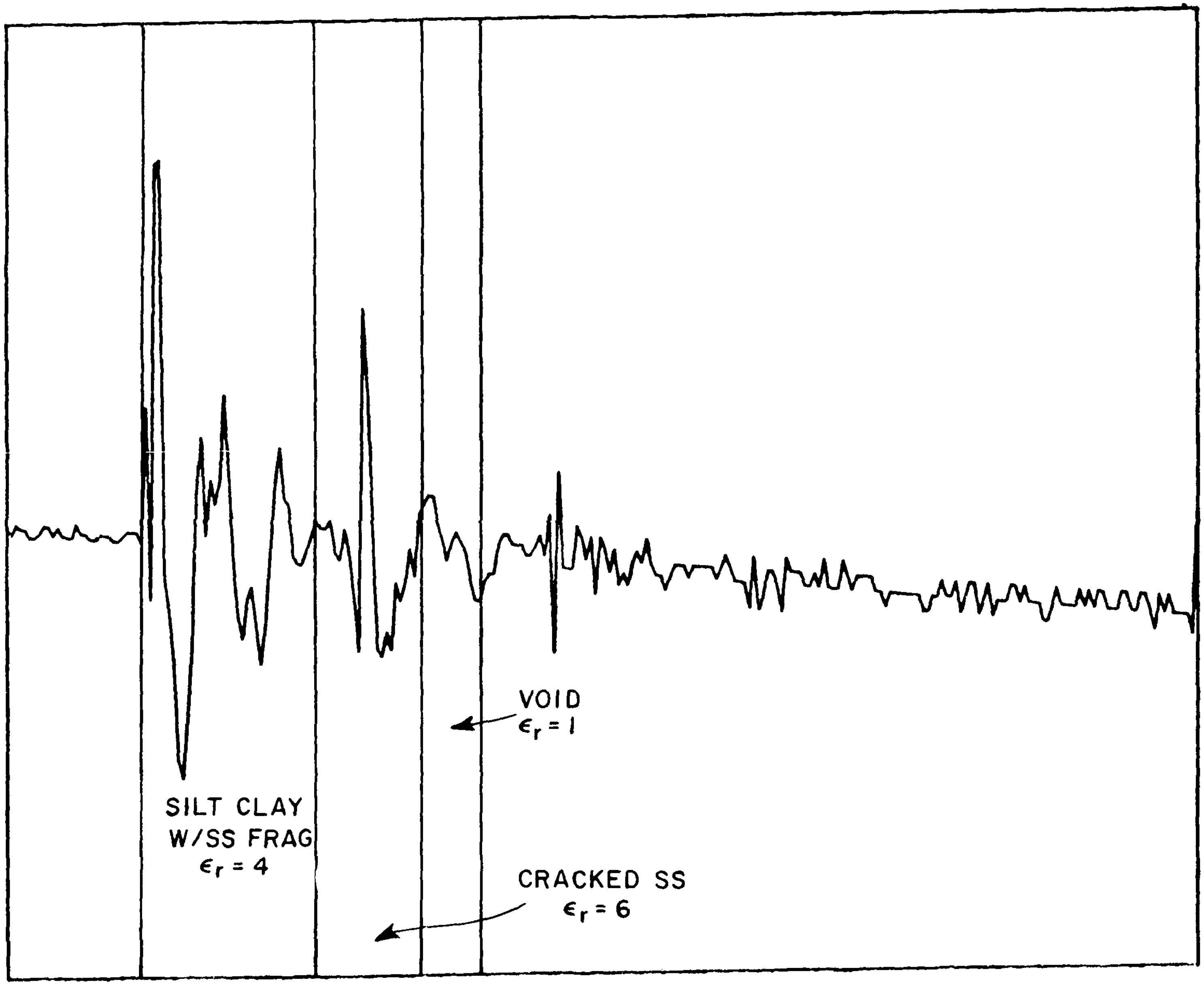

Figure A9. Waveform at drill coordinate D-3.

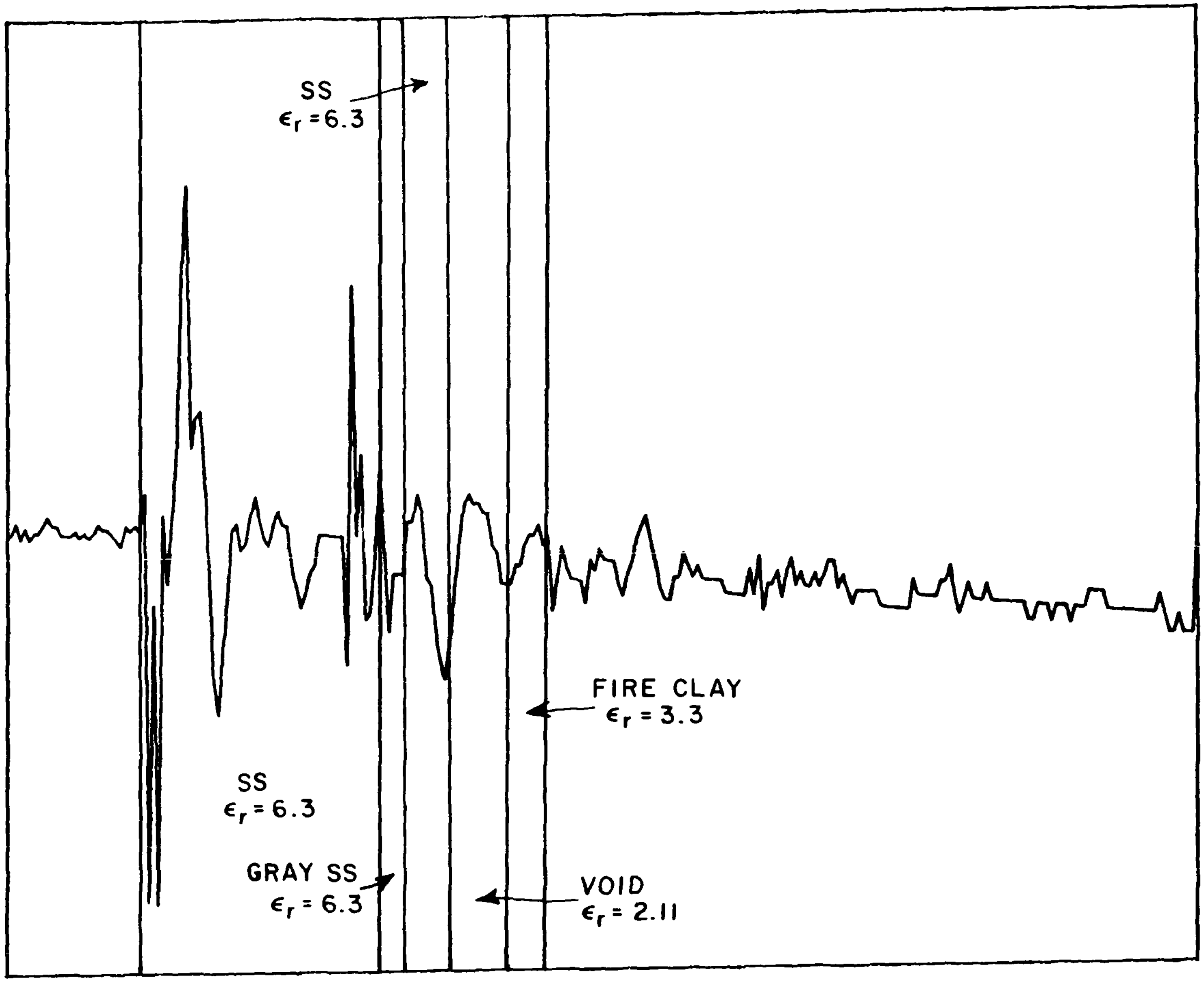

Figure A10. Waveform at drill coordinate D-4.

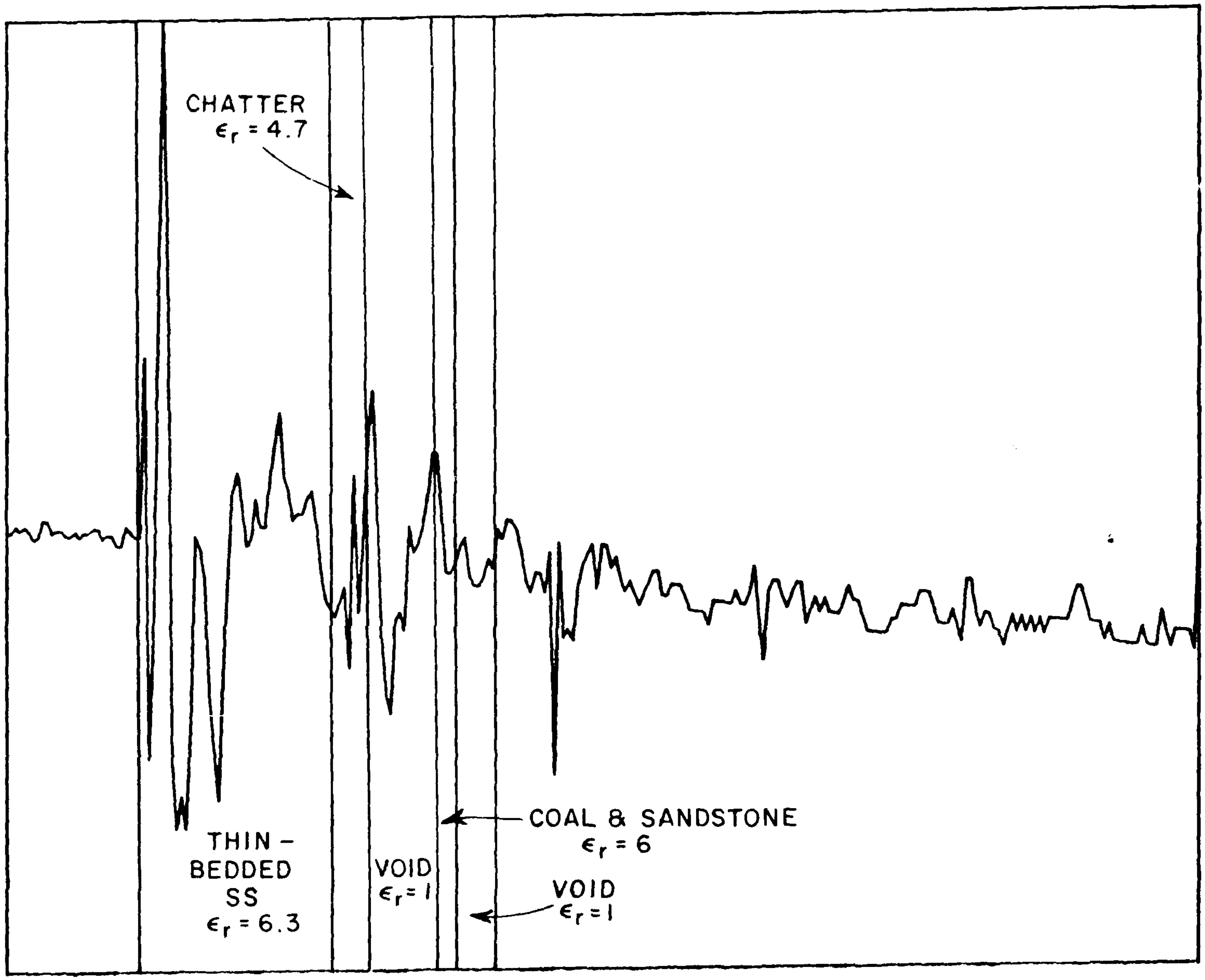

Figure A11. Waveform at drill coordinate D-5.

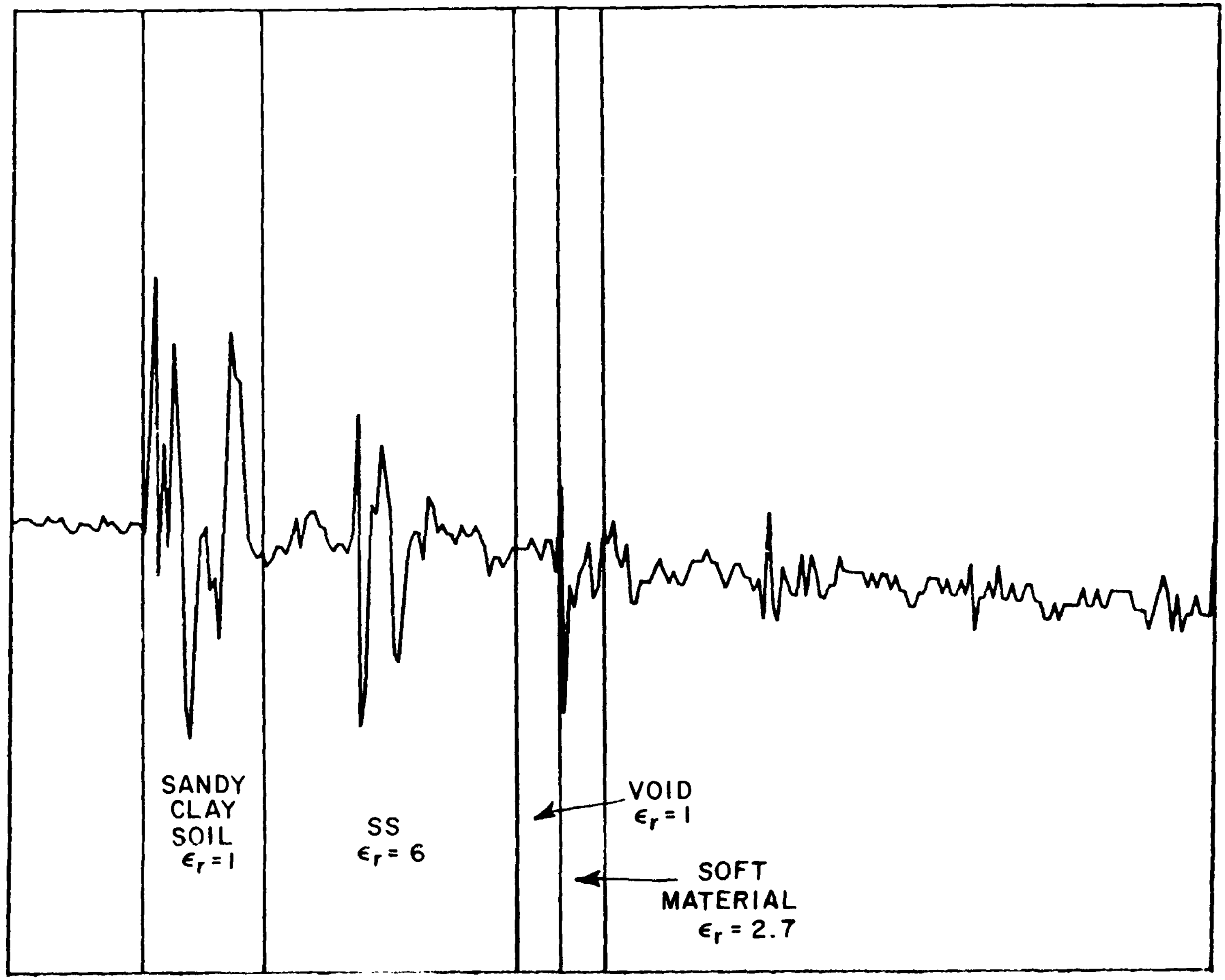

Figure A12. Waveform at drill coordinate E-1.

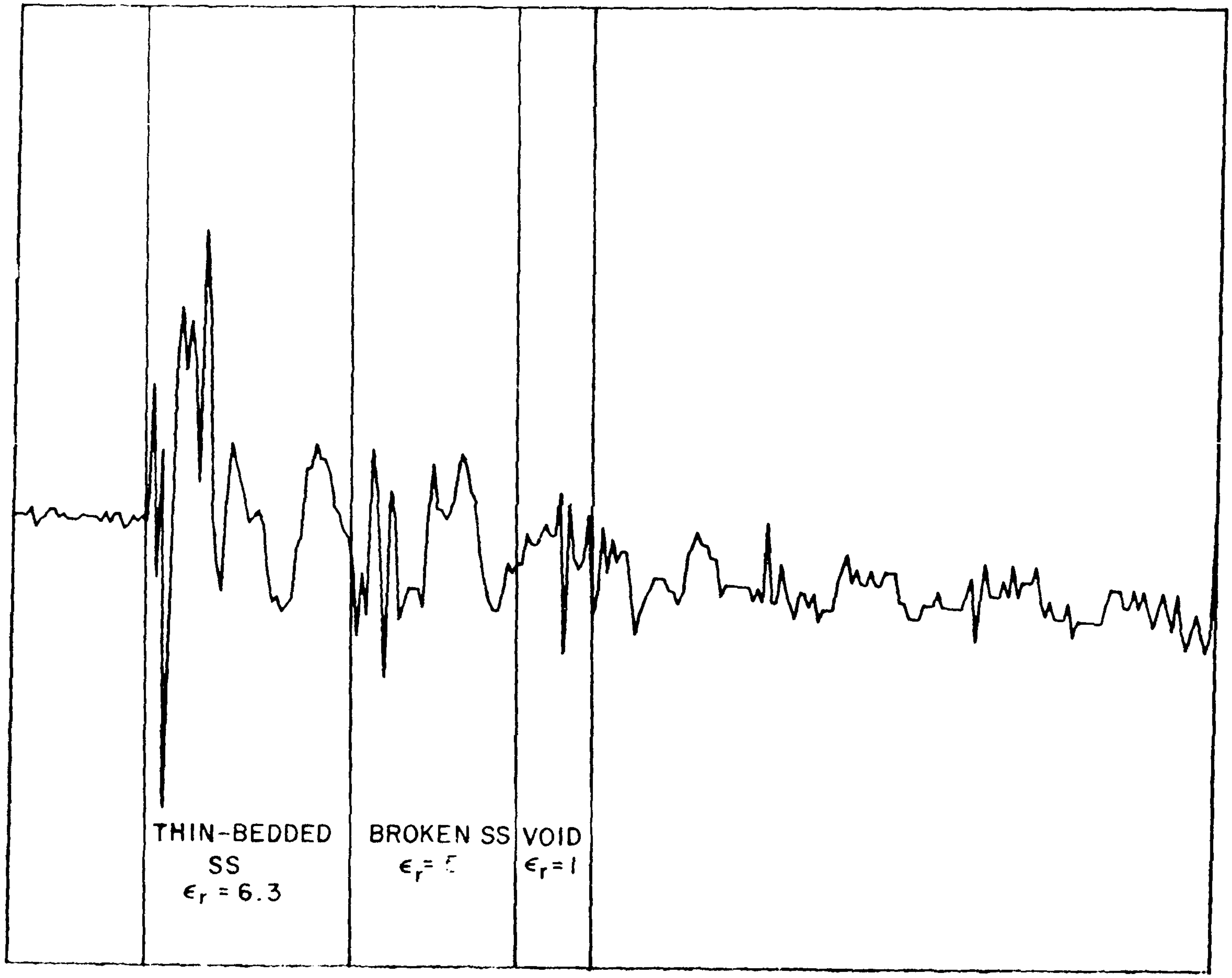

Figure A13. Waveform at drill coordinate E-2.

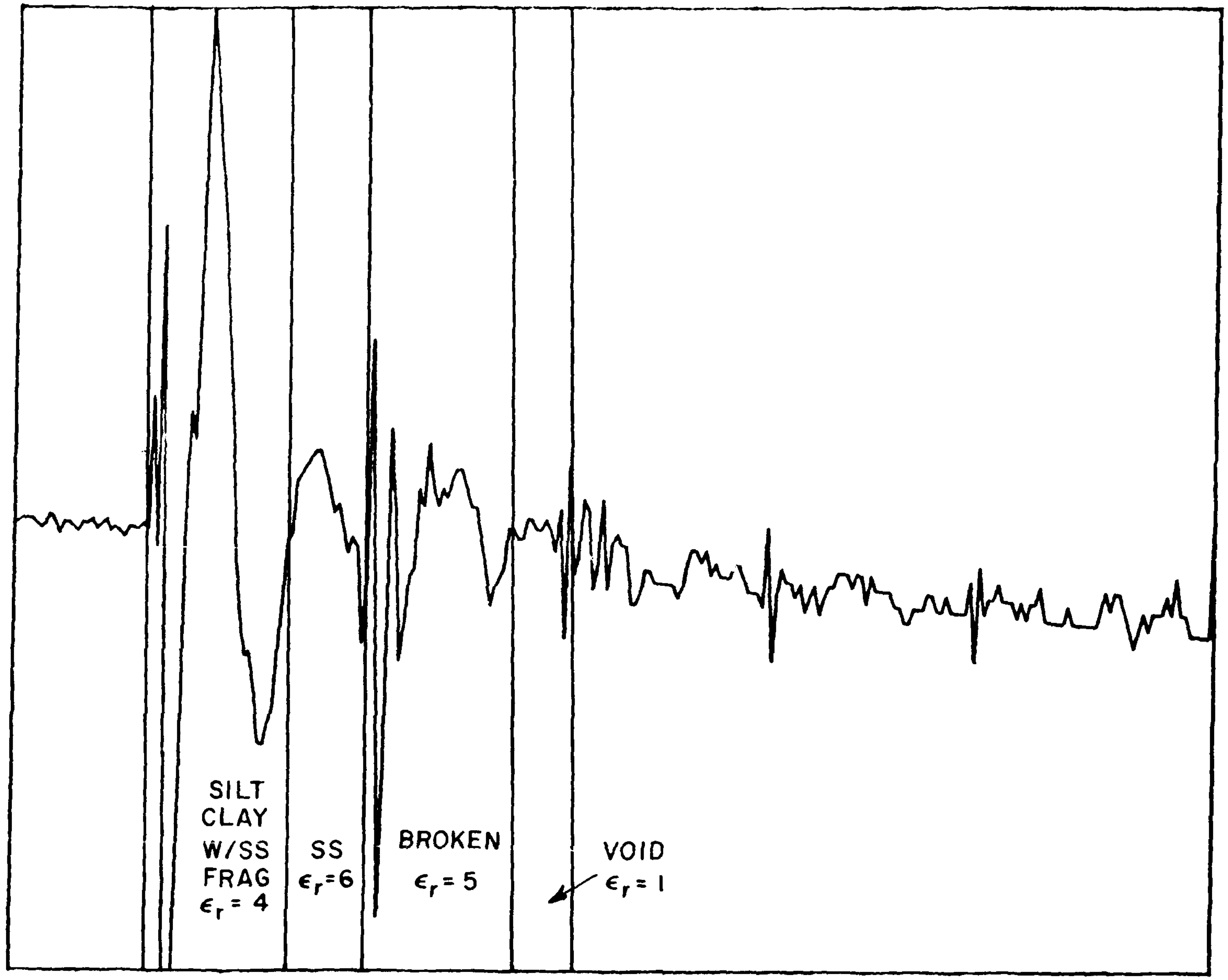

Figure A14. Waveform at drill coordinate E-3.

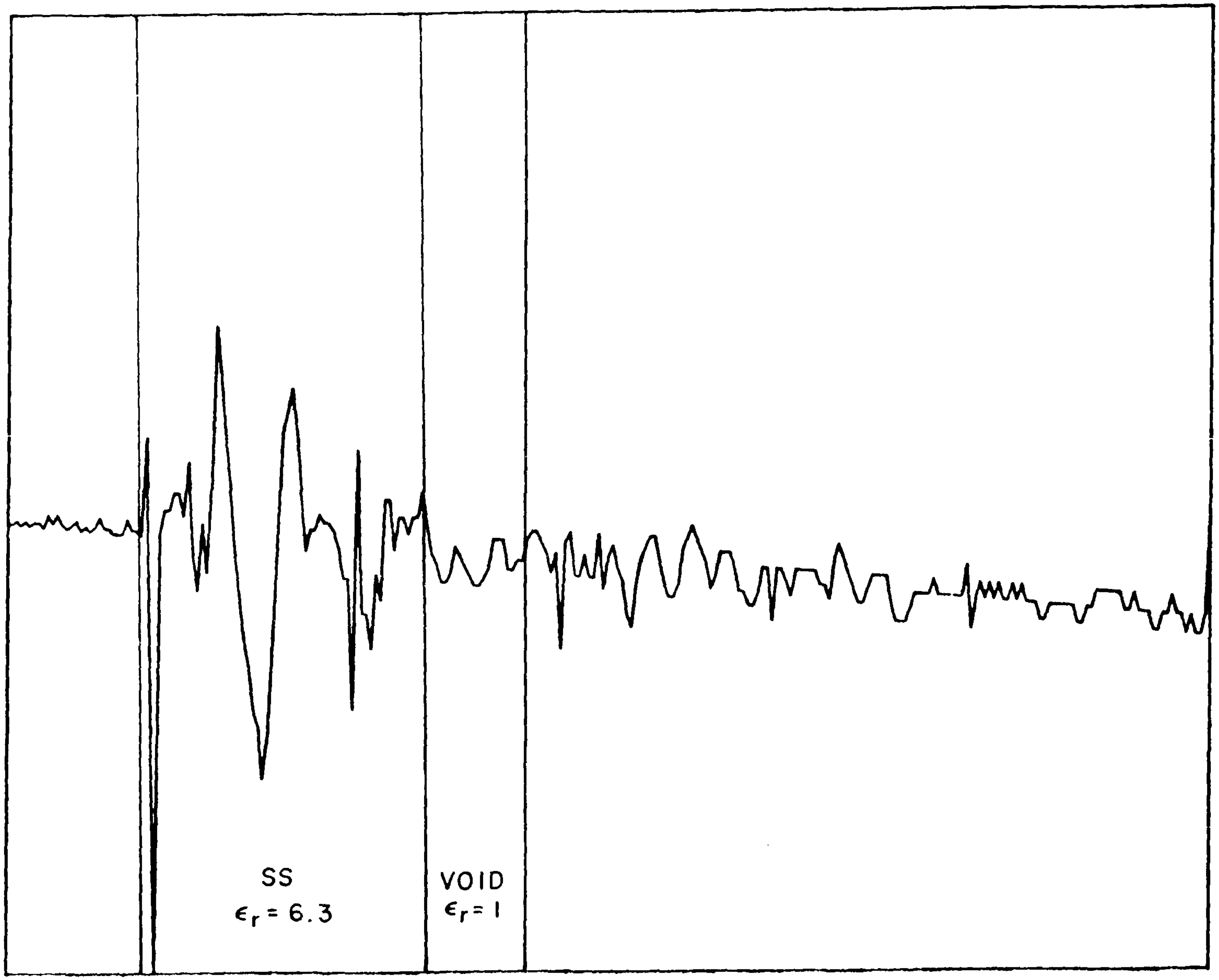

Figure A15. Waveform at drill coordinate E-4.

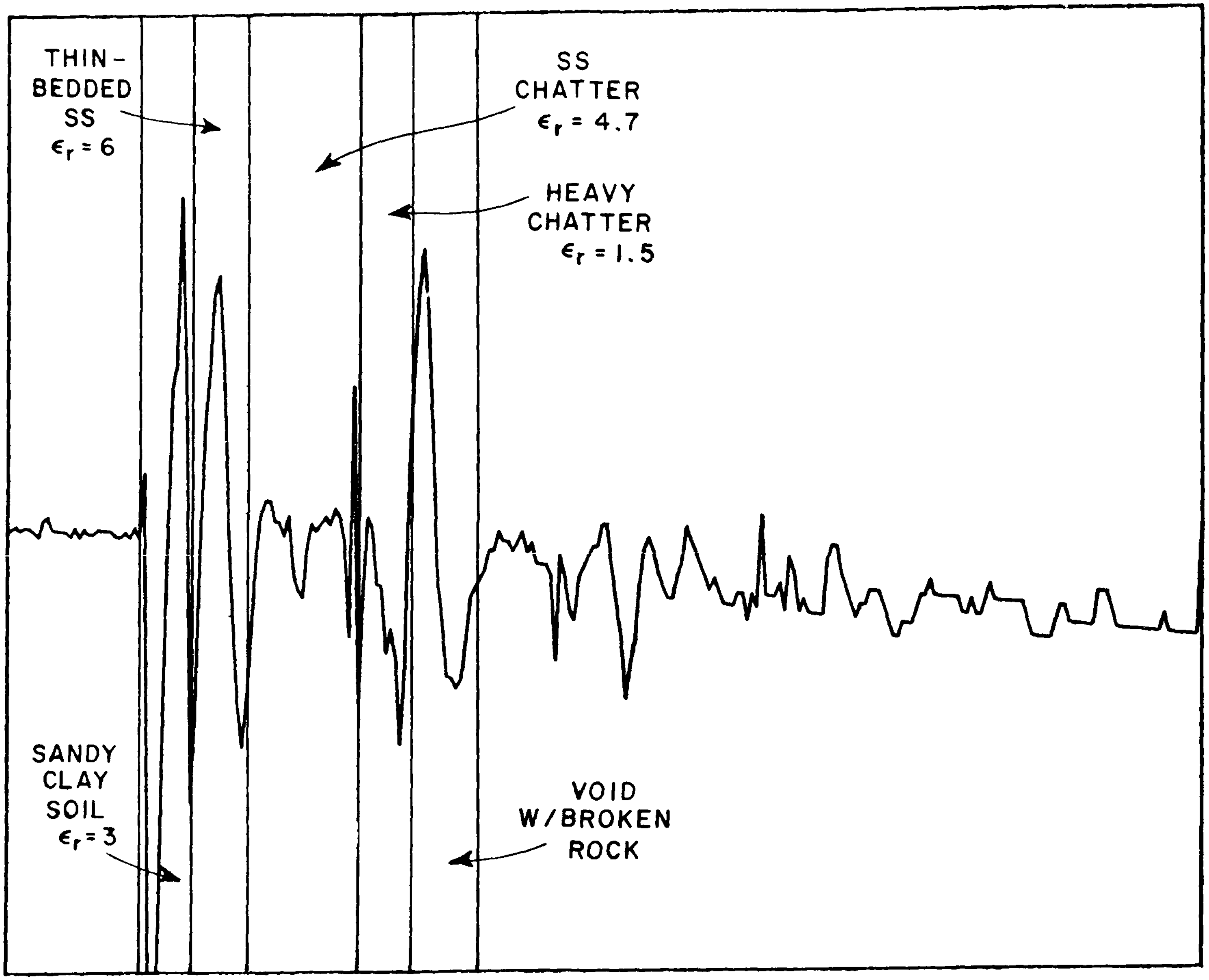

Figure A16. Waveform at drill coordinate E-5.