REPORT

ON SEISMOGRAPH SURVEYS

CONDUCTED IN

BARNWELL, AIKEN, AND ALLENDALE COUNTIES, SOUTH CAROLINA

PROJECT 8-1047

AXC-26657½ SEISMIC SURVEY

SAVANNAH RIVER PLANT

BEDROCK WASTE STORAGE

FOR

E. I. du PONT de NEMOURS & COMPANY, INC.

ENGINEERING DEPARTMENT

WILMINGTON, DELAWARE

Seismograph Service Corporation
A SUBSIDIARY OF RAYTHEON COMPANY
P.O. BOX 1590 TULSA, OKLAHOMA

C O N T E N T S

INTRODUCTION

The Seismograph Service Corporation was subcontracted in March, 1971, to E. I. du Pont de Nemours & Company, Inc., Wilmington, Delaware, to continue and expand seismic investigations on the U.S. Atomic Energy Commission's Savannah River Plant in Barnwell, Aiken, and Allendale Counties, South Carolina.

The purpose was to extend seismic lines previously recorded during the seismic program conducted in May, 1969, and primarily to obtain additional information on the attitude of surface and bedrocks in the study of the bedrock waste storage problem.

This new work program was conducted as Project 8-1047, AXC-26657½ Seismic Surveys. The field work was performed during the period from March 11th to 31st, 1971.

ASSIGNMENTS

The new assignments consisted of the following five lines covering approximately 23 miles of traverse:

Line 1:

Line 1 began with Shotpoint 4, near the same location of old Shotpoint 4 of the original shooting and approximately 500 feet north of DRB-9 well. This line proceeded southeastward along co-ordinate E-60,000 to Shotpoint 53 near co-ordinate N-12,260. At the conclusion of the survey, Shotpoints 54, 55, 56, and 57 were added at the northwest end of the line. These shotpoints overlapped the previous shooting with Shotpoint 56 being located near the DRB-9 well. Also, Shotpoints 15-A, 16-A, and 17-A and Shotpoints 48-A, 49-A, 50-A, and 51-A were reshot.

Line 2:

Line 2 begins with Shotpoint 61 located about 200 feet north of old Shotpoint 15 of the original shooting. The co-ordinates for Shotpoint 61 are approximately N-70,600 and E-60,000. Line 2 is a crooked line that meanders around, but was laid-out in such a manner as to cross DRB-7, DRB-6, DRB-5, DRB-1, and P8R holes. This line covers approximately 10.5 miles and terminates with Shotpoint 122 located at co-ordinates N-110,600 and E-57,150.

Line 3:

Line 3 includes Shotpoints 300 to 306 and is located approximately 3600 feet east of and parallels original Line 1. It extends about 7300 feet north from N-60,000.

Line 4:

Line 4 includes Shotpoints 400 to 406. It is about a mile west of original Line 1 but extends slightly south of N-60,000.

Line 5:

Line 5 takes off northwestward from Shotpoint 64 of Line 2 and includes Shotpoints 201 through 208. This line ties to DRB-7, DRB-2, and DRB-4 wells.

FIELD PROCEDURE

The seismic field crew again headquartered in Augusta, Georgia, a distance of approximately 30 miles west of the Savannah River Plant. The field equipment was inspected and the field crew personnel were processed through employment, security, and safety orientation on March 8, 9, and 10, 1971, and received safety helmets and badges which permitted access of personnel and equipment onto the Savannah River Plant. All field operations were conducted under the direction of Mr. George M. Vroman, Design Engineer, E. I. du Pont de Nemours & Company, Inc.

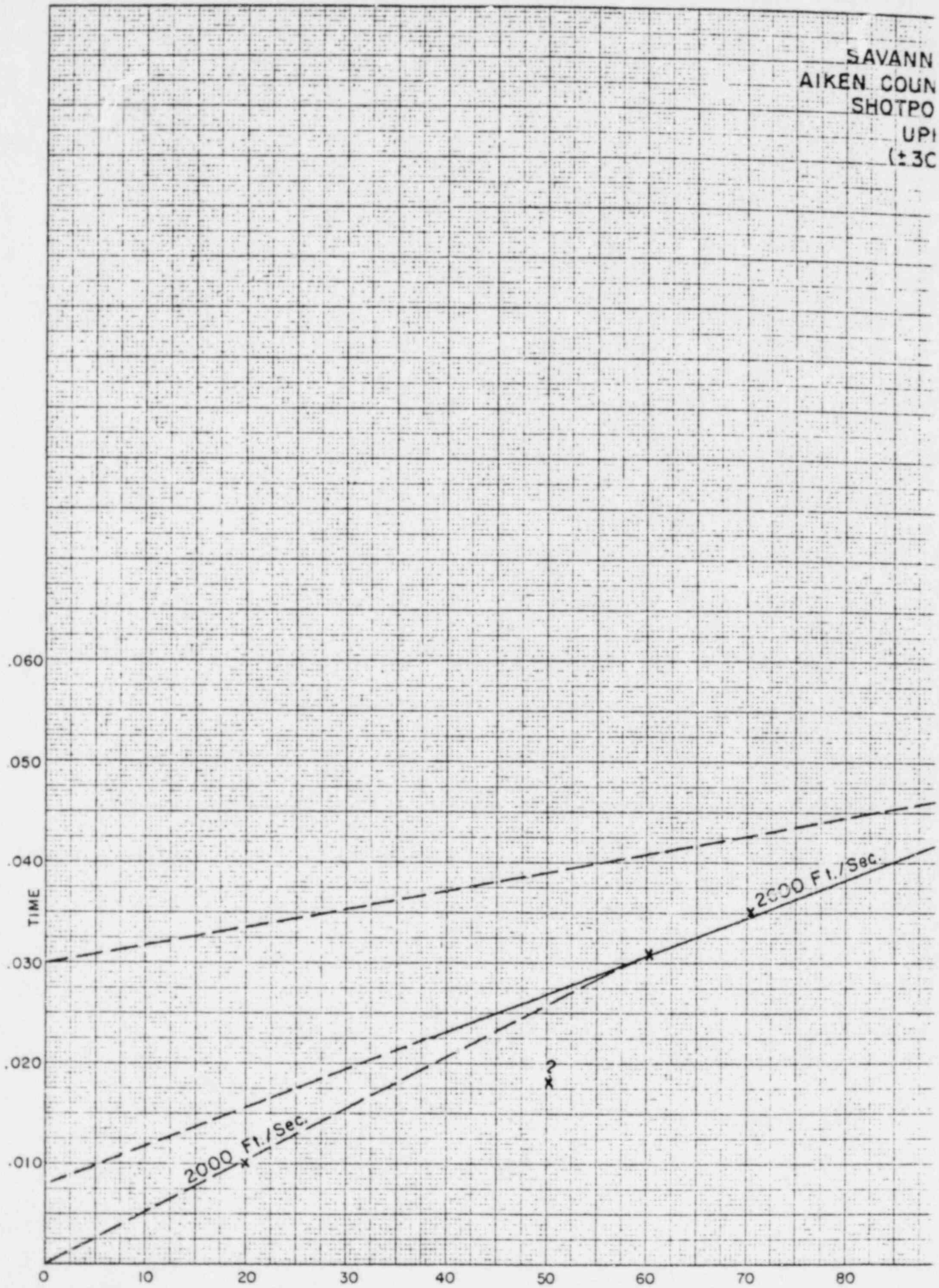
From the experience gained during the previous survey, it was determined that a continuous profile technique would be more advantageous than the correlation method originally used. The continuous profile method would be slower requiring more shotholes but would provide 100% subsurface coverage, ensure more precise correlations by having continuous coverage, provide detailed weathering information, and would furnish more control in the identification and location of possible faults. A straddle spread covering 900-75-0-75-900 feet (12 geophone stations on each side of the shotpoint at intervals of 75 feet) was the normal spread length used. Ten HSJ-14 Hz geophones were spaced 5 feet apart across each station.

In general, the shotholes were slightly deeper than the earlier survey especially in the extreme northern portion in the vicinity of the P8R hole. On Line 1 they ranged from 80 to 100 feet and were shot with 1 pound Nitramon charges. When Shotpoints 48-A, 49-A, 50-A, and 51-A were reshot, these holes were redrilled to 150 feet and shot with 2 pound charges. On Line 2 the shotholes ranged in depth from 100 feet at Shotpoint 61 to 150 feet at Shotpoint 122 and were shot with charge sizes generally from 1 to 2 pounds. Also on Line 2, two shotholes per location were drilled at Shotpoints 100 through 120. The original hole was drilled to 100 feet and the second or A-hole was drilled 30 to 50 feet deeper. Separate records were taken from each hole. On Lines 3, 4, and 5, all shotholes were drilled to 100 feet and shot with 2 pound charges.

Because of the poor results and indicated deep weathering from the previous survey at the P8R hole, a deep uphole survey was made before starting Line 2. A shothole was drilled to a depth of 150 feet at Shotpoint 105-A (Line 2 and near P8R) for this uphole survey. The driller logged this hole as follows: 0-30 red clay, 30-78 sand, 78-85 red clay, and 85-150 sand. A charge size of one pound was shot and recorded at depths of 150, 130, 110, 90, 70, 60, 50, 40, 30, and 20 feet. A time-depth plot revealed interval velocities of 2000 ft/sec from 0-60 feet, 2600 ft/sec from 60-110 feet, and 5500 ft/sec from 110-150 feet. A reproduction of this time-depth curve is shown on page 8. The break at 110 feet indicates this to be the depth of the weathered zone. The summation weathering across Shotpoint 105 later confirmed this to be the depth of the weathering. From the analysis of this uphole survey the shotholes were drilled deeper along Line 2.

The seismic data were digitally recorded by TI DFS-III digital instruments and "read after write" paper monitor records were made simultaneously for use in computing weathering corrections. A broad band filter of 27 to 248 Hz was used with a slope of 36 db/octave on the low cut and 72 db/octave on the high cut. Also, a 60-Hz notch filter was used to eliminate any 60 Hz highline signal. The field digital tapes are 9 track 800 bpi, with a 1 millisecond sample rate, and a record length of 2.0 seconds.

The depth of the weathering for each geophone station was computed in the field from a summation method employing the use of the first break refraction arrivals on the monitor records. An average velocity of 2500 ft/sec was used in computing the thickness of the weathered zone. These weathering values were then used in determining the static corrections applied to the preliminary replay sections. These corrections were made to a reference datum of +200 feet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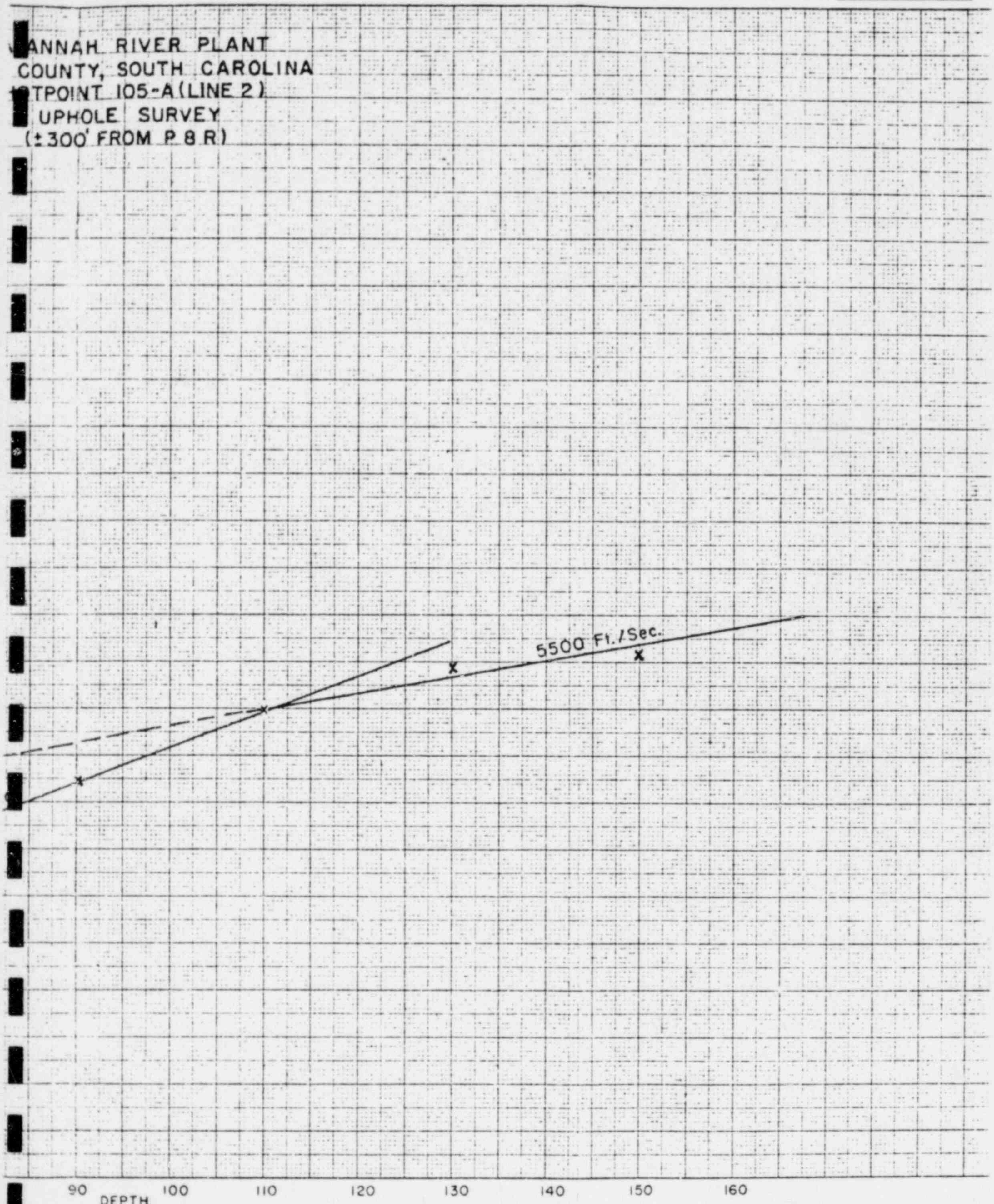

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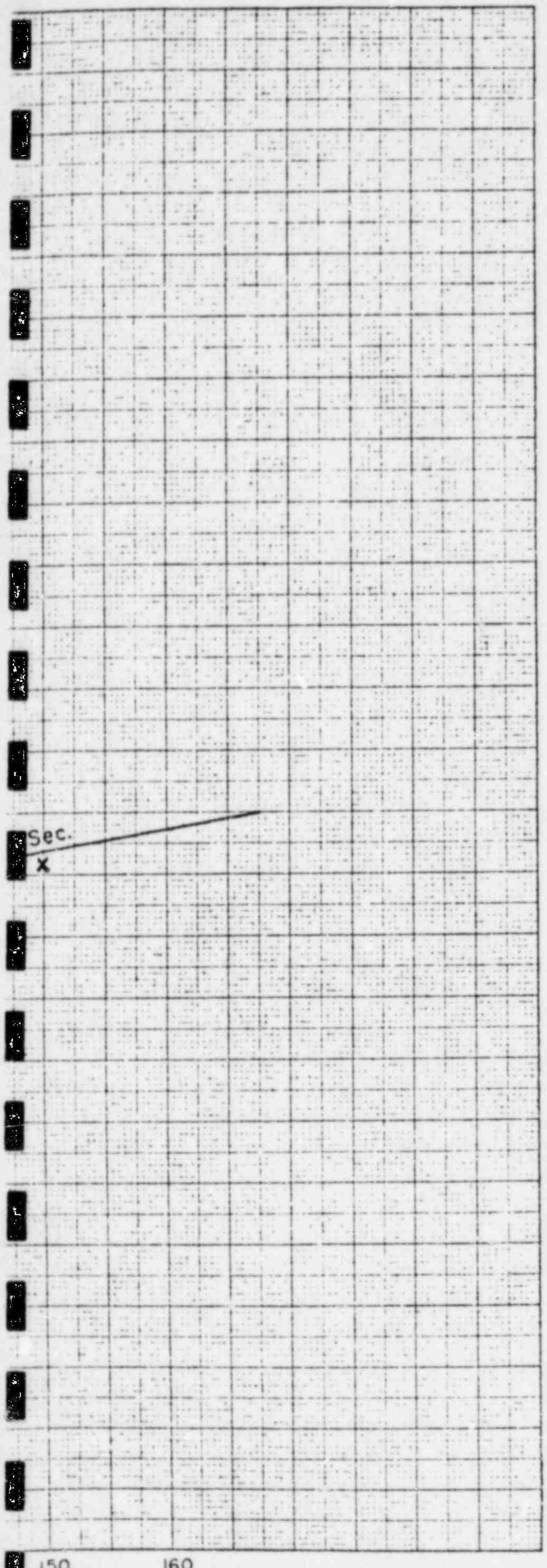


above sea level with an elevation velocity of 5500 feet per second, the same parameters as used in the original survey.

After completion of the shooting program, the drilling crew went back and grouted or cemented from bottom to top each hole that had been drilled over the area.

PROCESSING

The magnetic tapes were forwarded to the SSC Data Processing Center in Tulsa, Oklahoma, where they were digitally processed. After making some filter tests, some preliminary galvo-area sections were made by applying static and normal moveout corrections. These sections were then studied for further refinement and enhancement of the data. On Lines 1, 2, and 5, corrected filter paper records were displayed from which differential fiducial statics were obtained and applied before making the final galvo-area sections.

Lines 1, 1-Extension and Reshoots, 3, 4, and 5 were displayed with a 25-35-65-80 Hz filter while Lines 2 and 4 were displayed with a 50-60-120-150 Hz filter. A set of prints of these sections with the various reflecting events colored is placed in the pocket of this report.

DISCUSSION OF RESULTS

General

Two subsurface structural maps, one isopach map, and one velocity gradient map are presented with this report. They are designated as:

Structural
- Near Top Saprolite
- Near Top Crystalline Rock

Isopach
- Near Top Saprolite to Near Top Crystalline Rock

Velocity Gradient Map
- Near Top Crystalline Rock and Near Top Saprolite

In general, the record quality was fair to good, however, some poor data were recorded along portions of Line 1. Some holes were reshot in an effort to improve the data.

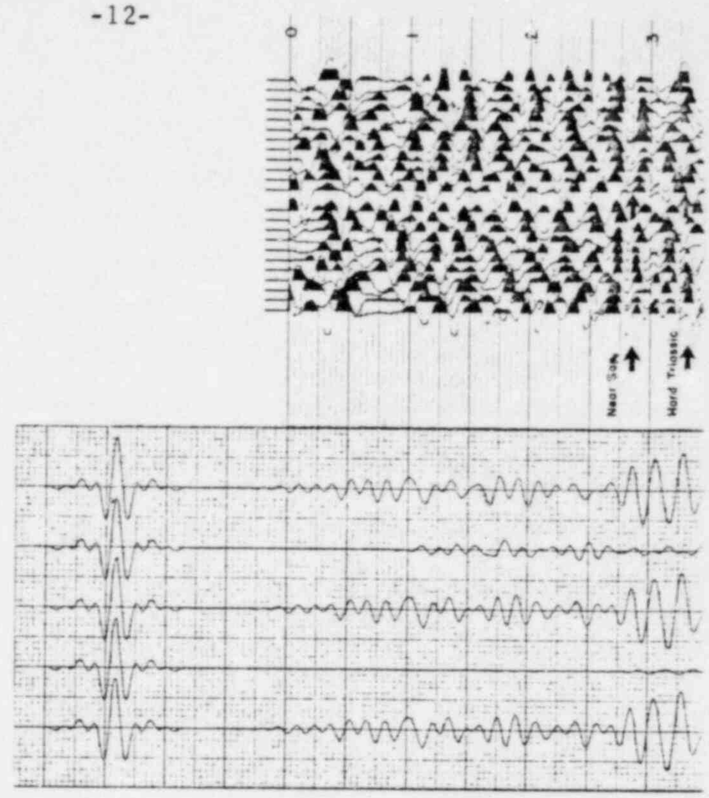
Shortly after the completion of the original seismic survey, both the DRB-8 and DRB-9 holes were drilled. The velocity data from the DRB-8 hole were used in preparing the final maps and confirmed the reflection identifications. Subsequently, the DRB-9 hole was drilled. It penetrated the Top of Triassic at a depth of 1041 feet (302 ft.-K.B.) and reached the Top of Crystalline Rock at 2630 feet (K.B.), and bottomed at 2701 feet.

Synthetic Record Comparison

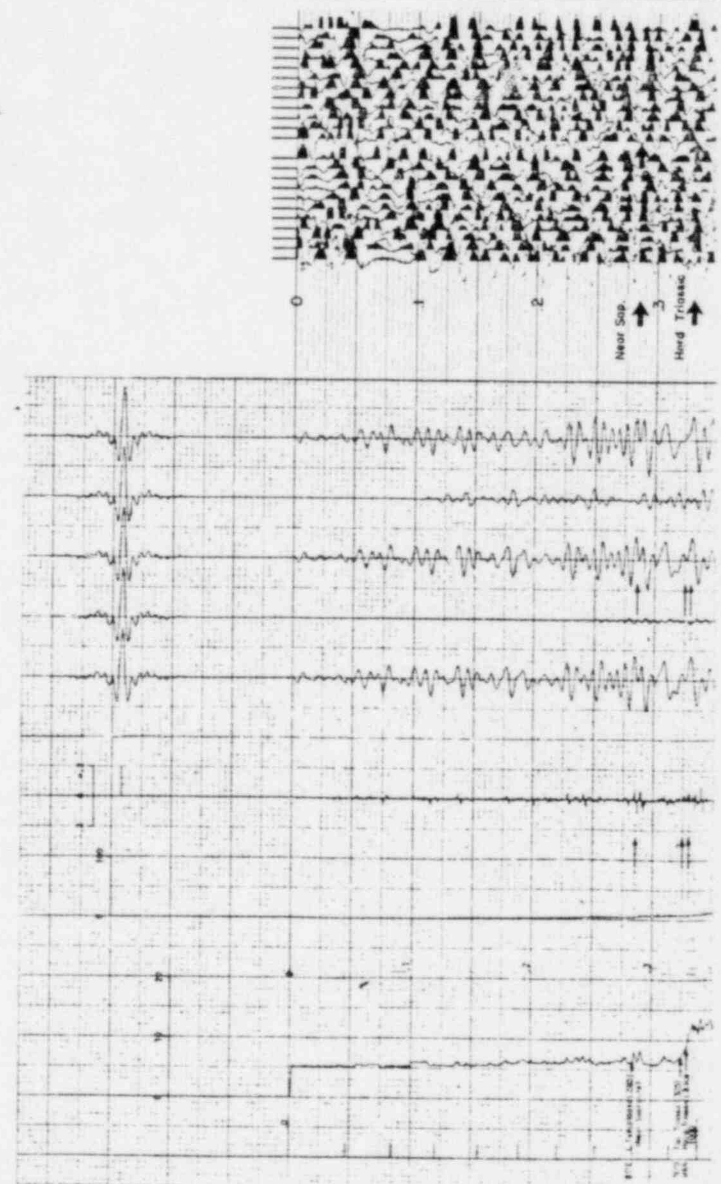
Upon the initiation of this new shooting program, the Birdwell Division prepared a synthetic seismogram from the 3-D Velocity Log run in the DRB-9 hole. A comparison of two different filters: 20-30-70-80 Hz and 30-40-150-160 Hz of the synthetic seismogram with that obtained from Shotpoint 56 located near the DRB-9 hole is shown on page 12 of this report.

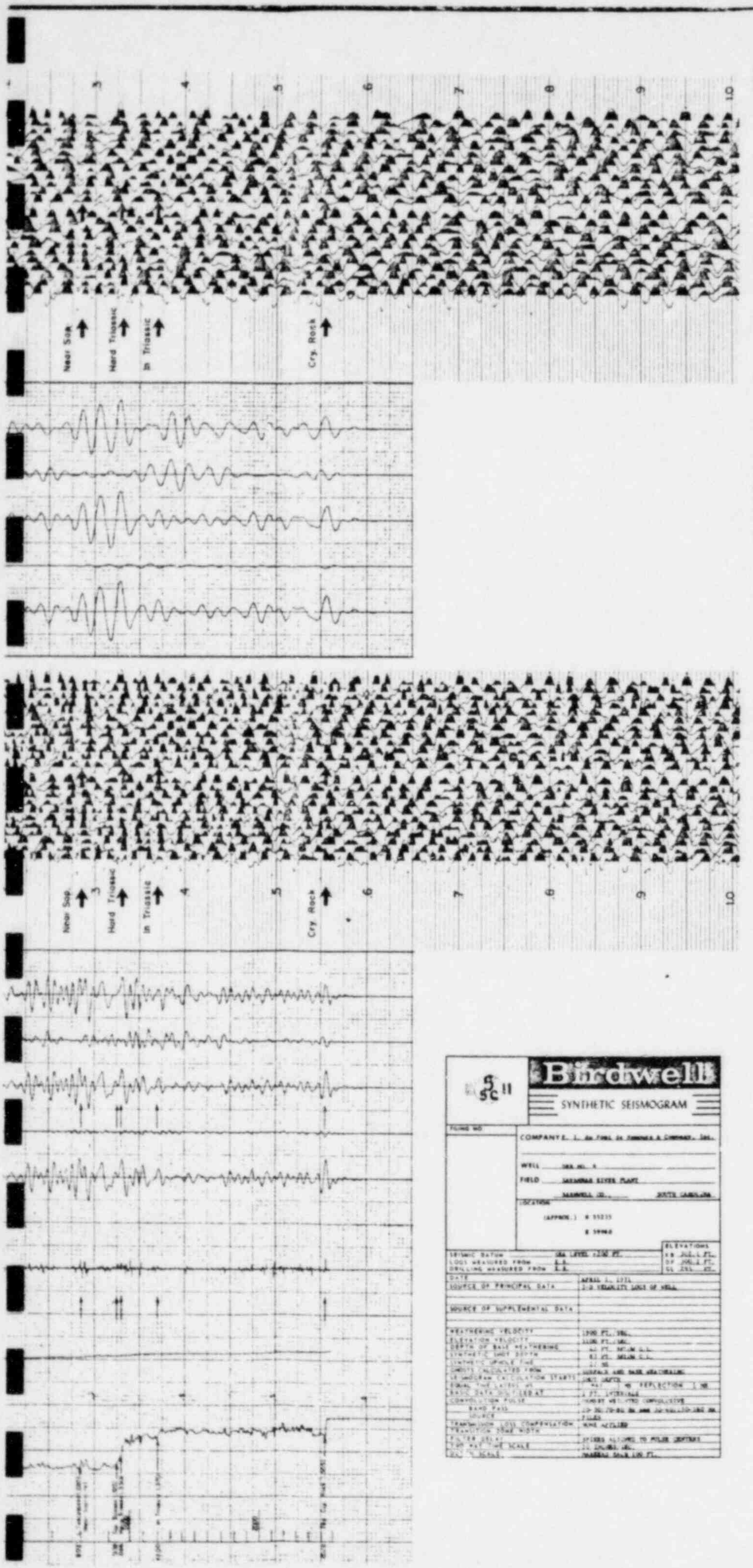
The interval velocity curve shows a contrast in the Lower Tuscaloosa (Near Top Saprolite) at a depth of 802 feet (ED=+200 Ft.) and a positive primary spike. Both synthetic records exhibit a reflection at a time of .285 seconds corresponding with this spike. The Top of the Triassic (at a depth of 939 feet) does not show sufficient contrast, however, the hard Triassic at 966 feet exhibits a seismic event at .330 seconds on the 30-40-150-160 Hz filter but seems to be combined with a later cycle of the shallower event on the 20-30-70-80 Hz filter. A weak event occurs at a time of .370 seconds from a depth of 1200 feet (ED=+200 Ft.) which is 261 feet below the Top of Triassic. The Crystalline Rock at a depth of 2528 feet (ED=+200 Ft.) indicates a velocity contrast and both synthetic records show a reflection at a time of .555 seconds.

SP 56
Filter 20-30-70-80 Hz
d_s = 100 Feet
t_s = .029 Sec.
E.D. + 200 Feet
V_e = 5500 Ft./Sec.



SP 56
Filter 30-40-150-160Hz.
d_s = 100 Feet
t_s = .029 Sec.
E.D. + 200 Feet
V_e = 5500 Ft./Sec.





DRB-9
COMPARISON BETWEEN SYNTHETIC AND SEISMIC RECORDS

The seismograms from Shotpoint 56 exhibit reflections at times comparable to those shown by the synthetic record. The data from Shotpoint 56 has been corrected to the reference datum of +200 feet using an elevation velocity of 5500 feet per second. The Crystalline Rock reflection appears to be slightly earlier on the Shotpoint 56 record. This is because of the steep dip in which the depth point is displaced northwestward 1110 feet showing a dip of 24° at -2245 feet.

Recently Drilled Holes

Since the completion of the recent field work, two additional holes have been drilled. These are DRB-10 near Shotpoint 27 on Line 1 and P9R near Shotpoint 100 on Line 2. These generally confirmed the preliminary seismic results. DRB-10 penetrated Top of Triassic at 1184 feet (257 ft.-K.B.) and was bottomed in Triassic at a total depth of 4212 feet, not having reached the Crystalline Rock. A 3-D Velocity Log was run in each of these holes by our Birdwell Division from which velocity information was obtained. The P9R hole penetrated the Crystalline Rock at a much shallower depth than expected reaching the rock at a depth of 743 feet from K.B. (328 ft.).

-10

Velocity Gradient Map

Approximately nine well ties were made to the Crystalline Rock in the northern portion of the survey from Lines 1, 2, and 4. From these well ties it was apparent that a velocity gradient was present. A velocity gradient map on the Crystalline Rock is submitted showing the various average velocities obtained at each well tie. This map shows a fairly strong gradient increasing in a westerly direction and exhibits average velocities ranging from 5800 ft/sec to 6300 ft/sec. Unfortunately, there is insufficient lateral control except along Line 4 and no control is present south of the DRB-8 hole. Consequently, the contour configuration of this map is subject to change pending other lateral well ties. In effect the same gradient was applied to the Near Top Saprolite event in the northern area because the average velocities used for the shallower event were 100 ft/sec smaller than those applied to the Crystalline Rock. This differential was established at the DRB-8 well tie. Although the DRB-9 well was drilled to the Crystalline Rock at a depth of 2528 feet (ED=+200 Ft.), it penetrated approximately 1600 feet of Triassic section exhibiting an interval velocity of 14,200 ft/sec which would greatly increase the average velocity to the Crystalline Rock. The first break average velocity from the two-way time-depth curve to a reference datum of +200 feet above sea level computes out to be 9220 ft/sec. This is considerably greater than that applied north of Shotpoint 5, the last continuous seismic control at this level. Consequently, a considerable velocity change may occur across a fault south of Shotpoint 5.

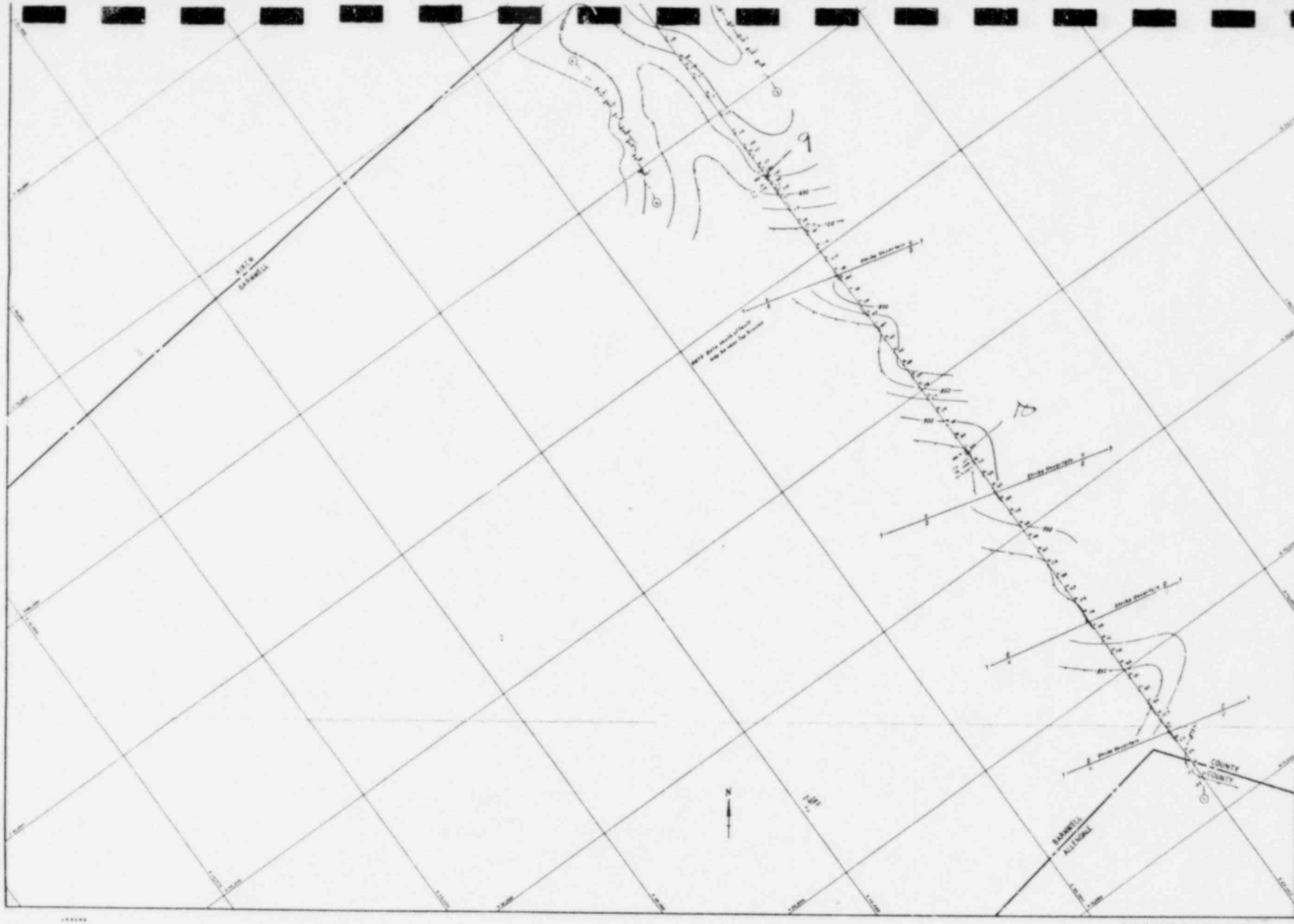
Two-way time-depth curves adjusted to a +200 E.D. from velocity surveys in the P5R, P6R, P8R, P9R, DRB-8, DRB-9, and DRB-10 holes are included in the calculation book.

Reduced prints of the structural maps, isopach map, and velocity gradient map are submitted as pages 16, 17, 18, and 19 of this report.

Since each of these maps covers only a portion of the survey and are not of sufficient detail control to adequately define the true structural conditions, only a brief discussion of these maps will be made and a more detailed discussion of a time cross section of each individual line will follow.

Detailed Discussion

An effort was made to map the same two events on this later survey. The Near Top Saprolite event was mappable throughout most of Line 1. However, this event could very well be from the Top of the Triassic instead of the Saprolite from Shotpoint 13 on southward. A deeper Triassic reflection was present over a portion of this line but the Crystalline Rock event could not



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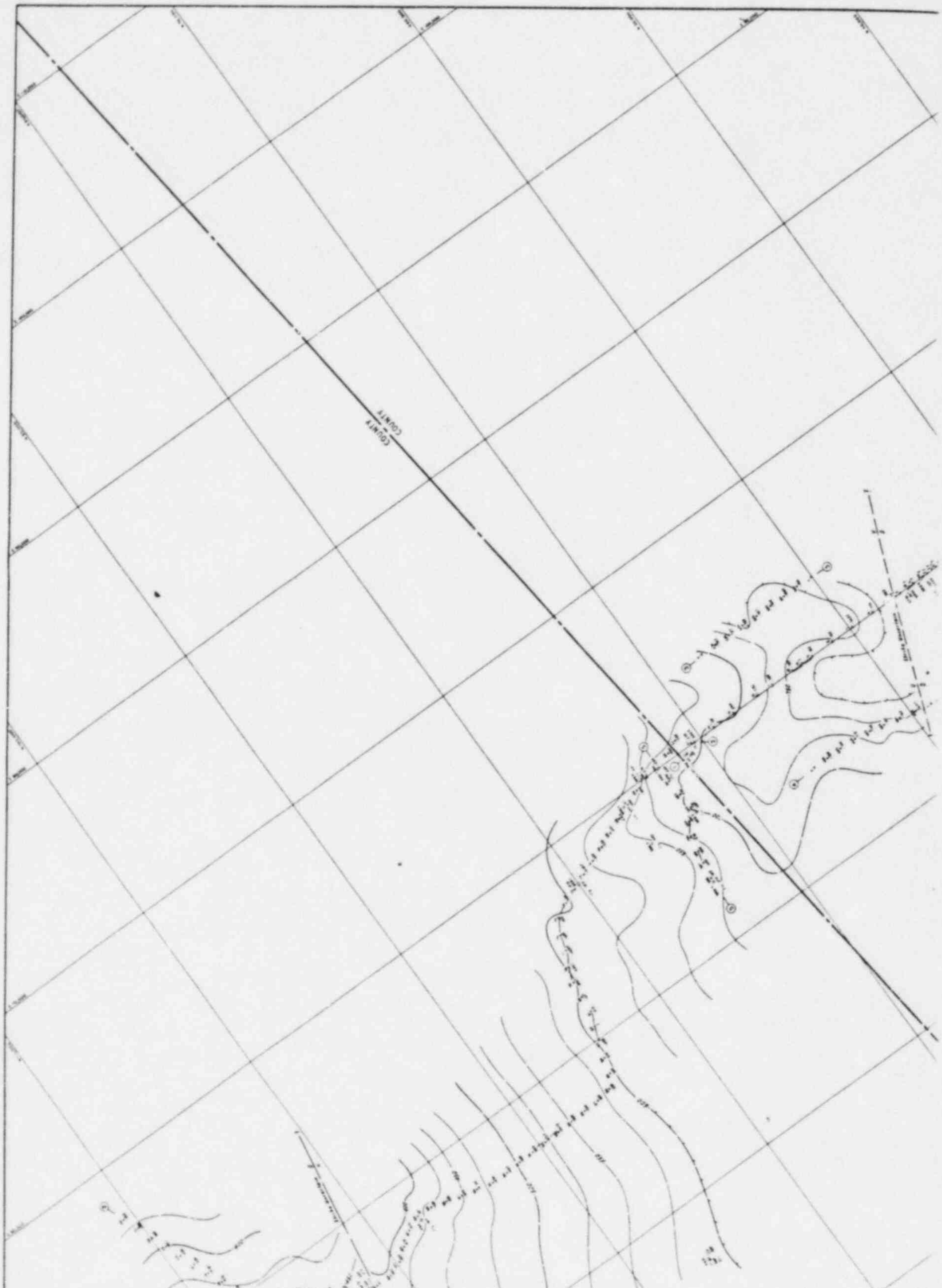
ABC-2665 TVII SEISMIC SURVEY
SAVANNAH RIVER PLANT
BEDROCK WASTE STORAGE
BARNWELL, AIKEN, AND ALLENDALE COUNTIES, SOUTH CAROLINA

NEAR TOP SAPROLITE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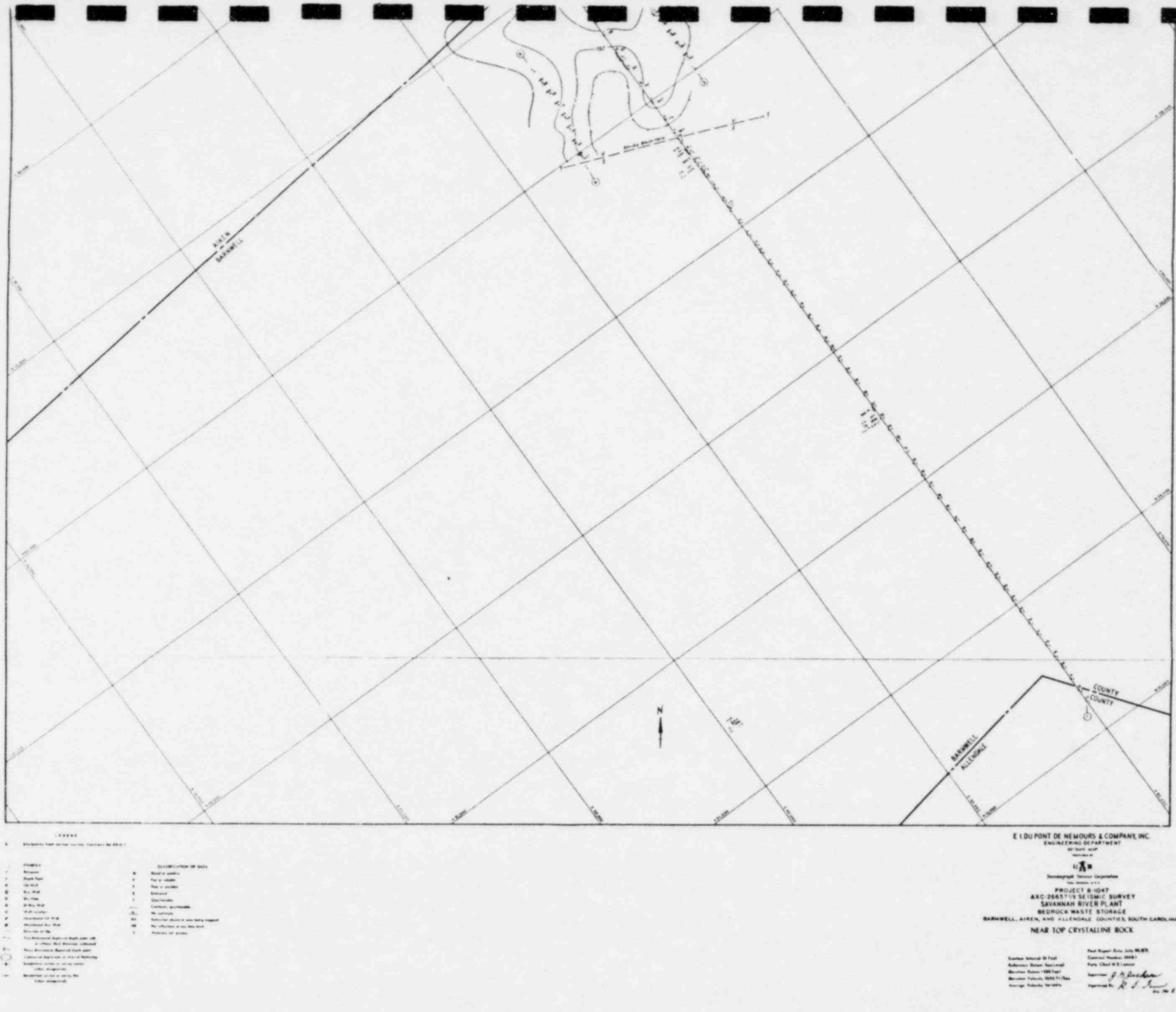

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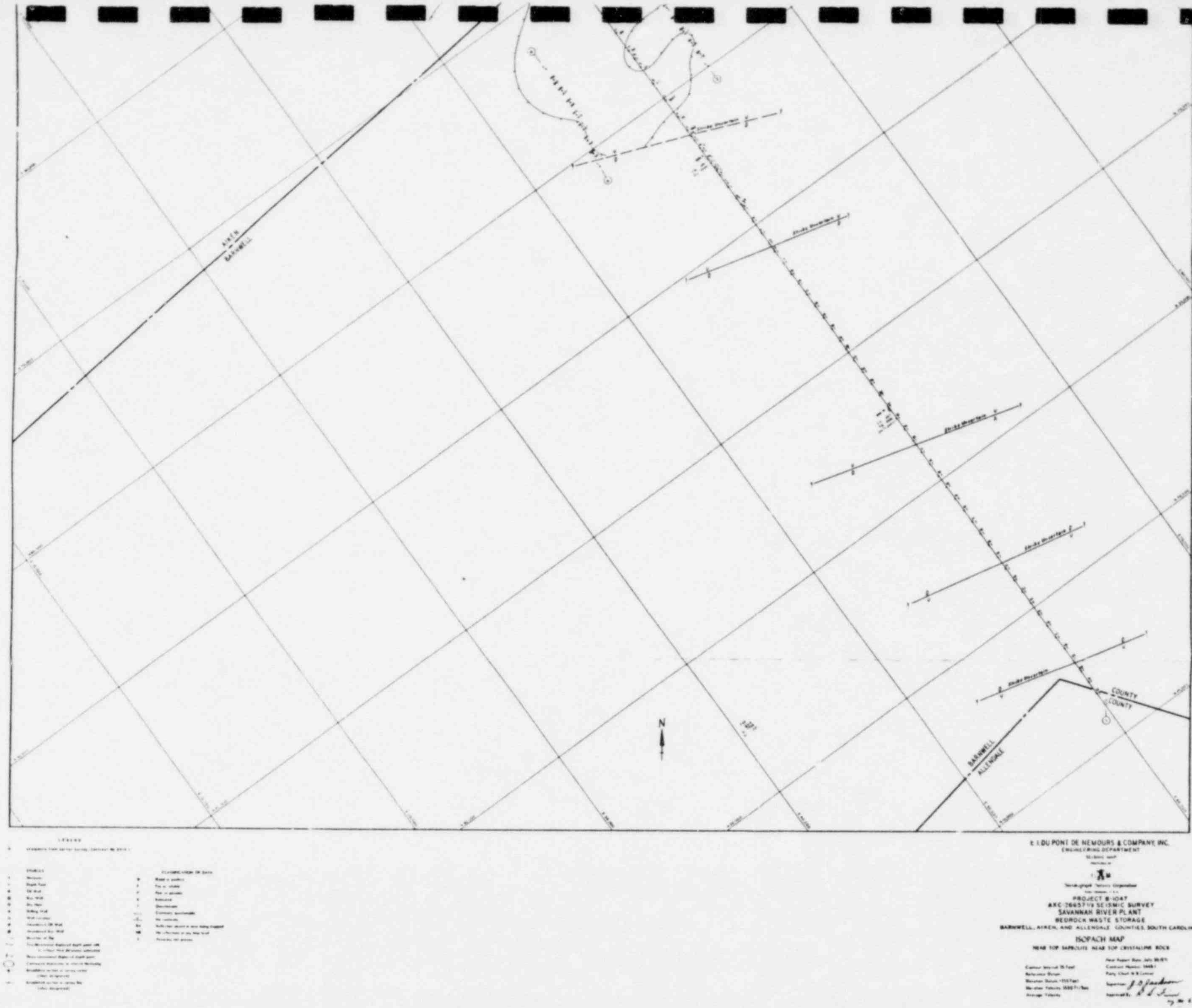
PROJECT 8-1047
AXC-266571/8 SEISMIC SURVEY
SAVANNAH RIVER PLANT
BEDROCK WASTE STORAGE
BARNWELL, AIKEN, AND ALLENDALE COUNTIES, SOUTH CAROLINA

NEAR TOP CRYSTALLINE ROCK


COUNTY
COUNTY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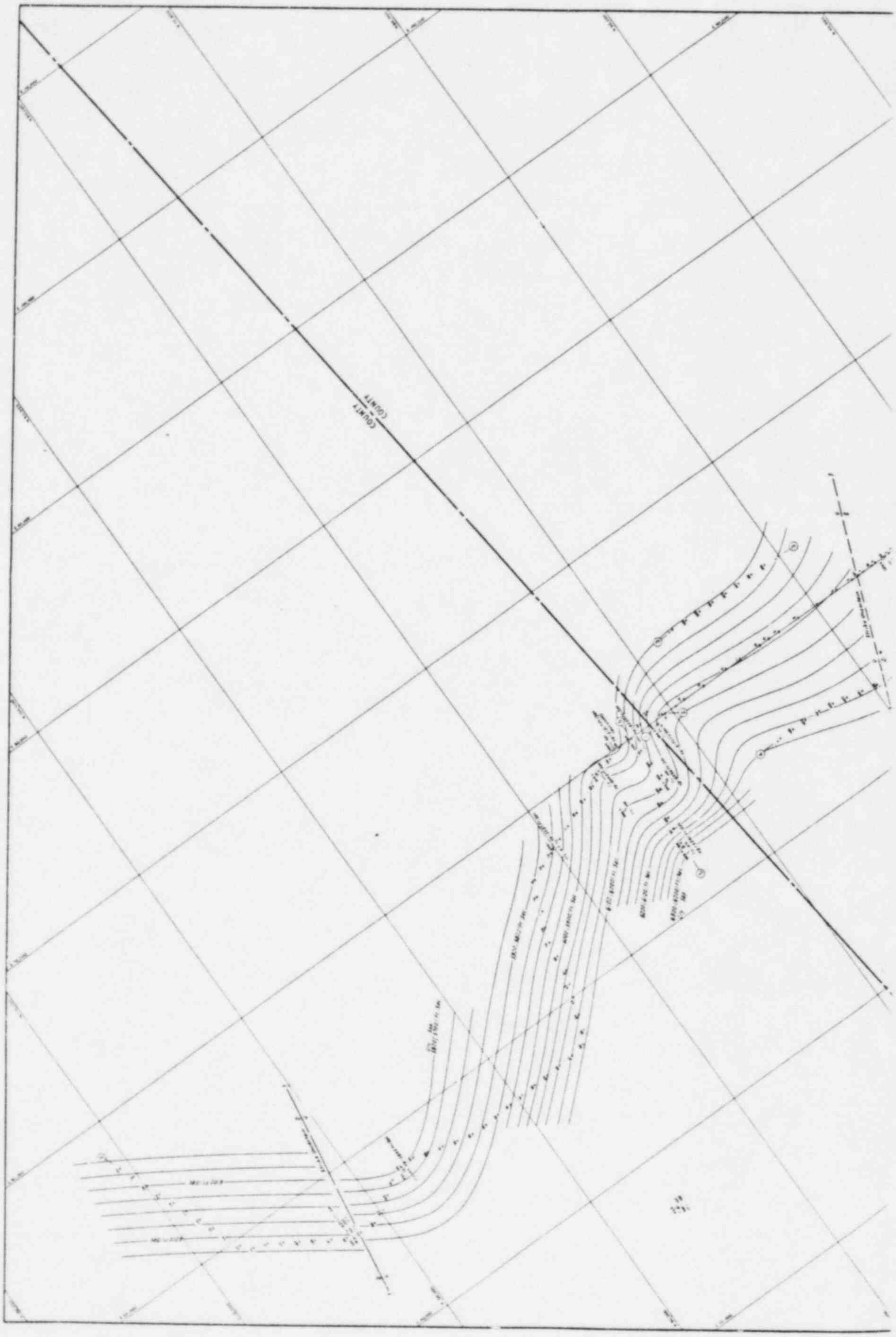
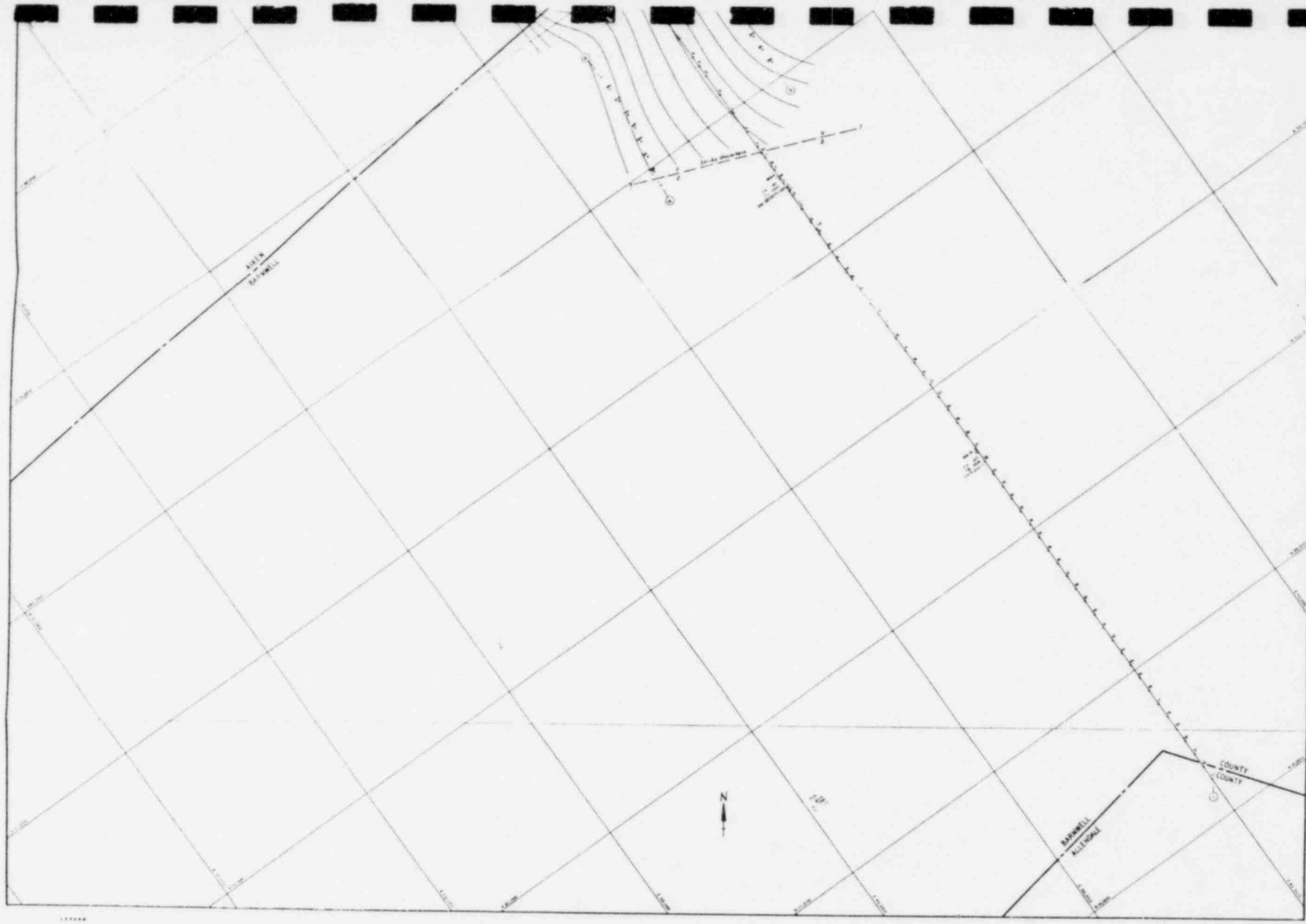
ENGINEERING DEPARTMENT
PROJECT B-1047
AXC-26657 1/3 SEISMIC SURVEY
SAVANNAH RIVER PLANT
BEDROCK WASTE STORAGE
BARNWELL, AIKEN, AND ALLENDALE COUNTIES, SOUTH CAROLINA
ISOPACH MAP





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PROJECT 8-1047
AXC-2665TVX SEISMIC SURVEY
SAVANNAH RIVER PLANT
BEDROCK WASTE STORAGE
BARNWELL, AIKEN, AND ALLENDALE COUNTIES, SOUTH CAROLINA

VELOCITY GRADIANT MAP

be recognized as no reliable reflection continuity was obtained from this horizon. Only sporadic events at various levels within the basement complex were recorded. The opposite condition prevailed towards the northwest with the shallower Saprolite event deteriorating to the extent it was not mapped beyond Shotpoint 92 on Line 2. On the other hand, a good seismic event was recorded from the Crystalline Rock in that area. Also some non-continuous deeper events within the basement rock were observed.

Near Top Saprolite

The seismic event previously identified as Near Top Saprolite was followed south from the DRB-9 hole to Shotpoint 12. These data exhibit another 100 feet of southeast dip along co-ordinate E-60,000. The continuity on this event is interrupted by a fault, downthrown to the southeast, interpreted between Shotpoints 12 and 13.

The seismic data in this downthrown block may be Near Top Triassic instead of Near Top Saprolite as an average velocity of 6025 ft/sec ties Top Triassic (-927 feet) in the DRB-10. These data suggest a minor anticlinal nose striking through Shotpoint 20 with approximately 30 feet of northwest reversal of dip into Shotpoint 17. Another 100 feet of southeast dip is recorded from Shotpoint 20 to Shotpoint 27 located near the DRB-10 hole.

Additional southeast dips are recorded into a possible syncline striking through Shotpoints 46 and 47. Three additional faults are indicated as cutting the traverse southeast of the DRB-10 hole. One fault strikes between Shotpoints 30 and 31 and appears to be displaced to the southeast approximately 30 feet. Another fault strikes between Shotpoints 40 and 41 with possibly 60 feet of displacement to the northwest. The third fault is shown striking between Shotpoints 49 and 50 and is interpreted as downthrown to the northwest approximately 50 feet. The direction of strike is uncertain on all of these faults.

In the northern portion of the survey, the Near Top Saprolite event deteriorates to the extent that it could not be mapped beyond Shotpoint 92 on Line 2. The quality of this event also is poor on Lines 3, 4, and 5. The seismic results disclose 320 feet of southeast dip from Shotpoint 92 to Shotpoint 12. Although Lines 3 and 4 are not actually tied to Line 1 the correlation suggests a possible syncline plunging southeastward between Lines 1 and 4 and a minor nosing trend between Lines 1 and 3.

Near Top Crystalline Rock

The Crystalline Rock reflection was only mappable over the northern portion of the survey. This event showed a gradual structural rise of approximately 290 feet from Shotpoint 61 near the DRB-8 hole to Shotpoint 104 (Line 2). Since the completion of the survey, the P9R well drilled near Shotpoint 100 (Line 2) confirms the high structural level of the Crystalline Rock in this area as the P9R hole appears to be 58 feet higher structurally than the P8R hole.

A fault, downthrown to the northwest with approximately 60 feet of displacement, is interpreted as striking between Shotpoint 105 and the P8R hole. The strike of this fault is uncertain. In the downthrown block, there is approximately 100 feet of southwesterly dip from Shotpoint 106 to Shotpoint 122.

Although Lines 3 and 4 are not tied to Line 1, the contour interpretation suggests structural conditions similar to those shown on the Near Top Saprolite map. At the southeast end of Line 4, the continuity of the Crystalline Rock reflection is interrupted similar to that encountered south of the original Shotpoint 5 on Line 1. For this reason, a possible fault is suggested as being present which would be downthrown to the southeast. The steep dip recorded from Shotpoint 56 shows a dip of 24° at -2245 feet and is displaced northwestward 1110 feet along the line of profile. This is the only recognizable Crystalline Rock reflection southeast of Shotpoint 5.

From Shotpoint 4 southward to Shotpoint 53, no continuous mappable data were recorded from the Crystalline Rock, but only miscellaneous dips at various depth levels within the basement rock complex.

The DRB-10 hole, drilled near Shotpoint 27 on Line 1 since the completion of this survey, was bottomed at 4212 feet in the Triassic formation, having penetrated 3028 feet of alternating claystone, hard and soft sandstones with quartzitic crystals. A plot of the velocity data from the 3-D Log of this well showed greater interval velocities through the Triassic section than that obtained at the DRB-9 hole.

Isopach Map

The isopach map depicts the thickness of the section between the Near Top Saprolite and Near Top Crystalline Rock horizons. These data are only available over the north central portion of the survey. A gradual thickening of approximately 60 feet is shown with a possible thinning trend suggested between Lines 1 and 4.

Discussion of Time Cross Sections

In addition to the digital replay sections, a set of hand plotted time cross sections were prepared on each line. The principal seismic events shown in color on the digital sections were picked and then plotted on time cross sections. The corresponding subsea depth values were computed and are shown with the possible exception of a few shallower events above the Near Top Saprolite. Also the steeper events have been migrated to their true inline position by a steep dip calculation procedure. The depths to these deeper events are based on interval velocities either below the Saprolite, Triassic, or Crystalline Rock reflections and were derived from the various velocity surveys. Some of the steep dips may be over-displaced because of the apparent large average velocity applied.

Line 1

Shotpoints 54 to 12

In addition to the continuous Near Top Saprolite event from Shotpoints 54 to 12, a deeper event with less reliable continuity is depicted at a depth approximately 200 feet below the Near Top Saprolite and has been designated as Below Top Triassic. This event was converted to subsea depths with a constant average velocity of 6100 ft/sec. It reveals the same structural attitude as the shallower event with some southeastward thickening indicated.

The steep 36°-39° dips underneath Shotpoint 5 appear to be in the upthrown fault block within the Crystalline Rock. The 24° dip at a time of .492 seconds (displaced from Shotpoint 56) and at a subsea depth of -2245 feet shown underneath Shotpoint 55 may be from the top of the Crystalline Rock as it approximates a tie with that depth shown in the DRB-9 hole.

Some miscellaneous milder dips are shown at depths near -2500 feet and -2900 feet which are probably within the Triassic formation. The steeper 17° and 24° dips at depths of -3322 feet and -4246 feet may be nearer the Crystalline Rock level.

Shotpoints 12 to 30

A fault, downthrown towards the southeast, is present between Shotpoints 12 and 13. The primary shallow event placed on the Near Top Saprolite map is converted to subsea depth with an average velocity of 6025 feet per second. The continuity and quality of this event is good to Shotpoint 30. It ties to the Top Triassic (-927 feet) at DRB-10 near Shotpoint 27.

A shallower Cretaceous event, about 200 milliseconds above the Top Triassic, is shown on the cross section.

A deeper Triassic event approximately 500 feet below the Top Triassic is depicted with poor continuity. This reflection was converted to depth using a constant average velocity of 7465 ft/sec. A few miscellaneous deeper events probably within the Triassic also are shown. Some deeper 12° to 24° southeast dips at depths of -4421 feet and -6134 feet may be more representative of the Crystalline Rock.

The DRB-10 hole near Shotpoint 27 was drilled after the shooting of this line and was bottomed at 4212 feet (K.B.) having penetrated 3028 feet of Triassic sediments. A reflection from Shotpoint 26 displaces southeast to a position underneath the DRB-10 hole showing a dip of 15° towards the northwest at a depth of

-4219 feet and other miscellaneous dips showing a northwest component of dip are recorded from depths near -5000 feet. Either of these dips could be representative of Crystalline Rock surface.

Shotpoints 30 to 40

A small fault, downthrown to the southeast with approximately 30 feet of displacement, strikes between Shotpoints 30 and 31. In the downthrown block, the Top Triassic data dips mildly to the southeast reaching its deepest depth at Shotpoints 39 and 40.

A shallow event near .170 seconds is recorded across this zone which is probably the same event shown between Shotpoints 21 and 27.

A few miscellaneous possibly deeper Triassic events are shown. No Crystalline Rock reflections are recognizable although a number of steeply northwest dipping partial segments can be seen on the replay sections.

Shotpoints 40 to 48

A fault, upthrown to the southeast, cuts the traverse between Shotpoints 40 and 41. This fault suggests about 60 feet of throw. The Top Triassic data continue to dip mildly to the southeast into a possible syncline through Shotpoints 46 and 47.

A single 23° northwest dip at a time of .725 seconds (-4132 feet) underneath Shotpoint 45 may depict the attitude of Crystalline Rock.

Shotpoints 48 to 53

The data quality is poor over this portion of Line 1. The weathering zone appears to thicken to approximately 100 feet from Shotpoints 47 to 53. The reshot, deeper holes did not appear to show any appreciable improvement in record quality. A possible fault, upthrown to the southeast, may strike between Shotpoints 49 and 50. The correlation of the Top Triassic across this possible fault is not certain. Two steeply dipping reflections shown between Shotpoints 48 and 49 on the replay sections may be diffractions from this possible fault zone.

In the upthrown block some steep northwesterly dips from 19° to 39° and at depths of -3049 feet to -3844 feet might reflect the attitude of the Crystalline Rock.

Line 2

Shotpoints 61 to 122

Line 2 begins at Shotpoint 61 near the DRB-8 hole and near Shotpoint 15 of the original Line 1. It extends generally northwestward and ties to DRB-7, DRB-6, DRB-5, DRB-1, P9R, and P8R holes.

The surface elevation of +300 feet above sea level near Shotpoint 61 declines to +140 feet above sea level near a small stream close to Shotpoint 81 and then gradually rises to +380 feet above sea level beyond Shotpoint 122. The apparent weathering mantle adjacent to the surface appears to be approximately 40 feet thick in the vicinity of Shotpoints 61 to 64, then gradually thickens to about 90 feet underneath the hill across Shotpoints 68 to 70, and thins to approximately 50 feet in the valley floor from Shotpoints 79 to 92. A gradual thickening again occurs towards Shotpoint 122 with generally 130 feet or more indicated from Shotpoints 109 to 122. The data from the deeper shotholes on this line were used in the final interpretation. Records from the 100-foot hole depths were processed through the digital computer, but these did not reveal any additional information.

The Near Top Saprolite reflection was picked only as far as Shotpoint 92, although the continuity of this event is questionable beyond Shotpoint 74.

The Crystalline Rock reflection is the outstanding event that is recognized on the replay section throughout the entire line. The continuity is fairly reliable on this event except for a few places such as between Shotpoints 74 to 79, Shotpoints 90 to 92, and Shotpoints 104 to 106. This horizon exhibits a gradual structural rise to the fault between Shotpoint 105 and the P8R hole. This fault appears to be downthrown towards the northwest with possibly 60 feet of displacement. The direction of strike is uncertain. A structural rise of approximately 100 feet is defined from Shotpoint 106 to Shotpoint 122 on the downthrown side of this fault.

A seismic event at a time of .330 seconds (-1070 feet) at Shotpoint 62 is approximately 382 feet below the Top Crystalline Rock. It shows a convergence of 127 feet between Shotpoints 62 and 67. A reflection at about the same interval below the Top Crystalline Rock is shown between Shotpoints 81 and 86 that reveals only minor convergence.

There is some evidence on the replay section of Line 2 between Shotpoints 65 and 68 in support of the inclined fracture zone within the virtually impermeable Crystalline Rock as depicted in Figure 1, Page 13, of the publication in the Geological Survey Water-Supply Paper 1544-I, "Two-Well Tracer Test in Fractured Crystalline Rock" by D. S. Webster, J. F. Proctor, and I. W. Marine. The displaced 12° southeasterly dip underneath Shotpoint 66 and at times of .331 seconds (-1227 feet) and .372 seconds (-1404 feet) and the displaced 14° dip at times of .359 seconds (-1566 feet) and .402 seconds (-1778 feet) is fairly well defined. However, the displaced 17° southeasterly dip underneath DRB-5 hole and at times of .359 seconds (-1617 feet) and .408 seconds (-1866 feet) is very questionable although some weak evidence for it can be seen on the replay section. There appears to be similar anomalous conditions possibly between Shotpoints 72 and 73, Shotpoints 77 and 78, and Shotpoints 85 and 86.

A few miscellaneous deeper events in the basement complex have been picked and put on the time cross section. Many other apparent reflection alignments that depicts dip in either direction can be seen on the replay section. These were not put on the time cross section.

Line 3

Shotpoints 300 to 306

The reflection continuity is very poor on the Near Top Saprolite event and a shallower event placed on the time cross section. The Near Top Crystalline Rock reflection is fair. Several miscellaneous deep reflections ranging in depths from -1700 feet to -4200 feet are shown. Some possible faulting or fractures are suggested in the deeper portions of the basement complex.

The two steep northwesterly dips appearing on the replay section near times of .8 second and 1.0 second possibly are reflections or diffractions from the fault shown cutting Line 1 between Shotpoints 5 and 4. The reflection near .8 second displaces slightly more than 4200 feet southeast of Shotpoint 300.

Line 4

Shotpoint 400 to 406

The quality of the data and the continuity are much better on Line 4 than on Line 3, especially on the Near Top Saprolite and Near Top Crystalline Rock reflections.

Many miscellaneous deeper events within the Crystalline Rock are shown on the time section ranging in depths from -1700 feet to -4800 feet. The depths from -1700 feet to -2400 feet exhibit southeast dip but with a steeper gradient than the Top of Crystalline Rock. The deeper data appear to have a northwest component of dip. Some faulting or fractures also appear to be present in this deeper section of the Crystalline Rock.

Possible faulting, downthrown to the southeast, is suggested south of Shotpoint 400. The Crystalline Rock reflection loses its continuity similar to the condition encountered south of Shotpoint 5 on Line 1 of the original survey.

Line 5

Shotpoints 64-A, 201 to 208

This line makes approximate ties to DRB-7, DRB-2, and DRB-4 holes and furnishes some lateral control for the Near Top Crystalline Rock velocity gradient map. The continuity on this event is fairly reliable except from Shotpoint 204 to Shotpoint 206. Minor faulting could possibly be present between Shotpoints 204 and 205.

The reflection continuity of the Near Top Saprolite event is very questionable on Line 5.

Several miscellaneous deep data below the Top of the Crystalline Rock are shown at depths of -1500 feet to -3700 feet. The shallower group of these data show a considerable amount of convergence with the Top Crystalline Rock.

CONCLUSIONS

The results of this second shooting program have furnished additional structural information on the behavior of the Near Top Saprolite event or Lower Tuscaloosa-Cretaceous sediments, possibly the Top Triassic in the southern portion of the area, and the Near Top Crystalline Rock in the northern part of the survey.

The failure to obtain a continuous mappable event from the Top Crystalline Rock over the southern portion of Line 1 was disappointing. The reason for this may be an insufficient velocity contrast between Crystalline Rock and the overlying hard Triassic sandstones and siltstones to produce a reflection. The 3-D Velocity Log ran in the DRB-10 which penetrated 3028 feet of Triassic section exhibited large interval velocities of 17,600 ft/sec and 18,600 ft/sec in the lower portion of the Triassic zone which approaches the 19,600 ft/sec interval velocity recorded in the Crystalline Rock of the DRB-8 hole. Some miscellaneous deep events shown on the replay and time cross sections may furnish some information as to the attitude of the Crystalline Rock formation in the southern area.

The deepest portion of the Near Top Triassic horizon was recorded in the vicinity of Shotpoints 39 and 40 on Line 1; however, additional southeast dip is recorded from Shotpoints 41 to 46 in an upthrown fault block. A possible syncline may strike through Shotpoints 46 and 47. Several small faults are depicted along Line 1 as cutting the Near Top Triassic. The strike of these faults is uncertain.

The Near Top Saprolite event could not be reliably mapped any farther north than Shotpoint 92 on Line 2. This event is also considered weak on Lines 3 and 5.

The Near Top Crystalline Rock is believed to be fairly reliably defined along the traverses in the northern area although Lines 3 and 4 are not tied to Line 1. It was necessary to apply a velocity gradient to effectively tie the seismic data to nine wells in this area. A fault, downthrown to the northwest, appears to cut Line 2 between Shotpoint 105 and the P8R hole. The direction of strike of this fault is unknown. A fault, downthrown to the southeast, could very well cut Line 4 south of Shotpoint 400 and strike between Shotpoints 5 and 4 of the original shooting on Line 1.

The inclined fracture zone within the impermeable Crystalline Rock as depicted between the DRB-5 and DRB-6 holes in the publication "Two-Well Tracer Test in Fractured Crystalline Rock" by D. S. Webster, J. F. Proctor, and I. W. Marine in the Geological Survey Water-Supply Paper 1544-I appears to have some evidence of this anomalous condition on the replay section of Line 2 between Shotpoints 65 and 68. Similar anomalous dips beneath the Top Crystalline Rock are suggested along this traverse.

Respectfully submitted,

SEISMOGRAPH SERVICE CORPORATION

By: W. B. Connor, Party Chief

By: J. G. Jackson

J. G. Jackson, Sr. Geophysicist

/ho
July 30, 1971

Approved by:

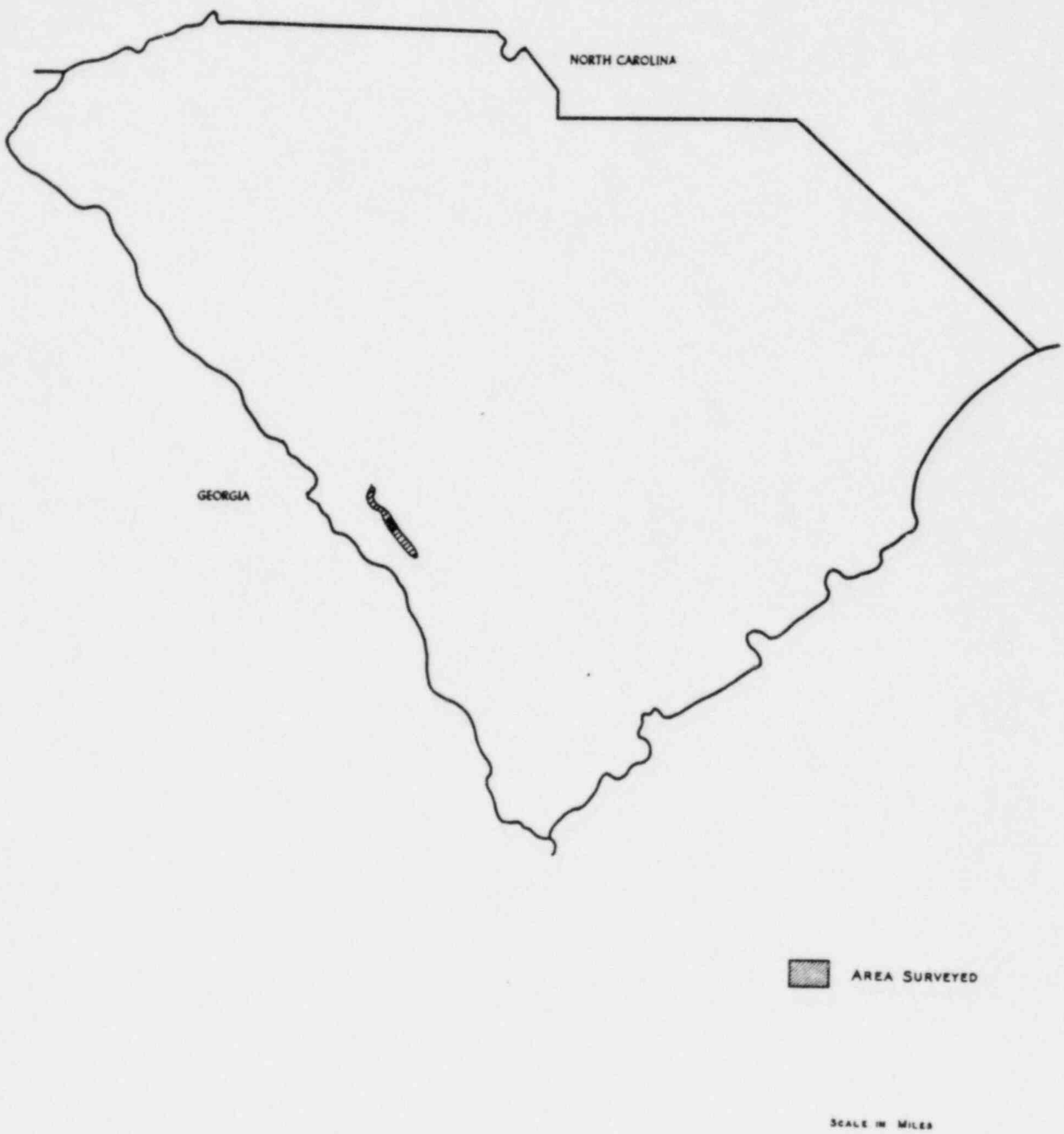
R. S. Finn

R. S. Finn, Vice President

2448-1

APPENDIX I

INDEX MAP OF SOUTH CAROLINA



APPENDIX II

PHYSIOGRAPHY

Topography:	Rolling plains
Population:	Unpopulated
Culture:	Brushland, timber; U.S. Atomic Energy Commission's Savannah River Plant
Drainage:	Well drained in a southeasterly direction, furnished by streams tributary to the Savannah River
Soil:	Brown, clay, sandy
Weather:	Generally fair, some rain
Roads:	Plentiful
Traverse difficulties:	Mud, timber, underbrush

APPENDIX III

GEOLOGY

Near-surface formation:	Barnwell formation of Jackson group of Eocene age
Subsurface log:	DRB-9 (near Shotpoint 56)
Dry hole	Elevation: 302 ft. K.B. Tuscaloosa(?) clay -602 Top Triassic -739 Hard Triassic -766 Crystalline Rock -2328 T.D. 2701 ft.
Major unconformities:	Between Eocene and Cretaceous Between Cretaceous and Triassic Between Triassic and Cambrian
Regional dip:	Approximately southeast
Type structures expected:	Folded structures: domes, anticlines; fault traps, stratigraphic traps
Well control:	Tied to 11 wells or dry holes in area of prospect

APPENDIX IV

OPERATION METHODS

Method used:	Continuous profiling
Spreads used:	Straddle
Normal length:	900 feet, between shotpoints
Distance from shothole to close geophone stations:	75 feet
Number of geophone stations adjacent to hole:	2
Relation of far geophone stations to interlocking shotholes:	At hole
Geophones used:	HSJ 14 Hz, .7 damping factor
Number per trace:	10
Connection:	Series
Spacing in group:	5 feet
Arrangement in group:	Straddling station, in line
Instrumentation:	
Type amplifiers:	TI DFS-III
Number of channels:	24
Filter settings:	
Monitor and tape:	27 to 248 Hz at 70.7% amplitude response
Replay playback:	25-35-65-80 Hz on Lines 1, 1-Extension, 3, 4, and 5 50-60-120-150 Hz on Lines 2 and 4
Type camera:	24 trace
Shothole data:	
Type drilling:	Rotary with water
Special equipment used:	Portable pits
Tractor mounted equipment:	Drilling, recording, shooting
Shothole depths:	
Normal:	100 feet
Range:	80 to 150 feet
Number of holes used per location:	1; 2 at Shotpoints 100 through 120 on Line 2
Formations encountered:	Sand, gravel, clay
Approximate depth water table:	55 feet
Best shooting depth:	80 to 100 feet except extreme south end of Line 1 and north end of Line 2 where the weathering thickened requiring 150-foot shotholes

APPENDIX IV (Contd.)

OPERATION METHODS (Contd.)

Shothole data (contd.):	
Dynamite charges:	
Normal:	1 pound
Range:	1 to 2 pounds of Nitramon, holes preloaded
Operational difficulties:	Traverse difficulties, caving holes, gravel holes

SSC T-146 A-Rev.

STATION AND SHOT HOLE ARRANGEMENT

LEGEND

Shot Hole Under Test	◎
Adjoining Shot Hole	○
Station Number	8
Line of Traverse	----
Geophones per Station	10
Geophone Spacing	5'

APPENDIX V

OPERATING STATISTICS

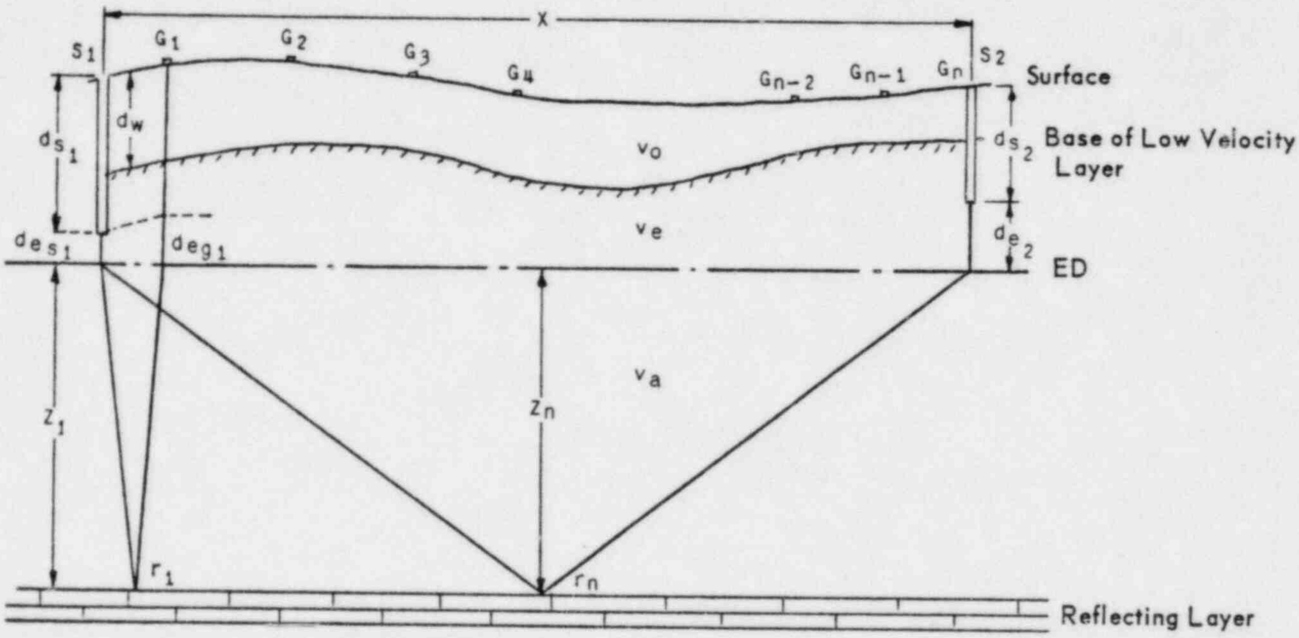
Basic crew:	
Crew headquarters:	Augusta, Georgia
Starting date:	March 11, 1971
Completion date:	March 31, 1971
Number of profiles shot:	292
Number of holes shot:	146
Linear miles covered:	23
Dynamite used:	250 pounds
Type:	Nitramon
Number of caps used:	187
Normal length leads:	150 feet
Drilling:	
Number of drills used:	2
Drill hours:	328.5
Extra drill hours:	163.5 cementing shotholes
Number of holes drilled:	167
Total footage drilled:	17,896 feet
Average length water hauls:	½ to 1 hour
Number of sets bit blades used:	6
Type:	Retipped 4 inches
Hole plugs:	200
Size:	9 inches

APPENDIX VI

CALCULATION AND INTERPRETATION METHODS

Record quality:	Good, poor, NR, high frequency
Type correction used for final data:	Summation
Other corrections calculated:	Normal uphole
Individual trace corrections used for replay sections:	Summation, differential statics
Interlock ties:	Datum-to-datum
Spread correction:	Applied to individual traces on replay sections
Displacement:	Worked for miscellaneous steep dips; straight line
Time reference datum:	+200 feet above sea level
Weathering velocity, v_o:	2500 feet per second
Elevation velocity, v_e:	5500 feet per second
Type replay cross sections prepared:	Galvo-area
Final data normally obtained from:	Galvo-area replay sections
Horizons and interval mapped:	
Near Top Saprolite	
Time range:	205 to 390 milliseconds
Depth range:	-400 to -975 feet
Velocity, v_a:	6015, 6025, and variable feet per second
Velocity formula:	Partially based on Velocity Gradient Map
Near Top Saprolite to Near Top Crystalline Rock	
Thickness range:	90 to 173 feet
Near Top Crystalline Rock	
Time range:	187 to 492 milliseconds
Depth range:	-368 to -2245 feet
Velocity, v_a:	Variable feet per second
Velocity formula:	Based on Velocity Gradient Map

DEPTH DETERMINATION FOR CONTINUOUS PROFILING
Using Normal Uphole Corrections



LEGEND

S	=	Shotpoint Location
G	=	Geophone Location
X	=	Surface Distance
d_s	=	Depth of Charge
d_w	=	Thickness of Low Velocity Layer
t_s	=	Uphole Time
ED	=	Elevation or Reference Datum
Z	=	Depth below ED
t_r	=	Recorded Reflection Time
t_c	=	Corrected Reflection Time
t_x	=	Normal Moveout Correction
v_o	=	Average Velocity in Low Velocity Layer
v_e	=	Elevation Correction Velocity
v_a	=	Average Velocity to Reflecting Horizon

t_e	=	de/ve
t_w	=	dw/v_o
E_s	=	Elevation of Shotpoint
E_g	=	Elevation of Geophone
E_m	=	$\frac{1}{2}(E_s + E_g)$
E'_m	=	$E_m - d_s = \frac{1}{2}(E'_s + E'_g)$
E'_s	=	$E_s - d_s$
E'_g	=	$E_g - d_s$
de_s	=	$E'_s - ED$
de_g	=	$E'_g - ED$
t_x	=	$\dfrac{X^2}{2{v_a}^2 t_c}$

$$tc_1 = tr_1 - tes_1 - teg_1 - ts_1$$

$$= tr_1 - 1/ve(E'_m - ED) - ts_1$$

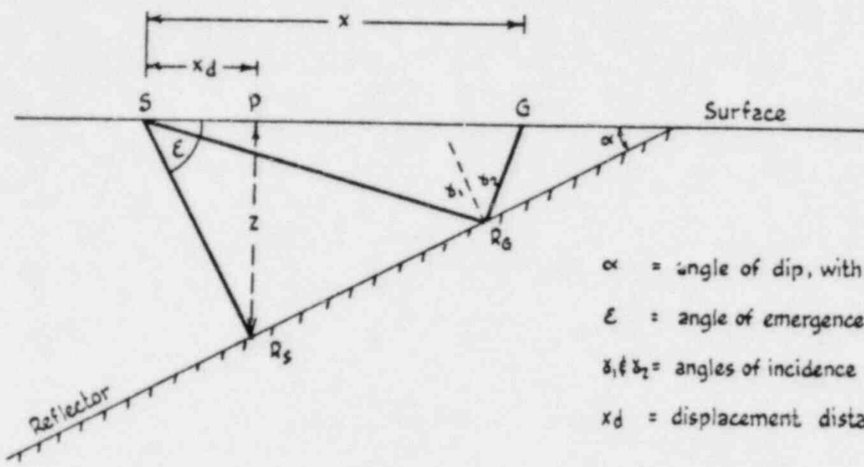
$$Z_1 = \tfrac{1}{2}\, va\, tc_1$$

$$tc_n = tr_n - tes_1 - teg_n - ts_2$$

$$Z_n = \tfrac{1}{2}\, va\,(tc_n - tx_n)$$

STEEP DIP CALCULATIONS

Using straight-line assumption



α = angle of dip, with horizontal

ε = angle of emergence, with normal to bed

δ_1 & δ_2 = angles of incidence and reflection

x_d = displacement distance

$$\cos \epsilon = \frac{SP}{SR_s} = \frac{x_d}{\frac{1}{2} v_a t_o}$$

$$x_d = \frac{1}{2} v_a t_o \cos \epsilon$$

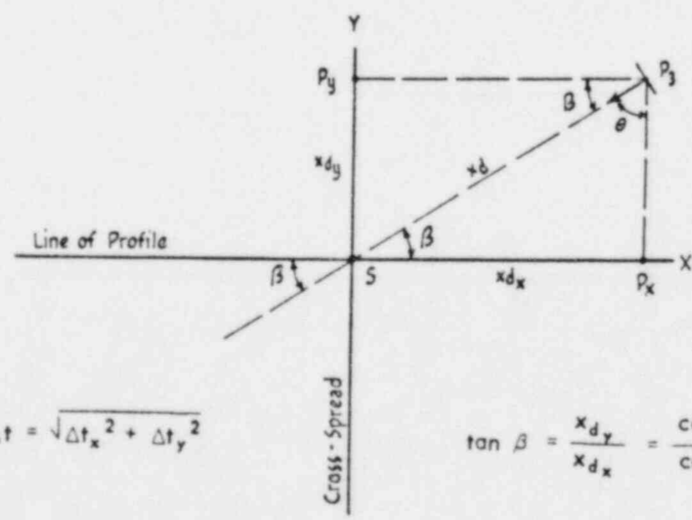
$$\sin \epsilon = \frac{z}{SR_s} = \frac{z}{\frac{1}{2} v_a t_o} = \frac{t_c}{t_o}$$

$$t_c = t_o \sin \epsilon$$

$$z = \frac{1}{2} v_a t_o \sin \epsilon$$

$$\alpha = 90^\circ - \epsilon$$

Three-Dimensional Plan



$$\Delta t = \sqrt{\Delta t_x^2 + \Delta t_y^2}$$

$$\tan \beta = \frac{x_{d_y}}{x_{d_x}} = \frac{\cos \epsilon_y}{\cos \epsilon_x} = \frac{\Delta t_y}{\Delta t_x}$$

APPENDIX VII

MATERIAL SUBMITTED SEPARATELY

Base shotpoint tracing
Sepias with data
All records for the survey - monitor and playbacks
Large hand-plotted cross sections
Magnetic tapes
Plane table sheets
Surveyor's field notes
Driller's reports
Replay sections:
  Galvo-area
  Films from which above sections were taken
Calculation book containing:
  Calculation and interpretation methods
  Velocity determinations
  Time-depth conversion tables
  Weathering graph sheets
  Fiducial correction calculations
  Dip calculations
  Small cross sections
  Observer's reports
  Shooter's reports

REPORT

ON SEISMOGRAPH SURVEYS

CONDUCTED IN

BARNWELL, AIKEN, AND ALLENDALE COUNTIES, SOUTH CAROLINA

WR 860188

AXC-26715½ SEISMIC SURVEY

SAVANNAH RIVER PLANT

BEDROCK WASTE STORAGE

FOR

E. I. DU PONT DE NEMOURS & COMPANY, INC.

ENGINEERING DEPARTMENT

WILMINGTON, DELAWARE

Seismograph Service Corporation

A SUBSIDIARY OF RAYTHEON COMPANY

P.O. BOX 1590 TULSA, OKLAHOMA

CONTENTS

INTRODUCTION

The Seismograph Service Corporation was subcontracted in September, 1971, to E. I. du Pont de Nemours & Company, Inc., Wilmington, Delaware, to perform supplemental seismic work on the U. S. Atomic Energy Commission's Savannah River Plant in Barnwell, Aiken, and Allendale Counties, South Carolina.

The purposes of this supplemental work were to obtain additional seismic information regarding the attitude of the surface and bedrocks; to determine the position and outline of the Triassic Basin; and to determine the strike of faults suggested as cutting Line 1 by the previous field work conducted in March, 1971.

This supplemental program was initiated under WR 860188, AXC-26715½ Seismic Surveys. [redacted] on [redacted] and was conducted during the period from September 15 to October 23, 1971.

ASSIGNMENTS

The third survey was primarily over the southern portion of the Savannah River Plant and consisted of eight additional lines covering about 53 miles of traverse. These lines are located as follows:

Line 6 (Shotpoints 501 to 560)

Line 6 started with Shotpoint 501 located adjacent to the Atlantic Coast Line Railroad about 2000 feet northwest of Robbins Station on the west side of the plant. The plant co-ordinates are approximately N-35,750 and E-28,400. The line proceeded northeastward paralleling the N - co-ordinate system, across the DRB-10 hole, intersecting Line 1 between Shotpoints 27 and 28, and terminated with Shotpoint 560 located slightly east of the E-80,000 co-ordinate.

Line 7 (Shotpoints 626 to 583; 501-A; 561 to 582)

Line 7 is on the west side of the plant and was laid out along the east side of the Atlantic Coast Line Railroad. Shotpoint 582 is at the southeastern end of this line near co-ordinates E-32,250, and N-17,000. At the northwestern end of Line 7 is Shotpoint 626 near co-ordinates E-25,100 and N-73,750. This line also ties to the western extremity of Line 6 at Shotpoint 501. Shotpoint 577 was not shot because of its inaccessibility.

Line 8 (Shotpoints 627 to 651, 652-L to 660-L, 657 to 665)

Line 8 represents the eastern boundary of the survey and is located approximately 300 feet east and parallels the E-80,000 co-ordinate. It begins with Shotpoint 627 which is approximately on the N-60,000 co-ordinate and proceeds southeastward to Shotpoint 651 which is located at the edge of Par Pond. The series of Shotpoints 652-L through 660-L were shot across the lake. A gap of about 2600 feet separates Shotpoint 660-L (over the lake) and Shotpoint 657 which furnishes a seismic tie to the eastern end of Line 6. Shotpoint 665 lies at the southeastern extremity of Line 8 near co-ordinates E-80,000 and N-26,600.

Line 9 (Shotpoints 547-A; 666 to 692)

Line 9 takes off from Shotpoint 547-A on Line 6 near Dunbarton and proceeds southeasterly along Road B-6 to the plant boundary. Shotpoint 692 is located at the southeastern extremity of Line 9.

Line 10 (Shotpoints 516-A; 716 to 736)

Line 10 takes off from Shotpoint 516-A of Line 6 and proceeds eastward along Road A-14, then southward on Road 9, and then southwestward along Road A-18 in order to tie to the P5R hole. Shotpoint 735 is located near this test hole.

Line 1-Extension (Shotpoints 47-B; 693 to 715)

Line 1-Extension is a southeastward extension of original Line 1 which is located along the E-60,000 co-ordinate. This extension starts with Shotpoint 47-B and runs diagonally to the intersection of Roads A-18 and A-18-2, then turns southward following Road

A-18-2 beyond the plant boundary generally along the E-60,000 co-ordinate and terminates at Shotpoint 715 in the vicinity of N-00,000 co-ordinate.

Line 3-Extension (Shotpoints 776 to 814)

This line is a southeastward continuation of Line 3, with Shotpoint 776 located at the interlocking tail position of old Shotpoint 300. This line intersects Line 6 slightly west of Shotpoint 540. Shotpoint 814 is located at the southeast terminus of the line near co-ordinates E-62,150 and N-27,350.

Line 4-Extension (Shotpoints 737 to 775)

This line is a southeastward extension of previous Line 4, with Shotpoint 737 located at the interlocking tail position of old Shotpoint 400. This line bends eastward from Shotpoints 756 to 760, then proceeds southeastward parallel to original Line 1. It crosses Line 6 near Shotpoint 535 and terminates with Shotpoint 775 located near co-ordinates E-57,750 and N-27,700.

FIELD PROCEDURE

The seismic field crew maintained headquarters in Augusta, Georgia, and drove a distance of some 30 miles each way to and from the Savannah River Plant. The field equipment was inspected and field crew personnel were processed through employment, security, and safety orientation on September 14 and 15, 1971, and received identification badges which permitted access of personnel and equipment onto the Savannah River Plant. Field operations also commenced on September 15, 1971.

The seismic lines through the brush and timber were cut by the Engineering Department, Construction Division of du Pont. No line cutting was required along the roads and railroad. Permission was granted by the Atlantic Coast Line Railroad to perform seismic operations along the railroad right-of-way.

For this third seismic survey, tractor mounted field equipment was used because of its mobility and adaptability to the Savannah River Plant terrain. The same continuous profile technique as used on the second survey (straddle spreads covering 900-75-0-75-900 feet) was employed for this latter work. Ten HSJ-14 Hz geophones were used; however, they were spaced 10 feet instead of 5 feet apart across each station.

The shotholes ranged in depth from 40 to 130 feet with the deeper holes generally required in areas of higher topography as the weathering seemed to thicken over the hills. The majority of the holes were shot at depths of 70 to 80 feet using a 1-pound charge of Nitramon or Primacord.

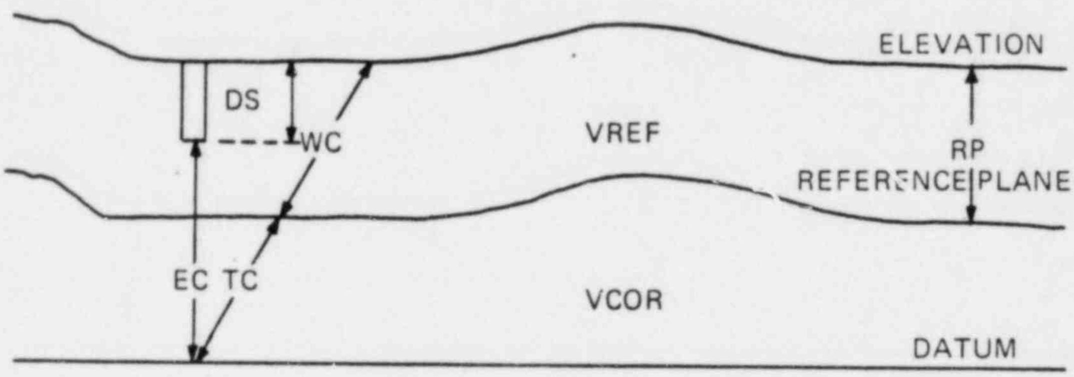
The seismic data were recorded digitally using the same instruments as were employed on the second survey assignment. These were TI DFS-III digital instruments from which "read-after-write" paper monitor records were made simultaneously and later used for weathering and normal uphole computations.

PROCESSING

A normal uphole method was used to correct the reflection times to a common reference datum of +200 feet above sea level using an elevation velocity of 5500 feet per second. A summation method employing the first breaks was computed on Line 6. However, an IBM program was used in computing the individual trace statics for the replay sections. A diagram on page 9 illustrates the computational procedure. A depth of from 5 to 10 feet below the deepest shothole was selected as the reference plane for each line in these computations. These corrections were checked against the hand computed normal uphole corrections.

The digital tapes were processed at the SSC Digital Replay Center in Tulsa, Oklahoma, where preliminary galvo-area sections were prepared after applying static and normal moveout corrections. The same 25-35-65-80 Hz filter as used on the second survey was applied to all the new lines. However, Line 7 was also processed with a time variant filter in an effort to improve the quality of some shallow

Static Computation for Shot Hole and Individual Trace Corrections



$$EC = \frac{DATUM - ELEVATION + DS}{VCOR}$$

$$TC = \frac{DATUM - ELEVATION + RP}{VCOR}$$

$$VREF = \frac{RP}{\frac{RP - DS}{VCOR} + UPHOLE}$$

$$WC = \frac{-RP}{VREF}$$

STATIC = EC + TC + WC

REFERENCE PLANE = 5 TO 10 FEET BELOW DEEPEST SHOTHOLE data. From these preliminary sections, time values were picked, correlations made, and fiducial statics were taken for later use in preparation of the final galvo-area sections. Both the mapping events and many other miscellaneous dips were colored on the final galvo-area digital replay sections.

The time values taken from the preliminary replay sections were used in preparing the small preliminary work sections contained in the calculation book. In addition, these time values were converted to depth and both time and depth values were hand plotted on large scale cross sections. Also the miscellaneous steep dips were calculated and migrated to their proper two-dimensional location on these sections.

[redacted].

In an effort to obtain seismic data across the Par Pond on Line 8 some special geophone cables with 10 hydrophone stations spaced 60 feet apart, using 5 hydrophones per station, 10 feet apart, on a straddle spread (300-60-0-60-300 feet) were prepared and these were towed by an AEC boat. The hydrophones were 9 feet below the water surface and the energy source was Primacord detonated at the bottom of the lake. Shotpoints 652-L through 660-L were shot over the lake but the results were not very satisfactory.

In addition to the regular filter used, this portion of Line 8 was processed with a 15-30-110-150 Hz filter because of the high frequency indicated by the monitor records.

DISCUSSION OF RESULTS

General

Three subsurface structural maps, one isopach map, and one velocity gradient map are presented with this report. They are designated as:

Structural
- Near Top Saprolite
- Near Top Triassic
- Near Top Crystalline Rock

Isopach
- Near Top Saprolite to Near Top Crystalline Rock

Velocity Gradient Map
- Near Top Crystalline Rock and Near Top Saprolite

In general the record quality is fair over the northern portion of Lines 7, 8, 3-Extension, and 4-Extension but deteriorates as these lines approach the intersection with Line 6. The record quality is very poor on parts of Lines 6, 9, 10, and 1-Extension; however, the quality improves on Line 1-Extension south of Shotpoint 710. Quite a number of holes were reshot at different hole depths in these poor record areas to seek an improvement in the data quality. Not all but some of these reshoots were successful.

The data from the two previous surveys are incorporated with that of the third survey and some minor depth changes have been made in the Near Top Crystalline Rock and Near Top Saprolite data on Lines 1, 3, and 4 resulting from a change in the Velocity Gradient Map to obtain a more precise tie to the Tuscaloosa (Cretaceous) marker in the DRB-9 hole.

The second survey which tied to a number of test holes indicated the presence of an areal velocity gradient to the Crystalline Rock. From this third survey some additional seismic information to the Near Top Crystalline Rock and Near Top Saprolite were obtained at the north end of Lines 7 and 8. Without any well ties, the precise velocities in these areas are indeterminate. Consequently, the average velocities applied to these horizons are only estimated values. The average velocities applied to the northern part of Lines 3-Extension and 4-Extension are based on the attitude of the velocity gradient map which is also lacking for lateral control. A constant average velocity of 5875 feet per second was applied to the Near Top Saprolite event on Lines 1, 3-Extension, 4-Extension, 7, and 8 in the area south of the major Crystalline Rock fault trace. This velocity is based on the tie to the Tuscaloosa marker (-603 feet) in the DRB-9 hole. Also a constant average velocity of 6025 feet per second was used in the Near Top Triassic time-to-depth conversions which gave satisfactory seismic ties at both the DRB-10 and P5R holes.

A two-way time versus velocity plot was made from the DRB-10 hole velocity information. A reduction of 200 feet per second was made in the average velocities shown by this curve to obtain the velocities to the various miscellaneous reflections below the Top Triassic.

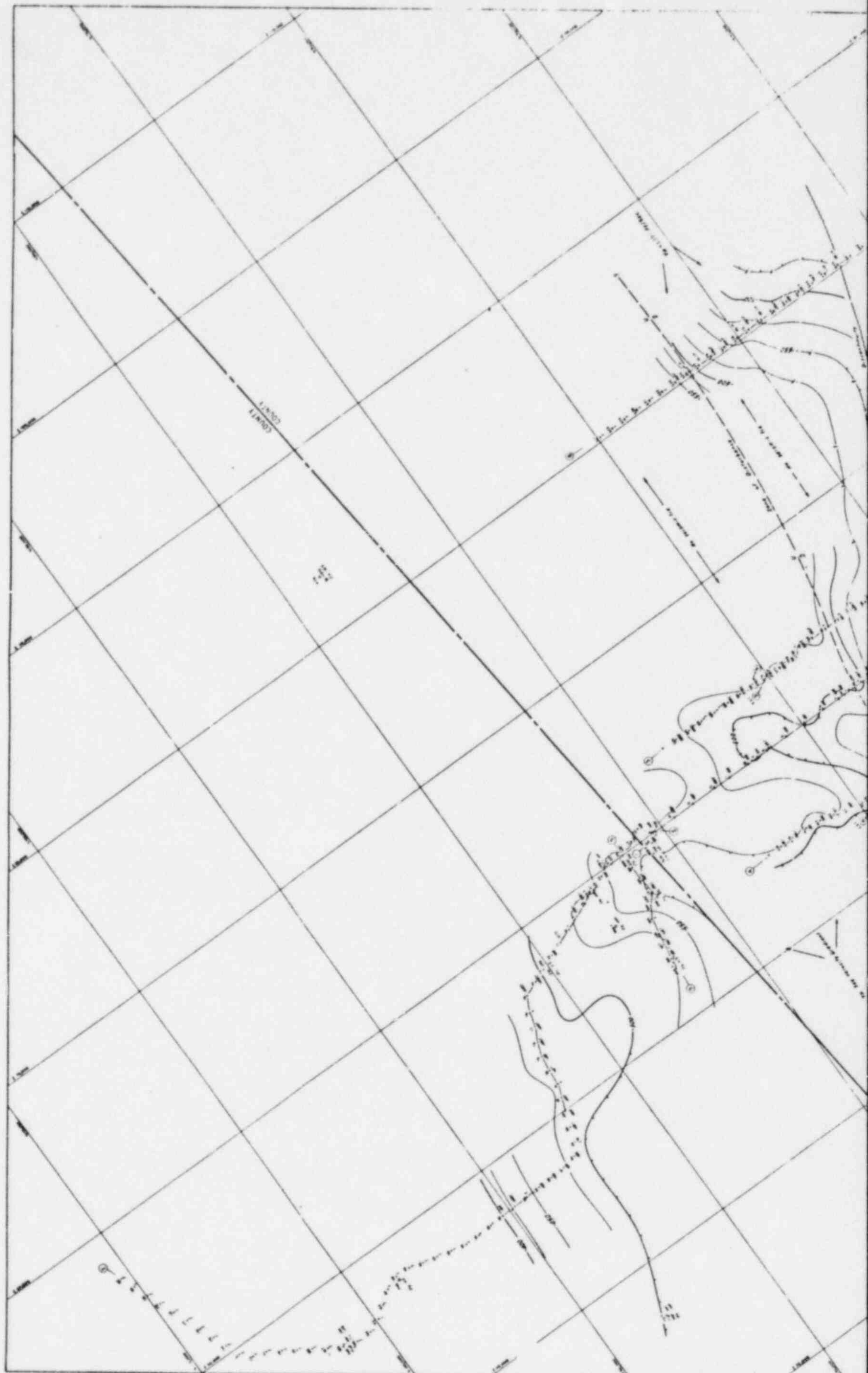
Reduced prints of the three structural, isopach, and velocity gradient maps are submitted as pages 14, 15, 16, 17, and 18 of this report.

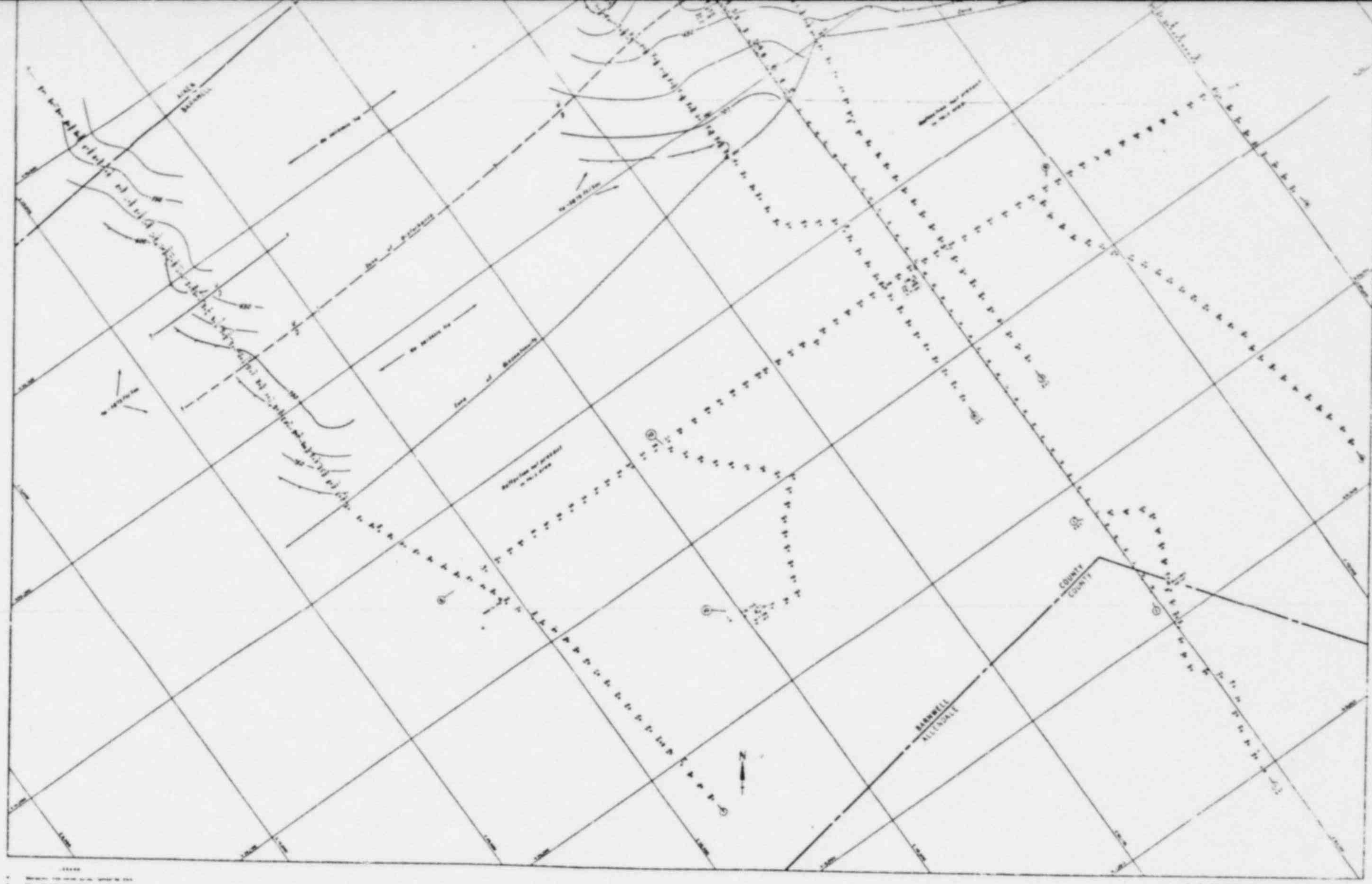
Detailed Discussion

Near Top Saprolite

The seismic event mapped over the northern portion of the Savannah River Plant is designated as Near Top Saprolite but appears to originate from a Cretaceous (Tuscaloosa) sandstone slightly above the Saprolite as indicated by the 3-D Velocity Log run in the DRB-8 hole and as indicated by the synthetic seismogram prepared from the 3-D Velocity Log run in the DRB-9 hole.

The contour interpretation exhibits mild south dip at a rate of approximately [illegible] feet per mile. Superimposed on the regional dip are several irregular anticlinal nosings generally plunging southward. One such nosing is shown at the north end of Line 4.

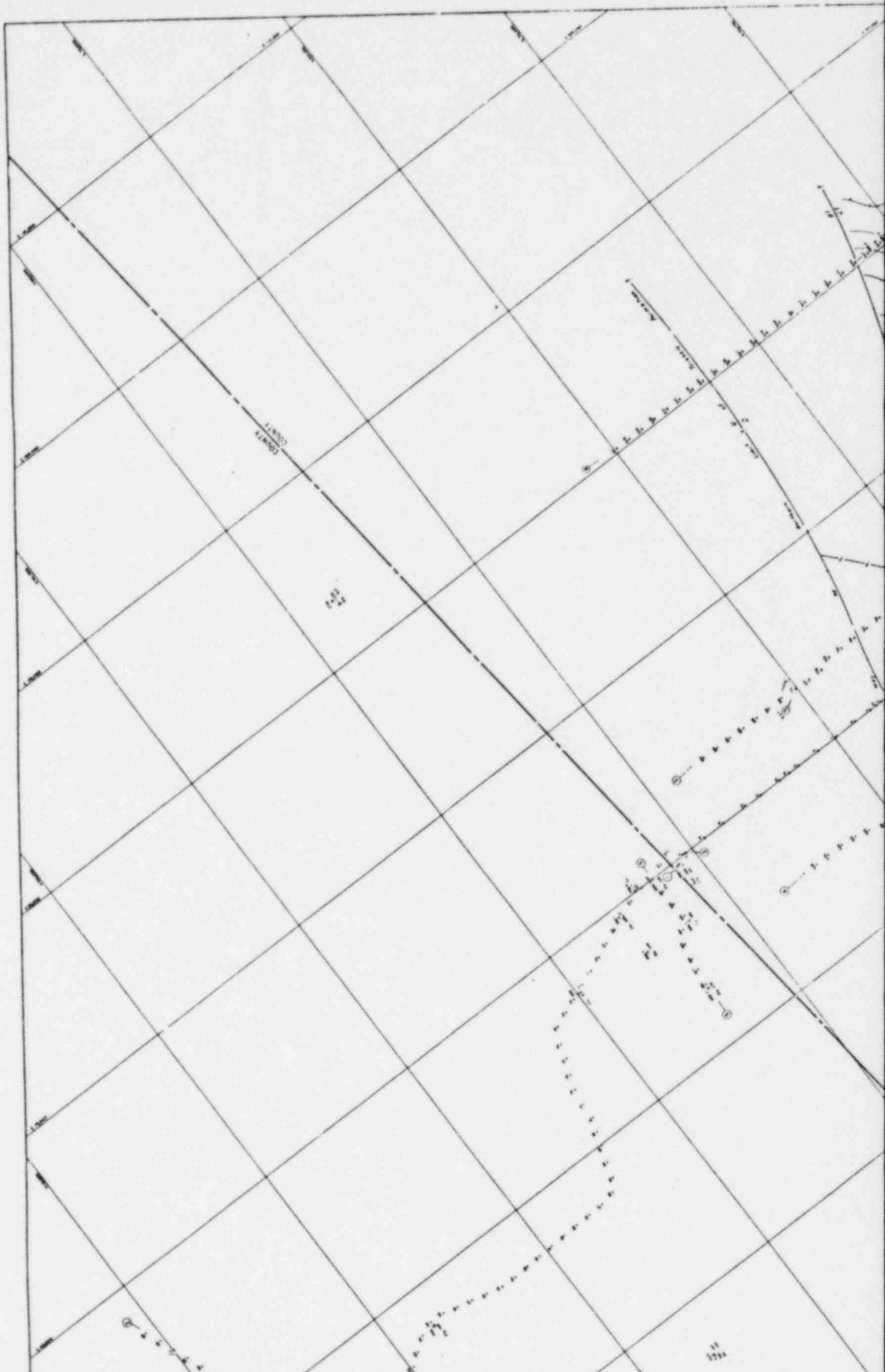


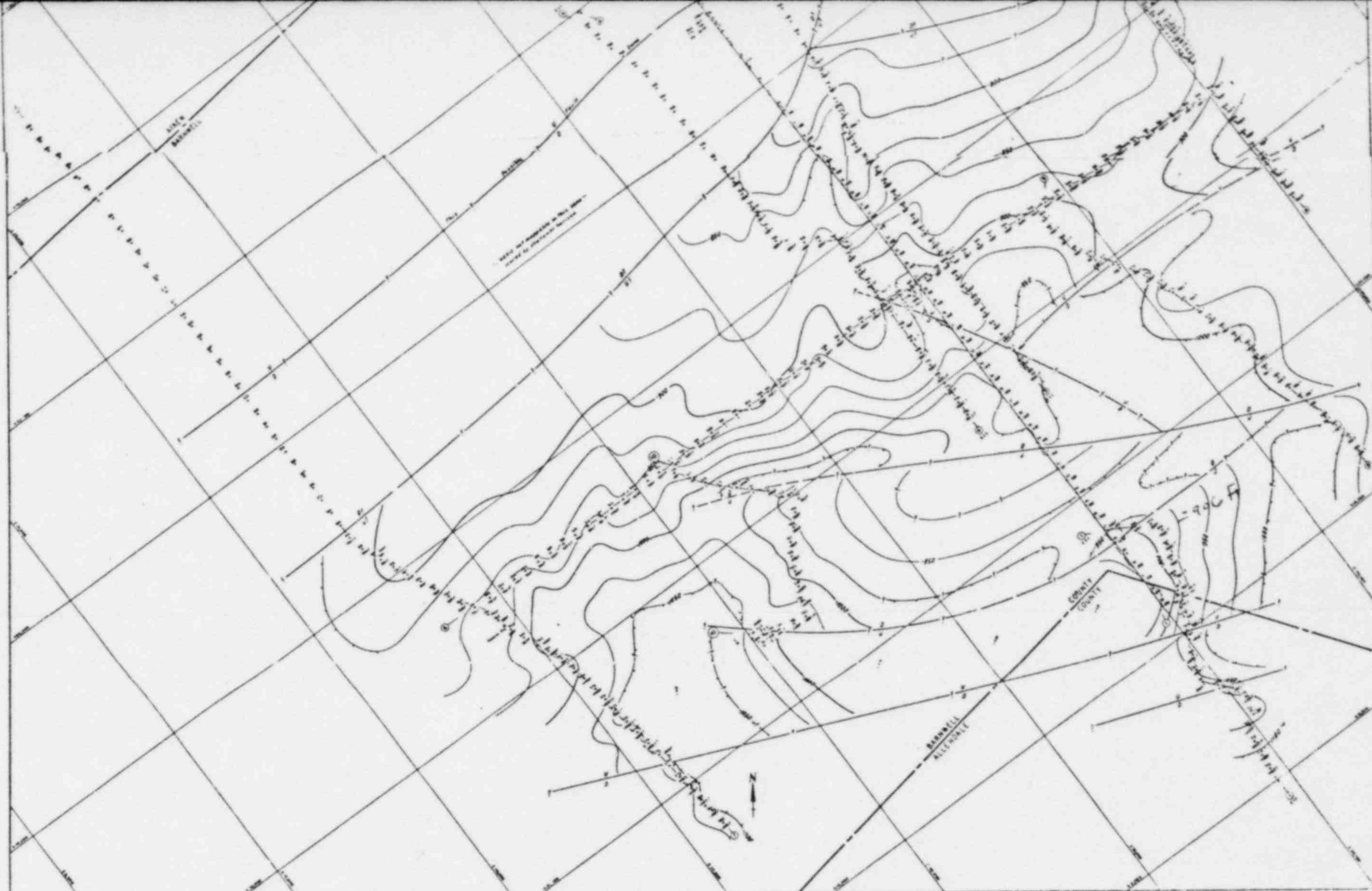


E. I. DU PONT DE NEMOURS & COMPANY INC
ENGINEERING DEPARTMENT

SAVANNAH RIVER PLANT
BEDROCK WASTE STORAGE

NEAR TOP SAPROLITE


COUNTY
COUNTY



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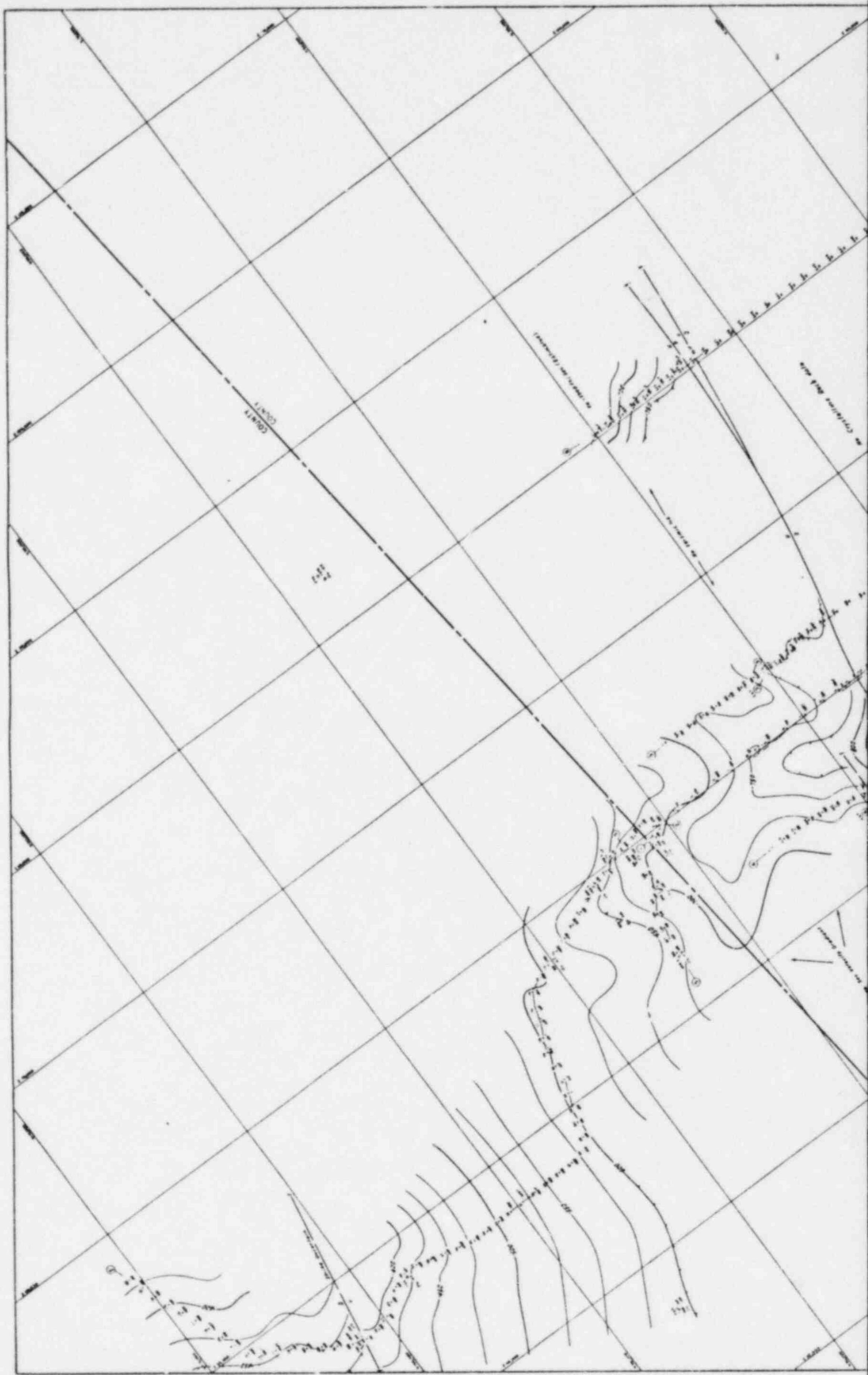
SAVANNAH RIVER PLANT

BEDROCK WASTE STORAGE

NEAR TOP TRIASSIC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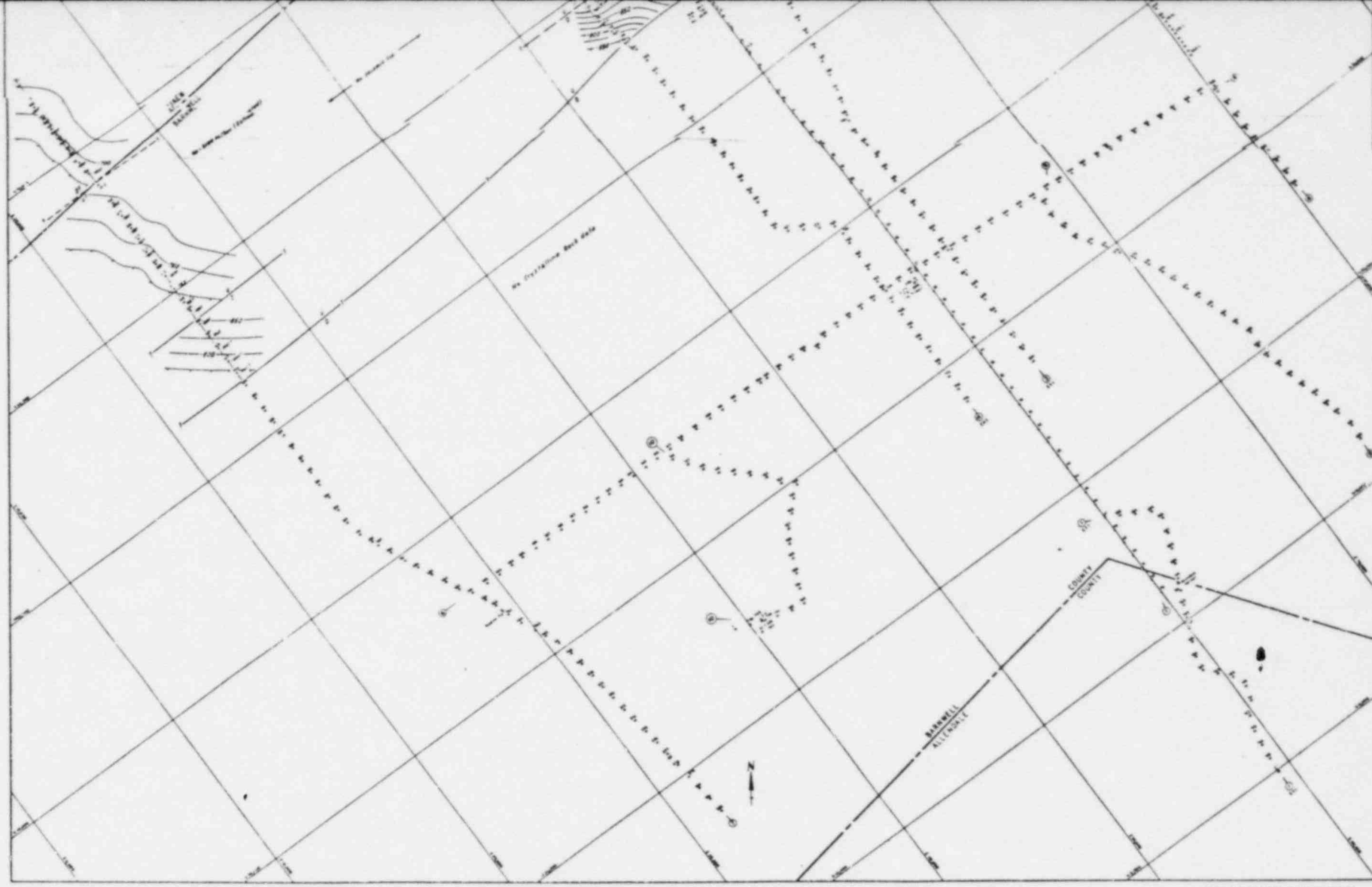

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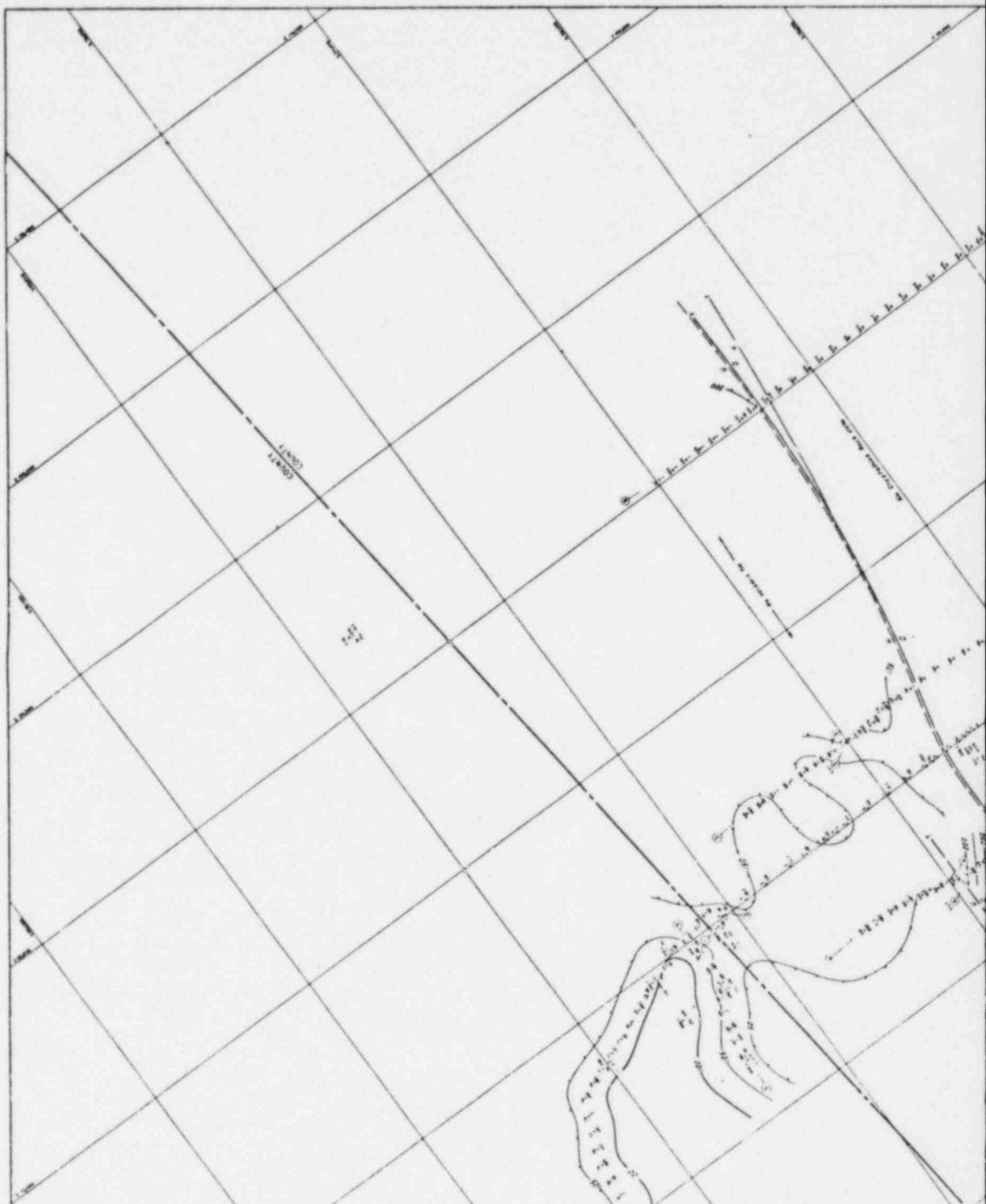
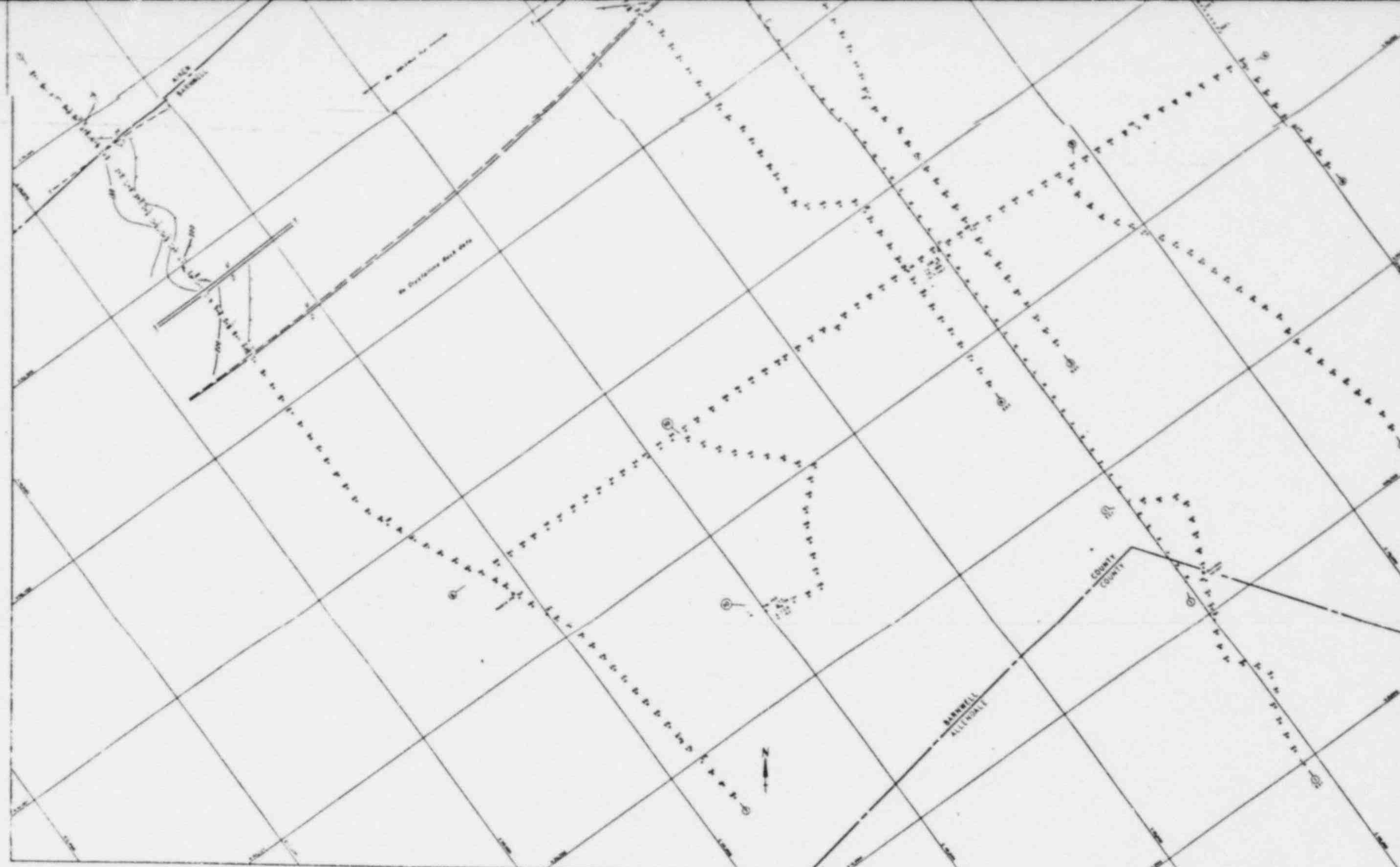
ENGINEERING DEPARTMENT

ARC 267-1-5 N SEISMIC SURVEY
SAVANNAH RIVER PLANT
BEDROCK WASTE STORAGE
BARNWELL, AIKEN AND ALLENDALE COUNTIES, SOUTH CAROLINA

NEAR TOP CRYSTALLINE ROCK





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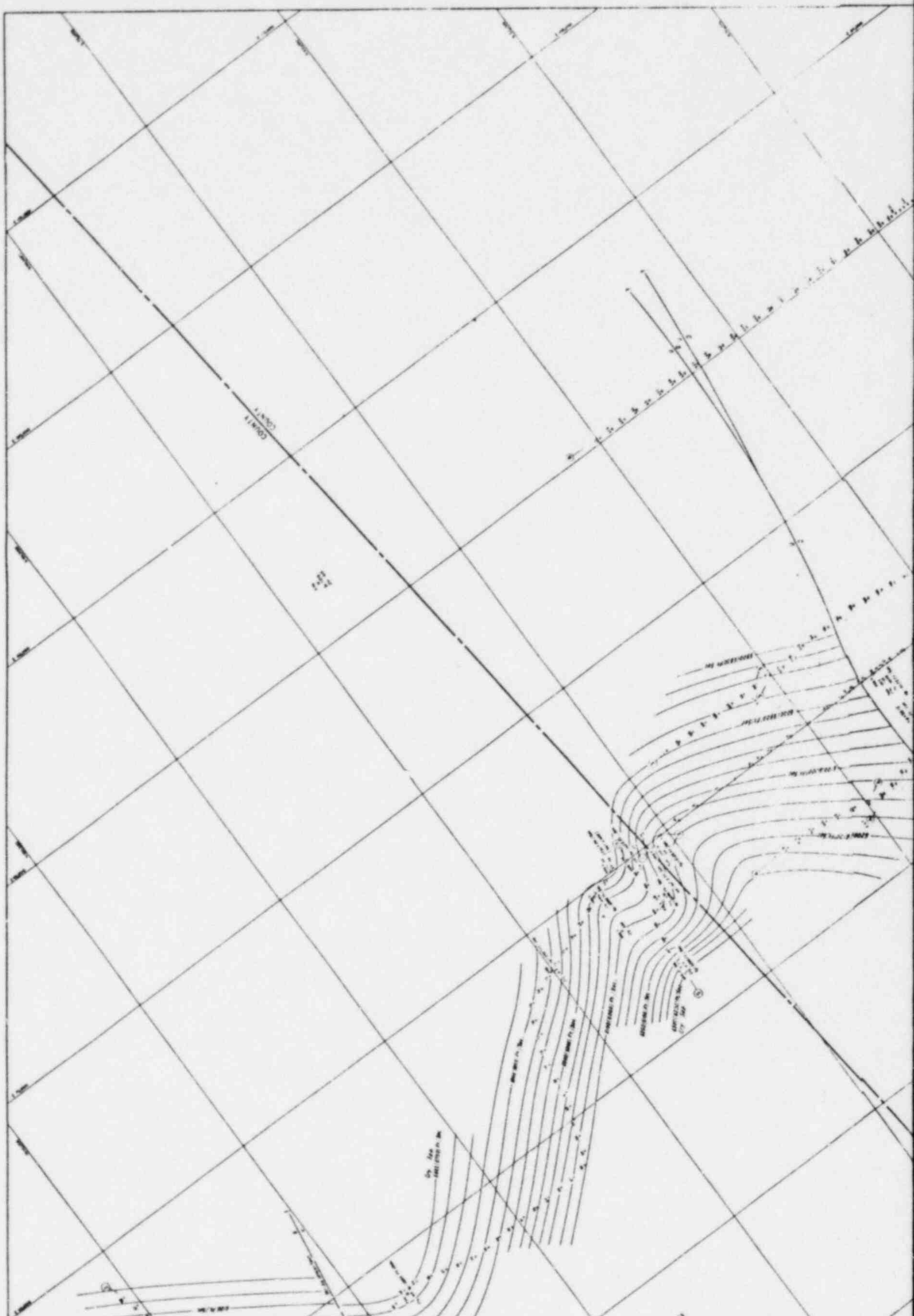
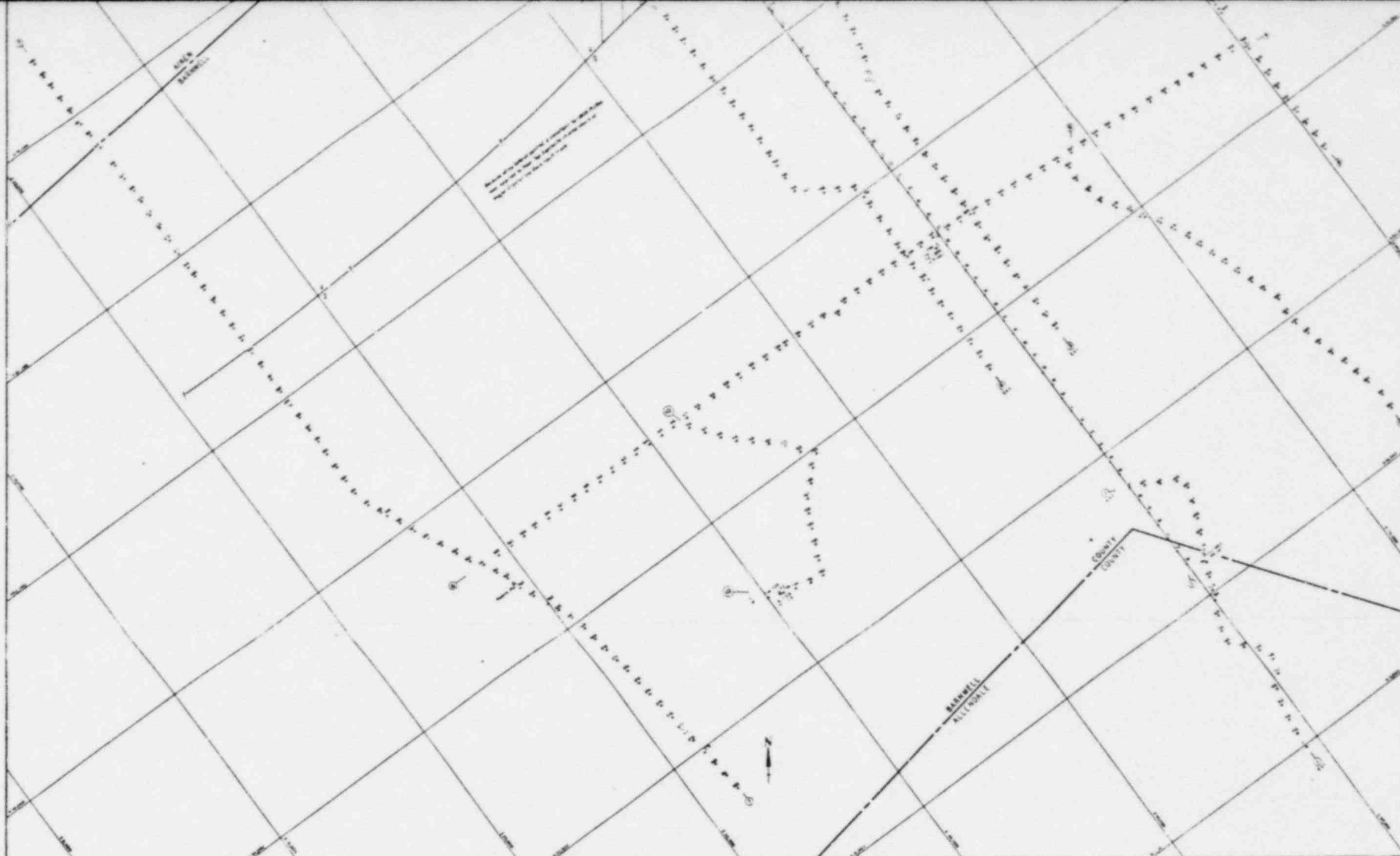
ARC-28715 N SEISMIC SURVEY
SAVANNAH RIVER PLANT
BEDROCK WASTE STORAGE
BARNWELL, AIKEN, AND ALLENDALE COUNTIES, SOUTH CAROLINA

ISOPACH MAP





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ENGINEERING DEPARTMENT

SAVANNAH RIVER PLANT
BEDROCK WASTE STORAGE

VELOCITY GRADIENT MAP

The data from both Lines 7 and 8 are not seismically tied at this level; consequently, the correlations shown could be in error.

The trace of the major fault that cuts the Crystalline Rock and strikes north of the DRB-9 hole is shown on this map as a disturbed zone. Although this horizon may not actually be faulted, minor disturbances in continuity across this zone are noted on several lines. A minor fault, downthrown to the southeast, strikes between Shotpoints 608 and 609 on Line 7. Approximately 50 feet of displacement is indicated at this level.

The data at this level terminate at a zone of discontinuity south of Shotpoint 646 on Line 8, Shotpoint 787 on Line 3-Extension, Shotpoint 12 on Line 1, Shotpoint 750 on Line 4-Extension, and Shotpoint 593 on Line 7. This zone may represent Triassic faulting as discussed later, but does mark a line of facies change in the Cretaceous as demonstrated by the absence of the reflecting horizon in the log of the DRB-10 borehole to the south.

Near Top Triassic

The seismic event designated as Near Top Triassic is mapped throughout the southern portion of the Savannah River Plant and as far north as the southern limit of the Near Top Saprolite map. This shallower event appears to obscure the Triassic reflection because the Triassic formation extends farther north (as evidenced by 1590 feet of Triassic strata penetrated by the DRB-9 hole) and truncates the

Crystalline Rock in the vicinity of the major fault immediately north of the DRB-9 hole. The continuity and quality of this event is very poor over much of the southern area. Some of these zones where loss of continuity occurs have been interpreted as faulting. All the faults appear to be minor normal faults and generally exhibit a displacement of 100 feet or less.

Faults

A short general description of each of the faults encountered at the Near Top Triassic level follows:

The northern limit of the Near Top Triassic seismic data is bounded by a possible minor fault, downthrown to the northwest, cutting Line 7 from 300 to 450 feet south of Shotpoint 593; Line 4-Extension from 100 to 400 feet south of Shotpoint 750; Line 1 from 50 feet south to 300 feet north of Shotpoint 13; and Line 3-Extension from 100 to 300 feet south of Shotpoint 787. The fault either truncates the major fault to the northeast or changes strike to cut Line 8 between Shotpoints 646 and 647. The fault cutting Line 8 also could be a different fault with a different strike than that which is shown. The decision for the direction of the throw on this possible fault is based on the interval of 136 feet between the Tuscaloosa (-603 feet) and Top Triassic (-739 feet) in the DRB-9 hole. If this interval thickness is added to the Near Top Saprolite depths to project Top Triassic depths across the fault, these values would imply a minor displacement to the northwest of approximately 30 feet.

This line of demarkation may not, however, represent faulting, but rather only an abrupt southerly termination of the Cretaceous reflector. The projected interval between the Cretaceous and Triassic reflection events is such that energy representing the Triassic surface would appear approximately one cycle after the Cretaceous, when the latter is present. Thus this Triassic energy would be effectively obscured and coalesced with the Cretaceous generated energy.

The mechanics of such abrupt facies termination still suggest, however, fault controlled genesis. A few steeply dipping and diffracted events observed on the time sections are calculated to emanate from near or within this zone of discontinuity, further substantiating the presence of faulting along this lineament.

The small fault, downthrown to the south with about 30 feet of displacement, cutting Line 1 about 200 to 400 feet south of Shotpoint 30 possibly extends eastward across Line 3-Extension between Shotpoints 812 and 813. It appears to be dieing-out towards the west as evidence is very weak where it possibly crosses Line 6 between Shotpoints 535 and 536 and Line 4-Extension between Shotpoints 765 and 766.

The fault, upthrown to the south, previously interpreted as striking midway between Shotpoints 40 and 41 on Line 1 exhibits 60 feet of displacement and may extend eastward to cut Line 9 between Shotpoints 687 and 688. This fault possibly extends westward to cut Line 10 between Shotpoints 721 and 722. The fault evidence is weak on Line 10 as the record quality is very questionable from Shotpoints 716 to 722. No evidence of this fault cutting either Line 6 or Line 7 is detected.

Another fault, upthrown to the south with possibly 50 feet of displacement appears to cut Line 1 between Shotpoints 48 and 49 and Line 1-Extension between Shotpoints 693 and 694. The eastward as well as the westward trace of this fault is uncertain because of lack of seismic control. The westward trace has been inferred as striking between Shotpoints 735 and 734 on Line 10.

Two additional faults, both downthrown to the south, are interpreted as cutting Line 1-Extension between Shotpoints 703 and 704 and between Shotpoints 708 and 709. The displacement on these faults appear to be slightly in excess of 100 feet. The evidence for these two faults is considered fair to good. Because of the single line control the strike of these faults is uncertain; however, the northernmost fault has been implied as striking westward to cut Line 7 between Shotpoints 576 and 577.

Another fault, downthrown to the south, appears to cut Line 9 between Shotpoints 671 and 672. Slightly more than 100 feet of displacement is shown. This fault may strike northeasterly across Line 8 between Shotpoints 662 and 663, although the fault evidence across Line 8 is not conclusive.

Structure

The structural behavior as revealed by the contour interpretation of the Near Top Triassic map shows gentle southeastward undulating dip at an approximate rate of 50 feet per mile. This regional trend is interrupted by the faulting as previously described.

A gap in the data exists north of the intersection of Line 6 with Line 8. This gap represents part of the area across Par Pond. The quality of the data over the lake is not considered very reliable. If the correlation as shown is correct, either a broad anticlinal nose or possible fault closure exists between Line 8 and Line 3-Extension. The strike of the fault that cuts Line 8 between Shotpoints 646 and 647 is uncertain.

The regional southeast plunge appears to terminate into a synclinal zone that extends eastward from Shotpoint 720 (Line 10) along the downthrown side of the fault cutting Line 1 between Shotpoints 40 and 41.

Sou' ı of this synclinal area, a horst block appear to be present with higher Triassic structure indicated thereon, although the seismic control is sparse and does not adequately define the structural attitude. The data from Shotpoints 41 to 45 on Line 1 are considered reliable. Shotpoints 724 to 731 on Li .e 10 exhibit some of the better data obtained in the southern area. The quality of the data south of Shotpoint 50 on Line 1 as well as from Shotpoints 694 to 703 on Line 1-Extension is considered weak.

The deepest Near Top Triassic data were recorded at the extreme southeast end of Line 1-Extension. Shotpoint 715 appears to be approximately 235 feet lower at the Top Triassic than at the DRB-10 hole near Shotpoint 27 on Line 1. A flattening or possible nosing may be contoured around Shotpoints 710 and 711 in the downthrown block of the fault striking between Shotpoints 708 and 709.

Near Top Crystalline Rock

Very little additional Crystalline Rock data were gained from this third survey assignment to add to the data shown in the northern portion of the Savannah River Plant obtained from the previous assignment.

The most important detail developed by this new control is probably the location of a major fault, downthrown to the southeast, which strikes between Shotpoints 603 and 604 on Line 7; between Shotpoints 740 and 741 on Line 4-Extension; between Shotpoints

5 and 4 (original Line 1); between Shotpoints 781 and 782 on Line 3-Extension; and between Shotpoints 634 and 635 on Line 8. This fault may bifurcate before reaching Line 8 so that a second fault may strike between Shotpoints 635 and 636.

Less than a mile north of this major fault, a minor fault, also downthrown to the southeast with approximately 50 to 70 feet of displacement, cuts Line 4 between Shotpoints 400 and 737 and probably extends westward to cut Line 7 between Shotpoints 608 and 609. This fault appears to die-out between Lines 4 and 1. The Crystalline Rock data appear to steepen in this downthrown block as it approaches the major fault.

Some weak evidence of a very minor fracture or small fault, downthrown to the northwest, is present between Shotpoints 619 and 620 on Line 7. If this fault exists, it appears to be dieing-out towards the east because of the small amount of displacement.

The Crystalline Rock data at the north end of Lines 7 and 8 were converted to depth with estimated average velocities of 6100 ft/sec and 5900 ft/sec, respectively, based on the general attitude shown by the velocity gradient map. The Crystalline Rock reflection from these two lines is not tied seismically to that event mapped in the north-central part of the plant area.

No Crystalline Rock data are available south of the major fault. A very steep miscellaneous dip located north of the DRB-9 hole on Line 1 appears to dip in such a manner as to tie to the Crystalline Rock (-2328 feet) in this hole. Only miscellaneous dips at various levels were recorded. Reflection continuity across no more than one or two spreads can be seen on the replay sections. The reason for the absence of a Crystalline Rock reflection is believed to be the presence of the intervening hard Triassic strata whose density and velocity approaches that of the Crystalline Rock so that there is not a sufficient velocity contrast between the two interfaces to produce a continuous reflecting event. The velocities provided by the 3-D Velocity Log in the DRB-10 hole which bottomed at -3955 feet after penetrating more than 3000 feet of Triassic section show interval velocities of 18,600 feet per second in the bottom part of the hole as compared to an interval velocity of 19,600 feet per second measured through more than 900 fect of Crystalline Rock at the DRB-8 hole.

Isopach Map: Near Top Saprolite to Near Top Crystalline Rock

The thickness of the sedimentary section between the Near Top Saprolite and Near Top Crystalline Rock horizons is depicted by the isopach map submitted with this report. Very little additional control on this interval thickness is supplied at the north end of the supplemental lines. The uncertainty of the correlations on Lines 7 and 8 may render these data suspect. These data do indicate a general southward thickening.

Velocity Gradient Map

The Velocity Gradient Map depicts the variable average velocities applied to the Near Top Saprolite and Near Top Crystalline Rock reflections in the northern part of the survey.

A minor change of the average velocity gradient of the second survey report was made at the south end in which the gradient lines were shifted westward to accommodate a more precise tie at the DRB-9 hole to the Tuscaloosa (-603 feet) or Near Top Saprolite map. However, there is no lateral well control to determine the accuracy in the spacing of the contours as shown. Consequently, a constant average velocity of 5875 feet per second was applied to the Near Top Saprolite event south of the trace of the major Crystalline Rock fault as well as all Saprolite data on both Lines 7 and 8.

CONCLUSIONS AND RECOMMENDATIONS

The results of the third seismic survey provided a considerable amount of structural information on the attitude of the Top Triassic formation across the southern portion of the Savannah River Plant. In general, the south to southeast regional trend is interrupted by several minor faults. Two possible basins separated by a horst are suggested by the data. One basin may be depicted by the syncline striking through Shotpoint 720 on Line 10 and the other appears to be south of the plant boundary as indicated by the deeper data recorded at the extreme southern end of Line 1-Extension.

Very little additional control was obtained at the Near Top Saprolite and Near Top Crystalline Rock levels. However, the major fault at the Crystalline Rock level that was previously interpreted as cutting Line 1 north of the DRB-9 hole appears to have been fairly well defined on Lines 7, 4-Extension, 3-Extension, and 8. No Crystalline Rock data were obtained south of this fault as only sporadic miscellaneous dips are observed on the replay sections. Insufficient velocity contrast between the Base Triassic and Top Crystalline Rock interface fails to produce a mappable reflection.

The inability to map the Top Crystalline Rock in the southern portion of the Savannah River Plant with the seismic program prevents mapping the thickness of the Triassic formation and thereby detecting the position of a Triassic basin. A preliminary analog gravity analysis was made by the Birdwell Division of SSC and the results of this study indicate that a gravity survey may offer some additional information on the possible faulting as well as the structural attitude of the Crystalline Rock.

Respectfully submitted,

SEISMOGRAPH SERVICE CORPORATION

By: W. E. McFarland, Party Chief

By: J. G. Jackson, Supervisor

/ho
January 14, 1972

Approved by:

R. S. Finn, Vice President

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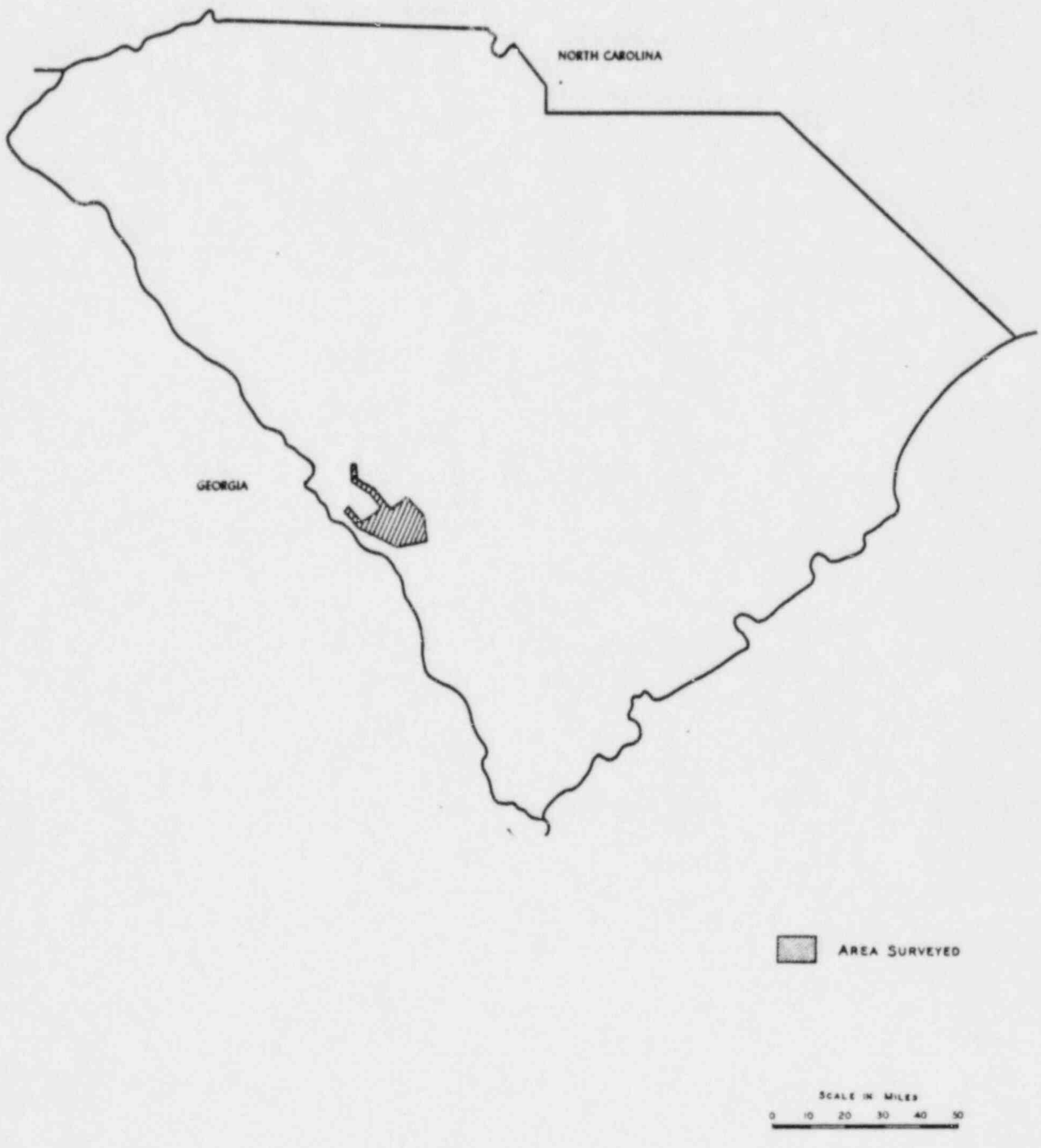
SSC

APPENDIX I

INDEX MAP OF SOUTH CAROLINA



APPENDIX II

PHYSIOGRAPHY

Topography:	Rolling plains
Population:	Unpopulated
Culture:	Brushland, timber; U. S. Atomic Energy Commission's Savannah River Plant
Drainage:	Well drained in a southeasterly direction, furnished by streams tributary to the Savannah River
Soil:	Brown, clay, sandy
Weather:	Generally fair, some rain
Roads:	Plentiful
Access to area from headquarters:	Via U. S. Highway No. 78 and South Carolina Highway No. 125, an average distance of about 30 miles from headquarters
Traverse difficulties:	Caused by: mud, swamps, drainage channels, timber

APPENDIX III

GEOLOGY

Near-surface formation:	Barnwell formation of Jackson group of Eocene age
Subsurface log:	DRB-9 (near Shotpoint 56)
Dry hole	Elevation: 302 ft. K. B. Tuscaloosa (?) clay -603 Top Triassic -739 Hard Triassic -766 Crystalline Rock -2328 T.D. 2701 ft.
Major unconformities:	Between Eocene and Cretaceous Between Cretaceous and Triassic Between Triassic and Cambrian
Regional dip:	Approximately southeast
Type structures expected:	Folded structures: domes, anticlines; fault traps, stratigraphic traps
Well control:	Tied to 12 wells or dry holes in area of prospect

APPENDIX IV

OPERATION METHODS

Method used:	Continuous profiling
Spreads used:	Straddle
Normal length:	900 feet, between shotpoints
Distance from shothole to close geophone stations:	75 feet
Number of geophone stations adjacent to hole:	2
Relation of far geophone stations to interlocking shotholes:	At hole
Geophones used:	HSJ 14 Hz
Number per trace:	10
Connection:	Series
Spacing in group:	10 feet
Arrangement in group:	Straddling station, in line
Instrumentation:	
Type amplifiers:	TI DFS-III
Number of channels:	24
Filter settings:	
Monitor and tape:	27 to 248 Hz at 70.7% amplitude response
Replay playback:	25-35-65-80 Hz on all lines
Replay playback:	Time Variant on Line 7 15-30-75-90 Hz 0 to .350 Sec. 15-30-65-80 Hz .350 to .500 Sec. 10-20-60-70 Hz .500 to 3.000 Sec.
Replay playback:	15-30-110-150 Hz on Line 8 across Par Pond
Type mixing:	Top record usually unmixed
Type camera:	24 trace

OPERATION METHODS (Contd.)

Shothole data:	
Type drilling:	Rotary
Special equipment used:	Portable pits
Tractor mounted equipment:	Drilling, recording, shooting
Shothole depths:	
Normal:	70 to 80 feet
Range:	40 to 130 feet, holes cemented
Number of holes used per location:	1
Formations encountered:	Sand, gravel, clay
Best shooting depth:	40 to 70 feet, varies with topography
Dynamite charges:	
Normal:	1 pound of Nitramon or Primacord, holes preloaded
Elevation survey:	Based on USGS bench marks. All seismic locations on closed elevation traverses tied within maximum limits of seismic accuracy.
Operational difficulties:	Traverse difficulties, caving holes, inaccessibility of prospect

SSC T-146 A-Rev.

STATION AND SHOT HOLE ARRANGEMENT

LEGEND

Shot Hole Under Test	◎
Adjoining Shot Hole	o
Station Number	9
Line of Traverse	----
Geophones per Station	10
Geophone Spacing	10'

APPENDIX V

OPERATING STATISTICS

Basic crew:	
Crew headquarters:	Augusta, Georgia
Starting date:	September 15, 1971
Completion date:	October 23, 1971
Working hours:	270.3 (on plant site)
Number of profiles shot:	712
Number of holes shot:	356
Linear miles covered:	53
Dynamite used:	366 pounds
Type:	Nitramon and Primacord
Number of caps used:	259 and 115
Normal length leads:	150 feet and 100 feet
Drilling:	
Number of drills used:	2
Extra drill hours:	225.5 cementing or grouting holes
Number of holes drilled:	351
Total footage drilled:	28,551 feet
Average length water hauls:	Less than ½ hour per round trip

APPENDIX VI

CALCULATION AND INTERPRETATION METHODS

Record quality:	Good, fair, poor; medium frequency, high frequency. Record quality deteriorated when weathering thickened over high topography.
Type correction used for final data:	Normal uphole
Other corrections calculated:	Summation on Line 6 only
Spread correction:	Used; applied to individual traces on replay sections
Displacement:	Worked for miscellaneous steep dips; straight line
Time reference datum:	+200 feet above sea level
Weathering velocity, v_o:	2500 feet per second
Elevation velocity, v_e:	5500 feet per second
Type replay cross sections prepared:	Galvo-area
Final data normally obtained from:	Galvo-area replay sections

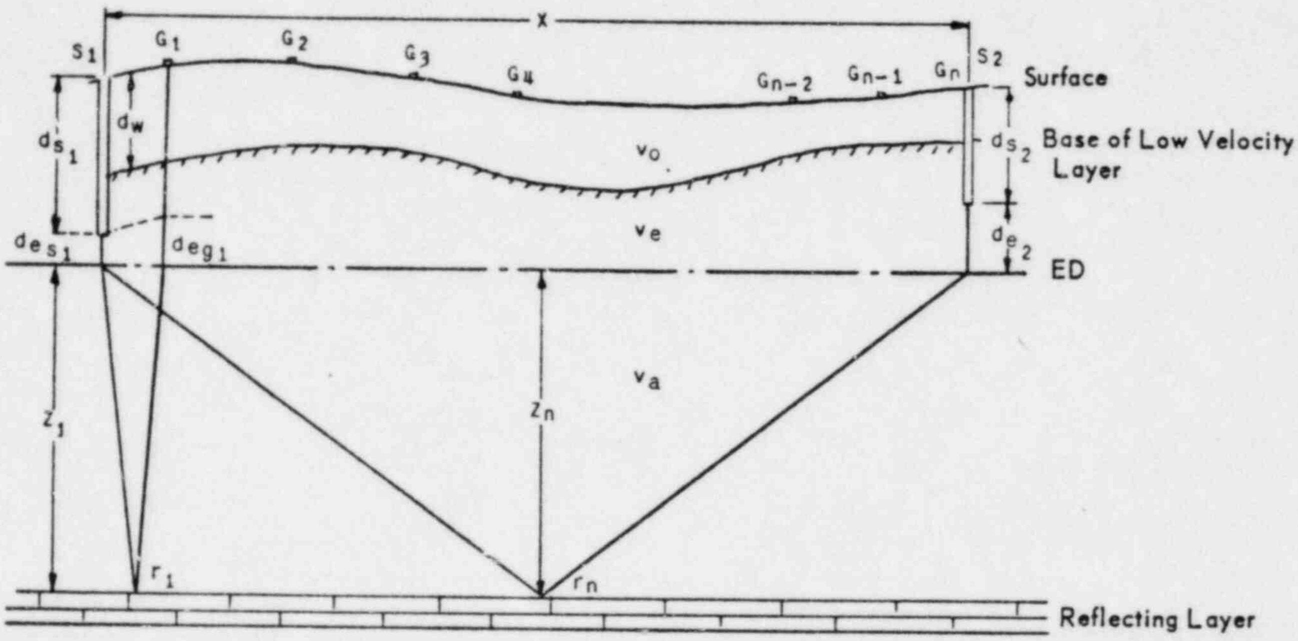
APPENDIX VI (Contd.)

CALCULATION AND INTERPRETATION METHODS (Contd.)

Horizons and interval mapped:

Near Top Saprolite	
Time range:	205 to 333 milliseconds
Depth range:	-400 to -778 feet
Velocity, v_a:	Variable feet per second
Velocity formula:	Partially based on Velocity Gradient Map
Near Top Saprolite to Near Top Crystalline Rock	
Thickness range:	90 to 284 feet, based on difference in calculated depths
Near Top Triassic	
Time range:	322 to 452 milliseconds
Depth range:	-770 to -1162 feet
Velocity, v_a:	6025 feet per second
Velocity formula:	Based on ties to DRB-10 and P5R holes
Near Top Crystalline Rock	
Time range:	187 to 376 milliseconds
Depth range:	-368 to -952 feet
Velocity, v_a:	Variable feet per second
Velocity formula:	Partially based on Velocity Gradient Map

DEPTH DETERMINATION FOR CONTINUOUS PROFILING
Using Normal Uphole Corrections



LEGEND

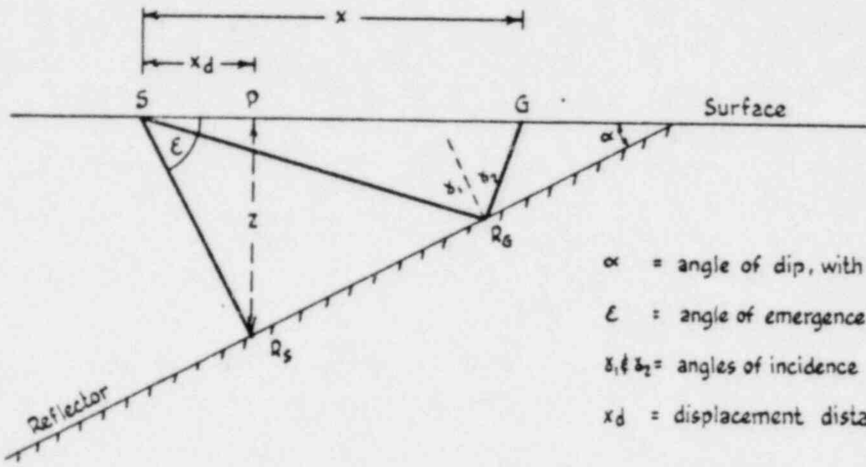
S	-	Shotpoint Location
G	-	Geophone Location
X	-	Surface Distance
d_s	-	Depth of Charge
d_w	-	Thickness of Low Velocity Layer
t_s	-	Uphole Time
ED	-	Elevation or Reference Datum
Z	-	Depth below ED
t_r	-	Recorded Reflection Time
t_c	-	Corrected Reflection Time
t_x	-	Normal Moveout Correction
v_o	-	Average Velocity in Low Velocity Layer
v_e	-	Elevation Correction Velocity
v_a	-	Average Velocity to Reflecting Horizon
t_e	-	d_e/v_e
t_w	-	d_w/v_o
E_s	-	Elevation of Shotpoint
E_g	-	Elevation of Geophone
E_m	-	$\frac{1}{2}(E_s + E_g)$
E'_m	-	$E_m - d_s = \frac{1}{2}(E'_s + E'_g)$
E'_s	-	$E_s - d_s$
E'_g	-	$E_g - d_s$
de_s	-	$E'_s - ED$
de_g	-	$E'_g - ED$
t_x	-	$\dfrac{x^2}{2 v_a^2 t_c}$

$$tc_1 = tr_1 - tes_1 - teg_1 - ts_1$$
$$= tr_1 - 1/ve(E'_m - ED) - ts_1$$
$$Z_1 = \tfrac{1}{2} v_a tc_1$$

$$tc_n = tr_n - tes_1 - teg_n - ts_2$$
$$Z_n = \tfrac{1}{2} v_a (tc_n - tx_n)$$

STEEP DIP CALCULATIONS

Using straight-line assumption



α = angle of dip, with horizontal

ε = angle of emergence, with normal to bed

δ_1 & δ_2 = angles of incidence and reflection

x_d = displacement distance

$$\cos \epsilon = \frac{SP}{SR_s} = \frac{x_d}{\frac{1}{2} v_a t_o}$$

$$x_d = \tfrac{1}{2} v_a t_o \cos \epsilon$$

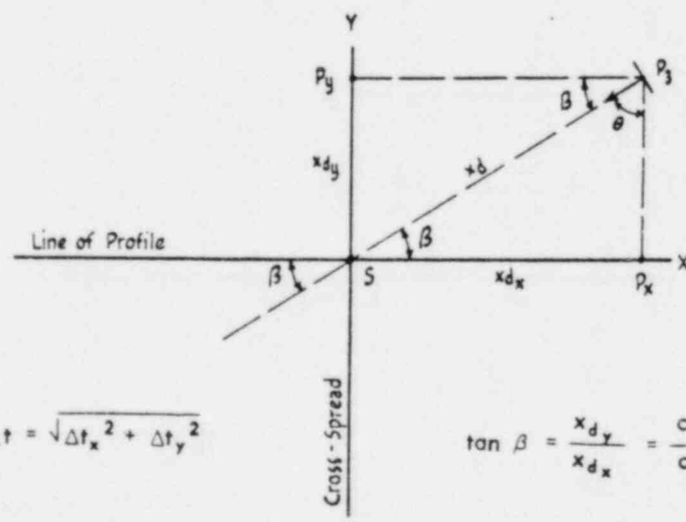
$$\sin \epsilon = \frac{z}{SR_s} = \frac{z}{\frac{1}{2} v_a t_o} = \frac{t_c}{t_o}$$

$$t_c = t_o \sin \epsilon$$

$$z = \tfrac{1}{2} v_a t_o \sin \epsilon$$

$$a = 90^\circ - \epsilon$$

Three-Dimensional Plan



$$\Delta t = \sqrt{\Delta t_x^{\,2} + \Delta t_y^{\,2}}$$

$$\tan \beta = \frac{x_{d_y}}{x_{d_x}} = \frac{\cos \epsilon_y}{\cos \epsilon_x} = \frac{\Delta t_y}{\Delta t_x}$$

APPENDIX VII

MATERIAL SUBMITTED SEPARATELY

Base shotpoint tracing
Sepias with data
All monitor (read-after-write) records for the survey
Preliminary replay sections
Large hand-plotted cross sections
Digital tapes
Plane table sheets
Surveyor's field notes
Driller's reports
Replay sections:
- Galvo-area
- Films from which above sections were taken

Calculation book containing:
- Calculation and interpretation methods
- Velocity determinations
- Time-depth conversion tables
- Weathering graph sheets
- Dip calculations
- Small cross sections
- NMO chart
- Surveyor's reports
- Observer's reports
- Shooter's reports

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