United States Department of Agriculture

Soil Conservation Service

401 SE 1st Avenue, Room 248
Gainesville, Florida
32601

Subject: SOILS - Ground-Penetrating Radar (GPR) - Trip Report - Louisiana

Date: December 12, 1983

To: Harry S. Rucker, State Conservationist
SCS, Alexandria, Louisiana

File Code: 430-5

During the period of October 31 to November 1, 1983, the ground-penetrating radar (GPR) was field tested in Claiborne Parish, Louisiana. The objectives of the GPR field work were to investigate the potential of GPR technology in the red land area of Louisiana; to study the depth to and the lateral continuity of petroferric layers; and to determine the composition of selected map units with the GPR in Claiborne Parish.

Participants in the field work included: C. Reese Berdanier, Soil Survey Investigation Specialist, SCS; Charlie Henry, Jr., Soil Scientist, SCS; Wayne Kilpatrick, Party Leader, SCS; and Robert Miller, Agronomy Department, Louisiana State University.

The equipment utilized during this field trip was the SIR System-8 with microprocessor, and the ADTEK SR-8004H graphic recorder. A complete complement of antennas (80, 120, 300, and 500 MHz) were utilized. Near the end of the second day of field work, the control unit intermittently failed to distribute high voltage power to the oscilliscope. Later, the system failed necessitating the termination of the field trip.

Prior to the termination of this field trip, the GPR was sufficiently tested in the field to evaluate the systems performance and to satisfy the objectives of this investigation. Generally, the GPR provided high quality and consistent data from the upper 1.2 meters of all soil profile. In many areas the radar effectively probed to depths of 2 meters. These results are remarkable considering the high clay content (40-60 percent) of the soils examined. With the GPR characterization of the depth to and the lateral continuity and variability of the argillic horizon and petroferric layers is possible.

The GPR successfully characterized the composition of an upland association along a 1,500 foot transect line. In general, the effectiveness of the GPR in this area of Louisiana is good. More field time is needed to fully characterize the systems potential and the develop interpretive expertise.

All graphic printouts have been returned to Jim Dreissen. A copy of the trip report is attached.

Thomas P. [illegible] for

James A. Doolittle
Soil Specialist (GPR)

Attachment

cc: w/attachment
Richard W. Arnold, Director, Soils, SCS, Washington, D.C.
Billy M. Johnson, Director, SNTC, SCS, Fort Worth, Texas
James W. Mitchell, State Conservationist, SCS, Gainesville, Florida

SOILS

The red land area of Claiborne Parish provided the geographic setting for the ground-penetrating radar's (GPR) investigation of petroferric layers in Louisiana. Five sites were scanned with multiple transects by the GPR during an abbreviated two-day field study. The field investigation was shortened by the untimely failure of the radar's control unit which had to be returned to the manufacturer for repairs.

The objectives of the field investigation were to determine the depth to and the lateral continuity of petroferric layers, and to document the composition of selected map units. The principal soil investigated was Kirvin (clayey, mixed, thermic Typic Hapludults).

A major portion of the field time was spent conducting trial transects along the tops of vertical road cuts in areas of Kirvin, Ruston (fine-loamy, siliceous, thermic Typic Paleudults) and, Briley (loamy, siliceous, thermic Arenic Paleudults) soils. Preliminary transects were conducted with the 80, 120, and 300 MHz antennas to determine the most suitable antenna in terms of range and resolution. Multiple transects were conducted with each antenna. The range was adjusted on the control unit to provide scanning times of either 98 or 49 nanoseconds (ns) which corresponded to probing depths of 4.7 meters or 2.3 meters, respectively. These depths were calculated from field derived values for the velocity of signal propagation (6.3 $ns.ft^{-1}$) and for the relative dielectric constant (9.7) of Kirvin soil.

The effective probing depth of the 80 and 120 MHz antennas was approximately two meters in some portions of each transect. This depth is remarkable considering the high clay content of the control section of

Kirvin soil (40 to 60 percent clay) and the systems dismal past performance in fine textured soils. The results confirm the prediction that the radar would perform better in soils dominated by 1:1 lattice clays than in soils dominated by 2:1 lattice clays.

The 120 MHz antenna is the most suitable antenna for investigating soils and petroferric layers in this portion of northwestern Louisiana. In Kirvin soil, the 120 MHz antenna penetrated almost as deeply as the 80 MHz antenna; the difference was insignificant. The 120 MHz antenna provided the best resolution of subsurface interfaces. Generally, the imagery from the 300 MHz antenna was poorly resolved and exceedingly depth restricted.

Though the maximum effective probing depth of the 120 and 80 MHz antenna was approximately 2 meters, consistent and reliable images were obtained from only the upper 1.2 meters of the soil profile.

The GPR system was designed to detect subsurface interfaces. The depth to an interface is determined by correlating a limited number of ground-truth soil borings with scaled imagery on the graphic printout. Usually one soil boring will suffice to identify and determine the depth to major subsurface interfaces along an entire transect line.

Slight discrepancies often exist between soil boring data and the radar imagery. In order to document the accuracy of the GPR system, a study was conducted comparing scaled radar imagery with ground-truth auger data. This study was conducted in an area of Kirvin soil.

Ground-truth measurements provide the basic data on which radar imagery is scaled and compared. This data can and often does contain an inherent degree of measurement error. Measurement error can be attributed to: the habit of rounding off numbers; the non-vertical and slightly twisted extension of the measuring tape across the roadcut; and slight spatial discrepancies between the site of measurement and the track of radar scanning.

The measured depths to the argillic horizon and petroferric layers, the scaled depths to the radar imagery, and the difference between these measurements are listed in Table 1. The average deviation between soil boring depths and scaled radar imagery for the argillic horizon was 4.0 cm. The deviation between the scaled radar imagery and the ground-truth auger data for the depth to the argillic horizon is as follows: within 10 cm at all sites; within 8 cm in 86 percent of all sites; within 5 cm in 71 percent of all sites; and within 3 cm in 43 percent of all sites. For the petroferric layer the average deviation between the soil boring depths and the scaled radar imagery was 5.8 cm. The deviation between the scaled imagery and the ground-truth auger data for the depth to the petroferric layer is as follows: within 21 cm at all sites; within 8 cm in 86 percent of all sites; and within 3 cm in 57 percent of all sites. The match between auger boring data and the scaled radar imagery is considered remarkable. This match may have been fortuitious in areas where the imagery overlapped and the lateral continuity of the argillic horizon and the petroferric layer was more uncertain.

To document the composition of an upland area a transect was conducted along a gas pipeline. The transect was conducted at an adjusted scanning time of 34 ns which corresponded to an effective probing depth of approximately 1.6 meters. The 120 MHz antenna was utilized. The transect was approximately 457 meters long and had 16 "flagged" reference sites which were spaced at intervals of 30.5 meters. The antenna was towed along the side of the pipeline at a speed of about 3 $km.hr^{-1}$. As the antenna was towed along the surface, a continuous printout of the soils is developed on the graphic recorder. This imagery (Figure 1) is very similar to the cross section of soils exposed in a vertical roadcut. As the antenna passed each "flagged" reference site an event marker was depressed causing a dashed vertical line to be impressed on the graphic printout.

The transect can be subdivided into three distinct "patterns" on the basis of the occurrence and the form of ironstone in the substratum. Figure 1 is a reproduction of a portion of this transect. The reference sites have been numbered at the top of each printout. Sites 1 through 5, 11, and 13 are underlain by coherent petroferric layers. In this transect 44 percent of the sites were underlain by soils having coherent petroferric layers. Sites 6 through 8, 10, and 12 are underlain by soils which are essentially free of indurated layers or fragments or have small amounts of these features in the substratum. These and similar sites occupy 44 percent of the sites along this transect. Site 9 is underlain by discontinuous beds of ironstone fragments which characterized colluvial sideslope deposits. Colluvial deposits occupy 12 percent of the sites along this transect.

Figure 2 is representative of areas underlain by coherent petroferric layers. The profile in this figure consists of three basic components: the transmitted pulse (A), the surface pulse, and the interface pulses (B and D). for each component dark bands occur at both the positive and the negative signal peaks. The narrow white lines are the zero or neutral crossing between the peaks.

The depth to and the lateral extent of the argillic horizon (B) is evident in this figure. Lateral changes in electromagnetic properties along the argillic horizon can be inferred from changes in the width of the dark and light bands on the graphic printout. As a general rule: the more abrupt or contrasting an interface, the blacker and wider the dark bands and the narrower the width of the white bands. If the soils are eroded and the upper part of the argillic horizon has been mixed with or is the surface layer, the contrast between eluvial and illuvial horizons is diminished and the width of the white bands of the argillic horizon should increase. Theoretically, in some soils, erosion can be measured on the

basis of the depth to the argillic horizon, and the relative strength (lightness or darkness) of the black bands and the width (to the exclusion of the dark bands) of the white bands.

In Figure 2 the image of eroded soils is apparent at C. In this area the argillic horizon is at the surface. Note the weakening (grayer colors) and the upward inclination of the dark bands to the left of C.

The black and white "blobs" in the upper part of the argillic horizon are caused by overlapping and mutual infringement of multiple signals.

Petroferric layers (D) from multiple bands across the lower portion of the graphic profile. As all layers were not identified in the field, some may represent lithologic discontinuities rather than petroferric layers. Additional interpretive experience and ground-truth data must be gained before these layers can be accurately identified and differentiated.

Figure 3 is representative of areas underlain by discontinuous indurated layers and ironstone fragments. The multiple reverberations from the argillic horizon (A) are evident in the upper part of the graphic profile. Interface signals are often displayed in groups of three bands. Each group of bands is the reflection from a single reflected pulse. Immediately below the surface pulse is an image (B) that is generally induced by organic materials near the surface. Within the substratum numerous, short, discontinuous signals of varying intensities are evident. These images are believed to be caused by fragments and layers of ironstone in various forms, thickness, and perhaps degrees of induration.

Figure 4 is from an area that is apparently underlain by discontinuous beds of ironstone fragments. The images of the ironstone fragments are disjointed and convulated and do not possess the linear regularity of the petroferric layers (see Figure 2).

A drainageway occurred near reference site 9. The occurrence and thickening of alluvial/colluvial deposits (B) is apparent across the lower

toeslope area which surrounds this reference site. The depth to the argillic horizon (A) increases within the drainageway as the soil is blanketed with alluvial/colluvial deposits.

TABLE 1

Observation Sites	1	2	3	4	5	6	7
Depth to argillic horizon (inches)	28	20	30	30	38	20	20
Scaled depth (inches)	28	25	30	30	28	25	28
Difference	0	+5	0	0	-10	+5	+8
Depth to petroferric layer (inches)	79	86	76	107	76	163	91
Scaled depth (inches)	86	86	79	107	69	142	94
Difference	+7	0	+3	0	-7	-21	-3

AN AREA OF PETROFERRIC LAYERS IN LOUISIANA

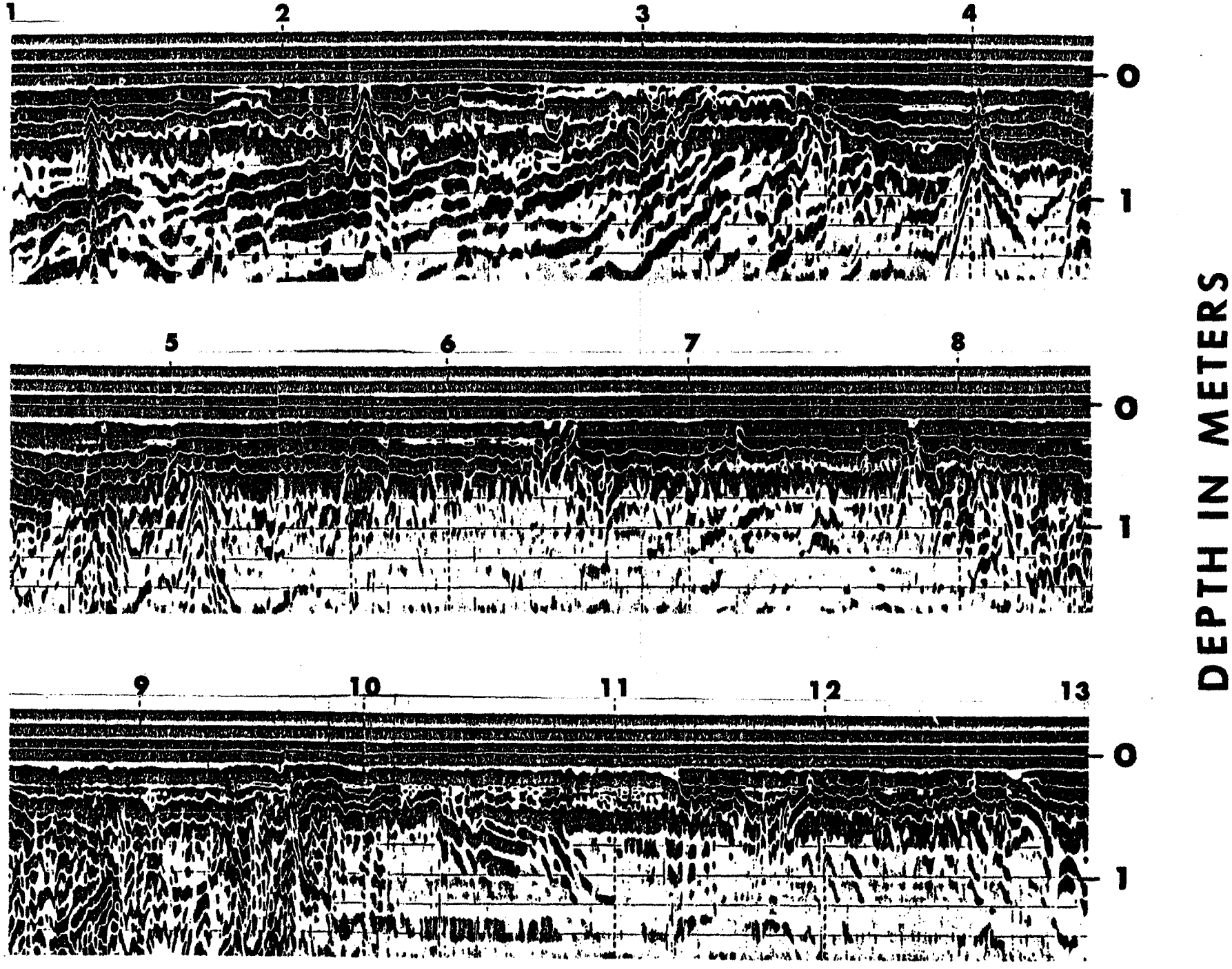
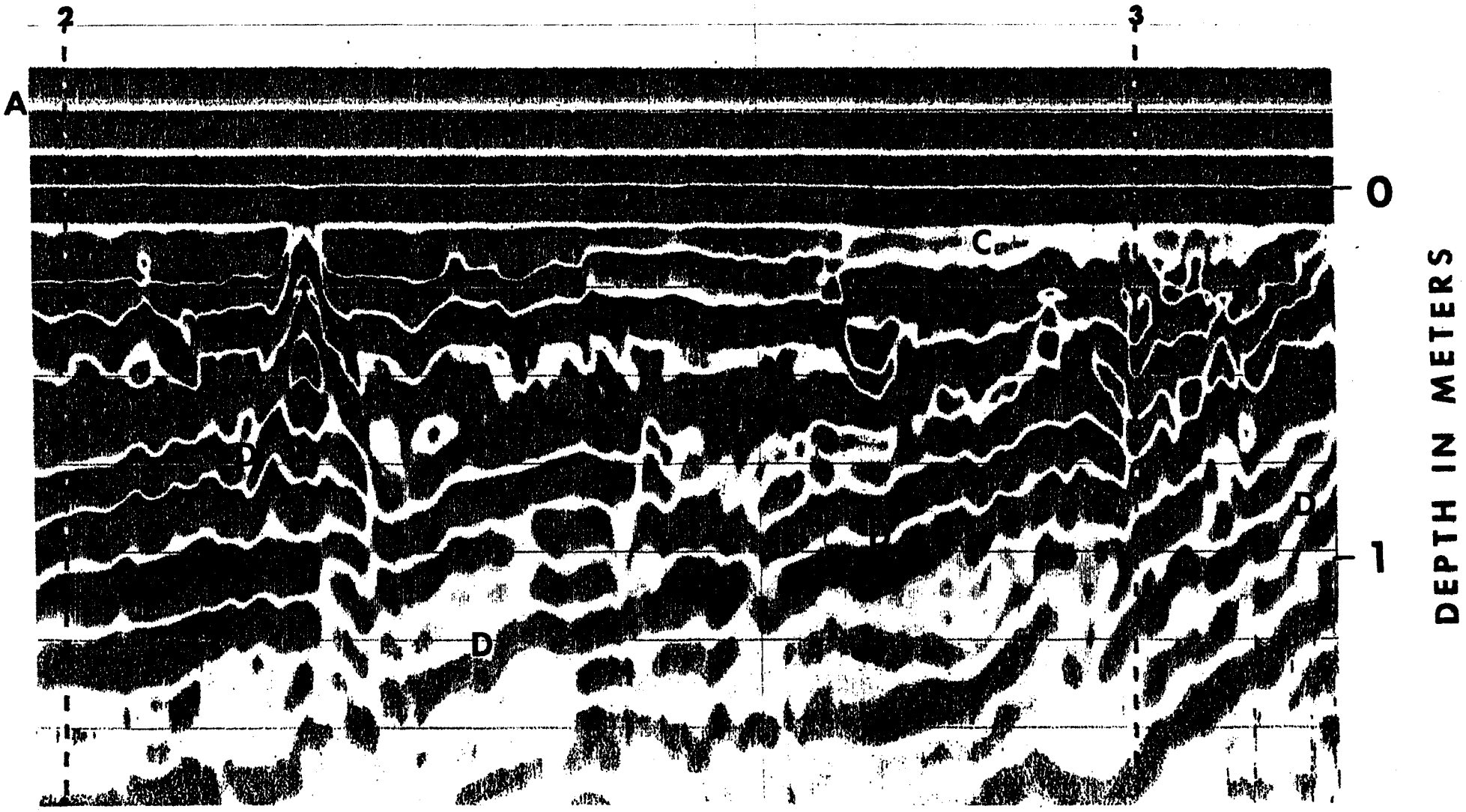


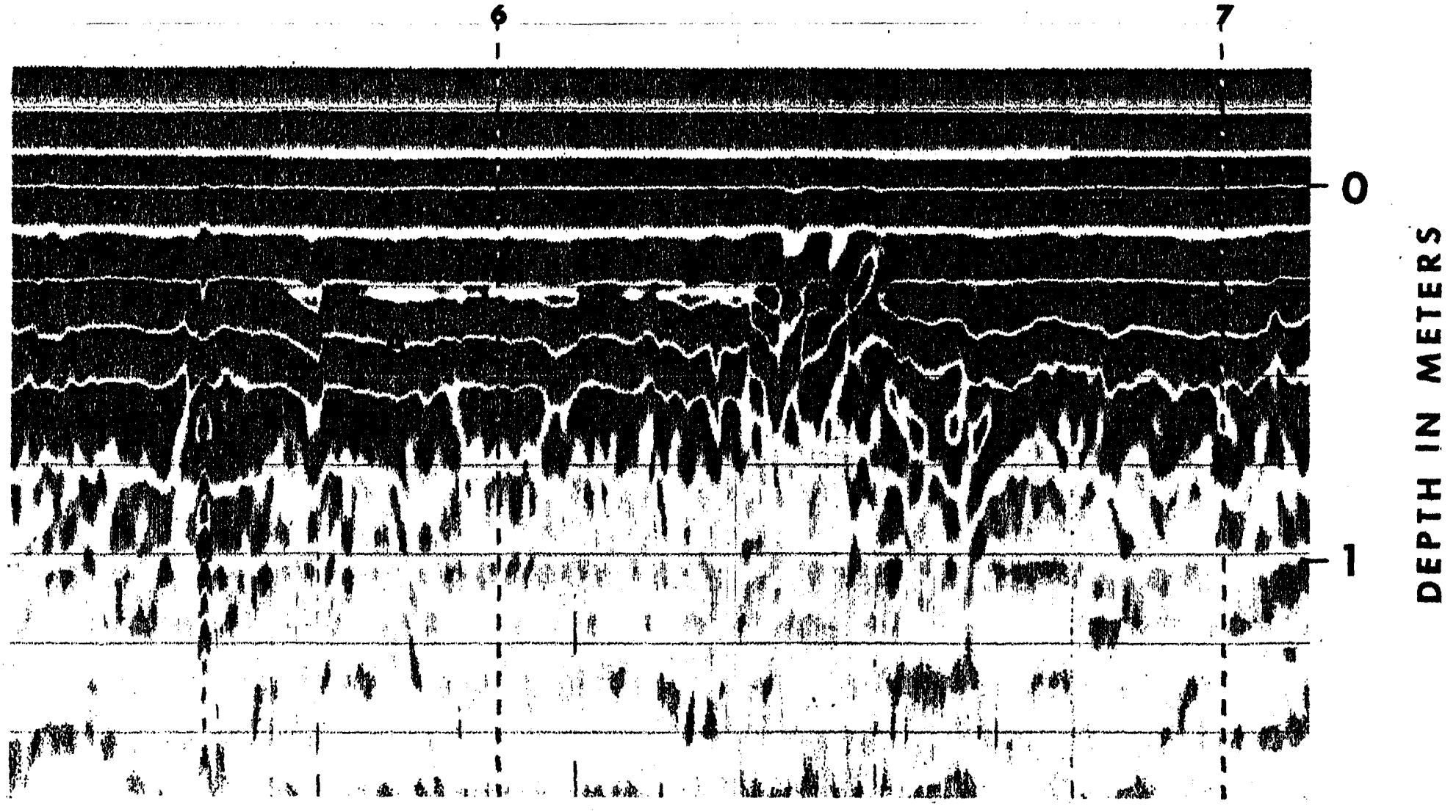
FIG. 1

FIG. 2



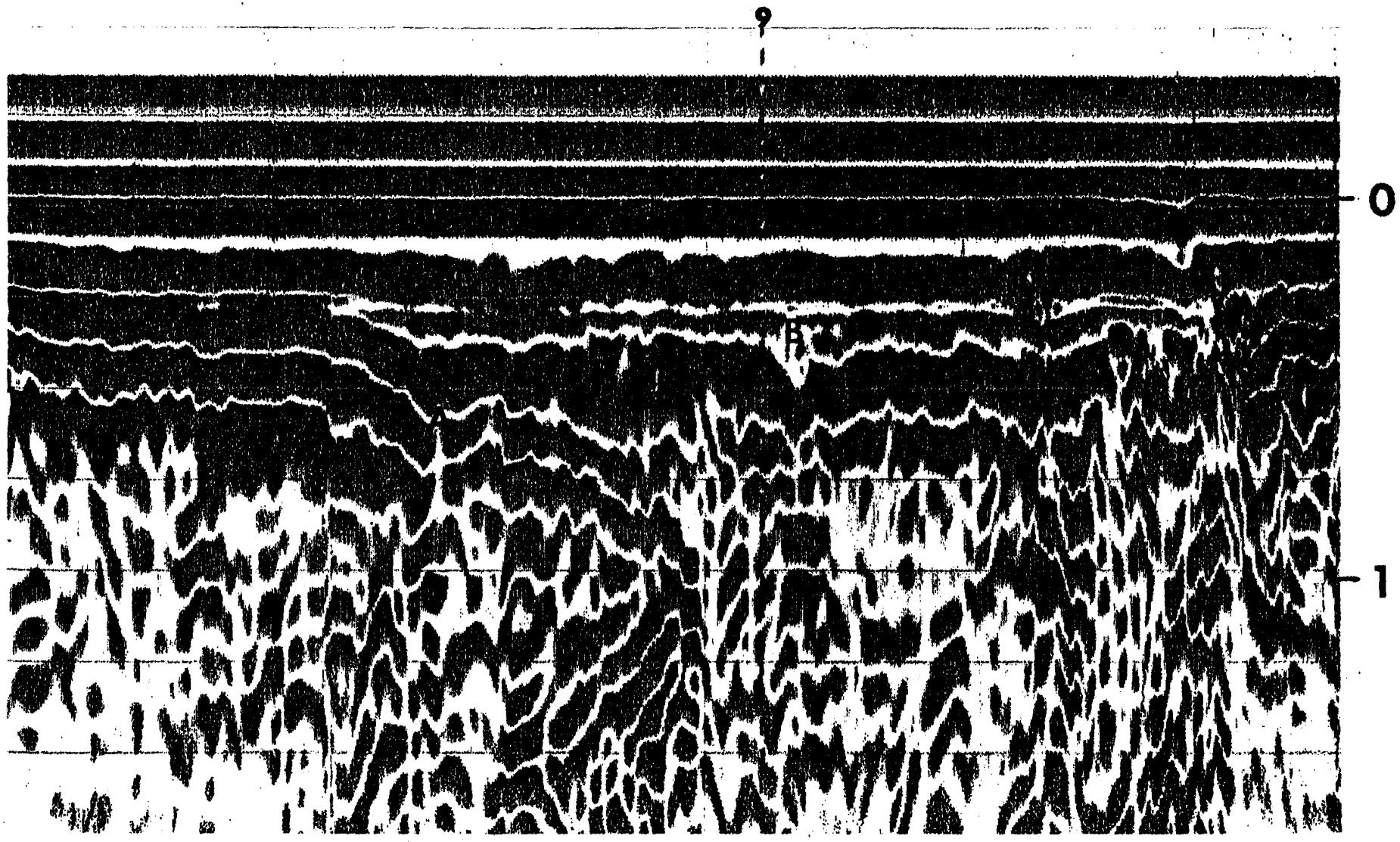
AN AREA UNDERLAIN BY PETROFERRIC LAYERS

FIG. 3



AN AREA UNDERLAIN BY IRONSTONE FRAGMENTS

FIG. 4



IRONSTONE COLLUVIUM ALONG LOWER SIDESLOPES