Jim D

United States Department of Agriculture

Soil Conservation Service

Northeast NTC
160 E. 7th Street
Chester, PA 19013

Subject: SOI - Ground-Penetrating-Radar (GPR) Trip Summary, Maryland

Date: May 2, 1985

To: Pearlie S. Reed
State Conservationist
Soil Conservation Service
College Park, MD

File Code: 430-7

During the period of April 23 through 26, 1985, a field study was conducted with Ground-Penetrating Radar (GPR), in Dorchester County, Maryland. The NENTC's GPR system completed its first field and shake-down trials, and was applied to a wide variety of soil and site conditions throughout the county.

PARTICIPANTS

Jim Brewer, Soil Scientist, SCS, Cambridge, MD
Jim Brown, Soil Scientist, SCS, Rockville, MD
Ed White, Area Soil Scientist, SCS, Easton, MD

The equipment utilized during this field trip was the SIR System-8 with microprocessor, the ADTEK SR-8004H graphic recorder, and the ADTEK DT-6000 tape recorder. Although the 80, 120, and 300 MH_z antennas were used at various times and under differing conditions, the most suitable antenna for soil investigations along Maryland's eastern shore is the 120 MH_z. The equipment operated well with one exception. The high power model 765 HP transmitter could not be operated due to the lack of a 30 meter transmitter trigger cable. The manufacturer has been notified of this deficiency and is forwarding the cable to my office.

The GPR worked exceptionally well at most sites. With the exception of "submerged upland" tidal marshes, the GPR is suitable for soil investigations in most areas of Dorchester County. On tidal marshes, the high salt content of the Rappahannock (loamy, mixed, euic, thermic Terric Sulfihemists) soils caused the rapid attenuation of the radar signal and severely limited the profiling depth. The present system appears ineffectual on tidal marshes.

Soils that were successfully profiled with the GPR included Downer (coarse-loamy, siliceous, mesic Typic Hapludults), Galestown (sandy, siliceous, mesic Psammentic Hapludults), Greensboro (coarse-loamy, mixed, mesic Aquic Hapludults), Klej (mesic, coated Aquic Quartzipsamments), Othello (fine-silty, mixed, mesic Typic Ochraquults), and Unicorn (coarse-loamy, mixed, mesic typic Hapludults). Major diagnostic soil horizons or features of these soils were discerned with the GPR.

On mineral soils of the eastern shore, the major limitation of the GPR is the development of calibration and interpretative skills to separate and identify the multiple, closely spaced and often superposed, near surface interfaces. Near surface interfaces (within 50 cm of the soil surface) are difficult to identify with the GPR. The soils investigated are sedimentologically stratified. It was not uncommon to observe multiple and often superposed near surface interfaces which are defined by vertical variations in grain size, textural class, bulk density, mineralogy, or moisture content. Without improved interpretative skills or intensive ground truth auger borings, it is difficult to unravel the identification of these near surface images on graphic profiles.

In some areas, horizons were inextensive, irregular in depth, or cross-bedded. Some horizons graded laterally into different textural classes. Often these changes occurred over a relatively short distance (less than 30 meters). While the radar did not miss any of these horizons in the soil profile (2 meters), the number of ground truth probings necessary to identify and trace the lateral extent of these subsurface features is higher than in areas of less variable soil horizonation.

With further field work along the eastern shore, GPR technology should provide an excellent means for quantifying the composition of map units; discerning lithologic discontinuities in soils; developing conceptual frameworks for soil genesis; documenting the lateral and seasonal variations in the depth to the water table and the effects of drainage; detecting point objects in soils such as pipes, septic tanks, and buried foundations; and providing detailed on-site information concerning the underlying earthen materials.

The enclosures summarize the major factors affecting the GPR's operation and provide examples of the graphic profiles and interpretations made in Dorchester County. All pertinent graphic profiles have been returned to Jim Brewer.

The field trip was exceptionally well planned and organized. I wish to pass along my personal thanks for the cooperation, assistance, and spirited enthusiasm of Jim Brewer and Ed White.

J. A. Doolittle

James A. Doolittle
Soil Specialist (GPR)

Enclosures

cc:
A. Holland
F. Miller
J. Brewer
D. Yost

PRINCIPLES OF OPERATION

The Ground-Penetrating Radar (GPR) is an impulse radar system that has been specifically designed to penetrate earthen materials. Relatively high frequency, short duration pulses of energy are transmitted into the ground from a coupled antenna. When a pulse strikes an interface (boundary) separating layers of differing electromagnetic properties, a portion of the pulse's energy is reflected back to the receiving antenna. The reflected pulse is received, amplified, sampled, and converted into a similarly shaped waveform in the audio frequency range. The processed reflected signal is displayed on the graphic recorder or is recorded and stored on magnetic tape.

The graphic recorder uses a variable gray scale to display the data. it produces images by recording strong signals as black, intermediate signals in shades of gray, and weak signals as white. As a general role, the more abrupt the interface and the greater the difference in electromagnetic properties across the interface, the stronger the reflected signal and the darker the generated image.

The graphic profile is developed as electrosensitive paper moves under the revolving styli of the graphic recorder. Reflections above a preset threshold level are "burned" onto the electrosensitive paper. Each scan of a stylus draws a line across the paper in the direction of increasing signal travel time (depth). The intensity of the images printed along each line is dependent upon the amplitude of the processed signals. A continuous profile of subsurface conditions is "burned" onto the paper by the graphic recorder as the antenna is towed along the ground surface.

Figure 1 is an example of a graphic profile. The horizontal scale represents units of distance traveled along the transect line. This scale is dependent upon the speed of antenna advance along the transect line and the rate of paper advance through the graphic recorder. The vertical scale is a time or depth scale which is based upon the velocity of signal propagation. The dashed vertical lines are event markers inserted by the operator on the graphic profile to indicate known antenna positions or reference points along the transect line. The evenly spaced horizontal lines are scale lines. Scale lines provide reference planes for relative depth assessments.

Most graphic profiles consist of four basic components: the start of scan image (A), inherent system images (B), surface images (c), and subsurface interface images (D). All of these components, with the exception of the start of scan image, are generally displayed in groups of three dark bands unless limited by the proximity of two or more closely spaced interface signals, or by high rates of signal attenuation. These bands, which are produced by oscillations in the reflected pulses, limit the ability of the GPR to discriminate shallow or closely spaced interfaces. The dark bands occur at both positive and negative signal amplitudes. The narrow white line(s) separating the bands represent the neutral or zero crossing between the polar amplitudes.

The start of scan image (A) is a result of the direct coupling of the transmit and receive antennas. Though a source of unwanted clutter, the start of scan image is often used as a time reference line.

Reflections inherent in and unique to each of the system's antennas are the first series of multiple bands on graphic profiles. Generally, the width of these bands increase with decreasing antenna frequency. These reflections (B) are a source of unwanted "noise" on graphic profiles.

The surface images (C) represent the first major interface signal. The first zero crossing of the surface images is normally selected as a matter of its convenience and repeatability as the soil surface for depth calibrations and measurements.

Below the images of the surface reflection are images from subsurface interfaces (D). Interfaces can be categorized as being either plane reflectors or point objects. Most soil horizons and geologic layers will appear as continuous, parallel, multiple bands similar to those appearing in the left-hand portion of Figure 1. Small objects, such as rocks, roots, or buried pipes, will appear as point objects and will produce hyperbolic patterns similar to those appearing in the right-hand portion of this figure. Hyperbolic patterns are a function of the radar's conical area of radiation which enables the antenna to receive echoes even though it is not directly over the object.

INTERPRETATIONS

The following section summarizes some of the interpretations that can be made from the graphic profiles obtained in Dorchester County.

The GPR can be used to identify soil series based on the presence of and depth to major diagnostic subsurface horizons. In the second figure, the thick dark band to the right of "A" is the image of an argillic horizon. The argillic horizon is sandy loam and ranges in depth from 50 to 60 cm. The soil to the right of "A" is classified as a coarse-loamy, mixed, mesic Arenic Hapludults (proposed Linchester series). The soil to the left of "A" does not have an argillic horizon and is Klej (mesic, coated Aquic Quartzipsamments).

This transect was conducted from a higher lying (right-hand margin) to a lower lying (left-hand margin) backslope position. Regardless of slope gradient, the soil surface on all graphic profiles is horizontal. The image of the water table (B) appears as multiple bands, and is the inverse of the topographic expression. The GPR can be used to map the spatial and temporal variations in the depth to the water table and to characterize the effects of drainage.

The irregular feature at "C" is a zone of sands and loamy sand lamallae.

The third figure is from an area of Greensboro (coarse-loamy, mixed, mesic Aquic Hapludults) soil. The moderately well drained Greensboro soil formed in stratified Coastal Plain sediments. This figure illustrates the interpretative dilemma associated with multiple, near surface (less than 50 cm) horizons or layers. These horizons are often cross-bedded, discontinuous, and irregular in depth making identification of images on the graphic profile exceedingly difficult.

Various strata can be identified in the middle part of this graphic profile. At a depth of about 1 meter a distinct silt loam layer (A) is apparent across the profile. A lower lying zone of stratified sands is evident below "B". The water table (C) is uniformly expressed by three multiple bands across the lower part of this profile.

The poorly drained Othello soil (fine-silty, mixed, mesic Typic Ochraquults) formed in silty sediments overlying coarser sediments of marine and alluvial origins. The fourth figure is from an area of Othello soil. Note the horizontal stratification in the upper part of this profile and the distinct angular unconformity at "D". This graphic profile documents two cycles of deposition separated by a period of erosion. Surface "D" consists of gravelly loamy sands. As the gravels are unique to this interface, they are believed to be a lag deposit. Although the strata underlying "D" appear to be steeply inclined, the vertical exaggeration is about 14 to 1 and the slope of these strata is significantly less.

The contact between the overlying silt loam (A) and sandy loam (B) deposits of Othello soil is well expressed in the upper part of this profile. The sandy loam deposits (B) are about 20 cm thick and are underlain by stratified sands, loamy sands, and sandy loam deposits (C). Each strata within these lower lying deposits (C) appears to be inextensive and cross-bedded. The images are closely spaced and often superposed producing mutual signal cancellation and large "white-out areas."

As a test, the 120 MH antenna was towed across a buried septic tank. In the last figure, the distinct hyperbolic pattern of the septic tank is apparent beneath "A".

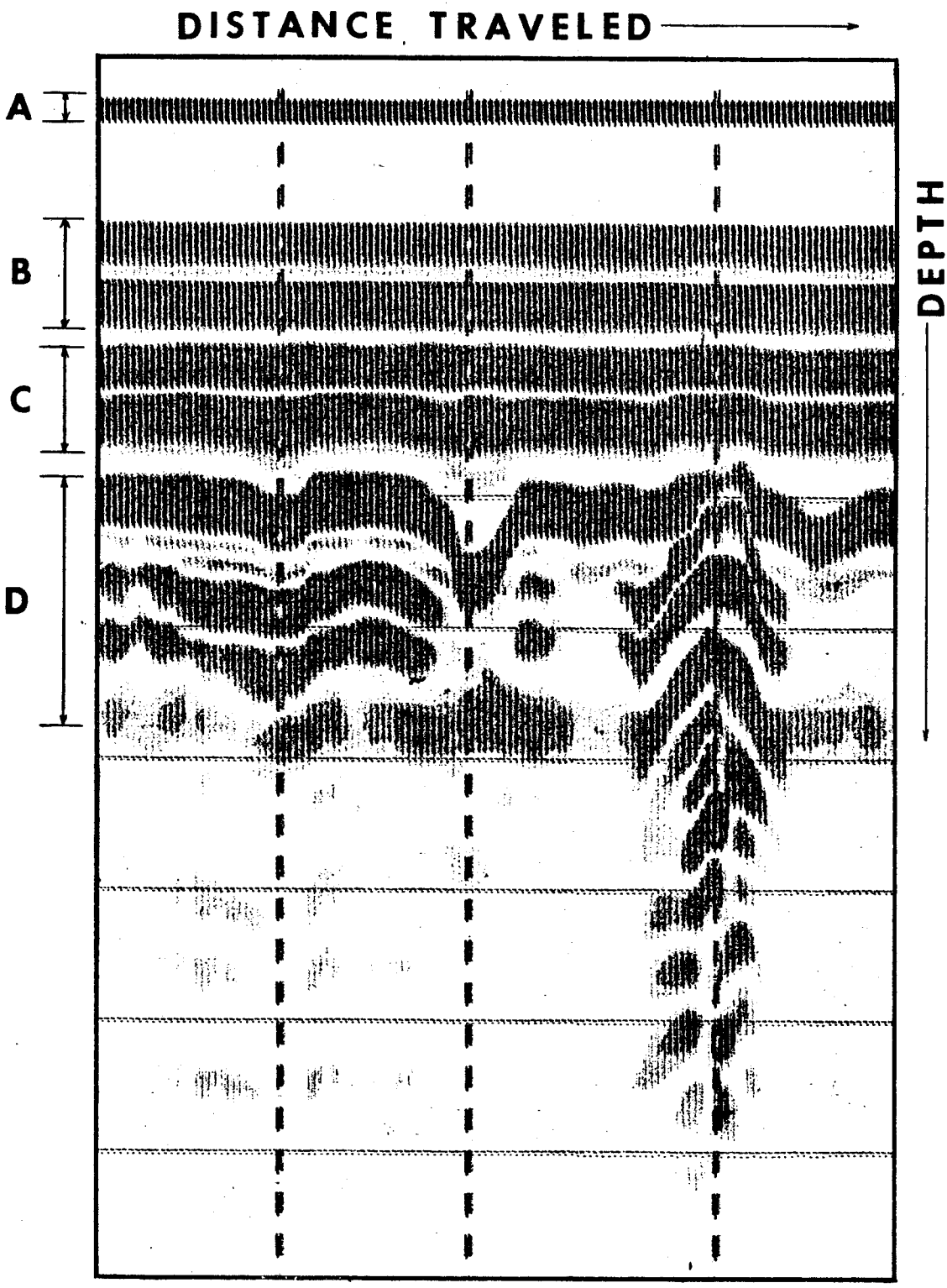
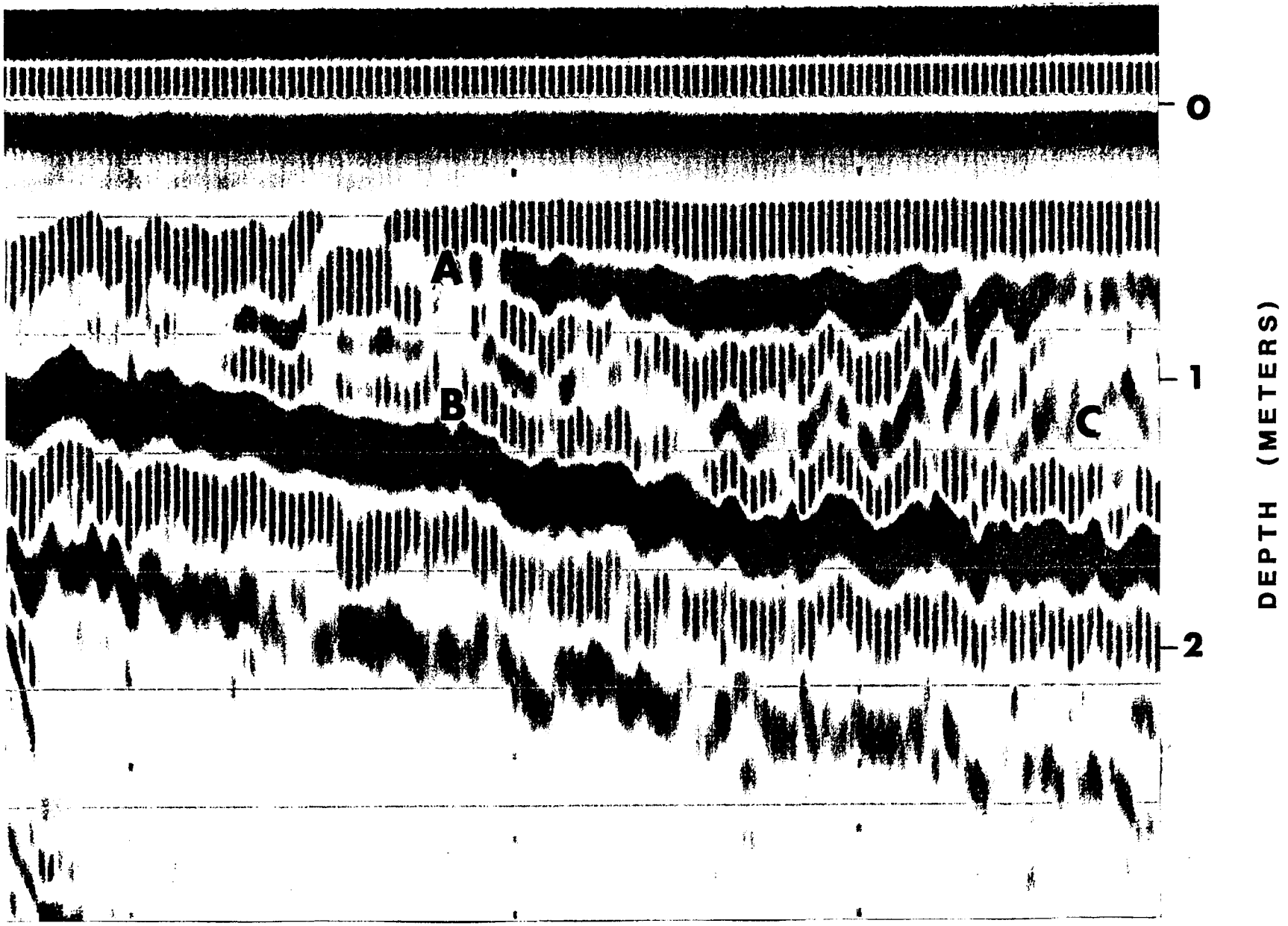
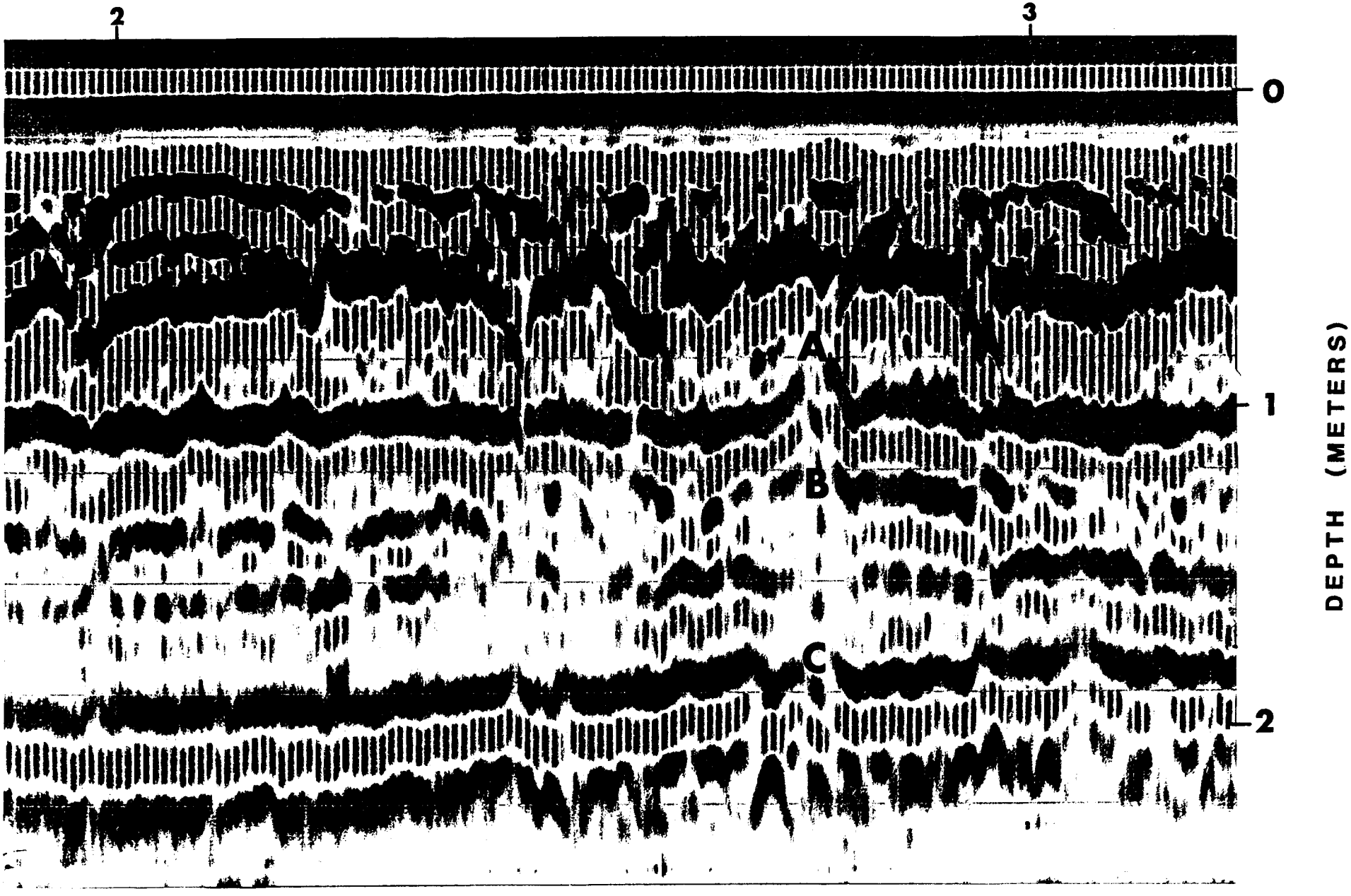


FIG. 1

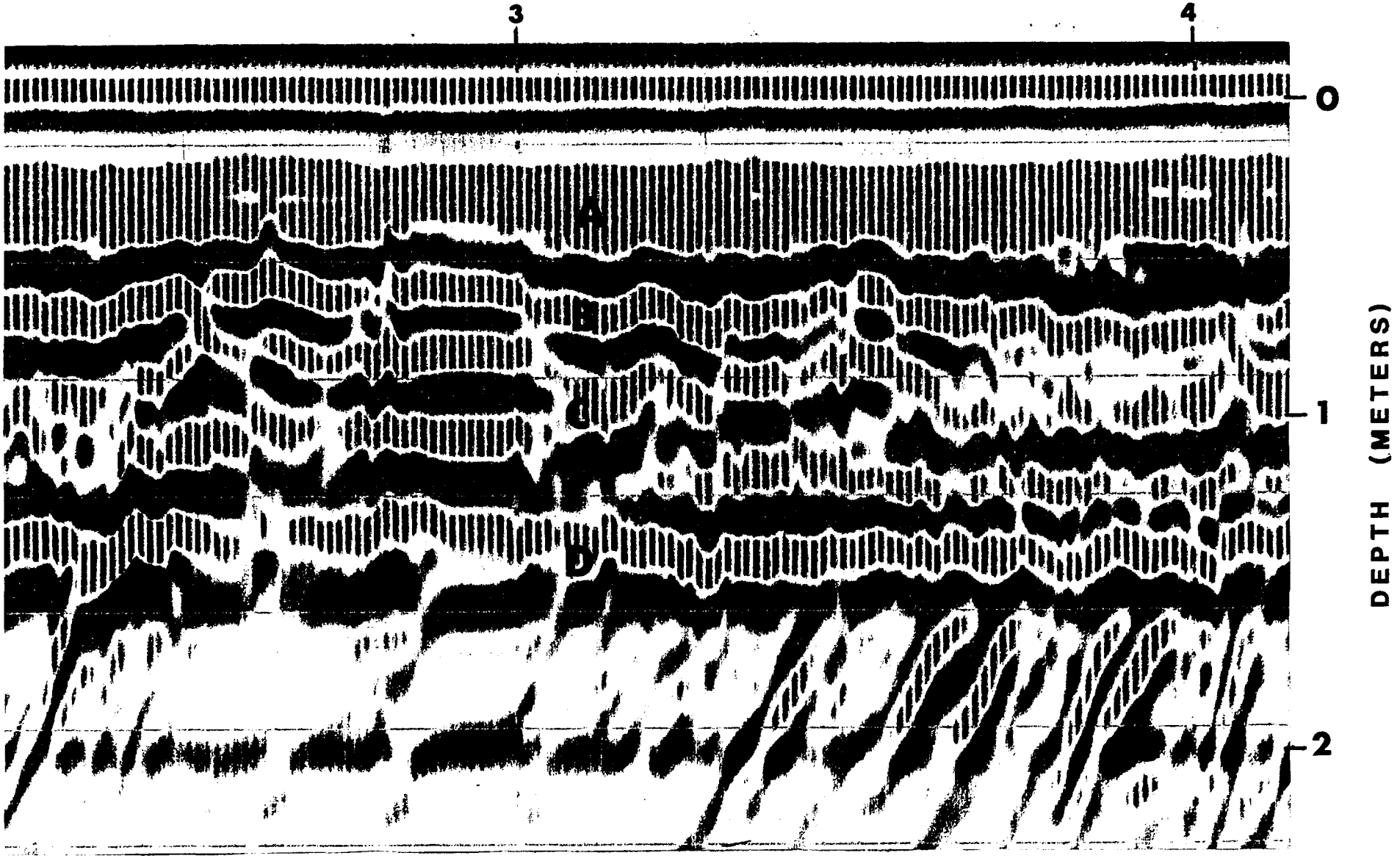
A GRAPHIC PROFILE



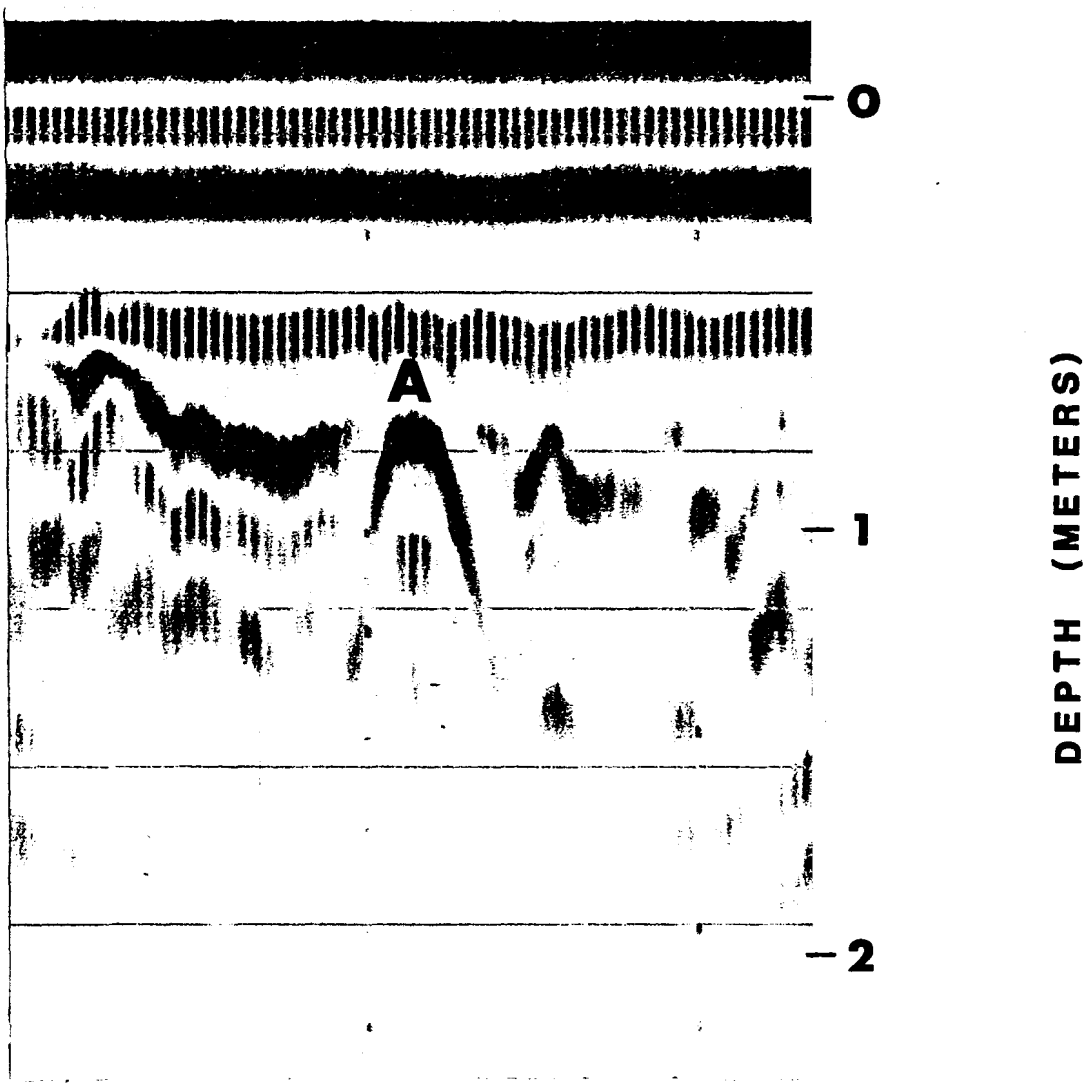
GPR PROFILE FROM AN AREA OF
ARENIC HAPLUDULTS AND AQUIC QUARTZIPSAMMENTS



GPR PROFILE FROM AN AREA OF GREENSBORO SOILS



GPR PROFILE FROM AN AREA OF OTHELLO SOILS



GPR PROFILE OF A SEPTIC TANK