United States Department of Agriculture

Soil Conservation Service

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

Subject: SOI - Ground-Penetrating Radar (GPR) Field Studies in Wisconsin, September 15-21, 1985

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To: Clifton A. Maguire
State Conservationist
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Madison, WI 53711

File Code: 430

PURPOSE

To field test the ground-penetrating radar (GPR) in Wisconsin and to evaluate the system's performance and potential applications.

PARTICIPANTS

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EQUIPMENT

The GPR equipment used during this field trip consisted of the SIR System-8 with microprocessor, the ADTEK SR-8004H graphic recorder, and the ADTEK DT-6000 tape recorder. The 80, 120, and 300 MH_z antennas were used at various times and under differing conditions.

The equipment operated well with two exceptions. The Model 705DA transducers operated erratically and eventually failed to transmit a signal as a result of loose and disconnected lead wires to the terminal connections. Repairs made during the evening of September 16 prolonged the field operation of these transducers. On the afternoon of September 19, the field study was terminated following erratic recordings of the radar signal. This malfunctioning was caused by the repeated vibration of the antennas and the parting of the resoldered lead wires in the transducers.

During field operations on September 18, a wheel supporting the 80 MH_z antenna fell off. This mishap is attributed to faulty equipment design. Subsequent to this field trip, the entire radar unit was returned to the manufacturer for corrective maintenance and an evaluation of the problems encountered in the field.

Although the 80, 120, and 300 MH_z antennas and a high power transmitter were used during the field work, the 120 MH_z antenna was preferred for soil investigations. The 120 MH_z antenna provided the best balance of resolution and probing depth. The 80 MH_z antenna was preferred for the geologic investigations conducted near Babcock.

ACTIVITIES

The GPR unit travelled from field assignments in Nebraska to Lancaster, Wisconsin on September 15. Soil investigations were conducted with the GPR at the Lancaster Agricultural Experiment Station on September 16, in Juneau County on September 17, and in Jackson County on September 19, 1985. A deeper stratigraphic study, investigating possible outlets of Glacial Lake Wisconsin, was conducted near Babcock on September 18, 1985. Equipment malfunctions necessitated the cancellation of scheduled activities on September 20, 1985, and my early return to the NENTC.

Field Results

At the Lancaster Experiment Station, the limited probing depth of the GPR in areas overlain by loess from the Missouri source region was confirmed. Previous studies near Vicksburg, Mississippi; Memphis, Tennessee; and in southeastern Minnesota have revealed high rates of signal attenuation and limited profiling depths in soils formed in loess. Generally, high rates of signal attenuation limit profiling of soil features to depths of less than one meter.

In an area of Dubuque (fine-silty, mixed, mesic Typic Hapuldalfs) soils, discernable features were limited with the radar to the upper 35 to 50 cm of the soil profile (see Figure 1). Below this depth, signal attenuation and weak electrical gradients between soil horizons resulted in "white-out areas" (zones of no signal return). In Figure 1, the upper boundary of a structural B horizon is apparent and has been highlighted with a dark line. Variations in the intensity of the image of the B horizon are related to variations in soil moisture and consistency. A strong reflection (A in Figure 1) is produced when the structural B horizon is relatively dry and firm. Moisture areas, having a more friable B horizon, produce a weaker reflection (see B in Figure 1). Generally, the more abrupt or contrasting an interface, the stronger the reflected signal and the darker the image. In this profile of Dubuque soil, moisture has, in places, diluted the electrical gradient between the surface layer and the subsoil, and contributed to the variation in the gray scale apparent along this interface.

The range of the radar was extended on repeated transects in Dubuque soils. However, the GPR was unable to discern the upper contact of the fine textured (60-70% clay) residuum and the residuum/bedrock interface.

The GPR has excellent potential in areas of coarse and moderately-coarse textured soils similar to those studied in Juneau County. Compared with conventional methods, the GPR provides a continuous record of subsurface features, is many times faster, minimizes the number of required borings, allows larger areas to be sampled per observation, and is less likely to miss inclusions. To illustrate these points, an area that had been mapped as Plainbo (mixed, frigid Typic Udipsamments) soils was transected with the GPR in Juneau County. The GPR completed a 1,000-ft transect in about four minutes. Although the continuous record appearing on the graphic profile could have been divided into a large number of observation points, ten observation sites had been referenced in the field with flags. As the antenna passed by each of these flags, the operator depressed an event marker which impressed a vertical pattern of reference marks on the graphic profile (Figure 2).

In Figure 2, the graphic profile reveals two distinct subsurface interfaces. These interfaces are the upper contact of an argillic horizon and the Cr horizon. The upper contact of the Cr horizon has been highlighted with a dark line; the argillic horizon is represented by the dark, overlying, subparallel band. The presence of the argillic horizon necessitated a re-evaluation of the delineation and a reclassification of the dominant soil (loamy, mixed, mesic Arenic Hapludalfs).

Why had the argillic horizon been missed during mapping? With conventional surveying tools, errors often result as a consequence of the small area actually observed and the incompleteness of soil definition at lower depths. While confirming the radar imagery along this transect with conventional tools (Oakfield probe), the soil was identified as Plainbo at an observation site where the GPR had profiled the Arenic Hapludalfs. However, after enlarging the observation site, it was apparent that the auger had entered a "hole" in the argillic horizon. Perhaps the argillic horizon is like swiss cheese and should be designated as a Bt/E horizon, but as profiled with the radar, it is continuous across the delineation.

The GPR, by averaging the characteristics of the interface within its arc of radiation, provided a better understanding of the dominant subsurface conditions, and has helped to improve our interpretations.

Water tables are apparent on graphic profiles of coarse textured soils. In coarse textured soils, the capillary fringe is abrupt producing a pronounced electrical gradient and strong images on most graphic profiles. As the amount of fines increase, the capillary fringe becomes more diffuse and the image of the water table becomes more indistinct. Also, as the number of subsurface interfaces increase, images of the water table are often superimposed on other images, making identification difficult.

In Figure 3, from an area of Friendship (mixed, frigid Typic Udipsamments) and Plainsfield (mixed, mesic Typic Udipsamments) soils, the water table produces a distinct image across the profile. Immediately above and parallel with the image of the water table is an image produced by the interface of the brownish Bw horizon with the gray C horizon. In the extreme right-hand portion of this profile, a distinct "jog" in these interfaces can be observed. This inflection corresponds with a major slope break.

Figure 4 is from an area of Loxley (Dysic Typic Borosaprists) soils in an open bog near Millston, Wisconsin. Remotely sensed imagery used by SCS provides a measure of the areal extent of peat deposits. With the GPR, it is possible to quickly assess the volume of peat reserves, estimate the thicknesses of layers varying in degrees of humification, and profile variations in the topography at the base of the organic materials.

In Figure 4, features have been identified on the basis of experience and casual observations made in the field rather than ground-truth data. Admittedly, more field work is necessary to identify the interfaces with a higher degree of confidence. But the imagery is exceptional in terms of detail and depth of penetration. The strong reflections from the organic (oa)/mineral (c) interface are readily apparent. Interfaces evident in the organic material are believed to represent variations in humification, bulk density, water content, and/or structure. The distinct sub-bottom layers are presumably stratifications within the underlying Eau Claire Formation.

CONCLUSIONS

This brief field investigation has demonstrated some of the limitations and potentials of present GPR technology in Wisconsin. Results, based on effective depth of penetration, range from poor in the fine-silty soils of southwestern Wisconsin to excellent in the coarse and moderately-coarse textured mineral soils and in the organic soils of central Wisconsin. At most sites, the quality of interpretations can be improved with additional field experiences. At all sites, the GPR provided some information. The significance of this information depends upon the needs of the user. Even when restricted to depths of less than 50 cm, as in the area of Dubuque soils, the GPR provided information concerning surface and near surface phenomenon. In other areas, results are most encouraging and similar to those obtained in Florida, where the GPR technology has become an established quality control and investigatory tool for soil operations.

The GPR is not the panacea for all our soil surveying needs; no one single tool is! However, if desires and needs are present, current GPR systems can be used as efficient, complimentary tools for soil survey investigations in many areas of Wisconsin.

A complete record of all graphic profiles have been returned to John Brubacher, State Soil Scientist, under a separate cover letter.

James A. Doolittle

James A. Doolittle
Soil Specialist (GPR)

Enclosures

cc:
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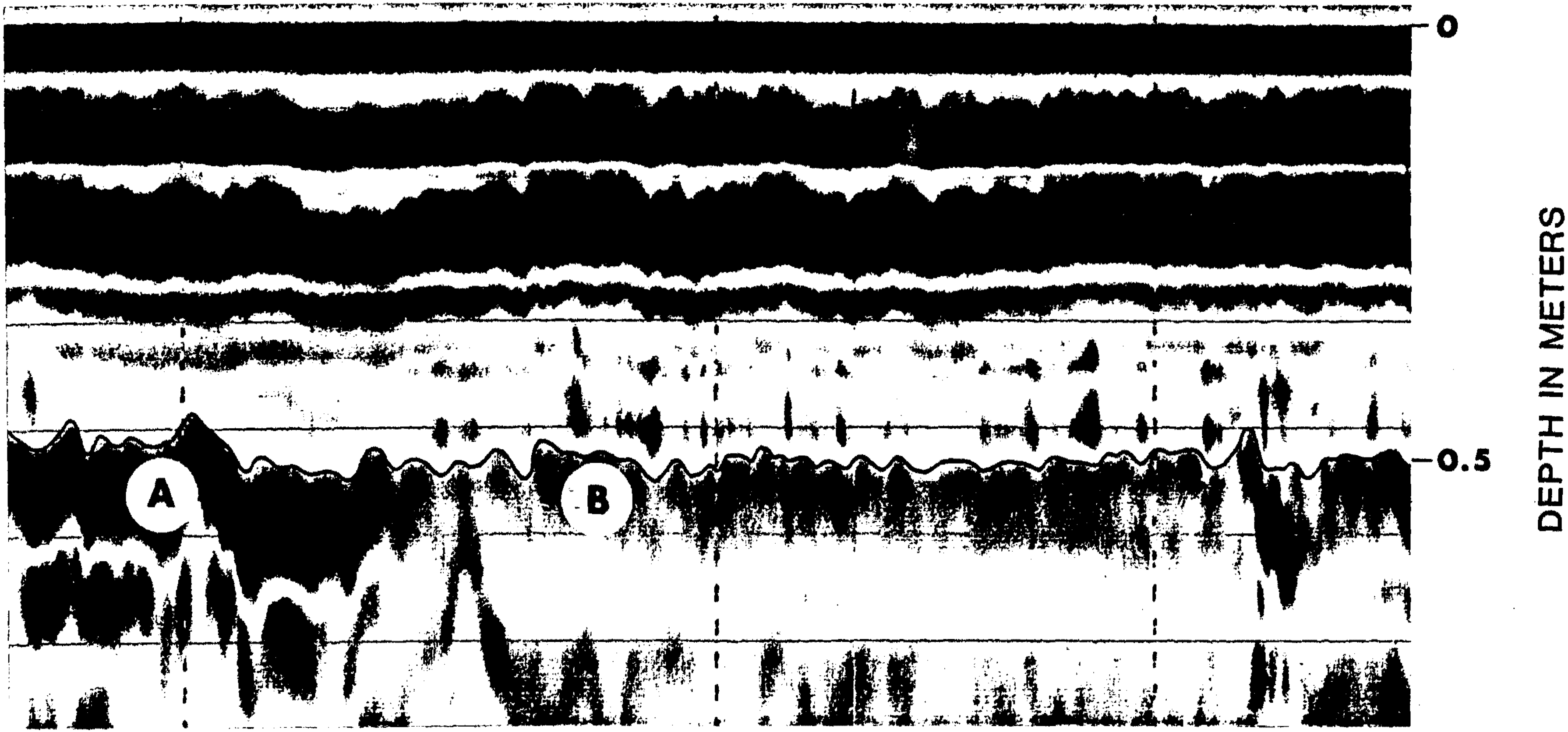
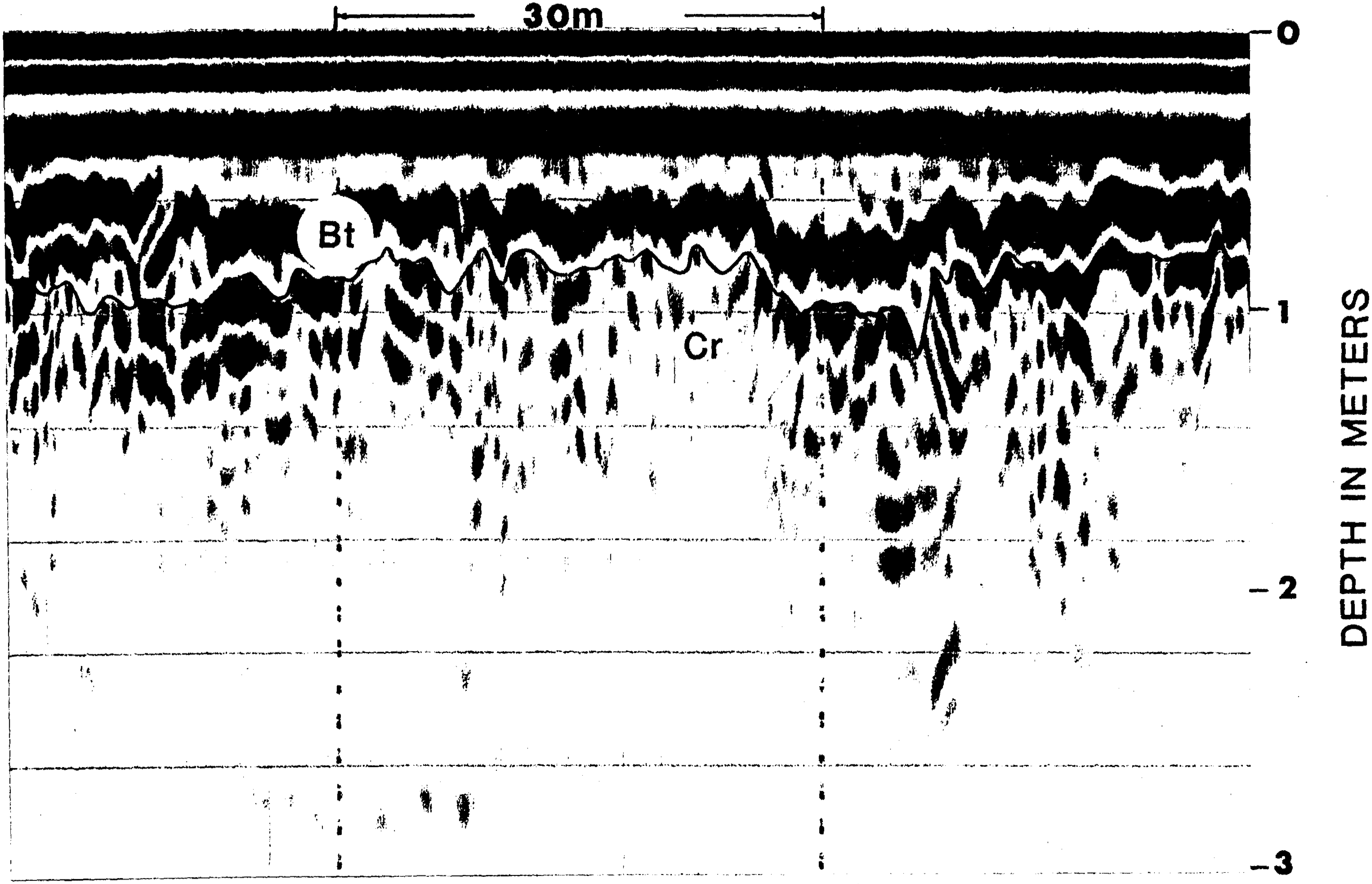
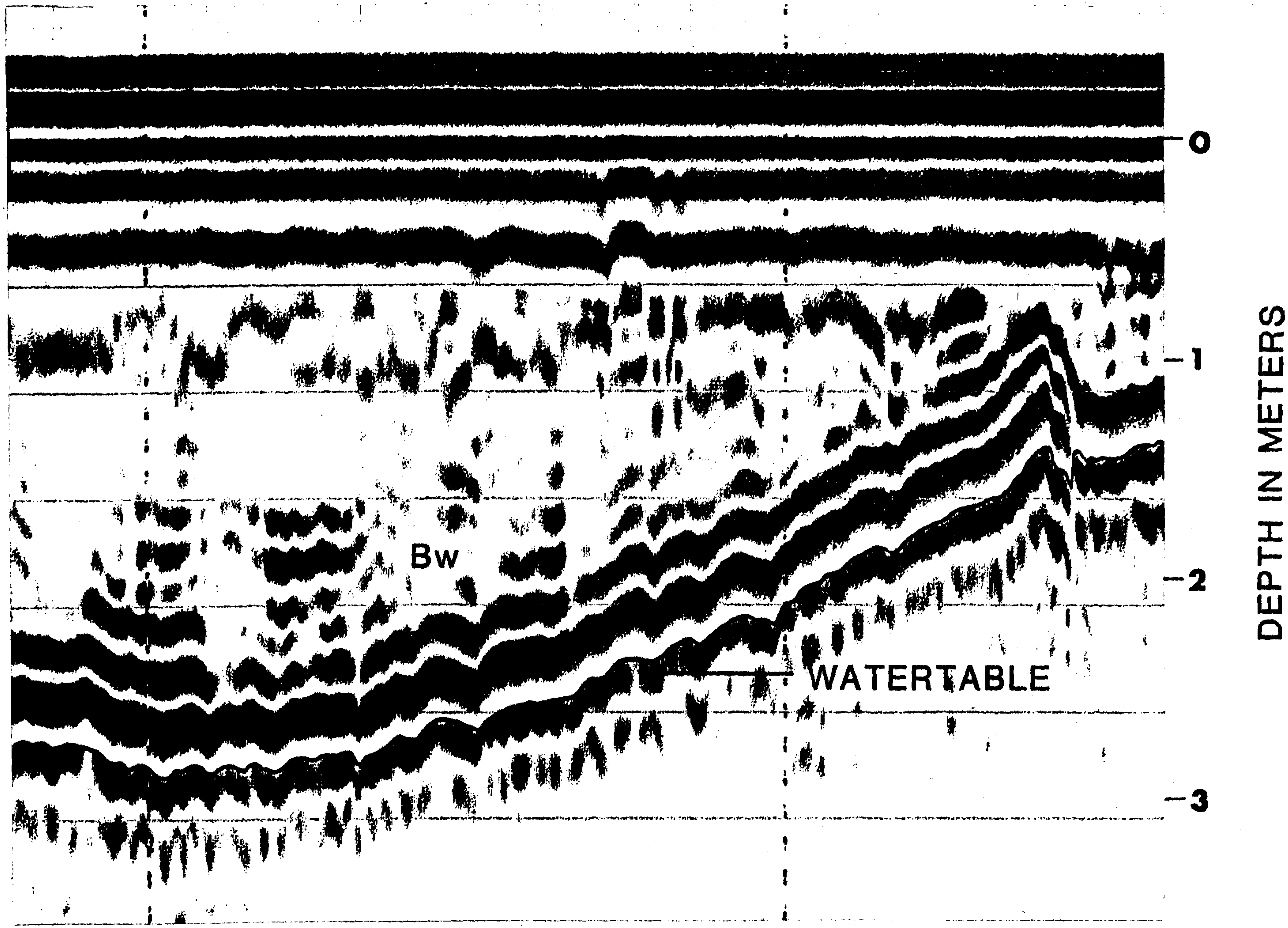


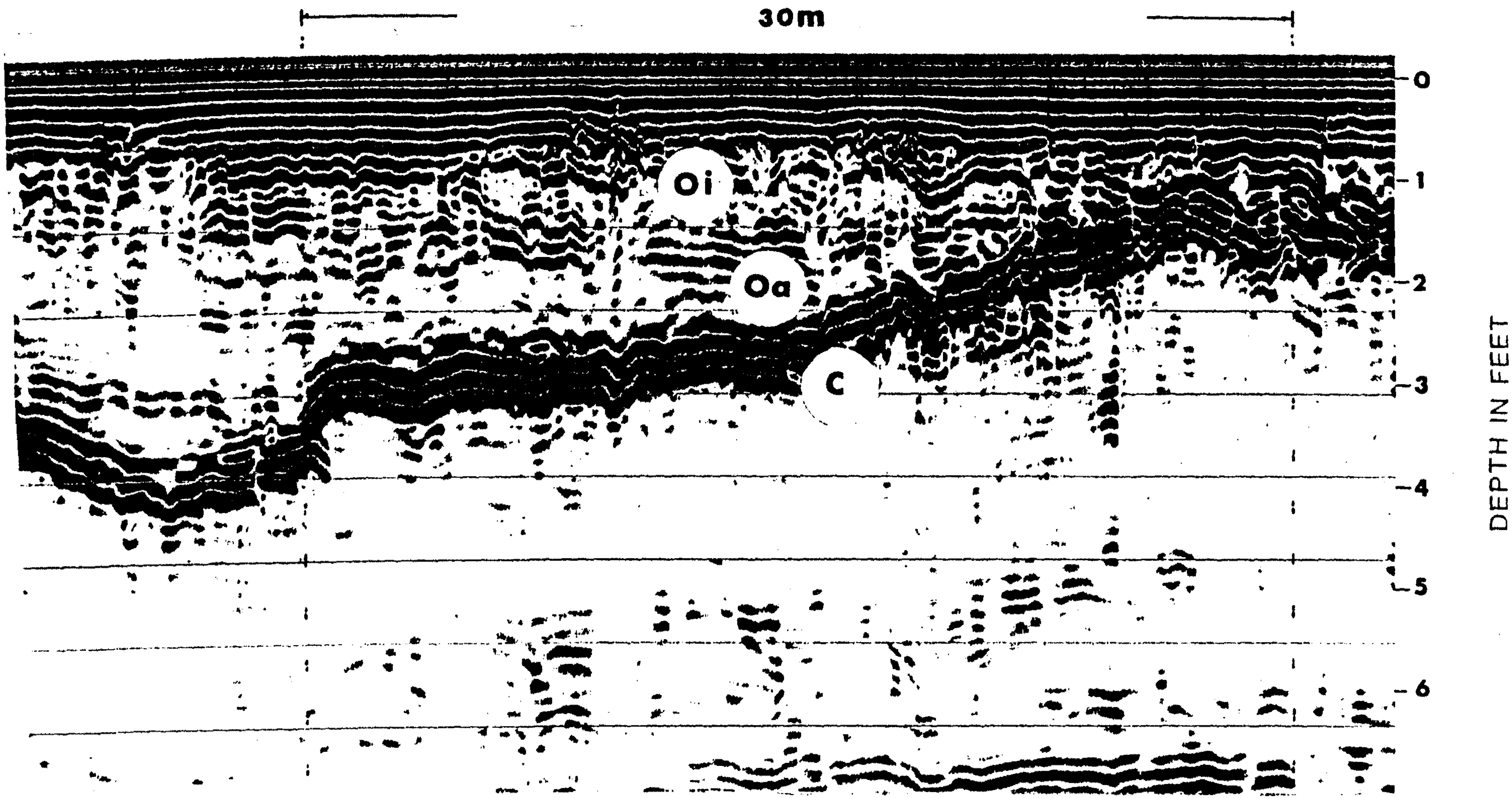
LIMITATIONS OF GPR IN AN AREA OF DUBUQUE SOILS
(FINE-SILTY, MIXED, MESIC TYPIC HAPLUDALFS)



PROFILING THE DEPTHS TO AN ARGILLIC HORIZON AND SANDSTONE BEDROCK



DEPTH TO WATERTABLE IN AREA OF TYPIC UDIPSAMMENTS



GRAPHIC PROFILE FROM AN AREA OF LOXLEY (DYSIC TYPIC BOROSAPRISTS) SOILS