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PURPOSE:

The purpose of this investigation was to further explore the suitability of ground-penetrating radar (GPR) for soil investigations in the southern Appalachian. In addition, training was provided to Wes Tuttle on the use, operation, and maintenance of the SIR System-2 radar.

PARTICIPANTS:

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ACTIVITIES:

All field activities were completed during the period of 3 to 5 November 1998.

EQUIPMENT:

The ground-penetrating radar (GPR) unit used in this study was the Subsurface Interface Radar (SIR) System-2, manufactured by Geophysical Survey Systems, Inc.[1] The SIR System-2 consists of a digital control unit (DC-2) with keypad, VGA video screen, and connector panel. A 12-volt battery powered the system. Morey (1974), Doolittle (1987), and Daniels and others (1988) have discussed the use and operation of GPR. A model 5106 (200 mHz) antenna was used in this investigation. A 12-volt battery powered the system. The scanning time was 60 nanoseconds.

FIELD PROCEDURES:

Pulling the antenna across selected sites in Buncombe County, North Carolina, completed radar surveys. Site selections were based upon soil and bedrock units.

Although, GPR provides a continuous profile of subsurface conditions, interpretations were restricted to observation points. These observation points were spaced at distances of about 30 feet along traverse lines. At each observation point, the radar operator impressed a dashed, vertical line on the radar profile. This line identified an observation point on the radar record. Radar records were reviewed in the field.

DISCUSSION:

[1] Trade names have been used in this report to provide specific information. Their use does not constitute endorsement.

Ground-penetrating radar is a time scaled system. This system measures the time that it takes electromagnetic energy to travel from an antenna to an interface (e.g., soil horizon, stratigraphic layer, bedrock surface) and back. To convert the travel time into a depth scale, either the velocity of pulse propagation or the depth to a reflector must be known. The relationships among depth (d), two-way, pulse travel time (t), and velocity of propagation (v) is described in the following equation (Morey, 1974):

$$v = 2d/t$$

The velocity of propagation is principally affected by the dielectric permittivity (e) of the profiled material(s) according to the equation:

$$e = (c/v)^2$$

Where c is the velocity of propagation in a vacuum (1 ft/nanosecond). Velocity is expressed in feet per nanosecond (ns). A nanosecond is one billionth of a second. The amount and physical state (temperature dependent) of water have the greatest effect on dielectric permittivity.

Velocities of propagation and depth scales were calculated at each site. A metallic reflector was buried at depths of about 19 or 20 inches. The depth to this reflector was used to determine the dielectric permittivity and velocity of propagation. Based on the round-trip travel time to the buried reflector, the averaged velocity of propagation through the upper part of the soil profile was determined. Table 1 lists the calculated velocities of propagation and the dielectric permittivity.

Table 1

Results of Calibration Trials

Map Unit	Velocity	Dielectric Permittivity
Evard-Cowee complex	0.3694 ft/ns	7.04
Oteen-Walnut-Marshall complex	0.4998 ft/ns	3.84
Tusquitee gravelly loam	0.4032 ft/ns	5.92
Dellwood-Reddies complex	0.4500 ft/ns	4.74
Burton-Craggy complex	0.4032 ft/ns	5.92

The velocity of propagation and the dielectric permittivity of these map units are remarkably similar. The similarity is related to comparable soil texture and water contents. At the time of this investigation, soils were dry.

For the purpose of this investigation, soils were considered uniform and large differences in the velocity of propagation were not assumed to exist along traverse lines. Unquestionably, this is not true and slight discrepancies exist in all depth measurements. While the actual measurements are considered close approximations, the grouping of observation points into relative soil depth classes (shallow, moderately deep, deep, and very deep) is more accurate and is preferred.

RESULTS:

Evard-Cowee complex

Ground-penetrating radar can be used successfully to document the depth to bedrock in areas of Evard and Cowee soils. In areas of these soils, GPR provided highly complex, but interpretable images of the depth to bedrock. These well-drained soils formed in residuum weathered from felsic to mafic, igneous and high-grade metamorphic rocks. These soils are members of the fine-loamy, parasesquic, mesic Typic Hapludults family. Evard soil is very deep and Cowee soils is moderately deep over bedrock.

In an earlier trip report (my report of 14 July 1997), the potential of using ground-penetrating radar to chart the depths to Cr and R materials was described. It was concluded in this report, that in areas of Evard and Cowee soils, with experience, it would be possible to differentiate weathered from unweathered rock materials with little ambiguity.

Traverse lines 1 and 2 were completed in an area of Evard-Cowee complex, 15 to 30 percent slopes. Traverse line 1 was conducted along a ridgeline and consisted of 16 observation points. Traverse line 2 was conducted along upper side slopes and consisted of 10 observation points. Along these traverses, bedrock was shallow (0 to 20 inches) at 4 percent, moderately deep (20 to 40 in) at 27 percent, deep (40 to 60 in) at 50 percent, and very deep (>60 in) at 19 percent of the observation points. The following tables listed the interpreted depths to bedrock along these two traverse lines.

Traverse # 1

35^{o}29'04.69 N Lat. 82^{o}36'05.74 W Long.

(All depths are in inches.)

Observation	Depth
1	66
2	60
3	51
4	45
5	21
6	18
7	46
8	30
9	28
10	65
11	58
12	30
13	26
14	53
15	40
16	41

Traverse # 2

35^{o}29'03.77 N Lat. 82^{o}36'09.08 W Long.

(All depths are in inches.)

Observation	Depth
1	53
2	42
3	41
4	43
5	45
6	66
7	55
8	72
9	48
10	37

Traverse lines 3 and 4 were completed in an area of Evard-Cowee complex, 30 to 50 percent slopes. These traverses were conducted along side slopes and consisted of 15 observation points. Along these traverses, bedrock was moderately deep (20 to 40 in) at 20 percent, deep (40 to 60 in) at 60 percent, and very deep (>60 in) at 20 percent of the observation points. The following tables listed the interpreted depths to bedrock along these two traverse lines.

Traverse # 3

35^{o}29'05.67 N Lat. 82^{o}36'09.44 W Long.

(All depths are in inches.)

Observation	Depth
1	40
2	45
3	45
4	53
5	43
6	37
7	56

Traverse # 4

35°29’06.23 N Lat. 82°36’11.44 W Long.

(All depths are in inches.)

Observation	Depth
1	48
2	71
3	66
4	89
5	40
6	50
7	58
8	43

<u>Oteen–Walnut–Marshall complex</u>

Ground-penetrating radar was found to be an inappropriate tool for documenting depths to bedrock in areas of Oteen–Walnut–Marshall Complex. These well-drained soils formed in residuum weathered from felsic to mafic, igneous and high-grade metamorphic rocks. High base saturation and the abundance (common to many) of mica flakes are believed to be the principal soil factors attenuating the radar’s signal and limiting the GPR’s observation depths. Oteen soil is a member of the loamy, mixed, shallow Dystric Eutrochrepts family. The moderately deep Walnut and the deep Marshall soils are members of the coarse-loamy, mixed, mesic Dystric Eutrochrepts family.

<u>Dellwood-Reddies complex</u>

These moderately well drained soils formed in alluvium on flood plains. Dellwood soil is a member of the sandy-skeletal, mixed, mesic Fluventic Haplumbrepts family. Reddies soil is a member of the coarse-loamy over sandy or sandy-skeletal, mixed, mesic Fluventic Haplumbrepts family. Dellwood soil is shallow and Reddies soil is moderately deep over sandy strata containing more than 35 percent gravel and cobbles.

Ground-penetrating radar provide exceptional depths of observation (greater than 34 feet in some areas) and good resolution of subsurface features in areas of Dellwood-Reddies complex. Some stratification and numerous point reflectors (presumed to be cobbles) were observed on radar profiles. However, strata were poorly expressed, highly segmented, and difficult to chart for long distances. Rock fragments produced numerous reflectors that disrupted and masked some subsurface layers. No water table was observed on the radar profiles. The water table may have been below the depth of observation. Radar can be used to distinguish areas of Dellwood and Reddies soils, and to determine the thickness recent loamy alluvium and coarse-textured alluvial sediments.

<u>Tusquitee gravelly loam</u>

This very deep, well drain soil formed in colluvium on benches and fans in coves. Tusquitee is a member of the fine-loamy, isotic, mesic Umbric Dystrochrepts family. The soil contains less than 35 percent rock fragments in the upper 40 inches. Rock fragments may range up to 60 percent below a depth of 40 inches.

Depth of observation ranged from about 9 to greater than 16 feet. The 200 mHz antenna provided good resolution of subsurface features in areas of Tusquitee gravelly loam. Soil horizons, strata, and numerous point reflectors (presumed to be cobbles) were observed on soil profiles. A highly attenuating subsurface interface restricted observation depths. Because of the rapid rate of signal attenuation below this interface, the underlying materials are considered dissimilar from the overlying colluvium. The underlying materials are presumed to be bedrock. The depth to this interface averaged 8.9 feet and ranged from about 5.8 to 12.2 feet. In some areas of Tusquitee soils, GPR can be used effectively to determine the thickness of colluvium and depth to bedrock .

Burton-Craggy complex

Ground-penetrating radar can be used successfully to document the depth to bedrock in areas of Burton-Craggy complex. The 200 mHz antenna provided highly complex, but interpretable images of the depth to bedrock. These soils formed in residuum affected by mass wasting of materials weathered from felsic to mafic, igneous and high-grade metamorphic rocks. Burton soil is well drained and moderately deep to bedrock. Burton soil is a member of the fine-loamy, isotic, frigid Typic Haplumbrepts family. Craggy soil is somewhat excessively drained and shallow to bedrock. Craggy soil is a member of the loamy, isotic, frigid Lithic Haplumbrepts family.

Two traverses were completed in an area of Burton-Craggy complex. Traverse #1 was conducted along a ridgeline. Traverse # 2 was conducted along a side slope leading to the Blue Ridge Parkway. Along these traverses, bedrock was shallow (0 to 20 inches) at 18 percent, moderately deep (20 to 40 in) at 44 percent, deep (40 to 60 in) at 20 percent, and very deep (>60 in) at 18 percent of the observation points. The following tables listed the interpreted depths to bedrock along these two traverse lines.

Traverse # 1

35°42’39.58” N Lat. 82°21’ 50.35” W Long.

(All depths are in inches.)

Observation	Depth
1	19
2	22
3	26
4	38
5	09
6	21
7	32
8	22
9	27
10	21
11	24
12	36
13	43
14	27
15	15
16	27
17	27
18	30
19	17
20	14
21	19
22	72
23	71
24	45
25	51
26	44

Traverse # 2

35°42’45.27” N Lat. 82°21’ 48.41” W Long.

(All depths are in inches.)

Observation	Depth
1	52
2	89

3	71
4	33
5	25
6	49
7	59
8	64

Summary:

1. This study further demonstrated the suitability of ground-penetrating radar to aid soil surveys in upland areas of MLRA Soil Survey Region 13. Ground-penetrating radar provides an efficient and accurate method to determine the depths to bedrock. Recent developments in GPR technology have resulted in more portable equipment that enabled surveys in the forested and highly sloping terrains of MLRA Soil Survey Region 13.

2. Ground-penetrating radar appears is well suited to bedrock and soil mapping in many upland areas of MLRA Soil Survey Region 13. This region has a large number of active soil surveys. Bedrock and soil data obtainable with GPR will benefit these surveys. Compared with traditional survey methods, GPR is faster and provides a greater number of observations per unit time. Ground-penetrating radar will reduce the time needed to obtain transect data by field soil scientists.

3. On 5 November, training was provided to Wes Tuttle on the use, operation, and maintenance of the SIR-2 System. Wes had assisted with three previous GPR studies and had expressed interest in learning more about this geophysical tool.

With kind regards,

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