SOIL

United States Department of Agriculture

Natural Resources Conservation Service

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Subject: SOI -- Geophysical Assistance --

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Purpose:
The purpose of this investigation was to evaluate the information provided by ground-penetrating radar (GPR) in an area of Kauder soil.

Participants:
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Activities:
All field activities were completed during the period of 21 to 22 September 1998.

Background:
Ground-penetrating radar (GPR) has been used for twenty years to chart the variability of soils and soil properties. In most studies, GPR has proven to be a valuable, noninvasive tool for the detection and accurate depth measurement of features in soils. This geophysical tool has been used to map the spatial variability of spodic horizons (Collins and Doolittle, 1987; Burgoa et al., 1991), the depth to bedrock (Collins et al, 1989; Collins et al., 1990; Doolittle and Collins, 1998), loamy substrata (Farrish et al., 1990), and argillic horizons (Truman et al., 1988); the continuity of ortstein (Mokma et al., 1990); and the thickness of active layers (Doolittle et al., 1990) loess (Rebertus et al., 1989), and peat (Shih and Doolittle, 1984).

Ground-penetrating radar has been used to investigate fragipans (Olson and Doolittle, 1985;Doolittle, 1987; Lyons et al., 1988). In an area of Laidig soils (fine-loamy, siliceous, mesic Typic Fragiudults), variations in the amplitude of the reflected signal were attributed to the abruptness and contrast of materials across the boundary separating the fragipan and overlying horizons (Olson and Doolittle, 1985; Doolittle, 1987). Working in areas of Canfield (fine-loamy, mixed, mesic Aquic Fragiudalfs) and Wooster (fine-loamy, mixed, mesic Oxyaquic Fragiudalfs) soils, Lyons and other (1988) noticed that fragipans produce strong and identifiable reflections. These researchers attributed the strong radar reflections to a significant increase in bulk density, clay and moisture contents across the abrupt upper boundary of fragipans.

In several studies (Collins et al., 1990; Doolittle and Collins, 1998; Truman et al., 1988), GPR was used to chart depths to the argillic horizon. However, in these studies, because of high rates of signal attenuation, the argillic horizon was virtually opaque to GPR and observation depths were restricted to the upper part of the Bt1 horizon. What is surprising in studies of fragipans is the apparent capacity of GPR to penetrate through Bt horizons and discern Btx horizons. Equally surprising in these studies was the inability of GPR to detect the overlying Bt1 and Bt2 horizons. In Laidig, Canfield and Wooster soils, the combined thickness of the Bt1 and Bt2 horizons can be substantial, varying from 6 to 42 inches. Nevertheless, the clay

Where c is the velocity of propagation in a vacuum (0.98 ft/nanosecond). The amount and physical state of water (temperature dependent) have the greatest effect on the dielectric permittivity of earthen materials.

Calibration trials were conducted at the site. The purposes of these trials were to optimize control, select the most appropriate antenna, determine the velocity of propagation through the soil materials, and establish a crude depth scale. A shovel blade was buried in the soil at a depth of 19 inches. The depth to this buried feature was used to estimate the velocity of propagation through the upper soil horizons. Based on the round-trip travel time to this reflector, the velocity of propagation through the upper part of the soil was estimated to be 0.2755 ft/ns with the 200 mHz antenna. The dielectric permittivity was estimated to be 12.8. With a scanning time of 50 ns, the maximum depth of observation was about 6.9 ft.

Results:

Radar Profile:

The 200 mHz antenna provided the best balance of observation depth and resolution. This antenna also provided the most easily interpretable profile of Kauder soil. A portion of this profile is shown in Figure 2. This profile has been processed through the WINRAD software package.[2] Processing was limited to signal stacking, horizontal scaling, color transforms and table customizing. Color transformation and table customization were used to reduce signal amplitudes and background noise. In Figure 2, the horizontal and vertical scale are expressed in feet. The numbers appearing at the top of this figure represent observation points. Observations are spaced at an interval of 5 ft. The vertical scale is a depth scale, which is based on the estimated velocity of signal propagation

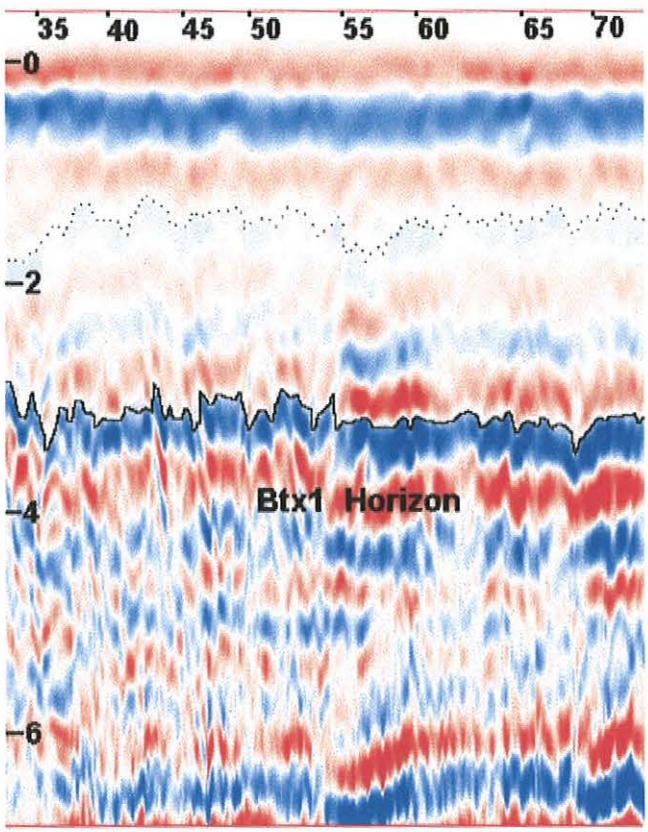

Figure 2 – Portion of the radar traverse in an area of Kauder Soils

In Figure 2, a conspicuously high amplitude, subsurface reflection has been highlighted with a dark line. This interface has a highly irregular topography, which is attributed to the intermingled components and tongues of E material. The interface is continuous across the profile but varies slightly in amplitude and expression. It is presumed that these variations are caused

[2] Trade names are provided for the benefit of the reader and do not imply endorsement.

principally by differences in density and moisture and clay contents across this interface. This interface occurs at an average depth of about 38 inches and has an irregular boundary. The identity of this interface was not known prior to the excavation of the trench. It was presumed to be either the Bt/E or the Btx/E horizon. Several weakly expressed and more discontinuous soil features are detectable in Figure 2 above and below this conspicuous interface. The identities of these interfaces were also unknown prior to excavation.

Comparison of Data on the Depth to Fragipan:

The interpreted depths to the interface most closely approximated the observed depths to the Btx1 horizon. The average depth to the Btx1 horizon measured within the trench was 37.3 inches with a range of 31 to 51 inches. The average depth to the interpreted interface was 38.5 inches with a range of 35.4 to 46.7 inches. Table 1 compares the observed and interpreted depth measurements.

Table 1

Depths to Btx1 horizon observed in trench wall and interpreted from GPR profile.

Station	Observed	Interpreted	Difference
0	51	46.7	-4.3
5	40	43.6	3.6
10	36	36.9	0.9
15	42	35.4	-6.6
20	40	36.4	-3.6
25	38	35.9	-2.1
30	36	41.1	5.1
35	36	36.9	0.9
40	42	38.5	-3.5
45	38	37.2	-0.8
50	33	38.1	5.1
55	37	38.9	1.9
60	39	38.1	-0.9
65	34	38.9	4.9
70	40	38.5	-1.5
75	31	39.0	8.0
80	38	39.0	1.0
85	35	38.0	3.0
90	32	35.0	3.0
95	35	38.0	3.0
100	31	38.5	7.5

Comparatively large differences exist between observed and predicted depths to the Btx1 horizon. The average difference between the observed and interpreted depth to the Btx1 horizon was 3.39 inches with a range of –6.6 to 8.0 inches. One half of the scaled radar imagery was within –1.95 to 3.45 inches of the actual depth to the Btx1 horizon. In addition, the correlation between observed and interpreted measurements was exceedingly low for GPR ($r = 0.5043$). Differences in these measurements and the low correlation can be attributed to the complexity of soil materials, highly irregular boundaries, mismatch between the track of the antenna and the actual point of measurement on the trench wall, and observation and interpretation errors.

Conclusions:

Ground-penetrating radar was used to predict the depth to fragipan (Btx1 horizon) in Kauder soil. The fragipan appeared as a conspicuously high amplitude, continuous subsurface reflector on the radar profile. This reflector was initially believed to be the interface separating the E/B from the Bt/E or Btx/E horizons because of observed soil features and differences in soil density, brittleness, and clay content. However, the interpreted depths to this interface most closely approximated the observed depths to the Btx1 horizon. The average difference between the observed and predicted depths to the Btx1 horizon was 3.39 inches. Differences in measurements ranged from –6.6 to 8.0 inches. A comparatively low correlation ($r = 0.5043$) was found between observed and predicted depths to the Btx1 horizon. The low correlation and the differences in these two sets of measurements were attributed to the complexity of soil materials, highly irregular boundaries, mismatch between the track of the antenna and the actual point of measurement on the trench wall, and observation and interpretation errors. Correlations

should be higher and differences between observed and predicted depths to the Btx1 horizon should be less in soils that lack combination horizons (E/Bt, Bt/E, and Btx/E).

This study confirms the value of *ground-truth* verifications of radar interpretations. Ground-truth verification was required to help confirm the identity of a subsurface reflector.

It was my pleasure to work again in Idaho and with members of your fine staff.

With kind regards,

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