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Soil Conservation Service

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Subject: SOI - Ground-Penetrating Radar (GPR) Field Studies in the Nebraska Sandhills; September 9-13, 1985

Date: October 7, 1985

To: Sherman L. Lewis
State Conservationist
Soil Conservation Service
Lincoln, Nebraska

File Code: 430

PURPOSE

To field test the ground-penetrating radar (GPR) and evaluate the system's performance and potential application in the Nebraska Sandhills.

PARTICIPANTS

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EQUIPMENT

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. The 80, 120, and 300 MH_z antennas were used at various times and under differing soil conditions.

The equipment operated well with the exceptions of the two Model 705DA transducers. These transducers provide the electronics for the 80 and 120 MH_z antennas. Lead wires to the terminal connection became disconnected following repeated changes of the transducers to accommodate the high power transmitter and other antenna permutations. Francis Belohlavy resoldered several disconnected or poorly soldered connections and brought the system back into an operational status. His assistance was vital to completion of this field study.

Although the 80, 120, and 300 MH_z antennas were used in this field study, the 120 MH_z antenna provided the best balance of depth of penetration and resolution of soil features. The 120 MH_z is the preferred antenna for further research and investigations in the Nebraska Sandhills.

ACTIVITIES

The GPR system travelled from Chester, Pennsylvania to Burwell, Nebraska on 7 and 8 September 1985. The equipment was calibrated and tested near the Calamus Dam and along the Calmus River in Loup County on September 9 and on the morning of September 10. Equipment repairs delayed field testing on the afternoon of September 9. Field testing was conducted in Blaine County on the afternoon of September 10, in Rock County on September 11, in Cherry County on September 12, and in Cedar County on the morning of September 13. Rain and inclement weather delayed and hampered field activities throughout the week.

RESULTS

The GPR provided data on the internal lithologic sequences and thicknesses of dunal sand deposits, assessed the nature of the underlying strata, and profiled soil horizons. Following initial calibration and field trials, the GPR provided highly encouraging results. Results are similar to those obtained in Florida, where GPR technology has become an established quality control and investigatory tool for soil survey operations.

In the Sandhills, the best balance of resolution and depth of penetration was achieved with the 120 MH_z antenna. The 80 MH_z antenna did not significantly extend the radar's probing depth and was noticeably inferior to the 120 MH_z antenna in its ability to discern subtle subsurface interfaces. Although the 300 MH_z antenna provided greater resolution of near surface features, it was more depth restricted.

Though the literature has alluded to the potential for deep radar profiling in coarse textured, upland soils (40 to 70 feet), clear and consistent profiles were obtained with the present GPR system to depths of about 20 feet in areas of Valentine (mixed, mesic Typic Ustipsamments) soils. The more restricted than expected probing depths can be attributed, in part, to the occurrence of thin multiple bands of lamellae within the profile. Lamellae contain small amounts of illuvial clays. The clays are assumed to be dominantly smectites which are recognized for their rapid dissipation of the radar's energy. While the amount of clay in each lamellae is small, collectively, the cumulative effect (over a depth of 20 feet) appears to be significant.

Depths were further restricted by layers having high contents of silts and clays, high concentrations of soluble salts, and/or saturated conditions. In areas of Sandose (sandy over loamy, mixed, mesic Typic Haplustolls) soils, the radar provided a high quality graphic picture of soil horizons and features to the more impervious 2Bw horizon (see Figure 2). The higher clay content of this horizon rapidly dissipated the radar's energy and restricted the probing depth. In areas of Duda (mixed, mesic Typic Ustipsamments) and Valentine soils, the GPR provided a highly detailed profile and traced the depth to and the lateral variations of the upper contact of the Ogallala formation (see Figure 3). However, little information was provided by the GPR below this carbonate enriched upper contact.

The minimum distance at which the GPR can resolve an interface is generally limited to 1/2 the antenna's wavelength in a medium. Closely spaced or near surface features will not be distinguishable on graphic profiles unless separation is greater than this distance. Resolution is dependent on antenna frequency and such soil features as moisture, clay, and organic matter content. Generally, with the 120 MH_z antenna, soil features present in the upper 7 to 18 inches were often superimposed and not clearly distinguishable on graphic profiles. Using the 300 or 500 MH_z antennas would provide greater resolution of near surface features.

In areas of Valentine soils, the loamy sand lamellae were too indistinct from the surrounding sand matrix to be individually plotted with the 120 MH_z antenna. However, the collective aggregate of lamellae appears to produce a unique and identifiable signature on graphic profiles (Figure 1). Similarly, multiple, closely spaced strata of colluvium, alluvium, or eolian deposits can be identified on graphic profiles while individual layers within the sequence often cannot be discerned.

The interrupted or variable episodes of eolian deposition on inclined surfaces can be seen in Figure 1. In order to "unclutter" this graphic profile, only the negative pulse has been printed. Cross-bedding is well expressed in this profile. Sets of moderately thick, similarly shaped, and essentially parallel beds appear to be separated from other sets by stratigraphic planes. It is difficult to determine the angle of repose of the sands from the graphic profile alone. Regardless of slope, the ground surface is horizontal on all graphic profiles. Presently, to reconstruct the hummocky terrain and the internal angles of repose, the elevation of the surface must be known. The GPR may provide a useful means for unraveling the stratigraphy of these eolian deposits.

In Figure 2, the abrupt textural change from sandy eolian deposits to loamy sediments (2B) has been labeled and can be traced across the profile. However, other less easily identified interfaces are apparent. A cursory investigation of the site revealed the possible identity of these superimposed features. Subparallel with and overlying the 2Bw horizon is a firm and perhaps more dense sand layer (Bwl horizon). Superimposed on this layer is a wetting front. Near surface features (such as the thickness of the organic mat) and beds of eolian deposits account for the other images occurring in this profile.

If data is needed to confirm the composition of soil map units and soil interpretations, the GPR can be an effective tool in the Nebrasks Sandhills. Compared with traditional sampling methods the GPR is (1) many times faster, (2) minimizes required borings, (3) allows greater areas to be sampled per observation, and (4) is less likely to miss inclusions.

The GPR can be used immediately to characterize the composition and variability of soil map units. In Figure 3, the GPR has provided a graphic picture characterizing the depth, nature, and variability of the upper contact of the Ogallala formation. The presence and depth to this contact are criteria for several soil series: Duda (mixed, mesic Typic Ustipsamments), Tassel (loamy, mixed (calcareous), mesic, shallow Ustic Torriorthents), and Valentine (mixed, mesic Typic Ustipsamments). Lateral variations in the degree of cementation are expressed on this profile. The graphic recorder produces images by recording strong reflections (strongly cemented) as black, intermediate reflections in shades of gray, and weak reflections (weakly cemented) as white. Table I provides a statistical summary of the data collected along two transects. With additional field work, expressions of confidence levels and limits can be made. Statistical information similar to the data expressed in Table I assists interpretations and can be included in tabular form in the technical portions of soil survey reports on their supplements.

While most soil features identified on graphic profiles were not examined in sufficient detail to warrant a definitive statement on the effectiveness of the GPR, sporadic probings confirmed the radar potential for soil investigations. Soil features discerned by the radar include: lithologic contacts, stratigraphic sequences, buried layers, colored B horizons, wetting fronts, water tables, and buried rocks or artifacts. With additional field experience in the Sandhills, more features will undoubtedly be added to this list, the interpretative complexities of some profiles will be unraveled, and most soil layers will be identified and traced with a high degree of confidence.

TABLE I

Frequency Distribution by Depth Class

Depth to the Ogallala Formation	Transect Numbers 1	2	X
0-10"	5.5%	0%	3%
10-20"	5.5%	11%	8%
20-40"	33.5%	50%	42%
40-60"	11%	28%	20%
60-72%	11%	11%	11%
>72%	33.5%	0%	16%

Statistical Summary of Transect Data

Name of Map Unit	No. of Transects	Named and Similar Soils	Composition	Dissimilar Soil	Composition
Duda-Valentine complex	2	Duda	42%	Tassel	8%
		Similar (40-72")	31%	Other (0-10")	3%
		Valentine	16%		

In 14% of the area, the upper contact of the Ogallala formation is noncemented. In the other 86% of the area, the upper contact of the Ogallala formation is moderately or strongly cemented.

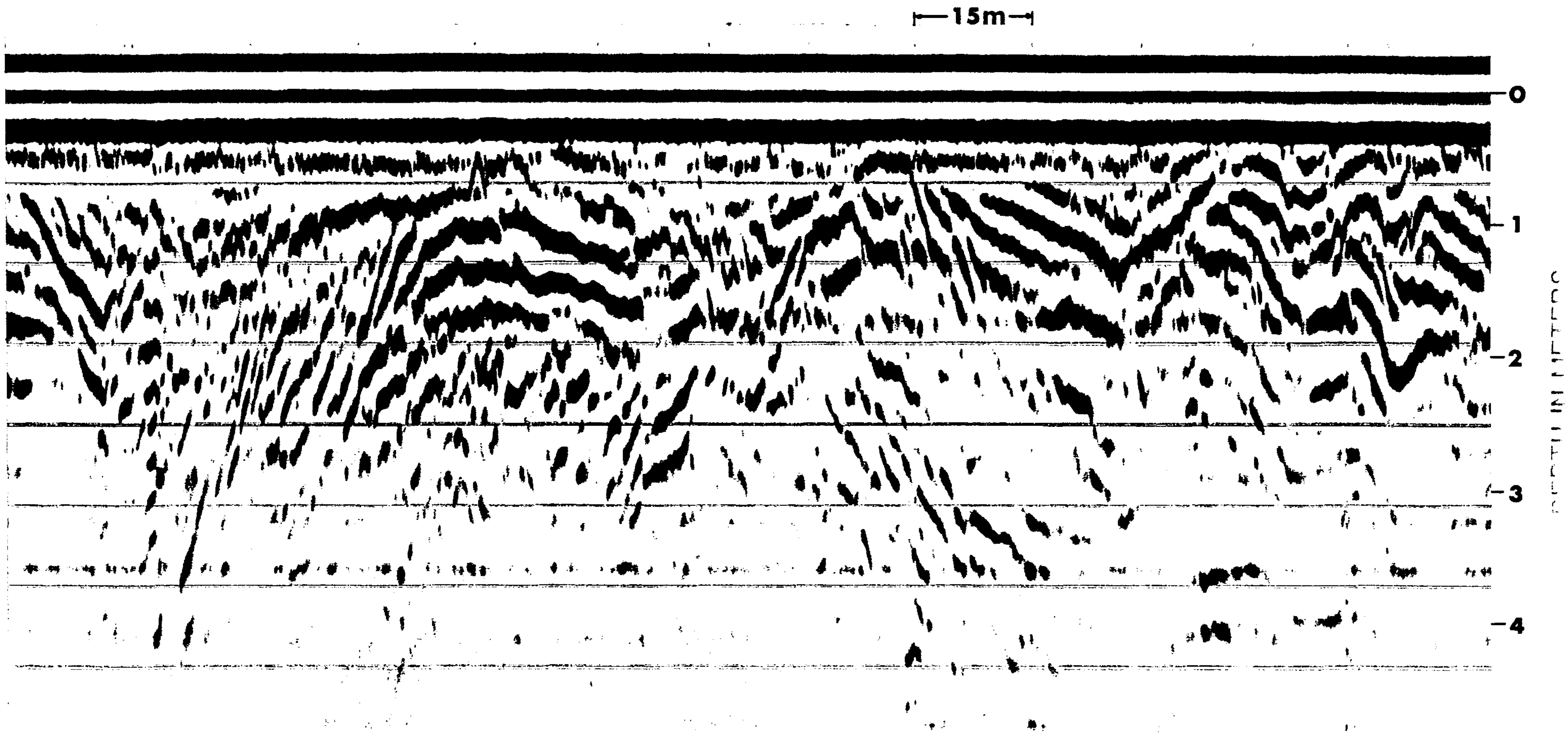
The potential application of the GPR will depend upon its need, use, and program development. The Nebraska Sandhills form a large continuous area having excellent potential for GPR applications. As soil survey parties are now progressing through the Sandhills, the time may be near to assess the utility of GPR technology in Nebraska.

A complete record of all graphic profiles have been returned to Jim Culver under a separate cover letter.

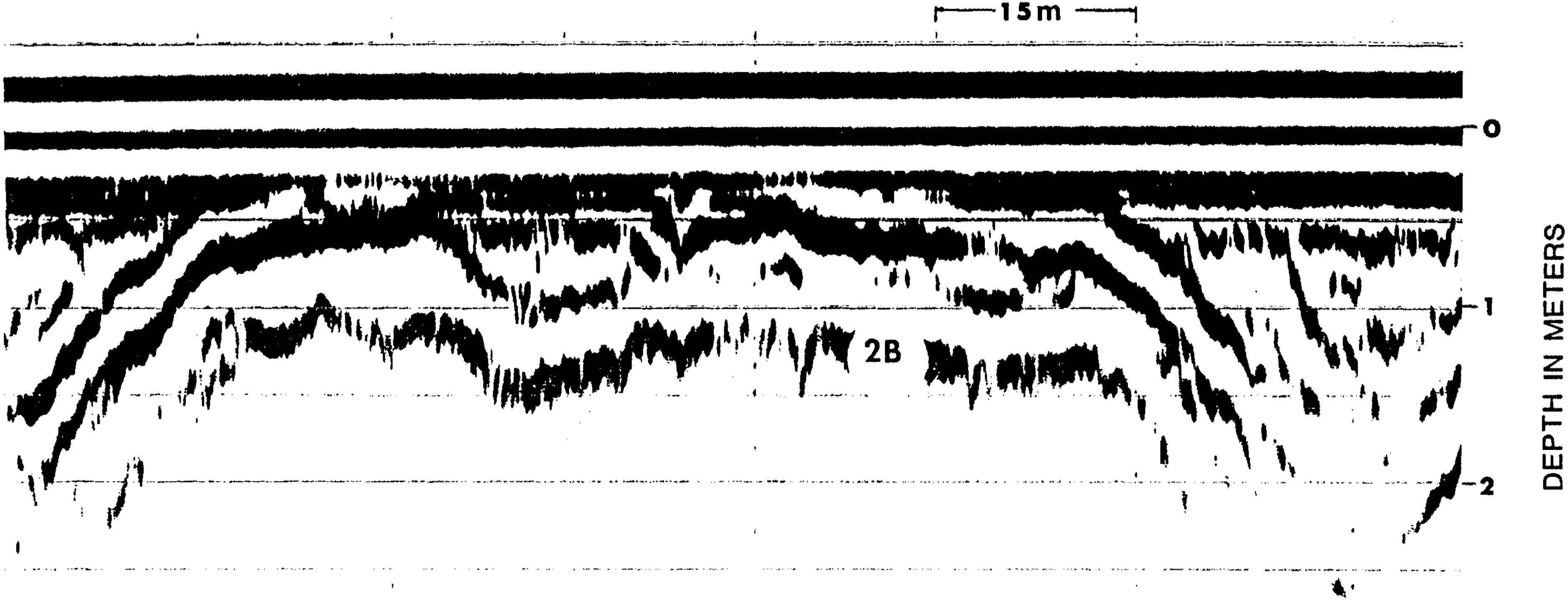
James A. Doolittle
James A. Doolittle
Soil Specialist (GPR)

Enclosures

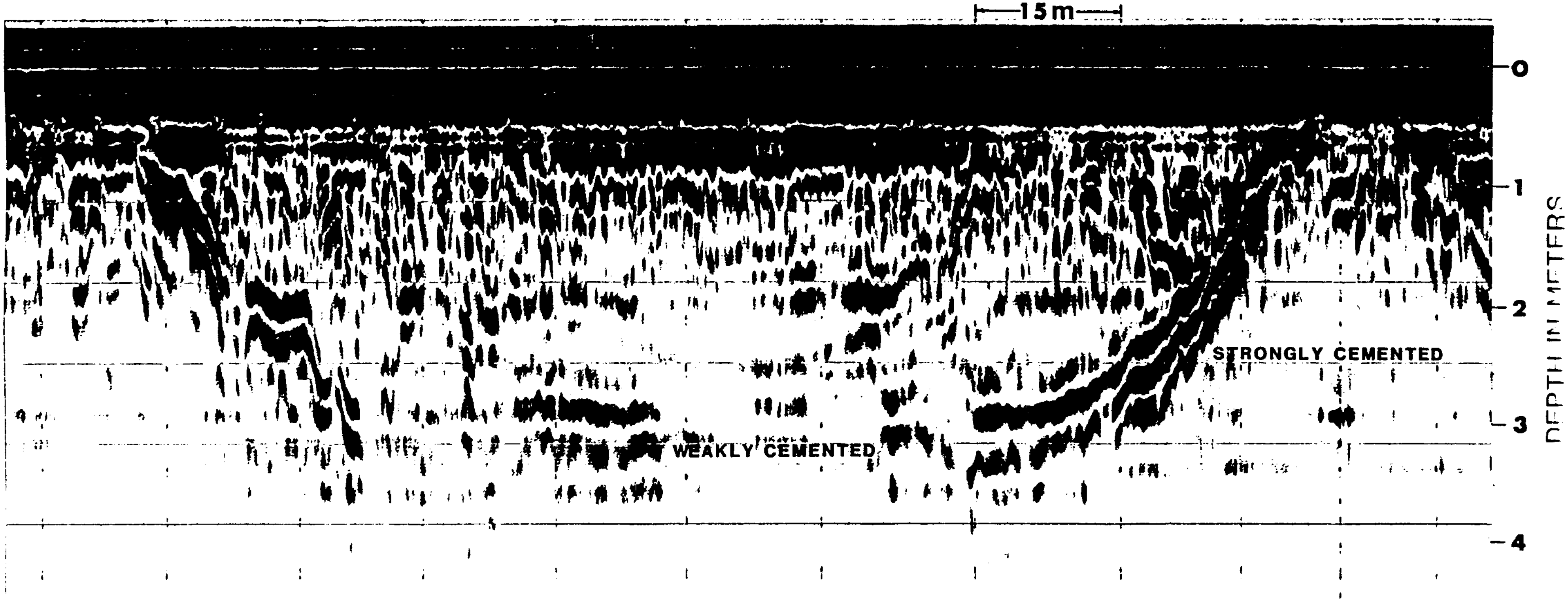
cc:
T. Shiflet w/ enclosures
A. Holland w/ enclosures
R. Arnold w/ enclosures
F. Miller w/ enclosures



CROSS-BEDDING OF EOLIAN SANDS
IN AN AREA OF
VALENTINE (MIXED, MESIC TYPIC USTIPSAMMENTS) SOILS



GRAPHIC PROFILE OF
SANDOSE (SANDY OVER LOAMY ,MIXED, MESIC TYPIC HAPLUSTOLLS) SOILS



CHARACTERISTICS OF THE OGALLALA SANDSTONE
IN AN AREA OF
DUDA AND VALENTINE (MIXED, MESIC TYPIC USTIPSAMMENTS) SOILS