United States Department of Agriculture

Soil Conservation Service

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

Subject: SOI - Field Investigations With Ground-penetrating Radar (GPR); July 7-11, 1986

Date: August 13, 1986

To: Homer R. Hilner
State Conservationist
Soil Conservation Service
1405 South Harrison Road, Room 101
East Lansing, Michigan

File code: 430

PURPOSE

To evaluate the efficiency of GPR techniques to determine the depth to finer textured materials in areas of Plainfield soils and the depth to bedrock in areas of loamy-skeletal soils.

PARTICIPANTS

William Angalone, Soil Scientist, SCS, Sault Sainte Marie, MI
Loren Berndt, Ass't State Soil Scientist, SCS, E. Lansing, MI
Joseph Calos, Soil Scientist, SCS, West Branch, MI
Roger Dekett, Soil Scientist, SCS, Saginaw, MI
Jim Doolittle, Soil Specialist (GPR), SCS, Chester, PA
Joseph Dumont, Soil Scientist, SCS, Cadillac, MI
Ken Farrish, Soil Scientist, SCS, White Cloud, MI
William Frederick, Ass't State Soil Scientist, SCS, E. Lansing, MI
Erling Gamble, Research Soil Scientist, SCS, Lincoln, NE
Carl Gregory, District Conservationist, SCS, Roger City, MI
Karl Hausler, Soil Scientist, MDA, Lansing, MI
Gay Lynn Kinter, Soil Scientist, Saginaw County, Saginaw, MI
Bruce Knapp, Party Leader, SCS, Roger City, MI
Martin Kroell III, Soil Scientist, SCS, Sault Sainte Marie, MI
Dave Lusch, Research Specialist, MSU, E. Lansing, MI
Joseph McCloskey, Party Leader, SCS, Saginaw, MI
Craig Outwater, Soil Scientist, MDA, Roger City, MI
Larry Parault, Soil Scientist, MDA, Sault Sainte Marie, MI
Thomas Porkey, Party Leader, SCS, White Cloud, MI
Richard Rieck, Associate Professor, MSU, E. Lansing, MI
Stephen Rodock, Soil Scientist, SCS, Iron Mountain, MI
Terri Smith, Soil Scientist, MDA, White Cloud, MI
Neil Stroesenreuther, State Soil Scientist, SCS, E. Lansing, MI
Stephen Tardy, Party Leader, SCS, Cheboygan, MI
George Teachman, Soil Scientist, SCS, Cheboygan, MI

John Werlein, Soil Scientist, MDA, Roger city, MI
Mary West, Soil Scientist, SCS, Saginaw, MI
Gregory Whitney, Party Leader, SCS, Kincheloe, MI
Tom William, Soil Scientist, MDA, Cheboygan, MI

EQUIPMENT

The equipment used during this field study was the SIR System-8 with the ADTEK SR-6004H graphic recorder and the ADTEK DT-6000 tape recorder. The 120 MHz antenna with the Model 705DA and 705DA2 transceivers were used. The equipment operated well with no observed malfunctions.

DISCUSSION

Soils in Newaygo and Presque Isle Counties were studied using the ground-penetrating radar. In Newaygo county, the GPR was used to determine the depth to finer textured materials in areas of Brems (mixed, mesic Alfic Udipsamments), Coloma (mixed, mesic, Alfic Udipsamments), Kingsville (mixed, mesic Mollic Psammaquents), Metea (loamy, mixed, mesic Arenic Hapludalfs), Pipestone (sandy, mixed, mesic Entic Haplaquods), Plainfield (mixed, mesic Typic Udipsamments), and Spinks (Sandy, mixed, mesic Psammentic Hapludalfs) soils. The GPR performed exceptionally well on these soils and accurately and consistently charted the depth to the underlying, finer textured materials. The GPR detected the presence of, depth to, and lateral extent of soil features including the water table, cambic horizon, spodic horizon, major tree roots, and geologic stratifications. The GPR provided detailed imagery of the upper 4.5 to 18.3 meters of earthen materials.

In addition to several longer reconnaisance transects, the GPR completed 42 detailed transects in forested areas of Brems, Coloma, Metea, and Plainfield soils. Data from these transects will be used to develop interpretative models based on the relationship of the depth to finer textured materials and site indices. These models will hopefully enhance interpretations and the predictive ability of soil scientists to recognize areas of deep, loamy substratum phases of Plainfield soils.

Figure 1 is a representative profile from an area of Plainfield soil. The depth to the finer textured materials range from 1.54 to 2.67 meters. In this profile, the imagery of the lithologic contact separating sandy from loamy sediments suggests an abrupt and regular boundary. The bold, dark images of this contact signify an abrupt textural change from sandy to loamy sediments. As the graphic recorder is a gray-scale recorder, the greater the electromagnetic gradient across an interface: The greater is the reflection of electromagnetic energy and the darker are the images recorded on the graphic profile. The exceptionally dark images in Figure 1 denotes an abrupt and strongly contrasting textural gradient.

In Figure 1, the contact of sandy and loamy sediments is expressed by two or three, similarly-shaped, dark bands. These bands represent a single interface, and are the positive and negative signal components and their reverberations. Below a depth of approximately 3 meters, the fabric of the till is more variable and produces spurious, segmented reflections.

In contrast to Figure 1, the imagery in Figure 2 suggests a more gradual transition from sandy to loamy sediments. Here, the depth to loamy sediment ranges from 1.08 to 1.44 meters. Generally, the imagery of this interface is grayer and less well expressed than the imagery occurring in Figure 1. Also, the occurrence of several closely spaced and weakly contrasting layers is suggested by multiple, superimposed signals. It is inferred that the interface between sandy and loamy sediments is more gradual and consists of several layers which grade from sands to loamy sands or sandy loams to sandy clay loams.

In both figures, the presence of roots and segmented portions of the cambic horizons is suggested by the imagery in the upper part of each profile. While it is unlikely that the cambic horizon is segmented, variations in its chemical constituents is likely.

Table 1 is a summary of the scaled radar data from the 42 detailed transects. This data was tabulated by dividing each transect into 10 equally spaced observation points. Each transect was approximately 27 meters long and conducted through wooded areas. All depths expressed in Table 1 are in meters.

Presently, ground-truth soil boring data provides the basis upon which the radar imagery is scaled or compared. Regardless of the radar specialists confidence in the radar, most users consider ground-truth auger measurements to be true, while radar imagery novel, untried, and at best inexact.

Figure 3 is a scatter diagram plotting the covariation between ground-truth auger measurements and scaled radar imagery. Data for this portion of the study were collected from seven observation points selected within the study area and based on the depths to loamy sediments or the water table. Determined at the initial observation site, a single factor was used to scale the radar imagery at each of the following sites. All data are expressed in meters. The value of r squared is 0.9976, the correlation is positive, and the accuracy of the radar is most remarkable.

Figure 4 is a frequency distribution of depths to loamy sediments for the 410 observation points. The depths to loamy sediments are not normally distributed within the study area, but appears to be bimodal and dispersed about the depths of 1.5 and 3 meters.

In Presque Isle County, the GPR was used to verify the depths to bedrock in areas of Longrie (coarse-loamy, mixed, frigid, Entic Haplorthods), Posen (loamy-skeletal, mixed, frigid Typic Eutrochrepts), and Summerville (loamy, mixed, frigid, Lithic Eutrochrepts) soils. The GPR was also used to determine the thickness of gravelly glacio-fluvial deposits and the depths to underlying till and bedrock in areas of Alpena (sandy-skeletal, mixed Udorthentic Haploborolls) soils.

It is exceedingly difficult to examine Alpena, Longrie, Posen, and Summerville soils with conventional surveying tools. Rock fragments limit the effectiveness of spades and augers. Soil Scientist are fatigued and frustrated, and work is slowed as the penetration of conventional tools is repeatedly stopped by rock fragments. Decisions made in the field are often based on widely-spaced exposures, experience, and anticipated rather than confirmed depths to the contrasting, underlying layers.

The GPR can be used most effectively in these soils. Unlike conventional tools, the efficieacey of GPR techniques is not impaired by rock fragments.

Interpretation of the radar imagery is dependent upon the skill and experience of the radar specialist. Initially, in areas of Longrie and Summerville soils, interpretations were retarded by the complexed imagery of the bedrock surface. After viewing the nature of the bedrock along a quarry face, interpretations and confidence levels were improved.

Figure 5 is a representative profile from an area of Longrie soils. The radar scanned to a depth of approximately 4 meters. The moderately deep bedrock surface has been highlighted with a dark line. Bedding and fracture planes are evident across this figure. On a micro-scale, the surface of the bedrock is irregular and appears to be segmented by fracture planes into a few large and numerous smaller blocks.

Table II is a summary of the depth to bedrock and the proportions of soils (based on depth criteria) along the transects.

The GPR charted the thickness of glacio-fluvial deposits and the depth to till in areas of Alpena soils (Figure 6). In areas of Alpena soils, the GPR probed to depths of 6 meters. The surface of the underlying limestone bedrock was also charted from depths of 3 to 6 meters.

Whether the medium is glacio-fluvial deposits, till, or limestone bedrock, each has a distinct and identifiable graphic signature. In figure 6, layers of gravel produce relatively smooth and continuous images. In contrast, the more heterogeneous and variable nature of the underlying till produce irregular and segmented images.

TABLE II
Depths to Bedrock in Areas of Longrie Soils

Observations*

Transect	1	2	3	4	5	6	$\overline{X}$	Composition
1	26	21	25	25	32	54	30.5	83% Longrie 17% Posen
2	33	32	28	22	33	35	30.5	100% Longrie
3	30	39	27	25	21	22	27.3	100% Longrie
4	44	22	35	32	35	23	31.8	83% Longrie 17% Posen
							30.0%	92% Longrie 8% Posen

*All depths are in inches

RESULTS

This field trip represents the first study conducted by SCS with the ground-penetrating radar in Michigan. Based on the established objectives, this study as successful. It has demonstrated the efficiency of using GPR as a quality control, reconnaissance, or mapping tool on selected soils in Michigan. This study provided an opportunity for a large number of soil scientists to view, understand, and evaluate the performance of a relatively new geophysical tool which is being used by SCS.

I strongly recommend the continuation of this study in other areas or soil conditions of Michigan. Within the areas and soils examined, the potential for successful applications of GPR techniques is high. I would strongly endorse the use of GPR technology in this area of the Mid-West.

Work from the Newaygo County study is being continued within the soil survey party and at the NENTC.

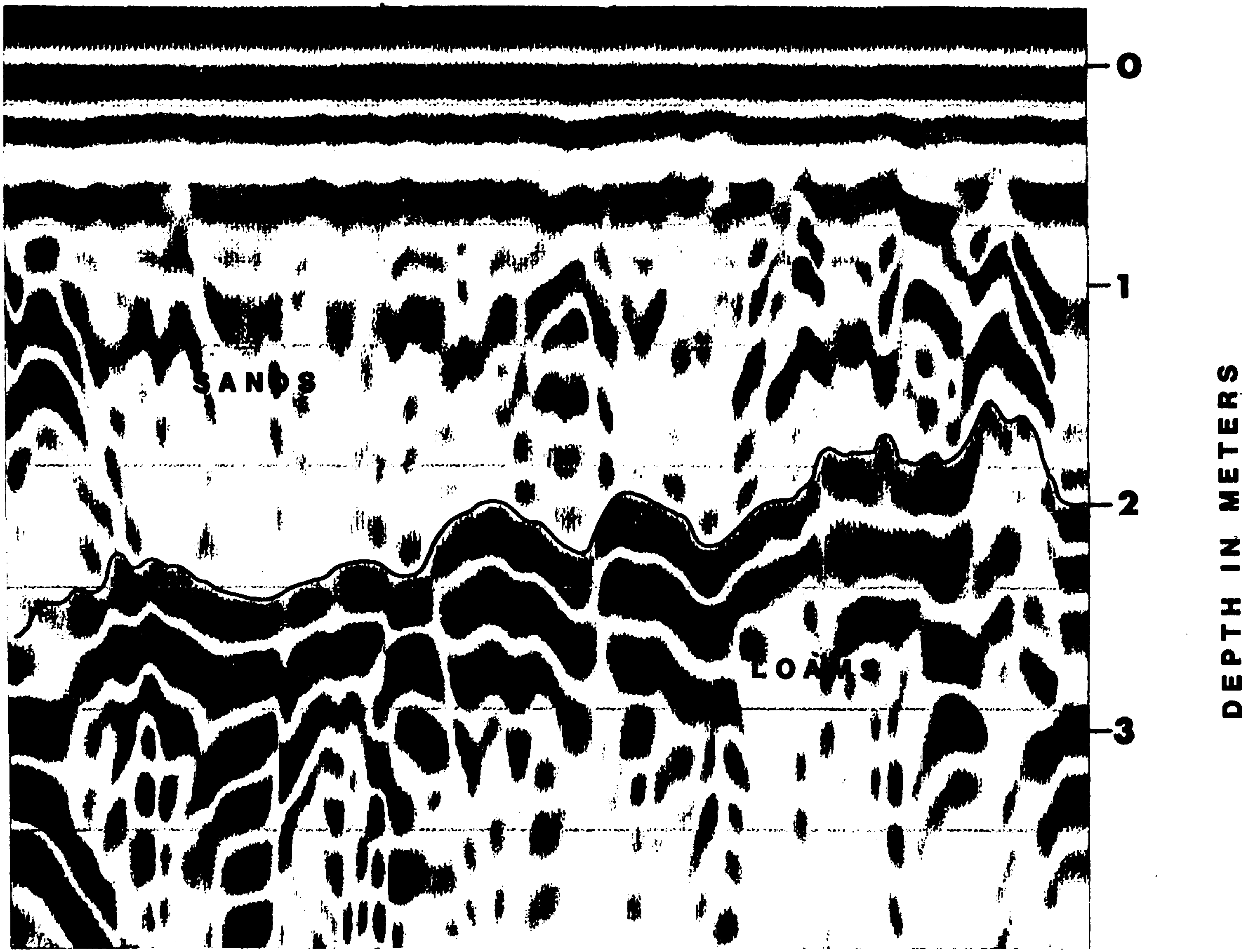
A complete record of the graphic profiles from this field study has been returned to Neil Stroesenreuther under a separate letter and is available for your viewing.

With kind regards.

JAMES A. DOOLITTLE
Soil Specialist (GPR)

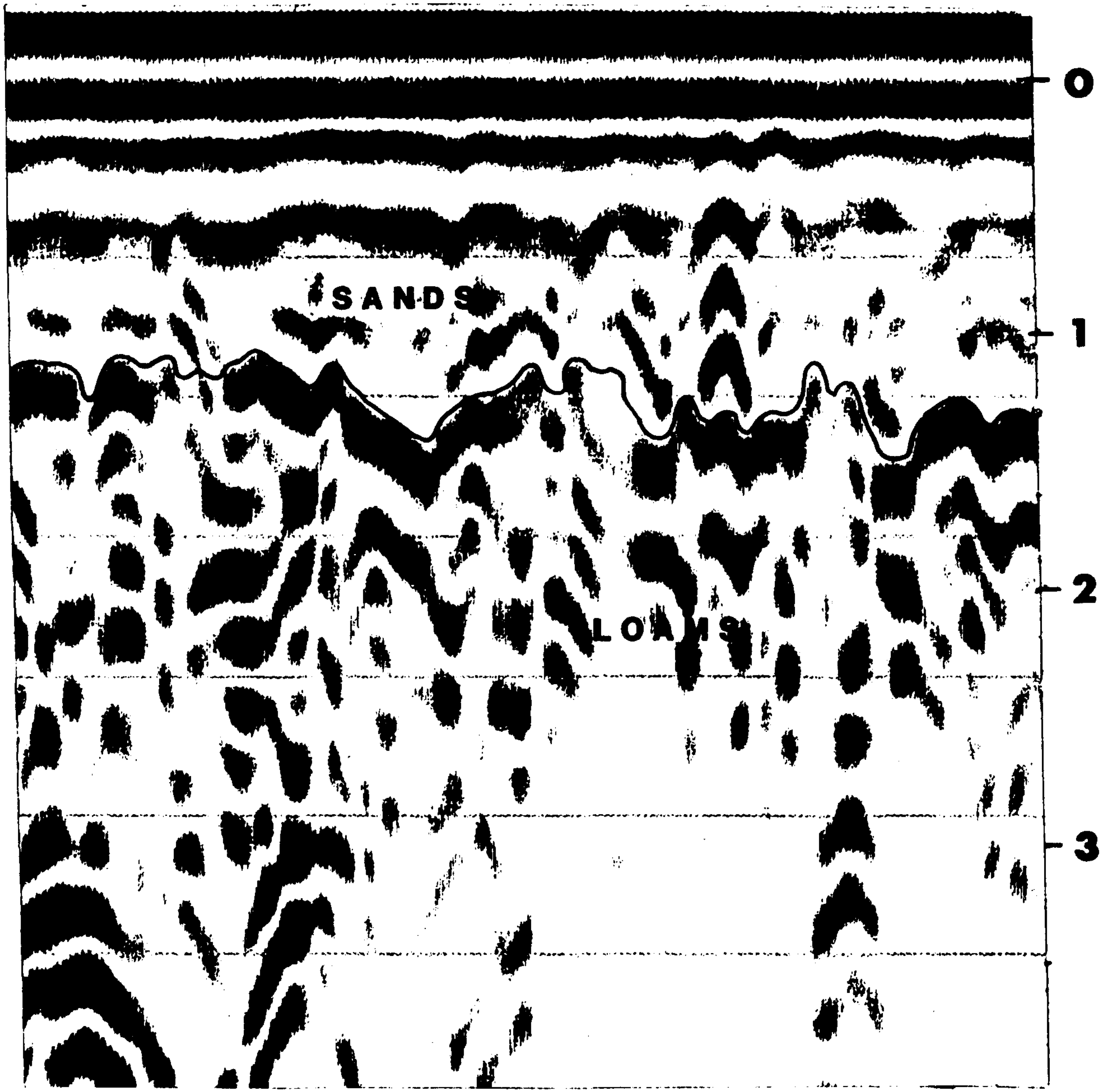
cc:
A. Holland, Director, NENTC, Chester, PA
T. Shiflet, Director Midwest NTC, Lincoln, NE
R. Arnold, Director, Soil Survey Division, SCS, Washington, DC
N. Stroesenreuther, State Soil Scientist, SCS, E. Lansing, MI

JADoolittle/ef

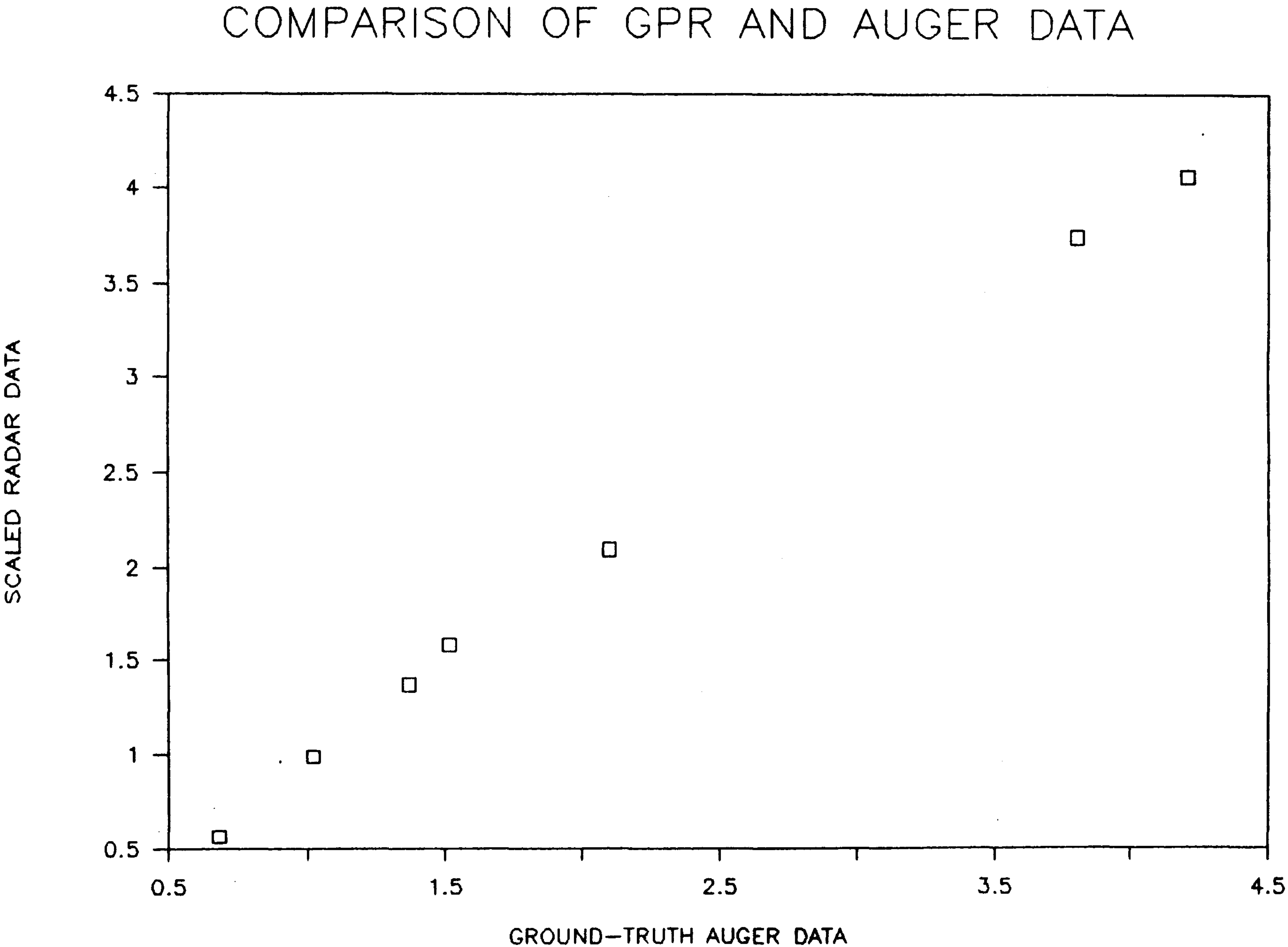


AN ABRUPT BOUNDARY

SEPARATING SANDY AND LOAMY DEPOSITS



A GRADUAL TRANSITION FROM SANDY TO LOAMY DEPOSITS

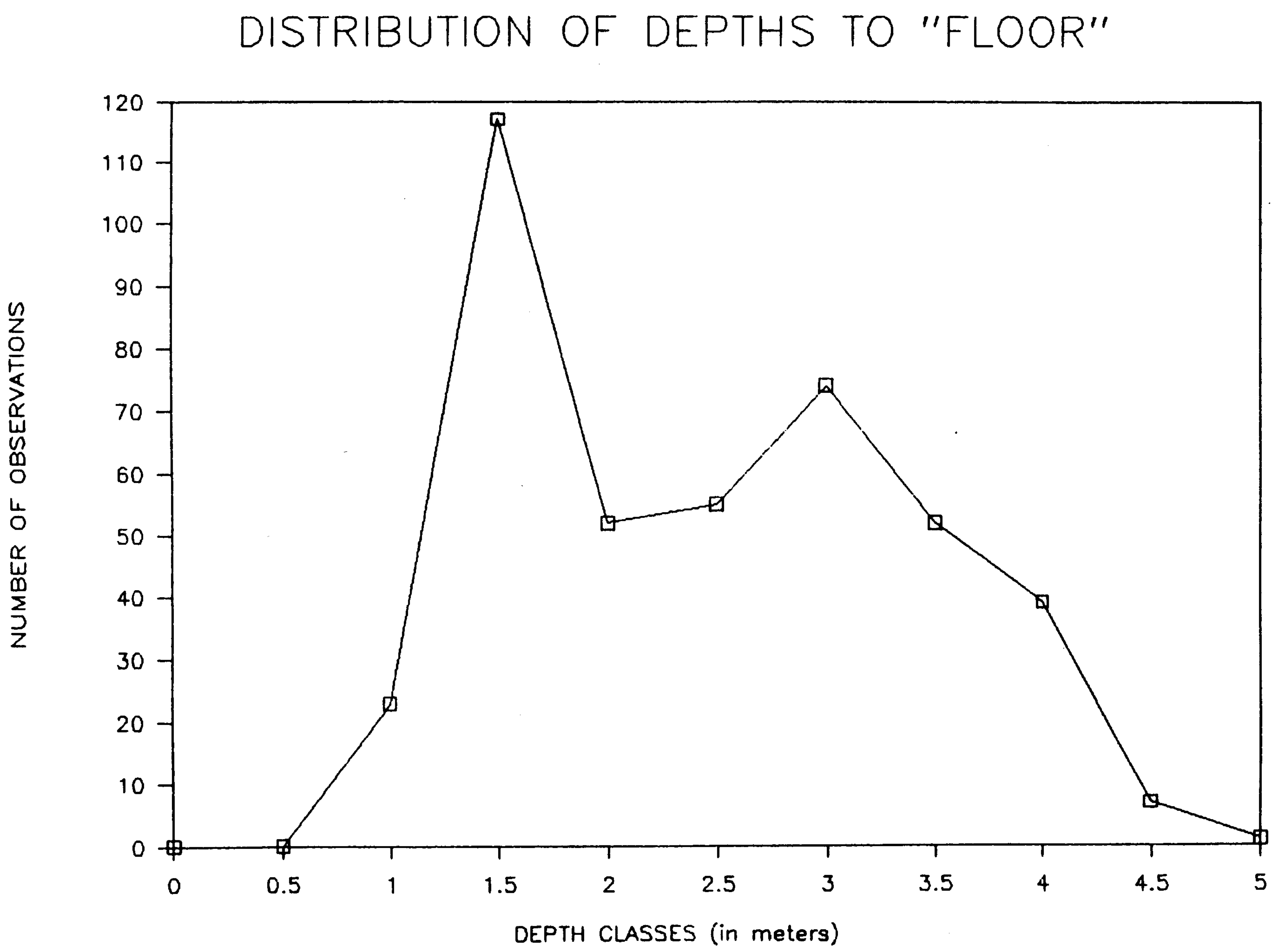


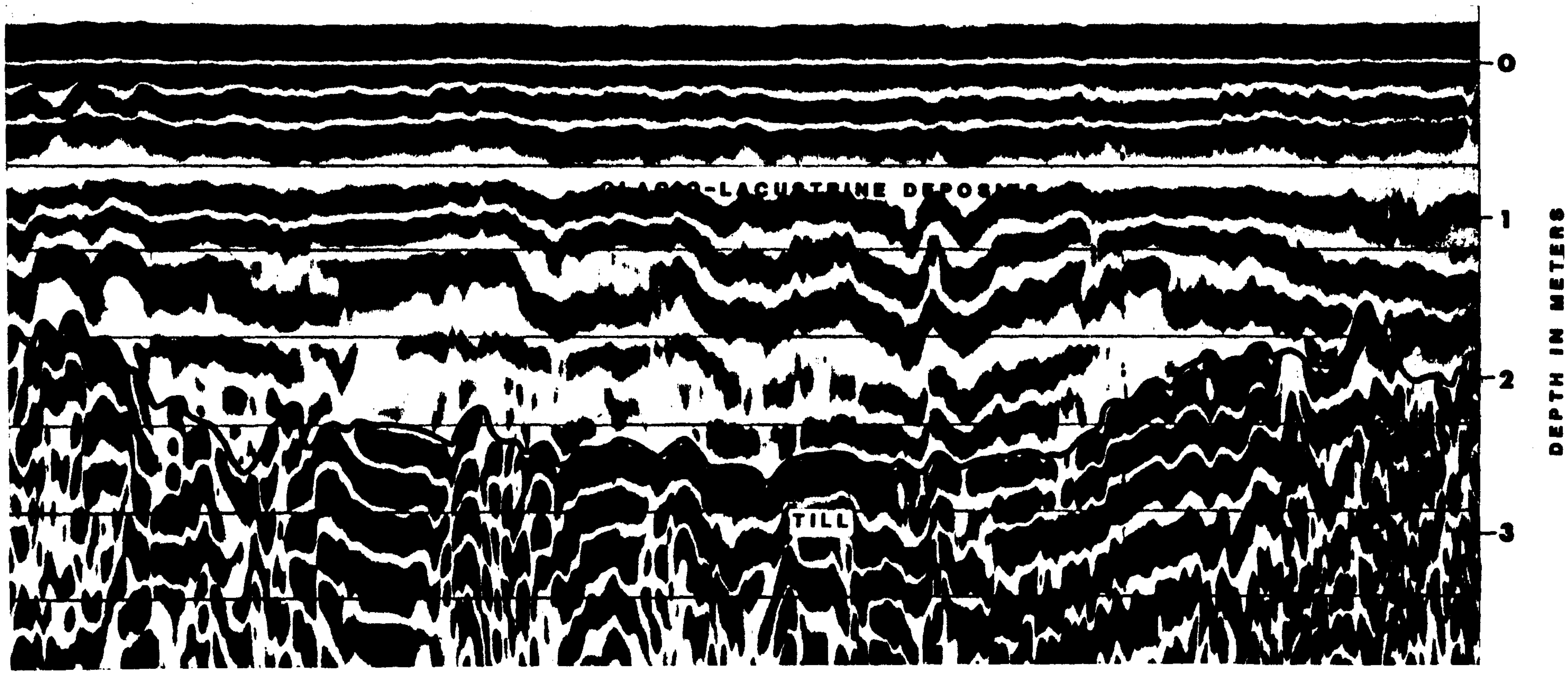
COMPARISON OF GPR AND AUGER DATA
SCALED RADAR DATA
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0.5
1.5
2.5
3.5
4.5
GROUND—TRUTH AUGER DATA

DEPTH TO "FLOOR" - WHITE CLOUD, MICHIGAN

OBSERVATIONS

Transect No.	1	2	3	4	5	6	7	8	9	10	AVG	STD	MAX	MIN
1	0.75	0.86	1	1	1.2	1.13	1.2	1.23	1.13	1.1	1.06	0.149264	1.23	0.75
2	1.13	1.27	0.89	1.13	1.06	1.13	1.23	1.1	1.2	1.2	1.134	0.101311	1.27	0.89
3	1.05	1.1	0.82	1.2	1.16	0.82	1.16	1.13	1.06	1.27	1.077	0.142341	1.27	0.82
4	0.78	1	0.96	1.3	1.06	1.06	1.16	1.41	1.37	1.54	1.164	0.223705	1.54	0.78
5	2.78	2.85	2.26	2.47	2.33	2.09	1.96	2.06	1.78	2.16	2.274	0.326318	2.85	1.78
6	0.79	0.79	0.96	0.75	0.82	0.92	1.2	1.1	1	1.06	0.939	0.144045	1.2	0.75
7	2.74	2.5	2.92	3.09	3.26	3.5	3.5	3.57	3.63	3.33	3.204	0.362524	3.63	2.5
8	1.37	1.03	1.47	1.51	1.88	2.26	2.5	2.57	2.88	2.88	2.035	0.636572	2.88	1.03
9	1.3	1.27	1.41	1.41	1.27	1.3	1.44	1.61	1.75	1.78	1.464	0.175965	1.78	1.27
10	1.37	1.1	1.16	1.13	1.41	1.23	1.3	1.16	1.23	1.37	1.246	0.105185	1.41	1.1
11	1.06	1.06	1.1	1.41	1.27	1.44	1.16	1.27	1.3	1.23	1.23	0.128140	1.44	1.06
12	1.37	1.2	1.37	1.1	1.06	1.54	1.3	1.2	1.3	1.4	1.284	0.138722	1.54	1.06
13	1.1	1.13	1.27	1.37	1.23	1.06	1.13	1.23	1.23	1.1	1.185	0.091460	1.37	1.06
14	1.23	1.27	1.3	1.06	1.23	1.3	1.16	1.2	1.23	1.3	1.228	0.071386	1.3	1.06
15	2.4	2.57	2.37	2.5	2.57	2.4	2.09	1.85	1.61	1.47	2.183	0.385410	2.57	1.47
16	1.96	2.09	2.4	2.23	2.23	2.19	2.4	2.16	2.16	2.33	2.215	0.130172	2.4	1.96
17	0.96	1.27	1	1.23	1.16	1.3	1.16	1.13	0.92	0.96	1.109	0.132170	1.3	0.92
18	1.2	1.3	1.3	1.23	1.3	1.3	1.3	1.54	1.2	1.23	1.29	0.092951	1.54	1.2
19	3.8	3.53	3.8	3.19	3.09	3.12	3.6	3.36	2.74	2.57	3.28	0.397190	3.8	2.57
20	3.12	2.84	2.71	2.92	2.64	2.81	3.05	2.81	2.98	2.88	2.876	0.139942	3.12	2.64
21	3.74	3.67	3.15	2.81	2.95	2.37	2.67	3.6	3.77	4.29	3.302	0.571695	4.29	2.37
22	3.77	3.6	3.09	2.4	2.5	2.4	2.23	4.35	4.42	4.35	3.311	0.849593	4.42	2.23
23	4.56	3.19	2.98	[illegible]	3.46	3.96	2.54	2.81	2.54	2.84	3.192	0.613[illegible]87	4.56	2.54
24	2.61	3.19	2.88	3.05	3.74	3.7	2.98	2.88	2.61	2.84	3.048	0.375797	3.74	2.61
25	3.26	3.63	2.98	2.81	3.15	3.74	2.98	2.88	3.6	3.8	3.283	0.358470	3.8	2.81
26	3.67	3.67	3.53	3.46	3.12	2.84	2.88	1.82	1.85	2.37	2.921	0.670379	3.67	1.82
27	3.6	3.94	3.53	3.29	3.86	2.23	2.3	1.88	1.88	2.23	2.876	0.800864	3.94	1.88
28	3.33	2.95	3.19	3.15	2.78	1.85	1.78	2.26	2.61	2.06	2.596	0.545934	3.33	1.78
29	3.43	3.19	2.84	1.71	1.65	0.89	1.1	1.54	1.2	1.37	1.892	0.868743	3.43	0.89
30	4.46	3.6	3.91	3.6	3.46	3.63	3.67	3.19	2.98	3.09	3.549	0.422100	4.46	2.98
31	2.67	2.4	2.16	1.96	1.51	1.64	1.75	1.51	1.58	1.54	1.872	0.391479	2.67	1.51
32	1.03	1.1	1.71	1.99	1.92	1.82	2.12	1.47	1.23	1.06	1.545	0.396919	2.12	1.03
33	1.71	1.54	1.44	1.51	2.57	1.61	0.82	1.37	1.99	2.16	1.672	0.454484	2.57	0.82
34	2.92	2.23	2.09	1.96	1.99	1.96	1.85	1.78	1.92	1.98	2.068	0.311249	2.92	1.78
35	1.96	1.96	2.02	2.02	2.26	2.5	2.71	2.92	3.09	2.91	2.435	0.414252	3.09	1.96
36	2.57	2.74	2.4	2.47	2.43	1.78	1.88	2.06	1.71	2.61	2.265	0.354774	2.74	1.71
52	2.74	3.29	3.29	3.15	3.12	3.19	3.26	3.26	3.22	3.15	3.167	0.153626	3.29	2.74
53	3.02	3.05	2.95	2.95	2.67	2.81	2.92	2.95	3.46	3.84	3.062	0.322577	3.84	2.67
54	2.98	2.3	2.3	2.4	3.09	2.98	2.16	2.57	3.09	3.19	2.706	0.376729	3.19	2.16
55	2.37	2.05	1.88	1.53	2.78	[illegible]	3.29	3.02	2.95	3.36	2.644	0.597615	3.36	1.53
56	3.77	3.63	3.63	3.63	3.74	3.74	3.6	4.36	3.36	4.18	3.764	0.278107	4.36	3.36
57	2.88	2.98	2.88	2.84	2.57	2.61	2.4	2.78	2.67	2.61	2.722	0.169811	2.98	2.4


DISTRIBUTION OF DEPTHS TO "FLOOR"
NUMBER OF OBSERVATIONS
0
10
20
30
40
50
60
70
80
90
100
110
120
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
DEPTH CLASSES (in meters)



THICKNESS OF CHANNERY GLACIO-LACUSTRINE DEPOSITS OVERLYING TILL
IN AN AREA OF ALPENA SOILS

DEPTH TO LIMESTONE BEDROCK IN AN AREA OF LONGRIE SOILS