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SOIL AND GEOMORPHIC RELATIONSHIPS OF TWO WATER QUALITY LANDSCAPES ON THE AMES PLANTATION

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Richard Lee Livingston

August, 1993

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DEDICATION

This thesis is dedicated to my family: my parents, Mr. and Mrs. Frank Livingston; my grandparents, Mrs. Lucille Norrod and the late Mr. Harshel Lee Norrod and Mr. and Mrs. Miles Livingston; my brother, his wife, and their family, Mr. and Mrs. Randall Livingston, Gerald, and Morgan; and my great aunt and uncle, Mrs. Artie Jane Rosenbaum and the late Mr. Earl Rosenbaum. Their interest in my education is everlasting.

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Thanks is given to my major professor, Dr. John T. Ammons for his guidance, patience, and persistence in helping me further my education and in the completion of this research. I also wish to thank the other members of my committee, Dr. Russell J. Lewis and Mr. Darwin L. Newton for their thoughtful comments, suggestions, and assistance over the past two years. Recognition is also given to my fellow graduate students and co-workers, Janice Branson, David McMillen, Nathan Hartgrove, Andy Gallagher, Mike Morris, Mike Timpson, Grant Dunn, Mike Haarbauer, Sonja Entricken, Randy Loftis, and Laura Ramsey for their assistance, encouragement, and friendship. I am also grateful to Dr. Roland Mote and Mr. John Buchanan for their help on this project.

Appreciation is given to the USDA Soil Conservation Service in Tennessee for allowing me to remain employed in a part-time status while pursuing this degree.

ABSTRACT

Spatial variability, parent material relationships, and geomorphic position are important factors in interpreting soil behavior.

This research project was conducted to evaluate soil properties, stratigraphy, and site properties of two experimental water quality areas on the Ames Plantation.

During the installation of two water quality experimental areas, twelve deep wells were established on each of the Hancock Tract area and the West Pasture Tract area in order to monitor water in the first permanent aquifer. Six of those wells (ranging from about 10.5 to 18.25 m) were sampled using either a CME or split-spoon sampler, in order to access parent material stratigraphy. Additionally, a total of 47 shallow wells (vadose zone wells ranging from about 1.85 to 2.40 meters) were installed and soil morphology was described and recorded. Topographic maps at a scale of 1:24,000 with approximately 6 meter contour interval were used to examine the overall geomorphic positions of the sites. Standard soil survey laboratory procedures were employed on the deep well samples for particle size, cation exchange capacity and base saturation, pH, total carbon, free iron oxides, and KCl exchangeable aluminum. A modified hydrofluoric acid/aqua-regia microwave procedure and inductively coupled argon plasma emission

spectrometry was used to determine total concentrations of iron, titanium, and zirconium.

An order 1 soil map was made of each site using the soil descriptions taken during shallow well installation. Map units were defined by taxonomic classification and further subdivisions were made at the phased level based on slope, erosion class, and depth to the lithologic discontinuity. Laboratory data and descriptions from the deep wells were used to confirm classification. Characterized profiles were used as typical pedons for map units when possible.

Evaluation of the 1:24,000 scale revealed that the two areas were located on two separate terrace levels. The West Pasture site was located on the Henderson terrace, and the Hancock Tract site was located on the Humbolt terrace as described by Saucier (1987). A sequence of loess/alluvium/tertiary sands was found in each of the six well cores. Thickness of the loess ranged from 1.43 to 3.05 meters; the mixing zone ranged from 1.37 to 1.89 meters thick; and thickness of the alluvium ranged from 2.75 to 6.76 meters. A paleosol was present in the mixing zone of the loess and alluvium in five of the cores sampled. Differences in the Peoria and Roxana loess depositions could not be determined. Stratigraphic position and morphological and chemical data suggested that the loessial material of the mixing zone paleosols was of the Loveland deposition.

The paleosol had formed in the unmixed Loveland loess layer in the remaining sample core.

A total of seven map units were defined which incorporated six different taxons at the subgroup level. Five of the taxons were in the fine-silty, mixed, thermic family of Alfisols; one of the map units was One of the map units was typified by fine-loamy, mixed, thermic family of Ultisols; and the other was typically in the fine-silty, mixed, thermic family of Inceptisols. Taxons at the subgroup level were Fragic Hapludalfs, Ultic Hapludalfs, Typic Fragiudalfs, Glossaquic Fragiudalfs, Typic Paleudults, and Dystric Eutrochrepts.

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1. INTRODUCTION

The Ames Plantation is located about 68 kilometers due east of Memphis, TN and about 250 kilometers southwest of Nashville, TN (Fig. 1). Being the largest experiment station of the University of Tennessee system at 18,430 acres, it is recognized for research on beef and dairy cattle grazing, forestry and wildlife, swine systems, crop variety trials, crop fertility experiments, herbicide evaluations and row crop research and production. This active research and production on Ames Plantation Experiment Station serves as an excellent training ground and provides training to many graduate and undergraduate students in plant and soil science, animal science, veterinary medicine, forestry, and wildlife.

Hobart Ames, founder of the Ames Plantation, purchased the plantation house from John W. Jones in the spring of 1901. He amassed about 25,000 acres near Grand Junction, TN through a lease and purchase program. Due to his interest in quail hunting and bird dogs, Mr. Ames began holding the National Championship for bird dogs in 1915. After Mr. Ames death in 1945, and before the death of his wife, Julia C. Ames in 1950, Mrs. Ames made arrangements to provide a location on the Plantation for the annual competition to select the National Champion bird dog and

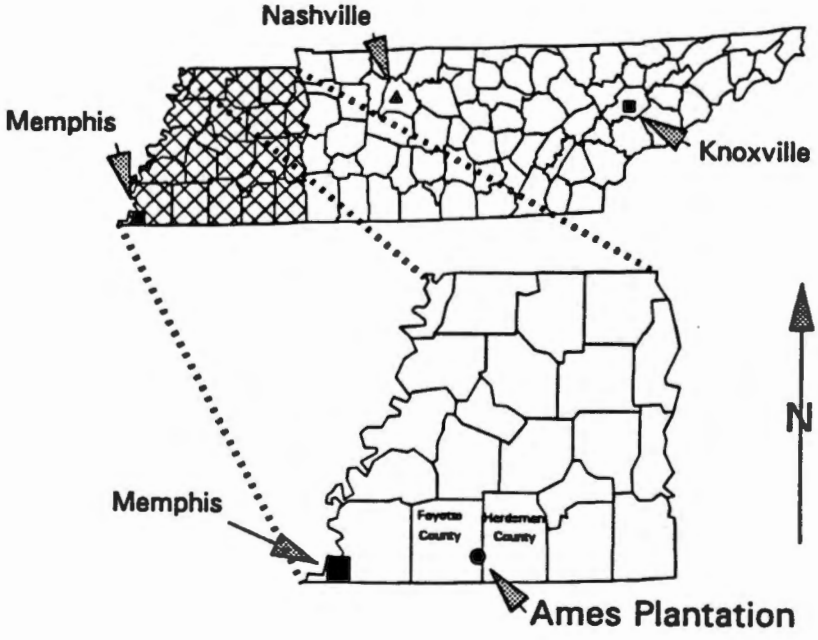


Figure 1. Location map of the Ames Plantation Experiment Station in relationship to Tennessee.

provide resources for educational research for the benefit of the University of Tennessee's College of Agriculture. A deal was made with C.E. Brehm, president of the University of Tennessee which allowed the current Experiment Station to be owned and operated by Richard Harte, Jr., Waldo E. Dodge, and The Bank of Boston, Boston MA, as Trustees. The Ames Plantation then became the largest land resource research facility in the state. Unlike most of the Stations in the U.T. Agriculture Experiment Station system, almost all of the operating and capital improvement funds are generated by the Ames Foundation without expense to taxpayers of the State of Tennessee.

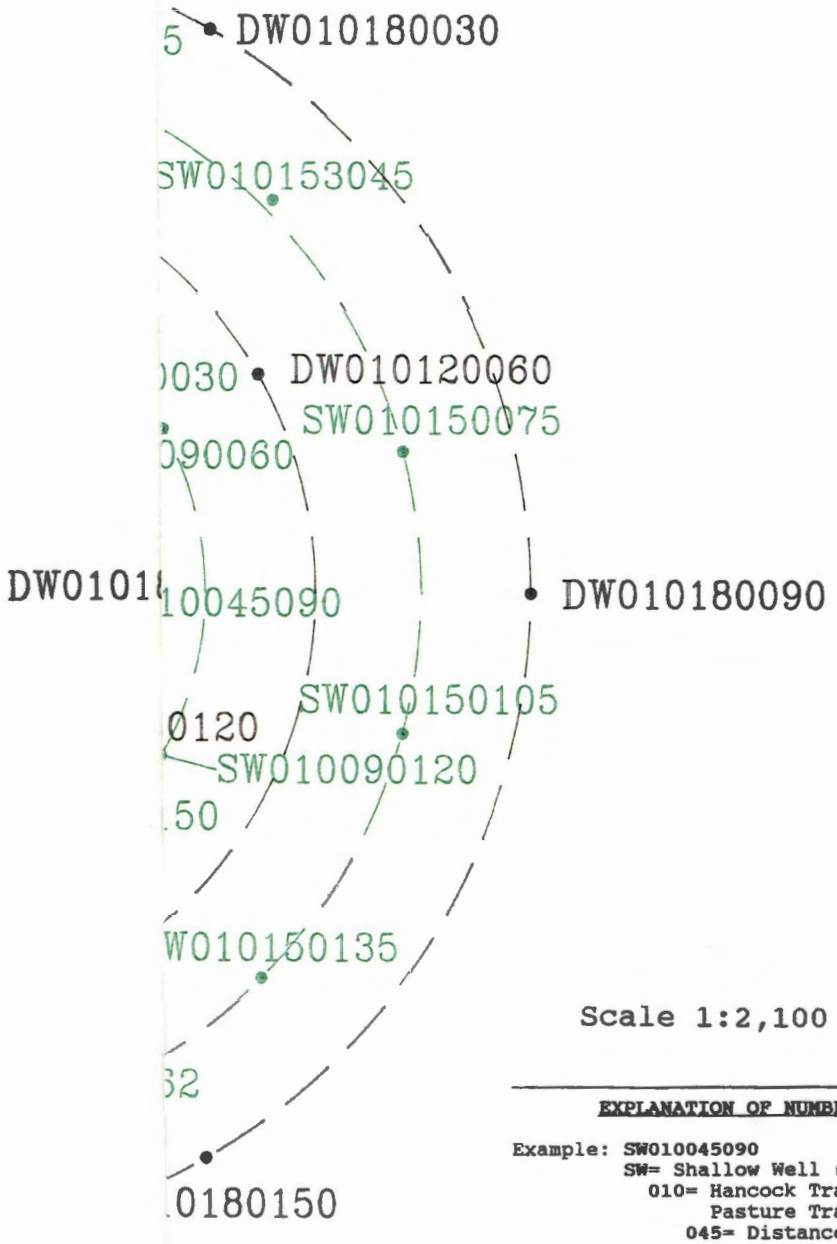
Concerns for water quality as affected from agricultural practices prompted a research project in Tennessee. In 1990, the U.T. Agricultural Experiment station funded such a project. The large acreage available and present cropping practices made the Ames Plantation an ideal site.

Preliminary investigations of soil and landscape characteristics were made and in 1990-91 and installation began for two water quality research sites. A one acre plot was established on each site where runoff could be monitored and cropping practices varied. Design and location of deep and shallow wells around the plot areas was based on a fractal geometric design (W.L. Sanders,

1992, personal communication) (Figs. 2 and 3). Twelve deep wells were installed on each site for monitoring water in the first aquifer. Two off-site deep wells were installed as control sites for comparison with on-site wells. Twenty-three shallow wells were installed on the Hancock tract and twenty-four shallow wells were installed on the West Pasture tract. Depth of the shallow wells was governed by the location of the first restrictive layer encountered from the soil surface.

The following two chapters of this thesis were based on data compiled from samples taken during the installation of six of the deep wells and the installation of the forty-seven shallow wells.

The overall objective of this study was to access the geomoprhic position, stratigraphy of parent materials, and soil resources in the vicinity of the two water quality experimental areas.

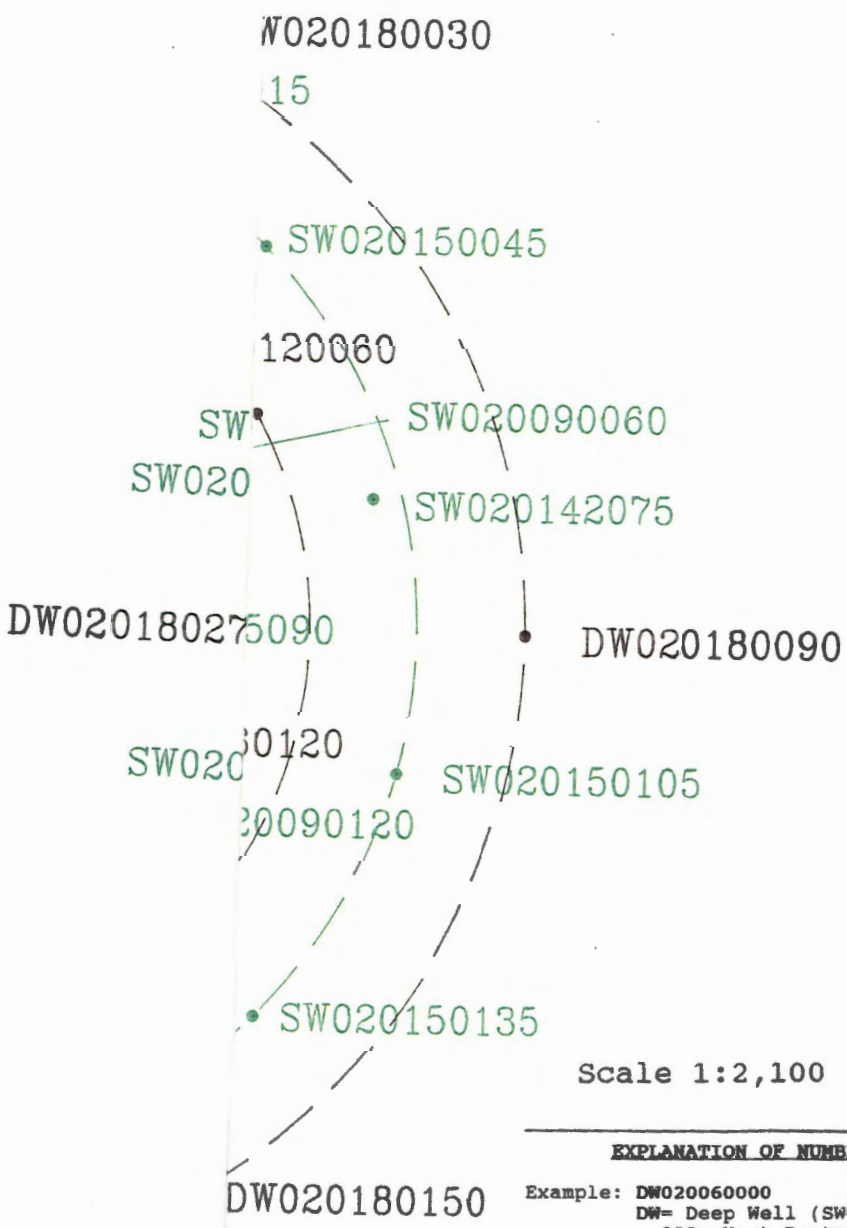


Scale 1:2,100 (1"=175')

EXPLANATION OF NUMBERING SYSTEM

Example: SW010045090
SW= Shallow Well (DW= Deep Well)
010= Hancock Tract (020= West Pasture Tract)
045= Distance from center of plot in feet (e.g. 45 feet from center of plot
090= Azimuth from center of plot (e.g. 90 degrees would be due east of the center of plot)

Figure 2



EXPLANATION OF NUMBERING SYSTEM

Example: **DW020060000**
DW= Deep Well (SW= Shallow Well)
020= West Pasture Tract (020= Hancock Pasture Tract)
060= Distance from center of pitt in feet (e.g. 60 feet from center of plot
000= Azimuth from center of plot (e.g. 000 degrees would be due north of the center of plot)

Figure 3. Lc
Pa

2. GEOMORPHOLOGY AND STRATIGRAPHY OF TWO WATER QUALITY LANDSCAPES ON THE AMES PLANTATION

Introduction

Parent material and landscape evolution are important factors in soil formation. A complete understanding of both is needed to accurately interpret soil behavior. The purpose of this chapter was to : 1) Geomorphically evaluate the landscape position of the two water quality plots on The Ames Plantation, 2) Determine the stratigraphic relationship of depositional sequences, and 3) Accumulate a set of data that would help correlate the layers of loess and underlying sandy material to their proper geologic formation.

Review of Literature

Geology

The geology of the area is dominated by the Tertiary age Claiborne and Wilcox formations that were capped by less than 1.2 meters of Quaternary Loess (Hardeman, 1966).

Loess has been described as a homogeneous mixture of silt particles that are unstratified. These deposits are usually porous and have the ability to maintain nearly vertical or vertical slopes (Lohnes and Handy, 1968).

Loess is usually fairly well sorted with at least one-half of the silt particles being between 0.01 and 0.05 mm in diameter (Pesci, 1968). Some early workers characterized loess as being calcareous but Smith (1942) pointed out that weathering during the depositional period may remove free carbonates as fast as the deposition is occurring. Washer and et al. (1947) reported that the requirement of free carbonates may be invalid because the loessial material may have come from sources that contain no carbonates.

Many loess deposits have been correlated with periods of glacial activity. Commonly, the upper and lower boundaries of loess layers in a depositional sequence can be identified and used for correlation of the deposits over a large area. Particle size distribution, color, fossils, mineralogical properties, and chemical properties are commonly used as correlation markers and help to aid in the regional correlation of a loess deposit. Quaternary history can often be interpreted from the sequence and thickness of the deposits (Ritter, 1986).

Researchers have found that the thickness of the loess layer can be expressed mathematically as a function of distance from the source (Smith, 1942; Frazee et al., 1970). Putman and et al. (1988) concluded that river valley width plays a major role in loess thickness, soil development, and particle-size distribution. The active

soil development processes in loessial soils of Southwest Iowa was shown to be the movement of cations and clay particles into lower horizons thus showing an increase in exchangeable acidity in the weathering mantle. The effects of these processes showed an increase as the thickness of the loess layer decreased (Hutton, 1947). The uniformity in the chemical and mineralogical properties of loess layers has been attributed to fluvial action more than to aeolian action. In a study of loess and alluvium along the Mississippi-Missouri River system, alluvium between Vicksburg, Mississippi and Rockport, Missouri showed striking similarities in chemical and mineralogical properties to loess on adjacent uplands. The mixing of the alluvium before aeolian activity was thought to be responsible for the uniformity of loess in that area (Beavers and Albrecht, 1948).

Loess deposits east of the Mississippi Valley were observed by Lyell in 1846 (Lyell, 1847). These deposits were recognized as wind blown deposits by Shimek (1902). Two major units, the Peorian (upper layer) and Late Sangamon (lower layer) were recognized by Leighton and MacClintock (1930).

Three separate loess layers were identified in the southern Mississippi Valley in the 1940's (Wascher et al., 1947). The uppermost layer was named the "Peorian"

loess and referred to all loess deposited after the Late Sangamon interglacial stage. The second layer was referred to as the "Late Sangamon or Farmdale" loess. In later publications, this layer was referred to as the Roxana silt. This layer is thought to have been covered by the Peorian layer before soil forming processes began. The lowermost layer was called the "Third" sheet. G.D. Smith suggested that this layer could possibly correlate with the Loveland loess (Wascher et al.,1947). A fossil soil could be identified in this layer in most of the sites observed.

Leighton and Willman (1950) also identified three layers of loess in the Lower Mississippi Valley. The name Peorian was kept as the name of the youngest loess layer. The Sangamon was renamed as Farmdale and was correlated with the early Wisconsin loess in Illinois instead of the Sangamon interglacial period. The Loveland name was still used for the third layer and was considered to be Illinoian in age.

Later, Frye and Willman (1960) changed Peorian to Peoria and the Late Sangamon or Farmdale layer was called the Roxana loess. The Farmdale name was used as the name of a weakly developed soil that formed in the top of the Roxana loess (Fehrenbacher et al., 1986). In this study of loess thickness in Illinois, the Loveland loess was present below the Roxana loess in unglaciated areas (Fig. 4).

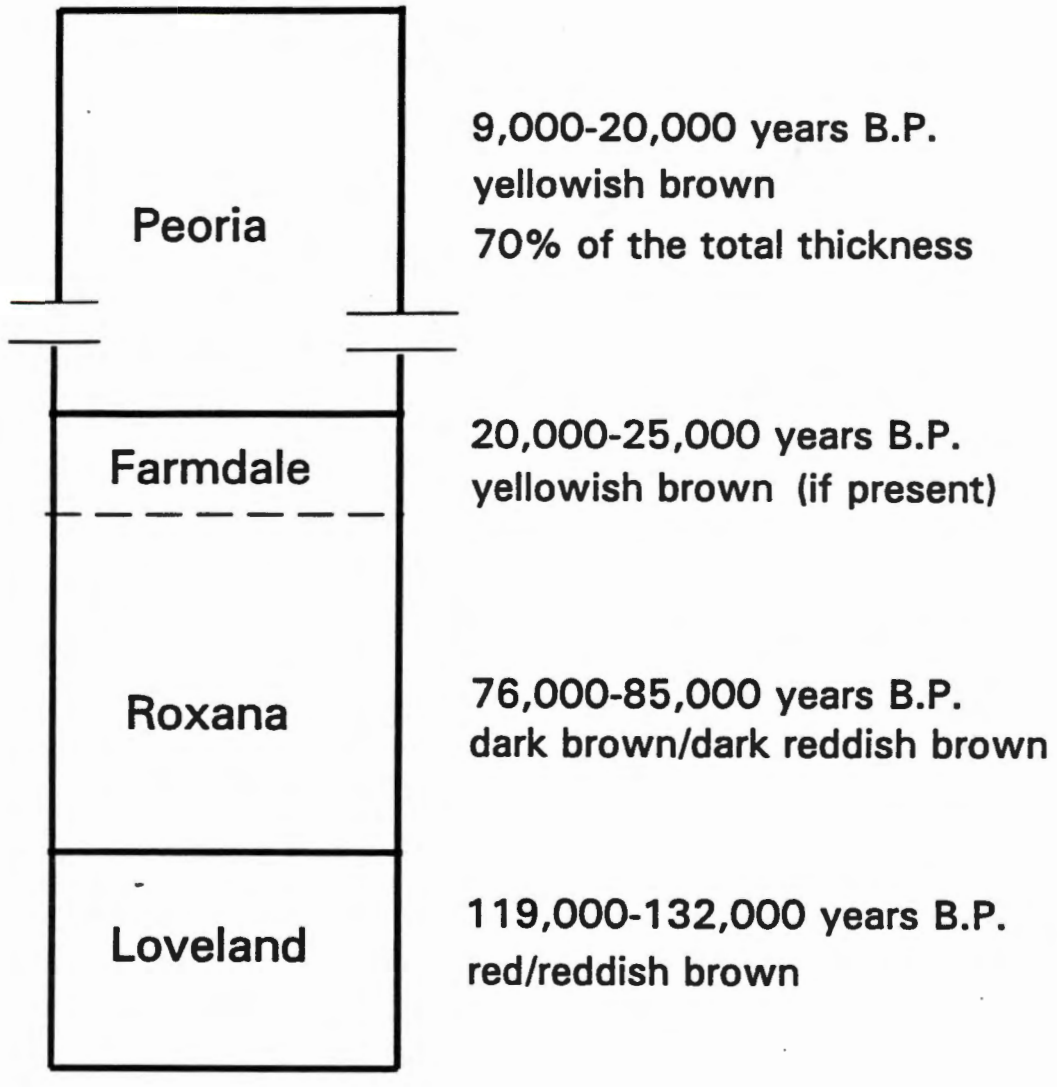


Figure 4. Loess layers and ages of the Mississippi Valley adapted from Wascher et al., 1947; Frye and Willman, 1960; and Pye and Johnson, 1988.

Rutledge and et al. (1985) found that two loess deposits could be observed on Pleistocene terraces in eastern Arkansas. The upper layer was correlated to the Peoria loess whose source area was east of Crowley's Ridge. The second layer was identified as the Loveland silt and was thought to have been deposited on Crowley's Ridge from the Western Lowlands.

Snowden (1966) provided absolute ages for some of the Southern Mississippi Valley loess by ^{14}C dating methods on fossil gastropods. Dates from 17,700 to 18,700 years B.P. and 24,300 to 26,300 years B.P. show that much of the loess is equivalent to the Peoria loess in Illinois. The Peoria loess was assigned to the Woodfordian substage of the Wisconsin glacial stage (12,500 to 22,000 years B.P.) by Frye and et al. 1962. These data also show that some of the loess is equivalent to the Farmdale loess in Illinois. The Farmdale loess was thought to have been deposited during the Farmdalian substage of the Wisconsin glacial stage (22,000 to 28,000 years B.P. according to Frye et al., 1962). In one location in the study by Snowden (1966) there were two other layers of loess below the Farmdale that were separated by a paleosol. These layers were carbonate rich and were tentatively correlated to the Roxana loess (from the Altonian Substage of the early

Wisconsinan) and the Loveland loess (of the Illinoian glacial stage) respectively.

Using thermoluminescence dating, geochemical and mineralogical criteria, and radiocarbon dating four periods of loess deposition were identified by Pye and Johnson (1988) in Mississippi. The loess layers were numbered 1, 2, 3, and 4, in order of increasing age. Unit 1 was shown to comprise more than 70 percent of the total thickness of the loess profiles. Thermoluminescence and ^{14}C dates indicate that the carbonate rich first layer was deposited between 9,000 and 20,000 years B.P. The second layer was thin and partially decalcified and was determined to be a slow depositional process between 20,000 and 25,000 years B.P. Layer 3 and 4 were highly weathered and thermoluminescence dates were 76,000-85,0000 and 119,000-132,000 years B.P. respectively. The four layers are stratigraphically equal to the Peoria, Farmdale, Roxana, and Loveland loess that were previously recognized in Illinois.

J. K. Roberts in cooperation with R. L. Collins studied the Tertiary and younger formations in west Tennessee in 1924 and 1925 (Roberts, 1928). Sediments in the embayment region of west Tennessee were characterized and a typical section was depicted (Fig. 5). The section showed alluvium and loess in the Quaternary Period, the

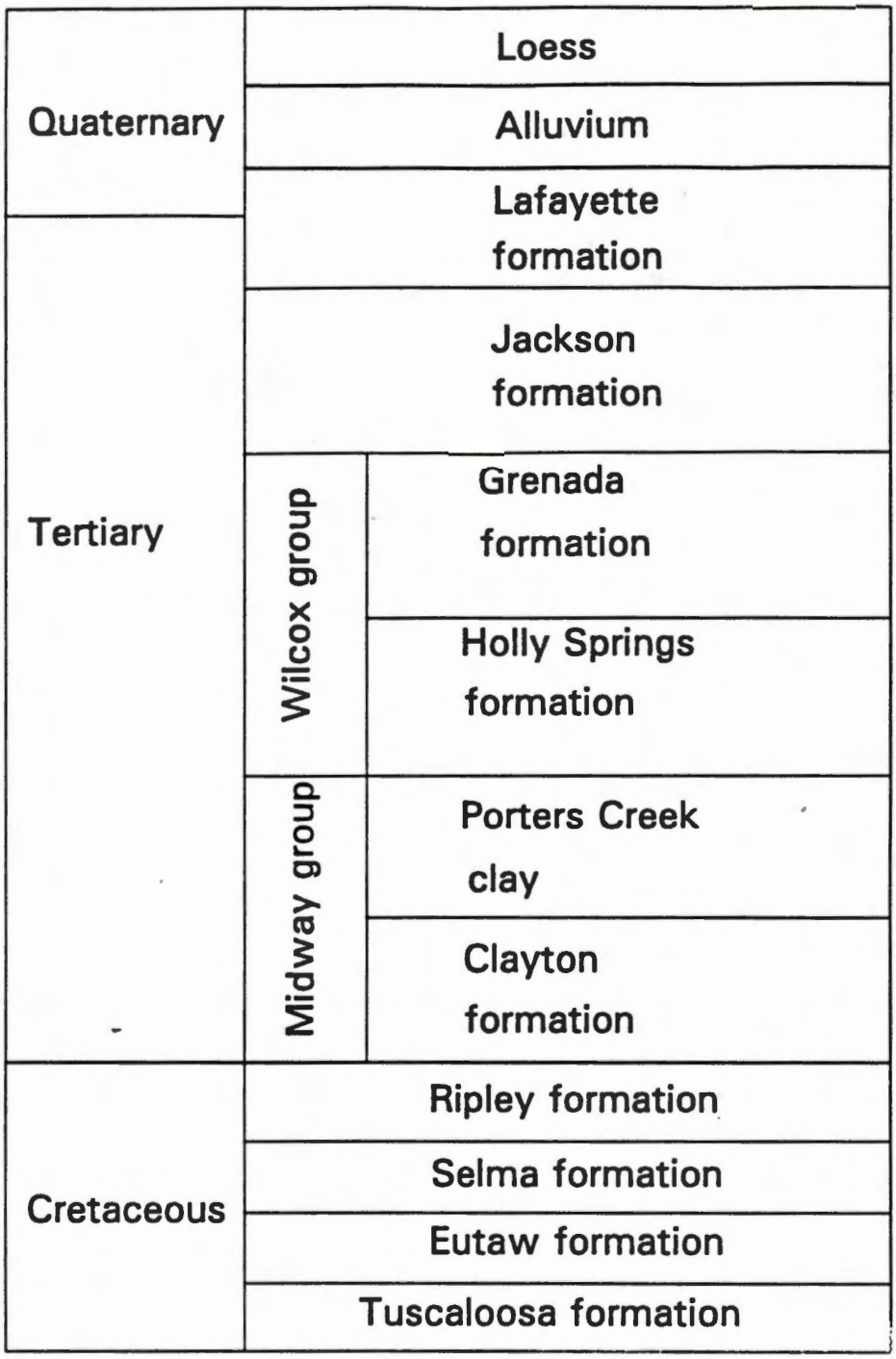


Figure 5. Geologic section of the embayment region of west Tennessee adapted from Roberts, 1928.

Lafayette Formation of sand and gravel at the Quaternary/Tertiary boundary, the Jackson Formation, the Wilcox Group, and the Midway group in the Tertiary period, and the Ripley, Selma, Eutaw, and Tuscaloosa Formations in the Cretaceous Period. The Claiborne Group (between the Jackson Formation and the Wilcox Group) was missing in this study. Stearns (1967) presented a generalized typical section from electric logs (resistivity logs) of wells in west Tennessee and Mississippi. This section showed the Jackson and Claiborne Groups (500-foot; 152.4-meter sand) of middle and upper Eocene underlain by the Wilcox Group (1400-foot; 426.7-meter sand) of lower Eocene. The Midway Group (Paleocene sand and Porters Creek clay) of Paleocene was underlain by the Cretaceous formations as follows: McNairy sand, the Selma chalk and clay, the Eutaw formation, and the Tuscaloosa formation.

The Claiborne and Wilcox formations were described in detail by Russell and Parks (1975). A portion of Hardeman County was included in this study. The following description was paraphrased from Russell and Parks (1975) unless otherwise referenced.

The Claiborne Formation was described as being about 72.6 meters thick. It was thought to reach a maximum thickness if about 335 meters along the axis of the Mississippi Embayment. It consisted mostly of quartz sand

with intermittent lenses of clay ranging from less than 0.3 meters to more than 15 meters in thickness. Some clay is in the form of clay-balls and lenses. Mention is made of crossbedded or lenticularly current-bedded sand with cut and fill features in the upper part of the formation. These poorly to moderately well sorted sands were thought to have been deposited by low-gradinet streams crossing a low costal area. The sand of the Claiborne formation was reported to be in shades of pink, gray, and orange and initially weathered to varying shades of yellow, orange, red and brown. Quartz was reported as the dominant mineral but mica and other heavy minerals were reported as local features. In many places the boundary between the Claiborne and Wilcox Formations was marked by a thin layer of ironstone or ferruginous sandstone.

The Wilcox Formation was described as being 0 to 61 meters thick. This formation consisted mostly of a heterogeneous layer of sand, silt, and clay with a few beds of lignite, kaolin, and siderite. These sediments were thought to be nonmarine and deposited in a fluvial environment. The authors mention "sawdust sand" as being distinctive of this layer. The "sawdust sand" was mostly fine-grain sand particles that are bound together by silt and clay so that upon initial investigation the fine grain sediments have a coarse grain appearance. The "sawdust

sand" typically shows cross bedding or no bedding. The sand was chiefly quartz. Kaolin beds ranged from 2.5 centimeters inch to one or more meters in thickness but were rarely greater than 30 centimeters. Outcrops of siderite, lignite and fossiliferous clay balls were also documented.

In the generalized section, mention was made of fluvial deposits 0 to 24.4 meters in thickness that overlay the Claiborne Formation in places. These layers were described as sand, gravel, silt and clay that may be high level remnants of present streams or from and ancient or earlier drainage system. These deposits have been observed on one or both valley walls of many of the present streams. Hershey (1959) observed samples of the McNairy sand, and the Claiborne and Wilcox groups. He concluded that these sands, which were extremely well sorted, had undergone at least three complete cycles of erosion and deposition. The heavy minerals were all of the stable-type. Most of the mica present was thought to be post-depositional.

Saucier (1987) identified four major terraces of Quaternary age along the Obion, Forked Deer, Hatchie, Loosahatchie, and Wolf Rivers in west Tennessee (Fig. 6). This study involved little field data and the terraces were identified on the basis of their geomorphic character from studies of 1:24,000 scale topographic maps and 1:62,500

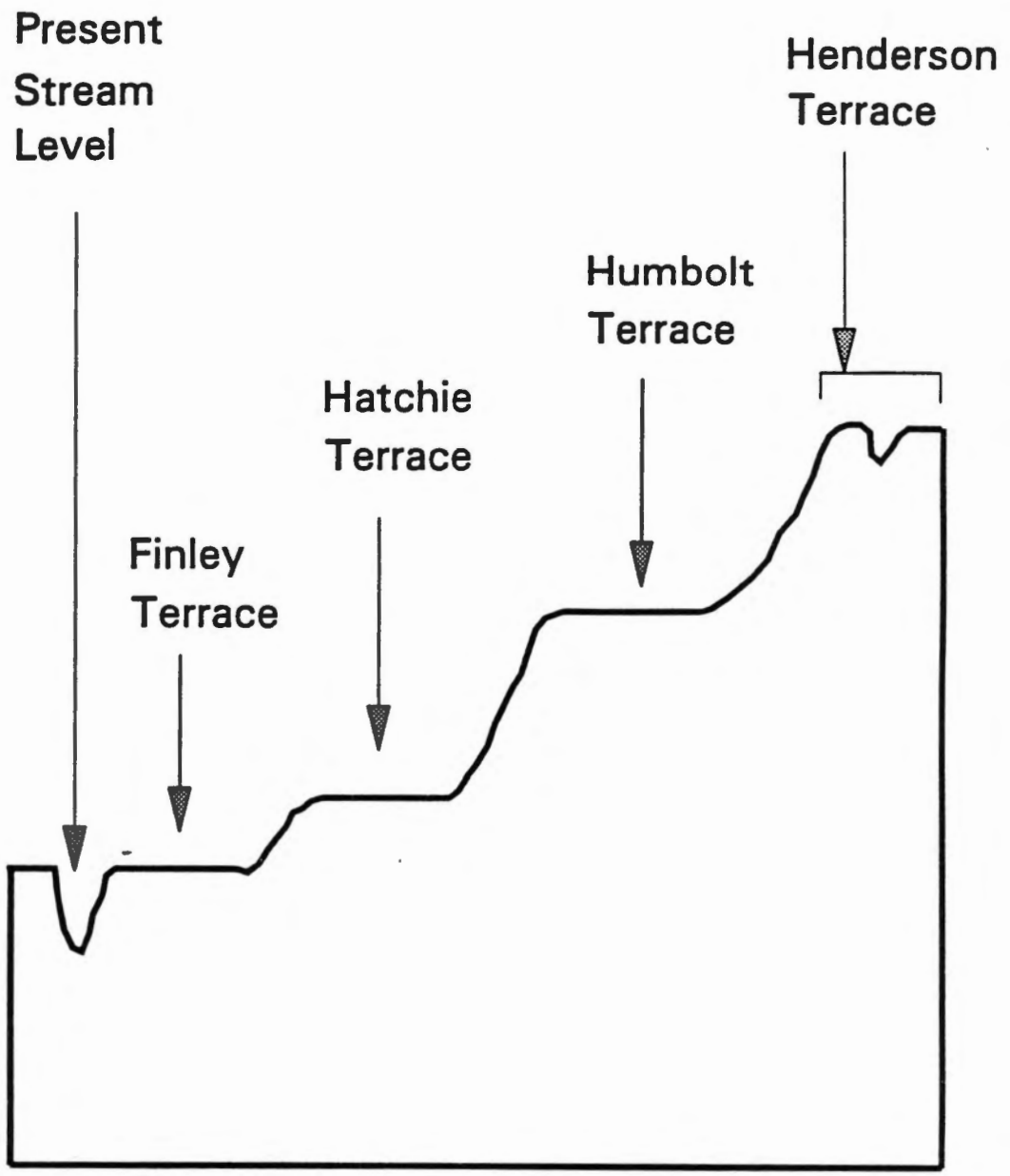


Figure 6. Cross-section of terrace levels in west Tennessee adapted from Saucier, 1987.

scale photo-mosaics. He identified the Finley terrace as the youngest terrace. This terrace was only 3 to 7 meters above the current flood plain. The second terrace level was called the Hatchie terrace. Near the mouth of rivers this terrace was located about 10 to 15 meters above the current flood plain. The third terrace was named the Humbolt terrace. This terrace was generally parallel to current streams and was 10 to 20 meters above the current flood plain. The Henderson terrace was the oldest of the terraces identified and was limited to the upper parts of the three forks of the Forked Deer River. Identification was difficult because of dissection. The original distribution of this terrace was thought to have been destroyed by sequences of valley degradation and aggradation and flood plain formation.

Materials and Methods

Field Methods

Six deep wells ranging from about 10 to 25 meters deep were chosen at random from a total of 26 deep wells. For five wells, core samples were taken using a drilling rig and a 1.5 meter CME sampler until the sample would no longer stay in the tube. A 0.6 meter drop-hammer split spoon sampler was used afterward. One well was sampled entirely with a 0.6 meter drop-hammer split spoon sampler.

Depth of the wells was governed by the depth of the first aquifer.

Samples were taken of each morphologic layer of the soil and underlying parent material. Each sample was described morphologically and depths of the layers were noted for each layer (Soil Survey Staff, 1984).

Forty-seven additional observations were made during the installation of shallow monitoring wells.

Laboratory Methods

Samples were air dried and crushed to pass a 2 millimeter sieve. Bulk soil samples and rock fragments were weighed. The less than 2 millimeter samples were then subsampled and ground as needed for some laboratory methods (Soil Survey Staff, 1984).

Particle size analysis was performed on all samples by the pipette method (Kilmer and Alexander, 1949). Particle size fractions determined were sand, silt, and clay as defined by the USDA system of soil textural classification. The sand fraction was then sieved and fractionated into very coarse, coarse, medium, fine, and very fine sizes as defined by the USDA system (Gee and Bauder, 1986).

Iron oxides were extracted using the citrate-dithionite method (Olsen and Ellis, 1982). The extracts were analyzed for iron by atomic absorption spectroscopy on a Perkin-Elmer model 5000 spectrophotometer.

Total analysis was performed on a whole soil basis of all samples by a modified aqua-regia, hydrofluoric acid procedure. A microwave oven was used to speed the reaction (Gallagher, 1993; Nadkarni, 1984). After the sample was completely digested the solution was analyzed for 23 elements by inductively coupled argon plasma emission spectrometry (ICAPES) using a Thermo Jarrell Ash ICAP 61. Of these 23 elements, total values of Iron and Titanium were used to assist in determining lithologic discontinuities.

Data Analysis

Data were manipulated to clarify some of the morphological and mineralogical characteristics. Titanium and Zirconium content have proven useful in analyses of parent materials (Chapman and Horn, 1968). Ratios of sand fractions on a clay free basis have been found useful when looking for lithologic discontinuities in polygenetic soils (Cabrera-Martinez, et al., 1989; Soil Survey Staff, 1983). Ratios of free iron to total iron have been used in soil profiles as indicators of soil age (Arduino et al., 1986).

Titanium was chosen as the primary index element because of relative stability of titanium minerals and quality of data obtained from ICAPES analyses. Zirconium values were very inconsistent and were not used due to the lack of repeatability between duplicate samples.

Titanium is often present in the primary oxide form (TiO_2) as rutile and ilmenite (Jackson, 1956.) Fine grained TiO_2 that is cryptocrystalline or amorphous to a polarizing microscope has been called leucoxene.

Reports from Scanning Electron Microscope analysis of silt and sand fractions from one of the well cores identified rutile in the silt fraction (Dixon and White, 1993). Other researchers have found that most of the titanium minerals are found in the silt fraction of soils and earthy materials (Chapman and Horn, 1968; Essington and Mattigod, 1990).

Correlation and regression analyses were completed on the total titanium values and the silt particle size fraction (SAS Institute, 1991). For 163 samples, the R value was 0.808 and regression analysis revealed an R-squared value of 0.653. In order to clarify variations in the titanium values caused by variation in the silt fraction, titanium was calculated on a silt basis by the following equation:

$$\frac{\text{Total soil titanium mg kg}^{-1}}{\text{Percent silt fraction.}} \quad X\ 100$$

Fine sand was chosen as the particle size indicator as the discontinuity between loessial material and alluvium

was easily ascertained. Fine sand fractions were calculated on a clay free basis by the equation:

$$\frac{\text{Percent fine sand}}{\text{Percent total sand + silt.}} \text{ X } 100$$

Total iron and free iron oxides were plotted on the same graph to illustrate differences in weathering sequences. Total iron was adjusted to 100 percent recovery based on a 88.9 percent recovery rate that was determined for the procedure by Gallagher (1993).

Morphological properties (mainly structure and Munsell color) were also used in determining discontinuities.

The Grand Junction, TN and Hickory Valley, TN 7.5 minute topographic maps were used for geomorphic analysis of the landforms. These maps were at a scale of 1:24,000 and contour interval was about 6 meters (U.S. Geol. Survey, 1980a; 1980b.).

Results and Discussion

Landscape Evaluation

Both water quality plots were located on broad interfluves ranging from about 140 to 155 meters (460 to 510 feet) above mean sea level. These broad ridges are about 600 meters across at their widest point and topographic maps illustrate a high degree of dissection

associated with the steeper side slopes adjacent to the major drainageways. Slopes of the ridge tops range from zero, in the more stable positions, to about 15 percent on shoulder slopes and near the 152 meter (500 foot) contour interval.

The most prominent flood plain lies about 2.5 kilometers due north of the Hancock Tract along the North Fork of the Wolf River. This flood plain ranges from 600 to 1200 meters across and elevations range from about 125 to 131 meters (410 to 430 feet) above mean sea level.

Elevations on the West Pasture tract experiment area ranged from 143.43 meters (472.22 feet) to 146.57 meters (480.89 feet) above mean sea level. The Hancock Tract area was somewhat higher in elevation and ranged from 148.97 meters (488.74 feet) to 153.71 meters (504.30 feet) above mean sea level (Fig. 7).

These elevation differences correlate closely with the work of Saucier (1987). Sacuier identified the Finley terrace as being buried by Holocene alluvium only a few kilometers from the mouth of the Wolf River. He also stated that the identification of the Hatchie terrace may have actually been a terrace of older age that does not correlate with the Hatchie terrace identified along other river systems. The mention is also made of a higher

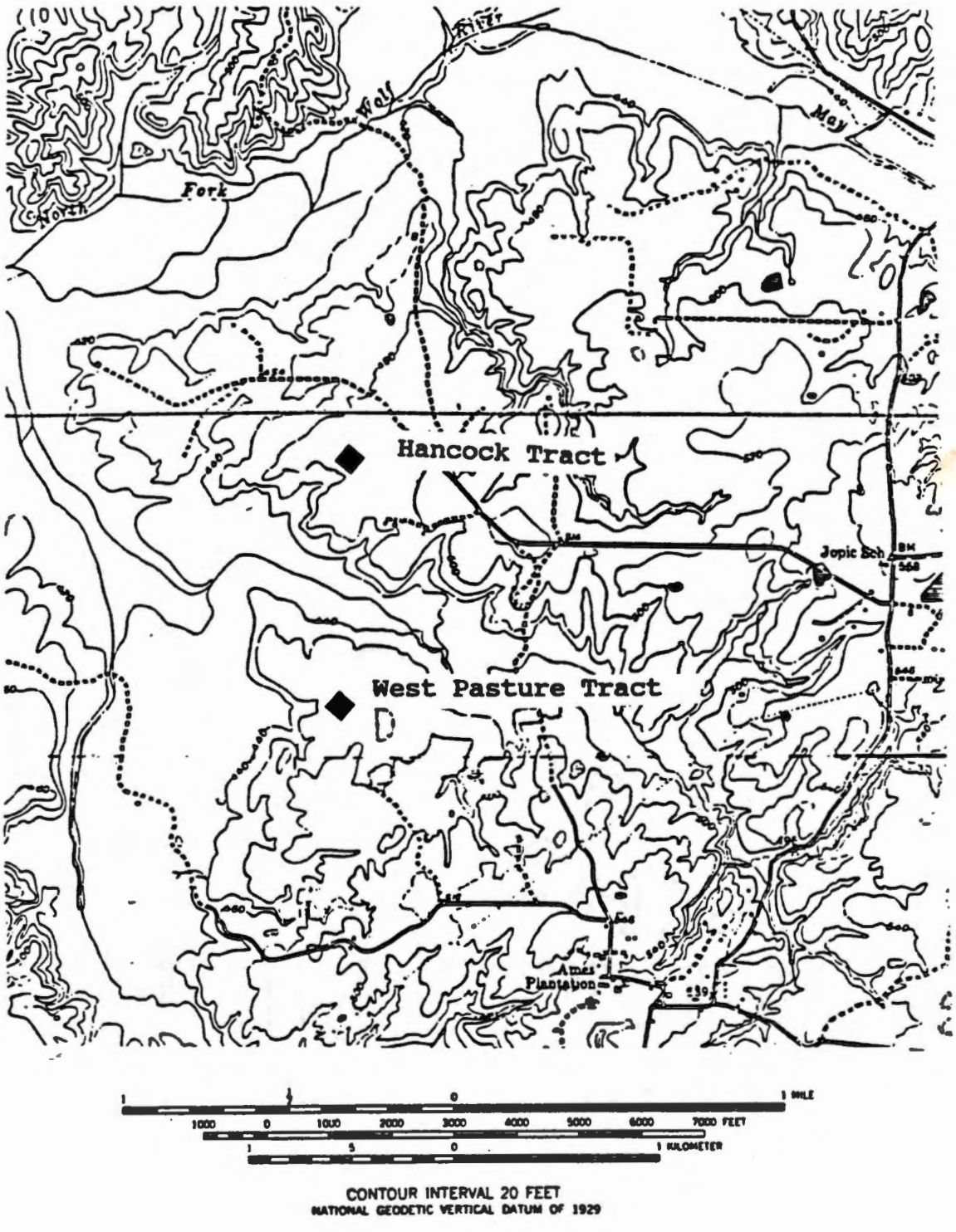


Figure 7. Topgraphic map showing the location of the West Pasture and Hancock Tract experimental areas (reduced for publication).

terrace level than the Hatchie level that could not be identified using physiographic evidence.

As Sacuier's study terminated near the center of Fayette County, maps do not depict the terraces on the Ames Plantation. Elevation and morphological data indicate that the two experimental areas are located on different terrace levels. The floodplain of the North Fork of the Wolf River most probably correlates with the Hatchie Terrace which may have been covered at varying depths by recent alluvium (post settlement). Flood plain elevations in the area average about 127 meters above mean sea level. Lying about 15 to 18 meters higher, at about 144 meters above mean sea level, is the West Pasture plot area. These differences in elevation correlate closely with the described relief of the Humbolt Terrace. The Hancock tract plot area is about 6 to 10 meters above the West Pasture area. From the evidence of dissection on topographic maps and elevation differences, the Hancock tract areas correlates closely with the Henderson terrace level.

West Pasture Tract

Deep Well 020060000. Free iron oxide plots show two distinct zones of increase between the surface (144.35 meters) and 141.20 meters above mean sea level. This increases in free iron oxides were consistent with increases in clay percentage (Fig. 8). The zone between

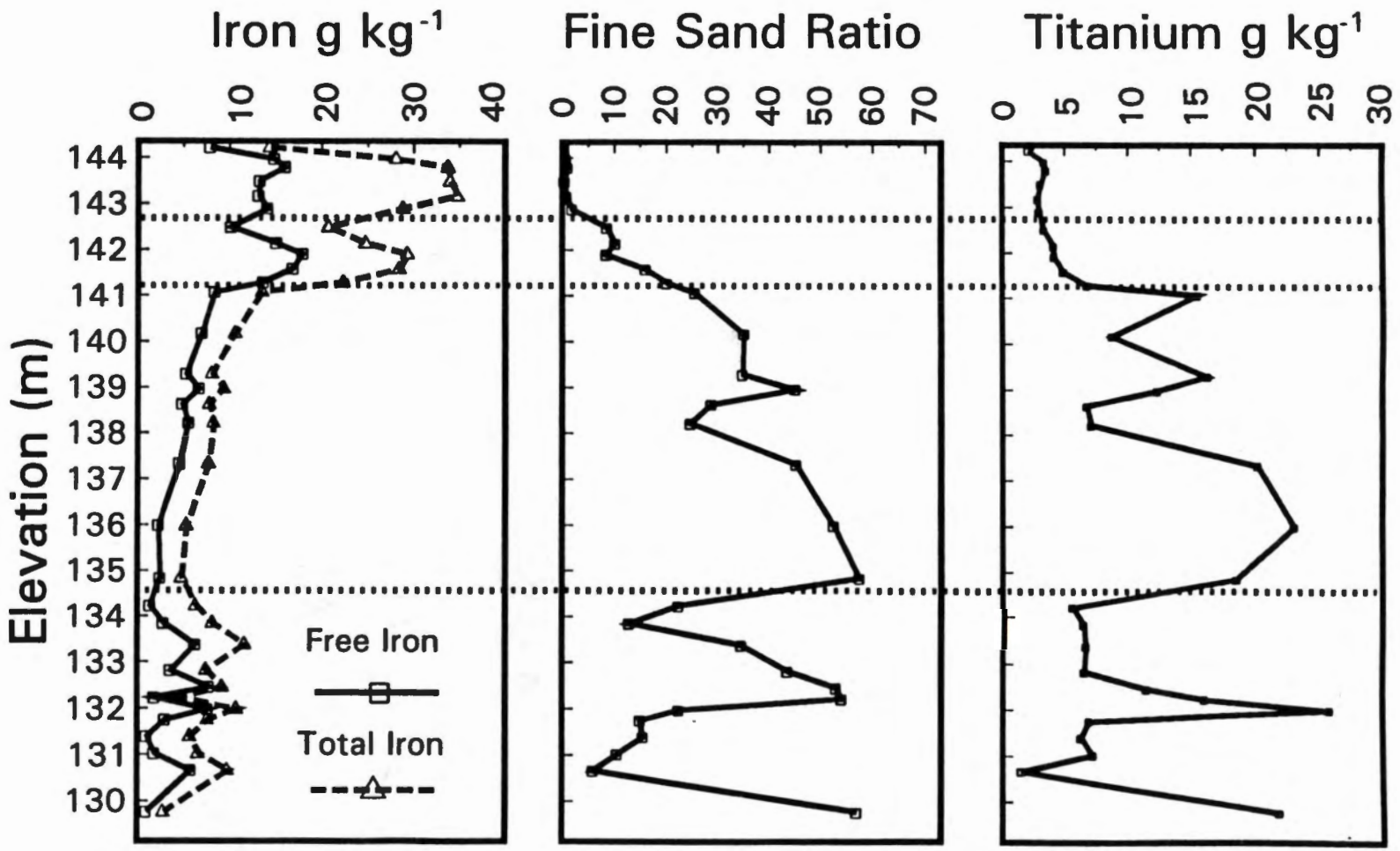


Figure 8. Plots of free iron, total iron, fine sand ratio, and titanium on a silt basis for Deep Well 020060000.

the surface (144.35 meters) and 142.70 meters above mean sea level was loessial material that contained a maximum of 4.7% sand. Chemical, physical, and morphological data did not differ enough to separate this layer into distinct loess depositions. The loessial material was most probably of the Peoria and Roxana depositions. The highest concentration of free iron oxides in the loessial material was between 144.08 and 143.71 meters above mean sea level (Bt1 and Bt2 horizons) and disparity in free iron and total iron contents was greatest. Silt based titanium values were consistent throughout this zone except for a slightly lower value in the surface layer. Evidence of weathering in the loess layer was higher than any other place in the well core.

The second bulge in free iron oxides occurred between 142.70 and 141.20 meters above mean sea level (Fig. 8). This zone of increase also coincided with an increase in clay percentage which was highest of any point within the well core. The fine sand fraction showed an increase (Fig. 8) along with a slight decrease in the silt fraction (Fig. 9). The silt based Titanium fraction began to increase with depth in this layer. The high free iron oxide content, high clay content coupled with the decrease in silt and increase in sand fraction indicated a discontinuity in parent materials and that significant

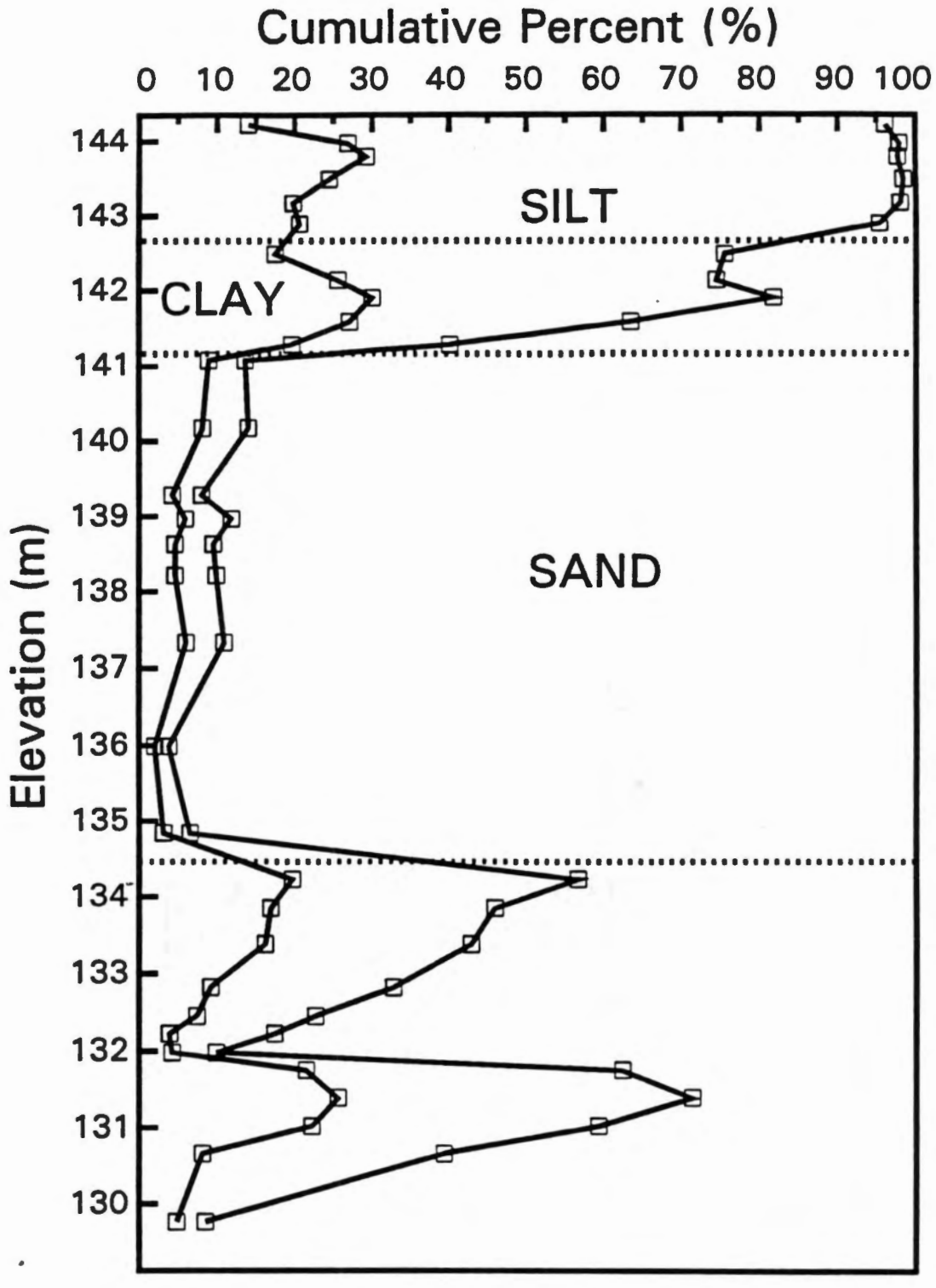


Figure 9. Particle size plot for Deep Well 020060000.

weathering had occurred before the overlying loessial material was deposited. The high silt content of this layer suggests the paleosol formed in a mixing zone of the sandy alluvium and loess. Munsell color, clay content, and stratigraphic location indicated that the source of the silt in the paleosol was probably from the Loveland loess deposition of Wascher et al. (1947).

The plots used in Figure 8 indicated that the alluvial material is confined to the layer between 142.70 and 141.20 meters above mean sea level but the particle size plot clearly indicates a zone between 141.20 and 134.44 meters that has consistent high sand values and low silt and clay underlying the paleosol (Figure 9). Beginning at 134.44 meters, two zones of increase in the silt and clay fractions were visible. Iron plots in Figure 8 indicated relatively low concentration of free iron oxides and total iron. Inflections in the iron concentrations were identified which approximated the locations of highest clay content but almost all of the total iron content was comprised of free iron oxides. Increases and decreases in silt and clay fractions were interpreted as periods of tidal advances and recessions in the costal plain material. The particle size plot indicated that the zone from 135.23 to 129.12 meters is in tertiary sand material.

Deep Well 020060120. Unlike well 02060000, only one zone of free iron oxide accumulation was observed in the upper part of this well core (Fig. 10). The clay percentage showed a slow increase from the surface and the maximum clay accumulation coincided with the highest concentrations of free iron oxides (Figs. 10 and 11). Again a large disparity in the free iron and total iron values indicated a zone of active weathering. The zone between the surface (145.15 meters above mean sea level) and 142.10 meters encompassed the entire loess layer which had maximum sand value of 4.9 percent in the surface layer. Loessial material was most likely of the Peoria and Roxana depositions. Titanium values were consistent in this layer (Fig. 10).

The alluvial layer was indicated best by the fine sand ratio plot, silt based titanium values, and particle size plot (Figs. 10 and 11). This layer was identified between 142.10 meters and 134.48 meters above mean sea level. The upper part of this layer again showed a significant amount of silt between above mean sea levels of 142.10 and 140.58 meters and the presence of a mixing zone paleosol was recognized. The silt in the mixing zone alluvium was probably of the Loveland deposition. A slight increase in clay was also noted in this layer (Fig. 11). Titanium values increased steadily to a maximum of about 1,500 mg

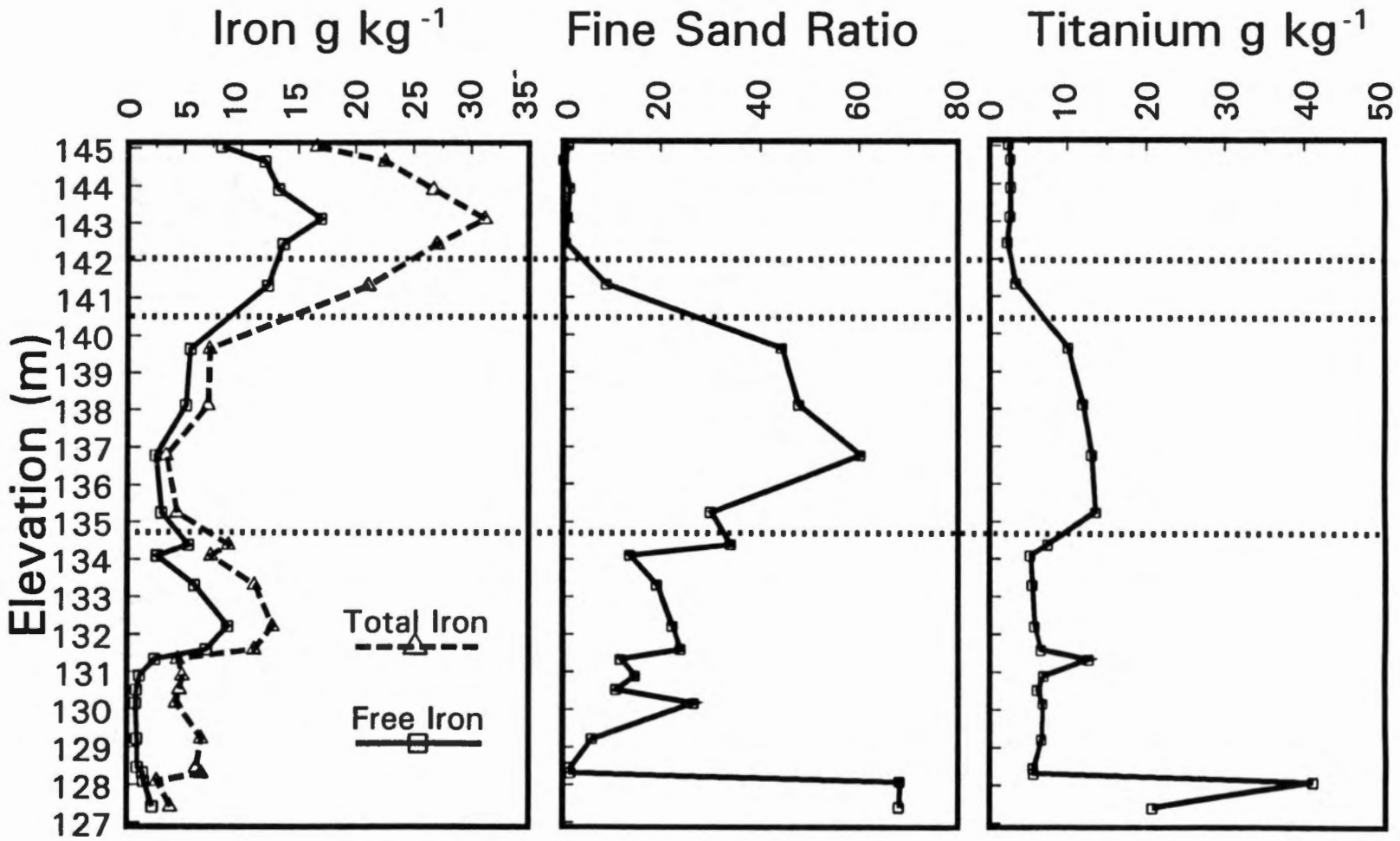


Figure 10. Plots of free iron, total iron, fine sand ratio, and titanium on a silt basis for Deep Well 020060120.

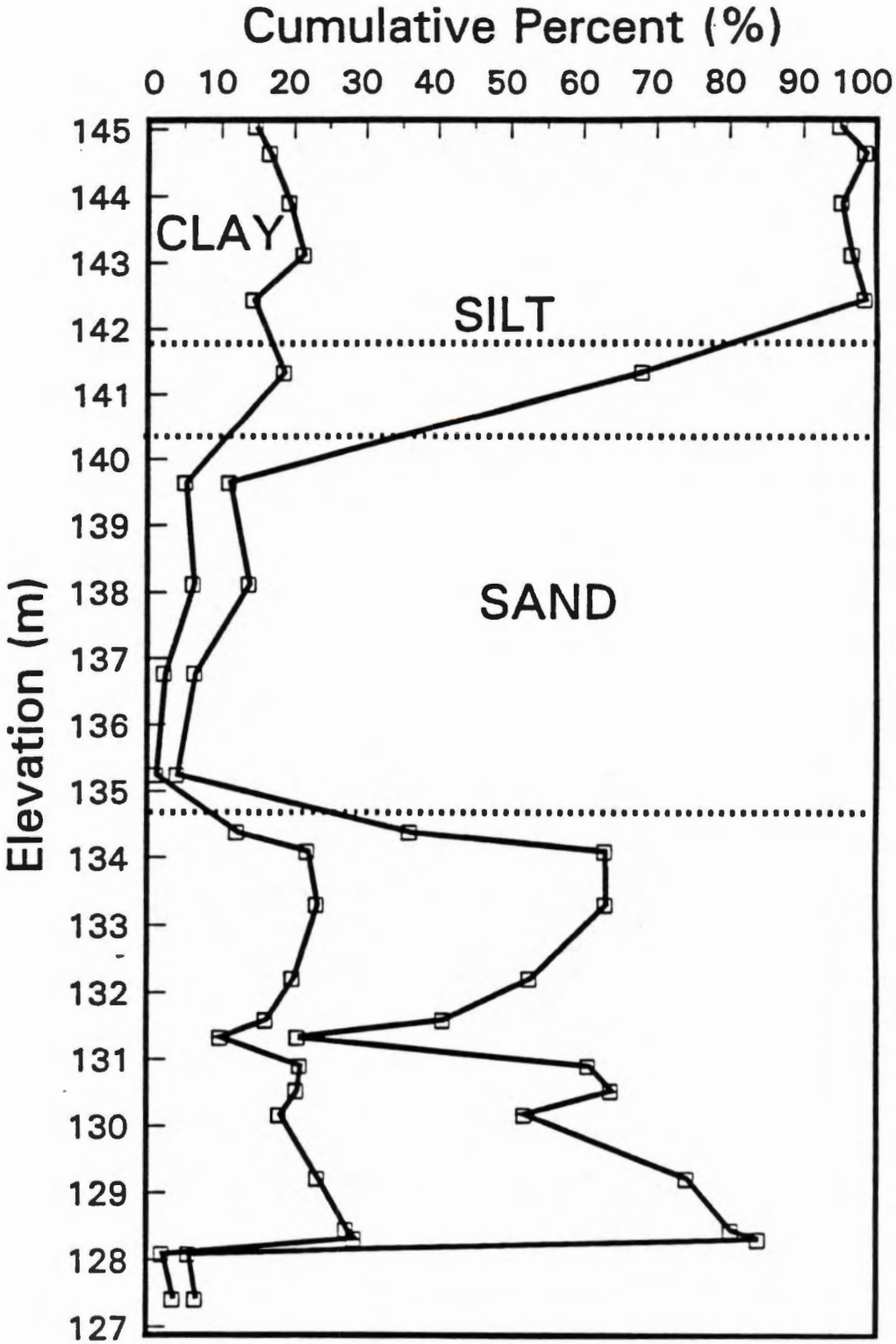


Figure 11. Particle size plot for Deep Well 020060120.

kg^{-1} for this layer before rapidly decreasing below 134.48 meters.

The Tertiary sands were best recognized by particle size distribution (Fig. 11) in the zone between 134.48 meters and bottom of the core at 126.88 meters. Two zones of silt and clay increase were visible as in well 020060000 with less than 1 meter difference in the upper elevation. Iron plots indicate similar inflections but do not accurately reflect the zones of highest clay accumulation (Fig. 10). These accumulations of silt and clay were again attributed to tidal advances and recessions. A plot of the fine sand fraction reflected the stratified nature of the material by illustrating inflections with almost every sample point.

Deep Well 020120300. Three zones of free iron oxide accumulation were evident in the loessial material and two distinct loess layers were identified between the surface at 143.77 meters and 140.34 meters (Fig. 12). The first loess layer occupied the zone from the surface to 141.88 meters. Maximum sand value was 5.1 percent (Fig. 13) and free iron oxides were most concentrated in the zone between 143.16 and 142.69 meters. Large differences in free iron and total iron values were detected. Loessial material in this layer was from the Peoria and Roxana depositions. The second loess sequence was identified between 141.88 and

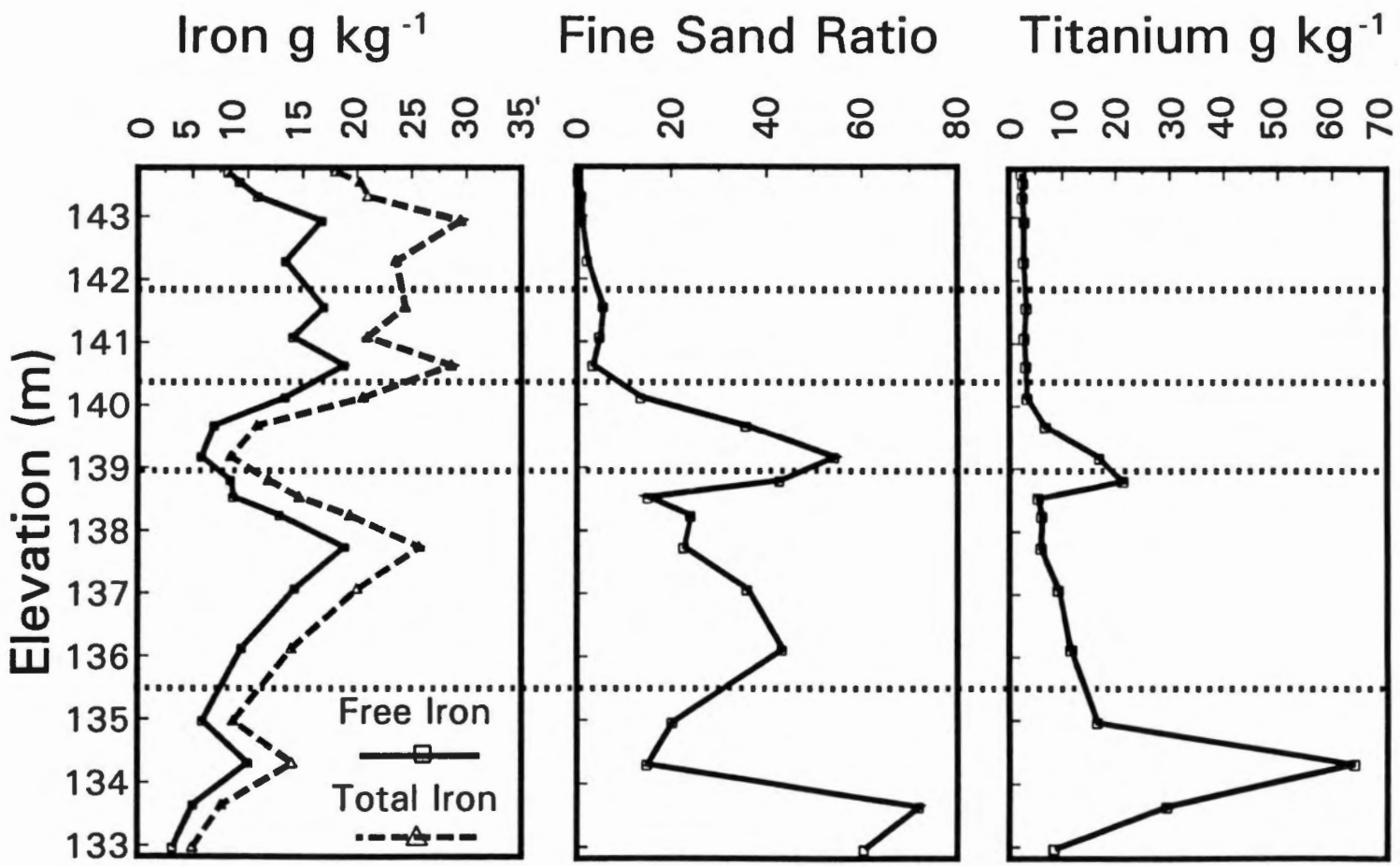


Figure 12. Plots of free iron, total iron, fine sand ratio, and titanium on a silt basis for Deep Well 020120300.

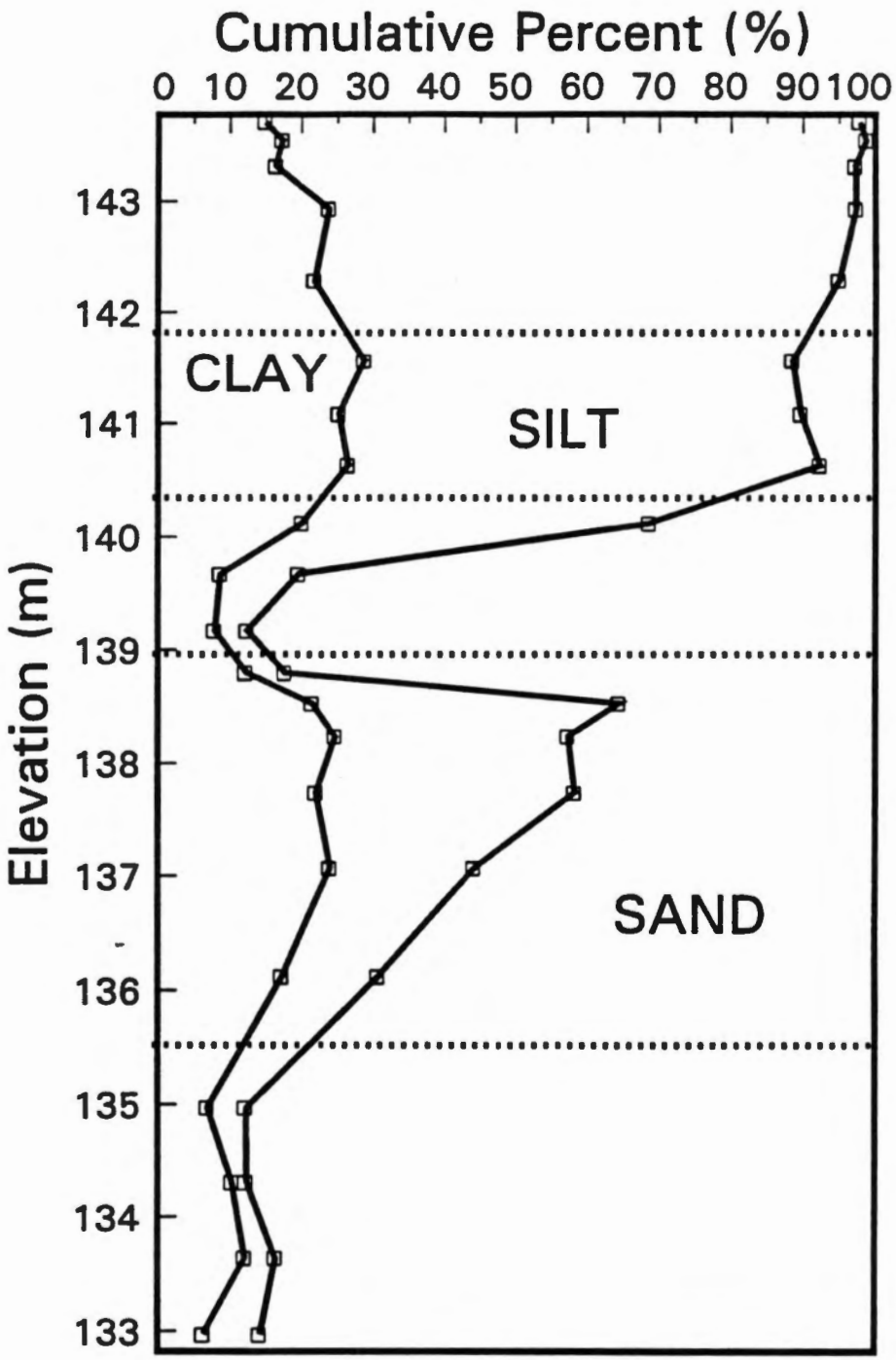


Figure 13. Particle size plot for Deep Well 020120300.

140.34 meters above mean sea level. Although 11.5 percent sand was present in this layer, a large number of manganese concentrations were present and contributed to the sand fraction. Clay percentage surpassed values of the first loess layer (Fig. 13) and free iron oxides were closer to total iron values than in the first identified loess layer. The increase in clay and higher free iron to total iron concentrations illustrate a higher degree of weathering in contrast to the overlying layer. Morphology and particle size data identified this zone almost identically to the Loveland loess of Wascher et al. (1947).

A thin mixing zone was evident in the zone between 140.34 and 138.90 meters. The presence of a paleosol was not evident in this zone as it had a steady decrease in the clay fraction and graded quickly into sandy material with small amounts of free iron oxides (Figs. 12 and 13). This zone reflects weathering processes which were occurring in the Loveland layer when it was exposed at the surface.

Another alluvial sequence was identified between 138.90 and 135.48 meters. Increases in free iron oxides, reach a maximum between 138.11 and 137.37 meters above mean sea level (Fig. 12). Clay and silt contents also peaked in the same area (Fig. 13). Silt based titanium values showed a slight increase over values of the loess materials and were assumed to be from a source other than loess.

Although this zone had a lack of soil structure, free iron oxide values and clay increases indicate that significant weathering had taken place before being covered by a layer of sandy material in the overlying layer. Plots of the fine sand fraction and titanium on a silt basis suggest that the entire layer between 138.90 and 135.48 meters was a fairly homogeneous deposition.

The layer between 135.48 and 132.82 meters exhibited large fluctuations in silt based titanium values and fine sand fractions (Fig. 12). Total sand exceeded 80 percent in each sample (Fig. 13). This zone was identified as the Tertiary sands.

Deep Well 020180150. The loess layer extended from the surface (146.21 meters above mean sea level) to 144.78 meters. Sand fraction increased to a maximum of 12 percent in the lowermost layer which may have experienced some mixing with the underlying material near the lower boundary (Fig. 14). The clay fraction in the loessial material was most abundant in the surface layer which indicated that some of the original surface layer may have been removed by erosion. Free iron oxides were most numerous in layer between elevations of 146.10 and 145.44 meters above mean sea level (Fig. 15).

The zone between 144.78 and 138.11 meters was determined to be alluvial material. As in deep wells

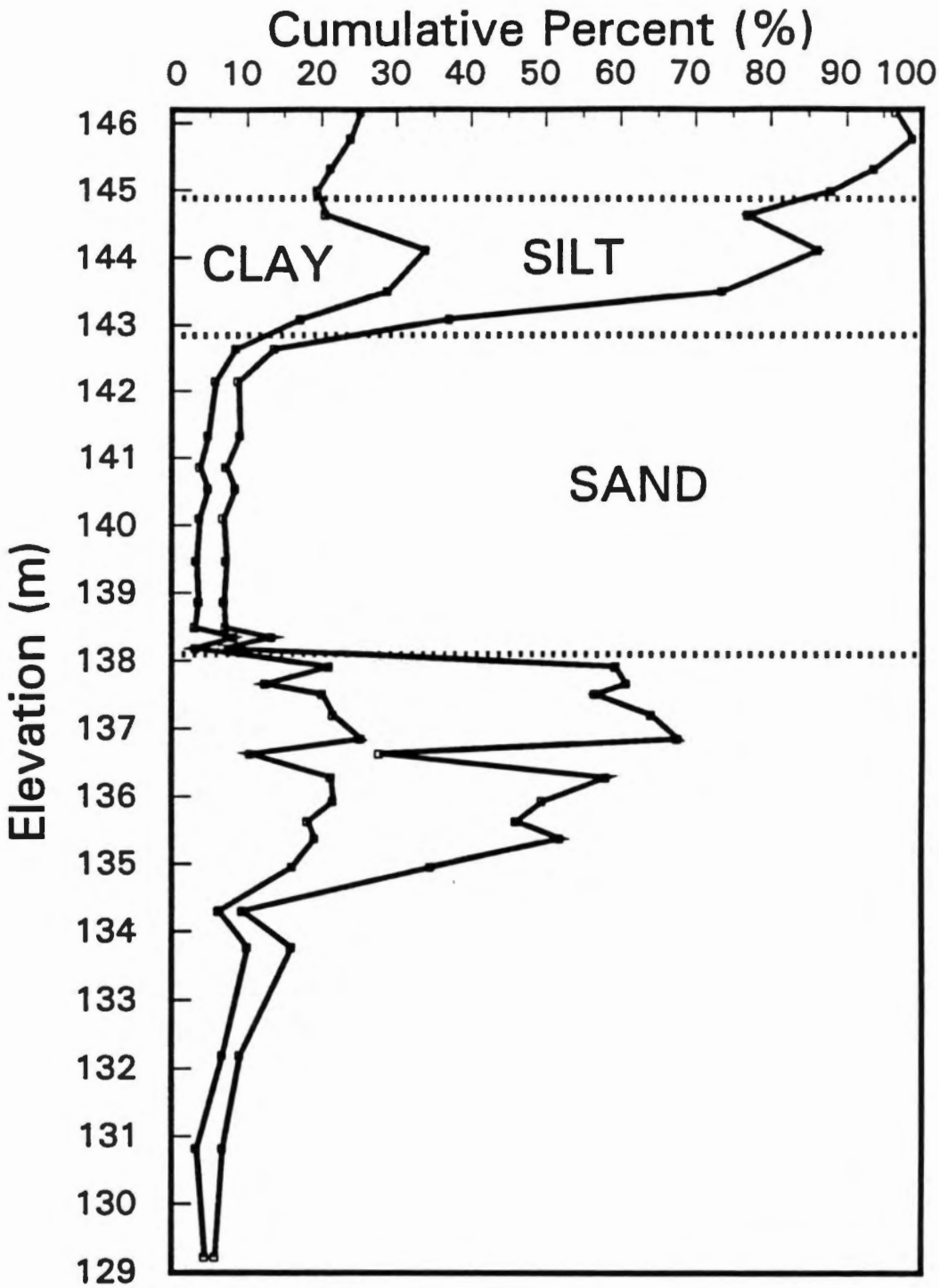


Figure 14. Particle size plot for Deep Well 020180150.

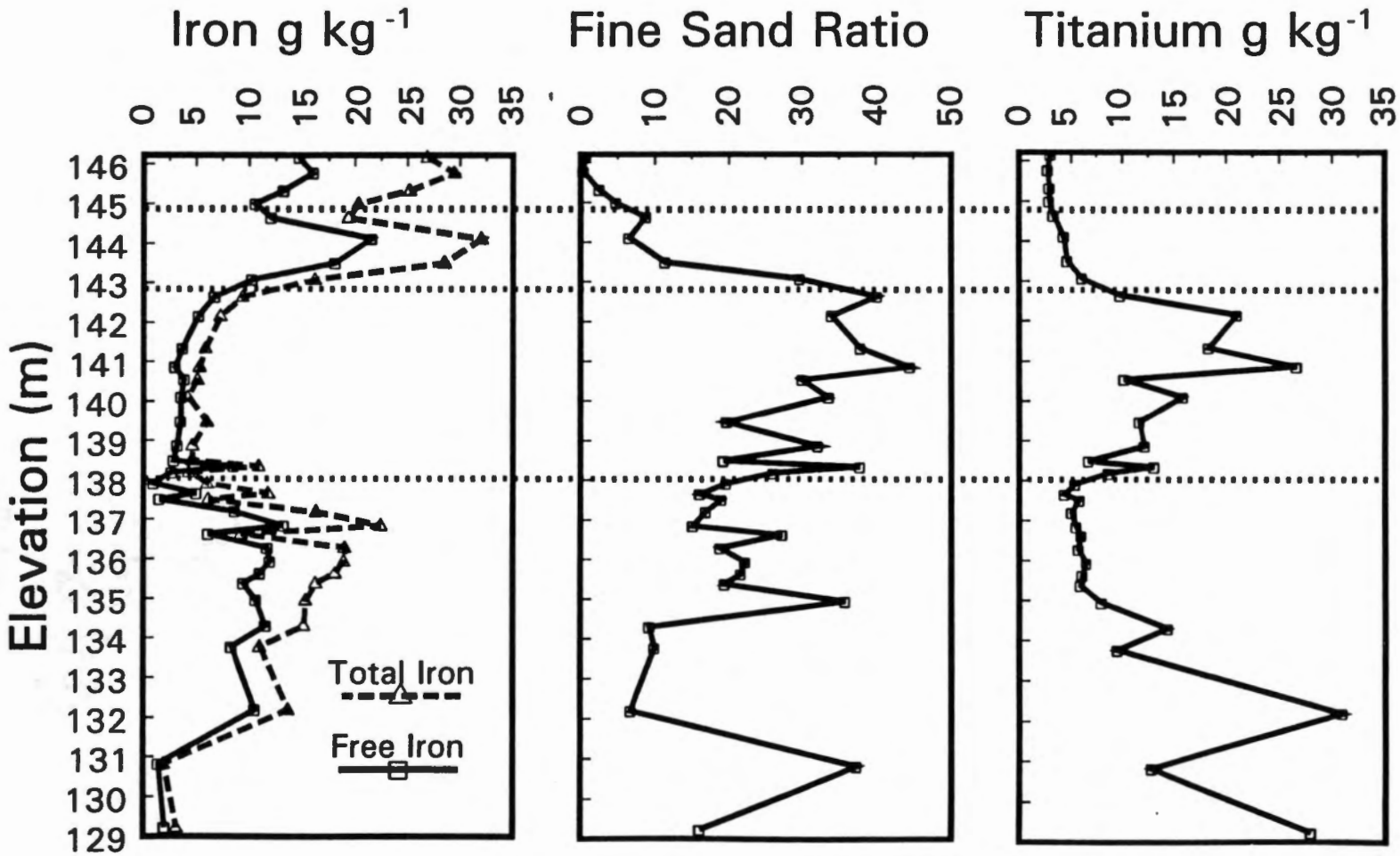


Figure 15. Plots of free iron, total iron, fine sand ratio, and titanium on a silt basis for Deep Well 020180150.

020060000 and 020060120, a paleosol was identified in the mixing zone between the loess and alluvium between elevation 144.78 and 143.28 meters above mean sea level. Free iron oxide concentrations and clay content peaked in the second layer of the mixing zone and were higher than any other place in the well core (Figs. 14 and 15). Titanium values increased gradually in the mixing zone and showed marked fluctuations in the unweathered part of the alluvium.

Material below 138.11 meters was determined to be Tertiary sands. Particle size distribution mimicked wells 020060000 and 020060120. Fine sand plots and titanium values showed two distinct zones of parent material in the Tertiary material, with the upper zone having two zones of silt and clay accumulation as in the two wells mentioned above.

Hancock Tract

Deep Well 010120300. The loess layer extended from the surface layer at 149.90 to 148.15 meters above mean sea level. Plots of particle size fractions show maximum sand values of about 11.8 percent (Fig. 16). Greatest differences in the free iron and total iron values were noted in the third horizon from the surface. Fine sand fraction and titanium values remained steady throughout the

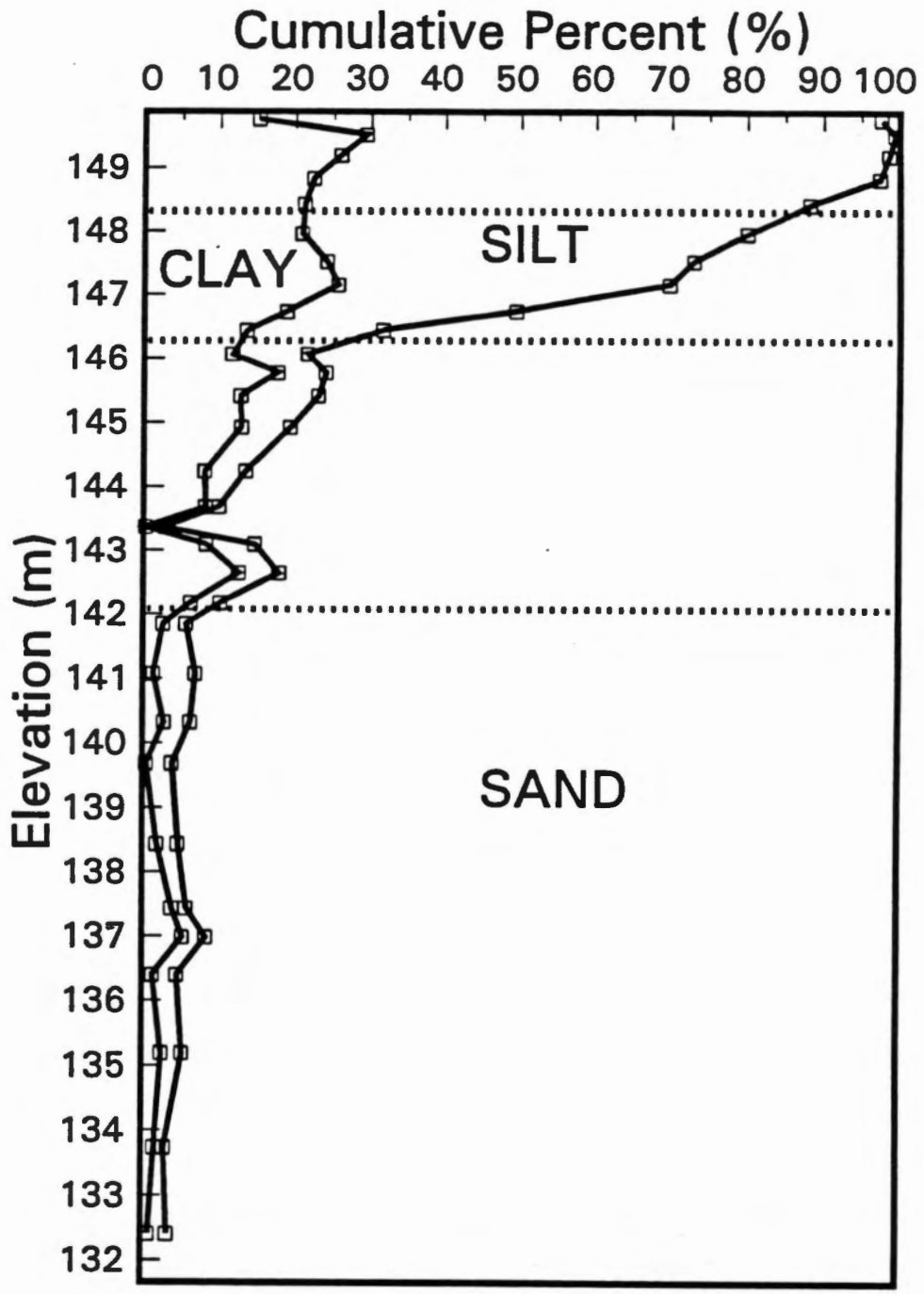


Figure 16. Particle size plot for Deep Well 010120300.

loessial material with slight increases near the lower part of the layer (Fig. 17).

The alluvial layer was present between 148.15 and 142.06 meters. A paleosol was identified in the upper part of the alluvial layer where loessial material and the alluvium were mixed (148.15 to 146.26 meters above mean sea level). Fine sand fraction increased steadily within the mixing zone and free iron values peaked and began to deceases as depth increased (Fig. 17). The clay fraction also reached a another maximum value within the mixing zone (Fig. 16). Little evidence was present to identify the break between alluvium and Tertiary sand material.

Below 142.06 meters, almost all of the total iron was comprised in the free iron state (Fig. 17). A slight increase in silt and clay particle size fractions was noted just above the 142.06 meter point. Below 142.06 meters sand, silt and clay values remained very consistent. Free iron oxide and total iron values indicated little evidence of weathering. Tertiary material was in the zone from 142.06 to 131.65 meters above mean sea level.

Deep Well 010060240. Although the total depth of this well was about ten meters less than the previous well, the similarities in the upper part of the core were numerous.

The loess layer extended from the surface at 151.21 to 149.45 meters above mean sea level. Free iron oxides were

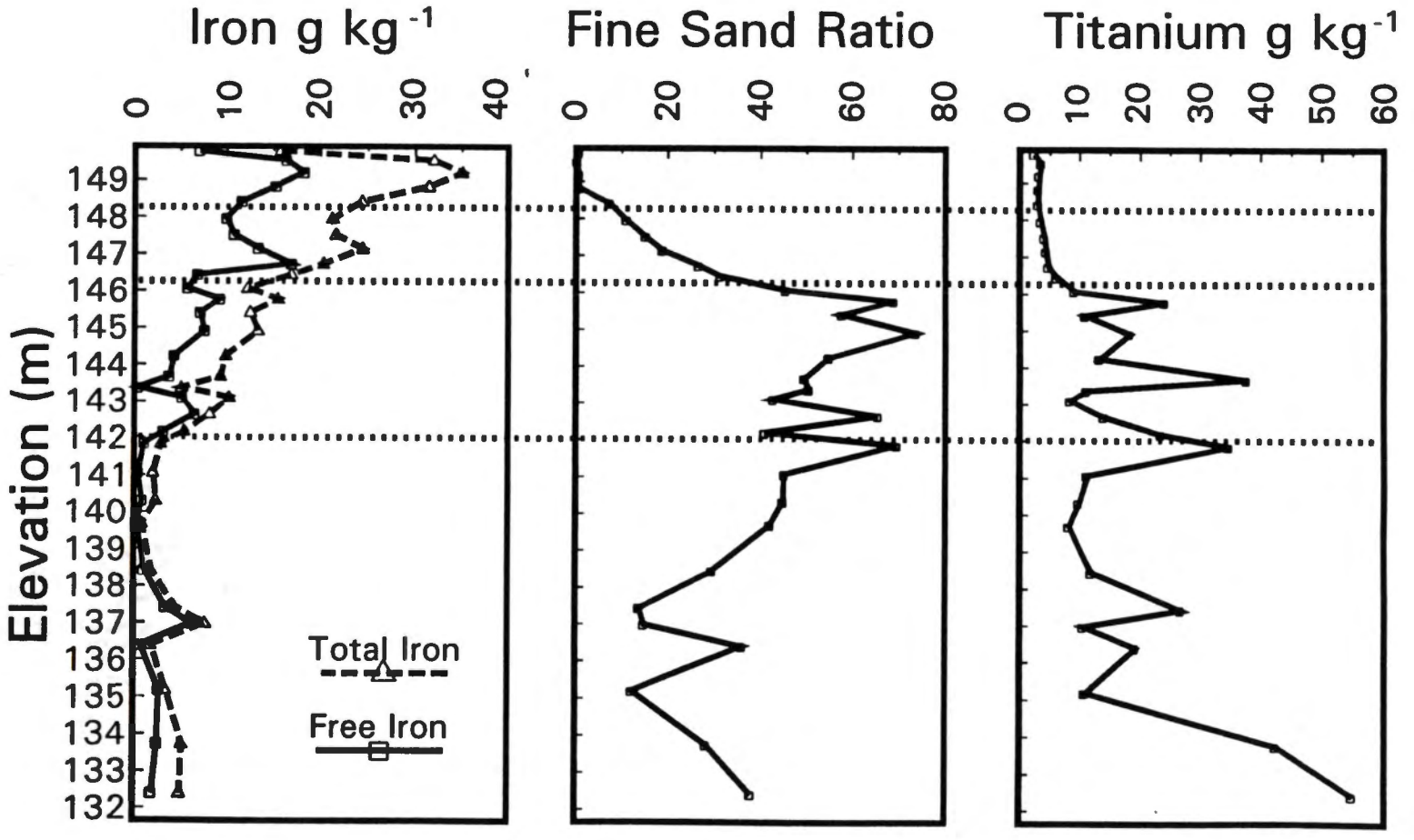


Figure 17. Plots of free iron, total iron, fine sand ratio, and titanium on a silt basis for Deep Well 010120300.

most abundant in the layer immediately below the surface as was the clay percentage (Figs. 18 and 19). The sand fraction was highest at 5.6 percent in the lowest layer of the loess deposition (Fig. 19).

The alluvial layer was between 149.74 and 145.13 meters. A paleosol was evident in the upper part of the alluvial material. From 149.45 to 147.88 meters, silt values between 50 and 60 percent coupled with sand values ranging from 10 to 16 percent suggested that mixing of the sandy alluvium and loessial material had occurred (Fig. 19). Increases in free iron oxides (Fig. 18) and clay percentage (Fig. 19) indicate that significant weathering of the material had occurred before being capped with a more recent loess deposition.

Tertiary sand material extended from 145.13 to the bottom of the sample core at 142.29 meters above mean sea level. Total iron values were dominated by free iron oxides, fine sand fraction increased greatly, and titanium values fluctuated erratically in this layer.

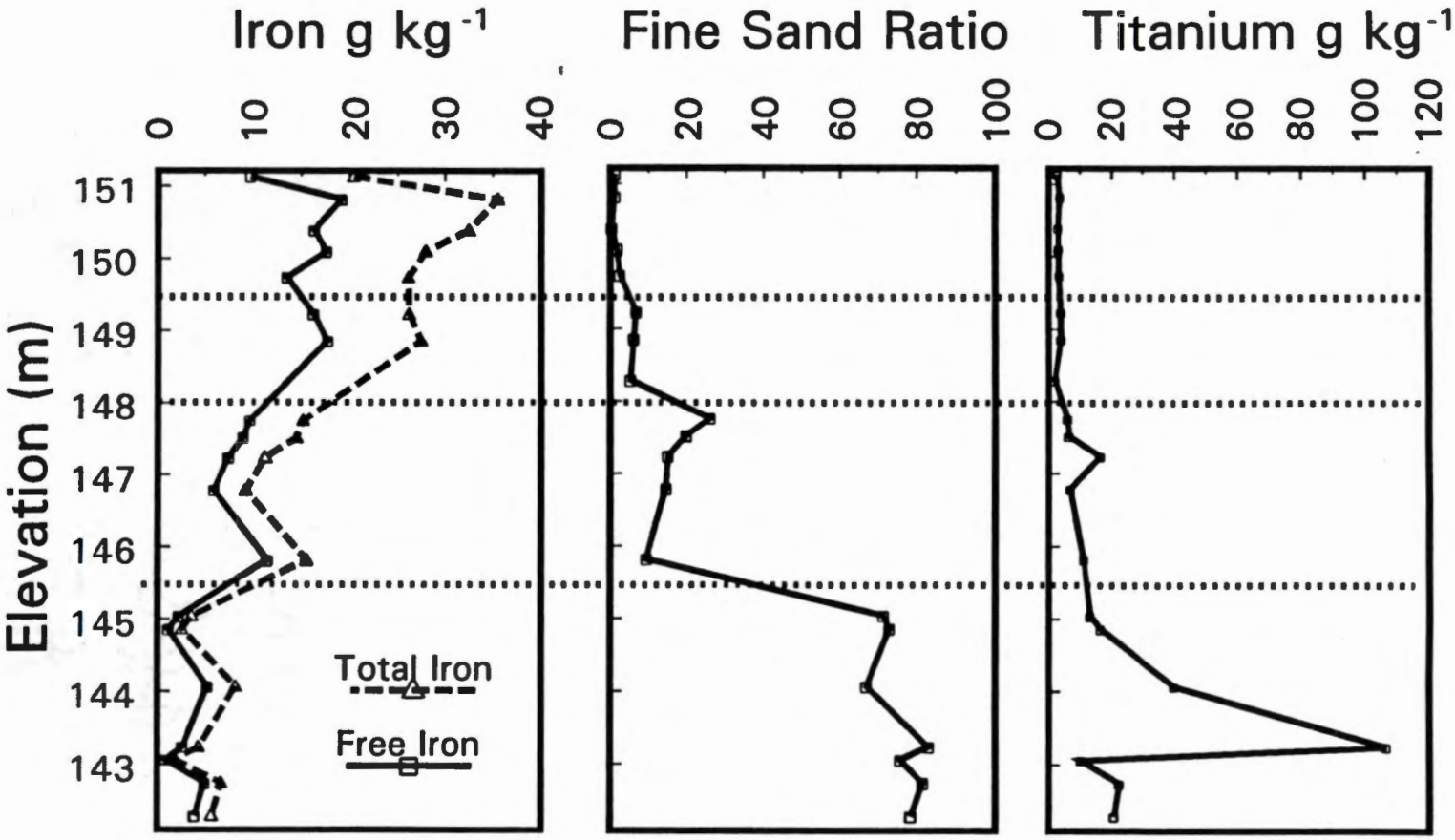


Figure 18. Plots of free iron, total iron, fine sand ratio, and titanium on a silt basis for Deep Well 010060240.

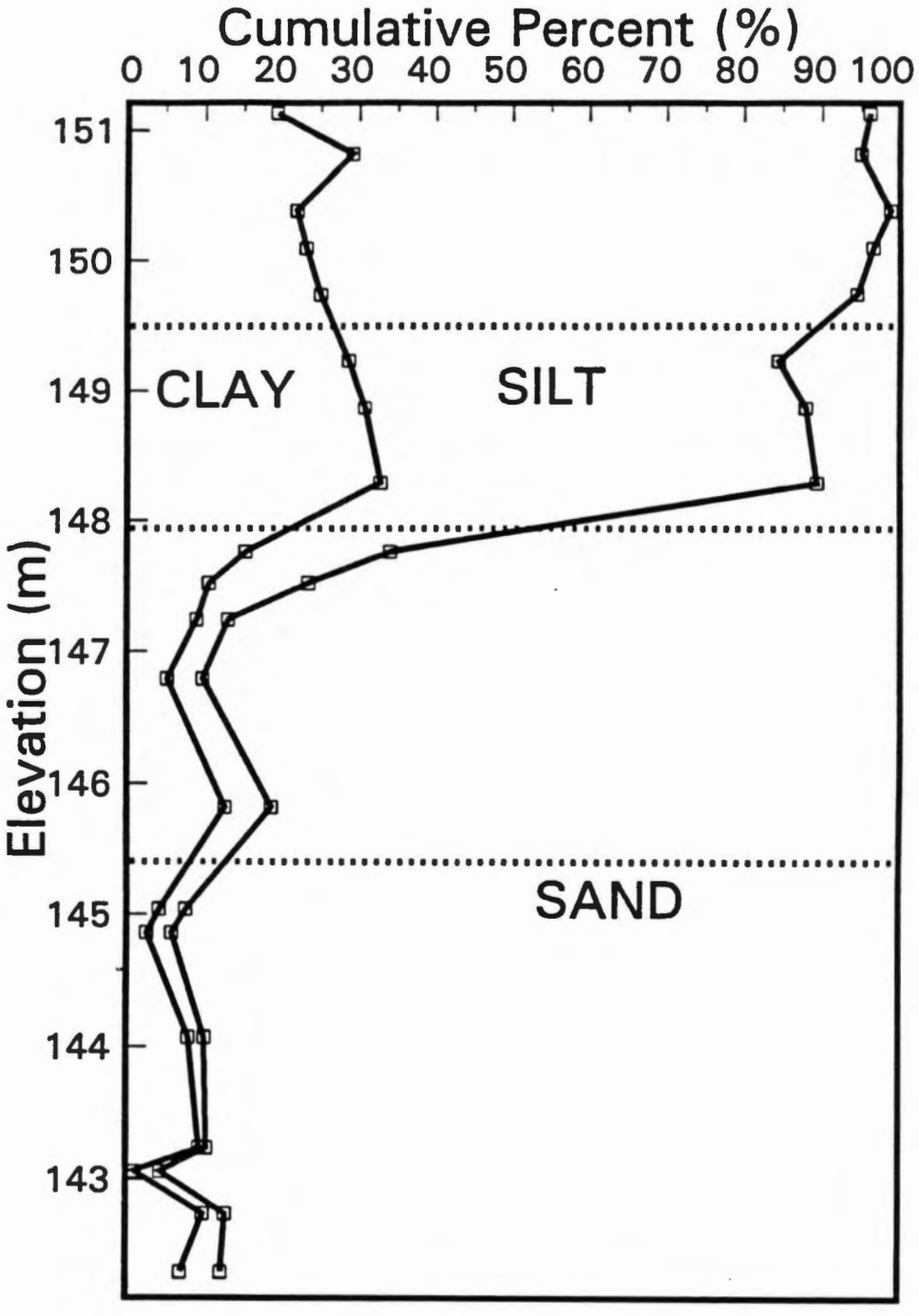


Figure 19. Particle size plot for Deep Well 010060240.

Conclusions

1. The West Pasture experimental plot was located on the Humbolt terrace and the Hancock plot was located on the Henderson terrace level as described by Saucier (1987).

2. Differences between the Peoria and Roxana loess deposits could not be determined by chemical and morphological data where significant weathering had occurred.

3. Thickness of the loess layer on the Hancock plot was very consistent at 1.75 and 1.76 meters. The mixing zone ranged from 1.37 meters to 1.89 meters thick. The Loveland loess was the source of the silt fraction of the mixing zone. Alluvial deposits ranged form 2.75 to 4.20 meters thick.

4. The combined thickness of the Peoria and Roxana loess layers ranged from 1.43 to 3.05 meters. The Loveland loess was identified in well 020120300 and was 1.54 meters thick. The mixing zone of well cores on the West Pasture plot area ranged from 1.44 to 1.52 meters thick. Thickness of the alluvial material ranged from 3.42 to 6.76 meters.

5. A paleosol was found in the mixing zone of every well except well 020120300 where the Loveland loess could be clearly identified. In this well, the paleosol had formed in the Loveland layer.

6. The silt fraction in the mixing zone paleosol of five wells, where the Loveland loess was not present, is likely of the Loveland deposition.

3. SPATIAL DISTRIBUTION OF SOILS ON TWO WATER QUALITY LANDSCAPES ON THE AMES PLANTATION

Introduction

Soil properties are known to vary a great deal over distance. The identification, classification and interpretation of these properties are important for all types of land use. The purpose of this chapter was to: 1) Identify soil taxons on the West Pasture and Hancock Tract experimental areas; 2) Create a mapping legend, soil map, and map unit descriptions for the each area; and 3) Generate a range of characteristics for each taxon.

Review of Literature

Historical Aspects of Soil Genesis

Pedogenesis is a dynamic process which takes different forms to modify the earth's crust into the collection of natural bodies which we call soil. The concept of soil being a natural body was first conceived by the Russian soil scientist V. V. Dokuchaev (1846-1927) in the 1870's. Later, Glinka (1869-1929) and S. S. Neustruev (1894-1927) re-emphasized the concept of weathering and the geological aspects of the earth's crust as a weathering mantle (Buol et al., 1989).

E. W. Hilgard (1833-1916) produced a treatise on soil as related to climate after many years of work (Buol et al., 1989). Hans Jenny later explained soil forming in 1941 in the formula S = F(cl, o, r, p, t...) meaning soil formation is a function of climate, organisms, topography, parent material, and time (Jenny, 1941).

Roy W. Simonson (1959) viewed soil genesis as consisting of two broad steps; (1) the accumulation of parent materials, and (2) the differentiation of horizons in the profile. The weathering of parent material and differentiation of horizons are basically explained in the soil forming factors as defined by Jenny.

Climate is without a doubt the most influential factor in soil genesis. Climate is so complex that it cannot accurately be measured. Numerous climatic factors contribute to soil forming but the two most prominent are moisture and temperature (Jenny, 1941). Temperature is recognized as a controlling factor in the rate of chemical reactions. For every 10^{o} C rise in temperature, the rate of chemical reactions double (Joffe, 1949). Radiation and temperature are closely related especially under clear skies. The surface of bare soils is the most responsive. Cultivated soils have higher temperatures than uncultivated, forest, and grass covered soils.

Uncultivated and vegetated soils have lower seasonal and daily ranges of temperature (Bunting, 1965).

Precipitation is also equally important in the climatic factor. Water plays a key role in; (1) transporting material from one part of the soil to another, (2) physically rupturing material when it freezes and , (3) the type and rate of reactions influencing pH and redox potential (Buol et al., 1989; Jenny, 1941; Joffe, 1949). The function of water in soil erosion and deposition and functions within the profile is regulated by runoff, and the rate of entry into the soil. This runoff potential is regulated by structure, porosity, soil texture, vegetative cover, and relief to name only a few factors. Generally as rainfall increases, cation exchange capacity and structure increase while bases are leached out. As primary minerals are removed, the secondary products such as clay begin to develop (Joffe, 1949; Jenny, 1941).

Living organisms along with climate probably play a major role in horizon differentiation. In grassland and forest situations the activity of organisms may be most evident (Bunting, 1965). Organic matter accumulation, profile mixing, and structural stability are all made possible by the presence of living organisms. The most observable of soil features influenced by organisms are the biotically shaped peds and voids, concentration of both

organic matter, alteration of mineral matter, and certain irregularities in the soil surface (Joffe, 1949). Organic material accumulation may be most contributed to by plant parts such as leaves, stems, and roots which stimulate microfaunal activity. The activity of microfauna in turn contributed the profile mixing and structural stability of the soil (Joffe, 1949).

Relief is a soil forming factor that has not received the attention that it should in many respects. The topography of the land may be such as to slow or speed along the work of climatic forces (Joffe, 1949). In respect to normal relief and normal soil, Marbut writes:

> "Experience has shown that in every region having what may be defined as normal relief there is a normal profile. By normal relief is meant the greater part of the earth's surface and may be described as smooth, undulation, or rolling, with a relation to drainage such that the present water table lies entirely below the bottom of the solum." (Jenny, 1941).

Zakharov states that two types of topography are considered in connection with the soil forming process. Macrotopography and microtopography namely are the two to be considered. Microtopography is defined as the slight elevations or depressions which differ in local areas. Dokuchaev established "The law of constant relations between the surface forms and the character of the soil" (Joffe, 1949). The depth of soil decreases as the

steepness of the slope increases thus the most pronounced influence of relief is found in mountainous country (Bunting, 1965). Slope exposure is another feature of soil formation. The southern exposure is generally warmer and drier and sustains marked fluctuations in temperature and moisture. Certain features on perfectly level smooth topography may be traced to the effects of microrelief.

Parent material is the most important of the passive soil forming factors. Parent material plays a secondary role in the genesis of the soil body. Neustruev stated, "Parent rocks are far from being a blank sheet of paper on which climate may write anything it desires" (Joffe, 1949). For example, the texture of sandy soils is determined largely by parent material. Chemical and mineralogical compositions of parent material often not only influence weathering efficiency but may also control the natural vegetation and chemical aspects of the soil such as pH in the case of limestone (Daniels et al., 1971).

Time is based primarily on horizon differentiation and may be expressed as the maturity of the soil. Although time may be continual, the "time-zero" or the start of a new cycle of development for soils may be very different (Buol et al., 1989; Jenny, 1941). The best evidence of the time factor may be seen by comparing the soils of a glacial episode. These glaciated areas along with alluvial and

lacustrine materials generally are too young to develop diagnostic horizons as the unmoved upland areas have; with exception of uplifted areas which occurred in "recent geologic time" (Brady, 1974).

These factors as described by Jenny are very interdependent and ever-changing. The many different combinations of these dynamic variables are responsible for the different character of the soils that are present on the earth's surface.

Soil Classification History

The evolution of soil classification can be subdivided into five periods; (1) the early technical era; (2) the period of the founding of pedology by a Russian group of soil scientists; (3) the early American period; (4) the middle period of general development of soil classification in the United States (Marbut Period); (5) the present modern period of quantitative pedology (Buol et al., 1989).

The early technical period of soil classification was in western Europe in the middle and later parts of the nineteenth century. These were technical systems of classification prepared for a specific purpose or objective and using factors or characteristics of soils instead of properties. For example, Thaer in 1853 published a classification system which combined textural properties as a primary dividing point of soil classes. The lower

classes were named as to what agriculture practice the land could be used for. Some examples were : strong wheat soil, weak wheat soil, and thin wheat soil (Buol et al., 1989).

During the latter part of the early technical period, the period of the founding of pedology was becoming established. Soil studies on the Moscow plains in Russia, had a tremendous impact on soil science and were the foundations of modern pedology. Differences of an increasing temperature gradient, different vegetation, and the shift from forest to prairie were noticed by V. V. Dokuchaev who was the founder of modern pedology. Dokuchaev understood the full significance of these soil differences and thereby established the concept of soil as an independent natural body (Buol et al., 1980).

In the Middle American Period of soil classification, C. F. Marbut was the central figure. Marbut introduced the concepts of Dokuchaev after translating into English a German edition of K. D. Glinka's work on types of soil formation and soil groups of the world. Glinka, one of Dokuchaev's students placed more emphasis on climate and vegetation rather than geologic properties. Marbut is considered the "Founder of American Pedology". He established the concept of the soil profile, focused on properties of soils, and produced the truly multicategorical system of soil taxonomy. Efforts were

made to revise the Marbut system by Baldwin, Kellogg, and Thorp by publishing the USDA Yearbook of Agriculture in 1938. This publication was a classification of all known soils in the United States.

The Modern Period of classification was started by the revision of the USDA Yearbook by Thorp, Riecken, and Smith. In these revisions new great groups were added and definitions were revised and sharpened. The actual start of the period was in 1951 when the USDA decided to adopt a new classification system. This system was called the "Comprehensive Soil Survey System". This new system permitted classification of soils rather than soil forming processes. It focused on the soil rather than related sciences and permits classification of soils of unknown genesis (Cline, 1974).

Even though replaced, the 1938 system has played a major role in the recent growth and development of soil science. The development of this new system was by a series of "approximations" which were circulated for criticism and comment. The final draft of soil classification was published as *Soil Taxonomy* by the Soil Survey Staff in 1975.

Materials and Methods

Field Methods

Sampling of six deep wells was described in the previous chapter.

Additionally, forty-seven vadose zone monitoring wells were installed on the West Pasture tract and the Hancock Tract experimental areas. Twenty-four wells were installed on the West Pasture tract. Twenty-three wells were installed on the Hancock tract. One of the wells was not installed as it was located in the bottom of a drainageway where the water was moving laterally on the soil surface from the substratum of the adjacent field. A Giddings GSRP-S-M hydraulic probe with a 7.62 cm sample tube was used to extract the soil core. Soil morphology was recorded for each soil core (Soil Survey Staff, 1984; Soil Survey Staff, 1981). The depth of each well was determined by the depth of a restrictive layer and the depth of redoximorphic mottles. The wells ranged from 1.8 m to about 2.5 m deep.

Laboratory Methods

Sample preparation, particle size analysis, and determination of iron oxides were described in the previous chapter. Total carbon analysis was determined on 60 mesh samples with a Leco CR-12 carbon analyzer. An Orion

Research Ionalyzer model 339A was used to determine soil pH. Two millimeter soil samples were mixed with deionized water in a 1:1 ratio.

Exchangeable base cations were determined by the ammonium acetate pH-7 method. The extract was analyzed on a Perkin-Elmer 5000 Atomic Absorption Spectrophotometer (Soil Survey Laboratory Staff, 1992). The ammonium acetate extracted soil samples were extracted with a solution of acidified NaCl. The displaced ammonium was distilled with a Lab Conco distillation unit to determine cation exchange capacity (Chapman, 1965). Extractable acidity was determined by the $BaCl_2$-TEA procedure. Calculations for ammonium acetate pH-7 base saturation, and sum of cations base saturation were made (Soil Survey Laboratory Staff, 1992). Exchangeable aluminum was determined by KCl extraction and the extract was analyzed on Perkin-Elmer 5000 Atomic Absorption Spectrophotometer (Thomas, 1982).

Soil Mapping and Topographic Maps

An order 1 soil survey was prepared for each landscape area at a scale of 1:1,200. Using the laboratory data for each of the eight deep wells in section 2 as a reference, soils were classified to the family level using the forty-seven soil descriptions that were collected on the sites. Supplemental transect data were collected on map units that contained less than three pedon descriptions. Soil

descriptions for each map unit were summarized and a range of morphological characteristics was developed for each taxon (Soil Survey Staff, 1981).

Topographic maps were made of the present soil surface and of the paleosol surface for each research area using a personal computer and Surfer^{R} software (Golden Software, 1991). Contour interval was set at 0.5 m. Data for the present surface were furnished by the Agriculture Engineering Department at the University of Tennessee. The paleosol contact was determined by soil morphology descriptions taken during the installation of the forty-seven shallow wells.

Results and Discussion

Soil Maps, Map Unit Design, and Paleosol Topography

Soil maps for each experimental plot area were drafted on a base map at 1:1,200 (1"=100′). Maps were reduced for publishing to the scale of 1:2,100 (1"=175′) (Figs. 20 and 21).

Map unit design was based primarily on taxonomic classification. Further subdivisions of map units were made at the phase level dependant upon the depth of loessial material over the paleosol layer and erosion class. Slope was 0 to 2 percent in all map units except for map unit 7, which ranged from 2 to 5 percent.

Soil Map Legend for the Hancock Tract experimental area

Symbol	Map unit name
1	Fine-silty, mixed, thermic Fragic Hapludalfs, 0 to 2 percent slopes, discontinuity less than 150 cm
2	Fine-silty, mixed, thermic Ultic Hapludalfs, 0 to 2 percent slopes, discontinuity less than 150 cm
3	Fine-silty, mixed, thermic Typic Fragiudalfs, 0 to 2 percent slopes, discontinuity greater than 150 cm
4	Fine-silty, mixed, thermic Ultic Hapludalfs, 0 to 2 percent slopes, discontinuity greater than 150 cm
5	Fine-silty, mixed, thermic Glossaquic Fragiudalfs, 0 to 2 percent slopes
6	Fine-loamy, mixed, thermic Typic Paleudults, 5 to 25 percent slopes, gullied
7	Fine-silty, mixed, thermic Dystric Eutrochrepts, 2 to 5 percent slopes, eroded
	Map Scale 1:2,100 (1"=175')
	Soil lines and symbols are in green.

DW01030090

Figure

Soil Map Legend for the West Pasture experimental area

Symbol	Map unit name
1	Fine-silty, mixed, thermic Fragic Hapludalfs, 0 to 2 percent slopes, discontinuity less than 150 cm
2	Fine-silty, mixed, thermic Ultic Hapludalfs, 0 to 2 percent slopes, discontinuity less than 150 cm
3	Fine-silty, mixed, thermic Typic Fragiudalfs, 0 to 2 percent slopes, discontinuity greater than 150 cm
4	Fine-silty, mixed, thermic Ultic Hapludalfs, 0 to 2 percent slopes, discontinuity greater than 150 cm
5	Fine-silty, mixed, thermic Glossaquic Fragiudalfs, 0 to 2 percent slopes
6	Fine-loamy, mixed, thermic Typic Paleudults, 5 to 25 percent slopes, gullied
7	Fine-silty, mixed, thermic Dystric Eutrochrepts, 2 to 5 percent slopes, eroded
	Map Scale 1:2,100 (1"=175')
	Soil lines and symbols are in green.

DW020180090

Figure

Six soil taxons were identified and seven map units were delineated demonstrating the spacial variability on a seemingly uniform geomorphic landform (Table 1). Map units 3,4, and 6 were common to both the Hancock Tract and the West Pasture tract. Map unit 2 was exclusive to the Hancock Tract and map units 1,5, and 7 were restricted to the West Pasture tract.

Topographic maps of the present-day soil surface and the surface of the paleosol show marked similarities (Figs. 22 and 23). Many of the map unit boundaries follow topographic breaks of the paleosol surface or the present-day soil surface.

These high intensity soil maps and maps of the paleosol surface can be used to help interpret data collected from the experiment areas, in future soil morphology/crop response studies, and in a variety of research projects. Presence or absence of a fragic properties and depth to the paleosol are important properties. Favorable rooting depth for crops and water movement through the soil will be mostly dependant on these properties.

Table 1. Mapping legend for the Hancock tract and the West Pasture tract experimental areas.

Symbol	Map unit name
1.	Fine-silty, mixed, thermic Fragic Hapludalfs, 0 to 2 percent slopes, discontinuity less than 150 cm
2.	Fine-silty, mixed, thermic Ultic Hapludalfs, 0 to 2 percent slopes, discontinuity less than 150 cm
3.	Fine-silty, mixed, thermic Typic Fragiudalfs, 0 to 2 percent slopes, discontinuity greater than 150 cm
4.	Fine-silty, mixed, thermic Ultic Hapludalfs, 0 to 2 percent slopes, discontinuity greater than 150 cm
5.	Fine-silty, mixed, thermic Glossaquic Fragiudalfs, 0 to 2 percent slopes
6.	Fine-loamy, mixed, thermic Typic Paleudults, 5 to 25 percent slopes, gullied
7.	Fine-silty, mixed, thermic Dystric Eutrochrepts, 2 to 5 percent slopes, eroded

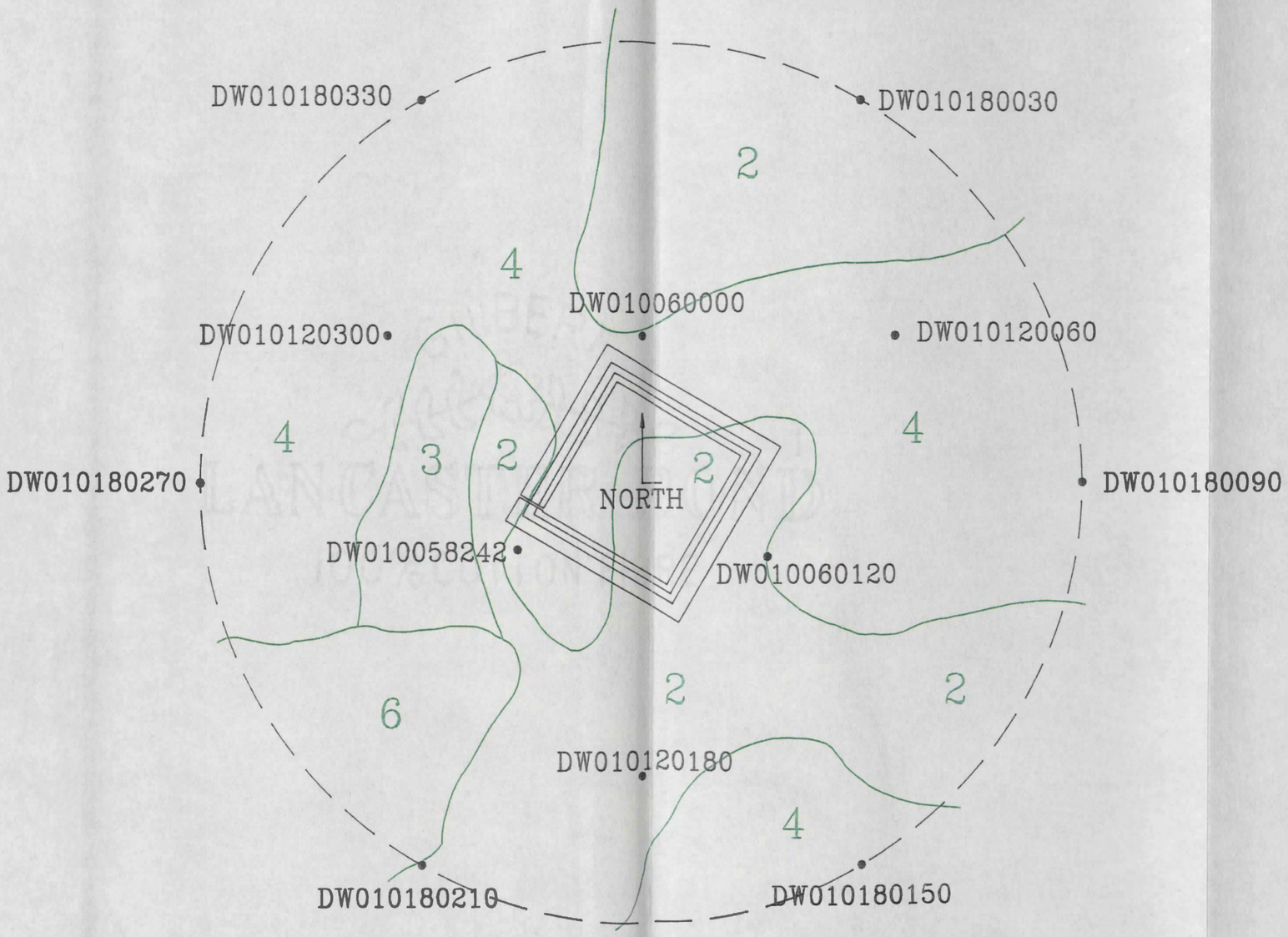


Figure 20. Soil map of the Hancock Tract water quality experimental area.

Soil Map Legend for the Hancock Tract experimental area

Symbol	Map unit name
1	Fine-silty, mixed, thermic Fragic Hapludalfs, 0 to 2 percent slopes, discontinuity less than 150 cm
2	Fine-silty, mixed, thermic Ultic Hapludalfs, 0 to 2 percent slopes, discontinuity less than 150 cm
3	Fine-silty, mixed, thermic Typic Fragiudalfs, 0 to 2 percent slopes, discontinuity greater than 150 cm
4	Fine-silty, mixed, thermic Ultic Hapludalfs, 0 to 2 percent slopes, discontinuity greater than 150 cm
5	Fine-silty, mixed, thermic Glossaquic Fragiudalfs, 0 to 2 percent slopes
6	Fine-loamy, mixed, thermic Typic Paleudults, 5 to 25 percent slopes, gullied
7	Fine-silty, mixed, thermic Dystric Eutrochrepts, 2 to 5 percent slopes, eroded
	Map Scale 1:2,100 (1"=175')
	Soil lines and symbols are in green.

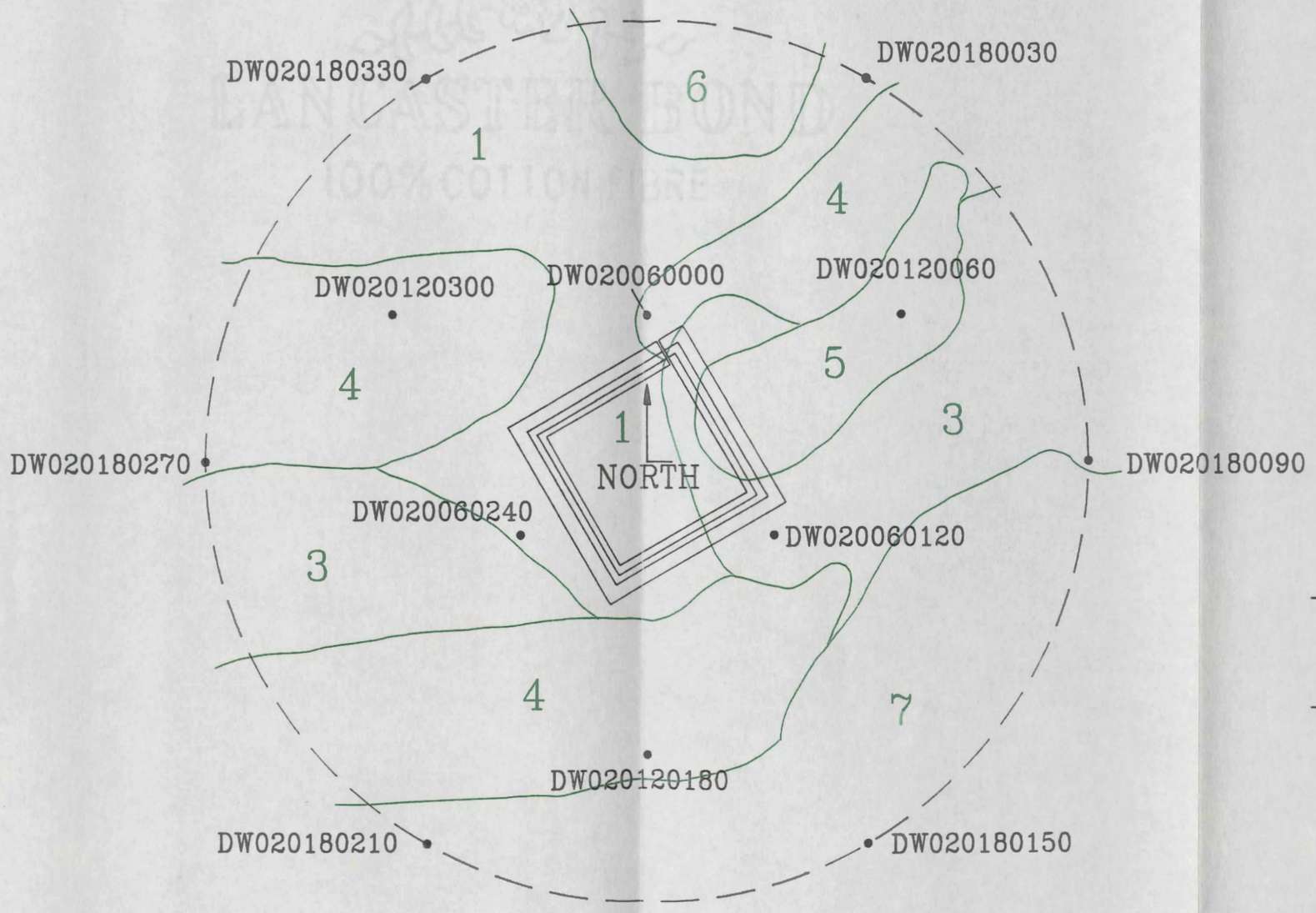


Figure 21. Soil map of the West Pasture Tract water quality experiment area.

Soil Map Legend for the West Pasture experimental area

Symbol	Map unit name
1	Fine-silty, mixed, thermic Fragic Hapludalfs, 0 to 2 percent slopes, discontinuity less than 150 cm
2	Fine-silty, mixed, thermic Ultic Hapludalfs, 0 to 2 percent slopes, discontinuity less than 150 cm
3	Fine-silty, mixed, thermic Typic Fragiudalfs, 0 to 2 percent slopes, discontinuity greater than 150 cm
4	Fine-silty, mixed, thermic Ultic Hapludalfs, 0 to 2 percent slopes, discontinuity greater than 150 cm
5	Fine-silty, mixed, thermic Glossaquic Fragiudalfs, 0 to 2 percent slopes
6	Fine-loamy, mixed, thermic Typic Paleudults, 5 to 25 percent slopes, gullied
7	Fine-silty, mixed, thermic Dystric Eutrochrepts, 2 to 5 percent slopes, eroded
	Map Scale 1:2,100 (1"=175')
	Soil lines and symbols are in green.

Map Unit 1

Fine-silty, mixed, thermic Fragic Hapludalfs, 0 to 2 percent slopes, discontinuity less than 150 cm. This area of nearly level, very deep, well drained and moderately well drained soils is in one map unit in the northern part of the West Pasture tract. A moderately slowly permeable fragic layer is present in loessial materials just above the lithologic discontinuity and in the upper part of the mixing zone. Thickness of loessial materials over a paleosol that formed in the mixing zone ranges from 110 to 150 cm. Shallow wells 020045210, 020045330, 020060270, 020090000, 020150345, and 020150345 are within this map unit.

Similar soils included in this map unit are Ultic Hapludalfs, and Typic Fragiudalfs.

Representative Pedon and Range in Characteristics. The representative pedon for map unit 1 is Shallow Well 020090000.

Ap--0 to 30 cm; brown (10YR 5/3) silt loam; weak medium subangular blocky structure; very friable; medium acid; abrupt smooth boundary.

Bt1--30 to 80 cm; yellowish brown (10YR 5/6) silt loam; weak medium subangular blocky structure; friable; few

faint clay films on faces of peds; medium acid; clear smooth boundary.

Btx--80 to 140 cm; strong brown (7.5YR 4/6) silt loam; common medium prominent brown (10YR 5.3) mottles along faces of peds; moderate medium prismatic structure; firm with 50 to 60 percent brittleness; strongly acid; clear smooth boundary.

2Btxb--140 to 180 cm; reddish brown (5YR 4/4) loam; common medium prominent grayish brown (10YR 5/2) mottles on faces of peds; moderate coarse prismatic structure; firm with 50 to 60 percent brittleness; strongly acid; clear wavy boundary;

2Btb--180 to 207 cm; red (2.5YR 4/6) clay loam; moderate medium subangualar blocky structure; firm; medium acid.

The Ap horizon has hue of 10YR, value of 5, and chroma of 3 or 4. Texture is silt loam.

The Bt horizon has hue of 10YR, value of 4 or 5, and chroma of 4 or 6. Texture is silt loam or silty clay loam.

The Btx horizon has hue of 7.5YR, value of 4, and chroma of 4 or 6. Mottles in shades of brown or gray range from few to many. Texture is silty clay loam or silt loam.

The 2Btxb horizon has hue of 5YR or 7.5YR, value of 4, and chroma of 4 or 6. Mottles in shades of brown or gray range from few to many. Texture is loam, clay loam, or silty clay loam.

The 2Btb horizon has hue of 2.5YR or 5YR, value of 4, and chroma of 6. Mottles in shades of brown or gray range from none to many. Texture is clay loam, loam, silty clay loam or clay.

Map Unit 2

Fine-silty, mixed, thermic Ultic Hapludalfs, 0 to 2 percent slopes, discontinuity less than 150 cm. This area of nearly level, very deep, well drained soils is in two map units on the Hancock tract. One map unit in the southern part including part of the plot area, and the other unit is in the northern part, adjacent to the plot area. A well developed argillic horizon is present in the upper part of the mixing zone underlying loessial materials. Thickness of loessial materials over the 2Btb horizon ranges from 80 to 145 cm. Shallow wells 01045090, 010060150, 010060270,010090000, 010090180, 010150015,010153045, 010150135, and 010150195 are within this map unit.

Similar soils included in this map unit are Fragic Hapludalfs, and areas that are more than 150 cm to the lithologic discontinuity.

Representative Pedon and Range in Characteristics. The representative pedon for map unit 2 is shallow well 010090180.

Ap--0 to 25 cm; dark yellowish brown (10YR 4/4) silt loam; weak medium subangular blocky structure; very friable; medium acid; abrupt smooth boundary.

Bt1--25 to 70 cm; dark yellowish brown (10YR 4/6) silty clay loam; moderate medium subangular blocky structure; friable; strongly acid; clear smooth boundary.

Bt2--70 to 125 cm; strong brown (7.5YR 4/6) silt loam; common medium prominent pale brown (10YR 6/3) mottles on faces of peds; moderate medium subangular blocky structure; friable; strongly acid; clear smooth boundary.

2Btb1--125 to 170 cm; reddish brown (5YR 4/6) silty clay loam; common medium prominent pale brown (10YR 6/3) mottles on faces of peds; moderate medium subangular blocky structure; firm; strongly acid; clear smooth boundary.

2Btb2--170 to 207 cm; red (2.5YR 4/6) sandy clay loam; common medium distinct reddish brown (5YR 5/4) mottles on faces of peds; moderate medium subangular blocky structure; firm; strongly acid; clear smooth boundary.

The Ap horizon has hue of 10YR, value of 4, and chroma of 3 or 4. Texture is silt loam.

The Bt horizon has hue of 10YR or 7.5YR, value of 4 or 5, and chroma of 4 or 6. Mottles in shades of brown range from none to common. Texture is silt loam or silty clay loam.

The 2Btb horizon has hue of 5YR or 2.5YR, value of 3 or 4, and chroma of 4 or 6. Mottles in shades of brown or grey range from few to many. Texture is clay loam, loam, clay, silty clay loam, or sandy clay loam.

Map Unit 3

Fine-silty, mixed, thermic Typic Fragiudalfs, 0 to 2 percent slopes, discontinuity greater than 150 cm. This area of nearly level, very deep, well drained and moderately well drained soils is in two map units in on the West Pasture tract and in one map unit on the Hancock tract. One area is in the eastern part, and one area is in the western part of the West Pasture tract the other area is just west of the plot area on the Hancock tract. A well developed fragipan is present in the loessial material that overlies a red argillic horizon that formed in the mixing zone. One pedon also has a fragipan in the mixing zone layer. Thickness of loessial material over the 2Bt horizon ranges from 160 to 305 cm. Shallow wells 010090300 and

and 010090240 on the Hancock tract are within these map units. Shallow wells 020060030, 020090240, 020150255, 020042075, and deep well 020060120 on the West Pasture tract are within these map units.

Similar soils included in this map unit are Fragic Hapludalfs, Ultic Hapludalfs, and areas that are less than 150 cm to the lithologic discontinuity. Shallow well 010090300 did not have a fragipan in the loessial material and exhibited fragipan character in the mixing zone which began at 200 cm.

Representative Pedon and Range in Characteristics. The representative pedon for map unit 3 is deep well 020060120. This pedon was chosen because extensive laboratory data was available although thickness of the loessial material was 305 cm, the maximum value for the range. The 2Btb horizon is thought to be the Loveland loess deposition.

Ap--0 to 21 cm; brown (10YR 4/3) silt loam; moderate medium subangular blocky structure; very friable; slightly acid; abrupt smooth boundary.

Bt1--21 to 80 cm; light yellowish brown (10YR 6/4) silt loam; moderate medium subangular blocky structure; very friable; very strongly acid; clear smooth boundary.

Btx--80 to 168 cm; light gray (10YR 7/2) silt loam; common medium distinct light yellowish brown (10YR 6/4) mottles on faces of peds; moderate medium subangular blocky and prismatic structure; friable; many fine and medium manganese and iron concretions; few prominent iron stains on faces of peds; strongly acid; clear smooth boundary.

2Btb--168 to 236 cm; reddish brown (5YR 4/4) silt loam; many medium distinct yellowish red (5YR 5/8) and many medium prominent light brownish gray (10YR 6/2) mottles on faces of peds; moderate medium subangular blocky structure; common fine manganese concretions; friable; medium acid.

The Ap horizon has hue of 10YR, value of 4 or 5, and chroma of 3 or 4. Texture is silt loam.

The Bt horizon has hue of 10YR or 7.5YR, value of 4 or 5, and chroma of 4 or 6. Mottles in shades of brown range from none to common. Texture is silt loam or silty clay loam.

The Btx horizon has hue of 10YR to 5YR, value of 4 or 5, and chroma of 4 or 6. Mottles in shades of brown or grey range from few to many. Texture is silt loam or silty clay loam.

The 2Bt horizon has hue of 5YR or 2.5YR, value of 4, and chroma or 4 or 6. Texture is clay loam, loam, clay, silty clay loam or sandy clay loam.

Map Unit 4

Fine-silty, mixed, thermic Ultic Hapludalfs, 0 to 2 percent slopes, discontinuity greater than 150 cm. This area of nearly level, very deep, well drained soils is in one map unit on the Hancock tract that roughly dissects the mapped area. Two areas of this map unit are on the West Pasture tract. The first area is in the southern part of the mapped area, and the second area is in the north-northeast portion. A well developed red argillic horizon is present in the mixing zone beneath the loessial material. Thickness of loessial material over the 2Btb horizon ranges from 150 to 200 cm. Shallow wells 010045210, 010045330, 010060030, 010090060, 010090120, 010150285, 010150315, 010153345, 010150075, 010150105, 010150162, 010150255, and deep wells 010060240 and 010120300 on the Hancock tract are within these map units. Shallow wells 020090300, 020090120, 020090180, 020150285, 020150045, 020150225, and deep wells 020060000, and 020120240 on the West Pasture tract are within these map units.

Similar soils included in this map unit are Typic Paleudults, and Fragic Hapludults. A few areas of soil

with the paleosol contact less than 150 cm are also included. The paleosol contact in shallow well 020060150 was at 130 cm.

Representative Pedon and Range in Characteristics. The representative pedon for map unit 4 is deep well 010120300. This pedon represents the modal concept of the map unit and characterization data was completed.

Ap--0 to 25 cm; brown (10YR 4/3) silt loam; weak fine subangular blocky structure; friable; medium acid; abrupt smooth boundary.

Bt1--25 to 49 cm; dark brown (7.5YR 4/4) silty clay loam; moderate medium subangular blocky structure; friable; few fine manganese concretions; medium acid; clear smooth boundary.

Bt2--49 to 92 cm; dark brown (7.5YR 4/4) silt loam; moderate medium subangular blocky; friable; medium acid; clear smooth boundary.

Bt3--92 to 122 cm; dark brown (7.5YR 4/4) silt loam; few medium distinct light yellowish brown (10YR 6/4) mottles on faces of peds; moderate medium subangular blocky structure; friable; strongly acid.

Bt4--122 to 175 cm; dark brown (7.5YR 4/4) silt loam; common medium prominent very pale brown (10YR 7/3) mottles on faces of peds; moderate medium subangular blocky structure; friable; few fine manganese concretions; strongly acid.

2Btb--175 to 213 cm; dark brown (7.5YR 4/4) silt loam with 20 percent sand; few medium distinct (10YR 5/3) mottles on faces of peds; weak medium subangular blocky structure; friable; strongly acid.

The Ap horizon has hue of 10YR, value of 4 or 5, and chroma of 3 or 4. Soils in wooded areas may have value of 3. Texture is silt loam.

The Bt horizon has hue of 10YR or 7.5YR, value of 4 or 5, and chroma of 4 or 6. Mottles in shades of brown range from none to common. Texture is silt loam or silty clay loam.

The 2Btb horizon has hue of 7.5YR to 2.5YR, value of 3 to 5, and chroma of 4 or 6. Mottles in shades of brown or grey range from few to many. Texture is loam, clay loam, silt loam, silty clay loam, or clay. All of these textural classes have more than 10 percent sand except where the Loveland deposition can be identified.

Map Unit 5

Fine-silty, mixed, thermic Glossaquic Fragiudalfs, 0 to 2 percent slopes. This area of nearly level, very deep, somewhat poorly drained soils is in one map unit on the West Pasture tract that lies within and adjacent to the northeast border of the plot area. A gelyed horizon is present at about 40 cm that in underlain by a fragipan at about 110 cm. The entire pedon formed in silty material, the upper part which may have been transported by water. Shallow wells 020045210 and 020090060 on the West Pasture tract is within this map unit. Additional observations were made to establish the extent of the map unit.

Similar soils in this map unit area Typic Fragiudalfs, Fragic Hapludalfs, Aquic Fragiudalfs, and possibly a few areas of Typic Fragiaqualfs.

Representative Pedon and Range in Characteristics. The representative pedon for map unit 5 is shallow well 020090060.

Ap--0 to 27 cm; brown (10YR 5/3) silt loam; weak fine subangular blocky structure; friable; medium acid; abrupt smooth boundary.

BA--27 to 40 cm; pale brown (10YR 6/3) silt loam; few fine faint yellowish brown (10YR 5/4) mottles; weak fine

subangular blocky structure; friable; medium acid; clear smooth boundary.

Bg--40 to 110 cm; gray (10YR 6/1) silt loam; weak medium subangular blocky; friable; many fine and medium iron and manganese concretions; medium acid; clear wavy boundary.

2Btxb--110 to 170 cm; dark brown (7.5YR 4/4) silty clay loam; many coarse prominent gray (N 6/) mottles on faces of peds; moderate medium prismatic blocky structure; firm with 70 percent brittleness; common fine and medium iron and manganese concretions; strongly acid; gradual wavy boundary.

2Btb--170 to 200 cm; reddish brown (5YR 4/4) silty clay loam; common medium prominent light gray (10YR 7/1) mottles on faces of peds; moderate medium subangular blocky structure; friable; few fine manganese concretions; strongly acid.

The Ap horizon has hue of 10YR, value of 4, and chroma of 3 or 4. Texture is silt loam.

The BA horizon has hue of 10YR, value of 4 or 5, and chroma of 4 or 6. Mottles in shades of brown range from none to common. Texture is silt loam.

The Bg horizon has hue of 10YR, value of 5 or 6, and chroma of 1 or 2. Mottles in shades of brown range from few to many. Texture is silt loam or silty clay loam. Some pedons may have a Btg horizon.

The 2Btxb horizon has hue of 7.5YR or 5YR, value of 4, and chroma of 4 or 6. Mottles in shades of gray are common or many. Texture is silt loam or silty clay loam.

The 2Btb horizon has hue of 7.5YR or 5YR, value of 4, and chroma of 4 or 6. Mottles in shades of gray are common or many. Texture is silt loam or silty clay loam.

Map Unit 6

Fine-loamy, mixed, thermic Typic Paleudults, 5 to 25 percent slopes, gullied. This area of sloping to steep, very deep, well drained soils is in two map units. The largest area is in the southwestern portion of the Hancock tract. Another area was identified in the northern portion of the West Pasture tract. Most of the loessial material has been eroded away leaving the red paleosol at varying depths. Thickness of loessial material over the 2Bt horizon ranges from 0 to more than 61 cm. One shallow well on the Hancock tract is within the map unit. This well was not installed because the paleosol surface was at the surface of the gully at the designated well location. Water moving from the plot site will outcrop in the gully

before reaching the proposed shallow well site by subsurface flow. Three pedon descriptions were taken in this map unit. Shallow well 020150015 on the West Pasture tract is within the map unit. This pedon had 40 cm of recent alluvium overlying a buried soil.

Similar soils included in this map unit are Fragic Hapludalfs and Ultic Hapludalfs where the loess layer has not been eroded away. Typic Fluvaquents may also be present where freshly eroded alluvium has been deposited. Areas of Alfisols and Ultisols that are buried by less than 50 cm of recent alluvium may also be present.

Representative Pedon and Range in Characteristics. The representative pedon for map unit 6 is from a pedon description taken within the map unit on the Hancock tract.

A--0 to 12 cm; brown (10YR 4/3) silt loam; weak medium granular structure; very friable; slightly acid; clear smooth boundary.

Bt1--12 to 38 cm; yellowish brown (10YR 5/6) silty clay loam; moderate medium subangular blocky structure; friable; strongly acid; clear smooth boundary.

2Btb1--38 to 66 cm; yellowish red (5YR 4/6) clay loam; common medium prominent brownish yellow (10YR 6/6) mottles on faces of peds; moderate medium subangular

blocky; friable; many fine and medium manganese stains; very strongly acid; clear smooth boundary.

2Btb2--66 to 80 cm; red (2.5YR 5/6) clay loam; moderate medium subangular blocky structure; friable; very strongly acid; clear smooth boundary.

2Btb3--80 to 100 cm; red (2.5YR 4/6) clay loam; many medium prominent strong brown (7.5YR 5/6) mottles; weak medium subangular blocky structure; friable; very strongly acid.

The Ap horizon has hue of 10YR, value of 4, and chroma of 3 or 4. Texture is silt loam, or loam.

The Bt horizon has hue of 10YR or 7.5YR, value of 4 or 5, and chroma of 4 or 6. Mottles in shades of brown range from none to common. Texture is silt loam, silty clay loam, or loam.

The 2Btb horizon has hue of 5YR or 2.5YR, value of 4 or 5, and chroma of 4 or 6. Mottles in shades of brown or grey range from few to many. Texture is loam, clay loam, or clay.

Map Unit 7

Fine-silty, mixed, thermic Dystric Eutrochrepts, 2 to 5 percent slopes, eroded. This area of gently sloping, very deep, well drained soils is in one map unit on the

southeast portion of the West Pasture site. A well developed argillic horizon is present in the mixing zone beneath the loessial material. One pedon also has a fragipan in the mixing zone layer. Thickness of loessial material over the 2Btb horizon ranges from 63 to 220 cm. Shallow wells 020150105, 020150135, 020150165, 020143195 and deep well 020180150 on the West Pasture tract within this map unit.

Similar soils included in this map unit are Fragic Hapludalfs, Ultic Hapludalfs, and Typic Paleudalfs.

Representative Pedon and Range in Characteristics. The representative pedon for map unit 7 is deep well 020180150. This pedon was chosen because extensive laboratory data was available and it represents the modal concept of the map unit.

Ap--0 to 11 cm; dark yellowish brown (10YR 4/4) silt loam; weak fine subangular blocky structure; very friable; medium acid; abrupt smooth boundary.

Bw1--11 to 77 cm; brown (10YR 4/3) silt loam; moderate medium subangular blocky structure; friable; common manganese stains on faces of peds; strongly acid; clear smooth boundary.

Bw2--77 to 102 cm; dark brown (7.5YR 4/4) silt loam; moderate medium subangular blocky structure; friable; few manganese stains on faces of peds; strongly acid; clear smooth boundary.

Bw3--102 to 143 cm; strong brown (7.5YR 4/6) silt loam; weak medium subangular blocky structure; very friable; few manganese stains on faces of peds; strongly acid; clear smooth boundary.

2Bwb--143 to 172 cm; yellowish red (5YR 4/6) silt loam with 23 percent sand; common medium prominent brown (10YR 5/3) mottles; moderate medium subangular blocky structure; friable; few manganese stains on faces of peds; strongly acid; clear smooth boundary.

2Btb--172 to 249 cm; dark red (2.5YR 3/6) silty clay loam; many medium prominent brown (10YR 5/3) and common medium faint yellowish red (2.5YR 4/6) mottles; moderate medium subangular blocky structure; friable; few manganese stains on faces of peds; strongly acid.

The Ap horizon has hue of 10YR, value of 4 or 5, and chroma of 3 or 4. Soils in wooded areas may have value of 3. Texture is silt loam.

The Bw horizon has hue of 10YR to 5YR, value of 4 or 5, and chroma of 4 or 6. Mottles in shades of brown range

from none to common. Texture is silt loam or silty clay loam.

The 2Btb horizon has hue of 7.5YR to 2.5YR, value of 3 to 5, and chroma of 4 or 6. Mottles in shades of brown or gray range from few to many. Texture is loam, clay loam, silt loam, silty clay loam, or clay.

Conclusions

1. Fragic Hapludalfs is not presently a subgroup defined in the Keys to Soil Taxonomy (1992). The Fragic subgroup, as defined in the Ultisol order best describes the Hapludalfs in Map Unit 1.

2. The variability of the loess layer thickness was mostly dependant on the topography of the underlying paleosol (Figs. 22 and 23).

3. Depth to the paleosol layer and restriction of water movement may have been influential in the formation of fragipans in Map Units 1,3, and 5 (Figures 20,21,22, and 23).

4. A topographic depression in the paleosol layer was partially responsible for formation and drainage class of the Glossaquic Fragiudalfs in Map Unit 5 (Figs. 20,21,22, and 23).

5. Post settlement land clearing and erosional/depositional processes were responsible the variable thickness of loessial materials in Map unit 6.

6. Slope steepness and erosion were responsible for the classification of the Dystric Eutrochrept in Map unit 7. This soil was likely a Ultic Hapludalf before erosion removed the original surface layer and possibly part of the upper subsoil.

7. The loessial material influenced the classification of soils more than the underlying paleosol.

8. The paleosol surface topography is the controlling factor of present-day landscapes of the study area (Figs. 22 and 23).

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APPENDICES

Appendix A. Morphology and Laboratory Data for Deep Well 020060000

Groundwater Core Sampling Log Ames Water Quality

Well Location Number020060000 (Textures corrected to lab analysis)

Sample#	Depth(cm)	Color	Texture	Structure	Consist.	Notes
1-Ap	0-27	10YR 4/3	SIL	2MGR	FR	
2-Bt1	27-49	7.5YR 4/4	SIL	2MSBK	FR	
3-Bt2	49-64	7.5YR 4/6	SICL	2MSBK	FR	Few Mn nodules
4-Bt3	64-109	7.5YR 5/6	SIL	2MSBK	FR	Few 10YR6/3 mottles. Few 10YR4/4 mottles. Common Mn nodules.
5-Bt4	109-128	7.5YR 4/4	SIL	2MSBK	FR	Common 10YR5/4 mottles. Few Mn nodules
6-Bt5	128-165	7.5YR 4/6	SIL	2MSBK	FR	Common 10YR7/3
7-2Btb1	165-208	7.5YR 4/4	SIL	2MSBK	FR	Few Mn nodules E Body. 7.5YR8/4 prism face development
8-2Btb2	208-234	2.5YR 3/6	L	2MSBK	FR	Common 10YR8/3 mottles
9-2Btb3	234-256	2.5YR 4/6	SICL	2MSBK	FR	Common 10YR7/4 mottles
10-2Btb4	256-299	2.5YR 4/6	CL	2MSBK	FR	Few 10YR6/4 mottles
11-2BC1	299-315	2.5YR 4/6	COSL	1MSBK	FR	
123C1	315-341	2.5YR 3/4	LCOS	OSG	FR	
133C2	341-496	2.5YR 4/8 2.5YR 3/4	LCOS	OSG	FR	Stratified common Mn inclusions
143C3	496-516	2.5YR 3/4 7.5YR 3/6	COS	OSG	FR	Few Mn nodules
153C4	516-561	2.5YR 4/6	S/LS	OSG	FR	Few 2.5YR3/6 mottles
163C5	561-584	2.5YR 4/8 5YR 5/8	COS	OSG	FR	Stratified
173C6	584-644	2.5YR 3/6 5YR 5/8	COS	OSG	FR	Common Mn nodules, cleaner sand between strata.
183C7	644-760	2.5YR 3/6 5YR 5/8	S	OSG	FR	Stratified, few Mn inclusions
193C8	760-912	5YR 5/8	FS	OSG	FR	Few E bodies of clean white sand. Few Mn nodules.
203C9	912-991	2.5YR 4/8	FS	OSG	FR	Few 5YR5/8 mottles. Few Mn nodules
213C10	991-1034	10YR 7/2	L	OM	FR	Common 7.5YR6/8, gleyed horizon
224C11	1034-1067	7.5YR 5/4	COSL	OM	FR	Few 5YR5/8 mottles. Few Mn nodules
23	1067-1128	5YR 5/8	FSL	OM	FR	Common 2.5YR5/8 mottles

Groundwater Core Sampling Log Ames Water Quality

Well Location Number020060000(Textures corrected by lab data)

Sample#	Depth(cm)	Color	Texture	Structure	Consist.	Notes
24	1128-1179	7.5YR 5/4	FSL	OM	FR	Common 5YR5/8. Weakly stratified Few Mn nodules. Some gleying noted.
25	1179-1201	5YR 7/3 5YR 5/8 7.5YR 5/8 10YR 6/6	FSL/ LFS	OSG	FR	Stratified large E body, common Mn nodules.
26	1201-1225	10YR 2/1 10YR 6/8	LFS	OSG	FR	Matrix dominated by Mn
27	1225-1250	7.5YR 5/8 7.5YR 8/6 5YR 5/8	CoS	OSG	FR	Limonite pan in bottom of sample
28	1250-1271	10YR 7/1	L	OM	FR	Few 5YR7/4 mottles, common 7.5YR6/8 mottles, gleyed.
29	1271-1322	2.5Y 8/0	L	OM	FR	Common 2.5Y6/8 mottles, few Mn nodules, few 2.5YR6/4 mottles, gleyed.
30	1322-1344	2.5Y 8/0	L	OM	FR	Many 10YR7/8 mottles, common 2.5YR6/4 mottles, Few Mn nodules,few sand lenses
31	1344-1395	7.5YR 6/8	CoS L	OSG	FR	Common 5YR5/8 mottles
32	1395-1523	10YR 6/6	FS	OSG	FR	E bodies throughout, few 5YR6/6 mottles common Mn nodules.

Classification: Fine-silty, mixed, thermic Ultic Hapludalf

Depth and elevation data from Deep Well 020060000. Surface elevation is 144.35 meters above mean sea level.

Sample I.D.	Horizon	Depth			Elevation above mean sea level		
		Top	Bottom	Midpoint	Top	Bottom	Midpoint
		cm			m		
1	Ap	0	27	13.5	144.35	144.08	144.22
2	Bt1	27	49	38.0	144.08	143.86	143.97
3	Bt2	49	64	56.5	143.86	143.71	143.79
4	Bt3	64	109	86.5	143.71	143.26	143.49
5	Bt4	109	128	118.5	143.26	143.07	143.17
6	Bt5	128	165	146.5	143.07	142.70	142.89
7	2Btb1	165	208	186.5	142.70	142.27	142.49
8	2Btb2	208	234	221.0	142.27	142.01	142.14
9	2Btb3	234	256	245.0	142.01	141.79	141.90
10	2Btb4	256	299	277.5	141.79	141.36	141.58
11	2BCb	299	315	307.0	141.36	141.20	141.28
12	3C1	315	341	328.0	141.20	140.94	141.07
13	3C2	341	496	418.5	140.94	139.39	140.17
14	3C3	496	516	506.0	139.39	139.19	139.29
15	3C4	516	561	538.5	139.19	138.74	138.97
16	3C5	561	584	572.5	138.74	138.51	138.63
17	3C6	584	644	614.0	138.51	137.91	138.21
18	3C7	644	760	702.0	137.91	136.75	137.33
19	3C8	760	912	836.0	136.75	135.23	135.99
20	3C9	912	991	951.5	135.23	134.44	134.84
21	3C10	991	1034	1012.5	134.44	134.01	134.23
22	4C11	1034	1067	1050.5	134.01	133.68	133.85
23	---	1067	1128	1097.5	133.68	133.07	133.38
24	---	1128	1179	1153.5	133.07	132.56	132.82
25	---	1179	1201	1190.0	132.56	132.34	132.45
26	---	1201	1225	1213.0	132.34	132.10	132.22

Depth and elevation data from Deep Well 020060000 (continued).
Surface elevation is 144.35 meters above mean sea level.

Sample I.D.	Horizon	Depth			Elevation above mean sea level		
		Top	Bottom	Midpoint	Top	Bottom	Midpoint
		cm			m		
27	---	1225	1250	1237.5	132.10	131.85	131.98
28	---	1250	1271	1260.5	131.85	131.64	131.75
29	---	1271	1322	1296.5	131.64	131.13	131.39
30	---	1322	1344	1333.0	131.13	130.91	131.02
31	---	1344	1395	1369.5	130.91	130.40	130.66
32	---	1395	1523	1459.0	130.40	129.12	129.76

Particle size distribution in Deep Well number 020060000.

Sample I.D.	Horizon	percent of < 2-mm fraction								
		vcos	cos	ms	fs	vfs	sand	silt	clay	fine clay <.2 micrometer
1	Ap	1.2	0.8	0.7	0.6	0.6	3.9	82.1	14.0	5.0
2	Bt1	0.1	0.6	0.6	0.5	0.3	2.1	71.0	26.9	14.1
3	Bt2	0.0	0.6	0.4	0.7	0.6	2.3	68.5	29.2	13.3
4	Bt3	0.1	0.3	0.4	0.3	0.4	1.5	74.0	24.5	8.4
5	Bt4	0.0	0.5	0.5	0.6	0.4	2.0	78.2	19.8	6.8
6	Bt5	0.0	1.1	1.3	1.4	0.9	4.7	74.7	20.6	8.4
7	2Btb1	1.1	8.1	7.1	7.0	1.2	24.5	60.0	17.5	7.9
8	2Btb2	0.9	8.4	7.6	7.6	1.1	25.6	48.8	25.6	14.4
9	2Btb3	0.6	5.6	5.8	5.9	0.4	18.3	51.7	30.0	18.0
10	2Btb4	0.6	11.6	11.4	11.7	1.3	36.6	36.3	27.1	14.8
11	2BCb	2.6	21.5	18.7	16.1	1.0	59.9	20.5	19.6	12.7
12	3C1	4.2	34.2	23.9	23.2	0.9	86.4	4.7	8.9	7.5
13	3C2	4.9	20.0	27.3	32.2	1.6	86.0	5.9	8.1	6.9
14	3C3	2.3	22.1	29.9	33.3	4.3	91.9	3.9	4.2	3.9
15	3C4	2.6	14.0	21.8	42.4	7.4	88.2	5.9	5.9	5.1
16	3C5	2.4	29.5	25.4	27.4	5.8	90.5	4.9	4.6	4.3
17	3C6	2.7	27.0	33.1	23.5	3.8	90.1	5.3	4.6	4.0
18	3C7	1.0	12.2	25.7	42.5	7.7	89.1	4.9	6.0	5.2
19	3C8	0.4	11.0	32.8	51.4	0.6	96.2	1.8	2.0	2.0
20	3C9	0.6	9.2	23.0	55.7	5.0	93.5	3.5	3.0	2.8
21	3C10	0.6	6.9	7.7	18.0	10.1	43.3	37.0	19.7	12.2
22	4C11	2.6	32.4	6.4	10.7	2.1	54.2	28.9	16.9	10.9
23	---	1.6	8.3	11.2	28.9	7.1	57.1	26.7	16.2	10.3
24	---	1.0	5.8	12.1	39.6	8.6	67.1	23.7	9.2	5.2
25	---	0.6	4.0	13.0	49.0	10.7	77.3	15.3	7.4	4.3
26	---	0.7	4.5	13.8	51.9	11.7	82.6	13.5	3.9	1.9
27	---	14.2	31.8	19.6	21.3	3.1	90.0	5.8	4.2	2.3
28	---	0.6	1.3	1.4	11.7	22.6	37.6	40.9	21.5	5.5
29	---	0.0	0.6	0.9	11.5	15.6	28.6	45.8	25.6	6.1

Particle size distribution in Deep Well number 020060000 (continued).

Sample I.D.	Horizon	percent of < 2-mm fraction								
		vcos	cos	ms	fs	vfs	sand	silt	clay	fine clay <.2 micrometer
30	---	0.1	1.1	0.9	8.2	30.4	40.7	37.1	22.2	5.9
31	---	9.0	36.2	8.5	5.4	1.6	60.7	31.2	8.1	5.4
32	---	0.2	1.6	32.4	54.2	3.0	91.4	3.8	4.8	2.4

Ammonium acetate extractable bases, barium chloride extractable acidity, cation exchange capacity, and base saturation data for Deep Well 020060000.

Sample I.D.	$cmol_c\ kg^{-1}$ Ca	Mg	Na	K	SUM	$BaCl_2$ Ext. Acid.	CEC pH 7.0	CEC pH 8.2	Percent Base Saturation NH_4OAc pH-7.0	Sum of Cations
1	5.18	0.70	0.31	0.18	6.36	5.98	6.61	12.34	96	51
2	7.17	1.66	0.66	0.21	9.71	7.10	11.23	16.80	86	57
3	6.16	2.61	0.21	0.24	9.22	10.85	13.76	20.07	67	45
4	3.99	4.14	0.11	0.22	8.47	10.70	13.57	19.17	62	44
5	3.73	3.12	0.09	0.18	7.12	8.20	10.47	15.32	68	46
6	3.63	2.97	0.10	0.20	6.90	8.62	10.82	15.52	63	44
7	3.12	2.12	0.08	0.14	5.46	6.02	6.30	11.49	86	47

pH data for Deep Well 020060000.

Sample I.D.	Horizon	pH 1:2 .01M $CaCl_2$	pH 1:1 H_2O
1	Ap	5.0	5.6
2	Bt1	4.9	5.5
3	Bt2	4.4	5.5
4	Bt3	4.2	5.0
5	Bt4	4.3	5.2
6	Bt5	4.3	5.0
7	2Btb1	4.2	5.0
8	2Btb2	4.2	5.0
9	2Btb3	4.2	4.9
10	2Btb4	4.1	5.0
11	2BCb	4.2	5.0
12	3C1	4.3	5.1
13	3C2	4.3	5.1
14	3C3	4.3	5.1
15	3C4	4.3	5.2
16	3C5	4.3	5.3
17	3C6	4.4	5.3
18	3C7	4.5	5.3
19	3C8	4.6	5.4
20	3C9	4.6	5.2
21	3C10	4.5	5.3
22	4C11	4.5	5.3
23	---	4.5	5.2
24	---	4.6	5.3
25	---	4.6	5.3
26	---	4.7	5.4
27	---	4.8	5.4
28	---	5.0	5.4
29	---	4.9	5.4
30	---	4.9	5.4
31	---	4.7	5.5
2	---	4.9	5.6

Concentration of free iron oxides, total iron, total titanium, and total zirconium in Deep Well 020060000.

Sample I.D.	Horizon	Free Fe (mg kg^{-1})	Total Fe (mg kg^{-1})	Total Ti (mg kg^{-1})	Total Zr (mg kg^{-1})
1	Ap	7,888	14,412	1,730	100.4
2	Bt1	14,857	28,105	2,379	96.4
3	Bt2	16,041	33,800	2,400	92.1
4	Bt3	13,295	34,035	2,281	121.1
5	Bt4	13,198	34,843	2,227	117.1
6	Bt5	14,115	28,892	2,218	122.0
7	2Btb1	10,199	20,810	1,944	100.1
8	2Btb2	15,078	24,814	2,005	96.3
9	2Btb3	17,945	29,372	2,155	111.5
10	2Btb4	16,890	28,487	1,779	87.7
11	2BCb	13,688	22,421	1,388	54.2
12	3C1	8,492	13,619	726	37.0
13	3C2	7,015	10,705	512	32.2
14	3C3	5,349	8,195	630	16.7
15	3C4	6,750	9,496	725	16.3
16	3C5	4,918	7,885	329	10.2
17	3C6	5,637	8,372	377	9.4
18	3C7	4,638	7,843	992	28.6
19	3C8	2,350	5,436	413	9.4
20	3C9	2,523	4,876	644	11.0
21	3C10	1,390	6,462	2,076	89.8
22	4C11	2,901	8,292	1,876	57.9
23	---	6,359	11,757	1,778	62.4
24	---	3,710	7,598	1,546	51.2
25	---	7,842	9,364	1,749	< 3.0
26	---	1,928	4,677	2,164	< 3.0
27	---	7,708	10,883	1,483	< 3.0
28	---	3,060	7,742	2,825	40.0
29	---	1,006	5,838	2,862	25.8
30	---	1,897	6,727	2,674	13.1
31	---	5,858	9,921	480	< 3.0
32	---	1,000	2,924	821	< 3.0

Organic carbon and KCl aluminum data for Deep Well 020060000.

Sample I.D.	Horizon	Organic Carbon %	KCl Aluminum mg kg^{-1}
1	Ap	0.64	0.02
2	Bt1	0.23	0.18
3	Bt2	0.20	2.16
4	Bt3	0.16	3.05
5	Bt4	0.12	2.18
6	Bt5	0.12	2.20
7	2Btb1	0.10	1.70
8	2Btb2	0.13	2.22
9	2Btb3	0.14	2.67
10	2Btb4	0.11	2.72
11	2BCb	0.09	1.89
12	3C1	0.06	0.75
13	3C2	0.04	0.53
14	3C3	0.01	0.21
15	3C4	0.04	0.29
16	3C5	0.03	0.22
17	3C6	0.03	0.16
18	3C7	0.03	0.11
19	3C8	0.01	0.01
20	3C9	0.01	0.01
21	3C10	0.04	0.33
22	4C11	0.04	0.31
23	---	0.02	0.26
24	---	0.01	0.13
25	---	0.00	0.06
26	---	0.01	0.02
27	---	0.01	0.00
28	---	0.01	0.00
29	---	0.01	0.00
30	---	0.01	0.00
31	---	0.02	0.01
32	---	0.00	0.00

Appendix B. Morphology and Laboratory Data for Deep Well 020060120

Groundwater Core Sampling Log Ames Water Quality

Well Location Number020060120 (Textures corrected by lab data)

Sample#	Depth(cm)	Color	Texture	Structure	Consist.	Notes
1 Ap	0-21	10YR 4/3	SIL	2MGR	VFR	
2 Bt	21-80	10YR 6/4	SIL	2MSbk	VFR	Few 10YR4/2 mottles. Few 7.5YR4/6 mottles.
3 Btx	80-168	10YR 7/3	SIL	2MSbk	FR	Mn and Fe nodules. Common 10YR6/4 mottles. Few 2.5YR4/8 mottles.
4 2Btb1	168-236	5YR 4/4	SIL	2MSbk	FR	Common Mn fine nodules. Many 5YR5/8 mottles. Many 10YR6/2 mottles.
5 2Btb2	236-305	10YR 5/4	SIL	2MSbk	FR	Few Mn nodules. Few 10YR6/1 mottles.
6 2Btb3	305-457	5YR 3/4	L	2MSbk	FR	Few Mn nodules. Few 10YR7/2 mottles.
7 3C	457-645	2.5YR 4/6	S	OSG	FR	Few Mn nodules. Common 7.5YR5/8 mottles.
8 3C2	645-761	2.5YR 4/8	LFS	OSG	FR	Common 7.5YR7/8 mottles. Mn streaks. E bodies present.
9 3C3	761-913	5YR 5/8	FS	OSG	FR	
10 4C4	913-1067	5YR 5/8	COS	OSG	FR	

Groundwater Core Sampling Log Ames Water Quality

Well Location Number020060120 (Textures corrected by lab data)

Sample#	Depth(cm)	Color	Texture	Structure	Consist.	Notes
11	1067-1085	10YR 6/6 10YR 6/2 7.5YR 5/8 5YR 5/8	VFSL	OM	FR	Mottled. Common Dist. Mn mottles. Stratified.
12	1085-1126	10YR 6/1 7.5YR 5/8	L	OM	FR	Common prominant Mn mottles.
13	1126-1243	7.5YR 6/4	L	OM	FR	7.5YR5/8 CD mottles
14	1243-1346	7.5YR 8/2 7.5YR 5/8	L	OM	FR	Common Mn mottles. Mottled. Stratified.
15	1346-1366	10YR 7/3	COSL	OM	FR	Few 7.5YR5/8 Some gleying, common Mn modules.
16	1366-1399	7.5YR 5/8 10YR 8/1	COSL	OM	FR	
17	1399-1452	10YR 8/1	L	OM	FR	10YR6/8 Common mottles.
18	1452-1473	10YR 8/1 10R 6/3	L	OM	EFI	Stratified. Fine, platy structure
19	1473-1523	10YR 8/1	L	OM	EFI	Sandy lense 7.5YR6/8, Med. platy structure, 10R6/3 many. Fe and Mn coatings, stratified.
20	1523-1663	10YR 8/1	SIL	OM	EFI	Few 5YR7/2, common 7.5YR5/8, common 10YR7/8, med play structure from pressure
21	1663-1675	10YR 8/1	SICL	OM	EFI	
22	1675-1692	10YR 7/1	SICL	OM	EFI	Common 10R5/3 & common 10R4/4 mottles
23	1692-1720	7.5YR 5/8 5YR 4/6 10YR 7/2	FS	OSG	FR	Mn/Fe pan at top of horizon, stratified, mottled
24	1720-1827	10YR 7/3 10R 6/4 7.5YR 6/8	FS	OSG	FR	E-bodies present, common Mn streaks, stratified, mottled.

Classification: Fine-silty, mixed, thermic Typic Fragiudalf

Depth and elevation data from Deep Well 020060120. Surface elevation is 145.15 meters above mean sea level.

Sample I.D.	Horizon	Depth			Elevation above mean sea level		
		Top	Bottom	Midpoint	Top	Bottom	Midpoint
		cm			m		
1	Ap	0	21	10.5	145.15	144.94	145.05
2	Bt	21	80	50.5	144.94	144.35	144.65
3	Btx	80	168	124.0	144.35	143.47	143.91
4	2Btb1	168	236	202.0	143.47	142.79	143.13
5	2Btb2	236	305	270.5	142.79	142.10	142.45
6	2Btb3	305	457	381.0	142.10	140.58	141.34
7	3C1	457	645	551.0	140.58	138.70	139.64
8	3C2	645	761	703.0	138.70	137.54	138.12
9	3C3	761	913	837.0	137.54	136.02	136.78
10	4C4	913	1067	990.0	136.02	134.48	135.25
11	---	1067	1085	1076.0	134.48	134.30	134.39
12	---	1085	1126	1105.5	134.30	133.89	134.10
13	---	1126	1243	1184.5	133.89	132.72	133.31
14	---	1243	1346	1294.5	132.72	131.69	132.21
15	---	1346	1366	1356.0	131.69	131.49	131.59
16	---	1366	1399	1382.5	131.49	131.16	131.33
17	---	1399	1452	1425.5	131.16	130.63	130.90
18	---	1452	1473	1462.5	130.63	130.42	130.53
19	---	1473	1523	1498.0	130.42	129.92	130.17
20	---	1523	1663	1593.0	129.92	128.52	129.22
21	---	1663	1675	1669.0	128.52	128.40	128.46
22	---	1675	1692	1683.5	128.40	128.23	128.32
23	---	1692	1720	1706.0	128.23	127.95	128.09
24	---	1720	1827	1773.5	127.95	126.88	127.42

Particle size distribution in Deep Well 020060120.

Sample I.D.	Horizon	percent of <2-mm fraction								
		vcos	cos	ms	fs	vfs	sand	silt	clay	fine clay <.2 micrometer
1	Ap	0.8	0.9	1.0	1.1	1.1	4.9	80.3	14.8	5.3
2	Bt	0.3	0.2	0.3	0.2	0.4	1.4	81.8	16.8	5.5
3	Btx	0.7	1.2	0.8	1.2	0.7	4.6	75.9	19.5	7.4
4	2Btb1	0.3	0.7	0.6	0.8	0.8	3.2	75.3	21.5	11.0
5	2Btb2	0.0	0.0	0.5	0.5	0.5	1.5	83.9	14.6	7.1
6	2Btb3	2.2	12.4	9.4	7.3	0.6	31.9	49.3	18.8	11.9
7	3C1	1.7	16.9	23.9	42.0	4.2	88.7	6.0	5.3	5.2
8	3C2	1.1	11.6	20.9	44.7	7.7	86.0	7.6	6.4	5.8
9	3C3	0.0	4.6	28.4	58.8	1.6	93.4	4.2	2.4	2.2
10	4C4	0.7	25.4	39.7	29.8	0.2	95.8	2.9	1.3	1.3
11	---	0.6	2.8	4.9	29.9	25.6	63.8	23.8	12.4	7.7
12	---	1.7	7.9	6.9	10.8	9.6	36.9	41.0	22.1	12.8
13	---	1.0	7.6	8.3	14.9	5.0	36.8	39.8	23.4	14.0
14	---	2.5	11.5	11.3	18.0	4.0	47.3	32.7	20.0	8.9
15	---	4.2	15.0	15.3	20.2	4.5	59.2	24.4	16.4	9.0
16	---	1.5	22.3	37.8	10.8	6.8	79.2	10.6	10.2	3.6
17	---	0.3	1.7	3.3	11.8	22.1	39.2	39.7	21.1	5.3
18	---	0.3	0.0	0.0	8.8	26.9	36.0	43.4	20.6	5.3
19	---	0.3	0.3	0.4	21.8	25.2	48.0	33.7	18.3	4.4
20	---	0.0	0.5	0.1	4.7	20.4	25.7	50.8	23.5	6.2
21	---	0.2	0.2	0.1	1.2	18.0	19.7	52.8	27.5	6.9
22	---	0.0	0.1	0.2	1.3	14.4	16.0	55.4	28.6	7.4
23	---	0.1	1.7	21.0	66.8	4.6	94.2	3.6	2.2	0.4
24	---	0.8	0.9	23.2	65.6	2.6	93.1	3.2	3.7	1.6

Ammonium acetate extractable bases, barium chloride extractable acidity, cation exchange capacity, and base saturation data for Deep Well 020060120.

Sample I.D.	$cmol_c\ kg^{-1}$ Ca	Mg	Na	K	SUM	$BaCl_2$ Ext. Acid.	CEC pH-7.0	CEC pH-8.2	Percent Base Saturation NH_4OAc pH-7.0	Sum of Cations
1	4.51	0.75	0.09	0.18	5.52	4.66	7.97	10.18	69	54
2	2.34	0.59	0.13	0.17	3.23	7.42	7.47	10.65	43	30
3	4.35	3.61	1.27	0.23	9.46	8.55	13.66	18.01	69	53
4	6.60	5.38	1.29	0.26	13.54	7.30	16.45	20.84	82	65

pH data for Deep Well 020060120.

Sample I.D.	Horizon	pH 1:2 .01M $CaCl_2$	pH 1:1 H_2O
1	Ap	5.6	6.2
2	Bt	4.3	5.0
3	Btx	4.3	5.2
4	2Btb1	4.8	5.6
5	2Btb2	5.5	6.3
6	2Btb3	5.7	6.3
7	3C1	5.4	6.4
8	3C2	5.0	6.2
9	3C3	4.8	5.8
10	4C4	4.7	5.8
11	---	4.7	5.4
12	---	4.7	5.6
13	---	4.7	5.4
14	---	4.8	5.4
15	---	4.8	5.5
16	---	4.9	5.8
17	---	5.0	5.7
18	---	5.5	5.5
19	---	5.5	5.9
20	---	5.5	5.8
21	---	5.4	5.7
22	---	4.5	5.8
23	---	5.8	6.1
24	---	6.0	6.2

Concentration of free iron oxides, total iron, total titanium, and total zirconium in Deep Well 020060120.

Sample I.D.	Horizon	mg kg^{-1} Free Fe	Total Fe	Total Ti	Total Zr
1	Ap	8,262	16,637	1,953	---
2	Bt1	12,070	22,585	2,171	---
3	Btx	13,291	26,759	2,063	---
4	2Btb1	16,965	31,201	1,955	---
5	2Btb2	13,698	27,045	1,913	---
6	2Btb3	12,337	21,142	1,657	---
7	3C1	5,547	7,233	608	---
8	3C2	5,137	7,092	908	---
9	3C3	2,508	3,416	550	---
10	4C4	2,992	4,386	394	---
11	---	5,336	8,901	1,793	---
12	---	2,623	7,373	2,126	---
13	---	5,925	11,209	2,165	---
14	---	8,838	12,801	1,876	---
15	---	6,969	11,196	1,606	---
16	---	2,459	4,475	1,340	---
17	---	1,110	4,863	2,764	---
18	---	833	4,620	2,645	---
19	---	764	4,308	2,314	---
20	---	880	6,547	3,395	---
21	---	916	6,080	2,940	---
22	---	1,397	6,530	3,117	---
23	---	1,465	2,625	1,513	---
24	---	2,239	3,820	654	---

Organic carbon and KCl aluminum data for Deep Well 010120300.

Sample I.D.	Horizon	Organic Carbon %	KCl Aluminum mg kg^{-1}
1	Ap	0.84	0.01
2	Bt1	0.20	1.19
3	Btx	0.14	0.90
4	2Btb1	0.16	0.16
5	2Btb2	0.18	0.02
6	2Btb3	0.20	0.01
7	3C1	0.03	0.01
8	3C2	0.01	0.03
9	3C3	0.00	0.05
10	4C4	0.00	0.05
11	---	0.03	0.18
12	---	0.08	0.27
13	---	0.05	0.13
14	---	0.03	0.12
15	---	0.02	0.09
16	---	0.01	0.08
17	---	0.01	0.06
18	---	0.01	0.02
19	---	0.01	0.01
20	---	0.03	0.04
21	---	0.03	0.03
22	---	0.01	0.06
23	---	0.00	0.00
24	---	0.00	0.00

Appendix C. Morphology and Laboratory Data for Deep Well 020120300

Groundwater Core Sampling Log Ames Water Quality

Well Location Number020120300 (Textures corrected by lab data)

Sample#	Depth(cm)	Color	Texture	Structure	Consist.	Notes
1 Ap	0-15	10YR 4/3	SIL	2MGr	FR	Common Mn nodules
2-BA	15-32	10YR 4/4	SIL	2MSBK	FR	Common 10YR3/3 mottles, few 2.5YR4/8 mottles, few Mn nodules.
3-Bw	32-61	10YR 4/3	SIL	2MSBK	FR	Few Mn nodules, root channels stained with Mn
4-Bt1	61-108	7.5YR 4/4	SIL	2MSBK	FR	Few Mn nodules
5-Bt2	108-189	5YR 3/4	SIL	2MSBK	FR	Few Mn nodules, few 10YR6/3 mottles
6-2Btb1	189-253	2.5YR 3/6	SICL	1MSBK	FR	Few 10YR6/4 mottles
7-2Btb2	253-285	5YR 4/6	SIL	1MSBK	FR	Common fine Mn nodules
8-2Btb3	285-343	5YR 4/6	SIL	1MSBK	FR	Few Mn nodules, many 10YR5/8 mottles
9-3Btxb	343-388	7.5YR 4/6	L	2MSBK	FR	Common 10YR7/2 mottles
103BCb	388-433	7.5YR 4/6	LCOS	1CSBK	FR	Many Mn nodules and coatings
113C	433-487	7.5YR 4/6	LFS	0SG	FR	Stratified
124C1	487-508	2.5YR 4/8	LS	OSG	FR	
134C2	508-540	7.5YR 6/4	L	OSG	FR	Common 10YR7/1 mottles
144C3	540-566	7.5YR 5/8	L	OM	FR	Many Mn nodules
154C4	566-640	2.5YR 4/6	L	OM	FR	
164C5	640-701	2.5YR 4/6	SCL	OM	FR	Few 10YR6/4 mottles, few Mn nodules
174C6	701-829	2.5YR 4/6	FSL	OSG	FR	Few Mn nodules, E bodies noted at bottom of sample
186C7	829-931	5YR 5/8	LCOS	OSG	FR	Big pieces of quartz and gravels, few Mn nodules
19	931-962	2.5YR 4/6	LCOS	OSG	FR	Iron pan at top of sample
20	962-1065	2.5YR 5/8 10YR 6/8	LFS	OSG	FR	E bodies noted throughout matrix, pure white
21	1065-1095	5YR 5/8 10YR 8/1 10YR 7/8	LFS	OSG	FR	Mn layer in matrix, stratified

Classification: Fine-silty, mixed, thermic Typic Paleudalf

Depth and elevation data from Deep Well 020120300. Surface elevation is 143.77 meters above mean sea level.

Sample I.D.	Horizon	Depth			Elevation above mean sea level		
		Top	Bottom	Midpoint	Top	Bottom	Midpoint
		cm			m		
1	Ap	0	15	7.5	143.77	143.62	143.70
2	BA	15	32	23.5	143.62	143.45	143.54
3	Bw	32	61	46.5	143.45	143.16	143.31
4	Bt1	61	108	84.5	143.16	142.69	142.93
5	Bt2	108	189	148.5	142.69	141.88	142.29
6	2Btb1	189	253	221.0	141.88	141.24	141.56
7	2Btb2	253	285	269.0	141.24	140.92	141.08
8	2Btb3	285	343	314.0	140.92	140.34	140.63
9	3Btxb	343	388	365.5	140.34	139.89	140.12
10	3BCb	388	433	410.5	139.89	139.44	139.67
11	3C	433	487	460.0	139.44	138.90	139.17
12	4C1	487	508	497.5	138.90	138.69	138.80
13	4C2	508	540	524.0	138.69	138.37	138.53
14	4C3	540	566	553.0	138.37	138.11	138.24
15	4C4	566	640	603.0	138.11	137.37	137.74
16	4C5	640	701	670.5	137.37	136.76	137.07
17	4C6	701	829	765.0	136.76	135.48	136.12
18	5C7	829	931	880.0	135.48	134.46	134.97
19	---	931	962	946.5	134.46	134.15	134.31
20	---	962	1065	1013.5	134.15	133.12	133.64
21	---	1065	1095	1080.0	133.12	132.82	132.97

Particle size distribution in Deep Well 020120300.

Sample I.D.	Horizon	percent of <2-mm fraction								fine clay <.2 micrometer
		vcos	cos	ms	fs	vfs	sand	silt	clay	
1	Ap	0.4	0.3	0.3	0.4	0.8	2.2	82.9	14.9	6.9
2	BA	0.1	0.5	0.0	0.4	0.3	1.3	81.4	17.3	8.9
3	Bw	0.3	0.5	0.2	0.9	0.9	2.8	80.8	16.4	7.3
4	Bt1	0.0	0.7	0.7	0.9	0.4	2.7	73.5	23.8	12.2
5	Bt2	0.1	0.9	1.0	1.8	1.3	5.1	73.1	21.8	12.0
6	2Btb1	0.4	3.0	3.0	4.0	1.1	11.5	59.7	28.8	18.9
7	2Btb2	0.4	2.6	2.7	3.7	0.8	10.3	64.5	25.2	14.1
8	2Btb3	0.3	2.2	2.2	2.5	0.5	7.7	65.7	26.5	13.5
9	3Btxb	1.3	8.2	8.9	10.9	2.1	31.4	48.5	20.1	6.9
10	3BCb	3.8	18.3	21.6	32.6	4.1	80.4	10.9	8.7	5.4
11	3C	0.7	9.2	18.7	50.1	8.9	87.6	4.5	7.9	5.5
12	4C1	2.9	15.0	20.0	37.6	6.8	82.3	5.5	12.2	7.9
13	4C2	0.2	3.3	4.7	11.9	15.5	35.6	42.9	21.5	12.4
14	4C3	0.9	8.5	10.2	18.2	4.8	42.6	32.7	24.7	14.5
15	4C4	1.4	8.8	9.9	17.7	4.0	41.8	36.2	22.0	13.1
16	4C5	1.4	8.7	13.1	27.4	5.2	55.8	20.2	24.0	17.4
17	4C6	1.8	9.4	15.9	35.8	6.3	69.2	13.5	17.3	12.1
18	5C7	7.3	36.4	23.2	18.9	2.0	87.8	5.3	6.9	4.8
19	---	18.5	35.2	20.1	13.4	0.5	87.7	2.0	10.3	6.0
20	---	0.6	1.8	13.5	63.3	4.4	83.6	4.3	12.1	6.1
21	---	0.0	0.7	19.5	56.8	8.8	85.8	7.9	6.3	3.7

Ammonium acetate extractable bases, barium chloride extractable acidity, cation exchange capacity, and base saturation data for Deep Well 020060000.

Sample I.D.	$cmol_c\ kg^{-1}$ Ca	Mg	Na	K	SUM	$BaCl_2$ Ext. Acid.	CEC pH 7.0	CEC pH 8.2	Percent Base Saturation NH_4OAc pH-7.0	Sum of Cations
1	7.28	1.45	0.04	0.29	9.06	5.37	12.07	14.43	75	63
2	6.16	1.24	0.06	0.17	7.63	6.28	8.95	13.91	85	55
3	4.72	1.33	0.07	0.16	6.29	7.14	8.59	13.43	73	47
4	4.76	2.98	0.13	0.21	8.08	11.72	12.51	19.80	65	41
5	3.04	2.79	0.13	0.18	6.14	9.02	9.86	15.16	62	41

pH data for Deep Well 010120300.

Sample I.D.	Horizon	pH 1:2 .01M $CaCl_2$	pH 1:1 H_2O
1	Ap	5.6	6.0
2	BA	4.9	5.5
3	Bw	4.4	5.0
4	Bt1	4.3	4.8
5	Bt2	4.2	4.5
6	2Btb1	4.3	4.9
7	2Btb2	4.4	5.2
8	2Btb3	4.5	5.3
9	3Btxb	4.6	5.4
10	3BCb	4.6	5.5
11	3C	4.6	5.5
12	4C1	4.5	5.6
13	4C2	4.6	5.4
14	4C3	4.6	5.5
15	4C4	4.6	5.5
16	4C5	4.7	5.4
17	4C6	4.7	5.6
18	5C7	4.8	5.7
19	---	4.7	5.6
20	---	4.8	5.7
21	---	5.0	5.6

Concentration of free iron oxides, total iron, total titanium, and total zirconium in Deep Well 020120300.

Sample I.D.	Horizon	mg kg^{-1}			
		Free Fe	Total Fe	Total Ti	Total Zr
1	Ap	8,162	17,947	1,941	14.10
2	BA	9,257	20,200	2,213	13.51
3	Bw	10,879	20,931	2,101	21.93
4	Bt1	16,731	29,370	2,138	18.94
5	Bt2	13,402	23,474	2,044	18.96
6	2Btb1	16,877	24,319	1,943	22.00
7	2Btb2	14,072	20,853	1,796	19.63
8	2Btb3	18,767	28,496	2,090	16.68
9	3Btxb	13,349	20,448	1,664	21.87
10	3BCb	6,949	10,787	730	35.10
11	3C	5,828	8,462	743	99.07
12	4C1	8,431	11,831	1,156	33.60
13	4C2	8,685	14,621	2,305	27.57
14	4C3	12,847	19,278	1,987	37.14
15	4C4	18,797	25,616	2,143	29.64
16	4C5	14,239	19,891	1,849	24.46
17	4C6	9,444	13,898	1,549	35.77
18	5C7	5,927	8,673	864	36.92
19	---	9,968	13,969	1,277	54.34
20	---	5,082	7,607	1,255	62.75
21	---	3,213	5,012	661	33.22

Organic carbon and KCl aluminum data for Deep Well 020120300.

Sample I.D.	Horizon	Organic Carbon %	KCl Aluminum mg kg^{-1}
1	Ap	1.24	0.00
2	BA	0.59	0.11
3	Bw	0.47	0.77
4	Bt1	0.44	1.95
5	Bt2	0.19	2.16
6	2Btb1	0.16	1.43
7	2Btb2	0.11	1.43
8	2Btb3	0.10	0.57
9	3Btxb	0.07	0.24
10	3BCb	0.04	0.16
11	3C	0.03	0.11
12	4C1	0.03	0.14
13	4C2	0.04	0.29
14	4C3	0.05	0.34
15	4C4	0.05	0.35
16	4C5	0.04	0.21
17	4C6	0.00	0.12
18	5C7	0.02	0.02
19	---	0.01	0.03
20	---	0.02	0.01
21	---	0.01	0.01

Appendix D. Morphology and Laboratory Data for Deep Well 020180150

Groundwater Core Sampling Log Ames Water Quality

Well Location Number020180150 (Textures corrected by lab data)

Sample#	Depth(cm)	Color	Texture	Structure	Consist.	Notes
1 Ap	0-11	10YR 4/4	SIL	--	VFR	Loess down to 143 cm
2Bw1	11-77	10YR 4/3	SIL	2MSBK	FR	Mn mottles common
3Bw2	77-102	7.5YR 4/4	SIL	2MSBK	FR	Mn mottles few
4Bw3	102-143	7.5YR 4/6	SIL	1MSBK	VFR	Few distinct mottles
5 2Bw4	143-172	5YR 4/6	SIL	2MSBK	FI	Few Mn mottles, Common Pr mottles 10YR5/3, common faint 2.5YR5/3 mottles
6 2Btb1	172-249	2.5YR 3/6	SICL	2MSBK	FR	Common Mn mottles common 2.5YR4/8 mottles, many 10YR5/3 mottles
7 2Btb2	249-293	2.5TR 3/6	CL	2MSBK	FR	Few 10YR5/3 mottles, few Mn stains
8 2BCb	293-333	2.5YR 4/6	CL	1FSBK	FR	Few 5YR5/6 mottles
9 3Cl	333-381	2.5YR 4/8	COS L	OSG	VFR	Common Mn modules,common prominent mottles 10YR6/8
103C2	381-431	2.5YR 4/6	COS	OSG	VFR	Common prominent 7.5YR5/8
						1 lost sample 1ft. Add 30 cm to next depth.
11 3C3	461-515	5YR 4/6 7.5YR 6/8	S	OSG	VFR	Coarse Mn fragments and medium rounded quartz grains. stratified, conc. of Mn between two sandy P.M.'s
12 3C4	515-555	7.5YR 5/6 7.5YT 4/4 5YR 5/6	S	OSG	VFR	Mottled from stratification. Mn layer between yellow and brown 5YR5/6 has few Mn modules. Stratified.
13 3C5	555-579	2.5YR 5/8	S	OSG	FR	Few fine Mn nodules partially cemented w/ iron coatings common faint 2 5YR5/6 mottles.
14 3C6	579-644	5YR 5/8	S	OSG	VFR	Mn streaks toward the bottom of sample. Common 5YR4/4 mottles common Mn nodules throughout, common 7.5YR7/6 mottles.
15 3C7	644-705	5YR 5/8	COS	OSG	VFR	Mn nodules few. Mn streaks few, common prominent mottles 7.5YR6/8, few prominent 10YR5/3 mottles.
16 3C8	705-766	5YR 5/8	COS	OSG	VFR	Many Mn modules few prominent 7.5YR7/4 mottles. Few pominent 5YR4/4 mottles.
17 3C9	766-779	5YR 5/8	COS	OSG	VFR	Common prominent 2.5YR3/0 mottles.
18 3C10	779-796	5YR 6/8	LS	OSG	VFR	Streak of Mn in the top of sample many 2.5YR4/6 prominent mottles.
19 3C11	796-810	5YR 6/8	COS	OSG	VFR	Few 2.5YR4/9 mottles.

Groundwater Core Sampling Log Ames Water Quality

Well Location Number 020180150

Sample#	Depth(cm)	Color	Texture	Structure	Consist.	Notes
20 4C12	810-851	5Y 6/1	L	OM	Fi	Reduced. Few Mn nodules. 2.5YR4/8 few distinct mottles
21	851-860	10YR 5/4	L	OM	Fi	2.5YR4/6, few distinct mottles
	860-864	2.5YR 4/8	S	OSG		Not sampled - Field texture only
22	864-877	5Y 6/1	L	OM		
	877-882	2.5YR 4/8	S	OSG		Not sampled - Field texture only
23	882-921	10YR 5/4	L	OM	Fi	Few 2.5YR4/6 mottles. Few Mn nodules
24	921-951	2.5YR 4/6	L	OM	Fi	Few Mn nodules. Common 10YR6/3 mottles. Few 7.5YR6/8 mottles
25	951-966	7.5YR 4/6	COSL	OM	FR	Few 10YR6/2 mottles. Few Mn nodules. Little clay lense
	966-973	5Y 6/1		OM	Fi	Gleyed horizon few Mn nodules. Not sampled
26	973-1013	5YR 4/6	L	OM	Fi	Few 10YR7/6 mottles from sand. Paleosol?
27	1013-1043	2.5YR 3/6	L	OM	Fi	Structure looks platy from being crushed, Few 10YR6/6 mottles. Few Mn mottles
28	1043-1073	2.5YR 3/6	COSL	OM	Fi	Few medium Mn nodules. Few 10YR6/4 mottles
29	1073-1094	7.5YR 4/4 2.5YR 2/6 5YR 6/1 10YR 6/4	L	OM	Fi	Vegetable oil on outside. Few medium Mn nodules.
30	1094-1159	2.5YR 4/6	FSL	OSG	VFR	
31	1159-1224	7.5YR 6/8 2.5YR 4/8	COS	OSG	VFR	Primarily Mn stains. Mn concentration sampled at 1209-1214 cm for lab.
32	1224-1265	2.5YR 4/6	LCOS	OSG	VFR	Wet toward bottom of unit. Mn streaks. Mn nodules and coarse quartz. Few 5YR6/8 mottles
						Augured through 107cm not sample (41.5' to 45')
33	1372-1433	5YR 6/8 7.5YR 6/8	COS	OSG	VFR	Mn & Fe nodules common Few gravels.
						Augured through 991cm (3ft.) (47'-50')
34	1524-1555	10R 6/6 7.5YR 6/8	S	OSG	VFR	Few medium Mn nodules. 7.5YR7/2 common prominent. E-bodies present
			COS			Augured through 122cm (51-55ft) water table at 53.3 ft.
35	1676-1722	5YR 6/6 10R 6/6	LS	OSG	VFR	E body present. Mn smears present. Few 10YR4/8 and few 7.5YR7/8 mottles

Classification: Fine-silty, mixed, thermic Dystric Eutrochrepts

Depth and elevation data from Deep Well 020180150. Surface elevation is 146.21 meters above mean sea level.

Sample I.D.	Horizon	Depth			Elevation above mean sea level		
		Top	Bottom	Midpoint	Top	Bottom	Midpoint
		cm			m		
1	Ap	0	11	5.5	146.21	146.10	146.16
2	Bw1	11	77	44.0	146.10	145.44	145.77
3	Bw2	77	102	89.5	145.44	145.19	145.32
4	Bw3	102	143	122.5	145.19	144.78	144.99
5	2Bw4	143	172	157.5	144.78	144.49	144.64
6	2Btb1	172	249	210.5	144.49	143.72	144.11
7	2Btb2	249	293	271.0	143.72	143.28	143.50
8	2BCb	293	333	313.0	143.28	142.88	143.08
9	3C1	333	381	357.0	142.88	142.40	142.64
10	3C2	381	431	406.0	142.40	141.90	142.15
11	3C3	461	515	488.0	141.60	141.06	141.33
12	3C4	515	555	535.0	141.06	140.66	140.86
13	3C5	555	579	567.0	140.66	140.42	140.54
14	3C6	579	644	611.5	140.42	139.77	140.10
15	3C7	644	705	674.5	139.77	139.16	139.47
16	3C8	705	766	735.5	139.16	138.55	138.86
17	3C9	766	779	772.5	138.55	138.42	138.49
18	3C10	779	796	787.5	138.42	138.25	138.34
19	3C11	796	810	803.0	138.25	138.11	138.18
20	4C12	810	851	830.5	138.11	137.70	137.91
21	---	851	860	855.5	137.70	137.61	137.66
22	---	864	877	870.5	137.57	137.44	137.51
23	---	882	921	901.5	137.39	137.00	137.20
24	---	921	951	936.0	137.00	136.70	136.85

Depth and elevation data from Deep Well 020180150 (continued).
Surface elevation is 146.21 meters above mean sea level.

Sample I.D.	Horizon	Depth			Elevation above mean sea level		
		Top	Bottom	Midpoint	Top	Bottom	Midpoint
		cm			m		
25	---	951	966	958.5	136.70	136.55	136.63
26	---	973	1013	993.0	136.48	136.08	136.28
27	---	1013	1043	1028.0	136.08	135.78	135.93
28	---	1043	1073	1058.0	135.78	135.48	135.63
29	---	1073	1094	1083.5	135.48	135.27	135.38
30	---	1094	1159	1126.5	135.27	134.62	134.95
31	---	1159	1224	1191.5	134.62	133.97	134.30
32	---	1224	1265	1244.5	133.97	133.56	133.77
33	---	1372	1433	1402.5	132.49	131.88	132.19
34	---	1524	1555	1539.5	130.97	130.66	130.82
35	---	1676	1722	1699.0	129.45	128.99	129.22

Particle size distribution in Deep Well 020180150.

Sample I.D.	Horizon	percent of <2-mm fraction								
		vcos	cos	ms	fs	vfs	sand	silt	clay	fine clay <.2 micrometer
1	Ap	0.7	0.5	0.9	0.5	0.8	3.4	71.4	25.2	12.4
2	Bw1	0.1	0.4	0.4	0.3	0.0	1.2	74.9	23.9	10.5
3	Bw2	0.2	1.4	1.7	2.0	1.1	6.4	72.4	21.2	10.7
4	Bw3	0.3	3.0	3.5	3.8	1.4	12.0	68.6	19.4	8.5
5	2Bw4	1.1	7.0	6.7	7.0	1.2	23.0	56.6	20.4	10.6
6	2Btb1	0.4	4.2	4.3	4.3	0.6	13.8	52.3	33.9	19.4
7	2Btb2	0.6	7.9	8.7	8.1	1.2	26.5	44.7	28.8	14.2
8	2BCb	1.5	15.2	18.9	24.6	2.6	62.8	20.0	17.2	9.5
9	3C1	3.9	15.4	29.4	36.7	0.9	86.3	5.1	8.6	6.6
10	3C2	1.4	25.6	30.1	32.0	2.0	91.1	3.0	5.9	3.6
11	3C3	4.4	17.5	28.6	36.1	4.3	90.9	4.2	4.9	3.4
12	3C4	1.8	16.7	23.8	42.8	7.6	92.7	3.5	3.8	1.9
13	3C5	1.1	22.8	37.2	28.6	1.9	91.6	3.5	4.9	3.2
14	3C6	0.4	18.9	39.6	32.4	1.8	93.1	3.2	3.7	1.3
15	3C7	3.0	38.4	30.8	19.1	1.4	92.7	4.0	3.3	0.9
16	3C8	1.4	23.4	33.3	31.0	3.9	93.0	3.4	3.6	2.6
17	3C9	2.0	34.6	34.7	18.7	2.8	92.8	4.1	3.1	2.0
18	3C10	0.0	13.7	32.4	34.7	5.9	86.7	5.0	8.3	5.7
19	3C11	2.2	28.2	36.0	25.2	1.5	93.1	3.7	3.2	2.6
20	4C12	1.0	8.3	11.6	15.5	4.3	40.7	38.3	21.0	13.6
21	---	0.9	9.4	11.5	14.1	3.4	39.3	48.2	12.5	12.5
22	---	1.1	9.6	12.0	15.2	5.5	43.4	36.5	20.1	12.6
23	---	0.9	8.0	10.2	13.2	3.6	35.9	42.5	21.6	14.0
24	---	0.8	8.2	9.5	11.3	2.6	32.4	42.3	25.3	16.1
25	---	1.7	18.0	23.4	24.4	4.7	72.2	17.3	10.5	6.3
26	---	1.4	10.8	12.6	14.8	2.3	41.9	36.8	21.3	13.3
27	---	3.3	12.8	14.7	17.4	2.2	50.4	28.0	21.6	14.8
28	---	2.9	14.9	16.4	17.7	2.0	53.9	27.9	18.2	12.2
29	---	1.6	12.0	14.9	15.7	3.8	48.0	32.9	19.1	11.2

Particle size distribution in Deep Well 020180150 (continued).

Sample I.D.	Horizon	percent of <2-mm fraction								
		vcos	cos	ms	fs	vfs	sand	silt	clay	fine clay < .2 micrometer
30	---	3.0	12.7	14.5	30.1	5.0	65.3	18.6	16.1	11.4
31	---	13.3	42.9	25.0	8.7	0.7	90.6	3.1	6.3	4.5
32	---	14.9	44.7	13.6	9.0	1.8	84.0	5.9	10.1	7.2
33	---	38.3	29.8	15.3	6.3	1.2	90.9	2.3	6.8	4.5
34	---	0.3	9.1	45.4	36.2	2.2	93.2	3.5	3.3	1.5
35	---	1.5	34.9	40.4	15.4	2.0	94.2	1.4	4.4	0.2

Ammonium acetate extractable bases, barium chloride extractable acidity, cation exchange capacity, and base saturation data for Deep Well 020180150.

Sample I.D.	$cmol_c\ kg^{-1}$ Ca	Mg	Na	K	SUM	$BaCl_2$ Ext. Acid.	CEC pH 7.0	CEC pH 8.2	Percent Base Saturation NH_4OAc pH-7.0	Sum of Cations
1	8.13	3.06	0.07	0.39	11.66	6.98	12.86	18.64	91	63
2	4.47	4.49	0.15	0.24	9.35	8.03	10.82	17.38	86	54
3	4.36	4.18	0.19	0.31	9.04	6.82	10.10	15.68	89	58
4	4.06	3.39	0.13	0.26	7.83	5.47	9.41	13.30	83	59
5	3.90	2.90	0.11	0.28	7.20	5.10	8.28	12.30	87	59
6	5.12	5.05	0.19	0.34	10.20	6.56	12.10	17.26	88	62

pH data for Deep Well 020080150.

Sample I.D.	Horizon	pH 1:2 .01M $CaCl_2$	pH 1:1 H_2O
1	Ap	5.1	5.7
2	Bw1	4.4	5.2
3	Bw2	4.5	5.3
4	Bw3	4.6	5.3
5	2Bw4	4.5	5.3
6	2Btb1	4.6	5.3
7	2Btb2	4.6	5.3
8	2BCb	4.6	5.2
9	3C1	4.6	5.1
10	3C2	4.6	5.3
11	3C3	4.5	5.3
12	3C4	6.1	6.5
13	3C5	4.7	5.3
14	3C6	4.7	5.4
15	3C7	4.8	5.5
16	3C8	4.7	5.4
17	3C9	6.6	6.8
18	3C10	4.6	5.3
19	3C11	5.7	6.0
20	4C12	4.5	5.2
21	---	4.6	5.2
22	---	4.5	5.2
23	---	4.6	5.3
24	---	4.6	5.4
25	---	4.7	4.7
26	---	4.7	4.7
27	---	4.7	4.7
28	---	4.7	4.7
29	---	5.6	5.6
30	---	4.7	4.7
31	---	4.9	4.9
32	---	4.8	4.8
33	---	5.0	5.0
34	---	5.7	5.7
35	---	6.2	6.2

Concentration of free iron oxides, total iron, total titanium, and total zirconium in Deep Well 020180150.

Sample I.D.	Horizon	Free Fe (mg kg^{-1})	Total Fe (mg kg^{-1})	Total Ti (mg kg^{-1})	Total Zr (mg kg^{-1})
1	Ap	14,684	26,879	2,143	82.0
2	Bw1	16,016	29,454	2,057	95.0
3	Bw2	13,215	25,206	2,089	88.7
4	Bw3	10,575	20,330	1,966	97.8
5	2Bw4	12,016	19,376	1,857	83.8
6	2Btb1	21,549	32,025	2,230	88.2
7	2Btb2	18,083	28,541	2,061	107.9
8	2BCb	10,245	16,215	1,205	21.8
9	3C1	6,729	9,393	495	<3.0
10	3C2	5,237	7,309	629	7.1
11	3C3	3,714	5,904	772	43.0
12	3C4	3,005	5,354	943	46.0
13	3C5	3,867	5,163	359	<3.0
14	3C6	3,574	4,249	499	<3.0
15	3C7	3,535	6,045	470	<3.0
16	3C8	3,215	4,687	417	21.8
17	3C9	2,887	4,634	273	42.5
18	3C10	8,518	10,906	657	5.6
19	3C11	2,668	4,333	321	12.3
20	4C12	978	6,085	2,034	74.4
21	---	4,991	11,814	2,081	80.3
22	---	1,549	6,184	2,099	108.5
23	---	8,639	16,308	2,119	82.7
24	---	13,204	22,452	2,295	90.0
25	---	6,147	9,263	1,026	32.7
26	---	11,689	19,021	2,076	85.0
27	---	11,932	18,935	1,807	61.3
28	---	11,016	18,085	1,678	63.7
29	---	9,477	16,277	1,923	71.9
30	---	10,602	15,341	1,478	44.4
31	---	11,520	15,150	438	28.5
32	---	8,351	11,016	562	12.1
33	---	10,512	13,676	724	22.0
34	---	1,482	1,996	451	17.0
35	---	2,051	3,191	384	8.4

Organic carbon and KCl aluminum data for Deep Well 020180150.

Sample I.D.	Horizon	Organic Carbon %	KCl Aluminum mg kg^{-1}
1	Ap	0.78	0.03
2	Bw1	0.12	1.48
3	Bw2	0.15	0.71
4	Bw3	0.15	0.43
5	2Bw4	0.12	0.47
6	2Btb1	0.16	0.52
7	2Btb2	0.10	0.45
8	2BCb	0.05	0.29
9	3C1	0.04	0.15
10	3C2	0.02	0.06
11	3C3	0.02	0.05
12	3C4	0.02	0.00
13	3C5	0.00	0.01
14	3C6	0.00	0.01
15	3C7	0.01	0.00
16	3C8	0.01	0.00
17	3C9	0.01	0.02
18	3C10	0.01	0.00
19	3C11	0.01	0.38
20	4C12	0.03	0.34
21	---	0.05	0.29
22	---	0.04	0.32
23	---	0.03	0.26
24	---	0.02	0.00
25	---	0.03	0.18
26	---	0.02	0.17
27	---	0.02	0.11
28	---	0.01	0.00
29	---	0.04	0.09
30	---	0.01	0.00
31	---	0.01	0.02
32	---	0.02	0.00
33	---	0.01	0.00
34	---	0.00	0.00
35	---	0.00	0.00

Appendix E. Morphology and Laboratory Data for Deep Well 010120300

Groundwater Core Sampling Log Ames Water Quality

Well Location Number010120300 (Textures corrected by lab data)

Sample#	Depth(cm)	Color	Texture	Structure	Consist.	Notes
1 Ap	0-25	10YR 4/3	SIL	1FSBk	FR	Few fine Mn nodules. Common 10YR5/3 mottles.
2 Bt1	25-49	7.5YR 4/4	SICL	2MSbk	FR	Few fine Mn nodules.
3 Bt2	49-92	7.5YR 4/4	SIL	2MSbk	FR	
4 Bt3	92-122	7.5YR 4/4	SIL	2MSbk	FR	Few 10YR6/4 mottles.
5 Bt4	122-175	7.5YR 4/4	SIL	2MSbk	FR	Very few fine Mn nodules. Common 10YR7/3 mottles.
6 2Btb1	175-213	7.5YR 4/4	SIL	1MSbk	FR	Few Mn nodules. Few 10YR5/3 mottles.
7 2Btb2	213-246	2.5YR 4/6	L	1MSbk	FR	Transition zone. Few 10YR5/3 mottles.
8 2Btb3	246-305	2.5YR 4/6	L	1MSbk	FR	Common 10YR5/4 mottles.
9 2Btb4	305-329	2.5YR 4/6	L	1MSbk	FR	Few 7.5YR5/8 mottles. Common 10YR/54 mottles. Few fine Mn nodules.
10 2BCb	329-364	2.5YR 3/6	COSL	1MSbk	FR	Few fine Mn nodules.
11 3C1	364-402	2.5YR 3/6	FSL	OM	FR	
12 3C2	402-425	2.5YR 4/8	FSL	OM	FR	Mica flakes.
13 3C3	425-474	2.5YR 4/8 2.5YR 3/6	FSL	OSG	FR	Few 7.5YR5/8 mottles. Mica flakes. Mn streaks.
14 3C4	474-523	5YR 4/4 2.5YR 4/8	FSL	OSG	FR	Mica flakes. Mn streaks and rinds.
15 3C5	523-609	7.5YR 5/8 5YR 5/8 2.5YR 3/4	LFS	OSG	FR	Stratified. Mn nodules. E bodies present. Clean quartz. Mica flakes.
16 3C6	609-636	5YR 3/4 2.5YR 4/8 10YR 8/2	FS	OSG	FR	Common mica.
17 3C7	636-671	7.5YR 8/3	FS	OSG	FR	Common 5YR5/8 mottles. Common mica.
18 3C8	671-690	2.5YR 4/6 5YR 5/6 7.5YR 4/6	LS	OSG	FR	Common mica.
19 3C9	690-761	2.5YR 4/6 7.5YR 6/8	FSL/ LFS	OSG	FR	Common mica. 2.5YR4/6 has a clay pick up.
20 3C10	761-784	5YR 5/8 10YR 8/1	S	OSG	FR	Common mica.

Groundwater Core Sampling Log Ames Water Quality

Well Location Number010120300 (Textures corrected by lab data)

Sample#	Depth(cm)	Color	Texture	Structure	Consist.	Notes
21 4C11	784-827	10YR 8/1 5YR 5/8 7.5YR 5/8	L/LFS	OSG	FR	Common mica.
22	827-940	5YR 5/8 10YR 8/1 2.5YR 5/6	S	OSG	FR	Stratified.
23	940-977	5YR 5/8 10YR 8/1	S	OSG	FR	Stratified. Common mica.
24	977-1065	10YR 8/1	S	OSG	FR	Common 5YR5/8 mottles.
25	1065-1228	10YR 8/1	S	OSG	FR	Common mica. Common 5YR5/8 mottles
26	1228-1267	2.5YR 5/8 5YR 5/8	S	OSG	FR	Few 10YR8/1
27	1267-1317	5YR 5/8	S	OSG	FR	Few 10YR4/6 mottles. Many 2.5YR5/8 mottles.
28	1317-1383	10YR 8/1	S	OSG	FR	Few 10R4/6 mottles. Many 7.5YR5/8 mottles. Mn layer at bottom of horizon.
29	1383-1559	10YR 8/1 2.5YR 6/6 7.5YR 5/8 10YR 3/6	COS	OSG	FR	Common Mn nodules.
30	1559-1673	5YR 5/8 7.5YR 5/8 10YR 8/1	COS	OSG	FR	Common quartz and mica.
31	1673-1825	10YR 8/1	S	OSG	FR	Common 5YR5/8. Thin lense of Kaolin noted.

Classification: Fine-silty, mixed, thermic Ultic Hapludalf

Depth and elevation data from Deep Well 010120300. Surface elevation is 149.90 meters above mean sea level.

Sample I.D.	Horizon	Depth			Elevation above mean sea level		
		Top	Bottom	Midpoint	Top	Bottom	Midpoint
		cm			m		
1	Ap	0	25	12.5	149.90	149.65	149.78
2	Bt1	25	49	37.0	149.65	149.41	149.53
3	Bt2	49	92	70.5	149.41	148.98	149.20
4	Bt3	92	122	107.0	148.98	148.68	148.83
5	Bt4	122	175	148.5	148.68	148.15	148.42
6	2Btb1	175	213	194.0	148.15	147.77	147.96
7	2Btb2	213	264	238.5	147.77	147.26	147.52
8	2Btb3	246	305	275.5	147.44	146.85	147.15
9	2Btb4	305	329	317.0	146.85	146.61	146.73
10	2BCb	329	364	346.5	146.61	146.26	146.44
11	3C1	364	402	383.0	146.26	145.88	146.07
12	3C2	402	425	413.5	145.88	145.65	145.77
13	3C3	425	474	449.5	145.65	145.16	145.41
14	3C4	474	523	498.5	145.16	144.67	144.92
15	3C5	523	609	566.0	144.67	143.81	144.24
16	3C6	609	636	622.5	143.81	143.54	143.68
17	3C7	636	671	653.5	143.54	143.19	143.37
18	3C8	671	690	680.5	143.19	143.00	143.10
19	3C9	690	761	725.5	143.00	142.29	142.65
20	3C10	761	784	772.5	142.29	142.06	142.18
21	4C11	784	827	805.5	142.06	141.63	141.85
22	---	827	940	883.5	141.63	140.50	141.07
23	---	940	977	958.5	140.50	140.13	140.32
24	---	977	1065	1021.0	140.13	139.25	139.69
25	---	1065	1228	1146.5	139.25	137.62	138.44

Depth and elevation data from Deep Well 010120300 (continued).
Surface elevation is 149.90 meters above mean sea level.

Sample I.D.	Horizon	Depth			Elevation above mean sea level		
		Top	Bottom	Midpoint	Top	Bottom	Midpoint
		cm			m		
26	---	1228	1267	1247.5	137.62	137.23	137.43
27	---	1267	1317	1292.0	137.23	136.73	136.98
28	---	1317	1383	1350.0	136.73	136.07	136.40
29	---	1383	1559	1471.0	136.07	134.31	135.19
30	---	1559	1673	1616.0	134.31	133.17	133.74
31	---	1673	1825	1749.0	133.17	131.65	132.41

Particle size distribution in Deep Well 010120300.

Sample I.D.	Horizon	percent of < 2-mm fraction								
		vcos	cos	ms	fs	vfs	sand	silt	clay	fine clay <.2 micrometer
1	Ap	0.5	0.3	0.7	0.5	0.4	2.4	82.5	15.1	5.1
2	Bt1	0.1	0.2	0.2	0.1	0.0	0.6	70.1	29.3	14.0
3	Bt2	0.2	0.0	0.4	0.4	0.4	1.4	72.6	26.0	12.4
4	Bt3	0.0	0.4	1.1	0.5	0.7	2.7	74.9	22.4	9.2
5	Bt4	0.2	2.5	2.9	5.7	0.5	11.8	67.0	21.2	10.7
6	2Btb1	1.1	3.7	5.4	8.7	1.1	20.0	59.1	20.9	11.7
7	2Btb2	1.1	5.5	7.8	11.5	1.2	27.1	48.7	24.2	14.5
8	2Btb3	0.7	5.8	9.0	14.0	0.8	30.3	44.0	25.7	14.5
9	2Btb4	0.5	11.0	16.4	21.6	1.1	50.6	30.5	18.9	10.9
10	2BCb	2.2	15.4	22.2	27.0	1.5	68.3	18.1	13.6	8.3
11	3C1	2.8	12.1	21.3	40.1	2.0	78.3	10.0	11.7	8.0
12	3C2	1.1	3.2	12.8	56.6	2.1	75.8	6.5	17.7	10.9
13	3C3	0.7	2.6	21.8	50.3	1.5	76.9	10.3	12.8	8.7
14	3C4	0.4	1.5	12.6	64.0	2.1	80.6	6.4	13.0	9.1
15	3C5	1.8	5.5	26.5	50.4	2.2	86.4	5.5	8.1	6.1
16	3C6	1.5	8.5	32.0	45.4	2.6	90.0	1.8	8.2	5.6
17	3C7	2.6	9.0	33.2	50.2	2.2	97.2	2.5	0.3	0.3
18	3C8	6.0	9.5	27.9	39.2	2.7	85.3	6.4	8.3	5.6
19	3C9	0.2	1.5	19.0	57.2	4.0	81.9	5.5	12.6	7.0
20	3C10	0.4	6.4	43.0	38.3	1.6	89.7	4.0	6.3	3.6
21	4C11	0.2	1.1	23.4	67.6	2.0	94.3	3.0	2.7	1.5
22	---	0.2	2.3	41.3	44.5	4.7	93.0	5.6	1.4	0.6
23	---	0.3	5.7	41.9	43.6	2.2	93.7	3.5	2.8	1.7
24	---	0.3	5.5	45.8	41.8	2.7	96.1	3.4	0.5	0.3
25	---	0.9	7.6	56.8	29.0	1.0	95.3	2.8	1.9	1.4
26	---	0.2	20.9	59.3	13.3	0.5	94.2	1.9	3.9	2.3
27	---	1.6	38.3	36.1	14.2	1.4	91.6	3.1	5.3	2.3
28	---	0.4	10.7	44.0	35.3	4.9	95.3	3.2	1.5	0.4

Particle size distribution in Deep Well 010120300 (continued).

Sample I.D.	Horizon	percent of < 2-mm fraction								
		vcos	cos	ms	fs	vfs	sand	silt	clay	fine clay <.2 micrometer
29	---	5.5	48.6	27.1	12.0	1.5	94.7	2.6	2.7	1.3
30	---	10.3	24.6	32.6	27.8	1.7	97.0	1.3	1.7	0.6
31	---	10.4	12.3	35.0	37.6	1.3	96.6	2.5	0.9	0.5

Ammonium acetate extractable bases, barium chloride extractable acidity, cation exchange capacity, and base saturation data for Deep Well 010120300.

Sample I.D.	$cmol_c\ kg^{-1}$ Ca	Mg	Na	K	SUM	$BaCl_2$ Ext. Acid.	CEC pH 7.0	CEC pH 8.2	Percent Base Saturation NH_4OAc pH-7.0	Sum of Cations
1	4.61	0.60	0.08	0.19	5.48	5.32	7.34	10.80	74	50
2	6.13	2.25	0.12	0.24	8.74	7.16	13.03	15.89	67	54
3	3.68	2.94	0.16	0.23	7.01	10.65	14.24	17.66	49	39
4	2.60	2.45	0.11	0.20	5.36	9.55	11.27	14.91	47	35
5	2.16	2.29	0.20	0.19	4.85	6.78	8.35	11.63	58	41
6	2.14	2.35	0.10	0.20	4.79	5.35	7.64	10.14	62	47

pH data for Deep Well 010020300.

Sample I.D.	Horizon	pH 1:2 .01M $CaCl_2$	pH 1:1 H_2O
1	Ap	6.0	6.0
2	Bt1	5.0	5.6
3	Bt2	4.4	5.6
4	Bt3	4.3	5.1
5	Bt4	4.5	5.4
6	2Btb1	4.6	5.5
7	2Btb2	4.6	5.4
8	2Btb3	4.6	5.4
9	2Btb4	5.1	5.4
10	2BCb	4.6	5.4
11	3C1	4.6	5.4
12	3C2	4.5	5.4
13	3C3	4.5	5.4
14	3C4	4.5	5.3
15	3C5	4.5	4.8
16	3C6	4.5	5.1
17	3C7	5.3	5.5
18	3C8	4.6	5.3
19	3C9	4.6	5.4
20	3C10	4.7	5.4
21	4C11	4.9	5.4
22	---	4.9	5.5
23	---	4.8	5.6
24	---	5.3	5.6
25	---	5.0	5.7
26	---	4.9	5.6
27	---	5.1	5.5
28	---	5.5	5.5
29	---	5.6	5.8
30	---	5.2	5.6
31	---	5.5	5.7

Concentration of free iron oxides, total iron, total titanium, and total zirconium in Deep Well 010120300.

Sample I.D.	Horizon	Free Fe (mg kg^{-1})	Total Fe (mg kg^{-1})	Total Ti (mg kg^{-1})	Total Zr (mg kg^{-1})
1	Ap	6,999	15,776	2,005	86.9
2	Bt1	16,356	32,030	2,510	99.1
3	Bt2	18,207	35,084	2,393	107.4
4	Bt3	15,287	31,507	2,363	116.7
5	Bt4	11,623	24,430	2,076	103.6
6	2Btb1	9,992	21,299	2,103	104,1
7	2Btb2	10,799	21,665	2,002	87.3
8	2Btb3	13,363	14,497	1,931	89.6
9	3C1	16,902	20,343	1,474	60.9
10	3C2	6,822	16,946	1,102	34.6
11	3C3	5,781	12,283	908	26.4
12	3C4	9,238	15,510	1,560	36.8
13	3C5	7,132	12,562	1,132	27.8
14	3C6	7,594	13,384	1,172	34.6
15	3C7	4,339	9,938	724	14.0
16	3C8	3,789	9,385	670	6.2
17	3C9	380	5,135	278	3.4
18	3C10	5,165	10,332	527	12.6
19	4C11	6,553	8,189	762	17.8
20	---	3,151	5,456	931	22.6
21	---	1,086	2,925	1,032	15.6
22	---	383	2,070	634	8.2
23	---	808	2,400	344	< 3.0
24	---	240	863	275	< 3.0
25	---	1,013	1,875	335	< 3.0
26	---	3,408	4,458	512	5.4
27	---	6,206	7,807	322	17.0
28	---	722	1,882	609	14.6
29	---	2,737	3,483	288	18.7
30	---	2,563	5,271	551	6.1
31	---	1,969	5,039	1,347	23.3

Organic carbon and KCl aluminum data for Deep Well 010120300.

Sample I.D.	Horizon	Organic Carbon %	KCl Aluminum mg kg^{-1}
1	Ap	0.79	0.00
2	Bt1	0.31	0.17
3	Bt2	0.18	3.29
4	Bt3	0.13	2.87
5	Bt4	0.12	1.23
6	2Btb1	0.13	0.47
7	2Btb2	0.15	0.62
8	2Btb3	0.10	0.82
9	2Btb4	0.07	0.60
10	2BCb	0.06	0.38
11	3C1	0.04	0.22
12	3C2	0.05	0.32
13	3C3	0.06	0.39
14	3C4	0.08	0.42
15	3C5	0.05	0.24
16	3C6	0.05	0.24
17	3C7	0.01	0.00
18	3C8	0.03	0.13
19	3C9	0.03	0.13
20	3C10	0.01	0.02
21	4C11	0.00	0.00
22	---	0.00	0.00
23	---	0.01	0.00
24	---	0.01	0.00
25	---	0.01	0.00
26	---	0.02	0.00
27	---	0.03	0.00
28	---	0.02	0.00
29	---	0.01	0.00
30	---	0.01	0.00
31	---	0.01	0.00

Appendix F. Morphology and Laboratory Data for Deep Well 010060240

Groundwater Core Sampling Log Ames Water Quality

Well Location Number010060240 (Textures corrected to lab analysis)

Sample#	Depth(cm)	Color	Texture	Structure	Consist.	Notes
1 Ap	0-17	10YR 4/4	SIL	2MGr	FR	
2 Bt1	17-61	7.5YR 4/6	SICL	2MSbk	FR	
3 Bt2	61-104	7.5YR 4/6	SIL	2MSbk	FR	
4 Bt3	104-119	5YR 4/4	SIL	2MSbk	FR	Few 10YR4/4 mottles.Few Med. Mn nodules, Pedogenic streak.
5 Bt4	119-176	5YR 4/4	SICL	1MSbk	FR	Few fine Mn nodules.
6 2Bb1	176-220	2.5YR 3/4	SICL	1MSbk	FR	Many fine Mn nodules. Few 10YR5/4 mottles.
7 2Bb2	220-251	2.5YR 4/6	SICL	1MSbk	FR	Many fine Mn nodules.
8 2Bb3	251-333	5YR 4/6	SICL	1MSbk	Fi	Few fine Mn nodules. Few 10YR5/4 mottles.
9 3BCb	333-357	5YR 4/6	COSL	1MSbk	FR	Iron pan noted.
10 3CBb	357-381	5YR 4/6	COSL	1MSbk	FR	Few 5YR4/8 mottles.
11 3C1	381-414	5YR 4/6	LCOS	OSG	FR	2.5YR4/8 mottles. Stratified.
12 3C2	414-471	7.5YR 5/6	COS	OSG	FR	
13 3C3	471-608	2.5YR 4/8	LCOS/ COSL	OSG	FR	E bodies present.
14 4C4	608-626	10YR 6/6	FS	OSG	FR	Many 2.5YR4/8 mottles.
15	626-644	10YR 8/1	FS	OSG	FR	Common 7.5YR5/8. Common 2.5Yr4/8. Mn layer.
16	644-784	2.5YR 4/8	FS	OSG	FR	Mica flakes.
17	784-811	5YR 5/8 10YR 8/1 10YR 6/8	FS/ LFS	OSG	FR	Mica flakes.
18	811-819	10YR 8/1	FS	OSG	FR	
Not sampled	819-827	5YR 6/8	LFS	OSG	FR	
Not sampled	827-832	10YR 8/1	LFS	OSG	FR	

Groundwater Core Sampling Log Ames Water Quality

Well Location Number010060240 (Textures corrected by lab data)

Sample#	Depth(cm)	Color	Texture	Structure	Consist.	Notes
19	832-863	5YR 6/8 2.5YR 4/8	SL	OSG	FR	Mica flakes.
Not sampled	863-873	10YR 8/1	FS	OSG	FR	Stratified.
20	873-912	5YR 6/8 2.5YR 4/8 10YR 8/1	LFS	OSG	FR	Mica flakes.
Not sampled	912-1064		S			Fell out of bottom of auger.

Classification: Fine-silty, mixed, thermic Ultic Aapludalfs

Depth and elevation data from Deep Well 010060240. Surface elevation is 151.21 meters above mean sea level.

Sample I.D.	Horizon	Depth			Elevation above mean sea level		
		Top	Bottom	Midpoint	Top	Bottom	Midpoint
		cm			m		
1	Ap	0	17	8.5	151.21	151.04	151.13
2	Bt1	17	61	39.0	151.04	150.60	150.82
3	Bt2	61	104	82.5	150.60	150.17	150.39
4	Bt3	104	119	111.5	150.17	150.02	150.10
5	Bt4	119	176	147.5	150.02	149.45	149.74
6	2Btb1	176	220	198.0	149.45	149.01	149.23
7	2Btb2	220	251	235.5	149.01	148.70	148.86
8	2Btb3	251	333	292.0	148.70	147.88	148.29
9	3BCb	333	357	345.0	147.88	147.64	147.76
10	3CBb	357	381	369.0	147.64	147.40	147.52
11	3C1	381	414	397.5	147.40	147.07	147.24
12	3C2	414	471	442.5	147.07	146.50	146.79
13	3C3	471	608	539.5	146.50	145.13	145.82
14	4C4	608	626	617.0	145.13	144.95	145.04
15	---	626	644	635.0	144.95	144.77	144.86
16	---	644	784	714.0	144.77	143.37	144.07
17	---	784	811	797.5	143.37	143.10	143.24
18	---	811	819	815.0	143.10	143.02	143.06
19	---	832	863	847.5	142.89	142.58	142.74
20	---	873	912	892.5	142.48	142.09	142.29

Particle size distribution in Deep Well number 010060240.

Sample I.D.	Horizon	percent of <2-mm fraction								
		vcos	cos	ms	fs	vfs	sand	silt	clay	fine clay <.2 micrometer
1	Ap	0.4	1.0	0.5	0.9	1.1	3.9	76.8	19.3	7.9
2	Bt1	0.7	1.6	1.4	0.7	0.6	5.0	65.9	29.1	13.1
3	Bt2	0.0	0.2	0.3	0.2	0.5	1.2	76.9	21.9	11.0
4	Bt3	0.2	0.9	0.3	1.3	0.8	3.5	73.4	23.1	13.3
5	Bt4	0.0	1.6	1.3	1.8	0.8	5.5	69.5	25.0	14.3
6	2Btb1	1.4	4.3	4.1	4.7	1.1	15.6	55.7	28.7	19.4
7	2Btb2	0.2	3.2	3.4	4.2	1.1	12.1	57.1	30.8	19.1
8	2Btb3	0.6	2.8	3.0	3.5	0.8	10.7	56.4	32.9	19.6
9	3BCb	6.7	17.2	17.5	22.0	2.7	65.9	18.8	15.3	9.8
10	3CBb	11.3	25.8	19.0	17.7	2.7	76.5	13.0	10.5	6.5
11	3C1	6.4	38.0	27.1	13.7	1.7	86.9	4.1	9.0	6.8
12	3C2	6.3	42.6	25.2	13.8	2.3	90.2	4.6	5.2	4.1
13	3C3	21.2	32.7	17.5	8.2	1.7	81.3	6.0	12.7	9.4
14	4C4	0.2	2.0	19.4	68.2	2.6	92.4	3.5	4.1	2.6
15	---	0.2	2.0	19.6	70.8	1.6	94.2	3.2	2.6	1.5
16	---	0.0	3.7	22.7	61.3	2.2	89.9	2.1	8.0	5.7
17	---	0.0	1.4	10.4	75.1	2.7	89.6	1.0	9.4	3.2
18	---	0.0	0.0	19.0	74.8	1.8	95.6	3.4	1.0	0.3
19	---	0.0	0.4	10.9	73.4	2.5	87.2	2.9	9.9	4.0
20	---	0.2	0.6	10.7	72.9	3.3	87.7	5.3	7.0	3.3

Ammonium acetate extractable bases, barium chloride extractable acidity, cation exchange capacity, and base saturation data for Deep Well 010060240.

Sample I.D.	$cmol_c\ kg^{-1}$ Ca	Mg	Na	K	SUM	$BaCl_2$ Ext. Acid.	CEC pH 7.0	CEC pH 8.2	Percent Base Saturation NH_4OAc pH-7.0	Sum of Cations
1	7.44	1.37	0.05	0.19	9.05	4.71	9.53	13.76	95	66
2	5.44	3.85	0.11	0.27	9.67	9.94	14.29	19.61	68	49
3	3.73	2.89	0.11	0.25	6.98	9.55	11.97	16.53	58	42
4	3.48	2.47	0.12	0.26	6.34	8.51	10.17	14.85	62	43
5	3.76	2.59	0.15	0.28	6.77	8.15	10.30	14.92	66	45
6	4.46	2.81	0.18	0.28	7.73	6.24	9.94	13.97	78	55

pH data for Deep Well 010060240.

Sample I.D.	Horizon	pH 1:2 .01M $CaCl_2$	pH 1:1 H_2O
1	Ap	5.6	6.4
2	Bt1	4.3	5.2
3	Bt2	4.2	5.2
4	Bt3	4.2	5.2
5	Bt4	4.3	5.2
6	2Btb1	4.5	5.3
7	2Btb2	4.7	5.4
8	2Btb3	4.7	5.4
9	3BCb	4.7	4.5
10	3CBb	4.8	5.5
11	3C1	4.7	5.5
12	3C2	4.8	5.6
13	3C3	4.8	5.6
14	4C4	4.9	5.5
15	---	5.0	5.6
16	---	4.8	5.6
17	---	4.9	5.7
18	---	5.0	5.6
19	---	4.9	5.6
20	---	4.8	5.7

Concentration of free iron oxides, total iron, total titanium, and total zirconium in Deep Well 010060240.

Sample I.D.	Horizon	Free Fe (mg kg^{-1})	Total Fe (mg kg^{-1})	Total Ti (mg kg^{-1})	Total Zr (mg kg^{-1})
1	Ap	9,701	18,172	2,122	126.2
2	Bt1	19,184	35,508	2,323	146.2
3	Bt2	16,342	32,505	2,261	119.1
4	Bt3	17,640	27,961	2,263	121.0
5	Bt4	13,511	26,119	2,287	113.2
6	2Btb1	16,246	26,200	2,153	95.0
7	2Btb2	17,740	27,435	2,207	110.5
8	2Btb3	21,888	------	1,121	65.6
9	3BCb	9,662	15,927	1,122	44.3
10	3CBb	8,933	14,488	829	30.5
11	3C1	7,443	11,260	674	14.2
12	3C2	5,921	9,215	312	11.0
13	3C3	11,413	15,562	662	19.7
14	4C4	2,236	3,622	453	12.3
15	---	1,149	2,588	521	12.1
16	---	5,240	8,231	844	12.5
17	---	2,637	4,366	1,116	41.6
18	---	855	1,963	341	25.5
19	---	4,973	6,729	652	18.8
20	---	3,908	5,686	1,108	25.8

Organic carbon and KCl aluminum data for Deep Well 010060240.

Sample I.D.	Horizon	Organic Carbon %	KCl Aluminum mg kg^{-1}
1	Ap	0.90	0.00
2	Bt1	0.18	2.22
3	Bt2	0.11	2.96
4	Bt3	0.12	2.13
5	Bt4	0.20	1.61
6	2Btb1	0.14	0.46
7	2Btb2	0.11	0.29
8	2Btb3	0.09	0.26
9	3BCb	0.03	0.10
10	3CBb	0.04	0.08
11	3C1	0.05	0.05
12	3C2	0.04	0.02
13	3C3	0.03	0.06
14	4C4	0.01	0.01
15	---	0.01	0.00
16	---	0.02	0.02
17	---	0.01	0.01
18	---	0.00	0.00
19	---	0.01	0.02
20	---	0.01	0.01

Appendix G. Shallow Well Installation Field Notes

SHALLOW WELL INSTALLATION FIELD NOTES
WEST PASTURE TRACT

Installation on 5/19-5/20/92
JTA/RLL/AOG
Filled with sand, soil, and grout by David Reese, Dr. Tyler, and Janet.
Specifications were followed as closely as possible. Well WP 4 Well WP 4 appeared to be located on the 30 rather than the 200 ft. circle. It was relocated as close as plossible by pacing. WP 13 appears to be located correctly but the wood line on the map seems to be incorrect. This site is in the field, not in woods. WP 19 was relocated by pacing as there was a missing stake. Well WP 23 was moved about 20 feet off of terrace toward the plot.

SW 020045090

Ap	0-40 cm	10YR 5/3 over 10YR 3/3	sil	disturbed
Bg1	40-100 cm	10YR 6/2 conc.	si/sil	common Mn & Fe
Btg	100-150 cm	10YR 6/2	sil	many Mn & Fe conc
2Btg	150-190 cm	5YR 4/6 & 10YR 6/2	sic	many Mn & Fe stains and concretions
2Bt	190-210 cm	7.5YR 4/4 w/ 10YR 6/2 tongues	sicl	

No red paleosol found but well set at restrictive layer.

Pipe set at 210 cm

SW 020045210

Ap	0-28 cm	10YR 5/4	sil	
Bt1	28-85 cm	10YR 4/6	sil	
Btx	85-110	7.5YR 4/4 w/ bottom 10YR 6/3 mottles	sicl/l	mixing zone in 50-60% brittleness
2Btx	110-185	5YR 4/6 w/ 7.5YR 7/3 ped faces	l/cl	mixing zone 50-60% brittleness
2Bt	185-218 cm	2.5YR 4/6	cl	Good paleosol

Pipe set at 218 cm

SW 020045330

Ap	0-26 cm	10YR 5/3	sil	
Bt1	26-90 cm	10YR 5/4	sil	
Btx	90-150 cm	7.5YR 4/4 w/ 10YR 6/3 ped faces	sicl	good fragipan
2Bx	150-200	5YR 4/6 w/ 7.5YR 7/3 mottles	l/cl	mixing zone
2Bt	200-230	2.5YR 4/6	c	about 20% sand

Pipe set at 230 cm

SW 020060030
This site was relocated from 300 ft. circle to the 200 ft. circle.

Ap	0-24 cm	10YR 5/3	sil	
Bt1	24-70 cm	10YR 4/6 w/ 10YR 5/4 mottles	sil/sicl	
Btx1	70-130 cm	7.5YR 4/6 w/ 10YR 6.2 mottles	sil/sicl	good prisims
Btx2	130-180 cm	5YR 4/4 w/ lower 10cm 10YR 6/2 mottles	sil/sicl	mixing in
2Bt	180-202 cm	2.5YR 4/6 w/ few 7.5YR 7/3 faces	scl/l	

Pipe set at 202 cm

SW 020060150

Ap	0-22 cm	10YR 5/3	sil	
Bt1	22-82 cm	10YR 4/6 & 10YR 5/6	sicl/sil	
Bt2	82-130 cm	7.5YR 4/6 w/ 7.5YR 7/3 mottles	sicl	
2Bt3	130-160 cm	7.5YR 4/4	sil	
2Bt4	160-180 cm	5YR 4/6 w/ 7.5YR 5/4 mottles	sicl/l	
2Bt5	180-210 cm	2.5YR 4/6	sc/c	

Pipe set at 210 cm.

SW 020060270

Ap	0-23 cm	10YR 5/3	sil	
AB	23-50 cm	10YR 4/4	sil	
Bt1	50-105 cm	10YR 4/6	sil/sicl	
Btx1	105-140 cm	10YR 4/6 & 10YR 6/3	sicl	30% brittleness
2Btx2	140-180 cm	5YR 4/4 w/ 7.5YR 7/3 mottles	sicl	Roxana?
2Bt	180-220 cm	2.5YR 4/6 & 5YR 4/6 mottles	sc/c	about 15% sand

Pipe set at 220 cm

SW 020090300

Ap	0-25 cm	10YR 5/3	sil	
AB	25-70 cm	10YR 4/4	sil	
Bt1	70-130 cm	7.5YR 4/4 w/	sicl	
Bt2	130-170 cm	5YR 4/4 w/ 7.5YR 7/3	sicl	20% brittleness
2Bt3	170-190 cm	5YR 4/6	sicl	
2Bt4	190-225 cm	2.5YR 3/6	sic/c	about 10% sand

Pipe set at 267 cm

SW 020090000

Ap	0-30 cm	10YR 5/3	sil	
Bt1	30-80 cm	10YR 5/6	sil	
Btx	80-140 cm	7.5YR 4/6 w/ 10YR 5/3 mottles	sicl	50-60% brittleness
2Btx	140-180 cm	5YR 4/4 w/ 10YR 5/2 mottles	sil/l	mixing zone
2Bt	180-207 cm	2.5YR 4/6	sicl/cl	

Pipe set at 207 cm

SW 020090060

Ap	0-27 cm	10YR 5/3	sil	
BA	27-40 cm	10YR 6/3 w/ 10YR 5/4 mottles	sil	
Bg	40-110 cm	10YR 6/1	sil	many Mn & Fe conc.
2Btx	110-170 cm	7.5YR 4/4 & N 6/	sicl	
2Bt	170-200 cm	5YR 4/4 w/ 10YR 7/1 mottles	sicl	

Red sandy paleosol not found. Set well at perched table in silty material.

Pipe set at 200 cm

SW 020090120

Ap	0-20 cm	10YR 4/3	sil	
Bt1	20-69 cm	10YR 5/6	sil/sicl	
Bt2	69-155 cm	10YR 4/4 w/ part 10YR 6/3 vertical E tounges	sicl/l	mixing in lower
2Bt3	155-182 cm	2.5YR 4/6 w/ 7.5YR 7/3 E bodies	sl/scl	
2Bt4	182-202 cm	2.5YR 4/6	c/sc	about 25% sand

Pipe set at 202 cm

SW 020090180

Ap	0-28 cm	10YR 4/3	sil	

Bt1	28-90 cm	10YR 4/4	sil	
Bt2	90-150 cm	10YR 5/4 w/ 10YR 6/3 ped faces	sicl	20-30% brittleness
2Bt3	150-180 cm	7.5YR 4/6 w/ prisims 7.5YR 7/3 ped faces	l/sil	mixing zone/few
2Bt4	180-200 cm	5YR 4/6 w/ 7.5YR 7/3 mottles	sl/l	
2Bt5	200-235 cm	2.5YR 4/6	scl	

Pipe set at 235 cm

SW 020090240

Ap	0-28 cm	10YR 5/4	sil	
Bt1	28-95 cm	10YR 4/6	sil	
Btx	195-180 cm	7.5YR 4/4 w/ 10YR 6/2 silt	sicl	few prisims coatings
2Bt1	180-190 cm	5YR 4/6	l	
2Bt2	190-216	2.5YR 4/6 w/	cl/scl	good paleosol

Pipe set at 216 cm

SW 020150255

Ap	0-20 cm	10YR 5/4	sil	
Bt1	20-95 cm	10YR 4/6	sil/sicl	
Btx1	95-130 cm	7.5YR 4/4 w/ 10YR 6/2 mottles	sicl	Roxana??
Btx2	130-160 cm	5YR 4/4 w/ 7.5YR 4/6 mottles	sicl	
2Bt1	160-180 cm	5YR 4/6 w/ 2.5YR 4/8 mottles	sicl	
2Bt2	180-213 cm	2.5YR 4/6	c/sic	

Pipe set at 213 cm

SW 020150285

Wooded site

Ap	0-10 cm	10YR 3/3	sil	
Bt1	10-65 cm	10YR 5/6	sil	

Bt2	65-150 cm	7.5YR 4/4 w/ 10YR 6/2 mottles	sicl	
2Bt3	150-180 cm	5YR 5/6 w/ 7.5YR 7/3 mottles	sicl	
2Bt4	180-210 cm	2.5YR 4/6	cl/c	

Pipe set at 210 cm

SW 020150345

Ap	0-50 cm	10YR 5/3	sil	disturbed
Bt1	50-94 cm	10YR 5/6 concretions	sil/sicl	common
Btx	94-135 cm	7.5YR 4/4 w/ 10YR 6/2 mottles	sicl	
2Btx	135-170 cm	5YR 4/4 w/ 10YR 6/2 mottles	l	mixing zone
2Bt	170-209 cm	5YR & 2.5YR 4/6	c	

Pipe set at 209 cm

SW 020150345

Ap	0-25 cm	10YR 5/3	sil	
Bt1	25-70 cm	10YR 5/6	sil/sicl	
Bt2	70-120 cm	10YR 4/6 brittleness	sil/sicl	20%
2Btx	120-190 cm	7.5YR 4/4 w/ N 6/ mottles	l	
2Bt	190-204 cm	2.5YR 4/6 w/ common black stains	cl/l	

Pipe set at 204 cm

SW 020150015
In wooded drainage head. Upper part appears to be alluvial deposit.

Ap	0-15 cm	10YR 6/2, 5YR 4/4, 7.5YR 4/6	sil	
Bw	15-40 cm	7.5YR 4/6 & 10YR 5/2	sil	
Btxb	40-79 cm	5YR 4/6w/ 7.5YR 6/2 mottles	sicl	
2Bt	79-104 cm	5YR 4/6 w/ 10YR 6/2 mottles	l	some mixing

Pipe set at 104 cm

SW 020150045

Ap	0-30 cm	10YR 5/3	sil	many Mn & Fe conc.
Bt	30-65 cm	10YR 5/3 w/ 10YR 5/6 mottles	sil	common concretions
Btx	65-135 cm	10YR 4/4, 10YR 5/2, 7.5YR 5/6	sil	
Bt'	135-160 cm	10YR 5/4 w/ 10YR 6/2 mottles	sil	
2Bt	160-190 cm	7.5YR 4/6 w/	sicl	
3Bt	190-210	5YR 4/4 w/ 10YR 6/2 mottles	l	

Pipe set at top of Roxana?

Pipe set at 210 cm

SW 020142075

This site had a missing stake. It was relocated by pacing

Ap	0-28 cm	10YR 5/3	sil	
Bt	28-61 cm	10YR 5/4	sil	
Btx1	61-140 cm	10YR 4/4 w/ 10YR 6/2 prisim faces	sicl	
Btx2	140-165 cm	7.5YR 4/4 w/ 10YR 6/2 prisim faces	sicl	
2Btx	165-195 cm	5YR 4/4 w/ N 6/ large E bodies	sicl/l	
2Bt	195-220	2.5YR 4/6	cl/c	about 20% sand

Pipe set at 220 cm

SW 020150105

Ap	0-22 cm	10YR 4/6 & 5/6		sil
Bt1	22-46 cm	10YR 5/6	sil	
Bt2	46-80 cm	10YR 4/4 w/ 10YR 6/3 ped faces	sicl	20% brittleness
Bt3	80-140 cm	7.5YR 4/4 w/ 10YR 6/2 E bodies	sicl/l	
2Bt4	140-180 cm	7.5YR 4/4 w/ 10YR 6/2 mottles	l/sl	mixing zone

2Bt5	180-209 cm	2.5YR 4/6 w/ 7.5YR 7/3 mottles	c

Pipe set at 209 cm

SW 020150135

Ap	0-20 cm	10YR 4/3	sil
Bt1	20-63 cm	10YR 4/4	sil/sicl
Bt2	63-110 cm	7.5YR 4/4	sicl/l mixing zone
2Bt3	110-156 cm	5YR 4/6	l
2Bt4	156-193 cm	2.5YR 4/6	scl

Pipe set at 193 cm

SW 020150165

Ap	0-30 cm	10YR 5/3, 4/3	sil	disturbed & compacted
Bt1	30-85 cm	10YR 4/4	sil/sicl	
Bt2	85-150 cm	7.5YR 4/4 w/ 10YR 6/2 mottles	sil/sicl	40% brittleness
2Bt3	150-200 cm	5YR 4/4 w/ 10YR 6/2 mottles	l/sl	mixing zone
2Bt4	200-220 cm	5YR 4/6 w/ 7.5YR 7/2 mottles	l/sl	
2Bt5	220-240 cm	2.5YR 4/6 w/ 2.5YR 7/3 mottles	sc	

Pipe set at 240 cm

SW 020143195

Moved off of terrace about 20 ft. toward plot.

Ap	0-35 cm	10YR 5/3	sil	
Bt1	35-100 cm	10YR 4/6	sil	
Bt2	100-160 cm	7.5YR 4/4 w/ 10YR 5/3 mottles	sicl	
Bt3	160-220 cm	5YR 4/4 w/ 7.5YR 5/6 and 7.5YR 7/2 mottles	sicl	Roxana?
2Bt4	220-240 cm	2.5YR 4/6	sic/sicl	about 5-10% sand

Pipe set at 240 cm

SW 020150225

Ap	0-30 cm	10YR 5/4	sil	
Bt1	30-105 cm	10YR 4/4	sil/sicl	
Bt2	105-160 cm	10YR 4/4 w/ 10YR 6/3 mottles	sicl	
2Bt3	160-190 cm	5YR 4/6	sicl	mixing zone
2Bt4	190-210 cm	2.5YR 4/6	sic/c	Loveland?

Pipe set at 210 cm

SHALLOW WELL INSTALLATION FIELD NOTES
HANCOCK TRACT

Installation on 3/24-3/26/92
JTA/RLL/AOG/MWM/DR
Filled with sand, soil, and grout at same time by same crew.
Specifications were followed as closely as possible.
Wells (12 wells) on the two inner circles did not appear to be located correctly on the blue-line map. The marker for well H 18 had been knocked over. Wells were installed where the wooden steak was located in the field or were relocated as close as possible if steak was knocked over.

SW 010045090

Ap	0-17 cm	10YR 4/4	sil	
Bt1	22-80 cm	10YR 5/4	sicl	
2Btb	80-220 cm	10YR 4/4	l	mixing zone
2BCb	220-276 cm	2.5YR 4/6	sl	not clayey paleosol

Pipe set at 276 cm

SW 010045210

Ap	0-28 cm	10YR 4/4	sil	
Bt1	28-120 cm	10YR 5/4	sicl	
Bt2	120-180	10YR 4/4 & 10YR 5/4	sicl	
2Btb1	180-210	7.5YR 4/6 w/ 10YR 6/3 faces	c	< 10% sand
2Btb2	210-230 cm	2.5YR 4/6 w/ 7.5YR 5/6 mottles	c	< 10% sand

Pipe set at 230 cm

SW 010045330

Ap	0-22 cm	10YR 4/3	sil	
Bt1	22-120 cm	10YR 5/4	sicl	
Bt2	120-180 cm	10YR 4/4 10YR 5/4 ped faces	sil	

2Btb1	180-213	5YR 4/6 w/ fragic 7.5YR 6/4 mottles	l/cl	mixing zone 10%
2Btb2	213-250	2.5YR 3/6 w/ 5YR 6/4 mottles	cl/c	

Pipe set at 250 cm

SW 010060030

Ap	0-17 cm	10YR 4/3	sil	
Bt1	17-105 cm	10YR 5/6	sicl	
Bt2	105-200 cm	10YR 4/6	sicl	
2Btb1	200-230 cm	7.5YR 4/6	cl	mixing zone
2Btb2	230-260 cm	2.5YR 4/6	c	

Pipe set at 260 cm

SW 010060150

Ap	0-14 cm	10YR 4/3	sil	
Bt1	14-110 cm	10YR 5/4	sicl	
Bt2	110-135 cm	10YR 4/4 w/ 10YR 6/2 mottles	sicl	
2Btb1	135-185 cm	7.5YR 4/4 w/ 10YR 5/6 mottles	l/cl	
2Btb2	185-220 cm	2.5YR 4/6 w/	c	

Pipe set at 220 cm

SW 010060270

Ap	0-20 cm	10YR 4/3	sil	
Bt1	20-120 cm	10YR 4/4	sicl	
Bt2	120-160 cm	7.5YR 4/6	sicl	
2Btb1	160-180 cm	7.5YR 4/6	cl	mixing zone
2Btb2	180-200 cm	7.5YR 4/6 w/ 10YR 6/3 mottles	cl/l	20-30% brittleness
2Btb3	200-231 cm	2.5YR 4/6 w/ 7.5YR 5/6 mottles	sc/c	

Pipe set at 231 cm

SW 010090300

Ap	0-16 cm	10YR 4/3	sil	
Bt1	16-65 cm	10YR 4/4 w/ 10YR 6/3 ped faces	sicl	
Bt2	65-200 cm	10YR 3/4 & 10YR 4/4	sicl	20% brittleness
2Btxb	200-230 cm	7.5YR 4/6 w/ 10YR 6/2 E bodies	l/cl	
2Btb	230-267 cm	2.5YR 4/6 w/ 7.5YR 6/4 ped faces; very moist on faces	c	

Pipe set at 267 cm

SW 010090000

Ap	0-20 cm	10YR 4/4	sil	
Bt1	20-96 cm	10YR 5/4 & 10YR 5/6	sil	
Bt2	96-140 cm	10YR 4/4 w/ 10YR 5/6 mottles	sicl	
2Btb1	140-192 cm	5YR 4/6	c/cl	mixing zone
2Btb2	192-231 cm	2.5YR 3/6	c	

Pipe set at 231 cm

SW 010090060

Ap	0-20 cm	10YR 4/4	sil	
Bt1	20-110 cm	10YR 4/6	sicl	
Bt2	110-155 cm	10YR 4/4	sicl	
2Btb1	155-230 cm	10YR 4/3 & 10YR 5/4	l	mixing zone
2Btb2	230-270 cm	2.5YR 4/6 w/ 10YR 4/4 mottles	sc/c	

Pipe set at 270 cm

SW 010090120

Ap	0-22 cm	10YR 4/4	sil
Bt1	22-150 cm	10YR 5/4	sil/sicl

Bt2	150-190 cm	10YR 4/4 w/ 10YR 5/4 mottles	sicl	
2Btb1	190-200 cm	5YR 4/6 & 7.5YR 4/6	sicl/sil	
2Btb2	200-253 cm	5YR 4/6	c	< 10% sand

Pipe set at 253 cm

SW 010090180

Ap	0-25 cm	10YR 4/4	sil	
Bt1	25-70 cm	10YR 4/4 & 10YR 4/6	sicl	
Bt2	70-125 cm	7.5YR 4/6 w/ 10YR 6/3 ped faces	sicl	20-30% brittleness
2Btb1	125-170 cm	5YR 4/6 w/ sand 10YR 6/3 ped faces	sicl/l	mixing zone <10%
2Btb2	170-207 cm	2.5YR 4/6 w/ 5YR 5/4 mottles	sc/scl	

Pipe set at 207 cm

SW 010090240

Ap	0-70 cm	10YR 4/4 road	sil	disturbed, edge of
Bt1	70-140 cm	10YR 5/6	sil/sicl	
Btx1	140-170 cm	10YR 4/4 w/ 10YR 6/2 silt coatings	sicl	60% brittleness
Btx2	170-200 cm	10YR 4/4 w/ 10YR 6/2 silt coatings	sicl	30-40% brittleness
2Btb/Eb2	00-217 cm	7.5YR 7/2 E bodies	5YR 4/6 w/	cl-B & sil-E
2Bt	217-251	2.5YR 4/6 w/ 7.5YR 7/2 ped faces	c	

Pipe set at 251 cm

SW 010150285

Ap	0-25 cm	10YR 4/4	sil	
Bt1	25-90 cm	10YR 5/4	sicl/sil	
Bt2	90-170 cm	10YR 4/6 bottom	sicl	grey mottles in

Some mixing in lower part between 150 & 170 cm

2Btb1	170-210 cm	7.5YR 4/6	cl	mixing zone
2Btb2	210-254 cm	2.5YR 5/6 w/ 7.5YR 4/6 mottles	c	

Pipe set at 254 cm

SW 010150315

Ap	0-33 cm	10YR 4/3	sil	

Ap is overthickened on edge of field

Bt1	33-100 cm	10YR 5/4	sicl	
Bt2	100-170 cm	10YR 4/4 w/ 10YR 5/6 mottles	sicl	
2Btb1	170-210 cm	5YR 4/6 w/ 7.5YR 5/4 mottles	cl/l	
2Btb2	210-252 cm	2.5YR 4/6	c	

94 cm of water in hole at time of pipe installation

Pipe set at 252 cm

SW 010153345

Ap	0-22 cm	10YR 4/3	sil	
Bt1	22-110 cm	10YR 4/6	sicl	
Bt2	110-190 cm	10YR 4/4	sicl	
2Btb1	190-215 cm	5YR 4/6 w/ 7.5YR 6/4 mottles	sicl/cl	10% brittleness mixing zone
2Btb2	215-230 cm	2.5YR 4/6 w/ 10YR 6/3 silt coatings	c	

Pipe set at 230 cm

SW 010150015

Ap	0-18 cm	10YR 4/4	sil	
Bt1	18-102 cm	10YR 5/4	sil/sicl	
Bt2	102-130 cm	10YR 4/4 w/ 10YR 6/3 mottles	sicl	
2Btb/Eb	130-197 cm	5YR 4/6 w/ 10YR 6/2 E material	cl/l	
2Btb	197-228 cm	2.5YR 4/6 w/ 7.5YR 6/4 ped faces	c	

Pipe set at 228 cm

SW 010153045

Ap	0-13 cm	10YR 4/4	sil	
Bt1	12-64 cm	10YR 5/4	sil/sicl	
Bt2	64-145 cm	7.5YR 4/6w/ 10YR 6/1 mottles	sicl	
2Btb1	145-207 cm	5YR 4/6 w/ 7.5YR 6/0 mottles	cl	mixing zone
2Btb2	207-249 cm	2.5YR 4/6	c	

Pipe set at 249 cm

SW 010150075

Ap	0-22 cm	10YR 4/3	sil	
Bt1	22-140 cm	10YR 5/4	sil/sicl	
Bt2	140-195 cm	10YR 4/4	sil	
2Btb1	195-255 cm	7.5YR 4/6	sicl/l	mixing zone
2Btb2	255-285 cm	5YR 4/6	c	< 10% sand

Some free water in bottom of hole

Pipe set at 185 cm

SW 010150105

Ap	0-18 cm	10YR 4/4	sil	
Bt1	18-115 cm	10YR 5/4	sicl/sil	
Bt2	115-165 cm	10YR 4/4 w/ 10YR 5/4 mottles	sicl	
2Btb1	165-220 cm	5YR 4/6 w/ faces 7.5YR 6/4 mottles	cl/l	free water on ped
2Btb2	220-257 cm	2.5YR 4/6 w/ 5YR 6/4 mottles	c	

Pipe set at 257 cm

SW 010150135

Ap	0-25 cm	10YR 4/4	sil	

Bt1	25-100 cm	10YR 5/4	sicl	possibly 2 Bt's
2Btb1	100-189 cm	5YR 4/6	cl	mixing zone
2Btb2	189-207 cm	2.5YR 4/6 & 2.5YR 3/6	c	

Pipe set at 207 cm

SW 010150162

Moved toward plot about 30 ft. Original site near head of a gully. This site in woods.

Ap	0-16 cm	10YR 4/3	sil	
BE	16-27 cm	10YR 4/4	sil	
Bt1	27-110 cm	10YR 5/4	sicl	
Bt2	110-160 cm	10YR 4/4 w/ 10YR 5/4 mottles	sicl	
2Btb1	160-180 cm	5YR 4/6 w/ 7.5YR 6/4 mottles	sicl/cl	mixing zone
2Btb2	180-193 cm	2.5YR 3/6 w/ 5YR 6/2 mottles	c	

Pipe set at 193 cm

SW 010150195

Near old house site in woods.

Ap	0-10 cm	10YR 4/3	sil	
Bt1	10-50 cm	10YR 4/4& 10YR 5/4	sicl	
Bt2	50-90 cm	7.5YR 4/4 w/ 10YR 6/2 mottles	sil	
2Btb1	90-150 cm	5YR 4/6 w/ 7.5YR 6/4 mottles	l/cl	mixing zone
2Btb2	150-193 cm	2.5YR 4/6 w/ 5YR 6/2 mottles	c	about 35% sand

Pipe set at 193 cm

H 23 (NO ASSIGNED NUMBER)

Located in woods near the drainageway where plastic pipe comes from plot. Well not installed. Water should outcrop in ditch before reaching this point underground. The old paleosol is in botton of drain.

SW 010150255

In woods.

O	10-0 cm	leaves, twigs, roots		
Ap	0-8 cm	10YR 3/4	sil	
BE	8-20 cm	10YR 5/4	sil	
Bt1	20-90 cm	10YR 5/6	sicl	
Bt2	90-180 cm	10YR 4/6 w/ Loveland? 10YR 6/2 ped faces	sicl	mixing zone
2Btb/Eb	180-210 cm	7.5YR 4/6 & 7.5YR 7/2 E bodies	1/cl	
2Btb	210-242 cm	2.5YR 4/6	c	about 30% sand

Pipe set at 242 cm

Additional notes taken on 5/29/93 in Map unit 6.

Stop 1

A	0-8 cm	10YR 4/3 sil	
2Btb1	8-32 cm	2.5YR 4/6 cl	
2Btb2	32-56 cm	2.5YR 4/6 w/7.5YR 5/6 mottles c/sc	
2BC1	56-69 cm	2.5YR 4/6 w/ 7.5YR 5/6 mottles	sl
2BC2	69-85 cm	2.5YR 4/6 w/7.5YR 6/6 mottles	sl
2CB	85-100 cm	2.5YR 4/6 sl	

Stop 2

A	0-12 cm	10YR 4/3	sil
Bt	12-38 cm	10YR 5/6	sicl
2Btb1	38-66 cm	5YR 4/6 w/10YR 6/6 mottles and Mn stains cl/l	
2Btb2	66-80 cm	2.5YR 5/6 w/10YR 5/3 mottles	cl
2Btb3	80-100 cm	2.5YR 4/6 w/7.5YR 5/6 mottles	c/sc

Stop 3

Oi	5-0	Leaves, twigs, and roots	
A	0-23	10YR 4/4	sil
Bt1	23-35	10YR 5/4	sil
Bt2	35-61	7.5YR 4/6	sicl
2Btb1	61-84	5YR 4/6	sicl about 10% sand
2Btb2	84-100	2.5YR 3/6 w/ 7.5YR 5/3 mottles	loam

Common Mn stains and concretions

VITA

Richard L. Livingston was born in Cookeville, Tennessee on January 11, 1959. He attended elementary school and high school at Rickman, Tennessee and graduated in 1977.

He entered college at Tennessee Technological University in 1977 while working part-time at various jobs. He graduated with a Bachelor of Science degree in Agriculture with an emphasis in Agricultural Science in June, 1983.

Immediately after graduation, he moved to Brownsville, Tennessee to accept a position with Haywood County, Tennessee as a soil scientist assisting the USDA Soil Conservation Service in the Soil Survey of Haywood County, Tennessee. In search for a more permanent position, he accepted a soils specialist position in Salisbury, North Carolina with the North Carolina Department of Natural Resources in April, 1985 assisting the USDA Soil Conservation Service with the Soil Survey of Rowan County, North Carolina. After working cooperatively with the USDA Soil Conservation Service for nearly three years, he desired to work with the lead agency in the National Cooperative Soil Survey.

In February, 1986 he was offered a soil scientist position with the USDA Soil Conservation Service working on the Soil Survey of Bell and Harlan Counties, Kentucky. Near the completion of this soil survey, he was transferred to Albany, Kentucky to assist with the Soil Survey of Clinton and Cumberland Counties. After about 9 months at this position, he was selected for a Soil Survey Project Leader position in Burkesville, Kentucky. Upon completion of the Soil Survey of Cumberland County, Kentucky, he was transferred to Sevierville, Tennessee to a part-time position with the agreement to continue his education.

He began work on a Master of Science degree in Plant and Soil Science with an emphasis in Soil Genesis and Classification in August, 1991 and received his degree in August, 1993.

He is presently employed full-time by the USDA Soil Conservation Service in Sevierville, Tennessee and expects to be relocated to Athens, Tennessee to begin the update of the Soil Survey of McMinn County, Tennessee in October, 1993.