Soil formation in Indian Mounds built from different parent materials in northeast Iowa

by

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INTRODUCTION

Soil formation is dependent upon the variables of climate, vegetation, relief, parent material, and time. Man can also be a factor since some of his activities modify the soil to varying extents. Ideally, soil genesis studies should be conducted where most of these variables can be held constant and the effect of differences in one or two variables can be evaluated.

Such a situation exists at the Keller Mound Group (13AM69) and at a related site, 13AM243 located in extreme northeastern Iowa, south center of the NE¼ Section 2, T98N, R3W (Fig. 1). Here prehistoric earthworks (mounds) were built from three texturally different parent materials over a 350-year period beginning about 1600 years ago. Dating of mounds based on associated pottery types provides quantification of the time variable and climate, vegetation, and relief are constant. This study, then, focuses on the effect of parent material on genesis of soils developed in the mound fills. Objectives of this study include:

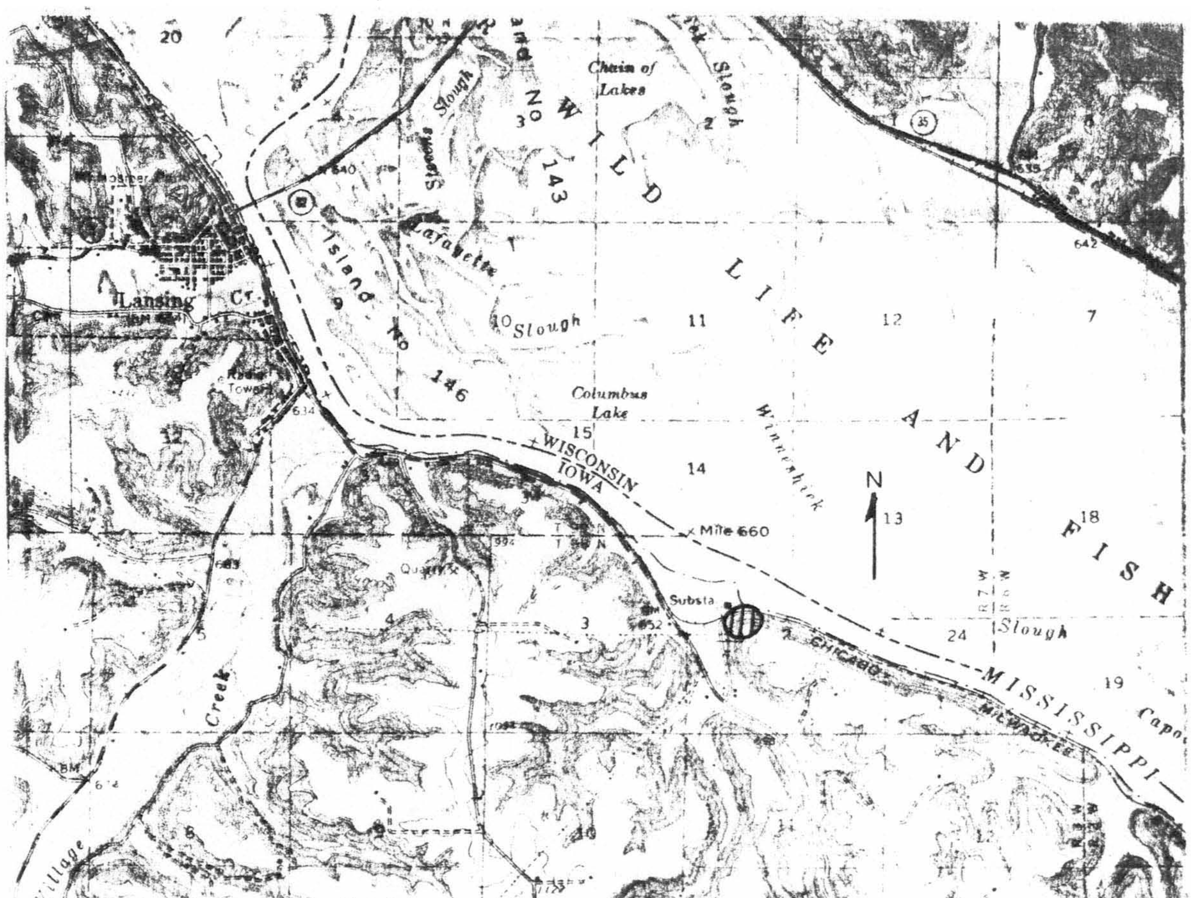
(1) Comparison of the morphology of soils developed on the mounds and adjacent undisturbed soils.

(2) Evaluation of selected physical and chemical characteristics of these soils.

(3) Determination of the mound construction sequence.

(4) Determination of the origin of the material used to build the mounds (mound fill).

(5) Evaluation of the extent of modification of the original soil cover at this site resulting from mound construction.



Study area

Figure 1. Topographic map showing location of study area. [From U.S.6.S Ferryville Quadrangle 1966. Scale 1:62500. Elevations are in feet above sea level]

LITERATURE REVIEW

Time as a soil forming factor

Time has been considered significant in the formation of soils since the recognition of soil as an independent natural body by Russian pedologists in the 1880's. The Academian Ruprecht (1886; cited in Dokuchaev 1883) studied the soils developed on burial mounds and the adjacent landscape in what is now the Ukraine U.S.S.R. During the 600 years since construction of the mounds, a "chernozem layer" had developed. This was compared to the chernozem layer formed in the adjacent older natural land surface. This study had several shortcomings as pointed out by Dokuchaev (1883, p. 374-375) but was valuable in that it stimulated interest in the effect of time on the development of certain morphologic properties of soils.

In a study of soils formed atop walls of the Staraya Ladoga Fortress in northwestern Russia, Dokuchaev (1883, p. 375-376) found that a soil about 6 inches thick had formed in Silurian limestone blocks during the 760 years since the fortress was constructed. He compared this soil to another formed on a natural exposure of similar rock, assumed to have been forming for a longer period of time, and concluded that they were very similar. This was cited as clear proof that "the process of the formation of vegetal-terrestrial soils is still in full swing" (Dokuchaev, 1883, p. 377).

Innumerable studies have focused on the effect of time in the genesis of soils. A distinction will be made here between studies involving a long time scale (>10^3 years) and those dealing with a shorter time scale (< 10^3 years). Both types of investigations are important in assessing the affect of time on soil formation, since some soil morphological properties appear to adjust to environmental conditions in less than 10^3 years while others take longer.

The term "chronosequence" has arisen as a by-product of Jenney's functional analytical approach to soil genesis. A chronosequence is "a sequence of related soils that differ, one from another, in certain properties primarily as a result of time as a soil forming factor" (Soil Science Society of America, 1965). Most of the studies of time as a soil forming factor have focused on chronosequences, using the comparative geographical technique (Rode, 1961) whereby ground soils of different age are arranged into a time sequence.

Salisbury (1925) studied vegetation succession and soils on a sandy dune complex in England. Soils studied ranged in age from 0 to 280 years based on historical maps showing the dunes at various times in the past. At first appreciably alkaline (pH 8.2), the dunes became neutral after the passage of around 100 years and appreciably acid (pH 6.4) after the passage of another century. Carbonates in the parent material, primarily in the form of shells, decreased rapidly at first. Their rate of loss slowed as the pH decreased to below neutral.

Successional vegetation changes on the dune complex also occurred as time passed. These changes were inferred to be in response to soil and hydrologic changes but the effect of vegetation changes on the development of the soils was not investigated.

Akimtzev (1932) conducted a study at the Kamenetz-Podolsk Fortress in the Ukraine, U.S.S.R., similar to the study conducted at the Staroya Lodoga Fortress by Dokuchaev. The former fortress was constructed from calcareous rocks and was abandoned in 1699 A.D. In the 231 years since this abandonment, soils 30 cm thick, which were very similar to soils nearby formed on Silurian limestone, were present atop the fortress walls.

Soils formed on recessional moraines of the Mendenhall Glacier near Juneau, Alaska, were studied by Chandler (1942). These moraines ranged in age from 15 to ≥ 1000 years. A comparison of the soils developed on these moraines led to the conclusion that Podzol profile formation is slight at the end of a 250-year period and requires at least 500 and more likely, 1000 years or more for the establishment of an equilibrium condition. He found that base saturation decreases markedly with time and that silt and clay formation increased with time at all depths.

A chronosequence developed on five hornblende/andesitic tuff-breccia sandy loam mudflows near Mt. Shasta, California, was studied by Crocker and Dickson (1953). Based on tree ring counts, these mudflows dated 27, 60, 205, 566, and 1,200 years before present (B.P.). The soils present had formed under a Ponderosa pine vegetation succession. They concluded that the development of the organic profile was the most important feature of the sequence since the time functions of a great many of the other soil properties appeared to be directly or indirectly related to it (Crocker and Dickson, 1953, p. 752).

A pronounced redistribution of carbon and nitrogen from forest floor to soil was noted in the 205 to 566 year period. Time functions of organic carbon and nitrogen reached a study state within 566 years.

Surfaces varying in age from 0 to 180 years in Glacier Bay, Alaska, were examined by Crocker and Major (1955). This chronosequence covered the main phases in vegetation succession from the initial colonization of a bare surface to establishment of a spruce (Picea stichensis) dominated forest.

Several systematic changes in soil properties were observed across the chronosequence including a decrease in bulk density from 1.5 g/cc in newly exposed material to .7 g/cc on the 180 year old surface and a teady increase in organic carbon content of the solum during the first 125 years of development. Total nitrogen content of the solum increased rapidly until alder was replaced by spruce and then dropped off. Soil pH decreased at an initial rapid rate, then leveled off after the alder thicket stage of succession ($\sim$75 years).

The authors concluded that the rate of development of several soil properties such as the nitrogen profile, reaction profile, etc. depends upon the pattern of plant distribution (Crocker and Major, 1955, p. 466). They further concluded that in the pioneer stages of succession as the rate of change in soil properties is dependent upon the actual micro-pattern of plant colorization, the accidents and factors of plant dispersal and establishment are highly significant (Crocker and Major, 1955).

A chronosequence extending from the present to about 200 years B.P. developed on recessional moraines of the Herbert and Mendenhall Glaciers in southeastern Alaska was investigated by Crocker and Dickson (1957).

They too recorded a decrease in bulk density with increasing age. This decrease was most apparent in the surface horizons and was attributed to the combined effects of root growth and decomposition, microbial activity, the building up of various epheremal residues and microbial by-products, the formation of organo-mineral complexes and the reorientation and rearrangement of mineral particles in such an environment when subjected to seasonal wetting and drying (Crocker and Dickson, 1957, p. 182).

Within 50 to 60 years soil pH decreased from initial values above neutral to 5.0 and less. This decrease was very rapid at first, then leveled off. Total nitrogen and organic carbon both increased with increasing age of the surface. After about 75 years of development, a thin A2 horizon was evident below the forest floor. No textural differentiation in the fine earth fraction attributable to soil forming factors was apparent in the field.

These observations and others led Crocker and Dickson to conclude that the pattern of soil development with time is dependent upon the particular array of ecosystem determining factors present (parent material, topography, climate, and biota) and their fluctuations (Crocker and Dickson, 1957, p. 181).

The time factor in the development of a chronosequence of dune soils spanning 350 years at South Haven Peninsula, Dorset, was investigated by Wilson (1960). An initial rapid decrease in soil pH was noted which slowed as time increased. Organic carbon content of the solum increased until an equilibrium was reached in about 250 years. High levels of carbonates were found to favor organic carbon accumulation. Wilson felt that in the early stages of succession, while $CaCO_3$ was still present, humic acids were important in enhancing the leaching capacity of rain-water percolating through the deposits.

In a study of the alluvial deposits and soils of the Otoe Bend area of the Missouri River near the southwest corner of Iowa, Ruhe et al. (1975) found that the organic carbon status of a soil's A horizon can develop in less than 30 years and can be comparable to the status of a soil more than a century old (Ruhe et al., 1975, p. 757). They also found that soils of the meader belt were leached to a depth of 18 to 48 inches. Younger soils of the channel belt of 1830 to 1890 were found to be calcareous to the surface.

Hallberg et al. (1978) studied soil development in leached loess spoil materials under prairie vegetation along a railroad cut in southeastern Iowa. The spoil material had been in place for about 100 years. In this amount of time a 25 to 30 cm A horizon had developed which met all the requirements of a mollic epipedon except for color. Comparison of this profile to an adjacent Tama Variant profile, no older than 14,000 years, showed a similar organic carbon distribution with lower absolute values in the recently developed profile.

Depletion and recycling of phosphorus were also evident in the soil formed in spoil. The distribution of available phosphorus (Bray 2) paralleled the organic carbon distribution to about 50 cm, being highest from 0 to 20 cm and decreasing gradually with depth.

The 100-year old soils also showed some translocation and accumulation of illuvial clay and fine silt. It should be noted that the spoil was originally leached and appeared to have been derived from the lower

B horizon of a former Tama soil which was originally high in clay and fine silt.

These studies of soil development concerned with chronosequences spanning <10^3 years show some general trends in early soil profile development. The first stage of soil profile development appears to be accumulation and decomposition of organic carbon at the surface. This is enhanced on parent materials with a high base status. As organic matter continues to accumulate and decompose, organic acids are transported downward along with CO_2-charged rainwater, and carbonates begin to move lower into the deposits. Carbonate leaching is rapid at first, then slows as fewer and fewer carbonates are present in the upper portion of the deposits. As leaching progresses, carbonates are returned to the surface by plant recycling. Soil pH also decreases with time of development in much the same way as carbonates.

Over periods of less than 1000 years, it appears that A1 horizons can become well developed, organic carbon and nitrogen profiles reach a dynamic equilibrium and pH approaches equilibrium. These properties are acquired by reversible, largely self-regulating processes and fall into Yaalon's (1971) easily altered category.

Incipient A2 horizons can begin to form in less than 1000 years under forest vegetation (Crocker and Dickson, 1957). Leaching of carbonates and a reaction below neutral seem to be prerequisites for development of an A2 horizon. If the parent material is leached throughout and contains large amounts of clay and fine silt, some translocation of the fine earth fraction can occur in less than 1000 years. To determine rates of development for other soil properties which develop more slowly than those just discussed, chronosequences spanning longer time periods must be studied.

Burgess and Drover (1953) studied Podzol development on a beach ridge complex spanning the last 4000 years in New South Wales, Australia. From the results of this study, they gave the following account of the development of a typical Podzol profile.

The original sand in which the soil began to form contained variable amounts of calcium carbonate in the form of shell debris. Rapid removal of the calcium carbonate ensued, and one-half the calcium carbonate was leached in 50 years and the remainder within 200 years. A concomitant drop in pH from 8.8 to 6.6 occurred and, as the pH fell below 6.6, leaching of iron began. After about 50 years, appreciable stratification had occurred in the developing profile. Iron was first removed from upper portions of the profile and transported iron was deposited in the form of a B horizon at 20-30 inches below the surface.

After about 100 years of leaching of iron, 300 years after pedogenesis ensued, a profile was developed in which a distinct A horizon was observed in the field. By about 1000 years the B horizon was quite distinct, but its lower boundary was very indistinct. Within 2000 years the profile had developed all the characteristics of an iron podzol with distinct A1, A2, and B horizons. As the age of the soil increased from this point, the B horizon moved progressively deeper into the profile.

This study also showed that after about 200 years all calcium carbonate had been leached from the upper solum. This figure agrees closely with others obtained on texturally dissimilar materials of varying carbonate content in the United States and Europe, for example Salisbury (1925) and Hissink (1938).

In a study of geomorphic surfaces in southwest Iowa Ruhe (1956) found differences among soils formed on some of these surfaces. Soils formed on the Late Wisconsin-Recent, Late Sangamon and Yarmouth-Sangamon surfaces were compared. These surfaces were exposed for 6800, 13,000 (minimum) and several hundred thousand years, respectively.

Thickness of the soil was found to increase with age. Sola thicknesses were as great as 80 inches on the Yarmouth-Sangamon surface. Thickness and clay content of the B horizon also increased with age.

Comparison of the average weathering ratios of the soils of the geomorphic surfaces showed progressive differences. An orderly arrangement among the weathering ratios (Wrh and Wrl)[1] had not been established in the Late Wisconsin-Recent soil indicating little mineralogic destruction. Late Sangamon soils did show an orderly arrangement indicating mineral destruction had occurred during their development. The most intensely weathered soil, the Yarmouth-Sangamon, also showed an orderly arrangement of weathering ratios. Values from comparable horizons were greater in older soils indicating that mineral weathering increases with increasing time of development.

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[1]Wrh is the heavy mineral weathering ratio and is determined as $\frac{\text{Zircon + Tourmadine}}{\text{Amphiboles and Pyroxenes}}$. Wrl is the light mineral weathering ratio and is determined as $\frac{\text{Quartz}}{\text{Feldspar}}$.

An 8000 year chronosequence and its associated vegetation succession on Southern Lake Michigan sand dunes were studied by Olson (1958). He found that the rate of carbonate loss was proportional to the carbonate left at any time resulting in an initial rapid loss which slowed considerably with time. Most of the free carbonates in the upper decimeter was gone within a few hundred years after stabilization. After 1000 years the leached zone extended to 2 meters.

Organic carbon, cation-exchange capacity and nitrogen were found to increase very rapidly, then level off with little net increase between 1000 and 8000 year old profiles. This further supports the rapidly adjusting character of these soil properties.

Leaching below the rooting zone predated A2 horizon development. Only dunes older than 1000 years had A2 horizons developed on them. Successional vegetation changes apparently caused some of the observed soil differences leading the authors to conclude that there was a large feedback between vegetation, microclimate, and soils in the dune complex.

An undated chronosequence, probably spanning several thousand years, on alluvial deposits in the Northwest Territories was studied by Wright et al. (1959). The parent materials were calcareous initially and organic matter accumulation ensued following deposition. As carbonates were decomposed and translocated, calcium was removed about twice as fast as magnesium. Loss of carbonates was followed by depletion of organic matter. While carbonates were being depleted, there was apparently a greater loss of silica relative to sesquioxides. As pH dropped below 6.4, marked eluviation of clay and accelerated leaching of iron and aluminum with respect to silica resulted in formation of a distinct A2 horizon underlain by a B horizon.

Soils formed on Indian Mounds of known age in northeastern Iowa were studied by Parsons (1960; 1962) and Parsons et al. (1962). These mounds were constructed 1000 to 2000 years ago from the leached upper horizons of a soil formed in loess. A1 horizons developed on the mounds were found to attain a maximum degree of expression in a period of 1000 years or less and remained relatively constant in composition with increasing age. Platy structure in the A2 horizon was evident in 1000 years and became moderately well-expressed in the mounds within 2500 years. Structural evidence within the A2 horizons suggested that the platy character of the horizon originated in its upper part in the first 1000 years and further development consisted of progressive downward movement of platy ped formation with increasing age.

Blocky structure did not form within 1000 years but after 2500 years blocky peds were well developed in the B horizon of a mound soil. Clay migration began to occur in the time span between 1000 and 2500 years. From these data Parsons concluded that soil formation under the conditions present proceeds rapidly during the first 1000 years and then continues at a diminishing rate or reaches an equilibrum with the environment.

A chronosequence of soils developed on basaltic mud flows in North Aukland, New Zealand, was studied by Walker (1965). The surfaces studied ranged from 5000 to 600,000 years in age. Vegetation and climatic changes had occurred during development of the sequence and some recent ash fall was incorporated into these soils. A progressive decrease in nitrogen content of the profiles occurred with time while the C/N ratio increased from 12 to 20.

Organic phosphorus content of the profiles decreased markedly with time while inorganic phosphorus increased steadily with time. It was not possible to determine the absolute losses of phosphorus from these profiles but high values of fixed phosphorus in the oldest soils, their known capacity for P fixation and extreme P deficiency suggest that fixation of phosphorus in very insoluble forms had taken precedence over loss of P by leaching.

A study of two Wisconsin Effigy Mound sites and associated village sites allowed Hurley (1970; 1971) to make observations on rates of soil profile development in sandy parent materials based on C-14 dates. He found that color and textural B horizons formed in 1000 years but that structural B horizons required more than 1000 years to develop. Platy structure in A2 horizons was evident after 1000 years. The formation of medium to coarse platy structure was aided by the fragic character of the A2X horizons (Hurley, 1971, p. 71).

The maximum degree of expression of A11 and A12 horizons within 1000 years under forest vegetation observed in northeast Iowa by Parsons (1960) was supported in Hurley's study. Soils developed at the Bigelow site indicated that this horizontation can occur in a minimum range of 530 to 870 years and with aeolian activity, in less than 100 years. A1 horizons formed in 1200 to 1300 years under grass vegetation.

Syers and Walker (1969) and Syers et al. (1970) studied a 10,000 year chronosequence of soils developed on wind-blown sand in New Zealand. They found that after initial rapid rates of accumulation of C, N and S during the first 1000 years, subsequent gains were slower, but that steady states for these elements had not been reached after 10,000 years (Syers et al., 1970).

Total phosphorus showed a very rapid initial increase and then a straight line loss between 500 and 10,000 years. Organic P remained at relatively low levels due to slow rates of formation coupled with rapid mineralization (Syers and Walker, 1969). They concluded that the loss of P by leaching was a consequence of the low phosphate retention capacity of these slightly weathered soils.

Properties of soils developed on several geomorphic surfaces of different age in the Willamette Valley, Oregon, showed progressive soil changes with time (Parsons et al., 1970). Under conditions present in this valley, argillic horizons took between 555 and 5,250 years to develop. The Ca/Mg ratio decreased with increasing age of the soil as did the CEC, indicating increased weathering and leaching with time.

Entisols and weakly developed Mollisols were found on the youngest surface, more well-developed Mollisols with clay films in the B horizon on progressively older surfaces, Alfisols on a probable Late Pleistocene surface (Calapooyia) and Ultisols on the oldest surface (Middle Pleistocene). These authors considered that it was not the total time a soil material had been exposed to weathering but the time a particular process had been active that warranted consideration.

Nørnberg (1977) studied profile development in sands of varying age in Verdsyssel, Denmark. Soils were placed into 4 age groups--300, 4000, 10,000 and 13,000 years--on the basis of the landscape unit on which they were formed. Organic matter accumulation was the main acquired feature after 300 years. After 4000 years a well-developed podzol profile was present but significant translocation of iron did not occur until 10,000 years had passed. Depth to the A/B interface decreased from 22 cm in the 300-year old soils to 10 cm in the 13,000-year old soils.

A long chronosequence extending from 35,000 to 3,300,000 years on the Coastal Plain of North Carolina was investigated by Daniels et al. (1978). They found that the great similarity of sediments, long duration of weathering, and dependence of soil morphology upon its internal environment resulted in the same or similar soil occurring on more than one surface. Some soil properties were found to be time related such as the decreasing aerial extent of plinthite and amount of gibbsite in Paleuldults with decreasing time of weathering. Some soils on the oldest surface were 7 to 9 meters thick while those on the youngest surface were generally <1.2 m thick.

Berg (1978, 1979) studied a chronosequence extending from 0 to 3500 years on the Illinois Beach Ridge complex along Lake Michigan in extreme northeastern Illinois. Based on geological evidence the beach-ridge complex and its associated soils was divided into six age groups:

Group A	-0 to 100 years old
Group B	100 to 300 years old
Group C	300 to 700 years old
Group D	700 to 1100 years old
Group E	1100 to 2300 years old
Group F	2300 to 3500 years old

He found that well-drained soils in the six age groups had the following characteristics: (1) Group A. Accumulation of organic matter and development of 3.5 cm thick A1 horizons. Soil pH began to decrease following organic matter buildup and initiation of carbonate leaching. (2) Group B. Development of an incipient A2 horizon ranging in thickness from 10 to 30 cm and translocation of clays into an incipient B horizon in the lower solum above a zone containing carbonates. (3) Group C. Attainment of the highest average percentage of clay in B horizons. (4) Group D. A1 horizons attain a maximum thickness of about 18 cm and minimum pH of about 6.2. (5) Group E. B horizons become thicker and manganese is preferentially precipitated in zones of minimum clay and iron. (6) Group F. The oldest soils of the complex had thicker A2 horizons, evidence of distinct free iron maxima associated with clay horizons and the first visible signs of incipient lamallae observed in the field.

The preceding chronosequences spanning $>10^3$ years show some general worldwide trends in soil profile development. A1 horizons maintain an equilibrium or gradually degrade over long time spans. Degradation may be a result of a decrease in vegetation lushness as the nutrient status of soil becomes less favorable over long time spans.

A2 horizons begin to develop after 1000 years and become well-expressed in about 2500 years under forest vegetation. Ruhe's (1956) data indicate a downward movement of the A2 horizon with time whereas Nørnberg's study suggests a decrease in the thickness of the A2 horizon after about 300 years. All authors agree that leaching below the rooting zone is a prerequisite for A2 horizon development.

Textural B horizons can begin to form after a few hundred years provided the parent material is leached. Structural B horizons seem to take between 1000 and 2500 years to develop. Clay content and thickness of the B horizon increase with increased age.

Little mineral weathering is evident in soils formed during the last 10,000 years. Soils exposed longer periods of time usually show evidence of mineral destruction and weathering ratios become larger with increased time of exposure.

These studies suffer from rather serious drawbacks which may explain some of the apparent contradictory conclusions. The major drawback is that most chronosequences spanning greater than 10,000 years (the approximate duration of the Holocene) have developed under different climates in the past. It is highly probable that drastic vegetation changes have occurred during this time also. Our general lack of precise knowledge about the magnitude and direction of these changes decreases the reliability of these sequences for giving information concerning the time factor in soil development. This drawback is inherent to the comparative geographical method of environmental investigation (Rode, 1961).

Another problem is that after a fairly long period of weathering, dependence of soil morphology upon its internal environment can become more important than the time factor, resulting in similar soils with great age differences.

Vreeken (1975) has distinguished between four principal kinds of chronosequences of soils. He uses isochrony and time-transgression of incipience and/or cessation of soil development and the presence or absence of partial overlap in the history of the soils as criteria for classifying chronosequences.

All the chronosequences previously discussed, except the one reported by Ruhe (1956), would be classified as post-incisive ground soil chronosequences by Vreeken. These are arrays of soils which began forming at different times in the past and are still exposed (Vreeken, 1975, p. 380). Ruhe's chronosequence is a time-transgressive chronosequence without historical overlap.

Discussions of time as a soil forming factor hinge on the concept of soil genesis held by various authors. Soil properties appear to reach equilibrium states at varying rates depending upon the combined effect of soil forming processes, and similar soils can develop through different pathways. This leads us to a consideration of what soils are conceived to be and how they develop.

Concept of soil

Through the ages the concept of "soil" has undergone drastic changes. When people first began to distinguish what we call soil today from the general surroundings will probably never be known. Simonson argues that so long as hunting and gathering was the mode of subsistence, mankind had no need for thought about the nature of soil except as physical support (Simonson, 1968, p. 2). It will be argued in a later section that this may not necessarily be the case among hunter-gatherers in northeastern Iowa and that, indeed, a concept of soil played a significant part in uniting the physical and cultural environments of these people.

The earliest written concept of soil may be that of Empedocles from about 400 B.C. (cited in Simonson, 1968). He held that earth or soil was one of the four basic components of all matter, the others being fire, water and air. This concept of basic elements (not in the chemical state) from which all else was constructed persisted for quite a long time. As late as 1862, Fallou (quoted in Simonson, 1968, p. 10) wrote "the basic forces, which have acted during the present and past ages to destroy and modify the massive rind of our planet, are air, fire, and water. These three elements have, since ancient times, been in conflict with the fourth, the earth."

In the 1820's and 1830's some men such as Eaton and Beck (1820), and Hitchcock (1838) began to view soils as disintegrated rock with additions of certain plant and animal substances. During and prior to this time, soil was also regarded as a medium for plant growth. By the mid 1800's many people including Hilgard held two concepts of soil simultaneously; a medium for plant growth and weathered rock. The former view of soil, as a medium for plant growth, is held by many today, since the greatest interest in soil worldwide is centered on crop production.

In the 1870's and 1880's a new concept of soil began to develop in Russia. V. V. Dokuchaev and his followers began to recognize soils as organized natural bodies worthy of scientific study. They recognized the operation of a number of factors in soil genesis and called attention to the significance of the interaction among these factors in producing observed soils (Simonson, 1968). This was a revolutionary concept which was to have a very large impact on pedology and soil classification in the next century.

The Russian concepts did not have much impact on science in the United States until the 1920's when C. F. Marbut introduced concepts outlined in K. D. Glinka's book, "Die Typen der Bodenbildung". Because of Marbut's writings and field studies, the earlier Russian concept that the horizons within a soil profile were genetically related and had evolved together was widely accepted in the U.S. by 1930 (Simonson, 1968). Parent material's influence on soil genesis was deemphasized while the role of organisms, climate, topography, and time received more emphasis.

Since Dokuchaev's time soil had been considered to develop or evolve under the influence of soil forming factors. Soils were considered to evolve through successive stages from youth to maturity, a belief, no doubt influenced by W. M. Davis' (1889) theories of landscape development. Each stage was marked by the development of certain morphological properties and upon reaching the penultimate stage, no further changes in morphology would occur so long as the factors of soil formation remained constant.

In the early 1940's, Hans Jenny (1941) developed equations to describe the relationship between a soil property and the "state factors": environmental climate, "species germules" of organisms (not their actual growth), topography (including hydrologic features), parent material, time, and additional unspecified factors (Buol et al., 1973). The classic state factor equation developed was:

$$S = f(cl, o, r, p, t, \cdots)$$

which defined the soil system. Problems arose when trying to define the boundaries of this system. The soil system was viewed as an open system with influxes and outfluxes of energy and matter (Jenny, 1961). By measuring these fluxes using lysimers and biotrons over limited periods of time, it was considered possible to substitute numerical values into the state factor equations and solve them. To date this has not been entirely successful due to technical difficulties.

Nikiforoff began to view soils as thermodynamic systems during the 1940's. He played down the importance of time in soil development and contended that morphological characteristics alone could not serve as criteria of soil maturity. He outlined his concept of soil maturity in an article in 1942 (Nikiforoff, 1942, p. 850):

> . . . we assume that the soil maturity indicates the steady state of the soil system which is obtained by a precise adjustment of the parent material to the environment and coordination of all factors comprising the soil system. Such an adjustment is not necessarily accompanied by a striking development of the profile or any morphological characteristic. Any soil, no matter how dull and inconspicuous its profile, can be adjusted to its particular environment and thus be just as mature as any other soil.

He pointed out a major drawback of the state factor approach to soil genesis outlined by Jenny (1941) and still widely used today. Soil and its environment, he argued, cannot be viewed as independent phenomena since most of factors influencing soil formation are in turn affected by changes within the soil. He proposed viewing soils in terms of balances between synthesis and decomposition, accumulation, and leaching.

Accumulation is possible only if production exceeds losses. Accumulation does not go on unchecked indefinitely and the rate of accumulation gradually approaches zero as soil maturity is approached. Upon reaching maturity no further accumulation occurs and the rate of production equals the rate of loss. The content of the accumulated material remains relatively constant as long as no change in the environment disturbs the equilibrium. Continuous replacement of lost material by newly-synthesized material indicates that the accumulated materials are not static but undergo continuous renovation while maintaining their overall form (Nikiforoff, 1942, p. 852).

Maturity, then, is a steady state of a dynamic soil system. This is not a static state, but one in which the precise coordination of functions of various parts of the soil system are maintained in spite of the general shift of the system through various stages of evolution (Nikiforoff, 1942, p. 865). This steady state of the existing systems is not real but only apparent, because of the slowness of the evolution of these systems (Nikiforoff, 1942, p. 859). In a later article Nikiforoff contends that the tendency toward equilibrium is characteristic of all thermodynamic systems and is an inevitable consequence of the law of mass action (Nikiforoff, 1959, p. 188). Pedogenic processes are seen as only a short segment of the broader geochemical cycles of the earth.

Simonson outlined a generalized theory of soil genesis in a 1959 article. He considered that horizon differentiation in soils occurs due to four kinds of changes: additions, removals, transfers, and transformations. Emphasis was placed upon the operation of these processes in combinations. Some combinations of processes are propedanisotrophic (promote horizon differentiation) while others are propedisotrophic (retard or destroy horizon differentiation (Hole, 1961). It was suggested that shifts in balance among combinations of processes were responsible for soil differences rather than the operation of markedly different processes. The relative importance of the various processes differs from one soil to another, from one horizon to another within a single soil and with changes in environment, within a single horizon of a given soil.

Simonson's model has been questioned recently by Yaalon (1971) who feels that it is inadequate when attempting to determine how the soil system will develop with time. Yaalon feels that on the basis of the concepts of equilibrium and dynamics there are three groups of processes and derived properties (Yaalon, 1971, p. 30): (1) reversible largely self-regulating processes, (2) processes or properties near equilibrium or in a state of metastability, and (3) irreversible, self-terminating reactions and derived properties. He further suggests that soil-forming processes can be viewed as belonging to one of two large groups each with two subgroups: (1) those approaching a state of dynamic equilibrium at (a) a fast or (b) a slower initial rate, and (2) the irreversible or self-terminating processes, where balance of input and output is not maintained with (c) gains greater than losses or (d) gains less than losses.

When determining whether the steady-state concept is applicable the size or dimension of the system is very significant. While an isolated pedon or feature may not attain a steady state of dynamic equilibrium, it may constitute part of a larger system (such as a catena) which more closely approximates a steady state. In essence then, we are dealing with a system which is dynamic vertically (the soil profile) and horizontally (the soil sequence), adjusting to and influencing its environment three dimensionally.

Soil-geomorphic systems

During the past two decades pedologists have begun to realize the importance of geomorphic processes of the past and present in influencing development of soils on the landscape. The pedologist studies soils in the field and laboratory to understand how certain chemical and morphological characteristics came to be and also to determine the importance and relative stability of these characteristics. A geomorphic study of the landscape can provide much information about several natural variables contributing to soil genesis. The geomorphic data on process of development of a surface, its age and past climatic and vegetational regimes provide far more control than is available in the properties of the soil and eliminates assumptions about the meaning of direct observations (Daniels et al., 1971).

Work by R. V. Ruhe and associates during the 1950's, 60's and 70's has shown that markedly different soils occur on some of the geomorphic surfaces in the midwest (Ruhe, 1956; Ruhe et al., 1967; Ruhe and Olson, 1978). These differences can be related to different lengths of weathering on the various surfaces and to changes in the composition of the parent materials through time. These studies have also shown that in some cases, similar soils can be found on different geomorphic surfaces

(Ruhe et al., 1968; Fenton, 1966; Miller, 1974). A close examination of these soils usually shows that those on a given geomorphic surface are more similar than those from different geomorphic surfaces (Daniels and Jordan, 1966).

Outside the midwest, the relationship between soil properties and geomorphic surfaces has been documented by several studies. Parsons et al. (1970) have shown that certain chemical and morphological properties of soils developed in the Willamette Valley, Oregon, are related to the age of the geomorphic surface on which they are located. In general, these soils show increasing development with increasing age of the surface on which they develop. Entisols and minimally developed Mollisols dominate a late Holocene surface while Ultisols dominate a Middle Pleistocene surface. A similar relationship between present soils and age of geomorphic surfaces has been demonstrated in the Upper Amazon Basin of Peru by Tyler et al. (1978).

In some cases, environmental conditions created by geomorphic processes, such as steam dissection or alluviation, are more important in determining soil properties than a direct age sequence (Daniels et al., 1971). Daniels et al. (1971, 1978) found that this was the case in explaining the distribution of plinthitic soils on the Coastal Plain of North Carolina.

Riecken and Poetsch (1960) showed that the path of genesis of individual soil horizons was of a different nature in cumulic versus non-cumulic soil systems in Iowa. The cumulic system had a greater depth distribution of nitrogen and base saturation and was finer textured than the equivalent non-cumulic system.

Norton and Franzmeier (1978) found that soil landscape position influenced fragipan formation in southwestern Indiana. The observed fragipans were formed by processes associated with the modern landscape, but their formation was influenced by pre-Peoria soils or weathering zones.

Ruhe and Walker (1968) and Walker and Ruhe (1968) found that systematic changes in soil properties across a toposequence could be related to changes in the geomorphic processes down a hillslope profile. This allowed them to formulate generalized hillslope soil formation models for open and closed systems. Working in northeastern Iowa, Kleiss (1970) found that many properties of the surface soils studied were inherited from the sedimentary nature of the hillslope surficial sediment. These investigations showed that on the same geomorphic surface differences in the magnitude and intensity of geomorphic processes along a hillslope profile resulted in differences of the modern soils which could be related to their topographic position.

Realization of the existence of relationships between geomorphology and soil genesis has prompted the formulation of soil-landscape models. Two major types of models have arisen: isomorphic models in which each variable of the soil-landscape system is an element in the model and homomorphic models in which several components of the system are grouped to form a single element in the model. Isomorphic models are essentially scale models or replicas (Carney, 1975) and are as complex as the system being modeled. Implementation of isomorphic models in soil genesis presents virtually insurmountable problems due to the complexity of the soil system (Huggett, 1975). An example of an attempt to use this type of modeling for the soil and slope systems was presented by Kirkby (1977). In order to model the slope and soil profiles, he found it necessary to reduce the number of variables describing the soil profile to those which were most relevant to the slope as a whole, a problem which was not solved very satisfactorially from the slope point of view (Kirkby, 1977, p. 203).

Homorphic models, on the other hand, are ones in which only the gross similarities, and not all the details of the thing being modeled, are replicated (Carney, 1975, p. 10). Modeling of this sort allows investigation at the level of the whole soil system (Huggett, 1975). This sort of modeling has been prevalent among geomorphologists when dealing with landscape evolution (King, 1957; Wood, 1942; Hack, 1960; Ruhe et al., 1967). Modeling of this sort has also been employed by pedologists (Arnold, 1965; Davidson, 1977; Huggett, 1975) and appears, at this time, to provide the best avenue for understanding soil genesis and similating soil systems.

Why geomorphology and pedology have operated relatively independently of each other while studying the landscape and its soils is not an easy question to answer. In many cases evolution of the landscape is significantly influenced by the soils on the landscape and their response to pedogenic and geomorphic processes acting on the land surface. Soils, on the other hand, are a product of the past and present processes acting on them and owe many of their characteristics to their geomorphic position on the landscape. Only through a simultaneous study of soils and geomorphology can we hope to interpret the evolution of a given landscape and thereby begin to understand the relationships between processes and responses in producing the soils and landscapes of today.

History and function of the Indian Mounds

Artifical earthen mounds have been one of the most widely examined yet poorly understood archaeological subjects in eastern North America. They appear to have attracted the attention of the New England colonists and by the time of Thomas Jefferson thousands had been examined, measured and excavated (Silverberg, 1968). These earthworks and the burials and grave offerings often found within them were attributed to Old World groups such as the Egyptians, Phoenicians, Welsh, the Ten Lost Tribes of Israel, among others (Mallam, 1976a). The "Mound Builders", whoever they might be, were assumed to be a superior civilization that had vanished from North America, possibly having been exterminated by American Indians found inhabiting the continent when the first colonists arrived (Silverberg, 1968; Lass, 1978). The "Mound Builder" myth dominated American thought about the past until the very late 1800's and attained its peak of popular support about 1880 (Lass, 1978).

The "Mound Builder" theory was formulated and persisted for several reasons. First, there was no well-developed true science in North American archaeology. Without a sound base of objective, scientific inquiry, the first excavators of the mounds could only speculate about the things they found (Mallam, 1976a). The American Indians were rejected as the builders since the contemporary Indians seemed to the whites, too primitive to have undertaken such tasks. The then dominant idea of always "progressive" and unilineal cultural evolution also prevented consideration of the Indian's ancestors as mound builders (Silverberg, 1968). By making the "Mound Builders" a "glorious" civilization destroyed by the Indians, the harassment of Indians carried on by whites at the time was rationalized as a campaign against "savages" and "destroyers of civilization" (Mallam, 1976a; Silverberg, 1968; Lass, 1978). The "Mound Builder" myth also created an instant heritage for American settlers (Silverberg, 1968). The American settlers lacked the deep past heritage that they had had in Europe and by attributing the mounds to Old World civilizations, placed America in time and provided a concrete link to the past (Lass, 1978).

In 1881 Congress allocated funds to John Wesley Powell, Director of the Smithsonian's Bureau of Ethnology, to investigate the earthworks. Powell created the Division of Mound Exploration with Cyris Thomas as its head. Thomas and his associates made a close, careful and somewhat systematic examination of mounds and other ancient monuments which were believed to be typical or representative of the area east of the Rocky Mountains. Thomas' final report, published in 1894, shattered the "Mound Builder" theory by demonstrating that (1) many contemporary Indian artifacts were like those found in mounds, (2) mound building had been practiced by some American Indians into historic times, and (3) mounds had been constructed throughout a timespan of hundreds or thousands of years and not just during the brief occupation of a "lost civilization"

(Lass, 1978).

Subsequent archaeological research has focused on building a cultural chronology for the mounds. It is now known that earthworks were constructed from Archaic into Historic times (ca. 4000-350 B.P.) by several distinct cultural groups.

The majority of the mound building activity occurred during the Woodland Period (ca. 3000-900 B.P.). Major earthworks and large mound groups were built by Adena and Hopewell peoples in the Ohio and Illinois River valleys where these sedentary populations apparently occupied villages for considerable periods of time, beginning about 3000 B.P. and fluorescing from 2250 to 1750 B.P. Materials from Hopewell Mounds constructed between 2250 and 1750 B.P. indicate that Hopewellians had an extensive trade network stretching from the Rocky Mountains to the Gulf Coast (Griffin, 1952). Trade was evidently one of the main factors uniting the widespread populations which exhibited Hopewell culture traits.

Cultures throughout the Midwest were influenced by the Hopewell centers. In Wisconsin, northeastern Iowa, northwestern Illinois and southeastern Minnesota the Effigy Mound Tradition began to develop about 700 A.D. (Benn, 1976). These people constructed earthworks in effigy, linear and conical forms until about 1300 A.D. The mounds investigated in this study appear to have been built immediately prior to this period and the remainder of this discussion will focus on this period.

The Effigy Mound manifestation is defined as both a distinct prehistoric culture and tradition[2] found primarily in a four state area of the Upper Mississippi River region (Fig. 2) (Mallam, 1976b). It is characterized by effigy and non-effigy shaped mounds, camp, rockshelter, cave, and village sites (Hurley, 1970). The effigy forms, after which the manifestation is named, are low-relief earthen mounds representing various presumed animal and other indeterminate forms. The effigies are frequently associated with other mound forms--conical (domed), linear (elongated), and compound (variable). The mounds investigated in this study are all conical forms; two effigies present in the Keller Group were not investigated (Fig. 3).

Many studies have focused on the Effigy Mound Tradition with emphasis on determining the cultural and temporal relationship of Effigy Mound to Hopewell. Several investigators viewed the two as contemporaneous (Cole, 1943; Bennett, 1945, 1952; Beaubien, 1953), while others saw no relationship between the two (Rowe, 1956; Wittry, 1959). Studies conducted by the University of Wisconsin in the mid to late 1960's partially resolved Effigy Mound's temporal placement by interpreting it as a tradition extending from 300 A.D. to 1642 A.D. (Baerreis, 1966; Hurley, 1970). Benn (1976) suggests that a time range from 700 A.D. to 1300 A.D. is more in line with the present radiocarbon dates.

Hurley's study and a subsequent study by Storck (1972) also

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[2]A culture is defined as "the learned patterns of thought and behavior characteristic of a population or society" (Harris, 1971, p. 629). Tradition, on the other hand, is a term which "implies persistence of a culture trait or complex of traits over a significant spatial range and in significant time depth" (Jennings, 1968, p. 22).

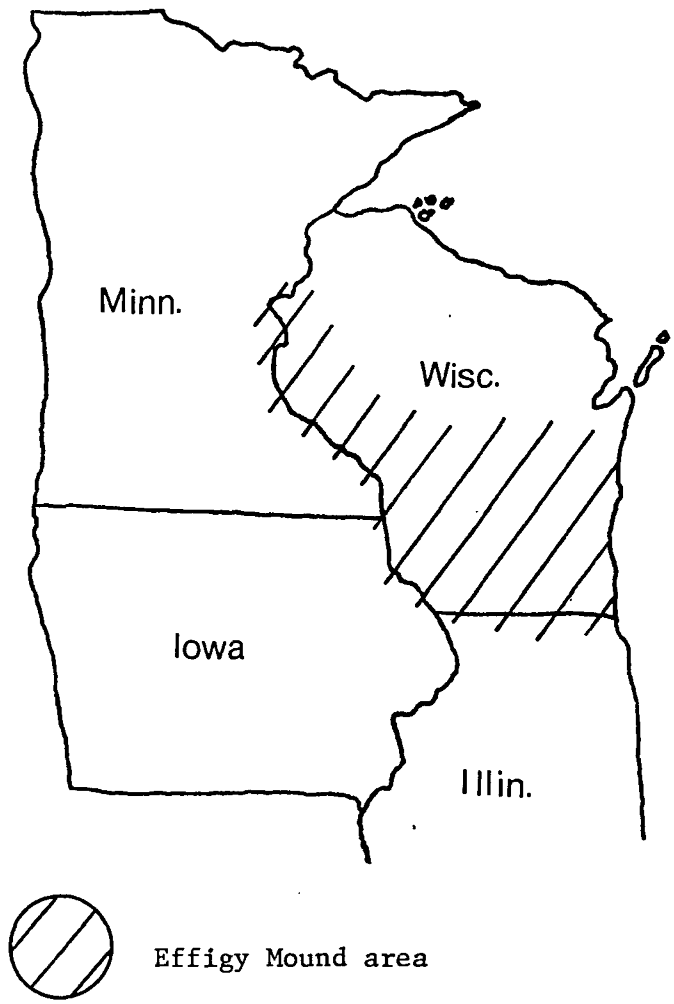


Figure 2. Distribution of the Effigy Mound Culture. [From Mallam (1976b)]

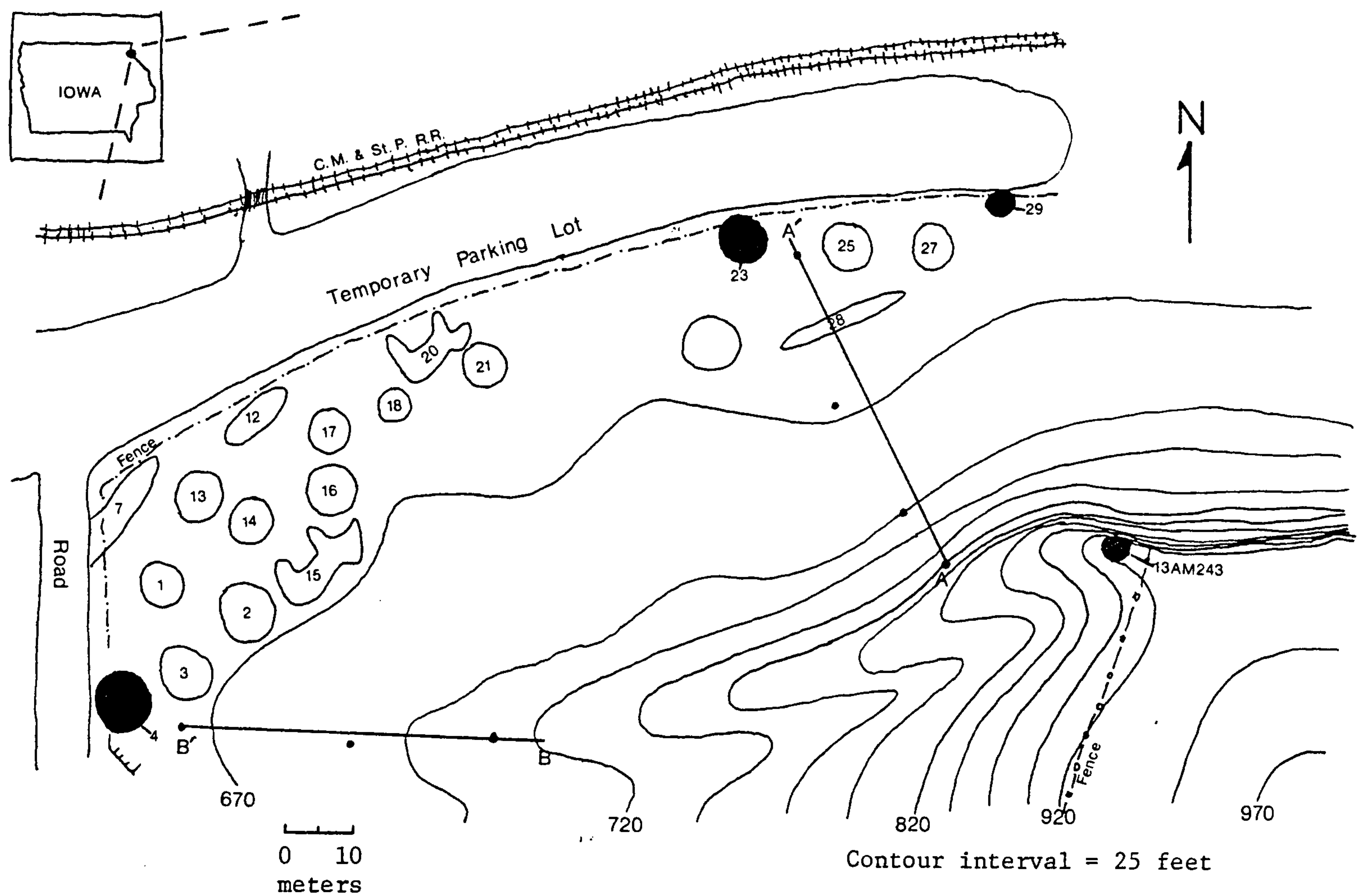


Figure 3. Map of Keller Mound Group and 13AM243. [Solid mounds were investigated in this study. Transects 1 (A-A') and 2 (B-B') are shown in Figures 7 and 8. Dots along transects are sampled profiles.]

attempted to define Effigy Mound subsistence-settlement patterns. After examining several mound and associated village sites in Wisconsin, Hurley (1970) concluded that the Effigy Mound settlement pattern was centered on Central-Based Wandering and Semi-Sedentary Village community types (Meggers, 1956). After excavating a rockshelter in Wisconsin, Storck (1972) compared this data with that obtained from other rock-shelters in the state. This comparison suggested to him that Effigy Mound subsistence-settlement patterns were characterized by a broad Archaic-like multifocus exploitation with seasonal occupation of rock-shelters. He proposed a generalized subsistence-settlement model (Storck, 1972, p. 411-12):

> The subsistence was probably largely if not entirely based on hunting, gathering, and fishing. . . . There is some evidence that family groups probably congregated into larger social groups for ceremonial and burial activities. . . . The majority of mound groups were probably constructed by small groups of related families and the Effigy Mound population may have been fairly dispersed throughout most of the year.

The differences between the interpretations of Hurley and Storck appear to have arisen because each of these authors was only looking at one aspect of the Effigy Mound subsistence-settlement system.

Since the second decade of the 20th century all Effigy Mound studies have been based on cultural-historical models, while little attention has been devoted to cultural ecology (Mallam, 1976b). In recent years there has been a shift in archaeology from cultural-historical models to models attempting to explain cultural dynamics. The main feature of this shift is the development of deductive models with derived hypotheses which can be tested against independency derived data (Binford, 1972; Binford and

Binford, 1968; Clarke, 1968; Watson et al., 1971; Redman, 1973; Plog, 1974). Recently Mallam (1976b, p. 34) has formulated an interpretive model for Iowa Effigy Mound emphasizing process:

> . . . the Iowa Effigy Mound manifestation was one part of a broad, generalized Upper Mississippi area cultural system. The mound complexes of this cultural system served as integrative mechanisms herein defined as institutions with consequences for combining social units into unified and supportive entities. As integrative mechanisms (Plog, 1974, p. 58, 65-66) the mound complexes cross-cut several cultural-historical sequences and articulated the activities of many hunting and gathering societies exploiting the northeastern Iowa ecotone on a seasonal and cyclical basis.

The unique character of the Driftless Area environment was important for the development and maintenance of this cultural system. The mosaic character of the ecotone resulted in environmental diversity which offered a broader selection of subsistence-settlement alternatives to hunter-gatherers than was available in the prairies to the west or the forests to the north and east. Through time a subsistence-settlement pattern similar to Primary Forest Efficiency (Caldwell, 1958) appears to have developed. Caldwell's concept refers to an Archaic tradition of eastern North America in which a hunting and gathering pattern involved seasonal and cyclical exploitation of natural resources contained in varying ecosystems.

Throughout the year, natural resources of interest to hunter-gatherers were abundant in northeastern Iowa, especially during certain seasons. Smith (1974, p. 291) gives an indication of the high biomass of the Mississippi floodplain in his discussion of the fauna. He states that this area "contains a great diversity of microenvironmental zones within relatively small geographical areas, with a resulting maximization of edge or interface areas between microenvironmental zones". By harvesting these resources at their highest productive levels, hunter-gatherers in this region may have developed an exploitation method similar to Intensive Harvest Collecting (Struever, 1968, p. 305):

> Intensive Harvest Collecting denotes an adaption centering on the exploitation of selected, high-yielding natural food resources characteristic of certain biomes that have sharply restricted geographic distribution within the woodland of the northeastern United States. Two factors are seen as essential to the biomes in which Intensive Harvest Collecting is feasible: (1) natural food products must occur in large concentrated populations and lend themselves to harvesting (that is, they can be collected in quantity with small labor output); (2) the plant and animal populations from which these products are derived must be regularly renewed.

With the establishment of a form of Primary Forest Efficiency in northeastern Iowa a complex cultural system involving many groups of hunter-gatherers evolved. Their subsistence-settlement systems were quite fluid and characterized by coalescence and dispersal of social units in response to seasonal and cyclical fluctuations in the availability and density of natural food resources in close proximity to the Mississippi trench. The basic social unit of the nuclear family probably operated relatively independently of other groups throughout most of the year (Mallam, 1976b, p. 36). Family groups may have joined into larger social groupings when certain plants and animals occurred in abundance during the spring, summer, and fall.

During these seasons, food resources were usually most concentrated along the Mississippi trench. The aquatic communities provided abundant faunal (fish, turtles, freshwater mussels, etc.) and vegetal food resources (arrowroot, cattails, wild rice, etc.) as well as attracting large numbers of waterfowl during annual migration. The oak-hickory associations along the bluffline provided acrons and hickory nuts, May apples, and other resources while the prairie openings and talus slopes contained large numbers of fruit-bearing plants. The concentration of fauna such as deer, elk, squirrel, etc. also varied seasonally with the availability of foods they preferred.

In essence, the ecotone contained abundant natural resources but these were concentrated in diverse microenvironmental zones whose productivity varied seasonally and cyclically. Alone, none of these zones were adequate to support a large population of hunter-gatherers but when exploited systematically on a seasonal and cyclical basis, they could have provided adequate resources to support many human communities.

During the winter the Mississippi trench went into a state of dormancy in relation to resources of interest to hunter-gatherers and, due to channeling of northerly winds down the trench, became rather inhospitable to these people. Megafauna such as deer, elk, and bison also found the trench less attractive and moved up into tributary valleys which afforded greater protection from the elements. At this time larger social groups fragmented into nuclear families and dispersed into the protection of the tributary valleys (Mallam, 1976b, p. 38). There they carried out winter subsistence activities on a reduced scale until the return of spring facilitated movement back into the Mississippi trench and coalescence into larger social groupings.

Building the mounds served to integrate and relieve tension bewteen the social groups participating in this seasonal exploitation of the ecotone (Mallam, 1976b, p. 38).

> In this subsistence-settlement pattern, intensive hunting and gathering pressure was placed seasonally on the resources of an extremely prolific but geographically limited region. Seasonal movements of dispersed social groups onto the Mississippi trench at peak productive periods would have created competition and conflict over access to the natural resources. These problems may have been resolved through construction of mound complexes which served in part as territorial demarcators for hunting and gathering groups.
>
> Each complex signified the territory of a number of loosely related family units which met seasonally and merged into a larger corporate entity. In this sense the mound complexes functioned as multipurpose institutions to coordinate and integrate the social, religious, economic, and political needs of the larger social groups. In addition to the other associated mounds, each complex contained one or more effigy forms constructed collectively by the combined family units. While many of the complexes possess similar effigy forms, variation among these forms at different complexes indicates their construction by distinct social groups.

Evidence from northeast Iowa suggests that the primary purpose of the mounds was not funerary, but interment of individuals or portions of individuals was one of the cultural activities carried out at the mound complex (Benn et al., 1978; Mallam, 1976b). Whenever these family groups began to move toward their mound complex with the intent of constructing a mound, they would gather up the remains of individuals who had died since their last visit to the mound complex. At the mound complex, the participation of the assembled family units in the mound construction ceremonies enhanced and reinforced the larger social group's solidarity, identity, and cohesiveness (Mallam, 1976b, p. 38).

Construction of the separate mound complexes would have mitigated tension and promoted cooperation between the family units exploiting a given territory but conflict could have arisen at a higher level between social groups of the separate mound complexes (Mallam, 1976b, p. 39). In order to relieve this tension a supracomplex of social organization may have evolved which was facilitated through a regional gathering of the distinct social groups at a specified location. Mallam (1976b) feels that the Harpers Ferry Great Mound Group (13AM79) may have served as a focus for such gatherings. This site would have been ideal for large gatherings since it is located on a very broad terrace of the Mississippi River approximately midway between the northern and southern boundaries of the Iowa Effigy Mound manifestation. This gathering probably only occurred every decade or so and was witnessed by a large coalescence of hunter-gatherers and mound construction.

Sociocultural integration at this level, involving members of the various complexes, constituted multiband interaction which functioned as an interaction sphere (Binford, 1965, p. 208):

> What is essential to the concept of an interaction sphere is that it denotes a situation in which there is a regular cultural means of institutionalizing intersocietal interaction.

In the case of Iowa Effigy Mound the interaction occurred at the intrasocietal rather than the intersocietal level (Mallam, 1976b, p. 40):

> Each of the distinct social groups would have subordinated their autonomy to this greater superordinate institution. This higher level of sociocultural solidarity and cohesiveness could resolve the cultural problems of diverse hunting and gathering groups exploiting a particular geographic region. The end result was cultural unity and stability.

Study of the internal stratigraphy of mounds within a single complex coupled with analysis of the associated artifacts should, therefore, provide insights into changes through time of the mound "blueprint" shared by the coalesced nuclear families. Since the mounds within a complex were probably built over several centuries, the degree of development of the soil profiles in the mounds could serve to chronologically order the mounds as suggested by Leighton (1929) and demonstrated by Parsons (1960) and Hurley (1971). Conversely, if the chronology of the mounds within a single complex constructed from different parent materials can be determined by archaeological methods, then the soil profile development in these parent materials can be compared.

SOIL FORMING FACTORS IN THE STUDY AREA

Climate

The present climate of northeastern Iowa is a moist subhumic type with cold, dry winters and hot summers with moderate precipitation (Simonson et al., 1952). Northwesterly winds dominate during the winters while southerly winds are frequent from April to October.

About 71 percent of the annual precipitation is received during the warm season from May to September (Reed, 1941). The maximum precipitation intensity occurs in June while the minimum occurs in January (Visher, 1954). During winter, the storm track is usually displaced to the south of Iowa, migrating northward with most of the annual precipitation in May and June and diminishing during July as the storms track through Canada (Waite, 1970). A secondary, lesser precipitation maximum is associated with the southward migration of the storm track.

Within the study area topography causes changes in the local climate. North- and east-facing slopes and low-lying areas are cooler and more moist than southern and western exposures or moderate elevations.

Work by several authors indicates that the climate in the study area has not been constant during the Late Pleistocene and Holocene. Bryson et al. (1970) suggests division of the Holocene into eight climatic episodes based on a correlation of pollen spectra from the U.S. and Europe. Wright (1975) cautions against such a detailed division based on this evidence and instead recommends use of the von Post (1930) triparate subdivision of the Holocene.

Around 14,000 radiocarbon years before the present (R.C.Y.B.P.) taiga vegetation was present around Sumner Bog located 130 km (70 miles) southwest of the study area (Van Zant, 1976; Van Zant and Hallberg, 1976), suggesting a cold, dry climate. Curtiss (1959), however, suggests that the "Driftless Area" (in which the study area is located in the approximate center) was a refuge for forest vegetation during the Late Pleistocene. If the latter were the case, the climate in this region and at the study location may have been more moist and possibly warmer than at Sumner Bog.

Beginning about 14,000 R.C.Y.B.P. the climate began to ameliorate and may have approached present conditions around 8,000 to 9,000 R.C.Y.B.P. The warmest, driest part of the Holocene (Hypsithermal) occurred in the study area from 7,500 to 6,200 R.C.Y.B.P. Following the Hypsithermal the climate approached that of the present and has remained as such with cyclic fluctuations. The soils formed in the mounds studied have developed during the last 1,700 years under climatic conditions similar to those prevalent in the area today.

Vegetation

The study area is located within a fragmented, mosaic-type prairie-deciduous forest ecotone (Davis, 1977). In the "Driftless Area" the mosaic nature of the ecotone is attributable to edaphic factors, topography, fire, the survival of relicts, and late migration rates of some taxa (Davis, 1977, p. 206). Throughout the western and southern portion of the area, islands and strips of woodland, usually on steep slopes, extend into the prairie. Prairie extends through the deciduous forest zone on broad interfluves and along terraces and wide valley floors.

Late and post-glacial climatic change has caused significant vegetational changes in the area during the last 14,000 years. The pollen sequence from Sumner Bog suggests that vegetation similar to the taiga that occupies portions of modern Manitoba north of the boreal forest was present in northeast Iowa during the late glacial (approx. 20,000 to 14,000 R.C.Y.B.P.) (Van Zant, 1976; Van Zant and Hallberg, 1976). Spruce (*Picea* dietr.) and larch (*Larix* mill.) trees grew in moist, protected areas while the uplands were inhabited by herbs.

As the climate began to ameliorate, birch (*Betula* l.) invaded the Sumner Bog area (Van Zant, 1976). Shortly after this invasion spruce and larch increased in abundance as the tiaga closed to a mixed coniferous-deciduous forest.

By 11,000 R.C.Y.B.P. birch and alder (*Alnus* B. Ehrh.) trees had increased and Black Ash (*Fraxinus nigra* Marsh.) was an important constituent of the forest (Van Zant, 1976). At this point there is a hiatus in the Sumner Bog sequence extending to 5,500 R.C.Y.B.P. This hiatus was created by subaerial erosion during the warmest, driest part of the postglacial (ca. 7,200 to 6,200 R.C.Y.B.P.) (Van Zant and Hallberg, 1976).

Curtis (1959) suggests that the "Driftless Area" was a refuge for a mixed coniferous-deciduous forest during the Late Pleistocene. He believes that during amelioration of the climate in the late glacial, trees spread out of this area into adjacent, recently glaciated portions of Minnesota and Wisconsin. If this is the case, then the study area may have been within a forest environment during most of the late glacial period.

By 9,000 R.C.Y.B.P. a closed oak, elm deciduous forest covered northeast Iowa. Wendland's (1978) and Bernabo and Webb's (1977) recent maps of Holocene pollen records suggest that sometime after 9,000 R.C.Y.B.P. this forest began to open and prairie meadows became established in well-drained upland areas. By 6,200 R.C.Y.B.P. prairie extended along major interfluves in the vicinity of the Mississippi trench, marking its greatest incursion into northeastern Iowa.

Following the Hypsithermal forest reinvaded the uplands in extreme northeastern Iowa. Prairie became restricted to openings in the forest along major interfluves, in wide valleys and on xeric southern and western exposures (Wendland, 1978; Weaver, 1954, p. 184-186). Fire and drought occurring from this time on resulted in fluctuations of the forest-prairie ecotone, helping to produce the mosaic character of the present ecotone.

The study area reflects the mosaic nature of the ecotone in which it is located. Topographic and hydrologic conditions appear to control the vegetation pattern at the site. Bluff Top Mound (13AM243) is located within a 1/2 acre prairie clearing on the bluff edge. This prairie contains a mixture of lowland and upland communities. Members of the lowland community such as Kentucky bluegrass (*Poa potensis* L.) and big bluestem (*Andropogon gerardi* Vitman.) are dominant, while upland prairie species such as little bluestem (*Andropogon scoparius* Michx.)

and side-oats grama (Bouteloua curtipenduala (Michx.) Torr.) are also present, usually on the upper convex portion of the west-facing side-slope.

Burr oak (Quercus macrocarpa) and white oak (Q. alba) trees grow on sideslopes south and southwest of the mound. A few cedar trees (Cupressaceae sp.) grow on ledges in the freeface northeast of the mound. The forest-prairie border is very sharp here. Shrubs such as raspberries (Rubus strigosus and R. occidentalis) and prickly ask (Zanthoxylum americanum) and climbing vines like Virginia creeper (Parthenocissus quinquefolia) and poison ivy (Rhus radicans) dominate in this 2 to 5 meter wide zone. A sharp prairie-forest transition is characteristic of prairie openings in this area according to Shimek (1924), Transeau (1935), and Vestal (1914).

On the north-facing slope where mounds 23 and 29 of the Keller Group (13AM69) are located, white birch (Betula papysera) are present in almost a pure stand on the upper slope while cedar and a few oak occupy the central and lower portions of the slope. Yew (Toxus canadensis) is an abundant shrub within the birch stand.

Grasses and forbs dominate the footslope and toeslopes of most west-facing slopes. Forbs such as Indian plantain (Cacalia tuberosa), smooth goldenrod (Solidago missouriensis) and many-flowered aster (Aster ericoides) are found on these slopes. Vegetation on the toeslope of the north-facing slope consists of approximately 50 percent cedar trees separated by areas where Kentucky bluegrass and many-flowered aster dominate.

Morphology of the soils present in the study area suggest formation under predominantly forest vegetation. A vegetation pattern similar to that present today is postulated during and subsequent to construction of the mounds. Extension and recession of the forest and shrub zones as suggested by Weaver (1954, p. 189-190) were probably common during this time.

Topography and drainage

The study area is within Prior's (1976) Paleozoic Plateau of northeastern Iowa. On the uplands a thin loess cover overlies patches of glacial drift or Paleozoic bedrock. The terrain is bedrock controlled and landscapes are deeply dissected, made up of V-shaped valleys and plateau-like uplands.

The Mississippi River borders the study area on the north (Fig. 1). Here the valley is approximately 4.6 kilometers (2.5 miles) wide and its valley floor lies 122 to 152 meters (400-500 feet) below the upland. Cambrian and Ordovician sedimentary rocks are exposed on escarpments forming the valley walls.

Uplands in the area are within soil association area 67 (Fig. 4) (Iowa State University Agr. and Home Econ. Expt. Sta., 1978) which consists of "nearly level to steep (0-40%) forest-derived soils developed in loess or loess over bedrock and adjacent areas that are too small to delineate." One of the latter areas contains the Keller Mound Group (13AM69) while the Bluff Top Mound (13AM243) is located on thin loess over bedrock.

Figure 4. Soil association map of Allamakee County [from Iowa Soil Association Map (1978)]

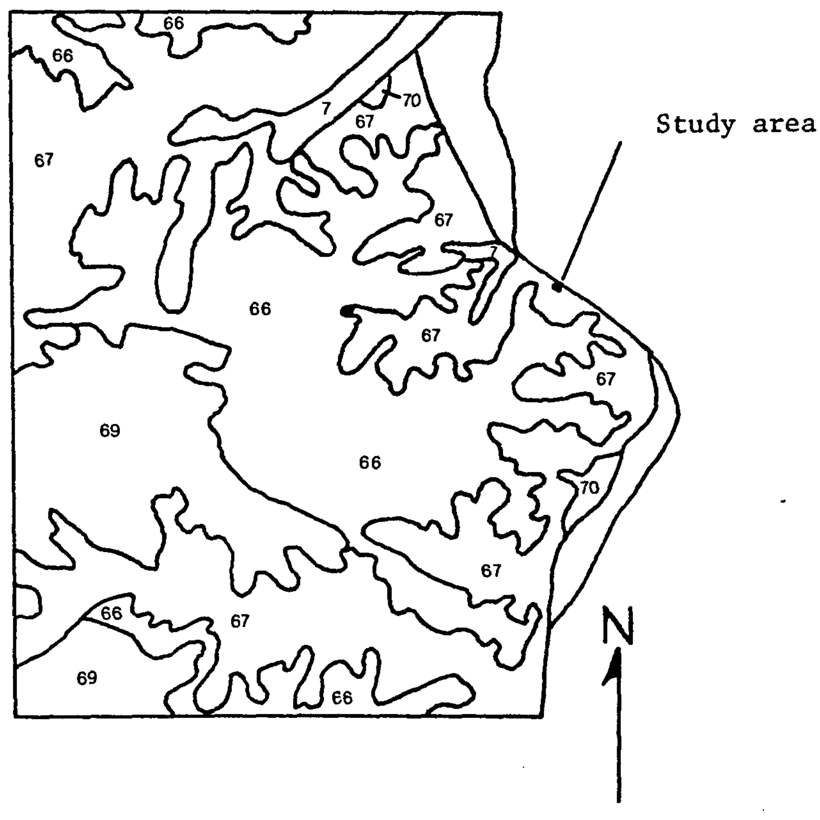
Legend

7 Nearly level and gently sloping (0-5%) prairie-derived soils developed from alluvium. Soils on steep adjacent upland slopes are included in some areas. Colo, Zook and Nodaway soils.

66 Moderately sloping to very steep (5-40%) forest and mixed prairie-forest-derived soils developed from loess or loess over bedrock. Fayette, Downs, Dubuque and Nordness soils and Steep Rock Land.

67 Nearly level to steep (0-40%) forest-derived soils developed from loess or loess over bedrock and adjacent areas that are too small to delineate. Fayette and Nordness soils and Steep Rock Land with smaller areas of Dubuque, Dorchester and other adjacent soils on narrow bottomlands and terraces.

70 Gently to strongly sloping (2-14%) prairie to forest-derived soils developed from loess or aeolian sand. Sparta, Fayette, Downs, Dickinson and Backbone soils.



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The majority of the loess mantling the uplands, benches, and pre-Holocene terraces was derived from the adjacent Mississippi Valley between about 29,000 and 14,000 R.C.Y.B.P. Erosion, coincident with and subsequent to loess deposition, has removed the loess cover from steep slopes exposing the underlying bedrock. Adjacent to the Mississippi Trench only relatively flat areas have remained loess lovered. Bluff Top Mound is located on a small step or bench in the Decorah-Platteville Formation which is overlain by 1 to 2 meters of loess. A truncated paleosol (regosol) is present at the loess-bedrock interface. This unconformity represents erosion prior to cessation of loess deposition and may be an expression of the Iowan Erosion Surface as defined by Ruhe et al. (1968).

Ordovician bedrock, formed from shallow marine sediments, underlies the bench on which the Bluff Top Mound is located, and outcrops on the sideslopes of ridges in the study area. A free-face is present on the east- and north-facing slopes rising about 46 meters (150 feet) above the upper footslope (see Fig. 3). The generalized stratigraphic section for the study area is shown in Fig. 5. Rocks of the Prairie du Chien Fm. do not outcrop in the study area today and are buried beneath talus and colluvium under the footslope and toeslope.

St. Peter Sandstone overlies the Prairie du Chien Fm. with an unconformity, or erosion surface separating the two. A surface of variable elevation had developed on the top of the Prairie du Chien prior to deposition of the St. Peter resulting in variable thickness of the overlying St. Peter (Wilman et al., 1975, p. 62). The St. Peter Formation

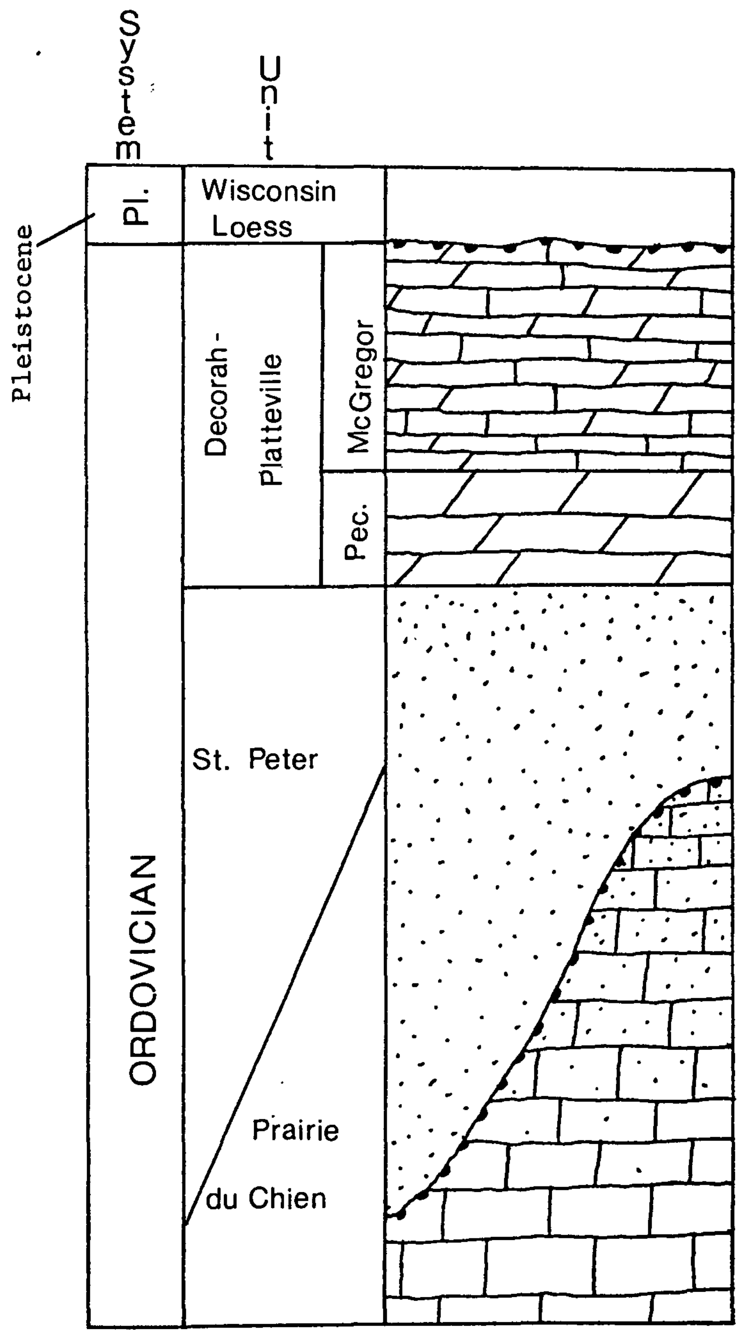

Figure 5. Generalized stratigraphic section for the study area

group CAS 8/21/86

consists of "very light-gray to white, massive sandstone composed of well rounded grains of quartz sand. These grains are frosted and usually poorly cemented" (Iowa Geological Survey, undated).

Glenwood Shale of the Decorah-Platteville Fm. usually overlies the St. Peter Fm. but is absent in the study area. The Pecatonica dolomite overlies the St. Peter Fm. in the study area and, being quite resistant, forms an overhanging ledge. This unit is "buff to gray fine-grained dolomite in massive beds" (IGS, undated) and is approximately 3 meters (10 feet) thick in the study area.

Limestones of the McGregor member overlie the Pecatonia Member and are buried by loess where the Bluff Top Mound is located. This member consists of "gray to buff to brown fragmented limestone. It is very fine-grained and has wavy to lenticular thin beds with very thin shale partings" (IGS, undated). Thickness is approximately 6 meters (20 feet) in the study area.

A relatively steep, concave debris slope has developed below the freeface and convex shoulder slopes formed in the bedrock. These slopes are formed in colluvial and talluvial (Carson and Kirkby, 1972, p. 92) materials derived from the bedrock outcrops. Formerly, the debris slope merged with and partially mantled a Holocene terrace extending north and west of the study area. Construction and expansion of the Lansing Substation of the Tri-State Power Company has obliterated this terrace.

Spring Brook, a small permanent tributary to the Mississippi River, flows to the west of the study area. Before construction of the power station, the mouth of this brook may have contained a slough. Preceding construction of the lock and dam system on the Mississippi River by the Corps of Engineers, river level was 2 to 3 meters (6-10 feet) lower than at present.

External drainage is good to excessive on the bench containing Bluff Top Mound. Internal drainage is good. Due to seeps present at the St. Peter-Prairie du Chien contact, external drainage is poor while internal drainage is excessive on the upper portion of the debris slope to the north. External drainage increases and is somewhat excessive in the central and lower portions of the debris slope. Internal drainage is excessive in this portion of the slope. As the base of the slope is approached, external drainage decreases due to run-on and internal drainage increases. The footslope is moderately well to somewhat poorly drained as a result of run-on and lateral movement of groundwater. The terrace originally present at the base of the slope was probably well to moderately well drained.

Parent materials

Mounds investigated in this study were built from three texturally different parent materials. Bluff Top Mound was built with loess gathered from the surrounding bench. The fill used was apparently a mixture of leached and unleached soil horizons. This material is in the silt loam textural class.

Mounds 23 and 29 of the Keller Group were built with a mixture of leached soil horizons gathered from the surrounding slope. This material contains a few weathered coarse fragments and is sand to sandy loam in texture. Most of this material is colluvial and originated from weathering of the freeface and overlying materials to the south.

A mixture of leached soil horizons developed in loamy sideslope deposits was used to construct Mound 4 of the Keller Group. Some village material was also incorporated into the fill of this mound (Benn et al., 1978).

The deposits examined in this study fall into the lower central and left-hand portion of the textural triangle (Fig. 6). The percent silt and clay are highest in the material from which the Bluff Top Mound was constructed, intermediate in Mound 4 of the Keller Group and lowest in Mounds 23 and 29 of the Keller Group.

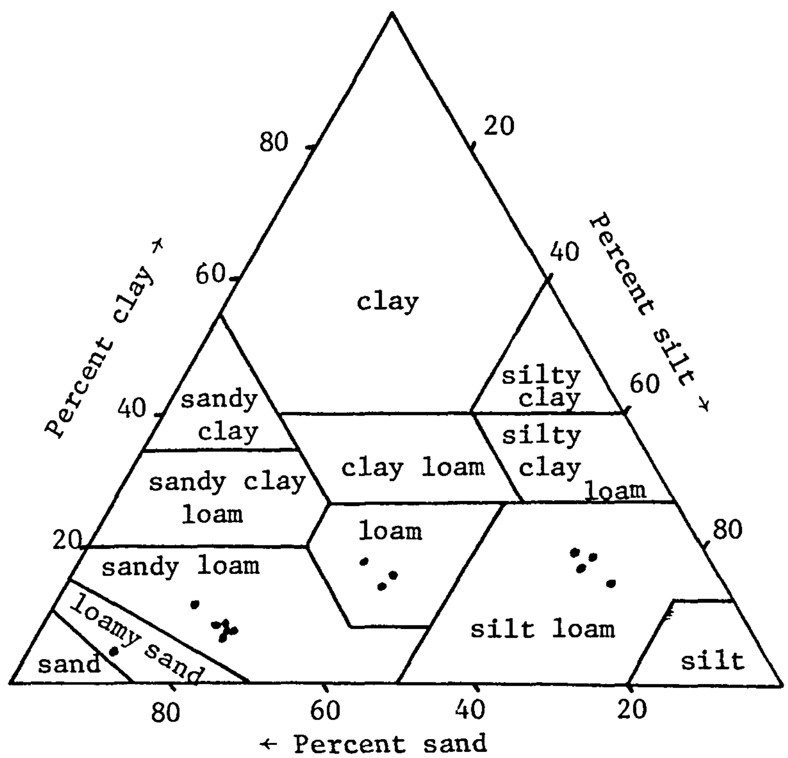

Figure 6. Textural triangle showing textural range of soils in this study

METHODS OF INVESTIGATION

Field procedures

Mounds 4, 23, and 29 of the Keller Group and Bluff Top Mound were excavated by archaeologists in one meter squares by 10 centimeter vertical control levels contoured to the inclination of the mound surface. All excavating was accomplished by hand troweling (see Benn et al. (1978) for a detailed description of the excavations and procedures).

The excavations continued until the pits had gone well into the buried soil or parent material beneath the mound floor. Buried soils under Mounds 23 and 29 were recognized by the presence of structure. The buried soil under Mound 4 was distinguished by its firm consistence, subangular blocky structure and absence of artifacts. Subangular blocky structure and firm consistence allowed recognition of the buried soil under Bluff Top Mound. The depth of fill ranged from 126 cm. in Bluff Top Mound to 81 cm. in Mound 4.

Detailed morphologic descriptions of the soil profiles developed in the mounds were taken *in situ* from pit walls according to the procedure outlined in the *Soil Survey Manual* (Soil Survey Staff, 1951). Soil samples were collected by horizon from profiles during the excavations of Mounds 23 and 29 of the Keller Group and from Bluff Top Mound. Since the writer was not present during excavation of Mound 4 of the Keller Group, samples were collected from a pit re-excavated to expose a profile wall. Vertical profiles of the mounds showing locations of the sampled profiles are provided in Appendix B.

Three transects of hand borings were run down the slope on which the

Keller Group is located (Fig. 3) in order to determine the nature of soils developed on the surrounding slopes in relation to those developed on the mounds. Cores were taken at 5 m intervals and the thickness of soil horizons present was recorded. Four cores were chosen to represent the range of soils present on the slope. The soils were sampled by horizon for lab analyses.

Cores were taken at 1 m intervals in transects extending in the four cardinal directions from Bluff Top Mound to determine if "borrow areas" were present. The depth to the B2t horizon and the thickness of the A1, A2, and B1 horizons were recorded. Previous experience has shown that in some cases the topsoil in areas where mound fill had been borrowed by the Indians is thinner and the A-B interface more abrupt than in adjacent, undisturbed profiles (Benn and Bettis, 1977; Mallam and Bettis, 1979). A profile located approximately 10 m southwest of Bluff Top Mound was sampled by horizon to compare this undisturbed profile with those developed on the mound. The data obtained from these traverses are given in Table 1.

<u>Laboratory procedures</u>

Soil samples collected were air-dried and then ground to pass a 2 mm sieve. Samples from Bluff Top Mound and the associated undisturbed profile were mechanically ground while the rest of the samples were ground using a mortar and pestle. Subsamples were fine-ground to pass a 60-mesh sieve for the total phosphorus procedure.

<u>Particle size analysis</u> The pipette method (Kilmer and Alexander, 1949) was used for particle size determination. Soil samples

were oven dried overnight. Ten gram subsamples were weighed, placed in baby bottles, and 5 ml of 1% acetic acid, 10 ml of hydrogen peroxide, and approximately 100 ml of distilled water were added. Twenty milliliters of hydrogen peroxide were added to samples from surface horizons due to the higher organic matter content of these samples. Samples were allowed to sit overnight to insure destruction of organic matter, after which approximately 50 ml of the liquid were boiled off to remove any remaining hydrogen peroxide and acetic acid. Exactly 10 ml of sodium hexametaphosphate (Calgon) were added to each sample and the bottle was then stoppered and shaken overnight to disperse the soil particles.

The sands were separated by wet-sieving and dried in an oven at 105°C overnight. They were then placed into a stack-type mechanical siever and shaken for 3 minutes. Each sieve was weighed before and after each sieving.

The soil suspensions containing silt and clay particles were poured into 1 liter graduated cylinders, stirred, and settling times determined from the U.S.D.A. Standard Size Fraction Chart. Fine silt and clay fractions were pipetted and allowed to dry in an oven for a minimum of 12 hours at 105°C.

Total carbon All samples analyzed for carbon, except six from Bluff Top Mound, were non-calcareous. With the exception of these six, total carbon is actually organic carbon since it may be assumed that carbon present is from organic sources. Total carbon was determined from subsamples weighing between .020 and .025 grams using a Leco automatic carbon analyzer according to the procedure outlined by Tabatabai and Bremner (1970). Metal ring standards were used to calibrate the machine.

Hydrogen ion activity (pH) Hydrogen ion activity was determined using a 1:1 soil to water ratio. The soil sample and water were placed in a 25 ml beaker. The mixture was stirred and allowed to settle for 30 minutes. A Corning Combination Electrode was placed in the supernatant liquid and the pH read on a Beckman Zeromatic pH meter.

Total phosphorus The total amount of phosphorus in the samples was determined using the procedure developed by Dick and Tabatabai (1977) and modified by Walter (Neil Walter, Dept. of Agronomy, I.S.U., personal communication). An air-dried soil sample weighing approximately .025 g and ground to pass a 60-mesh sieve was placed in a glass centrifuge tube. Three ml of sodium hypobromite solution were added and the mixture was swirled for a few seconds. The sodium hypobromite solution was prepared under a hood the day the samples were run. Tubes containing the soil-hypobromite mixture were allowed to stand for 5 minutes, swirled again, then placed in a sand bath (260-280°C) for approximately 45 minutes (until all liquid was boiled off and the contents of the tube were very dry). The tubes were allowed to cool and 4 ml of distilled water and 1 ml of formic acid were then added to each tube. The contents were mixed and 25 ml of 1N H_2SO_4 were added. The tubes were stoppered and carefully shaken for a few minutes until all material was loosened from the side and bottom of the tubes. After shaking, the stopper was carefully removed. Tubes were restoppered and shaken for a few additional seconds. All tubes were centrifuged at 3,000 rpm for 15 minutes.

A 2 ml aliquot was pipetted from each tube into a 25 ml volumetric flask and 4 ml of ascorbic acid solution were added. Each flask was then filled to volume with distilled water. The flasks were stoppered and the contents mixed. After standing 30 minutes the absorbance of the molybdenum blue color was read on a Bausch and Lomb Spectronic 20 spectrophotometer. The Spec. 20 was adjusted to a wavelength of 720 nm and a red filter was used.

Total P concentrations were determined using the line-slope method. The equation used was:

$$TP = \frac{\text{(Absorbance value)(Multiplication factor)(15)}}{\text{weight of sample}}$$

The multiplication factor was determined using standards of 0, 5, 10, 15, 20 and 25 ppm total phosphorus. Slope of the line joining the absorbance readings of the standards was obtained by dividing the absorbance reading by the concentration (in ppm) of the solutions. The inverse of the mean of these slope values was the multiplication factor used.

ARCHAEOLOGICAL CONCLUSIONS ON THE TEMPORAL PLACEMENT OF THE MOUNDS INVESTIGATED

Mounds investigated during this study contained no datable carbon and therefore temporal placement was accomplished by association of previously dated pottery types with the mounds. Bluff Top Mound contained Late Woodland ceramics and the head of a ceramic Hopewellian figurine (Benn et al., 1978). These artifacts suggest construction of this mound during the initial century of the Allamakee Phase which spans the period 300-650 A.D.

Late Woodland pottery types (Linn Ware and Lane Farm Chord Impressed) were found within the fill of Mounds 23 and 29. This suggests placement within the Allamakee Phase and construction of the mounds sometime between the commencement and termination of this period (Benn et al., 1978, p. 63).

Late Woodland pottery types were also found within Mound 4 (Linn Ware and Madison Ware). This pottery showed many shared attributes and Benn et al. (1978, p. 36) considered them to be indicative of a period of stylistic change in ceramics. According to the cultural sequence for northeast Iowa (Benn, 1977, 1978), Mound 4 would have been constructed at the end of the Allamakee Phase during the early 7th century A.D.

In summary then, all the mounds investigated were built between 300 and 650 A.D., during the Allamakee Phase of the Late Woodland period of northeastern Iowa. Soils formed on the mounds have been developing for the longest period of time (approximately 1700 years) while those on Mound 4 of the Keller group are only 1330 years old.

DISCUSSION OF RESULTS

Morphologic properties of the soils and slopes

Morphological descriptions of the profiles examined during the field investigations are presented in Appendix A.

13AM243 A soil profile formed in loess and located approximately 6 meters south of Bluff Top Mound (13AM243 off mound) on a 2-5% sloping toeslope had a thin very dark brown silt loam A1 horizon and a dark brown to dark yellowish brown A2 horizon. The B horizon was dark yellowish brown, had medium subangular blocky and angular blocky structure and was heavy silt loam in texture. Clay skins (cutans) in the B horizon were discontinuous and occurred as thin coatings on horizontal and vertical ped surfaces. Brown mottles were present in the lower B22t horizon and increased in abundance in the B3 horizon. This mottling may indicate restriction of water movement above the bedrock surface which is located about 1.5 meters below the soil surface. Morphologically this profile is within the range of the Seaton series, a fine-silty, mixed, mesic Typic Hapludalf.

The soils developed on Bluff Top Mound had thinner and darker A horizons. The platy structural development of the mound A2 horizon was usually more pronounced in the upper portion of the horizon. This suggests that initially A2 horizons generate downward into the profile and agrees with Parson's (1960) conclusions on A2 horizon development at Effigy Mounds National Monument under conditions similar to those present at 13AM243.

A textural B horizon had not developed in the mound fill. The mound B horizon was much thinner than, and a structural grade less developed than the adjacent Seaton B horizon. No clay skins were observed on peds in the color B horizon developed in the mound fill. The solum developed in the mound fill was thickest in the central portion of the mound (profile BT-2) and decreased in thickness on the sideslopes. Structural development in the B horizon was most pronounced in the central portion of the mound.

Soil profiles examined on the east and west sideslopes of Bluff Top Mound were buried by 10 and 6 centimeters of recently deposited material respectively (Appendix B). This burial probably occurred sometime during the last 100 to 150 years when backdirt from a hole dug into the mound was thrown on the mound surface. Prior to burial the upper portion of the A1 horizon appears to have been removed from these areas by whoever dug the hole. A1 horizons and incipient A2 horizons have developed in this recently deposited material during the last 100 to 150 years.

Morphologic differences allowed delineation of several distinct layers within the C horizon of the mound fill.[3] This material appears to have been borrowed from leached and unleached horizons of a soil developed on the bench at the time of mound construction.

Structural units (peds) were occasionally observed in the C horizons of the mound. These peds were usually moderately to strongly developed

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[3]Ce was used to designate mound fill parent materials following the nomenclature used by Parsons in his 1960 study.

and were coated with thin clay films. In the Ce horizons peds were randomly oriented and occurred within a predominantly structureless (massive) matrix. These relationships suggest that these peds are relict, having originally developed _in situ_ in the B horizon of a Seaton soil. They were later borrowed by the Indians and became incorporated into the mound fill.

The Ce4 layer was distinguished from the overlying Ce3 layer by color and structure. This layer extends across the Ce5 layer in the mound center and the mound floor elsewhere under the mound. The upper boundary is abrupt and smooth while the lower boundary is gradual and wavy. This may be a slightly weathered surface. If so, a period of time long enough to slightly leach the surface of the filled burial pit and exposed mound floor elapsed between the early and late phases of mound construction.

Standard horizon nomenclature was used to describe the buried B horizon encountered under some portions of the mound. The B horizon was distinguished from the mound fill on the basis of color, structure, and consistence. Under the central portion of the mound the Indians had excavated a pit deep into the C horizon of the original soil (Appendix B). This horizon was distinguished from the mound fill by color and by vertically oriented versus randomly oriented carbonate concretions.

The Seaton series is a fine-silty, mixed, mesic Typic Hapludalf and was formerly classified as a Gray Brown Podzolic soil. An Inceptisol is developed in the upper mound fill which formerly would probably have been classified with the Sol Brun Acide great soil group described by Baur and Lyford (1957).

Transects of cores taken at 5 meter intervals west and south of Bluff Top Mound showed that Seaton soils dominate the bench on which the mound is built. Transects were not extended to the north and east due to the presence of escarpments. Thicknesses of the soil horizons encountered in these transects are presented in Table 1.

It was thought that if material for mound fill had been borrowed from the surface of surrounding soils, then thicknesses of A horizons within these borrow areas would be less than the thickness of A horizons in adjacent undisturbed profiles. Parsons (1960) found that this was the case at Effigy Mounds National Monument.

Results of the transects at Bluff Top Mound do not support this hypothesis. A horizons here are about the same thickness adjacent to the mound as they are 10 meters away from the mound. The A/B horizon contact is very abrupt adjacent to the mound but is gradual at distances of 5 and 10 meters from the mound edge. Abrupt A/B horizon contacts have been observed in mound fill borrow areas at other mound groups in northeastern Iowa (Mallam and Bettis, 1979). It is suggested that the nature of the A/B horizon contact may be a better indicator of the presence of borrow areas than thickness of A horizons.

Transect 1 (north-facing slope) Transects of hand borings down the slope on which the Keller Mound Group (13AM69) is located showed that soil morphology here is greatly influenced by slope position. Thickness of the solum decreases upslope (Table 2), possibly indicating

Table 1. Thickness of horizons encountered in transverses west and south of Bluff Top Mound (13AM243)

West Transect (5 m intervals)

Hole #	Location	Horizon	Thickness (cm)
1	just off west edge of mound	A1	6
		A2	9
		B3b	7
		C	
2	5 m west of #1	A1	9
		A2	9
		B1	14
		B2	50
3	10 m west of #1	A1	9
		A2	11
		B1	8
		B2	42

South Transect

Hole #	Location	Horizon	Thickness (cm)
1	south edge of Bluff Top Mound	A1	7
		A2	12
		B1	6
		B2	10
2	5 m south of hold #1	A1	10
		A2	10
		B1	12
		B2	47
3	10 m south of hole #1	A1	9
		A2	12
		B1	17
		B2	46

Table 2. Thickness of soil horizons developed on natural sideslopes at the Keller Mound Group

Location	Slope	Horizon	Depth below surface (cm)
T-1-1	17%	A1	0-5
		A2	5-15
		B11	15-26
		B12	26-46
		B2t	46-91
		R	91-
T-1-2	35%	A1	0-7
		A2	7-13
		B1	13-21
		A1b	21-26
		A2b	26-31
		B1bt	31-60
		B2b	60-80
		C1	80-91
		R	91-
T-1-3	62%	A1	0-3
		A2	3-18
		B	18-41
		R	41-
T-1-4	80%	A1	0-5
		A2	5-10
		C	10-41
		R	41-
T-2-1	10%	A1	0-8
		A2	8-20
		B1	20-35
		B21	35-43
		B22	43-81
		B3	81-91
		C	91-
T-2-2	17%	A1	0-5
		A2	5-19
		B11	19-38
		B12	38-57
		B2t	57-84
		R	84-
T-2-3	80%	A-C	0-15
		R	15-

increased erosion on steeper slopes.

Soils located on the north-facing sideslope are within the sandy loam and loamy sand textural classes. These soils are developing in leached material weathered from the sandstone freeface (St. Peter) to the north.

On 10-20% slopes (T-1-1) a solum 91 plus centimeters thick has developed which has a structural and textural B horizon. This soil has a black to very dark brown sandy loam A1 horizon, a very dark grayish brown A2 horizon and a brown to dark brown (7.5YR hue) B horizon. Coarse material composed primarily of angular weathered sandstone fragments is in the lower B2t horizon. This horizon continues to an unknown depth. The soil at this site appears to be an Alfisol.

On the upper portion of the footslope, slope gradients range from 20 to 40%. Cedar trees dominate the vegetation. Large blocks of weathered sandstone cover about 5% of the land surface. The ground surface is composed of many small terracettes (cat steps) and some small stabilized slumps are evident. The bisequum present here (T-1-2, Table 2) attests to the importance of mass movement in this portion of the slope. The upper solum has developed on, or was already developed in material sliding downslope and burying the lower solum at some time in the past. Soil structure is one to two structural grades less developed here than lower on the footslope where T-1-1 was described. Fractured sandstone similar to that underlying the surficial deposits at T-1-1 was encountered at 90 to 100 centimeters below the surface in this portion of the slope.

Further upslope slope gradients average 50 to 70% and oaks and birch are the dominant vegetation. The forest floor is less well-covered than lower on the slope where cedar trees are dominant and about 50% of the soil surface is bare and eroded.

Soils developed here have very dark brown sandy loam A1 horizons, dark brown sandy loam A2 horizons and dark yellowish brown color B horizon (Appendix A, T-1-3). They are classified as Inceptisols. Weathered angular sandstone is present beginning about 40 centimeters below the surface.

Near the top of the debris slope the soils characteristically exhibit A-C profiles developed in 40 to 50 centimeters of medium to fine sand over sandstone bedrock. Slope gradients average 80% in this portion of the slope and about 80% of the surface is bare and severely eroded. These soils are classified as Entisols.

A schematic slope profile for this portion of the hillslope is presented in Figure 7. On the basis of soil morphological properties this slope profile can be divided into three units. Unit A comprises the sideslope in Ruhe's (1969) terminology. Slope gradients here exceed 50% and 40 to 80% of the soil surface is bare and eroded. Surficial erosion appears to be keeping pace with pedogenesis and Entisols and Inceptisols have developed here.

Unit B is the upper footslope and slope gradients range from 20 to 40%. The soil surface is covered with a thick litter and surficial erosion is minimal. As indicated previously, mass wasting dominates this portion of the slope. Terracettes and slump blocks are evident as well

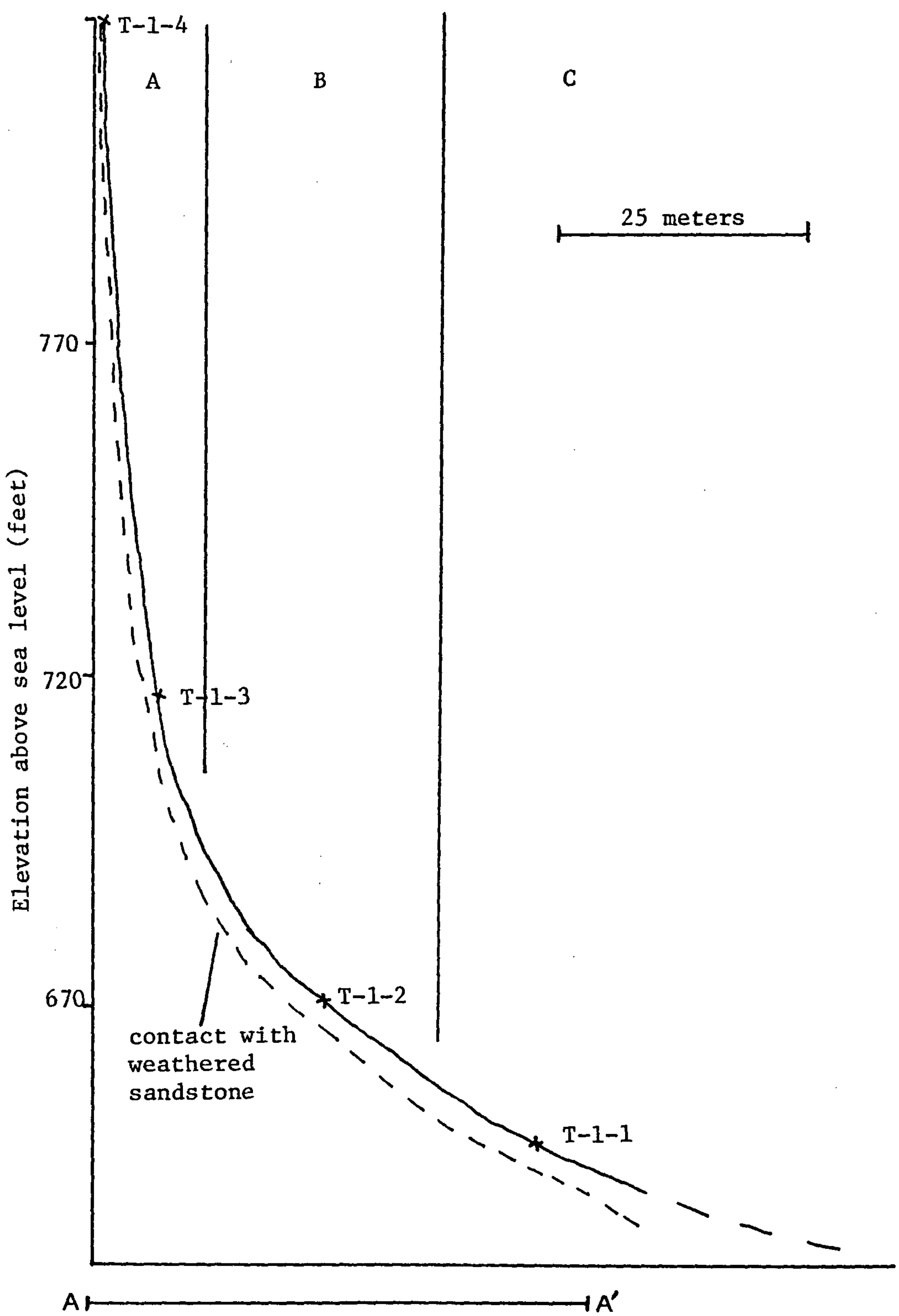

Figure 7. Schematic slope profile along Transect 1

as large sandstone blocks which appear to be slowly moving downslope. Soil sola are thicker in this portion of the slope than upslope. Many bisequa are present as a result of shallow burial of soils by material slumped from upslope. Inceptisols and very minimally developed Alfisols are on this portion of the slope.

Unit C encompasses the lower footslope and upper toeslope. Slope gradients range from 10 to 20%. The soil surface is covered by a thick leaf litter or bluegrass and no mass movement is evident. Soils are most strongly developed in this unit and the surface soils are usually Alfisols. Several small alluvial cones[4] terminate in this portion of the slope and have Entisols or Inceptisols developed in their surface. Deposition dominates in unit C but, aside from active alluvial cone areas, apparently occurs at a slow, steady rate. Mounds 23 and 29 of the Keller Group are located within this slope unit.

A sandy loam Inceptisol has developed in the surface of Mound 23. The A1 horizon is dark gray on the gently sloping (0-5%) mound center (profile 23-2) and very dark grayish brown on more steeply sloping (10-15%) mound sideslopes. A2 horizons are 1 to 2 chroma units darker on the sideslopes and slightly thicker than at the mound center.

A color B horizon is present which has weak structural development. It is slightly thinner and one value unit darker on the sideslopes.

Only one mound fill unit was delineated on the basis of morphology

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[4]An alluvial cone is a very steep alluvial fan. These features are most common where minor streams descend from an upland area.

in the field. This fill exhibited basket loading[5] with yellowish brown basketloads contrasting with dark yellowish brown basketloads of mound fill. Relict subangular blocky peds and charcoal flecks were randomly oriented throughout this unit.

Many discontinuous grayish brown grainy coats occur on some of the surfaces of the relict peds. According to Arnold and Riecken (1964), these coats are associated with forest vegetation and are most pronounced in the upper part of the argillic horizon. This could indicate that the mound fill was obtained from the upper B horizon of soils developed on the adjacent slope at the time of mound construction. The grainy coats indicate these soils probably have developed primarily under forest vegetation.

No grainy coats were observed in profiles on the slope in the vicinity of Mounds 23 and 29. It could be argued from this evidence alone that no grainy coats were observed because conditions for their formation have not been favorable at this site. It would be difficult to explain their presence on relict peds within the fill of Mound 23, however, unless it was assumed that the fill was obtained at another location. Most evidence from the Effigy Mound area indicates that mound fill was usually obtained from areas adjacent to mounds (Parsons, 1960; Hurley, 1970; Benn and Bettis, 1977) and therefore casts doubt on this assumption.

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[5]The Indians who built these mounds apparently used baskets or hides to transport soil from borrow areas to the mound. In certain mound fill layers individual basket loads are discernible because of color differences.

An alternate hypothesis is that in the process of constructing mounds on the lower portion of this slope, the Indians removed all of the A horizons and most of the B horizon of the original soil cover. By doing this, they removed portions of the original solum containing grainy coats and subsequently incorporated them into mounds. If this is the case, the soils developed on this portion of the slope are polygenetic. Following borrowing of fill for mound construction, the B horizon of the original soil was exposed to surface processes and a new pedogenic cycle ensued. This suggests that grainy coats are not present in the upper B horizon of soils on the slope today because conditions (external and/or internal) have not been favorable for their development since construction of the mounds.

A buried lower B horizon was distinguished from the mound fill by differences in color, structure, and the presence of discontinuous dark brown cutans. Large sandstone blocks and many smaller pieces of sandstone were encountered on the mound floor resting on and encompassed within the buried B horizon. These rocks appear to be part of the coarse angular deposit underlying the slope (see Table 2, Figure 7, Appendix A and Appendix B).

Mound 29 is located on the lower footslope about 40 meters east of Mound 23 (Figure 3). The mound was built on, and its south side is buried by, an alluvial cone. An Entisol has developed in the mound surface. It has a very dark gray loamy sand A1 horizon underlain by a dark brown and dark yellowish brown loamy sand A-C horizon (Appendix A, profile 29-2).

Three distinct mound fill layers were recognized in the field. The Ce2 layer was separated from the overlying and underlying units on the basis of color and the presence of observable basket loading within this horizon. Some randomly oriented relict medium subangular blocky peds were in this unit.

A buried B horizon was encountered at the base of the mound fill. This horizon was distinguished from the overlying material on the basis of color and structure. This B horizon consists of dark yellowish brown sandy loam lamallae ranging from 5 to 8 centimeters in thickness and separated by 10 to 15 centimeters of yellowish brown loamy sand. Lamallae have medium subangular blocky structure and faint yellowish brown mottles. Consistence is loose between lamallae.

Many authors have observed clay and iron-rich subsurface textural lamallae in sandy materials. Lamallae formation usually occurs one to four meters beneath the surface but genetic mechanisms are poorly understood. Most researchers believe that lamallae are pedogenic in origin (Smith et al., 1950; Folks and Riecken, 1956; Wurman et al., 1959; Berg, 1979), but some suggest that they are depositional features, wholly or mostly unrelated to pedogenesis (Dijkerman et al., 1966). The origin and/or genesis of these features are outside of the scope of this study.

Profile 29-2 is a soil described about .3 meters east of the eastern mound edge. This soil is an Inceptisol which has developed in 46 centimeters of sandy loam material. This material overlies a truncated B horizon.

Charcoal flecks are present in the B12 horizon of this Inceptisol.

Charcoal is usually not encountered in this position in the solum under natural conditions. It is possible that this charcoal was incorporated into these deposits during construction of Mound 29. This suggests that the Inceptisol has developed subsequent to construction of Mound 29. The greater degree of development in this soil relative to the one developed in the mound fill may be due to accretion at the mound surface by material being deposited on the alluvial cone burying the mound.

Transect 2 (west-facing slope) Another transect was run down the west-facing noseslope where Mound 4 is located (Figure 3). The upper portion of this slope is steep and weathered sandstone outcrops at the surface. Cedars dominate the vegetation in this portion of the slope and form a closed canopy. About 10 meters above profile T-2-3 the slope becomes gentler (approximately 80%) and vegetation changes from exclusively cedar to very scattered cedar and prairie.

A sandy loam Entisol has formed at profile T-2-3, which has an 8 centimeter thick very dark grayish brown A1 horizon which grades to a 7 centimeter thick sandy loam A-C horizon. Weathered sandstone is encountered about 15 centimeters below the surface. About 20 meters downslope a prominent topographic break occurs. Above this break weathered sandstone underlies the surficial deposit while below the contact weathered sandy limestone is encountered. This appears to be the contact of the St. Peter Sandstone with the underlying Prairie du Chien (Figure 8). Slopes are steeper above the contact and soils below the contact have loam rather than sandy loam textures.

Profile T-2-2 is located on a 17% slope on the upper footslope. It

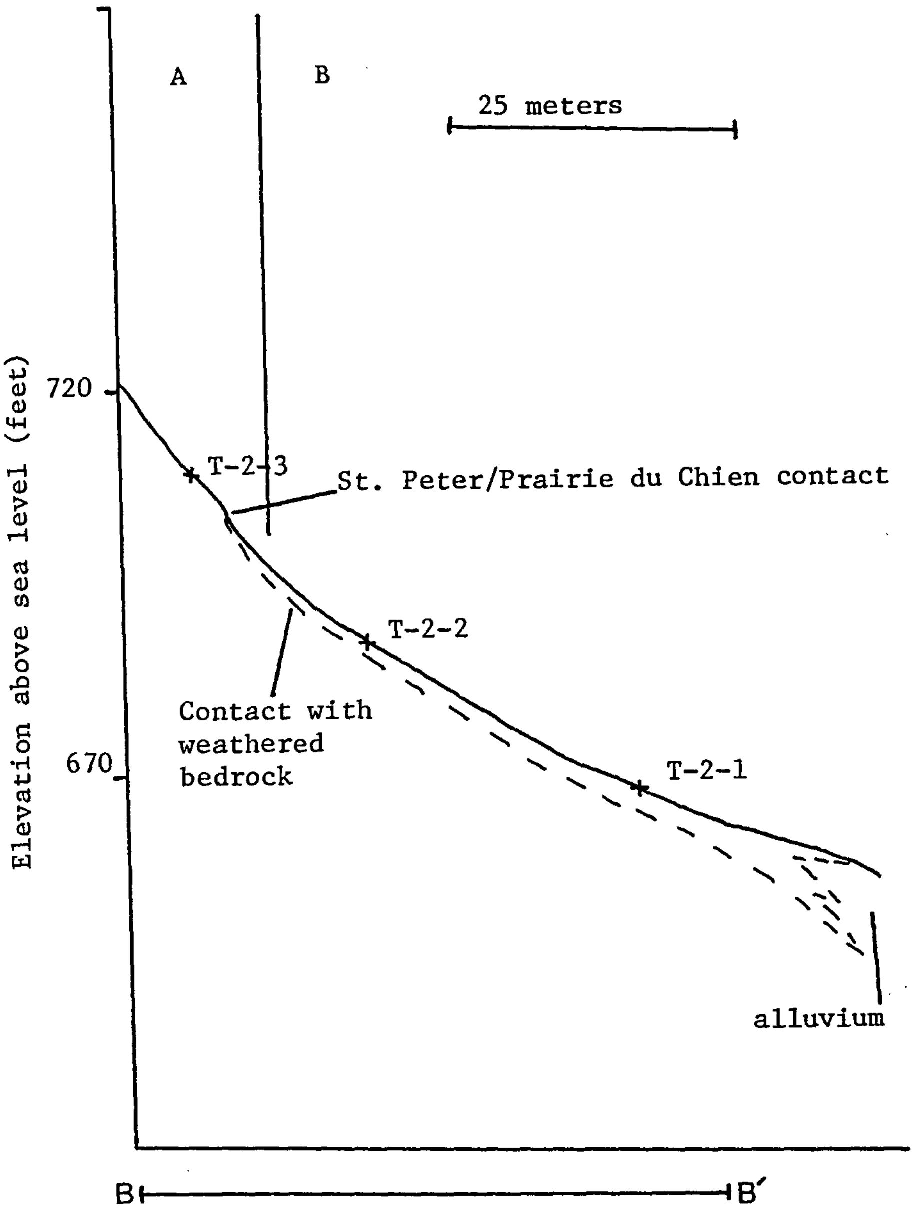


Figure 8. Schematic slope profile along Transect 2

has a very dark grayish brown A1 horizon, a dark brown A2 horizon and a dark brown B horizon. Structural expression is weak except in the B2 horizon. Thin discontinuous grainy coats were observed in the B2 horizon. Morphology of this profile suggests development under predominantly forest vegetation. This is an Inceptisol.

As the base of the footslope is approached, slopes decrease to 10% and solum thickness increases. Profile T-2-1 is located here approximately 5 meters southeast of Mound 4. The colors of this profile are similar to those in the previously discussed profile T-2-2. Soil horizons at T-2-1 are usually more strongly developed structurally and an argillic horizon is present. Thin discontinuous grainy coats were observed within the B2t horizon. This profile appears to be an Alfisol and has probably developed under trees.

On the basis of soil properties, this footslope can be divided into two distinct units (Figure 8). On the upper portion of the footslope (unit A) surface erosion is quite evident, the soil surface is usually bare and A-C profiles predominate. Profile T-2-3 is located near the base of this unit. The lower boundary of unit A is the St. Peter-Prairie du Chien contact. A decrease in slope gradient occurs at this contact.

The middle and lower footslope (unit B) has a 10 to 20% slope gradient and is developed on weathered sandy limestone. Soil sola are thicker toward the base of the slope and the surface is 100% covered by grass and cedars. The generalized soil pattern is similar to that encountered on the north-facing slope along transect 1. Entisols dominate the upper portion of the footslope and lower sideslope, Inceptisols are found downslope where slope gradients range between 20 and 40%. Alfisols are present on the lower footslope where slope gradients are generally less than 20%.

Mound 4 is located on the lower footslope and was constructed from leached, loamy deposits. An Inceptisol which exhibits a dark brown profile has developed in the central portion of the mound. The solum is 25 centimeters thick, contains an A3 rather than an A2 horizon and a few discontinuous grainy coats are present in the B horizon.

Two separate mound fill layers were recognized at profile 4-1 on the basis of morphology. The upper unit was dark brown while the lower unit was composed of dark yellowish brown and yellowish brown basketloads of earth. Pieces of burned earth, charcoal flecks, ash, and a few artifacts were disseminated throughout the lower unit.

A truncated B horizon was encountered at the base of the mound. This was distinguished from the overlying mound fill on the basis of structure and the presence of cutans and grainy coats. It also contained rounded metamorphic and igneous pebbles at about 1 meter below the mound surface. These pebbles appear to be within alluvium which, prior to mound construction, had been mantled with sideslope deposits. At the base of the footslope then, loamy sideslope deposits mantle a loamy terrace which contains rounded metamorphic and igneous pebbles. Soils present in this portion of the slope were originally formed in stratified material, but due to mound building activity the upper loamy sideslope deposit has been removed from most of the area and incorporated into mounds.

Summary

(1) Soils developed on the surrounding bench have thicker sola and more structural development than those on Bluff Top Mound.

(2) The fill of all mounds investigated appears to have been derived from the A and upper B horizons of soils developed on the surrounding slopes.

(3) At mound complexes in northeastern Iowa, an abrupt contact between the lower A and upper B horizon of soils developed in loess may indicate the presence of a mound fill borrow area.

(4) Stability of the soil surface increases downslope along transects 1 and 2.

(5) Along transect 1, Entisols occupy the least stable position, Inceptisols are developed on more stable positions, and Alfisols dominate the most stable position on the slope.

(6) It appears that a large portion of the lower footslope in the vicinity of mounds of the Keller Group was disturbed during mound construction.

(7) An Inceptisol has developed in the fill of Mound 23 while an Entisol has developed in the fill of Mound 29. Burial of Mound 29 by an alluvial cone accounts for this difference.

(8) An Inceptisol located .3 meters east of Mound 29 has developed in disturbed material overlying a truncated B horizon.

(9) Profiles sampled along transect 2 have developed on slope deposits overlying sandy Prairie du Chien limestone.

(10) Entisols are on the least stable landscape position along transect 2, Inceptisols on more stable portions of the slope, and Alfisols on the most stable position at the base of the footslope.

(11) An Inceptisol has developed in the fill of Mound 4.

(12) Soils developed on mounds of the Keller Group are less strongly developed than soils on the adjacent slopes.

(13) Weakly expressed A2 horizons have developed in the fill of Mounds 23 and 4 of the Keller Group and Bluff Top Mound during the 1600 years since their construction.

(14) Color B horizons have developed in all mounds studied except Mound 29 of the Keller Group.

<u>Particle size analysis</u>

Results of the particle size analysis are presented in tabular form in Appendix C and graphically in Figures 9 through 22.

<u>13AM243</u> The Seaton profile is within the silt loam and light silty clay loam textural classes (Figure 9). Percent sand (>50μ) ranges from 35 in the A1 horizon to between 14 and 10 in the rest of the solum. Silt (50-2μ) is most abundant in the A2 horizon. Fine silt (20-2μ) is most abundant in the A21 horizon while coarse silt (50-20μ) has its maximum in the A22 horizon. About twice as much coarse silt as fine silt is present in the Seaton profile. This relationship is characteristic of Seaton profiles (Soil Survey Staff, 1966; Hole, 1976) and reflects a local source area for the loess in which this series has developed.

Clay percentage is lowest in the A horizons (approximately 10

Figure 9. Particle size distribution of the Seaton profile

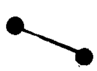
Key for particle-size depth distributions
(Figures 9 through 22)

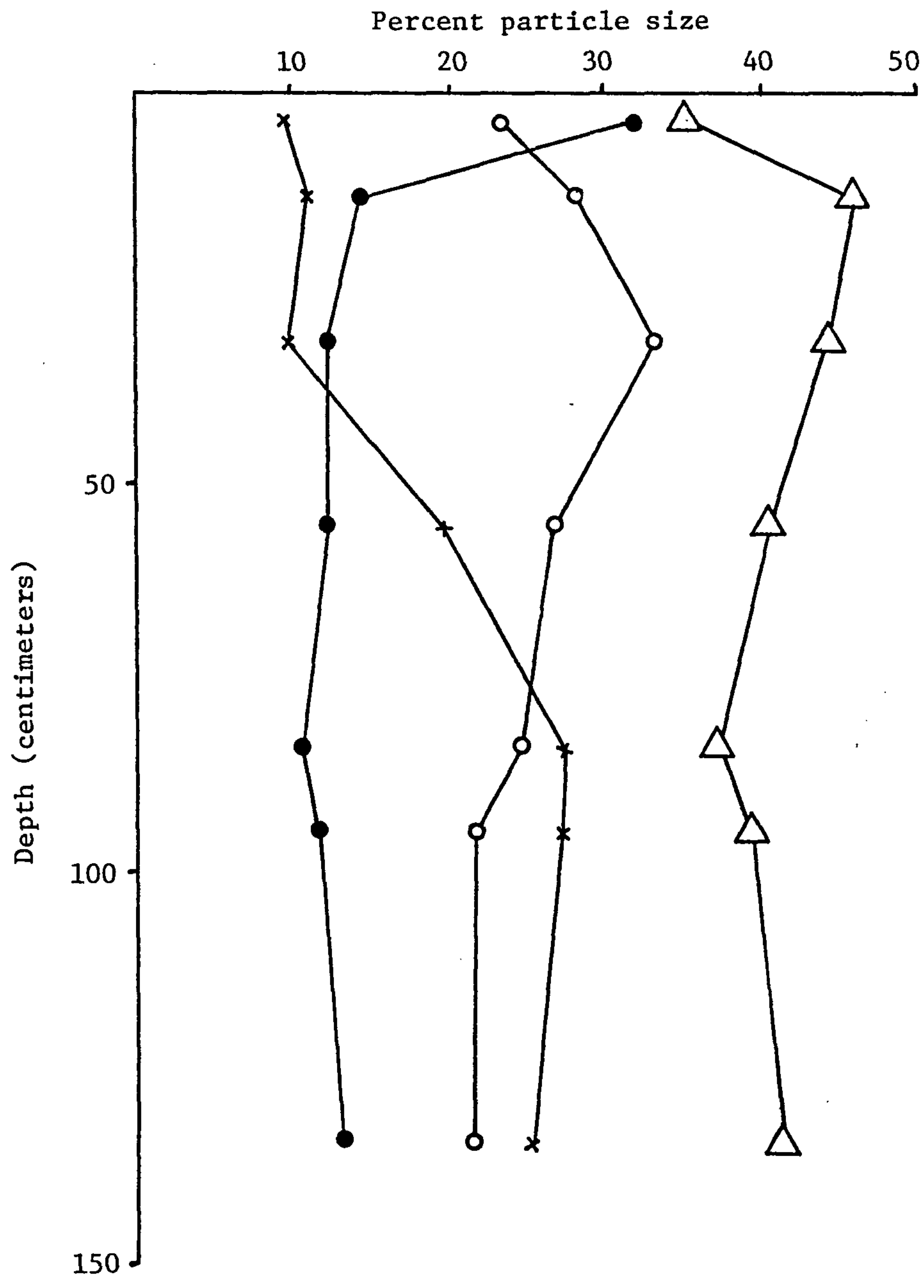
 Clay (<2μ)

 Coarse silt (50-20μ)

 Fine silt (20-2μ)

 Coarse silt plus fine silt (50-2μ)

 Sand (>50μ)


Percent particle size
10
20
30
40
50
Depth (centimeters)
50
100
150

percent) and reaches a maximum of 27 percent in the B25 horizon. An argillic horizon is an illuvial horizon in which layer-lattice silicate clays have accumulated to a significant extent (Soil Survey Staff, 1975). An argillic horizon was recognized in the Seaton profile on the basis of clay films described in the field. Another requirement for a horizon to be considered argillic is an increase of 20 percent or more in the clay content within a vertical distance of <15 centimeters (Soil Survey Staff, 1975, p. 20). A 37 percent clay increase occurs from the B1 to the B21t horizon in the Seaton profile. This clay increase and the morphology meet the criteria for an argillic horizon.

A coarse silt to fine silt ratio of 1.63 was calculated for the B2t horizon of the Seaton profile. Muckenhirn et al. (1955) reported coarse silt to fine silt ratios of 1.50 to 2.49 in the B2 horizon of Seaton soils in their study. The average ratio was 1.97.

McKim (1972) suggests that B/A clay ratios may be an indicator of horizon differentiation and profile development. This ratio is determined as:

$$\text{B/A clay ratio} = \frac{\text{maximum clay content in B horizon}}{\text{maximum clay content in A horizon}}$$

The B/A clay ratio of the Seaton soil is 2.91. Since the parent material appears to be relatively homogeneous, this value of the ratio suggests either formation of clay in place or its translocation from upper to lower horizons. It is probable that both of these processes have operated to produce the clay increase recorded in this profile.

As mentioned previously, an Inceptisol has developed in the surface of Bluff Top Mound. Particle size data support this classification and indicate that no textural B horizon has developed in the fill. Sand content is highest in the A1 horizon (39 to 24 percent), and remains relatively constant (14 to 18 percent) with depth in the remainder of the solum and mound fill. Particle-size distribution of the truncated B3 horizon encountered under the sideslopes of the mound (Figures 10 and 11) is similar to the particle size distribution of the B3 horizon in the Seaton soil off the mound.

Within the mound fill, average percents of clay, fine silt, coarse silt, and sand are 17, 24, 42 and 17. These averages are quite similar to the combined average percentage of these separates in the A1 through B22t horizon of the Seaton soil. In the Seaton soil, sand averages 16 percent; fine silt, 24 percent; coarse silt, 40 percent; and clay, 17 percent. These data support the hypothesis that mound fill was obtained from the A and B horizons of a Seaton soil developed on the bench at the time of mound construction.

Particle size distribution within the burial pit fill in the central portion of the mound (Ce6) is very similar to that in the underlying undisturbed C horizon (Figure 12). This fact, plus the presence of carbonate concretions in both units, suggests that this fill was removed from the burial pit area by the Indians and used to fill the pit after artifacts and bones were placed in the pit and ceremonies performed.

B/A clay ratios were calculated for the three mound profiles analyzed. This ratio was greatest on the east-facing sideslope (2.23), intermediate in the central portion of the mound (1.5), and lowest on the

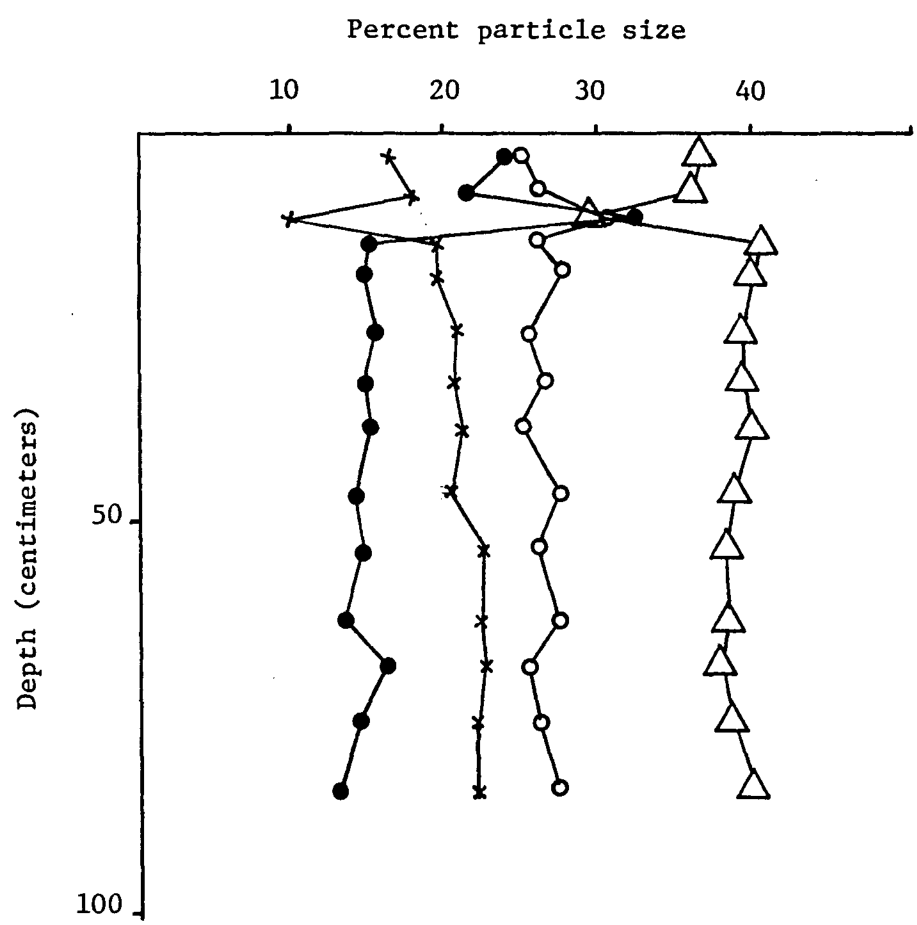


Figure 10. Particle size distribution of profile BT-1

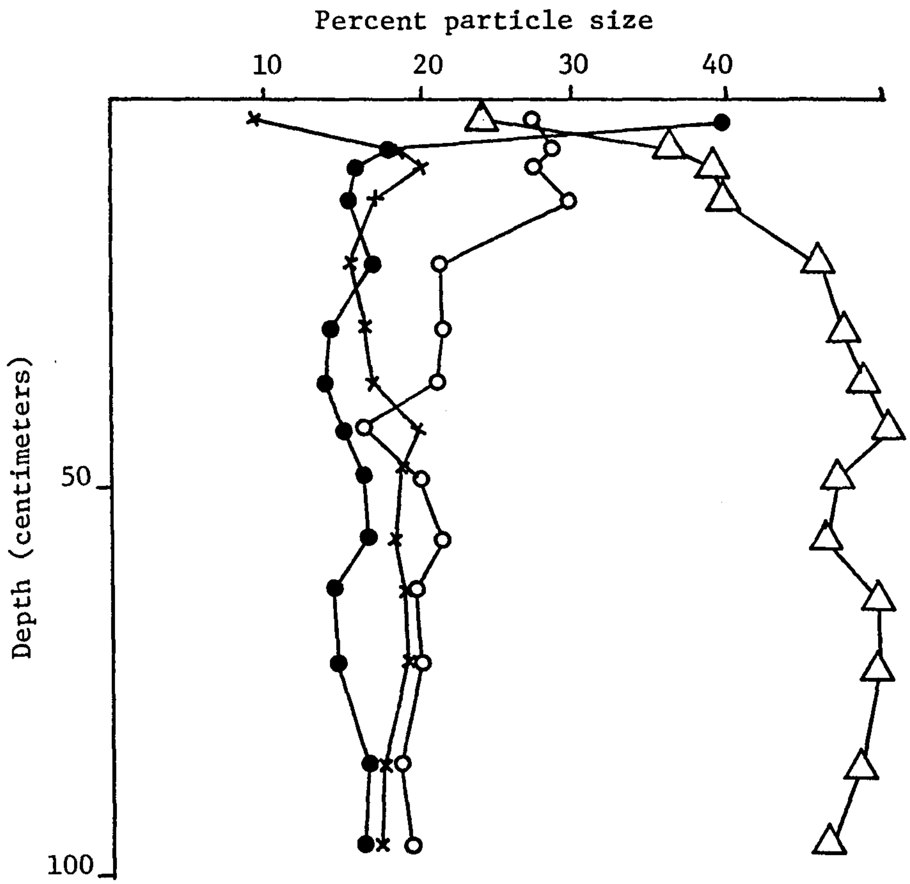


Figure 11. Particle size distribution of profile BT-3

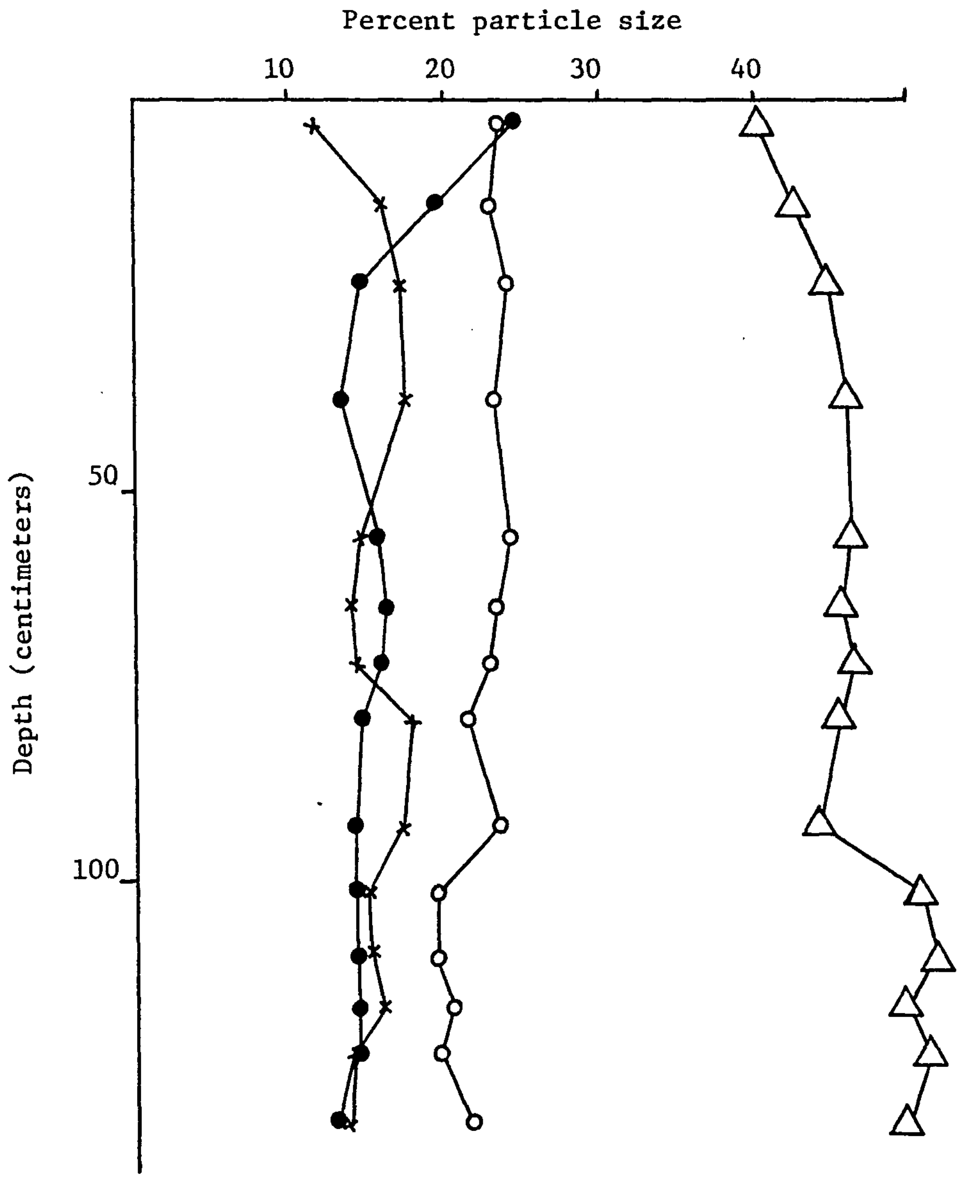


Figure 12. Particle size distribution of profile BT-2

west-facing sideslope (.93). These values are all less than the B/A clay ratio for the Seaton soil (2.91) and indicate that horizon differentiation is greatest in the Seaton soil.

Transect 1 (north-facing slope) Profile T-1-3, an Inceptisol located on the upper north-facing footslope, has sandy loam texture throughout (Fig. 13). Percent sand ranges from 67 to 73. The highest amount is in the B horizon. Separation of the sand into Wentworth size classes (Table 3) indicates that more than 65 percent of the sand is fine and very fine (>2.0ϕ) (Table 4). The A1 horizon has the coarsest sand fraction while that in the A2 horizon is the finest. This could indicate weathering of coarse and medium sand grains into fine and very fine grains within the A2 horizon.

Silt content averages 21 percent in this profile and reaches a maximum of 25 percent in the A1 horizon. Coarse silt (50-20μ) comprises over 50 percent of the silt fraction throughout this profile.

Percent clay was highest in the A2 horizon (9 percent) and lowest in the A1 (7 percent). No zone of clay accumulation was apparent in the B horizon. The B/A clay ratio for this profile is 1.29.

St. Peter Sandstone, forming a freeface above profile T-1-3, is a relatively pure, fine to medium grained sandstone (Willman et al., 1975). It appears that the parent material for the soil developed at T-1-3 consists predominantly of weathered St. Peter Sandstone with additions of aerosolic dust and silt and clay washed from the bluff above the freeface. Jackson et al. (1973) suggest that dustfall supplies fine silt and clay to soils at an approximate rate of 1.0 m/million years. Berg (1979)

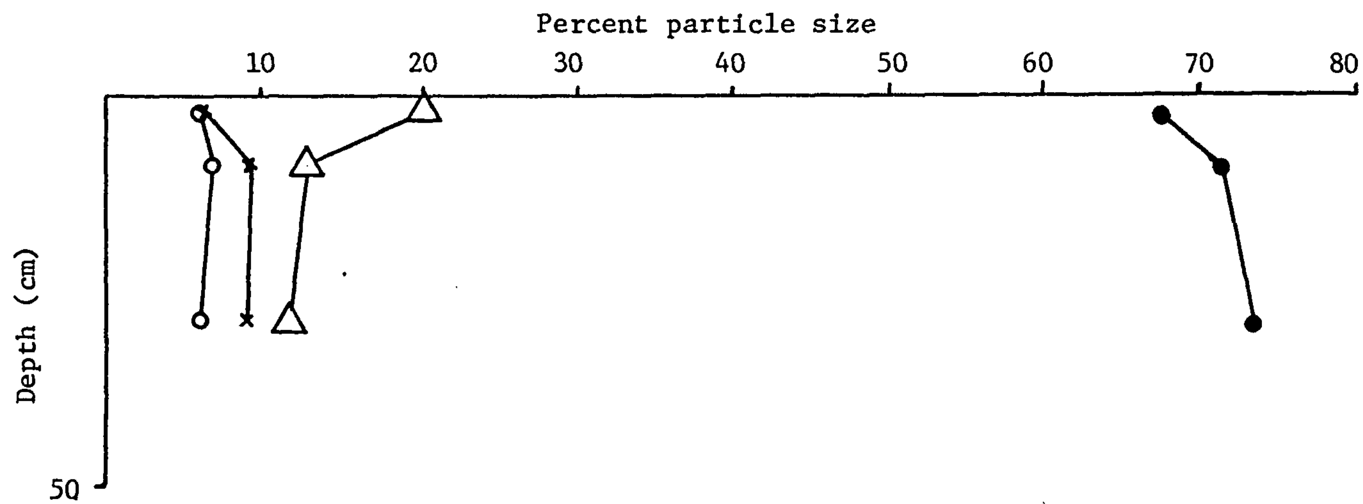


Figure 13. Particle size distribution for profile T-1-3

Table 3. Grain-size scales for sand particles

Phi (ϕ)	Millimeters (mm)	Wentworth size classes
-1.00	2.00	
-0.75	1.68	Very coarse sand
-0.50	1.41	
-0.25	1.19	
0.00	1.00	
0.25	0.84	
0.50	0.71	Coarse sand
0.75	0.59	
1.00	0.50	
1.25	0.42	
1.50	0.35	Medium sand
1.75	0.30	
2.00	0.25	
2.25	0.210	
2.50	0.177	Fine sand
2.75	0.149	
3.00	0.125	
3.25	0.105	
3.50	0.088	Very fine sand
3.75	0.074	
4.00	0.0625	

Table 4. Results of separation of sand fraction into Wentworth size classes

Profile	Horizon	Depth (cm)	Percent of total mineral weight				
			>.1 mm	>.5 mm	>.25 mm	>.125 mm	>.625 mm
T-1-3	A1	0-3	0	5	19	19	24
	A2	3-18	0	3	7	24	35
	B	18-41	0	4	10	27	32
	R	41-	--	--	--	--	--
T-1-1	A1	0-5	1	15	22	14	12
	A2	5-15	0	4	10	22	26
	B11	15-26	0	4	8	24	36
	B12	26-46	0	4	8	23	35
	B2t	46-70	0	3	6	20	30
	R	70-	--	--	--	--	--
T-2-2	A1	0-5	0	1	5	9	25
	A2	5-19	0	1	3	9	26
	B11	19-38	0	1	4	10	29
	B12	38-57	0	0	2	10	31
	B2	57-84	0	1	3	13	34
	R	84-	--	--	--	--	--
T-2-1	A1	0-8	0	2	3	10	27
	A2	8-20	0	1	2	10	30
	B11	20-35	0	0	2	9	28
	B12	35-43	0	0	2	8	27
	B2t	43-81	0	0	1	8	29
	B3	81-91	0	1	6	16	30
23-3	A1	0-8	0	3	9	10	38
	A2	8-18	1	3	7	20	38
	B1	18-24	0	3	7	22	41
		24-32	0	3	5	21	43
		32-38	0	3	5	20	43
	B2	38-46	0	3	5	21	43
	Ce	46-54	0	3	5	22	41
		54-62	1	4	7	21	37
		62-70	0	3	7	20	39
		70-78	0	3	5	20	41
		78-86	0	3	6	19	39
	IIBb	86-100	0	2	5	20	40
29-1	A1	0-7	1	11	31	22	16
	A&B	7-13	0	12	30	25	18
	Ce1	13-21	1	14	31	26	15
		21-29	0	10	26	30	22

Table 4. Continued

Profile	Horizon	Depth (cm)	Percent of total mineral weight				
			>.1 mm	>.5 mm	>.25 mm	>.125 mm	>.625 mm
	Ce2	29-34	1	14	31	28	16
		34-38	1	20	31	19	15
		38-42	0	12	30	26	18
		42-46	0	9	24	27	24
		46-50	0	14	28	25	19
		50-54	0	8	23	27	26
	Ce3	54-58	0	11	26	26	22
		58-62	0	6	21	30	27
		62-64			missing		
		64-70	0	11	24	25	21
		70-75	1	14	30	24	18
		75-80	0	9	26	26	23
		80-85	1	11	25	25	21
		85-94	1	11	24	26	23
	IIBb	94-107	1	11	25	26	22
29-2	A1	0-6	0	3	7	16	39
	A2	6-15	0	2	6	18	40
	B11	15-20	0	2	6	19	39
		20-25	0	2	4	18	42
		25-30	0	2	5	20	40
		30-36	0	3	5	18	42
	B12	36-41	0	3	5	20	40
		41-46	0	2	4	18	42
	B21	46-51	0	2	4	18	39
		51-56	0	1	4	18	42
		56-61	0	2	6	17	38
		61-66	0	2	5	20	39
		66-74	0	2	4	19	39
	B22	74-76	0	2	5	18	39
		76-81	0	1	5	20	38
		81-86	0	2	6	21	36
		86-94	0	2	6	20	35
	IIB2b	94-102	0	3	7	21	34
	IIB3b	102-110	0	3	7	23	31
		110-120	0	3	7	23	32

concluded that some of the clay present in soils developed on the Illinois Beach Ridge Complex originated from dustfall during and subsequent to dune formation. Location of the study area adjacent to the Mississippi River floodplain (a local dust source) makes it highly probable that accretion of airborne silt and clay has occurred here.

In profile T-1-1, an Alfisol located on the lower footslope in the vicinity of Mounds 23 and 29 of the Keller Group, percent sand ranges from a minimum of 61 in the B2t horizon to a maximum of 71 in the B12 horizon (Fig. 14). Again, this is predominantly fine and very fine sand (Table 4). Sand is coarsest in the A1 horizon and finest in the B2t.

Size distribution within the sand fraction is very similar in both profiles along transect 1. If surface wash was a significant factor in development of this slope, soils on the upper footslope should be coarser textured than those on the lower footslope. Walker (1965) and Kleiss (1970) reported this trend on slopes developed in glacial till and loess, respectively, in Iowa. A lack of significant differences in the sand fraction of profiles on the upper and lower footslope suggests that overland flow and surface wash are not significant factors influencing development of this slope. Due to the coarse texture and resulting rapid infiltration of precipitation on this slope, most water falling on the surface moves downslope as throughflow. It is inferred that overland flow does not occur except on alluvial cones.

Silt content averages 25 percent in profile T-1-1 and reaches a maximum of 29 percent in the A2 horizon and a minimum of 20 percent in

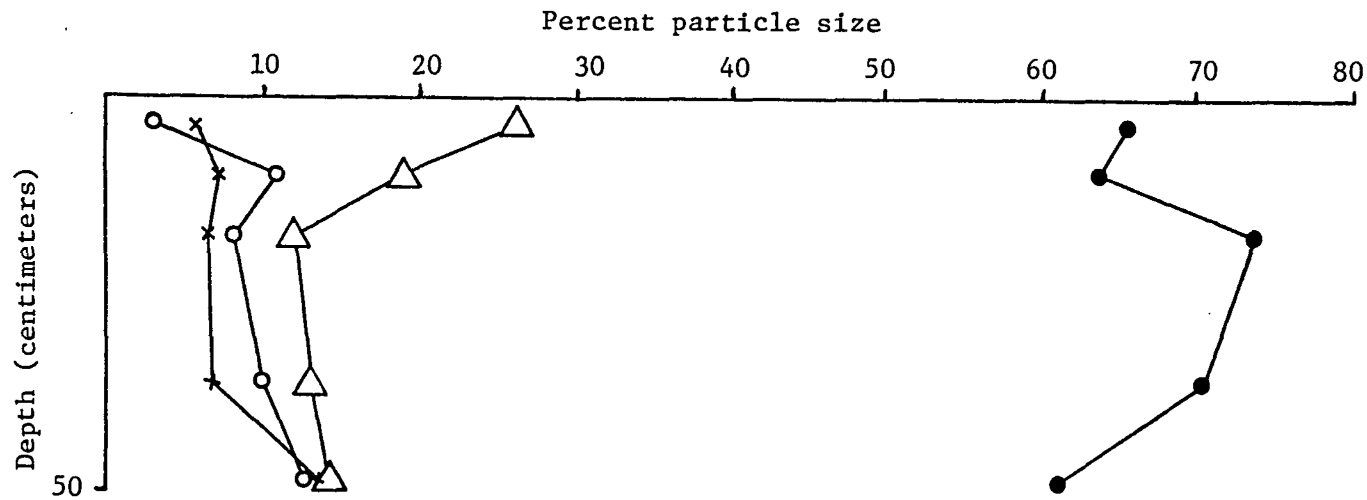


Figure 14. Particle size distribution of profile T-1-1

the B11. Over 60 percent of the silt present is coarse silt.

Clay content averages 8 percent in this profile. It ranges from 13 percent in the B2t horizon to 6 percent in the A1. A 100 percent clay increase occurs from the B12 to the B2t horizon and the latter horizon qualifies as argillic. The B/A clay ratio is 2.29. Compared to the value of 1.29 for this ratio at profile T-1-3, this indicates greater horizon differentiation on the lower footslope than on the upper footslope.

As mentioned previously, Mound 23 is located on the lower footslope and has an Inceptisol developed on its surface. Within the mound fill, sand ranges from a low of 65 percent to a high of 73 percent (Figs. 15, 16 and 17). Fractionation of the sand in profile 23-3 into Wentworth size classes shows a distribution similar to that in profile T-1-1 (Table 4) and suggests that the mound fill was obtained from the A and B horizons of soils developed on the lower footslope at the time of mound construction.

Silt averages 22 percent in the mound fill and usually reaches a peak of about 24 percent in the A2 horizon. Over 60 percent of the silt present is coarse silt.

Clay averages 9 percent within the mound fill. No zone of clay accumulation is apparent and it is inferred that differences in the clay content within the fill are a product of original differences in the clay content of the fill used to construct the mound.

B/A clay ratios were calculated for the profiles collected from Mound 23. Profile 23-1 (west-facing sideslope) has the largest value

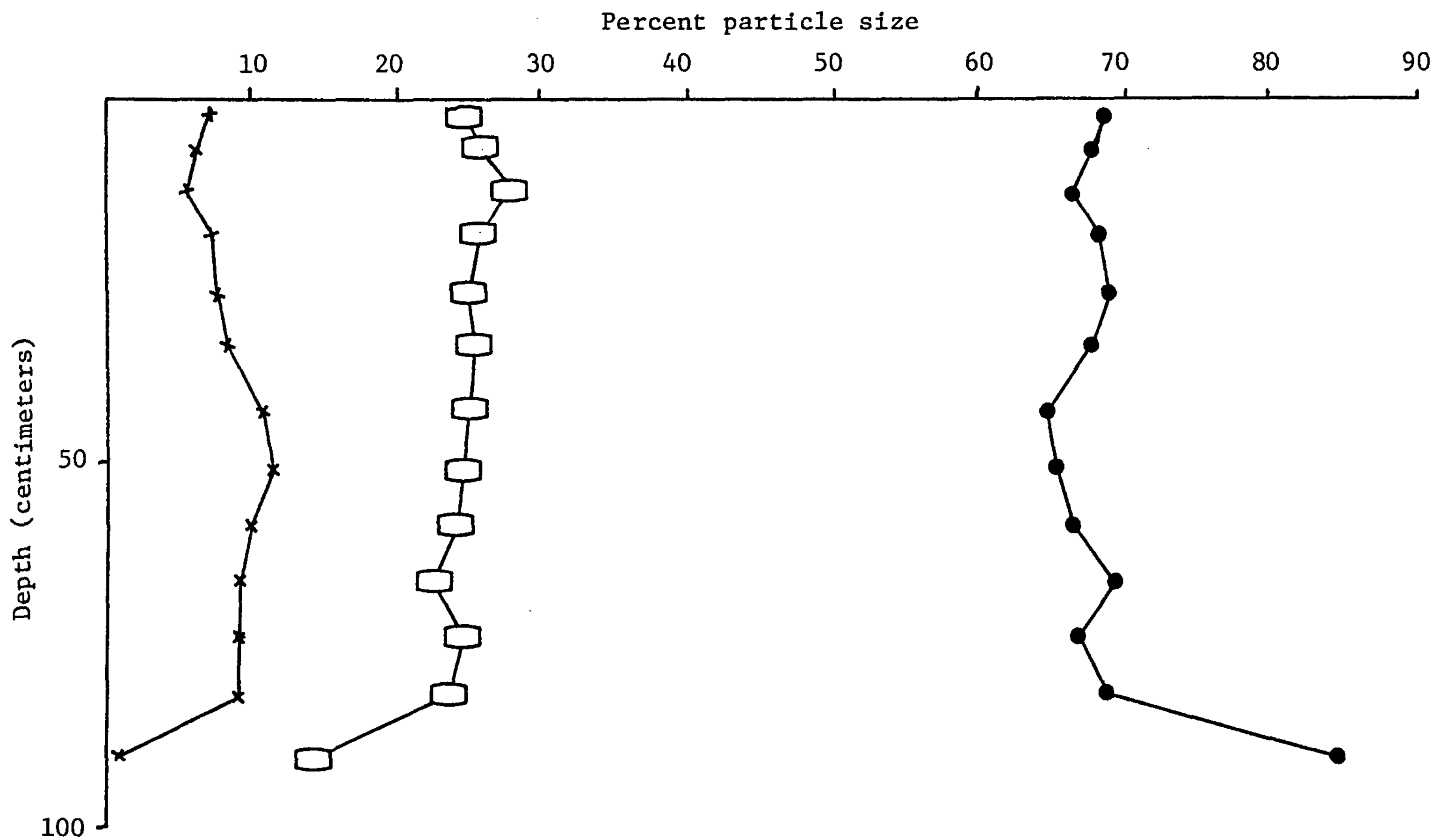


Figure 15. Particle size distribution of profile 23-1

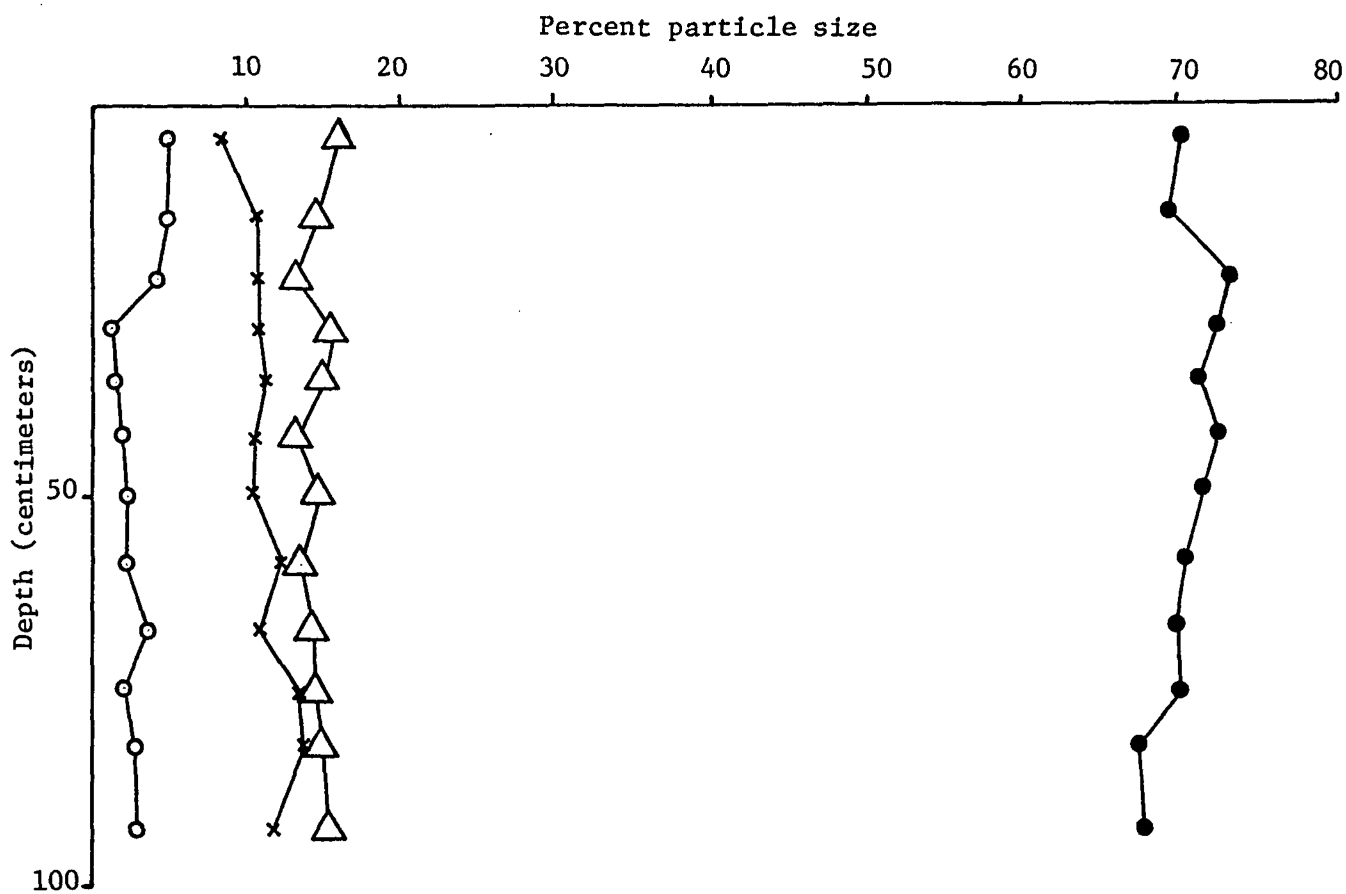
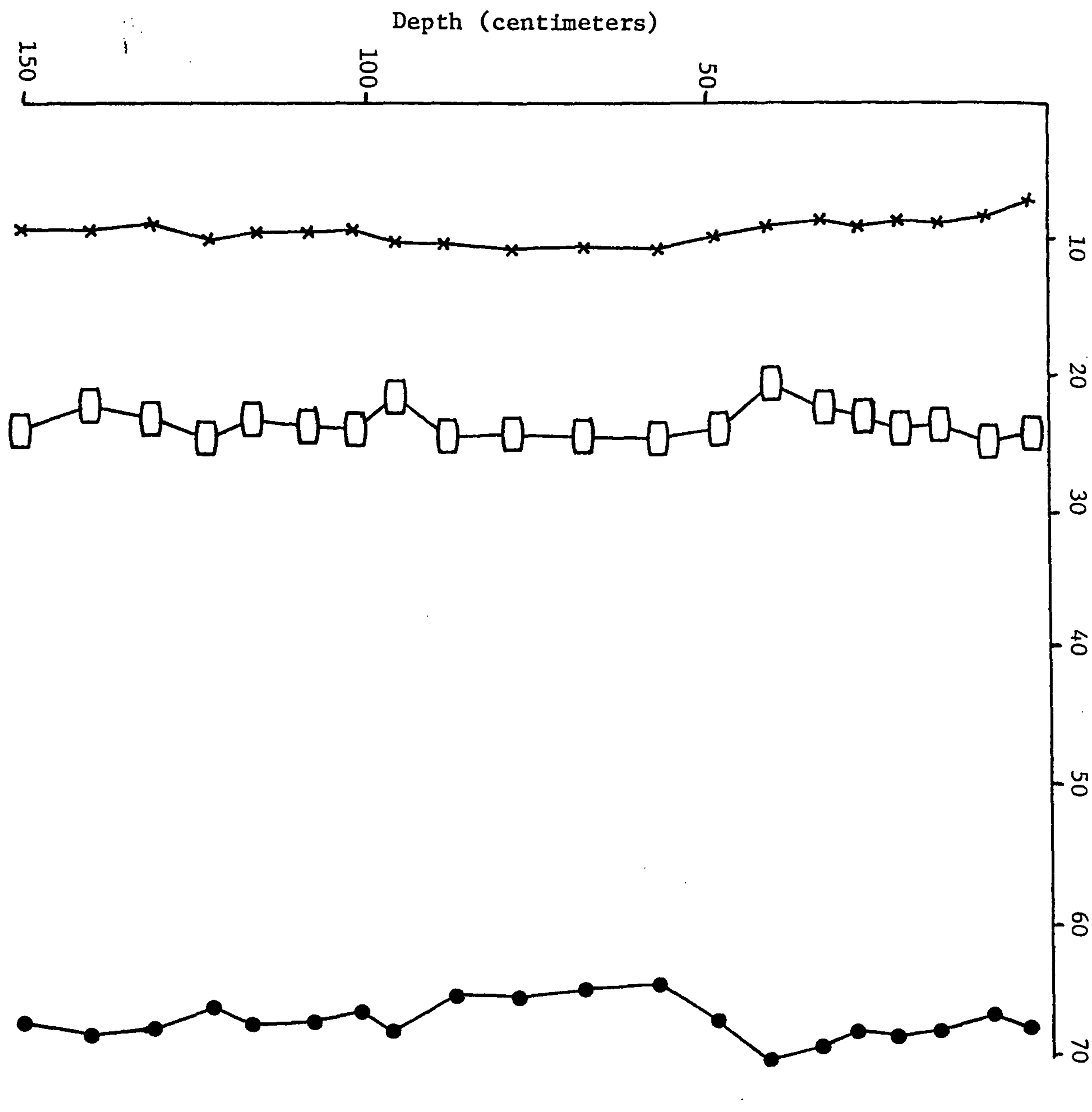


Figure 16. Particle size distribution of profile 23-3

Figure 17. Particle size distribution of profile 23-2


Depth (centimeters)
150
100
50
10
20
30
40
50
60
70

(1.91), 23-3 (east-facing sideslope) is intermediate (1.38) and 23-2 (mound center) has the lowest value (1.26). The wide variation of this ratio could be a result of low clay content of the solum, thereby accentuating the influence of small changes in clay percentage on the B/A ratio. Profiles on the mound do show a smaller B/A ratio than the profile off the mound (T-1-1), indicating less horizon differentiation in the mound profiles.

Silt and clay contents of the mound, when compared to those of profile T-1-1, indicate that a mixture of A and B horizons of a soil similar to the Alfisol at T-1-1 was used to build this mound. This follows the pattern of borrowing mound fill from the adjacent mound area exhibited throughout the Effigy Mound area.

Scholtes (1970) examined cores taken from several mounds at the Fish Farm Mound Group (13AM100), located on a north- and east-facing high terrace of the Mississippi River approximately 28 km (15 mi.) north of the Keller Group. Based on field morphology and results of laboratory analyses, he concluded that the soils developed in these mound fills showed no apparent zone of clay accumulation. They were generally very weakly developed.

Most of these mounds had particle size distributions similar to Mound 23 of the Keller Group. Mounds investigated at Fish Farm were larger than those of the Keller Group and may have been better drained. Charcoal from Mound 17 at Fish Farm was C-14 dated at 1615 ± 9S (Scholtes, 1970; I-5525) indicating the mound was constructed about 335 A.D. Therefore, soils on Mound 17 at Fish Farm and Mound 23 at

Keller have been developing for about the same amount of time. They have similar particle size distributions. It is inferred that the soil on Mound 23 at the Keller Group appears to be more strongly developed than those on mounds at Fish Farm due to differences in drainage and microclimate.

Mound 29, located about 40 meters east of Mound 23 at the base of an alluvial cone, has an Entisol developed on its surface (profile 29-1, Figure 18). Percent sand ranges from 81 in the A1 to 87 in the upper fill. Separation of the sand into Wentworth size classes shows that sand comprising the bulk of this mound is more poorly sorted than that at other profiles sampled on this slope (Table 4).

This mound is built on and partially buried by an alluvial cone which has coarser texture than deposits on the surrounding slope. Mound 29 also has a coarser texture than other profiles on the slope and therefore appears to have been built of material borrowed from the alluvial cone on which it is built.

Silt averages 10 percent in profile 29-1 and is composed of about equal amounts of the coarse and fine fractions. Silt content is highest in the A1 horizon (15 percent) and lowest in the IIBb horizon beneath the mound (7 percent).

Clay content reaches a maximum of 8 percent in the Ce3 horizon, a minimum of 20 percent within the Ce2 layer and averages 5 percent throughout the profile. A zone of clay accumulation is not apparent and a textural B horizon is absent. A B/A clay ratio of .88 calculated for this profile supports the weak development evident from field morphology.

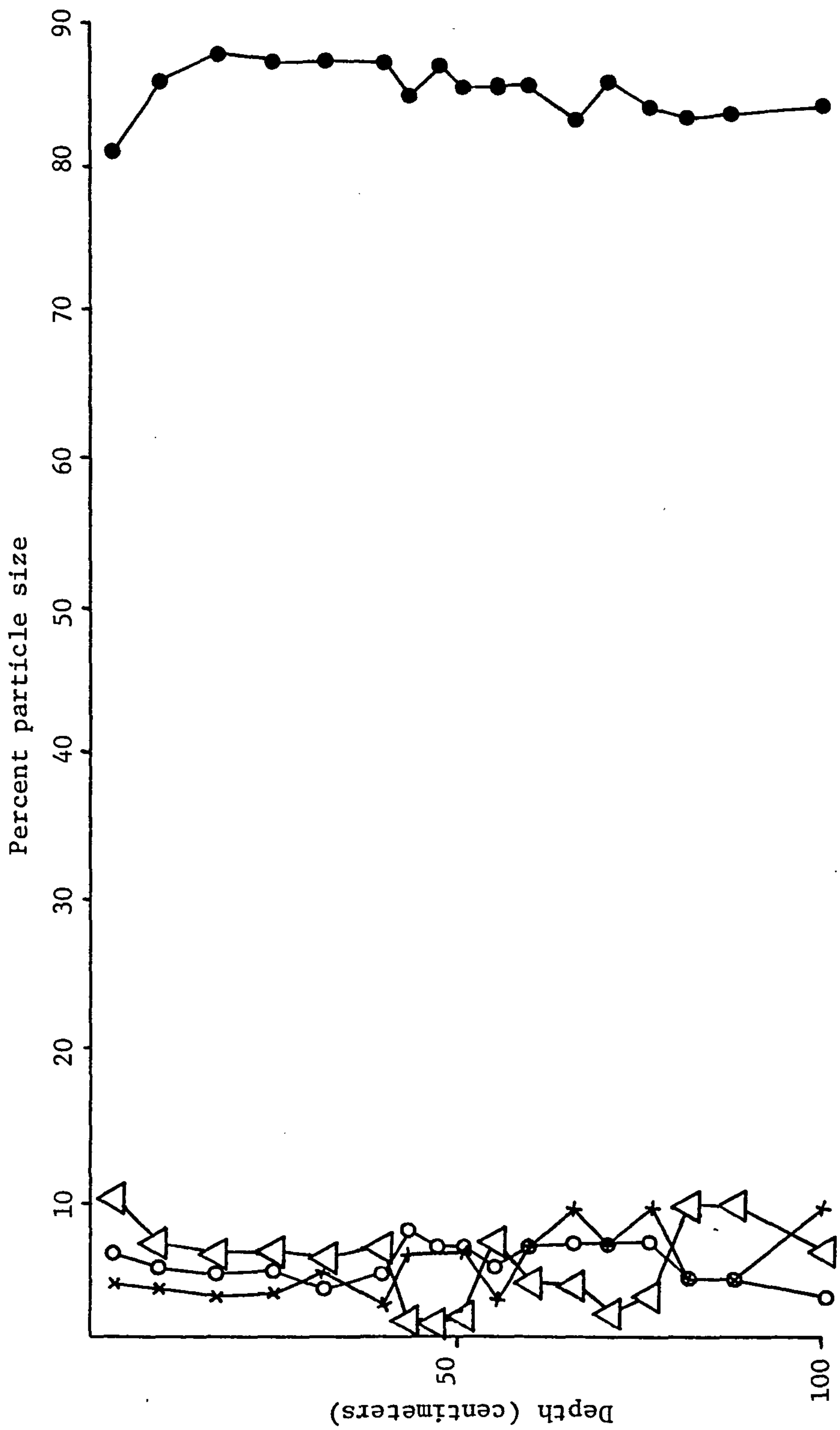


Figure 18. Particle size distribution of profile 29-1

Distribution of the particle size classes in this profile is quite different than in other profiles on the slope. It is suggested that the alluvial cone now burying the southern half of the mound was the source of fill used to build Mound 29. This fill averages 15 percent silt plus clay and contains approximately equal amounts of fine and coarse silt in contrast to an average of 31 percent silt plus clay and at least 50 percent more fine silt than coarse silt in profiles on other portions of this slope. It is suggested that horizon differentiation has been very minimal on Mound 29 due to the initial coarse texture of the fill coupled with relatively continuous burial of the developing soil profile by an alluvial cone.

Profile 29-2 is located .3 meters east of the eastern edge of Mound 29. Sand averages 68 percent in this profile (Figure 19). Separation of the sand into Wentworth size classes indicates that deposits here are very similar to those at T-1-1, over 80 percent of the sand being fine or very fine (Table 4). Silt averages 23 percent in this profile with a maximum of 29 percent in the A1 horizon. Silt is more abundant in the upper 46 centimeters of this profile. Over half of the silt present is in the coarse fraction.

Clay averages 9 percent in this profile with a maximum of 12 percent in the B21 horizon, and a minimum of 6 percent in the A1 horizon. Clay translocation or formation in place is evident below 46 centimeters in this profile. A B/A clay ratio of 1.93 indicates that soil horizons within this profile are well-differentiated.

This profile had been disturbed to a depth of at least 46 centimeters

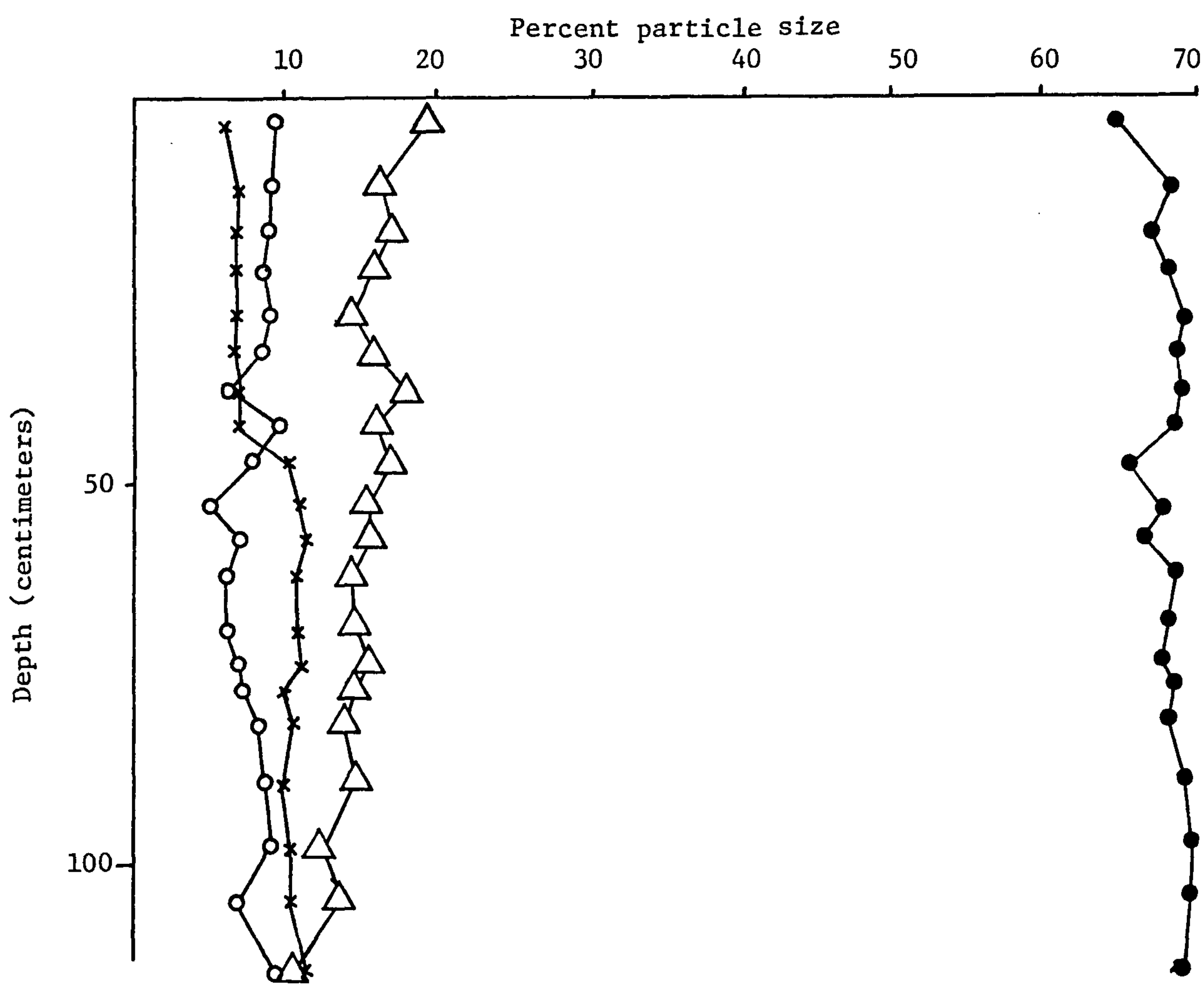


Figure 19. Particle size distribution of profile 29-2

during construction of Mound 29 as evidenced by the presence of charcoal flecks above this depth. Morphology also suggested disturbance to this depth. If the profile originally developed here was similar to that developed at T-1-1 and, if it was subsequently disturbed to a depth of 46 centimeters, the original soil would have been disturbed into the upper B2 horizon.

The horizon designated B31 in the field (94-102 centimeters) may have originally been a lamallae developed deep in the B horizon of the original soil. Following disturbance of the upper horizons, some clay appears to have been transported downward in the profile and deposited above the 94-102 centimeter zone. This profile then, is polygenetic just as other profiles located on this slope.

Transect 2 (west-facing slope) On the west-facing noseslope where Mound 4 is located, soils with loam textures have developed. Profile T-2-2 is located on the upper footslope and an Inceptisol has developed here (Figure 20).

Sand content on this slope is lower than on the previously discussed north-facing slope and averages 45 percent in profile T-2-2. Maximum sand content of this profile is 50 percent. This maximum is in the B2 horizon, which overlies sandy limestone (Prarie du Chien Fm.). Minimum sand content of this profile is 42 percent and occurs in the A2 horizon. Separation of the sand into Wentworth size classes indicates that this sand is finer than that on the north-facing slope (Table 4), with more than 75 percent in the very fine size class. Silt averages about 37 percent in this profile. About two-thirds of the silt present

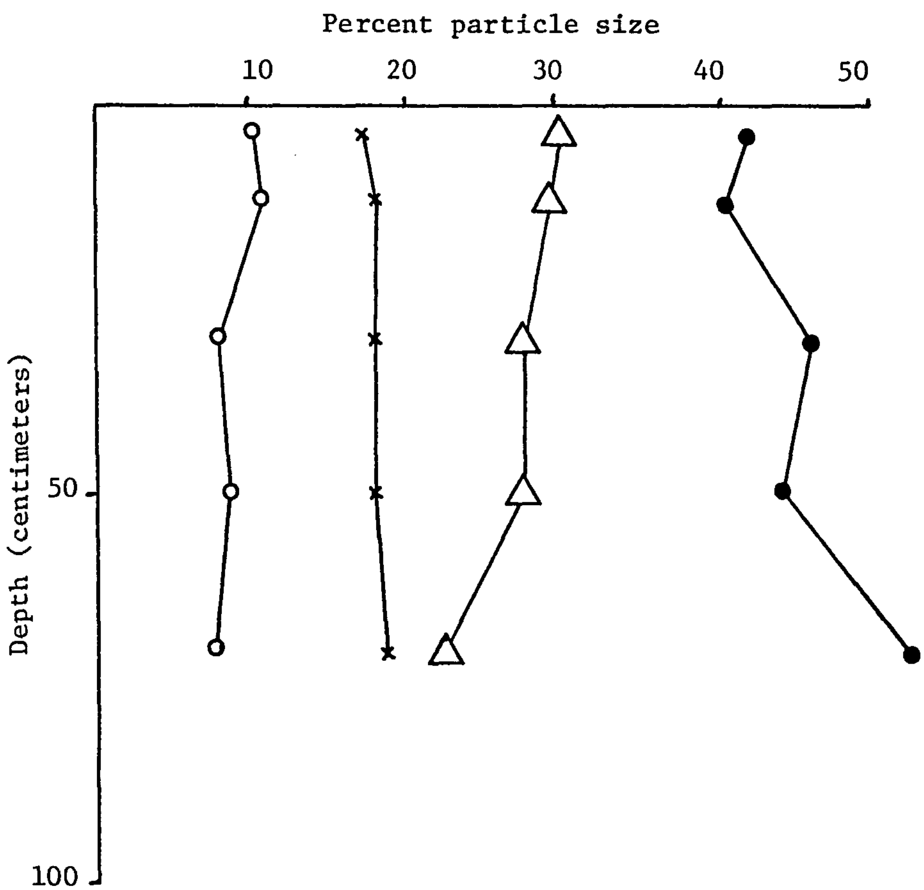


Figure 20. Particle size distribution of profile T-2-2

is coarse silt. Clay averages 18 percent and no zone of clay accumulation is apparent. The B/A clay ratio calculated for this profile is 1.10.

Profile T-2-1 is located lower on the footslope in the vicinity of Mound 4. Sand content averages 43 percent in this profile. The sand has a particle size distribution similar to that in profile T-2-1. Silt content averages 41 percent and decreases markedly in the lower part of the solum (Fig. 21). Coarse silt dominates this fraction.

Clay averages 16 percent in this profile. A zone of clay accumulation qualifying as an argillic horizon is evident beginning in the B21t horizon. Clay content is lowest in the A2 horizon (10 percent) and highest in the B3 horizon (23 percent). The B/A clay ratio is 2.2 for this profile indicating that horizon differentiation is more pronounced here than at profile T-2-2.

Both the north- and west-facing transects had larger B/A clay ratios in soils on the lower footslope than in those on the upper footslope. This could indicate either less surface erosion and more stability on the lower footslope or more favorable conditions for horizon differentiation on the lower footslope. A combination of these causes may also account for the relationship observed.

Mound 4 has an Inceptisol developed on its surface. This profile has loam texture throughout (Fig. 22). Sand content averages 46 percent. This profile is slightly coarser than those on the adjacent slope (T-2-1 and T-2-2). Separation of the sand into Wentworth size classes shows that it is predominantly very fine and quite similar to the sand in profiles

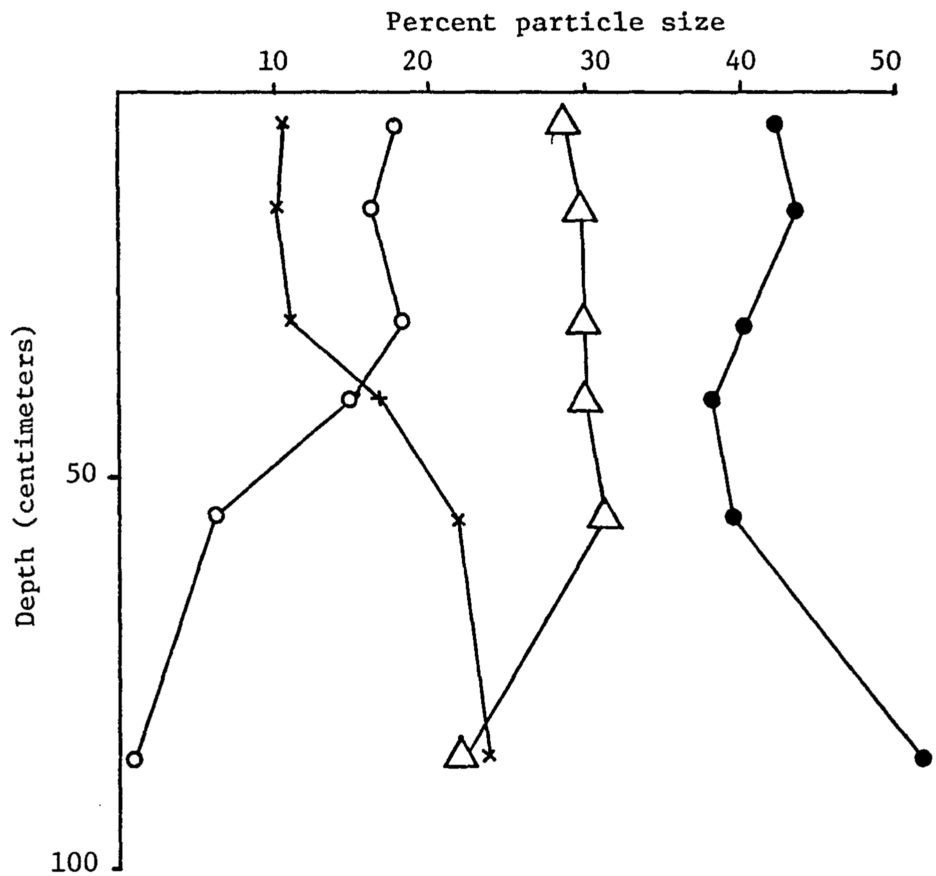


Figure 21. Particle size distribution of profile T-2-1

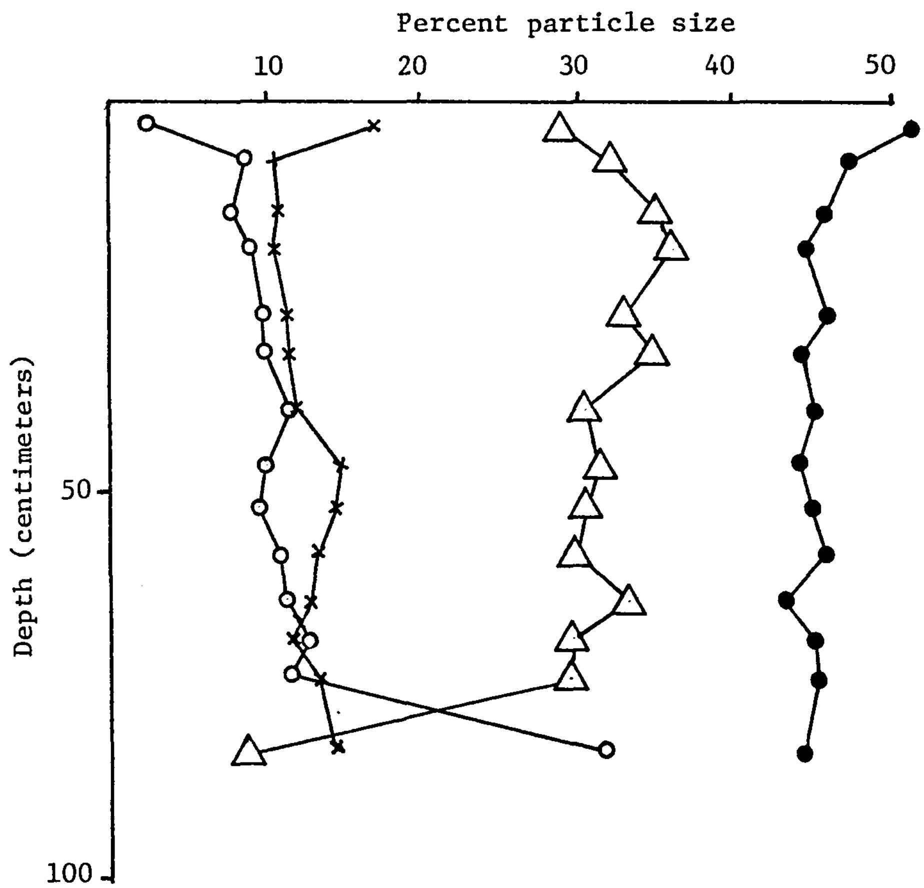


Figure 22. Particle size distribution of profile 4-1

T-2-1 and T-2-2 (Table 4).

Silt content averages 41 percent and, as in the transect profiles, about two-thirds of this size fraction is coarse silt. In the IIB1b horizon underlying the mound three-fourths of the silt is fine silt. This horizon is formed in alluvium and it is inferred that differences in the silt distribution between this horizon and the overlying mound fill are due to differences between the sideslope deposits used to build the mound and the underlying alluvium.

Clay content averages 13 percent in profile 4-1. A zone of clay accumulation is not evident. A B/A clay ratio of 1.0 was calculated for this profile indicating less horizon differentiation than in either of the profiles sampled along transect 2.

Texturally, the fill for Mound 4 is quite similar to the sideslope material on the adjacent slope. It is inferred that Mound 4 was constructed from loamy sideslope material. This material was derived from the upper leached horizons of soils originally developed on the slope in the immediate vicinity of the present mound.

<u>Summary</u>

(1) Soils developed on the surface of Bluff Top Mound and on the surrounding bench have silt loam texture.

(2) Texturally, soils developed on the loess covered bench at 13AM243 are within the range of the Seaton Series, a fine-silty, mixed, mesic Typic Hapludalf.

(3) A B/A clay ratio of 2.91 was calculated for the Seaton Profile. This indicates significant translocation of clay within the profile

or clay formation in place in the B2t horizon.

(4) Particle size data support an upper B or A horizon origin of the fill in the mounds investigated.

(5) B/A clay ratios were lower in mound soil profiles than in soil profiles on the surrounding slopes indicating less horizon differentiation in the mound profiles.

(6) Soils along transect 1 and on Mound 23 are within the sandy loam textural class.

(7) Particle size sorting in the sand fraction is not evident between profiles along either transect suggesting that surface wash is not very important on these slopes.

(8) B/A clay ratios increased downslope along transect 1.

(9) Over half of the silt present in profiles along transect 1 and in Mound 23 is coarse silt.

(10) Mound 29 appears to have been built from upper portions of a soil developed on an alluvial cone. Its fill is much sandier than that of Mound 23.

(11) Profile 29-2 appears to be polygenetic and exhibits clay translocation below the disturbed zone.

(12) Soils along transect 2 have loam textures.

(13) Just as along transect 1, B/A clay ratios increased downslope along transect 2.

(14) A zone of clay accumulation was not present in any of the mound profiles.

pH

Results of the pH analyses are presented in Appendix C.

13AM243 The Seaton profile has a somewhat atypical soil reaction (pH) profile. Maximum pH is encountered in the A1 and A2 horizons (6.7-6.6). A sharp decrease in pH occurs in the B1 horizon and the pH minimum (4.7) occurs in the zone of maximum clay accumulation at a depth of 69 to 120 centimeters.

Richardson (1974) reported that the minimum pH in forest soils in southeast Iowa is usually associated with the zone of maximum clay accumulation. In Fayette profiles from Clayton County Kuehl (1978) found that minimum pH values usually occurred below the zone of maximum clay accumulation. Fayette soils have formed under conditions similar to Seaton soils but Fayette soils have an average of 10 to 15 percent more clay in the B2 horizon than Seaton soils (Soil Survey Staff, 1966). Kuehl found that the Fayette soils in his study had pH curves that were mirror images of the clay curves (Kuehl, 1978, p. 207, also Figure 53). The pH curve for the Seaton soil is also a mirror image of its clay curve (Fig. 23).

Near neutral reaction values have been obtained for the A1 horizon of many Fayette profiles (see Kuehl, 1978; Soil Survey Staff, 1966). This is inferred to reflect accumulation of bases resulting from addition and decomposition of litter at the soil surface. The greater depth distribution of near neutral reaction in the Seaton profile may be a result of the coarser texture of Seaton in comparison to Fayette and a resultant deeper buffering effect of bases added at the soil surface.

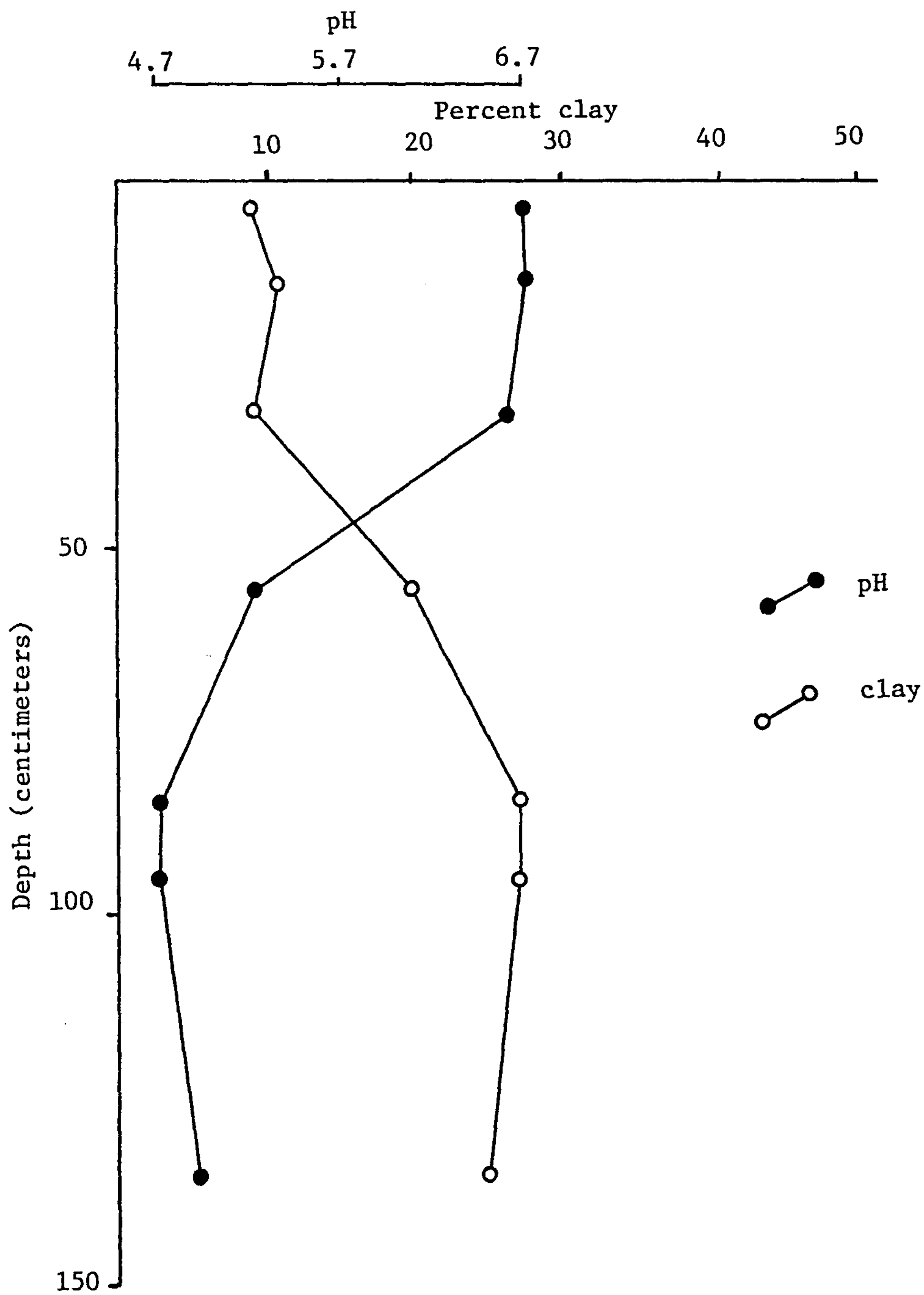


Figure 23. Clay and pH depth distributions of the Seaton profile

Profiles developed in the fill of Bluff Top Mound have reaction values comparable to those of the Seaton profile. Values were near neutral to depths of at least 50 centimeters. On the mound sideslopes (profiles BT-1 and BT-3) a marked decrease in pH occurred at about 50 centimeters below the surface. Within this zone, pH values were lowest in profile BT-1 (5.2-5.5) and about one pH unit higher in BT-3 (6.2). This reaction discontinuity may reflect borrowing of the lower fill material from the B horizon of a Seaton soil. The fill above 50 centimeters may have been borrowed from upper horizons of the same soil which had near neutral reaction.

Profile BT-2, located at the mound center, also has near neutral reaction values in the upper portion of the fill (6.6-6.9). A decrease in pH occurs (5.9-5.5) about 69 centimeters below the surface. The lowest value (5.5) was recorded in the Ce4 layer. On the basis of field morphology, this layer was interpreted as a former surface exposed for a short period of time. The minimum reaction value recorded here supports that interpretation.

A sharp rise in reaction occurs at the top of the Ce6 layer in the center of the mound. This layer is the previously discussed burial pit fill and contains unoriented carbonate concretions. Within this fill pH averages 7.3. Richardson (1974) noted that soils containing carbonates seemed to be buffered at pH levels around 7.8. Kuehl (1978) found that the pH was generally 7.4 to 7.8 where carbonates occurred below soil profiles developed in loess in northeastern Iowa. The relatively high reaction values within the Ce6 layer plus the presence of carbonate concretions suggest that this fill was obtained from the C horizon of the soil originally present at the mound location.

B horizons encountered beneath the fill of Bluff Top Mound have reaction values higher than that recorded in the B3 horizon of the sampled Seaton profile. This could reflect variable reaction values in comparable horizons of soils developed on this bench. The truncated and buried B horizons do show reaction values greater than those in the lower mound fill further supporting the hypothesis that the lower fill was obtained from upper B horizons of soil developed on the bench at the time of mound construction.

Transect 1 (north-facing slope) Soil on transect 1 have reaction values near neutral throughout. Little variation in reaction was noted between horizons. Clay content did not appear to have any effect on reaction. These relatively high reaction values may reflect buffering of the soil pH system by basic groundwater.

The presence of the Lansing Power Station immediately north of the study area may also account for the relatively high reaction values recorded here. Until quite recently flyash (average pH 9-10.0) was regularly released through the stacks and eventually was deposited on the soil surface. Because of the coarse texture and rapid permeability of the soils, the ash may have been washed down into the solum, thereby raising the pH.

Profiles in Mound 23 also had near neutral reaction values. Minimum reaction values were recorded in the surface horizons. Buried B horizons exhibited reaction values slightly lower than the overlying mound fill and significantly lower than the B horizons of soils developed on the adjacent slope. This may support the idea that fly ash has modified original reaction values of soils in the study area. Values obtained in the B horizons buried beneath the mounds may more closely approximate original reaction values.

The soil profile and fill of Mound 29 also exhibit near neutral reaction. A buried B horizon under the mound has a pH of 6.8.

Profile 29-2, located just east of the mound, has near neutral reaction in the upper 36 centimeters. Below this depth, pH begins to drop, reaching a minimum of 5.9 at a depth of 46 centimeters. This minimum reaction value is in the upper B21 horizon. Below this depth, pH gradually increases, reaching 6.9 in the B22 horizon at a depth of 81 centimeters.

After examination of the particle size data, it was concluded that this profile had been disturbed to a depth of 46 centimeters. The reaction data support this conclusion.

<u>Transect 2 (west-facing slope)</u> Profile T-2-2, located on the upper west-facing footslope, has a fairly constant pH of about 6.7. A minimum value of 6.4 was obtained for the A1 horizon, while a maximum value of 6.8 was recorded for the B12 and B2 horizons.

At the base of the footslope where T-2-1 is located a quite different reaction depth distribution occurs. A maximum pH of 6.9 is present in the A1 horizon. Reaction values decrease gradually with depth until a sharp drop from 6.3 in the B21t to 5.4 in the B22t occurs around 43 centimeters below the surface. Lowest reaction values are associated with the zone of maximum clay content in this profile, and the pH curve is almost a mirror image of the clay curve (Fig. 24).

Profile 4-1, located near the center of Mound 4, exhibits yet

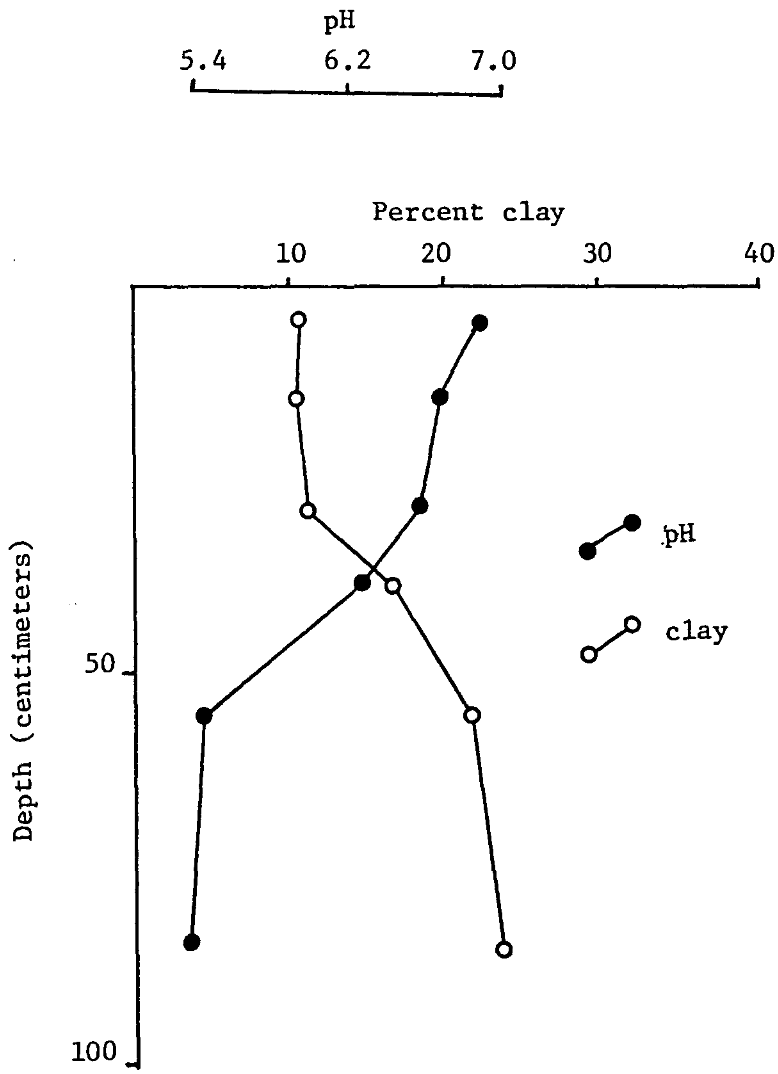


Figure 24. Clay and pH depth distributions in profile T-2-1

another distribution of reaction with depth. At first glance this appears to be a typical reaction profile for a forested soil. Maximum pH occurs in the A2 horizon (6.4) and a minimum (5.2) is reached from 37 to 43 centimeters at the base of the Cel fill. A gradual increase in reaction is recorded below this depth until a value of 6.4 is reached in the buried B horizon beneath the mound.

These relationships may indicate that surface horizons were incorporated into the base of the fill, B horizons with lower reaction values dominated the central portion of the fill, and yet lower portions of the B horizons, where pH was beginning to increase, made up the greater share of the upper mound fill. Formation of this reaction profile in place is unlikely due to the absence of similar profiles at T-2-1 and T-2-2 where the soils have been forming for a longer period of time than that formed in Mound 4.

<u>Summary</u>

(1) The Seaton profile has near neutral reaction values in the A1 and A2 horizons.

(2) The minimum reaction value in the Seaton profile and in profile T-2-1 was associated with the zone of maximum clay accumulation.

(3) pH values within the fill of Mounds 23, 29, and Bluff Top Mound, together with other data discussed previously, suggest placement of material borrowed from B horizons on the mound floor and capping of this fill by material borrowed from A horizons. Mound 4 was built by placing A horizons on the mound floor, followed by middle and finally lower portions of the B horizon.

(4) The Ce4 layer in Bluff Top Mound appears to be a slightly weathered surface.

(5) Little variability in reaction values is present between horizons in soils developed on the north-facing sideslope (transect 1). This may result from buffering of the soil system by fly ash originating at the Lansing Power Plant. Groundwater high in bases may also be a factor.

(6) Soils along transect 2 have decreasing average reaction values as the base of the slope is approached.

Total carbon

Results of the total carbon analyses are presented in Appendix C. With the exception of the lowest five samples from profile BT-2, all samples analyzed were free of carbonates and total carbon was assumed to be the same as organic carbon.

Percent total carbon was always highest in the A1 horizon and lowest at the greatest depth sampled in each profile. A decrease in total carbon occurred in the A2 and B1 horizons of all profiles analyzed. Jenny (1941) considers a high organic matter content which decreases markedly with increasing depth as an indication of the formation of podzolic soils. Podzols form under forest vegetation, and it is suggested that the total carbon distribution of all profiles in the study area indicates formation under the influence of forest vegetation.

13AM243 Total carbon ranged from a maximum of about 8 percent in the A1 horizon of the Seaton soil to a low of .02 percent in the B3 horizon. Comparable total carbon percentages were obtained for the

A1 horizons developed on Bluff Top Mound. Sideslopes had averages of 8 percent in the A1 horizons while the mound center contained 5 percent total carbon in the A1. Comparison of the total carbon content of the mound and Seaton A1 horizons indicates that maximum degree of expression of the A1 horizon has occurred since construction of the mound. The A1 horizon on the mound is not as thick as that in the Seaton profile.

Total carbon percentage of the mound fill below the solum developed in the mound averaged around .25. This value is much higher than the values obtained for the Seaton subsoil. This may reflect inclusion of charcoal and A1 horizon material in the fill during construction of the mound, thereby raising the total carbon level. Beginning about 100 centimeters below the surface in profile BT-2, total carbon percentage begins to increase steadily. This increase is most pronounced in the Ce6 layer, and it is inferred that the presence of free carbonates in this fill layer and the underlying C horizon account for the recorded increase in total carbon.

Transect 1 (north-facing slope) Profiles along transect 1 have the greatest percentage of total carbon within the A1 horizon of all soils analyzed in this study. On the upper footslope the A1 horizon contained 10 percent total carbon, while on the lower footslope total carbon percentage was 11.5 percent in the A1 horizon. The A2 horizons contained markedly less total carbon than the overlying A1 horizons but still had values of 2.7 percent and (T-1-1) 1.5 percent (T-1-2). A north aspect, resulting in cool, moist microclimatic conditions, may account for the relatively high total carbon percentage and greater depth distribution of total carbon on this slope.

On Mound 23 total carbon was much lower in the A1 horizon than in soils on the surrounding slopes. Depth distribution of total carbon was similar to that in profiles on transect 1 with lower absolute values present in the Mound. Profile 23-1, located on the west-facing side-slope, had the lowest total carbon value in the A1 horizon (1.5 percent) while profiles 23-2 (mound center) and 23-3 (east-facing sideslope) had values of 6.5 and 7 percent, respectively. This is inferred to reflect more surface erosion on the west-facing sideslope than on the rest of the mound.

Mound 29 had a total carbon distribution very similar to that at the center of Mound 23. A maximum total carbon content of 6.4 percent occurs in the A1 horizon. Profile 29-2, located just east of the mound, also has a similar total carbon profile but with a maximum of 5 percent in the A1 horizon.

Comparison of the total carbon content of the mound A1 horizon and that of the A1 horizons in transect 1 suggests that a maximum degree of expression of the A1 horizon has not occurred in the time since mound construction in this sandy parent material.

Transect 2 (west-facing slope) Profiles along transect 2 had the lowest total carbon values in the A1 horizon. Total carbon values for horizons below the A1 were comparable to those found in transect 1. The highest total carbon percentage was on the upper foot-slope (T-2-2). Profile T-2-1, located on the lower footslope, had a greater total carbon percentage with depth. It is suggested that differences in aspect account for the lower total carbon percentages of transect 2 in relation to the percentages of transect 1. Soils on the west-facing transect (transect 2) are probably warmer and drier than those along the north-facing transect (transect 1).

Mound 4 has 2 percent total carbon in the A1 horizon. More total carbon is present with depth in the mound than in the slope profiles. This may indicate inclusion of charcoal and A1 horizons in the fill resulting in a greater total carbon content. Comparison of the total carbon content of the A1 horizon on this mound with that of the A1 horizons of profiles T-2-1 and T-2-2 indicates that maximum expression of A1 horizons has not occurred in this material since construction of the mound.

A commonly used means of expressing the total or organic carbon content of soils is in terms of percent organic matter. Percent organic matter in the A1 horizon is used to determine the proper application rate of some herbicides. The percent organic matter of the soil horizon is calculated by multiplying the total carbon content by a factor of 1.72. The results are given in Table 5.

Summary

(1) Percent organic carbon was always highest in the A1 horizon and lowest at the greatest depth sampled in each profile.

(2) A marked decrease in total carbon occurred in the A2 and B1 horizon of all soils in this study.

(3) Total carbon profiles for all the soils in this study suggest development under forest vegetation.

(4) In terms of total carbon percentage, it appears that the A1 horizon

Table 5. Percent organic matter in the Al horizon of soils in this study

Profile	% O.M.	Profile	% O.M.
Seaton	13.5	29-1	11.0
BT-1	5.4	29-2	8.7
BT-2	8.7	T-2-1	6.5
BT-3	14.8	T-2-2	7.59
T-1-1	19.9	4-1	4.0
T-1-3	17.2		
23-1	2.6		
23-2	11.2		
23-3	12.0		

on Bluff Top Mound has reached a maximum degree of expression in the 1600 years since its construction.

(5) Soils developed on the north-facing slope along transect 1 had the highest percent total carbon in the A1 horizon of all soils in this study. This is inferred to be a product of aspect and accompanying microclimatic differences between soils in this study.

(6) Maximum expression of A1 horizons in terms of total carbon percentage has not occurred on Mounds 29, 23, and 4 of the Keller Group.

Total phosphorus

Results of the total phosphorus (TP) analyses are presented in tabular form in Appendix C and graphically in Figures 25 through 37.

13AM243 As shown in Figure 25, the TP maximum in the Seaton soil (494 ppm) occurred in the B22t horizon while the minimum (191 ppm) was in the A22 horizon. A weighted average TP content was calculated for the top 150 centimeters (60 inches) of this profile (Table 6). The value obtained for this profile (369 ppm/cm) is lower than weighted averages obtained by Kuehl (1978) for Fayette and Exette profiles in northeastern Iowa.

Godfrey and Riecken (1954) studied the distribution of TP in a soil development sequence extending from southwest Iowa to northeastern Missouri. They found decreasing amounts of TP in progressively more weathered soils and concluded that a relationship exists between the quantity and distribution of TP and the stage of profile development.

On the basis of TP content, then, the Seaton profile appears to be

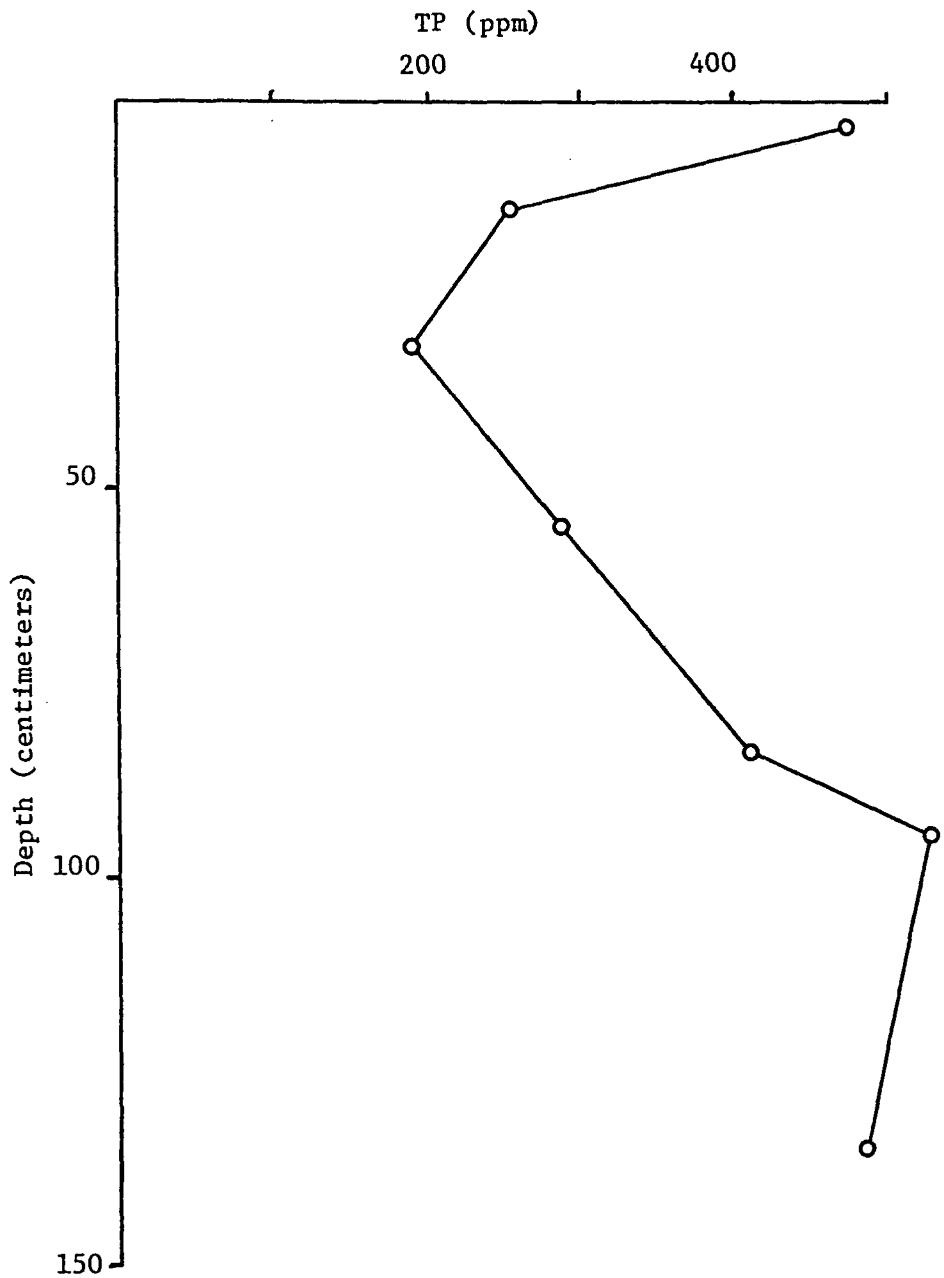


Figure 25. TP depth distribution of the Seaton profile

Table 6. Weighted average TP content and I/E ratios for soils in this study

Profile	Weighted average TP	I/E
Seaton	369 ppm/cm	2.58
T-1-3	284 ppm/cm	.89
T-1-1	403 ppm/cm	2.53
T-2-2	484 ppm/cm	1.17
T-2-1	530 ppm/cm	1.49
29-2	279 ppm/cm	1.60
29-1	159 ppm/cm[1]	.55[2]
23-1	340 ppm/cm	1.64
23-2	309 ppm/cm	1.38
23-3	227 ppm/cm	1.14
4-1	474 ppm/cm	1.22
BT-1	269 ppm/cm	.83
BT-3	272 ppm/cm	1.0
BT-2	295 ppm/cm	.91

[1]Weighted TP averages for mound profiles were calculated on the basis of the whole mound fill and not just the solum of the soil developed on the mound.

[2]I/E ratios are for the solum developed on the mound.

more well developed than the Fayette profiles in Kuehl's study. A B/A clay ratio calculated for the Seaton profile also suggested greater profile development here than was exhibited by the Fayette profiles in Kuehl's study. The greater degree of development of the Seaton profile may be a result of the coarser particle size of Seaton allowing for more rapid translocation of TP and clay. It is also possible that the landscape unit containing the Seaton profile is more stable than that containing Kuehl's Fayette profiles.

An illuvial/eluvial (I/E) TP ratio was calculated for the Seaton profile. Collins (1977) first used this ratio to quantify the movement of TP in soils from Tama County, Iowa. Kuehl (1978) also calculated this ratio for soils in his study.

The I/E ratio is calculated by dividing the maximum TP in the B3 or C horizon by the minimum TP in the A2 or B1 horizon. Kuehl (1978) found that this ratio was highest in Fayette soils on relatively stable summits and decreased with decreasing stability of the landscape position.

The value of this ratio for the Seaton profile is 2.58. This is comparable to the I/E values obtained for B and C slope Fayette profiles in Kuehl's study and indicates significant redistribution of TP within this profile.

Larsen (1967) stated that soil phosphorus can move in three ways: (1) by the action of soil organisms, (2) with flowing water (mass flow), and (3) by thermal movement along a concentration gradient (diffusion). Black (1968) suggests that a phosphorus minimum in the lower A or upper

B horizon of many soils may result from absorption of phosphorus by plants and downward transport of phosphorus by leaching.

Runge and Riecken (1966) and Fenton (1966) obtained evidence of accumulation of phosphorus at depths of 1.5 to 2 meters below the soil surface. The development of a TP illuvial/eluvial profile implies mobility of phosphorus and stability of the soil system in regard to parent material additions or losses. It is apparent, then, that the I/E ratio can be an indicator of the relative degree of development of soils formed in a uniform parent material.

TP profiles for Bluff Top Mound are presented in Figures 26 through 28. These profiles averaged about 100 ppm/cm less than the Seaton profile (Table 6). In profiles BT-1 and BT-3, the buried IIB3 horizon had higher TP contents than the overlying fill. TP values within the fill of these profiles supports an A and upper B horizon origin. It is further suggested that little illuviation/eluviation of phosphorus has occurred in the mound profiles and that the TP distribution here is a product of original TP differences within the fill used to build the mound coupled with post-construction pedogenic modification of these differences.

This modification consists primarily of a TP increase in the A1 horizon accompanied by a decrease lower in the weakly developed solum. Absorption of phosphorus by vegetation and redeposition on the soil surface in litter as suggested by Black (1968) could account for the observed TP profile in the upper mound fill. I/E ratios of the solum developed in the mound surface indicate that the zone of TP accumulation is at the surface (Table 6) and further substantiate vegetation recycling

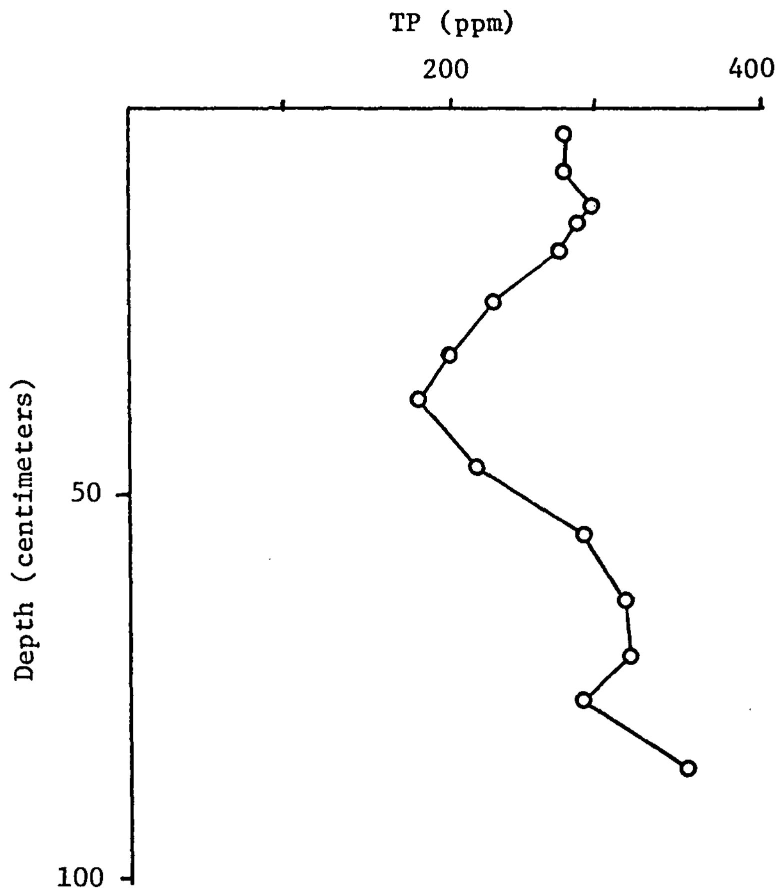


Figure 26. TP depth distribution in profile BT-1

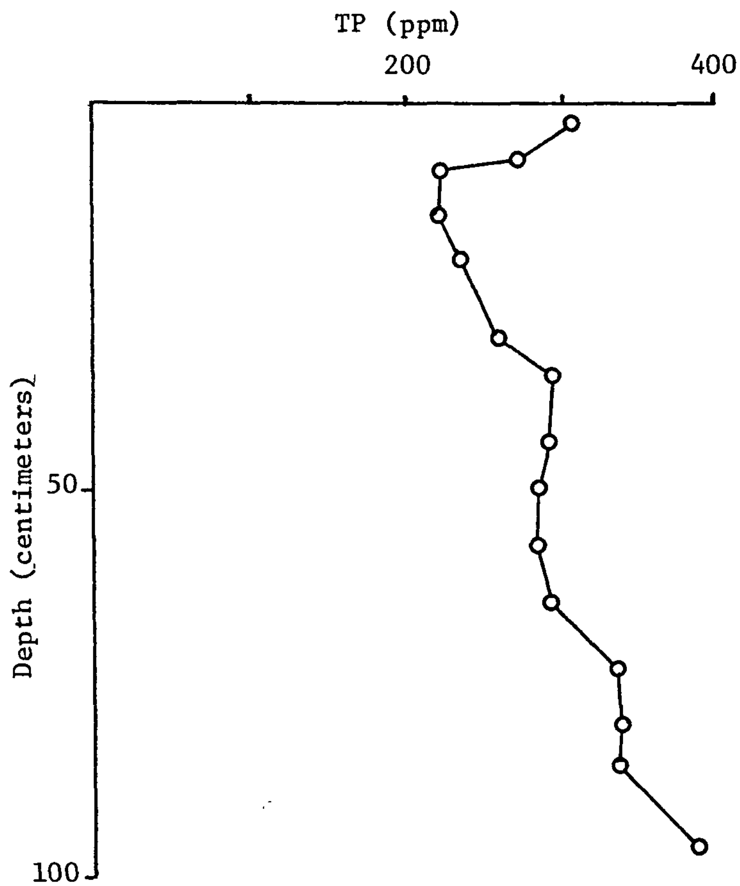


Figure 27. TP depth distribution in profile BT-3

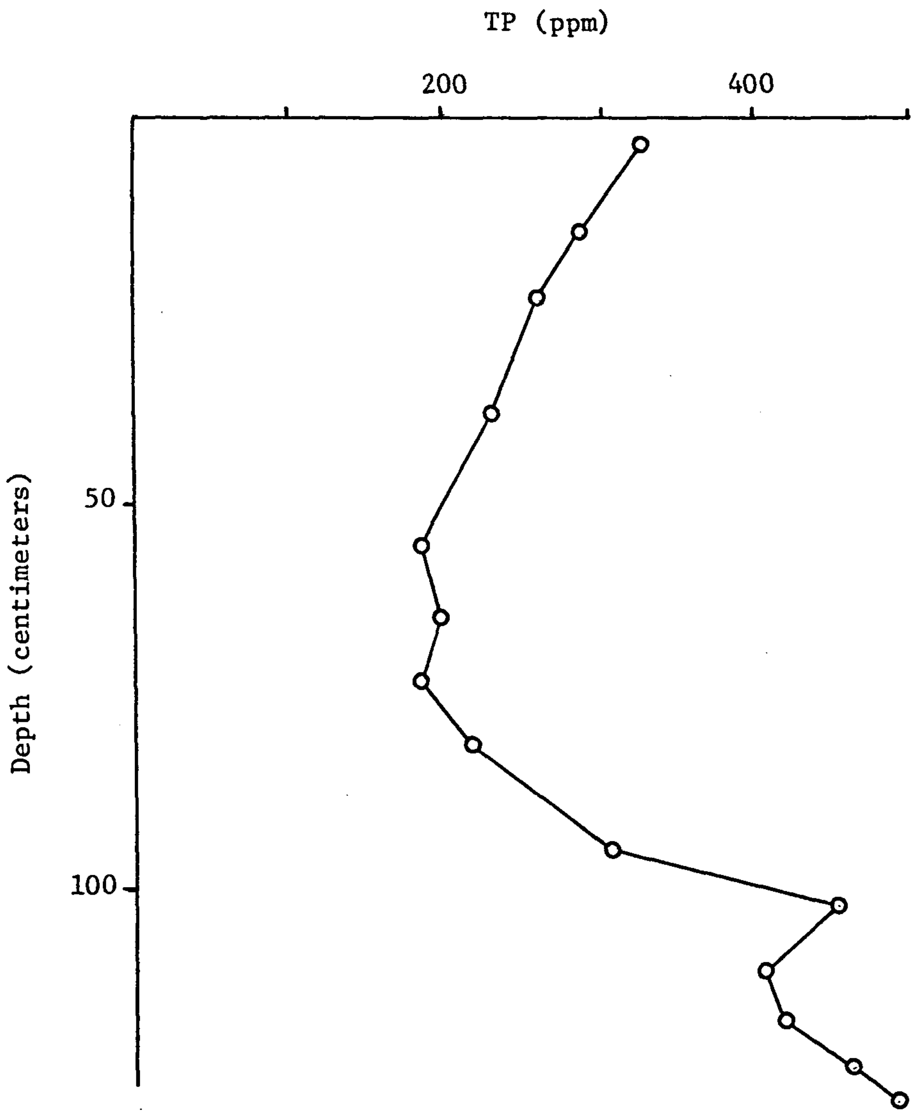


Figure 28. TP depth distribution in profile BT-2

of phosphorus.

The rest of the profile can be explained by differences in TP content of various soil horizons used for fill. Particle size and pH analyses suggested that fill for the Ce1 layer was borrowed from upper B and A horizons of a Seaton soil. TP values were less than 300 ppm in this fill layer and are comparable to TP values of 257 ppm, 191 ppm, and 283 ppm for the A21, A22, and B1 horizon of the Seaton profile.

The Ce3 and Ce4 layers appear to have been borrowed from the B2 and upper B3 horizon of the same Seaton soil. TP values are near 300 ppm in this fill on the sideslopes. These values are about 100 ppm less than those obtained in the B2t horizon of the Seaton soil. TP content of the B3 horizons buried beneath the mound is also about 100 ppm less than in the Seaton soil. These differences may result from TP variability within the same horizon in soils on the bench or continued accumulation of phosphorus in the lower B horizon of soils off the mound while the buried B horizon under the mound received none.

Further evidence that the mound fill was obtained from upper B and A horizons of a Seaton soil is the fact that buried B3 horizons under the mound have a higher TP content than any of the overlying fill. As discussed previously, TP maximum usually occurs in the B3 or C horizon.

Profile BT-2 does not have the TP increase in the Ce3 layer that is present in profile BT-1 and BT-3 (Fig. 28). TP values suggest this portion of the Ce3 layer was obtained from upper B and A horizons.

The Ce6 layer (profile BT-2) has relatively high TP values (Fig. 28). This layer contains free carbonates and was derived from the upper

C horizon of a Seaton soil developed on the bench at the time of mound construction. Several authors have noted the immobilization of TP by carbonates (Allaway and Rhoades, 1951; Huddleston and Riecken, 1973). Huddleston and Riecken (1973) concluded that insoluble calcium phosphates prevent pedogenic redistribution of TP.

A maximum TP value was obtained in the C horizon buried beneath the Ce6 layer. This suggests that TP continues to increase below the top of the carbonate zone here, but that the rate of increase is much lower than that above the carbonate zone.

Transect 1 (north-facing slope) In profile T-1-3 (Fig. 29b) the TP maximum occurs in the surface horizon (357 ppm) while the minimum occurs in the B horizon (264 ppm). Presence of rocks prevented sampling below the B horizon and it is possible that the TP maximum occurs below the lowest horizon sampled in this profile.

Profile T-1-1, located on the lower footslope below T-1-3, had a TP maximum in the B2t horizon and a minimum in the B11 horizon (Fig. 29a). It is probable that the TP maximum occurs below the layer of coarse fragments encountered around 70 centimeters. These rocks prevented sampling below the B2t horizon.

Weighted average TP content was highest in the profile on the lower footslope (Table 6). This may indicate relatively low TP content of the parent material on this slope and additions of phosphorus to these soils, possibly in dustfall. Since profile T-1-1 is in a more stable position than T-1-3, it has received more additions of dust and therefore more phosphorus additions than profile T-1-3.

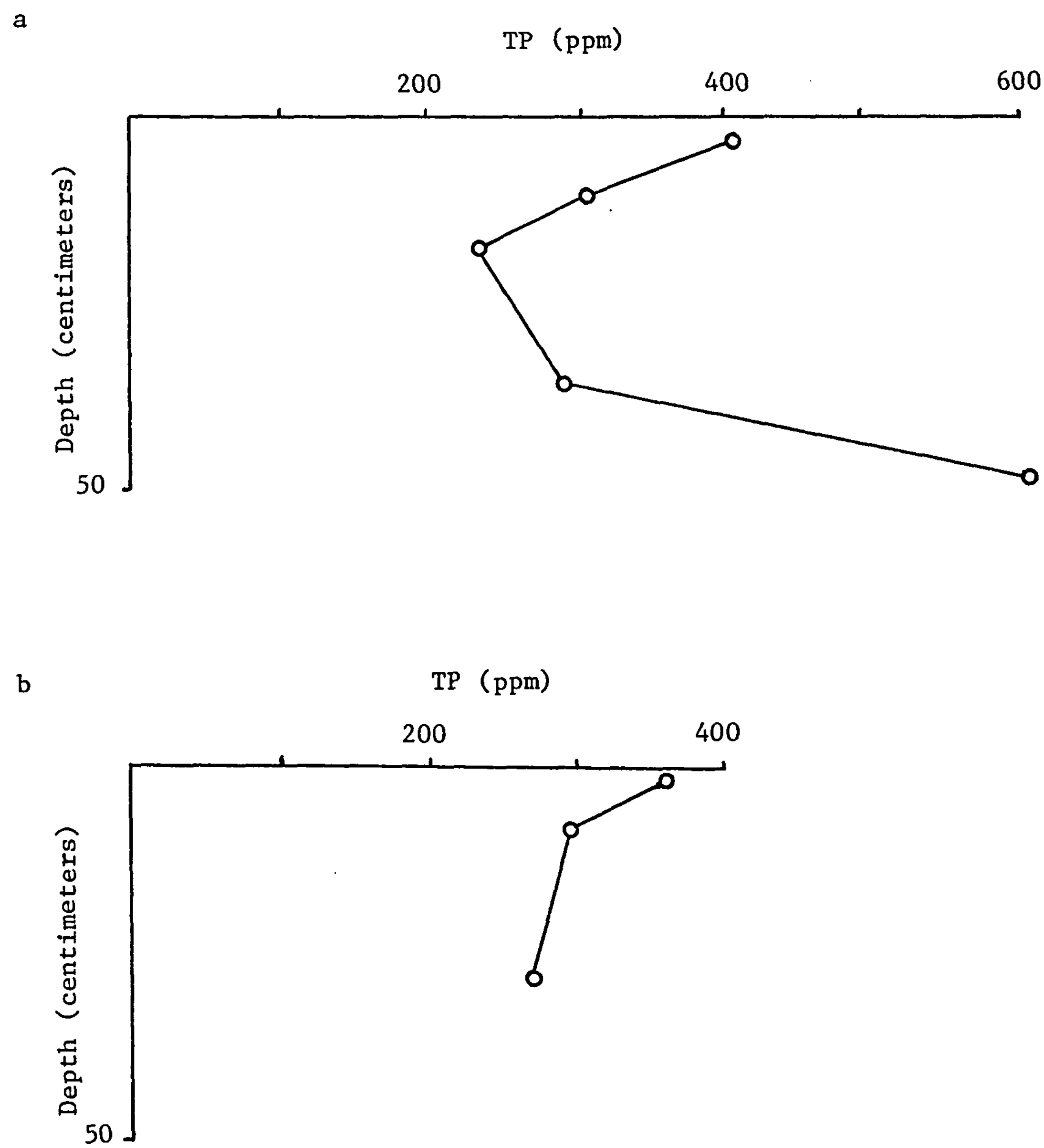


Figure 29. TP depth distributions in profiles (a) T-1-1 and (b) T-1-3

Another source for addition of TP to the lower footslope could be phosphorus dissolved in groundwater. The water table approaches the surface on the lower footslope during the spring but remains quite deep on the upper footslope. If significant amounts of phosphorus were present in the groundwater, more phosphorus would accumulate from this source in the lower portion of the footslope than in the upper portion.

I/E ratios calculated for profiles T-1-1 and T-1-3 are presented in Table 6. These rates indicate greater redistribution of TP on the lower footslope and agree with the greater degree of horizonation evident in profile T-1-1 based on the B/A clay ratio.

TP profiles for Mound 23 are presented in Figs. 30 through 32. All these profiles show a TP increase within or slightly below the B horizon. This increase is more pronounced and at a shallower depth on the west-facing sideslope (23-1) than at the mound center (23-2) and the east-facing sideslope (23-3).

It is suggested that these TP profiles are a result of original differences within the mound fill coupled with translocation of phosphorus in the upper 60 centimeters of the fill. Fill in the Ce layer may have been borrowed from the upper B2 horizon of an Alfisol developed on the adjacent slope at the time of mound construction. TP values in this fill average around 300 ppm in profiles 23-1 and 23-2 and about 250 ppm in profile 23-3. Original TP differences in the upper fill may have been quite low with the values in 23-3 being lower than those in the other profiles.

Absorption of phosphorus by vegetation and its return to the soil

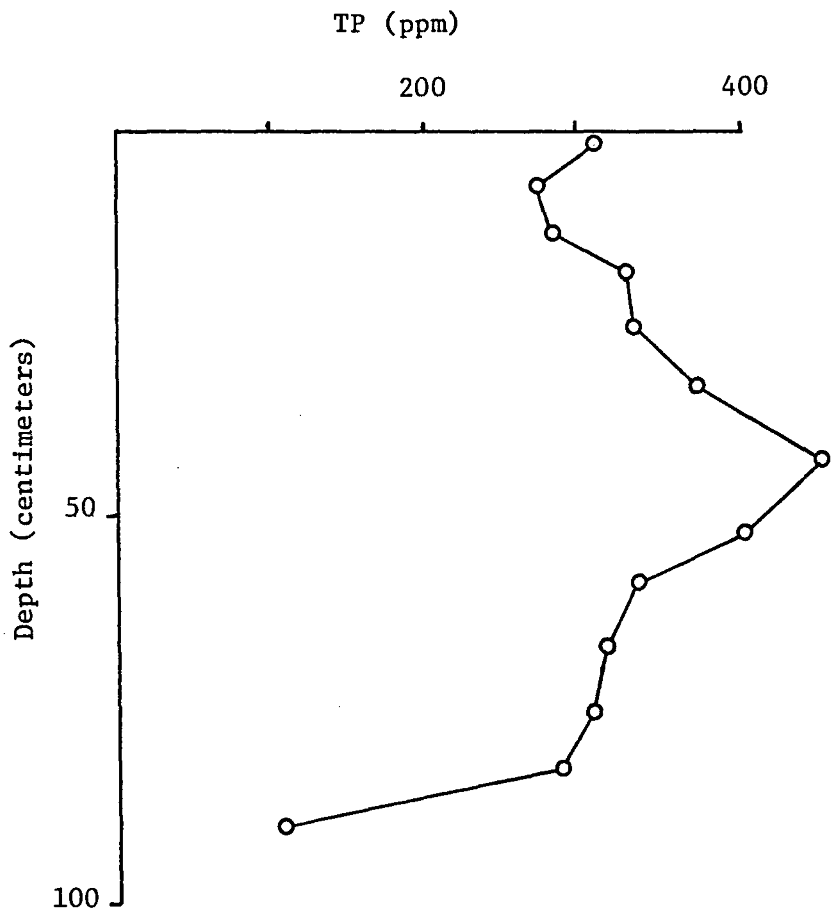


Figure 30. TP depth distribution in profile 23-1

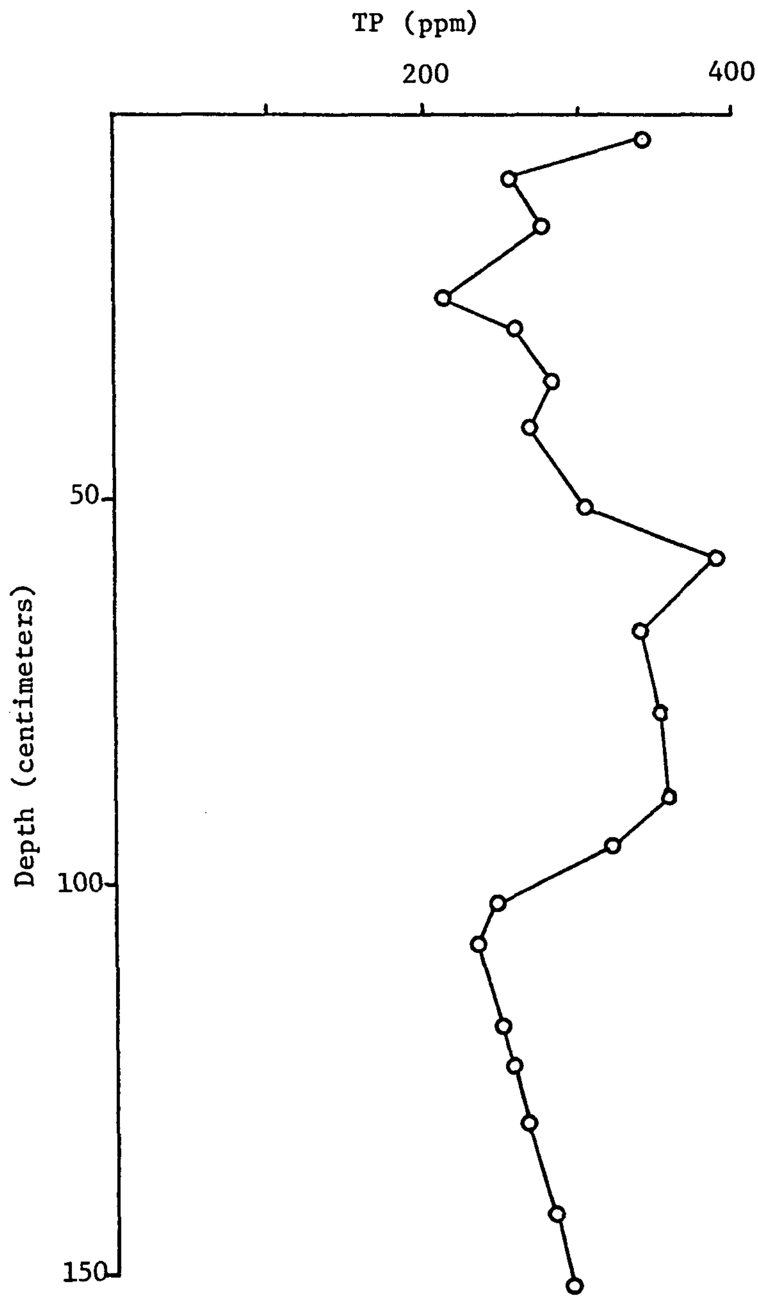


Figure 31. TP depth distribution in profile 23-2

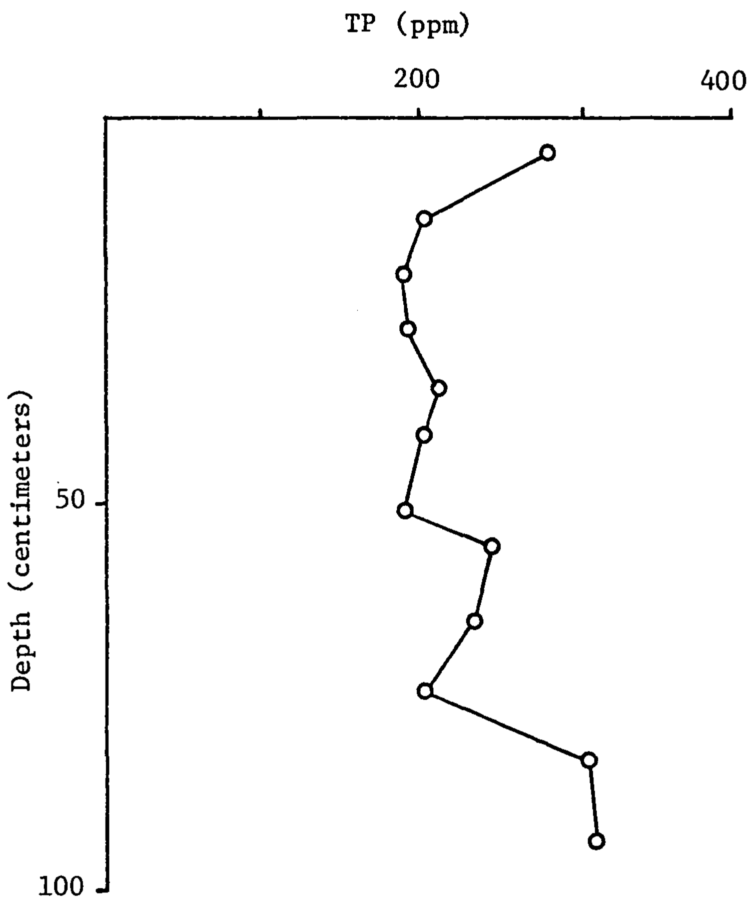


Figure 32. TP depth distribution in profile 23-3

surface in litter may account for TP values near 300 ppm in the mound A1 horizon. The surface TP increase is accompanied by a TP decrease due, in part at least, to absorption by plant roots in the A2 and B horizons.

The TP increase recorded at or just below the B2 horizon is inferred to have resulted from illuviation of phosphorus. Rapid permeability of these deposits may have promoted movement of phosphorus. In the weakly developed profiles on this mound, phosphorus illuviation appears to have occurred in the lower solum or slightly below the solum. TP maxima are found in this location within the profile of more well-developed soils. This further supports the contention that these profiles are partially genetic and indicates that genetic TP profiles develop more rapidly than genetic clay profiles under conditions present at Mound 23.

I/E ratios calculated for the mound profiles (Table 6) suggest some illuviation of phosphorus within the solum. These values are lower than those on the surrounding slope.

TP values of the IIB3 horizon buried beneath Mound 23 range bewteen 233 ppm and 313 ppm. TP increases gradually from the IIB3 into the IIC horizon beneath the mound center, while the IIC horizon below profile 23-1 has a very low TP reading (136 ppm).

A TP profile from the center of Mound 29 (Fig. 33, profile 29-1) has a maximum TP content in the A1 horizon, an eluvial zone from 5 to about 60 centimeters below the surface, and an illuvial zone from 65 to 70 centimeters. Values average about 150 ppm lower than in Mound 23. The buried B horizon beneath Mound 29 has a higher TP content than the overlying fill, supporting the hypothesis that mound fill was borrowed from

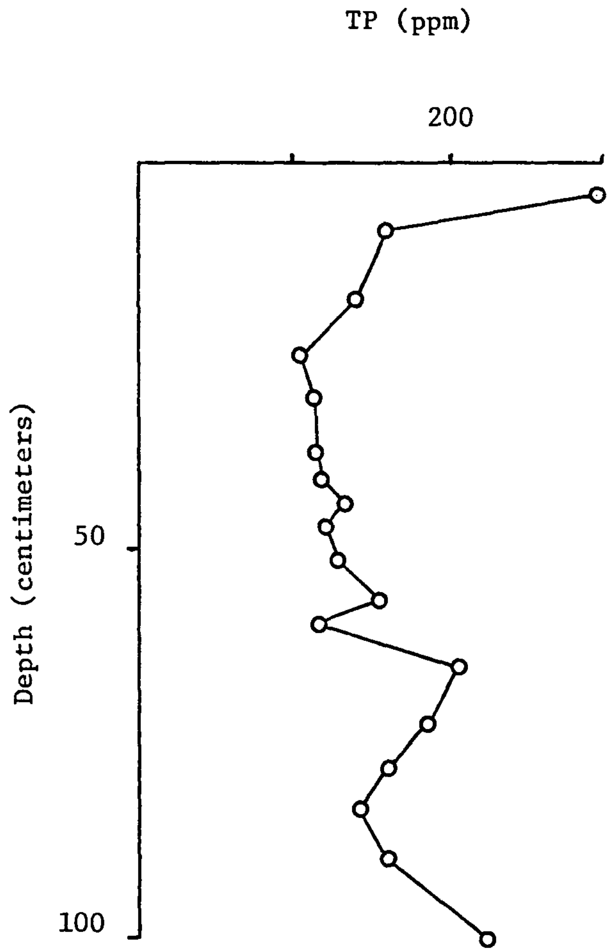


Figure 33. TP depth distribution in profile 29-1

upper B and A horizons of a soil developed on the surrounding slope.

Profile 29-2, located east of Mound 29, has a somewhat different TP profile (Figure 34). Illuviation and eluviation of phosphorus is evident in this profile. Two TP accumulation maxima are present, one at about 50 centimeters below the surface in the upper B21 horizon, and a second at the base of the profile in the B32 horizon.

Particle size and pH data suggest disturbance of this profile to a depth of 46 centimeters. This is further supported by the TP data. It appears that phosphorus eluviated from the material above 46 centimeters has accumulated at and just below the base of the disturbed area. The second accumulation located in the B3 horizon may reflect illuviation of phosphorus prior to disturbance of the upper part of the profile. This accumulation was observed in the truncated B3 horizon under Mounds 23 and 29 and, as previously mentioned, is characteristically found in soils developed on stable landscape positions.

Transect 2 (west-facing slope) Profiles sampled along transect 2 have higher TP contents than those along transect 1 (Figs. 35 and 36). TP content of the parent material on these two slopes may be the major variable contributing to these differences.

On the upper footslope (T-2-2) minimum TP is in the B12 horizon (430 ppm) while the TP maximum is in the A1 horizon (Fig. 35) (591 ppm). Illuviation of phosphorus in the B2 horizon is evident. Presence of rocks prevented deeper sampling. It is probable that a TP concentration occurs in the lower B horizon below the depth of sampling. Weighted average TP content is 484 ppm/cm in this profile.

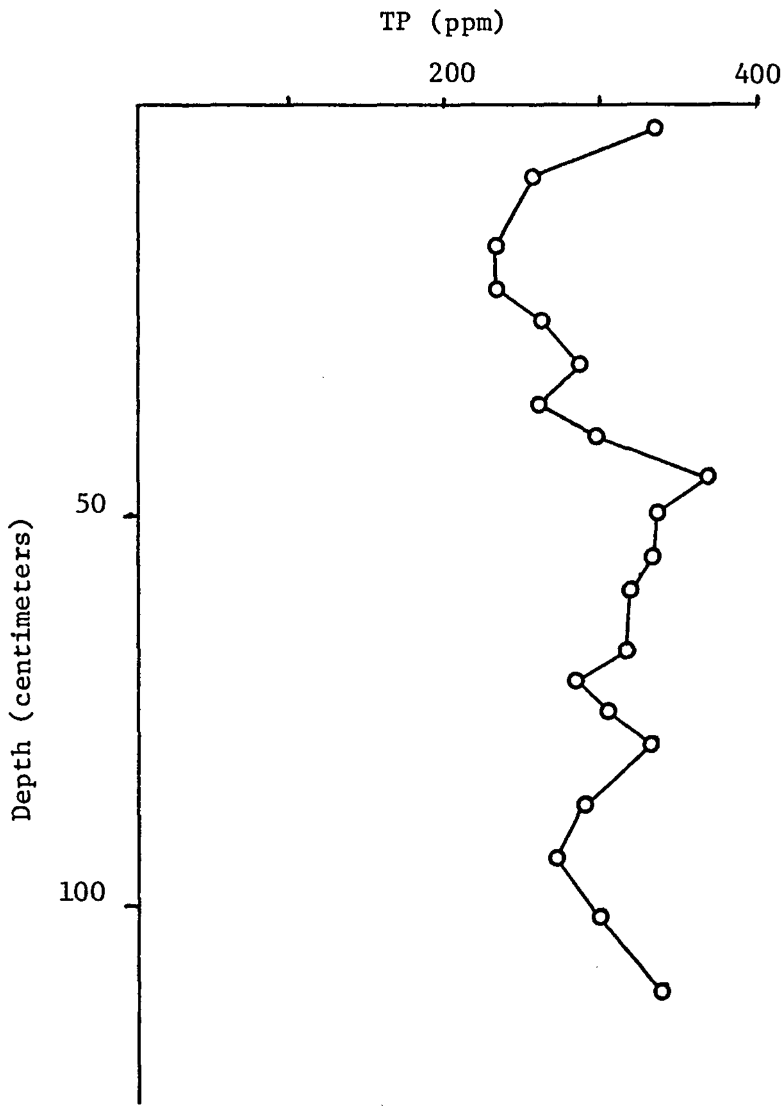


Figure 34. TP depth distribution in profile 29-2

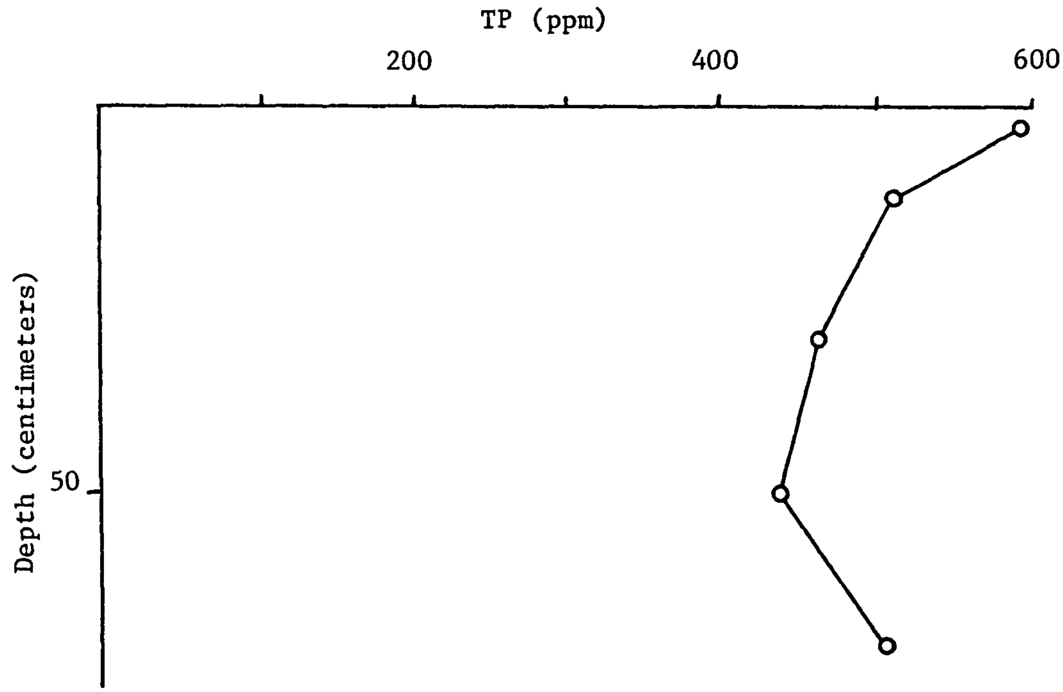


Figure 35. TP depth distribution in profile T-2-2

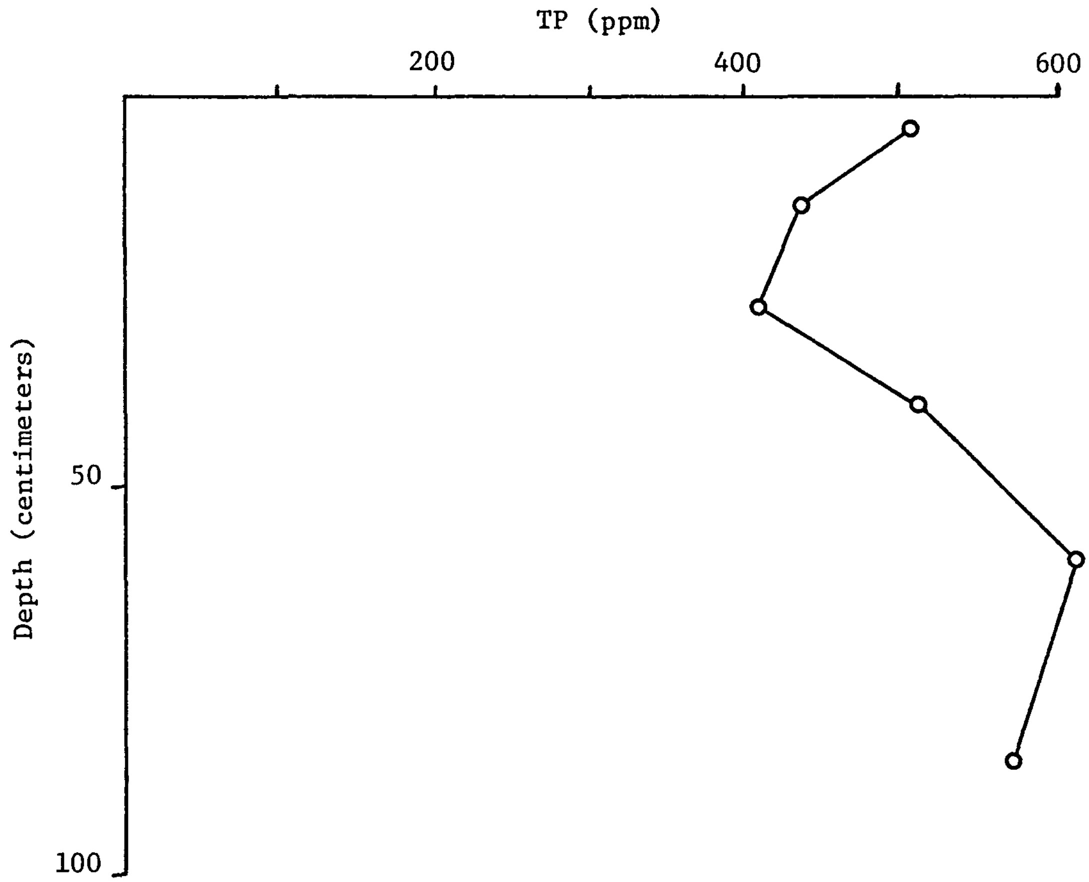


Figure 36. TP depth distribution in profile T-2-1

Profile T-2-1 is located on the lower footslope. This soil has a TP profile with distinct illuvial/eluvial zones (Fig. 36). The TP minimum is in the B11 horizon (408 ppm) while the TP maximum is associated with the B22t horizon (607 ppm). Weighted average TP content of this profile is 530 ppm.

It is suggested that weighted average TP is greatest in the most stable position on this slope since TP levels are low in the parent material and addition of phosphorus in dustfall and groundwater is significant. The more stable landscape position, then, would receive more phosphorus and, therefore, have a greater weighted TP average.

I/E ratios calculated for profiles along transect 2 are presented in Table 6. The ratio was highest on the lower footslope (most stable landscape position) along this transect agreeing with results from transect 1.

Profile 4-1, located north of the center of Mound 4, shows little evidence of illuviation or eluviation of phosphorus (Fig. 37). A TP maximum in the upper B horizon may reflect illuviation of a small amount of phosphorus to this depth. Below this peak, the TP profile observed is inferred to reflect original TP differences in the fill used to build the mound.

It is suggested that the Ce1 layer, averaging between 450 and 475 ppm of TP, was borrowed from upper B and A horizons of a soil developed on the adjacent slope. The Ce2 layer appears to have been borrowed from middle portions of the B horizon. Lower portions of the Ce2 fill may have been taken from the B12 or B21 horizon where a TP minimum usually occurs,

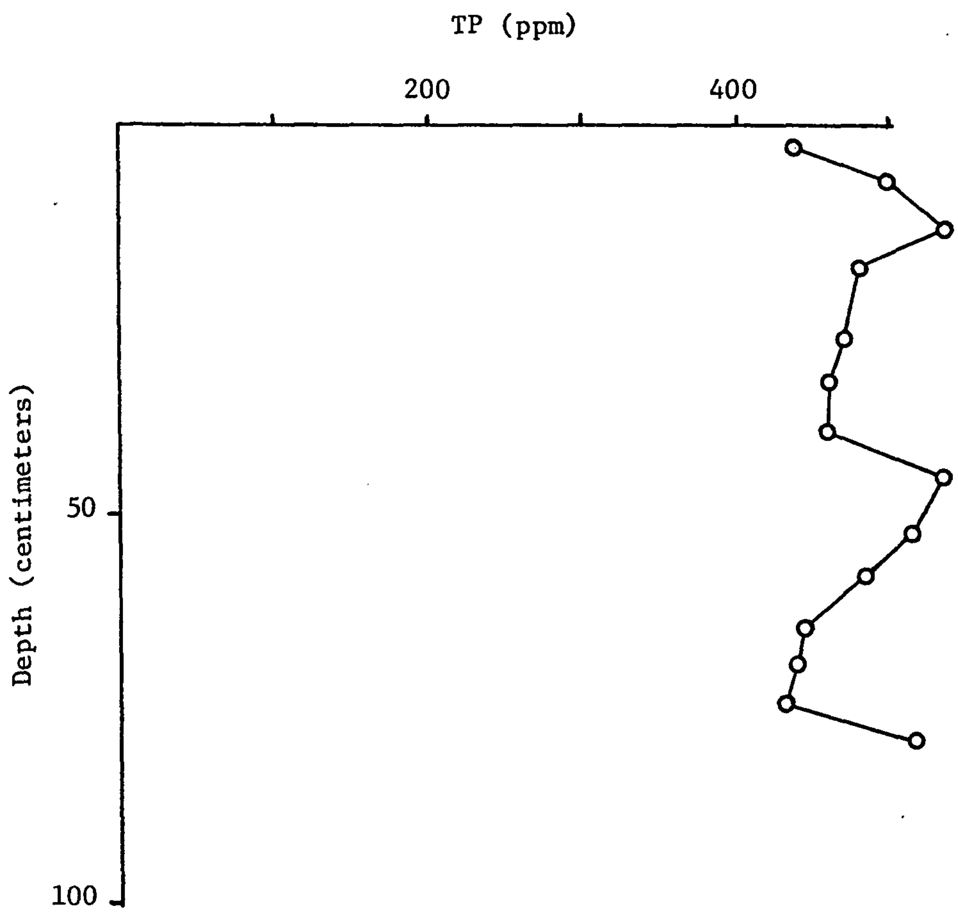


Figure 37. TP depth distribution in profile 4-1

while the upper portion of this layer appears to have been borrowed from deeper portions of the B horizon where TP increases as it approaches a maximum in the lower solum or C horizon.

Apparently phosphorus illuviation/eluviation since mound construction is minimal under conditions present at Bluff Top Mound and Mound 4. In the coarser materials from which Mounds 23 and 29 were constructed, significant phosphorus movement has occurred since mound construction.

Summary

(1) The TP maximum in the Seaton profile occurred in the B22t horizon while the minimum was in the A22 horizon.

(2) An I/E ratio of 2.58 was calculated for the Seaton profile. This is comparable to values of this ratio calculated for B and C slope Fayette profiles in northeastern Iowa by Kuehl (1978).

(3) Little movement of phosphorus has occurred in the fill of Bluff Top Mound. TP differences in this fill are inferred to reflect original differences in the TP content of soil horizons used to build the mound.

(4) TP illuviation/eluviation is evident in soil profiles along transect 1. Maximum TP values appear to occur in the lower solum or below the solum.

(5) Weighted average TP content of the solum increases as stability of the landscape position increases along transect 1. This may reflect low TP content of the parent material and additions of phosphorus to these soils in dustfall and groundwater.

(6) I/E ratios along transect 1 increased with increasing stability of

the slope position.

(7) TP profiles in Mounds 23 and 29 suggest that illuviation and eluviation of phosphorus has occurred since construction of these mounds.

(8) Soils along transect 2 have higher weighted average TP contents than those along transect 1. This may be due to differences in the TP content of the parent materials on these two slopes.

(9) Weighted average TP content along transect 2 was greatest on the most stable landscape position. I/E ratios were also higher on the most stable position.

(10) Little illuviation/eluviation of phosphorus was evident in the fill of Mound 4. The TP profile here is inferred to reflect original differences in the TP content of the soil horizons used for fill.

(11) Significant phosphorus movement has occurred in the sandy loam and loamy sand fills of Mounds 23 and 29. Little TP movement has occurred in the loam and silt loam fills of Mound 4 and Bluff Top Mound.

Correlation of clay and TP

Correlation coefficients and F-values for the relationship of clay (percent) to TP (ppm) in the Seaton profile and in profiles along transects 1 and 2 are given in Table 1. Graphs of these relationships are presented in Figs. 38 through 42.

There is little or no relationship between clay and TP in the Seaton profile (Fig. 38). The correlation coefficient for this profile is .57.

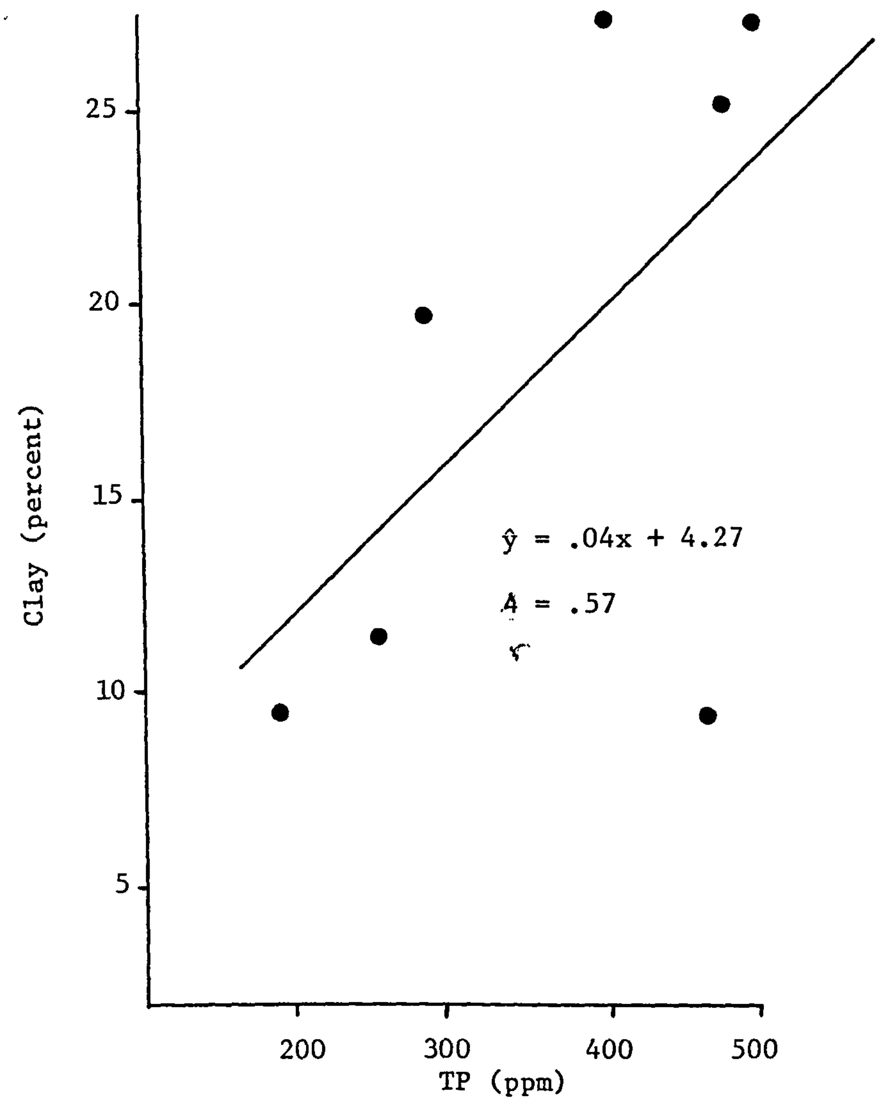


Figure 38. Clay vs. TP in the Seaton profile

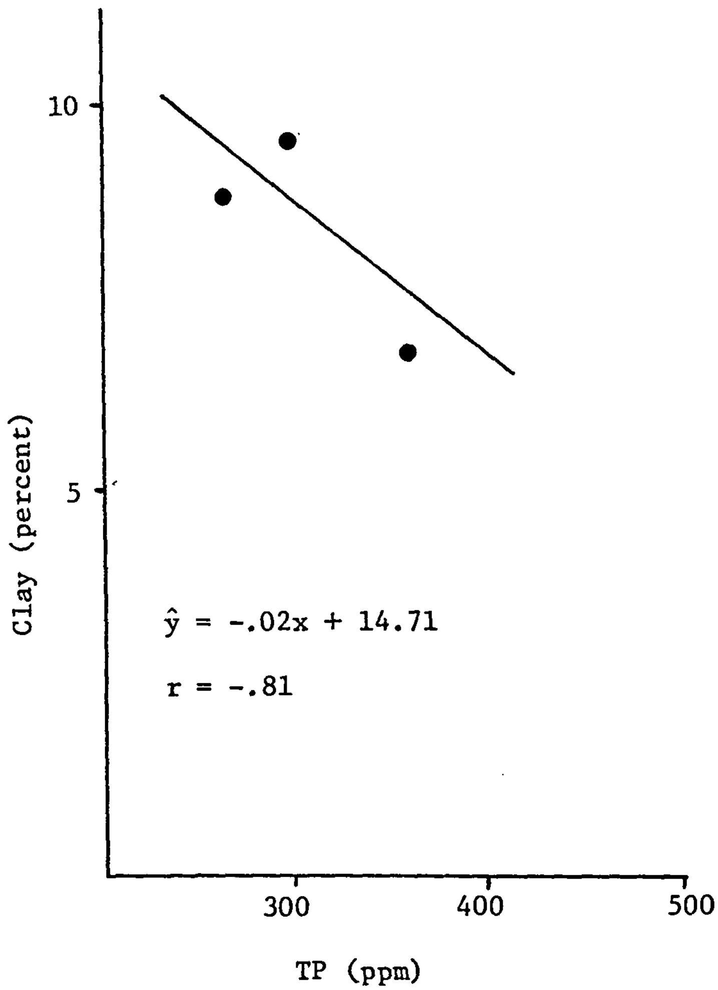


Figure 39. Clay vs. TP in profile T-1-3

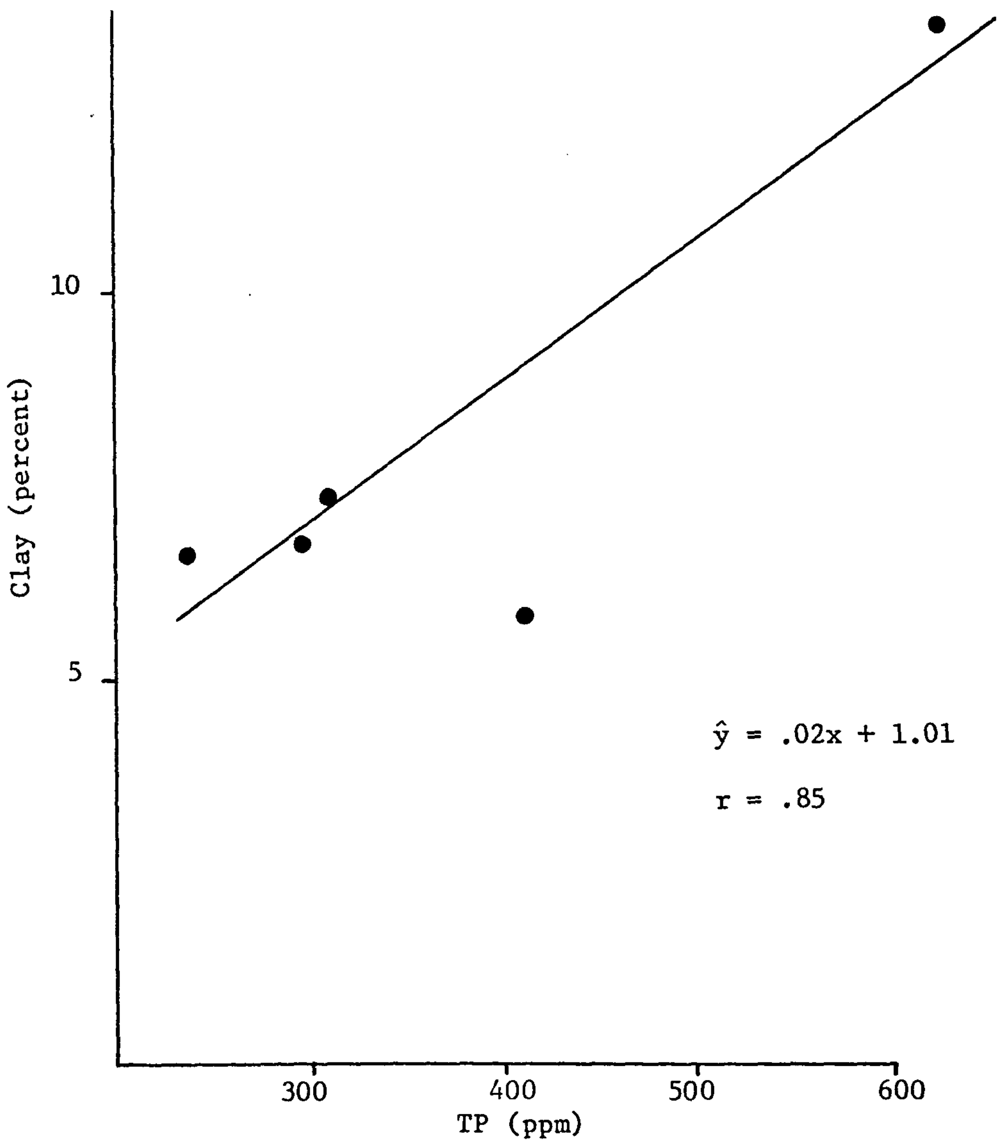


Figure 40. Clay vs. TP in profile T-1-1

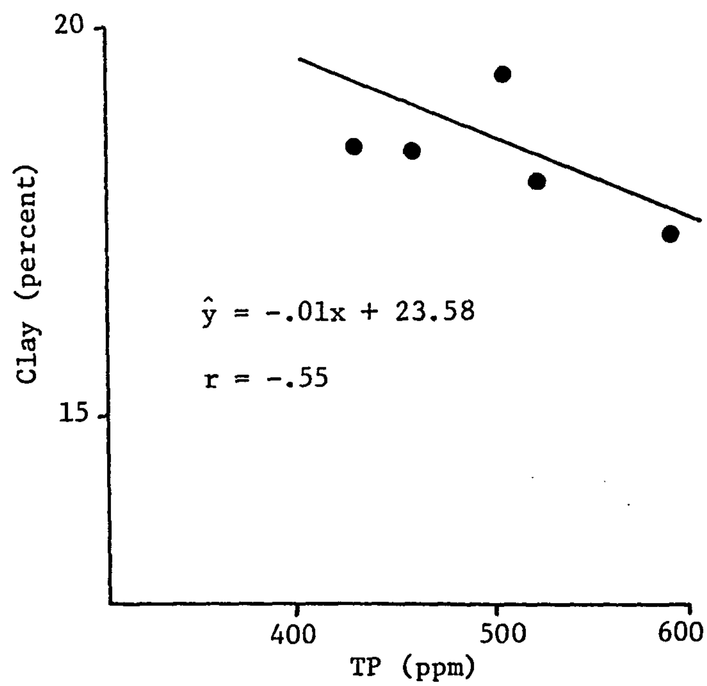


Figure 41. Clay vs. TP in profile T-2-2

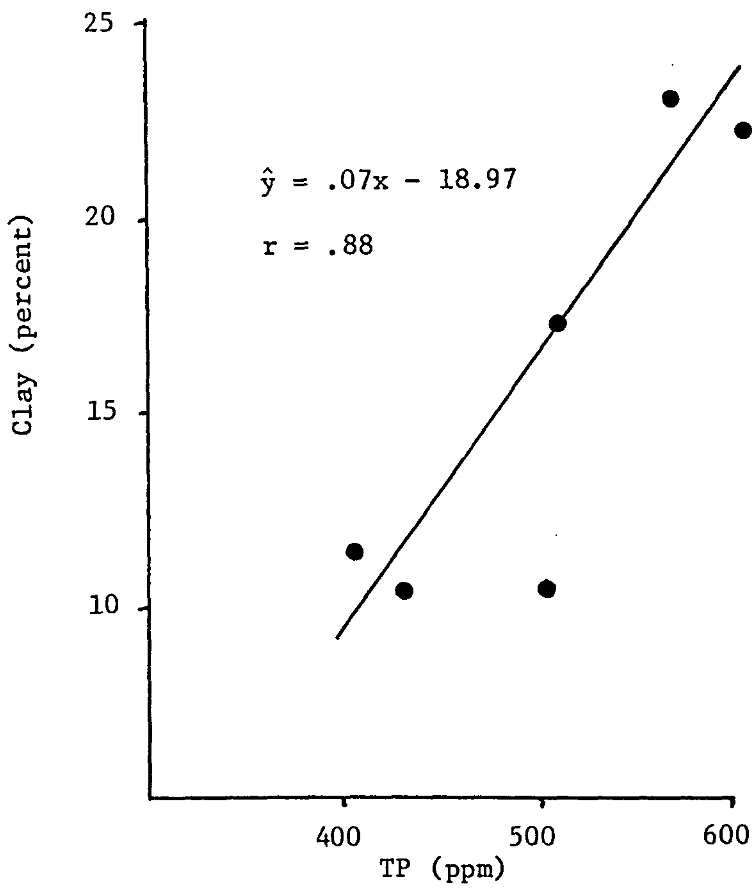


Figure 42. Clay vs. TP in profile T-2-1

An F-value calculated for this profile is significant at the .01 level. Kuehl (1978) found little relationship between clay and TP in Fayette profiles in his study.

On the upper footslope along transect 1 (profile T-1-3) an inverse relationship occurs between clay and TP (Fig. 39). An r-value of -.81 indicates a negative correlation between these two properties and the calculated F-value is significant at the .01 level.

At the base of the footslope (T-1-1) a fairly strong correlation (r = .85) is present between clay and TP (Fig. 40). The calculated F-value is also significant at the .01 level.

On the west-facing noseslope where transect 2 is located, similar relationships exist between the upper and lower footslope. Here an r-value of -.55 was calculated for the upper footslope (Fig. 41), while on the lower footslope r = .88 (Fig. 42). F-values calculated for these profiles were significant at the .01 level.

On both the slope transects, negative correlations between clay and TP were found in the least stable landscape position while positive correlations were found in the most stable position. A relationship between clay percentage and TP ppm exists on the lower footslope on these slopes.

This correlation could be a result of the geologic makeup of this slope and the resulting effect of movement of clay and TP through the deposits. Fractured rock is present at the base of the solum on the footslope. This coarse layer may perch water moving through the deposits resulting in illuviation of clay and TP above the contact. The correlation between clay and TP, then, does not suggest a genetic relationship between clay and TP, but instead reflects the influence of a coarse angular deposit underlying the slope on movement of material suspended or dissolved in water percolating through the solum.

Table 7. Correlation coefficients and F-values for the relationship between clay (percent) and TP (ppm) in the Seaton profile and in profiles along Transects 1 and 2

Profile	r	F
Seaton	.57	56.9**
T-1-3	-.81	117.5**
T-1-1	.85	32.5**
T-2-2	-.55	309.1**
T-2-1	.88	241.4**

**Significant at .01 level. F-value used to determine significance of correlation coefficient.

ARCHAEOLOGICAL CONCLUSIONS

David Benn and R. Clark Mallam of the Luther College Archaeological Research Center were in charge of excavations and made archaeological interpretations on the basis of artifact analysis and mound stratigraphy. The following is a summary of their conclusions (see Benn et al., 1978, for a detailed discussion).

(1) All mounds investigated in this study were built during the Allamakee phase of the Late Woodland period (300 A.D. to 650 A.D.).

(2) Bluff Top Mound was constructed near the beginning of the Allamakee phase and the decline of Hopewell (McGregor phase). This mound contains cultural traits indicative of a period of stress and transition which is inferred to reflect a shift from the socially ranked society characteristic of Hopewell to an egalitarian society during the Allamakee phase.

(3) The Keller Mounds (4, 29, and 23) were built by people having an egalitarian social order and ideology. Absence of exotic mortuary goods and a rather haphazard construction of features within the mounds give the impression of a transformed social and ideological order.

(4) Bluff Top Mound and Mound 4 appear to have been built in at least two stages with a period of time, possibly a year or so, elapsing between construction stages.

(5) The presence of burned earth layers, fired rocks, and mussel shells in the mounds may be representative of "life metaphors," the

spiritual forces inherent in the animistic Woodland universe. Their function could constitute the human attempt to symbolize their dependence on these life forces and to integrate themselves into the supernatural cosmos.

(6) Mound building activity constituted an on-going process whereby humans sought ideologically to maintain the material conditions necessary for the perpetuation of their lifeway.

Additional archaeological conclusions and speculations can be advanced following the field and laboratory investigations reported herein.

(7) People building these mounds followed a general construction pattern exhibited at other mound complexes in the upper Mississippi River basin. This consists of (a) removal of the upper solum on the future mound site and adjacent slope, (b) excavation of pits (if present), and (c) loading of borrowed material onto the prepared mound floor. The final step usually involves several phases and culminates with the upper-most fill. Pits are usually filled with the material removed to form them. Fill capping the mound floor where pits are not present was material borrowed from B horizons. Overlying fill layers are usually composed of material borrowed from overlying horizons.

(8) It is apparent that the Native Americans building thse mounds recognized some morphological differences between the horizons of a soil used for mound fill. An obvious morphological difference within these soil profiles is color. Dark A1 horizons overly

lighter A2 horizons which cap brown B horizons. These colors may have had symbolic significance among the builders.

(9) The mound profiles are very slightly developed (weathered). This suggests that bones and artifacts found within the mounds are probably in about the same state of preservation as when placed in the mound. Some crushing due to overburden weight and rodent and insect burrowing would be expected.

(10) Morphology of present surface soils and soil horizons buried beneath mound suggests that vegetation similar to that present in the area today has persisted for the last 2000 years. The slope above Mound 4 may have supported more cedars than today prior to construction of the power plant.

CONCLUSIONS

As a result of this study, several conclusions and speculations concerning soil development within the study area can be presented.

(1) Parent material differences account for many of the differences between soils formed on the slopes and mounds in the study area.

(2) Soils developed in the mound fills have formed in materials which were pedogenically altered prior to construction of the mounds.

(3) The physical and chemical characteristics of soils developed on the mounds are a product of differences in the original fill combined with post-construction pedogenic alteration of the fill.

(4) Pedogenesis since mound construction has altered the deposits in Mounds 23 and 29 to a greater depth than the deposits in Mound 4 and Bluff Top Mound. This is inferred to result from differences in texture of the fills with coarser fills allowing deeper alteration in the time elapsed since construction of these mounds.

(5) In terms of total carbon percentage, A1 horizons on Bluff Top Mound appear to have attained a maximum degree of expression in the 1600 years since construction of the mound. This agrees with Parsons' (1960) conclusions concerning A1 horizon development on mounds at Effigy Mounds National Monument.

(6) In terms of total carbon percentage A1 horizons developed on mounds of the Keller Group have not attained a maximum degree of expression in relation to non-mound soils on the adjacent slopes during the 1600 to 1300 years since their construction.

(7) A2 horizons of the mound soils were a structural grade less developed than comparable horizons in soils off the mounds. This suggests that the platy structure of A2 horizons is evident but not maximally expressed in 1600 years. This also agrees with Parsons' conclusions.

(8) Eluvial/illuvial clay profiles were not apparent in the mound profiles suggesting that under conditions present in the study area significant movement takes longer than 1600 years to occur.

(9) Most of the soils developed on the footslope in proximity to mounds of the Keller Group are polygenetic and have been significantly altered by scalping of the upper horizons during construction of the mounds. Man has been an important factor in their genesis.

(10) An abrupt A/B horizon contact in soils formed in loess at or adjacent to mound complexes may indicate the presence of mound fill borrow areas.

(11) Along transects 1 and 2, profiles at the base of the footslope are more strongly developed than those on the upper footslope. This suggests that on this hillslope the lower footslope is a more stable landscape position than the upper footslope.

(12) Weighted average TP content is highest in soils on the most stable position on these slopes. This contradicts Kuehl's findings in profiles formed in loess in northeast Iowa. Additions of phosphorus to the profiles in this study in dustfall and groundwater and the accumulation of suspended and dissolved materials above a discontinuity at the base of the solum may account for the

observed TP relationships on the slopes in this study.

(13) Eluvial/illuvial TP profiles have developed in mounds built from sandy loam material during the 1600 years since their construction.

(14) Slopes along transects 1 and 2 appear to have developed predominantly by creep and rainsplash. Little evidence of overland flow and transport of material by water exists outside of alluvial cone areas.

(15) The soil pattern in the study area is very complex and a more intensive study is needed to characterize it.

(16) Soil profiles along transects 1 and 2 are unlike any which have been assigned formal series status. From a land use point of view, slopes like those studied are of minimal use and may not need to be included in a formal series. In order to study the genesis of these soils, more intensive field and laboratory investigations are needed to characterize the soils.

(17) Parsons' inference that soil formation in northeastern Iowa proceeds rapidly during the first 1000 years or so and then continues at a diminishing rate or reaches an equilibrium with the environment so that certain soil features, such as organic matter content, show no net change with increasing age is supported by this study. It is further suggested that soils develop most rapidly in sandy materials, less rapidly in loamy deposits, and least rapidly in silty deposits under conditions present in the study

area. Al horizons apparently reach an equilibrium most rapidly in silty parent material.

REFERENCES

Akimtzev, V. V. 1932. Historical soils of the Kamenetz-Podolsk fortress. Second International Congress of Soil Science 5: 132-143. State Publishing House of Agriculture, Cooperative and Collective Farm Literature, Moscow.

Allaway, W. H., and H. F. Rhoades. 1951. Forms and distribution of phosphorus in the horizons of some Nebraska soils in relation to profile development. Soil Sci. 72: 119-128.

Arnold, R. W. 1965. Multiple working hypotheses in soil genesis. Soil Sci. Soc. Am. Proc. 29: 717-725.

Baerreis, David A. 1953. The Blackhawk Village Site (DA5) Dare County, Wisconsin. Jour. of the Iowa Archaeological Soc. 2(4): 5-20.

Baerreis, David A. 1966. Early salvage excavations in the Madison area, Dare County, Wisconsin. The Wisconsin Archaeologist 47(3): 101-136.

Barnhisel, R. I., and C. I. Rich. 1967. Clay mineral formation in different rock types of a weathering boulder conglomerate. Soil Sci. Soc. Am. Proc. 31(5): 627-631.

Baur, A. J., and W. H. Lyford. 1957. Sol Brun Acides of the northeastern United States. Soil Sci. Soc. Am. Proc. 21: 533-536.

Beaubien, Paul L. 1953. Cultural variation within two Woodland mound groups of northeastern Iowa. Am. Antiquity 19(1): 56-66.

Benn, David W. 1976. Preliminary excavations at the FTD Site (13 A.M.210). Manuscript on file. Luther College Archaeology Laboratory, Luther College, Decorah, Iowa.

Benn, David W. 1977. Some trends and traditions in Woodland cultures of the Quad-State region in the upper Mississippi river basin. Paper presented at the annual meeting of the Iowa Academy of Sciences, Drake University, Des Moines.

Benn, David W. 1978. The Woodland ceramic sequence in the culture history of northeast Iowa. Midcontinental Journal of Archaeology (in press).

Benn, David W., and Arthur Bettis. 1977. Salvage investigations at the John Henry Mound (13WH105), Winneshiek County, Iowa. Research Papers 2(14). Office of the State Archaeologist, Iowa City.

Benn, D. W., R. Clark Mallam, and Arthur Bettis. 1978. Archaeological investigations at the Keller Mounds (13AM69) and related manifestations: Insights into Woodland Indian Mythology. Research Papers 3(3). Office of the State Archaeologist, Iowa City.

Bennett, J. W. 1945. Archaeological explorations in Jo Daviess County, Illinois. University of Chicago Press, Chicago.

Bennett, J. W. 1952. The prehistory of the northern Mississippi Valley. In James B. Griffin (ed.) Archaeology of the Eastern United States. University of Chicago Press, Chicago.

Berg, Richard C. 1978. Stops 8 and 9 - Illinois Beach Ridge Complex. p. 63-69. In Leon R. Follmer, R. C. Berg, and L. Acker (eds.) Soil geomorphology of Illinois. Guidebook for a joint field conference of the Soil Sci. Soc. of Am. and the Geological Society of America, Dec. 1-3, 1978. Illinois State Geological Survey, Urbana, Ill.

Berg, R. C. 1979. The benesis of sandy soils on Beach Ridges along Lake Michigan, extreme northeast Illinois. Unpublished Ph.D. Dissertation. Univ. of Illinois, Urbana, Ill.

Bernabo, Christopher J., and Thompson Webb III. 1977. Changing patterns in the Holocene pollen record of northeastern North America: A mapped summary. Quat. Res. 8: 64-96.

Binford, Lewis R. 1965. Archaeological systematics and the study of cultural process. Am. Antiquity 32(1): 1-12.

Binford, Lewis R. 1972. An archaeological perspective. Seminar Press, New York.

Binford, Lewis R., and Sally R. Binford (eds.). 1968. New perspectives in archaeology. Aldine Press, Chicago.

Black, C. A. 1968. Soil-plant relationships. John Wiley and Sons, New York.

Bryson, R. A., D. A. Baerreis, and W. M. Wendland. 1970. The character of late- and postglacial climatic changes. p. 53-74. In W. Dort and J. K. Jones Jr. (eds.) Pleistocene and recent environments of the Central Great Plains. Univ. of Kansas Press, Lawrence.

Buol, S. W., F. D. Hole, and R. J. McCracken. 1973. Soil genesis and classification. ISU Press, Ames, Iowa.

Burgess, A., and D. P. Drover. 1953. The rate of podzol development in the sands of the Woy Woy District, N. S. W. Aust. J. Bot. 1(1): 83-94.

Caldwell, Joseph R. 1958. Trend and tradition in the prehistory of the Eastern United States. Memoirs of the American Anthropological Association No. 88. Am. Anthropol. 60(6): 1-82.

Carney, T. F. 1975. The shape of the past: Models and antiquity. Coronado Press, Lawrence, Kansas.

Carson, M. A., and M. J. Kirkby. 1972. Hillslope form and process. Cambridge, Univ. Press, London.

Chandler, Robert F., Jr. 1942. The time required for podzol profile formation as evidenced by the Mendenhall glacial deposits near Juneau, Alaska. Soil Sci. Soc. Am. Proc. 7: 454-459.

Chesworth, Ward. 1973. The parent rock effect in the genesis of soil. Catena 10: 215-225.

Clarke, David L. 1968. Analytical archaeology. Methuen, London.

Cline, Marlin. 1949. Profile studies of normal soils of New York: I. Soil profile sequences involving Brown Forest, Gray Brown Podzolic and Brown Podzolic soils. Soil Sci. 68(3): 259-272.

Cole, Fay-Cooper. 1943. Chronology in the Middle West. Proc. Am. Philosoph. Soc. 50: 299-203.

Collins, M. E. 1977. Comparison of soil survey techniques in Tama County, Iowa 1905, 1950, 1977. Unpublished M.S. thesis. Library, Iowa State University, Ames, Iowa.

Crocker, R. L., and J. Major. 1955. Soil development in relation to vegetation and surface age at Glacier Bay, Alaska. J. Ecol. 43(2): 425-448.

Crocker, Robert L., and B. A. Dickson. 1953. Soil development on the recessional moraines of the Herbert and Mendenhall Glaciers, southeastern Alaska. J. Ecol. 45(1): 169-185.

Curtiss, John T. 1959. The vegetation of Wisconsin. An ordination of plant communities. Univ. of Wisconsin Press, Madison.

Daniels, R. B., E. E. Gamble, and J. C. Cady. 1971. The relation between geomorphology and soil morphology and genesis. Adv. Agron. 23: 51-88.

Daniels, R. B., E. E. Gamble, and W. H. Wheeler. 1978. Age of soil landscapes in the coastal plain of North Carolina. Soil Sci. Soc. Am. Proc. 42: 98-105.

Daniels, R. B., and R. H. Jordan. 1966. Physiographic history and the soils, entrenched stream systems and gullies, Harrison County, Iowa. U.S. Dept. Agr. Tech. Bull. 1348.

Davidson, Donald A. 1977. The subdivision of a slope profile on the basis of soil properties: A case study from mid-Wales. Earth Surface Processes 2: 55-61.

Davis, Anthony M. 1977. The prairie-deciduous forest ecotone in the upper Middle West. Annals Ass. Am. Geographers 67(2): 204-213.

Davis, W. M. 1889. Topographic development of the Triassic Formations of the Connecticut Valley. 3rd series. Am. J. Sci. 37: 430.

Dick, Warren, and M. A. Tabatabai. 1977. An alkaline oxidation method for the determination of total phosphorus in soils. Soil Sci. Soc. Am. Proc. 41: 511-514.

Dijkerman, J. C., M. G. Cline, and G. W. Olson. 1966. Properties and genesis of textural subsoil lamellae. Soil Sci. 104: 7-16.

Dokuchaev, V. V. 1883. Russian Chernozem (Russkii Chernozem). (Transl. from Russian by N. Karer). Israel Prog. Soc. Sci. Trans. Jerusalem, 1967.

Eaton, A., and T. R. Beck. 1820. A geological survey of the County of Albany. Agr. Soc. of Albany County, New York.

Ehrlich, W. A., H. M. Rice, and J. H. Ellis. 1955. Influence of the composition of parent materials on soil formation in Manitoba. Can. J. Agric. Sci. 35: 407-421.

Eswaran, H., and Wong Chow Bin. 1978. A study of a deep weathering profile on granite in Peninsular Malaysia: I. Physiochemical and micromorphological properties; II. Mineralogy of the clay, silt and sand fractions; III. Alteration of feldspars. Soil Sci. Soc. Am. J. 42(1): 144-158.

Fallou, F. A. 1862. Pedologie oder allgemeine und besondere Bodenkunde. Dresden, Germany.

Fenton, T. E. 1966. Soils, weathering zones and landscapes in the upland loess of Tama and Grundy Counties, Iowa. Unpublished Ph.D. Dissertation. Iowa State University, Ames, Iowa.

Folks, H. C., and F. F. Riecken. 1956. Physical and chemical properties in some Iowa profiles with clay-iron bands. Soil Sci. Soc. Am. Proc. 20: 575-580.

Frei, Erwin, and Marlin G. Cline. 1949. Profile studies of the normal soils of New York: II. Micromorphological studies of the Gray-Brown Podzolic Brown Podzolic soil sequence. Soil Sci. 68(4): 333-344.

Frye, J. C., H. D. Glass, and H. B. Willman. 1968. Mineral zonation of woodfordian loesses of Illinois. Illinois State Geological Survey Circular 427.

Gardner, D. R., and E. P. Whiteside. 1952. Zonal soils in the transition region between the Podzol and Gray-Brown Podzolic regions in Michigan. Soil Sci. Soc. Am. Proc. 16(2): 137-141.

Gerasinov, I. P., and M. A. Glazouskaya. 1960. Fundamentals of soil science and soil geography (Osnovy pochvovedeniya i geografiya pochu). (Translated from Russian by A. Gourevitch). Israel Prog. for Sci. Trans. Jerusalem, 1965.

Godfrey, C. L., and F. F. Riecken. 1954. Distribution of phosphorus in some genetically related loess-derived soils. Soil Sci. Soc. Am. Proc. 18: 80-84.

Griffin, James B. 1948. Culture change and continuity in Eastern United Sates archaeology. Robert S. Peabody Foundation for Archaeology, Andover, Mass.

Griffin, James B. 1952. Culture periods in Eastern United States Archaeology. p. 352-364. In James B. Griffin (ed.) Archaeology of the Eastern United States. University of Chicago Press, Chicago.

Hack, J. T. 1960. Interpretation of erosional topography in humid temperate regions. Am. J. Sci. 258-A: 80-97.

Hallberg, George R., Thomas E. Fenton, Gerald A. Miller and Alan J. Luteneggar. 1978. The Iowan Erosion Surface: An old story, an important lesson and some new wrinkles. p. 2-2 to 2-94. In Raymond R. Anderson (ed.) 42nd Annual Tri-State Geological Conference Guidebook. Iowa Geological Survey, Iowa City.

Hallberg, George R., Nyle C. Wollenhaupt, and Gerald A. Miller. 1978. A century of soil development in spoil derived from loess in Iowa. Soil Sci. Soc. Am. Proc. 42(2): 339-343.

Harradine, Frank, and Hans Jenny. 1958. Influence of parent material and climate on texture and nitrogen and carbon contents of virgin California soils. Soil Sci. 85(5): 235-243.

Harris, Marvin. 1971. Culture, man and nature: An introduction to general anthropology. Thomas Y. Crowell Co., New York.

Hissink, D. J. 1938. The reclamation of the Dutch saline soils and their further weathering under humid climatic conditions of Holland. Soil Sci. 45: 83.

Hitchcock, E. W. 1838. Report on a re-examination of the economic geology of Massachusetts. Dutton & Wentworth State Printers, Boston.

Hole, Francis D. 1961. A classification of pedoturbations and some other processes and factors of soil formation in relation to isotropism and anisotropism. Soil Sci. 91: 375-377.

Hole, Francis D. 1976. Soils of Wisconsin. University of Wisconsin Press, Madison.

Huddleston, J. H., and F. F. Riecken. 1973. Local soil-landscape relationships in western Iowa. I. Distribution of selected chemical and physical properties. Soil Sci. Soc. Am. Proc. 37: 264-270.

Huggett, R. J. 1975. Soil landscape systems: A model of soil genesis. Geoderma 13: 1-22.

Hurley, William M. 1970. The Wisconsin Effigy Mound tradition. Unpublished Ph.D. Dissertation. University of Wisconsin, Madison.

Hurley, William M. 1971. Rates of soil development at two Wisconsin Effigy Mound sites. Prehistoric Investigations Report 3. Office of the State Archaeologist, Iowa State.

Iowa State University Agriculture and Home Economics Experiment Station. 1978. Iowa Soil Association Map.

Jackson, M. L., and G. D. Sherman. 1953. Chemical weathering of minerals in soils. Adv. Agron. 5: 219-318.

Jackson, M. L., D. A. Gillette, E. F. Danielson, I. H. Blifford, R. H. Bryson, and J. K. Syers. 1973. Global dustfall during the Quaternary as related to environments. Soil Sci. 116: 135-145.

Jennings, Jesse D. 1968. Prehistory of North America. McGraw-Hill Book Co., New York.

Jenny, H. 1941. Factors of soil formation. McGraw-Hill, New York.

Jenny, H. 1961. Derivation of state factor equations of soils and ecosystems. Soil Sci. Soc. Am. Proc. 25: 385-388.

Kilmer, V. J., and L. T. Alexander. 1949. Methods of making mechanical analyses of soils. Soil Sci. 68: 15-24.

King, L. C. 1957. The uniformatarian nature of hillslopes. Trans. Edinburgh Geol. Soc. 17: 81-102.

Kirkby, M. J. 1977. Soil development models as a component of slope models. Earth Surface Processes 2: 203-230.

Kleiss, H. J. 1970. Hillslope sedimentation and soil formation in northeastern Iowa. Soil Sci. Soc. Am. Proc. 34: 287-290.

Kleiss, H. J. 1973. Loess distribution along the Illinois soil-development sequence. Soil Sci. 15(3): 194-198.

Kuehl, R. J. 1978. Chemical and morphological properties of some loess-derived soils of northeast Iowa. Unpublished M.S. thesis. Library, Iowa State University, Ames.

Larsen, S. 1967. Soil phosphorus. Adv. Agron. 19: 151-210.

Lass, Barbara. 1978. The Woodland mounds and their cultural significance. The Journal of the Iowa Archaeological Society 25: 100-113.

Leighton, M. M. 1929. Geology and the Indian Mounds. Illinois State Academy of Science Transactions 22: 65-71.

Mallam, R. Clark. 1976a. The Mound Builders: An American myth. Journal of the Iowa Archaeological Society 23: 145-175.

Mallam, R. Clark. 1976b. The Iowa Effigy Mound Manifestation: An interpretive model. Report 9. Office of the State Archaeologist, Iowa City.

Mallam, R. Clark, and Arthur Bettis. 1979. Mound investigations in Garnavillo Township, Clayton County, Iowa. Research Papers 4(2). Office of the State Archaeologist, Iowa City.

Martin, Paul S., George I. Quimby, and Donald Collier. 1947. Indians before Columbus. University of Chicago Press, Chicago.

McKim, H. L. 1972. Porosity and iron relationships in loessial prairie soils of southern Iowa. Unpublished Ph.D. Dissertation. Library, Iowa State University, Ames.

Meggers, Betty J. 1956. Functional and evolutionary implications of community patterning. In Robert Wauchope (ed.) Seminars in Archaeology. Memoirs of the Society for American Archaeology No. 11. Society for American Archaeology, Salt Lake City, Utah.

Miller, G. A. 1974. Soil parent material, stratigraphy and soil development, Cedar County, Iowa. Unpublished Ph.D. Dissertation. Iowa State University, Ames.

Muckenhirn, R. J., L. T. Alexander, R. S. Smith, W. D. Shrader, F. F. Riecken, P. R. McMillen, and H. H. Krusekoph. 1955. Field descriptions and analytical data of certain loess-derived gray-brown podzolic soils in the upper Mississippi River Valley. Illinois Agr. Exp. Sta. Bull. 587.

Nikiforoff, C. C. 1942. Fundamental formula of soil formation. Am. J. Sci. 240(12): 847-866.

Nikiforoff, C. C. 1949. Weathering and soil evolution. Soil Sci. 67: 219-230.

Nikiforoff, C. C. 1959. Reappraisal of the soil. Science 129: 186-196.

Nørnberg, Per. 1977. Soil profile development in sands of varying age in Vendyssel, Denmark. Catena. 4: 165-179.

Norton, L. D., and D. P. Franzmeier. 1978. Toposequences of loess-derived soils in southwestern Indiana. Soil Sci. Soc. Am. Proc. 42(4): 622-627.

Ollier, Cliff. 1975. Weathering. Longman Group Limited, London.

Olson, Jerry S. 1958. Rates of succession and soil changes on Southern Lake Michigan sand dunes. Botanical Gazette 119(3): 125-170.

Parsons, Roger B. 1960. Soils of Indian Mounds in Northeast Iowa as soil genesis benchmarks. Unpublished Ph.D. Dissertation. Iowa State University, Ames.

Parsons, R. B. 1962. Indian mounds of northeast Iowa as soil genesis benchmarks. Iowa Archaeological Society Journal 12(2).

Parsons, R. B., C. A. Balster, and A. O. Ness. 1970. Soil development and geomorphic surfaces, Wilamette Valley, Oregon. Soil Sci. Soc. Am. Proc. 34: 485-491.

Parsons, R. B., W. H. Scholtes, and F. F. Riecken. 1962. Soils of Indian Mounds in northeast Iowa as benchmarks for studies of soil science. Soil Sci. Soc. Am. Proc. 26(5): 491-496.

Plog, Fred T. 1974. The study of prehistoric change. Academic Press, New York.

Prior, J. C. 1976. A regional guide to Iowa landforms. Iowa Geological Survey, Educational Series 3. Iowa City.

Redman, Charles L. (ed.) 1973. Research and theory in current archaeology. John Wiley and Sons, New York.

Reed, C. D. 1941. Supplementary climatic notes for Iowa. U.S. Dept. of Agric. Yearbook 1941: 871-872.

Richardson, J. L. 1974. Exchangeable aluminum and acidity in loess soils of south-central Iowa. Unpublished Ph.D. Dissertation. Library, Iowa State University, Ames.

Riecken, F. F., and Ernst Poetsch. 1960. Genesis and classification considerations of some prairie-formed soil profiles from local alluvium in Adair County, Iowa. Proc. Ia. Acad. Sci. 67: 268-276.

Richthofen, F. F. von. 1886. Fuhrer fur Forschungsreiserde. Berlin.

Rode, A. A. 1961. (Originally 1947). The soil forming processes and soil evolution. Israel Program for Scientific Translations, Jerusalem.

Rowe, Chandler W. 1956. The Effigy Mound culture of Wisconsin. Milwaukee Public Museum Publication in Anthropology No. 3. North American Press, Milwaukee.

Ruhe, R. V. 1956. Geomorphic surfaces and the nature of soils. Soil Sci. 82: 441-455.

Ruhe, R. V. 1969. Geomorphology. Houghton Mifflin, Boston.

Ruhe, R. V., R. B. Daniels, and J. G. Cady. 1967. Landscape evolution and soil formation in southwestern Iowa. U. S. Department of Agriculture Tech. Bull. 1349.

Ruhe, R. V., and P. H. Walker. 1968. Hillslope models and soil formation: I. Open systems. Trans. 9th Int. Congr. Soil Sci., Adelaide, Australia, 4: 551-560.

Ruhe, R. V., W. P. Dietz, T. E. Fenton, and G. F. Hall. 1968. Iowan drift problem, northeastern Iowa. Report of Investigations 7. Iowa Geological Survey, Iowa City.

Ruhe, R. V., T. E. Fenton, and L. L. Ledesma. 1975. Missouri River history floodplain construction, and soil formation in southwestern Iowa. Iowa Agric. and Home Econ. Exp. Station Res. Bull. 580.

Ruhe, R. V., and Carolyn Olson. 1978. Loess stratigraphy and Paleosols in southwest Indiana. Guidebook, 25th Field Conference of the Midwest Friends of the Pleistocene, May 19-21. Indiana University Water Resources Research Center and Department of Geology.

Runge, E. C. A., and F. F. Riecken. 1966. Influence of natural drainage on the distribution and forms of phosphorus in some Iowa prairie soils. Soil Sci. Soc. Am. Proc. 30: 624-630.

Salisbury, E. J. 1925. Note on the edaphic succession in some dune soils with special reference to the time factor. J. Ecol. 13(2): 322-328.

Scholtes, W. H. 1970. Fish farm mound investigations. Unpublished report submitted to the National Park Service.

Shimek, B. 1924. The prairie of the Mississippi River bluffs. Ia. Acad. Sci. 31: 205-212.

Silverberg, Robert. 1968. Mound builders of Ancient America: The archaeology of a myth. New York Graphic Society Ltd., Greenwich, Connecticut.

Simson, Roy W. 1959. Outline of a generalized theory of soil genesis. Soil Sci. Soc. Am. Proc. 23: 152-156.

Simonson, Z. W. 1968. Concept of soil. Adv. in Agron. 20: 1-47.

Simonson, R. W., F. F. Riecken, and G. D. Smith. 1952. Understanding Iowa soils. Wm. C. Brown Co., Dubuque, Iowa.

Smith, Bruce D. 1974. Middle Mississippi exploitation of animal populations: A predictive model. American Antiquity 39(2): 274-91.

Smith, G. D., W. H. Allaway, and F. F. Riecken. 1950. Prairie soils in the Upper Mississippi Valley. Adv. Agron. 2: 157-205.

Smith, Wilma. 1962. Weathering of some Scottish basic igneous rocks with reference to soil formation. Jour. Soil Sci. 13(2): 202-215.

Soil Science Society of America. 1965. Glossary of soil science terms. Soil Sci. Soc. Am. Proc. 29: 330-351.

Soil Survey Staff. 1951. Soil survey manual. U. S. Dept. Agr. Handbook 18. U. S. Govt. Printing Office, Washington, D.C.

Soil Survey Staff. 1966. Soil Survey Laboratory data and descriptions for some soils of Iowa. Soil Conservation Service, USDA, Soil Survey Investigations Report No. 3.

Soil Survey Staff. 1975. Soil toxonomy. U.S.D.A., Washington, D.C.

Storck, Peter L. 1972. The archaeology of Mayland Cave. Unpublished Ph.D. Dissertation. University of Wisconsin, Madison.

Struever, Stuart. 1968. Woodland subsistence-settlement systems in the Lower Illinois Valley. In Lewis R. Binford and Sally R. Binford (eds.) Perspectives in archaeology. Aldine Press, Chicago.

Syers, J. K., and T. W. Walker. 1969. Phosphorus transformations in a chronosequence of soils developed on wind-blown sand in New Zealand. I. Total and organic phosphorus. J. Soil Sci. 29(1): 57-64.

Syers, J. K., J. A. Adams, and T. W. Walker. 1970. Accumulation of organic matter in a chronosequence of soils developed on wind-blown sand in New Zealand. J. Soil Sci. 21: 146-153.

Tabatabai, M. A., and J. M. Bremner. 1970. Use of the Leco automatic 70-second carbon analyzer for total carbon analysis of soils. Soil Sci. Soc. Am. Proc. 24: 608-610.

Thomas, Cyris. 1894. Report on the Mound exploration of the Bureau of Ethnology. Bureau of American Ethnology, 12th Annual Report, 1890-1891. U. S. Govt. Printing Office, Washington, D.C.

Transeau, E. N. 1935. The prairie peninsula. Ecol. 16: 423-437.

Tyler, E. J., S. W. Buol, and P. A. Sanchez. 1978. Genetic association of properties of soils of an area in the Upper Amazon Basin of Peru. Soil Sci. Soc. Am. Jour. 42(5): 771-776.

Van Zant, K. L. 1976. Late and post-glacial vegetational history of northern Iowa. Unpublished Ph.D. Dissertation. University of Iowa, Iowa City.

Van Zant, K. L., and G. R. Hallberg. 1976. A late-glacial pollen sequence from northeastern Iowa: Sumner Bog revisited. Technical Information Series No. 3. Iowa Geological Survey, Iowa City.

Vestal, A. G. 1914. A black-soil prairie station in northeastern Illinois. Bull. Torrey Bot. Club 41: 351-363.

Visher, S. S. 1954. Climatic atlas of the United States. Harvard University Press, Cambridge, Mass.

Vreeken, W. J. 1975. Principal kinds of chronosequences and their significance in soil history. J. Soil Sci. 26(4): 378-394.

Waite, Paul J. 1970. Iowa precipitation. p. 3-15. In Paul J. Horick (ed.) Water resources of Iowa. University Printing Service, Iowa City.

Walker, P. H., and R. V. Ruhe. 1968. Hillslope models and soil formation II, closed systems. Trans. 9th Int. Congr. Soil Sci., Adelaide, Australia 4: 561-568.

Walker, T. W. 1965. The significance of phosphorus in pedogenesis. p. 295-316. In E. G. Hallsworth and D. V. Crawford (eds.) Experimental pedology. Butterworths, London.

Watson, Patty Jo, S. A. LeBlanc, and C. L. Redman. 1971. Explanation in archaeology: An explicitly scientific approach. Columbia University Press, New York.

Weaver, J. E. 1954. North American prairie. Johnsen Publishing Co., Lincoln, Nebraska.

Wendland, Wayne M. 1978. Holocene man in North America: The ecological setting and climatic background. Plains Anthropologist 23(82), Part 1: 273-287.

Whitney, M. 1909. Soils of the United States. U.S. Dept. Agr. Bur. Soils Bull. 55. U.S. Govt. Printing Office, Washington, D.C.

Willman, H. B., Elwood Atherton, T. C. Bushbach, Charles Collinson, John C. Frye, M. E. Hopkins, Jerry A. Lineback, and Jack A. Simon. 1975. Handbook of Illinois Stratigraphy Bull. 95. Illinois State Geological Survey, Urbana.

Wilson, K. 1960. The time factor in the development of dune soils at South Haven Peninsula, Dorset. J. Ecol. 48: 341-359.

Wittry, Warren J. 1959. Archaeological studies of four Wisconsin rock-shelters. The Wisconsin Archaeologist 40(4): 137-267.

Wood, Alan. 1942. The development of hillside slopes. Geol. Soc. Proc. 53: 128-140.

Wright, H. E., Jr. 1975. The dynamic nature of Holocene vegetation. Quat. Res. 6: 581-596.

Wright, J. R., A. Leahey, and H. M. Rice. 1959. Chemical morphological and mineralogical characteristics of a chronosequence of soils on alluvial deposits in the northwest territories. Canadian Journal of Soil Sci. 39: 32-43.

Wurman, E. E., E. P. Whiteside and M. M. Mortland. 1959. Properties and genesis of fine-textured subsoil bands in some sandy Michigan soils. Soil Sci. Soc. Am. Proc. 23: 135-143.

Yaalon, D. H. 1971. Soil forming processes in time and space. p. 29-39. In Dan H. Yaalon (ed.) Paleopedology: Origin, nature and dating of Paleosols. Israel Universities Press, Jerusalem.

APPENDIX A.

DESCRIPTIONS OF PROFILES IN THIS STUDY

13AM243 Off Mound (Seaton)

A1 0-7 cm, very dark brown (10YR 2/2) silt loam, weak medium granular structure, friable, many roots, clear smooth boundary, pH 6.7.

A21 8-21 cm, dark brown (10YR 3/3) silt loam, moderate fine platy structure, friable, common roots, clear smooth boundary, pH 6.7.

A22 21-41 cm, dark yellowish brown (10YR 4/4), silt loam, moderate medium platy structure, friable, gradual smooth boundary, pH 6.6.

B1 41-69 cm, dark yellowish brown (10YR 4/4), silt loam, moderate medium subangular blocky structure, friable, few very thin discontinuous silans, gradual smooth boundary, pH 5.2.

B21t 66-99 cm, dark yellowish brown (10YR 4/4), heavy silt loam, moderate medium angular blocky structure, friable, few thin discontinuous silans, few thin discontinuous cutans, gradual smooth boundary, pH 4.7.

B22t 99-120 cm, dark yellowish brown (10YR 4/4), heavy silt loam, moderate medium angular blocky structure, friable, few thin discontinuous cutans, few medium distinct brown (10YR 5/3) mottles in root channels, gradual smooth boundary, pH 4.7.

B3 120-140 cm, dark yellowish brown (10YR 4/4), silt loam, moderate medium subangular blocky structure, friable, common medium distinct brown (10YR 5/3) mottles increasing to common at base, gradual smooth boundary, pH 4.9.

13AM69 Bluff Top Mound -1

DD4EE4 S. wall, 10-15% slope, mixed prairie/oak-hickory vegetation with cedars in close proximity, 69.2 cm of mound fill over truncated B horizon, 12.7 cm of post-mound fill (resulting from pothunting activity) overly the soil formed in the mound fill

A1 0-1" (0-2.5 cm) very dark gray (10YR 3/1) silt loam; very weak fine granular structure; very friable; pH 6.6; abrupt wavy boundary; many roots

(A2)[1] 1-2" (2.5-5.1 cm) very dark grayish brown (10YR 3/2) silt loam; weak fine granular breaking to very weak fine platy structure; friable-very friable; pH 6.6; abrupt wavy boundary; many roots

A2 2-4" (5.1-10.2 cm) dark brown (10YR 3/3) silt loam; weak fine subangular blocky structure; very friable; pH 6.5; abrupt smooth boundary; many very dark grayish brown (10YR 3/2) worm channels; many roots

A1b 4-5" (10.2-12.7 cm) very dark gray (10YR 3/1) silt loam; moderate medium granular breaking to moderate fine granular structure; friable; pH 6.7; abrupt wavy boundary; many very dark grayish brown (10YR 2/2) worm channels; common roots; this horizon has been truncated by a pot hunter who dug into the mound sometime in the past. This pedon is 61 cm south of the pot hole. It appears that the sod was removed from the area surrounding the pot hole.

A21b 5-6.5" (12.7-16.5 cm) very dark grayish brown (10YR 3/2) silt loam; moderate medium platy structure; friable; pH 6.8; abrupt wavy boundary; few dark brown (10YR 3/3) worm channels; few roots

A22b 6.5-8.75" (16.5-22.2 cm) dark brown (10YR 3/3) silt loam; moderate medium subangular blocky breaking to moderate fine subangular blocky structure; friable; pH 7.0; abrupt wavy boundary; very few fine dark brown (10YR 4/3) mottles; few very dark grayish brown (10YR 3/2) worm channels

Bb 8.75-11.75" (22.2-29.9 cm) dark yellowish brown (10YR 4/4) silt loam; weak fine subangular blocky structure; very friable; pH 6.9; gradual wavy boundary; very few faint fine dark yellowish brown (10YR 4/6) mottles; few roots

C1b 11.75-26.25" (29.9-66.7 cm) dark yellowish brown (10YR 4/4) silt loam; massive tends to break into medium blocky units; very friable; pH 6.8 to 43 cm, 5.4 to 67 cm; gradual wavy boundary; dark

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[1](A2) Indicates an incipient eluvial horizon.

yellowish brown (10YR 4/6) mottles few fine at top common medium at base; few roots

Ce3b 26.25-31.25" (66.7-79.4 cm) dark yellowish brown (10YR 4/4) silt loam; massive breaks into coarse blocky units; pH 5.5; this lack of consistance in reaction may be reflecting basketloads of soil from leached and unleached horizons; very friable; abrupt smooth boundary

IIB3b 31.25-36" (79.4-91.4 cm) base of excavation; yellowish brown (10YR 5/4) silt loam; moderate medium to coarse subangular blocky structure; firm; pH 5.6; few faint medium yellowish brown (10YR 5/6) mottles; very few thin discontinuous dark yellowish brown (10YR 4/4) cutans

13AM69 Bluff Top Mound -2

Eastern side of intersection of N-S and E-W trenches on S wall, 0-5% slope; mound center, mixed prairie and tree vegetation

0 1-0" (2.5-0 cm) well-decomposed mixed sod and leaf litter

A1 0-2.5" (0-6.4 cm) very dark gray (10YR 3/1) silt loam; weak medium to fine granular structure; friable; pH 6.6; abrupt wavy boundary; many roots

A21 2.5-4" (6.4-10.2 cm) very dark grayish brown (10YR 3/2) silt loam; weak medium breaking to very weak fine platy structure; friable; pH 6.6; abrupt wavy boundary; many dark brown (10YR 3/3) worm channels; many roots

A22 4-7.5" (10.2-19.1 cm) dark brown (10YR 3/3) silt loam; weak medium to fine subangular blocky structure; friable; pH 6.8; gradual wavy boundary; many very dark grayish brown (10YR 3/2) worm channels

B 7.5-10.5" (19.1-26.7 cm) dark brown (10YR 4/3) silt loam; moderate medium subangular blocky structure; friable; pH 6.9; gradual wavy boundary; few very dark grayish brown (10YR 3/2) worm channels

Ce1 10.5-19.5" (26.7-49.5 cm) dark yellowish brown (10YR 4/4) silt loam; massive tends to break into medium blocky units; very friable; pH 6.9; abrupt smooth boundary; few roots

Ce2 19.5-24" (49.5-61 cm) brown to yellowish brown (10YR 5/3-5/4) silt loam; massive breaks into medium to fine blocky units; very friable; pH 6.9; abrupt smooth boundary; ash disseminated throughout the matrix ("ash layer")

Ce3 24-30" (61-76.2 cm) dark brown (10YR 4/3) silt loam matrix with light gray (10YR 7/2) pockets (ash); massive breaks into fine blocky units; very friable; pH 6.3; abrupt smooth boundary

Ce4 30-32.75" (76.2-83.2 cm) dark brown (10YR 4/3) silt loam; massive breaks into weak fine granular units; pH 5.5; gradual wavy boundary; friable; this appears to be a slightly weathered surface

Ce5 32.75-38.5" (83.2-97.8 cm) dark brown (10YR 4/3) silt loam; massive; very friable; pH 6.5; abrupt wavy boundary; burial pit fill

Ce6 38.5-49.75" (97.8-126.4 cm) dark yellowish brown (10YR 4/4) silt loam; massive; very friable; pH 7.2; abrupt smooth boundary; few medium $CaCO_3$ concretions (not formed in place); burial pit fill

IIC 49.75- (126.4-155 cm) base of excavation; yellowish brown (10YR 5/4) silt loam; massive; friable; pH 7.4; few faint medium light brownish gray (10YR 6/2) mottles; very few fine yellowish red (5YR 5/6) Fe concretions; many fine $CaCO_3$ concretions

13AM69 Bluff Top Mound -3

1.22m west of intersection of N-S and E-W trenches S wall, 20-25% slope, mixed prairie and tree vegetation

A1 0-2.25" (0-5.7 cm) very dark grayish brown (10YR 3/2) silt loam; weak fine granular structure; very friable; pH 6.7; abrupt wavy boundary; many roots

A1b 2.25-3.25" (5.7-8.3 cm) very dark gray (10YR 3/1) silt loam; moderate medium to fine granular structure; very friable; pH 6.8; abrupt wavy boundary; many roots; top of this horizon has been truncated by a pot hunter sometime in the past

A12b 3.25-4" (8.3-10.2 cm) very dark grayish brown (10YR 3/2) silt loam; weak fine subangular blocky structure; very friable; pH 7.0; abrupt wavy boundary; many dark brown (10YR 3/3) worm channels; many roots

(Bb)[2] 4-7.25" (10.2-18.4 cm) dark brown (10YR 3/3) silt loam; moderate medium to fine subangular blocky structure; friable; pH 7.0; gradual wavy boundary; common very dark grayish brown (10YR 3/2) worm channels

Ce1b 7.25-15.5" (18.4-39.4 cm) dark yellowish brown (10YR 4/4) silt loam; massive tends to break into medium blocky units; very friable; pH 6.9; abrupt smooth boundary; small limestone fragments present

Ce3b 15.5-27" (39.4-68.6 cm) dark yellowish brown (10YR 4/4-4/6) silt loam; massive breaks into medium blocky units; very friable; pH 6.3; abrupt smooth boundary; charcoal flecks disseminated throughout matrix

IIB3b 27-36" (68.6-91.4 cm) dark yellowish brown (10YR 4/4) silt loam; weak medium subangular blocky structure; friable; pH 6.5; gradual wavy boundary; few discontinuous dark brown (10YR 4/3) cutans

IIC1 36-50" (91.4-127 cm) base of excavation; dark yellowish brown (10YR 4/4) silt loam; massive; very friable; pH 6.9; many faint medium yellowish brown (10YR 5/4) mottles; few medium $CaCO_3$ concretions

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[2](Bb) Indicates a buried incipient B horizon.

T-1-1

Footslope, 17% slope, grass and cedar

A1 (0-5 cm); black to very dark brown (10YR 2/1-2/2) sandy loam; weak fine granular structure; very friable; abrupt smooth boundary; many roots

A2 (5-15 cm); very dark grayish brown (10YR 3/2) sandy loam; moderate medium subangular blocky structure; friable; clear smooth boundary; common roots

B11 (15-26 cm); dark yellowish brown (10YR 4/4) sandy loam; moderate medium subangular blocky structure; friable; gradual smooth boundary; few roots

B12 (26-46 cm); brown to dark brown (7.5YR 4/4) sandy loam; weak medium subangular blocky structure; friable; gradual smooth boundary

B2t (46-91 cm); brown to dark brown (7.5YR 4/4) heavy sandy loam; strong medium to fine subangular blocky structure; friable; many sandstone fragments increasing with depth, 50% of matrix at 70 cm, "stone line" composed of sandstone at 91 cm

T-1-3

Sideslope, birch and yew, 62% slope, ∿50% of surface is bare and scarred

A1 (0-3 cm) very dark brown (10YR 2/2) sandy loam; weak medium granular structure; very friable; abrupt wavy boundary; many roots

A2 (3-18 cm) dark brown (10YR 3/3) sandy loam; moderate medium platy structure; friable; clear smooth boundary; common roots; weathered sandstone fragments in lower 5 cm

B (18-41 cm) dark yellowish brown (10YR 4/4) sandy loam; moderate medium subangular blocky structure; friable; weathered sandstone fragments increase with depth; weathered sandstone at 41 cm

13AM69-23-1

West end of EW trench SW wall 1.52 m east of west end of mound, 10-15% slope, mixed grass and cedar vegetation

A1 0-1.5" (0-3.8 cm) very dark grayish brown (10YR 3/2) sandy loam; very weak fine granular structure; very friable; pH 6.6; clear wavy boundary; many roots

A2 1.5-6" (3.8-15.2 cm) dark brown to dark yellowish brown (10YR 4/3-4/4) sandy loam; weak fine granular breaking to weak very fine subangular blocky structure; very friable; pH 6.5; clear smooth boundary; many roots

B12 6-12" (15.2030.5 cm) dark yellowish brown (10YR 4/4) sandy loam; weak medium subangular blocky structure; very friable; pH 6.9; clear smooth boundary; many very dark grayish brown (10YR 3/2) worm channels; roots

B21 12-19" (30.5-48.3 cm) dark yellowish brown (10YR 4/4-4/6) sandy loam; weak medium subangular blocky structure; very friable; pH 6.8; very few discontinuous grainy coats; abrupt smooth boundary

Ce 19-34" (48.3-86.4 cm) dark yellowish brown (10YR 4/4) sandy loam matrix with yellowish brown (10YR 5/6) pockets (basket loads); structureless breaks into medium subangular blocky units; firm; pH 6.8; abrupt smooth boundary; many discontinuous grainy coats; ash and small charcoal flecks disseminated throughout the matrix; small sandstone fragments; decomposed tabular sandstone at 21-22" (53.3-55.9 cm)

IIB 34-48" (86.4-121.9 cm) base of excavation; dark brown (10YR 4/3) loamy sand; moderate medium subangular blocky structure; friable; pH 6.8; thin discontinuous dark grayish brown (10YR 4/2) cutans

13AM69-23-2

Center of mound S wall of EW trench, 0-5% slope, mixed grass and cedar vegetation

A1 0-2" (0-5.1 cm) dark gray (10YR 4/1) sandy loam; very weak very fine crumb structure; very friable; pH 7.1; abrupt wavy boundary

A2 2-5" (5.1-12.7 cm) dark grayish brown (10YR 4/2) sandy loam; weak fine subangular blocky breaking to weak very fine platy structure; friable; pH 7.1; gradual wavy boundary

B 5-21" (12.7-53.3 cm) yellowish brown (10YR 5/4) sandy loam; very weak medium subangular blocky breaking to weak fine subangular blocky structure; friable; pH 7.0; abrupt smooth boundary; few discontinuous grainy coats increasing slightly at the base; very few fine yellowish brown (10YR 5/8) Fe concretions; very few small sandstone fragments and charcoal flecks disseminated throughout the matrix

Ce 21-39.5" (53.3-100.3 cm) dark yellowish brown (10YR 4/4) sandy loam matrix with yellowish brown (10YR 5/6) pockets (basket loads); structureless breaks into medium subangular blocky units; firm; pH 6.1-6.5; abrupt smooth boundary; many discontinuous grainy coats; few very thin discontinuous dark brown (7.5YR 4/4) cutans; ash and small charcoal flecks disseminated throughout the matrix; small sandstone fragments

IIB2b 39.5-50" (100.3-127 cm) dark brown (7.5YR 4/4) sandy loam (exterior) strong brown (7.5YR 5/6) (interior); moderate medium subangular blocky structure; friable; pH 6.9; gradual wavy boundary; few thin discontinuous dark brown (10YR 4/3) cutans; sandstone blocks at top

IIB3b 50-58" (127-147.3 cm) dark brown (7.5YR 4/4) (exterior) sandy loam strong brown (7.5YR 5/6) (interior); moderate medium subangular blocky structure; friable; pH 7.0; gradual wavy boundary; very few thin discontinuous dark brown (10YR 4/3) cutans; few small sandstone fragments

IIC 58- (147.3- cm) base of excavation; strong brown (7.5YR 5/6) sandy loam; very weak medium subangular blocky breaking to single grain structure; very friable to loose; pH 7.0; many fine very dark gray (10YR 3/2) manganese concretions

13AM69-23-3

1.5 meters west of east end of East-West trench, South wall

A1 0-3" (0-7.6 cm); very dark grayish brown (10YR 3/2); sandy loam; weak fine granular structure; very friable; clear wavy boundary; many roots

A2 3-7" (7.6-17.8 cm); dark brown to dark yellowish brown (10YR 4/3-4/4) sandy loam; weak fine granular and weak fine subangular blocky structure; friable; clear smooth boundary; many roots

B1 7-15" (17.8-38.1 cm); dark yellowish brown (10YR 4/4) sandy loam; weak medium subangular blocky structure; very friable; clear smooth boundary; many very dark grayish brown (10YR 3/2) worm channels; common roots

B2 15-18" (38.1-45.7 cm); dark yellowish brown (10YR 4/4-4/6) sandy loam; weak medium subangular blocky structure; friable; very few discontinuous grainy coats; abrupt smooth boundary

Ce 18-34" (45.7-86.4 cm); dark yellowish brown (10YR 4/4) sandy loam matrix with yellowish brown (10YR 5/6) pockets (basket loads); structureless, breaks into medium subangular blocky units; firm; abrupt smooth boundary; wavy discontinuous grainy coats; ash and small charcoal flecks disseminated throughout the matrix; small sandstone fragments

IIBb 34-49" (86.4-123.4 cm) base of excavation; dark brown (10YR 4/3) sandy loam; moderate medium subangular blocky structure; friable; thin discontinuous grayish brown (10YR 4/2) cutans

13AM69-29-2

East wall of EW trench .3 m east of mound, 20% slope, mixed grass and cedar vegetation

O 2-0" (5.1-0 cm) moderately decomposed leaf litter

A1 0-2.5" (0-6.4 cm) very dark gray (10YR 3/1) sandy loam; weak fine granular structure; very friable; leached; abrupt wavy boundary; many roots

A2 2.5-6" (6.4-15.2 cm) dark brown (10YR 3/3) sandy loam; moderate medium to fine subangular blocky structure; friable; leached; clear wavy boundary; very few faint fine dark yellowish brown (10YR 4/4) mottles; many roots

B11 6-14" (15.2-35.6 cm) dark yellowish brown (10YR 4/4) sandy loam; moderate coarse subangular blocky breaking to moderate medium subangular blocky structure; friable; leached; gradual smooth boundary; common faint medium dark yellowish brown (10YR 4/6) mottles; many very dark grayish brown (10YR 3/2) worm channels; few sandstone fragments

B12 14-18" (35.6-46.7 cm) dark yellowish brown (10YR 4/4) sandy loam; moderate medium subangular blocky structure; friable; leached; gradual wavy boundary; many faint coarse yellowish brown (10YR 5/6) mottles; many fine charcoal flecks disseminated throughout the matrix; few roots

B21 18-29" (46.7-73.7 cm) dark yellowish brown (10YR 4/4) sandy loam; weak coarse to medium subangular blocky structure; very friable; leached; gradual wavy boundary; very few fine strong brown (7.5YR 5/6) Fe concretions; few roots

B22 29-37" (73.7-94 cm) dark yellowish brown (10YR 4/4) sandy loam; moderate medium subangular blocky structure; friable; leached; abrupt wavy boundary; few thin discontinuous dark brown (7.5YR 4/4) cutans; few roots

B31 37-40" (94-101.6 cm) dark brown (7.5YR 4/4) sandy loam; moderate medium to fine subangular blocky structure; firm; leached; common thin discontinuous dark brown (7.5YR 4/2) cutans; few sandstone fragments; gradual irregular boundary; slight strong brown (7.5YR 5/6) Fe accumulation at top

B32 40-48" (101.6-121.9 cm) base of excavation; dark brown (7.5YR 4/4) sandy loam; weak medium subangular blocky structure; friable; leached; very few thin discontinuous dark brown (7.5YR 4/2-4/4) cutans; common fine faint brown (7.5YR 5/2) mottles

13AM69-29-1

1.6 m from east edge of mound (S of mound center), 5-10% slope, mixed grass and cedar vegetation

O	1-0" (2.5-0 cm) well-decomposed leaf litter
A1	0-2.75" (0-7 cm) very dark gray (10YR 3/1) loamy sand weak medium granular structure; very friable; leached; abrupt wavy boundary; many roots
AC	2.75-5" (7-12.9 cm) dark brown (10YR 4/3) and dark yellowish brown (10YR 4/4) loamy sand; weak medium subangular blocky structure; friable; leached; gradual wavy boundary; many very dark grayish brown (10YR 3/2) worm channels; many roots
Ce1	5-11.5" (12.7-29.2 cm) dark yellowish brown (10YR 4/4) sand; single grain structure; loose; leached; abrupt smooth boundary; many very dark grayish brown (10YR 3/2) worm channels; few roots; sandstone fragments scattered throughout (common)
Ce2	11.5-25" (29.2-63.5 cm) dark yellowish brown (10YR 4/4-4/6) sand with yellowish brown (10YR 5/6) pockets (basket loads); massive tends to break into weak medium subangular blocky units; friable; leached; abrupt smooth boundary; common sandstone fragments
Ce3	25-37" (63.5-94 cm) dark yellowish brown (10YR 4/4) loamy sand; single grain; loose; leached; few charcoal flecks disseminated throughout the matrix; abrupt wavy boundary; few faint medium yellowish brown (10YR 5/4) mottles at base
IIBb	35-57" (94-144.8 cm) base of excavation; dark yellowish brown (10YR 4/6) sandy loam; lamallae 2-3" in thickness separated by yellowish brown (10YR 5/4) loamy sand 4-6" in thickness; moderate medium subangular blocky structure in lamallae; single grain structure between lamallae; friable consistence in lamallae, loose consistence between lamallae; lamallae contain few faint medium yellowish brown (10YR 5/4) mottles; friable; leached

T-2-1

Lower footslope, 10% slope, grass and forbs

A1 (0-8 cm); very dark grayish brown (10YR 3/2) loam; weak medium to fine granular structure; very friable; clear smooth boundary; many roots

A2 (8-20 cm); dark brown (10YR 3/3) loam; moderate medium to fine platy structure; very friable; clear smooth boundary; common roots

B11 (20-35 cm); dark yellowish brown (10YR 4/4) loam; weak medium subangular blocky structure; very friable; gradual smooth boundary; few roots

B12 (35-43 cm); dark yellowish brown (10YR 4/4) loam; moderate medium subangular blocky structure; friable; gradual smooth boundary; few roots

B2t (43-81 cm); brown to dark brown (7.5YR 4/4) loam; moderate medium angular blocky structure; friable; few thin discontinuous grainy coats; common thin discontinuous dark brown (10YR 3/3) cutans; gradual smooth boundary

B3 (81-91 cm); brown to dark brown (7.5YR 4/4) loam; moderate medium subangular blocky structure; friable; common thin discontinuous dark brown (10YR 3/3) cutans; sandy limestone fragments increase toward the base

R 91- weathered sandy limestone

T-2-2

Upper footslope, 17% slope, grass and forbs

A1 (0-5 cm); very dark grayish brown (10YR 3/2) loam; weak fine granular structure; very friable; clear smooth boundary; many roots

A2 (5-19 cm); dark brown (10YR 3/3) loam; weak medium platy structure; very friable; clear smooth boundary; common roots

B11 (19-38 cm); dark yellowish brown (10YR 4/4) loam; weak medium subangular blocky structure; very friable; gradual smooth boundary; few roots

B12 (38-57 cm); dark yellowish brown (10YR 4/4) loam; weak medium subangular blocky structure; very friable; gradual smooth boundary; few roots

B2 (57-84 cm); brown to dark brown (7.5YR 4/4) loam; moderate medium to fine angular blocky structure; friable; few thin discontinuous grainy coats; sandy limestone at the base

R 84- weathered sandy limestone

AM69-4-1

Center of mound, 5-10% slope, mixed grass and cedar vegetation

A1 0-2" (0-5.1 cm) dark brown (10YR 3/3) loam; moderate medium granular structure; friable; pH 6.1; abrupt wavy boundary; many roots

A 2-4" (5.1-10.2 cm) dark brown (10YR 4/3) loam; very weak medium subangular blocky breaking to weak fine subangular blocky structure; friable; pH 6.4; gradual wavy boundary; many faint dark brown (10YR 3/3) worm channels; few fine very dark gray (10YR 3/1) accumulations (oxides)

B 4-10" (10.2-25.4 cm) dark brown (10YR 4/3) loam; moderate medium subangular blocky structure; friable; pH 5.7; gradual wavy boundary; few thin discontinuous dark brown (10YR 3/3) cutans; few discontinuous grainy coats on vertical ped surfaces

Ce1 10-17" (25.4-43.2 cm) dark brown (10YR 3/3) (exterior) loam (10YR 4/3) (interior); very weak medium subangular blocky to massive structure; very friable; pH 5.3; abrupt smooth boundary; few very fine very dark gray (10YR 3/1) accumulations (oxides) at base

Ce2 17-32" (43.2-81.3 cm) dark yellowish brown (10YR 4/4) loam matrix with yellowish brown (10YR 5/6) pockets (basket loads); structureless breaks into moderate medium subangular units at the top to weak medium to fine subangular blocky units at the base; firm; pH 5.5 to 61 cm, 6.1 from 61-81 cm; many thin discontinuous dark brown (10YR 4/3) coatings decreasing to few at the base; abrupt smooth boundary; burned earth, charcoal, ash and artifacts disseminated throughout the matrix

IIB1b 32- (81.3- cm) base of excavation; dark yellowish brown (10YR 4/4-4/6) loam; moderate medium subangular blocky structure; firm; pH 6.4; few discontinuous dark brown (10YR 4/3) cutans; very few discontinuous grainy coats; pebbles >15% by volume

APPENDIX B.

VERTICAL PROFILES OF MOUNDS INVESTIGATED IN THIS STUDY

SHOWING LOCATION OF PROFILES SAMPLED

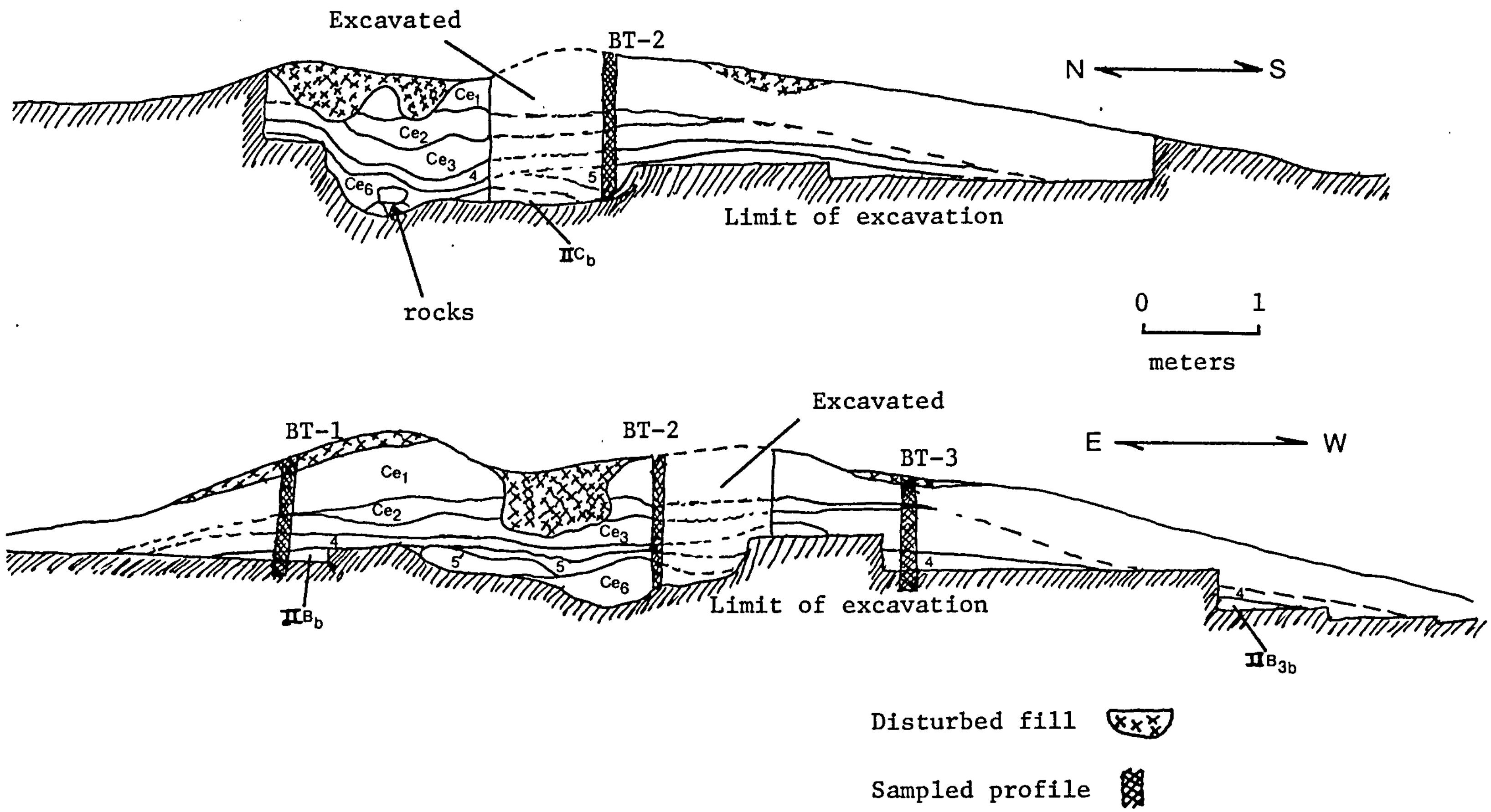

Figure 43. North to south and east to west vertical profiles of Bluff Top Mound (13AM243) showing location of sampled profiles

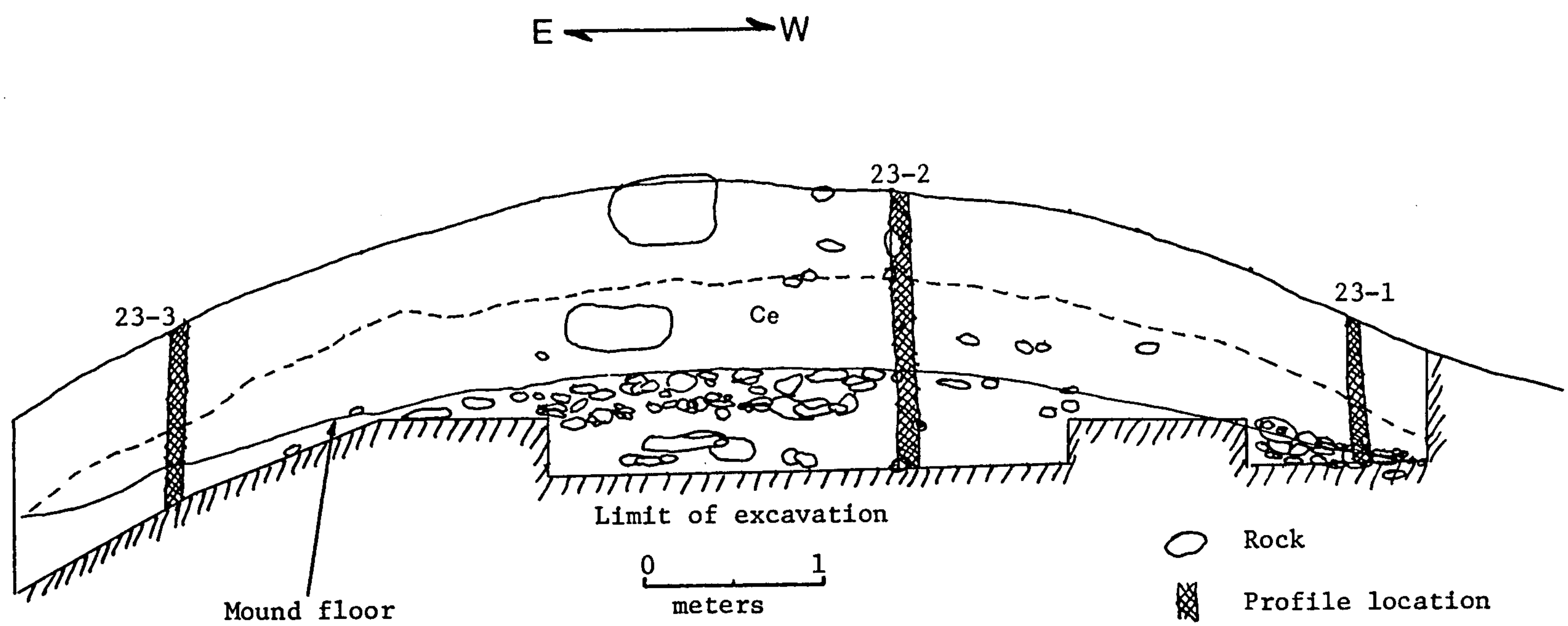

Figure 44. Mound 23 east to west vertical profile showing location of sampled profiles

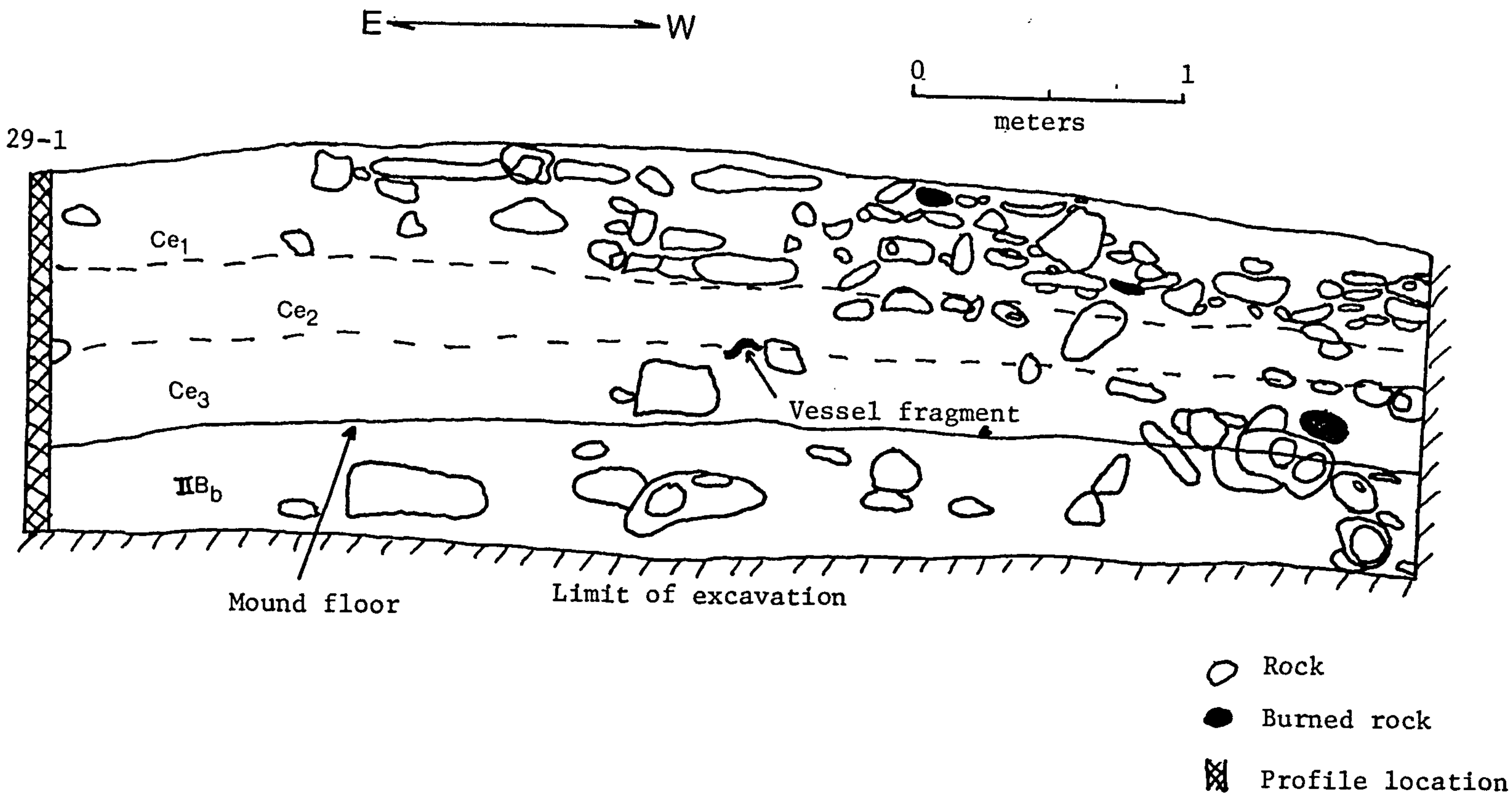

Figure 45. East to west vertical profile of Mound 29 of the Keller Group showing location of sampled profile

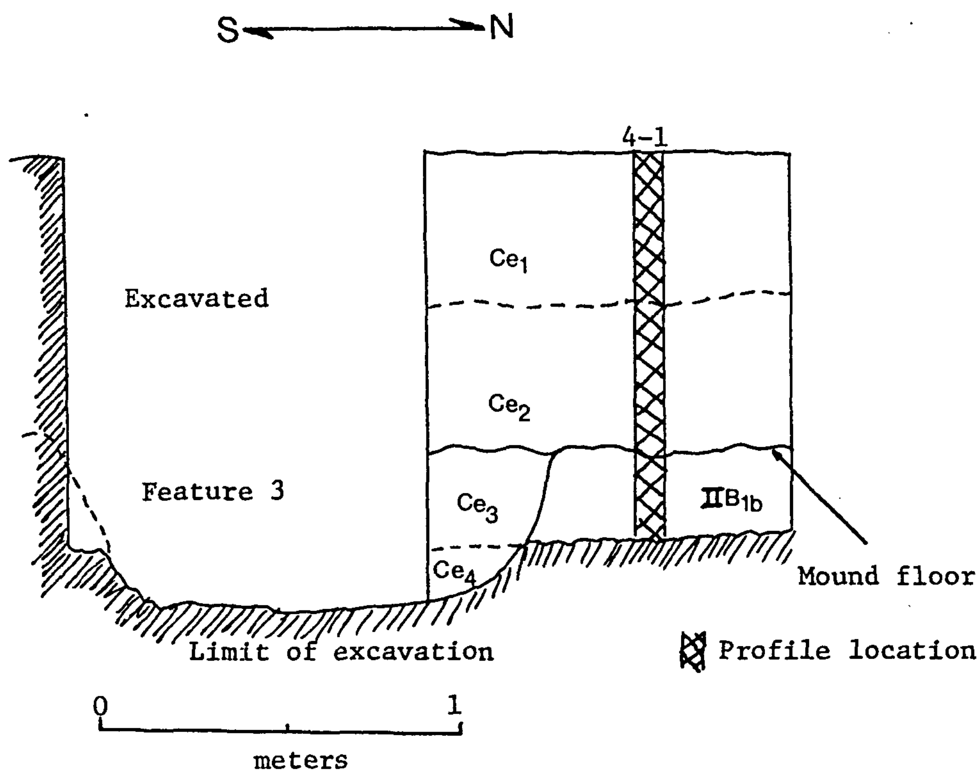

Figure 46. Vertical profile of pit reexcavated into central portion of Mound 4 of the Keller Group

APPENDIX C.

LABORATORY DATA FOR PROFILES SAMPLED

Profile	Hori-zon	Depth (cm)	Coarse silt	Fine silt	Clay	Sand	pH	TC (%)	TP (ppm)
AM243									
Off mound Seaton	A1	0-7	35.2	23.0	9.4	23.4	6.7	7.84	469.4
	A21	7-21	46.4	28.1	11.3	14.2	6.7	.90	257.8
	A22	21-41	44.3	33.4	9.4	12.4	6.6	.30	191.2
	B1	41-69	40.6	27.1	19.9	12.3	5.2	.29	283.6
	B21t	69-99	37.2	24.9	27.4	10.4	4.7	.13	401.6
	B22t	99-120	39.1	21.8	27.3	11.9	4.7	.04	493.8
	B3	120-150	41.1	21.3	25.0	12.7	4.9	.02	477
T-1-1	A1	0-5	25.9	2.6	5.9	65.6	6.8	11.59	410.6
	A2	5-15	17.9	11.7	7.1	63.3	6.9	2.71	310.3
	B11	15-26	12.2	7.9	6.6	73.3	7.0	.40	238.3
	B12	26-46	12.6	9.9	6.7	70.8	6.9	.23	298.5
	B2t	46-70	13.8	12.5	13.5	61	6.8	.15	602.1
T-1-3	A1	0-3	20.2	5.5	6.8	67.4	6.9	9.99	358.6
	A2	3-18	12.5	6.9	9.5	71.2	7.0	1.47	298.6
	B	18-41	11.5	6.2	8.8	73.4	6.9	.56	264.3
T-2-1	A1	0-8	29.4	17.6	10.6	42.4	6.9	3.77	504.2
	A2	8-20	29.9	16.2	10.5	43.4	6.7	.38	432.2
	B11	20-35	30	17.9	11.3	40.8	6.6	.71	408.5
	B21t	35-43	29.8	15.2	17.1	37.9	6.3	.28	511.6
	B22t	43-81	31.7	6.6	22.2	39.5	5.4	.11	607.3
	B3	81-91	22.3	0.7	23.1	53.8	5.4	.10	572.7
T-2-2	A1	0-5	30.3	10.1	17.4	42.2	6.4	4.62	591.2
	A2	5-19	29.5	10.9	18.2	41.5	6.6	1.61	510.1
	B11	19-38	27.7	7.9	18.4	46.1	6.7	.62	459.3
	B12	38-57	27.7	8.8	18.5	44.9	6.8	.31	430.3
	B2	57-84	22.8	7.9	19.4	50.1	6.8	.11	504.4
Mound BT-1									
	A1	0-5	36.1	24.3	16.8	22.8	6.6	3.13	280.3
	A2	5-10	35.6	25.7	17.9	20.8	6.5	2.67	281.9
	A1b	10-13	28.9	30.2	9.5	31.4	6.7	8.08	296.5
	A21b	13-16	40	25.8	19.2	15	6.8	1.87	283.4
	A22b	16-22	39	27.3	19.3	14.5	7.0	1.33	276.7
	Bb	22-30	38.5	25.2	21.2	15.1	6.9	.63	230.8
		30-36	38.5	26.3	20.8	14.3	6.8	.30	203.7
	Celb	36-43	39.5	24.5	21.1	15	6.8	.27	191.3
		43-51	38.4	27.1	20	14.4	6.7	.27	225.7
		51-58	37.3	25.8	22.1	14.8	5.5	.22	292.4
		58-67	37.2	24.7	22.4	15.7	5.5	.31	328.8

Profile	Hori-zon	Depth (cm)	Coarse silt	Fine silt	Clay	Sand	pH	TC (%)	TP (ppm)
	Ce3b	67-73	37.2	24.7	22.4	15.7	5.5	.31	328.8
		73-79	38	25.8	22.1	14.1	5.5	.26	320.3
	IIB3b	79-91	39.4	26.5	21.5	12.7	5.6	.21	367.8
BT-3	A1	0-6	24.4	27.4	8.9	39.2	6.7	8.63	305.2
	A1b	6-8	36	27.9	18.4	17.7	6.8	1.07	273.4
	A12b	8-10	37.6	27.1	20	15.3	7.0	.54	223.5
	Bb	10-18	38.8	29	17.2	15	7.0	.33	223.5
		18-26	46.3	21	15.8	16.9	7.0	.27	233.9
	Ce1b	26-34	47.4	21.3	16.5	14.8	6.9	.23	260.4
		34-40	48	20.5	17.1	14.5	6.7	.25	296.1
		40-46	49.4	15.9	19.9	14.8	6.6	.25	297.2
	Ce3b	46-53	46.9	19.0	18.2	15.9	6.2	.21	285.8
		53-60	45.3	20.3	17.6	16.9	6.2	.21	284.0
		60-69	48.2	19.1	18.5	14.2	6.3	.21	293.9
	IIB3b	69-80	48.5	18.8	18.2	14.5	6.4	.16	340.9
		80-91	48.2	18.2	17.5	16.1	6.5	.17	338.4
	IICb	91-102	46.2	19.6	17.3	16.9	6.9	.29	388.0
BT-2	A1	0-6	40.7	23.3	11.5	24.5	6.6	5.09	325.9
	A2	6-10		missing			--	--	--
	A22	10-19	42.5	22.8	16.5	18.3	6.8	1.03	285.9
	B	19-27	44.7	23.3	17.3	14.8	6.9	.71	259.7
	Ce1	27-50	46.2	22.8	17.4	13.6	6.9	.37	229.0
	Ce2	50-61	46.1	24.0	14.8	15.1	6.9	.27	189.1
	Ce3	61-69	45.4	23.8	14.2	16.6	6.6	.25	199.4
		69-76	46.1	23.2	14.9	15.8	5.9	.24	187.8
	Ce4	76-83	45	22.4	17.6	15	5.5	.23	220.8
	Ce5	83-89		missing			--	--	--
		89-98	44.4	24.3	17.2	14.1	6.5	.38	311.6
	Ce6	98-106	50.4	19.8	15.6	14.1	7.1	1.17*	451.7
		106-114	50.8	19.7	15.2	14.3	7.2	1.27*	414.9
		114-120	49.2	20.5	15.6	14.7	7.3	1.27*	422.0
		120-126	51.1	20.4	14.9	13.6	7.4	1.42*	468.2
	IIC	126-136	49.8	22.4	14.2	13.6	7.4	2.42*	520.7
Mound 4									
	A1	0-5	29	2.3	16.9	51.8	6.1	2.32	440.5
	A2	5-10	32.4	8.6	11.0	47.9	6.4	.97	498.1
	B	10-17	35	7.7	11.1	46.3	5.9	.51	535.7
		17-25	36.1	8.7	11	43.9	5.5	.50	475.0
	Ce1	25-31	32.8	9.5	11.6	46.1	5.3	.48	470.6
		31-37	34.5	9.6	11.8	44.1	5.4	.40	456.2
		37-43	30.3	11.9	12.2	45.6	5.2	.36	451.6

Profile	Hori-zon	Depth (cm)	Coarse silt	Fine silt	Clay	Sand	pH	TC (%)	TP (ppm)
	Ce2	43-49	31.5	9.7	14.8	44.0	5.4	.38	530.1
		49-55	30.8	9.5	14.6	45.1	5.5	.33	509.4
		55-61	29.9	10.5	13.2	46.4	5.7	.22	477.9
		61-68	33.2	10.7	12.6	43.5	5.9	.16	444.4
		68-74	29.3	12.5	12.2	45.9	6.1	.16	438.4
		74-81	28.8	11.6	13.1	46.5	6.3	.15	428.6
	IIB1b	81-88	8.7	31.7	14.7	44.8	6.4	.16	511.2
Mound 23-1									
	A1	0-4	24.9		7.0	68.1	6.6	1.53	310.7
		4-10	26.2		6.3	67.6	6.5	.68	274.3
	A2	10-15	27.6		5.7	66.8	6.9	.33	281.0
	B1	15-22	25.2		7.0	67.8	6.8	.32	332.8
		22-30	24.6		7.4	68	6.8	.28	337.7
	B2	30-39	24.9		7.6	67.5	6.9	.17	373.0
		39-48	24.4		10.9	64.7	6.8	.18	451.1
	Ce	48-55	24.2		11	64.9	6.8	.15	409.2
		55-63	23.6		10	66.5	6.7	.12	331.4
		63-70	22		9.0	69	6.8	.11	316.1
		70-78	24.4		8.5	67.1	6.9	.11	312.6
		78-86	22.8		8.3	68.9	6.8	.10	288.5
	IIC1b	86-94	13.7		1.3	85	6.8	.08	136.0
Mound 23-2									
	A1	0-5	24.1		7.4	68.4	6.5	6.51	342.7
	A2	5-13	24.5		8.6	67	6.4	.83	254.1
		13-19	23.1		8.7	68.2	6.4	.42	270.4
	B	19-25	23.1		8.2	68.6	6.8	.30	217.5
		25-31	22.7		8.8	68.4	6.9	.32	265.9
		31-37	22.3		8.7	68.9	6.8	.25	279.6
		37-45	20.9		8.8	70.3	6.7	.28	268.9
		45-54	23.1		9.3	67.6	6.7	.21	300.1
	Ce	54-63	24.4		11	64.6	6.7	.18	386.6
		63-73	23.5		11	65.5	6.8	.16	342.5
		73-83	23.5		10.9	65.6	6.6	.14	345.3
		83-92	24.1		10.4	65.5	6.5	.16	353.7
		92-100	21.8		10.1	68.1	6.6	.15	314.1
	IIB2b	100-106	23.0		9.8	66.8	6.7	.11	246.7
		106-113	23.0		9.5	67.5	6.4	.10	233.1
		113-120	22.9		9.5	67.6	6.3	.10	247.5
		120-127	23.6		10	66.4	6.3	.12	252.6
	IIC	127-137	22.9		9.3	67.8	6.2	.14	268.9
		137-147	22		9.6	68.4	6.1	.17	281.7
		147-157	23.4		9.1	67.5	6.0	.14	290.4

Profile	Hori-zon	Depth (cm)	Coarse silt	Fine silt	Clay	Sand	pH	TC (%)	TP (ppm)
Mound 23-3									
	A1	0-8	16.2	5.4	8.4	70	6.6	6.98	283.0
	AC	8-18	14.6	4.8	11	69	6.9	.74	206.5
	B1	18-24	12.8	4	10.8	73	6.8	.35	191.5
		24-32	15.6	1.4	11	72	7.0	.30	193.9
		32-38	14.8	2.6	11.6	61	6.8	.31	218.2
	B2	38-46	12.6	4.3	10.5	72.5	6.8	.25	202.1
	Ce	46-54	14.1	4.5	10.4	71	6.7	.41	193.6
		54-62	13	4.8	12.2	70	6.7	.16	218.2
		62-70	13.7	6.7	10.4	69	6.8	.30	241.2
		70-78	14.3	3.5	13.2	69	6.7	.14	204.5
		78-86	14.4	5.3	13.4	67	6.6	.20	309.4
	IIBb	86-100	15	5.2	12.3	67.5	6.4	.15	312.7
Mound 29-1									
	A1	0-7	9.6	6.0	3.4	81	6.8	6.40	295.4
	A&B	7-13	6.0	4.7	3.0	86.3	7.0	.73	161.7
	Ce1	13-21	5.8	4.0	2.6	87.6	6.9	.31	141.5
		21-29	6.0	4.1	2.8	87.1	7.0	.23	100.2
	Ce2	29-34	5.3	3.0	4.1	87.5	7.0	.19	115.5
		34-38	7.2	3.2	3.5	86.1	6.9	.13	117.7
		38-42	6.5	4.0	2.3	87.2	7.0	.10	122.0
		42-46	1.3	7.5	5.6	85.6	7.0	.13	131.2
		46-50	1.0	6.4	5.6	87	7.0	.11	118.8
		50-54	1.9	6.4	5.7	86	6.9	.12	126.3
	Ce3	54-58	6.8	4.4	2.4	86.4	6.9	.09	156.3
		58-62	2.9	5.9	6.0	85.2	6.8	.08	117.4
		62-64		missing			--	--	--
		64-70	2.7	5.9	8.4	83.1	7.0	.08	203.4
		70-75	1.7	6.2	6.6	85.5	7.0	.10	187.8
		75-80	2.5	5.5	8.5	83.5	6.9	.10	167.0
		80-85	8.2	4.1	4.2	83.5	6.9	.10	145.4
		85-94	8.3	3.9	3.9	84	6.9	.09	164.6
	IIBb	94-107	5.2	1.9	8.7	84.1	6.8	.12	225.0
Mound 29-2									
	A1	0-6	19.5	9.5	6.1	64.8	6.8	5.08	332.3
		6-15	16.5	9.0	6.7	67.8	6.8	.80	277.8
		15-20	16.8	9.6	6.3	67.2	6.9	.39	232.2

Profile	Hori-zon	Depth (cm)	Coarse silt	Fine silt	Clay	Sand	pH	TC (%)	TP (ppm)
	B11	20-25	16.2	8.6	6.4	68.8	6.9	.31	232.0
		25-30	14.8	9.4	6.5	69.3	6.8	.24	268.4
		30-36	16.4	8.6	6.1	68.9	6.7	.19	286.5
	B12	36-41	17.8	6.8	6.5	68.9	6.5	.17	263.5
		41-46	15.9	9.5	6.7	67.9	6.3	.22	298.3
	B21	46-51	16.5	8.1	10.3	65.1	5.9	.20	370.8
		51-56	15.5	5	11.8	67.6	6.3	.23	339.3
		56-61	15.1	6.8	11.7	66.5	6.4	.20	328.5
		61-66	14.7	6.3	10.4	68.7	6.6	.14	320.5
		66-74	14.9	6.3	10.6	68.2	6.6	.11	321.3
	B22	74-76	15.1	6.6	10.7	67.6	6.6	.10	280.2
		76-81	14	7.3	9.7	69.0	6.9	.15	304.5
		81-86	13.5	7.9	10.2	68.4	6.8	.12	327.7
		86-94	13.6	7.9	9.9	68.6	6.9	.09	286.3
	B31	94-102	12.5	8.3	10.2	69	6.8	.06	274.3
	B32	102-110	13.3	7.2	10.2	69.2	6.8	.09	296.3
		110-120	10.6	9.3	11.6	68.5	6.8	.10	337.7