THE ANTHROPIC EPIPEDON
AND
SOILS FORMED ON MIDDENS.

by

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I. Introduction: Man and the Soil.

Pedologists recognize five factors of soil formation: parent material, climate, topography, organisms and time. Some scientists specify a sixth factor: man, rather than include him with other organisms. (Bidwell and Hole, 1965. Yaalon and Yaron, 1966). The authors of the American system of soil taxonomy, hence referred to as the "Soil Taxonomy", have accepted the concept of man as a soil-forming factor and have defined four horizons that express man's impact on soil development. They are the Ap horizon, the Agric horizon, the Plaggen epipedon and the Anthropic epipedon.

The Ap horizon represents a surface layer or epipedon that has been altered by plowing or other disturbance. Tillage of the soil mixes colors and textures, destroys natural soil structure, modifies plant and animal populations and, seasonally, leaves bare soil to be sorted and eroded by wind and water. Pedologists recognize the Ap horizon by its weak or massive structure, its well-mixed appearance, its occurrence on the surface and its thickness that reflects past disturbance, especially tillage kind and depth (Soil Survey Staff, 1951).

Beneath the Ap, an illuvial layer known as the agric horizon may form. Plowing temporarily increases the number of macro-pores extending downward from the soil surface, allowing turbulent water to flow readily down to the base of the plow layer. The silt, clay and organic matter suspended in this flow are deposited on ped surfaces, in worm holes and in root channels. The resulting coatings and lamellae produce a horizon lower in value and chroma than the surrounding soil (Soil Survey Staff, 1975).

Plaggen epipedons form in response to additions of fresh mineral material. Farmers using sod or heath litter for animal bedding inadvertently add large quantities of soil to their fields while they are spreading manure. These additions eventually produce a greatly thickened epipedon. Pedologists recognize plaggen epipedons by the diverse materials they contain, the presence of cultural artifacts, spade marks, stratifications produced by pounding rains, and heightened position relative to surrounding soils (Soil Survey Staff, 1975).

Anthropic epipedons usually form in kitchen middens - the accumulations of debris found in association with long-inhabited or heavily used sites. Anthropic epipedons possess darkened surface layers and unusually high phosphorous contents as a consequence of the deposition of organic-waste materials (Soil Survey Staff, 1975).

Any system of classification, such as the Soil Taxonomy, has its basis largely in the experience and knowledge of a limited few. The great diversity of soils and the restricted input by taxonomists make it necessary to carry out an on-going program of field trial and subsequent revision, particularily for soils that are relatively uncommon, or less accessible to researchers in the United States.

In this research effort, I will characterize soils formed on kitchen middens and in adjacent areas of non-midden soils. This soil information will be used to assess the Soil Taxonomy's criteria for Anthropic epipedons.

II. Literature Review.

A. The Classification of Soils.

Soils vary infinitely in their morphological, physical and chemical properties. This complexity means that there can be no single, perfect, scheme of soil classification. Classifications must vary depending on which properties of the soil they attempt to describe (Cline, 1949. Soil Survey Staff, 1975).

Due to the impracticality of employing more than one system at the same time on a national level, most government-sponsored classification systems represent a compromise made among the needs of diverse users. The American system of soil taxonomy is an example of such a multi-purpose classification. The authors of the Soil Taxonomy clearly recognized the difficulties inherent in creating a generally useful national system of soil classification, and so devised the following rules to guide its development (Soil Survey Staff, 1975):

1. Categories of the taxonomy should be differentiated on the basis of quantifiable, universally recognizable, soil properties.

2. The taxonomy should be multicategoric, to make available information both on broad relationships and on useful specifics.

3. The taxonomy should relate to properties possessed by real soils.

4. Soils should be differentiated on the basis of properties observable in the field, or inferred from other data.

5. The taxonomy must be able to accomodate changes made necessary by new knowledge.

6. Undisturbed soils and their cultivated counterparts should remain in the same taxon.

7. The taxonomy must limit itself to artificial soil units based on defined ranges of properties.

8. All known soils must fit somewhere within the taxonomy.

B. The Anthropic Epipedon.

Soil horizons formed as a result of human activity have not been studied extensively in the United States. The Ap horizon is ubiquitous in cultivated soils and its properties are well known, but the Agric horizon, the Plaggen epipedon and the Anthropic epipedon have received little attention. The Agric and Plaggen horizons have been neglected because they are uncommon; however, the existence of thousands of ancient Indian middens thoughout the United States suggests that the study of Anthropic epipedons may be an important but overlooked topic of soil classification. For this reason the Anthropic epipedon has been chosen as the focus of this study.

The Anthropic epipedon possesses the following properties (Soil Survey Staff, 1975):

1. Anthropic epipedons must not have massive structure or a hard consistency. Aggregates must be less than 30 cm in diameter or they are considered massive.

2. The matrix of the epipedon must have a Munsell color value less than 3.5 when moist (5.5 when dry) and a moist chroma less than 3.5. The value for the epipedon should be at least one unit less, and the chroma two units less, than for the C horizon, or if this is absent, for the next underlying horizon. These color requirements are waived for soils formed from dark-colored parent material if the epipedon contains at least 0.6% more organic carbon than the C horizon, or if the epipedon extends down to a lithic or paralithic contact. The color value need only be less than 5 if the epipedon contains more than 40% powdery lime.

3. The epipedon must have a high base saturation relative to adjacent soils (Soil Survey Staff, 1982).

4. The epipedon must have a thickness of at least 10 cm if it is directly underlain by a lithic contact, a paralithic contact, a petrocalcic horizon or a duripan. The epipedon must have a thickness greater than 25 cm if the soil's texture is loamy fine sand or finer, and if pedogenic limes, fragipans, duripans, or argillic, natric, spodic, cambic or petrocalcic horizons occur at depths greater than 75 cm. If any of these features occur at depths shallower than 75 cm, then the epipedon must be at least 18 cm thick and compose at least one-third of the depth to this feature. The epipedon must be at least 25 cm thick if its texture is coarser than loamy fine sand, if there are no underlying diagnostic horizons, and if the organic matter within it decreases irregularly with depth. The epipedon must be at least 18 cm thick for soils in which none of the above apply.

5. The epipedon must have an organic-carbon content of at least 0.6% throughout its thickness, unless the epipedon contains in excess of 40% powdery lime, in which case the organic-carbon content must be at least 2.5%. The epipedon must contain less than 20% organic carbon if it is seldom saturated with water. Frequently saturated epipedons must contain less than 12% to 16% organic carbon in proportion to a clay content of from 0% to 60%.

6. The epipedon must contain in excess of 250 mg kg-1 P2O5 soluble in 1% citric acid, but must not contain phosphate

nodules. The profile must not increase in P205 below the epipedon (mg kg-1 is equivalent to ppm, and will continue to be used throughout this paper).

7. For epipedons formed as a result of prolonged human habitation, some part of the epipedon must be moist for a cumulative time of at least three months, in seven out of ten years, when soil temperatures at 50 cm exceed 5 degrees centrigrade.

8. The "n-value" must be less than 0.7 (N-values measure the relationships between the percentage of water present under field conditions, the percentage of inorganic clay and the percentage of humus).

The anthropic epipedon is described by the Soil Taxonomy as having "formed during long-continued use of the soil by men... as a place of residence...(the) disposal of bones and shells have supplied calcium and phosphorus... Such epipedons occur... mostly in kitchen middens."(Soil Survey Staff, 1975).

Dr. Guy D. Smith - one of the major contributors to the new taxonomy - made the following comments about the anthropic epipedon (Brasfield, 1982).

> "...There are many village sites in Europe along the old Roman roads where the kitchen wastes were thrown out into the fields. We have many aboriginal Indian villages in North and South America which were more or less permanent and where

> again kitchen wastes were thrown out onto the soil around the villages... Commonly the epipedons there are full of artifacts, flint chips, bones, and what have you, and one recognizes from that that this was a village site. Well, these soils originally in the earlier approximations got classified as Mollisols but it seemed to us that they were quite different particularly in that they would not respond to phosphate fertilizers. It happens in the Amazon that we have again the kitchen middens, the dark-colored epipedons, with high phosphate, but we don't quite reach the 50% base saturation because there were not enough shells to be thrown out to bring the base saturation up to 50%, so we waived the 50% base saturation limit on anthropic epipedons in Amazonia."

Dr. Guy Smith mentioned the anthropic epipedon during a discussion of the 250 mg kg-1 P205 upper limit for the mollic epipedon.

> "The purpose of this was to exclude from the mollic epipedon the more or less permanent village sites of aboriginal Indians, and the village sites of Medieval times in Europe where the kitchen refuse, including the bones, was thrown into the garden and the soil became dark colored, acquiring the characteristics of a mollic epipedon in so far

> as color, structure, carbon, and so on were concerned."

In summary, the anthropic epipedon is a surface soil horizon that has developed on accumulations of refuse. Generally, this epipedon can be recognized by its relatively great thickness, strong structure, dark color, high organic-matter content, high base saturation and by a citric-acid soluble P2O5 content in excess of 250 mg kg-1.

C. Phosphorus in Soils.

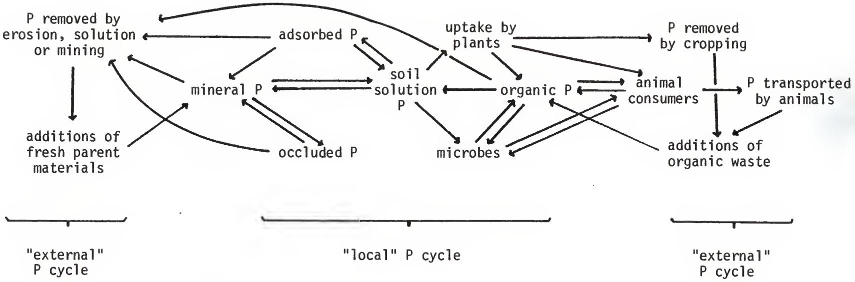
1. Geological Sources of Phosphorus.

All soil phosphorus has its origin in phosphorous-bearing geologic materials. Phosphorus is the eleventh most common element in the earth's crust, with most rocks containing from 1500 mg kg-1 to 2000 mg kg-1 P205, although this amount varies from zero to nearly 400,000 mg kg-1. (McKelvey, 1973) The sources of most soil phosphorus are weathered low-content rocks, such as sandstone (approximately 1600 mg kg-1 P205), shale (approximately 1100 mg kg-1 P205) and limestone (approximately 700 mg kg-1 P205) (Ronov and Yaroshevsky, 1969).

2. Phosphorous Cycling.

As phosphatic parent materials decompose they enter into the soil-phosphorus cycle, illustrated in Fig. 1. Most phosphorus in the soil has undergone extensive chemical alteration, although some particles may be occluded by virtually insoluble coatings of Fe203 and be excluded from further reactions (Olsen and Khasawneh, 1980). The chemical decomposition of non-occluded minerals releases ionic phosphate into the soil solution. Many of these ions are adsorbed onto the surfaces of calcium carbonate or to compounds of iron or aluminum as a prelude to incorporation into new, less soluble compounds (Sample *et al.*, 1980). The most common of these compounds in calcareous soils are the calcium phosphates: hydroxyapatite (CaOH(PO4)3), mono-calcium phosphate (CaH4(PO4)2), dicalcium phosphate (Ca2H2(PO4)2), tricalcium phosphate (Ca3(PO4)2) and octelcalcium phosphate (Ca4H(PO4)2). In acid soils variscite (AlPO4-2H2O), strengite

Figure #1: the soil-phosphorous cycle



($FePO_4 \cdot 2H_2O$) and other iron and aluminum compounds will dominate (Adams, 1980). Other phosphatic ions will be adsorbed to organic complexes or will substitute for silicates and hydroxyl groups or water molecules along the edges of clay minerals (Sample et al., 1980).

Significant amounts of ionic phosphorus may be "taken up" from the soil solution by plants or micro-organisms and then immobilized as part of organic molecules. This may be in the form of a living plant, an animal consumer, undecomposed residue, or as a stable organic complex. After death, decomposition or oxidation, this organically immobilized phosphorus returns to the soil solution.

Phosphorus may be added to or removed from the local cycle by the "external phosphorous cycle" shown in Fig. 1. Organic and inorganic phosphorus can be removed from the local soil cycle by the erosion of phosphatic parent materials, calcium or iron and aluminum phosphates, particles of occluded phosphorus, minerals carrying adsorbed phosphorus and phosphorus immobilized in soil organic matter. Soil-solution phosphorus may be lost to runoff, to leaching or to plant uptake and subsequent removal as a crop. The removal of phosphorus from one location implies its later addition to another. Phosphorus may be added to an area by the deposition of wind or water-borne sediments. Soil-solution phosphorus may be adsorbed onto other minerals, taken up by plants or micro-organisms or crystalized into a mineral form. Phosphorus in organic forms is commonly removed from local soil cycles when consumed by animals and then transported away in the digestive tract or tissue. Later, this phosphorus is redeposited in the soil as waste or as a corpse. This often results in significant phosphorous accumulations at the mouths of dens, nesting sites, watering holes or any place where animals congregate. The most spectacular of these animal-induced concentrations are the large guano deposits found in caverns or on islands where hundreds of thousands of tons of phosphorus-rich wastes have accumulated (Altschuler, 1973).

Humans are also prominent disturbers of local phosphorous cycles (Bidwell and Hole, 1965). Human activities that produce deforestation, overgrazing or over-cultivation hasten the loss of soil phosphorus by promoting erosion. Foodgathering removes phosphorus in organic forms. Construction and manufacturing immobilizes phosphorus inside mounds, bricks and pottery. Human activities also may increase local concentrations of soil phosphorus, commonly as a result of the deposition of organic wastes. Cook and Treganza (1950) determined that a 70-kilogram male concentrates an average of 2.5 grams of phosphorus per day in fecal matter and urine. The average human body contains approximately 650 grams of phosphorus, 86% of this in bones and 14% in soft tissues (Machlin, 1973). Lean muscle meats used for food commonly contain in excess of 2000 mg kg-1 total phosphorus (Sherman, 1947). In early Indian societies the phosphorus concentrated in plant foods, in animal carcasses and in organic-waste materials was deposited in kitchen middens surrounding continually used settlements.

3. The mobility of phosphorus in the soil.

Most research into the mobility of phosphorus in the soil has been carried out by researchers in the agronomic sciences. For the most part, these studies have been concerned with the short-term behavior of soil phosphorus as an element of soil fertility. This research has shown that the phosphorus added to the soil is quickly converted to relatively insoluble forms and so tends to remain near the surface (Tisdale and Nelson, 1975). This lack of mobility provides the theoretical basis for the formation of Anthropic epipedons.

The archaeologist is concerned with long time periods. During these extended intervals there is evidence that phosphorus can move through the soil profile in several ways. Brady (1974) showed that leaching annually removed very small, but detectable amounts of phosphorus from a variety of soils. These small amounts are negligible in the short term, but over long periods may produce significant movements of soil phosphorus. In certain soils phosphorus leaches readily. Acidic histisols contain complex organic anions that interfere with fixation leaving phosphorus extremely susceptible to leaching (Fox and Kamprath, 1971). Significant leaching also occurs in coarse-textured soils dominated by quartz sand that contains few sites for fixation (Barrow, 1980). Similarly, phosphorus can leach from any soil when phosphorous concentration exceeds soil-fixing capacity. Phosphorus also moves down soil profiles associated with translocated clays, organics and iron oxides (Bakkevig, 1980).

Considerable movement of soil phosphorus may be accomplished by biological activities. Plant roots remove phosphorus from large volumes of the subsoil. Much of this phosphorus is incorporated into above-ground plant tissues. At leaf fall or plant death this phosphorus will be added to, and "fixed" in the soil surface. Phosphorus also moves to surface layers as a result of animal activities. Baxter and Hole (1967) showed that ants transport large volumes of subsoils to the surface. The resulting ant hills are unusually high in phosphorus both because they are formed from phosphatic materials from lower horizons and because of secondary enrichment from ant wastes. Similar processes may redistribute phosphorus from the surface. Curtis (1959) estimated that the upper two feet of a prairie Hapludoll was turned over by earthworms, ants and rodents every one-hundred years. Lyford (1963) determined that ants had completely churned the top 35 cm of some forest soils. The krotovinas produced by burrowing animals and by plant roots enhance the downward movement of phosphorus.

There is some evidence that phosphorus added as fresh organic waste may be more mobile in the soil profile than phosphorus in an inorganic form. These organics may be consumed by organisms, transported and redeposited several times before transforming into stable, less mobile, organic or inorganic forms. Bakkevig (1980) sampled the soil underlying a refuse heap outside a cabin used by reindeer hunters in Sweden. He discovered that in twenty years large amounts of phosphorus had moved ten centimeters down the profile. This addition of phosphorus to the soil in the form of reindeer carcasses likely approximates the conditions that led to the formation of kitchen middens.

4. Soil-Test Phosphorus.

The early 1800s mark the beginning of modern studies of soil fertility. The work of scientists such as De Saussure, Boussingault and Liebig established that certain chemical elements were essential to plant nutrition. Initially it was believed that a soil's fertility status was proportional to the total amount of the critical elements present. The fact that nutrient elements might exist in the soil in both "active" and "dormant" forms (available and unavailable) was first suggested by Daubeny in 1845. In 1894 Dyer published a procedure designed to measure the plant-available phosphorous content of soils. He had observed plant roots etching marble blocks in the foundation of an old building. He concluded that roots exude dilute concentrations of citric acid in order to dissolve soil minerals prior to their uptake. Dyer believed he could simulate this process in the lab by extracting soils with a dilute solution of citric acid, and then determining the total amount of phosphorus contained in this extractant to give a measure of the total plant-available phosphorus in a soil.

Over the years much effort went into modifying and perfecting plant-available soil-phosphorous tests. Soil-fertility researchers tried measuring plant-available phosphorus using a wide variety of extraction procedures, but by the 1940s it was clear that none of these tests yielded precise measures of plant-available phosphorus. However, these tests were useful if they correlated with crop-yield response curves (Bray, 1948). Such tests could be used to generate meaningful fertilizer recommendations, even if they could not produce much quantitatively useful information.

Plant-available soil-phosphorous tests never have yielded quantitatively useful information due to variations in the physical and chemical properties of soils (Kamprath and Watson, 1980).

Soils vary widely in amounts of specific surface area. Reagents used to extract phosphorus will react on the surfaces of clays, losing their effectiveness, and so there is a tendency to underestimate the phosphorous content. The degree of underestimation will vary with soil texture and type of clay mineral.

Soils also vary in pH. Reagents are partially neutralized in reaction with soils of pH of 7 or higher, decreasing the amount of phosphorus extracted. Calcium phosphates can be extracted and quantified although they are unavailable to plants. Differences in pH, and in ionic composition, concentration and activity also determine the kinds of phosphorous compounds present in the soil. A single extractant used in a soil test likely will remove and measure a portion of several different fractions of phosphorus. This amount does not correspond to plant-available phosphorus except within a limited range of soil-chemical properties. Additionally, most of these tests do not assay organic-phosphorous fractions that may constitute over 50% of total soil phosphorus (Brady, 1974). The organic fraction also is an important reservoir of plant-available nutrients.

In summary, it is currently impossible to determine a soil's exact plant-available phosphorous status. The numerical data produced by phosphorous tests is useful only if this data correlates with crop-yield response curves. Furthermore, no single test will correlate with available-phosphorous content except under very limited ranges of soil conditions. Analysts must devise regional plant-available phosphorous tests that take account of the unique properties of local soils.

Archaeologists uncritically adopted these tests, with all their complexities, to test for anthropological additions of soil phosphorus. The Soil Taxonomy borrowed the very first of these plant-available phosphorous tests, Dyer's 1894 citric-acid extraction, to distinguish between Mollic and Anthropic epipedons.

D. Archaeological Soils.

The soil contained in archaeological excavations was long considered only an impediment to the discovery of larger, more dramatic artifacts. As archaeologists became more concerned with broader based, environmental studies and improved their techniques of excavation, they discovered that the soil was a repository for a wealth of micro-artifacts, such as pollen, charred seeds and chert chips. More recently, a few researchers became aware of another overlooked artifact, the soil itself (Cornwall, 1958).

The unusual chemical properties of archaeological soils had long been appreciated by farmers, who knew these soils to be highly fertile. Similarly, foresters had learned to identify old village sites on the basis of changes in color and composition of vegetation (Lutz, 1951). The first archaeologist to comment on the relationship between archaeological sites and soil fertility was Hughes who, in 1911, observed this relationship in Egypt (Russell, 1957). It wasn't until the late 1920s that Arrhenius, a Swede, observed this phenomena and undertook research to determine its cause. He discovered that these soils had unusually high phosphorous contents, apparently as a result of the long-continued deposition of organic wastes on these sites (Arrhenius, 1931). The decomposition of these organics released phosphatic ions onto the surface of the soil where they were "fixed". The strength of this fixation made soil phosphorus highly resistant to leaching and to movement down the profile. The continued additions of waste created the unusually high plant-available phosphorous levels observed by archaeologists. Arrhenius evaluated archaeological soil with chemical tests designed to detect plant-available phosphorus. Arrhenius used these tests because he was interested in the relationship between archaeological sites and soil fertility, and because these standard tests were available in any agronomic soil-analysis laboratory.

Archaeological soils with high phosphorous contents were reported from around the world: Arrhenius (1934) in Sweden, Christensen (1935) in Denmark, Castagnol (1939) in Indochina, Pendleton (1943) in Thailand, Thomas (1947) in Uganda, and others, particularily from sites in Europe. Lutz's (1951) study on Indian villages in Alaska marked the acceptance of the phosphorous testing of archaeological soils in the United States. Soil-phosphorous testing has since become a standard archaeological technique for evaluating the intensity of human activity on the soil, and has been used in the study of sites as diverse as Canadian Indian villages (Heidenreich and Navratil, 1973), Romano-British Huts (Conway, 1983), modern picnic grounds (Streeter, 1971) and cattle tracks (Bakkevig, 1980). The emphasis of most of these studies was on the horizontal variation of phosphorus in surface soils. The results were qualitatively useful for delineating the boundaries of sites, or for giving an indication of relative intensity of use, but were not used for rigid types of quantitative comparisons.

Another, less common, archaeological technique is the analysis of the vertical variation of phosphorus in soil profiles. An early qualitative use of these techniques was to detect the depth of burials in soils where the skeleton had completely disintegrated (Solecki, 1950, Nunez, 1975 and Keeley et al, 1977). Other researchers began using phosphorous variation in the vertical profile in a quantitative sense to estimate population densities, to date periods of intermittent settlement and to generate data for a variety of other ecological and environmental concerns. Studies of this sort were undertaken by Mulvaney and Joyce (1965) in Australia, Davidson (1973) in northeastern Greece, and by Ahler (1973) in Missouri.

The growing archaeological use of qualitative and quantitative soil-phosphorous comparisons, prompted a critical evaluation of the techniques of phosphorous analysis. A crucial topic of discussion centered on which fraction or fractions of soil phosphorus should be evaluated to reveal anthropologically accumulated phosphorus. Most early researchers, and some even today, uncritically borrowed agronomic tests designed to measure plant-available phosphorus. This was an easy alternative since samples could be sent to agronomic soil-testing labs, but no one has ever shown that concentrations of plant-available phosphorus correlate with anthropological phosphorus. For this reason, plant-available phosphorus tests are considered unsuitable for quantitative comparisons.

Some researchers advocate testing for total soil phosphorus as a means of evaluating anthropological additions. Total or near total phosphorus extraction was used by Provan (1973) in

Norway, by Konrad *et al*. (1983) in Maine, and Conway (1983) in England. Criticisms of the use of total soil-phosphorous data have centered on the inability to distinguish anthropic phosphorus from similar natural forms of phosphorus and on the tremendous variation in phosphorous content found in natural soils. Proudfoot (1976) reviewed several natural processes that produced movement and concentration of phosphorus in the soil. He noted that phosphorus may move in response to leaching, eluviation or plant-uptake. Soil-phosphorous variations result from a tendency for particular fractions of phosphorus to accumulate on certain particle-size fractions, or for specific compounds of phosphorus to occur at different pHs. He emphasized that phosphorus added to the soil surface, while strongly "fixed" in the short term, can be leached to great depths over the time periods of interest to archaeologists.

Bakkevig (1980) discussed how variations in the phosphorous contents of soils may be due to differences in parent material, biological processes and climate. He also stated that phosphorus can be eluviated in association with clay-sized particles, organic matter and iron oxide. The inability to be certain whether or not variations in soil phosphorus are natural or anthropic caused Bakkevig to conclude that phosphorous analysis should be used only for qualitative and not quantitative comparisons in archaeology.

Eidt (1977) recognized the problems inherent in testing for total soil phosphorus, and recommended a technique for separately evaluating several of the major inorganic fractions of soil phosphorus. He called for the evaluation of the "settlement phosphorus" fraction, but offered no solid theoretical basis by which this could be done.

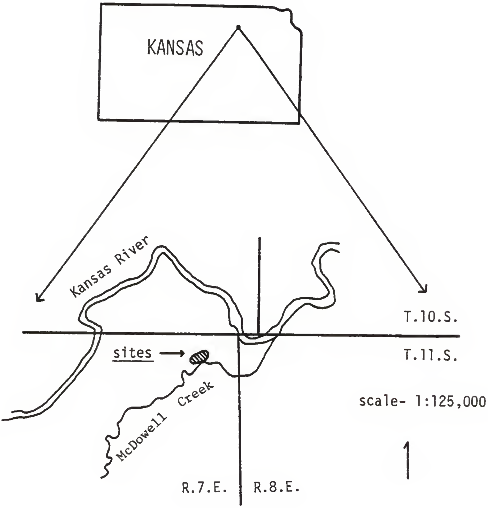
Woods (1977) also advocated the separate analysis of several different fractions of inorganic soil phosphorus. He contended that naturally contributed soil phophorus, or that added through modern fertilizers, tends to concentrate in just one fraction, but that anthropic phosphorus would be distributed among several fractions. Determination of the fractional distribution would thus allow the identification of anthropologic phosphorus in soils. This concept is as yet statistically unproven, and does not account for organic forms of soil phosphorus. White (1978) observed high variability of phosphorus among soil types, different profiles of the same series, and different horizons of the same pedon. He stated that comparisons between one profile and another could only be meaningful if the two soils had similar phosphorus contents prior to human disturbance. The extreme variability in phosphorous content that exists even within the same soil series at locations only a few meters apart, as Cipra et al. (1972) demonstrated, indicates that finding similar profiles would be difficult, if not impossible.

In summary, archaeologists have concluded that human activities often are associated with increased levels of soil phosphorus. They also have discovered that currently available soil-phosphorous information is not accurate enough to allow quantitative comparisons between diverse sites, or, without very careful and thorough sampling, even within single sites. Barring scientific advances, phosphorous testing in archaeology likely will be confined to quick field tests used to discover and qualitatively evaluate new sites, and to give clues about relative intensities of use within single sites.

III. Materials and Methods.

Seven kitchen middens were identified on a cultivated forty-acre tract located east of the Ashland community, in southern Riley County (Fig #2). These sites were located by Dr. P. J. O'Brien, Kansas State University archaeologist. A soil profile in each midden was morphologically described and sampled by horizon and by 10-cm increments. An additional site was selected adjacent to each midden (with one exception where construction activities had disturbed the adjacent soil) and was similarly described and sampled. Samples were collected during the summer of 1983 and analyzed for phosphorus during the spring of 1984. Sample size was limited to one core from each site in order to minimize disturbance of archaeological remains. Samples were sub-sampled in triplicate and tested for phosphorus using a 1% citric-acid soluble extraction, as designated in the Soil Taxonomy (Soil Survey Staff, 1975). This procedure is described in Appendix #1. The resulting chemical numeric data is in Appendix #2. This information in graphic form and soil-profile descriptions are presented in the following section.

Figure #2: locations of sampling sites



IV. Results.

A. Cultural Affiliations of Sampling Sites.

The soils of this study were formed in, or adjacent to, kitchen middens dating from Great Plains variants of the Archaic, the Early Woodland and the Late Woodland periods of North American Indian archaeology.

The Archaic cultural period lasted from approximately 6000 B.C. to 0 A.D.. These peoples were descendants of nomadic hunters of mammoth, tapir, horse and giant bison. The extinction of these large mammals forced a change in subsistence patterns which marked the beginning of the Archaic period. Archaic Indians developed highly stable hunting and gathering economies based on the American bison, deer, antelope and wild-plant foods. The middens formed at their campsites are identified by certain characteristic chert tools and the absence of pottery (Wedel, 1961).

The Woodland period, which began around 0 A.D., was a cultural era marked by the gradual introduction of domesticated-plant foods and pottery. Archaic-period nomadic hunters and gatherers did not use heavy, fragile pottery. Pottery increased in importance with the spread of domesticated crops, when people were at least seasonally tied to specific areas. In the Early Woodland period subsistence patterns were much like those of the Archaic period, but with some pottery. As these people adopted more sedentary lifestyles pottery became more abundant, deer (hunted locally) became a more important source of meat than bison (which were pursued over great distances) and domesticated crops increasingly supplemented wild-plant foods. Woodland-period middens can be recognized by certain characteristic chert tools and pottery fragments (Wedel, 1961). The Woodland period ended about 1000 A.D..

The kitchen middens sampled in this study have been assigned cultural affiliations on the basis of the chert and pottery artifacts that they contain. The middens provide little evidence for subsistence patterns, but these can be reasonably inferred from other sites in this region (O'Brien, personal communication).

B. Representative Profile of the Soil on which the Middens were Located.

All of the middens in this study were formed on the Reading Silt Loam, 0-1%, a Fine, Mixed, Mesic, Typic Argiudoll. In this area the Reading has formed on a late Wisconsin-age terrace, the second terrace from the bottom. The Indians chose to live on these soils because of the safety from flooding and because of the soil's proximity to floodplain, riparian and upland ecosystems. A description of a representative, cultivated, profile of this soil follows (Jantz, *et al*., 1975):

(All colors are for dry soil unless stated otherwise.)

> A--0 to 28 cm.; dark grayish-brown (10YR 4/2) silt loam, very dark brown (10YR 2/2) when moist; moderate, fine granular structure; hard when dry, friable when moist; few worm casts; medium acid; clear, smooth

boundary.

BA--28 to 51 cm.; dark grayish-brown (10YR 4/2) light silty clay loam, very dark grayish brown (10YR 3/2) when moist; moderate, fine, granular structure; hard when dry, friable when moist; few worm casts; medium acid; gradual smootn boundary.

Bt--51 to 102 cm.; dark grayish-brown (10YR 4/2) heavy silty clay loam, very dark grayish brown (10YR 3/2) when moist; moderate, fine, granular structure and fine subangular blocky structure; hard when dry, firm when moist; slightly acid; diffuse, smooth boundary.

BC--102 to 132 cm.; brown (10YR 5/3) heavy silty clay loam, dark grayish brown (10YR 4/2) when moist; few, fine, faint mottles of yellowish brown; weak, fine, subangular blocky structure; hard when dry, firm when moist; neutral; diffuse, smootn boundary.

Ck--132 to 152 cm.; brown (10YR 5/3) silty clay loam, dark brown (10YR 4/3) when moist; weak, fine, subangular blocky structure; hard when dry, firm when moist; many threads and few concretions of carbonate; calcareous; moderately alkaline.

These soils are well drained, have moderately slow permeability and rarely flood. The climax vegetation on these soils is a mixture of tall and short grasses and a variety of forbs. Annual precipitation averages 80.3 cm, but from 1858 to

1984 has varied from 38.4 to 153.4 cm. Three-quarters of the annual total precipitation falls during the growing season. Precipitation peaks in May and June. Less than 19.3 centimeters is usually received from December through February (Jantz, *et al.*, 1975).

C. Morphological Descriptions and Phosphorous Contents of the Midden and Non-midden Soils.

The soils sampled in this study have been farmed since the 1870s, except for site #10 that was recently put into fescue grass. These soils have received applications of manures and of both nitrogenous and phosphatic fertilizer (personal communications, Raleigh Eggers and Fred Lind).

This section contains a morphological description of each soil pedon, and a graph illustrating variation in 1% citric-acid soluble phosphorous content with depth. Circles represent the values obtained for each ten-centimeter increment sample. Phosphorous concentrations of genetic horizons are shown by vertical lines extending the depth of each horizon. Many genetic horizons lacked the phosphorous concentrations of the corresponding 10-cm increments. This illustrates the risks inherent in sampling by horizon alone, and suggests that phosphorous concentrations may vary within genetic horizons, or even among individual peds.

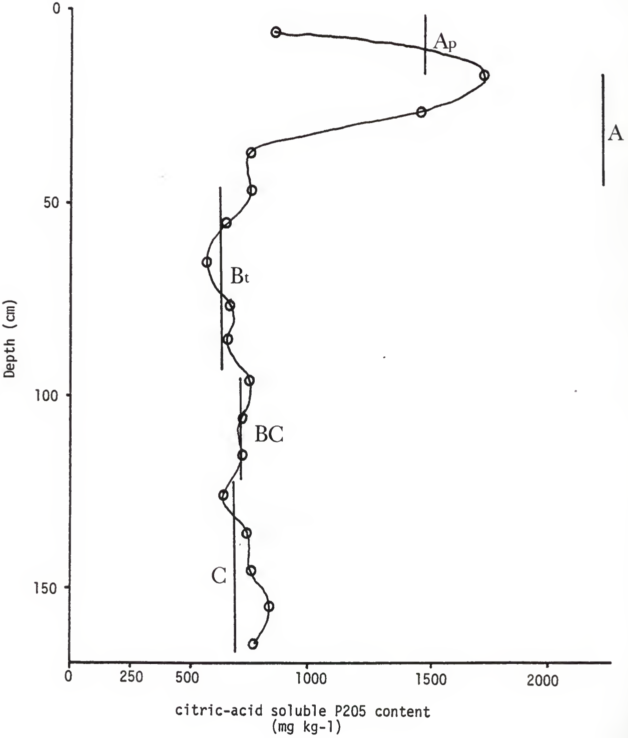
Some samples were analyzed using a modified Bray-Kurtz phosphorus test (The cited procedure is followed except that the volume of extractant is increased from 7.5 to 10.0 mls.) to provide a more standardized measure for comparing the phosphorous contents of the anthropological soils in this study to other soils (Bray and Kurtz, 1945). The Bray-Kurtz test indicated as much as 280 mg kg-1 P2O5 in the epipedons of both midden and non-midden soils, contrasted to average regional values of 30 to 60 mg kg-1 P2O5.

The notation in parentnesis following the site number is the Kansas Historical Society reference code number for each midden.

Site #1 (14RY609): This soil developed in a kitchen midden dating from the late Woodland period, between 500 and 1000 A.D. The depth of the midden, as indicated by the presence of artifacts, is approximately 45 cm.

> Ap--0 to 15 cm.; dark grayish-brown (10YR 4/2) silt loam, very dark gray (10YR 3/1) when moist; weak granular structure and weak subangular blocky structure; hard when dry, friable when moist; abrupt, smooth boundary.
>
> A--15 to 45 cm.; dark grayish-brown (10YR 4/2) silty clay loam, very dark gray (10YR 3/1) when moist; moderate subangular blocky structure; hard when dry, friable when moist; few worm casts; gradual, wavy boundary.
>
> Bt--45 to 95 cm.; brown (10YR 5/3) silty clay loam, very dark grayish brown (10YR 3/2) when moist; moderate

Figure # 3: phosphorous distribution in site #1



subangular blocky structure; hard when dry, firm when moist; few worm casts; abrupt, smooth boundary.

BC--95 to 123 cm.; pale brown (10YR 6/3) silt loam, dark yellowish brown (10YR 4/4) when moist; moderate subangular blocky structure; hard when dry, friable when moist; gradual, smooth boundary.

C--123 to 170 cm.; pale brown (10YR 6/3) silt loam, dark yellowish brown (10YR 4/4) when moist; weak subangular blocky structure; hard when dry, friable when moist.

Citric-acid soluble P205 contents for this profile are shown in Figure #3 and in Appendix #2.

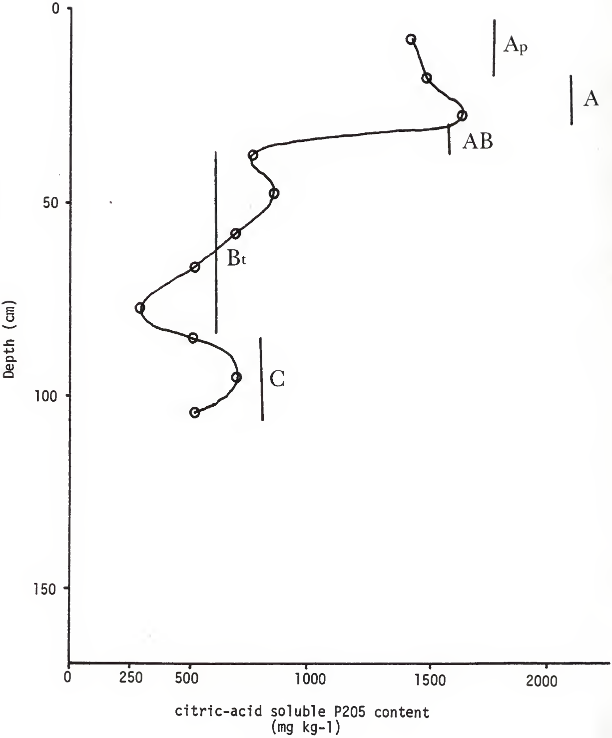
Site #2 (associated with 14RY609): This non-midden soil formed adjacent to the kitchen-midden containing site #1.

Ap--0 to 15 cm.; dark grayish-brown (10YR 4/2) silt loam, very dark brown (10YR 2/2) when moist; weak granular structure and moderate subangular blocky structure; hard when dry, friable when moist; abrupt boundary.

A--15 to 28 cm.; dark grayish-brown (10YR 4/2) silt loam, black (10YR 2/1) when moist; moderate subangular blocky structure; hard when dry, friable when moist; clear boundary.

AB--28 to 34 cm.; brown (10YR 5/3) silt loam, black

Figure #4 : phosphorous distribution in site # 2



(10YR 2/1) when moist; moderate subangular blocky structure; hard when dry, firm when moist; clear boundary.

Bt--34 to 83 cm.; brown (10YR 5/3) silty clay loam, very dark grayish brown (10YR 3/2) when moist; moderate subangular blocky structure; hard when dry, firm when moist; clear boundary.

C--83 to 105 cm.; dark grayish-brown (10YR 4/2) silt loam, very dark brown (10YR 2/2) when moist; moderate subangular blocky structure; hard when dry, friable when moist.

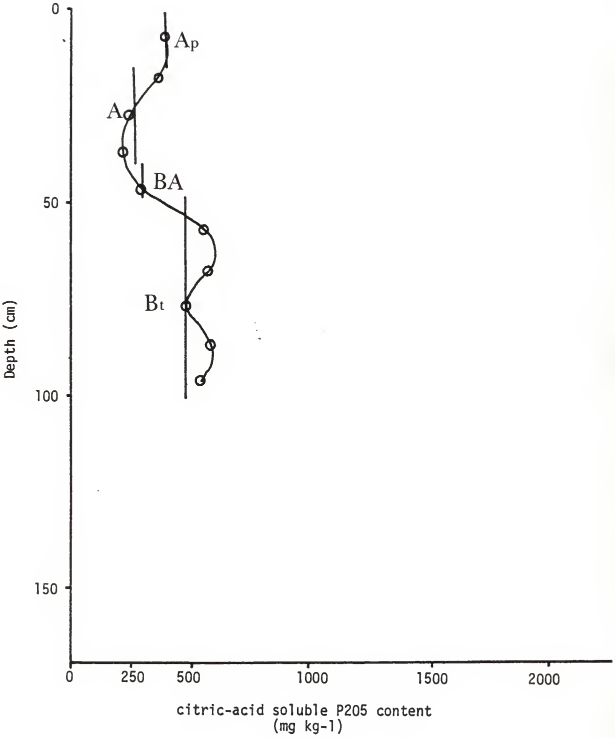
Citric-acid soluble P205 contents for this profile are shown in Figure #4 and in Appendix #2.

Site #3 (14RY614): This soil formed in a kitchen midden of unknown age and cultural affiliation. The midden extends to a depth of approximately 30 cm.

Ap--0 to 13 cm.; grayish-brown (10YR 5/2) silt loam, black (10YR 2/1) when moist; moderate subangular blocky structure; hard when dry, friable when moist; abrupt boundary.

A--13 to 38 cm.; dark grayish-brown (10YR 4/2) silty clay loam, black (10YR 2/1) when moist; moderate subangular blocky structure; hard when dry, firm when moist; gradual boundary.

Figure #5 : phosphorous distribution in site # 3



BA--38 to 47 cm.; dark grayish-brown (10YR 4/2) silty clay loam, very dark brown (10YR 2/2) when moist; moderate subangular blocky structure; hard when dry, firm when moist; abrupt boundary.

Bt--47 to 100 cm.; brown (10YR 5/3) silt loam, dark brown (10YR 3/3) when moist; strong subangular blocky structure; hard when dry, firm when moist.

Citric-acid soluble P205 contents for this profile are shown in Figure #5 and in Appendix #2.

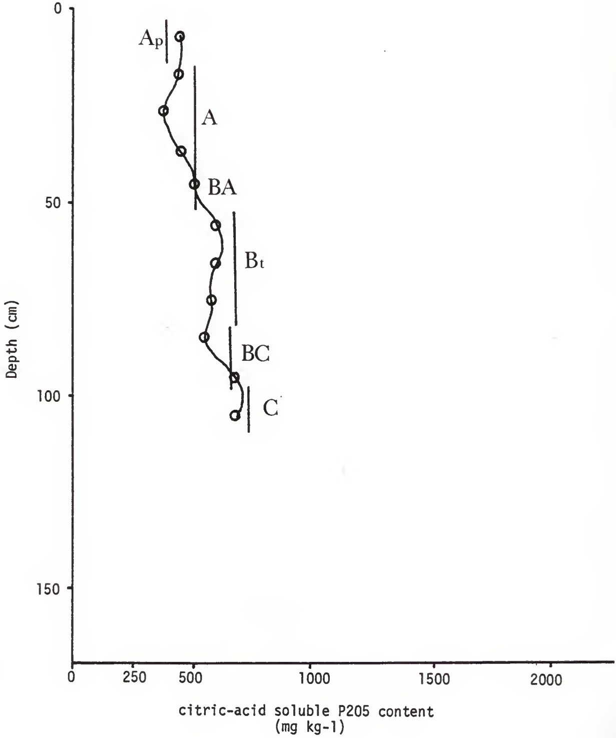
Site #4 (associated with 14RY614): This non-midden soil formed adjacent to the kitchen-midden containing site #3.

Ap--0 to 13 cm.; dark grayish-brown (10YR 4/2) silt loam, black (10YR 2/1) when moist; moderate subangular blocky structure; hard when dry, friable when moist; abrupt boundary.

A--13 to 40 cm.; grayish-brown (10YR 5/2) heavy silt loam, black (10YR 2/1) when moist; moderate subangular blocky structure; hard when dry, friable when moist; clear boundary.

BA--40 to 51 cm.; grayish-brown (10YR 5/2) silty clay loam, very dark gray (10YR 3/1) when moist; moderate subangular blocky structure; hard when dry, firm when moist; clear boundary.

Figure #6 : phosphorous distribution in site # 4



Bt--51 to 81 cm.; brown (10YR 5/3) silty clay loam, very dark brown (10YR 2/2) when moist; moderate subangular blocky structure; hard when dry, firm when moist; clear boundary.

BC--81 to 98 cm.; pale brown (10YR 6/3) silty clay loam, very dark brown (10YR 2/2) when moist; moderate subangular blocky structure; hard when dry, friable when moist; clear boundary.

C--98 to 110 cm.; pale brown (10YR 6/3) silty clay loam, very dark grayish brown (10YR 3/2) when moist; weak subangular blocky structure; hard when dry, friable when moist.

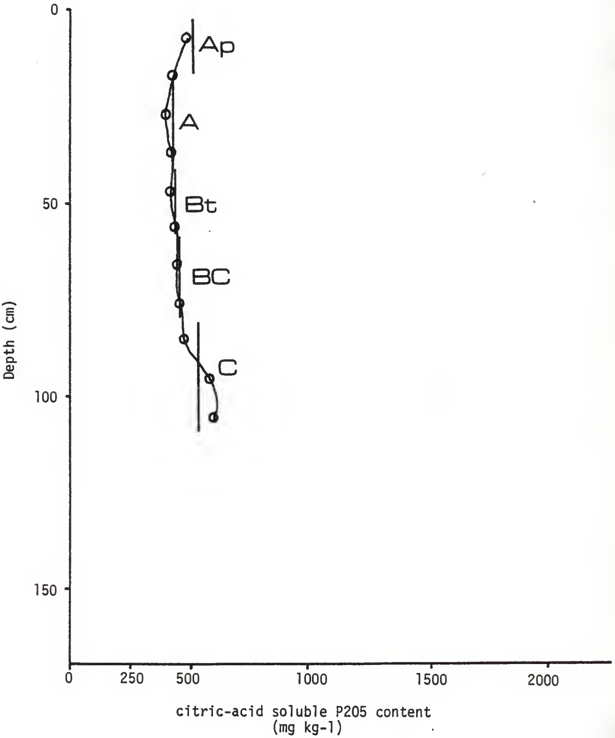
Citric-acid soluble P205 contents for this profile are shown in Figure #6 and in Appendix #2.

Site #5 (14RY613): This soil developed in a kitchen midden formed in late Woodland times, between 500-1000 A.D. This midden extends to a depth of approximately 20cm.

Ap--0 to 15 cm.; dark grayish-brown (10YR 4/2) silt loam, black (10YR 2/1) when moist; moderate granular structure and weak subangular blocky structure; hard when dry, friable when moist; abrupt boundary.

A--15 to 39 cm.; dark grayish-brown (10YR 4/2) silty clay loam, black (10YR 2/1) when moist; moderate subangular blocky structure; hard when dry, friable when

Figure #7 : phosphorous distribution in site # 5



moist; gradual boundary.

BA--39 to 57 cm.; grayish-brown (10YR 5/2) silty clay loam, very dark brown (10YR 2/2) when moist; moderate subangular blocky structure; hard when dry, friable when moist; clear, smooth boundary.

Bt--57 to 79 cm.; brown (10YR 5/3) silty clay loam, brown (10YR 4/3) when moist; moderate subangular blocky structure; hard when dry, firm when moist; clear boundary.

C--79 to 100 cm.; brown (10YR 5/3) silty clay loam, dark brown (10YR 3/3) when moist; weak subangular blocky structure; hard when dry, friable when moist.

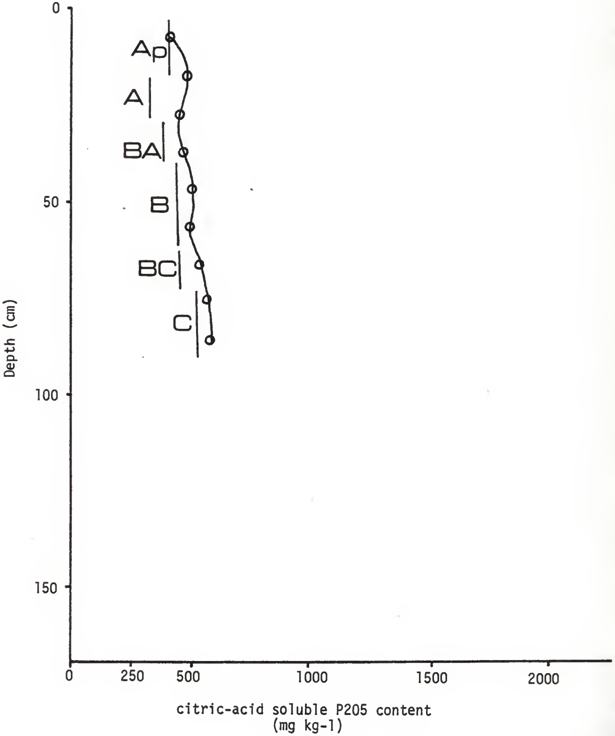
Citric-acid soluble P205 contents for this profile are shown in Figure #7 and in Appendix #2.

Site #6 (associated with 14RY613): This non-midden soil formed adjacent to the midden-containing site #5.

Ap--0 to 15 cm.; dark grayish-brown (10YR 4/2) silt loam, black (10YR 2/1) when moist; weak granular structure and moderate subangular blocky structure; hard when dry, friable when moist; abrupt boundary.

A--15 to 27 cm.; dark grayish-brown (10YR 4/2) silt loam, black (10YR 2/1) when moist; moderate subangular blocky structure; hard when dry, friable when moist;

Figure #8 : phosphorous distribution in site # 6



clear boundary.

BA--27 to 38 cm.; dark grayish-brown (10YR 4/2) silty clay loam, black (10YR 2/1) when moist; moderate subangular blocky structure; hard when dry, firm when moist; clear boundary.

Bt--38 to 61 cm.; brown (10YR 5/3) silty clay loam, very dark brown (10YR 2/2) when moist; moderate subangular blocky structure; hard when dry, firm when moist; clear boundary.

BC--61 to 72 cm.; brown (10YR 5/3) silty clay loam, dark brown (10YR 3/3) when moist; moderate subangular blocky structure; hard when dry, firm when moist; clear boundary.

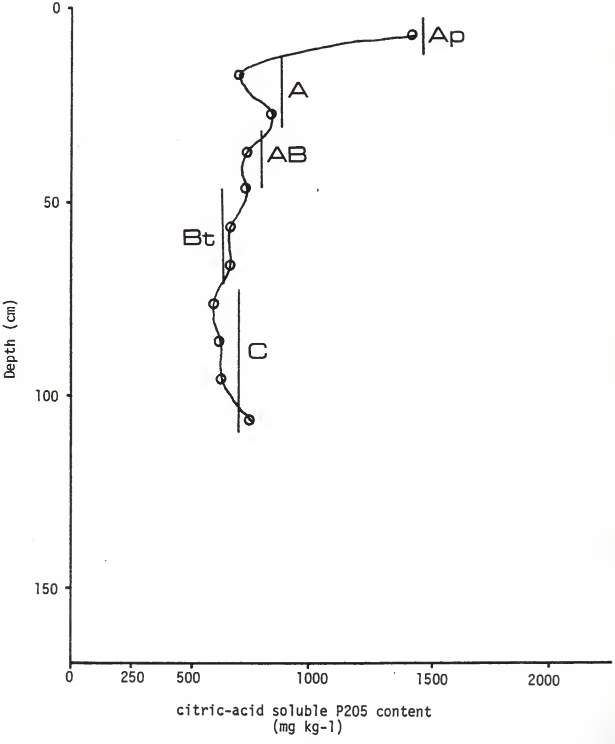
C--72 to 90 cm.; brown (10YR 5/3) silty clay loam, dark brown (10YR 3/3) when moist; weak subangular blocky structure; hard when dry, friable when moist.

Citric-acid soluble P205 contents for this profile are shown in Figure #8 and in Appendix #2.

Site #7 (14RY603): This soil developed in a kitchen midden formed in Woodland times. The lack of pottery may indicate a date of formation of 0-500 A.D.. The midden extends to a depth of from 30-50cm.

Ap--0 to 10 cm.; dark grayish-brown (10YR 4/2) silt loam, very dark gray (10YR 3/1) when moist; weak,

Figure #9 : phosphorous distribution in site # 7



subangular blocky structure; hard when dry, friable when moist; abrupt boundary.

A--10 to 30 cm.; dark grayish-brown (10YR 4/2) silty clay loam, very dark grayish brown (10YR 3/2) when moist; weak, subangular blocky structure; hard when dry, friable when moist; clear boundary.

AB--30 to 45 cm.; dark grayish-brown (10YR 4/2) silty clay loam, very dark grayish brown (10YR 3/2) when moist; moderate, subangular blocky structure; hard when dry, firm when moist; clear boundary.

Bt--45 to 70 cm.; grayish-brown (10YR 5/2) silty clay loam, dark grayish brown (10YR 4/2) when moist; moderate, subangular blocky structure; hard when dry, firm when moist; clear boundary.

C--70 to 110 cm.; pale brown (10YR 6/3) silt loam, dark yellowish brown (10YR 4/4) when moist; moderate, subangular blocky structure; hard when dry, firm when moist; clear boundary.

Citric-acid soluble P205 contents for this profile are shown in Figure #9 and in Appendix #2.

Site #8 (associated with 14RY603): This non-midden soil formed adjacent to the midden-containing site #7.

Ap--0 to 10 cm.; dark grayish-brown (10YR 4/2) silt loam, very dark brown (10YR 2/2) when moist; weak granular and weak subangular blocky structure; hard when dry, friable when moist; clear boundary.

A--15 to 28 cm.; dark grayish-brown (10YR 4/2) silt loam, very dark brown (10YR 2/2) when moist; weak granular and moderate subangular blocky structure; hard when dry, friable when moist; clear boundary.

BA--28 to 43 cm.; dark grayish-brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) when moist; moderate subangular blocky structure; hard when dry, friable when moist; clear boundary.

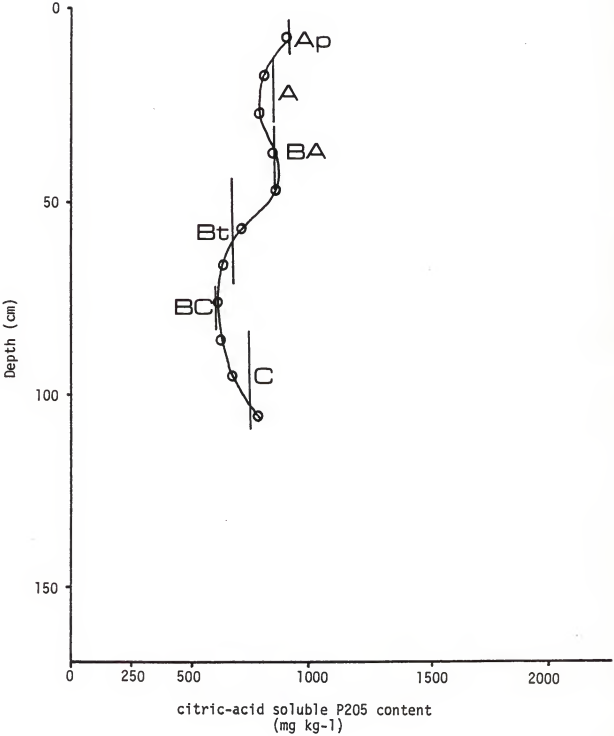
Bt--43 to 71 cm.; grayish-brown (10YR 5/2) silty clay loam, very dark grayish brown (10YR 3/3) when moist; moderate subangular blocky structure; hard when dry, firm when moist; clear boundary.

BC--71 to 82 cm.; pale brown (10YR 6/3) silt loam, very dark grayish brown (10YR 3/2) when moist; moderate subangular blocky structure; hard when dry, firm when moist; clear boundary.

C--82 to 112 cm.; pale brown (10YR 6/3) silt loam, very dark grayish brown (10YR 3/2) when moist; weak subangular blocky structure; hard when dry, friable when moist.

Citric-acid soluble P205 contents for this profile are shown in Figure #10 and in Appendix #2.

Figure # 10: phosphorous distribution in site # 8



Site #9 (14RY607): This soil developed in a kitchen midden formed in Archaic period, sometime between 6000 and 0 B.C. This midden may only be a few centimeters thick.

Ap--0 to 10 cm.; dark grayish-brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) when moist; weak, granular structure and weak, subangular blocky structure; hard when dry, friable when moist; distinct boundary.

A--10 to 25 cm.; grayish-brown (10YR 5/2) heavy silt loam, very dark gray (10YR 3/1) when moist; moderate, subangular blocky structure; hard when dry, friable when moist; clear boundary.

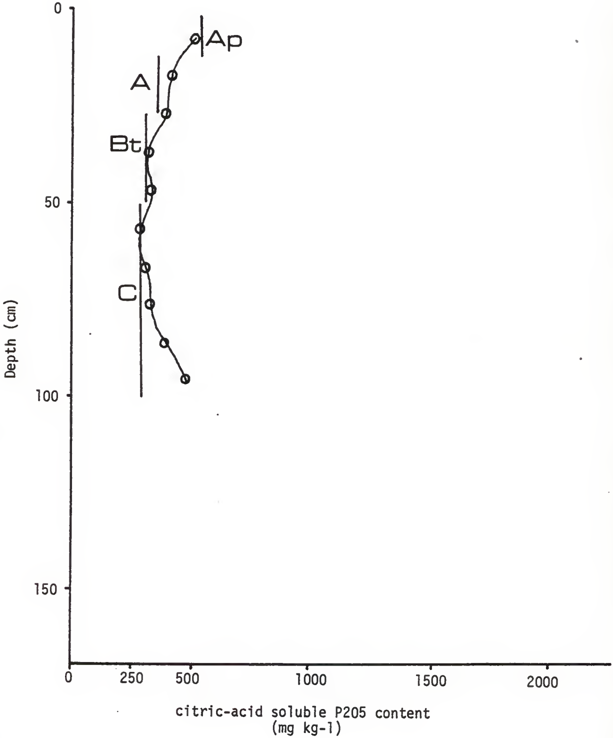
Bt--25 to 48 cm.; brown (10YR 5/3) silty clay loam, dark brown (10YR 3/3) when moist; moderate subangular blocky structure; hard when dry, friable when moist; clear boundary.

C--48 to 100 cm.; grayish-brown (10YR 5/2) silty clay loam, very dark gray (10YR 3/1) when moist; moderate, subangular blocky structure; hard when dry, friable when moist.

Citric-acid soluble P205 contents for this profile are shown in Figure #11 and in Appendix #2.

Site #10 (14RY601): This soil developed in a kitchen midden

Figure #11: phosphorous distribution in site # 9



formed during the Woodland period, sometime between 0 and 1000 A.D.. This midden is approximately 35-centimeters thick.

A--0 to 36 cm.; very dark grayish-brown (10YR 3/2) silt loam, very dark brown (10YR 2/2) when moist; moderate granular structure and moderate subangular blocky structure; hard when dry, friable when moist; clear boundary.

BA--36 to 60 cm.; dark grayish-brown (10YR 4/2) silt loam, very dark brown (10YR 2/2) when moist; moderate subangular blocky structure; hard when dry, friable when moist; abrupt boundary.

Bt--60 to 91 cm.; pale brown (10YR 6/3) silty clay loam, very dark grayish brown (10YR 3/2) when moist; moderate subangular blocky structure; hard when dry, firm when moist; clear boundary.

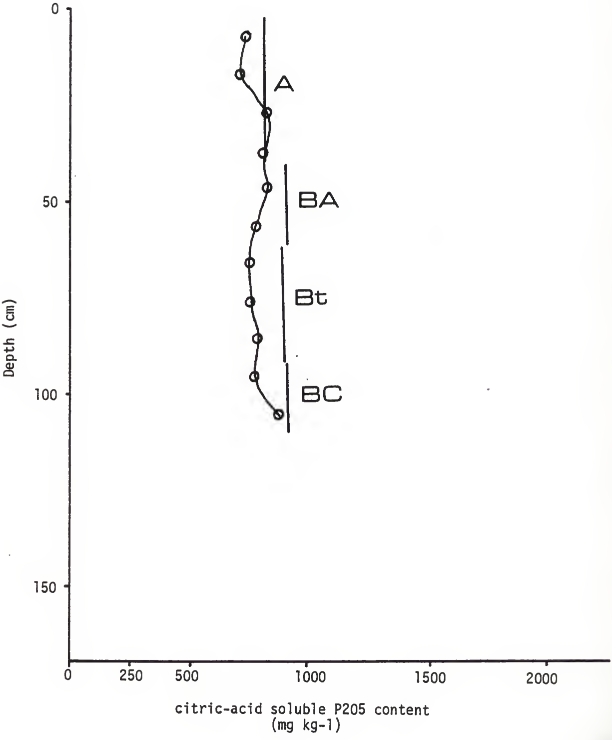
BC-- 91 to 105 cm.; pale brown (10YR 6/3) silt loam, dark brown (10YR 4/2) when moist; weak subangular blocky structure; slightly hard when dry, friable when moist.

Citric-acid soluble P205 contents for this profile are shown in Figure #12 and in Appendix #2.

Site #11 (associated with 14RY601): This non-midden soil formed adjacent to the kitchen-midden containing site #10.

Ap--0 to 15 cm.; dark grayish-brown (10YR 4/2) silt

Figure # 12: phosphorous distribution in site # 10



loam, very dark brown (10YR 2/2) when moist; weak granular structure and weak subangular blocky structure; hard when dry, friable when moist; abrupt boundary.

A--15 to 31 cm.; dark grayish-brown (10YR 4/2) silt loam, black (10YR 2/1) when moist; moderate subangular blocky structure; hard when dry, friable when moist; clear boundary.

AB--31 to 36 cm.; dark grayish-brown (10YR 4/2) silt loam, very dark brown (10YR 2/2) when moist; moderate subangular blocky structure; hard when dry, firm when moist; clear boundary.

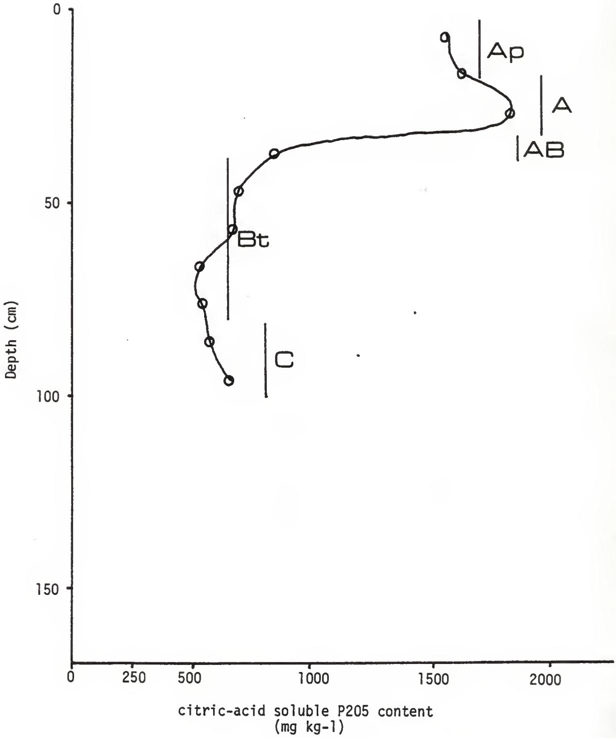
Bt--36 to 80 cm.; grayish-brown (10YR 5/2) silty clay loam, very dark brown (10YR 3/2) when moist; moderate subangular blocky structure; hard when dry, firm when moist; clear boundary.

C--80 to 100 cm.; pale brown (10YR 6/3) silt loam, dark yellowish brown (10YR 4/4) when moist; moderate subangular blocky structure; hard when dry, friable when moist.

Citric-acid soluble P205 contents of this profile are shown in Figure #13 and in Appendix #2.

Site #12 (14RY611): This soil developed in a kitchen midden from the Archaic Period, sometime between 6000-0 B.C. The midden extends to a depth of from 30 to 35 centimeters.

Figure #13: phosphorous distribution in site # 11



Ap--0 to 9 cm.; brown (10YR 4/3) silt loam, very dark gray (10YR 3/1) when moist; weak subangular blocky structure; hard when dry, friable when moist; abrupt boundary.

A--9 to 41 cm.; dark grayish-brown (10YR 4/2) silt loam, black (10YR 2/1) when moist; moderate subangular blocky structure; hard when dry, friable when moist; clear boundary.

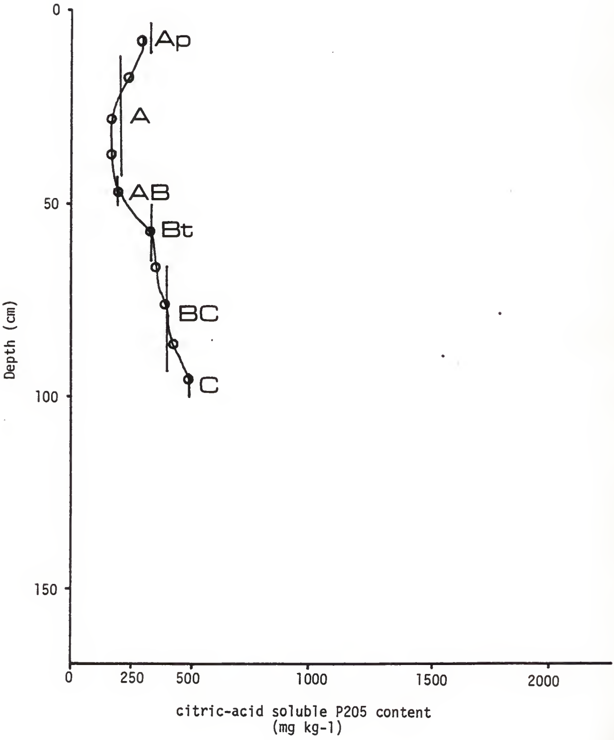
AB--41 to 48 cm.; dark grayish-brown (10YR 4/2) silty clay loam, black (10YR 2/1) when moist; moderate subangular blocky structure; hard when dry, friable when moist; clear boundary.

Bt--48 to 64 cm.; grayish-brown (10YR 5/2) silty clay loam, black (10YR 2/1) when moist; strong subangular blocky structure; hard when dry, firm when moist; clear boundary.

BC--64 to 93 cm.; brown (10YR 5/3) silty clay loam, very dark brown (10YR 2/2) when moist; moderate subangular blocky structure; hard when dry, friable when moist; clear boundary.

C--93 to 100 cm.; pale brown (10YR 6/3) silty clay loam, very dark brown (10YR 2/2) when moist; weak subangular blocky structure; slightly hard when dry, friable when moist.

Figure #14: phosphorous distribution in site #12



Citric-acid soluble P205 contents of this profile are shown in Figure #14 and in Appendix #2.

Site #13 (associated with 14RY611): This non-midden soil formed adjacent to the kitchen-midden containing site #12.

Ap--0 to 12 cm.; dark grayish-brown (10YR 4/2) silt loam, very dark gray (10YR 3/1) when moist; weak subangular blocky structure; hard when dry, friable when moist; abrupt boundary.

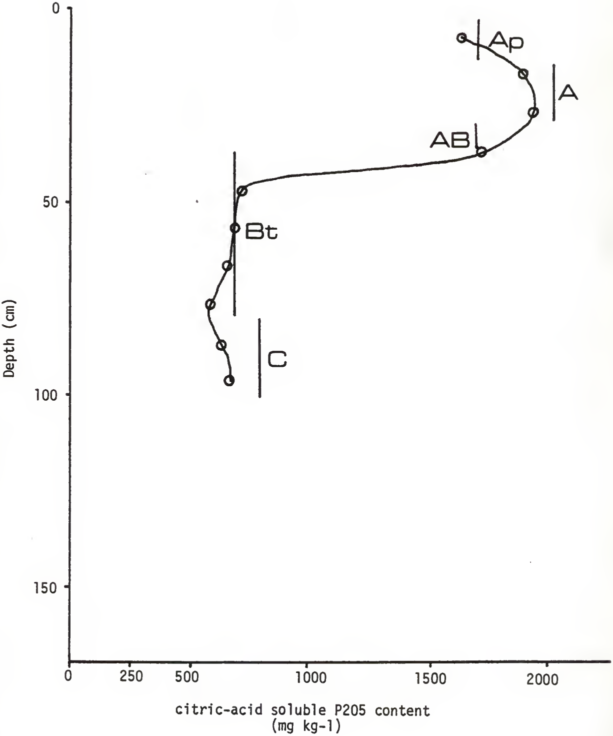
A--12 to 28 cm.; dark grayish-brown (10YR 4/2) silt loam, black (10YR 2/1) when moist; moderate subangular blocky structure; hard when dry, friable when moist; clear boundary.

AB--28 to 34 cm.; dark grayish-brown (10YR 4/2) silty clay loam, black (10YR 2/1) when moist; moderate subangular blocky structure; hard when dry, friable when moist; clear boundary.

Bt--34 to 79 cm.; grayish-brown (10YR 5/2) silty clay loam, very dark brown (10YR 2/2) when moist; strong subangular blocky structure; hard when dry, firm when moist; clear boundary.

C--79 to 100 cm.; pale brown (10YR 6/3) silty clay loam, very dark brown (10YR 2/2) when moist; weak subangular blocky structure; loose when dry, friable when moist.

Figure # 15: phosphorous distribution in site # 13



Citric-acid soluble P205 contents of this profile are shown in Figure #15 and in Appendix #2.

V. Discussion.

A. Phosphorous distribution in midden and non-midden soils.

Midden soils could not be distinguished from non-midden soils on the basis of phosphorous content or distribution, color, structure, texture, or any other morphological property, except for the presence of cultural artifacts. Seven pedons, including both midden and non-midden soils, possessed Anthropic epipedons. These anthropic soils can be grouped into two general types on the basis of the distribution of phosphorus through their profiles. The first type, represented by midden sites #1 and #7, and non-midden sites #2, #11 and #13, possessed distinctive maxima in P205 content in their A horizons. Phosphorous levels sharply diminished in the B horizons, but then increased slightly in the C horizons. The phosphorous contents for all horizons are extremely high relative to similar regional soils.

In sites #1, #2, #11 and #13 the Ap horizon contains substantially less phosphorus than does the A horizon. This may be the result of the deposition of a few centimeters of a low phosphorus, coarse-silty sediment from past floods. This layer has since been incorporated into the original surface by plowing and has decreased its P205 content. Another explanation assumes that middens accumulate very gradually, so that any depth at some time received surface additions of organic waste. Changes in land-use activities may have decreased the amount of phosphorus added per unit addition to the midden, resulting in reduced concentrations of phosphorus.

The strong maxima in phosphorus found in the A horizons are the result of the anthropological deposition of waste materials. After decomposition, much of the phosphorus contained in these wastes was strongly fixed near the surface. If the 250 mg kg-1 citric-acid soluble P205 content is accepted as a limit for "natural soil", then the high P205 contents found in the subsoil are the result of the redistribution of surface phosphorus. Another interpretation is that these high subsurface concentrations are simply the result of highly phosphatic parent materials. Variation within the subsoil may be a result of differing chemical conditions, biological micro-habitats or morphologies, all of which are common in these complex alluvial soils.

Anthropic epipedons with strong maxima in phosphorous concentration at the surface include sites #1 and #7, representing Woodland-period midden soils, and sites #2, #11 and #13, representing non-midden soils. Anthropic epipedons are not limited to midden-forming accumulations of inorganic debris, but also can be found where only organics were deposited. The decomposition of these organics did not produce a mound but did create a highly phosphatic "chemical midden".

The Anthropic epipedons at sites #8 and #9 are distinguished by high phosphorous contents throughout the profile (in excess of 250 mg kg-1 P205), but without a pronounced concentration maxima near the surface. Site #8 formed is a non-midden soil and site #9 formed on an Archaic-period midden. Presumably, if the

Taxonomy is correct, the unusually high phosphorous content of these archaeological soils is a result of contributions of organic wastes to the soil surface. The absence of a pronounced surface maxima and subsurface values in excess of 250 mg kg-1 suggest that phosphorus has been redistributed through the pedon by leaching, eluviation or biological activity. Another interpretation is that these soils have highly phosphatic parent materials and have since received very minor additions of phosphorus to the surface. This very reasonable interpretation suggests that the 250 mg kg-1 limit on citric-acid soluble P205 may be too low to separate out "natural" from "anthropic" soils.

The six soils that did not possess Anthropic epipedons, sites #3, #4, #5, #6, #10 and #12, can be divided into two general groups. Five of these soils were excluded from the anthropic classification because phosphorous content increased with depth, even though they possessed greater than 250 mg kg-1 citric-acid soluble P205 in their epipedons. This phosphorous distribution is represented by Woodland-period sites #3, #5 and #10 and by non-midden soils at sites #4 and #6. If, as suggested by the Taxonomy, 250 mg kg-1 citric-acid soluble P205 is a limit for natural soils, the high concentration of phosphorus found in the subsurface must be a result of the redistribution of surface-applied anthropological phosphorus. On midden sites this redistribution must have been particularily vigorous to have removed the surface-phosphorus maxima that would have resulted from surface-applied waste. A more likely explanation is that the soils in this area are naturally high in phosphorus and that these are normal profiles, although it is surprising that the middens do not have heightened phosphorus contents. Local chemical or biological conditions may have resulted in phosphorus removal or transition to forms not detectable with the citric-acid test.

Site #12 produced the only soil that did not qualify for an Anthropic epipedon due to inadequate P205 in the epipedon. The average citric-acid soluble P205 content for the combined Ap and A horizons was slightly less than 250 mg kg-1, although this level was exceeded in the B and C horizons. This soil developed in a kitchen midden that was approximately 30-35 cm thick, an indication of long-lasting and intensive human settlement. Either most of the phosphorus in this soil has been redistributed down the profile, or this soil has formed on highly phosphatic parent material and the process of midden development produced little organic waste.

The redistribution of surface-applied phosphorus is the product of several opposing forces. Fixation and plant uptake tend to keep phosphorus near the surface. Eluviation and leaching move phosphorus down into the subsoil. Certain biological activities concentrate phosphorus on the surface or in pockets, while others disperse these concentrations. The climatic, topographic, morphological, chemical, biological and temporal conditions specific to each site may have favored certain factors over the others, creating the variations in distribution seen in these soils.

The presence of Anthropic epipedons in both midden and in non-midden soils suggests that Soil Taxonomy may be using the expression "kitchen midden" incorrectly. To the archaeologist, kitchen midden is a general term used to describe 1) a "heap of domestic or food refuse" (Bray et al, 1980; 2) "any deposit thought to represent the domestic activities of prehistoric man" (Illustrated Dictionary of Archaeology, 1977); 3) "a mound containing the domestic refuse of early man" (Trent, 1959); or 4) "Refuse heaps, either for the remains of meals or for general rubbish." (Palmer and Lloyd, 1968). Each definition implies the deposition of inorganic materials to form a "mound" or "heap". Trent (1959) and The Illustrated Dictionary of Archaeology (1977) stated that kitchen midden is an obsolete term in this broad sense, and should be limited to mounds formed of shells. For general use in describing the heaps, mounds or strata of domestic rubbish found on the sites of ancient settlements, the word "midden" is preferable. Soil Taxonomy states that Anthropic epipedons usually form in kitchen middens. Since Soil Taxonomy and related publications describe these epipedons on soils other than those found in shell-middens, the general term "midden" should be substituted for "kitchen midden". Furthermore, our research has shown that Anthropic epipedons, as defined in Soil Taxonomy, also may form in non-midden soils. The creation of a midden soil possessing an Anthropic epipedon required the deposition of inorganic materials to form the mound, and organics to supply the phosphorus. The deposition of organic materials and no inorganics would not form a midden but would create an Anthropic epipedon. This may explain the non-midden or "chemical midden" Anthropic epipedons found in sites #2, #11 and #13. To better evoke the genesis of the Anthropic epipedon, the Taxonomy should simply state that these epipedons form in soils that have received significant deposition of organic wastes.

The variable antiquities of these middens has had an uncertain effect on the distribution of phosphorus in their profiles. Two of the sites possessing surface phosphorous concentration maxima, #1 and #7, date from the Woodland period (0 to 1000 A.D.). A third Woodland-period midden, #5, has a more uniform distribution, but since we are able only to date the Woodland period within a one-thousand year range, we might speculate that this midden is the older of the three. One Archaic midden with an Anthropic epipedon, site #8, possesses a uniform phosphorous distribution possibly the result of phosphorous movement from the surface. The other Archaic site, #12, does not have an anthropic epipedon, also possibly the result of the redistribution of phosphorus down the profile. One might postulate that young middens possess sharp peaks of phosphorous concentration in the surface, but with increased age these peaks diminish as phosphorus is redistributed. Unfortunately, evidence for this relationship is far too scanty to prove or disprove this supposition.

Woodland-period sites #1 and #7 possess much larger amounts of phosphorus than the older Archaic-period sites #8 and #12, suggesting a correlation between age and amount of phosphorus present. Contrary to this, Woodland-period site #5 contains relatively low amounts of phosphorus. In either case, it is more likely that these differences can be attributed to other factors, such as length of period of use or differences in site function.

Speculation about the relationships between midden age and phosphorous content is complicated by the clustered distribution of these sites and possibility that the middens overlap. Also, variables other than age influence total phosphorous content. Duration and intensity of settlement, quality of diet, type of waste and method of disposal and local traditions of land use would have a significant effect.

There are similarities in phosphorous distribution between adjacent midden and non-midden sites. Sites #1 and #2, sites #3 and #4, and sites #5 and #6 are generally similar in phosphorous content and distribution. Comparing site #10 to #11, and site #12 to #13 the non-midden soils possess significantly greater concentrations of phosphorus in the surface, but this may be due to overlap with the highly phosphatic soil of site #2. Midden site #7 is broadly similar to its non-midden counterpart #8, except for lacking a sharp peak in the Ap horizon. Phosphorous content and distribution similarities between adjacent midden and non-midden soils suggests similar characteristics of organic-waste deposition over broad areas, but localized deposition of midden-forming inorganic materials.

The effect of time on soil genesis has been studied with soils similar to those of our research. Parsons _et al_. (1962) investigated profile development in soils formed on Indian mounds located in northeastern Iowa where climate and vegetation compare with our study area. They discovered that genetic horizons formed rapidly during the first thousand years. After 2,500 years the soils formed on the Iowan Indian mounds had weakly expressed horizonation similar to that found in adjacent natural soils approximately 14,000 years in age. All of the middens in our study are older than 1,000 years, and several are likely older than 2,500 years. Based on Parsons *et al*. research, there has been ample time for the middens of our study to have undergone significant pedological alteration since the addition of phosphorus to their surfaces.

B. *Cultural Influences on Phosphorus Concentrations.*

Soil Taxonomy clearly recognizes man as a factor of soil formation. The Anthropic epipedon expresses man's ability to alter the nutrient status of the soil. However, the Taxonomy overlooks the fact that many cultural activities besides those embodied in the anthropic concept may influence soil-phosphorous levels. Applications of animal waste have long been recognized as a way to improve soil fertility. Provan (1973) demonstrated that the phosphorous levels of soil in fields last cultivated 500 or more years ago are still significantly higher than the phosphorous levels of nearby uncultivated soils. Woodland-period Indians practiced small-scale agriculture, and likely, perhaps unknowingly, enriched their fields with phosphorus-bearing wastes. The difficulty of breaking open native sod for planting resulted in the same plots being used continually. This long-term use and enrichment could have produced these high concentrations of phosphorus in these non-midden soils. This explanation does not account for the high phosphorus concentrations found in non-midden soils associated with non-agricultural, archaic-period middens. Over the last 150 years the availability of concentrated phosphatic fertilizer has allowed farmers to rapidly and radically alter the phosphorous status of their soils. A modern cultivated field of Mollisols could intentionally or accidentially be given an Anthropic epipedon by excessive application of phosphatic fertilizer. Epipedons formed in this way were not what the authors of the Taxonomy had in mind and should not be included under the anthropic classification. Such fertilizer anthropics would be extremely difficult to differentiate from anthropological anthropics on the basis of chemical or pedological information.

The addition of phosphorus to an area, whether intentional or not, implies its removal from another. Archaic-period hunters and gatherers procured foodstuffs from over large areas, little reducing the phosphorous status of their hunting grounds. The use of domesticated plant foods during the Woodland period concentrated phosphorus removal from small plots of cultivated soil. By the mid-1800s intensified-farming practices rapidly accelerated phosphorous extraction from the soil. A 180-bushel corn crop may remove 50 mg kg-1 of P205 from the soil per acre per year. A wheat crop of 80 bushels may annually remove 27 mg kg-1 P205 per acre (Potash Institute, 1972). The phosphorus lost to crop removal would have come from the plant-available fraction, the same fraction that the citric-acid test attempts to measure. This plant-available phosphorus will be partially replaced by the phosphorous reserves of the soil, but these midden soils undoubtedly have lost large amounts of phosphorus to a century of crop removal. This process, in time, may reduce P205 concentrations to the point where these midden soils no longer have an anthropic classification. This violates the sixth rule of the Taxonomy which states rather emphatically that cultivation should not change the classification of a soil.

C. Inadequacy of the Phosphorous Test.

The exclusion of soil naturally high in phosphorus from the Anthropic-epipedon classification shows that the Soil Taxonomy is concerned with anthropologically accumulated phosphorus only. The 1% citric-acid soluble test designated by the Soil Taxonomy was originally designed to measure the plant-available phosphorus. Plant-available phosphorous tests are probably the least adequate for detecting this anthropological fraction. It is currently impossible to consistently differentiate between natural and anthropological phosphorus in soils with the citric-acid test, any plant-available phosphorous test, or any known phosphorous test. An experienced archaeologist might surmise anthropological phosphorus by identifying a midden, but this is not expected of a soil surveyor. However, even the archaeologist would be unable to identify anthropological phosphorus in the "chemical middens" that form adjacent to middens.

Even if it were possible to devise a test that could distinguish anthropological phosphorus, it is unlikely that such a test could be accurately utilized on a global scale. Phosphorous-test results are significantly affected by a wide variety of factors, such as pH, texture, and the types and concentrations of chemical compounds present in the soil. Soil-fertility researchers recognize that no single plant-available phosphorous test can give valid results over large areas of dissimilar soils. For that reason it appears unlikely that the Soil Taxonomy may be able to recommend a single phosphorous test for world-wide identification of Anthropic epipedons.

D. Prior Problems in Classification.

There have been taxonomic and classification difficulties with the Anthropic epipedon since the inception of this concept. Natural soils developed in highly phosphatic parent material often meet the 250 mg kg-1 citric-acid soluble P205 qualification for an Anthropic epipedon (Brasfield, 1982). To remove these soils from the anthropic classification, the Soil Taxonomy excludes all epipedons that contain phosphorus nodules or that have an increase in P205 below the epipedon. This further illustrates how the Taxonomy is not interested simply in high phosphorous soil *per se*, but only in soils high in phosphorus as a result of human activities.

Natural soils formed in highly phosphatic recent alluvium with high phosphorous concentrations in their epipedons were discovered after the publication of Soil Taxonomy. These soils neither had an increase in P205 with depth nor contained phosphate nodules. Dr. Guy Smith, the major creator of the soil taxonomy, suggested that the criteria for anthropic epipedons be amended to exclude any soil whose phosphorus decreased irregularily with depth, thus excluding these alluvial soils (Brasfield, 1982).

Other classification problems may result from confusion between Anthropic and Plaggen epipedons. A Plaggen epipedon is used in the Soil Taxonomy to signify a horizon formed by the accumulation of fresh mineral materials inadvertently added during manuring. European pedologists recognize plaggen soils formed not only in response to manuring, but also by the conscious addition of fresh organic and mineral materials to soils to improve their productive capacity. These materials commonly have included heath litter, sea sand, sea weed, mor humus and powdered rock (Limbrey, 1975). Depending on the materials used, and on later land-use practices, these epipedons could easily develop phosphorous contents in excess of 250 mg kg-1, qualifying them as Anthropic epipedons. The Taxonomy offers little guidance for the classification of a plaggen with high phosphorous content. An example of this confusion can be found in Ranzani et al. (1970) in which the "terra preta" soils of the Amazon are judged, in strict accordance with Soil Taxonomy, to have plaggen epipedons. Eden, et al. (1984) determined that these soils had not formed in response to manuring or other attempts to improve soil quality, but to the deposition of wastes around settlements, a process that should have created an Anthropic epipedon.

The middens commonly associated with Anthropic epipedons are formed in accumulations of mineral materials. If any of these midden soils were found to have epipedons 50 cm or more thick they would qualify as Plaggen epipedons, clearly an invalid interpretation. Once again, the Taxonomy requires the soil surveyor to classify on the basis of the genesis of these soils, not on their morphologies. This violates the fourth general rule of the classification scheme used in the Soil Taxonomy, which states that soils should be differentiated on the basis of properties observable in the field.

VI. Conclusions.

The deposition of organic materials associated with human activities can produce significant accumulations of phosphorus in the soil. This phosphorus will tend to be "fixed" and collect in the surface, but over long periods of time may be redistributed down the soil profile or to the epipedons of adjoining soils. The rate and extent of this phosphorous removal depends on soil chemical characteristics, texture, mineralogy, biological activities, climate and topography.

The identification of an Anthropic epipedon is contingent upon the soil morphologist's ability to distinguish between anthropological phosphorus and naturally occurring geological phosphorus or intentionally placed chemical-fertilizer phosphorus. To evaluate soil phosphorus the Taxonomy specifies a 1% citric-acid extraction. Research has shown that neither this test nor any other is capable of isolating and measuring the anthropological fraction. Due to this inability to distinguish among the sources of soil phosphorus, the Taxonomy attempts to exclude soils naturally high in phosphorus from the anthropic classification by rejecting profiles in which phosphorus increases with depth, or irregularly decreases with depth. The clearly anthropological soils described in this study violate both of these criteria. Additionally, an anthropological soil was found that possessed less than the required 250 mg kg-1 P205 in the epipedon. Such difficulties in classification reveal a weakness in the fundamental assumptions underlying the anthropic concept.

The Soil Taxonomy states that anthropic epipedons usually form in kitchen middens. However, they also may form in other types of midden deposits and in non-midden soils, depending on the characteristics and quantities of organic wastes deposited. Thick middens containing cultural artifacts are difficult to distinguish from plaggens. Phosphatic Plaggen epipedons resemble Anthropic epipedons. The Soil Taxonomy offers little guidance for their separation.

We need to re-evaluate why we want to distinguish between natural and anthropological soils. Are we trying to make this separation on the basis of field-observable morphological properties or on presumed processes of genesis? We must determine what characteristics make anthropological soils unique and worthy of taxonomic separation. Are we truely interested in phosphorous contents *per se*, or are they just unreliable indicators of a soil-forming process? If anthropological derivation is considered important, the inability to isolate and accurately quantify this anthropic fraction makes the P205 determination a meaningless taxonomic exercise.

Until we isolate and quantify anthropological phosphorus, or until we devise other criteria for evaluating anthropological soils, I suggest abandoning phosphorous content as a taxonomic criterion. Instead, I suggest that all soils developed on mound-forming middens and plaggens be classed into a single taxa representing soils accumulated by human activities. Non-midden soils with epipedons now considered anthropic would be reclassified as Mollisols. This re-grouping would reduce the precision of classification of some soils, but would eliminate a great deal of ambiguity and inconsistency in the Taxonomy's treatment of human-affected soils.

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VIII. Appendices.

Appendix #1: 1% citric-acid soluble phosphorus test.

This test is based on a method published by Dyer (1894) and used by D. Sheen of the soil laboratory at the University of Reading, England. Alan Kosse of the Soil Conservation Service, at Santa Rosa, New Mexico compiled this procedure from Sheen's unpublished worksheet. I obtained a copy of Kosse's procedure from Jim Luzader, a graduate student (1984) at the University of Maryland, who used it in his research.

Soils were ground to pass through a number 60 sieve (approximately .0424 millimeters). This grinding revealed fine chert chips and other artifacts to positively establish the presence of a kitchen midden. Each sample was then analyzed for its calcium-carbonate content. This was done using an HCl-NaOH titration as described in Allison and Moodie, 1965.

To determine the phosphorous content, seven and one-half grams of each ground soil sample was placed in a 250-milliliter flask. Varying volumes of ten-percent citric acid were added to the flasks depending on the soil's calcium-carbonate content, as described in Table #1. Samples were swirled at intervals to help release carbon dioxide. After six hours, the tops of the flasks were sealed with parafilm and placed in a Burrell wrist-action shaker. They were allowed to shake for 16 hours, at 260 shakes per minute, through an angle of 8 degrees. The samples were then filtered through Whatman number 2 paper. One milliliter of each aliquot was placed in a 50-milliliter beaker, to which 4 milliliters of ammonium molybdate solution, 20 milliliters of distilled water, and 2 milliliters of stannous chloride were added. The samples were mixed by shaking and given twenty minutes for color development. Color was read using a Bausch and Lomb Spectronic 20 spectrometer. Earlier, maximum absorbance was determmined to be at 660 nanometers, and an absorption curve was constructed using known samples with phosphorous contents corresponding to sample concentrations of 50, 100, 200, 300, 400 and 500 mg kg-1. Samples found to be in excess of the 500 mg kg-1 value were diluted and retested. These tests were done in triplicate. Replications that yielded large amounts of error were discarded and presumed to be the result of excessive laboratory error. The results represent the means of three replications.

Table #1: the volume of 10% citric acid required to decompose all calcium-carbonate and to give a 1% solution upon dilution.

%CaCO3	mls. citric acid	%CaCO3	mls. citric acid
0.0	7.5	10.5	18.6
0.5	8.1	11.0	19.1
1.0	8.6	11.5	19.6
1.5	9.1	12.0	20.1
2.0	9.6	12.5	20.7
2.5	10.2	13.0	21.2
3.0	10.7	13.5	21.7
3.5	11.2	14.0	22.2
4.0	11.7	14.5	22.8
4.5	12.3	15.0	23.3
5.0	12.8	15.5	23.8
5.5	13.3	16.0	24.3
6.0	13.8	16.5	24.9
6.5	14.4	17.0	25.4
7.0	14.9	17.5	25.9
7.5	15.4	18.0	26.4
8.0	15.9	18.5	27.0
8.5	16.5	19.0	27.5
9.0	17.0	19.5	28.0
9.5	17.5	20.0	28.5

10.0	18.0

Appendix 2: 1% citric-acid soluble phosphorous contents of the sampled soils.

All values represent the means of three replications.

Site and sample	P205 conc. (mg kg-1)	Standard deviation
Site #1.		
Ap-0 to 15 cm.	1509.3	50.8
A-15to 45 cm.	2292.7	4.6
Bt-45 to 95 cm.	653.6	11.2
BC-95 to 123 cm.	745.8	16.2
C-123 to 170 cm.	715.8	32.1
0 to 10 cm.	879.1	19.0
10 to 20 cm.	1787.3	18.3
20 to 30 cm.	1483.5	17.9
30 to 40 cm.	782.7	7.8
40 to 50 cm.	791.0	28.2
50 to 60 cm.	636.6	27.2
60 to 70 cm.	606.2	33.2
70 to 80 cm.	700.7	14.2
80 to 90 cm.	687.2	15.1
90 to 100 cm.	780.0	1.1
100 to 110 cm.	752.3	15.1
110 to 120 cm.	756.4	19.9
120 to 130 cm.	667.8	27.5
130 to 140 cm.	764.4	23.1
140 to 150 cm.	773.1	11.0
150 to 160 cm.	870.2	30.4
160 to 170 cm.	805.2	36.0
Site #2.		
Ap-0 to 15 cm.	1852.2	36.9
A-15 to 28 cm.	2183.7	53.1
AB-28 to 34 cm.	1647.4	44.6
Bt-34 to 83 cm.	641.0	22.2
C-83-105 cm.	855.3	8.0
0 to 10 cm.	1478.4	17.9
10 to 20 cm.	1536.8	12.8
20 to 30 cm.	1701.0	12.8
30 to 40 cm.	803.1	10.3
40 to 50 cm.	904.1	19.9
50 to 60 cm.	747.0	6.6
60 to 70 cm.	564.2	23.6
70 to 80 cm.	313.5	7.6
80 to 90 cm.	623.1	10.5
90 to 100 cm.	753.4	47.2
100 to 105 cm.	558.5	2.5

Site #3.		
Ap-0 to 13 cm.	401.2	15.6
A-13 to 38 cm.	264.0	7.3
BA-38 to 47 cm.	313.3	3.0
Bt-47 to 100 cm.	499.7	10.1
0 to 10 cm.	421.1	17.2
10 to 20 cm.	374.9	19.0
20 to 30 cm.	254.6	4.6
30 to 40 cm.	239.1	13.5
40 to 50 cm.	305.7	3.9
50 to 60 cm.	586.2	13.7
60 to 70 cm.	600.7	7.6
70 to 80 cm.	506.3	4.6
80 to 90 cm.	609.4	2.3
90 to 100 cm.	572.3	13.7
Site #4.		
Ap-0 to 13 cm.	422.5	5.5
A-13 to 40 cm.	538.2	18.1
BA-40 to 51 cm.	544.3	12.1
Bt-51 to 81 cm.	715.4	1.4
BC-81 to 98 cm.	700.7	12.4
C-98 to 110 cm.	793.7	24.0
0 to 10 cm.	483.9	11.0
10 to 20 cm.	478.2	2.7
20 to 30 cm.	415.9	6.4
30 to 40 cm.	487.8	8.9
40 to 50 cm.	538.6	8.0
50 to 60 cm.	648.8	25.0
60 to 70 cm.	632.0	19.0
70 to 80 cm.	611.7	17.9
80 to 90 cm.	584.4	10.3
90 to 100 cm.	719.7	8.5
100 to 110 cm.	723.9	11.4
Site #5.		
Ap-0 to 15 cm.	520.7	11.4
A-15 to 39 cm.	450.4	7.1
Bt-39 to 57 cm.	458.2	8.2
BC-57 to 79 cm.	480.4	5.0
C-79 to 110 cm.	562.9	10.5
0 to 10 cm.	500.8	10.5
10 to 20 cm.	444.3	14.0
20 to 30 cm.	415.2	13.5
30 to 40 cm.	435.8	12.1
40 to 50 cm.	432.1	13.7
50 to 60 cm.	454.1	3.9
60 to 70 cm.	459.0	.9
70 to 80 cm.	468.8	4.6
80 to 90 cm.	500.4	10.3
90 to 100 cm.	608.2	.4
100 to 110 cm.	608.4	1.1

<u>Site #6.</u>		
Ap-0 to 15 cm.	441.5	3.9
A-15 to 27 cm.	369.1	10.8
BA-27 to 38 cm.	428.2	17.9
B-38 to 61 cm.	483.0	11.0
C-72 to 90 cm.	563.3	13.3
0 to 10 cm.	465.1	4.4
10 to 20 cm.	525.3	5.5
20 to 30 cm.	499.2	10.1
30 to 40 cm.	510.2	9.4
40 to 50 cm.	553.3	11.4
50 to 60 cm.	544.6	20.6
60 to 70 cm.	586.5	19.9
70 to 80 cm.	609.9	9.8
80 to 90 cm.	623.8	17.9
<u>Site #7.</u>		
Ap-0 to 10 cm.	1493.1	16.0
A-10 to 30 cm.	903.4	16.0
AB-30 to 45 cm.	826.7	23.6
Bt-45 to 70 cm.	645.6	11.2
C-70 to 110 cm.	709.0	32.3
0 to 10 cm.	1455.7	8.0
10 to 20 cm.	725.9	13.3
20 to 30 cm.	856.7	6.6
30 to 40 cm.	746.5	8.0
40 to 50 cm.	743.3	10.1
50 to 60 cm.	670.3	2.3
60 to 70 cm.	674.4	7.1
70 to 80 cm.	611.0	26.8
80 to 90 cm.	639.4	16.5
90 to 100 cm.	642.6	16.0
100 to 110 cm.	772.0	69.8
<u>Site #8.</u>		
Ap-0 to 10 cm.	959.5	49.2
A-10 to 28 cm.	894.5	50.2
BA-28 to 43 cm.	898.6	50.2
Bt-43 to 71 cm.	701.7	21.8
BC-71 to 82 cm.	641.4	12.4
C-82 to 112 cm.	794.2	23.4
0 to 10 cm.	959.5	15.1
10 to 20 cm.	849.8	29.1
20 to 30 cm.	839.7	30.0
30 to 40 cm.	898.6	15.1
40 to 50 cm.	902.7	17.2
50 to 60 cm.	741.3	11.7
60 to 70 cm.	676.7	14.9
70 to 80 cm.	662.5	24.3
80 to 90 cm.	666.2	24.3
90 to 100 cm.	707.6	19.7

100 to 110 cm.	827.4	24.5
Site #9.		
Ap-0 to 10 cm.	565.4	6.0
A-10 to 25 cm.	440.0	19.5
Bt-25 to 48 cm.	333.9	5.7
C-48 to 100 cm.	327.7	10.3
0 to 10 cm.	535.4	15.3
10 to 20 cm.	435.8	11.2
20 to 30 cm.	429.4	2.8
30 to 40 cm.	332.8	14.4
40 to 50 cm.	340.8	3.7
50 to 60 cm.	307.1	30.9
60 to 70 cm.	333.2	14.9
70 to 80 cm.	342.4	6.6
80 to 90 cm.	414.3	15.8
90 to 100 cm.	501.7	.9
Site #10.		
A-0 to 36 cm.	840.9	25.9
BA-36 to 60 cm.	941.2	20.2
Bt-60 to 91 cm.	922.9	5.7
BC-91 to 105 cm.	947.4	40.1
0 to 10 cm.	765.8	26.6
10 to 20 cm.	744.2	10.1
20 to 30 cm.	857.8	11.4
30 to 40 cm.	853.7	26.3
40 to 50 cm.	862.0	41.4
50 to 60 cm.	813.2	15.1
60 to 70 cm.	792.8	17.2
70 to 80 cm.	792.8	0.0
80 to 90 cm.	829.4	9.8
90 to 100 cm.	805.2	10.1
100 to 105 cm.	910.7	20.6
Site #11.		
Ap-0 to 15 cm.	1740.4	20.4
A-15 to 31 cm.	2048.9	69.8
AB-31 to 36 cm.	1910.8	2.3
Bt-36 to 80 cm.	675.1	20.6
C-80 to 100 cm.	839.7	20.2
0 to 10 cm.	1602.1	79.5
10 to 20 cm.	1626.4	14.4
20 to 30 cm.	1889.5	24.3
30 to 40 cm.	890.4	10.1
40 to 50 cm.	719.7	26.3
50 to 60 cm.	707.6	9.8
60 to 70 cm.	557.4	25.0
70 to 80 cm.	565.4	28.6
80 to 90 cm.	600.0	12.6
90 to 100 cm.	691.4	5.7

Site #12.

Ap-0 to 9 cm.	348.5	4.6
A-9 to 41 cm.	216.9	3.7
AB-41 to 48 cm.	210.0	10.3
Bt-48 to 64 cm.	359.5	16.7
BC-64 to 93 cm.	420.7	21.3
C-93 to 100 cm.	505.4	7.6
0 to 10 cm.	318.1	2.1
10 to 20 cm.	262.4	3.0
20 to 30 cm.	181.1	1.8
30 to 40 cm.	184.8	8.2
40 to 50 cm.	203.1	4.4
50 to 60 cm.	338.7	16.7
60 to 70 cm.	376.5	15.1
70 to 80 cm.	415.9	16.7
80 to 90 cm.	449.3	16.5
90 to 100 cm.	521.2	10.1

Site #13.

Ap-0 to 12 cm.	1762.8	24.3
A-12 to 28 cm.	2084.6	31.1
AB-28 to 34 cm.	1753.0	31.6
Bt-34 to 79 cm.	728.0	37.6
C-79 to 100 cm.	829.4	30.0
0 to 10 cm.	1675.1	25.0
10 to 20 cm.	1966.0	32.5
20 to 30 cm.	2004.9	10.1
30 to 40 cm.	1761.2	8.2
40 to 50 cm.	745.8	1.6
50 to 60 cm.	728.2	14.0
60 to 70 cm.	659.7	25.9
70 to 80 cm.	600.4	24.7
80 to 90 cm.	659.1	17.2
90 to 100 cm.	685.6	7.6

THE ANTHROPIC EPIPEDON

AND

SOILS FORMED IN MIDDENS

by

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AN ABSTRACT OF A MASTER'S THESIS

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ABSTRACT

The Anthropic epipedon and soils formed in middens.

The Anthropic epipedon is similar to the Mollic epipedon except for a larger quantity of citric-acid soluble P205. Anthropic epipedons often form in middens, mounds of domestic refuse accumulated by ancient man. Thirteen pedons were described and sampled from both midden and non-midden sites on a Wisconsinan terrace of the Kansas River. Seven pedons, from both midden and non-midden locations, possessed an Anthropic epipedon. Five midden and non-midden pedons, containing 250 mg kg-1 P205 in the epipedon, had Mollic rather than Anthropic epipedons because the P205 content increased with depth. A pedon from a midden site was excluded from the anthropic classification because the citric-acid soluble P205 content exceeded 250 mg kg-1 only below the surface horizon. These data suggest that the chemical criteria for the Anthropic epipedon may not be suitable due to (1) the mobility of phosphorus in the soil and (2) the inability of a citric acid extraction to distinguish among anthropological, geological and fertilizer phosphorus.