GENESIS, MINERALOGY, AND MICROMORPHOLOGY OF VERTIC SOILS IN SOUTHEASTERN KANSAS

by

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Abstract

Many soils in southeastern Kansas are characterized by high clay contents and high shrink-swell potentials. Their vertic properties and claypan characteristics cause soil management to be difficult and pose problems for agricultural, environmental, and engineering uses. Thus, collecting more information and improving our understanding of these soils is an important step towards bettering our soil management techniques. The objectives of this study were to examine the morphology, processes of soil genesis, clay mineralogy, micromorphology, and potassium fixation potential of the soils of interest and how these characteristics varied between and within individual pedons. Ten pedons expected to represent varying degrees of vertic expression were selected. Methods included the use of field descriptions, routine soil laboratory characterization, micromorphological investigations, the determination of clay mineralogy by X-ray diffraction, and the measurement of potassium fixation potential. Field morphology reflected the geologic parent materials available in the region. The fine sediments that compose these clayey soils are primarily provided by the Pennsylvanian and Permian shales and limestones underlying this region and the Flint Hills to the west. Dominant pedogenic processes currently at work are clay illuviation and shrink-swell processes. Silty, non-expansive surface soils at all but sites 6 and 7 are thought to buffer the rapid wetting and drying cycles needed for maximum vertic expression. Four of the soils were dominated by smectitic minerals in the clay fraction while the rest exhibited a more mixed mineralogy. Disruption of illuvial clay features by shrink-swell movement was evident in thin section. Striated b-fabrics dominated the micromorphology except in non-expansive surface soils. K fixation of the soil surface was found to be negative in all soils, thus K fixation potential is considered very low. In subsurface horizons, K fixation generally increased with increasing vermiculite content. In addition to limited quantities of K-fixing clay minerals, naturally high K levels limited the amount of K fixation in this study. The information presented can be used to improve our understanding and management of high clay, vertic and claypan soils in southeastern Kansas.

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Dedication

This work is dedicated to my grandpa, Dr. Martin Hartley.

CHAPTER 1 - Literature Review

1.1 Genesis of Soils with Vertic Properties

1.1.1 Definition of Vertic Properties

The central concept behind the order of Vertisols is of a soil having a high content of 2:1 expandable clay minerals that undergo significant changes in volume due to seasonal fluctuations in moisture content. These changes in volume cause a considerable amount of shrink-swell movement within the soil. This soil movement causes stresses to build within the soil material which often results in failures along shear planes, or slickensides. The soil surface may even rise and fall with the seasonal moisture changes. Vertic properties are defined as soil characteristics caused by the seasonal changes in volume, or shrinking and swelling. Cracks that open and close periodically, slickensides, wedge-shaped structural aggregates that are tilted at an angle from the horizontal, vertical infillings, and high linear extensibility values are all good examples of properties associated with vertic soils (Soil Survey Staff, 1999). Due to variations among soil forming factors soils exhibit a wide array of these vertic properties. Vertic soils occur in many areas around the globe such as Australia, India, the Sudan, and in the United States. In fact, Krohn and Slosson (1980) estimated that up to 20% of the U.S. may be mantled with soils subject to shrink-swell behavior. The majority of true Vertisols in the U.S. are found in east-central Texas, southern Texas, Alabama, and Mississippi. They can also be found in the U.S. southwest and in the northern Great Plains (Ahmad, 1996). These soils tend to be very hard when dry and very sticky when wet, and their characteristics combine to make them difficult soils to manage (Soil Survey Staff, 1999). Vertisols have been widely studied by the engineering community because of the structural challenges they pose to building foundations, highways, piplines, etc. (Buol et al., 1980). Despite their problems, vertic soils are generally known for having high fertility and have proven to be highly productive agricultural soils. Water management is an important concept when farming high clay, vertic soils. Producers must be able to properly time operations to deal with excesses and deficits of water (Ahmad, 1996). Thus, collecting more information and improving our understanding of vertic soils is an important step towards bettering soil management techniques.

1.1.2 Vertic Soil Forming Factors

As previously mentioned, Vertisols and other vertic intergrades exhibit a wide range of vertic properties due to the complexity of their formation. Many researchers have studied the genesis of vertic soils and have found these soils to have formed in a number of different environmental conditions. There are two general conditions which are common to all vertic soils and thus must be present for the formation of vertic characteristics. The first condition is a large quantity of expandable clay. The mineralogy of these clays is most commonly smectitic. Second, a seasonal wet-dry cycle is required to cause the expansion and contraction of the soil material (Soil Survey Staff, 1999).

Vertic soils are found in nearly every major climatic zone. A monsoonal type climate is the most common climate of formation, and at least some distinct wet and dry periods are needed to provide many of the physical attributes of these soils (Ahmad, 1996). The seasonal variations in precipitation and temperature result in weathering of primary and secondary minerals during the wet season but encourage the accumulation of basic cations in the dry season. The variation in climatic conditions also favors the formation of smectitic clays. Wet Vertisols form in humid regions, and their cracks remain closed for much of the year while Vertisols which have formed in more arid regions have open cracks for much longer periods of time (Buol et al., 1980). The duration the cracks are open and closed is used to differentiate the various soil moisture regimes in Soil Taxonomy (Soil Survey Staff, 1999). Worldwide 56% of Vertisols are within an ustic soil moisture regime, 28% aridic, 13% udic, and 3% xeric (Eswaran et al., 1999). Vertisols occur in all soil temperature regimes that are cryic and warmer (Soil Survey Staff, 1999).

The vegetation found on vertic soils is governed both by the constraints imposed on it from the climate and the harsh physical and hydrological characteristics of vertic soils. Vertic soils predominantly occur under grasslands, savanna, open forest, or desert scrub vegetation (Soil Survey Staff, 1999). High clay content and hard consistence along with shear stresses and soil movement can hinder rooting. Natural vegetation is limited generally to grasses and trees which have deep, hearty root systems in order to survive periods of drought and cracking. Vertic soils in temperate humid areas have a greater amount of vegetative cover and thus have higher organic matter contents. These high organic matter contents have in some cases been found to reduce the shrink-swell potential and limit crack formation in the surface horizon. Maintaining high organic matter levels is an important management strategy. Increased organic matter levels raise the moisture content of the plastic limit allowing farmers to work the soil at higher moisture contents (Dudal and Eswaran, 1988). This allows a greater window of time for farmers to complete field operations. The properties of vertic soils generally allow only a narrow time frame of workability.

Macro-topography, as well as micro-topography, is important when studying vertic soils. Vertic soils predominantly form on stable, relatively level to rolling landscapes (Ahmad, 1996). On areas of greater slopes, increased erosion prevents the development of vertic features. Level slopes in combination with low hydraulic conductivity often results in surface ponding (Eswaran et al., 1999). Mico-topography features have received a considerable amount of attention from researchers (Wilding et al., 1991; Thompson and Beckmann, 1982; Stace et al., 1968; Hubble et al., 1983). Many vertic soils exhibit sub-circular depressions (microlows) surrounded by slightly higher ridges or knolls (microhighs). This type of relief comprised of microlows and microhighs is referred to a gilgai relief (Dudal and Eswaran, 1988). Wilding et al. (1991) studied the close-interval spatial variability between micro-topographic gilgai elements of a vertisol in Texas and found several distinct differences between the morphological, physical/chemical, mineralogical, and hydrological attributes of the microlows and microhighs. Nordt et al. (2004) found that in response to greater water recharge, the microlow of a Texas coastal plain Vertisol contained darker colors, more organic carbon, greater depth of carbonate leaching, and lower pH than the microhigh.

Parent material is one of the most important factors involved in the formation and distribution of Vertisols. Vertic soils develop on a wide range of parent material including alluvial, colluvial and lacustrine deposits, marl and other calcareaous rocks, limestone, shales, igneous, metamorphic and volcanic rocks of basic nature. Vertisols are known to develop on basalts in Australia, gneisses and sandstones in India, and glacio-lacustrine materials in Saskatchewan (Dudal, 1965; Ahmad, 1983; Probert et al., 1987; Coulombe et al., 1996b; Dasog et al., 1987). For the most part in the U.S., they develop on calcareous clay or in residuum weathered from soft, calcareous sedimentary rocks (Ahmad, 1996). The smectitic clays may be inherited from the original rock parent material or may have formed in place as a result of neogenesis or transformations from primary minerals. The limestones and clay mineral rich shales present in southeastern Kansas provide an abundance of expanding clays minerals. Vertic parent materials commonly have a high base status which favors formation and stability of clay minerals (Coulombe et al., 1996b).

Vertic soils are generally considered young soils in relatively unadvanced stages of weathering and soil formation. However, Buol et al. (1980) proposed that one may consider them old soils in which the B horizon had become so clayey through illuviation that shrink-swell cycles developed and eventually "swallowed" the A horizon. It is true that vertic soils are often found on older, stable landscapes. Another interpretation from Buol et al. (1980) was that Vertisols are in equilibrium with their environment, and the expanding clays will be preserved barring a climatic change. Others have suggested that once the 2:1 expanding clays are further weathered to non-expanding clay minerals, vertic soils will cease to churn and crack. The age of vertic soils is of course variable. Some unconsolidated parent materials may require only a few hundred years to develop because high clay contents are indigenous, while for consolidated parent materials sufficient time is needed for weathering, clay formation, and shrink-swell dynamics to develop (Coulombe et al., 1996b). Thus age must be inferred from the underlying parent material.

1.1.3 Pedogenic Processes of Soils with Vertic Properties

Vertic soils form under multiple complex genetic pathways. In general, soil forming processes that lead to the formation of vertic soils are those which control the formation and stability of smectites in the soil. Such minerals are capable of expanding and contracting with changes in moisture status. It is this expansion and contraction within the minerals, the microstructure, and submicroscopic porosity that induces soil movement (Eswaran et al., 1988). The shrink-swell phenomenon responsible for the formation of vertic properties has been studied extensively, however; it is still incompletely understood. Linear and normal gilgai, cyclic horizons, surface cracking upon desiccation, and the formation of slickensides all can result from this process (Soil Survey Staff, 1999). Wilding and Tessier (1988) and Coulombe et al. (1996b) provide excellent reviews of the current ideas surrounding Vertisol genesis including summaries of three pedogenic models.

Pedogenic Models of Vertic Soils

The first model is the pedoturbation model or self-swallowing model (Buol et al., 1980). It was first proposed by Hilgard (1906) to explain the formation of "hog-wallows." It states that during the dry season the soil material dries and shrinks in volume forming large cracks that can extend to a depth of one meter or more. Surficial and sidewall soil material are disturbed due to biological activity, wind, water, or gravity and falls into the cracks. Upon rewetting, the cracks close as the soil material expands; however, because the fallen surface soil is occupying a portion of the initial soil volume, a space problem is created. Swelling pressures cause soil to move horizontally and vertically away from the infilled former cracks to accommodate for the space occupied by the infilled material. This process will result in mixing of existing horizons leading toward a homogenization of the soil profile and the development of vertic morphologic features such as pressure faces, slickensides, gilgai topography, etc. (Wilding and Tessier, 1988). However, Wilding and Tessier (1988) point out that vertic soils often do have systematic depth functions of organic carbon, carbonates, and soluble salts, and the formation of albic and argillic horizons does occur. Also, slickensides commonly develop below the depth of maximum seasonal cracking. The pedoturbation model alone does not explain these occurrences; thus, long-term pedogenic translocation processes must still play a role.

The second model proposed is the differential loading model. This model attempts to explain the formation of gilai topography and states that clays move from areas of higher confining pressure to areas of lower confining pressure under plastic-viscous flow (Paton, 1974). This theory was borrowed from the geologic literature for sedimentary load structures. Wilding and Tessier (1988) also reject this model as only partially functional as it does not explain the formation of vertic features such as slickensides.

The third model, first proposed by Howard (1932) and later supported by Yaalon and Kalmar (1978) and Wilding (1985), is the soil mechanics model. This model best explains the formation of slickensides. It states that soil materials will fail along shear planes whenever the swelling pressures of a confined system exceed the shear strength of the soil (Wilding, 1985). During the dry season, deep cracks form. Upon rewetting, the cracks close, and horizontal and vertical stresses cause shear failures (slickensides) in a three dimensional direction going outward and upward. This forms thrust cones around the polygonal network of cracks. Formation of these thrust cones forces the soil to move up inducing a slightly undulating topography (gilgai) which helps to further drive the process through differential wetting between the microhighs and microlows (Coulombe et al., 1996b). While the soil mechanics model has come to be well accepted and probably the favored theory behind Vertisol genesis, in reality it is most likely the combination of all three models that best explain the formation of vertic properties in soils. Wilding and Tessier (1988) give a thorough discussion of the various interconnected factors affecting the shrink-swell phenomenon. These factors as discussed by them include the soil fabric, clay content and specific surface area, soil moisture content, confining pressure, microclimate and management factors, and clay mineralogy under which topics such as charge deficiency, microstructure, and electrolyte concentration and speciation are discussed.

Although the process of shrinking and swelling is very important, it does not preclude the formation of diagnostic horizons and features. Other pedogenic processes are responsible for variations among Vertisols and vertic intergrades. These processes include accumulation of organic matter, carbonates, gypsum, and soluble salts, and acidification processes through leaching (Eswaran et al., 1988). Clay translocation in vertic soils is not usually well expressed due to shrinking and swelling and the constant mixing of pedoturbation. However, it is still a common and important process occurring in these clayey soils. Well expressed clay skins are not generally preserved, and any translocated clay is engulfed in the matrix or slickensides as a result of shrinking and swelling. Nettleton et al. (1969) studied argillic Bt horizons in which clay skins were absent in areas of desert and Mediterranean climates in the southwestern U.S. They found that clay skins were absent in horizons having linear extensibility values greater than 4% or a masepic or omnisepic plasmic fabric while clay skins were present in equivalent horizons having low shrink-swell potentials and an insepic or mosepic plasmic fabric. They concluded that clay may be illuviated but clay skins were not present because ped faces did not persist long enough due to shrinking and swelling movement. Also, preexisting clay skins could be destroyed by shrink-swell. They added that these findings should only apply to desert or Mediterranean climates and that clay skins may very well form in shrink-swell soils of more humid environments (Nettleton et al., 1969). Blokhuis (1982) cited several reports of clay illuviation expressed as thin cutans found in Vertisols.

1.1.4 Field and Laboratory Identification of Vertic Properties

Many vertic features are quite evident in the field. If the soil is dry, cracks should be apparent. Cracks can be several centimeters wide, over a meter deep, and very tortuous. Tillage may destroy surface cracks, but subsurface cracks continue to exist (Dudal and Eswaran, 1988).

Slickensides are the next most recognized feature as evidence of shrink-swell. They appear as polished, grooved surfaces inclined 20-60° from horizontal and form as a result of one soil mass sliding past another during shear failure when the soil material is in a plastic state. Overburden pressure from overlying soil is required to create the shear stresses that create slickensides. For this reason, the optimum depth of slickenside formation is usually 50-125 cm. Past about 125 cm depth, the soil moisture fluctuations are generally not great enough to cause slickensides (Dudal and Eswaran, 1988). Structure can also be quite distinct in high clay vertic soils. Granular or blocky structure is usually exhibited in surface horizons giving way to prismatic structure or wedge-shaped structural aggregates. Gilgai micro-topography may also be present but are not common to all vertic soil landscapes (Coulombe et al., 1996).

In the laboratory, several measurements are commonly made to characterized vertic soils. Bulk density and coefficient of linear extensibility (COLE) values are high for vertic soils (0.06-0.2 COLE). Bulk density values reported for Vertisols by Coulombe et al. (1996) range from 0.9 to 1.2 Mg m^3 at 0.33 MPa (field capacity) and 1.6 to 2.0 Mg m^3 at 1.5 Mpa (permanent wilting point). Cation exchange capacity (CEC) is generally high (20-45 cmol kg^{-1} soil) due to the large clay fraction and a high content of smectite (Eswaran et al., 1999). Soil textural analysis is important as total and fine clay content is a defining property of vertic soils. X-ray diffraction is useful for determining the types and abundances of clay minerals present. Finally, many stress induced features can be identified in soil thin sections such as planar voids, slickensides, and microshear within the soil fabric causing linear zones of oriented clay particles (Wilding, 1985; Wilding and Tessier, 1988; Eswaran et al., 1988; Blokhuis, 1982).

1.1.5 Claypan Soils

Claypan soils are defined as soils having a dense, compact, slowly permeable layer in the subsoil with a much higher clay content than the overlying material, from which it is separated by a sharply defined boundary. Claypans are usually hard when dry, and plastic and sticky when wet (SSSA, 2010). There are approximately 4 million hectares of claypan soils in the Midwestern United States (Jamison et al., 1968). The clayey subsoil can impede downward root growth (Clark et al., 1998). Also, due to the low hydraulic conductivity of the clayey subsoil, claypan soils often have reduced drainage which can result in soil wetness problems and increased surface runoff (Buckley, 2008; Blanco-Canqui et al., 2002). At times, cracking networks in these high clay soils promote preferential flow (Kelly and Pomes, 1998). Wilkison and Belvins (1999) reported that preferential flow accounted for 35 percent of water drainage through a claypan soil in Missouri. Despite the large amount of water held within the claypan, availability of that water to crops is low due to high water retention (Buckley, 2008; Blanco-Canqui et al., 2002). There are a number of ways in which claypan soils may form. A change in parent material stratigraphy is one way that can result in layers having contrasting textures. For example, the deposition of a thin loess deposit directly on top of clayey alluvium or residuum is one situation that could form a claypan soil. Translocation of clay downward in the soils, and clay accumulation within an argillic horizon are pedogenic processes that can aid in the formation of claypans. Due to restricted drainage, claypan soils have a high potential for lateral movement of water above the claypan (Buckley, 2008). It is possible that in some claypan soils, lateral flow is responsible for leaching of clays and other materials. This lateral pattern of translocation could help produce the very abupt textural change observed in some claypan soils. Destruction of clay particles through the process of ferrolysis (Brinkman, 1970) is also suspected to contribute to the loss of clay content in the surface soil.

1.2 Mineralogy of Soils with Vertic Properties

1.2.1 Sources of 2:1 Expansive Layer Silicates

Clay mineralogy is a defining property for vertic soils. Without high contents of smectitic expanding clay, the physical properties for which Vertisols are known would not be possible. Clay percentage and surface area are very closely correlated with shrink-swell potential; thus, the higher the percentage of fine clay particles, the higher the surface area and shrink-swell potential (Wilding and Tessier, 1988). The clay minerals may be present in the original parent material, usually alluvial and marine sediments and shales, and thus inherited, or they may be formed in place through neogenesis and transformations. Vertic soils formed in sediment with the potential to shrink and swell are more geographically extensive and occupy lower parts of the landscape than those formed from igneous and metamorphic rocks (Eswaran, 1988). The development and persistence of smectitic clays is favored by a high pH with sufficient Ca^{2+} and Mg^{2+} in the soil system. The presence of a relatively impermeable layer at some depth within the soil prevents the leaching of the various components needed to form smectites. Dixon (1982) suggested that dissolved Si may be important for the stability of smectites. Eswaran et al. (1988) states that when Si potential is low, such as in a leaching environment, kaolinite forms, but in an environment high in pH, Si, and Mg, smectites form. Low hydraulic conductivity and poor drainage conditions common to vertic soils help to create soil conditions favoring the stability of smectites.

1.2.2 Nature of 2:1 Expansive Layer Silicates

Clay minerals are part of the mineral group phyllosilicates, or layer silicates. The chemical structure is composed of sheets of Si tetrahedrons and Al octahedrons linked together forming Si tetrahedral sheets and Al octahedral sheets. These Si and Al sheets are joined into a layer by sharing oxygen atoms and OH^- groups. 1:1 layer silicates such as kaolinite are formed by these layers with each layer consisting of one Si tetrahedral sheet joined to one Al octahedral sheet. The 2:1 layer silicates associated with vertic properties are also composed of Si tetrahedral sheets and Al octahedral sheets; however, one 2:1 layer consists of one Al octahedral sheet sandwiched between two Si tetrahedral sheets.

The force of attraction between the structural layers of clay minerals determines their expanding capabilities. The layers of 1:1 clay minerals are strongly bound together by hydrogen bonding. Thus, no water molecules or other ions are able to fit into the interlayer spaces and cause expansion. The layers of 2:1 smectitic minerals are only weakly bound together by Van der Waals attractive force, so the interlayers are able to expand to accommodate water molecules and ions. This also accounts for smectite's very large internal surface area and its tendency to swell when wet. Other 2:1 layer silicates such as chlorite do not display the ability to shrink and swell because their layers are held together tightly by an interlayer hydroxide sheet. Similarly, clay mica is not expandable due to strongly bound K cations in the interlayers. As the K cations are slowly weathered out from the interlayers, clay mica is transformed into vermiculite. Vermiculite is an expanding 2:1 clay mineral; however, the expansion and contraction is limited by the amount of K cations remaining fixed in the interlayers.

Layer charge is another important aspect of clay mineralogy. In 2:1 layer silicates, isomorphous substitution of lower valence cations for Si and Al in tetrahedral and octahedral sheets causes a net negative charge, or layer charge deficit. This charge deficit is balanced by cations within the interlayer spaces and surrounding the clay particles. The magnitude and location of the charge deficit governs many of the clay mineral attributes which influence shrink-swell properties (Wilding and Tessier, 1988). Tessier (1984) found that clays with the lowest charge deficiency have the highest degree of hydration, most complete interlayer exchange, the most flexible clay particles, and exhibit the greatest shrink-swell potential. Smectites have a layer charge of 0.2-0.6 electron per half unit cell, vermiculite has a layer charge of 0.6-0.9 electron per half unit cell, and clay micas (mica particles in the clay size fraction) have a layer charge of 1.0 electron per half unit cell. Smectites having a high layer charge (0.45-0.6) have been found to have incomplete interlayer exchange and are transitional to vermiculite species (Ransom et al, 1988; Tessier and Pedro, 1987). Smectite minerals have also been reported in Vertisols having a layer charge in the range of vermiculite (0.6-0.9) (Chen et al., 1989; Badraoui and Bloom, 1990). A large portion of the layer charge in these minerals was found to come from isomorphic substitution in the tetrahedral sheet. This is important because there is less interlayer expansion when the majority of the charge is located in the tetrahedral than when it is located in the octahedral sheet. These smectite/vermiculite transitional minerals are common in soils, and like vermiculite and partially weathered illite/clay mica, they have the ability to fix K^+ and NH_4^+ (Coulombe et al., 1996a). Kaolinite generally has no isomorphous substitution and thus no permanent charge, but it does have pH dependent charge (Coulombe et al., 1996a).

Smectitic minerals dominate the vast majority of vertic soils. The expanding and contracting of interlayer spaces as well as interparticle shrinking within the microstructure is responsible for the shrink-swell phenomenon that defines vertic soils. It should be noted that Wilding (1985) stated that shrink-swell potential is a function of the amount of external surface area associated with plasma aggregates or individual clay domains and not clay mineralogy. Wilding (1985) believed that kaolinite, illite, and other clay minerals could exhibit significant shrink-swell potential if they had a particle size of fine clay and high specific surface areas as does smectite (Tessier, 1984). He cited Green-Kelly (1974) as having concluded that the dehydration shrinkage between stacked clay particles and clay particle aggregates (domains) in the microstructure is the principle component of bulk shrinkage rather than interlayer shrinkage within the clay minerals. Despite this observation, smectites continue to be considered a fundamental part of Vertisol formation. Their d-spacing can range from 1.0 to 1.9 nm due to interlayer expansion. Smectite X-ray diffraction peaks are often broad due to the fact that they occur as very thin crystallites (Coulombe et al., 1996a). Montmorillonite and beidellite are the two most common species of smectite occurring in vertic soils, although nontronite has also been reported in high iron soils (Dixon, 1982).

Several other minerals are present in the clay fraction of vertic soils as well and can be in equal or greater abundance than smectite. Kaolinite is considered the second most abundant clay mineral in vertic soils. In fact, kaolinite has been reported as a very large mineralogical component of Vertisols in El Salvador (Yerima et al., 1987), Sudan (Yousif et al., 1988), Hawaii (Ikawa, 1985), and Australia (Norrish and Pickering, 1977). Kaolinite may be inherited from the parent material or formed as a product of smectite weathering usually under leaching conditions. Inherited kaolinite tends to be present as well crystallized particles whereas neoformed kaolinite tends to occur as smaller, poorly crystallized particles and give broader X-ray diffraction peaks (Dixon, 1982). Thus, it seems neoformed kaolinite would increase the shrink-swell potential of the soil due to an increased surface area.

Clay mica is usually present only in small amounts in high clay, vertic soils. Micas are primary minerals inherited from igneous and metamorphic rocks and sedimentary deposits and can be present in the sand, silt, and clay sized fraction of soils. Vermiculite weathers from clay mica minerals, or illite, through an edge weathering process which strips out interlayer cations (Ransom et al., 1988). Vermiculite has been identified as a minor constituent in many vertic soils. Trioctahedral vermiculite can be present in all particle size fractions, whereas dioctahedral vermiculite, like smectite, is typically concentrated in the clay size fraction. Chlorite, hydroxyl-interlayered vermiculite (HIV), and hydroxyl-interlayered smectite (HIS) have all been reported in vertic soils as well as many types of interstratified phyllosilicates such as interstratified kaolinite-smectite (Yerima et al., 1985) and vermiculite-smectite (Carson and Dixon, 1972).

Minerals not in the phyllosilicate group are not of as great importance in vertic soils, and so they have not received as much attention in previous studies. The most common include quartz, feldspars, iron and manganese oxides, and carbonates (Coulombe et al., 1996a).

1.3 Micromorphology of Soils with Vertic Properties

1.3.1 Micromorphology of Shear Features

The shrink-swell phenomenon in vertic soils creates vertic properties and features at both the macroscopic and microscopic levels. Macroscopic features such as deep cracks, unique structure, pressure faces, and slickensides have already been discussed. At the microscopic level, plasma separations, stress cutans, and planar voids are characteristic of Vertisols and vertic intergrades (Blokhuis et al., 1988).

Lineated zones of oriented plasma (clay particles) in which clay platelets are stacked face-to-face form within the microfabrics of vertic soils due to the shear stresses associated with swelling. These elongated zones of oriented plasma are known as plasma separations and represent zones of previous shear failure (Coulombe et al., 1996a; Wilding and Tessier, 1988). They can occur in the soil matrix, around skeleton grains, and/or along voids. These stress-oriented plasma fabrics fall into the sepic plasma fabrics as termed by Brewer (1964, 1976) and the striated birefringence fabrics or b-fabrics as termed by Bullock et al. (1985). Zones of parallel oriented clay display interference colors, or birefringence, when observed with cross polarized light. This study uses the terminology used by Bullock et al. (1985) and Stoops (2003), and reports from previous studies have been translated to fit this newer terminology.

Identification of stress-oriented plasma fabrics can be achieved with the use of a scanning electron microscope or in soil thin section using a petrographic microscope with cross-polarized light. According to Wilding and Tessier (1988) these shear zones reduce the strength of the soil fabric; thus, they enhance the formation of ped pressure faces and slickensides. The striated b-fabrics are those associated with vertic properties (Gunal and Ransom, 2006b). Porostriated (vosepic), granostriated (skelsepic), parallel striated (masepic), and cross-striated (lattisepic) b-fabrics indicate microshear (Wilding and Tessier, 1988; Wilding, 1985). Nettleton and Sleeman (1985) cite many authors who found that shearing produced parallel striated b-fabrics within the clay-sized material. Gunal and Ransom (2006a) found shrink-swell associated striated b-fabrics in Bt horizons in central Kansas. Often the striated b-fabrics occurred in the upper part of the argillic horizons with higher COLE values (Gunal and Ransom, 2006a and 2006b). Shearing in both the horizontal and vertical directions is believed to produce cross-striated fabric (McCormick and Wilding, 1974). Blokhuis et al. (1988) organized the b-fabrics found in vertic and other high clay soils into three categories: surface-related plasma separations, subcutanic plasma separations, and unrelated plasma separations. Surface-related plasma separations are those b-fabrics associated with the surfaces of voids and skeleton grains or nodules, and they include porostriated and granostriated b-fabrics. The occurance of these b-fabrics has been found to increase with depth generally to the zone of maximum slickenside development

(Blokhuis et al., 1988). Subcutanic plasma separations are striated b-fabrics that are unrelated to the surfaces of voids, grains, and nodules. Parallel striated b-fabric is an example of these subcutanic plasma separations. Unrelated plasma separations are not considered characteristic of vertic soils by Blokhuis et al. (1988). However, they are commonly described in these type soils. Speckled (asepic), stipple speckled (argillasepic or insepic), mosaic speckled (mosepic), random striated (omnisepic), and cross-striated (lattisepic) are considered unrelated b-fabrics by Blokhuis et al. (1988). Speckled b-fabrics are described by Stoops (2003) as randomly arranged, equidimensional domains of oriented clay which go extinct successively; whereas in striated b-fabrics, the oriented clay is present in elongated zones or streaks, at least 30 µm long, in which the domains show more or less simultaneous extinction.

Wilding and Drees (1988) found that these speckled and striated b-fabrics are often masked by crystallitic b-fabrics of calcareous soils. Special techniques can be used to remove the carbonates from thin sections in order to reveal masked b-fabrics. Organic matter can also mask b-fabrics.

Void types found in vertic soils are not so different than other soils. Chambers, channels, and vughs are all common, but planar voids tend to dominate at depths below the surface horizons. Planar voids are generally linear and can be jointed or oriented in oblique directions (Blokhuis et al., 1988). Planar voids often form at shear planes and thus, represent slickensides and pressure faces.

1.3.2 Other Pedofeatures

Illuviation argillans may be found in vertic soils especially if shrink-swell processes and pedoturbation are not severe. These argillans appear as clay films or coatings of oriented clay surrounding skeleton grains or lining voids and ped faces. In soils with high shrink-swell potential, these argillans have often been interpreted as being relic features left over from a past period of pedogenesis (Nettleton and Sleeman, 1985). As discussed earlier, shrink-swell processes tend to destroy evidence of previous clay illuviation and prevent new clay films from forming on unstable ped faces. Distorted, embedded argillans are described as past accumulations of oriented illuvial clay that have been deformed and embedded within the soil matrix by pressure and shearing (Stoops, 2003). Gunal and Ransom (2006b) described embedded grain coatings as formed by in-situ modification of the micromass due to shink-swell activity and did not consider them illuvial pedofeatures. Thick, continuous argillans were not observed by Gunal and Ransom (2006a) when cross-striated b-fabric dominated. Other pedofeatures identifiable in thin section include iron and manganese concentrations, carbonate nodules, and papules (pseudomorphs of biotite mica) (Nettleton and Sleeman, 1985).

1.4 Classification of Soils with Vertic Properties

To classify as a Vertisol, a soil first must fail to meet the classification requirements for Gelisols, Histosols, Spodosols, Andisols, and Oxisols according to the fall-out-first system of Keys to Soil Taxonomy (Soil Survey Staff, 2006). After this, in general a soil must contain: 1) a layer at least 25 cm thick with slickensides or wedge-shaped peds, 2) a clay content of at least 30 percent from the surface to a depth of at least 50 cm, or a lithic or paralithic contact, duripan, or a petrocalcic horizon if shallower, and 3) cracks that open and close periodically. Specifically, Keys to Soil Taxonomy requires:

1. A layer 25 cm or more thick, with an upper boundary within 100 cm of the mineral soil surface, that has either slickensides or wedge-shaped peds that have their long axes tilted 10 to 60 degrees form the horizontal; and
2. A weighted average of 30 percent or more clay in the fine-earth fraction either between the mineral soil surface and a depth of 18 cm or in an Ap horizon, whichever is thicker, and 30 percent of more clay in the fine-earth fraction of all horizons between a depth of 18 cm and either a depth of 50 cm or a densic, lithic, or paralithic contact, a duripan, or a petrocalcic horizon if shallower; and
3. Cracks that open and close periodically.

There are six suborders of Vertisols that are recognized based upon aquic conditions, soil temperature regime, and soil moisture regime. The suborders include Aquerts, Cryerts, Xererts, Torrerts, Usterts, and Uderts. Soil moisture regimes for vertisols are differentiated based on the duration that the cracks are open and closed (Soil Survey Staff, 1999).

Several of the other soil orders contain vertic subgroups for recognizing soils with vertic properties that do not meet the Vertisol requirements. There are basically two kinds of these vertic intergrades. There are soils that show evidence of shrinking and swelling due to fluctuations in moisture content, but they do not meet the minimum requirements for vertisols. The other type of vertic intergrade actually shows little or no evidence of soil movement, but they have potential for soil movement due to relatively high COLE values. Often, these soils do not experience a fluctuation in moisture content great enough to produce significant shrinking and swelling (Soil Survey Staff, 1999).

1.5 K^+ and NH_4^+ Fixation in Soils with Vertic Properties

Many vertic and claypan soils have the capacity to both fix and release K^+ and NH_4^+. K^+ and NH_4^+ have similar selectivity on exchange sites of clay minerals because they are similar in charge, size, and hydration energy. High clay contents and high cation exchange capacities contribute to the adsorption and release of K^+ and NH_4^+. Pal and Durge (1987) found the coarse and fine clay fractions to be responsible for most of the K^+ fixation. However, K^+ and NH_4^+ fixation does occur within the silt fraction. Other factors such as the type of clay minerals, site and amount of layer charge of clay minerals, variation in moisture and temperature conditions, topographic position, and the type of cation and electrolyte concentration also play a role in controlling the retention and release of K^+ and NH_4^+ (Coulombe et al., 1996). These factors should receive attention when considering soil fertility management in high clay, vertic and claypan soils.

The type and abundance of phyllosilicate minerals along with their layer charge is probably the most important factor governing K^+ and NH_4^+ fixation. Vermiculite minerals are known for their ability to fix K^+ ions within their interlayers. Carson and Dixon (1972) and Dixon (1982) reported that vermiculite and mica control the K^+ selectivity in certain Vertisols in Texas. As discussed earlier, smectitic minerals with layer charges in the range of vermiculite (0.6 to 0.9 electron per half unit cell) have been identified and would thus also be able to fix K^+ and NH_4^+ (Chen et al., 1989; Badraoui and Bloom, 1990). The primary site (tetrahedral or octahedral) of isomorphous substitution, or source of layer charge, is also an important factor influencing ion retention. Chen et al. (1989) and Badraoui and Bloom (1990) found the charge in these high charge smectites to be distributed between both the tetrahedral and octahedral sheets with the majority of the layer charge coming from the tetrahedral sheet. With much of the negative charge located in the tetrahedral sheets, the distance between the source of negative charge and interlayer cations is reduced, and the force of attraction between the opposing charges is increased, which cause interlayer cations to be retained. High layer charge smectites with a layer charge in the range of 0.45 to 0.6 also have been found to contribute to K^+ and NH_4^+

retention. Above a layer charge of 0.45, K^+ and NH_4^+ are not freely exchangeable (Tessier and Pédro, 1987). According to Coulombe et al. (1996) K^+ retention was not considered a major problem in Vertisols dominated by smectitic mineralogy before the recognition of these high charge smectites. Interstratified clay minerals with layer charges within the high charge smectite and vermiculite ranges may also influence K^+ and NH_4^+ retention and release. A high layer charge and the site of charge deficiency are very important attributes contributing to K^+ and NH_4^+ fixation.

Variation in temperature and moisture conditions, which can be influenced by topography as well as climate, has also been related to K^+ and NH_4^+ fixation. Shadfan (1983) and Thompson and Beckmann (1982) reported that vertic soils in the higher landscape positions contained greater amounts of exchangeable K^+ than those at lower areas. This was attributed to the differences in drainage, moisture fluctuations, and temperature. In addition, the concentration of K^+ and NH_4^+ and other ions present in the soil environment is a fundamental factor involved with fixation and release from exchange sites (Bouabid et al., 1991). With a recent addition of K^+, air drying gererally causes significant fixation (Olk et al., 1995). An increase in K^+ fertilizer rate was reported to be a factor responsible for NH_4^+ fixation which caused a decrease in rice yield in vertic soils dominated by high charge smectite (Chen et al., 1989). Simonsson et al. (2007 and 2009) found K^+ fixation to increase as a function of the K^+ fertilization rate in long term field experiments. They also found that K^+ fertilization and the resulting fixation impacted soil mineralogical content by increasing the clay mica/illite component. These are important consideration for the management of vertic soils.

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CHAPTER 2 - Morphology, Genesis, and Classification of Vertic Soils in the Cherokee Prairies Major Land Resource Area of Kansas

2.1 Abstract

Many of the soils of the Cherokee Prairies of southeastern Kansas are characterized by high clay contents and high shrink-swell potentials. The fine sediments that make up these vertic soils are dominantly provided by the local parent materials, namely alluvium, colluvium, and residuum derived from weathered Pennsylvanian and Permian shales and limestones. The objective of this study was to describe the morphology and investigate processes of soil genesis in these vertic, claypan soils. Factors and environmental conditions influencing the expression of vertic characteristics were examined. Ten pedons were sampled by horizon and described in the field. Laboratory analyses were conducted and included particle size distribution, coefficient of linear extensibility (COLE), pH, total carbon, and cation exchange capacity (CEC). Field morphology dominantly reflected the geologic parent materials available in the region as well as the significant weathering provided by the humid continental climate with an average annual rainfall of 865 to 1,145 millimeters. The dominant pedogenic processes currently at work are clay illuviation and shrink-swell processes. Relatively high COLE values were found in all soils. Silty surface soils overly high shink-swell argillic horizons at all but two of the sites. In these claypan soils, the shrink-swell potential of the argillic horizon is not fully expressed as the subsurface horizons dry out less rapidly and are not as subject to differential wetting by preferential flow down surface cracks due to the buffering effect of the non-expansive top soil. Sites 6 and 7 classify as Vertisols, and no argillic horizon or clay films were described. In these two soils, shrink-swell and pedoturbation provides great enough mixing of surface and subsurface horizons to effectively counteract downward clay translocation. This action maintains a clayey, high COLE value surface, as well as deep cracking that extends to the soil surface. Subtle changes in parent material and landscape position are suspected to cause the differences in vertic characteristics found in this study.

2.2 Introduction

The Cherokee Prairies Major Land Resource Area (MLRA 112) is an area characterized by gently sloping to rolling, dissected plains situated within Kansas, Missouri, and Oklahoma. In southeastern Kansas, the region is bounded on the north by the Kansas River and on the west by the Flint Hills physiographic region. Local relief is typically only one to three meters, and major valleys are generally less than 25 meters below adjacent uplands. Nearly the entire region is underlain with alternating layers of Pennsylvanian and Mississippian aged marine shales, limestones, and sandstones. The soils reflect this geology, and multiple parent materials are often described. Soils form in loess, alluvium, colluvium, and residuum.

Many of the soils in the Cherokee Prairies are characterized by high clay contents and high shrink-swell potentials. Most soils in this region are not classified as Vertisols; however, their vertic properties and claypan characteristics cause soil management to be difficult and pose problems for agricultural, environmental, and engineering uses. Vertic soils occur in many areas around the globe such as Australia, India, the Sudan, and in the United States. In fact, Krohn and Slosson (1980) estimated that up to 20% of the U.S. may be mantled with soils subject to shrink-swell behavior. Vertisols have been widely studied by the engineering community because of the structural challenges they pose to building foundations, highways, piplines, etc. (Buol et al., 1980). Despite their problems, vertic soils are generally known for having high fertility and have proven to be highly productive agricultural soils. Water management is an important concept when farming high clay, vertic soils. Producers must be able to properly time operations to deal with excesses and deficits of water (Ahmad, 1996). Thus, collecting more information and improving our understanding of vertic soils is an important step towards bettering our soil management techniques.

The genesis of nearly all Vertisols and vertic intergrades is dependent upon two conditions: 1) a large quantity of expandable clay; and 2) a seasonal wet-dry cycle that causes the expansion and contraction of the soil material (Soil Survey Staff, 1999). Within these two requirements there exists a wide spectrum of vertic characteristics and properties. Vertic soils occur in nearly every major climatic zone and under many different vegetation types. Parent material is one of the most important factors involved in the formation and distribution of vertic soils. Vertic soils develop on a wide range of parent materials including alluvial, colluvial and lacustrine deposits, marl and other calcareaous rocks, limestone, shales, igneous, metamorphic and volcanic rocks of basic nature. Vertisols are known to develop on basalts in Australia, gneisses and sandstones in India, and glacio-lacustrine materials in Saskatchewan (Dudal, 1965; Ahmad, 1983; Probert et al., 1987; Coulombe et al., 1996; Dasog et al., 1987). For the most part, in the U.S., they develop on calcareous clay or in residuum weathered from soft, calcareous sedimentary rocks (Ahmad, 1996). The smectitic clays may be inherited from the original rock parent material or may have formed in place as a result of neogenesis or transformations from primary minerals. The limestones and shales present in southeastern Kansas are a direct source for much of the clay mineral content. Vertic parent materials commonly have a high base status that favors formation and stability of clay minerals (Coulombe et al., 1996). Poor drainage also favors the formation of smectites.

Although the shrink-swell phenomenon responsible for the formation of vertic properties has been studied extensively, it is still incompletely understood. Linear and normal gilgai, cyclic horizons, surface cracking upon desiccation, and the formation of slickensides all can result from this process (Soil Survey Staff, 1999). Wilding and Tessier (1988) and Coulombe et al. (1996) provide excellent reviews of the current ideas surrounding Vertisol genesis including summaries of various pedogenic models. The pedoturbation model, or self-swallowing model, as proposed by Buol et al. (1980) suggests that surface soil is disturbed and falls into shrinkage cracks. Upon rewetting, the cracks close as the soil material expands; however, because the fallen surface soil is occupying a portion of the initial soil volume, a space problem is created. This results in high pressures, which are relieved by displacing the soil to the sides and upwards, forming slickensides, gilgai, and other vertic features. Another pedogenic model of Vertisol formation is the soil mechanics model first proposed by Howard (1932) and later supported by Yaalon and Kalmar (1978). In this model, differential wetting of the subsoil by preferential flow along cracks causes horizontal and vertical stresses in excess of the shear strength of the soil, resulting in shear failure planes or slickensides (Wilding, 1985). Often, both of these processes occur simultaneously. However, most current investigations cite the soil mechanics model as being primarily responsible for Vertisol formation. Nordt et al. (2004) and Dasog et al. (1987) support this idea. Both studies found the depth of cracking was above the zone of maximum slickenside development. Therefore, Nordt et al. (2004) concluded that the soil mechanics model best explains the preservation of systematic pedogenic depth functions for many soil properties such as color, organic carbon, calcium carbonate, pH, and the formation of slickensides. This suggests the pedoturbation model is of lesser importance. Nordt et al. (2004) also noted that cracks were never observed during sampling of a Vertisol formed in a udic moisture regime on the coastal plain of Texas. Many interconnected factors influence the shink-swell phenomenon including the soil fabric, specific surface area, soil moisture content, clay mineralogy, etc. (Wilding and Tessier, 1988).

Although the process of shrinking and swelling is very important, it does not preclude the formation of diagnostic horizons and features. Other pedogenic processes are responsible for variations among Vertisols and vertic intergrades. These processes include accumulation of organic matter, carbonates, gypsum, and soluble salts, and acidification processes through leaching (Eswaran et al., 1988). Clay translocation in vertic soils is not usually well expressed due to shrinking and swelling and the constant mixing of pedoturbation. However, it is still a common and important process occurring in these clayey soils. Well-expressed clay skins are not generally preserved and any translocated clay is engulfed in the matrix or slickensides as a result of shrinking and swelling. Nettleton et al. (1969) studied argillic horizons in which clay skins were absent in areas of desert and mediterranean climates in the southwestern U.S. They found that clay skins were absent in horizons having linear extensibility values greater than 4 percent or a masepic or omnisepic plasmic fabric. Clay skins were present in equivalent horizons having low shrink-swell potentials and an insepic or mosepic plasmic fabric. They concluded that clay may be illuviated but clay skins could not form because ped faces did not persist long enough due to shrinking and swelling movement. Also, preexisting clay skins could be destroyed by shrink-swell. They added that these findings should only apply to desert or mediterranean climates and that clay skins may very well form in shrink-swell soils of more humid environments (Nettleton et al., 1969). Blokhuis (1982) cited several reports of clay illuviation expressed as thin cutans found in vertisols.

The objective of this study was to describe the morphology and genesis of claypan soils in the Cherokee Prairies Major Land Resource Area (MLRA 112). Features of soil development and pedogenic processes currently acting upon these soils will be identified and discussed. The soils selected for this study were hypothesized to express varying degrees of vertic characteristics. Therefore, factors and environmental conditions influencing the expression of these vertic characteristics will be examined as well as the classification of these soils using *Keys to Soil Taxonomy* (Soil Survey Staff, 2010).

2.3 Materials and Methods

2.3.1 Description of the Study Area

2.3.1.1 Location and Physiography

The Cherokee Prairies Major Land Resource Area (MLRA 112) is an area characterized by gently sloping to rolling, dissected plains situated within Kansas, Missouri, and Oklahoma (Fig. 2.1). A section of this region and the area in which all sampling occurred for this study is referred to as the Osage Questas physiographic region of Kansas. In southeastern Kansas, the region is bounded on the north by the Kansas River and on the west by the Flint Hills physiographic region. The foundation rocks of this region are among the oldest exposed in Kansas. The Osage Cuestas are typified by rolling hills and low ridges that are somewhat steep on one side and gently sloping on the other. These landforms are known as cuestas. Local relief is typically only one to three meters, and major valleys are generally less than 25 meters below adjacent uplands (MLRA Explorer Custom Report, 2006). A total of ten pedons were selected for this study. Pedons were sampled in the following counties: Osage, Franklin, Miami, Woodson, Allen, Wilson, and Neosho.

2.3.1.2 Geology and Parent Materials

The entire study area is underlain with alternating layers of Pennsylvanian-aged shales, limestones, and sandstones. The soils reflect this geology, and multiple parent materials are often described. Soils form in residuum, colluvium/local alluvium, and alluvium. It is also very common to find a thin loess cap on upland areas throughout this region. Soil derived from residuum forms in the 300 million year old Pennsylvanian deposits of limestone, shale, or sandstone. Alluvial soils in stream valleys seem to form in similar sediments as nearly all of the rivers in this region have their headwaters located within the region or within the Flint Hills to the west, which has a similar limestone and shale geology. Loess, having blown in from the west during the Pleistocene and Holocene, is thought to have contributed a significant amount of sediment to this region. However, since the time of deposition most of the loess sediment has been transported by water and gravity, mixed with other parent materials, and redeposited. In many of the studied soils this is evidenced by the lack of a clearly defined boundary between the loess mantle and the underlying parent material. On these relatively old landscapes, parent material changes are not always easily discernable in the soil profile. Several soils observed in this study show evidence of having paleosols representing past land surfaces; however, it seems that time and ongoing pedogenic processes have welded the old and new soils together.

The Pennsylvanian rocks in Kansas have been extensively studied. These sedimentary beds are well known for their lateral extensiveness especially in relation to their small thicknesses. Their cyclic nature is also a very distinguishing characteristic. In fact, R.C. Moore developed the concept of cyclic sedimentation in the 1930s while studying these Upper Pennsylvanian and Lower Permian deposits. For the most part the deposits consist of marine limestone and shale, alternating with non-marine, clastic shale and sandstone. The cyclic sedimentation patterns were termed cyclothems by Moore, and they have become widely accepted in the geologic community (Cubitt, 1979; Merriam, 1963; Moore, 1949). Cyclothems are related to the regular fluctuations of the shallow sea which covered the midcontinent of North America during the Pennsylvanian Period. Changes in the sea level resulted from the melting and freezing of polar ice caps and tectonic movements. An ideal cylothem goes through a non-marine to marine to non-marine succession and represents a single advance and retreat of the sea. As sea level rose and fell, the shoreline migrated back and forth across the midcontinent area (Merriam, 1963). The limestone and calcareous shale were deposited during periods of maximum marine transgression; while at times when sea level fell, deltas and river channels developed and were infilled with sand, silt, or clay with the particle size depending upon the distance from the source area and the water depth. Non-marine shale accumulated as floodplain and delta mud (silt and clay), and the sandstone fills former river and delta channels. Coal beds formed in lagoons or estuaries, and thin limestone beds represent minor marine incursions (Aber, 2005). Soil textures in this study reflect the clayey nature of the shale deposits, and much of the clay is hypothesized to have been inherited from the parent materials. Clay weathering from limestone has also most likely contributed to the high clay contents often found in this part of Kansas.

During the Pennsylvanian, North America was situated over the equator and experienced a mild, tropical climate. While the Kansas region was relatively stable during this time, great tectonic events took place to the east, south, and west. The Appalachian and Ouachita mountain systems were thrust up as North America collided with a vast southern continent named *Gondwana*, which included modern Africa, South America, India, Australia and Antarctica. The result of these collisions was the creation of a supercontinent named *Pangaea*, meaning all lands, which encompassed all modern continents. Meanwhile to the west, the Ancestral Rocky Mountains were uplifted in Colorado adjacent to a convergent plate boundary on the margin of the continent (Aber, 2005). Surrounding Kansas during the Pennsylvanian and Permian was a series of mountain ranges stretching from the Ozarks of Missouri to the Black Hills of South Dakota. These were the major sources of sediment for the Kansas Basins, and tectonic events within the mountain regions produced dramatic changes in sediment deposition in the shelf seas of Kansas and Colorado. It has been speculated that the cyclic nature of subduction and the subsequent mountain uplift helps to account for the regular repetition of clastic shales and sandstones in the Pennsylvanian and Permian rocks. Thus, during periods of sudden uplift and resulting erosion, "clastic wedges" would spread out over Kansas coming primarily from the mountains in Texas, Oklahoma, Arkansas, and Missouri. To the north and east, deltaic lowlands stretching from North Dakota to the Ozark Dome also supplied limited amounts of sediment to the basins in Kansas (Cubitt, 1979).

Since the Pennsylvanian, tectonic forces have tilted these strata in eastern Kansas, and they now dip gradually to the west and northwest. This gentle dip and the differential erosion that has taken place over millions of years combines to form the rolling, cuesta landscape for which the region is named. Limestone and some sandstones cap uplands and form escarpments or benches trending generally north and south with relatively steep east faces that gently slope to the west. Shales generally form gently rolling plains or lowlands, and commonly they occur in the lower slopes of escarpments beneath the protecting cap of hard strata which make the top of the escarpments (Moore, 1949). The many east and southeast flowing streams have incised into these escarpments and dissected the landscape carrying away and re-working thousands of feet sedimentary material over time.

Study of Pleistocene geology in Kansas has shown that geologic events that occurred during this time have shaped the landscapes into what they are today. According to Frye and Leonard (1952) Kansas during the Late Tertiary was a vast alluvial and erosional plain sloping gently eastward with little topographic relief. The early Pleistocene was a time of great erosion and valley deepening especially in eastern Kansas. Aber (1997) supports this and suggests that erosion in regions to the east and west of the Flint Hills occurred at a greater rate than in the Flint Hills region capped by very resistant cherty limestones. Thus, it was during this time that the Flint Hills emerged as a bedrock-controlled upland. Nearly all of Kansas has been either directly or indirectly influenced by the glacial advances and interglacial periods that occurred throughout the Pleistocene. In general, periods of glacial advance are associated with erosion and stream downcutting while periods of glacial retreat were depositional periods of stream alluviation and eolian deposition. Geologically stable times existed during interglacial periods as evidenced by several stratigraphically important paleosols (Frye and Leonard, 1952).

The southern Flint Hills and the Osage Questa region of southeast Kansas show the least influence of glaciation. The southerly extent of glaciations in Kansas is generally bounded by the Kansas River valley. Drainages in the study area have their headwaters in the Flint Hills and drain to the east and southeast. Frye and Leonard (1952) concluded that "some time during the Tertiary the Flint Hills became a major drainage divide separating two strongly contrasting depositional provinces." According to this idea, no alluvial material has entered the Osage Questa drainage area either from west of the Flint Hills or from north of the Kansas River. Frye and Leonard (1952) state this in saying that "...the late Tertiary sediments in the eastern one-fourth of Kansas are entirely attributable to the Permian and Pennsylvanian rocks eastward from and including the Herington Limestone." The Tertiary sediments they refer to are alluvial deposits of chert gravel found on drainage divides, isolated hilltops, and high terraces throughout eastern Kansas. These layers, composed of crudely-bedded chert derived from the cherty, lower Permian limestones, were deposited in late Tertiary or early Quaternary stream channels which would have been the lowest landscape positions at the time. After much erosion through stream channel shifting and cutting, these former low points now currently occupy the high positions in the landscape suggesting an inversion of the topography since their time of deposition. Frye and Leonard report that many of these chert gravel deposits have a red clay matrix and an absence of limestone gravel suggesting these deposits are highly weathered and have been at the surface for much of the Quaternary (Frye and Leonard, 1952).

While studying these chert gravel deposits, J.S. Aber found trace amounts (less than 1%) of quartzite and other exotic pebbles on hill tops and high terraces throughout the region (Aber, 1997). He concluded the origin of these exotic pebbles was from a Tertiary or Cretaceous source west of the Flint Hills, such as the arkosic alluvial sediments of the Wellington-McPherson-Arkansas River Lowlands, and, in contrast to Frye and Leonard, that a drainage did in fact exist through the Flint Hills in the late Tertiary. He proposed that the ancestral Arkansas River flowed from the Wichita vicinity eastward across what would become the Flint Hills and into what is now the Fall River drainage basin. He further proposed that a through drainage occurred near where the current Cottonwood-Neosho River flows across Marion, Chase, Lyon, and Coffey counties. These rivers would have brought sediment from the High Plains region into eastern Kansas. According to Aber, the ancestral drainages in eastern Kansas bear no relation to many of the modern rivers, and through a series of stream captures and ongoing channel shifting throughout the Pleistocene they have evolved into their current state (Aber, 1997).

Despite these conflicting views on Tertiary and Quaternary drainage development, the fact remains that very little of this exotic sediment has been found in the chert gravels of eastern Kansas (Aber, 1997). In the event that rivers did carry western sediment into eastern Kasas during the Tertiary, it is presumed that subsequent erosion removed these deposits (other than trace amounts left behind). By the time streams were cutting into the cherty, lower Permian limestones in the Flint Hills, the through drainage across the Flint Hills must have been cut off since these deposits are nearly 99 percent chert derived solely from the Flint Hills. Thus, soil forming parent materials in the study area generally include only Pennsylvanian bedrock, various aged alluvium derived from local Pennsylvanian and lower Permian bedrock, and relatively small quantities of Pleistocene loess.

2.3.1.3 Climate and Vegetation

The soils in this study area dominantly have a thermic soil temperature regime and a udic soil moisture regime. Some soils classify with aquic conditions. The average annual temperature ranges from 11 to 17 °C. The region has a humid continental climate and average annual rainfall of 865 to 1,145 millimeters. Most precipitation falls from high-intensity, convective thunderstorms from late spring through autumn. This area receives more rainfall than all other parts of Kansas. Soils of this study originally developed under a prairie grassland vegetation (MLRA Explorer Custom Report, 2006).

2.3.2 Field Description and Sampling

Ten pedons were used in this study. Four pedons were sampled through the spring and summer of 2009. These pedons include: Site 1 Bucyrus 09KS139001, Site 2 Woodson 09KS059001, Site 3 Aliceville 09KS121001, and Site 4 Summit 09KS207001. The remaining six pedons were sampled and described by Natural Resource Conservation Service (NRCS) soil scientists prior to the beginning of this study. These pedons include: Site 5 Woodson 73KS001003, Site 6 Zaar 05KS205002, Site 7 Zaar 97KS205001, Site 8 Kenoma 05KS133003, Site 9 Parsons 06KS133001, and Site 10 Eram 86KS133005. Soil samples and thin sections were retrieved from the NRCS Soil Survey archive in Lincoln, Nebraska, for additional laboratory and micromorphology analysis. All pedons were sampled by excavating to a depth of one to two meters with a backhoe. Pedons were described using the Field Book for Describing and Sampling Soils (Schoenenberger et al., 2002). For each horizon, bulk samples were taken for laboratory characterization, oriented clods were collected for thin section preparation, and un-oriented clods were sampled and coated in Saran for bulk density measurement.

2.3.3 Laboratory Characterization

Laboratory analyses performed by the Kansas State University Soil Characterization Laboratory will be described. Other laboratory data generated by the National Soil Survey Laboratory will be presented with the results. Bulk samples were allowed to air dry and then were ground with a wooden rolling pin and passed through a No. 10 sieve with 2 mm square openings. Soil pH was determined in a 1:1 soil to water suspension as well as a 1:2 soil to 0.1 M $CaCl_2$ solution ratio using methods 4C1a2a1a1 and 4C1a2a2a1, respectfully, of the Soil Survey Laboratory Methods Manual (Soil Survey Laboratory Staff, 2004). Total carbon and total nitrogen were determined using a high-frequency induction furnace (Leco Model CNS-2000, St. Joseph, MI) following the procedure of Tabatabai and Bremner (1970). Particle size distribution was determined using a modification of the pipet method of Kilmer and Alexander (1949) and method 3A1 form the Soil Survey Laboratory Methods Manual (Soil Survey Laboratory Staff, 2004). Organic matter was removed prior to particle size analysis from samples containing greater than 1.7% total C with 30% hydrogen peroxide.

2.4 Results and Discussion

The field morphology of these soils dominantly reflects the geologic parent materials present in the Osage Questa region of Kansas. On the level, upland sites a thin, silty textured loess cap was often observed. Colluvium or alluvium derived from weathered shale and limestone was described in all soils. There seems to be confusion as to the nature of this colluvium/alluvium among soil scientists in Kansas. Many of these soils were originally mapped with the parent material described with the term "old alluvium." This term is meant to portray the general age of deposition as much of these soils occur across ancient terraces and rolling uplands far from the current floodplain. These broad, ancient terraces have often been called "paleoterraces" and are thought to have formed during periods of erosion, deposition, and drainage development in the late Tertiary and Pleistocene. It seems that soil mappers in the past have hesitated to describe alluvium and colluvium on high terraces and rolling uplands at great distances from the current floodplains. However, the river systems in this region have migrated and changed courses several times throughout the Quaternary leaving alluvial deposits on hilltops and effectively causing an inversion of the topography. Thus, "old alluvium" soils are exactly what they appear to be – water and gravity transported sediment composed of weathered shale and limestone from both the Osage Questas and the Flint Hills regions. It is often difficult to determine a definite boundary between alluvial/colluvial material and underlying residuum composed of highly weathered shale.

Dominant pedogenic processes currently at work are clay illuviation and shrink-swell processes. The humid climate of this region provides adequate precipitation for clay translocation and the formation of clay films on the surfaces of peds and voids. Clay films are observed in the field in the majority of soils in the region; however, they are best expressed in soils exhibiting the least shrink-swell potential. The reverse is true in that soils exhibiting high shrink-swell potential have less strongly developed clay films or none at all. Soils of the Zaar series in this study showed little evidence of clay illuviation, and an argillic horizon was not described. Clay illuviation and shrink-swell tend to be opposing pedogenic processes because the soil movement associated with shink-swell and pedoturbation acts to destroy ped faces before clay has the opportunity to accumulate. These two processes occur simultaneously. Therefore, it could be conceived that if the rate of clay illuviation exceeded the rate at which shrink-swell could destroy ped faces, then accumulations of translocated clay would be observable in shrink-swell soils. Results of this study show that given the right climate and soil conditions, clay soils can develop relatively well expressed clay films and argillic horizons while having moderate vertic characteristics.

2.4.1 Macomorphology/ Field Descriptions

2.4.1.1 Site 1

Pedon 09KS139001 was sampled from a prairie hay field in eastern Osage County just north of Pomona Lake. Table 2.1 displays site characteristics for each pedon. The soil pit was dug on a backslope of an interfluve near a short escarpment that appeared to have formed due to erosion when the field was in cultivation. The slope was measured as 4 percent. The slope faced generally southeast and sloped down to an ephemeral stream just to the east. The nearest large stream now feeding into Pomona Lake is One Hundred Ten Mile Creek which joins the Marais des Cygnes River a few kilometers south of the lake. Site 1 is located within a delineation of Eram silty clay loam, 3 to 7 percent slopes (map unit 8735), but the lower part of the pedon is formed in limestone instead of shale and is deeper than the typical Eram soil. The pedon is taxadjunct to the Bucyrus series and outside the range because it does not classify as a Paleudoll. Colors in the lower argillic horizon are not red enough. Aliceville is also a similar soil, but it is outside the range of that series because the limestone bedrock is below 150 cm. The drainage class is moderately well. Parent materials were described as colluvium (0-100 cm) over residuum (100-200 cm) weathered from cherty limestone. Table 2.2 gives pedon characteristics for each soil. Although not described, there is probably a thin loess cap mixed with the upper colluvial materials, and the boundary between loess and colluvium is not clearly discernible. Indurated limestone bedrock was observed at 186 cm and is likely a member of the Lecompton Limestone Formation of the Shawnee Group. An argillic horizon and clay films were described from 46 cm to bedrock. Common slickensides were found occurring from 81 cm to bedrock, and prismatic structure parting to subangular blocky structure occurred throughout the subsoil. Redoximorphic features were observed from 46 cm to bedrock, and 1 to 3 percent chert fragments were described from 11 cm to bedrock. Table 2.3 shows selected field morphology data for each pedon.

2.4.1.2 Site 2

Pedon 09KS059001 was sampled in a brome hay field on the Kansas State University East Central Experiment Field south of Ottawa, Kansas, in Franklin County (Fig. 2.2). The site had at one time been in row crop production, but at time of sampling it had been in brome for several years. The whole field was a nearly level plain with portions slightly rolling. The slope was 1 percent, and landscape position was described as a very gradual shoulder of an interfluve (Table 2.1). From this point, water flows into an ephemeral stream which joins the Marais des Cygnes River to the north. Major streams to the south include Middle Creek and Pottawatomie Creek both of which eventually flow into the Marais des Cygnes River to the east. The site is located on the boundary between delineations of Woodson 0 to 1 percent slopes (map unit 8962) and Woodson 1 to 3 percent slopes. The drainage class is somewhat poorly. Parent materials described include loess over clayey alluvium derived from weathered shale; however, there is no observable lithologic discontinuity where loess ends and alluvium begins. It was also considered that the bottom of the profile was composed of highly weathered residuum derived from shale (Table 2.2). A relatively abrupt textural change occurred where the argillic horizon began at 26 cm. Silt coatings were observed in the lower A and upper Bt1 horizons on vertical faces of peds. Slickensides were encountered from 56 to 117 cm, and the structure was prismatic parting to subangular blocky through most of the subsoil (Table 2.3). Colors in this soil were particularly dark turning to low chroma gray colors with depth. Redoximorphic features and aquic conditions were described starting at 26 cm.

2.4.1.3 Site 3

Pedon 09KS121001 was sampled on a grassy hilltop near Miola Lake northeast of Paola, Kansas, in Miami County. The slope was measured as 2 percent on a summit of and interfluve (Table 2.1). The nearest stream which feeds Miola Lake is Sixmile Creek. Water from this creek eventually flows into the Marais des Cygnes River south of Paola. At time of sampling, the site area was mapped as Catoosa silt loam, 1 to 3 percent slopes (map unit 8645), but after completion of the current MLRA 112 update project, the map unit will be changed to Wagstaff. The Aliceville series is a common deeper inclusion of Wagstaff map units. The drainage class is moderately well. Parent materials were described as loess over residuum weathered from limestone (Table 2.2). There was no clear discontinuity between loess and residuum. The limestone bedrock encountered at 140 cm is one of the members of the Iola Limestone

Formation of the Kansas City Group. An argillic horizon and clay films were described from 45 cm to bedrock (Table 2.3). Common slickensides were found in the horizon overlying the bedrock, and prismatic structure occurred from 31 cm to bedrock. Redoximorphic features were observed starting at 45 cm.

2.4.1.4 Site 4

Pedon 09KS207001 was sampled in a large prairie southeast of Yates Center, Kansas, in Woodson County (Fig. 2.3 and 2.4). The soil pit was excavated on a 4 percent backslope of an interfluve (Table 2.1). The site is nearly located on a drainage divide. Water flowing east goes into an ephemeral gully that eventually becomes South Owl Creek, which empties into the Neosho River in southwestern Allen County. Water flowing south enters an ephemeral gully connected to Sandy Creek, which empties into the Verdigris River in northwestern Wilson County. The site was located within a delineation of Ringo silty clay loam, 3 to 8 percent slopes (map unit 8871) but is very near the boundary to Summit 1 to 3 percent slopes. The pedon description fits the Summit series best. Drainage class is somewhat poorly. Parent materials described include loess over colluvium over residuum weathered from limestone and shale (Table 2.2). The boundary between loess and colluvium is not clearly discernible. This suggests a considerable amount of soil mixing, which may be attributed to both erosion-deposition processes and shrink-swell, pedoturbation processes. The colluvial material is most likely a mixure of colluviated loess and transported material derived from weather shale and limestone. Residuum is considered to start at 177 cm. The bottom of the profile was beginning to look like shale, and it was assumed that shale would not be too much deeper. The shale belongs to a member of the Douglas Group. The argillic horizon and clay films were described from 29 cm to depth (Table 2.3), though the textural change at the top of the argillic is not as abrupt as in the Woodson series. Common to many strongly expressed slickensides were present thoughout much of the profile (53-210 cm). Prismatic and wedge structure occurred from 29 cm to depth. It should be noted that although wedge structure was observed, no subsurface structural waviness associated with gilgai topography was apparent in any of the pedons. Redoximorphic features were observed starting at 18 cm.

2.4.1.5 Site 5

Pedon 73KS001003 was sampled on a nearly level upland with a slope of 1 percent in southern Allen County (Table 2.1). The nearest stream is Goose Creek just to the east. This stream flows into Big Creek to the south which eventually empties into the Neosho River in northern Neosho County. The site is mapped in an area of Zaar silty clay, 1 to 3 percent slopes (map unit 8991). Drainage class is somewhat poorly. Soil material is composed of sediments high in clay. Possible parent materials include loess, alluvium derived from weathered shale and limestone, and residuum from highly weathered shale (Table 2.2). No lithic or paralithic contact was described in this soil. The argillic horizon starts at 20 cm where there is an abrupt textural change. Slickensides were noted in one horizon from 97 to 132 cm (Table 2.3).

2.4.1.6 Site 6

Pedon 05KS205002 was sampled in a row cropped field just north of Fredonia, Kansas, in Wilson County. The site was located on a nearly level (0.2 percent slope) toeslope of a large terrace described as a paleoterrace four miles wide and oriented north-northeast by south-southwest (Table 2.1). Water from this field flows through ephemeral streams to the Fall River just a few miles south. However, the site is not far from the drainage divide where water flows northward to the Verdigris River. The area is mapped as Zaar silty clay, 0 to 1 percent slopes (map unit 8990), and the drainage class is somewhat poorly. The parent material is described as fine, clayey alluvium most likely derived from weathered shale and limestone (Table 2.2). A cambic horizon is described from 56 to 212 cm. No clay films or argillic horizon was described. This suggests either very little clay translocation is occurring in this soil or, more likely, clay translocation is occurring but shink-swell soil movement is erasing all evidence of it. Pressure faces and slickensides were observed from 28 cm to the bottom of the profile at 212 cm, and prismatic structure parting to subangular blocky structure dominated the majority of the profile (Table 2.3). Redoximorphic features and aquic conditions were described from 28 to 212 cm. 1 to 5 percent coarse, prominent, spherical, strongly cemented carbonate concretions were present in the matrix from 56 cm to depth.

2.4.1.7 Site 7

Pedon 97KS205001 was sampled in a row-cropped field about ten km south of Fredonia, Kansas, in southwest Wilson County. The site was located on a 1 percent, concave footslope (Table 2.1). Water from the field flows into ephemeral Elm Creek which flows south to join

Duck Creek. Duck Creek joins the Elk River in northwest Montgomery County, and it eventually ends up in the Verdigris River near Independence, Kansas. Also the Fall River drainage basin is just a few miles north of the site. Like site 6, this site is also mapped as Zaar silty clay, 0 to 1 percent slopes (map unit 8990), and the drainage class is somewhat poorly. Likely parent materials include clayey alluvium derived from weathered shale and limestone and residuum of weathered limestone (Table 2.2). Also similar to site 6, no argillic horizon or clay films were observed in this soil (Table 2.3). A cambic horizon is described from 53 to 179 cm. A lithic contact occurred at 179 cm of hard limestone bedrock described as a Cr (179 to 219 cm) and an R at 219 cm. Slickensides were found from 53 cm to bedrock. Redoximorphic features and aquic conditions occurred from 22 cm to bedrock. 1 to 5 percent weakly cemented carbonate concretions were found from 53 to 179 cm.

2.4.1.8 Site 8

Pedon 05KS133003 was sampled in a row-cropped field north of Galesburg, Kansas, in Neosho County. The site was located on a 0.5 percent toeslope of a paleoterrace (Table 2.1). Water from this field flows into Rock Creek, which joins the Neosho River about six kilometers to the north. The largest stream to the south is Labette Creek. The site is mapped as Kenoma silt loam, 1 to 3 percent slopes (map unit 8775), and the drainage class is borderline between moderately well to somewhat poorly. Parent materials are described as silty loess (0 to 17 cm) over clayey alluvium (17 to 71 cm) over residuum weathered from shale (71 to 195 cm) (Table 2.2). An argillic horizon occurs from 17 to 128 cm, and clay films are described down to 174 cm (Table 2.3). Slickensides were found in Bt2 horizon and from 101 to 174 cm. Prismatic parting to subangular block structure is described throughout the majority of the profile. Redoximorphic features are described from 17 to 195 cm. Subrounded, noncemented shale fragments (1 to 5 percent) were found from 101 to 174 cm with that volume increasing to 50 percent in the bottom horizon. 1 percent weakly cemented, white gypsum crystals were found lining pores in the 2Btg1 horizon.

2.4.1.9 Site 9

Pedon 06KS133001 was sampled in a prairie about one half mile southwest of site 8 in Neosho County, Kansas. The site was located on a 1 percent shoulder slope of an alluvial paleoterrace (Table 2.1). The erosional shoulder is caused by the small, intermittent stream that is about 200 feet to the west. The drainage pattern is similar to that of site 8; however, this site is even closer to a drainage divide where water would instead flow south into Labette Creek. This site is mapped as Verdigris silt loam, channeled (map unit 8300), and the drainage class is somewhat poorly. Parent materials are described as silty loess (0 to 28 cm) over clayey alluvium (28 to 176 cm) over residuum weathered from shale (176 to 205 cm) (Table 2.2). No hard bedrock was encountered. This is the only pedon in this study not classified as a Mollisol. It is described with an ochric epipedon (0 to 18 cm) and an albic horizon (E horizon, 18 to 28 cm). This suggests that significant eluviation of clay, organic matter, and other material has occurred in this soil. The argillic horizon starts at 28 cm and continues to depth. Clay films are described from 28 cm to depth (Table 2.3). No slickensides were observed in this soil, but 10 percent pressure faces were found in the bottom horizon. Prismatic parting to subangular blocky structure was described from 28 to 176 cm. Redoximorphic features occurred from 28 to 205 cm. Up to 10 percent prominent, irregular, moderately cemented gypsum crystals were described on surfaces along pores and on faces of peds from 91 to 205 cm.

2.4.1.10 Site 10

Pedon 86KS133005 was sampled in a grass pasture about four and one half miles east of Galesburg, Kansas, in southern Neosho County. The site was located on a 4 percent upland backslope (Table 2.1). The upland provides a drainage divide where water flows north and east directly to the Neosho River and south to Labette Creek, which eventually joins the Neosho River near Chetopa, Kansas, in southern Labette County. The site is mapped as Eram silty clay loam, 3 to 7 percent slopes (map unit 8735), and the drainage class is moderately well. Likely parent materials include colluvium derived of fine, clayey sediments weathered from shale and limestone and residuum weathered from shale (Table 2.2). However, a lithologic discontinuity was not described and was probably not clearly discernible. A lithic contact of weathered, soft, platy shale was encountered at 91 cm (Cr horizon). The argillic horizon, clay films, and redoximorphic features were all observed from 16 to 65 cm. No slickensides were described.

2.4.2 Laboratory Characterization

Table 2.4 contains selected physical and chemical data for all pedons. Laboratory data shows evidence of clay illuviation and high COLE values in the majority of the pedons. In general, clay contents and fine clay contents are high, and sand and coarse fragment (>2 mm) contents were low. COLE values and bulk density values are high in the subsoils. For the most part, pH ranges from 6 to 7 for these soils. Sites 4, 6, 7, 8, and 10 have higher pH values in their lower horizons due to residuum weathered from calcareous shale. All soils exhibited typical total carbon distributions with depth. Cation exchange capacities (CEC) were high due to the relatively large contents of expandable clay minerals. Exchangeable sodium percentages were low and generally were not more than 10 percent in most horizons.

2.4.2.1 Site 1

The laboratory data for site 1's pedon 09KS139001 shows that both clay illuviation and shrink-swell are dominant processes occurring in this soil despite being positioned on a 4 percent backslope where recent erosion has the potential to truncate soils and erase evidence of clay illuviation and soil cracking. The particle size distribution shows a steady increase in clay content down to the Bt2 horizon with 55.2 percent. The argillic horizon starts at 46 cm which is deeper than most of the pedons with argillic horizons in this study. Similarly, Pedon 09KS121001 at site 3 has an argillic horizon starting at 45 cm. The deeper depth to the argillic horizon and gradual clay increase may be due in combination to the translocation of clay downward in the profile and the deposition of colluvium and loess on the surface. Ratios of fine clay to total clay are generally higher in the argillic horizion. In the last horizon formed in residuum (2Btss3), the clay content increases to 67.4 percent, and sand content falls off to only 1.7 percent. This difference in texture may point to a third, un-recognized lithologic discontinuity for this horizon. COLE values and bulk density values enter the range associated vertic soils in the Bt1 horizon and stay high until bedrock. COLE values seem well correlated with total clay content values in this pedon.

2.4.2.2 Site 2

Pedon 09KS059001 has a clay distribution with depth that exhibits an abrupt textural change of 22.1 percent clay at 26 cm, which is the top of the argillic horizon. After this initial increase, the clay content stays fairly constant with depth. Sand content increases slightly in the bottom few horizons which may indicate a different age of alluvium or perhaps highly weathered residuum. Fine clay to total clay ratios start at 0.68 and generally increase throughout. COLE values and bulk density values are highest in the Bt1 horizon but remain relatively large with increasing depth.

2.4.2.3 Site 3

Pedon 09KS121001 is similar to the Bucyrus soil at site 1; however, it is not as deep. Clay content at the surface is relatively high with 32.7 percent clay, silty clay loam. Like at site 1, this soil has a steady clay increase to the top of the argillic horizion at 45 cm, then the clay content increases slightly in the Btss horizon overlying the limestone bedrock. The fine clay to total clay ratio ranges from 0.59 to 0.74. Both COLE and bulk density values generally increase with increasing depth and increasing clay content. They approach the vertic range in the BA horizon, and COLE values are well correlated with total clay content.

2.4.2.4 Site 4

Pedon 09KS207001 is similar to the Woodson soil described at site 2. The textural change between the surface soil and the argillic horizon is not quite as abrupt as at site 2. The surface texture is relatively clayey with 35.3 percent clay, silty clay loam. In the Bt1 horizon, the clay content jumps up to 54.4 percent and remains high throughout. The fine clay to total clay ratio is significantly higher in the upper parent material described as the top four horizons. This increase in the fine clay content may be due to intense weathering of the upper part of the pedon. Alternatively, the upper part of the pedon may be composed of sediment that is from a source with greater amounts of fine clay than that of the lower parent materials. The COLE value at the surface is nearly 0.08, and it remains greater than 0.1 throughout much of the pedon.

2.4.2.5 Site 5

Pedon 73KS001003 is also similar to the soils at sites 2 and 4. Lab data shows that there is an abrupt texture change at 20 cm. The clay percentage remains in the silty clay range from 20 cm to the bottom of the profile. Sand content is 1 to 2 percent higher in the lower part of the pedon. Ratio of fine clay to total clay ranges from 0.6 in the surface to 0.79 in the upper argillic. The COLE value of the surface is 0.033, but it jumps to 0.103 in the Bt1 and reflects changes in clay content with depth.

2.4.2.6 Site 6

Pedons 05KS205002 and 97KS205001, at sites 6 and 7 respectively, are both Zaar soils and differ significantly from the other soils studied. At site 6, the clay content increases 10 percent from the Ap to the A horizon; however, the 13 cm thick Ap horizon has a clay content of

46.7 percent and no clay films were observed in the field. Thus, no argillic horizon is described at either site 6 or 7. This type of clay distribution could be caused by two possibilities. Either these soils are relatively young and unweathered with little translocation of clay having occurred, or the soil movement and pedoturbation caused by shrink-swell is great enough to have destroyed evidence of clay illuviation. Given the relatively old and stable landscape positions and the depth to pedogenic carbonates, it is unlikely that this is a young, unweathered soil. Therefore, it is assumed that shrink-swell processes are preventing the formation of an argillic horizon. Also, ratios of fine clay to total clay are highest in the surface, which is the reverse of most of the pedons in this study. The component of coarse clay is much greater in the subsoil horizons. Bulk density is highest at site 6. The surface horizon bulk density value is 1.89 g cm^{-3}, and it increases up to 1.98 in the Bg horizon. Similarly, COLE values are also high throughout.

2.4.2.7 Site 7

Pedon 97KS205001is similar to the soil at site 6; however, limestone bedrock is encountered at 179 cm. Textures are silty clay throughout, clay content peaks in the Bss1 horizon. Sand content increases slightly with depth, and like site 4 and 6, the fine clay to total clay ratio is much smaller in the lower half of the pedon. Bulk density and COLE values are high throughout and reflect changes in clay content with depth.

2.4.2.8 Site 8

Particle size distribution data for pedon 05KS133003 shows a sharp clay increase from the surface to the Bt1 horizon at 20 cm, providing evidence of clay translocation. The clay content falls off some with depth, but textures remain in the silty clay and clay range to the bottom of the profile. Sand contents are higher in this pedon than most other pedons in this study, increasing in the lower pedon and topping out at 12.7 percent in the 2Bssg1 horizon. The fine clay to total clay ratio is highest in the surface and upper argillic horizons. It drops below 0.50 in the horizons below 49 cm, similar to sites 4, 6, and 7. COLE values respond to the large clay increase near 20 cm and raise to 0.117 from 0.018. In the lower part of the argillic however, COLE values drop off to about 0.05 and only increase slightly with depth.

2.4.2.9 Site 9

Pedon 06KS133001 was described with an albic horizon (18 to 28 cm). In this horizon there is a small decrease in clay content from the surface. Then, there is a sharp clay increase in the 2Btg1 at 28 cm, and the clay content remains high to depth. Bulk density increases in the argillic horizon as does COLE.

2.4.2.10 Site 10

Pedon 86KS133005 has a high clay content of 47.2 percent in the surface. Clay content increases to 53.9 percent in the Bt1 horizon and stays relatively constant with depth. This type of clay distribution is similar to the Zaar soils at sites 6 and 7. Sand contents are also higher in this soil which is comparable to that of site 8. Bulk density and COLE values are moderately high throughout.

2.4.3 Taxonomy

Pedon 09KS139001 at site 1 classifies as a fine, smectitic, thermic Oxyaquic Vertic Argiudoll. The soil misses classifying as a Vertisol since it does not have a weighted average of 30 percent or more clay in the top 18 cm. The weighted average of clay in the top 18 cm is 28.2 percent. The clay content in the Ap horizon (26.6 percent) is lowered by the eluviation of clay out of this horizon and potentially by the deposition of silty colluvium and loess. The aquic conditions that create the redoximorphic features are assumed to be of short duration in normal years because there is not any indication of hydrophitic vegetation; thus, the suborder is Udoll. The pedon is a taxadjunct to the Bucyrus series and outside the range because it does not classify as a Paleudoll. The colors are not red enough in the lower argillic horizon. The Pale great group requires colors of 7.5YR or redder and chroma of 5 or more in 50 percent of the matrix in one or more subhorizons. This pedon is described with 20 percent 5YR 4/4, 40 percent 7.5YR 5/8, and 40 percent 10YR 6/4 in the 2Btss3. With a weighted average of 52 percent clay in the particle size control section (46 to 96 cm), the particle size class is fine. Though the clay mineralogy (data not shown) of this soil appears somewhat mixed (40% smectite, 30% kaolinite, 10% vermiculite, 15% clay mica, and 5% quartz in the control section), smectite is still in greater quantity than any other clay mineral. Therefore, the mineralogy class is smectitic.

Pedon 09KS059001 at site 2 is a fine, smectitic, thermic Vertic Argiaquoll. Based on field estimates of clay this soil was initially thought to be borderline to a Vertisol; however, the weighted average of clay in the top 18 cm calculates to be 24.5 percent; thus, the soil does not classify as a Vertisol but instead as a Mollisol. The relatively abrupt textural change from the surface to the argillic horizon, limited amount of slickensides, and limited amount of evidence of cracking in the pedon suggests this soil does not have as much cracking and pedoturbation typical of a Vertisol. The mollic epipedon extends from the surface to 84 cm based on color, organic carbon content, and base saturation. Low chroma and redox concentrations in the lower part of the mollic epipedon and the presence of an argillic horizon classify it as an Argiaquoll. Slickensides found in the Btssg horizon put the soil in a Vertic subgroup. The weighted average of clay in the particle size control section (26 to 76 cm) is 46.6 percent, making the particle size class fine. Based on clay mineralogy data, which will be discussed in the following chapter, the mineralogy class is clearly smectitic. This pedon is taxajunct to the Woodson series because it exhibits Vertic properties, and the Vertic subgroup keys out before the Abruptic subgroup (Soil Survey Staff, 2006). The aquic properties are weakly expressed, and it is assumed that this soil is better drained than most Aquolls.

At site 3, pedon 09KS121001 is classified similarly to pedon 09KS139001 at site 1. It is a fine, mixed, active, thermic Oxyaquic Vertic Argiudoll. The clay content is greater than 30 percent in the surface, and slickensides were found in this soil, however not within 100 cm of the surface. Because of this, the soil fails to meet the requirements for a Vertisol. The soil is too shallow to make the Pale great group, so it keys out as an Argiudoll. Slickensides were encountered at 102 cm, allowing the soil to make the Oxiaquic Vertic subgroup. The weighted average of total clay is 54 percent in the particle size control section (45 to 95 cm), so the particle size class is fine. Mineralogy data for this pedon is not available. The official series description for the Aliceville series places it in a mixed mineralogy class.

Pedon 09KS207001 at site 4 classifies as a fine, smectitic, thermic Aquertic Argiudoll. In the field, it appeared similar to the Woodson series described at site 2. This soil however, does not have a texture change as abrupt as the Woodson, and it is thought to be slightly better drained because of grayer colors in the Woodson. The aquic conditions that form the redoximorphic features are assumed to be of short duration. The pedon is placed in the Summit series. Like at site 2, this soil was thought to be borderline to a Vertisol based on field estimates of clay and the slickensides encountered at 53 cm. The lab data confirms that this soil does meet the requirements to classify as a Vertisol; however, the clear boundary and increase of 18.2 percent clay from the A to Bt1 horizon suggests this soil does not have enough shrink-swell and pedoturbation to classify as a Vertisol. Therefore, with soil interpretations in mind, it was the consensus of the sampling party that the pedon is not a Vertisol. The weighted average of clay in the particle size control section (29 to 70 cm) is 57 percent, making the particle size class fine. Similar to at site 1, the clay mineralogy data for this pedon appears mixed; however, in the control section smectite is in slightly greater quantity than any other clay mineral (40% smectite, 35% kaolinite, 5% vermiculite, 10% clay mica, 10% quartz, and feldspars present in trace amounts in the control section). Thus, the mineralogy class is smectitic.

Pedon 73KS001003 at site 5 is classified in the Woodson series as a fine, smectitic, thermic Vertic Argiaquoll. The A horizon has a clay content of 25.2; thus, this soil cannot classify as a Vertisol. Low chroma and redox concentrations in the lower part of the mollic epipedon and the presence of an argillic horizon classify it as an Argiaquoll. Slickensides found at 97 cm place it in the Vertic subgroup. The weighted average of clay in the particle size control section (20 to 70 cm) is 52 percent, making the particle size class fine, and the mineralogy class, based on the clay size fraction, is smectitic.

Pedon 05KS205002 at site 6 classifies as a fine, smectitic, thermic Aeric Endoaquert in the Zaar series. With slickensides found at 84 cm, clay content greater than 30 percent throughout, and cracks that open and close periodically this soil meets the requirements for a Vertisol. The low chroma and redox features present in the majority of the pedon suggest endosaturation and place the soil in the Endoaquert great group. The pedon is further placed into the Aeric subgroup based on colors in the Bg horizon. The weighted average of clay in the particle size control section (25 to 100 cm) is 53 percent, making the particle size class fine. Based on clay mineralogy data the mineralogy class is smectitic.

Pedon 97KS205001 at site 7 is also in the Zaar series and classifies similarly to the soil at site 6. It is a fine, smectitic, thermic Typic Epiaquert. Like at site 6, the cracking characteristics, high clay content throughout, and slickensides starting at 53 cm meet the criteria for a Vertisol. The relatively impermeable bedrock at 179 cm causes this soil to exhibit episaturation, which is the result of a perched water table. The weighted average of clay in the particle size control section (25 to 100 cm) is 51 percent, making the particle size class fine. Based on clay mineralogy data the mineralogy class is smectitic.

At site 8, pedon 05KS133003 is classified as a fine, mixed, superactive, thermic Vertic Argiaquoll in the Kenoma series. In this soil, slickensides are not encountered until 101 cm, and there is a sharp clay increase at 17 cm giving evidence for a significant amount of clay illuviation. Therefore, this soil does not classify as a Vertisol, but the mollic epipedon (0 to 71 cm) and high base saturation throughout meet the requirements for a Mollisol. This pedon is an Aquoll based on the low chroma and redox concentrations in the lower mollic horizon. It classifies in a Vertic subgroup based on its cracking characteristics and the presence of slickensides starting at 101 cm. The weighted average of clay in the particle size control section (17 to 67 cm) is 54 percent, making the particle size class fine. Based on clay mineralogy data in the control section, the mineralogy class is mixed. Smectite and kaolinite are estimated to make up 75 percent of the clay fraction in the control section (40% kaolinite, 35% smectite, 10% clay mica, 10% quartz, and 5% feldspars).

Pedon 06KS133001 at site 9 is the only soil in this study with an ochric epipedon and an albic horizon. It is classified as a fine, smectitic, thermic Vertic Albaqualf in the Parsons series. No slickensides or wedge-shaped peds are described, and the high clay content does not extend to the surface. Dark colors do not extend deep enough to meet the requirements for a mollic epipedon, so this soil is classified as an Alfisol. This is a relatively wet soil and exhibits aquic conditions within 50 cm of the surface. There is an abrupt textural change between the albic and argillic horizons. These properties and the low saturated hydraulic conductivity of the argillic horizon place it in the Albaqualf great group. The soil classifies in the Vertic subgroup because linear extensibility values greater than 6.0 cm in the argillic horizon. The weighted average of clay in the particle size control section (28 to 78 cm) is 53 percent, making the particle size class fine. The clay mineralogy of this soil appears to be more mixed. In the control section, smectite is in greater quantity than any other clay mineral (40% smectite, 30% kaolinite, 10% vermiculite, 10 % clay mica, 10% quartz, and trace amounts of both goethite and lepidocrocite. Therefore, the mineralogy class is smectitic.

At site 10, pedon 86KS133005 is classified as a fine, mixed, active, thermic Aquic Argiudoll in the Eram series. The clay increase of only 6.7 percent from the Ap to the Bt1 horizon is not quite great enough to classify as an argillic horizon. However, based on the observation of illuvial clay and the erosion suspected to have occurred at this site, the argillic horizon classification was not revised. The clay content is greater than 30 percent throughout; however, no slickensides or wedge-shaped peds were described. The mollic epipedon extends from the surface to 28 cm, and base saturation is greater than 50 percent throughout, classing this soil as a Mollisol. The soil is close to classifying as an Aquoll, but falls out as an Argiudoll. Also based on the description and limited linear extensibility data, this soil does not meet the requirements for an Aquertic or Vertic subgroup, and thus classifies as an Aquic Argiudoll. The weighted average of clay in the particle size control section (16 to 66 cm) is 53 percent, making the particle size class fine. Based on clay mineralogy data of the control section this soil is very close to classifying as kaolinitic as kaolinite make up 50% of the clay fraction. However, it is believed that a mixed mineralogy class is more representative of this soil.

2.5 Conclusions

The morphology and genesis of these soils dominantly reflects the geologic parent materials available in the Osage Questas region of Kansas. When examining parent material sources on a regional scale, the vast majority of the sediment out of which these soils have developed is from a single and local source region. Based on the study of Tertiary and Quaternary drainage basin development in Kansas, it is assumed that all of the alluvium, colluvium, and residuum found in this study is derived from the Pennsylvanian and Permian rocks found at the surface in the Osage Questas and adjacent Flint Hills region. This is unlike much of the rest of Kansas in that deep loess deposits, alluvial deposits, and glacial sediments were transported great distances, and these exotic sediments now cover areas north of the Kansas River and west of the Flint Hills. The easily weathered shales are composed of silt and clay sized particles and directly provide the fine textured sediments necessary for vertic soil development. Most of the sites studied occur on stable landforms that have been in place for hundreds to thousands of years, and the soils have thus been exposed to extended periods of weathering.

Many pedogenic processes are currently at work in the studied pedons including accumulation of organic matter, leaching of carbonate and other soluble salts, and weathering of clay minerals. Pedogenic carbonates were found well below 100 cm in all soils. However, the dominant pedogenic processes of interest to this study are translocation of clay and shrink-swell processes. Clay increases and the formation of argillic horizons in the upper part of the profile is primarily caused by clay illuviation. However, given the humid climate, clay mineral formation through neogenesis is thought to have contributed to the abundance of clay throughout these soils. About half of the pedons showed rather abrupt textural changes forming the top of the argillic horizon. These soils are often referred to as claypan soils. Sites 2, 5, 8, and 9 all contain greater than 20 percent clay increases between the argillic horizon and the overlying surface horizon, and clay films are observed in these soils. Also, evidence of soil movement, cracking, and pedoturbation was least apparent at these sites.

Alternatively, the Zaar soils at sites 6 and 7 contained little evidence of clay illuviation. No argillic horizon or abrupt textural changes were observed, and no clay films were described in the field. Evidence of soil movement and cracking due to shear stress associated with soil volume fluctuations was apparent. Many slickensides were described, and the two soils exhibit high COLE values throughout. Vertic processes have apparently destroyed clay films and mixed surface and subsoil horizons.

The soil at site 4 appears to express characteristics of both the claypan soils and the Zaar soils. Site 4 has a well defined argillic horizon; however, the clay increase is not as abrupt. Many slickensides were described as well as wedge structure. Sites 1 and 3 are similar soils and are both formed over limestone bedrock. The clay films and argillic horizons occur at a greater depth than in the claypan soils, and the clay increase with depth is much more gradual. Slickensides occur in the lower part of these pedons. Site 10 is a shallow soil formed over shale at 91 cm. Like the Zaar soils, this soil shows a high clay content in the surface and only a slight clay increase with depth. Clay films and an argillic horizon were observed, however. COLE values are significantly lower than in the Zaar soils.

There are many possible factors responsible for the marked differences in clay illuviation and vertic properties displayed among theses soils. With the potential for clay translocation relatively constant, the differences lie with the shrink-swell potentials. Wilding and Tessier (1988) give a thorough discussion of the various interconnected factors affecting the shrink-swell phenomenon. According to them, vertic properties are a function of the amount of fine clay and the proportion of smectites in this fraction. They go on to state that "the higher the percentage of fine clay, the higher the surface area and shrink-swell potential." Interestingly, the fine clay to total clay ratios for soils in this study tend not to support this idea (Table 2.4). Soils that express the strongest vertic properties, sites 4, 6, and 7, have the lowest fine clay to total clay ratios, and the ratio values tend to decrease with depth. Eswaran et al. (1988) also found inconsistencies with Wilding and Tessier's claim. Eswaran found total clay and COLE to be well correlated with an R^2 value of 0.7642 indicating that shrink-swell is strongly related to the amount of clay. However, they found fine clay to be poorly correlated with COLE ($R^2 = 0.2958$).

While studying Vertisol formation in a humid climate, Nordt et al. (2004) observed argillans in the lower part of the pedon, but not in the upper where shrink-swell activity was greatest. They concluded that translocation of clay was certainly occurring, but clay films were only preserved in the lower pedon where ped and void surfaces were more stable. Nordt et al. cites other studies of soils in humid climates that reached similar conclusions (Mermut and Jongerius, 1980; Yeríma et al., 1987; Wilding and Drees, 1990). Dasog et al. (1987) studied vertic soils in Saskatchewan and found subhumid soils to contain argillic horizons and prominent mollic epipedons. Graham and Southard (1983) studied Vertisols and associated Mollisols in Utah and found both soils to exhibit cracking, slickensides, and high COLE values. The Mollisol's subsoil however, was overlain abruptly by a loam surface soil; thus, cracking and high COLE values were not present in the surface as these features were in the Vertisol. A similar situation occurs with the claypan soils with abrupt clay increases found in this study. Graham and Southard proposed the formation of the Vertisols in their study was probably initiated with the erosion of the A horizon of the Mollisols which exposed the clayey argillic horizons at the surface. Similarly, Nettleton et al. (1969) and Buol et al. (1980) proposed that argillic horizons may at times become so enriched in clay through illuviation and in situ clay formation that their shrink-swell activity could become great enough to incorporate the surface horizons, destroy clay films, and effectively transform the soil into a Vertisol.

Pedoturbation is of minor importance to the formation of vertic properties in the soils of this study. Limited mixing of soil horizons has occurred as evidenced by the normal distribution of pedogenic properties, such as color, total carbon, and pH, with depth. Silt loam and silty clay loam surface soils overly high shink-swell argillic horizons at all but sites 6 and 7. In these claypan soils, the shrink-swell potential of the argillic horizon is not fully expressed as the subsurface horizons dry out less rapidly and are not as subject to differential wetting by preferential flow down surface cracks due to the buffering effect of the non-expansive top soil. Subtle changes in parent material and landscape position are suspected to cause the differences in vertic characteristics found in this study. Changes in parent material and landscape position can in turn affect other related factors such as soil moisture content, confining pressure, and clay mineralogy which will be discussed later. Further studies are needed to determine quantitatively the influence these factors have on vertic processes.

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2.7 Figures and Tables

Figure 2.1 - Pedon locations (sites 1-10) within the Cherokee Prairies Major Land Resource Area 112.

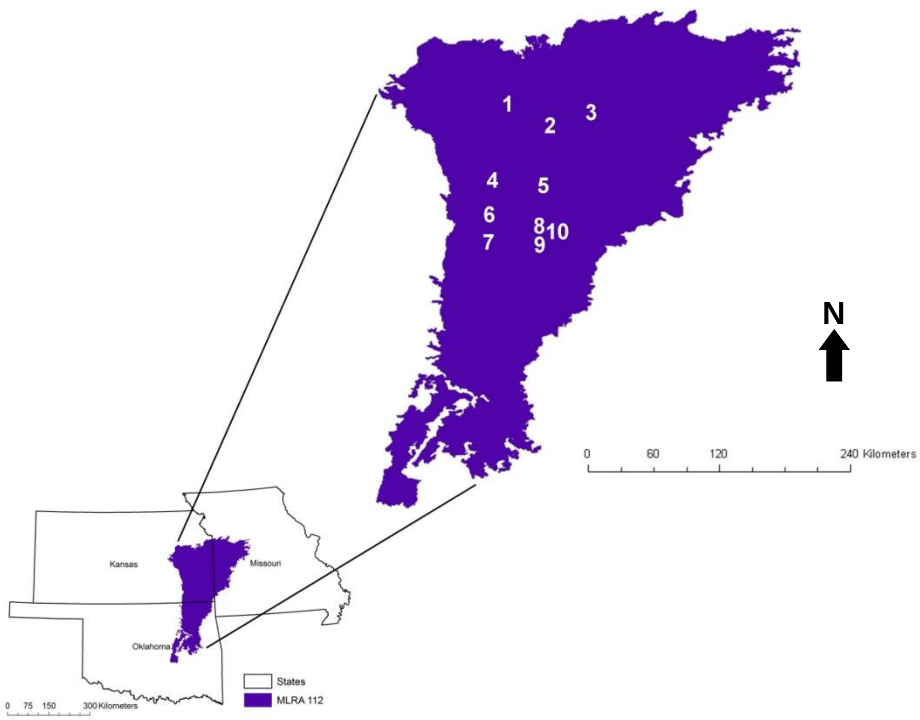

Figure 2.2 - Site 2, pedon 09KS059001, Woodson, fine, smectitic, thermic Vertic Argiaquoll, sampled in Franklin County, Kansas

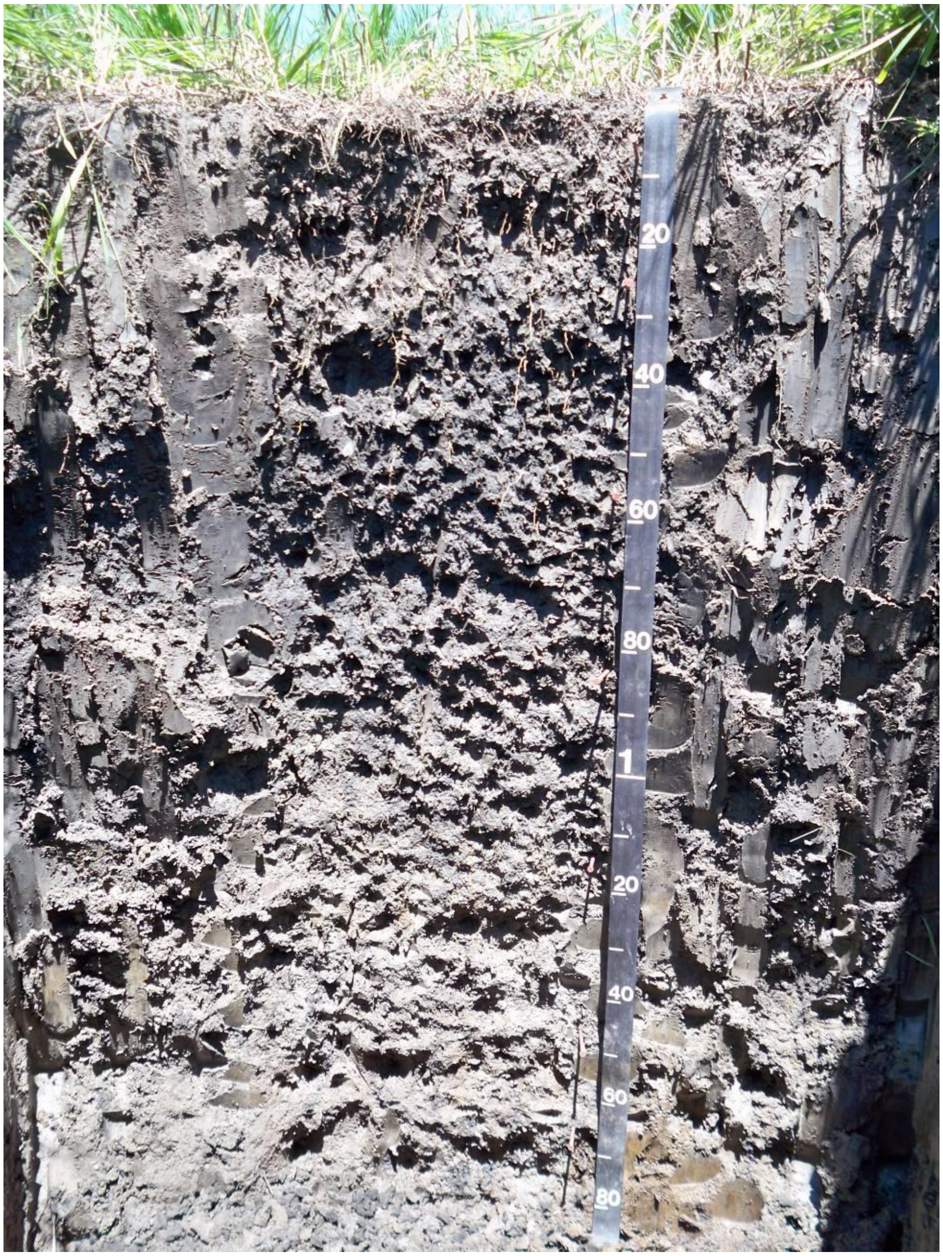

Figure 2.3 - Site 4, pedon 09KS207001, Summit, fine, smectitic, thermic Aquertic Argiudoll, sampled in Woodson County, Kansas.

Figure 2.4 - Landscape and vegetation at site 4, pedon 09KS207001.

Table 2.1 - Site Characteristics.

Site	Soil Series	Pedon No.	County	Elevation (m)	Topographic Position	Slope (%)	Drainage Class	Vegetation
1	Bucyrus	09KS139001	Osage	308	backslope of interfluve on plains	4	moderately well	grass/herbaceous cover
2	Woodson	09KS059001	Franklin	296	shoulder of crest of interfluve on plains	1	somewhat poorly	grass/herbaceous cover
3	Aliceville	09KS121001	Miami	290	summit of interfluve on plains	2	moderately well	grass/herbaceous cover
4	Summit	09KS207001	Woodson	341	backslope of interfluve on plains	4	somewhat poorly	grass/herbaceous cover
5	Woodson	73KS001003	Allen	—	upland summit or shoulder	1	somewhat poorly	grass/herbaceous cover
6	Zaar	05KS205002	Wilson	265	broad paleoterrace summit or shoulder	0.2	somewhat poorly	row crop
7	Zaar	97KS205001	Wilson	216	footslope	1	somewhat poorly	row crop
8	Kenoma	05KS133003	Neosho	294	toeslope of broad paleoterrace	0.5	moderately well	row crop
9	Parsons	06KS133001	Neosho	296	shoulder of paleoterrace on alluvial plain	1	somewhat poorly	grass/herbaceous cover
10	Eram	86KS133005	Neosho	—	backslope of upland	4	moderately well	grass/herbaceous cover

Table 2.2 - Pedon Characteristics.

Site	Soil Series	Pedon No.	Mollic Epipedon (cm)	Ochric Epipedon (cm)	Argillic Horizon (cm)	Cambic Horizon	Albic Horizon	Redox Concentrations (cm)	Slickensides (cm)	Paralithic/Lithic Contact (cm)	Parent Material	Classification
1	Bucyrus	09KS139001	0-46	—	46-186	—	—	46-186	81-186	186	colluvium over residuum weathered from cherty limestone	Fine, smectitic, thermic Oxyaquic Vertic Argiudoll
2	Woodson	09KS059001	0-84	—	26-200	—	—	26-200	56-117	—	loess over alluvium/residuum weathered from shale	Fine, smectitic, thermic Vertic Argiaquoll
3	Aliceville	09KS121001	0-45	—	45-140	—	—	45-140	102-140	140	loess over residuum weathered from limestone	Fine, mixed, active, thermic Oxyaquic Vertic Argiudoll
4	Summit	09KS207001	0-103	—	29-210	—	—	18-210	53-210	—	loess over colluvium over residuum	Fine, smectitic, thermic Aquertic Argiudoll
5	Woodson	73KS001003	0-80	—	20-318	—	—	48-318	97-132	—	loess over clayey alluvium	Fine, smectitic, thermic Vertic Argiaquoll
6	Zaar	05KS205002	0-56	—	—	56-212	—	28-212	84-212	—	clayey alluvium	Fine, smectitic, thermic Aeric Endoaquert
7	Zaar	97KS205001		—	—	53-179	—	22-179	53-179	179	clayey alluvium over residuum weathered from shale and limestone	Fine, smectitic, thermic Typic Epiaquert
8	Kenoma	05KS133003	0-71	—	17-128	—	—	17-195	38-71, 101-174	—	loess over alluvium over residuum weathered from shale	Fine, smectitic, thermic Vertic Argiaquoll
9	Parsons	06KS133001	—	0-18	28-205	—	18-28	28-205	—	—	loess over alluvium over residuum weathered from shale	Fine, mixed, active, thermic Vertic Albaqualf
10	Eram	86KS133005	0-28	—	16-65	—	—	16-65	—	91	colluvium over residuum weathered from shale	Fine, mixed, active, thermic Aquic Argiudoll

Table 2.3 - Macromorphology.

Horizon	Depth (cm)	Dominant Color	Structure§	Consistence§	Field Texture§	Fe-Mn Concentrations (%)	Clay Films	Slickensides
				Site 1 - Bucyrus 09KS139001				
Ap	0-11	10YR 2/1	2mgr	fr	sicl	—	—	—
A	11-28	10YR 2/1	2mgr	fr	sicl	—	—	—
BA	28-46	10YR 3/2	1mpr-2fsbk	fr	sicl	2	—	—
Bt1	46-60	10YR 4/3	2mpr-2fsbk	fi	sic	12	30% discontinuous	—
Bt2	60-81	10YR 4/2	2mpr-2msbk	fi	sic	12	25% discontinuous	1% discontinuous
Btss1	81-100	10YR 4/2	2mpr-2msbk	fi	c	9	35% discontinuous	10% discontinuous
2Btss2	100-159	10YR 4/2	2copr-2cosbk	fi	c	7	30% discontinuous	15% discontinuous
2Btss3	159-186	10YR 6/4	2copr-2msbk	fi	c	5	40% discontinuous	20% discontinuous
2R	186-200	—	—	—	—	—	—	—
				Site 2 - Woodson 09KS059001				
Ap	0-8	10YR 3/2	2fsbk-2fgr	fr	sicl	—	—	—
A	8-26	10YR 3/2	2fpr-2mabk	fr	sicl	—	—	—
Bt1	26-56	10YR 3/1	2mpr-2coabk	vfi	sic	2	70% continuous	—
Bt2	56-84	10YR 3/1	2mpr-2msbk	fi	sic	10	60% continuous	5% discontinuous
Btssg	84-117	10YR 5/2	2mpr-2msbk	fi	sic	10	50% continuous	25% continuous
Btg1	117-148	10YR 5/1	2mpr-2msbk	fi	sic	50	30% continuous	—
Btg2	148-166	10YR 5/1	1mpr-2msbk	fi	sic	60	25% continuous	—
Btg3	166-200	10YR 6/1	1mpr-2msbk	fi	sic	60	20% continuous	—
				Site 3 - Aliceville 09KS121001				
Ap	0-16	7.5YR 3/1	2fsbk-2mgr	vfr	sicl	—	—	—
A	16-31	7.5YR 2.5/1	2fsbk-2mgr	fr	sicl	—	—	—
BA	31-45	7.5YR 4/3	2fpr-2fsbk	fi	sic	—	50% discontinuous	—
Bt1	45-68	10YR 4/3	2mpr-2fpr	fi	sic	10	40% discontinuous	—
Bt2	68-102	10YR 4/3	2copr-2msbk	fi	c	7	30% discontinuous	—
Btss	102-140	7.5YR 4/6	2copr-2msbk	vfi	c	30	40% discontinuous	20% discontinuous
R	140-200	—	—	—	—	—	—	—
				Site 4 - Summit 09KS207001				
Ap	0-18	10YR 2/1	1msbk-2fgr	vfr	sicl	—	—	—
A	18-29	10YR 3/1	2msbk-2fgr	fr	sic	5	—	—
Bt1	29-53	10YR 3/2	2mpr-2msbk	fi	c	15	30% continuous	—
Bt2	53-103	10YR 3/1	2mpr-2mabk	fi	c	25	10% continuous	25% continuous
2Btss1	103-135	10YR 4/3	2cowg	vfi	sic	8	40% continuous	20% continuous
2Btss2	135-177	10YR 3/3	2mpr-2msbk	vfi	sic	3	20% continuous	5% continuous
3Btkss	177-210	7.5YR 4/6	3vcowg-3fwg	vfi	c	3	70% continuous	50% continuous
				Site 5 - Woodson 73KS001003				
A	0-20	10YR 3/1	1fgr	fr	sil	nd	nd	—
Bt1	20-32	10YR 3/1	2fsbk	vfi	sic	nd	nd	—
Bt2	32-49	10YR 3/1	2fsbk	vfi	sic	nd	nd	—
Bt3	49-80	10YR 3/1	2msbk	vfi	sic	nd	nd	—
Bt4	80-97	5Y 5/1	1msbk	vfi	sic	nd	nd	—
Bt5	97-133	10YR 5/1	2fsbk	vfi	sic	nd	nd	5% discontinuous
Bt6	133-159	10YR 5/1	2fsbk	vfi	sic	nd	nd	—
Bt7	159-188	10YR 5/1	2mpr-2msbk	vfi	sic	nd	nd	—
Bt8	188-228	10YR 5/1	2mpr-2msbk	vfi	sic	nd	nd	—
Bt9	228-318	10YR 5/1	1msbk	vfi	sic	nd	nd	—

Table 2.3 - Morphology (Continued).

Horizon	Depth (cm)	Dominant Color	Structure§	Consistence§	Field Texture§	Fe-Mn Concentrations (%)	Clay Films	Slickensides
				Site 6 - Zaar 05KS205002				
Ap	0-13	10YR 3/1	2msbk-2mgr	fi	sicl	—	—	—
A	13-28	10YR 3/1	2fpr-1mgr	vfi	sic	—	—	—
BA	28-56	10YR 3/1	2mpr-2cogr	vfi	sic	1	—	2% pressure faces
Bg	56-84	2.5Y 4/3	2mpr-2cosbk	vfi	sic	7	—	1% pressure faces
Bssg1	84-106	2.5Y 3/2	3vcopr-2cosbk	vfi	sic	5	—	3% continuous
Bssg2	106-142	2.5Y 4/1	3vcopr-2vcosbk	vfi	sic	10	—	5% continous
Bssg3	142-163	2.5Y 4/1	3vcopr-2vcosbk	vfi	sic	20	—	15% continous
Bssg4	163-212	2.5Y 4/1	2vcopr	vfi	c	35	—	10% continous
				Site 7 - Zaar 97KS205001				
Ap	0-22	10YR 2/1	1mabk-1mgr	vfi	sic	—	—	—
BA	22-53	10YR 2/1	2mpr-1msbk	vfi	sic	2	—	—
Bss1	53-86	10YR 3/1	2copr-2msbk	vfi	sic	2	—	15% continuous
Bss2	86-117	10YR 3/1	2copr-1msbk	vfi	sic	—	—	25% continuous
Bkss	117-147	10YR 3/2	2copr-2msbk	vfi	sic	6	—	25% continuous
Bss	147-179	10YR 3/1	1cosbk-1msbk	vfi	sic	60	—	35% continuous
Cr	179-219	—	—	—	—	—	—	—
				Site 8 - Kenoma 05KS133003				
Ap	0-17	10YR 3/2	1msbk-2mgr	fr	sil	1	—	—
Bt1	17-38	10YR 3/2	2mpr-2mabk	fr	sic	3	30% continuous	—
Bt2	38-71	10YR 3/2	2copr-2cosbk	fr	sic	8	30% continuous	5% continuous
2Btg1	71-101	10YR 4/4	1copr	vfi	sic	10	20% continuous	—
2Btg2	101-128	10YR 4/2	2mpr-2mabk	vfi	sic	30	20% continuous	2% continuous
2Bssg1	128-156	10YR 4/2	2copr-2cosbk	fi	sic	10	40% continuous	2% continuous
2Bssg2	156-174	10YR 4/1	2copr-2cosbk	fi	sic	10	20% continuous	20% continuous
2BC	174-195	2.5Y 4/1	1msbk	fi	sic	15	—	1% pressure faces
				Site 9 - Parsons 06KS133001				
A	0-18	10YR 3/2	2fgr	vfr	sil	—	—	—
E	18-28	10YR 4/2	2fsbk-1mgr	fr	sil	1	—	—
2Btg1	28-55	10YR 4/2	2copr-2msbk	vfi	sic	7	40% continuous	—
2Btg2	55-91	10YR 4/2	2copr-2cosbk	vfi	sic	22	15% continuous	—
2Btyg1	91-115	10YR 4/2	2mpr-2cosbk	vfi	sic	17	20% continuous	—
2Btyg2	115-142	2.5Y 4/2	1mpr-2msbk	vfi	sic	40	20% continuous	—
2Btg3	142-176	2.5Y 4/1	1mpr-2msbk	vfi	sic	45	20% continuous	—
3Btg4	176-205	2.5Y 5/1	2cosbk-2mabk	vfi	sic	40	40% continuous	10% pressure faces
				Site 10 - Eram 86KS133005				
Ap	0-16	10YR 3/2	1mgr-1fgr	fr	sicl	—	—	nd
Bt1	16-28	2.5Y 3/2	2msbk-2fsbk	vfi	sic	1	patchy	nd
Bt2	28-43	2.5Y 4/2	2mabk	vfi	c	11	patchy	nd
Bt3	43-65	2.5Y 5/2	2mabk	vfi	c	1	patchy	nd
BC	65-91	5Y 5/2	1mabk	vfi	c	—	—	nd
Cr	91+	—	—	—	—	—	—	nd

§ Abbreviations: 1-weak, 2-moderate, 3-strong, f-fine, m-medium, co-coarse, v-very, gr-granular, sbk-subangular blocky, abk-angular blocky, pr-prismatic, wg-wedge, fr-friable, fi-firm, sil-silt loam, sicl-silty clay loam, sic-silty clay, c-clay, nd-no data

Table 2.4 - Selected Physical and Chemical Properties.

Horizon	Depth (cm)	Texture	Sand (%)	Clay (%)	FC:TC†	Bulk Density† Oven Dry (g cm^{-3})	COLE†	pH (H_2O)	Total Carbon (%)	CEC† NH4OAc (cmol(+)/kg)
					Site 1 - Bucyrus 09KS139001					
Ap	0-11	SiL	4.4	26.6	0.64	1.26	0.049	7.0	3.77	23.2
A	11-28	SiCL	4.2	30.7	0.64	1.48	0.036	6.4	2.05	22.0
BA	28-46	SiCL	4.0	35.6	0.68	1.39	0.05	6.2	1.64	21.7
Bt1	46-60	SiC	4.2	47.4	0.77	1.68	0.088	6.3	1.18	27.6
Bt2	60-81	SiC	3.5	55.2	0.8	1.85	0.102	6.2	0.78	30.9
Btss1	81-100	SiC	3.3	52.1	0.77	1.83	0.088	6.1	0.30	28.5
2Btss2	100-159	SiC	4.3	51.6	0.76	1.88	0.089	6.4	0.00	29.9
2Btss3	159-186	C	1.7	67.4	0.67	1.6	0.118	6.8	0.00	35.7
2R	186-200	—	—	—	—	—	—	—	—	—
					Site 2 - Woodson 09KS059001					
Ap	0-8	SiL	2.0	23.9	0.68	1.28	0.033	6.2	3.02	21.6
A	8-26	SiL	2.0	24.9	0.69	1.49	0.044	6.3	1.76	20.4
Bt1	26-56	SiC	1.5	47.0	0.77	2	0.126	6.4	1.26	33.5
Bt2	56-84	SiC	1.3	45.9	0.75	1.96	0.103	6.6	0.49	32.3
Btssg	84-117	SiC	2.2	45.1	0.76	1.88	0.103	6.6	0.29	30.9
Btg1	117-148	SiC	4.3	45.9	0.8	1.85	0.082	6.8	0.00	30.3
Btg2	148-166	SiC	5.2	46.1	0.83	1.83	0.096	6.9	0.00	30.5
Btg3	166-200	SiC	4.7	48.1	0.82	1.81	0.108	7.0	0.00	31.4
					Site 3 - Aliceville 09KS121001					
Ap	0-16	SiCL	4.1	32.7	0.65	1.35	0.058	5.8	3.29	25.5
A	16-31	SiCL	3.1	37.1	0.7	1.51	0.054	6.0	1.49	25.0
BA	31-45	SiC	2.9	44.1	0.73	1.56	0.068	6.0	1.56	27.3
Bt1	45-68	SiC	3.9	54.0	0.74	1.82	0.107	6.1	0.92	32.1
Bt2	68-102	SiC	3.9	54.4	0.71	1.88	0.119	6.4	0.17	33.0
Btss	102-140	C	5.1	58.6	0.59	1.84	0.121	6.8	0.04	38.1
R	140-200	—	—	—	—	—	—	—	—	—
					Site 4 - Summit 09KS207001					
Ap	0-18	SiCL	4.9	35.3	0.68	1.33	0.079	6.0	4.95	31.4
A	18-29	SiCL	5.3	36.2	0.7	1.54	0.072	6.2	2.66	29.2
Bt1	29-53	SiC	3.6	54.4	0.77	1.85	0.131	6.4	1.52	37.8
Bt2	53-103	C	2.6	59.6	0.75	1.82	0.127	6.7	0.62	39.2
2Btss1	103-135	C	4.5	58.0	0.33	1.89	0.107	7.0	0.60	35.3
2Btss2	135-177	SiC	5.4	49.1	0.53	1.82	0.088	7.4	0.32	36.7
3Btkss	177-210	C	2.3	62.1	0.28	1.92	0.107	7.4	0.00	27.2
					Site 5 - Woodson 73KS001003					
A	0-20	SiL	2.2	25.2	0.6	1.42	0.033	5.9	2.49	20.7
Bt1	20-32	SiC	1.2	46.1	0.78	1.76	0.103	5.2	1.5	33.0
Bt2	32-49	SiC	0.7	56.3	0.79	1.9	0.138	5.4	1.27	39.6
Bt3	49-80	SiC	1.0	52.5	0.76	1.87	0.099	5.6	0.96	36.7
Bt4	80-97	SiC	3.0	45.5	0.76	—	—	5.3	0.48	31.2
Bt5	97-133	SiC	2.9	45.9	0.77	1.79	0.075	5.7	0.2	32.2
Bt6	133-159	SiC	2.9	47.8	0.77	1.77	0.087	6.3	0.15	34.1
Bt7	159-188	SiC	3.5	49.1	0.69	—	—	6.6	0.14	36.3
Bt8	188-228	SiC	4.2	46.2	0.73	1.85	0.097	6.8	0.08	33.7
Bt9	228-318	SiC	3.3	50.6	0.64	—	—	7.2	0.07	37.1

Table 2.4 - Selected Physical and Chemical Properties (Continued).

Horizon	Depth (cm)	Texture	Sand (%)	Clay (%)	FC:TC†	Bulk Density† Oven Dry (g cm^{-3})	COLE†	pH (H_2O)	Total Carbon (%)	CEC† NH4OAc (cmol(+)/kg)
					Site 6 - Zaar 05KS205002					
Ap	0-13	SiC	1.7	46.7	0.72	1.89	0.113	6.9	1.65	35.8
A	13-28	SiC	1.3	56.8	0.65	1.9	0.135	7.4	0.81	40.3
BA	28-56	SiC	1.8	56.1	0.5	1.94	0.143	7.8	0.63	38.5
Bg	56-84	SiC	2.5	53.1	0.32	1.98	0.141	8	0.64	36.2
Bssg1	84-106	SiC	4.7	48.8	0.25	1.96	0.144	8.1	0.78	33.4
Bssg2	106-142	SiC	3.6	46.6	0.19	1.95	0.13	8.2	0.54	36.1
Bssg3	142-163	SiC	3.5	48.4	0.22	1.88	0.122	8.3	0.37	35.8
Bssg4	163-212	SiC	3.3	50.6	0.3	1.88	0.125	7.9	0.24	34.5
					Site 7 - Zaar 97KS205001					
Ap	0-22	SiC	2.7	42.5	0.7	1.77	0.12	6.9	2.33	40.5
BA	22-53	SiC	3.3	44.4	0.71	1.81	0.137	7.3	1.81	40.6
Bss1	53-86	SiC	2.3	55.6	0.67	1.85	0.182	7.4	1.26	47.6
Bss2	86-117	SiC	3.3	54.2	0.44	1.87	0.164	7.8	0.93	45.1
Bkss	117-147	SiC	6.3	50.0	0.38	1.86	0.141	8.2	1.11	42.5
Bss	147-179	SiC	6.4	51.0	0.39	1.83	0.131	8.1		42.1
Cr	179-219	—	—	—	—	—	—	—	—	—
					Site 8 - Kenoma 05KS133003					
Ap	0-17	SiL	6.2	22.1	0.62	1.53	0.018	5.9	2.05	16.7
Bt1	17-38	SiC	3.3	53.3	0.76	1.77	0.117	5.6	1.48	33.4
Bt2	38-71	SiC	2.9	55.0	0.74	1.85	0.125	6	1.31	33.2
2Btg1	71-101	SiC	10.7	43.5	0.46	1.67	0.051	6.4	0.29	19.5
2Btg2	101-128	SiC	11.9	44.2	0.48	1.7	0.051	6.8	0.29	19.8
2Bssg1	128-156	SiC	12.7	44.5	0.47	1.79	0.044	7	0.33	19.8
2Bssg2	156-174	C	11.1	50.4	0.46	1.75	0.057	7.1	0.33	21.3
2BC	174-195	SiC	12.1	43.4	0.32	1.88	0.062	7.3	0.25	19.1
					Site 9 - Parsons 06KS133001					
A	0-18	SiL	4.6	25.0	—	1.2	0.029	5.6	2.28	19.0
E	18-28	SiL	4.9	23.1	—	1.4	0.027	5.6	1.01	12.9
2Btg1	28-55	SiC	2.8	54.4	—	1.78	0.105	5.9	0.71	28.0
2Btg2	55-91	SiC	2.4	50.8	—	1.94	0.112	6.6	0.41	26.7
2Btyg1	91-115	C	5.0	55.8	—	1.83	0.096	6	0.32	27.3
2Btyg2	115-142	C	4.3	61.6	—	1.81	0.111	5.9	0.31	28.9
2Btg3	142-176	C	3.4	65.1	—	1.82	0.124	6	0.26	31.3
3Btg4	176-205	C	4.4	60.0	—	1.87	0.104	6.4	0.23	28.4
					Site 10 - Eram 86KS133005					
Ap	0-16	SiC	10.1	47.2	—	1.64	0.076	6.7	3.87	35.6
Bt1	16-28	C	9.4	53.9	—	1.65	0.074	7	1.55	33.6
Bt2	28-43	C	7.7	54.5	—	1.71	0.065	7.1	1.06	29.7
Bt3	43-65	SiC	8.7	50.7	—	1.77	0.06	7.2	0.97	26.0
BC	65-91	SiC	6.1	50.2	—	1.86	0.051	7.4	0.76	23.4
Cr	91+	SiC	10.5	41.2	—	—	—	8	0.59	19.6

† Analysis by National Soil Survey Laboratory

CHAPTER 3 - Mineralogy and Micromophology of Vertic Soils in the Cherokee Prairies Major Land Resource Area of Kansas

3.1 Abstract

Many of the soils of the Cherokee Prairies are characterized by high clay contents and high shrink-swell potentials. The fine sediments that make up these vertic soils are dominantly provided by the local parent materials, namely alluvium, colluvium, and residuum derived from weathered Pennsylvanian and Permian shales and limestones. Clay mineralogy and micromorphology of nine soils in the Kansas Cherokee Prairies were investigated with the objective being to investigate differences between and within pedons. Pedogenic processes, especially clay illuviation and shrink-swell processes were evaluated as well as the effect of clay mineralogy on the expression of vertic properties. Silt loam and silty clay loam surface soils and overly high shink-swell argillic horizons occurred at all but sites 6 and 7. Sites 6 and 7 classify as Vertisols, and no argillic horizon or clay films were described. Relatively high coefficients of linear extensibility (COLE) values were found in all soils. Clay mineralogy for sites 2, 5, 6, and 7 was dominated by smectite while sites 1, 4, 8, 9, and 10 exhibited a more mixed mineralogy, though smectite still played a major role in many of the horizons. In all soils, disruption of illuvial clay features by shrink-swell movement was evident in thin section. Striated b-fabrics dominated except in surface soils that exhibited a low COLE value and that occurred above an argillic horizon. Linear planes lined with stress oriented clay and representing zones of shear failure were observed along with argillans that had been distorted and embedded within the matrix by swelling pressure and soil movement. Mineralogy is not the only factor influencing the expression of vertic properties in these soils. This is apparent due to the differences observed between sites 6 and 7 and 2 and 5 despite their similar mineralogies. It is hypothesized that the non-expansive silty surface layer at all but sites 6 and 7, acted as a buffer and limited shink-swell by causing expansive subsoils to dry out less rapidly.

3.2 Introduction

The Cherokee Prairies Major Land Resource Area (MLRA 112) is an area characterized by gently sloping to rolling, dissected plains situated within Kansas, Missouri, and Oklahoma. In southeastern Kansas, the region is bounded on the north by the Kansas River and on the west by the Flint Hills physiographic region. Many of the soils in the Cherokee Prairies are characterized by high clay contents and high shrink-swell potentials. Athough most soils in this region are not classified as Vertisols, their vertic properties and claypan characteristics cause soil management to be difficult and pose problems for agricultural, environmental, and engineering uses. Collecting more information and improving our understanding of vertic soils are important steps towards bettering soil management techniques.

A section of MLRA 112 and the area in which all sampling occurred for this study is referred to as the Osage Questas physiographic region of Kansas. The Osage Cuestas are named for the low, rolling escarpments known as cuestas, which are somewhat steep on one side and gently sloping on the other. Local relief is typically only one to three meters, and major valleys are generally less than 25 meters below adjacent uplands. The region is underlain with alternating layers of Pennsylvanian and Mississippian aged marine shales and limestones. The soils reflect this geology, and multiple parent materials are often described. Soils form in residuum, colluvium/local alluvium, and alluvium. It is also very common to find a thin loess cap on upland areas throughout this region. The soils in this study area dominantly have a thermic soil temperature regime and a udic soil moisture regime. The region has a humid continental climate with an average annual rainfall of 865 to 1,145 millimeters. Most precipitation falls from high-intensity, convective thunderstorms from late spring through autumn (MLRA Explorer Custom Report, 2006). The humid climate provides adequate moisture for the processes of in situ clay mineral formation and clay translocation. The majority of studied pedons contained argillic horizons. The inherently clayey parent materials directly provide the fine textured sediments necessary for shrink-swell processes, and the monsoonal-type rainfall distribution enhances these processes by providing seasonal wet-dry cycles. Nine pedons representative of the clayey, vertic soils found in this region were selected for this study. Pedons were sampled in the following Kansas counties: Osage, Franklin, Woodson, Allen, Wilson, and Neosho. Clay mineralogy and micromorphology were investigated with an emphasis on understanding how mineralogy influences the expression of vertic properties.

The genesis of nearly all Vertisols and vertic intergrades is dependent upon two conditions: 1) a large quantity of 2:1 expandable clay minerals and 2) a seasonal wet-dry cycle is required to cause the expansion and contraction of the soil material (Soil Survey Staff, 1999).

Within these two requirements there exists a wide spectrum of vertic characteristics and properties. Vertic soils occur in nearly every major climatic zone and under many different vegetation types. Parent material is one of the most important factors involved in the formation and distribution of vertic soils. Variation in parent material often results in variation in soil mineralogy. The vast majority of vertic soils are known to be dominated by smectite. The smectitic clays may be inherited from the original rock parent material or may have formed in place as a result of neogenesis or transformations from primary minerals. In general, soil forming processes that lead to the formation of vertic soils are those which control the formation and stability of smectites in the soil. Such minerals are capable of expanding and contracting with changes in moisture status (Eswaran et al., 1988). The expanding and contracting of interlayer spaces as well as interparticle shrinkage between stacked clay particles and clay particle aggregates (domains) in the microstructure is responsible for the shrink-swell phenomenon that defines vertic soils. Several other minerals can be present in the clay fraction of vertic soils as well, and can be in equal or greater abundance than smectite. Kaolinite, vermiculite, clay mica, and quartz can often contribute a significant amount of the clay fraction.

In this study, expression of vertic properties is assessed using field descriptions (macromorphology), laboratory characterization data, and soil thin section description (micromorphology). At the microscopic level, plasma separations, stress cutans, and planar voids are characteristic of Vertisols and vertic intergrades (Blokhuis et al., 1988). Lineated zones of oriented plasma (clay particles) in which clay platelets are stacked face-to-face form within the microfabrics of vertic soils due to the shear stresses associated with swelling. These elongated zones of oriented plasma are known as plasma separations and represent zones of previous shear failure (Coulombe et al., 1996; Wilding and Tessier, 1988). They can occur in the soil matrix, around skeleton grains, and/or along voids. These stress-oriented plasma fabrics are sepic plasma fabrics as termed by Brewer (1964, 1976) and the striated birefringence fabrics or b-fabrics as termed by Bullock et al. (1985) (Gunal and Ransom, 2006b). This study uses the terminology used by Bullock et al. (1985) and Stoops (2003), and reports from previous studies have been translated to fit this newer terminology. Zones of parallel-oriented clay display interference colors, or birefringence, when observed with cross polarized light. Porostriated (vosepic), granostriated (skelsepic), parallel striated (masepic), and cross-striated (lattisepic) b-fabrics indicate microshear (Wilding and Tessier, 1988; Wilding, 1985). Nettleton and Sleeman

(1985) cite many authors who found that shearing produced parallel striated b-fabrics within the clay-sized material. Gunal and Ransom (2006a) found shrink-swell was associated with striated b-fabrics in Bt horizons in central Kansas. Often the striated b-fabrics occurred in the upper part of the argillic horizons with higher COLE values (Gunal and Ransom, 2006a and 2006b). Shearing in both the horizontal and vertical directions is believed to produce cross-striated fabric (McCormick and Wilding, 1974). Unrelated plasma separations are not considered characteristic of vertic soils by Blokhuis et al. (1988). However, they are commonly described in these type soils. Speckled (asepic), stipple speckled (argillasepic or insepic), mosaic speckled (mosepic), and random striated (omnisepic) are considered unrelated b-fabrics by Blokhuis et al. (1988). Speckled b-fabrics are described by Stoops (2003) as randomly arranged, equidimensional domains of oriented clay which go extinct successively; whereas in striated b-fabrics, the oriented clay is present in elongated zones or streaks, at least 30 μm long, in which the domains show more or less simultaneous extinction. Void types found in vertic soils are not so different than other soils. Chambers, channels, and vughs are all common, but planar voids tend to dominate at depths below the surface horizons. Planar voids are generally linear and can be jointed or oriented in oblique directions (Blokhuis et al., 1988). Planar voids often form at shear planes and thus, represent slickensides and pressure faces.

The objective of this study was to investigate clay mineralogy and micromorphology for selected vertic soils of the Cherokee Prairies Major Land Resource Area. Pedogenic processes, especially clay illuviation and shrink-swell processes were evaluated as well as the effect of clay mineralogy on the expression of vertic properties.

3.3 Materials and Methods

3.3.1 Field Description and Sampling

Nine pedons were used in this study. Site and pedon numbers are consistent with those in the previous chapter. Site 3 Aliceville 09KS121001 is left out of this chapter because mineralogy and micromorphology analysises were not performed on this pedon. Three pedons were sampled through the spring and summer of 2009. These pedons include: Site 1 Bucyrus 09KS139001, Site 2 Woodson 09KS059001, and Site 4 Summit 09KS207001. The remaining six pedons were sampled and described by Natural Resource Conservation Service (NRCS) soil scientists prior to the beginning of this study. These pedons include: Site 5 Woodson 73KS001003, Site 6 Zaar 05KS205002, Site 7 Zaar 97KS205001, Site 8 Kenoma 05KS133003, Site 9 Parsons 06KS133001, and Site 10 Eram 86KS133005. Soil horizon samples and thin sections for these six pedons were provided by the NRCS Soil Survey archive in Lincoln, Nebraska, for additional mineralogy and micromorphology analysis by the Kansas State University Soil Characterization Laboratory. All pedons were sampled by excavating to a depth of one to two meters with a backhoe. Pedons were described using the Field Book for Describing and Sampling Soils (Schoenenberger et al., 2002). For each horizon, bulk samples were taken for laboratory characterization, oriented clods were collected for thin section preparation, and non-oriented clods were sampled and coated in Saran for bulk density measurement.

3.3.2 Mineralogy

Total clay and silt mineralogy were analyzed for selected horizons by the methods of Jackson (1975). Forty gram samples of the less than 2 mm air dry fraction were pretreated with 1 M NaOAc and 30% hydrogen peroxide to remove carbonates and organic matter, respectively. The samples were dispersed and passed through a 300 mesh sieve (50 µm openings) where the sand was collected. The silt and clay fractions were separated through a series of eight sedimentation cycles where Stokes' law was used to calculate sedimentation times for a 10 cm depth of fall (Jackson, 1975). The clay fraction was flocculated with $MgCl_2$, quick-frozen in a bath of dry ice and ethanol, and then water was removed through freeze drying. The silt fraction was oven dried to a powder.

Six clay treatments were prepared for each sample: Mg 25°C, Mg-Ethylene Glycol (Mg-EG), Mg-Glycerol (Mg-GLY), K 25°C, K 350°C, and K 550°C. Solutions containing 30 mg of clay for each treatment were pipetted onto a glass slide and allowed to dry to provide a parallel oriented mount.

A Phillips XRG-3100 generator and an APD X-ray diffractometer were used to analyze all samples. The instrument was equipped with a Theta compensating slit, and a monochromatic X-ray beam was obtained using a graphite monochromator. The instrument was operated with VisualXRD software (GBC Scientific Equipment Pty. Ltd., Victoria, Australia). Instrument operating conditions were as follows:

Target:	Cu
Radiation:	CuKα
Potential:	35 kV
Current:	20 mA
Detector:	Scintillation
Step Size:	0.02°2θ
Time/Step:	0.6 seconds

The clay slides were scanned from 2°2θ to 34°2θ for the Mg 25°C treatment and from 2°2θ to 15°2θ for the other five treatments. Silt samples were scanned from 18°2θ to 54°2θ using randomly oriented powder diffraction specimen holders. Mineral peaks were identified by their d-spacing, and relative abundance of each clay mineral was estimated using peak intensities.

3.3.3 Micromorphology

Thin sections were prepared for each horizon by a commercial laboratory (Texas Petrographics, Houston, Texas) for sites 1, 2, and 4. For sites 5, 7, 8, 9 and 10, thin sections were prepared for selected horizons by the National Soil Survey Laboratory. (Oriented clods for thin section preparation were not available for sites 3 and 6.) Natural fabric clods were not available for thin section preparation for pedon 05KS205002 at site 6. Thin sections were examined with a petrographic microscope (Model Optiphot-Pol, Nikon, Melville, New York) using plane and cross polarized light. Photographs were taken using a camera system (Model UFX, Nikon, Melville, New York) attached to the microscope. Thin sections were qualitatively described using the terminology of Stoops (2003). Particular attention was given to the description of micromass and pedofeatures.

3.3.4 Laboratory Characterization

Particle size distribution, pH, and total carbon were measured at the Kansas State University Soil Characterization Laboratory for sites 1 through 4. All other routine soil characterization (not including mineralogy and micromorphology) was done at the National Soil Survey Laboratory and methods can be found in the Soil Survey Laboratory Methods Manual (Soil Survey Laboratory Staff, 2004). Bulk samples were allowed to air dry and then were ground with a wooden rolling pin and passed through a No. 10 sieve with 2 mm square openings. Soil pH was determined in a 1:1 soil to water suspension as well as a 1:2 soil to 0.1 M $CaCl_2$ solution ratio using methods 4C1a2a1a1 and 4C1a2a2a1, respectfully, of the Soil Survey Laboratory Methods Manual (Soil Survey Laboratory Staff, 2004). Total carbon and total nitrogen were determined using a high-frequency induction furnace (Leco Model CNS-2000, St. Joseph, MI) following the procedure of Tabatabai and Bremner (1970). Particle size distribution was determined using a modification of the pipet method of Kilmer and Alexander (1949) and method 3A1 form the Soil Survey Laboratory Methods Manual (Soil Survey Laboratory Staff, 2004). Organic matter was removed prior to particle size analysis from samples containing greater than 1.7% total C with 30% hydrogen peroxide.

3.4 Results and Discussion

3.4.1 Field Morphology and Laboratory Data

The field morphology of these soils reflects the geologic parent materials present in the Osage Questa region of Kansas. Many pedogenic processes are currently at work in the studied pedons including accumulation of organic matter, leaching of carbonate and other soluble salts, and weathering of clay minerals. Pedogenic carbonates were found well below 100 cm in all soils. However, the dominant pedogenic processes of interest to this study are translocation of clay and shrink-swell processes. Soil movement and mixing associated with shink-swell tends to destroy evidence of clay illuviation (Nettleton et al., 1969). These two processes can occur simultaneously. Therefore, it could be conceived that if the rate of clay illuviation exceeded the rate at which shrink-swell could destroy ped faces, then accumulations of translocated clay would be observable in soils with high shrink-swell properties. Clay increases and the formation of argillic horizons in the upper part of the profile is primarily caused by clay illuviation. However, given the humid climate, clay mineral formation through neogenesis is thought to have contributed to the abundance of clay throughout these soils. Clay films are observed in the field in the majority of soils in the region; however, they are best expressed in soils exhibiting the least shrink-swell potential. This is shown in the upper argillic horizons at site 2 which generally expressed little evidence of vertic soil movement. The Bt1 horizon is described with 70 percent continuous faint black (10YR 2/1), moist, and very dark gray (10YR 3/1), moist, clay films on all faces of peds. The reverse is true in that soils exhibiting high shrink-swell potential have less strongly developed clay films or none at all. The Vertisols at sites 6 and 7 were not described with any clay films. Table 3.1 shows selected physical and chemical characterization data for all pedons.

The study pedons generally seem to belong to two different categories with regards to clay illuviation and vertic properties: soils with silty surface layers and strongly developed argillic horizons (i.e., claypan soils); and soils without argillic horizons, having a more even clay distribution throughout. Silt loam and silty clay loam surface soils overly high shink-swell argillic horizons at all but sites 6 and 7. In these claypan soils, the shrink-swell potential of the argillic horizon may not be fully expressed as these subsurface horizons dry out less rapidly and are not as subject to differential wetting by preferential flow down surface cracks due to the buffering effect of the non-expansive surface layer. Half of the pedons showed strong evidence of clay illuviation. These soils are often referred to as claypan soils. Sites 2, 5, 8, and 9 all contain a very abrupt textural change at the top of the argillic horizon with greater than 20 percent clay increases from the overlying horizon. Slickensides were described at sites 2 and 8, and all four soils contained high COLE values in the argillic horizon. However, evidence of soil movement, cracking, and pedoturbation was least apparent at these sites. Pedon 09KS059001 at site 2 classifies as a fine, smectitic, thermic Vertic Argiaquoll. At site 5, pedon 73KS001003 is a fine, smectitic, Abruptic Argiaquoll. Pedon 05KS133003 at site 8 is classified as a fine, smectitic, thermic Vertic Argiudoll. Pedon 06KS133001 at site 9 is the only soil in this study with an ochric epipedon and an albic horizon. It is classified as a fine, mixed, active, thermic Vertic Albaqualf.

Alternatively, the Zaar soils at sites 6 and 7 contained little evidence of clay illuviation. No argillic horizon or abrupt textural changes were observed, and no clay films were described in the field. Evidence of soil movement and cracking due to shear stress associated with soil volume fluctuations was apparent. Many slickensides were described, and the soils exhibit high COLE values throughout. Vertic processes have apparently destroyed clay films and caused the mixing of surface and subsurface horizons. Site 6 is a fine, smectitic, superactive, thermic Aeric Endoaquert, while pedon 7 classifies as a fine, smectitic, thermic Typic Epiaquert.

The soil at site 4 appears to express characteristics of both the claypan soils and the Zaar soils. Site 4 has a well defined argillic horizon; however, the clay increase is not as abrupt.

Many slickensides were described as well as wedge structure. The soil at site 4 classifies as a fine, smectitic, thermic Aquertic Argiudoll. Site 1 is formed over limestone bedrock. It exhibits clay films, but the clay films and argillic horizon occur at a greater depth than in the claypan soils, and the clay increase with depth is much more gradual. Slickensides occur in the lower part of the pedon, and the soil is a fine, mixed, active, thermic Oxyaquic Vertic Argiudoll. Site 10 is a shallow soil formed over shale at 91 cm. Like the Zaar soils, this soil shows a high clay content in the surface and only a slight clay increase with depth. Clay films and an argillic horizon were observed, however. COLE values are significantly lower than in the Zaar soils. The soil at site 10 is classified as a fine, mixed, active, thermic, Aquic Argiudoll.

3.4.2 Mineralogy

Based on the total clay mineralogy results, these nine pedons can again be grouped into two differing categories: soils dominated by smectite, and soils exhibiting a more mixed clay mineralogy. Clay mineral abundance graphs and X-ray diffraction (XRD) patterns are shown for all sites (Fig. 3.1 through 3.18). At sites 2, 5, 6, and 7, smectite dominated the clay fraction with abundances in selected horizons ranging from 40 to 60 percent throughout. The XRD patterns often showed that the width of the smectite peak (Mg-25°C) at half height increased in horizons near the soil surface, e.g., the Ap and BA horizons of Pedon 6 (Fig. 3.10). This may indicate increased weathering in the upper part of the soil as compared to the lower part of the soil. Increased weathering could cause greater neoformation of smectites in the upper horizons, explaining the broader smectite peaks. Kaolinite was the next most common clay mineral in all horizons (15 to 30 percent). Clay mica made up 5 to 15 percent of clay, and clay-sized quartz usually accounted for less than 10 percent. In even smaller amounts, feldspars were detected in all four soils. In the upper parts of both Woodson soils, sites 2 and 5, as well as in the Ap horizon at site 4, a hydroxy-interlayered mineral was found and estimated to be as much as 10 percent in the A horizon at site 5. This mineral is probably a hydroxy-interlayered smectite (HIS) or vermiculite (HIV) and is evidenced by the broad shoulder on the 10Å peak of the K-25°C treatment that persists when heated to 350°C and 550°C (treatments K-350°C and K-550°C) (Fig. 3.19).

The soils at sites 1, 4, 8, 9, and 10 exhibited a more mixed mineralogy. At sites 1, 4, 8, and 9, smectite still made up a significant portion of the clay fraction, and as would be expected, this is especially true in the argillic horizons. At sites 1, 4, and 9, smectite contents increased to as much as 40 percent in the argillic horizons. The fluctuations in the smectite content tended to reflect changes in the fine clay to total clay ratio. When the fine clay to total clay ratio increased in the argillic horizon, smectite content increased as well. Mineralogy of the fine clay fraction was not determined for this study; however, many studies have found that smectites often make up nearly the entire fine clay fraction (Gunal and Ransom, 2006a).

Kaolinite contents at sites 1, 4 ,8 ,9 , and 10 were generally greater than in the Woodson and Zaar soils (sites 2, 5, 6, and 7) and ranged from about 25 to 45 percent. Vermiculite was found in all five of the more mixed soils (sites 1, 4, 8, 9, and 10). Figures 3.20 and 3.21 show the Mg-25°C, Mg-EG, and Mg-GLY treatments for the 3Btkss and BC horizons at sites 4 and 10, respectively. The interlayer spacing of smectite is known to expand from 14 Å to 18 Å when treated with ethylene glycol and glycerol. No interlayer expansion is observed in these X-ray diffraction patterns; thus the majority of the 14 Å peak is contributed to vermiculite. It contributed anywhere from 5 to 30 percent of the clay fraction and generally increased with depth. Clay mica and quartz usually contributed 5 to 15 percent each, and feldspars were detected in all but sites 1 and 10. Goethite and/or lepidocrocite were found in small amounts at sites 1, 8, 9, and 10.

The clay mineralogy of pedon 86KS133005 at site 10 proved to be very different from all the other soils. Site 10 was estimated to have the highest kaolinite content of about 50 percent throughout, and the lowest smectite content at 10 percent throughout. Even though site 10 did have high total clay contents thoughout like the Zaar soils, its COLE and CEC values are much lower. These findings support the mineralogy results for this pedon as smectite is known to contribute a great deal to COLE and CEC. Much of the profile at site 10 is formed in residuum derived from weathered shale, which is thought to be one of the lower members of the Kansas City Group. The vastly different mineralogy found at this site is probably inherited from the geologic material found locally at the surface.

At sites 1, 4, 8, and 10, an interstratified mineral was identified in some of the horizons. This mineral was interpreted to be a regularly interstratified mica-smectite (RIMS) or regularly interstratified mica-vermiculite (RIMV) (a distinction between the two was not made) having a regular repeating pattern of interstratified layers of mica and either smectite or vermiculite. This mineral was identified in XRD patterns of the Mg-25°C treatment based on the presence of shoulders and small peaks at about 24Å (Fig. 3.20 and 3.21) as well as the presence of broad peaks at 12Å which were only observed in horizons at site 10 (Fig. 3.21). Several other researchers have found both regularly and randomly interstratified minerals similar to these (Sawhney, 1989; Gunal and Ransom, 2006a; Murashkina et al., 2007; Fanning et al., 1989; Moore and Reynolds, 1997). Murashkina et al. (2007) and Sawhney (1989) termed this mineral hydobiotite. It is thought to form as an alteration product of mica weathering involving the replacement of K by Mg or Ca in alternate interlayer zones (Sawhney, 1989).

The broad peaks found between 10Å and 14Å (~12Å) (Fig. 3.21) that increase in d-spacing upon treatment with ethylene glycol and glycerol in the horizons at site 10 suggest the presence of a randomly interstratified mica-smectite (Sawhney, 1989). However, the distinction between regularly and randomly interstratified minerals was not made in figures 3.1 through 3.18. Randomly interstratified minerals are composed similar to that described above for regular interstratification; however, the distribution of the different clay mineral layers lacks a regular repeating pattern. Random interstratification of layer silicates in soil clays is much more common than regular interstratification (Sawhney, 1989).

3.4.3 Micromorphology

Micromorphology investigations were primarily undertaken in order to examine the extent of clay illuviation and the effects of shrink-swell. In all soils, disruption of illuvial clay features by shrink-swell movement was evident. Striated b-fabrics dominated except in soils with low COLE values in the surface layer overlying argillic horizons. Differences among soils and soil horizons generally occurred with the varying amounts of illuviated clay that were preserved either on void and grain surfaces or embedded within the matrix. Illuviated clay was distinguished from stress oriented clay based on the sharpness of boundaries and the thickness of the normally linear-shaped oriented clay zones. Stress oriented clay and illuvial clay that has been deformed by pressure tended to have characteristics of the matrix fabric, more diffuse boundaries, and often resembled large linear striations under cross polarized light. Some well developed clay films were observed in the argillic horizons of these soils; however, they appeared discontinuous in thin section (Fig. 3.22, 3.23, and 3.24). Gunal and Ransom (2006a) reported in a study of loess derived soils in Kansas that illuvial argillans were not observed when the plasmic fabric was lattisepic or striated. This suggests that large voids and ped surfaces do not persist long enough for the accumulation of clay particles. However, based on the distorted, embedded remnants of old illuvial features, it seems apparent that significant translocation and illuviation of clay has occurred. Thus, the description of argillic and Bt horizons is justified. While studying Vertisol formation in a humid climate, Nordt et al. (2004) observed argillans in the lower part of the pedon, but not in the upper where shrink-swell activity was greatest. They concluded that translocation of clay was occurring, but clay films were only preserved in the lower pedon where ped and void surfaces were more stable. Nordt et al. (2004) cite other studies of soils in humid climates that reached similar conclusions (Mermut and Jongerius, 1980; Yeríma et al., 1987; Wilding and Drees, 1990).

Surface layers at sites 1, 2, 4, 5, and 9 revealed no evidence of accumulations of oriented clay and were nearly entirely dominated by stipple-speckled b-fabric in the plasma fabric or micromass. Microstructure of these surface soils as compared to their subsoils differed as well. Surface soils at these sites exhibited a more open granular or subangular blocky structure whereas the argillic horizons in the subsoils were much more dense with accommodating channels and many linear planes resulting from shrinkage and shear slippage (Stoops, 2003). The microstructure of the clayey surface at site 7 resembled that of the subsoils described above with its blocky, dense appearance and the presence of linear planes (Fig. 3.25). Some small zones of weakly developed striated b-fabric were present in the Ap horizon at site 7, but stipple-speckled b-fabric was much more common. The Ap horizon at site 10 showed striations of oriented clay in the plasma fabric. Stress oriented clay was also observed surrounding several iron-manganese nodules and sand grains. (Thin sections of the Ap horizon at site 8 were not available.)

All subsoils exhibited features that were interpreted as being remnants of older illuvial argillans that had been deformed and/or embedded within the matrix by pressure and shearing (Fig. 3.26, 3.27, and 3.28). Similar embedded grain argillans were observed by Wehmueller (1996), Rabenhorst and Wilding (1986), and Ransom and Bidwell (1990). Sites 1, 2, 5, 8, and 9 appeared to show the least deformation of argillans. Some illuvial clay coatings appeared undisturbed, and many others had been embedded, but their deformation was not as severe as at sites 4, 7, and 10. Coatings and infillings of silt were found in channels in several soils, especially in the upper argillic horizons of sites 1, 2, 5, 8, and 9 (Fig. 3.29). These silt coatings exhibited no birefringence colors. Parallel striated, granostriated, and porostriated b-fabrics were present in all subsoils examined (Fig. 3.30, 3.31, and 3,32). Gunal and Ransom (2006a and 2006b), Presley et al. (2004), Wehmueller (1996), and Glaze (1998) also observed striated b-fabrics in argillic horizons in Kansas. Monostriated, cross-striated, and crescent striated b-fabrics were also observed. Striated b-fabrics generally were the most strongly expressed in the lower part of the profile, or in the zone of maximum slickenside development. Many linear planes were observed of all sizes (Fig. 3.33 and 3.25). Some are thought to represent slickenside surfaces or zones of shear failure. Large linear zones of stress oriented clay are present on either side of these planes and are associated with monostriated b-fabrics. Other pedofeatures observed include many redoximorphic iron-manganese accumulations in all soils. These iron-manganese accumulations occur as matrix accumulations, ferriargillan hypocoatings around voids, and intrusive nodules. At sites 4 and 7, calcium carbonate nodules were observed in the lower horizons.

3.4.4 Model of Soil Genesis

The distortion of illuvial clay features observed in thin section suggests that these claypan soils have developed through at least two differing environments: a period of significant clay illuviation to create the clay films followed by a period of shink-swell activity that effectively distorted and embedded the clay films. At some point during soil formation, silty, non-expansive surface soils with underlying claypans developed due to a variety of possible reasons. Loess deposition on top of clayey alluvium or residuum, translocation of clay downward and/or laterally in the soil, and clay particle destruction through ferrolysis are all proposed methods of claypan formation. Once the silty, non-expansive top soil forms, the soil ceases to crack to the surface. Preferential flow through surface cracks is drastically reduced. Thus, differential wetting of the subsoil, needed in the soil mechanics model of Vertisol formation, becomes limited due to the buffering effect of the non-expansive surface soil. Therefore, the shink-swell potential of the clayey subsoil is not fully expressed as these horizons dry out less rapidly. This prevents these soils from developing strongly expressed vertic properties and classifying as Vertisols. In some soils of the region (i.e. Zaar series, Osage series, etc., soils which are similar to sites 6 and 7), shrink-swell and pedoturbation may provide great enough mixing of surface and subsurface horizons to effectively counteract clay translocation. These soils are thought to be younger soils than the soils formed with claypans. Therefore, the upper horizons lack the contribution from loess deposition observed in other pedons of the study. These soils maintain a clayey, high COLE value surface soil, as well as deep cracking that extends to the surface.

3.5 Conclusions

Clay mineralogy data shows that sites 2, 5, 6, and 7 are clearly dominated by smectite whereas sites 1, 4, 8, 9, and 10 exhibit a more mixed mineralogy with a smaller abundance of expanding clay minerals. In the mixed mineralogy pedons, kaolinite, vermiculite, and clay mica often played larger roles even though smectite content was still significant. Some of these soils are borderline to both the smectitic and mixed mineralogy classes. Based on shrink-swell characteristics, a smectitic mineralogy class may be most appropriate since shrink-swell characteristics are historically associated with smectitic mineralogy. Smectite content generally has a positive relationship with shink-swell potential. This concept is partially supported in that sites 6 and 7 displayed strong vertic characteristics in the field, in thin section, and in the laboratory data. These two soils classified as Vertisols. However, the smectitic Woodson soils at sites 2 and 5 displayed limited evidence of soil movement and cracking in the field. These sites classified as Vertic Argiaquolls. This indicates that clay mineralogy alone does not influence the amount of soil volume contraction and expansion or the expression of vertic properties. Also, the total clay content and fine clay to total clay ratios for all soils are relatively high. Therefore, even the soils exhibiting mixed mineralogies contain a significant quantity of expanding clay minerals. This fact, in combination with seasonal moisture changes, provides enough shrink-swell movement to deform clay films and create the striated b-fabrics observed in thin section. The distortion of illuvial clay features observed in thin section suggests that these claypan soils have developed through at least two differing environments: a period of significant clay illuviation followed by a period of shink-swell activity. Since the formation of silty, non-expansive surface soils with underlying claypans, the rate and magnitude of soil volume change has been limited by buffering of the wetting and drying process. Sites 6 and 7 are younger soils lacking a developed claypan.

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3.7 Figures and Tables

Figure 3.1 - Mineralogy of total clay fraction of site 1, pedon 09KS139001, sampled in Osage County, Kansas.

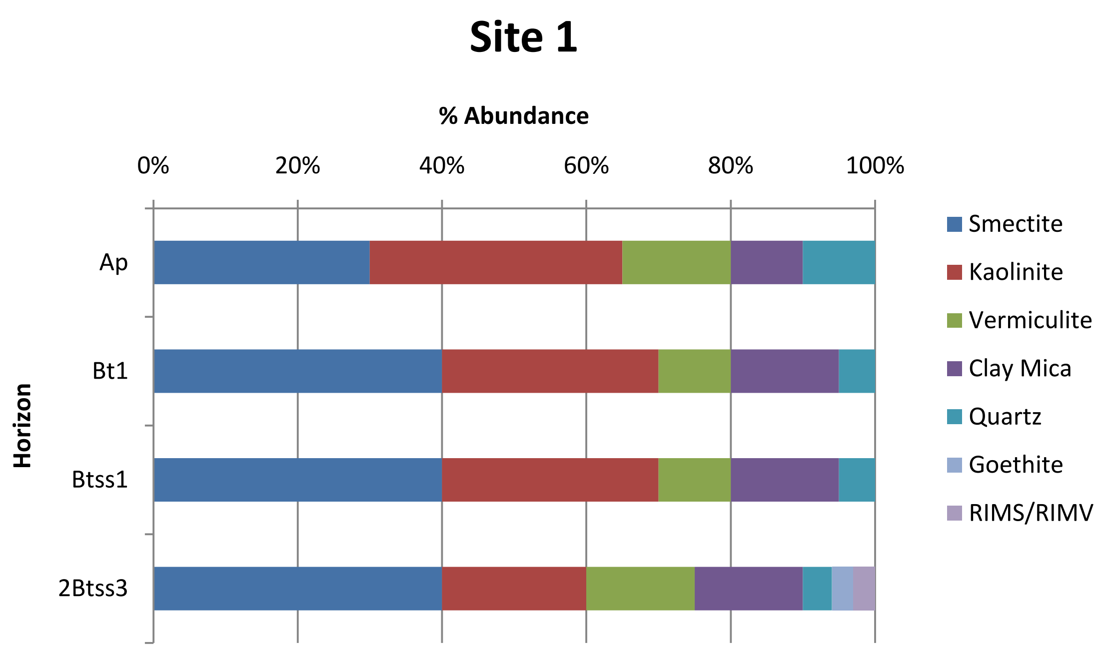

Figure 3.2 - X-ray diffraction pattern of selected horizons for site 1. Mg-25°C treatment.

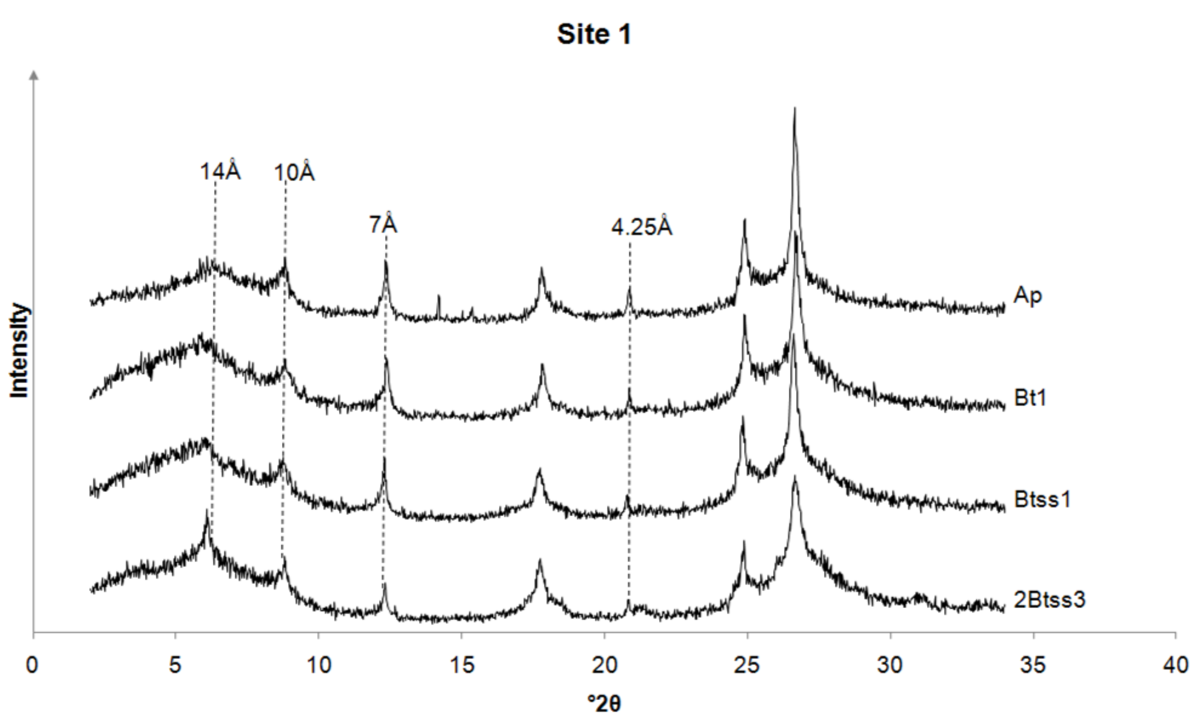

Figure 3.3 - Mineralogy of total clay fraction of site 2, pedon 09KS059001, sampled in Franklin County, Kansas.

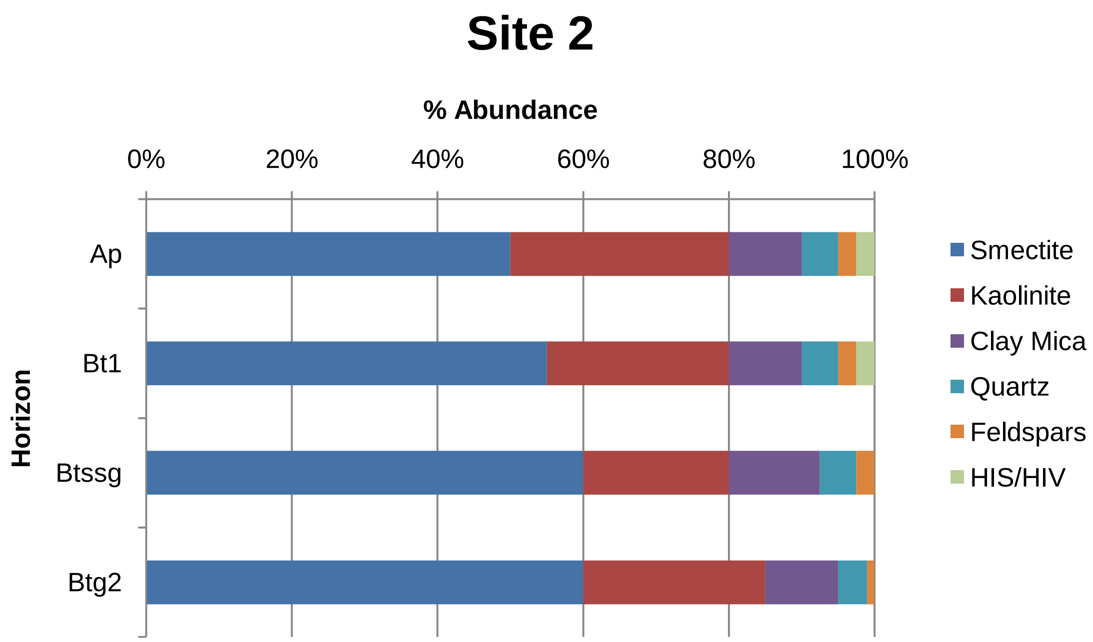

Figure 3.4 - X-ray diffraction pattern of selected horizons for site 2. Mg-25°C treatment.

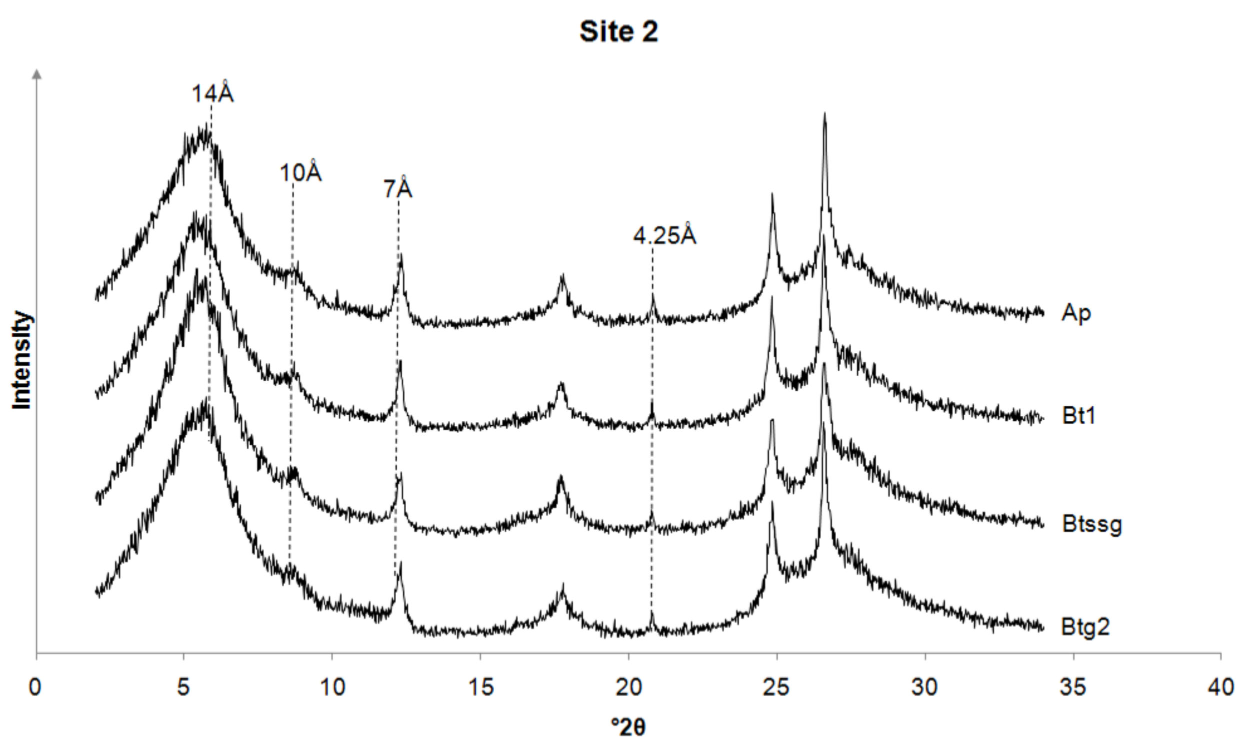

Figure 3.5 - Mineralogy of total clay fraction of site 4, pedon 09KS207001, sampled in Woodson County, Kansas.

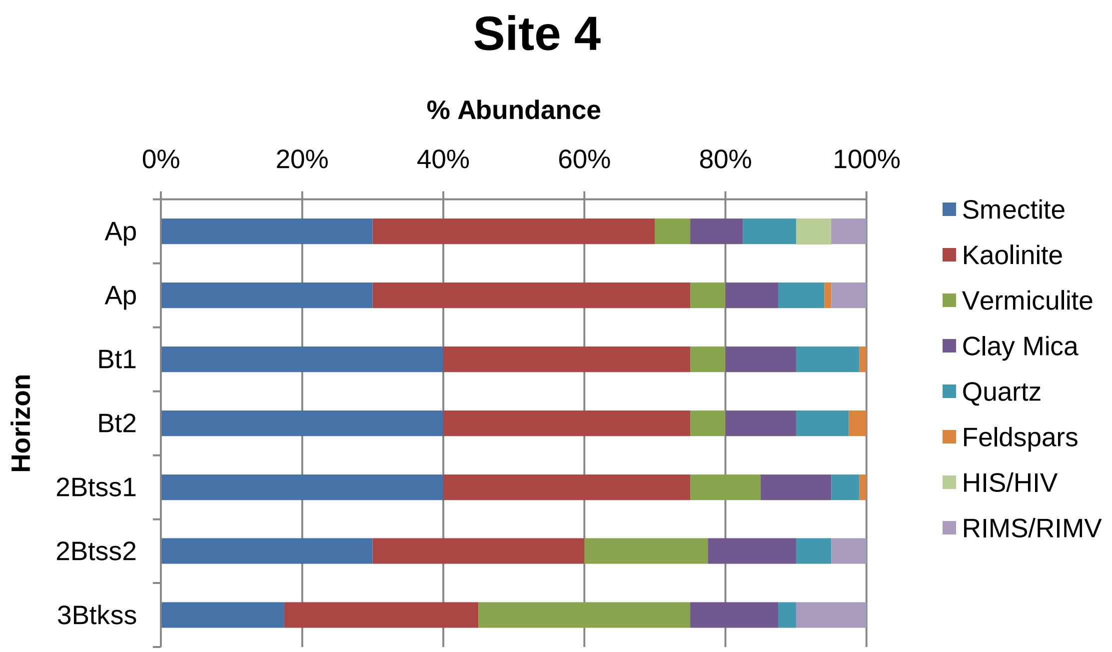

Figure 3.6 - X-ray diffraction pattern of all horizons for site 4. Mg-25°C treatment.

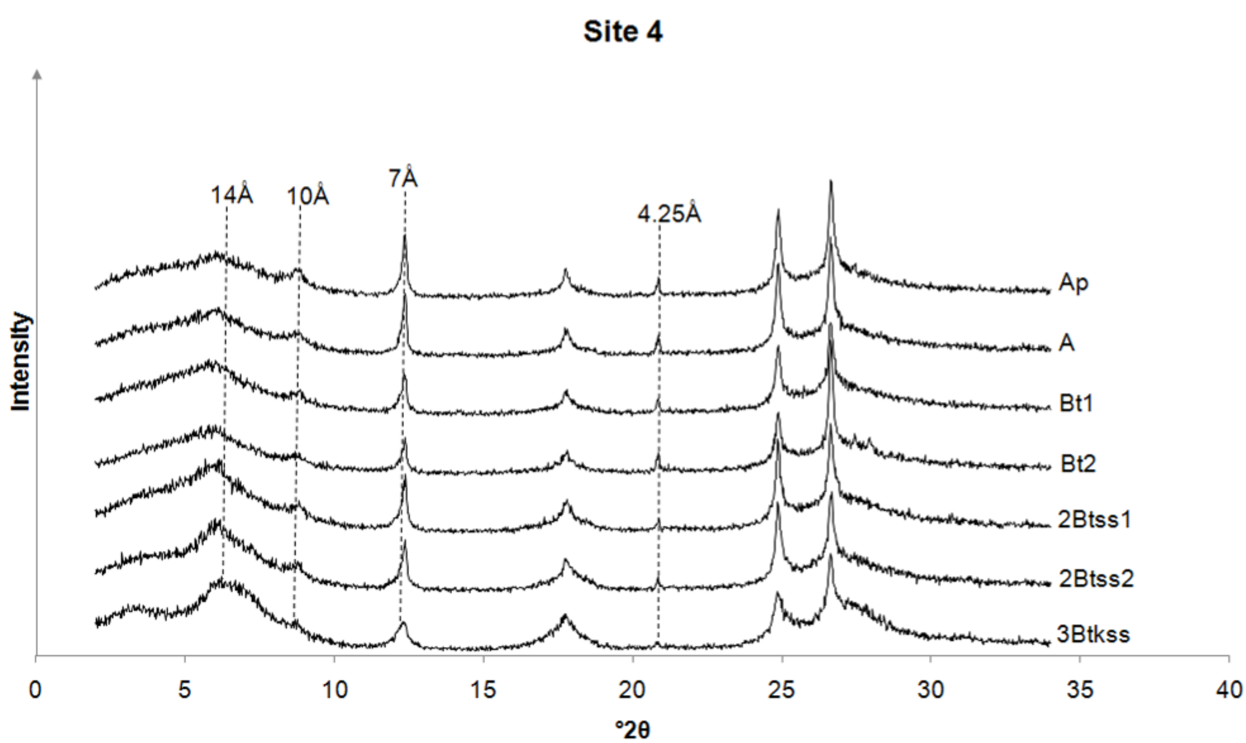

Figure 3.7 - Mineralogy of total clay fraction of site 5, pedon 73KS001003, sampled in Allen County, Kansas.

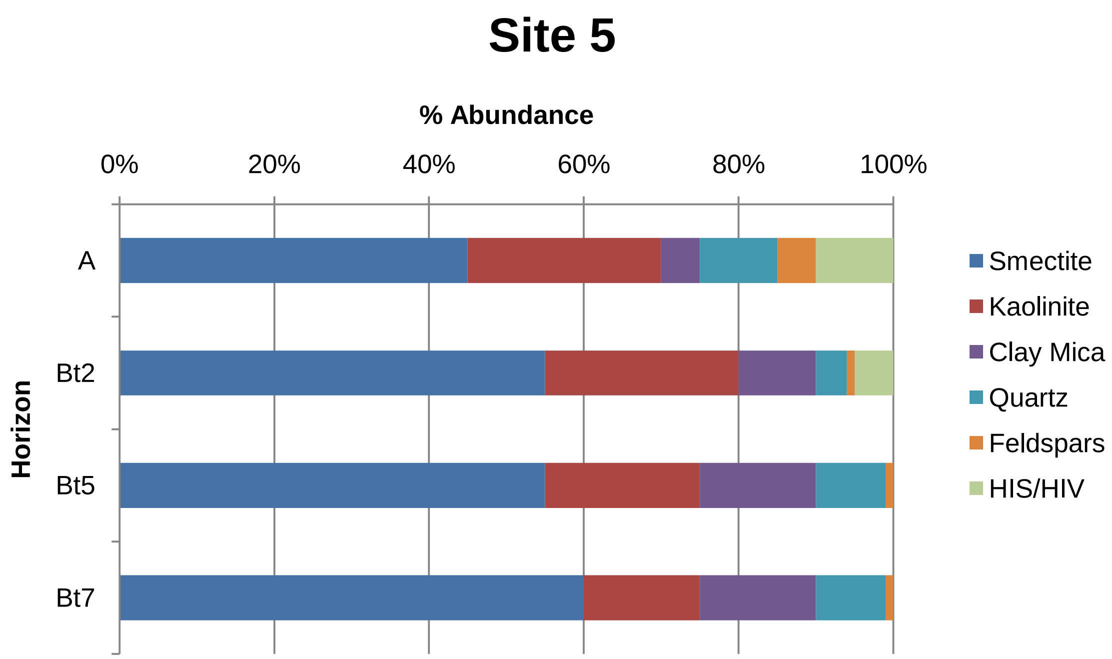

Figure 3.8 - X-ray diffraction pattern of selected horizons for site 5. Mg-25°C treatment.

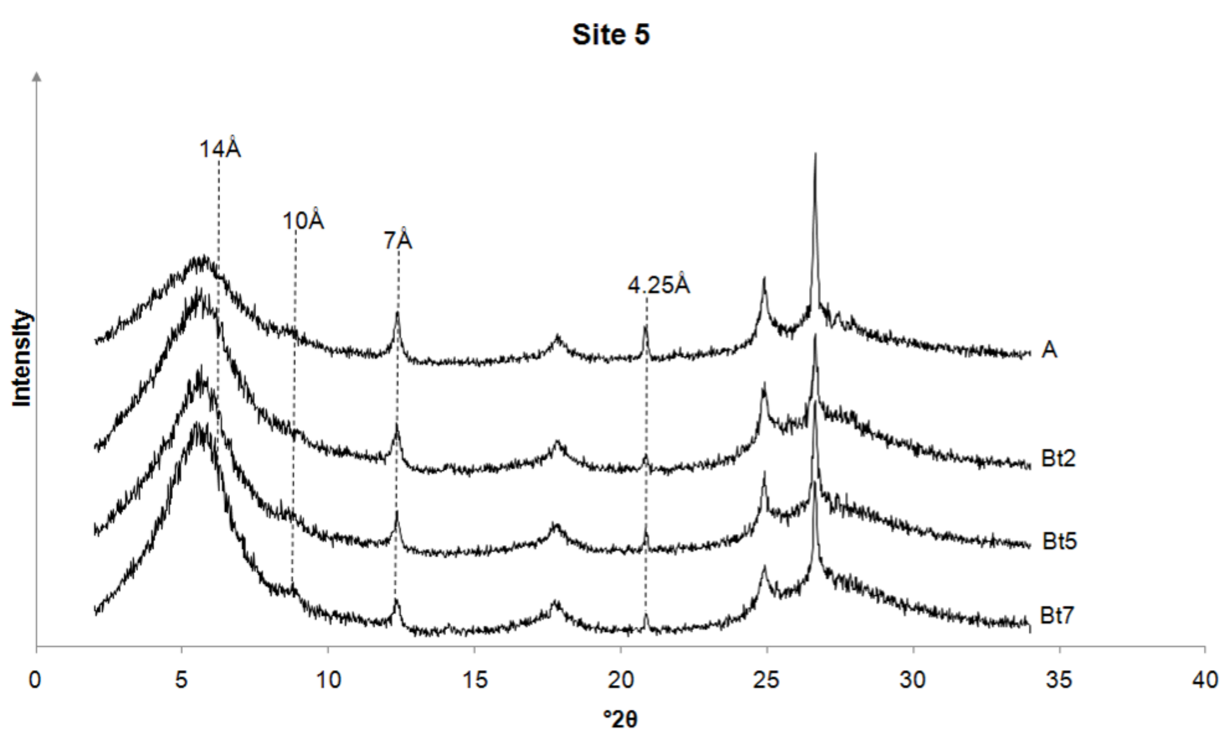

Figure 3.9 - Mineralogy of total clay fraction of site 6, pedon 05KS205002, sampled in Wilson County, Kansas.

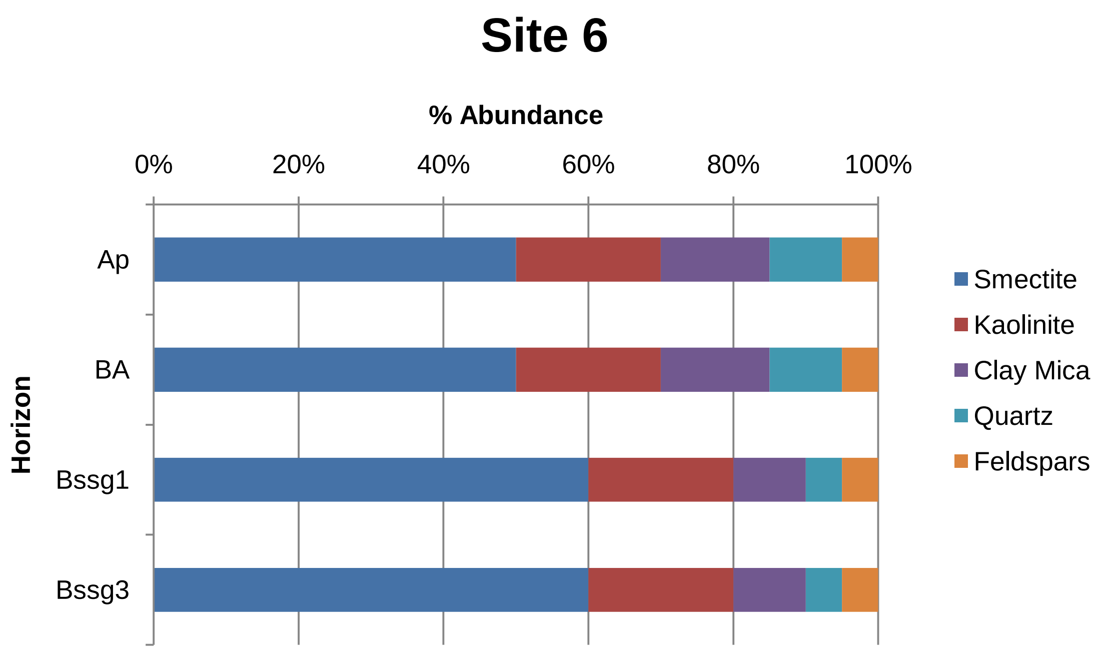

Figure 3.10 - X-ray diffraction pattern of selected horizons for site 6. Mg-25°C treatment.

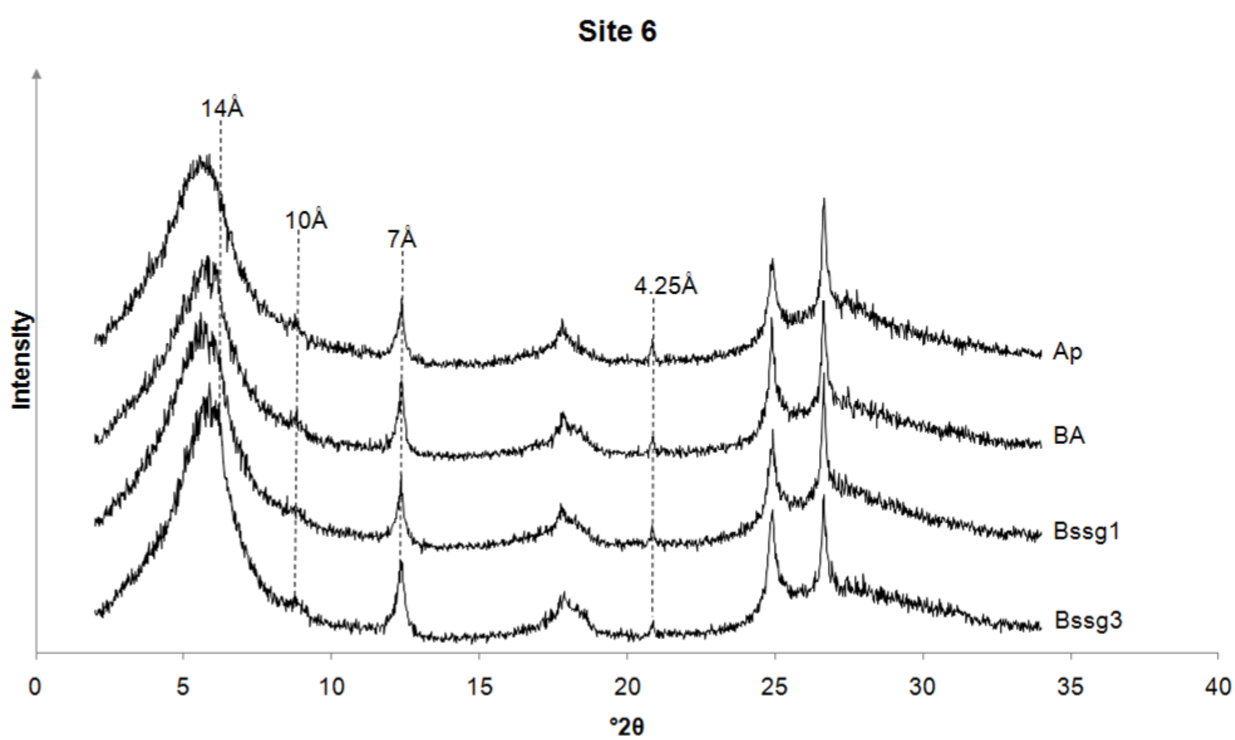

Figure 3.11 - Mineralogy of total clay fraction of site 7, pedon 97KS205001, sampled in Wilson County, Kansas.

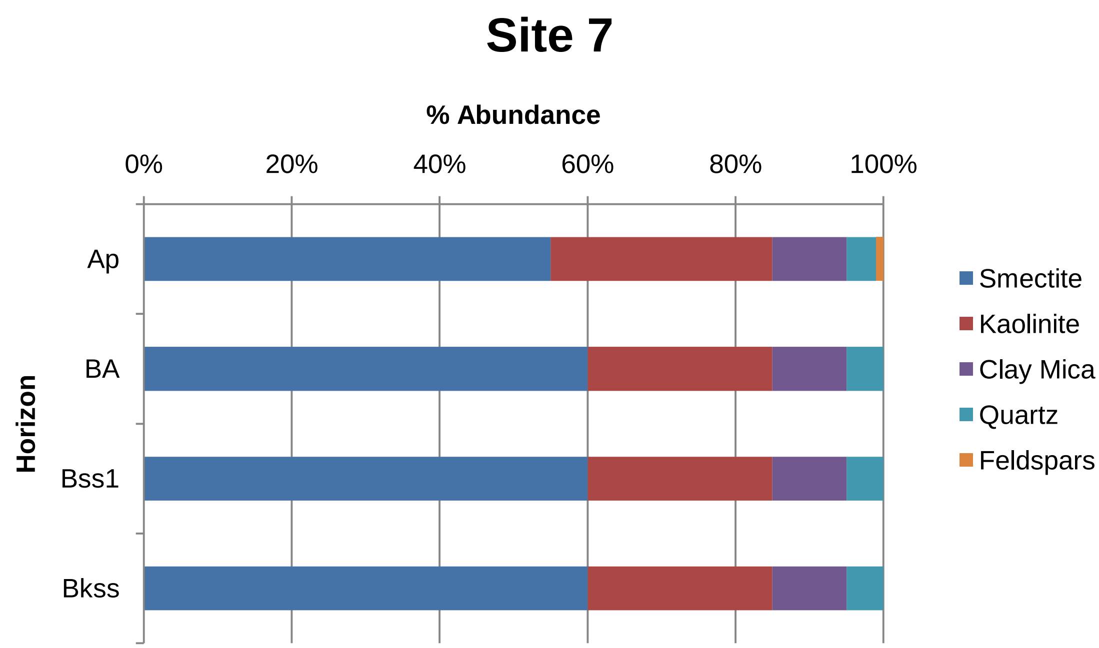

Figure 3.12 - X-ray diffraction pattern of selected horizons for site 7. Mg-25°C treatment.

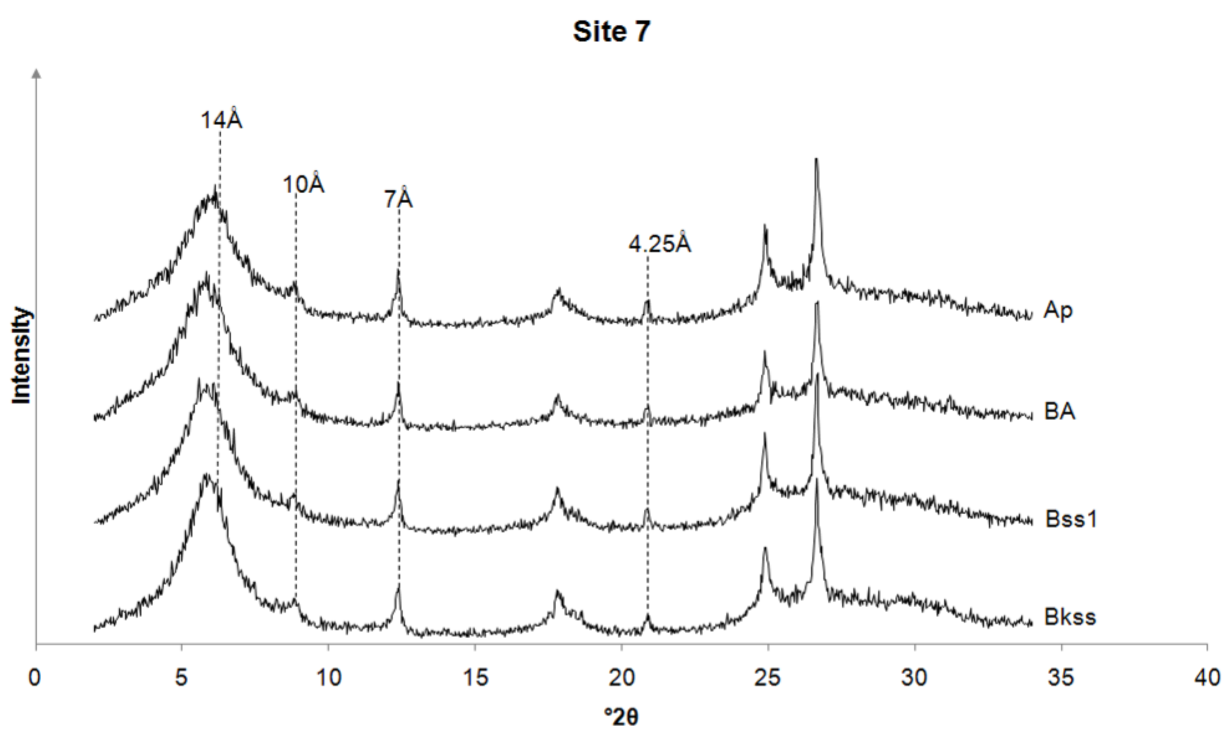

Figure 3.13 - Mineralogy of total clay fraction of site 8, pedon 05KS133003, sampled in Neosho County, Kansas.

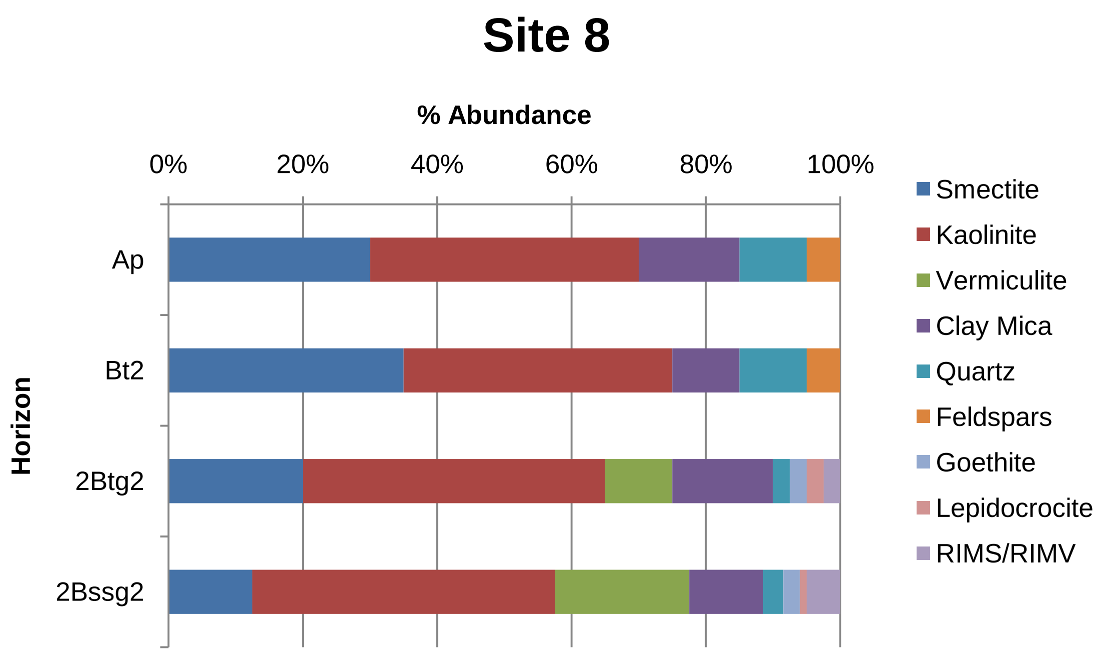

Figure 3.14 - X-ray diffraction pattern of selected horizons for site 8. Mg-25°C treatment.

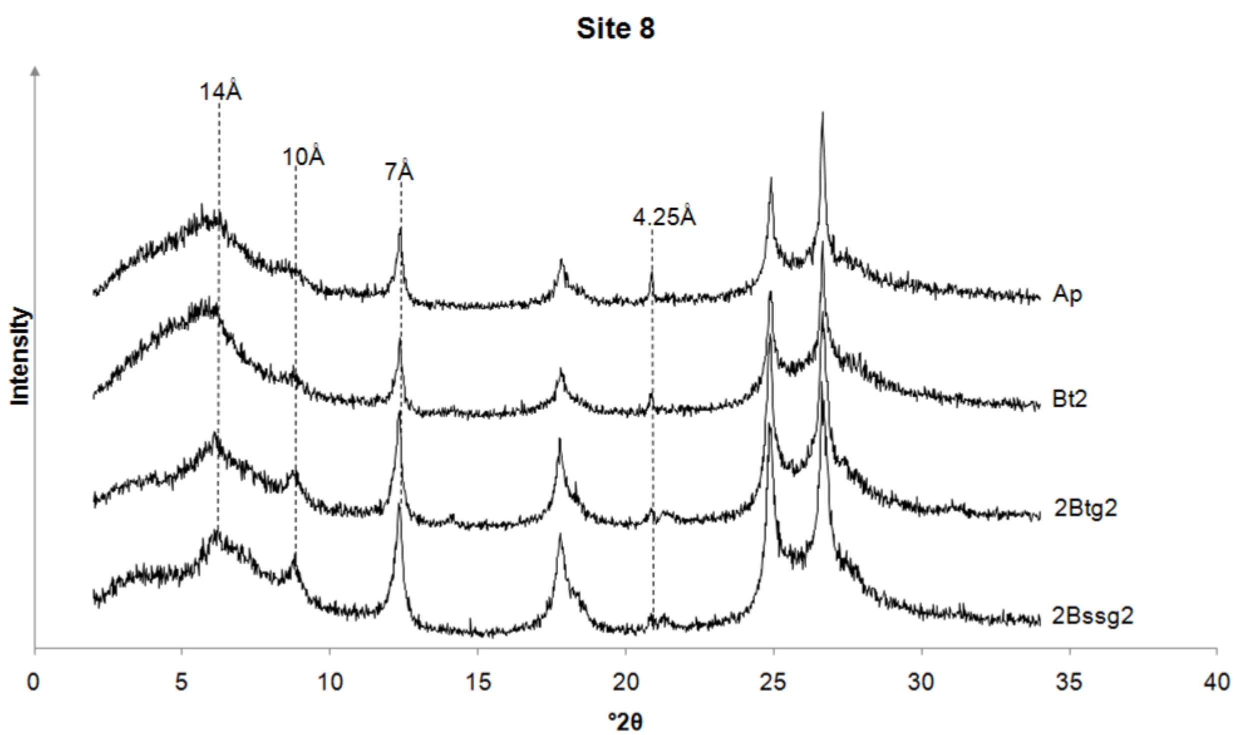

Figure 3.15 - Mineralogy of total clay fraction of site 9, pedon 06KS133001, sampled in Neosho County, Kansas.

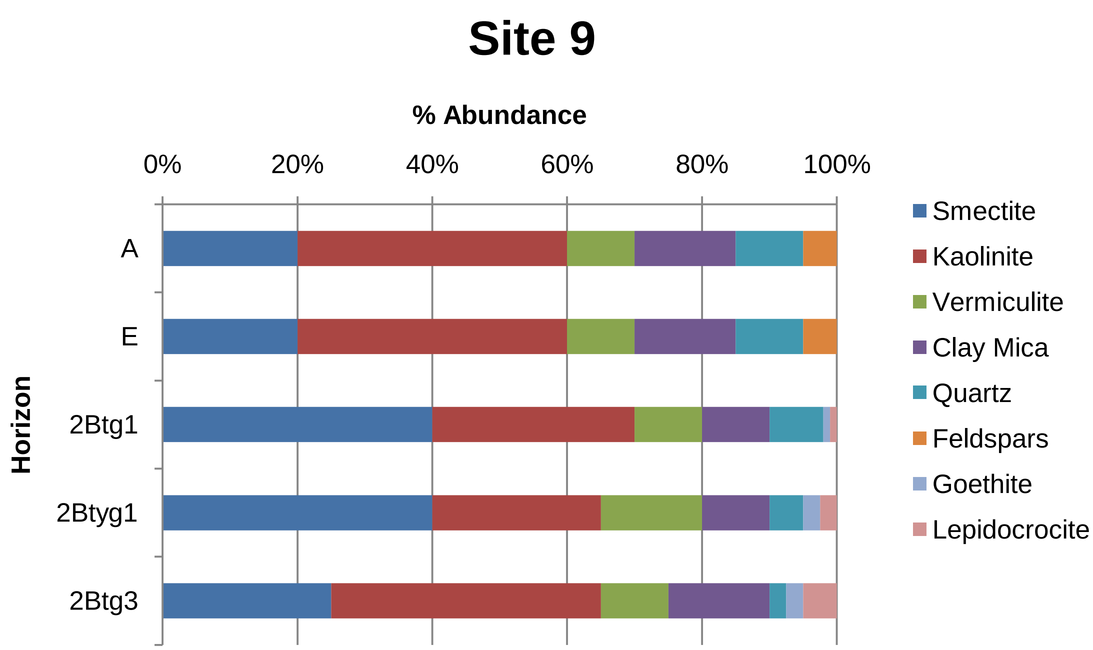

Figure 3.16 - X-ray diffraction pattern of selected horizons for site 9. Mg-25°C treatment.

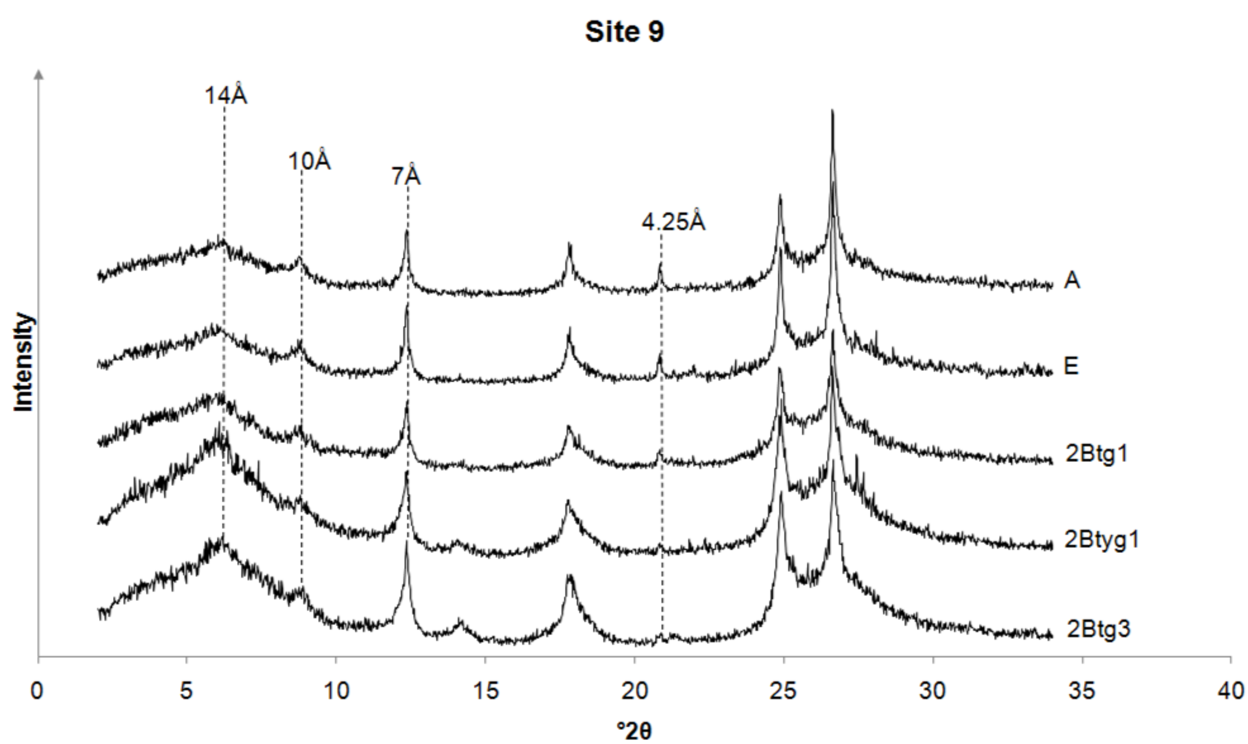

Figure 3.17 - Mineralogy of total clay fraction of site 10, pedon 86KS133005, sampled in Neosho County, Kansas.

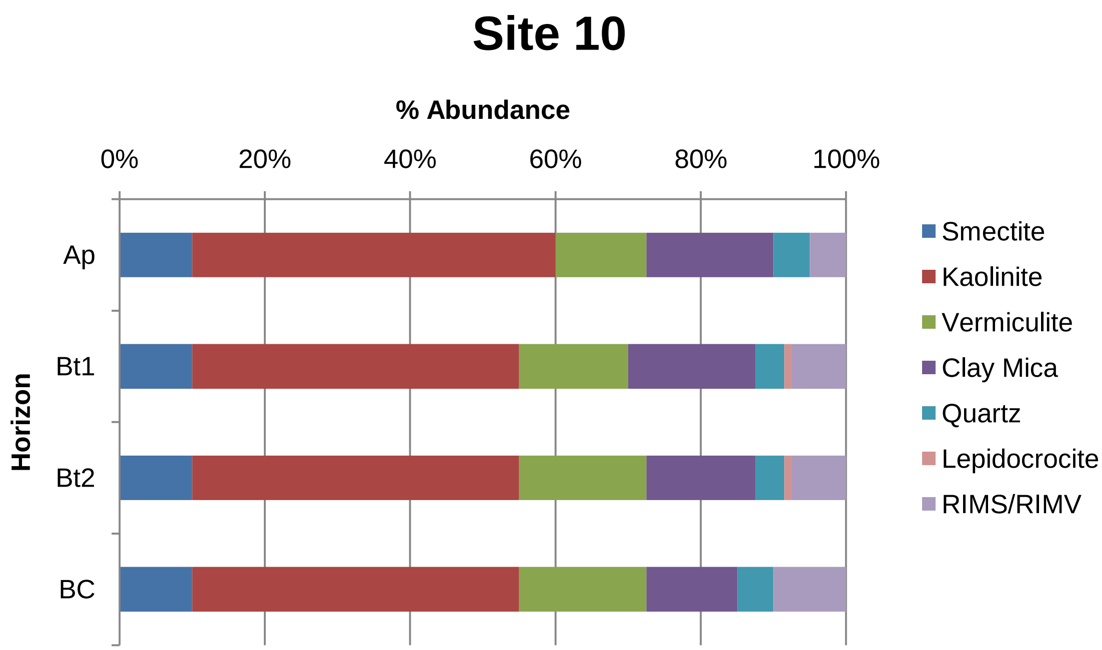

Figure 3.18 - X-ray diffraction pattern of selected horizons for site 10. Mg-25°C treatment.

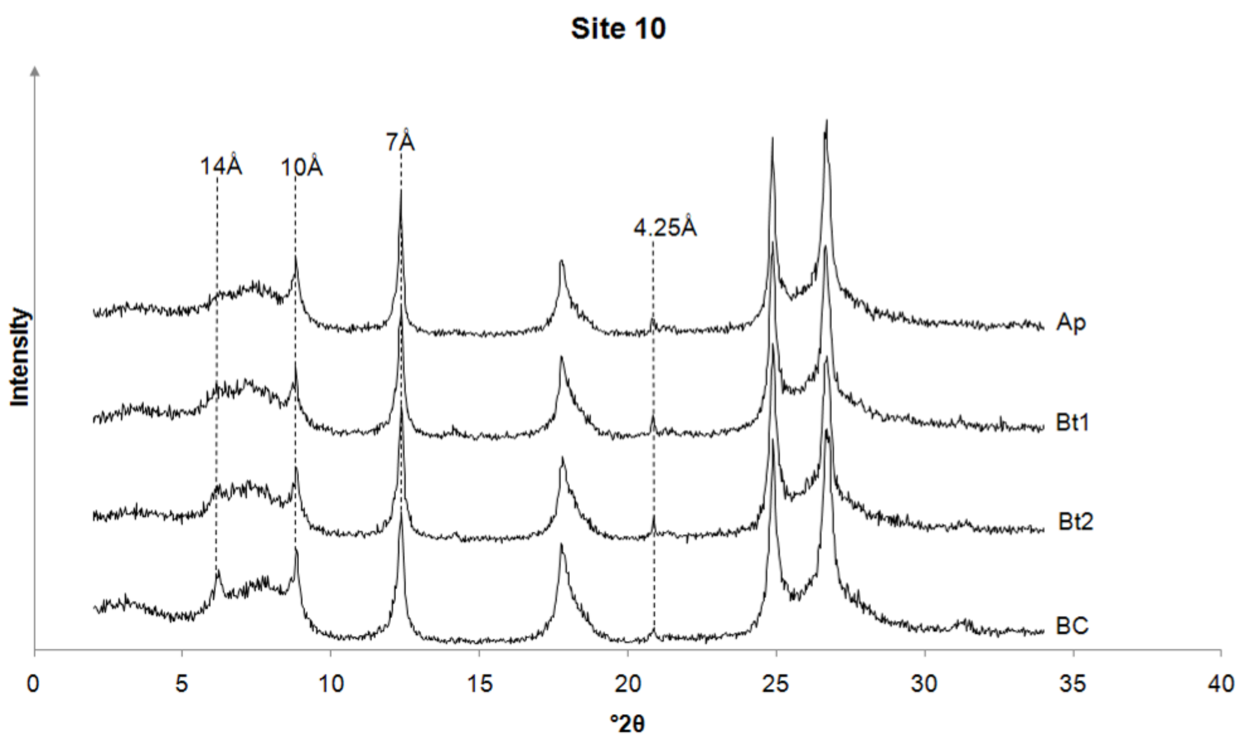

Figure 3.19 - X-ray diffraction pattern of the A horizon at site 5. K-25°C, K-350°C, and K-550°C treatments. Broad 10Å to 14Å peak persists when sample is heated. This is evidence that the mineral layers are not collapsing and suggests the presence of a hydroxyl-interlayered mineral such as hydroxyl-interlayered smectite or vermiculite.

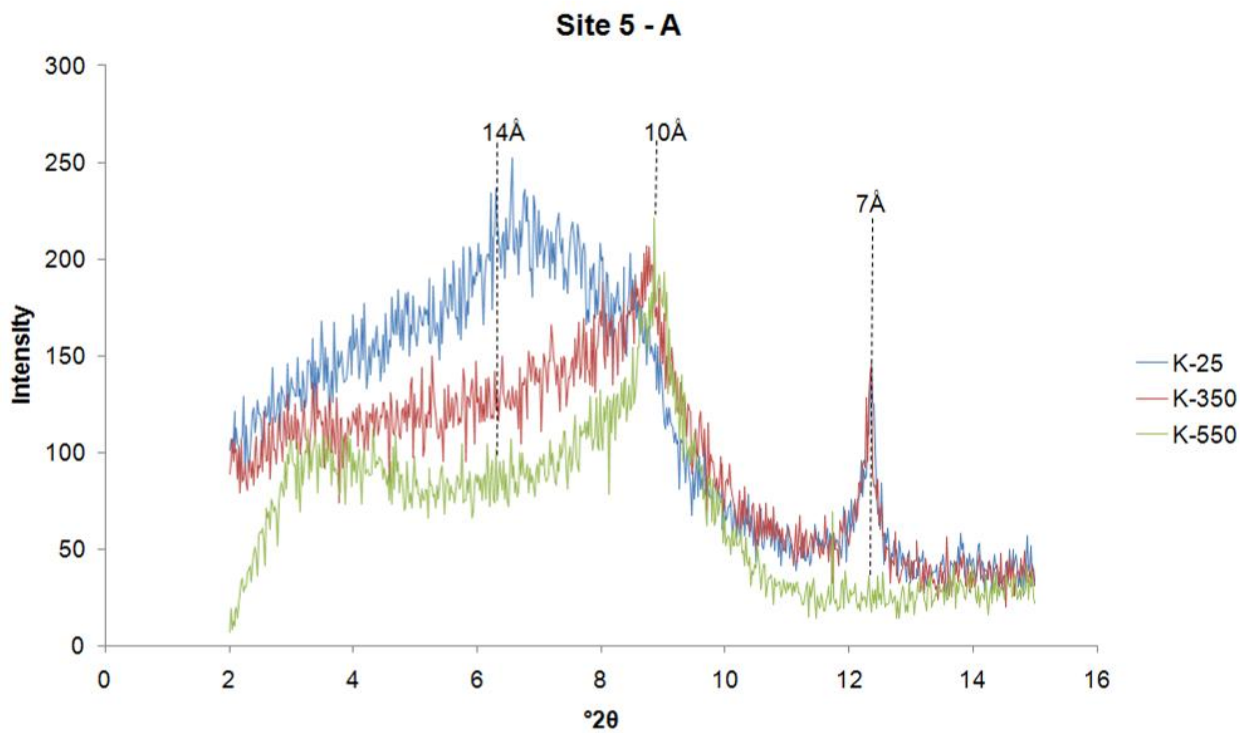

Figure 3.20 - X-ray diffraction pattern of the 3Btkss horizon at site 4. Mg-25°C, Mg-EG, and Mg-GLY treatments. The 14Å peak does not shift to 18Å when treated with ethylene glycol or glycerol showing that the interlayers are not expanding. This is diagnostic of vermiculite. The peak at ~24Å indicates a regularly interstratified mica-smectite or mica-vermiculite.

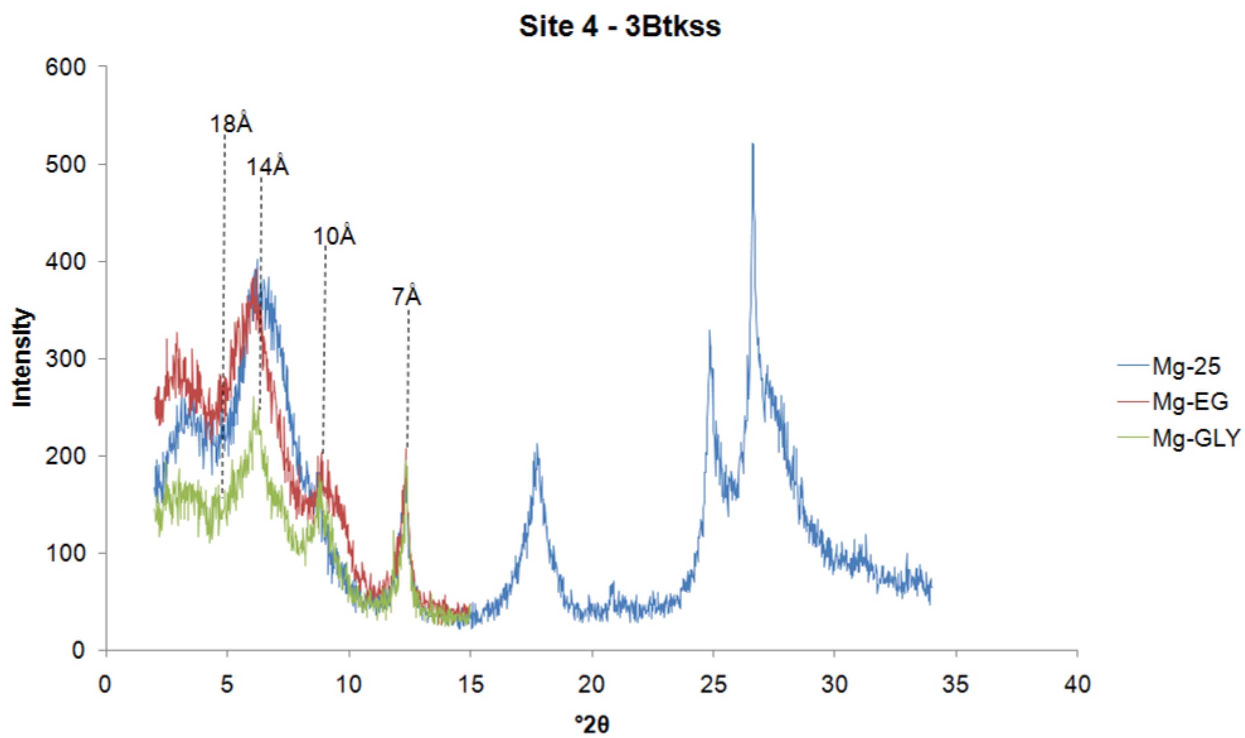

Figure 3.21 - X-ray diffraction pattern of the BC horizon at site 10. Mg-25°C, Mg-EG, and Mg-GLY treatments. The 14Å peak does not shift to 18Å when treated with ethylene glycol or glycerol showing that the interlayers are not expanding. This is diagnostic of vermiculite. The peak at ~24Å indicates a regularly interstratified mica-smectite or mica-vermiculite. The broad peak between 10Å and 14Å, whose d-spacing increases with the ethylene glycol and glycerol treatments, indicates a randomly interstratified mica-smectite.

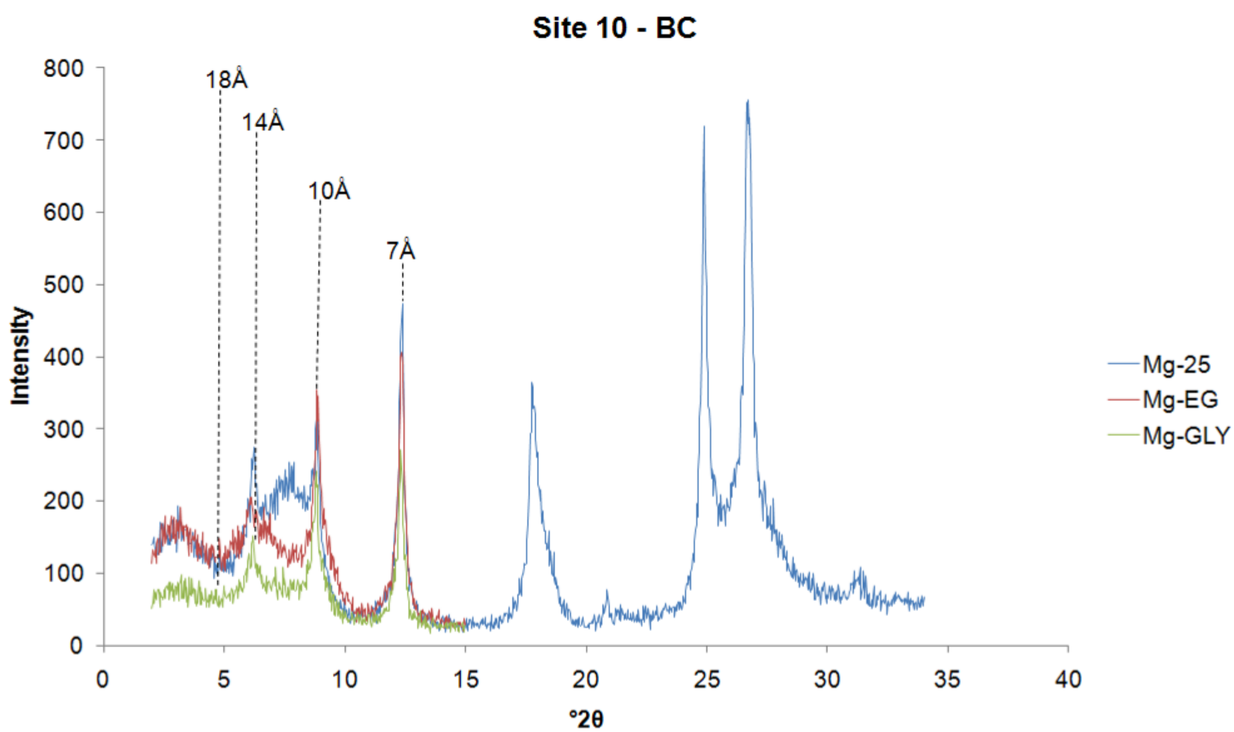

Figure 3.22 - 2Btg1 horizon at site 9. A) Limpid, laminated illuvial clay coating appears relatively undisturbed by soil movement. B) Note the lack of illuvial clay coatings in the larger channel. This suggests that this channel opened more recently, and clay has not yet been deposited on its walls. Crossed-polarized light. Framelength is 665 µm.

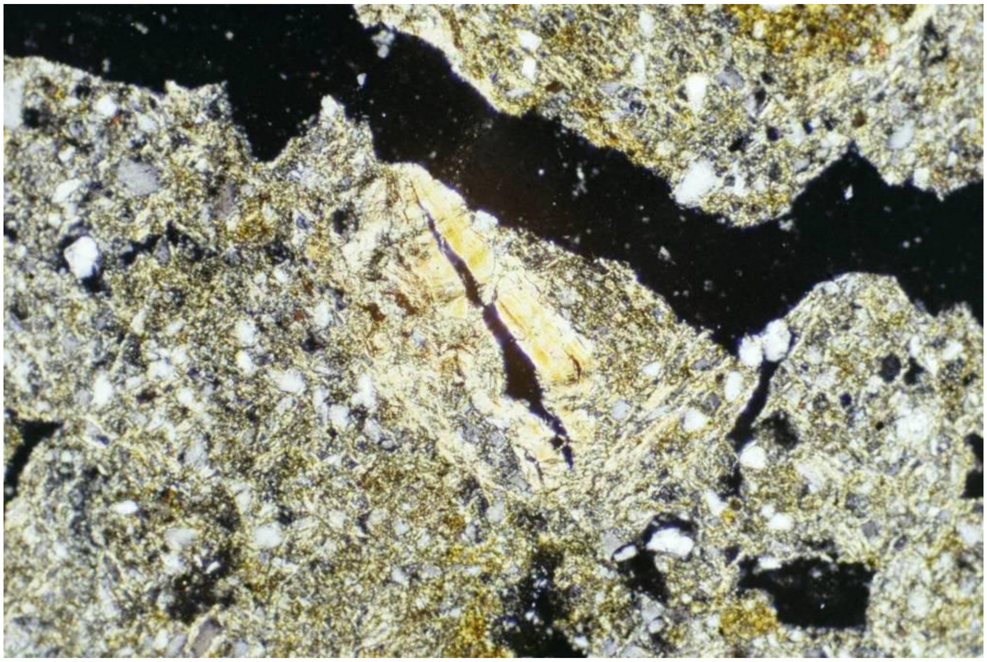

Figure 3.23 - 2Btss3 horizon at site 1. A) Thick illuvial clay coatings along linear plains. B) Large zone of oriented clay displaying orange interference colors embedded in the matrix. Crossed-polarized light. Framelength is 1330 µm.

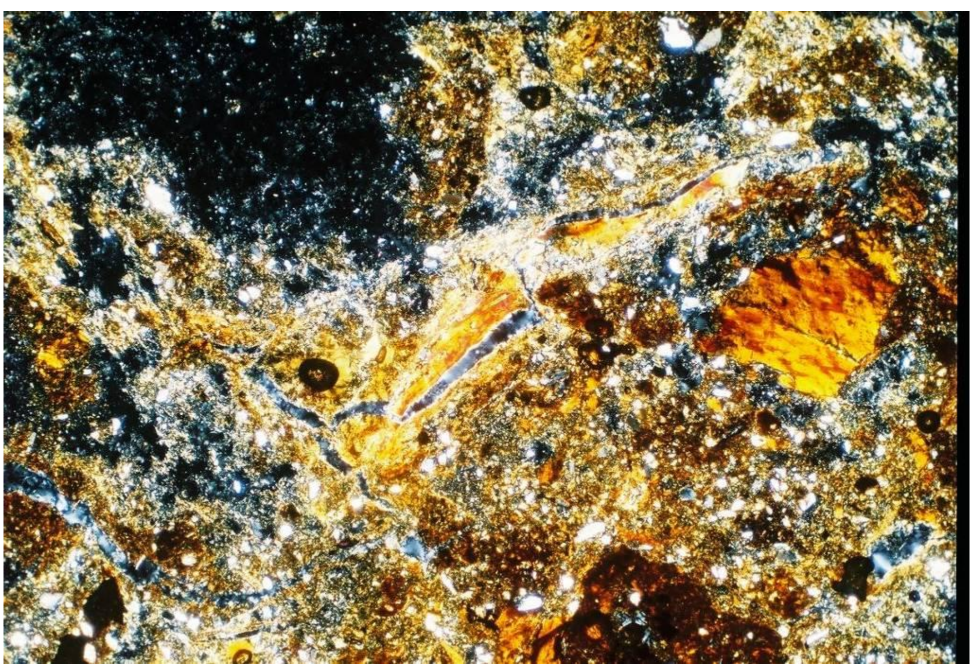

Figure 3.24 - Btg3 horizon at site 2. Laminated illuvial clay feature filling a pore. Crossed-polarized light. Framelength is 3325 µm.

Figure 3.25 - BA horizon at site 7. Cracked, blocky microstructure with large linear plane. Plain-polarized light. Framelength is 3325 µm.

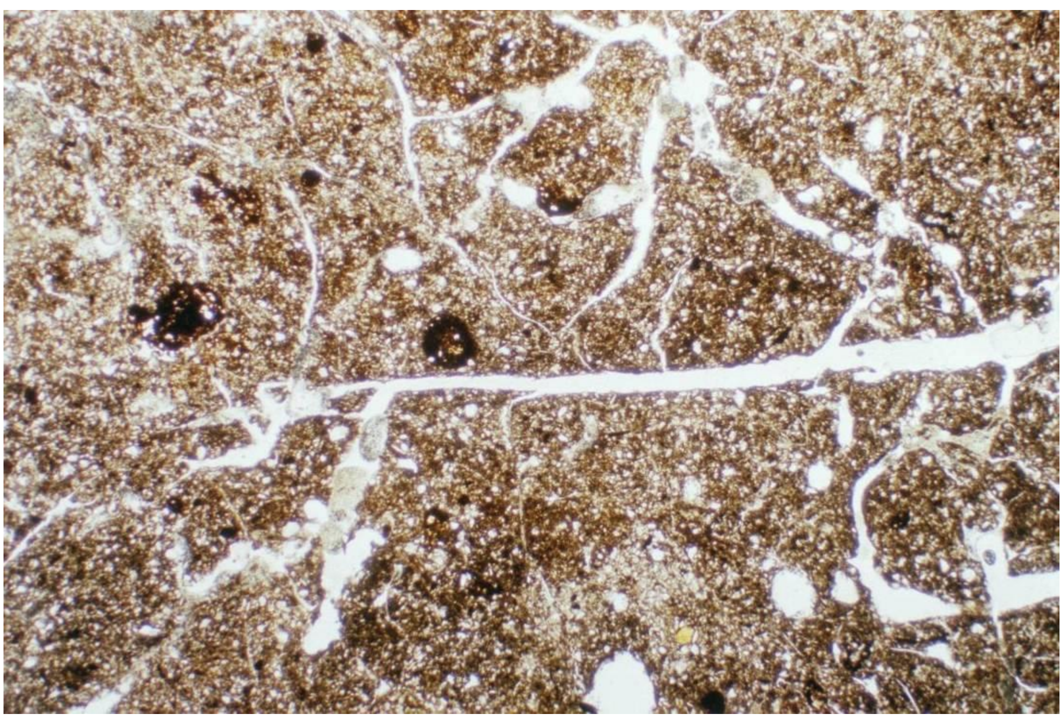

Figure 3.26 - Btg1 horizon at site 2. Distorted, embedded argillan and stress oriented clay along linear plains. Crossed-polarized light. Framelength is 1330 µm.

Figure 3.27 - Bt1 horizon at site 2. Distorted, embedded argillan separated by a linear shrinkage plain. Note the lack of illuvial clay coatings on large void surfaces. Crossed-polarized light. Framelength is 1330 µm.

Figure 3.28 - Btg3 horizon at site 2. Distorted, embedded argillans. Crossed-polarized light. Framelength is 665 µm.

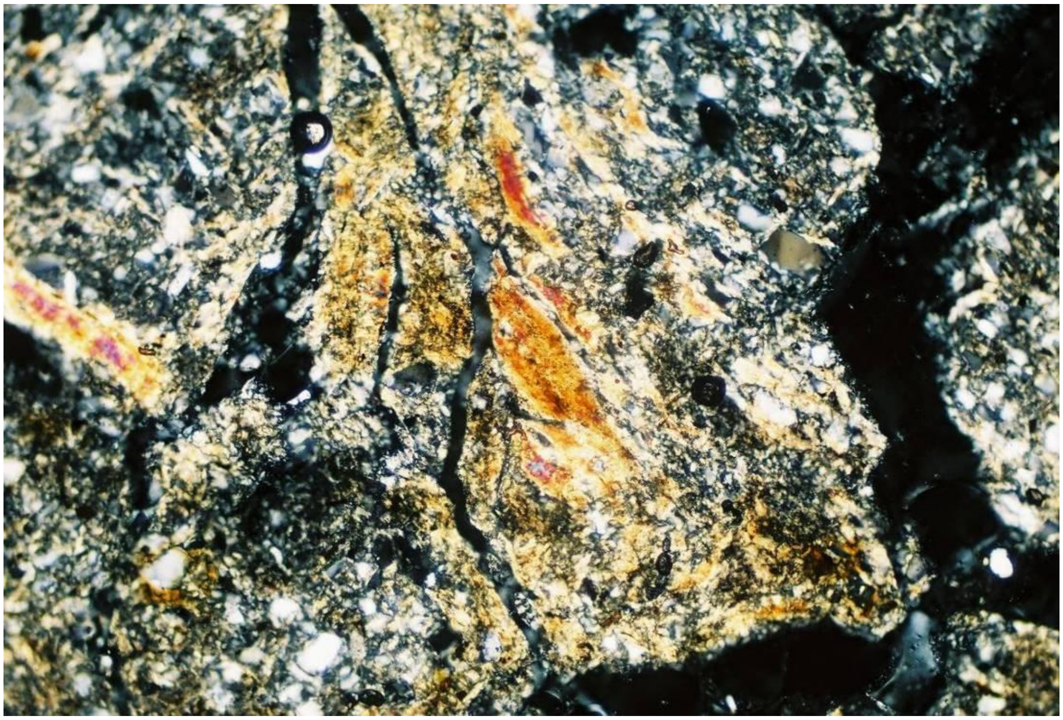

Figure 3.29 - Btss1 horizon at site 1. Silt infilling a channel and stress related linear plains. Plain-polarized light. Framelength is 3325 µm.

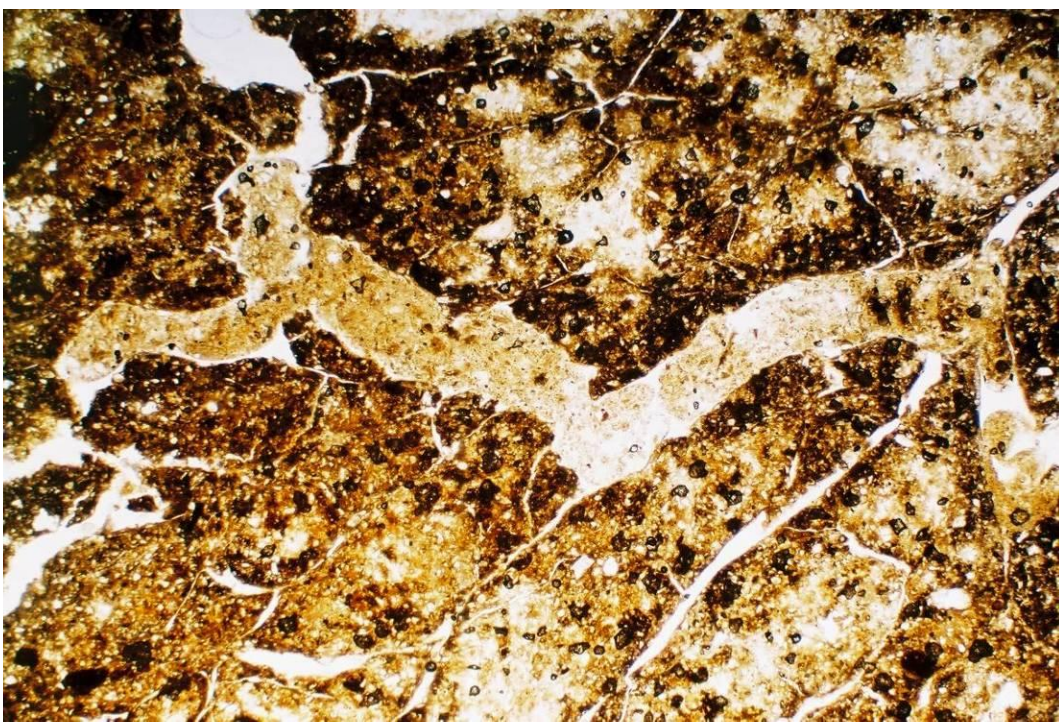

Figure 3.30 - Btg1 horizon at site 2. Strongly expressed parallel striated b-fabric caused by micro-shear due to shrink-swell. Crossed-polarized light. Framelength is 665 µm.

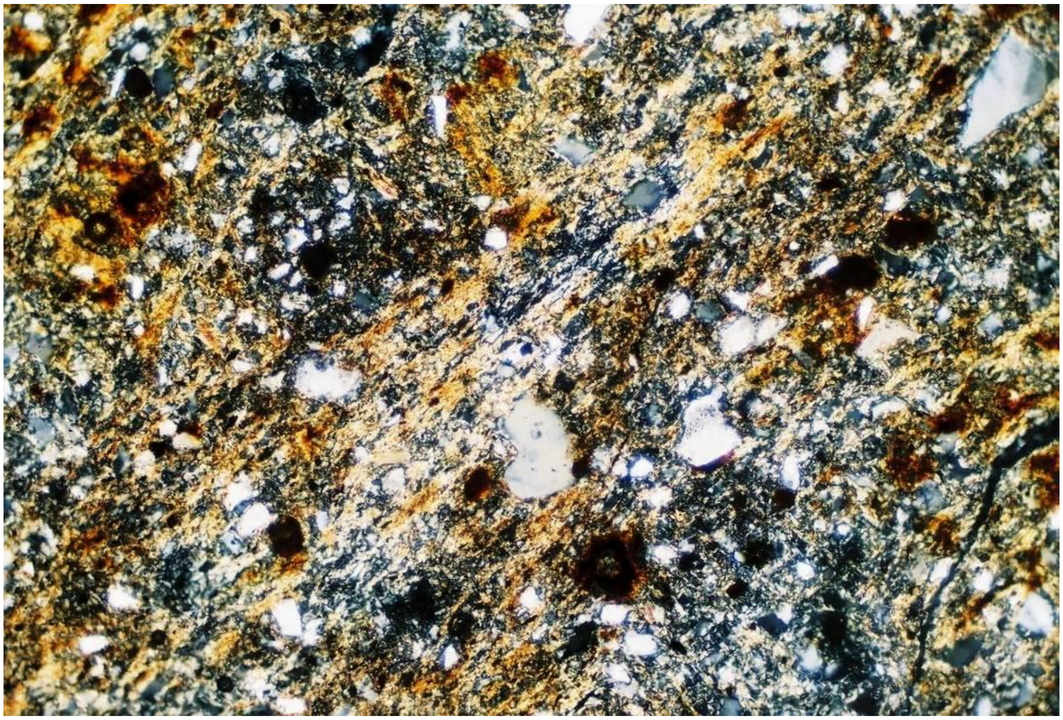

Figure 3.31 - Bt1 horizon at site 4. Granostriated b-fabric around Fe-Mn nodules. Crossed-polarized light. Framelength is 665 µm.

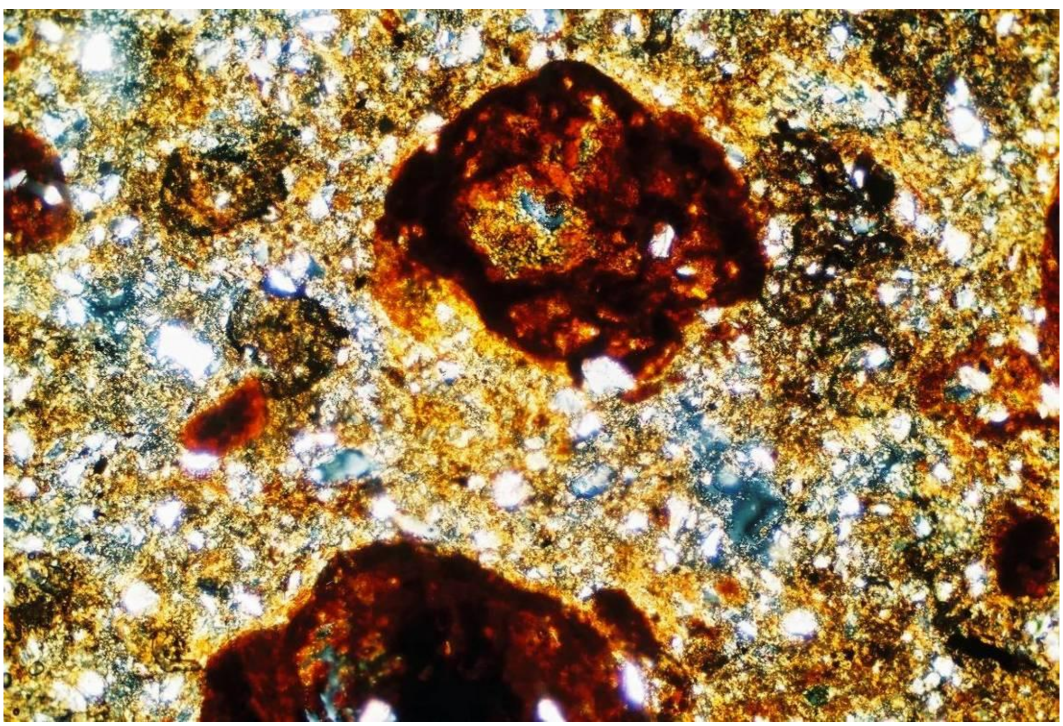

Figure 3.32 - Btg1 horizon at site 2. A) Porostriated b-fabric. B) Distorted, embedded argillan. Crossed-polarized light. Framelength is 665 μm.

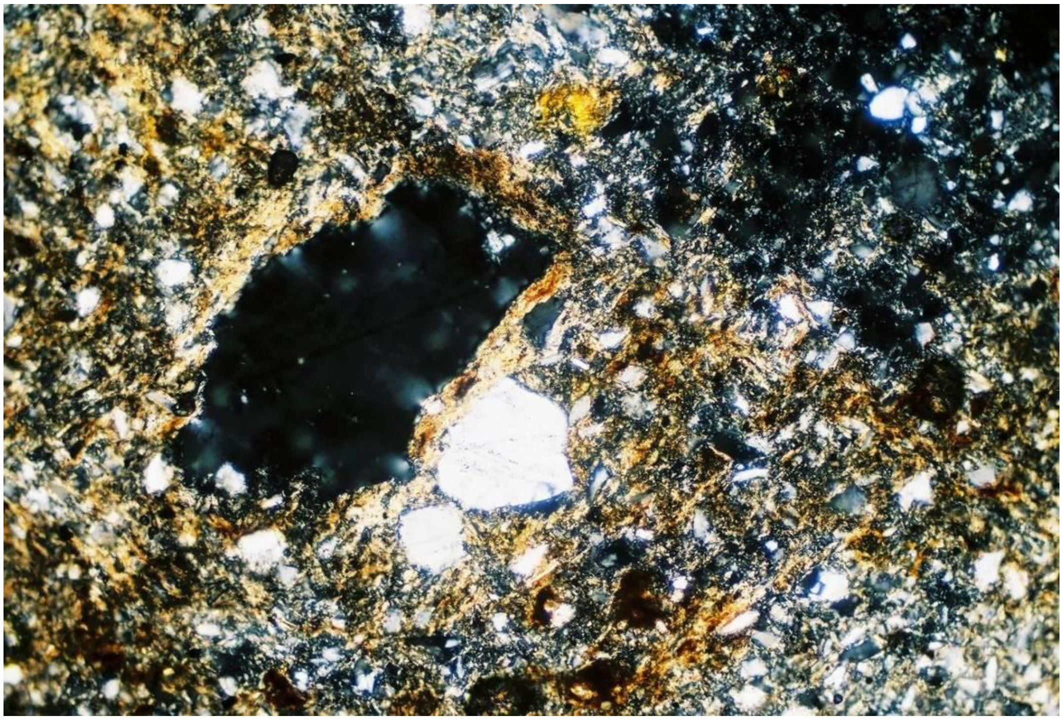

Figure 3.33 - at site 10. Linear plane with thin, stress oriented clay on either side. Crossed-polarized light. Framelength is 1330 μm.

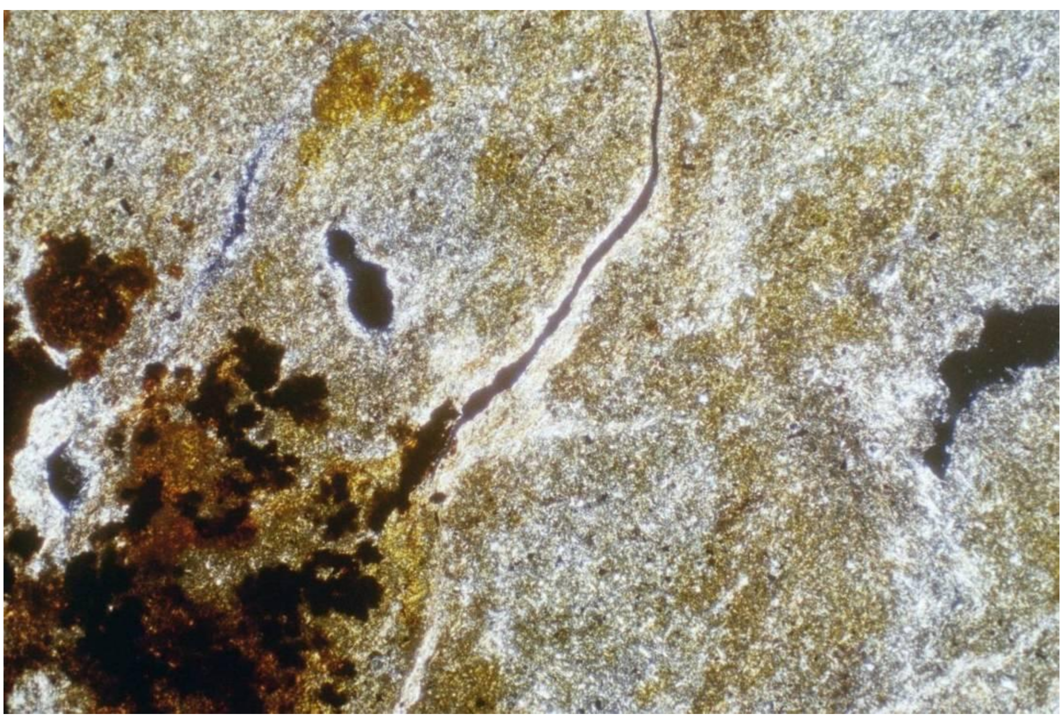

Table 3.1 - Selected Physical and Chemical Properties

Horizon	Depth (cm)	Texture	Sand (%)	Clay (%)	FC:TC†	Bulk Density† Oven Dry (g cm^{-3})	COLE†	pH (H_2O)	Total Carbon (%)	CEC† NH4OAc (cmol(+)/kg)
					Site 1 - Bucyrus 09KS139001					
Ap	0-11	SiL	4.4	26.6	0.64	1.26	0.049	7.0	3.77	23.2
A	11-28	SiCL	4.2	30.7	0.64	1.48	0.036	6.4	2.05	22.0
BA	28-46	SiCL	4.0	35.6	0.68	1.39	0.05	6.2	1.64	21.7
Bt1	46-60	SiC	4.2	47.4	0.77	1.68	0.088	6.3	1.18	27.6
Bt2	60-81	SiC	3.5	55.2	0.8	1.85	0.102	6.2	0.78	30.9
Btss1	81-100	SiC	3.3	52.1	0.77	1.83	0.088	6.1	0.30	28.5
2Btss2	100-159	SiC	4.3	51.6	0.76	1.88	0.089	6.4	0.00	29.9
2Btss3	159-186	C	1.7	67.4	0.67	1.6	0.118	6.8	0.00	35.7
2R	186-200	—	—	—	—	—	—	—	—	—
					Site 2 - Woodson 09KS059001					
Ap	0-8	SiL	2.0	23.9	0.68	1.28	0.033	6.2	3.02	21.6
A	8-26	SiL	2.0	24.9	0.69	1.49	0.044	6.3	1.76	20.4
Bt1	26-56	SiC	1.5	47.0	0.77	2	0.126	6.4	1.26	33.5
Bt2	56-84	SiC	1.3	45.9	0.75	1.96	0.103	6.6	0.49	32.3
Btssg	84-117	SiC	2.2	45.1	0.76	1.88	0.103	6.6	0.29	30.9
Btg1	117-148	SiC	4.3	45.9	0.8	1.85	0.082	6.8	0.00	30.3
Btg2	148-166	SiC	5.2	46.1	0.83	1.83	0.096	6.9	0.00	30.5
Btg3	166-200	SiC	4.7	48.1	0.82	1.81	0.108	7.0	0.00	31.4
					Site 3 - Aliceville 09KS121001					
Ap	0-16	SiCL	4.1	32.7	0.65	1.35	0.058	5.8	3.29	25.5
A	16-31	SiCL	3.1	37.1	0.7	1.51	0.054	6.0	1.49	25.0
BA	31-45	SiC	2.9	44.1	0.73	1.56	0.068	6.0	1.56	27.3
Bt1	45-68	SiC	3.9	54.0	0.74	1.82	0.107	6.1	0.92	32.1
Bt2	68-102	SiC	3.9	54.4	0.71	1.88	0.119	6.4	0.17	33.0
Btss	102-140	C	5.1	58.6	0.59	1.84	0.121	6.8	0.04	38.1
R	140-200	—	—	—	—	—	—	—	—	—
					Site 4 - Summit 09KS207001					
Ap	0-18	SiCL	4.9	35.3	0.68	1.33	0.079	6.0	4.95	31.4
A	18-29	SiCL	5.3	36.2	0.7	1.54	0.072	6.2	2.66	29.2
Bt1	29-53	SiC	3.6	54.4	0.77	1.85	0.131	6.4	1.52	37.8
Bt2	53-103	C	2.6	59.6	0.75	1.82	0.127	6.7	0.62	39.2
2Btss1	103-135	C	4.5	58.0	0.33	1.89	0.107	7.0	0.60	35.3
2Btss2	135-177	SiC	5.4	49.1	0.53	1.82	0.088	7.4	0.32	36.7
3Btkss	177-210	C	2.3	62.1	0.28	1.92	0.107	7.4	0.00	27.2
					Site 5 - Woodson 73KS001003					
A	0-20	SiL	2.2	25.2	0.6	1.42	0.033	5.9	2.49	20.7
Bt1	20-32	SiC	1.2	46.1	0.78	1.76	0.103	5.2	1.5	33.0
Bt2	32-49	SiC	0.7	56.3	0.79	1.9	0.138	5.4	1.27	39.6
Bt3	49-80	SiC	1.0	52.5	0.76	1.87	0.099	5.6	0.96	36.7
Bt4	80-97	SiC	3.0	45.5	0.76	—	—	5.3	0.48	31.2
Bt5	97-133	SiC	2.9	45.9	0.77	1.79	0.075	5.7	0.2	32.2
Bt6	133-159	SiC	2.9	47.8	0.77	1.77	0.087	6.3	0.15	34.1
Bt7	159-188	SiC	3.5	49.1	0.69	—	—	6.6	0.14	36.3
Bt8	188-228	SiC	4.2	46.2	0.73	1.85	0.097	6.8	0.08	33.7
Bt9	228-318	SiC	3.3	50.6	0.64	—	—	7.2	0.07	37.1

Table 3.1 - Selected Physical and Chemical Properties (Continued)

Horizon	Depth (cm)	Texture	Sand (%)	Clay (%)	FC:TC†	Bulk Density† Oven Dry (g cm^{-3})	COLE†	pH (H_2O)	Total Carbon (%)	CEC† NH4OAc (cmol(+)/kg)
					Site 6 - Zaar 05KS205002					
Ap	0-13	SiC	1.7	46.7	0.72	1.89	0.113	6.9	1.65	35.8
A	13-28	SiC	1.3	56.8	0.65	1.9	0.135	7.4	0.81	40.3
BA	28-56	SiC	1.8	56.1	0.5	1.94	0.143	7.8	0.63	38.5
Bg	56-84	SiC	2.5	53.1	0.32	1.98	0.141	8	0.64	36.2
Bssg1	84-106	SiC	4.7	48.8	0.25	1.96	0.144	8.1	0.78	33.4
Bssg2	106-142	SiC	3.6	46.6	0.19	1.95	0.13	8.2	0.54	36.1
Bssg3	142-163	SiC	3.5	48.4	0.22	1.88	0.122	8.3	0.37	35.8
Bssg4	163-212	SiC	3.3	50.6	0.3	1.88	0.125	7.9	0.24	34.5
					Site 7 - Zaar 97KS205001					
Ap	0-22	SiC	2.7	42.5	0.7	1.77	0.12	6.9	2.33	40.5
BA	22-53	SiC	3.3	44.4	0.71	1.81	0.137	7.3	1.81	40.6
Bss1	53-86	SiC	2.3	55.6	0.67	1.85	0.182	7.4	1.26	47.6
Bss2	86-117	SiC	3.3	54.2	0.44	1.87	0.164	7.8	0.93	45.1
Bkss	117-147	SiC	6.3	50.0	0.38	1.86	0.141	8.2	1.11	42.5
Bss	147-179	SiC	6.4	51.0	0.39	1.83	0.131	8.1		42.1
Cr	179-219	—	—	—	—	—	—	—	—	—
					Site 8 - Kenoma 05KS133003					
Ap	0-17	SiL	6.2	22.1	0.62	1.53	0.018	5.9	2.05	16.7
Bt1	17-38	SiC	3.3	53.3	0.76	1.77	0.117	5.6	1.48	33.4
Bt2	38-71	SiC	2.9	55.0	0.74	1.85	0.125	6	1.31	33.2
2Btg1	71-101	SiC	10.7	43.5	0.46	1.67	0.051	6.4	0.29	19.5
2Btg2	101-128	SiC	11.9	44.2	0.48	1.7	0.051	6.8	0.29	19.8
2Bssg1	128-156	SiC	12.7	44.5	0.47	1.79	0.044	7	0.33	19.8
2Bssg2	156-174	C	11.1	50.4	0.46	1.75	0.057	7.1	0.33	21.3
2BC	174-195	SiC	12.1	43.4	0.32	1.88	0.062	7.3	0.25	19.1
					Site 9 - Parsons 06KS133001					
A	0-18	SiL	4.6	25.0	—	1.2	0.029	5.6	2.28	19.0
E	18-28	SiL	4.9	23.1	—	1.4	0.027	5.6	1.01	12.9
2Btg1	28-55	SiC	2.8	54.4	—	1.78	0.105	5.9	0.71	28.0
2Btg2	55-91	SiC	2.4	50.8	—	1.94	0.112	6.6	0.41	26.7
2Btyg1	91-115	C	5.0	55.8	—	1.83	0.096	6	0.32	27.3
2Btyg2	115-142	C	4.3	61.6	—	1.81	0.111	5.9	0.31	28.9
2Btg3	142-176	C	3.4	65.1	—	1.82	0.124	6	0.26	31.3
3Btg4	176-205	C	4.4	60.0	—	1.87	0.104	6.4	0.23	28.4
					Site 10 - Eram 86KS133005					
Ap	0-16	SiC	10.1	47.2	—	1.64	0.076	6.7	3.87	35.6
Bt1	16-28	C	9.4	53.9	—	1.65	0.074	7	1.55	33.6
Bt2	28-43	C	7.7	54.5	—	1.71	0.065	7.1	1.06	29.7
Bt3	43-65	SiC	8.7	50.7	—	1.77	0.06	7.2	0.97	26.0
BC	65-91	SiC	6.1	50.2	—	1.86	0.051	7.4	0.76	23.4
Cr	91+	SiC	10.5	41.2	—	—	—	8	0.59	19.6

† Analysis by National Soil Survey Laboratory

CHAPTER 4 - Potassium Fixation Potential of Vertic Soils in the Cherokee Prairies Major Land Resource Area of Kansas

4.1 Abstract

Certain clay minerals have the ability to fix potassium (K) within their interlayers making the K unavailable for plant uptake. This process of K fixation can influence the effectiveness of K fertilizers and has been suspected to be a factor causing K deficiencies in row crops in southeastern Kansas. Therefore, the objectives of this study were to measure K fixation in high clay, vertic soils of this region and to relate the K fixation results to the soils' clay mineralogy. Ten pedons from around the region were sampled by horizon, and morphology was described in the field. Laboratory analyses were conducted including particle size distribution, pH, cation exchange capacity (CEC), and NH_4OAc-extractable K. Clay minerals in the < 2 mm fraction were identified, and their percent abundances were estimated by X-ray diffraction (XRD). A K fixation test using a 1 hour incubation period was used to measure K fixation potential in all samples. All soils had high clay contents and CEC values in the argillic subsurface horizons. NH_4OAc-extractable K varied widely from 78 to 469 mg kg^{-1}. Clay mineralogy for sites 2, 5, 6, and 7 was dominated by smectite while sites 1, 4, 8, 9, and 10 exhibited a more mixed mineralogy including vermiculite, which is a K-fixing mineral. K fixation occurred in clayey subsoil horizons at sites 3, 4, 6, 8, 9, and 10, and K fixation values ranged from -441 to 413 mg kg^{-1}. Positive values show K being fixed, and negative values show K being released. The occurrence of fixation generally corresponded to the presence of vermiculite. The presence of K fixing minerals other than vermiculite is verified by positive K fixation values at site 6 which does not contain vermiculite. High-charge smectite with tetrahedral substitution is hypothesized to contribute to K fixation. In addition to limited quantities of K fixing clay minerals, naturally high K levels limited the amount of K fixation in this study and caused the release of soil K in many soil horizons.

4.2 Introduction

Historically, soils in the state of Kansas as a whole have demonstrated relatively high levels of potassium (K) in soil tests. In recent years however, K deficiencies in row crops in the southeastern region of Kansas have become much more common and at times have proven unresponsive to K fertilizer. Environmental conditions at time of sampling are thought to influence the plant available K soil test results, which in turn influences fertilizer recommendations. K fixation by soil minerals has been speculated to be one of the possible causes of these deficiencies. Furthermore, K fixation can influence the effectiveness of fertilizers in the soil. Plant availability of K in soils is strongly influenced by the presence of K-fixing clay minerals. Vermiculite and hydrous mica are known to be the main minerals contributing to this fixation (Murashkina et al., 2007b). Their ability to fix K has been attributed to the location of the primary site of isomorphous substitution in the tetrahedral sheet. This places the source of negative charge in close proximity with positively charged K ions in the interlayers. Therefore, the electrostatic forces of attraction exceed forces of hydration causing interlayer cations to be retained (Bouabid et al., 1991; Kittrick, 1966). Smectites, on the other hand, have most of the negative charge in the octahedral sheet, and less fixation of K occurs.

Smectites with a high layer charge have also been found to be responsible for K fixation (Weir, 1965; Singh and Heffernan, 2002). These high-charge smectites are transitional to vermiculites in the clay mica-vermiculite-smectite weathering sequence and are thought have inherited characteristics of mica including a negative charge in the tetrahedral sheet (Ransom et al., 1988; Robert, 1973; Badraoui et al., 1987; Borchardt, 1989). Chen et al. (1989) and Badraoui and Bloom (1990) also found the charge in these high charge smectites to be distributed between both the tetrahedral and octahedral sheets with the majority of the layer charge coming from the tetrahedral sheet. These high-charge smectites have been reported in Vertisols all over the world (Badraoui and Bloom, 1990; Buhmann and Schoeman, 1995; Righi et al., 1998; Singh and Heffernan, 2002; Coulombe et al., 1996). In studies related to K fixation and the estimation of vermiculite content in San Joaquin Valley soils of California, Murashkina et al. (2007a and 2008) speculated that K-fixation in some smectite dominated soils may be due to high-charge smectites. Dowdy et al. (1963) found vermiculite to be responsible for K fixation at soil moisture levels above 4 percent while below this level, smectite was associated with fixation. They also found clay mica (illite) to be the main source of K release upon drying.

Given the clayey nature of the soils in southeastern Kansas, along with the known existence of clay mica, vermiculite, and smectite in this region, it is possible that K fertilizers are being fixed, resulting in K deficiencies in crops. Therefore, the objectives of this study were to measure K fixation in high clay, vertic soils of this region and to relate the K fixation results to the soils' clay mineralogy.

4.3 Materials and Methods

4.3.1 Sampling

As part of a larger study on soil genesis and mineralogy, ten pedons were selected for use in this study. The soils are all developed in colluvium, alluvium, and/or residuum derived from weathered Pennsylvanian and Permian age limestone and shale. In this region, a thin layer of loess can often be found capping the most stable landscape positions as well. Four pedons were sampled through the spring and summer of 2009. These pedons include: Site 1 Bucyrus 09KS139001, Site 2 Woodson 09KS059001, Site 3 Aliceville 09KS121001, and Site 4 Summit 09KS207001. The remaining six pedons were sampled and described by Natural Resource Conservation Service (NRCS) soil scientists prior to the beginning of this study. These pedons include: Site 5 Woodson 73KS001003, Site 6 Zaar 05KS205002, Site 7 Zaar 97KS205001, Site 8 Kenoma 05KS133003, Site 9 Parsons 06KS133001, and Site 10 Eram 86KS133005. Soil samples were retrieved from the NRCS National Soil Survey Laboratory archive in Lincoln, Nebraska, for additional laboratory analysis. All pedons were sampled by excavating to a depth of one to two meters with a backhoe. Pedons were described using the Field Book for Describing and Sampling Soils (Schoenenberger et al., 2002). For each horizon, bulk samples were taken for laboratory characterization, oriented clods were collected for thin section preparation, and un-oriented clods were sampled and coated in Saran for bulk density measurement.

4.3.2 Laboratory Characterization

Bulk samples were allowed to air dry and then were ground with a wooden rolling pin and passed through a No. 10 sieve with 2 mm square openings. Soil pH was determined in a 1:1 soil to water suspension as well as a 1:2 soil to 0.1 M $CaCl_2$ solution ratio using methods 4C1a2a1a1 and 4C1a2a2a1, respectfully, of the Soil Survey Laboratory Methods Manual (Soil Survey Laboratory Staff, 2004). Particle size distribution was determined using a modification of the pipet method of Kilmer and Alexander (1949) and method 3A1 form the Soil Survey Laboratory Methods Manual (Soil Survey Laboratory Staff, 2004). Organic matter was removed prior to particle size analysis from samples containing greater than 1.7% total C with 30% hydrogen peroxide. At the National Soil Survey Laboratory, K^+, Ca^{2+}, $Mg2^+$, and Na^+ cations were extracted with 1 mol L^{-1} NH_4OAc (pH 7), and cation exchange capacity (CEC) was determined by the NH_4OAc extraction method (Soil Survey Laboratory Staff, 2004).

4.3.3 Mineralogy

Mineralogy of the total clay (<2 mm) fraction was analyzed for selected horizons by the methods of Jackson (1975). Forty gram samples of the less than 2 mm air dry fraction were pretreated with 1 M NaOAc and 30% hydrogen peroxide to remove carbonates and organic matter, respectively. The samples were dispersed and passed through a 300 mesh sieve (50 µm openings) where the sand was collected. The silt and clay fractions were separated through a series of eight sedimentation cycles where Stokes' law was used to calculate sedimentation times for a ten cm depth of fall (Jackson, 1975). The clay fraction was flocculated with $MgCl_2$, quick-frozen in a bath of dry ice and ethanol, and then water was removed through freeze drying. The silt fraction was oven dried to a powder.

Six clay treatments were prepared for each sample: Mg 25°C, Mg-Ethylene Glycol (Mg-EG), Mg-Glycerol (Mg-GLY), K 25°C, K 350°C, and K 550°C. Solutions containing 30 mg of clay for each treatment were pipetted onto a glass slide and allowed to dry to provide a parallel oriented mount.

A Phillips XRG-3100 generator and an APD X-ray diffractometer were used to analyze all samples. The instrument was equipped with a Theta compensating slit, and a monochromatic X-ray beam was obtained using a graphite monochromator. The instrument was operated with VisualXRD software (GBC Scientific Equipment Pty. Ltd., Victoria, Australia). Instrument operating conditions were as follows:

Target:	Cu
Radiation:	CuKα
Potential:	35 kV
Current:	20 mA
Detector:	Scintillation
Step Size:	0.02°2θ
Time/Step:	0.6 seconds

The clay slides were scanned from 2°2θ to 34°2θ for the Mg 25°C treatment and from 2°2θ to 15°2θ for the other five treatments. Mineral peaks were identified by their d-spacing, and relative abundance of each clay mineral was estimated using peak intensities.

4.3.4 Potassium Fixation

Potassium fixation potential was determined for all samples using a method from Murashkina et al. (2007a), which is a modified method of Cassman et al. (1990). The Cassman K fixation test uses a 7 day incubation period and requires daily shaking for 45 minutes. This extended time period limits its usefulness as a routine laboratory procedure implemented in commercial soil testing laboratories used for soil fertility studies. The Murashkina K fixation test is based on the same principles as the Cassman method but uses a 1 hour incubation time. Murashkina (2007a) reported high correlation between the results of their modified method and that of the Cassman method ($R^2 = 0.95$, $P < 0.0001$). They also reported that the 1 hour test recovered about 73 percent of the values from the Cassman 7 day procedure. The study cites many other sources that show that K fixation is a rapid process (Stanford and Pierre, 1946; Sparks et al., 1980; Olk, 1995). The researchers concluded that the 1 hour test was a reliable method for predicting K fixation potential that is rapid enough for use in commercial soil testing laboratories.

Five gram samples of less than 2 mm air dried soil were placed in duplicate into 50 mL centrifuge tubes along with 15 mL of 2 mmol L^{-1} KCl solution and shaken for one hour. Five mL of 4 mol L^{-1} NH_4Cl were added, and the samples were shaken for an additional 30 minutes. Samples were centrifuged at 1500 rpm for 5 minutes. Then solutions were filtered through Whatman #40 filter paper. A 1:10 dilution was prepared for each sample, and K was measured using a Varian model 720-ES inductively coupled plasma optical emission spectrometer. The amount of K^+ not displaced by $NH4^+$ was considered fixed and was calculated as the difference between the initial K added and the extracted K.

In a follow-up study, Murashkina et al. (2007b) analyzed X-ray diffraction (XRD) patterns of Mg saturated silt before and after the K fixation procedure. Results showed an intensity decrease of the 14Å vermiculite peak and 12Å hydrobiotite peak and an increase in the 10Å clay mica peak. This verifies that K was fixed in the vermiculite interlayers causing the interlayer spacing to collapse from 14Å and 12Å to 10Å (Murashkina et al., 2007b).

4.4 Results and Discussion

4.4.1 Soil Physical and Chemical Properties

Predominant pedogenic features generally included dark mollic epipedons, argillic horizons, and, in some pedons, slickensides. Table 4.1 gives information on site and pedon characteristics as well as soil classification. Clay content increases associated with argillic subsurface horizons were observed at all but sites 6 and 7 (Table 4.2). Most soils with argillic horizons had silt loam or silty clay loam textures at the surface, and all pedons featured silty clay or clay textures in the argillic horizon. Sites 6, 7, and 10 had high clay contents throughout the profile and showed only subtle clay increases from the surface to the subsoil. It is thought that vertic processes and pedoturbation are great enough at site 6 and 7 to counteract clay illuviation and the development of an argillic hoizon. Overall, clay content generally increased or remained relatively constant with depth. The silt fraction made up the majority of the remainder of the particle size distribution while sand content for all soils was minimal, generally less than 10 percent.

The pH values ranged from 5.2 to 8.3. Sites 6, 7, and 10 exhibited the highest pH values (6.7 to 8.3) which increased with depth. Most other pH values were in the pH 6 to 7 range. CEC values reflected the high total clay contents and were relatively high and increased with depth. They varied from 16.7 cmol kg^{-1} in the Ap horizon at site 8 to 47.6 cmol kg^{-1} in the Bss1 horizon at site 7. Calcium was the dominant NH_4OAc-extractable cation in all soils. NH_4OAc-extractable K varied widely from 78 to 469 mg kg^{-1} (Table 4.2). Extractable K values are much higher and are spread over a much wider range than those of the alluvial San Joaquin Valley soils used to test the 1 hour K fixation test in Murashkina et al. (2007a). In Kansas, the critical value for extractable K used to base fertilizer recommendations on is 130 mg K^+ kg^{-1} (Leikam et al., 2003). Therefore, the majority of extractable K values are over the critical value including the A horizons at all but sites 2, 3, and 5 (Fig. 4.4). It is recommended for future soil fertility K fixation studies in Kansas that sampling sites be carefully selected from fields exhibiting K deficiencies or having NH_4OAc-extractable K values below the critical value.

4.4.2 K Fixation Potential and Clay Mineralogy

K fixation values ranged from -441 to 413 mg kg^{-1} (Table 4.2). Positive values show that K was fixed making it non-extractable by the NH_4Cl; thus, less than the initial amount of added K was accounted for in the extracted K. Negative values show that K release exceeded K fixation, or more K was extracted than initially added. This additional extracted K is assumed to have been released from cation exchange sites.

Figure 4.1 compares semi-quantitative clay mineralogy to K fixation for each pedon (mineralogy of pedon 09KS121001 at site 3 was not determined). Clay mineralogy results revealed sites 2, 5, 6, and 7 to be dominated by smectite. Sites 1, 4, 8, 9, and 10, exhibit a more mixed mineralogy, though smectite still plays a major role in many of the horizons. Vermiculite was only identified at these five sites with the more mixed mineralogy. K was fixed at six of the 10 pedons (sites 3, 4, 6, 8, 9, and 10). K fixation generally corresponds to where vermiculite was present; however, K fixation values were negative throughout the pedon at site 1. Also, no vermiculite was identified in the clay fraction at site 6 despite the fact that K was fixed in the lower half of the pedon. K fixation values up to 187 mg K^+ kg^{-1} (32 percent of added K) were present at site 6. Other potential K fixing minerals present at site 6 include weathered clay mica and possibly high-charge smectites. Murashkina et al. (2007a) found K fixation occurring in horizons with no evidence of vermiculite. They also suggested that fixation in this case may be due to high-charge smectites.

Site 10 fixed the most K with values up to 341 mg K^+ kg^{-1} in its bottom horizon, which accounted for 56 percent of added K. The clay mineralogy of the soil at site 10 proved to be very different from all the other soils. Much of the profile at site 10 is residuum derived from weathered shale thought to be one of the lower members of the Kansas City Group. It is hypothesized that the vastly different mineralogy found at this site is inherited from the geologic material found locally at the surface. Site 10 was estimated to have the highest kaolinite content of about 50 percent throughout and the lowest smectite content at 10 percent throughout. Abundant vermiculite was present as X-ray diffraction (XRD) patterns showed relatively large 14Å peaks (Mg-25°C) that persisted after treatment with ethylene glycol (Mg-EG) and glycerol (Mg-GLY) in the lower horizons at sites 4 and 10 (Fig. 4.2 and 4.3). Figures 4.2 and 4.3 also show examples of the shoulders or small peaks at about 24Å as well as the presence of broad peaks at 12Å which were only observed in horizons at site 10. These XRD features indicate the presence of a regularly interstratified mica-smectite (RIMS) or a regularly interstratified mica-vermiculite (RIMV) (a distinction between the two was not made) having a regular repeating pattern of interstratified layers of mica and either smectite or vermiculite. This mineral was identified in horizons at sites 1, 4, 8, and 10. Several other researchers have found both regularly and randomly interstratified minerals similar to these (Sawhney, 1989; Gunal and Ransom, 2006; Murashkina et al., 2007b; Fanning et al., 1989; Moore and Reynolds, 1997). Sawhney (1989) termed this mineral hydobiotite. Murashkina et al. (2007b) found hydrobiotite to be very common in the silt fractions of soils derived from granitic alluvium of the San Joaquin Valley, California, and attributed K fixation in these soils to both hydrobiotite and vermiculite. It is thought to form as an alteration product of mica weathering involving the replacement of K by Mg or Ca in alternate interlayer zones (Sawhney, 1989).

The broad peaks found between 10Å and 14Å (~12Å) (Fig. 4.3) that increase in d-spacing upon treatment with ethylene glycol and glycerol in the horizons at site 10 suggest the presence of a randomly interstratified mica-smectite (Sawhney, 1989). However, the distinction between regularly and randomly interstratified minerals was not made in figure 4.1. Randomly interstratified minerals are composed similarly to that described above for regular interstratification; however, the distribution of the different clay mineral layers lacks a regular repeating pattern. Random interstratification of layer silicates in soil clays is much more common than regular interstratification (Sawhney, 1989). It should also be noted that a hydroxyl-interlayered mineral was identified in horizons near the soil surface at sites 2, 4, and 5. This mineral is probably a hydroxy-interlayered smectite (HIS) or vermiculite (HIV) and is evidenced by the broad shoulder on the 10Å peak of the K-25°C treatment that persists when heated to 350°C and 550°C (treatments K-350°C and K-550°C).

The relatively high vermiculite contents, especially at sites 4 and 10, correspond to high K fixation values. No K fixation occurred at sites 1, 2, 5, and 7, and site 5 actually released the most K (-79 to -303 mg K^+ kg^{-1}). K release is associated with high NH_4OAc-extractable K levels. Depth weighted average K fixation for sites 1 through 10 were calculated and are presented in mg K^+ kg^{-1}: (1) -133, (2) -130, (3) -141, (4) 78, (5) -175, (6) 47, (7) -142, (8) 27, (9) -40, and (10) 139. Therefore, sites 4, 6, 8, and 10 were the only pedons which fixed more K than they released.

With all pedons represented, K fixation occurred over a wide range of NH_4OAc-extractable K (78 to 274 mg kg^{-1}) (Fig. 4.4). However, only two horizons with NH_4OAc-extractable K values over 200 mg kg^{-1} expressed positive K fixation. Both of these horizons were at site 6. When excluding these two site 6 horizons, K fixation occurred over an NH_4OAc-extractable K range of 78 to 195 mg kg^{-1}. Dowdy et al. (1963) found K levels to exist in equilibrium where soils high in exchangeable K fixed K while soils with low exchangeable K released K. Results of this study do not agree with these findings as there was a weak negative correlation between K fixation and NH_4OAc-extractable K (R^2 = 0.106) (Fig. 4.4). The variability in K fixation is attributed to variations in mineralogy between and within pedons. K fixation was also graphed against clay content but no correlation was present due to variations in clay mineralogy (R^2 = 0.022). Therefore, in addition to limited quantities of K fixing clay minerals, naturally high K levels limited the amount of K fixation in this study.

4.5 Conclusions

The 1 hour K fixation method proved to be a reliable and rapid test for measuring relative K fixation potential. For the studied soils, no K fixation occurred in surface horizons, thus K fixation potential is considered very low. K fixation did occur in clayey subsurface horizons in soils exhibiting a more mixed mineralogy. This fixation generally corresponds to the presence of vermiculite. The presence of K fixing minerals other than vermiculite is verified by positive K fixation values at site 6 which does not contain vermiculite. High-charge smectite with tetrahedral substitution is hypothesized to contribute to K fixation. Naturally high K levels in these soils limited the amount of K fixation in this study and caused the release of K. K fixation is influenced by several factors not considered in this study such as soil moisture (Olk et al., 1995). Future studies are needed to investigate these other factors influencing the retention and release of K and the spatial distribution of K fixing soils in southeast Kansas.

4.6 References

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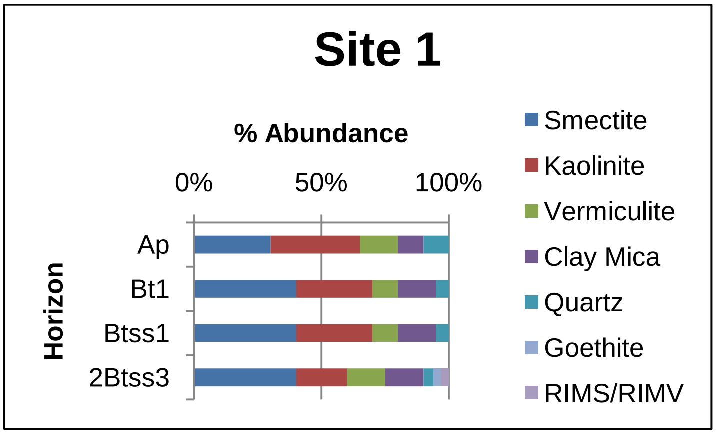
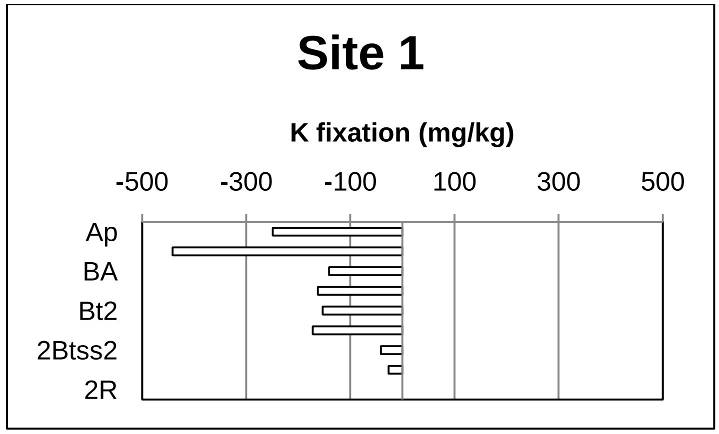
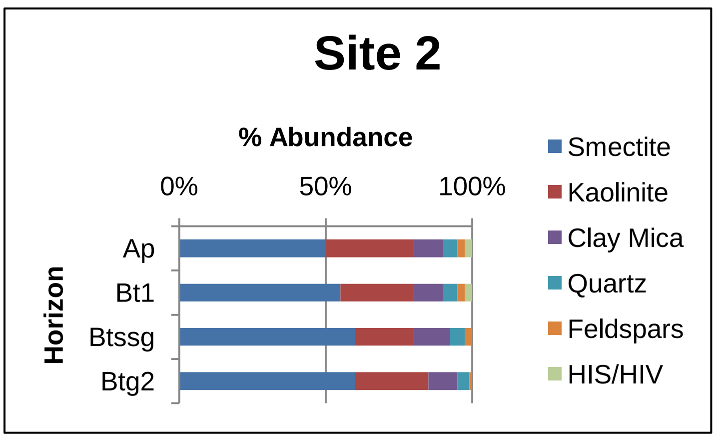
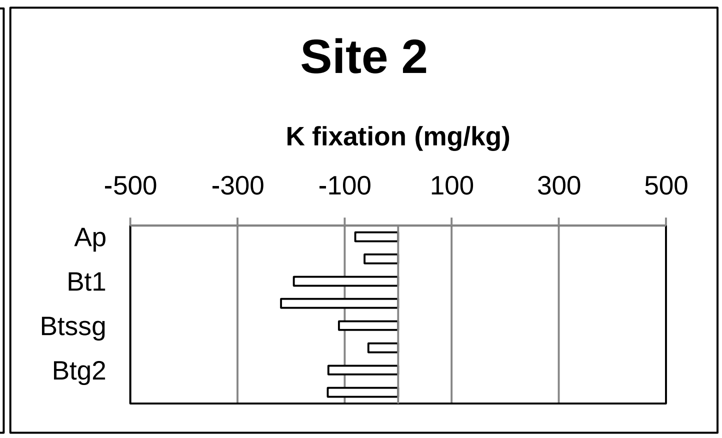
4.7 Figures and Tables

Figure 4.1 - Comparison of semi-quantitative clay mineralogy and K fixation for sites 1 through 10. (Clay mineralogy for site 3 was not determined.)









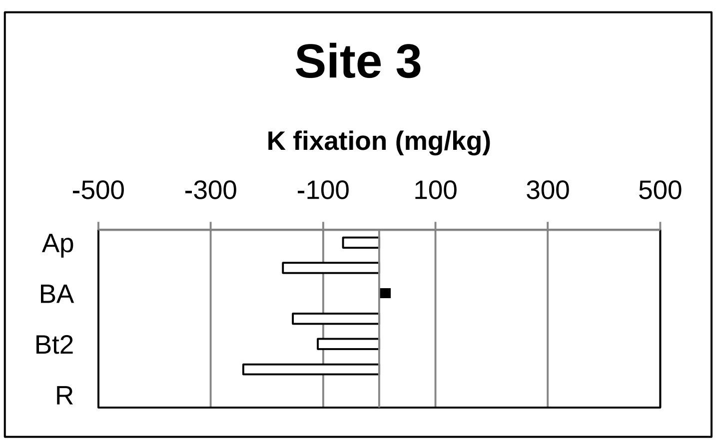


Figure 4.1 - (Continued)

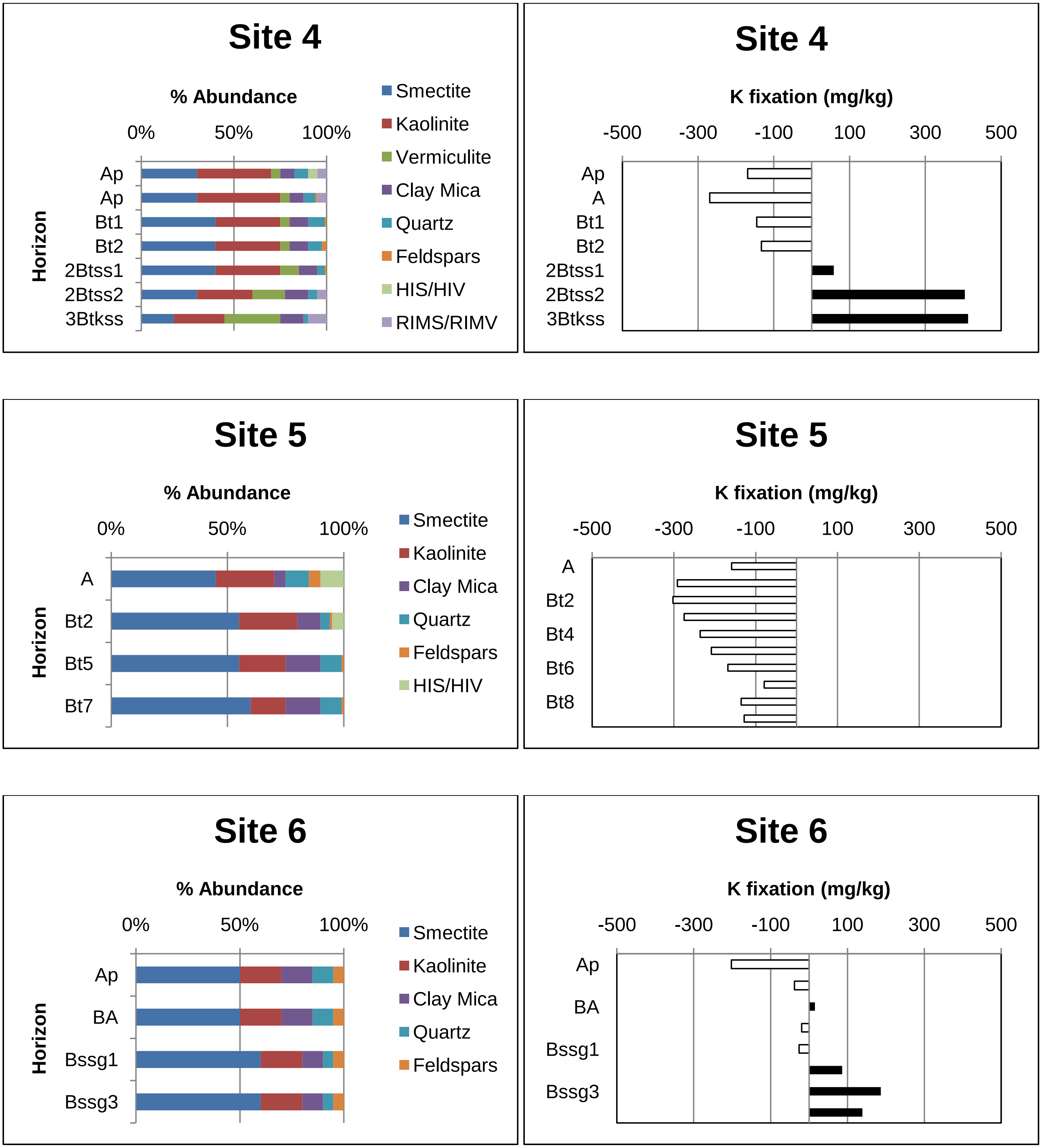


Figure 4.1 - (Continued)

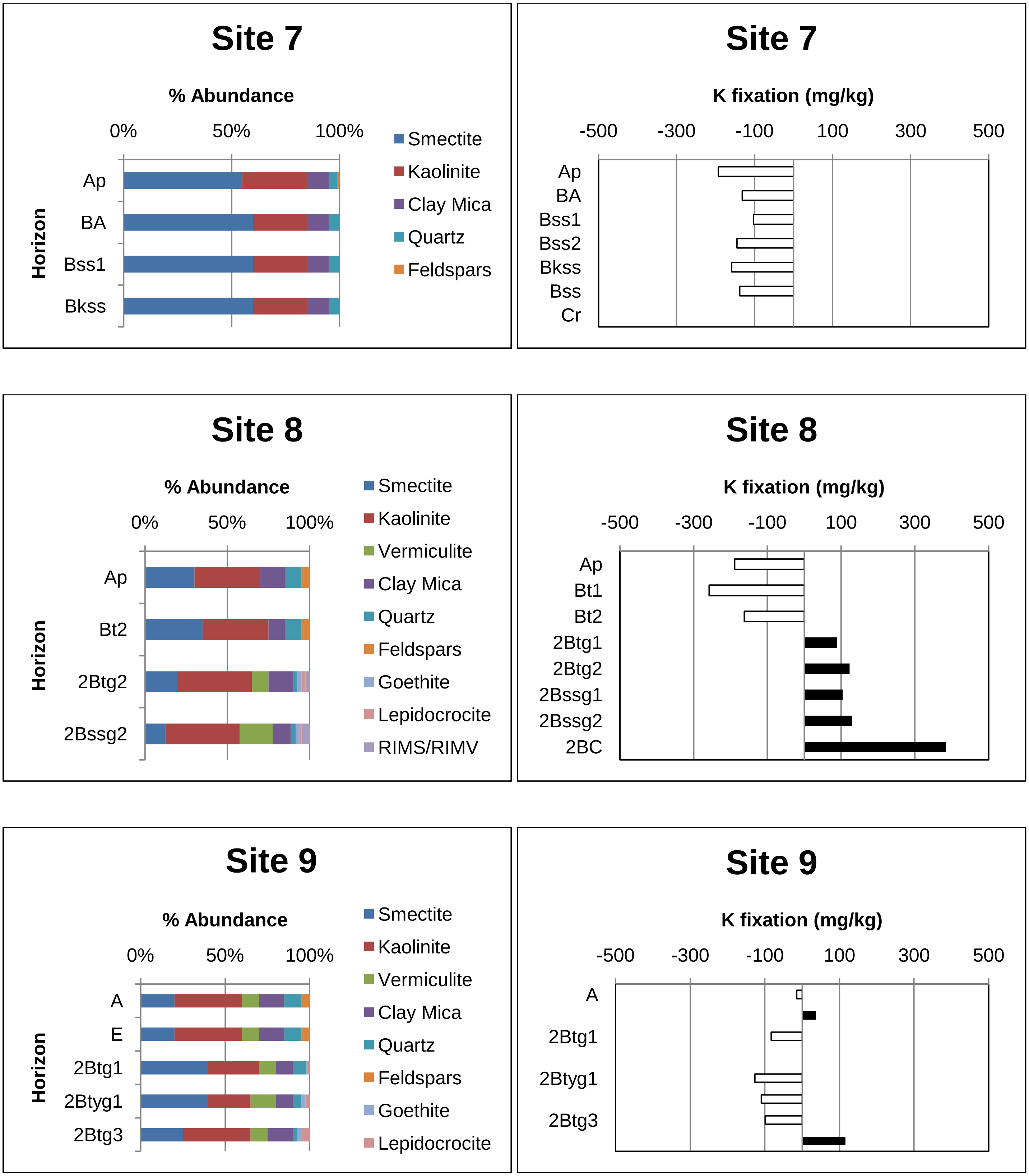
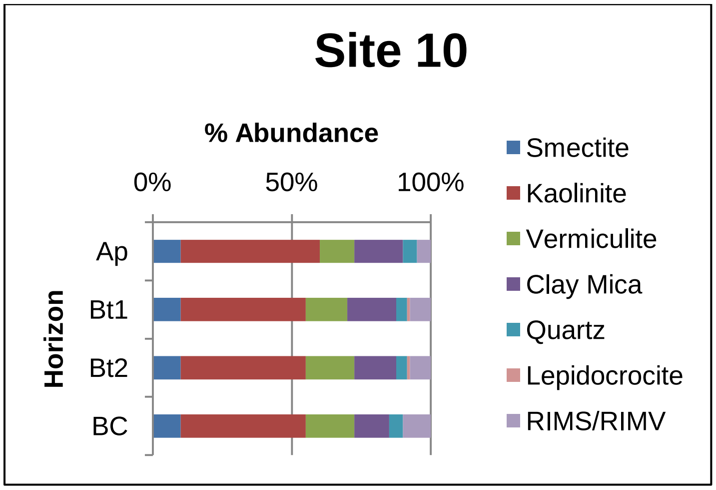


Figure 4.1 - (Continued)



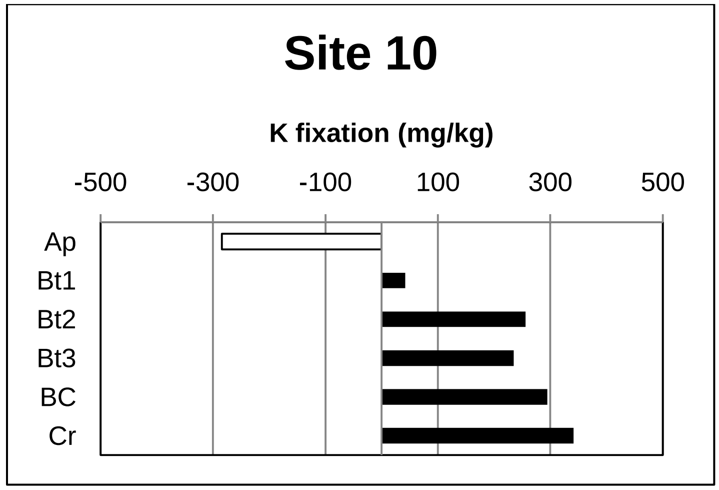


Figure 4.2 - X-ray diffraction pattern of the 3Btkss horizon at site 4. Mg-25°C, Mg-EG, and Mg-GLY treatments. The 14Å peak does not shift to 18Å when treated with ethylene glycol or glycerol showing that the interlayers are not expanding. This is diagnostic of vermiculite. The peak at ~24Å indicates a regularly interstratified mica-smectite or mica-vermiculite.

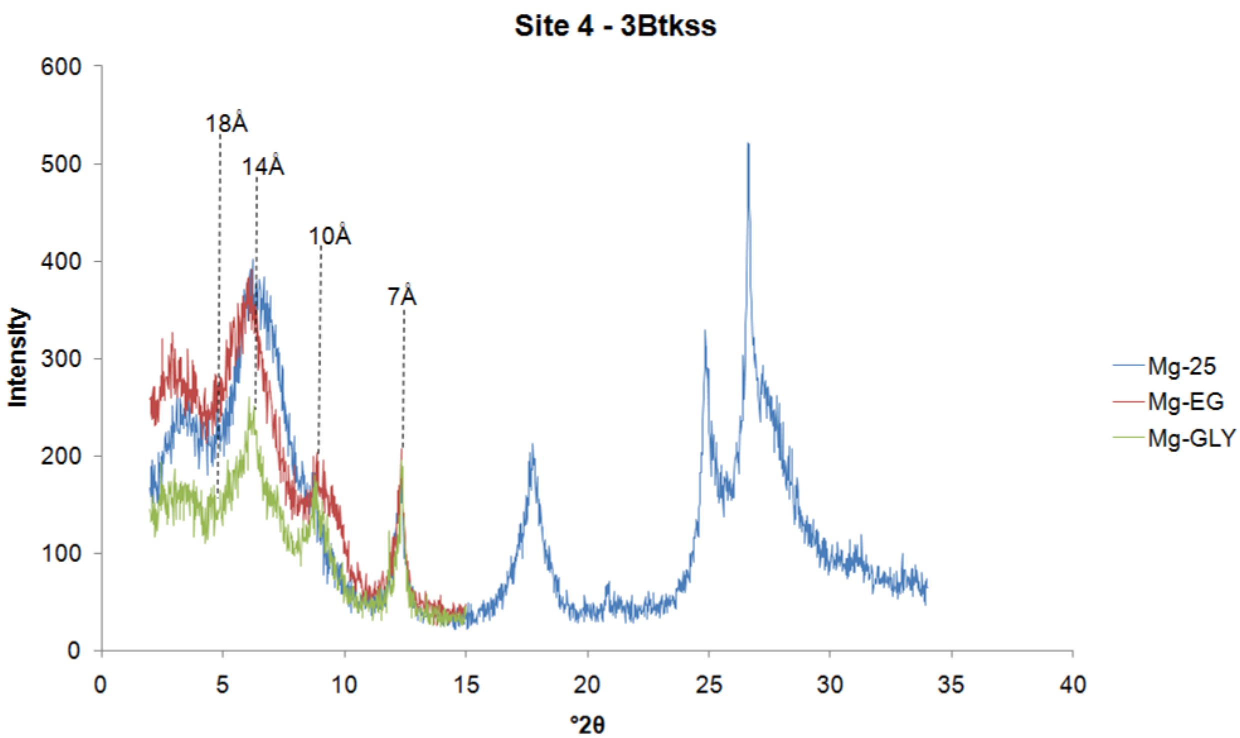


Figure 4.3 - X-ray diffraction pattern of the BC horizon at site 10. Mg-25°C, Mg-EG, and Mg-GLY treatments. The 14Å peak does not shift to 18Å when treated with ethylene glycol or glycerol showing that the interlayers are not expanding. This is diagnostic of vermiculite. The peak at ~24Å indicates a regularly interstratified mica-smectite or mica-vermiculite. The broad peak between 10Å and 14Å, whose d-spacing increases with the ethylene glycol and glycerol treatments, indicates a randomly interstratified mica-smectite.

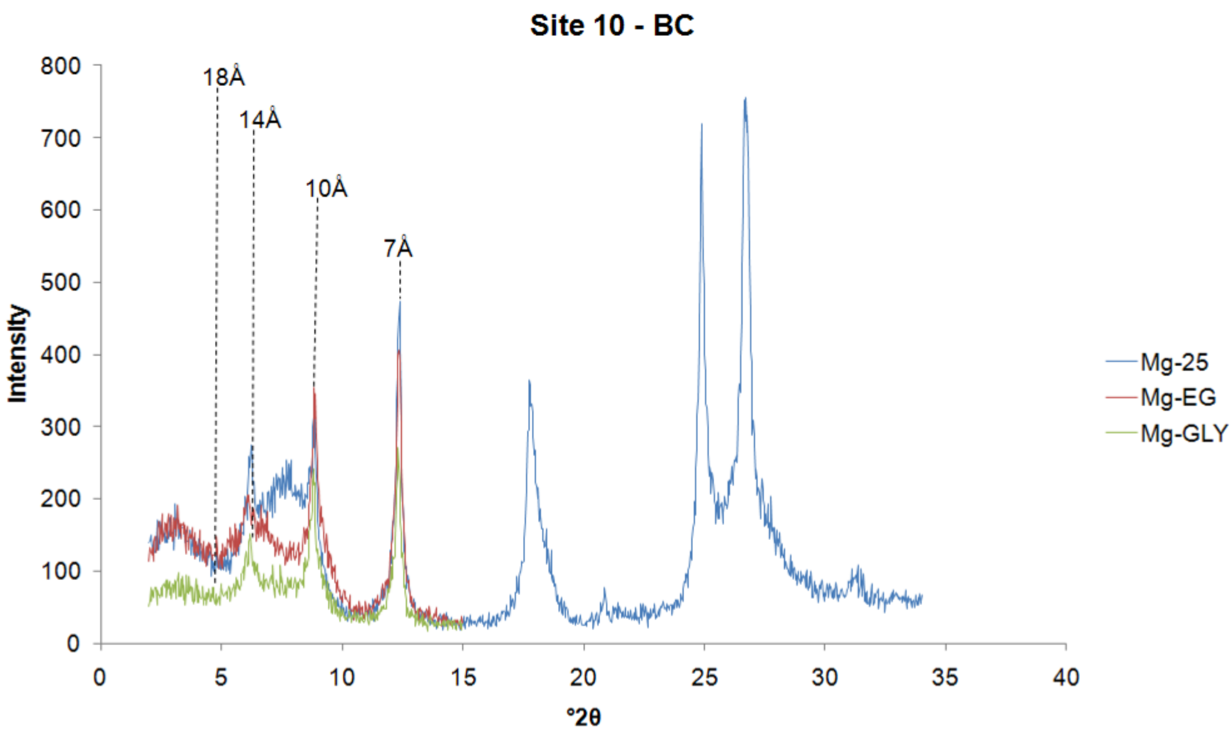


Figure 4.4 - Relationship between K fixation potential and NH_4OAc-extractable K.

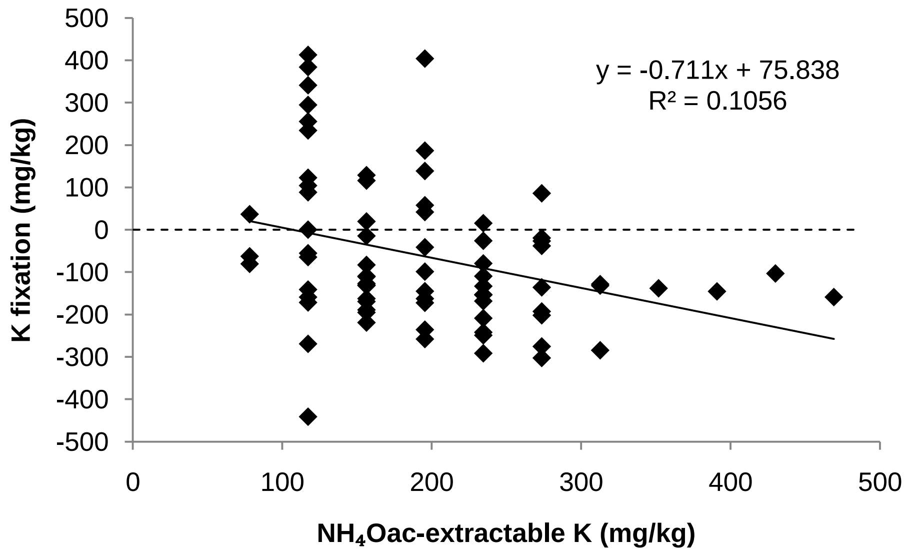


Table 4.1 - Site characteristics and soil classification.

Site	Soil Series	Pedon No.	County	Elevation (m)	Topographic Position	Slope (%)	Drainage Class	Vegetation	Parent Material	Classification
1	Bucyrus	09KS139001	Osage	308	backslope of interfluve on plains	4	moderately well	grass/herbaceous cover	colluvium over residuum weathered from cherty limestone	Fine, smectitic, thermic Oxyaquic Vertic Argiudoll
2	Woodson	09KS059001	Franklin	296	shoulder of crest of interfluve on plains	1	somewhat poorly	grass/herbaceous cover	loess over alluvium/residuum weathered from shale	Fine, smectitic, thermic Vertic Argiaquoll
3	Aliceville	09KS121001	Miami	290	summit of interfluve on plains	2	moderately well	grass/herbaceous cover	loess over residuum weathered from limestone	Fine, mixed, active, thermic Oxyaquic Vertic Argiudoll
4	Summit	09KS207001	Woodson	341	backslope of interfluve on plains	4	somewhat poorly	grass/herbaceous cover	loess over colluvium over residuum	Fine, smectitic, thermic Aquertic Argiudoll
5	Woodson	73KS001003	Allen	—	upland summit or shoulder	1	somewhat poorly	grass/herbaceous cover	loess over clayey alluvium	Fine, smectitic, thermic Vertic Argiaquoll
6	Zaar	05KS205002	Wilson	265	broad paleoterrace summit or shoulder	0.2	somewhat poorly	row crop	clayey alluvium	Fine, smectitic, thermic Aeric Endoaquert
7	Zaar	97KS205001	Wilson	216	footslope	1	somewhat poorly	row crop	clayey alluvium over residuum weathered from shale and limestone	Fine, smectitic, thermic Typic Epiaquert
8	Kenoma	05KS133003	Neosho	294	toeslope of broad paleoterrace	0.5	moderately well	row crop	loess over alluvium over residuum weathered from shale	Fine, mixed, superactive, thermic Vertic Argiaquoll
9	Parsons	06KS133001	Neosho	296	shoulder of paleoterrace on alluvial plain	1	somewhat poorly	grass/herbaceous cover	loess over alluvium over residuum weathered from shale	Fine, smectitic, thermic Vertic Albaqualf
10	Eram	86KS133005	Neosho	—	backslope of upland	4	moderately well	grass/herbaceous cover	colluvium over residuum weathered from shale	Fine, mixed, active, thermic Aquic Argiudoll

Table 4.2 - Physical and chemical properties.

Horizon	Depth (cm)	Texture	Sand (%)	Clay (%)	pH (H_2O)	CEC NH_4OAc (cmol(+)/kg)	Extractable K NH_4OAc (mg K/kg)	K Fixation (mg K/kg)	% Fixation †
					Site 1 - Bucyrus 09KS139001				
Ap	0-11	SiL	4.4	26.6	7.0	23.2	235	-249	-43
A	11-28	SiCL	4.2	30.7	6.4	22.0	117	-441	-76
BA	28-46	SiCL	4.0	35.6	6.2	21.7	117	-141	-24
Bt1	46-60	SiC	4.2	47.4	6.3	27.6	156	-162	-28
Bt2	60-81	SiC	3.5	55.2	6.2	30.9	235	-153	-26
Btss1	81-100	SiC	3.3	52.1	6.1	28.5	195	-172	-30
2Btss2	100-159	SiC	4.3	51.6	6.4	29.9	195	-41	-7
2Btss3	159-186	C	1.7	67.4	6.8	35.7	274	-26	-4
2R	186-200	—	—	—	—	—	—	—	—
					Site 2 - Woodson 09KS059001				
Ap	0-8	SiL	2.0	23.9	6.2	21.6	78	-80	-13
A	8-26	SiL	2.0	24.9	6.3	20.4	78	-63	-10
Bt1	26-56	SiC	1.5	47.0	6.4	33.5	156	-195	-32
Bt2	56-84	SiC	1.3	45.9	6.6	32.3	156	-219	-36
Btssg	84-117	SiC	2.2	45.1	6.6	30.9	156	-111	-18
Btg1	117-148	SiC	4.3	45.9	6.8	30.3	117	-55	-9
Btg2	148-166	SiC	5.2	46.1	6.9	30.5	156	-130	-21
Btg3	166-200	SiC	4.7	48.1	7.0	31.4	156	-132	-22
					Site 3 - Aliceville 09KS121001				
Ap	0-16	SiCL	4.1	32.7	5.8	25.5	117	-64	-12
A	16-31	SiCL	3.1	37.1	6.0	25.0	117	-171	-31
BA	31-45	SiC	2.9	44.1	6.0	27.3	156	20	4
Bt1	45-68	SiC	3.9	54.0	6.1	32.1	235	-154	-28
Bt2	68-102	SiC	3.9	54.4	6.4	33.0	235	-110	-19
Btss	102-140	C	5.1	58.6	6.8	38.1	235	-242	-42
R	140-200	—	—	—	—	—	—	—	—
					Site 4 - Summit 09KS207001				
Ap	0-18	SiCL	4.9	35.3	6.0	31.4	156	-169	-29
A	18-29	SiCL	5.3	36.2	6.2	29.2	117	-269	-46
Bt1	29-53	SiC	3.6	54.4	6.4	37.8	195	-145	-25
Bt2	53-103	C	2.6	59.6	6.7	39.2	235	-133	-23
2Btss1	103-135	C	4.5	58.0	7.0	35.3	195	58	10
2Btss2	135-177	SiC	5.4	49.1	7.4	36.7	195	404	69
3Btkss	177-210	C	2.3	62.1	7.4	27.2	117	413	71
					Site 5 - Woodson 73KS001003				
A	0-20	SiL	2.2	25.2	5.9	20.7	117	-159	-29
Bt1	20-32	SiC	1.2	46.1	5.2	33.0	235	-291	-52
Bt2	32-49	SiC	0.7	56.3	5.4	39.6	274	-303	-54
Bt3	49-80	SiC	1.0	52.5	5.6	36.7	274	-275	-49
Bt4	80-97	SiC	3.0	45.5	5.3	31.2	195	-236	-42
Bt5	97-133	SiC	2.9	45.9	5.7	32.2	235	-209	-37
Bt6	133-159	SiC	2.9	47.8	6.3	34.1	235	-168	-30
Bt7	159-188	SiC	3.5	49.1	6.6	36.3	235	-79	-14
Bt8	188-228	SiC	4.2	46.2	6.8	33.7	274	-136	-24
Bt9	228-318	SiC	3.3	50.6	7.2	37.1	313	-128	-23

Table 4.2 - (Continued)

Horizon	Depth (cm)	Texture	Sand (%)	Clay (%)	pH (H_2O)	CEC NH_4OAc (cmol(+)/kg)	Extractable K NH_4OAc (mg K/kg)	K Fixation (mg K/kg)	% Fixation †
				Site 6 - Zaar 05KS205002					
Ap	0-13	SiC	1.7	46.7	6.9	35.8	274	-202	-35
A	13-28	SiC	1.3	56.8	7.4	40.3	274	-38	-6
BA	28-56	SiC	1.8	56.1	7.8	38.5	235	16	3
Bg	56-84	SiC	2.5	53.1	8	36.2	274	-19	-3
Bssg1	84-106	SiC	4.7	48.8	8.1	33.4	235	-26	-4
Bssg2	106-142	SiC	3.6	46.6	8.2	36.1	274	86	15
Bssg3	142-163	SiC	3.5	48.4	8.3	35.8	195	187	32
Bssg4	163-212	SiC	3.3	50.6	7.9	34.5	195	139	24
				Site 7 - Zaar 97KS205001					
Ap	0-22	SiC	2.7	42.5	6.9	40.5	274	-193	-33
BA	22-53	SiC	3.3	44.4	7.3	40.6	313	-132	-23
Bss1	53-86	SiC	2.3	55.6	7.4	47.6	430	-103	-18
Bss2	86-117	SiC	3.3	54.2	7.8	45.1	391	-145	-25
Bkss	117-147	SiC	6.3	50.0	8.2	42.5	469	-159	-27
Bss	147-179	SiC	6.4	51.0	8.1	42.1	352	-138	-24
Cr	179-219	—	—	—	—	—	—	—	—
				Site 8 - Kenoma 05KS133003					
Ap	0-17	SiL	6.2	22.1	5.9	16.7	156	-189	-34
Bt1	17-38	SiC	3.3	53.3	5.6	33.4	195	-258	-46
Bt2	38-71	SiC	2.9	55.0	6	33.2	195	-162	-29
2Btg1	71-101	SiC	10.7	43.5	6.4	19.5	117	89	16
2Btg2	101-128	SiC	11.9	44.2	6.8	19.8	117	123	22
2Bssg1	128-156	SiC	12.7	44.5	7	19.8	117	104	19
2Bssg2	156-174	C	11.1	50.4	7.1	21.3	156	129	23
2BC	174-195	SiC	12.1	43.4	7.3	19.1	117	384	69
				Site 9 - Parsons 06KS133001					
A	0-18	SiL	4.6	25.0	5.6	19.0	156	-14	-3
E	18-28	SiL	4.9	23.1	5.6	12.9	78	37	7
2Btg1	28-55	SiC	2.8	54.4	5.9	28.0	156	-83	-15
2Btg2	55-91	SiC	2.4	50.8	6.6	26.7	117	0	0
2Btyg1	91-115	C	5.0	55.8	6	27.3	156	-127	-23
2Btyg2	115-142	C	4.3	61.6	5.9	28.9	156	-109	-20
2Btg3	142-176	C	3.4	65.1	6	31.3	195	-99	-18
3Btg4	176-205	C	4.4	60.0	6.4	28.4	156	116	21
				Site 10 - Eram 86KS133005					
Ap	0-16	SiC	10.1	47.2	6.7	35.6	313	-284	-47
Bt1	16-28	C	9.4	53.9	7	33.6	195	42	7
Bt2	28-43	C	7.7	54.5	7.1	29.7	117	256	42
Bt3	43-65	SiC	8.7	50.7	7.2	26.0	117	235	39
BC	65-91	SiC	6.1	50.2	7.4	23.4	117	295	48
Cr	91+	SiC	10.5	41.2	8	19.6	117	341	56

† Percent of added K that was fixed (+) or released (-)

CHAPTER 5 - Summary and Conclusions

Clayey, vertic soils were studied in the Cherokee Prairies Major Land Resource Area of southeastern Kansas. Chapter 2 investigated the morphology, physical and chemical properties, and processes of soil genesis associated with these soils. Soils were often formed in multiple parent materials; however, alluvium, colluvium, and residuum parent materials are all originally derived from weathered Pennsylvanian and Permian shales and limestones found in this region and in the Flint Hills to the west. Field morphology reflected the geologic parent materials available in the region as well as the significant weathering provided by the humid continental climate with an average annual rainfall of 865 to 1,145 millimeters. Both clay films and slickensides commonly occurred. Dominant pedogenic processes currently at work are clay illuviation and shrink-swell processes. Relatively high COLE values were found in all soils. Silt loam and silty clay loam surface horizons and argillic horizons with overly high shink-swell occurredat all but sites 6 and 7. In these claypan soils, the shrink-swell potential of the argillic horizon is not fully expressed. The subsurface horizons dry out less rapidly and are not as subject to differential wetting by preferential flow down surface cracks. This is due to the buffering effect of the non-expansive surface soil. Sites 6 and 7 classify as Vertisols, and no argillic horizon or clay films were described. In these two soils shrink-swell and pedoturbation provides great enough mixing of surface and subsurface horizons to effectively counteract downward clay translocation. This action maintains a clayey, high COLE value surface, as well as deep cracking that extends to the surface. Subtle changes in parent material and landscape position are suspected to cause the differences in vertic characteristics found in this study.

Clay mineralogy and micromorphology were studied in chapter 3. Four of the soils were dominated by smectitic minerals in the clay fraction (sites 2, 5, 6, and 7). Of these smectitic soils, two (sites 6 and 7) expressed strongly developed vertic properties including slickensides, high COLE values, and an absence of preserved illuvial clay films and an associated argillic horizon. In thin section, these soils showed strong striated b-fabrics, many linear planes with stress oriented clay, and argillans that had been distorted and embedded in the matrix by swelling pressures and soil movement. Sites 2 and 5 exhibited smectitic mineralogy but lacked strong vertic properties in the field.

In pedons exhibiting a more mixed mineralogy (sites 1, 4, 8, 9, and 10), kaolinite, vermiculite, and clay mica often play larger roles even though smectite content was still significant. Some of these soils are borderline to both the smectitic and mixed mineralogy classes. Based on shrink-swell characteristics, a smectitic mineralogy class would be most appropriate since shrink-swell characteristics are historically associated with smectitic mineralogy. These pedons were all described with clay films and argillic horizons which suggest clay illuviation is a dominant process. However, slickensides were described in several of the argillic horizons, and similar striated b-fabrics and stress features similar to ones described above were apparent in thin section. Even the soils exhibiting mixed mineralogies contain a significant quantity of expanding clay minerals. This fact, in combination with seasonal moisture changes, provides enough shrink-swell movement to deform clay films and create the striated b-fabrics observed in thin section for all soils in this study.

In chapter 4, potassium (K) fixation potential was measured for each horizon and compared to the clay mineralogy results. K fixation at the surface was found to be negative in all soils. Consequently, K fixation potential is considered very low in the studied pedons. In subsurface horizons, K fixation increased with increasing vermiculite content. However, K fixation was observed at site 6 in which no vermiculite was observed. This suggests that K fixing clay minerals other than vermiculite are present at this site and could possibly be more widespread in this region. High-charge smectite is one mineral suspected of fixing K at site 6. In addition to limited quantities of K fixing clay minerals, naturally high K levels limited the amount of K fixation in this study.

In conclusion, it is hoped that the information presented here can be used to improve our understanding and management of high clay, vertic and claypan soils in the Cherokee Prairies.

Appendix A - Pedon Descriptions

Classification and horizonation of some pedons has been revised since time of sampling. In these cases, pedon descriptions in Appendix A may not agree with those referred to in the text.

Site 1

Description Date: 05/19/2009
Describer: Mark Abney, Sheila Staton-Clifton, G. Campbell, Wm. Wehmueller, JC Remley, P. Hartley, M. Ransom

Soil Name as Described/Sampled: Bucyrus
Soil Name as Correlated:
Classification: Fine, mixed, active, thermic Oxyaquic Vertic Argiudolls

Site ID: 09KS139001
Site Note: Adjacent to a Kansas State University mesonet station where soil moisture, temperature, and salinity sensors have been installed. Pit is next to a fence and near a short escaprment that appears to be from erosion when the field was in cultivation. The site is within a delineation of Eram soils but the lower part of the pedon is formed in limestone instead of shale and is deeper than typical Eram. The limestone is most likely one of the members of the Lecompton limestone formation of the Shawnee Group based on the Geology, Mineral Resources, and Ground-Water Resources of Osage County, Kansas, Part 1 Rock Formations of Osage County. Howard G. O'Conner, Kansas Geological Survey Report Vol. 13, 1955.

Pedon ID: 09KS139001
Pedon Note: The pedon is a taxadjunct to the Bucyrus series and outside the range because it does not classify as a Paleudoll. The colors are not red enough in the lower argillic horizon. The Pale great group requires colors of 7.5YR or redder and chroma of 5 or more in 50 percent of the matrix in one or more subhorizons. This pedon is described with 40% 7.5YR 5/8 in the 2Btss3. Aliceville is also a similar soil but it is outside the range of that series because the limestone bedrock is below 150 cm. The aquic conditions that create the redoximorphic features are assumed to be of short duration in normal years because there is not any indication of hydrophitic vegetation. There was much discussion about the parent materials of this pedon. The consensus was that there is probably a thin loess cap mixed with colluvium (hillslope sediment) over residuum from limestone. The break between loess and colluvial material is not clearly discernible.

County: Osage
State: Kansas
MLRA: 112 -- Cherokee Prairies
Soil Survey Area: KS139 -- Osage County, Kansas
Map Unit: 8735 -- Eram silty clay loam, 3 to 7 percent slopes
Quad Name: Vassar, Kansas
Location Description: About 6 miles west and 5 miles north of Pomona, Kansas.
Legal Description: SW 1/4 SW 1/4 of Section 35, Township T. 15 S., Range R. 17 E.
Latitude: 38 degrees 41 minutes 49.74 seconds north
Longitude: 95 degrees 36 minutes 30.56 seconds west
Datum: NAD83
UTM Zone: 15
UTM Easting: 273149 meters
UTM Northing: 4286400 meters

Lab Source ID: SSL
Lab Pedon #: 09N0905
Pedon Type: outside range of series
Pedon Purpose: full pedon description
Taxon Kind: taxadjunct
Associated Soils:

Physiographic Division:
Physiographic Province:
Physiographic Section:
State Physiographic Area:
Local Physiographic Area:
Geomorphic Setting: on backslope of interfluve on plains
Upslope Shape: convex
Cross Slope Shape: convex
Description origin: NASIS

Primary Earth Cover: Grass/herbaceous cover
Secondary Earth Cover:
Existing Vegetation:
Parent Material: colluvium over residuum weathered from cherty limestone
Bedrock Kind: limestone
Bedrock Depth: 186 centimeters
Bedrock Hardness: indurated
Bedrock Fracture Interval:
Surface Fragments:
Description database: NSSL

Particle Size Control Section: 46 to 96 cm.
Diagnostic Features:

mollic epipedon 0 to 46 cm.
argillic horizon 46 to 186 cm.
redox concentrations 46 to 186 cm.
aquic conditions 60 to 159 cm.
slickensides 81 to 186 cm.
lithic contact 186 to 200 cm.

Slope (%): 4.0
Elevation (meters): 3.8.0
Aspect (deg): 90
Drainage Class: moderately well

Ap--0 to 11 centimeters; black (10YR 2/1) broken face silty clay loam; 30 percent clay; moderate medium granular structure; friable; many fine roots throughout; abrupt smooth boundary. Lab sample # 09N03253

A--11 to 28 centimeters; black (10YR 2/1) broken face silty clay loam; 32 percent clay; moderate medium granular structure; friable; many fine roots throughout and few medium roots throughout; clear smooth boundary. Lab sample # 09N03254

BA--28 to 46 centimeters; 80 percent very dark grayish brown (10YR 3/2) broken face and 20 percent brown (10YR 4/3) broken face silty clay loam; 37 percent clay; weak medium prismatic parting to moderate fine subangular blocky structure; friable; many fine roots throughout and few medium roots throughout; 2 percent fine prominent irregular black (7.5YR 2.5/1), moist, iron manganese masses throughout; 1 percent nonflat subrounded indurated 2- to 10-millimeter chert fragments; clear wavy boundary. Lab sample # 09N03255

Bt1--46 to 60 centimeters; 60 percent brown (10YR 4/3) broken face and 40 percent very dark grayish brown (10YR 3/2) broken face silty clay; 45 percent clay; moderate medium prismatic parting to moderate fine subangular blocky structure; firm; common fine roots throughout and common very fine roots throughout; 30 percent discontinuous distinct dark grayish brown (10YR 4/2), moist, clay films on all faces of peds; 2 percent fine prominent irregular black (7.5YR 2.5/1), moist, iron-manganese masses throughout and 10 percent fine prominent irregular reddish brown (2.5YR 4/4), moist, masses of oxidized iron throughout; 2 percent nonflat subrounded indurated 2- to 10-millimeter chert fragments; clear smooth boundary. Lab sample # 09N03256

Bt2--60 to 81 centimeters; 60 percent dark grayish brown (10YR 4/2) broken face and 40 percent dark yellowish brown (10YR 4/4) broken face silty clay; 47 percent clay; moderate medium prismatic parting to moderate medium subangular blocky structure; firm; common very fine roots throughout; 1 percent slickensides (pedogenic) and 25 percent discontinuous distinct dark grayish brown (10YR 4/2), moist, clay films on all faces of peds; 2 percent fine prominent irregular black (7.5YR 2.5/1), moist, iron-manganese masses throughout and 10 percent fine prominent irregular reddish brown (2.5YR 4/4), moist, masses of oxidized iron throughout; 3 percent nonflat subrounded indurated 2- to 10-millimeter chert fragments; clear wavy boundary. Lab sample # 09N03257. slickenslides at contact with lower horizon.

Btss1--81 to 100 centimeters; 60 percent dark grayish brown (10YR 4/2) broken face and 40 percent dark yellowish brown (10YR 4/4) broken face clay; 51 percent clay; moderate medium prismatic parting to moderate medium subangular blocky structure; firm; few very fine roots throughout; 10 percent slickensides (pedogenic) and 35 percent discontinuous prominent grayish brown (10YR 5/2), moist, clay films on all faces of peds; 2 percent fine prominent spherical weakly cemented black (7.5YR 2.5/1), moist, iron-manganese concretions throughout and 7 percent fine prominent irregular black (7.5YR 2.5/1), moist, ironmanganese masses throughout; 2 percent nonflat subrounded indurated 2- to 10-millimeter chert fragments; clear wavy boundary. Lab sample # 09N03258

2Btss2--100 to 159 centimeters; 70 percent dark grayish brown (10YR 4/2) broken face and 30 percent dark yellowish brown (10YR 4/4) broken face clay; 52 percent clay; moderate coarse prismatic parting to moderate coarse subangular blocky structure; firm; 15 percent slickensides (pedogenic) and 30 percent discontinuous prominent grayish brown (10YR 5/2), moist, clay films on all faces of peds; 2 percent fine prominent spherical weakly cemented black (7.5YR 2.5/1), moist, iron-manganese concretions throughout and 5 percent fine prominent irregular black (7.5YR 2.5/1), moist, iron- manganese masses throughout; 2 percent nonflat subrounded indurated 2- to 10-millimeter chert fragments; clear smooth boundary. Lab sample # 09N03259

2Btss3--159 to 186 centimeters; 40 percent light yellowish brown (10YR 6/4) broken face and 40 percent strong brown (7.5YR 5/8) broken face and 20 percent reddish brown (5YR 4/4) broken face clay; 57 percent clay; moderate coarse prismatic parting to moderate medium subangular blocky structure; firm; 20 percent discontinuous prominent reddish brown (2.5YR 4/4), moist, clay films on all faces of peds and 20 percent slickensides (pedogenic) and 20 percent discontinuous prominent dark gray (10YR 4/1), moist, clay films on all faces of peds; 5 percent fine prominent irregular black (7.5YR 2.5/1), moist, iron-manganese masses throughout; 2 percent nonflat subrounded indurated 2- to 10-millimeter chert fragments; abrupt wavy boundary. Lab sample # 09N03260

2R--186 to 200 centimeters; indurated limestone bedrock; one of the limestone members of the Lecompton Limestone formation, Shawnee Group.

Site 2

Description Date: 06/30/2009
Describer: Mark Abney, Paul Hartley (KSU), M.D. Ransom (KSU), C. Watts, W. Wehmueller

Soil Name as Described/Sampled: Woodson
Soil Name as Correlated:
Classification: Fine, smectitic, thermic Vertic Argiaquolls

Site ID: 09KS059001
Site Note:
Site is located in a brome hay field on the Kansas State University East Central Experiment Field at Ottawa, Kansas. The site is located right on the boundary between delineations of Woodson 0 to 1 percent slope and Woodson 1 to 3 percent slopes.

Pedon ID: 09KS059001
Pedon Notes:
This pedon is a taxajucnt to the Woodson series because it exhibits Vertic properties and the Vertic Argiaquolls key out before Abruptic (10th edition Keys to Soil Taxonomy). The aquic properties are weakly expressed and it is the concensus of the sampling party that the soil is better drained than most Aquolls.
Based on field estimates of clay it also is borderline to a Vertisol because there is greater than 30% clay throughout and slickensides within 100 cm. The relatively abrupt textural change from surface to argillic horizon, limited amount of slickensides and limited amount of eveidence of cracks in the pedon suggest this soil does not have as much cracking and pedoturbation typical of a Vertisol.
There was a lengthy discussion of the parent materials including old alluvium, residuum, or loess. There is no observable lithologic discontinuity where loess ends and residuum or old alluvium begins.

County: Franklin
State: Kansas
MLRA: 112 -- Cherokee Prairies
Soil Survey Area: KS059 -- Franklin County, Kansas
Map Unit: 8962 - Woodson silt loam, 1 to 3 percent slopes Map Unit Status: correlated
Quad Sheet Name: Peoria, Kansas
Location Description: About 4.5 miles south and 1 mile east of Ottawa, Kansas.
Legal Description: About 900 feet east and 900 feet north of the southwest corner of Section 30, Township 17 S., Range 20 E.
Latitude: 38 degrees 32 minutes 17.70 seconds north
Longitude: 95 degrees 14 minutes 45.20 seconds west
Datum: NAD83
UTM Zone: 15, UTM Easting: 304255 meters
UTM Northing: 4267929 meters

Pedon Type: taxadjunct to the series
Pedon Purpose: full pedon description
Taxon Kind: taxadjunct
Physiographic Division: Interior Plains
Physiographic Province: Central Lowland Province
Physiographic Section: Osage Plain
State Physiographic Area: Osage Cuestas
Geomorphic Setting: on shoulder of crest of interfluve on plains
Upslope Shape: linear Cross Slope Shape: linear

Primary Earth Cover: Grass/herbaceous cover
Secondary Earth Cover: Hayland

Parent Material: loess and/or residuum

Particle Size Control Section: 10.2 to 29.9 in. (26 to 76 cm)
Diagnostic Features:

Kind	Top Depth (in)	Bottom Depth (in)	Top Depth (cm)	Bottom Depth (cm)
Mollic epipedon	0.0	33.1	0	84
Argillic horizon	10.2		26	
Redox concentrations	10.2	78.7	26	200
Slickensides	22.0	46.1	56	117

Slope: 1.0 percent
Aspect: 360 (deg)
Elevation: 971 feet, 296.0 meters
Drainage class: somewhat poorly

Ap--0 to 3 inches, (0 to 8 cm); very dark grayish brown (10YR 3/2) exterior, silty clay loam; 3 percent sand; 30 percent clay; moderate fine subangular blocky parting to moderate fine granular structure; friable; many very fine roots throughout; abrupt smooth boundary.

A--3 to 10 inches, (8 to 26 cm); very dark grayish brown (10YR 3/2) exterior, silty clay loam; 3 percent sand; 36 percent clay; moderate fine prismatic parting to moderate medium angular blocky structure; friable; many fine roots throughout; 10 percent patchy faint dark grayish brown (10YR 4/2), moist, and gray (10YR 5/1), dry, silt coats on vertical faces of peds; the silt coats are in the lower part of the horizon and are very thin and observed only in discontinous patches throughout the pit; clear smooth boundary.

Bt1--10 to 22 inches, (26 to 56 cm); very dark gray (10YR 3/1) exterior, silty clay; 3 percent sand; 55 percent clay; moderate medium prismatic parting to moderate coarse angular blocky structure; very firm; many very fine roots between peds; 5 percent patchy distinct gray (10YR 5/1), dry, silt coats on vertical faces of peds and 70 percent continuous faint black (10YR 2/1), moist, and very dark gray (10YR 3/1), moist, clay films on all faces of peds; 2 percent fine distinct spherical dark yellowish brown (10YR 4/4), moist, iron-manganese masses in matrix; the very fine redoximorphic concentrations are not readily observable on first examination, but do show as a streak when the ped is crushed and smeared; gradual smooth boundary.

Bt2--22 to 33 inches, (56 to 84 cm); very dark gray (10YR 3/1) exterior, silty clay; 3 percent sand; 50 percent clay; moderate medium prismatic parting to moderate medium subangular blocky structure; firm; many very fine roots throughout; 5 percent slickensides (pedogenic) and 60 percent continuous faint dark gray (10YR 4/1), moist, clay films on all faces of peds; 10 percent fine distinct irregular extremely weakly cemented brown (10YR 5/3), moist, iron-manganese masses infused into matrix along faces of peds; gradual smooth boundary.

Btssg--33 to 46 inches, (84 to 117 cm); 40 percent very dark gray (10YR 3/1) exterior and 60 percent grayish brown (10YR 5/2) exterior, silty clay; 3 percent sand; 50 percent clay; moderate medium prismatic parting to moderate medium subangular blocky structure; firm; common very fine roots throughout; 25 percent continuous slickensides (pedogenic) and 50 percent continuous faint very dark gray (10YR 3/1), moist, clay films on all faces of peds; 10 percent fine distinct irregular extremely weakly cemented dark yellowish brown (10YR 4/4), moist, iron-manganese masses infused into matrix along faces of peds; the slickensides were not readily seen in the profile wall but when the peds are broken out for sampling and clods the slickensides were visible and had a thin film of free water on the face; clear smooth boundary.

Btg1--46 to 58 inches, (117 to 148 cm); 25 percent dark gray (10YR 4/1) exterior and 75 percent gray (10YR 5/1) exterior, silty clay; 3 percent sand; 48 percent clay; moderate medium prismatic parting to moderate medium subangular blocky structure; firm; common very fine roots throughout; 30 percent continuous faint gray (10YR 5/1), moist, clay films on all faces of peds; 10 percent medium distinct irregular black (10YR 2/1), moist, manganese coatings on faces of peds and 40 percent fine prominent irregular extremely weakly cemented yellowish brown (10YR 5/6), moist, iron-manganese masses infused into matrix along faces of peds; gradual smooth boundary.

Btg2--58 to 65 inches, (148 to 166 cm); 25 percent dark gray (10YR 4/1) exterior and 75 percent gray (10YR 5/1) exterior, silty clay; 10 percent sand; 47 percent clay; weak medium prismatic parting to moderate medium subangular blocky structure; firm; common very fine roots throughout; 25 percent continuous faint gray (10YR 5/1), moist, clay films on all faces of peds; 10 percent medium distinct irregular black (10YR 2/1), moist, manganese coatings on faces of peds and 50 percent medium prominent irregular extremely weakly cemented dark yellowish brown (10YR 4/4), moist, iron-manganese masses infused into matrix along faces of peds; gradual smooth boundary.

Btg3--65 to 79 inches, (166 to 200 cm); 30 percent dark gray (10YR 4/1) exterior and 70 percent gray (10YR 6/1) exterior, silty clay; 10 percent sand; 45 percent clay; weak medium prismatic parting to moderate medium subangular blocky structure; firm; 20 percent continuous faint gray (10YR 5/1), moist, clay films on all faces of peds; 10 percent medium distinct irregular black (10YR 2/1), moist, manganese coatings on faces of peds and 50 percent medium prominent irregular extremely weakly cemented dark yellowish brown (10YR 4/4), moist, iron-manganese masses infused into matrix along faces of peds; this horizon has a more greasy feel than the horizons above which suggests a different mineralogy.

Site 3

Description Date: 05/18/2009
Describer: Mark Abney, Sheila Staton-Clifton, G. Campbell, Wm. Wehmueller, JC Remley, P. Hartley

Soil Name as Described/Sampled: Aliceville
Classification: Fine, mixed, active, thermic Oxyaquic Vertic Argiudolls

Site ID: 09KS121001
Site Note: Site is adjacent to the Kansas State University mesonet station that has soil moisture, temperature and salinity sensors installed. Limestone is a member of the Iola Formation, Kansas City Group, Pennsylvanian System, based on Geolgy and Ground-Water Resources of Miami County, Kansas. Don E. Miller Kansas Geological Survey Bulletin 181. 1966.

Pedon ID: 09KS121001
Pedon Note: There was much discussion about the parent materials, the consensus was that the pedon formed in loess over residuum from limestone but there was no clear discontinuity where loess ends and residuum begins. When sampled in 2009 this pedon is in a map unit currently called Catoosa. After completion of the MLRA 112 update project the map unit will be changed to Wagstaff. Aliceville is a common deeper inclusion is Wagstaff map units.

State: Kansas
County: Miami
MLRA: 112 -- Cherokee Prairies
Soil Survey Area: KS121 -- Miami County, Kansas
Map Unit: 8645 -- Catoosa silt loam, 1 to 3 percent slopes
Quad Name: Paola East, Kansas
Location Description: About 1.5 miles east and 1.5 miles north of Paola, Kansas.
Legal Description: about 750 feet west and 160 feet south of the northeast corner of Section 10, Township T. 17 S., Range R. 23 E.
Latitude: 38 degrees 35 minutes 31.81 seconds north
Soil Name as Correlated: Longitude: 94 degrees 50 minutes 52.37 seconds west
Datum: NAD83
UTM Zone: 15
UTM Easting: 339068 meters
UTM Northing: 4273140 meters

Lab Source ID: SSL
Lab Pedon #: 09N0904
Pedon Type: within range of series
Pedon Purpose: full pedon description
Taxon Kind: series
Associated Soils:
Physiographic Division: Interior Plains
Physiographic Province: Central Lowland Province
Physiographic Section: Osage plain
State Physiographic Area:
Local Physiographic Area:
Geomorphic Setting: on summit of interfluve on plains
Upslope Shape: convex
Cross Slope Shape: convex
Description origin: NASIS

Primary Earth Cover: Grass/herbaceous cover
Secondary Earth Cover:
Existing Vegetation:
Parent Material: Loess over Residuum weathered from Limestone
Bedrock Kind: limestone
Bedrock Depth: 140 centimeters
Bedrock Hardness: indurated
Bedrock Fracture Interval:
Surface Fragments:
Description database: NSSL

Particle Size Control Section: 45 to 95 cm.
Diagnostic
Features:
mollic epipedon 0 to 45 cm.
argillic horizon 45 to 140 cm.
redox concentrations 45 to 140 cm.
lithic contact 140 to 200 cm.

Slope (%): 2.0
Elevation (meters): 290.0
Aspect (deg): 135
Drainage Class: moderately well

Ap--0 to 16 centimeters; very dark gray (7.5YR 3/1) broken face silty clay loam; 36 percent clay; moderate fine subangular blocky parting to moderate medium granular structure; very friable; very few fine roots throughout and many very fine roots throughout; abrupt smooth boundary. Lab sample # 09N03247

A--16 to 31 centimeters; black (7.5YR 2.5/1) broken face silty clay loam; 38 percent clay; moderate fine subangular blocky parting to moderate medium granular structure; friable; few fine roots throughout and common very fine roots throughout; clear smooth boundary. Lab sample # 09N03248

BA--31 to 45 centimeters; 50 percent brown (7.5YR 4/3) broken face and 40 percent dark brown (7.5YR 3/2) broken face and 10 percent strong brown (7.5YR 4/6) broken face silty clay; 42 percent clay; moderate fine prismatic parting to moderate fine subangular blocky structure; firm; very few fine roots throughout and very few very fine roots throughout; 50 percent discontinuous faint dark grayish brown (10YR 4/2), moist, clay films on all faces of peds; clear smooth boundary. Lab sample # 09N03249

Bt1--45 to 68 centimeters; 55 percent brown (10YR 4/3) broken face and 30 percent brown (7.5YR 4/2) broken face and 15 percent dark yellowish brown (10YR 4/6) broken face silty clay; 45 percent clay; moderate medium prismatic parting to moderate fine prismatic structure; firm; very few very fine roots throughout; 40 percent discontinuous distinct dark grayish brown (10YR 4/2), moist, clay films on all faces of peds; 10 percent fine prominent irregular black (10YR 2/1), moist, manganese masses with clear boundaries on faces of peds; clear smooth boundary. Lab sample # 09N03250

Bt2--68 to 102 centimeters; 60 percent brown (10YR 4/3) broken face and 20 percent dark grayish brown (10YR 4/2) broken face and 20 percent strong brown (7.5YR 4/6) broken face clay; 50 percent clay; moderate coarse prismatic parting to moderate medium prismatic parting to moderate medium subangular blocky structure; firm; very few very fine roots throughout; 30 percent discontinuous faint brown (10YR 5/3), moist, clay films on all faces of peds; 2 percent fine prominent spherical moderately cemented black (10YR 2/1), moist, iron-manganese concretions with sharp boundaries throughout and 5 percent fine prominent irregular black (10YR 2/1), moist, manganese masses with clear boundaries on faces of peds; clear smooth boundary. Lab sample # 09N03251

Btss--102 to 140 centimeters; 70 percent strong brown (7.5YR 4/6) broken face and 30 percent dark grayish brown (10YR 4/2) broken face clay; 55 percent clay; moderate coarse prismatic parting to moderate medium prismatic parting to moderate medium subangular blocky structure; very firm; very few very fine roots throughout; slickensides (pedogenic) on vertical faces of peds and 40 percent discontinuous prominent brown (10YR 4/3), moist, clay films on all faces of peds; 5 percent fine prominent spherical moderately cemented black (10YR 2/1), moist, iron-manganese concretions with sharp boundaries throughout and 25 percent fine prominent irregular black (10YR 2/1), moist, manganese masses with clear boundaries on faces of peds. Lab sample # 09N03252

R--140 to 200 centimeters; indurated limestone bedrock; one of the limestone members of the Iola limestone formation, Kansas City group.

Site 4

Description Date: 05/19/2009
Describer: Mark Abney, Sheila Staton-Clifton, G. Campbell, Wm. Wehmueller, JC Remley, P. Hartley, M. Ransom

Soil Name as Described/Sampled: Summit
Soil Name as Correlated:
Classification: Fine, smectitic, thermic Aquertic Argiudolls

Site ID: 09KS207001
Site Note:
Site is adjacent to Kansas State University mesonet station that has soil moisture, temperature, and salinity sensors.
The site is located within a delineation of Ringo but very near the boundary to a Summit 1 to 3 percent slopes map unit. The pedon fits the Summit series best. The soil is also near and similar to a Woodson map unit but does not have as abrupt of texture change that Woodson should have.
The bottom of the pit was beginning to look like shale would not be too much deeper. Based on Map M-118 Surficial Geology of Kansas, Kansas Geological Survey, March 2008, the geology is the Douglas Group, Pennsylvanian age.

Pedon ID: 09KS207001
Pedon Notes:
There was much discussion about the parent materials and the consensus was that the pedon formed in loess over colluvium over residuum. Also considered was a loess colluvium mix over an older age of colluvium over residuum. The break between loess and colluvial sediments is not clearly discernible. The discontinuity to material considered residuum was easier to define and describe.
There was also discussion about the classification of the pedon. Field estimates of the textures and the slickensides would have this pedon classify as a vertisol. However, the clear boundary and increase of about 20 percent clay from surface to subsoil suggests this soil does not have enough shrink-swell pedoturbation to classify as a vertisol.
If it is assumed that the pedon is not a vertisol then the pedon is borderline between an aquoll or argiudoll. Without long term moisture data to assess whether there are aquic conditions between 40 and 50 cm in normal years the drainage class and overall nature of the pedon suggests aquertic argiudoll is the best fit. It is assumed the aquic conditions that form the redoximorphic features are of short duration.

County: Woodson
State: Kansas
MLRA: 112 -- Cherokee Prairies
Soil Survey Area: KS207 -- Woodson County, Kansas
Map Unit: 8871 - Ringo silty clay loam, 3 to 8 percent slopes — Map Unit Status: correlated
Quad Sheet Name: Toronto Se, Kansas
Location Description: About 2.5 miles west and 1.5 miles south of Yates Center, Kansas.
Legal Description: about 2270 feet west and 1375 feet south of the northeast corner of Section 20, Township T. 25 S.,

Range R. 15 E.
Latitude: 37 degrees 51 minutes 40.14 seconds north
Longitude: 95 degrees 47 minutes 1.00 seconds west
Datum: NAD83
UTM Zone: 15, UTM Easting: 255122 meters, UTM Northing: 4194062 meters

Pedon Type: outside range of series
Pedon Purpose: full pedon description
Taxon Kind: series
Physiographic Division: Interior Plains
Physiographic Province: Central Lowland Province
Physiographic Section: Osage Plain
Geomorphic Setting: on backslope of interfluve on plains
Upslope Shape: concave
Cross Slope Shape: convex

Primary Earth Cover: Grass/herbaceous cover
Parent Material: loess over colluvium over residuum weathered from limestone and shale
Bedrock Kind: limestone and shale

Particle Size Control Section: 11.4 to 31.1 in. (29 to 79 cm)
Diagnostic Features:

Kind	Top Depth (in)	Bottom Depth (in)	Top Depth (cm)	Bottom Depth (cm)
Mollic epipedon	0.0	20.9	0	53
Redox concentrations	7.1	82.7	18	210
Aquic conditions	7.1	20.9	18	53
Argillic horizon	11.4	82.7	29	210
Slickensides	20.9	82.7	53	210

Slope: 4.0 percent
Aspect: 45 (deg)
Elevation: 1119 feet, 341.0 meters
Drainage class: somewhat poorly

Ap--0 to 7 inches, (0 to 18 cm); black (10YR 2/1), silty clay loam, very dark gray (10YR 3/1), dry; 35 percent clay; weak medium subangular blocky parting to moderate fine granular structure; very friable; common fine roots and many very fine roots; abrupt smooth boundary.

A--7 to 11 inches, (18 to 29 cm); very dark gray (10YR 3/1), silty clay; 42 percent clay; moderate medium subangular blocky parting to weak fine subangular blocky parting to moderate fine granular structure; friable; common very fine roots; 5 percent fine distinct dark yellowish brown (10YR 3/4), moist, masses of oxidized iron; clear smooth boundary.

Bt1--11 to 21 inches, (29 to 53 cm); very dark grayish brown (10YR 3/2), clay; 60 percent clay; moderate medium prismatic parting to moderate medium subangular blocky structure; firm; few very fine roots; 30 percent dark brown (10YR 3/3) clay films; 5 percent fine black (10YR 2/1), moist, iron-manganese concretions and 10 percent fine distinct dark reddish brown (5YR 3/3), moist, masses of oxidized iron; gradual smooth boundary.

Bt2--21 to 41 inches, (53 to 103 cm); 30 percent dark brown (10YR 3/3) and 70 percent very dark gray (10YR 3/1), clay; 65 percent clay; moderate medium prismatic parting to moderate medium wedge parting to moderate medium angular blocky structure; firm; few fine roots and common very fine roots; 10 percent dark gray (10YR 4/1) clay films and 25 percent slickensides (pedogenic); 5 percent fine black (10YR 2/1), moist, iron-manganese concretions and 20 percent fine prominent dark yellowish brown (10YR 3/6), moist, masses of oxidized iron; clear wavy boundary.

2Btss1--41 to 53 inches, (103 to 135 cm); 20 percent very dark grayish brown (10YR 3/2) and 80 percent brown (10YR 4/3), silty clay; 58 percent clay; moderate coarse wedge structure; very firm; few fine roots and common very fine roots; 20 percent slickensides (pedogenic) and 40 percent dark brown (7.5YR 3/2) clay films; 3 percent fine yellowish red (5YR 5/6), moist, masses of oxidized iron and 5 percent fine distinct black (10YR 2/1), moist, iron-manganese concretions; gradual smooth boundary.

2Btss2--53 to 70 inches, (135 to 177 cm); 30 percent dark yellowish brown (10YR 4/4) and 70 percent dark brown (10YR 3/3), silty clay; 56 percent clay; moderate medium prismatic parting to moderate medium subangular blocky structure; very firm; few fine roots and common very fine roots; 5 percent slickensides (pedogenic) and 20 percent distinct dark brown (7.5YR 3/2) clay films; 3 percent fine prominent yellowish red (5YR 5/6), moist, masses of oxidized iron; clear wavy boundary.

3Btss--70 to 83 inches, (177 to 210 cm); 10 percent dark brown (7.5YR 3/2) and 20 percent brown (7.5YR 5/2) and 70 percent strong brown (7.5YR 4/6), clay; 58 percent clay; strong very coarse wedge and strong fine and medium wedge structure; very firm; few very fine roots; 5 percent light brownish gray (10YR 6/2) clay films on surfaces along root channels and 50 percent slickensides (pedogenic) and 65 percent distinct brown (7.5YR 5/3) clay films; 3 percent fine prominent reddish brown (5YR 4/3), moist, masses of oxidized iron; 40 percent medium and coarse carbonate nodules.

Site 5

Description Date: 06/01/1973
Describer: E. Fleming, J. Fortner, R. Haberman

Soil Name as Described/Sampled: Woodson
Soil Name as Correlated:
Classification: Fine, montmorillonitic, thermic Abruptic Argiaquolls

Site ID: 73KS001003

Pedon ID: 73KS001003
Pedon Note: Parent Material: sediments high in clay; Physiography: nearly level upland.

County: Allen
State: Kansas
MLRA: 112 -- Cherokee Prairies
Soil Survey Area:
Location Description: Allen County, KS.
Legal Description: 100 feet S and 1420 feet E of the NW corner of Section 23, Township 25S, Range 19E
Latitude: 37 degrees 51 minutes 47.88 seconds north
Longitude: 95 degrees 17 minutes 39.04 seconds west
Datum: NAD83

Lab Source ID: SSL Lab Pedon #: 40A1872
Pedon Purpose: full pedon description
Geomorphic Setting: upland
Description origin: Converted from SSL-CMS data
Description database: NSSL
Earth Cover: Grass/herbaceous cover

Slope (%): 1.0
Drainage Class: somewhat poorly

A* --0 to 20 centimeters; silt loam, very dark gray (10YR 3/1) interior, dry; weak fine granular structure; friable, slightly hard; many fine roots; moderately acid, pH 5.8, Hellige-Truog; abrupt smooth boundary. Lab sample # 40A14929. 1099; many fine roots

Bt1* --20 to 33 centimeters; silty clay, very dark gray (10YR 3/1) interior, dry; 1 percent fine faint dark brown (10YR 3/3) mottles; moderate fine blocky structure; extremely firm*, extremely hard; common fine roots; moderately acid, pH 5.8, Hellige-Truog. Lab sample # 40A14930. 1100; common fine roots; few fine faint 10YR33 mottles

Bt2* --33 to 48 centimeters; gradual smooth boundary. Lab sample # 40A14931. 1101; continuation of above horizon.

Bt3* --48 to 79 centimeters; silty clay, very dark gray (10YR 3/1) interior, dry; 1 percent medium distinct olive brown (2.5Y 4/3) and 30 percent medium distinct strong brown (7.5YR 5/6) mottles; moderate fine and medium blocky structure; extremely firm*, extremely hard; common fine roots; slightly acid, pH 6.3, Hellige-

Truog; gradual smooth boundary. Lab sample # 40A14932. 1102; less roots than above horizon.; common fine roots; many medium distinct 7.5YR56 mottles; few medium distinct 2.5Y43 mottles

Bt4* --79 to 97 centimeters; silty clay, gray (5Y 5/1) interior, dry; 1 percent medium distinct dark reddish brown (5YR 3/4) mottles; weak medium blocky structure; extremely firm*, extremely hard; few fine roots; slightly acid, pH 6.3, Hellige-Truog; diffuse wavy boundary. Lab sample # 40A14933. 1103; few to common fine gypsum particles.; few fine roots; few medium distinct 5YR34 mottles

Bt5* --97 to 132 centimeters; silty clay, gray (10YR 5/1) interior, dry; 30 percent fine distinct (5Y 4/6) mottles; moderate very fine and fine blocky structure; extremely firm*, extremely hard; neutral, pH 7.0, Hellige-Truog. Lab sample # 40A14934. 1104; few slickensides; common black stains; few fine gypsum particles.; many fine distinct 5Y46 mottles

Bt6* --132 to 160 centimeters; gradual wavy boundary. Lab sample # 40A14935. 1105; continuation of above horizon.

Bt7* --160 to 188 centimeters; silty clay, gray (10YR 5/1) interior and strong brown (7.5YR 5/6) interior and dark reddish brown (5YR 3/4) interior, dry; moderate medium prismatic, and moderate fine and medium blocky structure; extremely firm*, extremely hard; 55 percent , dry, black stains; slightly alkaline, pH 7.6, Hellige-Truog; gradual wavy boundary. Lab sample # 40A14936. 1106; also contains yellowish red (5YR 4/6) material.; many black stains surface features

Bt8* --188 to 229 centimeters; silty clay, gray (10YR 5/1) interior and (5Y 4/6) interior, dry; moderate medium prismatic, and moderate fine and medium blocky structure; extremely firm*, extremely hard; 15 percent , dry, black stains; moderately alkaline, pH 8.2, Hellige-Truog; gradual wavy boundary. Lab sample # 40A14937. 1107; few black stains surface features

Bt9* --229 to 318 centimeters; silty clay, gray (10YR 5/1) interior and (5Y 4/6) interior, dry; weak fine and medium blocky structure; extremely firm*, extremely hard; 15 percent , dry, black stains; moderately alkaline, pH 8.2, Hellige-Truog. Lab sample # 40A14938. 1108; few brown masses.; few black stains surface features

* Horizonation has been updated to conform with current definitions.

Site 6

Description Date: 09/22/2005
Describer: D. Gastineau, W. Wehmueller, JC Remley

Soil Name as Described/Sampled: Zaar
Classification: Fine, smectitic, thermic Typic Epiaquerts

Site ID: 05KS205002
Site Note: Global Water water level equipment is installed at this site today to monitor soil water at 3 depths. This pedon is located on a fallow crop field. It is on a paleoterrace that is oriented NNE/SSW west of the Stanton limestone and east of the Stranger formation. The paleoterrace is about 4 mi. wide. This polygon of Zaar is fairly typical of the Zaar that has been mapped on toeslopes below Cuestas in SE KS.

Pedon ID: 05KS205002
Pedon Note:

County: Wilson
State: Kansas
Osage Cuestas
MLRA: 112 -- Cherokee Prairies
Soil Survey Area: KS205 -- Wilson County, Kansas
Map Unit: 8990 -- Zaar silty clay, 0 to 1 percent slopes
Quad Name: Fredonia, Kansas
Location Description: Approximately 1.5 miles north of Fredonia, KS
Legal Description: approximately 2000 ft east and 2000 ft south of the northwest corner of Section 1, Township 29S, Range 14E
Latitude: 37 degrees 33 minutes 12.50 seconds north
Longitude: 95 degrees 49 minutes 33.20 seconds west
Datum: NAD83
UTM Zone: 15
UTM Easting: 250371 meters
UTM Northing: 4160028 meters

Lab Source ID: SSL
Lab Pedon #: 06N0123
Soil Name as Correlated:
Pedon Type: within range of series
Pedon Purpose: full pedon description
Taxon Kind: series
Associated Soils: Woodson
Physiographic Division: Interior Plains
Physiographic Province: Central Lowland Province
Physiographic Section: Osage plain
State Physiographic Area: Osage Cuestas
Local Physiographic Area:
Geomorphic Setting: on tread of paleoterrace on hills
Upslope Shape: convex
Cross Slope Shape: convex
Description origin: NASIS

Primary Earth Cover: Crop cover

Secondary Earth Cover: Row crop
Existing Vegetation:
Parent Material: fine alluvium
Description database: NSSL

Particle Size Control Section: 25 to 100 cm.
Diagnostic
Features:
mollic epipedon 0 to 56 cm.
aquic conditions 28 to 212 cm.
cambic horizon 56 to 212 cm.
slickensides 84 to 212 cm.

Slope (%): 0.2
Elevation (meters): 265.0
Aspect (deg): 240
MAAT (C): 14.0
MAP (mm): 89
Drainage Class: somewhat poorly

Ap--0 to 13 centimeters; very dark gray (10YR 3/1) crushed silty clay loam; 37 percent clay; moderate medium subangular blocky parting to moderate medium granular structure; firm, extremely hard, very sticky, very plastic; common very fine roots throughout; common very fine low-continuity tubular pores; clear smooth boundary. Lab sample # 06N00343

A--13 to 28 centimeters; very dark gray (10YR 3/1) crushed silty clay; 42 percent clay; moderate fine prismatic parting to moderate medium angular blocky parting to weak medium granular structure; very firm, extremely hard, very sticky, very plastic; common very fine roots in cracks; common very fine moderate-continuity tubular pores; A few (3) nightcrawlers were observed near the bottom of this horizon. One of them was curled in a ball about 1 cm in diameter.; gradual wavy boundary. Lab sample # 06N00344

BA--28 to 56 centimeters; very dark gray (10YR 3/1) crushed silty clay; 45 percent clay; moderate medium prismatic parting to moderate medium subangular blocky parting to moderate coarse granular structure; very firm, extremely hard, very sticky, very plastic; common very fine roots throughout; common fine moderate-continuity tubular and common very fine moderate-continuity tubular pores; 2 percent continuous faint dark gray (2.5Y 4/1), moist, pressure faces on top faces of peds; 1 percent very fine distinct irregular olive brown (2.5Y 4/3), moist, iron-manganese masses with diffuse boundaries lining pores; clear wavy boundary. Lab sample # 06N00345

Bg--56 to 84 centimeters; olive brown (2.5Y 4/3) interior silty clay; 55 percent clay; moderate medium prismatic parting to moderate coarse subangular blocky structure; very firm, extremely hard, very sticky, very plastic; common very fine roots throughout; common very fine high-continuity tubular pores; 1 percent continuous faint dark gray (2.5Y 4/1), moist, pressure faces on top faces of peds; 2 percent very fine distinct spherical black (N 2/0), moist, iron-manganese concretions with clear boundaries in matrix and 5 percent very fine distinct irregular light olive brown (2.5Y 5/4), moist, iron-manganese masses with diffuse boundaries lining pores; 5 percent coarse prominent spherical strongly cemented brownish yellow (10YR 6/6), moist, carbonate concretions with sharp boundaries in matrix; 3 cracks in this horizon that are 0.5 cm wide filled with 10YR 3/1 soil from above; gradual wavy boundary. Lab sample # 06N00346

Bssg1--84 to 106 centimeters; very dark grayish brown (2.5Y 3/2) interior silty clay; 52 percent clay; strong very coarse prismatic parting to moderate coarse subangular blocky structure; very firm, extremely hard, very sticky, very plastic; common very fine roots throughout; common very fine high-continuity tubular pores; 3 percent continuous distinct dark gray (10YR 4/1), moist, slickensides (pedogenic) on top faces of peds; 5 percent very fine distinct irregular yellowish brown (10YR 5/6), moist, iron-manganese masses with diffuse boundaries lining pores; 2 percent coarse prominent spherical strongly cemented light brownish gray (10YR 6/2), moist, carbonate concretions with sharp boundaries in matrix; 3 cracks in this horizon that are 1 cm wide filled with 10YR 3/1 soil from above; gradual wavy boundary. Lab sample # 06N00347

Bssg2--106 to 142 centimeters; dark gray (2.5Y 4/1) interior silty clay; 55 percent clay; strong very coarse prismatic parting to moderate very coarse subangular blocky structure; very firm, extremely hard, very sticky, very plastic; common very fine roots throughout; common very fine moderate-continuity tubular pores; 5 percent continuous faint dark gray (2.5Y 4/1), moist, slickensides (pedogenic) on top faces of peds; 10 percent medium distinct irregular yellowish brown (10YR 5/6), moist, iron-manganese masses with diffuse boundaries lining pores; 1 percent coarse prominent spherical strongly cemented light brownish gray (10YR 6/2), moist, carbonate concretions with sharp boundaries in matrix; gradual smooth boundary. Lab sample # 06N00348

Bssg3--142 to 163 centimeters; dark gray (2.5Y 4/1) interior silty clay; 56 percent clay; strong very coarse prismatic parting to moderate very coarse subangular blocky structure; very firm, extremely hard, very sticky, very plastic; common very fine roots throughout; common very fine moderate-continuity tubular pores; 15 percent continuous faint dark gray (2.5Y 4/1), moist, slickensides (pedogenic) on top faces of peds; 20 percent medium distinct irregular yellowish brown (10YR 5/6), moist, iron-manganese masses with diffuse boundaries lining pores; 1 percent coarse prominent spherical strongly cemented light brownish gray (10YR 6/2), moist, carbonate concretions with sharp boundaries in matrix; clear smooth boundary. Lab sample # 06N00349

Bssg4--163 to 212 centimeters; dark gray (2.5Y 4/1) interior clay; 62 percent clay; moderate very coarse prismatic structure; very firm, extremely hard, very sticky, very plastic; common very fine roots throughout; common very fine moderate-continuity tubular pores; 10 percent continuous distinct dark gray (10YR 4/1), moist, slickensides (pedogenic) on top faces of peds; 5 percent medium distinct spherical black (N 2/0), moist, iron-manganese concretions with clear boundaries in matrix and 10 percent medium distinct irregular light olive brown (2.5Y 5/6), moist, iron-manganese masses with diffuse boundaries lining pores and 20 percent medium distinct irregular dark yellowish brown (10YR 4/6), moist, iron-manganese masses with diffuse boundaries lining pores; 1 percent coarse prominent spherical strongly cemented light brownish gray (10YR 6/2), moist, carbonate concretions with sharp boundaries in matrix. Lab sample # 06N00350

Site 7

Description Date: 10/09/1997
Describer: Owens, Gastineau, Assmus

Soil Name as Described/Sampled: ZAAR
Soil Name as Correlated: ZAAR
Classification: fine, smectitic, thermic Typic Epiaquert

Site ID: 97KS205001
Pedon ID: 97KS205001

County: Wilson
State: Kansas
MLRA: 112 -- Cherokee Prairies
Soil Survey Area: KS205 -- Wilson County, Kansas
Quad Name: Lafontaine, Kansas
Location Description: 229 meters east recorded on description changed to 229 meters west
Legal Description: 716 meters south and 229 meters west of the NE corner of Section 23, Township 30S, Range 14E
Latitude: 37 degrees 25 minutes 20.80 seconds north
Longitude: 95 degrees 50 minutes 6.90 seconds west

Lab Source ID: SSL
Lab Pedon #: 98P0063
Pedon Type: within range of map unit
Pedon Purpose: full pedon description
Taxon Kind: series
Geomorphic Setting: on footslope of hills
Upslope Shape: concave
Cross Slope Shape: concave
Description origin: Converted from PDP 3.x
Primary Earth Cover: Crop cover
Description database: NSSL

Particle Size Control Section:
Diagnostic
Features: cambic horizon 53 to 179 cm.

Slope (%): 1.0
Elevation (meters): 216.0
Aspect (deg): 180
Drainage Class: somewhat poorly

Ap--0 to 22 centimeters; black (10YR 2/1) broken face silty clay; weak medium angular blocky parting to weak medium granular structure; very firm, very hard, very sticky, very plastic; common very fine and fine roots throughout; common very fine and fine moderate-continuity tubular pores; 1 percent subrounded 2- to 75-millimeter unspecified fragments; noneffervescent; clear smooth boundary. Lab sample # 98P00453. The rock fragments were water-worn chert. Krotovinas present in all Horizons to Cr. From 2 to 10 cm in vertical position.

BA--22 to 53 centimeters; black (10YR 2/1) broken face silty clay; moderate medium prismatic parting to weak medium subangular blocky structure; very firm, extremely hard, very sticky, very plastic; common very fine and fine roots throughout; common very fine moderate-continuity tubular pores; 2 percent fine irregular olive brown (2.5Y 4/3) masses of oxidized iron throughout; noneffervescent; gradual wavy boundary. Lab sample # 98P00454

Bss1--53 to 86 centimeters; very dark gray (10YR 3/1) broken face silty clay; moderate coarse prismatic parting to moderate medium prismatic parting to moderate medium subangular blocky structure; very firm, extremely hard, very sticky, very plastic; common very fine roots throughout; common very fine moderate-continuity tubular pores; 15 percent continuous prominent very dark gray (10YR 3/1), moist, slickensides (pedogenic) on horizontal faces of peds; 2 percent fine irregular olive brown (2.5Y 4/3) masses of oxidized iron throughout; 1 percent fine spherical carbonate concretions; noneffervescent; clear wavy boundary. Lab sample # 98P00455

Bss2--86 to 117 centimeters; very dark gray (10YR 3/1) broken face silty clay; moderate coarse prismatic parting to weak medium subangular blocky structure; very firm, extremely hard, very sticky, very plastic; common very fine roots throughout; common very fine moderate-continuity tubular pores; 25 percent continuous prominent very dark gray (10YR 3/1), moist, slickensides (pedogenic) on horizontal faces of peds; 1 percent medium irregular light gray (10YR 7/1) lime masses between peds and 4 percent medium and coarse irregular weakly cemented light gray (10YR 7/1) carbonate concretions throughout; noneffervescent; clear smooth boundary. Lab sample # 98P00456

Bkss--117 to 147 centimeters; very dark grayish brown (10YR 3/2) broken face silty clay; moderate coarse prismatic parting to moderate medium subangular blocky structure; very firm, extremely hard, very sticky, very plastic; common very fine roots throughout; common very fine moderate-continuity tubular pores; 25 percent continuous prominent very dark gray (10YR 3/1), moist, slickensides (pedogenic) on horizontal faces of peds; 6 percent medium irregular brown (10YR 4/3) masses of oxidized iron throughout; noneffervescent; clear wavy boundary. Lab sample # 98P00457

Bss--147 to 179 centimeters; very dark gray (10YR 3/1) crushed silty clay; weak coarse subangular blocky parting to weak medium subangular blocky structure; very firm, extremely hard, very sticky, very plastic; common very fine roots throughout; common very fine moderate-continuity tubular pores; 35 percent continuous prominent very dark gray (10YR 3/1), moist, slickensides (pedogenic) on horizontal faces of peds; 60 percent medium irregular olive brown (2.5Y 4/3) masses of oxidized iron throughout; 1 percent medium irregular weakly cemented light gray (10YR 7/1) carbonate concretions throughout; 1 percent subrounded 2- to 75-millimeter unspecified fragments; noneffervescent; clear smooth boundary. Lab sample # 98P00458. Soft limestone bedrock

Cr--179 to 219 centimeters. Lab sample # 98P00459. Hard limestone bedrock

R--219 centimeters. Lab sample # 98P00460

Site 8

Description Date: 09/20/2005
Describer: D. Gastineau, W. Wehmueller

Soil Name as Described/Sampled: Kenoma
Classification: Fine, smectitic, thermic Vertic Argiudolls

Site ID: 05KS133003
Site Note: Global Water water level monitors are being installed at this site. This site is in a crop field a few feet west of a fence row in which water monitoring equipment is installed. The fence row and adjacent pasture are dominantly fescue. The majority of pedons (including typical pedon for the series) support Aquertic Argiudoll classification. Drainage class could be MW or SP depending on whether free water or plant effects are considered. The water table study should improve understanding of these issues.

Pedon ID: 05KS133003
Pedon Note: This pedon is located on a paleoterrace near a ridge on plains. The ancient alluvium of the paleoterrace appears to overlay material weathered from residuum. The contact between the alluvium and residuum is at 71 cm. The SiL surface horizon appears to be formed in loess that was deposited on the paleoterrace. Because the horizon formed in loess is only 17 cm thick, a discontinuity was not described by the horizon nomenclature.

County: Neosho
State: Kansas Osage Cuestas
MLRA: 112 -- Cherokee Prairies
Soil Survey Area: KS133 -- Neosho County, Kansas
Map Unit: 8775 -- Kenoma silt loam, 1 to 3 percent slopes
Quad Name: Shaw, Kansas
Location Description: Approximately 3 miles north of Galesburg, KS.
Legal Description: approximately 2640 ft east and 225 ft south of the northwest corner of Section 20, Township 29S, Range 19E
Latitude: 37 degrees 30 minutes 50.00 seconds north
Longitude: 95 degrees 21 minutes 9.80 seconds west
Datum: NAD83
UTM Zone: 15
UTM Easting: 292067 meters
UTM Northing: 4154482 meters

Lab Source ID: SSL
Lab Pedon #: 06N0122
Pedon Type: within range of series
Pedon Purpose: full pedon description
Taxon Kind: series
Associated Soils: Dennis, Parsons, Zaar
Physiographic Division: Interior Plains
Physiographic Province: Central Lowland Province
Physiographic Section: Osage plain
State Physiographic Area: Osage Cuestas
Local Physiographic Area:
Geomorphic Setting: on toeslope of base slope of paleoterrace on plains
Upslope Shape: convex

Cross Slope Shape: convex
Description origin: NASIS

Primary Earth Cover: Crop cover
Secondary Earth Cover: Row crop
Existing Vegetation: Bare Ground
Parent Material: silty loess derived from sedimentary rock over clayey alluvium derived from sedimentary rock over clayey residuum weathered from shale
Bedrock Kind:
Bedrock Depth:
Bedrock Hardness:
Bedrock Fracture Interval:
Surface Fragments:
Description database: NSSL

Particle Size Control Section: 17 to 67 cm.
Diagnostic
Features:

- mollic epipedon 0 to 71 cm.
- argillic horizon 17 to 128 cm.
- slickensides 38 to 71 cm.
- lithologic discontinuity 71 cm.
- slickensides 101 to 174 cm.

Slope (%): 0.5
Elevation (meters): 294.0
Aspect (deg): 90
MAAT (C): 14.0
MAP (mm): 104
Drainage Class: moderately well

Ap--0 to 17 centimeters; very dark grayish brown (10YR 3/2) crushed silt loam; 22 percent clay; weak medium subangular blocky parting to moderate medium granular structure; friable, slightly hard, nonsticky, nonplastic; common fine roots throughout and many very fine roots throughout; common fine moderatecontinuity tubular and common very fine moderate-continuity tubular pores; 1 percent fine distinct irregular dark brown (7.5YR 3/4), moist, masses of oxidized iron with diffuse boundaries infused into matrix adjacent to pores; moist; clear smooth boundary. Lab sample # 06N00335

Bt1--17 to 38 centimeters; very dark grayish brown (10YR 3/2) crushed silty clay; 49 percent clay; moderate medium prismatic parting to moderate medium angular blocky structure; friable, slightly hard, nonsticky, nonplastic; common fine roots throughout and common very fine roots throughout; common fine moderate-continuity tubular and common very fine moderate-continuity tubular pores; 30 percent continuous faint very dark grayish brown (10YR 3/2), moist, clay films on all faces of peds; 3 percent fine distinct irregular dark brown (7.5YR 3/4), moist, masses of oxidized iron with diffuse boundaries infused into matrix adjacent to pores; moist matrix much free water on ped faces 5 days since 1.2 in. rain; clear smooth boundary. Lab sample # 06N00336

Bt2--38 to 71 centimeters; very dark grayish brown (10YR 3/2) crushed silty clay; 55 percent clay; moderate coarse prismatic parting to moderate coarse subangular blocky structure; friable, slightly hard, nonsticky, nonplastic; common very fine roots throughout; common fine moderate-continuity tubular and common very fine moderate-continuity tubular pores; 5 percent continuous distinct very dark gray (10YR 3/1), moist, slickensides (pedogenic) on all faces of peds and 30 percent continuous faint very dark grayish brown (10YR 3/2), moist, clay films on all faces of peds; 1 percent fine distinct irregular dark brown (7.5YR 3/4), moist, masses of oxidized iron with diffuse boundaries infused into matrix along faces of peds and 7 percent fine prominent spherical moderately cemented black (N 2/0), moist, iron-manganese nodules with diffuse boundaries in matrix; moist matrix some free water on ped faces 5 days since 1.2 in. rain; clear wavy boundary. Lab sample # 06N00337

2Btg1--71 to 101 centimeters; dark yellowish brown (10YR 4/4) broken face silty clay; 50 percent clay; weak coarse prismatic structure; very firm, extremely hard, very sticky, very plastic; common very fine roots throughout; common very fine moderate-continuity tubular pores; 15 percent continuous distinct gray (10YR 5/1), moist, silt coats on vertical faces of peds and 20 percent continuous faint dark gray (10YR 4/1), moist, clay films on all faces of peds; 10 percent fine distinct irregular very weakly cemented black (N 2/0), moist, manganese masses with diffuse boundaries infused into matrix along faces of peds and 20 percent coarse distinct irregular gray (10YR 5/1), moist, iron depletions with diffuse boundaries in matrix; 1 percent fine prominent dendritic weakly cemented white (10YR 8/1), moist, gypsum crystals with sharp boundaries lining pores; moderately dry; clear wavy boundary. Lab sample # 06N00338

2Btg2--101 to 128 centimeters; dark grayish brown (10YR 4/2) broken face silty clay; 55 percent clay; moderate medium prismatic parting to moderate medium angular blocky structure; very firm, extremely hard, very sticky, very plastic; common very fine roots throughout; common fine moderate- continuity tubular and common very fine moderate-continuity tubular pores; 2 percent continuous distinct very dark gray (10YR 3/1), moist, slickensides (pedogenic) on all faces of peds and 3 percent continuous distinct organoargillans on all faces of peds and 20 percent continuous faint dark grayish brown (10YR 4/2), moist, clay films on all faces of peds; 10 percent coarse distinct irregular very weakly cemented black (N 2/0), moist, manganese masses with diffuse boundaries infused into matrix along faces of peds and 20 percent coarse distinct irregular dark yellowish brown (10YR 4/4), moist, masses of oxidized iron with diffuse boundaries infused into matrix along faces of peds; 1 percent flat subrounded noncemented 2- to 150-millimeter shale fragments; some free moisture on ped faces 3 cm dia. vertical krotovina (crayfish); clear wavy boundary. Lab sample # 06N00339

2Bssg1--128 to 156 centimeters; dark grayish brown (10YR 4/2) broken face silty clay; 55 percent clay; moderate coarse prismatic parting to moderate coarse subangular blocky structure; firm, extremely hard, moderately sticky, moderately plastic; common very fine roots throughout; common fine moderate-continuity tubular and common very fine moderate-continuity tubular pores; 2 percent continuous distinct dark gray (10YR 4/1), moist, slickensides (pedogenic) on all faces of peds and 40 percent continuous faint dark gray (10YR 4/1), moist, clay films on all faces of peds; 5 percent coarse distinct irregular yellowish brown (10YR 5/6), moist, masses of oxidized iron with diffuse boundaries infused into matrix along faces of peds and 5 percent coarse distinct irregular very weakly cemented black (N 2/0), moist, manganese masses with diffuse boundaries infused into matrix along faces of peds; 3 percent flat subrounded noncemented 2- to 150-millimeter shale fragments; moist matrix no free water on peds; clear smooth boundary. Lab sample # 06N00340

2Bssg2--156 to 174 centimeters; dark gray (10YR 4/1) broken face silty clay; 52 percent clay; moderate coarse prismatic parting to moderate coarse subangular blocky structure; firm, extremely hard, moderately sticky, moderately plastic; common very fine roots throughout; common very fine moderate-continuity tubular pores; 1 percent continuous distinct brown (10YR 4/3), moist, clay films on surfaces along pores and 20 percent continuous faint dark gray (10YR 4/1), moist, clay films on all faces of peds and 20 percent continuous distinct dark grayish brown (10YR 4/2), moist, slickensides (pedogenic) on all faces of peds; 10 percent medium distinct irregular yellowish brown (10YR 5/6), moist, masses of oxidized iron with diffuse boundaries infused into matrix along faces of peds; 5 percent flat subrounded noncemented 2- to 150-millimeter shale fragments; moist matrix no free water on peds; gradual smooth boundary. Lab sample # 06N00341

2BC--174 to 195 centimeters; 50 percent dark gray (2.5Y 4/1) broken face and 40 percent gray (5Y 6/1) broken face and 10 percent black (N 2/0) broken face silty clay; 55 percent clay; weak medium subangular blocky structure; firm, extremely hard, moderately sticky, moderately plastic; common very fine roots throughout; common very fine moderate-continuity tubular pores; 1 percent discontinuous faint gray (2.5Y 5/1), moist, pressure faces on all faces of peds; 5 percent coarse prominent irregular moderately cemented black (N 2/0), moist, manganese masses with diffuse boundaries in matrix and 10 percent medium distinct irregular yellowish brown (10YR 5/6), moist, masses of oxidized iron with diffuse boundaries infused into matrix along faces of peds; 50 percent flat subrounded noncemented 2- to 150-millimeter shale fragments; 50% noncemented weathered shale; after drying and rewetting the material slakes; gradual smooth boundary. Lab sample # 06N00342

Site 9

Description Date: 10/18/2006
Describer: D. Gastineau, W. Wehmueller & JC Remley

Soil Name as Described/Sampled: Parsons
Classification: Fine, mixed, active, thermic Vertic Albaqualfs

Site ID: 06KS133001
Site Note: Global water water table monitors are being installed at this site. Drainage class of somewhat poorly drained in this pedon is based on the periodic occurrence of free water in the upper 20 inches of the soil. It is not my (Don Gastineau) opinion that this wetness markedly restricts the growth of mesophytic crops. Since the Soil Survey Manual gives both the presence of free water at shallow depths and the restriction to mesophytic crops as criteria for somewhat poorly drained soil, I am choosing to apply the more objective (presence of free water) of these two in order to assign the drainage class. In looking at similar soils (Taloka, Woodson, Medoc & Opolis) it appears that this reasoning is dominant. The exception may be Opolis. This pedon is near an erosional shoulder of an ancient terrace tread. The erosional shoulder is being caused by a small, intermittent stream that is about 200 ft West of this pedon.

Pedon ID: 06KS133001

County: Neosho
State: Kansas Osage Cuestas
MLRA: 112 -- Cherokee Prairies
Soil Survey Area: KS133 -- Neosho County, Kansas
Quad Name: Shaw, Kansas
Map Unit: 8863 -- Parsons silt loam, 0 to 1 percent slopes
Location Description: About 2.5 miles north of Galesburg, Kansas.
Legal Description: 2680 ft S, 1315 ft E of NW corner of section of Section 20, Township 29 S, Range 19 E
Latitude: 37 degrees 30 minutes 26.90 seconds north
Longitude: 95 degrees 21 minutes 25.90 seconds west
Datum: NAD83
UTM Zone: 15
UTM Easting: 291654 meters
UTM Northing: 4153782 meters

Lab Source ID: SSL
Lab Pedon #: 07N0134
Pedon Type: within range of map unit
Pedon Purpose: full pedon description
Taxon Kind: series
Associated Soils: Bates, Dennis, Kenoma, Zaar
Physiographic Division: Interior Plains
Physiographic Province: Central Lowland Province
Physiographic Section: Osage plain
State Physiographic Area: Osage Cuestas
Local Physiographic Area:
Geomorphic Setting: on shoulder of tread of paleoterrace on alluvial plain remnant
Upslope Shape: convex
Cross Slope Shape: convex

Description origin: NASIS

Primary Earth Cover: Grass/herbaceous cover
Secondary Earth Cover:
Existing Vegetation: big bluestem, switchgrass
Parent Material: silty loess over clayey alluvium over clayey residuum
Bedrock Kind: shale
Description database: NSSL

Particle Size Control Section: 28 to 78 cm.
Diagnostic
Features:

- ochric epipedon 0 to 18 cm.
- albic horizon 18 to 28 cm.
- abrupt textural change 27 to 29 cm.
- argillic horizon 28 to 205 cm.
- redox concentrations 28 to 205 cm.

Slope (%): 1.0
Elevation (meters): 296.0
Aspect (deg): 340
MAAT (C): 14.0
MAP (mm): 106
Drainage Class Slope: somewhat poorly

A--0 to 18 centimeters; very dark grayish brown (10YR 3/2) rubbed silt loam, light brownish gray (10YR 6/2) crushed and grayish brown (10YR 5/2) broken face, dry; 24 percent clay; moderate fine granular structure; very friable, slightly hard, nonsticky, nonplastic; low excavation difficulty; many fine roots throughout and many very fine roots throughout; common fine moderate-continuity tubular and many very fine moderate-continuity tubular pores; noneffervescent, by HCl, 1 normal; gradual smooth boundary. Lab sample # 07N00882

E--18 to 28 centimeters; dark grayish brown (10YR 4/2) rubbed silt loam, light brownish gray (10YR 6/2) broken face, dry; 24 percent clay; moderate fine subangular blocky parting to weak medium granular structure; friable, slightly hard, nonsticky, nonplastic; low excavation difficulty; common fine roots throughout and many very fine roots throughout; common fine moderate-continuity tubular and common very fine moderate-continuity tubular pores; 1 percent fine prominent irregular dark yellowish brown (10YR 4/6), moist, masses of oxidized iron with diffuse boundaries in matrix; noneffervescent, by HCl, 1 normal; abrupt smooth boundary. Lab sample # 07N00883

2Btg1--28 to 55 centimeters; dark grayish brown (10YR 4/2) broken face silty clay; 58 percent clay; moderate coarse prismatic parting to moderate medium subangular blocky structure; very firm, extremely hard, moderately sticky, very plastic; high excavation difficulty; common fine roots throughout and many very fine roots throughout; many very fine moderate-continuity tubular pores; 40 percent continuous faint very dark grayish brown (10YR 3/2), moist, clay films on all faces of peds; 2 percent medium distinct irregular black (N 2/0), moist, manganese coatings with diffuse boundaries on vertical faces of peds and 5 percent medium distinct irregular dark yellowish brown (10YR 4/6), moist, masses of oxidized iron with diffuse boundaries in matrix; noneffervescent, by HCl, 1 normal; clear smooth boundary. Lab sample # 07N00884

2Btg2--55 to 91 centimeters; dark grayish brown (10YR 4/2) broken face silty clay; 58 percent clay; moderate coarse prismatic parting to moderate medium prismatic parting to moderate coarse subangular blocky structure; very firm, extremely hard, moderately sticky, very plastic; high excavation difficulty; many very fine roots throughout; many very fine moderate-continuity tubular pores; 15 percent continuous faint very dark grayish brown (10YR 3/2), moist, clay films on all faces of peds; 2 percent medium distinct irregular black (N 2/0), moist, manganese coatings with diffuse boundaries on vertical faces of peds and 20 percent medium distinct irregular dark yellowish brown (10YR 4/6), moist, masses of oxidized iron with diffuse boundaries in matrix; noneffervescent, by HCl, 1 normal; gradual smooth boundary. Lab sample # 07N00885

2Btyg1--91 to 115 centimeters; dark grayish brown (10YR 4/2) broken face silty clay; 55 percent clay; moderate medium prismatic parting to moderate coarse subangular blocky structure; very firm, extremely hard, moderately sticky, very plastic; high excavation difficulty; many very fine roots throughout; common very fine moderate-continuity tubular pores; 20 percent continuous faint very dark grayish brown (10YR 3/2), moist, clay films on all faces of peds; 2 percent medium distinct irregular black (N 2/0), moist, manganese coatings with diffuse boundaries on vertical faces of peds and 15 percent medium prominent irregular red (2.5YR 4/6), moist, masses of oxidized iron with diffuse boundaries in matrix and 15 percent medium distinct irregular dark gray (2.5Y 4/1), moist, iron depletions with diffuse boundaries infused into matrix along faces of peds; 10 percent coarse prominent irregular moderately cemented gypsum nests on surfaces along pores; noneffervescent, by HCl, 1 normal; gradual smooth boundary. Lab sample # 07N00886

2Btyg2--115 to 142 centimeters; dark grayish brown (2.5Y 4/2) broken face silty clay; 55 percent clay; weak medium prismatic parting to moderate medium subangular blocky structure; very firm, extremely hard, moderately sticky, very plastic; high excavation difficulty; common very fine roots throughout; common very fine moderate-continuity tubular pores; 20 percent continuous faint dark gray (2.5Y 4/1), moist, clay films on all faces of peds; 5 percent fine prominent spherical black (N 2/0), moist, iron-manganese nodules with diffuse boundaries throughout and 5 percent medium distinct irregular dark yellowish brown (10YR 4/6), moist, masses of oxidized iron with diffuse boundaries throughout and 30 percent coarse prominent irregular red (2.5YR 4/6), moist, masses of oxidized iron with diffuse boundaries throughout; 2 percent medium prominent irregular moderately cemented gypsum nests on surfaces along pores and 2 percent medium prominent irregular moderately cemented gypsum nests on faces of peds; noneffervescent, by HCl, 1 normal; Black FeMn accumulations up to 1 mm thick; gradual smooth boundary. Lab sample # 07N00887

2Btg3--142 to 176 centimeters; dark gray (2.5Y 4/1) broken face silty clay; 55 percent clay; weak medium prismatic parting to moderate medium subangular blocky structure; very firm, extremely hard, moderately sticky, very plastic; moderate excavation difficulty; common very fine roots throughout; common very fine moderate-continuity tubular pores; 20 percent continuous faint dark gray (10YR 4/1), moist, clay films on all faces of peds; 5 percent fine prominent spherical black (N 2/0), moist, iron-manganese nodules with diffuse boundaries throughout and 10 percent medium distinct irregular dark yellowish brown (10YR 4/6), moist, masses of oxidized iron with diffuse boundaries throughout and 30 percent coarse prominent irregular red (2.5YR 4/6), moist, masses of oxidized iron with diffuse boundaries infused into matrix adjacent to pores; 1 percent medium prominent irregular moderately cemented gypsum nests on faces of peds; noneffervescent, by HCl, 1 normal; Black FeMn accumulations up to 1 mm thick; clear smooth boundary. Lab sample # 07N00888

3Btg4--176 to 205 centimeters; gray (2.5Y 5/1) broken face silty clay; 55 percent clay; moderate coarse subangular blocky parting to moderate medium angular blocky structure; very firm, extremely hard, moderately sticky, very plastic; moderate excavation difficulty; common very fine roots throughout; common very fine moderate-continuity tubular pores; 10 percent continuous faint dark gray (2.5Y 4/1), moist, pressure faces on vertical faces of peds and 40 percent continuous faint dark gray (2.5Y 4/1), moist, clay films on vertical faces of peds; 20 percent coarse distinct irregular (2.5Y 4/6), moist, masses of oxidized iron with diffuse boundaries throughout and 20 percent medium distinct irregular dark yellowish brown (10YR 4/6), moist, masses of oxidized iron with diffuse boundaries throughout; 1 percent medium prominent irregular moderately cemented gypsum nests on faces of peds; noneffervescent, by HCl, 1 normal. Lab sample # 07N00889

Site 10

Description Date: 08/01/1986

Soil Name as Described/Sampled: Eram
Soil Name as Correlated: Eram
Classification: Fine, mixed, active, thermic Aquic Argiudolls

Site ID: 86KS133005
Pedon ID: 86KS133005

County: Neosho
State: Kansas
MLRA: 112 -- Cherokee Prairies
Location Description: Neosho County, KS.
Legal Description: 2300 feet north and 325 feet east of the SW corner of Section 6, Township 30S, Range 20E
Latitude: 37 degrees 27 minutes 47.00 seconds north
Longitude: 95 degrees 16 minutes 4.00 seconds west

Lab Source ID: SSL
Lab Pedon #: 86P0872
Pedon Purpose: full pedon description
Taxon Kind: series
Geomorphic Setting: on backslope of side slope of upland slope
on backslope of side slope of upland
Upslope Shape: concave
Primary Earth Cover: Grass/herbaceous cover
Description origin: Converted from SSL-CMS data

Particle Size Control Section: 16 to 66 cm.
Description database: NSSL
Diagnostic
Features:
- mollic epipedon 0 to 28 cm.
- argillic horizon 16 to 65 cm.
- lithic contact 91 to 0 cm.

Slope (%): 4.0
Elevation (meters):
Aspect (deg): 180
MAAT (C): 18.0
MAP (mm): 100
Drainage Class: moderately well

Ap--0 to 16 centimeters; very dark grayish brown (10YR 3/2) interior silty clay loam, dark grayish brown (10YR 4/2) interior, dry; weak fine and medium granular structure; friable, hard; many fine roots; clear smooth boundary. Lab sample # 86P5215. many fine roots

Bt1--16 to 28 centimeters; very dark grayish brown (2.5Y 3/2) interior silty clay, dark grayish brown (2.5Y 4/2) interior, dry; 1 percent fine faint brown (10YR 4/3) mottles; moderate fine and medium subangular blocky structure;

very firm, very hard; common fine roots; patchy faint clay films; 1 percent fine spherical iron concretions; clear wavy boundary. Lab sample # 86P5216. few fine iron concretions concentrations;
common fine roots; few fine faint 10YR43 mottles

Bt2--28 to 43 centimeters; dark grayish brown (2.5Y 4/2) interior clay; 11 percent fine prominent light olive brown (2.5Y 5/6) mottles; moderate medium angular blocky structure; very firm, extremely hard; common fine roots; patchy faint , moist, clay films; 11 percent fine spherical iron concretions; gradual wavy boundary. Lab sample # 86P5217. Few fine shale fragments less than 2% by volume.; common fine iron concretions concentrations;
common fine roots; common fine prominent 2.5Y56 mottles

Bt3--43 to 65 centimeters; grayish brown (2.5Y 5/2) interior and light olive brown (2.5Y 5/6) interior clay; moderate medium angular blocky structure; very firm, extremely hard; few fine roots; patchy faint , moist, clay films; 1 percent fine spherical iron concretions; gradual wavy boundary. Lab sample # 86P5218. Common fine shale fragments about 5% by volume.; few fine iron concretions concentrations; few fine roots

BC--65 to 91 centimeters; olive gray (5Y 5/2) interior and olive (5Y 5/6) interior shaly clay; weak medium angular blocky structure; very firm, extremely hard; few fine roots; clear wavy boundary. Lab sample # 86P5219. About 30% soft shale fragments by volume.; few fine roots

Cr--91 centimeters; weathered bedrock. Lab sample # 86P5220. Soft, platy, gray shale. Some calcareous seams in Cr horizon.

Appendix B - Laboratory Characterization Data

Appendix B contains full soil characterization data as completed by the U.S. Department of Agriculture, Natural Resource Conservation Service, National Soil Survey Laboratory.

Site 1

Pedon ID: S09KS139001 (Osage, Kansas) Print Date: Apr 4 2010 3:03PM

Sampled as : Bucyrus ; Fine, mixed, active, thermic Oxyaquic Vertic Argiudoll
Revised to :

United States Department of Agriculture
Natural Resources Conservation Service
National Soil Survey Center
Soil Survey Laboratory
Lincoln, Nebraska 68508-3866

SSL - Project C2009USKS101 Mesonet Series
- Site ID S09KS139001 Lat: 38° 41' 49.74" north Long: 95° 36' 30.56" west NAD83 MLRA: 112
- Pedon No. 09N0905
- General Methods 1B1A, 2A1, 2B

Layer	Horizon	Orig Hzn	Depth (cm)	Field Label 1	Field Label 2	Field Label 3	Field Texture	Lab Texture
09N03253	Ap		0-11	S09KS139001-1			SICL	SIL
09N03254	A		11-28	S09KS139001-2			SICL	SICL
09N03255	BA		28-46	S09KS139001-3			SICL	SICL
09N03256	Bt1		46-60	S09KS139001-4			SIC	SIC
09N03257	Bt2		60-81	S09KS139001-5			SIC	SIC
09N03258	Btss1		81-100	S09KS139001-6			C	SIC
09N03259	2Btss2		100-159	S09KS139001-7			C	SIC
09N03260	2Btss3		159-186	S09KS139001-8			C	C

Pedon Calculations

Calculation Name	Result	Units of Measure
Weighted Particles, 0.1-75mm, 75 mm Base	3	% wt
Volume, >2mm, Weighted Average	1	% vol
Clay, total, Weighted Average	52	% wt
Clay, total, Weighted Average	52	% wt
Clay, total, Weighted Average	52	% wt
Clay, total, Weighted Average	52	% wt
Clay, total, Weighted Average	52	% wt
Clay, total, Weighted Average	52	% wt
Clay, total, Weighted Average	52	% wt
Clay, total, Weighted Average	52	% wt
Clay, carbonate free, Weighted Average	52	% wt
Clay, carbonate free, Weighted Average	52	% wt
Clay, carbonate free, Weighted Average	52	% wt
Clay, carbonate free, Weighted Average	52	% wt
Clay, carbonate free, Weighted Average	52	% wt
Clay, carbonate free, Weighted Average	52	% wt
Clay, carbonate free, Weighted Average	52	% wt
Clay, carbonate free, Weighted Average	52	% wt
CEC Activity, CEC7/Clay, Weighted Average, CECd, Set 1	0.56	(NA)
CEC Activity, CEC7/Clay, Weighted Average, CECd, Set 1	0.56	(NA)
CEC Activity, CEC7/Clay, Weighted Average, CECd, Set 1	0.56	(NA)
CEC Activity, CEC7/Clay, Weighted Average, CECd, Set 1	0.56	(NA)
CEC Activity, CEC7/Clay, Weighted Average, CECd, Set 1	0.56	(NA)
CEC Activity, CEC7/Clay, Weighted Average, CECd, Set 1	0.56	(NA)
CEC Activity, CEC7/Clay, Weighted Average, CECd, Set 1	0.56	(NA)
CEC Activity, CEC7/Clay, Weighted Average, CECd, Set 1	0.56	(NA)
LE, Whole Soil, Summed to 1m	7	cm/m
LE, Whole Soil, Summed to 1m	7	cm/m
LE, Whole Soil, Summed to 1m	7	cm/m
LE, Whole Soil, Summed to 1m	7	cm/m
LE, Whole Soil, Summed to 1m	7	cm/m
LE, Whole Soil, Summed to 1m	7	cm/m
LE, Whole Soil, Summed to 1m	7	cm/m
LE, Whole Soil, Summed to 1m	7	cm/m

Weighted averages based on control section: 46-96 cm

*** Primary Characterization Data ***

Pedon ID: S09KS139001 (Osage, Kansas) Print Date: Apr 4 2010 3:03PM

Sampled As : Bucyrus Fine, mixed, active, thermic Oxyaquic Vertic Argiudoll

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 09N0905

PSDA & Rock Fragments

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-
				(- - - - - Total - - - - - -)			(- - Clay - - -)		(- - - - Silt - - - - -)		(- - - - - - - - - - - - Sand - - - - - - - - - - - -)					(Rock Fragments (mm))				
				Clay	Silt	Sand	Fine	CO_3	Fine	Coarse	VF	F	M	C	VC	(- - - - - - - - Weight - - - - - - - -)				>2 mm
				<	.002	.05	<	<	.002	.02	.05	.10	.25	.5	1	2	5	20	.1-	wt %
	Depth			.002	-.05	-2	.0002	.002	-.02	-.05	-.10	-.25	-.50	-1	-2	-5	-20	-75	75	whole
Layer	(cm)	Horz	Prep	(- % of <2mm Mineral Soil -)												(- - - - - - - % of <75mm - - - - - -)				soil
				3A1a1a			3A1a1a		3A1a1a		3A1a1a	3A1a1a	3A1a1a	3A1a1a	3A1a1a					
09N03253	0-11	Ap	S	26.6	69.0	4.4	17.1		33.4	35.6	2.7	1.0	0.5	0.1	0.1	1	tr	--	3	1
09N03254	11-28	A	S	30.7	65.1	4.2	19.6		33.4	31.7	2.2	1.0	0.6	0.1	0.3	tr	tr	--	2	tr
09N03255	28-46	BA	S	35.6	60.4	4.0	24.2		30.6	29.8	2.3	0.9	0.6	0.2	tr	tr	1	--	3	1
09N03256	46-60	Bt1	S	47.4	48.4	4.2	36.3		27.3	21.1	2.2	1.0	0.6	0.3	0.1	tr	1	--	3	1
09N03257	60-81	Bt2	S	55.2	41.3	3.5	44.2		24.0	17.3	2.1	0.7	0.4	0.2	0.1	1	tr	--	2	1
09N03258	81-100	Btss1	S	52.1	44.6	3.3	40.3		25.3	19.3	2.0	0.7	0.2	0.2	0.2	tr	1	--	2	1
09N03259	100-159	2Btss2	S	51.6	44.1	4.3	39.0		23.5	20.6	2.7	0.8	0.2	0.3	0.3	1	1	--	4	2
09N03260	159-186	2Btss3	S	67.4	30.9	1.7	44.9		25.5	5.4	0.9	0.5	0.2	0.1	--	tr	2	--	3	2

Water Dispersible PSDA

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-
				(- Water Dispersible -)											
				(- - - - - Total - - - - - -)			(- - Clay - - -)		(- - - - Silt - - - - -)		(- - - - - - - - - - - - Sand - - - - - - - - - - - -)				
				Clay	Silt	Sand	F	CO_3	F	C	VF	F	M	C	VC
				<	.002	.05	<	<	.002	.02	.05	.10	.25	.5	1
	Depth			.002	-.05	-2	.0002	.002	-.02	-.05	-.10	-.25	-.50	-1	-2
Layer	(cm)	Horz	Prep	(- % of <2mm -)											
				3A1a6a					3A1a6a		3A1a6a	3A1a6a	3A1a6a	3A1a6a	3A1a6a
09N03253	0-11	Ap	S	8.8	72.1	19.1			36.6	35.5	6.8	6.5	4.0	1.3	0.5

*** Primary Characterization Data ***

Pedon ID: S09KS139001 (Osage, Kansas) Print Date: Apr 4 2010 3:03PM

Sampled As : Bucyrus Fine, mixed, active, thermic Oxyaquic Vertic Argiudoll

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 09N0905

Bulk Density & Moisture

Layer	Depth (cm)	Horz	Prep	-1- (Bulk Density) 33 kPa (- - - g cm^{-3} - - -) DbWR1	-2- (Bulk Density) Oven Dry DbWR1	-3- Cole Whole Soil	-4- Water Content 6 kPa (% of < 2mm)	-5- Water Content 10 kPa	-6- Water Content 33 kPa DbWR1	-7- Water Content 1500 kPa 3C2a1a	-8- 1500 kPa Moist	-9- Ratio AD/OD 3D1	-10- WRD Whole Soil cm^3 cm^{-3}	-11- Aggst Stabl 2-0.5mm % 3F1a1a	-12- (Ratio/Clay) CEC7	-13- (Ratio/Clay) 1500 kPa
09N03253	0-11	Ap	S	1.09	1.26	0.049			30.2	15.5		1.031	0.16	79	0.87	0.58
09N03254	11-28	A	S	1.33	1.48	0.036			25.7	13.8		1.031	0.16		0.72	0.45
09N03255	28-46	BA	S	1.20	1.39	0.050			27.7	15.3		1.036	0.15		0.61	0.43
09N03256	46-60	Bt1	S	1.30	1.68	0.088			30.2	20.2		1.051	0.13		0.58	0.43
09N03257	60-81	Bt2	S	1.38	1.85	0.102			30.9	23.2		1.061	0.11		0.56	0.42
09N03258	81-100	Btss1	S	1.42	1.83	0.088			29.8	21.7		1.059	0.11		0.55	0.42
09N03259	100-159	2Btss2	S	1.45	1.88	0.089			29.3	22.0		1.062	0.10		0.58	0.43
09N03260	159-186	2Btss3	S	1.14	1.60	0.118			46.1	31.1		1.076	0.17		0.53	0.46

Water Content

Layer	Depth (cm)	Horz	Prep	-1- (Atterberg Limits) LL pct <0.4mm	-2- (Atterberg Limits) PI	-3- Bulk Density Field (g cm^{-3})	-4- Bulk Density Recon 33 kPa 3B2	-5- Bulk Density Recon Oven Dry 3B2	-6- Water Content Field (% of < 2mm)	-7- Water Content Recon 33 kPa 3B2	-8- Sieved Samples 6 kPa	-9- Sieved Samples 10 kPa	-10- Sieved Samples 33 kPa	-11- Sieved Samples 100 kPa 3C1d1a	-12- Sieved Samples 200 kPa 3C1e1a	-13- Sieved Samples 500 kPa 3C2b
09N03253	0-11	Ap	S				1.03	1.13		34.8				22.6	21.2	20.5
09N03254	11-28	A	S											20.8	18.5	18.2
09N03255	28-46	BA	S											24.3	21.7	19.7
09N03256	46-60	Bt1	S											27.8	25.6	24.7
09N03257	60-81	Bt2	S											31.3	29.1	27.9
09N03258	81-100	Btss1	S											29.8	28.0	25.6
09N03259	100-159	2Btss2	S											31.5	29.2	26.7
09N03260	159-186	2Btss3	S											43.1	40.2	37.2

*** Primary Characterization Data ***

Pedon ID: S09KS139001 (Osage, Kansas) Print Date: Apr 4 2010 3:03PM

Sampled As : Bucyrus Fine, mixed, active, thermic Oxyaquic Vertic Argiudoll

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 09N0905

Carbon & Extractions

Layer	Depth (cm)	Horz	Prep	-1- Total C (% of <2 mm) 4H2a	-2- Total N (% of <2 mm) 4H2a	-3- Total S (% of <2 mm) 4H2a	-4- Org C	-5- C/N Ratio	-6- Dith-Cit Ext Fe (% of < 2mm) 4G1	-7- Dith-Cit Ext Al 4G1	-8- Dith-Cit Ext Mn 4G1	-9- Ammonium Oxalate Extraction Al+½Fe	-10- ODOE	-11- Fe	-12- Al	-13- Si	-14- Mn mg kg^{-1}	-15- Na Pyro-Phosphate C (% of < 2mm)	-16- Fe	-17- Al	-18- Mn
09N03253	0-11	Ap	S	3.68	0.32	0.04		11	1.3	0.1	0.1										
09N03254	11-28	A	S	2.31	0.21	0.01		11	1.4	0.2	0.1										
09N03255	28-46	BA	S	1.89	0.16	0.01		12	1.6	0.2	0.1										
09N03256	46-60	Bt1	S	1.47	0.12	0.01		12	2.1	0.3	0.1										
09N03257	60-81	Bt2	S	1.09	0.12	--		9	2.5	0.4	0.1										
09N03258	81-100	Btss1	S	0.60	0.06	--		11	2.2	0.4	0.1										
09N03259	100-159	2Btss2	S	0.35	0.08	--		4	2.2	0.3	0.1										
09N03260	159-186	2Btss3	S	0.30	0.07	tr		4	4.0	0.3	0.1										

CEC & Bases

Layer	Depth (cm)	Horz	Prep	-1- NH_4OAC Extractable Bases Ca (cmol(+) kg^{-1}) 4B1a1a	-2- Mg 4B1a1a	-3- Na 4B1a1a	-4- K 4B1a1a	-5- Sum Bases	-6- Acid-ity 4B2b1a1	-7- Extr Al 4B3a1a	-8- KCl Mn mg kg^{-1} 4B3a1a	-9- CEC8 Sum Cats (cmol(+) kg^{-1})	-10- CEC7 NH_4 OAC 4B1a1a	-11- ECEC Bases +Al	-12- Al Sat (%)	-13- Base Saturation Sum	-14- Base Saturation NH_4OAC
09N03253	0-11	Ap	S	17.4	3.5	0.1	0.6	21.6	10.4			32.0	23.2			68	93
09N03254	11-28	A	S	14.0	3.6	0.1	0.3	18.0	12.6	tr	1.3	30.6	22.0			59	82
09N03255	28-46	BA	S	14.4	4.0	0.1	0.3	18.8	11.4			30.2	21.7			62	87
09N03256	46-60	Bt1	S	15.8	5.2	0.2	0.4	21.6	13.1			34.7	27.6			62	78
09N03257	60-81	Bt2	S	19.1	6.5	0.4	0.6	26.6	12.5			39.1	30.9			68	86
09N03258	81-100	Btss1	S	20.5	6.3	0.4	0.5	27.7	9.2			36.9	28.5			75	97
09N03259	100-159	2Btss2	S	25.1*	6.6	0.6	0.5	32.8	5.8			38.6	29.9			85	100
09N03260	159-186	2Btss3	S	35.0*	7.8	0.9	0.7	44.4	5.8				35.7				100

*Extractable Ca may contain Ca from calcium carbonate or gypsum., CEC7 base saturation set to 100.

*** Primary Characterization Data ***

Pedon ID: S09KS139001 (Osage, Kansas) Print Date: Apr 4 2010 3:03PM

Sampled As : Bucyrus Fine, mixed, active, thermic Oxyaquic Vertic Argiudoll

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 09N0905

Salt

-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-	-18-	-19-	-20-
(- - - Water Extracted From Saturated Paste - - -)															Total	Elec	Pred Elec	Exch	

Layer	Depth (cm)	Horz	Prep	Ca	Mg	Na	K	CO_3	HCO_3	F	Cl	PO_4	Br	OAC	SO_4	NO_2	NO_3	H_2O	Salts	Cond	Cond	Na	SAR
				(- - - - - mmol(+) L^{-1} - - - - -)				(- mmol(-) L^{-1} -)										(- - - - % - - - -)		(- - dS m^{-1} - -)		%	
																					4F1a1a1		
09N03253	0-11	Ap	S																		0.20	tr	
09N03254	11-28	A	S																		0.05	1	
09N03255	28-46	BA	S																		0.04	1	
09N03256	46-60	Bt1	S																		0.04	1	
09N03257	60-81	Bt2	S																		0.05	1	
09N03258	81-100	Btss1	S																		0.08	1	
09N03259	100-159	2Btss2	S																		0.12	2	
09N03260	159-186	2Btss3	S																		0.23	3	

pH & Carbonates

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-
				(- - - - - - - - - - - - - - - - - - pH - - - - - - - - - - - - - - - - - -)						(- - Carbonate - -) As $CaCO_3$		(- - Gypsum - - -) As $CaSO_4*2H_2O$		
Layer	Depth (cm)	Horz	Prep	KCl	$CaCl_2$ 0.01M 1:2	H_2O 1:1	Sat Paste	Sulf	NaF	<2mm	<20mm	<2mm	<20mm	Resist ohms cm^{-1}
										(- - - - - - - - - - - - % - - - - - - - - - - - -)				
					4C1a2a	4C1a2a				4E1a1a1a1				
09N03253	0-11	Ap	S		5.7	6.2								
09N03254	11-28	A	S		5.1	5.9								
09N03255	28-46	BA	S		5.1	5.9								
09N03256	46-60	Bt1	S		5.2	6.1								
09N03257	60-81	Bt2	S		5.4	6.1								
09N03258	81-100	Btss1	S		5.7	6.2								
09N03259	100-159	2Btss2	S		6.4	6.8								
09N03260	159-186	2Btss3	S		7.2	7.5				tr				

Site 2

Pedon ID: S09KS059001 (Franklin, Kansas) Print Date: Apr 4 2010 3:11PM

Sampled as : Woodson ; Fine, smectitic, thermic Vertic Argiaquoll
Revised to :

United States Department of Agriculture
Natural Resources Conservation Service
National Soil Survey Center
Soil Survey Laboratory
Lincoln, Nebraska 68508-3866

SSL - Project C2009USKS125 Woodson - Series
- Site ID 09KS059001 Lat: 38° 32' 17.70" north Long: 95° 14' 45.20" west NAD83 MLRA: 112
- Pedon No. 09N1014
- General Methods 1B1A, 2A1, 2B

Layer	Horizon	Orig Hzn	Depth (cm)	Field Label 1	Field Label 2	Field Label 3	Field Texture	Lab Texture
09N03903	Ap		0-8	S09KS059001-1			SICL	SIL
09N03904	A		8-26	S09KS059001-2			SICL	SIL
09N03905	Bt1		26-56	S09KS059001-3			SIC	SIC
09N03906	Bt2		56-84	S09KS059001-4			SIC	SIC
09N03907	Btssg		84-117	S09KS059001-5			SIC	SIC
09N03908	Btg1		117-148	S09KS059001-6			SIC	SIC
09N03909	Btg2		148-166	S09KS059001-7			SIC	SIC
09N03910	Btg3		166-200	S09KS059001-8			SIC	SIC

Pedon Calculations

Calculation Name	Result	Units of Measure
Weighted Particles, 0.1-75mm, 75 mm Base	1	% wt
Volume, >2mm, Weighted Average	0	% vol
Clay, total, Weighted Average	47	% wt
Clay, carbonate free, Weighted Average	47	% wt
CEC Activity, CEC7/Clay, Weighted Average, CECd, Set 1	0.71	(NA)
LE, Whole Soil, Summed to 1m	9	cm/m

Weighted averages based on control section: 26-76 cm

*** Primary Characterization Data ***

Pedon ID: S09KS059001 (Franklin, Kansas) Print Date: Apr 4 2010 3:11PM

Sampled As : Woodson Fine, smectitic, thermic Vertic Argiaquoll

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 09N1014

PSDA & Rock Fragments

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-
				(- - - - - Total - - - - - -)			(- - Clay - - -)		(- - - - Silt - - - - -)		(- - - - - - - - - - - - Sand - - - - - - - - - - - -)					(Rock Fragments (mm))				
				Clay	Silt	Sand	Fine	CO_3	Fine	Coarse	VF	F	M	C	VC	(- - - - - - - - Weight - - - - - - - -)				>2 mm
				<	.002	.05	<	<	.002	.02	.05	.10	.25	.5	1	2	5	20	.1-	wt %
	Depth			.002	-.05	-2	.0002	.002	-.02	-.05	-.10	-.25	-.50	-1	-2	-5	-20	-75	75	whole
Layer	(cm)	Horz	Prep	(- % of <2mm Mineral Soil -)												(- - - - - - - % of <75mm - - - - - -)				soil
				3A1a1a			3A1a1a		3A1a1a		3A1a1a	3A1a1a	3A1a1a	3A1a1a	3A1a1a					
09N03903	0-8	Ap	S	23.9	74.1	2.0	16.3		45.9	28.2	1.0	0.6	0.3	0.1	--	1	--	--	2	1
09N03904	8-26	A	S	24.9	73.1	2.0	17.2		42.8	30.3	0.9	0.7	0.3	0.1	--	1	--	--	2	1
09N03905	26-56	Bt1	S	47.0	51.5	1.5	36.0		32.4	19.1	0.7	0.4	0.2	0.1	0.1	--	--	--	1	--
09N03906	56-84	Bt2	S	45.9	52.8	1.3	34.6		34.8	18.0	0.7	0.4	0.2	tr	--	--	--	--	1	--
09N03907	84-117	Btssg	S	45.1	52.7	2.2	34.3		33.3	19.4	1.3	0.7	0.2	tr	--	--	--	--	1	--
09N03908	117-148	Btg1	S	45.9	49.8	4.3	36.6		30.0	19.8	2.4	1.8	0.1	tr	--	8	--	--	10	8
09N03909	148-166	Btg2	S	46.1	48.7	5.2	38.2		27.2	21.5	3.3	1.8	0.1	tr	tr	--	--	--	2	--
09N03910	166-200	Btg3	S	48.1	47.2	4.7	39.6		25.9	21.3	2.9	1.6	0.2	--	--	--	--	--	2	--

Bulk Density & Moisture

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-
				(Bulk Density)		Cole	(- - - - - - - - - - - - Water Content - - - - - - - - - - - -)						WRD	Aggst		
				33	Oven	Whole	6	10	33	1500	1500 kPa	Ratio	Whole	Stabl	(- - Ratio/Clay - -)	
	Depth			kPa	Dry	Soil	kPa	kPa	kPa	kPa	Moist	AD/OD	Soil	2-0.5mm	CEC7	1500 kPa
Layer	(cm)	Horz	Prep	(- - - g cm^{-3} - - -)			(- - - - - - - - - - - - % of < 2mm - - - - - - - - - - - -)						cm^3 cm^{-3}	%		
				DbWR1	DbWR1				DbWR1	3C2a1a		3D1				
09N03903	0-8	Ap	S	1.16	1.28	0.033			28.4	14.0		1.039	0.17		0.90	0.59
09N03904	8-26	A	S	1.31	1.49	0.044			25.4	12.0		1.039	0.18		0.82	0.48
09N03905	26-56	Bt1	S	1.40	2.00	0.126			28.4	21.9		1.070	0.09		0.71	0.47
09N03906	56-84	Bt2	S	1.46	1.96	0.103			26.8	20.6		1.068	0.09		0.70	0.45
09N03907	84-117	Btssg	S	1.40	1.88	0.103			29.5	20.8		1.067	0.12		0.69	0.46
09N03908	117-148	Btg1	S	1.44	1.85	0.082			26.9	20.5		1.066	0.09		0.66	0.45
09N03909	148-166	Btg2	S	1.39	1.83	0.096			28.7	21.3		1.064	0.10		0.66	0.46
09N03910	166-200	Btg3	S	1.33	1.81	0.108			31.7	21.1		1.065	0.14		0.65	0.44

*** Primary Characterization Data ***

Pedon ID: S09KS059001 — (Franklin, Kansas) — Print Date: Apr 4 2010 3:11PM

Sampled As : Woodson — Fine, smectitic, thermic Vertic Argiaquoll

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 09N1014

Water Content

Layer	Depth (cm)	Horz	Prep	-1- Atterberg Limits LL (pct <0.4mm)	-2- Atterberg Limits PI (pct <0.4mm)	-3- Bulk Density Field ($g\ cm^{-3}$)	-4- Bulk Density Recon 33 kPa ($g\ cm^{-3}$)	-5- Bulk Density Recon Oven Dry ($g\ cm^{-3}$)	-6- Water Content Field (% of < 2mm)	-7- Water Content Recon 33 kPa (% of < 2mm)	-8- Sieved Samples 6 kPa (% of < 2mm)	-9- Sieved Samples 10 kPa (% of < 2mm)	-10- Sieved Samples 33 kPa (% of < 2mm)	-11- Sieved Samples 100 kPa (% of < 2mm) 3C1d1a	-12- Sieved Samples 200 kPa (% of < 2mm) 3C1e1a	-13- Sieved Samples 500 kPa (% of < 2mm) 3C2b
09N03903	0-8	Ap	S											18.2	17.6	17.1
09N03904	8-26	A	S											17.5	17.0	16.0
09N03905	26-56	Bt1	S											33.6	30.3	27.4
09N03906	56-84	Bt2	S											32.9	29.7	26.1
09N03907	84-117	Btssg	S											32.5	29.3	26.0
09N03908	117-148	Btg1	S											32.0	29.0	26.1
09N03909	148-166	Btg2	S											32.9	30.1	26.8
09N03910	166-200	Btg3	S											32.9	30.2	27.2

Carbon & Extractions

Layer	Depth (cm)	Horz	Prep	-1- Total C (% of <2 mm) 4H2a	-2- Total N (% of <2 mm) 4H2a	-3- Total S (% of <2 mm) 4H2a	-4- Org C	-5- C/N Ratio	-6- Dith-Cit Ext Fe (% of < 2mm)	-7- Dith-Cit Ext Al (% of < 2mm)	-8- Dith-Cit Ext Mn (% of < 2mm)	-9- Ammonium Oxalate Al+½Fe (% of < 2mm)	-10- Ammonium Oxalate ODOE	-11- Ammonium Oxalate Fe (% of < 2mm)	-12- Ammonium Oxalate Al (% of < 2mm)	-13- Ammonium Oxalate Si (% of < 2mm)	-14- Ammonium Oxalate Mn ($mg\ kg^{-1}$)	-15- Na Pyro-Phosphate C (% of < 2mm)	-16- Na Pyro-Phosphate Fe (% of < 2mm)	-17- Na Pyro-Phosphate Al (% of < 2mm)	-18- Na Pyro-Phosphate Mn (% of < 2mm)
09N03903	0-8	Ap	S	2.53	0.23	0.04		11													
09N03904	8-26	A	S	1.58	0.15	0.02		10													
09N03905	26-56	Bt1	S	1.05	0.08	0.02		13													
09N03906	56-84	Bt2	S	0.70	0.08	0.01		9													
09N03907	84-117	Btssg	S	0.50	0.04	0.01		11													
09N03908	117-148	Btg1	S	0.36	0.08	0.01		5													
09N03909	148-166	Btg2	S	0.29	0.03	tr		9													
09N03910	166-200	Btg3	S	0.26	0.06	--		4													

*** Primary Characterization Data ***

Pedon ID: S09KS059001 (Franklin, Kansas) Print Date: Apr 4 2010 3:11PM

Sampled As : Woodson Fine, smectitic, thermic Vertic Argiaquoll

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 09N1014

CEC & Bases

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-
				(- - - - - - NH_4OAC Extractable Bases - - - - -)												(- - - - Base - - - -) (- Saturation -)	
Layer	Depth (cm)	Horz	Prep	Ca	Mg	Na	K	Sum Bases	Acid-ity	Extr Al	KCl Mn	CEC8 Sum Cats	CEC7 NH_4 OAC	ECEC Bases +Al	Al Sat	Sum	NH_4OAC
				(- - - - - - - - - - - - - - - - - cmol(+) kg^{-1} - - - - - - - - - - - - - - - - - - -)							mg kg^{-1}	(- - - - cmol(+) kg^{-1} - - -)			(- - - - - - - - % - - - - - - - -)		
				4B1a1a	4B1a1a	4B1a1a	4B1a1a		4B2b1a1				4B1a1a				
09N03903	0-8	Ap	S	16.7	2.8	--	0.2	19.7	7.8			27.5	21.6			72	91
09N03904	8-26	A	S	17.1*	3.1	0.1	0.2	20.5	4.7			25.2	20.4			81	100
09N03905	26-56	Bt1	S	23.1	7.7	1.3	0.4	32.5	8.6			41.1	33.5			79	97
09N03906	56-84	Bt2	S	22.4	7.5	1.6	0.4	31.9	6.5			38.4	32.3			83	99
09N03907	84-117	Btssg	S	21.3	7.2	1.8	0.4	30.7	6.5			37.2	30.9			83	99
09N03908	117-148	Btg1	S	20.6	7.1	1.9	0.3	29.9	8.5			38.4	30.3			78	99
09N03909	148-166	Btg2	S	20.8	7.1	2.0	0.4	30.3	8.2			38.5	30.5			79	99
09N03910	166-200	Btg3	S	21.5*	7.4	2.0	0.4	31.3	10.0			41.3	31.4			76	100

*Extractable Ca may contain Ca from calcium carbonate or gypsum., CEC7 base saturation set to 100.

Salt

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-	-18-	-19-	-20-
				(- Water Extracted From Saturated Paste -)																			
Layer	Depth (cm)	Horz	Prep	Ca	Mg	Na	K	CO_3	HCO_3	F	Cl	PO_4	Br	OAC	SO_4	NO_2	NO_3	H_2O	Total Salts	Elec Cond	Pred Elec Cond	Exch Na	SAR
				(- - - - - mmol(+) L^{-1} - - - - -)				(- mmol(-) L^{-1} -)										(- - - - % - - - -)		(- - dS m^{-1} - -)		%	
				4F2	4F2	4F2	4F2	4F2	4F2	4F2	4F2	4F2	4F2		4F2	4F2	4F2	4F2		4F2	4F1a1a1		
09N03903	0-8	Ap	S	0.6	0.3	0.6	0.2	--	0.5	--	0.6	--	tr		0.4	0.3	0.1	67.0		0.24	0.10		
09N03904	8-26	A	S	0.5	0.2	0.8	0.2	--	1.0	--	0.2	--	--		0.3	tr	--	61.4		0.20	0.06		
09N03905	26-56	Bt1	S	--	0.1	1.8	0.3	--	0.4	tr	0.4	--	--		1.0	tr	--	76.8		0.27	0.11		
09N03906	56-84	Bt2	S	--	0.1	2.1	0.2	--	0.3	tr	0.5	--	--		1.2	0.1	0.3	85.5		0.29	0.14		
09N03907	84-117	Btssg	S	--	0.1	2.2	0.2	--	0.3	tr	0.6	--	--		1.4	tr	0.3	76.2		0.32	0.13		
09N03908	117-148	Btg1	S	--	0.1	1.7	0.2	--	0.3	tr	0.5	--	--		0.9	tr	0.1	69.2		0.25	0.09		
09N03909	148-166	Btg2	S	--	--	1.8	0.1	--	0.2	tr	0.8	--	--		0.6	tr	tr	69.6		0.27	0.08		
09N03910	166-200	Btg3	S	--	0.1	1.6	0.2	--	0.2	tr	0.7	--	--		0.6	tr	0.1	69.2		0.24	0.07		

*** Primary Characterization Data ***

Pedon ID: S09KS059001 (Franklin, Kansas) Print Date: Apr 4 2010 3:11PM

Sampled As : Woodson Fine, smectitic, thermic Vertic Argiaquoll

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 09N1014

pH & Carbonates

Layer	Depth (cm)	Horz	Prep	-1- KCl	-2- pH $CaCl_2$ 0.01M 1:2 4C1a2a	-3- pH H_2O 1:1 4C1a2a	-4- pH Sat Paste 4F2	-5- pH Sulf	-6- pH NaF	-7- Carbonate As $CaCO_3$ <2mm % 4E1a1a1a1	-8- Carbonate As $CaCO_3$ <20mm %	-9- Gypsum As $CaSO_4*2H_2O$ <2mm %	-10- Gypsum As $CaSO_4*2H_2O$ <20mm %	-11- Resist ohms cm^{-1}
09N03903	0-8	Ap	S		5.3	5.9	5.8							
09N03904	8-26	A	S		5.9	6.7	6.4							
09N03905	26-56	Bt1	S		6.0	6.5	6.1							
09N03906	56-84	Bt2	S		6.1	6.6	6.5							
09N03907	84-117	Btssg	S		6.2	6.7	6.4							
09N03908	117-148	Btg1	S		6.3	6.8	6.4							
09N03909	148-166	Btg2	S		6.3	7.0	6.4			--				
09N03910	166-200	Btg3	S		6.4	6.9	6.4			--				

*** Primary Characterization Data ***

Pedon ID: S09KS059001 (Franklin, Kansas) Print Date: Apr 4 2010 3:11PM

Sampled As : Woodson Fine, smectitic, thermic Vertic Argiaquoll

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 09N1014

Clay Mineralogy (<.002 mm)

Layer	Depth (cm)	Horz	Fraction	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-	-18-
						X-Ray					Thermal					Elemental				EGME	Inter
													SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	K_2O	Na_2O	Retn	preta
						7A1a1					7A4a										tion
				(- - - - - - - - - peak size - - - - - - - - - -)					(- - - - - - - - - % - - - - - - - - - -)				(- - - - - - - - - - - - - - - - - - - % - - - - - - - - - - - - - - - - - - -)							mg g^{-1}	
09N03903	0-8	Ap	tcly	MT 3	KK 2	MI 1					KK 12										SMEC
09N03905	26-56	Bt1	tcly	MT 4	KK 3	MI 2	VR 1				KK 31										SMEC
09N03907	84-117	Btssg	tcly	MT 3	KK 3	VR 2	MI 2	QZ 1			KK 30										SMEC
09N03910	166-200	Btg3	tcly	MT 3	KK 3	MI 2					KK 37										SMEC

FRACTION INTERPRETATION:

tcly - Total Clay, <0.002 mm

MINERAL INTERPRETATION:

KK - Kaolinite MI - Mica MT - Montmorillonite QZ - Quartz VR - Vermiculite

RELATIVE PEAK SIZE: 5 Very Large 4 Large 3 Medium 2 Small 1 Very Small 6 No Peaks

Site 3

Pedon ID: S09KS121001 (Miami, Kansas) Print Date: Apr 4 2010 3:15PM

Sampled as : Aliceville ; Fine, mixed, active, thermic Oxyaquic Vertic Argiudoll
Revised to :

United States Department of Agriculture
Natural Resources Conservation Service
National Soil Survey Center
Soil Survey Laboratory
Lincoln, Nebraska 68508-3866

SSL - Project C2009USKS101 Mesonet Series
- Site ID S09USKS121001 Lat: 38° 35' 31.81" north Long: 94° 50' 52.37" west NAD83 MLRA: 112
- Pedon No. 09N0904
- General Methods 1B1A, 2A1, 2B

Layer	Horizon	Orig Hzn	Depth (cm)	Field Label 1	Field Label 2	Field Label 3	Field Texture	Lab Texture
09N03247	Ap		0-16	S09KS121001-1			SICL	SICL
09N03248	A		16-31	S09KS121001-2			SICL	SICL
09N03249	BA		31-45	S09KS121001-3			SIC	SIC
09N03250	Bt1		45-68	S09KS121001-4			SIC	SIC
09N03251	Bt2		68-102	S09KS121001-5			C	SIC
09N03252	Btss		102-140	S09USKS121001-6			C	C

Pedon Calculations

Calculation Name	Result	Units of Measure
Weighted Particles, 0.1-75mm, 75 mm Base	3	% wt
Volume, >2mm, Weighted Average	1	% vol
Clay, total, Weighted Average	54	% wt
Clay, total, Weighted Average	54	% wt
Clay, total, Weighted Average	54	% wt
Clay, total, Weighted Average	54	% wt
Clay, total, Weighted Average	54	% wt
Clay, total, Weighted Average	54	% wt
Clay, carbonate free, Weighted Average	54	% wt
Clay, carbonate free, Weighted Average	54	% wt
Clay, carbonate free, Weighted Average	54	% wt
Clay, carbonate free, Weighted Average	54	% wt
Clay, carbonate free, Weighted Average	54	% wt
Clay, carbonate free, Weighted Average	54	% wt
CEC Activity, CEC7/Clay, Weighted Average, CECd, Set 1	0.6	(NA)
CEC Activity, CEC7/Clay, Weighted Average, CECd, Set 1	horizon 1 depth is not consistent with previous horizon	(NA)
CEC Activity, CEC7/Clay, Weighted Average, CECd, Set 1	horizon 1 depth is not consistent with previous horizon	(NA)
CEC Activity, CEC7/Clay, Weighted Average, CECd, Set 1	horizon 1 depth is not consistent with previous horizon	(NA)
CEC Activity, CEC7/Clay, Weighted Average, CECd, Set 1	horizon 1 depth is not consistent with previous horizon	(NA)
CEC Activity, CEC7/Clay, Weighted Average, CECd, Set 1	0.6	(NA)
LE, Whole Soil, Summed to 1m	9	cm/m
LE, Whole Soil, Summed to 1m	9	cm/m
LE, Whole Soil, Summed to 1m	9	cm/m
LE, Whole Soil, Summed to 1m	9	cm/m
LE, Whole Soil, Summed to 1m	9	cm/m
LE, Whole Soil, Summed to 1m	9	cm/m

Weighted averages based on control section: 45-95 cm

PSDA & Rock Fragments

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-
				(- - - - - Total - - - - - -)			(- - Clay - - -)		(- - - - Silt - - - - -)		(- - - - - - - - - - - - Sand - - - - - - - - - - - - -)					(Rock Fragments (mm))				
				Clay	Silt	Sand	Fine	CO_3	Fine	Coarse	VF	F	M	C	VC	(- - - - - - - - Weight - - - - - - - -)				>2 mm
				<	.002	.05	<	<	.002	.02	.05	.10	.25	.5	1	2	5	20	.1-	wt %
	Depth			.002	-.05	-2	.0002	.002	-.02	-.05	-.10	-.25	-.50	-1	-2	-5	-20	-75	75	whole
Layer	(cm)	Horz	Prep	(- % of <2mm Mineral Soil -)												(- - - - - - - % of <75mm - - - - - -)				soil
				3A1a1a			3A1a1a		3A1a1a		3A1a1a	3A1a1a	3A1a1a	3A1a1a	3A1a1a					
09N03247	0-16	Ap	S	32.7	63.2	4.1	21.2		34.2	29.0	2.1	1.4	0.5	0.1	--	--	--	--	2	--

09N03248	16-31	A	S	37.1	59.8	3.1	25.9	33.6	26.2	1.6	1.0	0.4	0.1	--	--	tr	--	2	tr
09N03249	31-45	BA	S	44.1	53.0	2.9	32.2	30.7	22.3	1.5	0.9	0.4	0.1	tr	tr	--	--	1	tr
09N03250	45-68	Bt1	S	54.0	42.1	3.9	39.8	28.4	13.7	1.5	1.1	1.0	0.2	0.1	1	tr	--	3	1
09N03251	68-102	Bt2	S	54.4	41.7	3.9	38.5	26.5	15.2	1.6	1.5	0.4	0.2	0.2	tr	tr	--	2	1
09N03252	102-140	Btss	S	58.6	36.3	5.1	34.7	25.1	11.2	2.2	1.6	0.7	0.3	0.3	1	1	--	5	2

*** Primary Characterization Data ***

Pedon ID: S09KS121001 — (Miami, Kansas) — Print Date: Apr 4 2010 3:15PM

Sampled As : Aliceville — Fine, mixed, active, thermic Oxyaquic Vertic Argiudoll

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 09N0904

Water Dispersible PSDA

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-
				Water Dispersible											
				Total			Clay		Silt		Sand				
				Clay	Silt	Sand	F	CO_3	F	C	VF	F	M	C	VC
				<	.002	.05	<	<	.002	.02	.05	.10	.25	.5	1
	Depth			.002	-.05	-2	.0002	.002	-.02	-.05	-.10	-.25	-.50	-1	-2
Layer	(cm)	Horz	Prep	% of <2mm											
				3A1a6a					3A1a6a		3A1a6a	3A1a6a	3A1a6a	3A1a6a	3A1a6a
09N03247	0-16	Ap	S	10.3	67.7	22.0			37.2	30.5	6.9	8.7	4.8	1.2	0.4

Bulk Density & Moisture

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-
				(Bulk Density)		Cole	Water Content						WRD	Aggst		
				33	Oven	Whole	6	10	33	1500	1500 kPa	Ratio	Whole	Stabl	Ratio/Clay	
	Depth			kPa	Dry	Soil	kPa	kPa	kPa	kPa	Moist	AD/OD	Soil	2-0.5mm	CEC7	1500 kPa
Layer	(cm)	Horz	Prep	g cm^{-3}			% of < 2mm						cm^3 cm^{-3}	%		
				DbWR1	DbWR1				DbWR1	3C2a1a		3D1		3F1a1a		
09N03247	0-16	Ap	S	1.14	1.35	0.058			34.6	18.9		1.038	0.18	86	0.78	0.58
09N03248	16-31	A	S	1.29	1.51	0.054			28.3	17.4		1.038	0.14		0.67	0.47
09N03249	31-45	BA	S	1.28	1.56	0.068			29.1	19.9		1.049	0.12		0.62	0.45
09N03250	45-68	Bt1	S	1.34	1.82	0.107			32.6	23.6		1.062	0.12		0.59	0.44
09N03251	68-102	Bt2	S	1.34	1.88	0.119			33.0	23.7		1.070	0.12		0.61	0.44
09N03252	102-140	Btss	S	1.30	1.84	0.121			36.2	27.9		1.082	0.11		0.65	0.48

*** Primary Characterization Data ***

Pedon ID: S09KS121001 (Miami, Kansas) Print Date: Apr 4 2010 3:15PM

Sampled As : Aliceville Fine, mixed, active, thermic Oxyaquic Vertic Argiudoll

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 09N0904

Water Content

Layer	Depth (cm)	Horz	Prep	-1- Atterberg Limits LL	-2- Atterberg Limits PI	-3- Bulk Density Field	-4- Bulk Density Recon 33 kPa	-5- Bulk Density Recon Oven Dry	-6- Water Content Field	-7- Water Content Recon 33 kPa	-8- Sieved Samples 6 kPa	-9- Sieved Samples 10 kPa	-10- Sieved Samples 33 kPa	-11- Sieved Samples 100 kPa	-12- Sieved Samples 200 kPa	-13- Sieved Samples 500 kPa
				pct <0.4mm		g cm^{-3}			% of < 2mm							
							3B2	3B2		3B2				3C1d1a	3C1e1a	3C2b
09N03247	0-16	Ap	S				1.00	1.15		39.3				25.0	23.9	22.3
09N03248	16-31	A	S											24.0	22.5	21.1
09N03249	31-45	BA	S											27.1	25.2	23.4
09N03250	45-68	Bt1	S											31.8	30.0	27.2
09N03251	68-102	Bt2	S											33.6	31.9	28.8
09N03252	102-140	Btss	S											38.4	36.0	33.7

Carbon & Extractions

Layer	Depth (cm)	Horz	Prep	-1- Total C	-2- Total N	-3- Total S	-4- Org C	-5- C/N Ratio	-6- Dith-Cit Ext Fe	-7- Dith-Cit Ext Al	-8- Dith-Cit Ext Mn	-9- Ammonium Oxalate Al+½Fe	-10- Ammonium Oxalate ODOE	-11- Ammonium Oxalate Fe	-12- Ammonium Oxalate Al	-13- Ammonium Oxalate Si	-14- Ammonium Oxalate Mn	-15- Na Pyro-Phosphate C	-16- Na Pyro-Phosphate Fe	-17- Na Pyro-Phosphate Al	-18- Na Pyro-Phosphate Mn
				% of <2 mm					% of < 2mm								mg kg^{-1}	% of < 2mm			
				4H2a	4H2a	4H2a			4G1	4G1	4G1										
09N03247	0-16	Ap	S	3.72	0.33	0.04		11	1.8	0.2	0.1										
09N03248	16-31	A	S	2.30	0.22	0.01		10	2.2	0.2	0.2										
09N03249	31-45	BA	S	1.71	0.14	tr		12	2.4	0.3	0.1										
09N03250	45-68	Bt1	S	1.18	0.15	--		8	2.7	0.3	0.3										
09N03251	68-102	Bt2	S	0.53	0.08	--		7	3.2	0.3	0.3										
09N03252	102-140	Btss	S	0.40	0.05	--		7	4.9	0.4	0.4										

*** Primary Characterization Data ***

Pedon ID: S09KS121001 (Miami, Kansas) Print Date: Apr 4 2010 3:15PM

Sampled As : Aliceville Fine, mixed, active, thermic Oxyaquic Vertic Argiudoll

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 09N0904

CEC & Bases

Layer	Depth (cm)	Horz	Prep	-1- Ca	-2- Mg	-3- Na	-4- K	-5- Sum Bases	-6- Acid-ity	-7- Extr Al	-8- KCl Mn	-9- CEC8 Sum Cats	-10- CEC7 NH_4 OAC	-11- ECEC Bases +Al	-12- Al Sat	-13- Base Saturation Sum	-14- Base Saturation NH_4OAC
				(- - - - - - - - - - - - - - - - - - cmol(+) kg^{-1}						- - - - - - - - - - - - - - - - - - -)	mg kg^{-1}	(- - - - cmol(+) kg^{-1}		- - -)	(- - - - - - - - %		- - - - - - - -)
				4B1a1a	4B1a1a	4B1a1a	4B1a1a		4B2b1a1				4B1a1a				
09N03247	0-16	Ap	S	16.5	5.3	0.1	0.3	22.2	14.4			36.6	25.5			61	87
09N03248	16-31	A	S	16.2	4.0	0.2	0.3	20.7	12.2			32.9	25.0			63	83
09N03249	31-45	BA	S	17.4	4.8	0.5	0.4	23.1	12.5			35.6	27.3			65	85
09N03250	45-68	Bt1	S	20.8	6.2	0.5	0.6	28.1	12.5			40.6	32.1			69	88
09N03251	68-102	Bt2	S	25.9*	7.1	0.6	0.6	34.2	8.0			42.2	33.0			81	100
09N03252	102-140	Btss	S	34.7*	8.6	0.9	0.6	44.8	5.9				38.1				100

*Extractable Ca may contain Ca from calcium carbonate or gypsum., CEC7 base saturation set to 100.

Salt

Columns -1- to -15-: Water Extracted From Saturated Paste

Layer	Depth (cm)	Horz	Prep	-1- Ca	-2- Mg	-3- Na	-4- K	-5- CO_3	-6- HCO_3	-7- F	-8- Cl	-9- PO_4	-10- Br	-11- OAC	-12- SO_4	-13- NO_2	-14- NO_3	-15- H_2O	-16- Total Salts	-17- Elec Cond	-18- Pred Elec Cond	-19- Exch Na	-20- SAR
				(- - - - - mmol(+) L^{-1}			- - - - -)	(- - - - - - - - - - - mmol(-) L^{-1}									- - - - - - - - - -)	(- - - - %	- - - -)	(- - dS m^{-1}	- -)	%	
																					4F1a1a1		
09N03247	0-16	Ap	S																		0.12	1	
09N03248	16-31	A	S																		0.05	1	
09N03249	31-45	BA	S																		0.04	2	
09N03250	45-68	Bt1	S																		0.05	1	
09N03251	68-102	Bt2	S																		0.11	2	
09N03252	102-140	Btss	S																		0.19	2	

*** Primary Characterization Data ***

Pedon ID: S09KS121001 (Miami, Kansas) Print Date: Apr 4 2010 3:15PM

Sampled As : Aliceville Fine, mixed, active, thermic Oxyaquic Vertic Argiudoll

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 09N0904

pH & Carbonates

Layer	Depth (cm)	Horz	Prep	-1- KCl	-2- CaCl2 0.01M 1:2 4C1a2a	-3- H_2O 1:1 4C1a2a	-4- Sat Paste	-5- Sulf	-6- NaF	-7- Carbonate As $CaCO_3$ <2mm (%) 4E1a1a1a1	-8- Carbonate As $CaCO_3$ <20mm (%)	-9- Gypsum As $CaSO_4*2H_2O$ <2mm (%)	-10- Gypsum As $CaSO_4*2H_2O$ <20mm (%)	-11- Resist ohms cm^{-1}
09N03247	0-16	Ap	S		5.4	6.2								
09N03248	16-31	A	S		5.3	6.1								
09N03249	31-45	BA	S		5.2	6.1								
09N03250	45-68	Bt1	S		5.4	6.2								
09N03251	68-102	Bt2	S		6.4	6.8								
09N03252	102-140	Btss	S		7.1	7.7				tr				

Site 4

Pedon ID: S09KS207001 (Woodson, Kansas) Print Date: Apr 4 2010 3:20PM

Sampled as : Summit ; Fine, smectitic, thermic Aquertic Argiudoll
Revised to :

United States Department of Agriculture
Natural Resources Conservation Service
National Soil Survey Center
Soil Survey Laboratory
Lincoln, Nebraska 68508-3866

SSL - Project C2009USKS101 Mesonet Series
- Site ID S09KS207001 Lat: 37° 51' 40.14" north Long: 95° 47' 1.00" west NAD83 MLRA: 112
- Pedon No. 09N0906
- General Methods 1B1A, 2A1, 2B

Layer	Horizon	Orig Hzn	Depth (cm)	Field Label 1	Field Label 2	Field Label 3	Field Texture	Lab Texture
09N03261	Ap		0-18	S09KS207001-1			SICL	SICL
09N03262	A		18-29	S09KS207001-2			SIC	SICL
09N03263	Bt1		29-53	S09KS207001-3			C	SIC
09N03264	Bt2		53-103	S09KS207001-4			C	C
09N03265	2Btss1		103-135	S09KS207001-5			SIC	C
09N03266	2Btss2		135-177	S09KS207001-6			SIC	SIC
09N03267	3Btss		177-210	S09KS207001-7			C	C

Pedon Calculations Calculation Name	Result	Units of Measure
Weighted Particles, 0.1-75mm, 75 mm Base	6	% wt
Volume, >2mm, Weighted Average	2	% vol
Clay, total, Weighted Average	57	% wt
Clay, total, Weighted Average	control depth 79 beyond last horizon depth 18	% wt
Clay, total, Weighted Average	control depth 79 beyond last horizon depth 18	% wt
Clay, total, Weighted Average	control depth 79 beyond last horizon depth 18	% wt
Clay, total, Weighted Average	control depth 79 beyond last horizon depth 18	% wt
Clay, total, Weighted Average	control depth 79 beyond last horizon depth 18	% wt
Clay, total, Weighted Average	57	% wt
Clay, carbonate free, Weighted Average	control depth 79 beyond last horizon depth 18	% wt
Clay, carbonate free, Weighted Average	control depth 79 beyond last horizon depth 18	% wt
Clay, carbonate free, Weighted Average	control depth 79 beyond last horizon depth 18	% wt
Clay, carbonate free, Weighted Average	control depth 79 beyond last horizon depth 18	% wt
Clay, carbonate free, Weighted Average	control depth 79 beyond last horizon depth 18	% wt
Clay, carbonate free, Weighted Average	control depth 79 beyond last horizon depth 18	% wt
Clay, carbonate free, Weighted Average	57	% wt
CEC Activity, CEC7/Clay, Weighted Average, CECd, Set 1	control depth 79 beyond last horizon depth 18	(NA)
CEC Activity, CEC7/Clay, Weighted Average, CECd, Set 1	control depth 79 beyond last horizon depth 18	(NA)
CEC Activity, CEC7/Clay, Weighted Average, CECd, Set 1	control depth 79 beyond last horizon depth 18	(NA)
CEC Activity, CEC7/Clay, Weighted Average, CECd, Set 1	control depth 79	(NA)

	beyond last horizon depth 18 control depth 79	
CEC Activity, CEC7/Clay, Weighted Average, CECd, Set 1	beyond last horizon depth 18 control depth 79	(NA)
CEC Activity, CEC7/Clay, Weighted Average, CECd, Set 1	beyond last horizon depth 18	(NA)
CEC Activity, CEC7/Clay, Weighted Average, CECd, Set 1	0.68	(NA)
LE, Whole Soil, Summed to 1m	11	cm/m
LE, Whole Soil, Summed to 1m	11	cm/m
LE, Whole Soil, Summed to 1m	11	cm/m
LE, Whole Soil, Summed to 1m	11	cm/m
LE, Whole Soil, Summed to 1m	11	cm/m
LE, Whole Soil, Summed to 1m	11	cm/m
LE, Whole Soil, Summed to 1m	11	cm/m

Weighted averages based on control section: 29-79 cm

*** Primary Characterization Data ***

Pedon ID: S09KS207001 (Woodson, Kansas) Print Date: Apr 4 2010 3:20PM

Sampled As : Summit Fine, smectitic, thermic Aquertic Argiudoll

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 09N0906

PSDA & Rock Fragments

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-
				(- - - - - Total - - - - - -)			(- - Clay - - -)		(- - - - Silt - - - - -)		(- - - - - - - - - - - - Sand - - - - - - - - - - - -)					(Rock Fragments (mm))				
				Clay	Silt	Sand	Fine	CO_3	Fine	Coarse	VF	F	M	C	VC	(- - - - - - - - Weight - - - - - - - -)				>2 mm
				<	.002	.05	<	<	.002	.02	.05	.10	.25	.5	1	2	5	20	.1-	wt %
	Depth			.002	-.05	-2	.0002	.002	-.02	-.05	-.10	-.25	-.50	-1	-2	-5	-20	-75	75	whole
Layer	(cm)	Horz	Prep	(- % of <2mm Mineral Soil -)												(- - - - - - - % of <75mm - - - - - -)				soil
				3A1a1a			3A1a1a		3A1a1a		3A1a1a	3A1a1a	3A1a1a	3A1a1a	3A1a1a					
09N03261	0-18	Ap	S	35.3	59.8	4.9	24.1		35.6	24.2	2.5	1.7	0.6	0.1	--	tr	--	--	2	tr
09N03262	18-29	A	S	36.2	58.5	5.3	25.2		35.3	23.2	2.6	1.8	0.8	0.1	tr	tr	tr	--	3	1
09N03263	29-53	Bt1	S	54.4	42.0	3.6	42.1		26.4	15.6	1.7	1.3	0.5	0.1	tr	tr	--	--	2	tr
09N03264	53-103	Bt2	S	59.6	37.8	2.6	44.8		24.8	13.0	1.2	0.8	0.4	0.2	--	tr	8	--	9	8
09N03265	103-135	2Btss1	S	58.0	37.5	4.5	19.4		24.5	13.0	2.2	1.3	0.5	0.3	0.2	1	1	--	4	2
09N03266	135-177	2Btss2	S	49.1	45.5	5.4	26.1		35.4	10.1	2.8	1.9	0.3	0.2	0.2	tr	17	--	19	17
09N03267	177-210	3Btss	S	62.1	35.6	2.3	17.5		30.5	5.1	1.0	0.7	0.2	0.2	0.2	1	4	--	6	5

Water Dispersible PSDA

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-
				(- Water Dispersible -)											
				(- - - - - Total - - - - - -)			(- - Clay - - -)		(- - - - Silt - - - - -)		(- - - - - - - - - - - - Sand - - - - - - - - - - - -)				
				Clay	Silt	Sand	F	CO_3	F	C	VF	F	M	C	VC
				<	.002	.05	<	<	.002	.02	.05	.10	.25	.5	1
	Depth			.002	-.05	-2	.0002	.002	-.02	-.05	-.10	-.25	-.50	-1	-2
Layer	(cm)	Horz	Prep	(- % of <2mm -)											
				3A1a6a					3A1a6a		3A1a6a	3A1a6a	3A1a6a	3A1a6a	3A1a6a
09N03261	0-18	Ap	S	13.9	65.5	20.6			40.4	25.1	6.2	7.6	5.1	1.6	0.1

*** Primary Characterization Data ***

Pedon ID: S09KS207001 (Woodson, Kansas) Print Date: Apr 4 2010 3:20PM

Sampled As : Summit Fine, smectitic, thermic Aquertic Argiudoll

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 09N0906

Bulk Density & Moisture

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-
				(Bulk Density)		Cole	(- - - Water Content				- - -)		WRD	Aggst		
				33	Oven	Whole	6	10	33	1500	1500 kPa	Ratio	Whole	Stabl	(- - Ratio/Clay - -)	
	Depth			kPa	Dry	Soil	kPa	kPa	kPa	kPa	Moist	AD/OD	Soil	2-0.5mm	CEC7	1500 kPa
Layer	(cm)	Horz	Prep	(- - - g cm^{-3} - - -)			(- - - % of < 2mm				- - -)		cm^{3} cm^{-3}	%		
				DbWR1	DbWR1				DbWR1	3C2a1a		3D1		3F1a1a		
09N03261	0-18	Ap	S	1.06	1.33	0.079			42.8	20.7		1.041	0.23	81	0.89	0.59
09N03262	18-29	A	S	1.25	1.54	0.072			31.5	18.2		1.041	0.17		0.81	0.50
09N03263	29-53	Bt1	S	1.28	1.85	0.131			36.7	23.4		1.062	0.17		0.69	0.43
09N03264	53-103	Bt2	S	1.25	1.82	0.127			37.0	26.0		1.075	0.13		0.66	0.44
09N03265	103-135	2Btss1	S	1.39	1.89	0.107			31.2	23.8		1.071	0.10		0.61	0.41
09N03266	135-177	2Btss2	S	1.37	1.82	0.088			31.3	24.6		1.071	0.08		0.75	0.50
09N03267	177-210	3Btss	S	1.40	1.92	0.107			32.1	22.6		1.061	0.13		0.44	0.36

Water Content

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-
				(- - Atterberg - -)		(- - - Bulk Density		- - -)	(- - - Water Content							- - -)
				(- - - Limits - - -)		Field	Recon	Recon	Field	Recon	(- - - Sieved Samples					- - -)
				LL	PI		33	Oven		33	6	10	33	100	200	500
	Depth						kPa	Dry		kPa	kPa	kPa	kPa	kPa	kPa	kPa
Layer	(cm)	Horz	Prep	pct <0.4mm		(- - - g cm^{-3}		- - -)	(- - - % of < 2mm							- - -)
							3B2	3B2		3B2				3C1d1a	3C1e1a	3C2b
09N03261	0-18	Ap	S				0.99	1.16		36.9				29.8	27.0	24.5
09N03262	18-29	A	S											25.5	23.3	22.5
09N03263	29-53	Bt1	S											33.3	30.5	29.3
09N03264	53-103	Bt2	S											35.5	32.6	31.0
09N03265	103-135	2Btss1	S											34.7	32.5	29.2
09N03266	135-177	2Btss2	S											34.9	32.8	29.9
09N03267	177-210	3Btss	S											32.6	30.9	27.9

*** Primary Characterization Data ***

Pedon ID: S09KS207001 | (Woodson, Kansas) | Print Date: Apr 4 2010 3:20PM

Sampled As : Summit | Fine, smectitic, thermic Aquertic Argiudoll

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 09N0906

Carbon & Extractions

Layer	Depth (cm)	Horz	Prep	-1- C	-2- N	-3- S	-4- Org C	-5- C/N Ratio	-6- Fe	-7- Al	-8- Mn	-9- Al+½Fe	-10- ODOE	-11- Fe	-12- Al	-13- Si	-14- Mn	-15- C	-16- Fe	-17- Al	-18- Mn
				(- - - - - Total - - - - -)					(- - - Dith-Cit Ext - - -)			(- - - - - - Ammonium Oxalate Extraction - - - - - -)						(- - - Na Pyro-Phosphate - - -)			
				(- - - - - - % of <2 mm - - - - - -)					(- % of < 2mm - - - - - - - - - - - - - - - - - - -)								mg kg^{-1}	(- - - - - - % of < 2mm - - - - -)			
				4H2a	4H2a	4H2a			4G1	4G1	4G1										
09N03261	0-18	Ap	S	4.09	0.30	0.03		13	1.4	0.2	0.1										
09N03262	18-29	A	S	2.77	0.22	0.01		13	1.6	0.2	0.1										
09N03263	29-53	Bt1	S	1.86	0.13	tr		14	2.1	0.3	0.2										
09N03264	53-103	Bt2	S	1.10	0.09	--		13	2.0	0.3	0.1										
09N03265	103-135	2Btss1	S	0.74	0.06	0.01		10	2.0	0.2	0.1										
09N03266	135-177	2Btss2	S	0.66	0.06	0.02		10	2.3	0.3	tr										
09N03267	177-210	3Btss	S	0.89	0.13	0.15		1	2.4	0.2	0.1										

CEC & Bases

Layer	Depth (cm)	Horz	Prep	-1- Ca	-2- Mg	-3- Na	-4- K	-5- Sum Bases	-6- Acid-ity	-7- Extr Al	-8- KCl Mn	-9- CEC8 Sum Cats	-10- CEC7 NH_4 OAC	-11- ECEC Bases +Al	-12- Al Sat	-13- Base Saturation Sum	-14- Base Saturation NH_4OAC
				(- - - - - - NH_4OAC Extractable Bases - - - - -)												(- - - - Base - - - -) (- Saturation -)	
				(- - - - - - - - - - - - - - - - - - cmol(+) kg^{-1} -)							mg kg^{-1}	(- - - - cmol(+) kg^{-1} - - -)			(- - - - - - - - - % - - - - - - - - -)		
				4B1a1a	4B1a1a	4B1a1a	4B1a1a		4B2b1a1				4B1a1a				
09N03261	0-18	Ap	S	25.1	4.1	0.2	0.4	29.8	11.6			41.4	31.4			72	95
09N03262	18-29	A	S	22.4	4.0	0.4	0.3	27.1	11.5			38.6	29.2			70	93
09N03263	29-53	Bt1	S	27.2	6.6	0.8	0.5	35.1	13.9			49.0	37.8			72	93
09N03264	53-103	Bt2	S	30.3*	8.2	1.6	0.6	40.7	9.3			50.0	39.2			81	100
09N03265	103-135	2Btss1	S	41.2*	8.6	2.6	0.5	52.9	3.3				35.3				100
09N03266	135-177	2Btss2	S	37.8*	9.1	2.9	0.5	50.3	5.9				36.7				100
09N03267	177-210	3Btss	S	67.2*	8.5	2.5	0.3	78.5	0.4				27.2				100

*Extractable Ca may contain Ca from calcium carbonate or gypsum., CEC7 base saturation set to 100.

*** Primary Characterization Data ***

Pedon ID: S09KS207001 | (Woodson, Kansas) | Print Date: Apr 4 2010 3:20PM

Sampled As : Summit | Fine, smectitic, thermic Aquertic Argiudoll

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 09N0906

Salt

Layer	Depth (cm)	Horz	Prep	-1- Ca	-2- Mg	-3- Na	-4- K	-5- CO_3	-6- HCO_3	-7- F	-8- Cl	-9- PO_4	-10- Br	-11- OAC	-12- SO_4	-13- NO_2	-14- NO_3	-15- H_2O	-16- Total Salts	-17- Elec Cond	-18- Pred Elec Cond	-19- Exch Na	-20- SAR
				(- Water Extracted From Saturated Paste -)																			
				(- - - - - mmol(+) L^{-1} - - - - -)				(- mmol(-) L^{-1} -)										(- - - - % - - - -)		(- - dS m^{-1} - -)		%	

				4F2	4F2	4F2	4F2	4F2	4F2	4F2	4F2	4F2	4F2	4F2	4F2	4F2	4F2	4F2	4F2	4F1a1a1	
09N03261	0-18	Ap	S																	0.15	1
09N03262	18-29	A	S																	0.08	1
09N03263	29-53	Bt1	S																	0.06	2
09N03264	53-103	Bt2	S																	0.15	4
09N03265	103-135	2Btss1	S	2.2	0.9	5.4	0.5	--	1.9	0.3	0.5	--	--	--	6.3	--	0.1	86.1	0.94	0.58	
09N03266	135-177	2Btss2	S	4.7	1.7	7.0	0.4	--	1.4	--	0.3	--	--	--	12.0	--	0.1	86.0	1.36	0.76	
09N03267	177-210	3Btss	S	22.3	6.6	9.9	--	--	0.9	--	--	--	--	--	38.1	--	--	108.6	2.95	1.68	

pH & Carbonates

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-
				(- - - - - - - - - - - - - - - - - - pH	- - - - - - - - - - - - - - - - - -)					(- - Carbonate - -) As $CaCO_3$		(- - Gypsum - - -) As $CaSO_4$*$2H_2O$		Resist
Layer	Depth (cm)	Horz	Prep	KCl	$CaCl_2$ 0.01M 1:2 4C1a2a	H_2O 1:1 4C1a2a	Sat Paste 4F2	Sulf	NaF	<2mm (- - - - - - - - - - - - % 4E1a1a1a1	<20mm	<2mm	<20mm - - - - - - - - - - - -)	ohms cm^{-1}
09N03261	0-18	Ap	S		5.6	6.3								
09N03262	18-29	A	S		5.5	6.4								
09N03263	29-53	Bt1	S		5.5	6.1								
09N03264	53-103	Bt2	S		6.3	6.7								
09N03265	103-135	2Btss1	S		7.5	7.7	7.8			1				
09N03266	135-177	2Btss2	S		7.4	7.6	7.7			1				
09N03267	177-210	3Btss	S		7.5	7.6	7.6			6				

Site 5

Pedon ID: 73KS001003 (Allen, Kansas) Print Date: Apr 4 2010 3:23PM

Sampled as : Woodson
Revised to correlated on Jul 02, 2009 : Woodson ; Fine, smectitic, thermic Vertic Argiaquoll

SSL - Project NL40001 SSIR SAMPLES
- Site ID 73KS001003 Lat: 37° 51' 47.88" north Long: 95° 17' 39.04" west NAD83 MLRA: 112
- Pedon No. 40A1872
- General Methods 1B1A, 2A1, 2B

United States Department of Agriculture
Soil Conservation Service
Lincoln Soil Survey Laboratory
Soil Laboratory
Lincoln, Nebraska

Layer	Horizon	Orig Hzn	Depth (cm)	Field Label 1	Field Label 2	Field Label 3	Field Texture	Lab Texture
40A14929	A	A1	0-20	73L1099				SIL
40A14930	Bt1	B21T	20-32	73L1100				SIC
40A14931	Bt2	B22T	32-49	73L1101				SIC
40A14932	Bt3	B23T	49-80	73L1102				SIC
40A14933	B1	B31	80-97	73L1103				SIC
40A14934	B2	B32	97-133	73L1104				SIC
40A14935	B3	B33	133-159	73L1105				SIC
40A14936	B4	B34	159-188	73L1106				SIC
40A14937	B5	B35	188-228	73L1107				SIC
40A14938	B6	B36	228-318	73L1108				SIC
40A14939	Ap	AP	0-15	73L1109				SIL

Pedon Calculations

Calculation Name	Result	Units of Measure
CEC Activity, CEC7/Clay, Weighted Average	0.7	(NA)
Clay, carbonate free, Weighted Average	52	% wt
Weighted Particles, 0.1-75mm, 75 mm Base	1	% wt
Volume, >2mm, Weighted Average	0	% vol
Clay, total, Weighted Average	52	% wt

Weighted averages based on control section: 20-70 cm

*** Primary Characterization Data ***

Pedon ID: 73KS001003 (Allen, Kansas) Print Date: Apr 4 2010 3:23PM

Sampled As : Woodson

USDA-SCS-Soil Survey Laboratory ; Pedon No. 40A1872

PSDA & Rock Fragments

Layer	Depth (cm)	Horz	Prep	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-
				(- - - - - Total - - - - - -)			(- - Clay - - -)		(- - - - Silt - - - - -)		(- - - - - - - - - - - - Sand - - - - - - - - - - - -)					(Rock Fragments (mm))				
				Clay	Silt	Sand	Fine	CO_3	Fine	Coarse	VF	F	M	C	VC	(- - - - - - - - Weight - - - - - - - -)				>2 mm
				<	.002	.05	<	<	.002	.02	.05	.10	.25	.5	1	2	5	20	.1-	wt %
				.002	-.05	-2	.0002	.002	-.02	-.05	-.10	-.25	-.50	-1	-2	-5	-20	-75	75	whole
				(- % of <2mm Mineral Soil -)												(- - - - - - - % of <75mm - - - - - -)				soil
				3A1	3A1	3A1	3A1		3A1	3A1	3A1	3A1	3A1	3A1	3A1	3B1	3B1	3B1		
40A14929	0-20	A	S	25.2	72.6	2.2	15.1		45.4	27.2	1.0	0.3	0.4	0.4	0.1	--	--	--	1	--
40A14930	20-32	Bt1	S	46.1	52.7	1.2	35.9		33.9	18.8	0.6	0.1	0.2	0.3	tr	--	--	--	1	--
40A14931	32-49	Bt2	S	56.3	43.0	0.7	44.5		29.2	13.8	0.4	tr	0.1	0.2	--	--	--	--	tr	--
40A14932	49-80	Bt3	S	52.5	46.5	1.0	39.7		32.0	14.5	0.6	0.1	0.1	0.1	0.1	--	--	--	tr	--
40A14933	80-97	B1	S	45.5	51.5	3.0	34.4		29.4	22.1	2.3	0.5	0.1	0.1	tr	--	--	--	1	--
40A14934	97-133	B2	S	45.9	51.2	2.9	35.4		29.2	22.0	2.3	0.4	0.1	0.1	--	--	--	--	1	--
40A14935	133-159	B3	S	47.8	49.3	2.9	36.8		27.8	21.5	2.4	0.4	0.1	tr	--	--	--	--	1	--
40A14936	159-188	B4	S	49.1	47.4	3.5	33.9		27.0	20.4	2.4	0.8	0.2	0.1	--	--	--	--	1	--
40A14937	188-228	B5	S	46.2	49.6	4.2	33.9		26.5	23.1	2.7	0.8	0.2	0.3	0.2	--	--	--	2	--
40A14938	228-318	B6	S	50.6	46.1	3.3	32.6		26.4	19.7	2.0	0.5	0.2	0.3	0.3	--	--	--	1	--
40A14939	0-15	Ap	S	20.1	77.6	2.3	13.1		45.1	32.5	1.2	0.3	0.3	0.4	0.1	--	--	--	1	--

Bulk Density & Moisture

Layer	Depth (cm)	Horz	Prep	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-
				(Bulk Density)		Cole	(- - - - - - - - - - - Water Content - - - - - - - - - - -)						WRD	Aggst		
				33	Oven	Whole	6	10	33	1500	1500 kPa Ratio		Whole	Stabl	(- - Ratio/Clay - -)	
				kPa	Dry	Soil	kPa	kPa	kPa	kPa	Moist	AD/OD	Soil	2-0.5mm	CEC7	1500 kPa
				(- - - g cm^{-3} - - -)			(- - - - - - - - - - - - % of < 2mm - - - - - - - - - - - - -)						$cm^3\ cm^{-3}$	%		
				4A1d	4A1h			4B1c	4B1c	4B2a						
40A14929	0-20	A	S	1.29	1.42	0.033		35.6	33.2	12.3			0.27		0.82	0.49
40A14930	20-32	Bt1	S	1.31	1.76	0.103		35.6	33.4	20.6			0.17		0.72	0.45
40A14931	32-49	Bt2	S	1.29	1.90	0.138		36.1	34.9	24.4			0.14		0.70	0.43
40A14932	49-80	Bt3	S	1.41	1.87	0.099		31.2	29.8	22.4			0.10		0.70	0.43
40A14933	80-97	B1	S	1.40						19.4					0.69	0.43
40A14934	97-133	B2	S	1.44	1.79	0.075		28.4	26.9	20.1			0.10		0.70	0.44
40A14935	133-159	B3	S	1.38	1.77	0.087		31.5	30.2	21.1			0.13		0.71	0.44
40A14936	159-188	B4	S	1.40						22.1					0.74	0.45
40A14937	188-228	B5	S	1.40	1.85	0.097		31.4	30.1	21.1			0.13		0.73	0.46
40A14938	228-318	B6	S	1.40						21.7					0.73	0.43
40A14939	0-15	Ap	S	1.43	1.52	0.021		28.9	26.9	8.9			0.26		0.87	0.44

*** Primary Characterization Data ***

Pedon ID: 73KS001003 (Allen, Kansas) Print Date: Apr 4 2010 3:23PM

Sampled As : Woodson

USDA-SCS-Soil Survey Laboratory ; Pedon No. 40A1872

Carbon & Extractions

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-	-18-
				(- - - - - Total - - - - -)			Org	C/N	(- - - Dith-Cit Ext - - -)			(- - - - - - Ammonium Oxalate Extraction - - - - - -)						(- - - Na Pyro-Phosphate - - -)			
	Depth			C	N	S	C	Ratio	Fe	Al	Mn	Al+½Fe	ODOE	Fe	Al	Si	Mn	C	Fe	Al	Mn
Layer	(cm)	Horz	Prep	(- - - - - - % of <2 mm - - - - - -)					(- % of < 2mm - - - - - - - - - - - - - - - - - -)								mg kg^{-1}	(- - - - - - % of < 2mm - - - - -)			
					6B1a		6A1a		6C1b												
40A14929	0-20	A	S		0.194		2.49		0.5												
40A14930	20-32	Bt1	S		0.141		1.50		0.5												
40A14931	32-49	Bt2	S		0.122		1.27		0.5												
40A14932	49-80	Bt3	S				0.96		0.5												
40A14933	80-97	B1	S				0.48		0.5												
40A14934	97-133	B2	S				0.20		0.4												
40A14935	133-159	B3	S				0.15		0.4												
40A14936	159-188	B4	S				0.14		0.9												
40A14937	188-228	B5	S				0.08		1.4												
40A14938	228-318	B6	S				0.07		0.9												
40A14939	0-15	Ap	S		0.115		1.25		0.5												

CEC & Bases

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-
				(- - - - - - NH_4OAC Extractable Bases - - - - -)								CEC8	CEC7	ECEC		(- - - - Base - - - -)	
								Sum	Acid-	Extr	KCl	Sum	NH_4	Bases	Al	(- Saturation -)	
	Depth			Ca	Mg	Na	K	Bases	ity	Al	Mn	Cats	OAC	+Al	Sat	Sum	NH_4OAC
Layer	(cm)	Horz	Prep	(- - - - - - - - - - - - - - - - - - cmol(+) kg^{-1} -)							mg kg^{-1}	(- - - - cmol(+) kg^{-1} - - -)			(- - - - - - - - - % - - - - - - - - -)		
				6N2e	6O2d	6P2b	6Q2b		6H1a				5A6a				
40A14929	0-20	A	S	12.5	3.4	0.4	0.3	16.6	8.0			24.6	20.7			67	80
40A14930	20-32	Bt1	S	16.4	8.0	1.3	0.6	26.3	12.2			38.5	33.0			68	80
40A14931	32-49	Bt2	S	20.8	11.2	1.9	0.7	34.6	11.2			45.8	39.6			76	87
40A14932	49-80	Bt3	S	20.3	11.2	2.2	0.7	34.4	9.2			43.6	36.7			79	94
40A14933	80-97	B1	S		10.4	2.2	0.5		6.5				31.2			67	
40A14934	97-133	B2	S		11.8	2.4	0.6		5.3				32.2			74	
40A14935	133-159	B3	S		13.3	2.5	0.6		4.7				34.1			78	
40A14936	159-188	B4	S		14.9	2.6	0.6		4.5				36.3			80	
40A14937	188-228	B5	S		14.9	2.4	0.7		3.5				33.7			84	
40A14938	228-318	B6	S		19.1	2.6	0.8						37.1			100	
40A14939	0-15	Ap	S		2.5	0.2	0.3						17.5			100	

*** Primary Characterization Data ***

Pedon ID: 73KS001003 (Allen, Kansas) Print Date: Apr 4 2010 3:23PM

Sampled As : Woodson

USDA-SCS-Soil Survey Laboratory ; Pedon No. 40A1872

Salt

Layer	Depth (cm)	Horz	Prep	-1- Ca	-2- Mg	-3- Na	-4- K	-5- CO_3	-6- HCO_3	-7- F	-8- Cl	-9- PO_4	-10- Br	-11- OAC	-12- SO_4	-13- NO_2	-14- NO_3	-15- H_2O	-16- Total Salts	-17- Elec Cond	-18- Pred Elec Cond	-19- Exch Na	-20- SAR
				(- - - - - - Water Extracted From Saturated Paste													- - - - - -)						
				(- - - - mmol(+) L^{-1} - - - -)				(- - - - mmol(-) L^{-1} - - - -)										(- - % - -)		(- - dS m^{-1} - -)		%	
				6N1b	6O1b	6P1a	6Q1a											8A	8D5	8A1a		5D2	
40A14929	0-20	A	S																			2	
40A14930	20-32	Bt1	S																			4	
40A14931	32-49	Bt2	S																			5	
40A14932	49-80	Bt3	S																			6	
40A14933	80-97	B1	S																			7	
40A14934	97-133	B2	S	24.2	15.5	15.1	0.1											65.4	0.1	3.06		4	3
40A14935	133-159	B3	S																			7	
40A14936	159-188	B4	S																			7	
40A14937	188-228	B5	S																			7	
40A14938	228-318	B6	S																			7	
40A14939	0-15	Ap	S																			1	

pH & Carbonates

Layer	Depth (cm)	Horz	Prep	-1- KCl	-2- $CaCl_2$ 0.01M 1:2	-3- H_2O 1:1	-4- Sat Paste	-5- Sulf	-6- NaF	-7- Carbonate As $CaCO_3$ <2mm	-8- Carbonate As $CaCO_3$ <20mm	-9- Gypsum As $CaSO_4*2H_2O$ <2mm	-10- Gypsum As $CaSO_4*2H_2O$ <20mm	-11- Resist ohms cm^{-1}
				(- - - - - pH					- - - - -)	(- - - - %			- - - -)	
					8C1e	8C1a	8C1b			6E1a		6F1a		
40A14929	0-20	A	S		5.4	5.9								
40A14930	20-32	Bt1	S		4.8	5.2								
40A14931	32-49	Bt2	S		5.1	5.4								
40A14932	49-80	Bt3	S		5.3	5.6								
40A14933	80-97	B1	S		5.3	5.3						--		
40A14934	97-133	B2	S		5.7	5.7	5.6					--		
40A14935	133-159	B3	S		6.2	6.3						--		
40A14936	159-188	B4	S		6.5	6.6						--		
40A14937	188-228	B5	S		6.8	6.8								
40A14938	228-318	B6	S		7.1	7.2				--				
40A14939	0-15	Ap	S		7.2	7.6				--				

*** Primary Characterization Data ***

Pedon ID: 73KS001003 (Allen, Kansas) Print Date: Apr 4 2010 3:23PM

Sampled As : Woodson

USDA-SCS-Soil Survey Laboratory ; Pedon No. 40A1872

Clay Mineralogy (<.002 mm)				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-	-18-
						X-Ray					Thermal					Elemental				EGME	Inter
													SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	K_2O	Na_2O	Retn	preta
	Depth		Fract			7A2i															tion
Layer	(cm)	Horz	ion	(- - - - - - - - - peak size				- - - - - - - - - -)	(- - - - - - - - - %			- - - - - - - - - -)	(- - - - - - - - - - - - - - - - - - - %						- - - - - - - - - - - - - - - - - - -)	mg g^{-1}	
40A14929	0-20	A	tcly	MM 2	KK 2	MI 1															
40A14931	32-49	Bt2	tcly	MT 3	KK 2	MI 1															
40A14934	97-133	B2	tcly	MT 4	KK 2	MI 1															
40A14936	159-188	B4	tcly	MT 4	KK 2	MI 1															
40A14938	228-318	B6	tcly	MT 4	KK 2	MI 1															

FRACTION INTERPRETATION:

tcly - Total Clay, <0.002 mm

MINERAL INTERPRETATION:

KK - Kaolinite MI - Mica MM - Montmorillonite-Mica MT - Montmorillonite

RELATIVE PEAK SIZE: 5 Very Large 4 Large 3 Medium 2 Small 1 Very Small 6 No Peaks

Site 6

Pedon ID: S05KS205002 (Wilson, Kansas) Print Date: Apr 4 2010 3:26PM

Sampled as on Sep 22, 2005 : Zaar ; Fine, smectitic, thermic Typic Epiaquert
Revised to SSL on Sep 21, 2006 : ; Fine, smectitic, superactive, thermic Aeric Endoaquert

United States Department of Agriculture
Natural Resources Conservation Service
National Soil Survey Center
Soil Survey Laboratory
Lincoln, Nebraska 68508-3866

SSL - Project C2006USNL029 MLRA 112 Water Table St.
- Site ID S05KS205002 Lat: 37° 33' 12.50" north Long: 95° 49' 33.20" west NAD83 MLRA: 112
- Pedon No. 06N0123
- General Methods 1B1A, 2A1, 2B

Layer	Horizon	Orig Hzn	Depth (cm)	Field Label 1	Field Label 2	Field Label 3	Field Texture	Lab Texture
06N00343	Ap		0-13	S05KS205002-1			SICL	SIC
06N00344	A		13-28	S05KS205002-2			SIC	SIC
06N00345	BA		28-56	S05KS205002-3			SIC	SIC
06N00346	Bg		56-84	S05KS205002-4			SIC	SIC
06N00347	Bssg1		84-106	S05KS205002-5			SIC	SIC
06N00348	Bssg2		106-142	S05KS205002-6			SIC	SIC
06N00349	Bssg3		142-163	S05KS205002-7			SIC	SIC
06N00350	Bssg4		163-212	S05KS205002-8			C	SIC

Pedon Calculations

Calculation Name	Result	Units of Measure
Weighted Particles, 0.1-75mm, 75 mm Base	2	% wt
Volume, >2mm, Weighted Average	0	% vol
LE, Whole Soil, Summed to 1m	14	cm/m
Clay, total, Weighted Average	53	% wt
Clay, carbonate free, Weighted Average	53	% wt
CEC Activity, CEC7/Clay, Weighted Average, CECd, Set 1	0.69	(NA)

Weighted averages based on control section: 25-100 cm

*** Primary Characterization Data ***

Pedon ID: S05KS205002 | (Wilson, Kansas) | Print Date: Apr 4 2010 3:26PM

Sampled As : Zaar | Fine, smectitic, thermic Typic Epiaquert

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 06N0123

PSDA & Rock Fragments

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-
				(- - - - - Total - - - - - -)			(- - Clay - - -)		(- - - - Silt - - - - -)		(- - - - - - - - - - - - Sand - - - - - - - - - - - -)					(Rock Fragments (mm))				
				Clay	Silt	Sand	Fine	CO_3	Fine	Coarse	VF	F	M	C	VC	(- - - - - - - - Weight - - - - - - - -)				>2 mm
				<	.002	.05	<	<	.002	.02	.05	.10	.25	.5	1	2	5	20	.1-	wt %
	Depth			.002	-.05	-2	.0002	.002	-.02	-.05	-.10	-.25	-.50	-1	-2	-5	-20	-75	75	whole
Layer	(cm)	Horz	Prep	(- % of <2mm Mineral Soil -)												(- - - - - - - % of <75mm - - - - - -)				soil
				3A1a1a			3A1a1a		3A1a1a		3A1a1a	3A1a1a	3A1a1a	3A1a1a	3A1a1a					
06N00343	0-13	Ap	S	46.7	51.6	1.7	33.5		29.5	22.1	0.9	0.3	0.3	0.1	0.1	--	--	--	1	--
06N00344	13-28	A	S	56.8	41.9	1.3	36.9		27.4	14.5	0.7	0.3	0.2	0.1	tr	--	--	--	1	--
06N00345	28-56	BA	S	56.1	42.1	1.8	28.1		27.7	14.4	0.8	0.4	0.3	0.2	0.1	--	--	--	1	--
06N00346	56-84	Bg	S	53.1	44.4	2.5	17.0		29.3	15.1	0.7	0.4	0.4	0.5	0.5	--	1	--	3	1
06N00347	84-106	Bssg1	S	48.8	46.5	4.7	12.4		30.7	15.8	0.7	0.4	0.5	1.0	2.1	--	--	--	4	--
06N00348	106-142	Bssg2	S	46.6	49.8	3.6	9.0		31.7	18.1	1.3	0.9	0.7	0.6	0.1	--	--	--	2	--
06N00349	142-163	Bssg3	S	48.4	48.1	3.5	10.8		29.1	19.0	1.8	1.1	0.4	0.1	0.1	--	--	--	2	--
06N00350	163-212	Bssg4	S	50.6	46.1	3.3	15.0		26.4	19.7	2.0	0.8	0.3	0.1	0.1	--	--	--	1	--

Bulk Density & Moisture

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-
				(Bulk Density)		Cole	(- - - - - - - - - - - - Water Content - - - - - - - - - - - -)						WRD	Aggst		
				33	Oven	Whole	6	10	33	1500	1500 kPa	Ratio	Whole	Stabl	(- - Ratio/Clay - -)	
	Depth			kPa	Dry	Soil	kPa	kPa	kPa	kPa	Moist	AD/OD	Soil	2-0.5mm	CEC7	1500 kPa
Layer	(cm)	Horz	Prep	(- - - g cm^{-3} - - -)			(- - - - - - - - - - - - % of < 2mm - - - - - - - - - - - -)						cm^3 cm^{-3}	%		
				DbWR1	DbWR1				DbWR1	3C2a1a		3D1				
06N00343	0-13	Ap	S	1.37	1.89	0.113			28.9	25.8		1.035	0.04		0.77	0.55
06N00344	13-28	A	S	1.30	1.90	0.135			33.3	25.1		1.042	0.11		0.71	0.44
06N00345	28-56	BA	S	1.30	1.94	0.143			33.5	22.6		1.042	0.14		0.69	0.40
06N00346	56-84	Bg	S	1.33	1.98	0.141			32.3	22.7		1.038	0.13		0.68	0.43
06N00347	84-106	Bssg1	S	1.31	1.96	0.144			32.9	21.0		1.035	0.16		0.68	0.43
06N00348	106-142	Bssg2	S	1.35	1.95	0.130			31.7	24.4		1.035	0.10		0.77	0.52
06N00349	142-163	Bssg3	S	1.33	1.88	0.122			32.6	22.0		1.038	0.14		0.74	0.45
06N00350	163-212	Bssg4	S	1.32	1.88	0.125			33.0	22.2		1.036	0.14		0.68	0.44

*** Primary Characterization Data ***

Pedon ID: S05KS205002 (Wilson, Kansas) Print Date: Apr 4 2010 3:26PM

Sampled As : Zaar Fine, smectitic, thermic Typic Epiaquert

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 06N0123

Carbon & Extractions

Layer	Depth (cm)	Horz	Prep	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-	-18-
				(- - - - - Total - - - - -)			Org	C/N	(- - - Dith-Cit Ext - - -)			(- - - - - - Ammonium Oxalate Extraction - - - - - -)						(- - - Na Pyro-Phosphate - - -)			
				C	N	S	C	Ratio	Fe	Al	Mn	Al+½Fe	ODOE	Fe	Al	Si	Mn	C	Fe	Al	Mn
				(- - - - - - % of <2 mm - - - - - -)					(- % of < 2mm - - - - - - - - - - - - - - - - - -)								mg kg^{-1}	(- - - - - - % of < 2mm - - - - -)			
				4H2a	4H2a	4H2a			4G1	4G1	4G1										
06N00343	0-13	Ap	S	1.65	0.16	0.03		11	0.8	0.2	tr										
06N00344	13-28	A	S	0.81	0.07	0.01		12	0.9	0.3	tr										
06N00345	28-56	BA	S	0.63	0.05	0.01		11	1.0	0.2	tr										
06N00346	56-84	Bg	S	0.64	0.05	0.01		9	0.9	0.2	0.1										
06N00347	84-106	Bssg1	S	0.78	0.04	0.01		8	0.8	0.2	tr										
06N00348	106-142	Bssg2	S	0.54	0.05	0.01		5	0.8	0.2	0.1										
06N00349	142-163	Bssg3	S	0.37	0.03	0.01		8	1.0	0.2	0.2										
06N00350	163-212	Bssg4	S	0.24	0.04	0.01		5	1.5	0.2	0.1										

CEC & Bases

Layer	Depth (cm)	Horz	Prep	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-
				(- - - - - - NH_4OAC Extractable Bases - - - - -)				Sum	Acid-	Extr	KCl	CEC8	CEC7	ECEC		(- - - - Base - - - -)	
												Sum	NH_4	Bases	Al	(- Saturation -)	
				Ca	Mg	Na	K	Bases	ity	Al	Mn	Cats	OAC	+Al	Sat	Sum	NH_4OAC
				(- - - - - - - - - - - - - - - - - - cmol(+) kg^{-1} -)							mg kg^{-1}	(- - - - cmol(+) kg^{-1} - - -)			(- - - - - - - - - % - - - - - - - - -)		
				4B1a1a	4B1a1a	4B1a1a	4B1a1a		4B2b1a1				4B1a1a				
06N00343	0-13	Ap	S	32.0*	3.6	tr	0.7	36.3	9.5			45.8	35.8			79	100
06N00344	13-28	A	S	36.1*	4.9	0.7	0.7	42.4	4.8			47.2	40.3			90	100
06N00345	28-56	BA	S	37.0*	6.3	1.5	0.6	45.4	4.2				38.5				100
06N00346	56-84	Bg	S	42.5*	5.9	2.3	0.7	51.4	3.5				36.2				100
06N00347	84-106	Bssg1	S	46.3*	5.7	3.4	0.6	56.0	2.3				33.4				100
06N00348	106-142	Bssg2	S	55.8*	6.2	4.5	0.7	67.2	2.2				36.1				100
06N00349	142-163	Bssg3	S	37.6*	6.2	5.3	0.5	49.6	4.6				35.8				100
06N00350	163-212	Bssg4	S	30.9*	5.7	5.5	0.5	42.6	3.0				34.5				100

*Extractable Ca may contain Ca from calcium carbonate or gypsum., CEC7 base saturation set to 100.

*** Primary Characterization Data ***

Pedon ID: S05KS205002 (Wilson, Kansas) Print Date: Apr 4 2010 3:26PM

Sampled As : Zaar Fine, smectitic, thermic Typic Epiaquert

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 06N0123

Salt

-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-	-18-	-19-	-20-
(- Water Extracted From Saturated Paste -)																	Pred		
															Total	Elec	Elec	Exch	

Layer	Depth (cm)	Horz	Prep	Ca	Mg	Na	K	CO_3	HCO_3	F	Cl	PO_4	Br	OAC	SO_4	NO_2	NO_3	H_2O	Salts	Cond	Cond	Na	SAR
				(- - - - - mmol(+) L^{-1} - - - - -)				(- mmol(-) L^{-1} -)										(- - - - % - - - -)		(- - dS m^{-1} - -)		%	
06N00343	0-13	Ap	S																			tr	
06N00344	13-28	A	S																			2	
06N00345	28-56	BA	S																			4	
06N00346	56-84	Bg	S																			6	
06N00347	84-106	Bssg1	S																			10	
06N00348	106-142	Bssg2	S																			13	
06N00349	142-163	Bssg3	S																			15	
06N00350	163-212	Bssg4	S																			16	

pH & Carbonates

Layer	Depth (cm)	Horz	Prep	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-
				(- - - - - - - - - - - - - - - - - - pH					- - - - - - - - - - - - - - - - -)	(- - Carbonate - -) As $CaCO_3$		(- - Gypsum - - -) As $CaSO_4$*$2H_2O$		Resist
				KCl	$CaCl_2$ 0.01M 1:2	H_2O 1:1	Sat Paste	Sulf	NaF	<2mm	<20mm	<2mm	<20mm	ohms cm^{-1}
										(- - - - - - - - - - - - %			- - - - - - - - - - -)	
					4C1a2a	4C1a2a				4E1a1a1a1				
06N00343	0-13	Ap	S		6.6	6.9								
06N00344	13-28	A	S		7.0	7.4				--				
06N00345	28-56	BA	S		7.2	7.8				tr				
06N00346	56-84	Bg	S		7.4	8.0				1				
06N00347	84-106	Bssg1	S		7.6	8.1				4				
06N00348	106-142	Bssg2	S		7.6	8.2				2				
06N00349	142-163	Bssg3	S		7.7	8.3				1				
06N00350	163-212	Bssg4	S		7.5	7.9				tr				

Phosphorous

Layer	Depth (cm)	Horz	Prep	-1- Melanic Index	-2- NZ (Phosphorous) %	-3- Acid Oxal mg kg^{-1}	-4- Bray 1 mg kg^{-1}	-5- Bray 2 mg kg^{-1}	-6- Olsen mg kg^{-1}	-7- H_2O mg kg^{-1}	-8- Citric Acid mg kg^{-1}	-9- Mehlich III mg kg^{-1} 4D6a1	-10- Extr NO_3 mg kg^{-1}
06N00343	0-13	Ap	S									40.6	
06N00344	13-28	A	S									1.3	
06N00345	28-56	BA	S									0.6	
06N00346	56-84	Bg	S									1.4	
06N00347	84-106	Bssg1	S									1.1	
06N00348	106-142	Bssg2	S									4.1	
06N00349	142-163	Bssg3	S									6.0	
06N00350	163-212	Bssg4	S									2.9	

Clay Mineralogy (<.002 mm)				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-	-18-
						X-Ray					Thermal					Elemental				EGME	Inter
													SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	K_2O	Na_2O	Retn	preta
	Depth		Fract			7A1a1															tion
Layer	(cm)	Horz	ion	(- - - - - - - - -	peak size	- - - - - - - - - -)			(- - - - - - - - -	%	- - - - - - - - - -)		(- - - - - - - - - -			%			- - - - - - - - - -)	mg g^{-1}	
06N00343	0-13	Ap	tcly	HS 3	KK 3	MI 2	QZ 1														CMIX
06N00344	13-28	A	tcly	MT 3	KK 2	MI 2	QZ 1														SMEC
06N00345	28-56	BA	tcly	HS 3	KK 3	MI 2	VR 1	QZ 1													CMIX
06N00346	56-84	Bg	tcly	HS 3	KK 3	MI 2	QZ 1														CMIX
06N00347	84-106	Bssg1	tcly	MT 3	KK 2	MI 1	QZ 1														SMEC
06N00348	106-142	Bssg2	tcly	MT 3	KK 3	MI 1	VR 1	QZ 1													SMEC
06N00349	142-163	Bssg3	tcly	MT 3	KK 3	VR 2	MI 1	QZ 1													SMEC
06N00350	163-212	Bssg4	tcly	MT 3	KK 3	VR 2	MI 2	QZ 1													SMEC

FRACTION INTERPRETATION:

tcly - Total Clay, <0.002 mm

MINERAL INTERPRETATION:

HS - Hydroxy-Interlayer Smectite KK - Kaolinite MI - Mica MT - Montmorillonite QZ - Quartz

VR - Vermiculite

RELATIVE PEAK SIZE: 5 Very Large 4 Large 3 Medium 2 Small 1 Very Small 6 No Peaks

Site 7

Pedon ID: 97KS205001 (Wilson, Kansas) Print Date: Apr 4 2010 3:28PM

Sampled as : Zaar ; Fine, smectitic, thermic Typic Endoaquert
Revised to correlated: Zaar ; Fine, smectitic, thermic Typic Epiaquert

SSL - Project CP98KS013 OSAGE-ZAAR
- Site ID 97KS205001 Lat: 37° 25' 20.00" north Long: 95° 50' 6.90" west MLRA: 112
- Pedon No. 98P0063
- General Methods 1B1A, 2A1, 2B

United States Department of Agriculture
Natural Resources Conservation Service
National Soil Survey Center
Soil Survey Laboratory
Lincoln, Nebraska 68508-3866

Layer	Horizon	Orig Hzn	Depth (cm)	Field Label 1	Field Label 2	Field Label 3	Field Texture	Lab Texture
98P00453	Ap	Ap	0-22				SIC	SIC
98P00454	BA	BA	22-53				SIC	SIC
98P00455	Bss1	Bss1	53-86				SIC	SIC
98P00456	Bss2	Bss2	86-117				SIC	SIC
98P00457	Bkss	Bkss	117-147				SIC	SIC
98P00458	Bss	Bss	147-179				SIC	SIC
98P00459	Cr	Cr	179-219					
98P00460		No Sample	219-0					

Pedon Calculations

Calculation Name	Result	Units of Measure
CEC Activity, CEC7/Clay, Weighted Average	0.87	(NA)
Clay, carbonate free, Weighted Average	51	% wt
Weighted Particles, 0.1-75mm, 75 mm Base	1	% wt
Volume, >2mm, Weighted Average	0	% vol
Clay, total, Weighted Average	51	% wt
LE, Whole Soil, Summed to 1m	15	cm/m

Weighted averages based on control section: 25-100 cm

PSDA & Rock Fragments

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-
				(- - - - - Total - - - - - -)			(- - Clay - - -)		(- - - - Silt - - - - -)		(- - - - - - - - - - - - Sand - - - - - - - - - - - - -)					(Rock Fragments (mm))				
				Clay	Silt	Sand	Fine	CO_3	Fine	Coarse	VF	F	M	C	VC	(- - - - - - - - Weight - - - - - - - -)				>2 mm
				<	.002	.05	<	<	.002	.02	.05	.10	.25	.5	1	2	5	20	.1-	wt %
	Depth			.002	-.05	-2	.0002	.002	-.02	-.05	-.10	-.25	-.50	-1	-2	-5	-20	-75	75	whole
Layer	(cm)	Horz	Prep	(- % of <2mm Mineral Soil -)												(- - - - - - - % of <75mm - - - - - -)				soil
				3A1	3A1	3A1	3A1		3A1	3A1	3A1	3A1	3A1	3A1	3A1	3B1	3B1	3B1		
98P00453	0-22	Ap	S	42.5	54.8	2.7	29.7		33.4	21.4	1.8	0.5	0.2	0.1	0.1	--	--	--	1	--
98P00454	22-53	BA	S	44.4	52.3	3.3	31.6		30.2	22.1	2.1	0.6	0.3	0.2	0.1	--	--	--	1	--
98P00455	53-86	Bss1	S	55.6	42.1	2.3	37.5		27.7	14.4	1.1	0.7	0.3	0.1	0.1	--	--	--	1	--
98P00456	86-117	Bss2	S	54.2	42.5	3.3	23.8		29.4	13.1	1.2	0.7	0.5	0.5	0.4	tr	1	--	3	1

98P00457	117-147	Bkss	S	50.0	43.7	6.3	18.8		28.9	14.8	1.2	0.9	1.0	1.3	1.9	tr	4	--	9	4
98P00458	147-179	Bss	S	51.0	42.6	6.4	20.0		28.6	14.0	1.2	1.0	1.0	1.2	2.0	tr	2	--	7	2

*** Primary Characterization Data ***

Pedon ID: 97KS205001 (Wilson, Kansas) Print Date: Apr 4 2010 3:28PM

Sampled As : Zaar Fine, smectitic, thermic Typic Endoaquert

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 98P0063

Water Dispersible PSDA

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-
				Water Dispersible											
				Total			Clay		Silt		Sand				
				Clay	Silt	Sand	F	CO_3	F	C	VF	F	M	C	VC
				<	.002	.05	<	<	.002	.02	.05	.10	.25	.5	1
	Depth			.002	-.05	-2	.0002	.002	-.02	-.05	-.10	-.25	-.50	-1	-2
Layer	(cm)	Horz	Prep	% of <2mm											
				3A1c	3A1c	3A1c			3A1c	3A1c	3A1c	3A1c	3A1c	3A1c	3A1c
98P00453	0-22	Ap	S	16.9	71.6	11.5			46.2	25.4	4.7	4.0	1.7	0.9	0.2

Bulk Density & Moisture

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-
				(Bulk Density)		Cole	Water Content						WRD	Aggst		
				33	Oven	Whole	6	10	33	1500	1500 kPa	Ratio	Whole	Stabl	Ratio/Clay	
	Depth			kPa	Dry	Soil	kPa	kPa	kPa	kPa	Moist	AD/OD	Soil	2-0.5mm	CEC7	1500 kPa
Layer	(cm)	Horz	Prep	g cm^{-3}			% of < 2mm						cm^3 cm^{-3}	%		
				4A1d	4A1h				4B1c	4B2a		4B5	4C1	4G1	8D1	8D1
98P00453	0-22	Ap	S	1.26	1.77	0.120			34.6	20.0		1.034	0.18	52	0.95	0.47
98P00454	22-53	BA	S	1.23	1.81	0.137			36.6	28.2		1.035	0.10		0.91	0.64
98P00455	53-86	Bss1	S	1.12	1.85	0.182			44.5	33.3		1.045	0.13		0.86	0.60
98P00456	86-117	Bss2	S	1.18	1.87	0.164			41.9	21.8		1.044	0.24		0.83	0.40
98P00457	117-147	Bkss	S	1.24	1.86	0.141			37.4	21.5		1.042	0.19		0.85	0.43
98P00458	147-179	Bss	S	1.26	1.83	0.131			36.0	21.5		1.043	0.18		0.83	0.42

*** Primary Characterization Data ***

Pedon ID: 97KS205001 (Wilson, Kansas) Print Date: Apr 4 2010 3:28PM

Sampled As : Zaar Fine, smectitic, thermic Typic Endoaquert

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 98P0063

Water Content

Layer	Depth (cm)	Horz	Prep	-1- LL (Atterberg Limits) pct <0.4mm	-2- PI (Atterberg Limits)	-3- Field (Bulk Density) g cm^{-3}	-4- Recon 33 kPa (Bulk Density)	-5- Recon Oven Dry (Bulk Density)	-6- Field (Water Content) % of < 2mm	-7- Recon 33 kPa	-8- 6 kPa (Sieved Samples)	-9- 10 kPa	-10- 33 kPa	-11- 100 kPa	-12- 200 kPa 4B1a	-13- 500 kPa
98P00453	0-22	Ap	S												28.4	
98P00454	22-53	BA	S												28.1	
98P00455	53-86	Bss1	S												32.4	
98P00456	86-117	Bss2	S												29.5	
98P00457	117-147	Bkss	S												30.9	
98P00458	147-179	Bss	S												31.4	

Carbon & Extractions

Layer	Depth (cm)	Horz	Prep	-1- Total C % of <2 mm 6A2e	-2- Total N 6B4a	-3- Total S	-4- Org C	-5- C/N Ratio	-6- Dith-Cit Ext Fe % of < 2mm 6C2b	-7- Dith-Cit Ext Al 6G7a	-8- Dith-Cit Ext Mn 6D2a	-9- Ammonium Oxalate Al+½Fe	-10- ODOE 8J	-11- Fe 6C9b	-12- Al 6G12b	-13- Si 6V2b	-14- Mn mg kg^{-1} 6D5b	-15- Na Pyro-Phosphate C % of < 2mm	-16- Fe	-17- Al	-18- Mn
98P00453	0-22	Ap	S	2.33	0.212			11	1.6	0.3	0.2	0.37	0.08	0.39	0.18	0.08	360.0				
98P00454	22-53	BA	S	1.81	0.159			11	1.5	0.3	0.2	0.36	0.07	0.37	0.17	0.09	578.0				
98P00455	53-86	Bss1	S	1.26	0.122			10	1.8	0.4	0.3	0.36	0.06	0.30	0.22	0.10	511.0				
98P00456	86-117	Bss2	S	0.93	0.079				1.9	0.4	0.2	0.31	0.05	0.26	0.18	0.10	877.0				
98P00457	117-147	Bkss	S	1.11					2.3	0.4	0.2	0.35	0.05	0.31	0.19	0.11	299.0				
98P00458	147-179	Bss	S						2.6	0.4	0.2	0.36	0.04	0.36	0.19	0.10	260.0				

CEC & Bases

Layer	Depth (cm)	Horz	Prep	-1- Ca	-2- Mg	-3- Na	-4- K	-5- Sum Bases	-6- Acid-ity	-7- Extr Al	-8- KCl Mn	-9- CEC8 Sum Cats	-10- CEC7 NH_4 OAC	-11- ECEC Bases +Al	-12- Al Sat	-13- Base Saturation Sum	-14- Base Saturation NH_4OAC
				(- - - - - - NH_4OAC Extractable Bases - - - - -)													
				(- - - cmol(+) kg^{-1} - - -)							mg kg^{-1}	(- - - cmol(+) kg^{-1} - - -)			(- - - % - - -)		
				6N2e	6O2d	6P2b	6Q2b		6H5a			5A3a	5A8b			5C3	5C1
98P00453	0-22	Ap	S	32.3	6.4	0.5	0.7	39.9	6.4			46.3	40.5			86	99
98P00454	22-53	BA	S	31.7*	7.4	0.7	0.8	40.6	4.6			45.2	40.6			90	100
98P00455	53-86	Bss1	S	35.8*	9.8	1.5	1.1	48.2	4.7			52.9	47.6			91	100
98P00456	86-117	Bss2	S	39.7*	11.8	1.1	1.0		3.0				45.1			95	100
98P00457	117-147	Bkss	S	52.2*	14.2	1.6	1.2		0.6				42.5			99	100
98P00458	147-179	Bss	S	47.3*	13.7	1.5	0.9		1.0				42.1			98	100

*Extractable Ca may contain Ca from calcium carbonate or gypsum., CEC7 base saturation set to 100.

Salt

Layer	Depth (cm)	Horz	Prep	-1- Ca	-2- Mg	-3- Na	-4- K	-5- CO_3	-6- HCO_3	-7- F	-8- Cl	-9- PO_4	-10- Br	-11- OAC	-12- SO_4	-13- NO_2	-14- NO_3	-15- H_2O	-16- Total Salts	-17- Elec Cond	-18- Pred Elec Cond	-19- Exch Na	-20- SAR
				(- - - Water Extracted From Saturated Paste - - -)																			
				(- - - - mmol(+) L^{-1} - - - -)				(- - - mmol(-) L^{-1} - - -)										(- - - % - - -)		(- - dS m^{-1} - -)		%	
				6N1b	6O1b	6P1b	6Q1b	6I1b	6J1b	6U1b	6K1d				6L1d	6W1b	6M1d	8A	8D5	8A3a	8I	5D2	5E
98P00453	0-22	Ap	S																		0.20	1	
98P00454	22-53	BA	S																		0.21	2	
98P00455	53-86	Bss1	S																		0.19	3	
98P00456	86-117	Bss2	S	2.2	1.1	2.1	0.2	--	3.9	--	0.4				1.1	--	0.1	85.3	tr	0.59	0.28	2	2
98P00457	117-147	Bkss	S	1.9	1.4	3.0	0.2	--	4.0	0.1	0.4				2.0	tr	0.1	92.1	tr	0.67	0.36	3	2
98P00458	147-179	Bss	S	2.7	1.3	3.0	0.2	--	4.0	0.1	0.3				2.2	0.1	0.1	84.0	tr	0.67	0.39	3	2

Sampled As : Zaar Fine, smectitic, thermic Typic Endoaquert

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 98P0063

pH & Carbonates

Layer	Depth (cm)	Horz	Prep	-1- KCl	-2- pH CaCl2 0.01M 1:2 4C1a2a	-3- pH H_2O 1:1 4C1a2a	-4- pH Sat Paste 8C1b	-5- pH Sulf	-6- pH NaF	-7- Carbonate As $CaCO_3$ <2mm % 6E1g	-8- Carbonate As $CaCO_3$ <20mm %	-9- Gypsum As $CaSO_4*2H_2O$ <2mm %	-10- Gypsum As $CaSO_4*2H_2O$ <20mm %	-11- Resist ohms cm^{-1}
98P00453	0-22	Ap	S		6.5	6.9								
98P00454	22-53	BA	S		6.8	7.3								
98P00455	53-86	Bss1	S		7.0	7.4				tr				
98P00456	86-117	Bss2	S		7.6	7.8	7.5			1				
98P00457	117-147	Bkss	S		7.8	8.2	7.7			5				
98P00458	147-179	Bss	S		7.8	8.1	7.7			6				

Phosphorous

Layer	Depth (cm)	Horz	Prep	-1- Melanic Index	-2- Phosphorous NZ %	-3- Acid Oxal mg kg^{-1} 6S8a	-4- Bray 1 mg kg^{-1} 6S3b	-5- Bray 2 mg kg^{-1}	-6- Olsen mg kg^{-1}	-7- H_2O mg kg^{-1}	-8- Citric Acid mg kg^{-1}	-9- Mehlich III mg kg^{-1}	-10- Extr NO_3 mg kg^{-1}
98P00453	0-22	Ap	S			288.0	22.0						
98P00454	22-53	BA	S			124.0							
98P00455	53-86	Bss1	S			104.0							
98P00456	86-117	Bss2	S			194.0							
98P00457	117-147	Bkss	S			351.0							
98P00458	147-179	Bss	S			479.0							

Pedon ID: 97KS205001 (Wilson, Kansas) Print Date: Apr 4 2010 3:28PM

Sampled As : Zaar Fine, smectitic, thermic Typic Endoaquert

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 98P0063

Clay Mineralogy (<.002 mm)				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-	-18-
						X-Ray					Thermal					Elemental				EGME	Inter
													SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	K_2O	Na_2O	Retn	preta
	Depth		Fract			7A2i															tion
Layer	(cm)	Horz	ion	(- - - - - - - - - - peak size - - - - - - - - - - -)					(- - - - - - - - - - % - - - - - - - - - - -)				(- % -)							$mg\ g^{-1}$	
98P00454	22-53	BA	tcly	MT 3	KK 2	MI 2	QZ 2														
98P00455	53-86	Bss1	tcly	MT 3	MI 2	KK 2	QZ 2														
98P00456	86-117	Bss2	tcly	MT 3	VR 2	KK 2	MI 2	QZ 2													
98P00457	117-147	Bkss	tcly	MT 3	VR 2	KK 2	MI 2	QZ 2													
98P00458	147-179	Bss	tcly	MT 4	VR 2	MI 2	KK 2	QZ 1													

FRACTION INTERPRETATION:

tcly - Total Clay, <0.002 mm

MINERAL INTERPRETATION:

KK - Kaolinite MI - Mica MT - Montmorillonite QZ - Quartz VR - Vermiculite

RELATIVE PEAK SIZE: 5 Very Large 4 Large 3 Medium 2 Small 1 Very Small 6 No Peaks

*** Primary Characterization Data ***

Pedon ID: 97KS205001 (Wilson, Kansas) Print Date: Apr 4 2010 3:28PM

Sampled As : Zaar Fine, smectitic, thermic Typic Endoaquert

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 98P0063

Sand - Silt Mineralogy (2.0-0.002 mm)				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-	-18-
				X-Ray					Thermal				Optical							EGME	Inter
													Tot Re	Grain Count						Retn	preta
	Depth		Fract											7B1a							tion
Layer	(cm)	Horz	ion	(- - - - - - - - peak size - - - - - - - - -)					(- - - - - - - - % - - - - - - - - - -)				(- % - - - - - - - - - - - - - - - - - - -)							$mg\ g^{-1}$	
98P00458	147-179	Bss	csi										81	QZ 78	FK 14	FE 2	OP 1	CA 1	MS 1		
														PR 1	HN tr	FP tr	TM tr	ZR tr	PO tr		
														BT tr	CB tr						

FRACTION INTERPRETATION:

csi - Coarse Silt, 0.02-0.05 mm

MINERAL INTERPRETATION:

BT - Biotite	CA - Calcite	CB - Carbonate Aggregates	FE - Iron Oxides (Goethite	FK - Potassium Feldspar
FP - Plagioclase Feldspar	HN - Hornblende	MS - Muscovite	OP - Opaques	PO - Plant Opal
PR - Pyroxene	QZ - Quartz	TM - Tourmaline	ZR - Zircon	

Site 8

Pedon ID: S05KS133003 (Neosho, Kansas) Print Date: Apr 4 2010 3:31PM

Sampled as on Sep 20, 2005 : Kenoma ; Fine, smectitic, thermic Vertic Argiudoll
Revised to SSL on Sep 21, 2006 : ; Fine, smectitic, superactive, thermic Typic Epiaquert

SSL - Project C2006USNL029 MLRA 112 Water Table St.
- Site ID S05KS133003 Lat: 37° 30' 50.00" north Long: 95° 21' 9.80" west NAD83 MLRA: 112
- Pedon No. 06N0122
- General Methods 1B1A, 2A1, 2B

United States Department of Agriculture
Natural Resources Conservation Service
National Soil Survey Center
Soil Survey Laboratory
Lincoln, Nebraska 68508-3866

Layer	Horizon	Orig Hzn	Depth (cm)	Field Label 1	Field Label 2	Field Label 3	Field Texture	Lab Texture
06N00335	Ap		0-17	S05KS133003-1			SIL	SIL
06N00336	Bt1		17-38	S05KS133003-2			SIC	SIC
06N00337	Bt2		38-71	S05KS133003-3			SIC	SIC
06N00338	2Btg1		71-101	S05KS133003-4			SIC	SIC
06N00339	2Btg2		101-128	S05KS133003-5			SIC	SIC
06N00340	2Bssg1		128-156	S05KS133003-6			SIC	SIC
06N00341	2Bssg2		156-174	S05KS133003-7			SIC	C
06N00342	2BC		174-195	S05KS133003-8			SIC	SIC

Pedon Calculations

Calculation Name	Result	Units of Measure
Weighted Particles, 0.1-75mm, 75 mm Base	2	% wt
Volume, >2mm, Weighted Average	0	% vol
LE, Whole Soil, Summed to 1m	8	cm/m
Clay, total, Weighted Average	54	% wt
Clay, carbonate free, Weighted Average	54	% wt
CEC Activity, CEC7/Clay, Weighted Average, CECd, Set 1	0.61	(NA)

Weighted averages based on control section: 17-67 cm

*** Primary Characterization Data ***

Pedon ID: S05KS133003 (Neosho, Kansas) Print Date: Apr 4 2010 3:31PM

Sampled As : Kenoma Fine, smectitic, thermic Vertic Argiudoll

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 06N0122

PSDA & Rock Fragments

Layer	Depth (cm)	Horz	Prep	-1- Total Clay < .002	-2- Total Silt .002 -.05	-3- Total Sand .05 -2	-4- Clay Fine < .0002	-5- Clay CO_3 < .002	-6- Silt Fine .002 -.02	-7- Silt Coarse .02 -.05	-8- Sand VF .05 -.10	-9- Sand F .10 -.25	-10- Sand M .25 -.50	-11- Sand C .5 -1	-12- Sand VC 1 -2	-13- Rock Fragments (mm) Weight 2 -5	-14- Weight 5 -20	-15- Weight 20 -75	-16- Weight .1- 75	-17- >2 mm wt % whole soil
				(- - - % of <2mm Mineral Soil - - -)												(- - % of <75mm - -)				
				3A1a1a			3A1a1a		3A1a1a		3A1a1a	3A1a1a	3A1a1a	3A1a1a	3A1a1a					
06N00335	0-17	Ap	S	22.1	71.7	6.2	13.6		39.1	32.6	1.5	0.7	1.3	1.5	1.2	--	--	--	5	--
06N00336	17-38	Bt1	S	53.3	43.4	3.3	40.4		26.6	16.8	0.8	0.5	0.8	0.7	0.5	--	--	--	3	--
06N00337	38-71	Bt2	S	55.0	42.1	2.9	40.9		27.5	14.6	0.8	0.6	0.8	0.7	tr	--	--	--	2	--
06N00338	71-101	2Btg1	S	43.5	45.8	10.7	19.9		31.3	14.5	2.1	1.1	1.6	3.3	2.6	--	--	--	9	--
06N00339	101-128	2Btg2	S	44.2	43.9	11.9	21.1		30.0	13.9	1.1	1.4	2.1	4.8	2.5	3	1	--	14	4
06N00340	128-156	2Bssg1	S	44.5	42.8	12.7	20.7		29.7	13.1	2.2	1.4	3.2	4.2	1.7	3	1	--	14	4
06N00341	156-174	2Bssg2	S	50.4	38.5	11.1	23.1		27.6	10.9	1.8	1.3	1.9	3.4	2.7	2	tr	--	11	2
06N00342	174-195	2BC	S	43.4	44.5	12.1	14.1		39.6	4.9	1.6	2.2	2.7	3.8	1.8	--	--	--	11	--

Bulk Density & Moisture

Layer	Depth (cm)	Horz	Prep	-1- (Bulk Density) 33 kPa	-2- Oven Dry	-3- Cole Whole Soil	-4- Water Content 6 kPa	-5- 10 kPa	-6- 33 kPa	-7- 1500 kPa	-8- 1500 kPa Moist	-9- Ratio AD/OD	-10- WRD Whole Soil	-11- Aggst Stabl 2-0.5mm	-12- (Ratio/Clay) CEC7	-13- 1500 kPa
				(- - - g cm^{-3} - - -)			(- - % of < 2mm - -)						cm^3 cm^{-3}	%		
				DbWR1	DbWR1				DbWR1	3C2a1a		3D1				
06N00335	0-17	Ap	S	1.45	1.53	0.018			24.4	10.9		1.016	0.20		0.76	0.49
06N00336	17-38	Bt1	S	1.27	1.77	0.117			31.6	23.0		1.034	0.11		0.63	0.43
06N00337	38-71	Bt2	S	1.30	1.85	0.125			31.3	23.7		1.034	0.10		0.60	0.43
06N00338	71-101	2Btg1	S	1.44	1.67	0.051			25.3	20.4		1.024	0.07		0.45	0.47
06N00339	101-128	2Btg2	S	1.46	1.70	0.051			26.3	19.6		1.025	0.10		0.45	0.44
06N00340	128-156	2Bssg1	S	1.57	1.79	0.044			24.0	19.1		1.024	0.07		0.44	0.43
06N00341	156-174	2Bssg2	S	1.48	1.75	0.057			26.8	20.7		1.026	0.09		0.42	0.41
06N00342	174-195	2BC	S	1.57	1.88	0.062			24.5	19.1		1.024	0.08		0.44	0.44

*** Primary Characterization Data ***

Pedon ID: S05KS133003 — (Neosho, Kansas) — Print Date: Apr 4 2010 3:31PM

Sampled As : Kenoma — Fine, smectitic, thermic Vertic Argiudoll

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 06N0122

Carbon & Extractions

Layer	Depth (cm)	Horz	Prep	-1- C	-2- N	-3- S	-4- Org C	-5- C/N Ratio	-6- Fe	-7- Al	-8- Mn	-9- Al+½Fe	-10- ODOE	-11- Fe	-12- Al	-13- Si	-14- Mn	-15- C	-16- Fe	-17- Al	-18- Mn
				(- - - - - Total - - - - -)					(- - - Dith-Cit Ext - - -)			(- - - - - - Ammonium Oxalate Extraction - - - - - -)						(- - - Na Pyro-Phosphate - - -)			
				(- - - - - - % of <2 mm - - - - - -)					(- % of < 2mm - - - - - - - - - - - - - - - - - - -)								mg kg^{-1}	(- - - - - - % of < 2mm - - - - -)			
				4H2a	4H2a	4H2a			4G1	4G1	4G1										
06N00335	0-17	Ap	S	2.05	0.20	0.02		10	1.7	0.2	0.1										
06N00336	17-38	Bt1	S	1.48	0.16	0.03		9	2.3	0.4	tr										
06N00337	38-71	Bt2	S	1.31	0.13	0.02		10	2.5	0.3	tr										
06N00338	71-101	2Btg1	S	0.29	0.06	0.02		5	3.7	0.3	0.1										
06N00339	101-128	2Btg2	S	0.29	0.05	0.03		6	4.0	0.4	0.1										
06N00340	128-156	2Bssg1	S	0.33	0.05	0.03		7	3.9	0.4	0.1										
06N00341	156-174	2Bssg2	S	0.33	0.06	0.04		6	3.7	0.3	0.1										
06N00342	174-195	2BC	S	0.25	0.10	0.03		3	3.1	0.3	0.2										

CEC & Bases

Layer	Depth (cm)	Horz	Prep	-1- Ca	-2- Mg	-3- Na	-4- K	-5- Sum Bases	-6- Acid-ity	-7- Extr Al	-8- KCl Mn	-9- CEC8 Sum Cats	-10- CEC7 NH_4 OAC	-11- ECEC Bases +Al	-12- Al Sat	-13- Sum	-14- NH_4OAC
				(- - - - - - NH_4OAC Extractable Bases - - - - -)												(- - - - Base - - - -) (- Saturation -)	
				(- - - - - - - - - - - - - - - - - cmol(+) kg^{-1} -)							mg kg^{-1}	(- - - - cmol(+) kg^{-1} - - -)			(- - - - - - - - % - - - - - - - -)		
				4B1a1a	4B1a1a	4B1a1a	4B1a1a		4B2b1a1	4B3a1a	4B3a1a		4B1a1a				
06N00335	0-17	Ap	S	12.5	2.6	tr	0.4	15.5	7.7			23.2	16.7			67	93
06N00336	17-38	Bt1	S	15.7	9.8	1.0	0.5	27.0	15.2	0.5	0.1	42.2	33.4	27.5	2	64	81
06N00337	38-71	Bt2	S	17.1	11.2	1.7	0.5	30.5	12.2			42.7	33.2			71	92
06N00338	71-101	2Btg1	S	10.8*	7.6	2.0	0.3	20.7	7.8			28.5	19.5			73	100
06N00339	101-128	2Btg2	S	12.4*	8.8	2.7	0.3	24.2	7.9			32.1	19.8			75	100
06N00340	128-156	2Bssg1	S	12.2*	8.8	2.8	0.3	24.1	6.5			30.6	19.8			79	100
06N00341	156-174	2Bssg2	S	14.9*	10.2	3.5	0.4	29.0	5.9			34.9	21.3			83	100
06N00342	174-195	2BC	S	14.6*	10.3	3.4	0.3	28.6	6.3			34.9	19.1			82	100

*Extractable Ca may contain Ca from calcium carbonate or gypsum., CEC7 base saturation set to 100.

*** Primary Characterization Data ***

Pedon ID: S05KS133003 — (Neosho, Kansas) — Print Date: Apr 4 2010 3:31PM

Sampled As : Kenoma — Fine, smectitic, thermic Vertic Argiudoll

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 06N0122

Salt

-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-	-18-	-19-	-20-
(- Water Extracted From Saturated Paste -)															Total	Elec	Pred Elec	Exch	

Layer	Depth (cm)	Horz	Prep	Ca	Mg	Na	K	CO_3	HCO_3	F	Cl	PO_4	Br	OAC	SO_4	NO_2	NO_3	H_2O	Salts	Cond	Cond	Na	SAR
				(- - - - - mmol(+) L^{-1} - - - - -)				(- mmol(-) L^{-1} -)										(- - - - % - - - -)		(- - dS m^{-1} - -)		%	
06N00335	0-17	Ap	S																			tr	
06N00336	17-38	Bt1	S																			3	
06N00337	38-71	Bt2	S																			5	
06N00338	71-101	2Btg1	S																			10	
06N00339	101-128	2Btg2	S																			14	
06N00340	128-156	2Bssg1	S																			14	
06N00341	156-174	2Bssg2	S																			16	
06N00342	174-195	2BC	S																			18	

pH & Carbonates

Layer	Depth (cm)	Horz	Prep	KCl	$CaCl_2$ 0.01M 1:2 4C1a2a	H_2O 1:1 4C1a2a	Sat Paste	Sulf	NaF	Carbonate As $CaCO_3$ <2mm	Carbonate As $CaCO_3$ <20mm	Gypsum As $CaSO_4*2H_2O$ <2mm	Gypsum As $CaSO_4*2H_2O$ <20mm	Resist ohms cm^{-1}
				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-
				(- - - - - - - - - - - - - - - - - - pH - - - - - - - - - - - - - - - - - -)						(- - - - - - - - - - - - % - - - - - - - - - - - -)				
06N00335	0-17	Ap	S		5.4	5.9								
06N00336	17-38	Bt1	S		4.8	5.6								
06N00337	38-71	Bt2	S		5.3	6.0								
06N00338	71-101	2Btg1	S		5.9	6.4								
06N00339	101-128	2Btg2	S		6.3	6.8								
06N00340	128-156	2Bssg1	S		6.6	7.0								
06N00341	156-174	2Bssg2	S		6.8	7.1								
06N00342	174-195	2BC	S		6.9	7.3								

*** Primary Characterization Data ***

Pedon ID: S05KS133003 (Neosho, Kansas) Print Date: Apr 4 2010 3:31PM

Sampled As : Kenoma Fine, smectitic, thermic Vertic Argiudoll

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 06N0122

Phosphorous

Layer	Depth (cm)	Horz	Prep	-1- Melanic Index	-2- NZ %	-3- Acid Oxal	-4- Bray 1	-5- Bray 2	-6- Olsen	-7- H_2O	-8- Citric Acid	-9- Mehlich III	-10- Extr NO_3 mg kg^{-1}
					(- - Phosphorous	mg kg^{-1}						- -)	
							4D3						
06N00335	0-17	Ap	S				8.7						
06N00336	17-38	Bt1	S				1.4						
06N00337	38-71	Bt2	S				0.4						
06N00338	71-101	2Btg1	S				0.6						
06N00339	101-128	2Btg2	S				1.5						
06N00340	128-156	2Bssg1	S				2.0						
06N00341	156-174	2Bssg2	S				2.0						
06N00342	174-195	2BC	S				1.8						

*** Primary Characterization Data ***

Pedon ID: S05KS133003 (Neosho, Kansas) Print Date: Apr 4 2010 3:31PM

Sampled As : Kenoma Fine, smectitic, thermic Vertic Argiudoll

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 06N0122

Clay Mineralogy (<.002 mm)				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-	-18-
						X-Ray					Thermal					Elemental				EGME	Inter
													SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	K_2O	Na_2O	Retn	preta
	Depth		Fract			7A1a1															tion
Layer	(cm)	Horz	ion	(- - - - - - - - - peak size - - - - - - - - - -)					(- - - - - - - - - % - - - - - - - - - -)				(- - - - - - - - - - - - - - - - - - % - - - - - - - - - - - - - - - - - - -)							mg g^{-1}	
06N00335	0-17	Ap	tcly	KK 3	MI 2	VR 2	QZ 1														CMIX
06N00336	17-38	Bt1	tcly	LE 2	MM 3	KK 3	MI 2	QZ 1													CMIX
				HS 1																	
06N00337	38-71	Bt2	tcly	HS 3	KK 3	MI 2	QZ 1														CMIX
06N00338	71-101	2Btg1	tcly	KK 3	MI 2	VR 2	GE 1	HS 1													CMIX
				QZ 1																	
06N00339	101-128	2Btg2	tcly	KK 3	MI 3	MM 1	LE 1	GE 1													CMIX
				QZ 1																	
06N00340	128-156	2Bssg1	tcly	KK 3	MT 2	MI 2	VR 1	LE 1													CMIX
				GE 1	QZ 1																
06N00341	156-174	2Bssg2	tcly	KK 3	MI 2	VR 2	GE 1	QZ 1													CMIX
06N00342	174-195	2BC	tcly	MI 3	KK 3	VR 2	GE 1	QZ 1													CMIX

FRACTION INTERPRETATION:

tcly - Total Clay, <0.002 mm

MINERAL INTERPRETATION:

GE - Goethite
HS - Hydroxy-Interlayer Smectite
KK - Kaolinite
LE - Lepidocrocite
MI - Mica
MM - Montmorillonite-Mica
MT - Montmorillonite
QZ - Quartz
VR - Vermiculite

RELATIVE PEAK SIZE: 5 Very Large 4 Large 3 Medium 2 Small 1 Very Small 6 No Peaks

Site 9

Pedon ID: S06KS133-001 (Neosho, Kansas) Print Date: Apr 4 2010 3:33PM

Sampled as : Parsons ; Fine, mixed, active, thermic Vertic Albaqualf
Revised to :

SSL - Project C2007USKS025 MLRA 112 Water Table Study
- Site ID S06KS-133-001 Lat: 37° 30' 26.90" north Long: 95° 21' 25.90" west NAD83 MLRA: 112
- Pedon No. 07N0134
- General Methods 1B1A, 2A1, 2B

United States Department of Agriculture
Natural Resources Conservation Service
National Soil Survey Center
Soil Survey Laboratory
Lincoln, Nebraska 68508-3866

Layer	Horizon	Orig Hzn	Depth (cm)	Field Label 1	Field Label 2	Field Label 3	Field Texture	Lab Texture
07N00882	A		0-18	S06KS133-001-1			SIL	SIL
07N00883	E		18-28	S06KS133-001-2			SIL	SIL
07N00884	2Btg1		28-55	S06KS133-001-3			SIC	SIC
07N00885	2Btg2		55-91	S06KS133-001-4			SIC	SIC
07N00886	2Btyg1		91-115	S06KS133-001-5			SIC	C
07N00887	2Btyg2		115-142	S06KS133-001-6			SIC	C
07N00888	2Btg3		142-176	S06KS133-001-7			SIC	C
07N00889	2Btg4		176-205	S06KS133-001-8			SIC	C

Pedon Calculations

Calculation Name	Result	Units of Measure
Weighted Particles, 0.1-75mm, 75 mm Base	1	% wt
Volume, >2mm, Weighted Average	0	% vol
Clay, total, Weighted Average	53	% wt
Clay, carbonate free, Weighted Average	53	% wt
CEC Activity, CEC7/Clay, Weighted Average, CECd, Set 1	0.52	(NA)
LE, Whole Soil, Summed to 1m	9	cm/m

Weighted averages based on control section: 28-78 cm

*** Primary Characterization Data ***

Pedon ID: S06KS133-001 (Neosho, Kansas) Print Date: Apr 4 2010 3:33PM

Sampled As : Parsons — Fine, mixed, active, thermic Vertic Albaqualf

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 07N0134

PSDA & Rock Fragments

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-
				(- - - - - Total - - - - - -)			(- - Clay - - -)		(- - - - Silt - - - - -)		(- - - - - - - - - - - - Sand - - - - - - - - - - - -)					(Rock Fragments (mm))				
				Clay	Silt	Sand	Fine	CO_3	Fine	Coarse	VF	F	M	C	VC	(- - - - - - - - Weight - - - - - - - -)				>2 mm
				<	.002	.05	<	<	.002	.02	.05	.10	.25	.5	1	2	5	20	.1-	wt %
	Depth			.002	-.05	-2	.0002	.002	-.02	-.05	-.10	-.25	-.50	-1	-2	-5	-20	-75	75	whole
Layer	(cm)	Horz	Prep	(- % of <2mm Mineral Soil -)												(- - - - - - - % of <75mm - - - - - -)				soil
				3A1a1a					3A1a1a		3A1a1a	3A1a1a	3A1a1a	3A1a1a	3A1a1a					
07N00882	0-18	A	S	25.0	70.4	4.6			37.5	32.9	3.6	0.5	0.4	0.1	--	tr	--	--	1	tr
07N00883	18-28	E	S	23.1	72.0	4.9			36.3	35.7	4.0	0.4	0.3	0.2	tr	tr	1	--	2	1
07N00884	28-55	2Btg1	S	54.4	42.8	2.8			24.4	18.4	2.1	0.4	0.2	0.1	tr	--	--	--	1	--
07N00885	55-91	2Btg2	S	50.8	46.8	2.4			28.3	18.5	1.8	0.3	0.2	0.1	tr	--	--	--	1	--
07N00886	91-115	2Btyg1	S	55.8	39.2	5.0			25.9	13.3	2.3	1.0	0.9	0.4	0.4	--	--	--	3	--
07N00887	115-142	2Btyg2	S	61.6	34.1	4.3			22.6	11.5	3.0	1.0	0.2	0.1	tr	--	--	--	1	--
07N00888	142-176	2Btg3	S	65.1	31.5	3.4			20.7	10.8	2.6	0.7	0.1	tr	tr	--	--	--	1	--
07N00889	176-205	2Btg4	S	60.0	35.6	4.4			23.5	12.1	3.2	0.7	0.3	0.2	tr	--	tr	--	1	tr

Bulk Density & Moisture

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-
				(Bulk Density)		Cole	(- - - - - - - - - - - - Water Content - - - - - - - - - - - -)						WRD	Aggst		
				33	Oven	Whole	6	10	33	1500	1500 kPa	Ratio	Whole	Stabl	(- - Ratio/Clay - -)	
	Depth			kPa	Dry	Soil	kPa	kPa	kPa	kPa	Moist	AD/OD	Soil	2-0.5mm	CEC7	1500 kPa
Layer	(cm)	Horz	Prep	(- - - g cm^{-3} - - -)			(- - - - - - - - - - - - % of < 2mm - - - - - - - - - - - -)						cm^3 cm^{-3}	%		
				DbWR1	DbWR1				DbWR1	3C2a1a		3D1				
07N00882	0-18	A	S	1.10	1.20	0.029			26.0	12.5		1.017	0.15		0.76	0.50
07N00883	18-28	E	S	1.29	1.40	0.027			25.4	8.7		1.014	0.21		0.56	0.38
07N00884	28-55	2Btg1	S	1.32	1.78	0.105			31.0	20.8		1.032	0.13		0.51	0.38
07N00885	55-91	2Btg2	S	1.41	1.94	0.112			29.0	19.6		1.031	0.13		0.53	0.39
07N00886	91-115	2Btyg1	S	1.39	1.83	0.096			30.9	21.5		1.034	0.13		0.49	0.39
07N00887	115-142	2Btyg2	S	1.32	1.81	0.111			33.7	23.9		1.033	0.13		0.47	0.39
07N00888	142-176	2Btg3	S	1.28	1.82	0.124			35.4	25.9		1.035	0.12		0.48	0.40
07N00889	176-205	2Btg4	S	1.31	1.87	0.126			34.1	23.1		1.034	0.14		0.47	0.39

*** Primary Characterization Data ***

Pedon ID: S06KS133-001 (Neosho, Kansas) Print Date: Apr 4 2010 3:33PM

Sampled As : Parsons Fine, mixed, active, thermic Vertic Albaqualf

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 07N0134

Carbon & Extractions

Layer	Depth (cm)	Horz	Prep	-1- C	-2- N	-3- S	-4- Org C	-5- C/N Ratio	-6- Fe	-7- Al	-8- Mn	-9- Al+½Fe	-10- ODOE	-11- Fe	-12- Al	-13- Si	-14- Mn	-15- C	-16- Fe	-17- Al	-18- Mn
				(- - - - - Total - - - - -)					(- - - Dith-Cit Ext - - -)			(- - - - - - Ammonium Oxalate Extraction - - - - - -)						(- - - Na Pyro-Phosphate - - -)			
				(- - - - - - % of <2 mm - - - - - -)					(- % of < 2mm - - - - - - - - - - - - - - - - - - -)								mg kg^{-1}	(- - - - - - % of < 2mm - - - - -)			
				4H2a	4H2a	4H2a															
07N00882	0-18	A	S	2.28	0.21	0.01		11													
07N00883	18-28	E	S	1.01	0.12	tr		8													
07N00884	28-55	2Btg1	S	0.71	0.08	tr		9													
07N00885	55-91	2Btg2	S	0.41	0.07	0.02		6													
07N00886	91-115	2Btyg1	S	0.32	0.08	0.19		4													
07N00887	115-142	2Btyg2	S	0.31	0.06	0.09		5													
07N00888	142-176	2Btg3	S	0.26	0.11	0.07		3													
07N00889	176-205	2Btg4	S	0.23	0.05	0.10		4													

CEC & Bases

Layer	Depth (cm)	Horz	Prep	-1- Ca	-2- Mg	-3- Na	-4- K	-5- Sum Bases	-6- Acid-ity	-7- Extr Al	-8- KCl Mn	-9- CEC8 Sum Cats	-10- CEC7 NH_4 OAC	-11- ECEC Bases +Al	-12- Al Sat	-13- Sum	-14- NH_4OAC
				(- - - - - - NH_4OAC Extractable Bases - - - - -)												(- - - - Base - - - -) (- Saturation -)	
				(- - - - - - - - - - - - - - - - - - cmol(+) kg^{-1} -)							mg kg^{-1}	(- - - - cmol(+) kg^{-1} - - -)			(- - - - - - - - % - - - - - - - -)		
				4B1a1a	4B1a1a	4B1a1a	4B1a1a		4B2b1a1	4B3a1a	4B3a1a		4B1a1a				
07N00882	0-18	A	S	20.7*	3.4	0.4	0.4	24.9	10.0			34.9	19.0			71	100
07N00883	18-28	E	S	6.3	2.5	0.4	0.2	9.4	9.1	0.6	0.7	18.5	12.9	10.0	6	51	73
07N00884	28-55	2Btg1	S	12.3	9.3	tr	0.4	22.0	13.2	1.0	0.8	35.2	28.0	23.0	4	63	79
07N00885	55-91	2Btg2	S	13.0*	11.5	3.5	0.3	28.3	7.9			36.2	26.7			78	100
07N00886	91-115	2Btyg1	S	22.8*	13.3	5.5	0.4	42.0	10.2			52.2	27.3			80	100
07N00887	115-142	2Btyg2	S	15.9*	13.1	5.4	0.4	34.8	11.0			45.8	28.9			76	100
07N00888	142-176	2Btg3	S	14.7*	14.2	5.4	0.5	34.8	11.3			46.1	31.3			75	100
07N00889	176-205	2Btg4	S	20.1*	14.6	5.2	0.4	40.3	8.6			48.9	28.4			82	100

*Extractable Ca may contain Ca from calcium carbonate or gypsum., CEC7 base saturation set to 100.

*** Primary Characterization Data ***

Pedon ID: S06KS133-001 (Neosho, Kansas) Print Date: Apr 4 2010 3:33PM

Sampled As : Parsons Fine, mixed, active, thermic Vertic Albaqualf

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 07N0134

Salt

-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-	-18-	-19-	-20-
(- Water Extracted From Saturated Paste -)															Total	Elec	Pred Elec	Exch	

Layer	Depth (cm)	Horz	Prep	Ca	Mg	Na	K	CO_3	HCO_3	F	Cl	PO_4	Br	OAC	SO_4	NO_2	NO_3	H_2O	Salts	Cond	Cond	Na	SAR
				(- - - - - mmol(+) L^{-1} - - - - -)				(- mmol(-) L^{-1} -)										(- - - - % - - - -)		(- - dS m^{-1} - -)		%	
				4F2	4F2	4F2	4F2	4F2	4F2	4F2	4F2	4F2	4F2	4F2	4F2	4F2	4F2	4F2		4F2	4F1a1a1		
07N00882	0-18	A	S																		0.20	2	
07N00883	18-28	E	S																		0.05	3	
07N00884	28-55	2Btg1	S																		0.08	tr	
07N00885	55-91	2Btg2	S	2.8	2.6	10.9	0.1	--	0.4	0.2	1.1	--	--	--	16.2	--	--	79.7	0.1	1.62	0.75	10	7
07N00886	91-115	2Btyg1	S	20.3	20.6	31.9	0.1	--	0.5	0.9	0.8	--	--	--	77.3	--	--	78.5	0.3	5.24	2.57	11	7
07N00887	115-142	2Btyg2	S	14.5	14.6	26.9	0.1	--	0.1	0.6	0.7	--	--	--	59.3	--	--	83.6	0.3	4.33	1.81	11	7
07N00888	142-176	2Btg3	S	7.5	8.2	20.3	0.1	--	0.1	0.2	0.7	--	--	--	37.8	--	--	98.9	0.2	3.06	1.42	11	7
07N00889	176-205	2Btg4	S	15.7	14.8	24.6	0.1	--	tr	0.3	0.6	--	--	--	58.8	--	--	93.2	0.3	4.19	1.75	10	6

pH & Carbonates

Layer	Depth (cm)	Horz	Prep	KCl	$CaCl_2$ 0.01M 1:2	H_2O 1:1	Sat Paste	Sulf	NaF	Carbonate As $CaCO_3$ <2mm	Carbonate As $CaCO_3$ <20mm	Gypsum As $CaSO_4$*$2H_2O$ <2mm	Gypsum As $CaSO_4$*$2H_2O$ <20mm	Resist ohms cm^{-1}
				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-
				(- - - - - - - - - - - - - - - - - - pH					- - - - - - - - - - - - - - - - - -)	(- - - - - - - - - - - - - %			- - - - - - - - - - - -)	
					4C1a2a	4C1a2a	4F2					4E2a1a1a1		
07N00882	0-18	A	S		5.1	5.6								
07N00883	18-28	E	S		4.7	5.6								
07N00884	28-55	2Btg1	S		4.9	5.9								
07N00885	55-91	2Btg2	S		5.8	6.6	5.8					--		
07N00886	91-115	2Btyg1	S		5.6	6.0	5.4					--		
07N00887	115-142	2Btyg2	S		5.5	5.9	5.3					--		
07N00888	142-176	2Btg3	S		5.6	6.0	5.5					--		
07N00889	176-205	2Btg4	S		6.0	6.4	5.8					--		

*** Primary Characterization Data ***

Pedon ID: S06KS133-001 (Neosho, Kansas) Print Date: Apr 4 2010 3:33PM

Sampled As : Parsons Fine, mixed, active, thermic Vertic Albaqualf

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 07N0134

Phosphorous				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-
					(- - - - Phosphorous							- - - -)	
	Depth			Melanic Index	NZ	Acid Oxal	Bray 1	Bray 2	Olsen	H_2O	Citric Acid	Mehlich III	Extr NO_3
Layer	(cm)	Horz	Prep		%	(- - - - mg kg^{-1}						- - - -)	mg kg^{-1}
							4D3					4D6a1	
07N00882	0-18	A	S				2.9					3.7	
07N00883	18-28	E	S				0.7					1.0	
07N00884	28-55	2Btg1	S				--					0.1	
07N00885	55-91	2Btg2	S				--					0.6	
07N00886	91-115	2Btyg1	S				9.6					14.6	
07N00887	115-142	2Btyg2	S				7.2					11.5	
07N00888	142-176	2Btg3	S				1.4					4.5	
07N00889	176-205	2Btg4	S				0.3					1.1	

Pedon ID: S06KS133-001 (Neosho, Kansas) Print Date: Apr 4 2010 3:33PM

Sampled As : Parsons Fine, mixed, active, thermic Vertic Albaqualf

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 07N0134

Clay Mineralogy (<.002 mm)				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-	-18-
						X-Ray					Thermal					Elemental				EGME	Inter
													SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	K_2O	Na_2O	Retn	preta
	Depth		Fract			7A1a1															tion
Layer	(cm)	Horz	ion	(- - - - - - - - - peak size				- - - - - - - - - -)	(- - - - - - - - - %			- - - - - - - - - -)	(- - - - - - - - - - - - - - - - - - - %						- - - - - - - - - - - - - - - - - - -)	mg g^{-1}	
07N00882	0-18	A	tcly	KK 2	VR 2	MI 1															CMIX
07N00883	18-28	E	tcly	VR 2	KK 2	MI 1															VERM
07N00884	28-55	2Btg1	tcly	VM 3	KK 3	MI 1															CMIX
07N00885	55-91	2Btg2	tcly	VM 3	KK 3	MI 1															CMIX
07N00886	91-115	2Btyg1	tcly	KK 2	VM 2	MI 2	QZ 1	LE 1													CMIX
07N00887	115-142	2Btyg2	tcly	KK 3	MI 2	VM 2	LE 2	QZ 1													CMIX
07N00888	142-176	2Btg3	tcly	MI 3	KK 3	LE 1	QZ 1														CMIX
07N00889	176-205	2Btg4	tcly	MI 3	KK 3	GE 1	QZ 1														CMIX

FRACTION INTERPRETATION:

tcly - Total Clay, <0.002 mm

MINERAL INTERPRETATION:

GE - Goethite　KK - Kaolinite　LE - Lepidocrocite　MI - Mica　QZ - Quartz

VM - Vermiculite-Mica　VR - Vermiculite

RELATIVE PEAK SIZE: 5 Very Large　4 Large　3 Medium　2 Small　1 Very Small　6 No Peaks

Site 10

Pedon ID: 86KS133005 (Neosho, Kansas) Print Date: Apr 4 2010 3:35PM

Sampled as on Aug 01, 1986 : Eram ; Fine, mixed, thermic Aquic Argiudoll
Revised to correlated on Jun 01, 1987 : Eram ; Fine, mixed, active, thermic Aquic Argiudoll

United States Department of Agriculture
Natural Resources Conservation Service
National Soil Survey Center
Soil Survey Laboratory
Lincoln, Nebraska 68508-3866

SSL - Project CP86KS228 SOUTHEAST AREA
- Site ID 86KS133005 Lat: 37° 27' 47.00" north Long: 95° 16' 4.00" west MLRA: 112
- Pedon No. 86P0872
- General Methods 1B1A, 2A1, 2B

Layer	Horizon	Orig Hzn	Depth (cm)	Field Label 1	Field Label 2	Field Label 3	Field Texture	Lab Texture
86P05215	Ap	AP	0-16				SICL	SIC
86P05216	Bt1	BT1	16-28				SIC	C
86P05217	Bt2	BT2	28-43				C	C
86P05218	Bt3	BT3	43-65				C	SIC
86P05219	BC	BC	65-91				C	SIC
86P05220	Cr	CR	91-91					SIC

Pedon Calculations

Calculation Name	Result	Units of Measure
CEC Activity, CEC7/Clay, Weighted Average	0.55	(NA)
Clay, carbonate free, Weighted Average	53	% wt
Weighted Particles, 0.1-75mm, 75 mm Base	11	% wt
Volume, >2mm, Weighted Average	2	% vol
Clay, total, Weighted Average	53	% wt

Weighted averages based on control section: 16-66 cm

PSDA & Rock Fragments

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-
				(- - - - - Total - - - - - -)			(- - Clay - - -)		(- - - - Silt - - - - -)		(- - - - - - - - - - - - Sand - - - - - - - - - - - -)					(Rock Fragments (mm))				
				Clay	Silt	Sand	Fine	CO_3	Fine	Coarse	VF	F	M	C	VC	(- - - - - - - - Weight - - - - - - - -)				>2 mm
				<	.002	.05	<	<	.002	.02	.05	.10	.25	.5	1	2	5	20	.1-	wt %
	Depth			.002	-.05	-2	.0002	.002	-.02	-.05	-.10	-.25	-.50	-1	-2	-5	-20	-75	75	whole
Layer	(cm)	Horz	Prep	(- % of <2mm Mineral Soil -)												(- - - - - - - % of <75mm - - - - - -)				soil
				3A1	3A1	3A1		3A1	3A1	3A1	3A1	3A1	3A1	3A1	3A1	3B1	3B1	3B1		
86P05215	0-16	Ap	S	47.2	42.7	10.1			28.6	14.1	2.4	2.1	2.2	2.1	1.3	1	2	--	10	3
86P05216	16-28	Bt1	S	53.9	36.7	9.4			28.8	7.9	1.3	1.6	2.2	2.7	1.6	1	1	--	10	2
86P05217	28-43	Bt2	S	54.5	37.8	7.7			32.8	5.0	0.7	0.8	1.3	2.4	2.5	2	1	--	10	3
86P05218	43-65	Bt3	S	50.7	40.6	8.7			37.4	3.2	0.5	1.0	1.6	2.7	2.9	2	3	--	13	5
86P05219	65-91	BC	S	50.2	43.7	6.1			40.8	2.9	0.4	0.8	1.3	1.8	1.8	tr	--	--	6	--
86P05220	91-91	Cr	GP	41.2	48.3	10.5		--	44.8	3.5	1.6	3.1	2.6	1.9	1.3					

*** Primary Characterization Data ***

Pedon ID: 86KS133005 | (Neosho, Kansas) | Print Date: Apr 4 2010 3:35PM

Sampled As : Eram | Fine, mixed, thermic Aquic Argiudoll

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 86P0872

Bulk Density & Moisture

Layer	Depth (cm)	Horz	Prep	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-
				(Bulk Density)		Cole	(- - - Water Content - - -)						WRD	Aggst		
				33 kPa	Oven Dry	Whole Soil	6 kPa	10 kPa	33 kPa	1500 kPa	1500 kPa Moist	Ratio AD/OD	Whole Soil	Stabl 2-0.5mm	(- - Ratio/Clay - -) CEC7	1500 kPa
				(- - - g cm^{-3} - - -)			(- - - % of < 2mm - - -)						cm^{3} cm^{-3}	%		
				4A1d	4A1h				4B1c	4B2a		4B5	4C1		8D1	8D1
86P05215	0-16	Ap	S	1.31	1.64	0.076			31.3	19.6		1.023	0.15		0.75	0.42
86P05216	16-28	Bt1	S	1.33	1.65	0.074			29.4	20.2		1.022	0.12		0.62	0.37
86P05217	28-43	Bt2	S	1.41	1.71	0.065			27.6	20.1		1.031	0.10		0.54	0.37
86P05218	43-65	Bt3	S	1.48	1.77	0.060			25.8	18.9		1.019	0.10		0.51	0.37
86P05219	65-91	BC	S	1.60	1.86	0.051			22.3	17.9		1.016	0.07		0.47	0.36
86P05220	91-91	Cr	S												0.48	0.40
86P05220	91-91	Cr	GP							16.6		1.015				

Water Content

Layer	Depth (cm)	Horz	Prep	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-
				(- - Atterberg - -)		(- - Bulk Density - -)			(- - - Water Content - - -)							
				(- - - Limits - - -) LL	PI	Field	Recon 33 kPa	Recon Oven Dry	Field	Recon 33 kPa	(- - Sieved Samples - -) 6 kPa	10 kPa	33 kPa	100 kPa	200 kPa	500 kPa
				pct <0.4mm		(- - - g cm^{-3} - - -)			(- - - % of < 2mm - - -)							
				4F1	4F											
86P05215	0-16	Ap	S	60	28											
86P05217	28-43	Bt2	S	58	32											

Carbon & Extractions

Layer	Depth (cm)	Horz	Prep	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-	-18-
				(- - Total - -) C	N	S	Org C	C/N Ratio	(- - - Dith-Cit Ext - - -) Fe	Al	Mn	(- - Ammonium Oxalate Extraction - -) Al+½Fe	ODOE	Fe	Al	Si	Mn	(- - - Na Pyro-Phosphate - - -) C	Fe	Al	Mn
				(- - - % of <2 mm - - -)					(- - - % of < 2mm - - -)								mg kg^{-1}	(- - - % of < 2mm - - -)			
					6B3a		6A1c		6C2b	6G7a	6D2a								6C8a	6G10	
86P05215	0-16	Ap	S		0.343		3.87	11	3.5	0.3	0.2								0.1	0.1	
86P05216	16-28	Bt1	S		0.184		1.55	8	3.5	0.4	0.1								0.2	0.1	
86P05217	28-43	Bt2	S				1.06		3.5	0.4	--								0.2	0.1	
86P05218	43-65	Bt3	S				0.97		4.7	0.4	tr								0.2	0.1	
86P05219	65-91	BC	S				0.76		3.1	0.3	--								0.1	tr	
86P05220	91-91	Cr	GP				0.59		2.2	0.1	--								tr	tr	

*** Primary Characterization Data ***

Pedon ID: 86KS133005 (Neosho, Kansas) Print Date: Apr 4 2010 3:35PM

Sampled As : Eram Fine, mixed, thermic Aquic Argiudoll

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 86P0872

CEC & Bases				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-
				(- - - - - - NH_4OAC Extractable Bases - - - - -)				Sum Bases	Acid-ity	Extr Al	KCl Mn	CEC8 Sum Cats	CEC7 NH_4 OAC	ECEC Bases +Al	Al Sat	(- - - - Base - - - -) (- Saturation -) Sum	NH_4OAC
				Ca	Mg	Na	K										
Layer	Depth (cm)	Horz	Prep	(- - - - - - - - - - - - - - - - - cmol(+) kg^{-1}						- - - - - - - - - - - - - - - - - - -)	mg kg^{-1}	(- - - - cmol(+) kg^{-1} - - -)			(- - - - - - - - % - - - - - - - -)		
				6N2e	6O2d	6P2b	6Q2b		6H5a			5A3a	5A8b			5C3	5C1
86P05215	0-16	Ap	S	34.1*	3.0	0.1	0.8	38.0	5.3			43.3	35.6			88	100
86P05216	16-28	Bt1	S	30.0	2.7	0.2	0.5	33.4	5.7			39.1	33.6			85	99
86P05217	28-43	Bt2	S	24.2	2.3	0.2	0.3	27.0	5.1			32.1	29.7			84	91
86P05218	43-65	Bt3	S	22.9	2.4	0.2	0.3	25.8	4.2			30.0	26.0			86	99
86P05219	65-91	BC	S	20.6*	2.4	0.3	0.3	23.6	2.5			26.1	23.4			90	100
86P05220	91-91	Cr	GP	50.3*	2.8	0.5	0.3		--				19.6			100	100

*Extractable Ca may contain Ca from calcium carbonate or gypsum., CEC7 base saturation set to 100.

Salt				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-	-18-	-19-	-20-
				(- Water Extracted From Saturated Paste -)															Total Salts	Elec Cond	Pred Elec Cond	Exch Na	SAR
				Ca	Mg	Na	K	CO_3	HCO_3	F	Cl	PO_4	Br	OAC	SO_4	NO_2	NO_3	H_2O					
Layer	Depth (cm)	Horz	Prep	(- - - - - mmol(+) L^{-1} - - - - -)				(- mmol(-) L^{-1} -)										(- - - - % - - - -)		(- - dS m^{-1} - -)		%	
																						5D2	
86P05215	0-16	Ap	S																			tr	
86P05216	16-28	Bt1	S																			1	
86P05217	28-43	Bt2	S																			1	
86P05218	43-65	Bt3	S																			1	
86P05219	65-91	BC	S																			1	
86P05220	91-91	Cr	GP																			3	

*** Primary Characterization Data ***

Pedon ID: 86KS133005 (Neosho, Kansas) Print Date: Apr 4 2010 3:35PM

Sampled As : Eram Fine, mixed, thermic Aquic Argiudoll

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 86P0872

pH & Carbonates

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-
				(- - - - pH					- - - -)	(- - Carbonate - -) As $CaCO_3$		(- - Gypsum - - -) As $CaSO_4$*2H_2O		Resist
Layer	Depth (cm)	Horz	Prep	KCl	$CaCl_2$ 0.01M 1:2 4C1a2a	H_2O 1:1 4C1a2a	Sat Paste	Sulf	NaF	<2mm (- - - % 6E1g	<20mm	<2mm	<20mm - - -)	ohms cm^{-1}
86P05215	0-16	Ap	S		6.6	6.7								
86P05216	16-28	Bt1	S		6.4	7.0								
86P05217	28-43	Bt2	S		6.4	7.1								
86P05218	43-65	Bt3	S		6.5	7.2								
86P05219	65-91	BC	S		6.8	7.4								
86P05220	91-91	Cr	GP		7.6	8.0				6				

Clay Mineralogy (<.002 mm)

Layer	Depth (cm)	Horz	Fraction	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-	-18-
						X-Ray				Thermal						Elemental				EGME	Inter
													SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	K_2O	Na_2O	Retn	preta
						7A2i				7A6						7C3					tion
				(- - - - peak size - - - -)					(- - - - % - - - -)				(- - - - - - - - % - - - - - - - -)							mg g^{-1}	
86P05215	0-16	Ap	tcly	VM 3	KK 3	MI 3	LE 1	QZ 1	KK 9	GI tr					7.7			3.1			
				GE 1																	
86P05216	16-28	Bt1	tcly	KK 3	MI 2	VM 2	MT 1	LE 1	KK 14	GI tr					7.4			3.3			
				QZ 1	GE 1																
86P05217	28-43	Bt2	tcly	KK 3	MI 3	VM 3	LE 1	QZ 1	KK 20	GI tr					7.7			3.5			
				GE 1																	
86P05218	43-65	Bt3	tcly	MI 3	KK 3	VM 2	QZ 1	GE 1	KK 14	GI tr					7.9			3.5			
86P05220	91-91	Cr	tcly	MI 3	KK 3	VM 2	QZ 1		KK 20	GI tr					7.3			4.5			

FRACTION INTERPRETATION:

tcly - Total Clay, <0.002 mm

MINERAL INTERPRETATION:

GE - Goethite GI - Gibbsite KK - Kaolinite LE - Lepidocrocite MI - Mica

MT - Montmorillonite QZ - Quartz VM - Vermiculite-Mica

RELATIVE PEAK SIZE: 5 Very Large 4 Large 3 Medium 2 Small 1 Very Small 6 No Peaks

*** Glossary of Codes ***

Print Date: Apr 4 2010 3:35PM

Reports: Primary Characterization Report;
Pedons: 86P0872;

*** Method Codes ***

Code	Description
3A1	PSDA, Routine, Pipet
3B1	Particles >2 mm, Weight Estimates
4A1d	Bulk Density, 1/3-Bar Desorption I
4A1h	Bulk Density, Oven-Dry
4B1c	Water Retention, clod, 0.06, 0.1, 0.33, or 1 bar, pressure-plate extraction
4B2a	Water Retention, 15 Bar, Pressure-Plate, <2mm
4B5	Water Retention, ADOD
4C1	derived WRD, 4C1
8D1	Ratio, to Total Clay - 8D1
4F	derived Plasticity Index
4F1	Plasticity Index, Liquid Limit
6A1c	Organic Carbon, acid dichromate digestion, FeSO4 titration, automatic titrator
6B3a	Total Nitrogen, Kjeldahl digestion II, ammonia steam distillation, automatic titrator
6C2b	Iron, Dithionite-Citrate Extraction, Atomic Absorption I
6C8a	Iron, Sodium Pyrophosphate Extraction II, Atomic Absorption
6D2a	Manganese, Dithionite-Citrate Extraction, Atomic Absorption I
6G10	Aluminum, Sodium Pyrophosphate Extraction II
6G7a	Aluminum, Dithionite-Citrate Extraction, Atomic Absorption I
5A3a	derived CEC_SUM, 5A3a
5A8b	CEC, NH4OAc, pH 7.0, automatic extractor, steam distillation I
5C1	derived BSESAT, 5C1
5C3	derived BSECAT, 5C3
6H5a	Extractable Acidity, BaCl2-Triethanolamine IV, automatic extractor
6N2e	Calcium, NH4OAc Extraction, Atomic Absorption I
6O2d	Magnesium, NH4OAc Extraction, Atomic Absorption I
6P2b	Sodium, NH4OAc Extraction, Atomic Absorption I
6Q2b	Potassium, NHOAc Extraction, Atomic Absorption I
5D2	derived NA_EXCH, 5D2
4C1a2a	pH, Routine, 1:1 Water and 1:2 0.01M CaCl2
6E1g	Calcium Carbonate Equivalent, HCl, <2mm, manometer, electronic (6E1g)
7A2i	X-ray Diffraction, Thin Film on Glass, Resin Pretreatment II
7A6	Differential Scanning Calorimetry, Thermal Analyzer
7C3	Total Analysis, HF Dissolution

*** Preparation Codes ***

Code	Description / List of Methods
Gaj	The air-dried whole soil including all coarse fragments ground to pass a No. 10-mesh sieve 3A1, 4B2a, 4B5, 6A1c, 6C2b, 6C8a, 6D2a, 6G10, 6G7a, 5A8b, 6H5a, 6N2e, 6O2d, 6P2b, 6Q2b, 4C1a2a, 6E1g
Sjj	The air-dried soil passing a No. 10-mesh sieve 3A1, 4B2a, 4B5, 4F, 4F1, 6A1c, 6B3a, 6C2b, 6C8a, 6D2a, 6G10, 6G7a, 5A8b, 6H5a, 6N2e, 6O2d, 6P2b, 6Q2b, 4C1a2a, 7A2i, 7A6, 7C3
Caj	The moist soil clod used for bulk density determinations 4A1d, 4A1h, 4B1c

*** Instrument Sets ***

Instrument Set Name	List of Methods
Instrument Not Specified	3A1, 3B1, 4A1d, 4A1h, 4B1c, 4B2a, 4B5, 4F, 4F1, 7A2i, 7A6, 7C3
titrator	6A1c, 6H5a
distillation titirator	6B3a, 5A8b
atomic adsorption spectrophotometer	6C2b, 6C8a, 6D2a, 6G10, 6G7a, 6N2e, 6O2d, 6P2b, 6Q2b
pH meter	4C1a2a
manometer	6E1g

*** Analyzed Size Fractions ***

Size Fraction	List of Methods
<2 mm	3A1, 4A1d, 4A1h, 4B1c, 4B2a, 4B5, 8D1, 4F, 4F1, 6A1c, 6B3a, 6C2b, 6C8a, 6D2a, 6G10, 6G7a, 5A3a, 5A8b, 5C1, 5C3, 6H5a, 6N2e, 6O2d, 6P2b, 6Q2b, 5D2, 4C1a2a, 6E1g
<75 mm	3B1
whole soil	4C1
<0.002 mm	7A2i, 7A6, 7C3