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I am submitting herewith a thesis written by Christopher David Banet entitled "Relation of Parent Materials and Landforms to the Genesis and Morphology of Upland Fragipan Soils in Weakley County, Tennessee." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Plant and Soil Science.

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B

RELATION OF PARENT MATERIALS AND LANDFORMS TO THE GENESIS AND MORPHOLOGY OF UPLAND FRAGIPAN SOILS IN WEAKLEY COUNTY, TENNESSEE

A Thesis

Presented for the

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ABSTRACT

Relations of the upland fragipan soils of Weakley county to parent material and topography are not well known. Information on variability within upland soil series in Weakley county, expecially Loring, is lacking. This study attempts to provide some information on these relationships.

Thirty-two transects were conducted and four representative pedons sampled in Weakley county. Transects provided field data. Laboratory analyses were made to determine soil texture, particle size ratios, CEC, base saturation, and pH, along with mineralogical characterization.

Data gathered indicated that loess thinned eastward in the county from 465 cm to 165 cm. Two separate loess layers--Peoria and Roxana--were identified, each occupying one half the total loess. The two loess layers were separated on the basis of morphology, particle size, and mineralogy.

Fragipan thickness was related to parent material thickness and prevailing slope gradients, with thicker fragipans on more gentle slopes. Fragipans became harder with thinning loess, regardless of soil series. Fragipans were considered genetic soil horizons whose hardness was enhanced by past weathering zones near the fragipan upper boundary.

Soil series varied according to landform with Loring soils occurring on narrow ridgetops and convex sideslopes and Grenada soils on broad, level ridgetops and concave sideslopes. The Grenada soil was more highly weathered than the Loring as revealed by chloritized vermiculite in the clay fraction and low pH values in the Grenada.

Regardless of series, soils were more weathered eastward in the county due to the thinning loess becoming effectively older. This increased soil weathering in the east was revealed by lower CEC, base saturation, and salt pH, along with an increase in quartz relative to feldspar content compared to values for soils in the west. West Weakley county soils were formed entirely in Peoria loess while those in the east were formed in the entire loess column.

The Loring series encompasses wide variation within the county, developing a harder fragipan and more highly weathered profile in the east and a more variable B horizon color and clay content in west Weakley county.

Sufficient difference between the Loring of the west and of the east was found to define a thin loess phase of the Loring series occurring in loess less than 220 cm deep. Actual creation of a new phase will depend on discovering the range of the Loring variants outside of Weakley county.

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CHAPTER I

INTRODUCTION

Weakley county, in West Tennessee, is in one of the most important agricultural regions in the state. Crop production is the big business of this county. Weakley, the 18th largest county in Tennessee (55), is a major producer of corn and soybeans. Its yield averages are among the highest in the state. During 1979, average corn yields in Weakley county were 94 bushes/acre; soybeans averaged 28 bushels/acre (54).

Obtaining high yields is not an easy task. The farming abilities and management strategies of the landowners are pitted against the many inconsistencies of nature. Although the loess derived soils of Weakley county are very productive, they are also very easily eroded. Man, in his endeavor to reap the benefits of intensive use of the soil, must make use of his agronomic knowledge to obtain high yields of valuable crops without losing the soil which is his means of support. To increase and improve the knowledge of the upland soils of Weakley county, Tennessee, is the aim of this research.

Most of the upland soils of Weakley county contain a fragipan, an undesirable soil feature. Three fragipan soils - Grenada, Loring and Providence - are mapped extensively in Weakley county. The morphologic features of the Grenada and Providence series are known and established, but those for the Loring series are not as well defined. The geomorphic relationships and soil properties of the upland soils are not well

understood. Detailed data on the loess of Weakley county and how it relates to the upland soils is very limited. In addition, little is known about the physical, chemical, and mineralogical properties of these soils as they relate to morphology, drainage, slope position and parent material.

The objectives of this research are to relate differences among and within upland soil types of Weakley county to the soil forming factors of topography, time, and parent material. The experimental approach to these objectives involves: (1) characterizing the upland soils of Weakley county so as to define the properties of these soils which relate to topographic features, the age and thickness of the loess, and the associated soils; (2) dating, identifying, and describing the various loesses in Weakley county; and (3) obtaining a more precise concept of the upland series involved, and better defining them with particular attention to soils within the taxonomic concept of the Loring Series.

CHAPTER II

LITERATURE REVIEW

Weakley county is situated in the northern part of West Tennessee. It adjoins Kentucky along its northern border and is otherwise surrounded by counties of Tennessee. Weakley county is located approximately 70 km east of the Mississippi river. The shape of Weakley county and its relation to other counties in Tennessee is seen in Figure 1. Average elevations in the uplands of Weakley county are from 120 to 140 meters above sea level (56). The entire county slopes gently downward to the west.

Topographically, the county is mostly rolling to gently undulating. In eastern Weakley county there are higher, hillier areas where the landscape is more dissected.

Soil Parent Materials

The close proximity to the Mississippi river has provided Weakley county with a great endowment of loess. This aeolian material composed of silt sized particles is blown from the valleys of rivers which once flowed with glacial melt waters. Wascher et al. (58) state that for the West Tennessee area, including Weakley county, the source of loess was the Mississippi river, as it was the only river in the area to have once carried glacial melt waters. Loess deposits in the Mississippi river basin are found to become thinner with distance from their presumed source. Smith (47) and other workers (7, 10, 12, 15, 46, 57, 58) were able to establish a linear relationship between the thinning

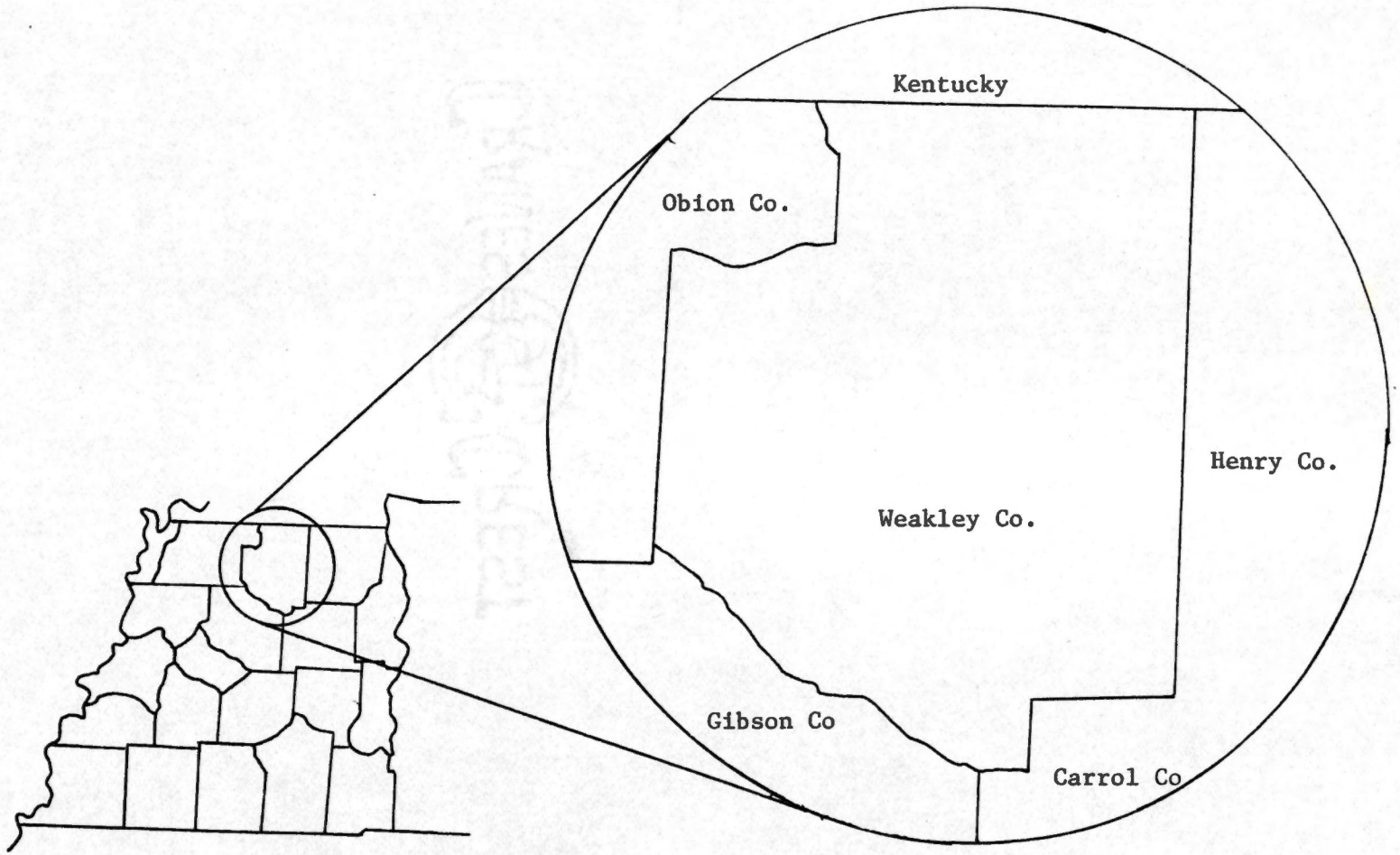


Figure 1. Weakley county and its relation to counties in West Tennessee

of loess and the logarithm of the distance from its source. Wascher found the loess of Weakley county to be of intermediate thickness, ranging from four feet (1.2 meters) to more than ten feet (3.0 meters) thick, the thickest part being on the western edge of the county. Deposition of the loess occurred during the pliestocene epoch of geologic time when continental glaciers covered much of North America (61).

According to Wilson (62), the material below the loess of West Tennessee are Pliocene epoch iron stained gravels and sands with local clay lenses. This material is of coastal plain origin and is generally less than 30.5 meters thick. Below this are thick sandy and clayey coastal plains deposits that extend to crystalline Paleozoic rocks. Some of these coastal plain deposits and the paleosol in the old coastal plain surface have been exhumed by erosion in the eastern-most part of Weakley county. The two major parent materials of Weakley county upland soils then, are loess and the underlying coastal plains material.

Because the loess is so extensive in the Mississippi river basin, numerous workers have devoted time to studying it in detail. Wascher et al. (58), in an area of which Weakley county is a part, found three major subdivisions within the loess corresponding to three major periods of deposition, each related to a separate glacial advance.

Wascher, et al. (59), called the uppermost loess of the southern Mississippi valley Peoria loess and described it as follows:

> Near the bluff the leached Peorian loess is underlain by calcareous Peorian loess, a nearly uniform silt of

> pale brown to yellowish brown color or about 10YR6/3 to 7.5YR5/6 and 6/4. This material usually, though not always, contains fossil snail shells and irregularly shaped lime concretions and stands vertically in road cuts and gully banks.

Wascher et al. (58) in examining the layer below the Peoria loess, called it either Late Sangamon or the middle loess and described it as follows:

> It is generally noncalcareous, even though part of the overlying Peorian may have high carbonate content. It is somewhat more compact than the calcareous Peorian above but is not cohesive. With good drainage it is nearly always a darker brown or redder brown than the overlying calcareous or noncalcareous Peorian. Its color ranges mostly from 5YR4/4-4/8 but may be gray if poorly oxidized.

The third, lowest loess, they called the Loveland loess. It contains a strongly developed soil in its upper part. Below this, they explain, "The silty clay loam subsoil varied depending on internal drainage but usually ranged between yellowish brown and brownish yellow under what seemed to be well drained conditions." Coastal plain fluvial sediments are found below the Loveland loess.

Willman and Frye (61), working in Illinois, found these same three layers of loess. In explaining these individual layers, they called the uppermost and latest loess, the Peoria, and described it as containing the modern soil. It is light yellow-tan to gray in color and calcareous only at great depth. The Peoria loess was deposited during the Woodfordian substage of the Wisconsinan glacial period, between 7,000 years and 23,000 years before present. This was the last major glacial advance of the Wisconsinan stage.

The layer directly below the Peoria loess they termed the Roxana silt. It is pinkish-brown to yellow-gray, and is leached of carbonates except when very thick. Sometimes it contains a weathering zone or very young soil at its upper boundary which they called the Farmdale soil. They also recognized two other soils in the Roxana silt. This loess was deposited during the earliest major glacial advance of the Wisconsinan stage, the Altonian substage. It dates from between 28,000 and 75,000 years before present.

The lowest loess, as described by Willman and Frye (61) is called the Loveland silt. It was deposited between 90,000 and 125,000 years ago during the Illinoian stage of glaciation. This loess has a conspicuous paleosol in its upper part which is referred to as the Sangamon soil. Otherwise, the Loveland silt is leached and is a tan to reddish-brown silty clay or clayey silt.

Other workers in areas where the Mississippi river was the source of loess have confirmed these earlier findings and used the terms of Willman and Frye (61) - Peoria for the uppermost loess layer, Roxana for the middle loess layer, and Loveland for the lowest loess layer.

Some work has been done concerning the absolute and relative thicknesses of the three individual loess sheets as well as the total loess thickness. In southern Illinois, an area like West Tennessee in relation to source of loesses, the total loess thickness ranges from 1.37 to 7.62 meters depending on distance from the source (12). The Loveland loess is rarely found in Illinois and is very thin and sporadic if found at all. The Roxana loess is also thin, on the order of 25

centimenters or less in south central Illinois at the limit of the Wisconsinan glaciation (12). In extreme southern Illinois it becomes more evident and is sometimes as thick as the Peoria. It is generally less than one third as thick as the Peoria loess, however the maximum thickness of the Roxana in Illinois is 3.8 meters. An increase in the proportion of Roxana loess compared to the total loess thickness is observed from north to south in Illinois.

Some measurements of loess thickness have been made in West Tennessee. Wascher et al. (58) reported on a boring in Obion county, which contained 3.35, 2.74, and 1.52 meters of Peoria, middle (Roxana), and Loveland respectively. A location in Dyer county, Tennessee, contained 8.22, 4.26, and 1.22 meters of the same loesses. At a Mississippi river bluff in Dyer county, Tennessee, Buntley et al. (6) found 13.75 meters of Peoria loess, 2.67 meters of Roxana loess, and 2.95 meters of Loveland loess. These limited observations indicate that the greatest part of the West Tennessee loess in composed of the Peoria layer. The Roxana and Loveland occur in varying proportions. Data on loess thicknesses in areas of West Tennessee where the loess is of thin or intermediate thickness are scanty and contradictory (6, 58).

Referring to the contact between the Peoria and Roxana loesses, Wascher et al. (58) observed an indistinct gradation, while the Roxana/Loveland contact occurred over a shorter distance and was easier to identify. In contrast, Buntley et al. (6) observed both the Peoria/Roxana contact and the Roxana/Loveland contact as being abrupt. The transition from loess to coastal plain material is apparently gradual (6, 58), occurring over a distance of from two to three feet.

Caldwell and White (7) studied the distribution of loess in southern Indiana. Where the loess was thin, they found it difficult to determine where the loess ended and the underlying till began. Harlan and Franzmeier (21), in southern Indiana, found that in areas of thin and intermediate loess thickness, the identification of the loesses was obscured by soil forming processes. They were unable to use color or structure consistently as diagnostic criteria for identification of Peoria loess. In Kentucky, Hutcheson and Bailey (24) found that the "thinner loess overlays tend to exhibit significant mixing with underlying materials from the residuum." Tamura (53) made a study of the characteristics of eolian influenced soils in Connecticut and found that greater mixing with materials below the loess occurred as the loess thinned. When the loess was 30 to 90 centimeters thick, a thorough mixing occurred. The rate of mixing and depth at which mixing started was dependent on vegetation, tree throw playing a large part in the mixing process.

With respect to the mineralogy of the loesses Wascher et al. (58) explains:

> The mineralogical makeup of the Sangamon (Roxana) loess is very much like that of the Peorian. Most of it appears to be weathered more than the calcareous Peorian material but less than the soil profiles developed from Peorian. Its composition roughly corresponds to that of the leached non-calcareous "C" horizon of Peorian.

In examining the .05-.02 mm fraction of unweathered Peoria loess Wascher et al. (58) found that "About 15% of the quartz in this size fraction consists of aggregates of smaller grains cemented together by secondary

quartz." Wascher et al. (58) characterize the mineralogy of the Loveland loess as significantly more weathered than either of the other two loesses, which confirms the claims to the depositional sequence of the three loesses.

Weathering of loess in western Kentucky was studied by Hutcheson and Bailey (24). They found the loess mantle to be more greatly weathered when underlain by coarser versus finer textured residual material. Also, they discovered that with coarser textured residual material below the loess, illuviation of materials into and/or through the coarse material occurred to a greater degree than when a finer material underlaid the loess.

The clay composition of the three loesses was examined in southern Illinois by Ferhenbacher et al. (11) who found the Peoria and Roxana loesses to be high in montmorillonite and vermiculite. The Roxana, which contained more total clay, contained less illite but more chlorite and kaolinite than the Peoria loess. The Loveland loess was found to be similar to the Roxana.

Four distinct layers resulting from pauses in loess deposition were found within the Peoria loess in an area of Illinois where the loess had two sources--the Mississippi and Illinois rivers (31). The uppermost layer was the thickest found, accounting for more than one half the total Peoria loess. It contained montmorillonite as the dominant clay mineral. The second layer was characterized by a dominance of illite in the clay fraction. In the third layer, illite dominated to an even greater degree. The fourth, lowest layer was

characterized by pronounced montmorillonite in the clay fraction. Of the four layers, the uppermost was the one which accumulated most rapidly. The others were deposited more slowly, and being thinner, allowed for greater leaching before burial by additional loess.

Fehrenbacher et al. (12) investigated loess stratigraphy in southeastern Illinois and found within the Peoria loess a very weak paleosol which they attributed to a pause in the deposition of loess. Beavers et al. (4), studying loess soils in southern Illinois, also found hints of a buried surface two to three feet below the surface within the Hosmer and Ava soils. These soils are found in both thin and intermediate thickness of loess. In West Tennessee, Jared (27) studied Hapludalfs developed in loess and found evidence within these soils of a pause in the Peoria loess deposition.

Soil Development in Loess Areas

Numerous studies have been made concerning soil development in relation to thickness of loess. Throughout the Mississippi River Basin workers have noted an increasing degree of soil maturity as loess becomes progressively thinner (26).

Springer (51) studied the development of soils from loess in northwest Missouri and found that with distance from the loess source the clay content of the A and B horizons increased. In addition, he discovered that in the silt fractions of the A horizons, the quartz/calcium and potassium/calcium ratios increased with distance from the source of loess, while these ratios in the loess below the soils remained fairly constant.

Beavers et al. (4) examined the weathering of loess soils at different distances from the loess source in southern Illinois. Using $CaO-ZrO_2$ molar ratios as indices of weathering, they found a definite increase in the weathering of soils with distance from the loess source. They pointed out two reasons for this weathering sequence. First, they noted that the coarse silt/fine silt ratio decreases with distance from the loess source, and since the fine silt weathered at a faster rate than the coarse silt, the soils furthest from the loess source were the most weathered. Second, they perceived that the time during which the Peoria loess was deposited, about 11,000 years, equaled the time since the end of the loess deposition. Knowing that the loess thinned away from its source, they concluded that in areas of thin loess, the period during which soil profile development occurred was up to twice that of areas of thick loess. The soil profiles in thick loess have formed only in recent loess, whereas those in thin loess have formed within loess of varied ages.

In northeastern Kansas, Hanna and Bidwell (19) noted that loess decreased in mean particle size with distance from its source. Increased weathering and development of loess soils was indicated by the clay content in the B horizons which increased with loess thinning.

Jones and Beavers (29) found a close relationship of loess thickness to intensity of soil development in surface horizons of Illinois soils by using CaO, K_2O and Fe_2O_3 to ZrO_2 ratios as indices. They also noted that weathering increased as the loess thinned.

In Illinois, Smith (47) investigated a maturity sequence, the progression of soil away from the loess source and found that as the

loess thinned, the soils decreased in base saturation and increased in clay content. Later, Kliess (31) explored this same maturity sequence. He attributed the greater development of the soils most distant from the loess source to a number of factors. First, he said, the finer particle size of the more distant loess contributed to its greater weathering. Secondly, the acidity of the underlying paleosol appeared to influence the weathering of the thinner loess. The differential water table and water movement were also factors. The loess further from the source was in a wetter environment due to the slowly permeable paleosol being closer to the surface. Lastly, the restricted root volume of the thinner loess was a factor that increased the rate of weathering.

Caldwell and White (7), in southern Indiana also noted the increased weathering with greater distance from the loess source. They used as an index of weathering, quartz/feldspar ratios of X-ray patterns from the medium and fine silts.

Harlan and Franzmeier (21) reasoned that the greater soil development in thin versus thick loess was due in large part to the increasing proximity of the Sangamon paleosol and a sandy loess above that paleosol to the solum as the loess thinned. This occurred, though not necessarily, because the paleosol promoted a wetter soil environment.

Ruhe (45) summarized many studies made in the Mississippi River Basin on loess thickness and soil development. He gave three reasons for the recurring observations. First, the finer texture in the thin loess permitted more intensive soil formation than the coarser

textured parent material in the thick loess. Second, a shallower depth to the somewhat impermeable paleosols in the thinner loess areas, led to a wetter weathering environment and more rapid soil development. Lastly, he noted that the thin loess was more weathered because of slower deposition and a smaller amount of deposition. As a result, he postulated the effective age theory which states that thin loess soils are actually older than thick loess soils. These thin loess soils are allowed to weather without being covered with as much loess and are not covered as fast with loess as the soils in thick loess areas.

In Illinois, Fehrenbacher (10) noted the influence of the paleosol beneath the loess in contributing to greater soil development in the thinner loess. He concluded that the matter was more complex than previously realized and stated, "Loess deposition was interrupted many times in a loess deposit and rates of deposition of loess were not uniform at any locality."

Jared (27) examined soil development in the thinning loess of West Tennessee. He observed a greater amount of weathering in the soils of thinner loess, stating "Soils in thin loess were redder in color below 100 cm; contained less exchangeable Ca, K, and extractable P; were lower in CEC; had small Ca/Mg and coarse silt/fine silt ratios; and contained more sand." The soils in thick and intermediate loess were developed entirely in Peoria loess while the thin loess soils were polygenetic, developing in all three loesses.

Soils of the Study Area

Major Soils

A recent soil survey from Obion county, directly to the west of Weakley, affords an initial picture of what can be found in west Weakley county. According to this survey (5), the upland soils consist of three series--Memphis, Loring, and Grenada. A 1937 soil survey of Henry county (60), immediately to the east of Weakley county, reports that the uplands contain these same three soils as well as three others--Lexington, Providence, and Dulac. The appearance of these three soils in Henry county, but not in Obion county, reflects the influence of coastal plain materials on the thin loess-derived soils further east of the Mississippi river. Aside from the parent material difference, all of these soils are differentiated by the appearance and occurance of two diagnostic horizons--the argillic and fragipan horizons.

Argillic Horizon

The argillic horizon is certainly the best understood of these two horizons and is described in the Obion and Henry soil survey reports (5, 60). Noteworthy features of the argillic horizon are color and clay content. As the drainage becomes progressively poorer, soil colors become less red and more yellow. Thus the well drained Memphis soil has an argillic horizon which is generally described best as dark brown (7.5YR4/4 in Munsell color notation). The Grenada, a moderately-well drained soil has an argillic horizon which is approximately yellowish-brown (10YR5/4 in Munsell color notation).

The clay content of these soils increases as the drainage improves. Silty clay loam is the usual texture found in a Memphis B horizon. In the Grenada soil the B horizon rarely exceeds a clay content of 27 percent.

In his study of the Memphis and Lexington series, soils without a fragipan formed in the loess of West Tennessee, Jared (27) observed weak prismatic structure throughout the entire B Horizon of the soils in thick and intermediate loess thickness. The thin loess-derived soils had weak prismatic structure in the lower B horizon. He also noted the B horizons as becoming redder at loess thicknesses of 100 centimeters or less.

Fragipan Horizon

In comparison to the argillic horizon, the fragipan is more conspicuous and has a greater effect on crop growth. It is, therefore, more often used as a guide to distinguish soil series.

A fragipan, as described in Soil Taxonomy (50) is:

> a loamy or uncommonly sandy subsurface horizon that may but does not necessarily underlie a cambic, spodic, argillic, or albic horizon. It has a very low content of organic matter, has high bulk density relative to the horizons above it, and is seemingly cemented when dry, having then hard or very hard consistence. When moist, a fragipan has moderate or weak brittleness, which is the tendency for a ped or clod to rupture suddenly when pressure is applied rather than to undergo slow deformation. A dry fragment slakes or fractures when placed in water. A fragipan is usually mottled, is slowly or very slowly permeable to water and has few or many bleached, roughly vertical planes that are faces of coarse or very coarse polyhedrons or prisms.

And:

> Most commonly a fragipan has an abrupt or clear boundary at a depth of 33 to 100 cm below the original surface. Thickness ranges from about 15 to 220 cm and ordinarily the lower boundary is gradual or diffuse. A fragipan is virtually free of roots except along the bleached prism faces.

Fragipans are found in both glacial and non-glacial material throughout the eastern United States. They are formed sometimes in material the same as the rest of the solum and sometimes in a differing parent material or in a buried soil. They generally lie below an eluvial horizon and there commonly is a bleached A'2 horizon between the pan and an overlying argillic or cambic horizon (50). The salient feature of a fragipan is its compactness creating very slow permeability to water and an obstruction to roots.

What causes this soil horizon to become compacted and brittle is of great concern to many investigators. Many workers have put effort into discovering the reason for the density and brittleness of the fragipan and many schools of thought have appeared.

Some workers claim that the compaction and structure of the fragipan was inherited entirely from the parent material which the soil formed in. Fitzpatrick(13) explained the creation of fragipans in Scotland as a consequence of permafrost related to glacial activity and its affect on parent material. Buntley et al. (6) show the fragipans of West Tennessee to have existed before modern soil forming processes began.

The great bulk of fragipan investigators hold the idea that the fragipan was formed along with the rest of the solum, concurrent with

modern soil forming processes, calling the fragipan a genetic soil horizon. This group of workers is divided into those who claim that a cementing agent is involved and those who claim that the induration is a result of packing and reorientation of the soil particles.

In West Virginia, Smith and Browning (48) looked into fragipan soils from various parent materials throughout the state. On the genesis of the fragipan they stated "The firmness and hardness evident when the material is dry, is primarily the result of the high density of packing and the complete lack of any effective aggregation." In the coastal plain soils of Maryland, Nikiforoff and his co-workers (39) concluded that the pan density was due to close packing of soil particles. They stated that the pan existence may reflect both parent material stratification and soil forming processes.

Hutcheson et al. (25) examined the Memphis catena of soils in western Kentucky and concluded that the fragipan formation was associated with the packing of dispersed clay particles. Jha and Cline (28) studied fragipans in New York soils formed in glacial material and attributed the density and firmness of the pan to the organization of particles upon wetting and drying, possible by seasonal frost action and illuviation of clays. Dessication was given as the major factor causing polygonal fracture planes.

A fragiudalf in Ohio was found to have platy structure and a dense particle arrangement which was partially inherited from the parent material (35). These properties were enhanced and additional properties of brittleness and fabric compaction appeared through modern

processes of dessication and rehydration along with reorientation of illuvial clay within the fabric.

Hutcheson and Bailey (23) explained the pan density and brittleness as a result of the tight packing of silt and clay particles forming a brick and mortar structure. Fragipans in New York soil may be rigid due to illite and colloidal silica bridges of gel-like material (16, 32).

Pan genesis in soils of northern Michigan (64) may first involve leaching of carbonates, after which expandable clay is removed. After this, contraction from gravity, roots, wetting and drying, and freeze-thaw cycles causes cracks and the characteristic polygonal pattern. With subsequent contractions, rearrangement of the particles occurs and clay bridges form which cause brittleness. It is also possible that aluminum oxides act as cementing agents in these soils.

Compounds containing key elements have been suggested as cementing agents in fragipans. Investigating hardpans in Tennessee, Winters (63) postulated that when an impervious substratum perches water, proceeded by a drought, the water is removed and secondary SiO_2 is precipitated. The SiO_2 acts as a cement, causing brittleness and compaction in the pan. With reference to pan genesis in California soils, Nikiforoff et al. (38) stated, "The hardpan was formed subsequent to profile development by cementation of the soil by iron oxides and silica." In the Ozark region, Krusekoph (33) studied the hardpans and wrote:

> In brief the hardpan is a product of the highly siliceous material weathered in place, under normal soil forming processes. Silica is the cementing agent and gives the hardpan extreme hardness. It is a condition where the composition of the parent rock is a determining factor in the character of the resulting soil.

Anderson and White (1), studying the loessal fragipan soils of southern Indiana concluded that soil particles were weakly cemented by iron oxides bringing about the brittleness and denseness of the fragipan.

In Washington county, Arkansas, Horn and Rutledge (22) studied fragipan soils and produced tentative conclusions concerning fragipan brittleness. They postulated that the brittleness and polygonal patterns result from precipitation of iron oxides and clays through diffusion processes within the soil matrix along with movements of water suspensions and solutions in the void system of the soil. Also, they contend that fragipans have formed coincidentally with the rest of the solum and can be explained by processes of soil genesis in operation today.

Nettleton et al. (37) explain that the removal of iron and clay allows the collapse of the soil matrix to cause the high bulk density of North Carolina fragipans. Subsequently, amorphous alumina and silica develop strong hydrogen bonds with quartz and other silicates in the soil, thus producing the brittleness and compaction.

Harland and Franzmeier (21) found that free silica was highest in the fragipan horizons of southern Indiana soils, while neither extractable iron or aluminum increased in conjuction with fragipan horizons. They concluded silica acted as the cementing agent of the fragipan. Stienhardt and Franzmeier (52) noted similar distributions in southern Indiana fragipan soils. In addition they performed vacuum extractions of fragipan samples which led them to believe that silica was a cementing agent and that clay may be significant, but not critical in the binding of particles.

Hallmark and Smeck (18) summarized their findings concerning fragipans in northeastern Ohio as follows:

> Al, Fe, and Si are released in the weathering process and subsequently leach into the lower horizons where precipitation of these elements occurs. It seems likely that the precipitants would be concentrated at contact points between particles upon dessication and that further polymerization would occur resulting in bonding between particles which imparts strength to the fragipans and probably is the source of the brittleness observed in fragipans. This study indicates that HCl-acetylacetone extractable Al is the most diagnostic element for the amorphous component effecting the bonding between particles.

Along with studies on the genesis of fragipans, countless efforts have been made in describing fragipan properties and examining the relationship of the fragipan to other horizons. McCracken and Weed (34) observed a thin section from the upper part of a Grenada fragipan from Haywood county Tennessee and reported a close packed silt-rich matrix with only a few pores. The clay was oriented in patchy films. The C horizon in thin section showed more pores. Mineralogically, quartz, feldspar, and mica were abundant in the clay-free portion throughout the soil. Within and just above the fragipan was a concentration of chlorite-vermiculite intergrade which expanded and collapsed only after removal of aluminum.

In the loessal soils of Kentucky, Hutcheson et al. (25) found that the Bx horizons had a higher vermiculite/montmorillonite ratio than the B22 or C horizons. Associated with this were low Ca/Mg+Na ratios in the fragipans compared to the other horizons. They concluded that vermiculite formed from montmorillonite with the high Mg in the fragipan. Studying loessal fragipans in southern Indiana, Anderson and White (1)

found that the fragipan contained less montmorillonite clay than the horizons above it. Only a small amount of the montmorillonite in the fragipan was expandable without treatment.

Fragipans in glacial drift, studied by Carlisle et al. (8) in New York, had the strongest structural expression in their uppermost part. This same feature was found in loess fragipans of Illinois by Grossman and Fehrenbacher (17).

The bleached A'2 horizon, often occurring above the fragipan, has been studied by a number of people. Fragipans in New York formed in glacial material (28) were devoid of clay in the A'2 horizon, possibly due to weathering and destruction of clay. Also, they perceived that the A'2 material encroaches on the pan, degrading it.

Looking at Mississippi and Louisiana fragipans in loess of different ages, Bartelli (3) noted that the presence of A'2 material above a pan was indicative of degradation of the pan as well as the disappearance of the argillic horizon. He explained a process called ferrolysis which operates above the fragipan during alternating anaerobic and aerobic periods. This process brought about bleaching and degradation of the pan. He also observed the progressive increase of albic material at the expense of the argillic horizon, in comparing well versus poorly drained soils. In all fragipan soils, regardless of drainage, the albic material tongued into the pan. In older soils developed in loess, he noted a greater amount of tonguing of albic material into the fragipan, than in the fragipans of soils developed in a younger (Peoria) loess. Thus, he concluded that the amount of albic material associated with a

fragipan is an index of weathering, with a greater amount of albic material indicating greater weathering of the soil.

Ranney et al. (43) looked at the albic material separating the prisms of fragipans in the soils of Pennsylvania. They found that the bleached material was moved in from above and subsequently lost iron oxides to the prisms and prism faces.

Miller and his co-workers (35) studied fragipans from glacial till in northeastern Ohio and Pennsylvania and found that the lateral movement of water above a fragipan is as much as 30% of the rainfall.

Kentucky fragipans formed in varied parent materials including loess were observed to have colors more yellow and of a lower chroma than horizons above the pan (2). Also, more clay and less silt were noted in the fragipan than the horizons above the pan. In a study of similar fragipans, Hutcheson and Bailey (23) discovered that soil horizons were severely leached prior to the formation of the fragipan.

Peterson et al. (42), on the other hand, studied fragipan soils throughout Pennsylvania formed in several parent material types and concluded that the fragipan horizons were less leached and less weathered than the other horizons in the soil. The fragipan horizons had a higher base saturation, a lower Ca/Mg ratio, and lower organic carbon content than other soil horizons. In addition, the fragipans were either loamy or silty whereas other soil horizons had a wide range of textures.

In West Virginia, Smith and Browning (48) found fragipan horizons to have low bases and low base saturation when compared to the rest of the soil. The fragipan soils were formed in siltstone, sandstone and

alluvial silts and sands, but never in parent materials high in clay. In addition, the fragipan soils occurred most commonly on slopes of 5 percent or less.

Hardpans were found on gently sloping and level land by Krusekoph (33), and rarely on steep land. He studied the hardpans of the Ozark region formed in cherty limestone and reported:

> It is assumed that in comparison to the solum the hardpan is a more recent development and that it still is in an active process of formation. The existence of the pan cannot be taken as evidence of the maturity of the soil.

In the coastal plains of North Carolina, Daniels and co-workers (9) found the fragipan to occur independent of vertical changes in sediment, the nature of the underlying material, feldspar content of the soil, or the silt and fine sand contents of the soil.

Soil Relationships

A good many studies have been done to define the relationship of fragipan soils to other soils in the landscape and to the landscape itself. Winters (63) observed that loessal fragipans in Tennessee began at 18-24 inches (46-61 cm) below the surface and were up to four or six feet (1.2 or 1.8 meters) thick. The hardness of pan was proportional to the extent of root and water penetration. He noted that the pan often stopped at a contact with a new parent material, and added that pan soils most commonly occur on slopes of less than ten percent. Concerning the pan soil and its relation to drainage and the development of impedance he wrote:

> All soils with hardpans show evidence of restricted internal drainage, as judged by color. It might be argued that the pan gradually produced the impedance, particularly in soils on slopes as great as ten percent where pans have been observed. However, field evidence usually points to some previous natural cause for impeded internal drainage, such as an impervious substratum.

And,

> Usually the more restricted the drainage, the harder the pan and closer it is to the surface...Impervious substrata are associated with hardpans more so than are the more previous substrata.

Bailey (2), studying morphological relationships of loess fragipan soils in western Kentucky, observed that soils with poorer drainage had a thicker more strongly developed fragipan. Another study in western Kentucky, involving soils of the Memphis catena, found that soils of progressively poorer drainage had fragipans occurred nearer the surface and increased in thickness within the profile (25). These authors stated that the more poorly drained members have been subjected to more severe weathering and leaching than the better drained members. This was evidenced by a lower base saturation in the more poorly drained soils. The well drained Memphis contained predominantly illite whereas the poorly drained Henry soil was dominated by expanding 2:1 type clays.

Fragipan properties of New York soils have been related to soil drainage and texture of the fragipan (8). The best developed pans were found with medium and fine textures. The position between moderately well and somewhat poorly drained soils contained the highest expression of the fragipan. It was also noted that the fragipan thickness

increased and the depth to the fragipan decreased proceeding from well to somewhat poorly drained soils. However, the development of a pan was not dependent on a poor drainage site or a high water table.

On the coastal plain of North Carolina, Nettleton et al. (36) studied fragipan development and morphology and observed fragipans to occur on older coastal plain surfaces more commonly than on younger ones. But locally, they rarely found fragipans on ridgetops, the oldest part of the landscape. They stated, "Apparently there are factors more important than length of weathering in fragipan development. The sites between moderately well and somewhat poor drainage were those with the most highly developed pans." Clay in fragipan horizons ranged from 5 to 17 percent, with the strongest pans to be those with the lower clay percentages.

An investigation was undertaken in southern Illinois by Grossman and Fehrenbacher (17) in an area much like West Tennessee with respect to soils. The Peoria and Roxana sheets of loess were present, but the Loveland was scarcely found. The character and expression of the fragipan was influenced by topographic position, thickness of the total loess, and latitude. Fragipans on moderately well to somewhat poorly drained sites had the greatest expression. With respect to latitude the fragipans became more strongly developed proceeding north to south, reaching their highest expression in the state of Mississippi. One change noted in particular, was that the amount of clay within the fragipan decreased with a change in latitude from north to south.

Examining the soils for relation to parent material changes, they concluded that as the total loess thinned, fragipans became more strongly expressed. A loess thickness of 80 inches (203 cm) was noted as the break between soils with strongly versus moderately expressed fragipans. The loess depth separating weakley and moderately expressed fragipans was 130 inches (330 cm). In analyzing soil from the intermediate thickness with a moderately expressed fragipan, they found no evidence mineralogically, chemically, or physically, that a change in age of the loess occurred within the solum. Along with these observations, they noted that in one county of sourthern Illinois, for which a soil map was available, the depth to the fragipan became less and less with increasing distance from the Mississippi river, the source of the loess.

Field relationships of fragipan soils were also investigated in West Tennessee by Buntley et al. (6). Their claim was that the fragipan occurs when the upper boundary of the Roxana loess became close enough to the actual land surface. They found that the upper part of the Roxana loess, even when deep enough to be unaffected by modern soil forming processes, was brittle and dense, and concluded that when the upper boundary of the Roxana was within the solum, it manifested itself as a fragipan. Fragipans reportedly occurred when the uppermost Peoria loess thinned enough to allow the Roxana to near the surface. They stated that the Peoria loess thinning pattern occurred from the Mississippi river eastward across West Tennessee as well as from the top to bottom of slopes throughout West Tennessee. Thus, soils with fragipans would be more prevelant both with increased distance from the

Mississippi river and downslope from the ridgetops in West Tennessee. They found this in agreement with field observations and soil survey reports of West Tennessee.

Just across the Mississippi river from West Tennessee, West et al. (59) studied fragipan soils and loess and observed the three loesses - Peoria, Roxana, and Loveland. Each site they investigated contained fragipans in the present soil profile which they said had formed entirely in Peoria loess.

Another study dealing with field relationships of fragipan soils was done in New York (20). The parent materials in this case were various forms of glacial drift--till, congeliturbate, and erosion sediments. In the valley studied, the fragipans occurred only on the side slope and not at the summit position. They recognized the movement of water laterally above the fragipan. The changing expression of the fragipan along the slope was explained: "The increased expression of the pan in the footslope segment, as compared to the pans on the shoulder and backslope, appears related to the slight decrease in drainage rather than to a change in lithology." Their observations indicated a pedologic origin of the fragipan, but they did state, "Although the weak stratification produces no distinct lithologic changes, except for the stone line, thicknesses of soil horizons generally appear to coincide with various strata."

In southern Indiana, Franzmeier (14) examined the relation between loess deposits and fragipan horizons and made the statement,

"Fragipans in southwest Indiana parallel the soil surface and cut across various parent material deposits." He considered fragipan horizons to be genetic horizons of the modern soil.

Later, Harlan and Franzmeier (21) reported on soil formation in loess of southwest Indiana where the Peoria loess overlays a sandy loess which in turn is above the Sangamon paleosol in till, sandstone, or shale. In areas containing one meter of loess, they found fragipans to be prevelant at sites with underlying paleosols derived from shale or siltstone, but not from sandstone. They also found that fragipans occurred only in areas where the total loess was between 0.75 and 1.25 meters thick. They concluded that the fragipans developed because the paleosol and perhaps the sandy loess transmit water more slowly than the silty Peoria loess. Often, the fragipans had their lower boundary coinciding with a parent material discontinuity; as would the upper boundary in some instances. Taking a broad view of southwest Indiana, they stated:

> There is a tendency to progress from soils with no fragipan to those with a weak pan to those with a more strongly developed pan with distance from the loess source, but this progression occurs entirely in well drained soils (sites on rounded ridgetops) with no apparent change in wetness.

These authors found fragipans to have formed in all of the parent materials described, at one point or another. The soil they described with a weak pan was called Hosmer. Its solum was nearly always found entirely within the Peoria loess. Two well drained soils with the strongly expressed pan, the Zanesville and Cincinnati series, have a fragipan which is always found in the sandy loess, but is never confined to it, reaching above or below into other age materials.

Norton and Franzmeier (40) examined topographic relations in fragipan soils of southeast Indiana and found soils with fragipans located only on level hillslopes and shoulders. They attributed fragipan development to the impermeability of the underlying paleosol and its ability to perch water. Concerning this they wrote, "A fragipan was present on summit and shoulder positions, where the underlying paleosol formed in weathered sandstone and shale, but not on lower slope positions over these rocks or on any position where the paleosol formed in outwash." Here they found that the loess was of uniform thickness down slopes. They concluded, "We believe that the fragipan forms by processes associated with the modern landscape, but its formation is influenced by pre-Peoria soils or weathering zones."

In Jenning county of south central Indiana, Steinhardt and Franzmeier (52) examined the fragipans of the Cincinnati catena. This is an area of broad upland flats where poorly drained soils are in the center of broad flat areas and the drainage improves progressively downslope. Here, the workers found that the loess thinned appreciably from the top to the bottom of the slopes. The depth to the pan decreased going downshipe, so that the fragipans occurred at a greater depth in the more poorly drained soils. This area is very near the limit of the Wisconsinan stage of glaciation. About two meters of total loess was found on the flats throughout the area. The boundaries separating the two loesses and the till below were indistinct.

CHAPTER III

MATERIALS AND METHODS

Field Investigations

In order to characterize the upland soils of Weakley county, field investigations were divided into two endeavors: (1) the conducting of transects and (2) describing and sampling the most representative soils in freshly dug pits.

Thirty-two transects were conducted in the county. Involved in a transect was the examination of soil changes occurring over a one half to one kilometer distance in a straight line. The transects ran from a hilltop to a drainageway where a somewhat poorly or poorly drained soil was encountered. Sometimes they continued to encompass several other hillside slopes.

Two methods were used in locating the transect sites. The first method involved the following steps. Eligible locations for transects were drawn onto USGS topographic maps (7.5' series) at the rate of about 20 per square kilometer. Thirty-six transects were chosen randomly from this group of eligible locations. Of the 36 chosen, twelve were conducted. After these twelve were conducted, a different method of locating the transects was adopted in order to facilitate correlation of field observations to soil forming factors and finish the field work in the time alloted. This second series of transects was located along roads in Weakley county. State highway 22 in the county makes a line very nearly perpendicular to the lines of equal loess thickness.

State highways 89 and 54 along with county roads 8015 and 8016, joined together, make a line approximately parallel to the lines of equal loess thickness (58). A transect adjacent to these two routes was made every three miles (8.4 km). The transects were always within 0.25 miles (0.4 km) of the road. The first transects in this series were made where the highway routes intersected the north and west borders of the county. Subsequent transects were located by advancing to the first eligible position at or beyond the point three miles from the previous transect.

Two types of holes were dug along all the transects. The most common type was the shallow observation with a push tube or barrel auger. These holes penetrated to a depth of 107 cm. The other type of observation was the deep barrel auger boring. With a 7.5 cm barrel auger, deep borings were made through the entire loess column until coastal plain material was encountered. Two deep borings, and occasionally several more, were made at each transect at points along the transect which were judged best able to provide the most information on the loess layers below. Soil augerings, at the first 12 transects, were made only at points between which a significant soil change was judged to have occurred. With the remaining transects, it was decided to additionally make a soil augering every 30 meters, in order that greater detail could be achieved and so that no important soil changes should be missed.

The deep borings at every transect were generally made at the positions of hilltop and footslope, along with other positions deemed appropriate. At these points, the depth of total loess and of any individual loess layers recognizeable on the basis of morphology were recorded. At each of the soil augerings, soil horizons and depths, soil colors, mottling, and field texture were described. Each hole was labeled with a soil series name according to the concepts then in use. A sketch was made of each transect containing pertinent features.

The second part of the field investigations entailed the digging of four soil pits. Soil surveyors familiar with the soils of Weakley county assisted in the site selections. Three Loring pedons, and one Grenada pedon, were selected in areas felt to be most representative of these soils in Weakley county. The three Loring pedons were distinguished by using the roman numerals I, II, and III. Transects were also conducted at each pit location.

Profile descriptions were made from the face of the pits and Munsell color notations were used on moist soil. Samples were collected from each described horizon to the depth of the pit. These were taken from the bottom of the pit upward to avoid contamination of unsampled horizons. At all but the Loring II pit, samples of the C horizons were taken with a bucket auger. At the sites of the Loring I and Grenada pits, additional samples were taken from an augered hole somewhat down slope from the pit, between a shoulder and the footslope, along the transect conducted at that site. In both cases,

this was an erosional surface where the Roxana loess could be distinguished. Two samples were taken at the Loring I site erosional surface, one in what was considered the upper Peoria loess, and one in what was considered the lower Roxana loess. At the Grenada site one sample, downslope in a modern erosion scarp was taken in what was considered the B horizon of a paleosol in the Roxana loess. Each sample taken at the pits and at the erosional surfaces was placed in a plastic bag, labeled, and sealed.

Laboratory Procedures

Sample Preparation

After samples were collected and transported to the laboratory, they were air dried and ground with a rubber-tipped pestle to pass a 2 mm sieve. The samples were mixed thoroughly by rotating them on a large piece of paper. They were stored in cylindrical pint and quart cartons. From these, subsamples were taken for subsequent laboratory analyses using a sample splitter.

Chemical

Soil reaction was determined by measuring pH in suspensions consisting of a 1:1 soil to solution ratio of distilled water and N KCl using a glass electrode.

Extractable acidity was determined by the $BaCl_2$-triethanolamine method of Peech (41). Five grams of soil were equilibrated with excess of $BaCl_2$-triethanolamine (TEA) solution adjusted to pH 8.2. The unreacted TEA was then back titrated with 0.2 N HCl using

bromcresol green-methyl red as an indicator.

Exchangeable bases were determined by extracting five grams of soil with 85 ml of N ammonium acetate buffered at pH 7.0 (49). Calcium, magnesium, potassium, and sodium were determined from the extract with a Perkin-Elmer model 5000 atomic absorption spectrophotometer.

Cation exchange capacity was calculated as the sum of the exchangeable bases plus extractable acidity. Base saturation was calculated as percent of the cation exchange capacity accounted for by exchangeable bases.

Physical

Particle size distribution was determined by the method of Kilmer and Alexander (30). Ten grams of soil were treated with hydrogen peroxide, dispersed with ten ml of 1.2N sodium hexa-meta-phosphate and placed on a reciprocating shaker for 16 hours. The sand fraction (2.0-0.5 mm) was separated from the remaining sample by wet sieving on a 300 mesh sieve, oven dried and weighed. The very coarse sand (2.0-1.0 mm), coarse sand (1.0-0.5 mm), medium sand (0.5-0.25 mm), fine sand (0.25-0.1 mm), and very fine sand (0.1-.05 mm), were determined by dry sieving with an appropriate nest of sieves. The fine silt (0.02-0.002 mm) and clay (less than 0.002 mm) fractions were determined from 25 ml aliquots pipetted, after appropriate settling times, at a depth of 10 centimeters which were subsequently dried and weighed. The coarse silt (0.05-0.02 mm) fraction was calculated by difference of fine silt and clay. The erosional surface samples taken at the Loring I and Grenada sites were not analyzed for particle size distribution.

Mineralogical

Samples were treated with hydrogen peroxide for removal of organic matter. Free iron was removed from all fractions by the DCB technique (49). Samples were sodium dispersed, but not mechanically shaken for dispersion. Sand, silt, and clay separations were made for mineralogical analyses by appropriate sieving, centrifugation and decanting, and siphoning.

Representative samples of the fine sand plus very fine sand fraction were prepared as grain mounts for viewing under the petrographic microscope. Grains were counted by the field method. Successive countings of entire fields of grains were made until a minimum of 300 grains were counted. (Petrographic grain counts were performed by D. A. Lietzke.)

Mounts of the fine silt were made on glass slides. Oriented mounts of the clay fraction were prepared on ceramic tiles and contained approximately 15 mg of clay/cm^2(44).

Clay X-ray diffractograms were prepared using the following treatments: Mg saturation plus glycerol solvation at room temperature; and K saturation at room temperature and after heating at 110°, 300°, and 500°C in excess of four hours. X-ray diffraction spectra were obtained with a Norelco X-ray diffraction unit using CuKα radiation.

Semi-quantitative estimates of mineral percentages were made by comparison of peak intensities. Mineral identification from the x-ray diffractograms was based on the following criteria. Kaolinite gives 7.2 and 3.5 Å peaks with both K and Mg saturation. The peaks are

stable to 300°C, but are destroyed by heating at 550°C. Vermiculite gives a 14 Å peak for Mg saturation and glycerol solvation. This peak collapses to 10 Å for K saturation and this collapse may not be complete until heating to 300°C. Chloritized vermiculite gives a 14 Å peak for Mg saturation and collapses toward 10 Å upon heating. Mica, which includes both biotite and muscovite, gives a peak for both Mg and K saturation at 10 Å. This peak is not altered by heat treatment. Montmorillonite gives an 18 Å peak upon Mg saturation and glycerol solvation, and 14 Å peak when K saturated whick collapses to 10 Å upon heating. Chlorite gives a 14 Å peak for Mg and K saturation which is not altered by any heat treatments. Quartz has a 4.21 and 3.34 Å peak, neither which are affected by cation saturation or heat treatment. Feldspars have characteristic doublet peaks between 3.25 and 3.4 Å.

Differential thermograms were obtained with a DuPont R90 thermal analyzer. Selected samples were Na saturated and heated at a rate of 20° C per minute from 375-600° C. Quantitative estimates of the quartz and kaolinite percentages were made by measuring the peak area of endotherms. This technique was employed with samples of the clay fraction and samples of the fine sand plus very fine sand, coarse silt, and fine silt fractions.

CHAPTER IV

RESULTS

Field Investigations

In order to facilitate utilizing data from transects which covered more than one hillslope, each slope was treated as a separate observation. Transects covering only one slope were treated as one observation. In all, information on 49 observations, or slopes, was gathered from 32 transects. Figure 2 shows an idealized slope and its separate sections, as they will be referred to in this and later chapters. Transect locations with respect to Weakley county borders are seen in Figure 3.

Identification of Loess Sheets

The contact between the lowermost loess and the coastal plains material was easily perceived. A mixed zone of loess and coastal plains material separated the two parent materials. In this mixed zone the clay content increased, the sand content went up dramatically, and the color reddened considerably. There were exceptions to this general pattern, but an introduction of coastal plains material into the loess was always readily observed. Both upper and lower boundaries of the mixed layer were fairly easy to identify. Thus, for each boring, the total loess depth was known.

In no case was there positive identification of the lowest loess known to occur in the Weakley county area, the Loveland. The loess was apparently too thin to afford ready identification, and is evidently within this mixed layer.

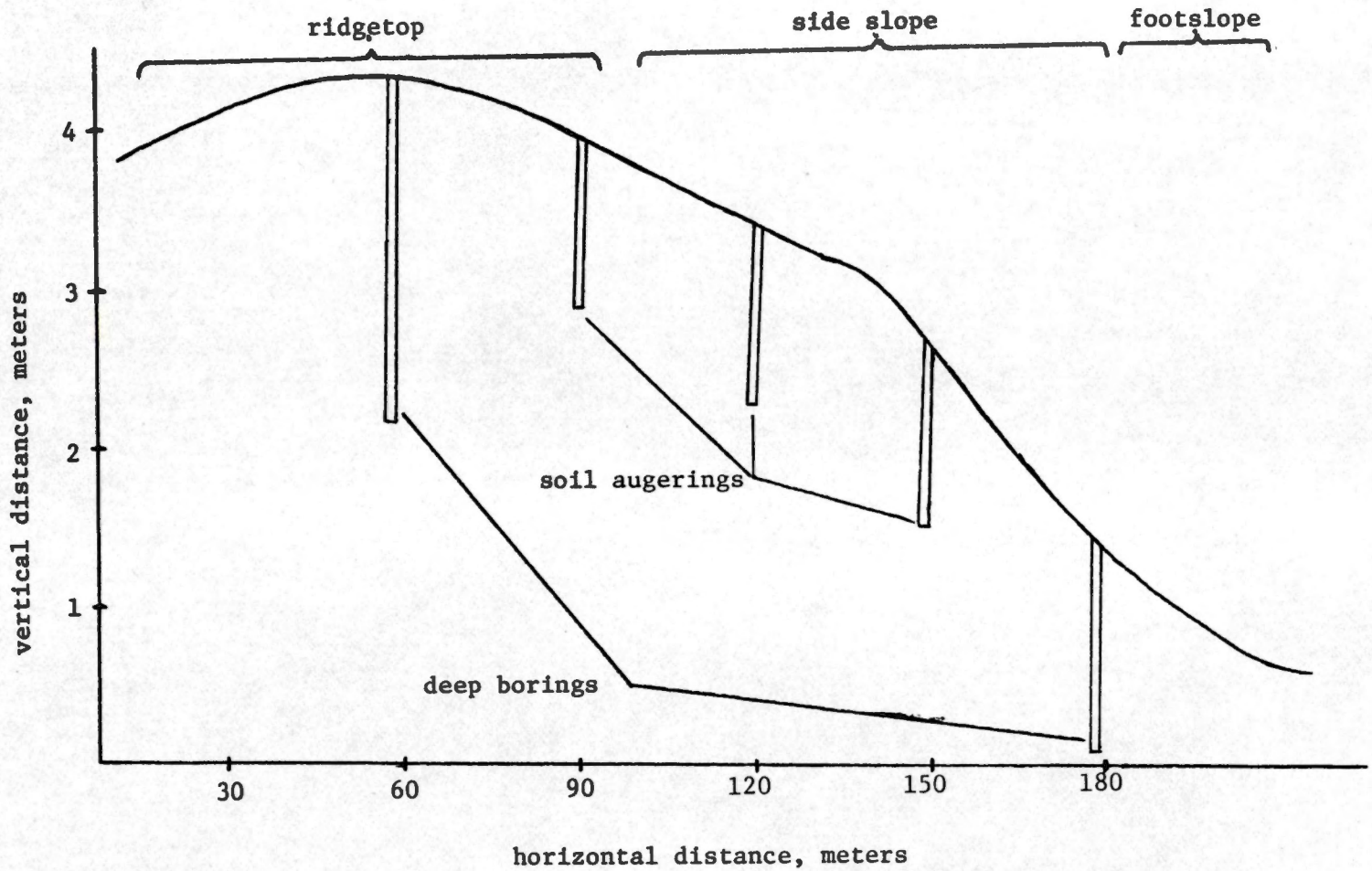


Figure 2. Idealized slope of Weakley county, Tennessee, divided into sections and with typical augerings.

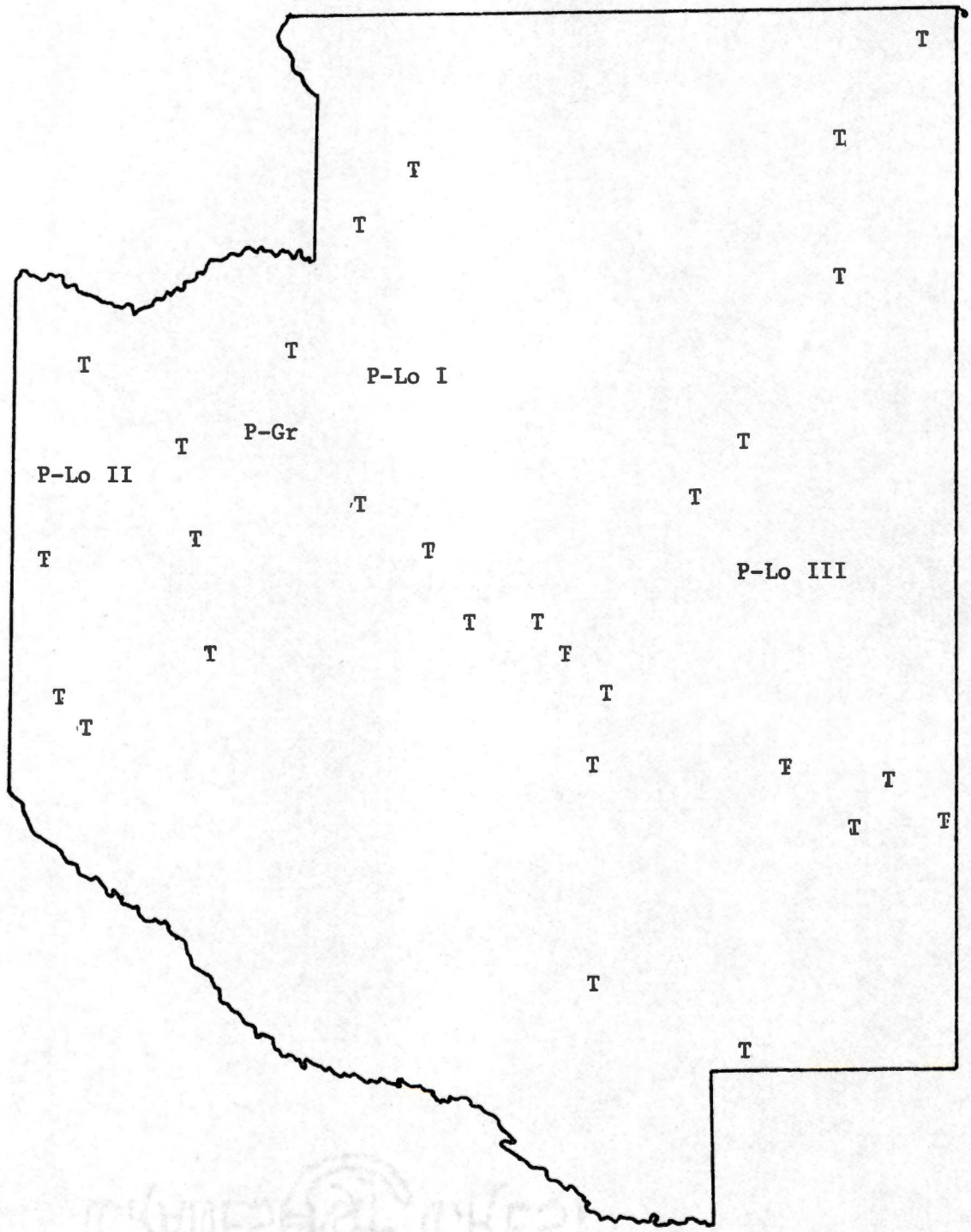


Figure 3. Sampling pedon and transect locations within the county.

"T" identifies transects
"P-Lo" identifies Loring pedons
"P-Gr" identified Grenada pits

When the total loess was sufficiently thick and conditions were favorable, the upper boundary of the Roxana loess was recognized, occurring at 15 of 69 deep borings. The boundary between the Peoria and Roxana loesses was always clear, occurring over 10 cm or less. The changes occurring over this boundary, enabling detection of the Roxana loess, varied somewhat between transects, but at borings within a transect these changes were consistent.

The Peoria-Roxana break is most often recognized by an albic zone. The Peoria loess frequently has zones and streaks of albic material increasing with depth until the lower Peoria boundary where it resembles an A'2 horizon. The Roxana immediately below, contains few streaks of the albic material. Another change occurring at this break is in the structure of the two materials. Whereas the Peoria loess is structureless or has only a weak grade of structure, the Roxana will contain medium blocky peds of moderate grade, and will sometimes be brittle or compact in place. The third contrast between the two loesses is color. The Roxana nearly always has a Munsell color of 7.5YR, 3/6, 4/6, or 4/4, although it will occasionally have a 10YR hue with the same range of values and chroma. The Peoria is generally 10YR, but can be a 7.5YR hue. The value and chroma will range among 4/6, 5/6, and 5/8. Finally, in several but not all cases, an increase in sand content of about 5 percent, from 2 or 3 in the Peoria loess to 7 or 8 in the Roxana loess, was noted.

When the total loess depth was less than 220 cm, the Roxana loess was very difficult to distinguish from the Peoria. As the Peoria-Roxana

contact nears the soil surface, soil forming processes evidently have obscured it. This contact was never positively identified in the field when it occurred within a fragipan, except in the lower part of some thick fragipans in west Weakley county. It was identified in these cases by an A'2 horizon. Otherwise the contact is apparently erased when within a fragipan. The loess layers as related to soil profiles in east versus west Weakley county is seen in Figure 4.

Parent Material Trends

Loess was found to be spread uniformly down slopes. There was no evidence of the total loess or any individual loess sheet thickening or thinning from ridgetops to the base of side slopes.

In order to evaluate the cross county changes in loess depth, each slope transected was given one value for total loess depth, calculated by averaging the loess depths at an individual slope from borings at which neither modern erosion or deposition had greatly modified the landscape. Included in the total loess depth values is the mixed zone containing loess and coastal plains material. The depth of total loess, thus determined, is highly correlated to the distance from the loess source, decreasing in depth with increasing distance from the loess source, as shown in Figure 5. The loess ranged from 146 to 435 cm in thickness.

At the deep borings where the Peoria-Roxana break was identifiable, the Peoria ranged between 34 and 68 percent of the total loess when the lower boundary of the mixed zone at the coastal plain contact was considered the lower boundary of the total loess. Both the Peoria loess and the loess below the Peoria thinned at the same rate. As the total

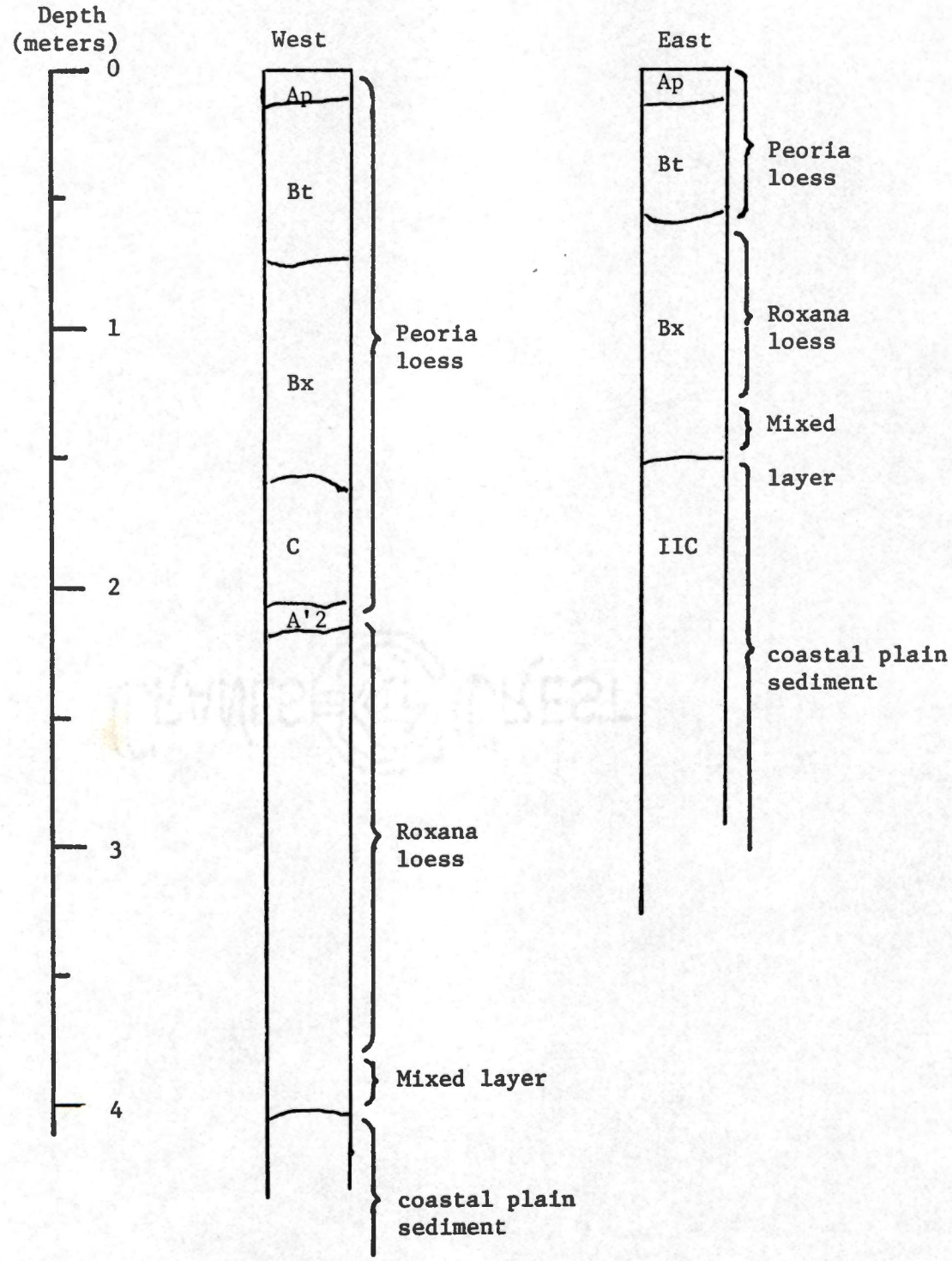


Figure 4. Stratigraphic colums from west and east Weakley county, Tennessee, showing relation between loess sheets and soil profiles.

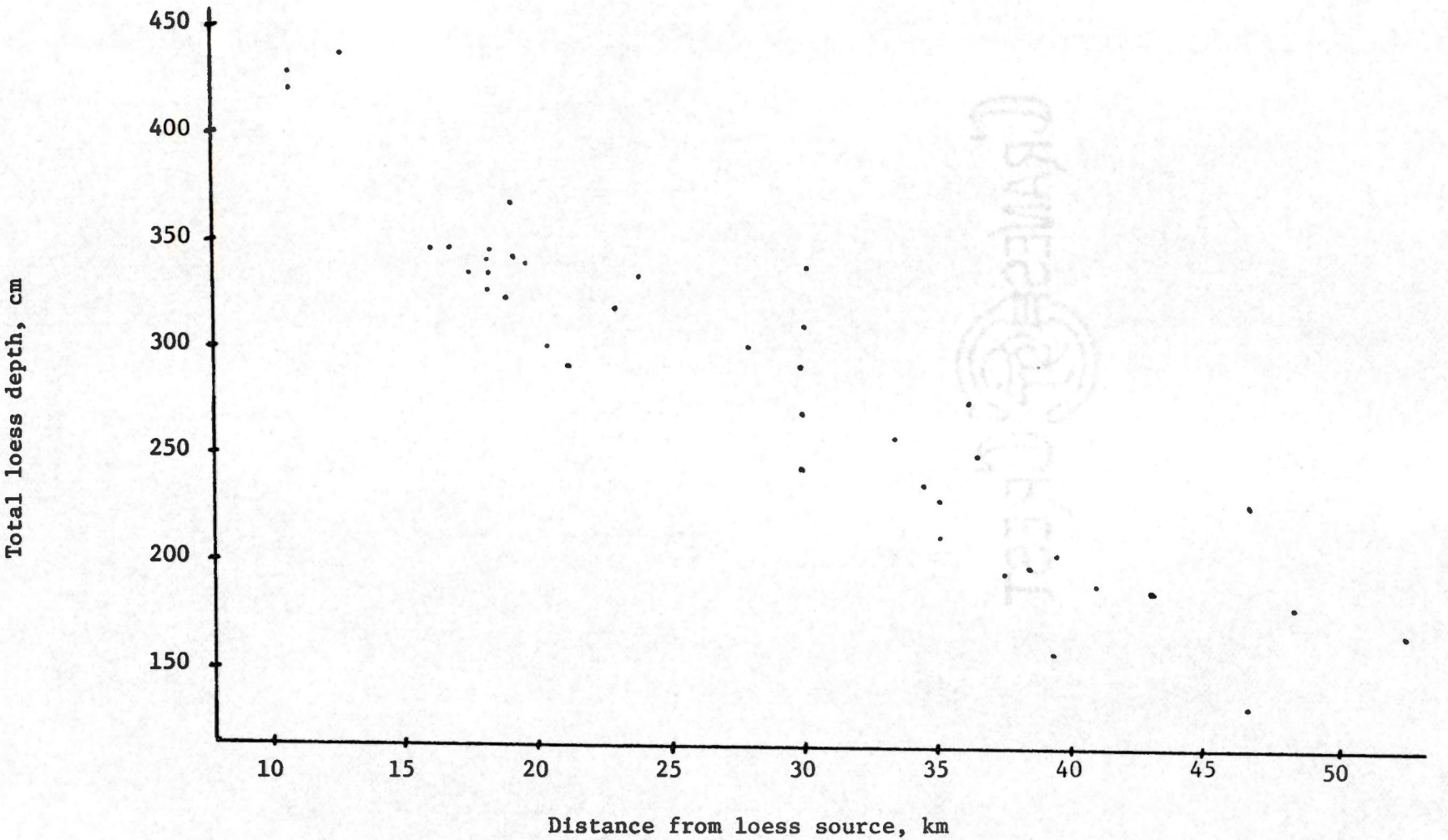


Figure 5. Total loess depth vs. distance from loess source, with points representing measurements taken at transects and sampling pedons.

loess thinned from west to east, the percentage of total loess as Peoria remained constant, averaging 52 percent throughout the county.

There was no apparent trend in the mixed zone thickness on summit borings with increasing distance from the loess source. It neither thickened nor thinned in any pattern from west to east across the county. The same results were observed when the thickness of the mixed zone at non-summit borings was plotted against the distance from the loess source. The range in thickness of the mixed zones measured was 13 to 138 cm, with the average thickness being 63 cm.

The mixed zone, as it progressed down each slope, did exhibit a consistent pattern. The mixed layer was thicker at the borings farther from the summit. This trend was observed by plotting the change in adjacent mixed layer measurements against the average distance of the measurements from the summit. Also, through a t-test, the differences in the thickness of the mixed layer between adjacent deep borings on the same slope were found to be different from zero at the .01 level of probability. This showed that the mixed layer was thicker at measurements farther from the summit, but the amount by which the mixed layer thickened was not consistent among transects.

The mixed layer was also observed to thicken as the elevation decreased at a slope. But once again, the amount of mixed layer change between borings did not depend on the amount of elevation difference between the borings and the summit. The mixed layer increased in thickness down slopes, but not at a predictable rate or in any certain pattern.

Soil Associations

The 49 slopes were each placed into a soil association. Judging from the soil names given during field observation, the soil characterizing the side slope determined the name of the association. Thus each association had two soil names. The most prevalent association was the Loring-Loring. In this case the Loring soil was found both on the ridgetop and the sideslope and continued downslope until the foot or toe slope was encountered. Aside from the Loring-Loring association, the Memphis-Loring and Grenada-Loring associations occurred most commonly, although less than half as frequently. In the Memphis-Loring association, Memphis soil was found on the ridgetop while Loring was on the side slope proceeding as far as the foot or toe slope. In the Grenada-Loring association, Grenada occurred on the ridgetop changing to Loring on the side slopes. Other soil associations were found. The names and frequency of occurrence of all of these associations are listed in Table 1. Thirteen of the slopes defied being placed into an association, because of the variety and irregularity of soils appearing on them.

The soil association found at a slope was regulated by the topography defining the slope. At places where the ridgetop was relatively flat, level, and broad, the soil on the ridgetop was moderately well drained or rarely somewhat poorly drained and the side slope soil was generally better drained. Associations found in areas such as this were: Grenada-Loring, Grenada-Grenada, Grenada-Memphis, and Calloway-Loring.

Table 1. Soil associations of Weakley county and their frequency

Association	Number found
Memphis-Memphis	1
Loring-Loring	14
Memphis-Loring	5
Grenada-Loring	5
Loring-Grenada	3
Grenada-Grenada	2
Lexington-Providence	2
Grenada-Memphis	1
Calloway-Loring	1
Smithdale-Smithdale	1
Providence-Providence	1
Others	13
Total	49

On slopes with rounded ridgetops, a different set of associations was found. In these cases, the drainage either remained the same or became poorer moving from ridgetop to the sideslope. Among these slope types the Loring-Loring association prevailed. Also found in these areas were the Memphis-Memphis, Memphis-Loring, Lexington-Providence, and Loring-Grenada associations, along with situations where either Providence or Smithdale were the only soils from ridgetop to footslope.

The associations including Lexington, Providence, or Smithdale soils were all in the easternmost third of the county. The westernmost third of the county contained all but one of the slopes where the Memphis soil was part of the association. The remaining associations occurred without regard to location in the county.

Of the slopes placed into associations, eight had side slopes characterized by a moderately well drained soil, either Grenada or Providence. The other 28 slopes had well to moderately well drained soils occurring on the side slopes, usually Loring. A consistent pattern throughout the county was that convex sideslopes housed well drained soils and the concave sideslopes, moderately well drained soils.

Another pattern in the county was that wherever a shoulder on a slope was encountered, the soil on that convex shoulder was better drained than the surrounding soils. Likewise, where a small concave slope segment occurred, the soil there was more poorly drained than surrounding soils.

Of the 13 slopes which were not placed into associations, three were complex, containing several shoulders or alternating convex and

concave slope segments. Insufficient information concerning the other 10 slopes was available to enable their placement into associations. The complex slopes were always found adjoining bottomlands of major rivers in the county and encompassed (relative to the other transects) a large change in elevation from hilltop to footslope.

Fragipan Property Trends

The fragipan and its properties were observed as they changed across the county from east to west. The distance from the source of the loess, the Mississippi river flood plain, was the variable against which properties were measured. The thickness of fragipans at slope summits showed no trend when plotted against the distance from the loess source. The same results were seen when non-summit fragipan thicknesses were plotted against the distance from the loess source.

Even though from east to west no trend in fragipan thickness was perceived, there was a consistent pattern of fragipan thickness change in the county. Dividing the county into quadrants of approximately equal area, and examining the fragipan measurements in each, there are significant changes in fragipan thickness among the quadrants.

A line through the city of Dresden, drawn parallel to the Mississippi river flood plain separates the two east quadrants from the two west quarrants. Highway 22 separates north and south quadrants. Due to the angle highway 22 makes relative to a true east-west line, the transects along highway 22 west of Dresden were considered in the northwest quadrant, whereas those west of Dresden were considered to be in the southeast quadrant. Figure 6 shows Weakley county divided into these quadrants, and the fragipan thickness found.

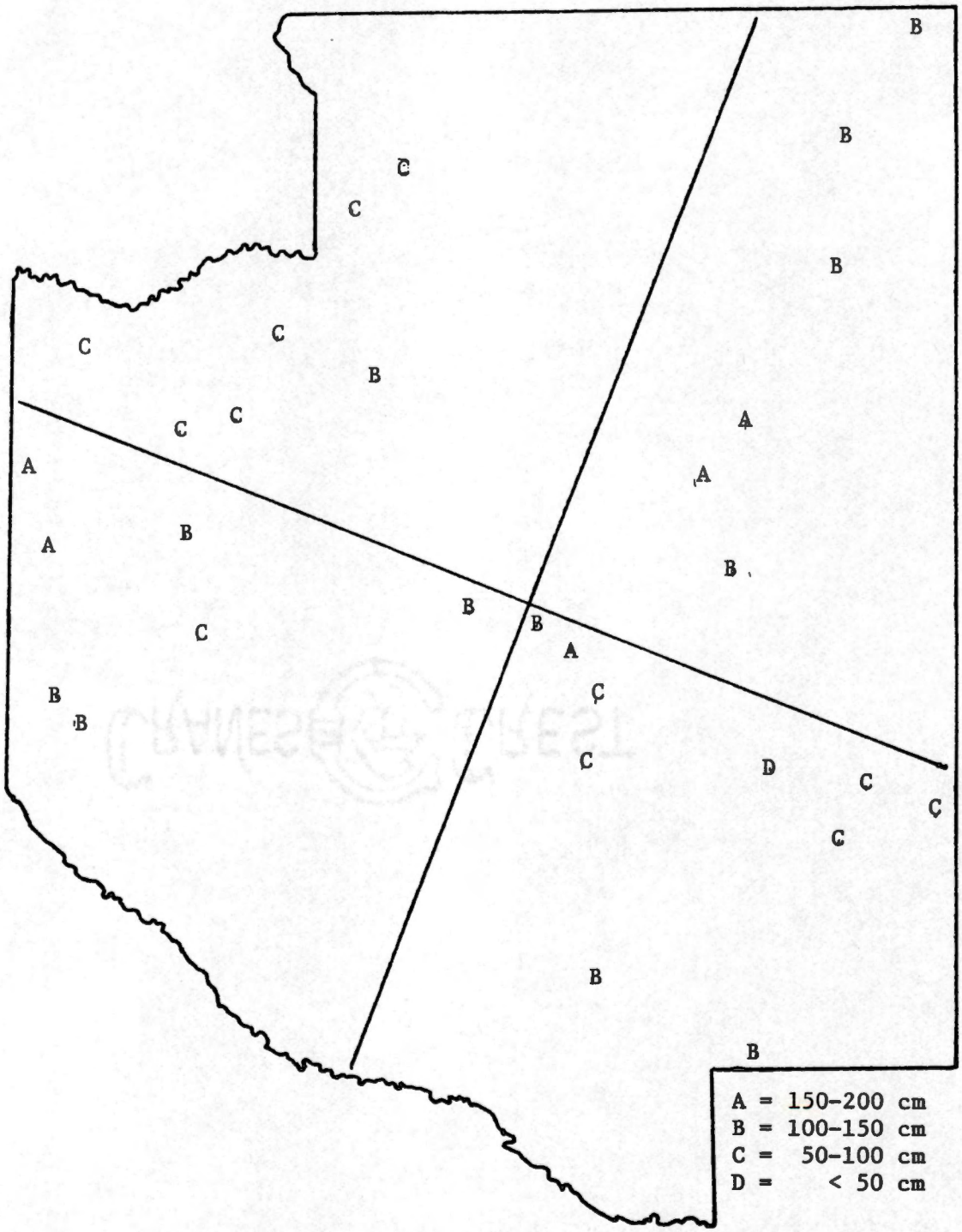


Figure 6. Weakley county partitioned into quadrants, with location and amount of fragipan thickness measurements shown by letters.

Statistics on fragipan thickness are shown in Table 2. With a series of t-tests, each possible pair of quadrants was tested for differences in mean fragipan thickness at the .05 level of probability. There was no difference in fragipan thickness between the southwest and northeast quadrants. Likewise, between the southwest and northeast quadrant there was no difference. However, in comparing the southwest quadrant to the northwest, and the southwest to the southeast quadrant, a significant difference was found in mean fragipan thickness. When testing the northeast quadrant against the southeast and northwest quadrants, a significant difference was noted. Thus, two quadrants, the northeast and southwest, have similarly thick fragipans. The other two quadrants, the northwest and southeast, have similarly thin fragipans. Fragipans ranged in thickness from 18 to 219 cm, averaging 110 cm.

The depth to the top of fragipans was also investigated. This property was unrelated to the distance from the loess source for fragipans located at either summit or non-summit positions. These findings were revealed when a plot of the two variables produced no trend. Depths to fragipans varied between 13 and 172 cm, averaging 70 cm.

Fragipans across the county varied in the degree to which they were hard and compact. Progressing from west to east, fragipans became harder and more compact, as judged by their resistance to augering.

The same parameters, depth to fragipan, thickness of fragipan, and hardness of fragipan were examined as they changed from summit to footslope at the slopes transected. The changes in fragipan thickness

Table 2. Fragipan thickness statistics.

Quadrant	Observations	Mean, cm[a]	Deviation	Range, cm
Northwest	17	81.5b	25.94	26-125
Southwest	12	133.7a	47.32	56-219
Northeast	9	148.7a	29.15	93-180
Southeast	31	99.0b	45.27	18-200

[a]Like letters indicate means were shown not significantly different by t-tests at the .05 level of probability

between adjacent measurements did not differ from zero at the .05 level of significance. As well, the differences between adjacent measurements of the depth to fragipan did not differ from zero at the .05 level of significance.

Plotting the change in depth to fragipan between adjacent measurements against the average distance of those measurements from the summit of the slope on which they occurred showed no trend. The same results were found when the change in fragipan thickness between adjacent measurements was plotted in the same fashion.

No change in the hardness of the fragipans was detected within slopes transected that could be related to slope position. In addition, no change in fragipan hardness was detected in fragipan soils of different drainage in the same transect.

The colors found in fragipans were not related to location in the county. Hues of both 7.5YR and 10YR were seen in fragipans, with equally common occurrence and often in the same fragipan. Value and chroma measurements were most commonly 5/6 in fragipans. Occasionally, 4/6 and 5/8 were observed.

Soil Characteristics - Geomorphic and Morphologic

The colors found in fragipans were not related to location in concerning where it was found and its range of characteristics. The Memphis soil is not commonly found in Weakley county, but when it is found, it occurs in small areas, rarely more than 1 hectare in size. The places where Memphis appeared were closely regulated by topography. This soil was found on rounded or narrow ridgetops and seldom reached

to more than 60 meters below a summit. Another location where Memphis was found was shoulder slopes where a sharp change in slope occurred. At two slopes transected, the Memphis soil occurred on the entire side slope. Both of these were in the extreme northwest corner of the county.

Within the Memphis series of Weakley county, streaks and ped coatings of clean washed silt appeared below a depth of 75 to 100 cm. This was often accompanied by a 10YR matrix hue (as compared to the 7.5YR hue found in the upper part of the profile) and slight brittleness.

The Loring soil was encountered more than any other throughout the county. It was found in positions from ridgetop to footslope, and was the soil predominating the sideslopes. Loring was associated with convex shaped sideslopes. Adjoining Loring at the footslopes was either Grenada, Calloway, or an alluvial soil. Which of these three was encountered normally depended on the steepness of the sideslope. Where the sideslope was gentle, such as sideslopes encountered in west Weakley county, Loring was adjacent to the Calloway soil. At the base of steeper slopes, as those commonly found in east Weakley county, Loring was joined by an alluvial soil. Grenada was encountered at the footslopes when Loring was on a sideslope of intermediate steepness.

The argillic horizon of the Loring soil varied in color following a pattern throughout the county. In the western half of the county, hues of colors in the argillic horizons were equally distributed between 7.5YR and 10YR. Value-chroma readings were among 4/4, 4/6,

5/8 and 5/6. Lorings in the eastern half of the county consistently had hues of 7.5YR in the argillic horizon, with values and chromas similar to those in the western half. Clay skins in the argillic horizon of Loring soils were patchy if present at all.

An incipient A'2 horizon was not uncommon in the Loring soil. Color in the fragipan varied in hue between 7.5YR and 10YR. Contained in the Loring fragipan were few gray mottles and common streaks of gray bleached material along prism faces. Thin, 2-3 mm rinds of bright oxidized soil material often coated prisms.

Grenada soil was found commonly throughout the county, mainly in two landscape types, both defined by topography. The first was in areas of broad level uplands, while the second occurred on concave slope phases. These concave slopes were found at footslopes and at heads of drainageways and draws. Grenada was often the only soil across entire drainageways at their heads. At five slopes transected, Grenada was identified as the soil characterizing the sideslope.

Grenada soil consistently had a 10YR5/6 or 5/8 color in the B horizon, although in the eastern half of the county, it occasionally had a 7.5YR hue. The B horizon contained few fine gray mottles in its upper part which increased with depth until meeting the A'2 horizon. Though it contained slightly more clay than the A horizon, the B horizon was void of clay skins. The A'2 horizon was present, but sometimes weak and incipient. The fragipan below the A'2 horizon had colors following a similar pattern to those in the B horizon, generally 10YR in hue except an occasional 7.5YR hue in the eastern half of the county. The fragipan contained common streaks of gray bleached

material on prism faces, common gray mottling, and occasional zones of clay concentration. The upper part of the fragipan often had portions of the A'2 horizon projecting into it. Prisms, especially those in the upper part of the fragipan, were covered with a 5-8 mm rind of bright oxidized material and often a 3-8 mm clay coating as well.

The Memphis, Loring, and Grenada soils were found throughout the county except on the eastern edge and in areas where considerable erosion had taken place. Here, soils derived partly from the underlying coastal plain materials were found.

The Lexington soil was in landscape positions similar to those in which Memphis occurred whenever coastal plain material influenced the solum. Like Memphis, Lexington soils contained gray bleached zones or gray bleached silt coatings at depth of 75 to 100 cm and lower. However, unlike Memphis, no brittleness was associated with these areas and the color ordinarily was a uniform 7.5YR4/4 or 4/6 throughout the profile.

The Smithdale soil, and exhumed paleosol in Weakley county, was rarely found except in areas of extreme erosion in the far eastern part of the county where nearly the entire overlying loess sequence had been removed.

Many of the upland soils of Weakley county contain fragipans. Among soils with fragipans--Loring, Grenada, and Providence--the depth at which fragipans occurred was unrelated to soil series. In order to determine whether fragipan thickness changed from one soil series to another, a series of t-tests were made. No significant differences at the .05 level were found among the Loring, Grenada, and Providence series.

Pedon Descriptions

Important information was gained through description of the pedon at each site where a pit was dug and samples taken.

Loring I

Ap	0-20 cm	Brown (10YR4/3) silt loam; weak fine granular structure; very friable; many fine and few medium roots; abrupt smooth boundary.
B21t	20-46 cm	Dark brown (7.5YR4/4) silt loam; weak medium prismatic structure parting to moderate medium subangular blocky; friable; common fine roots; common fine pores and fine root channels; few thin patchy clay films on faces peds and in pores and root channels; gradual wavy boundary.
B22	46-74 cm	Dark brown (7.5YR4/4) silt loam; common medium faint yellowish brown (10 YR5/4) mottles or skeletans; weak medium prismatic structure parting to moderate medium subangular blocky; friable; few fine roots; common medium and many fine vesicular pores; common medium very dark brown stains; few fine black concretions; gradual wavy boundary.
Bx1	74-94 cm	Dark brown (7.5YR4/4) silt loam; common medium distinct light brownish gray (loYR6/2) mottles; weak coarse prismatic structure parting to moderate

		medium subangular blocky;hard, firm, compact, brittle;prisms have intervening wedges of friable, light brownish gray (10YR6/2) silt (A'2 material) about 8 cm across the top-narrowing rapidly with depth to become prism coats 1 to 2 cm thick; outer 1 to 2 cm of prisms is yellowish brown (10YR5/6) rind; patchy clay films on faces of peds and in pores; few fine roots within silt coats; many fine and vesicular pores in wedges; few fine vesicular pores within prisms; few fine black stains; gradual irregular boundary.
Bx2	94-180 cm	Dark brown (7.5YR4/4) silt loam; moderate coarse prismatic structure parting to moderate medium subangular blocky; very hard, very firm, compact, very brittle; prisms have continuous coats of light brownish gray (10YR6/2) silt about 1.5 cm thick; few fine black stains within prisms; diffuse boundary.
C	180-240 cm	Dark brown (7.5YR4/4) silt loam with common vertical streaks of light brownish gray (10YR6/2); massive compact, firm.

Remarks: Coastal plain contact was augered to at 315 cm. Below this was about 150 cm of red clay loam, underlain by sandy loam and loamy sand.

Location: The pit site was on Campground Road, 2.0 km north of the intersection of Campground and Hyndsver Roads, in a soybean field. It was 61 meters southwest of an old concrete factory built on the north side of Campground Road and 30 meters south of the roadside. This pit was 62 km from the Mississippi river flood plain.

Topography: The landscape was relatively undissected with gentle slopes. The pit was on a 2 percent slope, 10 meters from the crest of a hill.

Loring II

Ap	0-21 cm	Dark brown (10YR4/3) silt loam; moderate fine granular structure; very friable; common fine roots; abrupt smooth boundary.
B21t	21-54 cm	Dark brown (7.5YR4/4) silt loam; weak medium prismatic structure parting to moderate medium subangular blocky; few fine Mn stains; few fine Fe stains; friable; few fine roots; common fine pores; clear wavy boundary.
B22	54-64 cm	Mixed dark brown (7.5YR4/4) and yellowish brown (10YR5/4) silt loam; common dark brown (7.5YR4/4) stains on ped faces; moderate, fine subangular blocky structure; common medium Mn stains and concretions; few fine Fe stains; few fine roots; few fine pores; gradual wavy boundary.
Bx1	64-110 cm	Dark brown (7.5YR4/4) and brown (7.5YR5/4) silt loam; weak coarse prismatic structure;

thin discontinuous reddish brown (5YR4/3) clay films on faces of peds; common vertical pale brown (10YR6/3) silt coats 2.5-3.5 cm thick between prisms; few pockets about 8 cm in diameter of pale brown (10YR6/3) silt loam near upper boundary; firm, brittle, compact; common medium concretions of both Mn and Fe within pale brown silt coats; strong brown (7YR5/8) rind on prism faces 5-8 cm thick; common fine Mn and few fine Fe concretions in matrix of prisms; few fine and few medium pores; few fine roots; gradual wavy boundary.

Bx2 110-168 cm Dark brown (7.5YR4/4) silt loam; weak coarse prismatic structure; strong brown (7.5YR5/8) rind on prism faces 3-4 mm thick; pale brown (10YR6/3) 7-8 mm thick; few fine medium Mn and Fe concretions; firm, brittle, compact; few fine vesicular pores; C horizon is below.

Remarks: The C horizon had a diffuse lower boundary between 190 and 284 cm. The pale brown (10YR6/3) seams and streaks stopped at a depth of 284 cm. The coastal plains contact was reached at a depth of 417 cm.

Location: This pit was in a recently plowed field along the east-west gravel road 2.0 km north of Mt. Pelia, 0.4 km east of the Obion county line. It was 61.1 meters southwest of the point where the gravel road turns 90 degrees to the north and a field road is the continuation of the gravel road in a straight line. This pit was 50 km east from the Mississippi river flood plain.

Topography: At this site the landscape was of gentle relief and relatively undissected. The pit was on a narrow ridgetop at a 2 percent slope which broke to a 5 percent slope within 10 meters of the ridge. The ridge continued level in one direction and increased in elevation towards the other direction.

Loring III

Ap	0-17 cm	Dark brown (7.5YR4/4) silt loam; weak medium granular structure; very friable; few medium and fine roots; abrupt smooth boundary.
B21t	17-41 cm	Dark brown (7.5YR4/4) silt loam; moderate medium and fine subangular blocky structure; friable; few fine pores and roots; clear wavy boundary.
B22	41-61 cm	Dark brown (7.5YR4/4) silt loam; moderate coarse subangular blocky structure; almost continuous pale brown (10YR6/3) silt coats on faces of peds; few fine pale brown (10YR6/3) skeletans in matrix of peds; few fine orange Fe stains; common fine Mn concretions; slightly brittle, compact, firm; common fine pores; few fine roots; clear wavy boundary.
Bx1	61-91 cm	Dark brown (7.5YR4/4) silt loam; common medium yellowish brown (10YR5/4) mottles; weak coarse prismatic structure; nearly continuous pinkish gray (7.5YR6/2) silt coats on faces of prisms; common thin discontinuous clay films on faces

		of peds; few 10-15 mm thick vertical streaks of pinkish gray (7.5YR6/2) silt; firm, brittle, compact; gradual wavy boundary.
Bx2	91-114 cm	Dark brown (7.5YR4/4-4/6) silt loam; weak coarse prismatic structure; nearly continuous pinkish brown (7.5YR6/2) silt coats on faces of peds; common 10-15 mm vertical gray streaks; firm, brittle, compact; gradual wavy boundary.
Bx3	114-198 cm	Reddish brown (5-7.5YR4/4) silt loam with noticeable sand increase with depth; weak coarse prismatic structure; common gray streaks; clear boundary.
IIC	198-212 cm	Reddish brown (5YR4/4) silt loam

Remarks: The upper boundary of the IIC horizon was where the coastal plains material began.

Location: This site was 8.04 km east of Dresden along highway 54, 0.4 km east-northeast of the Kenneth Moore residence. The pit was 114 meters north of an old roadway and 194 meters east of the gravel road off of highway 54. The pit was dug in recently disked soybean residue and was 80 km east of the Mississippi river flood plain.

Topography: The pit was located on a narrow ridgetop, the ridge crest continuing level in two directions. The slopes coming off the ridge on either side of the pit were 2 percent, becoming greater, to 6 percent with increasing distance from the ridge crest. The landscape was slightly more dissected than that at the other pits and the slopes a little steeper.

Grenada

Ap	0-17 cm	Brown and dark brown (10YR4/3) silt; few very fine dark brown (10YR3/3) stains; moderate medium granular structure; friable; many roots; abrupt boundary.
B21	17-53 cm	Yellowish brown (10YR5/6) silt loam with few very fine dark brown (10YR3/3) stains; weak coarse prismatic parting to moderate fine and medium subangular blocky structure; friable; many fine roots; gradual smooth boundary.
B22	53-75 cm	Yellowish brown (10YR5/6) silt loam with common faint fine gray mottles and common fine distinct dark brown (10YR3/3) stains; weak coarse prismatic parting to moderate fine and medium subangular blocky structure; friable; many fine roots; smooth clear boundary.
A'2	75-84 cm	Pale brown (10YR6/3) silt loam with few dark brown (10YR3/3) stains; fine moderate subangular blocky structure with common fine rounded peds of strong brown (7.5YR5/8); friable; many fine roots; clear wavy boundary.
B'x1	84-102 cm	Brown to dark brown (7.5YR4/4) silt loam; coarse moderate prisms parting to medium subangular blocky structure; polygons are greater than 15 cm across between gray streaks which are two or less cm wide; minor thin gray streaks

throughout polygons; wide gray streaks often bounded by strong brown (7.5YR 5/8) zone; many dark brown (7.5YR3/4) stains throughout horizon; firm; no roots in polygons; few roots in gray streaks; horizon is very hard and brittle; gradual wavy boundary.

B'x2	102-181 cm	Brown to dark brown (7.5YR4/4) silt loam; coarse moderate prisms parting to medium subangular blocky structure; polygons are greater than 15 cm across between gray streaks which are two or less cm wide; minor thin gray streaks are common throughout polygons; few to common dark brown (7.5YR3/4) stains; very firm; no roots; horizon is very hard and brittle; diffuse wavy boundary.
C	181-220 cm	Dark yellowish brown (10YR4/4) and strong brown (7.5YR4/6) silt loam; few fine streaks of gray; massive; friable; horizon is compact and hard; no roots.

Remarks: Coastal plain material begins at 365 cm.

Location: The site was at the University of Tennessee farm on old Fulton highway in Martin, Tennessee. The pit was in a bermuda grass pasture 650 meters south of the southwest corner of the church built directly north of the pasture and 150 meters north of the creek running to the south of the pasture. The pit was 58 km east of the Mississippi river flood plain.

Topography: The pit was dug at a broad nearly level upland flat area. At the pit the slope was 2 percent. The landscape was relatively undissected and of gentle relief.

Physical Properties of Samples

Particle size distribution for the soils at each site are shown in Table 3, along with ratios of coarse silt to fine silt and fine sand plus very fine sand to total silt.

In all soils, except Loring III, the very coarse sand, coarse sand, and medium sand fractions were composed entirely of concretions--black, brown, or tan. The A horizons generally contained pieces of charcoal or brick in these coarser sand fractions. In the Grenada, Loring I, and Loring II profiles, the fluctuations in the sand content were caused by variation in concretion amount among horizons. The very fine plus fine sand content of these three profiles remained below 2.5 percent in all cases except the C horizon of the Loring I. Sand in the Loring III profile increased dramatically with depth beginning at the Bx2 horizon. The horizons above the Bx2 were similar to those of the other three profiles in sand distribution.

Silt varied between 68 and 85 percent among all four profiles, except the IIC of Loring III, which contained 53 percent silt.

The ratio of fine sand plus very fine sand to total silt demonstrated a different trend within each profile, although among the four profiles the only evident trend was that the ratio in the A horizons was always greater than that the B21. The Loring III profile exhibited the greatest change with respect to this ratio. Remaining fairly constant from

Table 3. Physical properties of some fragipan soils of Weakley county.

Soil	Horizon	Depth (cm)	Particle distribution (mm) % sand 2.0-.25	% sand .25-.10	% sand .10-.05	% silt 0.05-0.02	% silt 0.02-0.002	% clay <.002	Textural class	fs+vfs/silt ratio[a]	csi/fsi ratio[b]
Loring I	Ap	0-20	1.5	0.7	0.7	49.2	35.1	12.7	Sil	0.017	1.40
	B21t	20-46	0.4	0.3	0.3	36.8	35.0	27.1	Sil/sicl	0.009	1.05
	B22t	46-74	1.0	0.4	0.4	38.2	33.4	26.3	Sil/sicl	0.013	1.04
	Bx1	74-94	1.3	0.4	0.4	42.8	32.6	22.5	Sil	0.010	1.31
	Bx2	94-180	0.6	0.4	0.5	44.9	33.8	19.8	Sil	0.011	1.33
	C	180-240	2.8	2.1	1.2	45.6	30.8	17.3	Sil	0.043	1.49
	incipient A'2	74	0.8	0.2	0.4	43.3	37.0	18.2	Sil	0.008	1.17
	Bx2	151	1.0	0.3	0.4	43.3	37.4	17.5	Sil	0.008	1.16
	Bx2 gray seam	151	0.4	0.2	0.2	47.0	38.3	13.9	Sil	0.004	1.23
Loring III	Ap	0-21	1.2	1.0	1.0	48.6	31.5	16.7	Sil	0.025	1.54
	B21t	21-54	0.8	0.3	0.9	39.3	34.8	24.0	Sil	0.016	1.13
	B22	54-64	4.3	1.2	1.6	38.1	31.3	23.5	Sil	0.040	1.22
	Bx1	64-110	1.6	0.6	1.2	40.1	30.5	26.0	Sil	0.025	1.34
	upper Bx2	110-139	0.3	0.2	1.0	45.6	28.2	24.6	Sil	0.017	1.62
	lower Bx2	139-168	1.9	0.5	1.0	45.0	33.8	17.9	Sil	0.019	1.33

Table 3. Continued

Soils	Horizon	Depth (cm)	Particle size distribution (mm) % sand 2.0-.25	% sand .25-.10	% sand .10-.05	% silt 0.05-0.02	% silt 0.02-0.002	% Clay <.002	Textural class	fs+vfs/silt ratio[a]	csi/fsi ratio[b]
Loring III	Ap	0-17	0.8	0.5	1.1	43.7	34.4	19.4	Sil	0.021	1.27
	B21t	17-41	0.3	0.3	0.6	34.8	37.0	27.0	Sil/sicl	0.013	0.94
	B22	41-64	1.0	0.5	0.6	36.7	40.6	20.6	Sil	0.014	0.90
	Bx1	61-91	0.7	0.4	0.5	39.0	35.4	23.8	Sil	0.012	1.10
	Bx2	91-114	1.6	1.0	0.8	40.1	34.6	21.9	Sil	0.023	1.16
	Bx3	114-136	3.2	4.5	2.0	40.1	30.5	19.7	Sil	0.092	1.32
	Bx3	136-198	4.0	5.9	2.2	40.4	28.2	19.2	Sil	0.118	1.44
	IIC	198-212	7.5	15.8	3.4	27.3	26.1	19.8	Sil	0.361	1.05
Grenada	Ap	0-17	1.6	1.0	1.2	45.7	40.4	10.1	Silt	0.026	1.13
	B21	17-53	0.4	0.3	0.3	39.5	36.1	23.3	Sil	0.008	1.09
	B22	53-75	1.6	0.7	0.7	41.2	35.6	20.1	Sil	0.018	1.16
	A'2	75-84	3.6	0.6	0.6	44.4	34.9	16.0	Sil	0.015	1.27
	B'x1	84-102	1.7	0.6	0.4	43.2	31.6	22.0	Sil	0.013	1.37
	B'x2	102-181	0.8	0.2	0.4	42.3	34.9	21.3	Sil	0.018	1.22
	C	181-220	0.3	0.3	0.3	47.9	36.0	15.2	Sil	0.007	1.33
	B'x2 clay pocket	94	1.5	0.3	0.3	37.4	30.5	30.0	Sicl	0.009	1.23

[a] fs is percent fine sand (0.25-0.10 mm)
vfs is percent very fine sand (0.10-0.05 mm)

[b] csi is percent coarse silt (0.05-0.02mm)
fsi is percent fine silt (0.02-0.002mm)

the surface through the Bx1 horizon, it increased strikingly from the Bx1 to the IIC horizon. The Loring II and Grenada profiles showed a definite break in the fine plus very fine sand to total silt ratio between the B21t and the B22 horizon by nearly doubling. The ratio then receded at greater depth to values near those in the surface horizons. In the Loring I profile no fluctuation was observed to a depth of 150 cm where the ratio began to increase. At a depth of 238 cm in the Loring II profile, the ratio is .043, showing a four fold increase from the 151 cm point.

When similar horizons among the profiles were compared, the coarse silt to fine silt ratio tended to decrease as the loess thinned. In all of the profiles the ratio had its minimum within the B horizon. Lorings I and III profiles had this minimum in the B22t whereas the other two profiles had it in the B21. The coarse silt/fine silt ratio had, in all four profiles, its maximum value within the fragipan. In the lowest horizon sampled of Lorings II and III this ratio decreased considerably from the horizons directly above. The same horizon of the Grenada and Loring I profiles showed an increase from the horizons above.

Clay percentages in the B horizons varied among the profiles. The Grenada soil had the lowest with 23.3 and 20.1 percent clay in the two B horizons. The B21 horizon of the Loring I soil had the highest clay content of any horizon (27.1 percent). All four of the B22 horizons contained percentages at or below that in their corresponding B21 horizon.

A secondary clay bulge occurred in the fragipan of the Grenada soil. The incipient A'2 horizon of the Loring I soil contained less clay than

adjacent horizons. In the Loring III profile the Bx1 horizon showed a clay increase from the B22. The Loring II soil exhibited its greatest clay percentage in the Bx1 horizon. With depth, clay content of all four profiles subsided to less than 20 percent.

Chemical Properties of Samples

Differences within and among profiles in chemical properties were revealed by chemical analyses of the samples. Some chemical properties of the samples are in Table 4.

Cation exchange capacity per 100 grams of soil showed a general decreasing trend from west to east in the county when like horizons were compared. CEC trends within profiles followed clay fluctuations closely as seen by the consistency in the CEC to percent clay ratio which ranged from 0.8 to 1.1. This ratio in all four profiles remained fairly constant, slightly increasing with depth. The ratio in the Loring III profile though, while increasing with depth to the Bx3 horizon, diminished by nearly half from the Bx3 to the IIC horizons.

Exchangeable Ca followed a similar pattern in all four profiles. First, a decrease from the B21 through the Bx1 or Bx2 horizon was noted. Then Ca increased with depth to the lowest horizon sampled. This increasing trend was most marked in the Loring II and Grenada profiles. From west to east among profiles, in similar horizons, there was a definite pattern of decreasing exchangeable Ca. Exchangeable Ca ranged from a low of 1.4 meq/100g soil in the Bx2 of the Loring III soil to a high of 9.4 in the B21t of the Loring II soil.

Table 4. Chemical properties of some fragipan soils of Weakley county.

Site	Horizon	Depth (cm)	CEC	Exchangeable cations Ca	Mg	K	Na	Extractable Acidity	Base Sat %	pHw[b]	pHs[c]	Ca/Mg	CEC %clay
			(milliquivilants/100g soil)										
Loring I	Ap	0-20	10.4	1.8	0.7	0.7	0.1	7.1	32	5.7	4.9	2.5	0.8
	B21t	20-46	22.3	5.2	3.9	0.3	0.1	12.8	43	5.2	4.1	1.3	0.8
	B22t	46-74	19.8	3.4	4.8	0.3	0.2	11.1	44	4.0	4.0	0.7	0.8
	Bx1	74-94	18.7	3.0	4.0	tr.	0.4	11.4	39	4.8	3.5	0.8	1.2
	Bx2	94-180	19.8	2.2	5.7	0.3	0.6	11.0	44	5.3	3.5	0.4	1.0
	C incip	180-240	17.2	5.0	3.9	0.2	0.9	7.2	58	6.0	4.1	1.3	1.0
	A'2[a]	74	19.2	3.0	3.4	0.3	0.2	12.2	36	4.8	3.7	0.9	0.9
	Bx2[a]	151	18.1	1.9	6.4	0.2	0.7	8.6	53	4.2	3.4	0.6	1.0
	Bx2 gray seam	151	11.9	1.1	3.3	0.2	0.4	6.9	42	5.0	3.2	0.3	1.2
erosional surface													
Upper loess			15.8	4.2	4.2	0.2	1.1	6.1	62	5.8	4.5	0.9	---
Lower loess			19.3	4.4	4.6	0.2	1.5	8.6	54	5.1	4.4	1.1	---
Loring II	Ap	0-21	13.8	4.3	0.8	0.2	0.1	8.4	39	5.5	4.7	5.4	0.8
	B21t	21-54	19.0	9.4	1.8	0.2	0.1	7.5	61	5.7	4.8	5.2	0.8
	B22	54-64	19.2	7.8	2.7	0.2	0.1	8.5	56	5.8	4.7	2.9	0.8
	Bx1	64-110	21.7	4.5	3.2	0.2	0.3	13.6	37	5.1	3.6	1.4	0.8
upper	Bx2	110-139	22.0	4.0	6.0	0.3	0.2	11.6	47	5.1	3.5	0.6	0.9
lower	Bx2[a]	139-168	19.6	4.4	4.2	0.2	0.2	10.6	46	5.4	3.6	1.0	1.1

Table 4. Continued

Site	Horizon	Depth (cm)	CEC	Exchangeable cations Ca	Mg	K	Na	Extractable Acidity	Base sat %	pHw[b]	pHs[c]	Ca/Mg	CEC %clay
			(millequivilants/100g soil)										
Loring III	Ap	0-17	13.7	6.8	1.5	0.2	0.1	5.1	63	6.3	5.6	4.5	0.7
	B21t	17-41	20.6	4.3	3.4	0.3	0.1	12.5	39	5.0	3.7	1.2	0.8
	B22t	41-61	17.6	1.8	2.4	0.2	0.2	13.0	26	4.9	3.7	0.8	0.8
	Bx1	61-91	18.7	1.3	3.8	0.2	0.3	11.7	34	5.0	3.4	0.3	0.8
	Bx2	91-114	17.8	1.4	4.2	0.2	0.3	9.6	43	5.3	3.3	0.4	0.9
	Bx3[a]	114-136	17.0	1.6	5.2	0.1	0.4	10.5	40	5.3	3.3	0.4	0.9
	IIC	198-212	10.6	1.8	2.6	0.2	0.2	5.8	46	5.3	3.6	0.7	0.5
Grenada	Ap	0-17	12.5	6.6	0.7	0.1	0.1	5.0	60	6.4	5.4	9.4	1.2
	B21	17-53	16.2	4.1	2.1	0.2	0.2	9.7	40	5.2	3.9	2.0	0.7
	B22	53-75	18.4	2.0	2.4	0.2	0.2	13.6	26	4.8	3.5	0.6	0.9
	A'2	75-84	17.0	1.8	2.6	0.2	0.2	12.2	28	4.7	3.4	0.8	1.0
	B'x1	84-102	21.2	4.6	5.1	0.3	0.3	10.9	48	4.9	3.4	1.0	0.9
	B'x2[a]	102-181	18.5	4.0	5.4	0.3	0.5	8.3	55	4.7	3.1	0.8	0.9
	C	181-220	16.7	3.8	5.8	0.2	0.6	6.2	62	5.5	3.8	0.7	1.1
	B'x1 clay pocket	94	25.2	4.8	5.9	0.3	0.3	13.9	45	4.7	3.4	0.8	0.8
erosional surface													
Roxana paleosol			23.5	5.5	4.6	0.2	0.4	12.8	46	5.2	3.6	1.2	

[a] indicates critical depth

[b] pH determined in a 1:1 soil to water solution

[c] pH determined in a 1:1 soil to N KCl solution

The four profiles are similar with respect to exchangeable Mg. Each of the A horizons contain less than 1.5 meq/100g soil. All four profiles had an increasing trend from A horizon to C horizon. Only the Loring II profile deviated from this with a 1.7 meq/100g soil decrease between 124 cm and 142 cm, the 142 cm depth being the center of the lowest sampled horizon.

The ratio of meq/100g soil Ca to meq/100g soil of Mg reached a minimum in the Bx2 horizon of all three Loring soils. In the Grenada profile, the minimum of this ratio was in the B22 horizon.

Exchangeable K remained below 0.3 meq/100g soil in all samples except the A horizon of the Loring I soil, where it reached 0.7 meq/100g soil.

Exchangeable Na followed a similar pattern in all of the profiles. In all of the A and B horizons it was either 0.1 or 0.2 meq/100g soil. At the Bx1 horizon of all four soils, Na began to increase. This increase was most notable in the Loring I soil where Na reached 0.9 meq/100g soil in the C horizon, and in the Grenada soil where it reached 0.6 meq/100g soil in the C horizon. In the Loring III soil Na reached 0.4 meq/100g soil in the Bx3 and dropped to 0.2 meq/100g soil in the IIC horizon. The Loring II soil had values of 0.2 and 0.3 meq/100g soil in the Bx horizon, only slightly rising above the 0.1 meq/100g soil in the A and B horizons.

Extractable acidity had its highest values in the B2 or Bx1 horizon of all four soils. Total averages of extractable acidity for the four soils were between 9.4 and 10.2 meq/100g soil.

Base saturation showed considerable fluctuation within all of the profiles. The Loring III and Grenada soils showed similar patterns though, both have a minimum in the B horizon and slightly increased within the fragipan and C horizon. Lorings I and II are somewhat similar profiles with respect to base saturation, each with a maximum in the B horizon. Slight increases with depth were noted from the Bx1 horizon to horizons below. At the critical depth for differentiation between Alfisols and Ultisols, each soil had a base saturation greater than 35 percent, the delineation point. From west to east, the base saturations of the four profiles at their critical depths were: Loring II--46 percent, Grenada--55 percent, Loring I--53 percent, and Loring III--40 percent.

Soil pH in water ranged from 4.8 to 5.8 in the B2 horizons. In Bx horizons it was between 4.7 and 5.3, and C horizons are 5.3 and 6.0. Soil pH in salt differed from that measured in water by 0.8 to 1.8, the difference always increasing with depth in profiles.

Mineralogical Properties of Samples

Fine Sand plus Very Fine Sand Fraction

Results[a] of the observation of the fine sand plus very fine sand fraction (0.25-0.05 mm) under the petrographic microscope are in Table 5. The percent quartz in this fraction fluctuated considerably. A definite increasing trend with depth was seen in the Loring III soil.

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[a]Grain counts were made by Dr. D. A. Lietzke

Table 5. Minerals in fine sand plus very fine sand fraction from grain counts under a petrographic microscope.

Site	Horizon	Depth (cm)	Percentages						Ratios	
			QZ	FD	M	Mn Nodules	Silt Clumps	other	QZ/FD	QZ/M
Loring I	Ap	0-20	35	50	5	0	4	5	0.71	7.14
	B21t	20-46	7	51	25	0	6	9	0.15	0.30
	B22t	46-74	9	71	7	0	4	1	0.13	1.28
	Bx1	74-94	15	64	4	7	2	6	0.23	3.49
	Bx2	94-180	11	57	13	6	5	6	0.21	0.86
	C	180-280	44	42	5	5	0	0	1.04	7.58
incipient	A'2	74	19	46	20	1	0	0	0.41	0.96
	Bx2	151								
	Bx2 (gray seam)	151	8	34	13	3	40	0	0.23	0.61
erosional surface										
upper-Peoria loess			39	46	9	0	2	2	0.85	4.30
lower-Roxana loess			37	33	21	6	2	0	1.13	1.76
Loring II	Ap	0-21	30	24	26	18	1	0	1.25	1.12
	B21t	21-54	36	26	5	26	0	5	1.39	6.74
	B22	54-64	12	6	8	72	0	0	1.80	1.39
	Bx1	64-110	20	21	15	43	0	0	0.96	1.32
Upper	Bx2	110-139	26	32	30	3	7	0	0.84	0.87
Lower	Bx2	139-145	20	33	36	8	2	0	0.60	0.56

Table 5. Continued

Site	Horizon	Depth (cm)	Percentages QZ	FD	M	Mn Nodules	Silt Clumps	other	Ratios QZ/FD	QZ/M
Loring III	Ap	0-17	57	22	1	2	9	6	2.56	35.00
	B21t	17-41	46	28	9	2	4	14	1.64	11.09
	B22	41-61	11	38	22	22	4	0	0.30	0.50
	Bx1	61-91	35	17	14	9	23	0	2.08	2.45
	Bx2	91-114	64	1	2	30	0	0	37.65	24.65
upper	Bx3	114-136	62	8	7	7	14	0	7.41	8.79
lower	Bx3	136-198	47	3	0	47	0	0	14.00	68.00
	IIC	198-207	93	3	0	2	0	0	25.97	133.60
Grenada	Ap	0-17	24	40	4	0	24	6	0.60	6.05
	B21	17-53	25	59	10	0	2	0	0.43	2.37
	B22	53-75	18	35	41	0	3	0	0.43	0.45
	A'2	75-84	10	35	21	4	36	1	0.39	0.47
	B'x1	84-102	17	35	20	0	26	0	0.50	0.90
	B'x2	102-181	25	14	16	1	32	9	1.74	1.51
	C	181-220	18	14	12	0	50	2	1.28	1.54
	B'x1 (clay pocket)		29	17	13	30	8	2	1.73	2.16
erosional surface										
Roxana paleosol			32	4	1	60	0	0	6.67	18.17

QZ = Quartz

FD = Feldspar

M - Muscouite and biotite mica

The Loring I C horizon increased in quartz by 25 percent above that in the B and Bx horizons. The two samples taken from an erosional surface down slope from the Loring I pit both contained at least 10 percent more quartz than the average horizon in the Loring I soil. The similar sample taken down slope from the Grenada pit followed the same pattern. Quartz in the upper two horizons of the Loring II profile was 10 to 20 percent higher than in lower horizons.

The percent feldspar in this fraction also fluctuated a great deal within profiles. Feldspar in the Loring III profile was between 22 and 39 percent in the uppermost three horizons. It was then seen to decrease dramatically between the B22t and Bx2 horizons and remained low with increasing depth. Feldspar in the Grenada steadily decreased with depth with a break at the Bx1 horizon. Feldspar percentages varied greatly among profiles from an average of 56 percent in the Loring I profile to 15 percent in the Loring III profile.

Mica in the fine sand plus very fine sand fraction rarely exceeded 20 percent in any of the profiles and varied considerably within profiles.

Sand size clumps of silt particles composed of quartz and feldspar grains cemented together composed from 0 to 50 percent of the grains in this fraction. Clumps were abundant in the Grenada fragipan and C horizon, averaging 36 percent, and in the Loring III fragipan, averaging 10 percent. Otherwise, values in horizons were generally less than 8 percent.

Manganese nodules found in this fraction varied a great deal within profiles. The Loring II soil had a conspicuous manganese nodule

maximum of 72 percent in the B22t horizon. The Loring III soil averaged 16 percent throughout its profile. Horizons in the other two soils all contained less than 10 percent manganese nodules. Some of these nodules were heavily coated silt clumps, but most contained only a few sand or silt grains.

Other minerals found in trace quantities in the fine sand plus very fine fraction included plant opal, isotropic and opaque minerals.

Ratios of percentages of quartz to feldspar and quartz to mica vary widely among and within profiles. The quartz to feldspar ratio increased dramatically with depth in the Loring III profile. In the Loring II profile this ratio steadily and slowly decreased. The Loring I profile contained a quartz/feldspar minimum at 60 cm in the B22t horizon. The A through Bx horizons of the Grenada soil had simialr ratios. From the Bx1 to the Bx2 horizon this ratio tripled and remained high in the C horizon.

The quartz/mica ratio also increased quickly with depth in the Loring III profile. This ratio was lowest in the B22 horizon of the Grenada soil. The B21t horizon of the Loring II soil had a conspicuously higher ratio than any other Loring II horizons. Quartz/mica in Loring I was sporadic.

Fine sand plus very fine sand samples run on the thermal analyser produced more accurate estimates of the quartz percentage, as seen in Table 6. These results are not in complete agreement with the quartz percents found by viewing grain mounts under the petrographic microscope. Discrepancies can be traced to various factors. Some sampling error is inherently involved. Even though at least 300 grains per sample were counted under the microscope counting errors could be

Table 6. Quartz content of soil fractions by differential scanning calorimetry.[a]

Site	Horizon	Depth (cm)	Percent Quartz Size fraction (mm) 0.25-0.10	0.05-0.02	0.02-0.002
Loring I	Ap	0-20	49	52	18
	B21t	20-46	45	38	18
	B22t	46-74	46	40	15
	Bx1	74-94	45	47	20
	Bx2	94-150	42	38	18
	C	180-240	58	40	23
incipient	A'2	74	42	33	18
	Bx2	151	37	28	30
	Bx2 (gray seam)	151	40	44	18
erosional surface					
upper-Peoria loess			63	45	32
lower-Roxana loess			64	48	20
Loring II	Ap	0-21	58	44	20
	B21t	21-54	17	31	16
	B22	54-64	10	33	17
	Bx1	64-110	10	31	20
upper	Bx2	110-139	27	30	18
lower	Bx2	139-145	22	30	17

Table 6. Continued

Site	Horizon	Depth (cm)	Percent Quartz Size fraction (mm) 0.25-0.10	0.05-0.02	0.02-0.002
Loring III	Ap	0-17	62	44	18
	B21t	17-41	51	40	20
	B22	41-61	56	44	22
	Bx1	61-91	57	46	20
	Bx2	91-114	67	47	30
	upper Bx3	114-136	82	49	37
	lower Bx3	136-198	63	47	31
	IIC	198-212	85	52	33
Grenada	Ap	0-17	46	52	20
	B21t	17-53	52	40	16
	B22	53-75	36	43	15
	A'2	75-84	30	41	18
	B'x1	84-102	22	36	16
	B'x2	102-181	20	36	17
	C	181-220	31	47	19
	B'x1 (clay pocket)	94	24	36	20
	erosional surface Roxana paleosol		24	56	29

[a]sample scanned from 375°C to 600°C

present. Another factor is that under the microscope quartz may sometimes have been misidentified as feldspar. Probably the major causes of the discrepancies are the silt clumps and manganese nodules present in this fraction. Quartz grains coated with manganese were disguised and interpreted as manganese modules under the microscope. Likewise, quartz grains within silt clumps were not included in the quartz but in the silt clump category. The thermal analyzer, however, measures the quartz regardless of whether it is coated or in a silt clump, because the alpha-beta transition of crystalline quartz occurs at 575^{o}C regardless of particle size or coatings on grains. This method provides a more accurate estimate of the quartz content, and the results from the thermal analyzer were used over those from grain countings for interpretational purposes.

In the profile of the Loring I soil, the quartz percent as estimated by thermal analysis for the fine sand plus very fine sand fluctuated little until the C horizon where it increased 9 to 10 percentage points over horizons higher in the profile. The two samples from the Loring I erosional surface were very similar in quartz content, but both had considerably higher values than those in the Loring I profile. Quartz in the Loring II profile was seen to decrease dramatically from the A to the B21t horizon, and remain low until the Bx2 and Bx3 horizons where it increased slightly. The Loring III quartz displays an increasing pattern from the B21t to the IIC horizon. In the Grenada soil, quartz slowly decreased from the surface horizon to the B'x2 horizon, then increased by 10 percentage points to the C horizon.

Coarse Silt Fraction

Samples of coarse silt (0.05-0.02 mm) from each horizon were run on the thermal analyzer to estimate the quartz content, shown in Table 6. Quartz content of coarse silts in surface horizons were all considerably greater than lower horizons except for the Loring III A horizon. Quartz in the Loring III soil steadily increased with depth from 40 percent in the B21t horizon to 52 percent in the IIC horizon. The other three soils were very different. Loring I, aside from the A horizon, had between 38 and 40 percent quartz throughout its profile, except in the Bx1, where it reached 47 percent. The Loring II profile had 30 to 33 percent quartz in all horizons below the surface. The quartz range in the Grenada profile was 36 to 43 percent below the surface horizon, with lowest values in the fragipan horizons. The Grenada site erosional surface sample contained the greatest percent quartz of all the samples, having 56 percent.

Fine Silt Fraction

Table 6, pages 78-79, contains estimates of quartz percent in the fine silt fraction by thermal analysis. Profiles of the Loring I, Loring II, and Grenada soils show little fluctuation in quartz content, all horizons being between 15 and 23 percent. The Loring III profile was within this range in the four uppermost horizons, then the quartz increased by 10 percentage points to the Bx2 horizon and is between 33 and 37 percent in the remaining horizons.

Measuring the heights of quartz, (4.21 Angstroms), feldspar (3.25-3.4 Angstroms), and mica (10 Angstroms) peaks from x-ray

diffractograms enables quartz/feldspar and quartz/mica ratios to be calculated for the fine silt fraction (0.02-0.002mm) as seen in Table 7. Absolute values of these ratios are not of value, but changes in the ratio within profiles do yield valuable information. The quartz/feldspar ratio of the Loring III soil was lowest in the Bx2 horizon with larger values both in upper horizons and lower horizons. The profiles of Lorings I and II and the Grenada soil follow very similar patterns of quartz/feldspar ratios, slowly decreasing from the A horizon to the Bx2 and C horizons.

The quartz/mica ratio in the Loring III profile had a minimum in the B22t horizon, with values up to three times higher in the upper and lower horizons. The Grenada profile had a minimum in the B'x1 horizon, with values in the upper and lower horizons averaging two times higher. Loring I quartz/mica ratios were fairly constant between the Ap and Bx1 horizon, averaging 2.5, then decreasing to 0.8 in the Bx2 and rising again to 2.3 in the C horizon. This ratio in the Loring II decreased by one unit between the Ap and B horizon, changing from 3.8 in the Ap horizon to an average of 2.7 in the B horizon. At the Bx1 horizon it increased to 3.5, then began to decrease again to 1.7 in the lower Bx2 horizon.

Results from both x-ray and thermal analysis of clay samples enabled estimation of mineral percentages in the clay fraction (0.002 mm) as shown in Table 8. These are rough estimates, considered to be within 5 percent of actual values. Thermal analysis results provided information on quartz and kaolinite, along with relative values of vermiculite, while the X-ray diffractograms contained information on all of the minerals listed. Quartz was rarely found in the clay

Table 7. X-ray diffractogram data for fine silts.

Site	Horizon	Depth (cm)	Ratios of peak heights: Quartz/ Feldspar	Ratios of peak heights: Quartz/ Mica
Loring I	Ap	0-20	2.97	1.96
	B21t	20-46	2.57	2.75
	B22t	46-74	2.65	2.90
	Bx1	74-94	2.17	2.52
	Bx2	94-180	1.69	0.81
	C	180-240	1.94	2.31
incipient	A'2	74	2.42	2.10
	Bx2	151	1.09	1.54
gray seam from	Bx2	151	2.03	2.52
erosional surface				
upper-Peoria loess			1.70	2.31
lower-Roxana loess			1.70	3.94
Loring II	Ap	0-20	2.81	3.80
	B21t	21-54	2.80	2.47
	B22	54-64	2.74	2.91
	Bx1	64-110	2.09	3.54
upper	Bx2	110-139	1.76	2.08
lower	Bx2	139-145	1.58	1.74

Table 7. Continued

Site	Horizon	Depth (cm)	Ratios of peak heights: Quartz/ Feldspar	Ratios of peak heights: Quartz/ Mica
Loring III	Ap	0-17	3.76	5.19
	B21t	17-41	2.87	2.60
	B22	41-61	2.03	1.54
	Bx1	61-91	2.40	3.00
	Bx2	91-114	1.78	1.97
upper	Bx3	114-136	2.45	4.91
lower	Bx3	136-198	2.58	0.70
	IIC	198-212	4.02	4.97
Grenada	Ap	0-17	3.38	13.50
	B21	17-53	2.50	2.20
	B22	53-75	1.92	1.35
	A'2	75-84	1.92	1.35
	B'x1	84-102	1.74	1.70
	B'x2	102-181	1.48	1.28
	C	181-220	1.36	1.52
	Bx1 clay pocket	94	1.49	1.83
erosional surface				
Roxana paleosol			4.85	4.84

Table 8. Estimated percentages of minerals* in the clay fraction (<0.002 mm).

Site	Horizon	Depth (cm)	QZ	KK	M	VR	SM	VR-SM	HIV
Loring I	Ap	0-20	5	10	10	20	20	25	10
	B21t	20-46	0	10	10	20	35	25	0
	B22t	46-74	0	10	10	25	35	20	0
	Bx1	74-94	0	10	10	20	35	25	0
	Bx2	94-180	0	10	10	25	30	25	0
	C	180-240	0	10	10	35	20	20	5
incipient	A'2	74	0	10	10	25	30	20	5
	Bx2	151	0	10	10	25	30	20	5
gray seam	Bx2	151	0	10	10	30	30	20	0
erosional surface									
upper-Peoria loess			5	5	10	40	30	10	0
lower-Roxana loess			0	10	10	30	30	20	0
Loring II	Ap	0-21	2	10	28	20	20	20	0
	B21t	21-54	0	5	5	15	45	30	0
	B22	54-64	1	5	10	24	30	30	0
	Bx1	64-110	0	5	5	15	50	25	0
upper	Bx2	110-139	0	5	5	25	45	20	0
lower	Bx2	139-145	0	5	20	20	35	20	0

Table 8. Continued

Site	Horizon	Depth (cm)	QZ	KK	M	VR	SM	VR-SM	HIV
Loring III	Ap	0-17	5	10	10	15	15	15	30
	B21t	17-41	5	10	15	25	25	20	0
	B22	41-61	0	10	15	25	35	15	0
	Bx1	61-91	0	5	10	25	40	20	0
	Bx2	91-114	0	5	15	30	35	15	0
upper	Bx3	114-136	0	5	10	35	25	25	0
lower	Bx3	136-198	7	10	10	30	20	23	0
	IIC	198-212	15	15	10	20	18	17	5
Grenada	Ap	0-17	5	15	10	30	15	15	10
	B21	17-53	0	12	10	20	25	28	5
	B22	53-75	0	10	10	20	25	30	5
	A'1	75-84	0	10	10	20	20	30	10
	B'x1	84-102	0	5	10	20	40	20	5
	B'x2	102-181	0	5	10	20	40	20	5
	C	181-220	0	5	10	25	30	20	10
clay pocket	B'x1	94	0	5	10	15	45	25	0
erosional surface									
Roxana paleosol			0	30	10	20	10	30	0

*QZ = quartz
KK = kaolinite
M = hydrous mica
VR = vermiculite
SM = smectite
HIV = hydroxy interlayered vermiculite

in surface horizons and in the two lowest horizons of the Loring III soil. Kaolinite was found in all horizons sampled, in quantities between 5 and 15 percent. One sample, the Roxana paleosol exposed at the erosional surface at the Grenada site, contained 30 percent Kaolinite. Illite, in all of the samples was between 10 and 15 percent, except for higher values in the surface and lowest horizons of the Loring II soil. Vermiculite, in the Loring II soil, was between 15 and 25 percent. In the other soils vermiculite generally ranged between 20 and 30 percent. Percentages of smectite varied somewhat within profiles. The Loring I soil had a smectite maximum spanning the B21t, B22t, and Bx1 horizons. In the Loring II profile, two maxima occurred, one the B21 horizon and one in the Bx1 horizon. The Loring III soil had a maximum in the Bx1 horizon, while the Grenada soil had maxima in the B2 and B'x1 horizons. Interstratified clay minerals were found, mainly with spacings near 31 Angstroms, with some found at 27 Angstroms. These were considered to be mostly of smectite and vermiculite. The percentages of interstratified clay were lowest in the Loring III soil profile, between 15 and 20 percent, while in the other three profiles, it ranged from 20 to 30 percent. Chloritized vermiculite was also found in the clay fraction. The Loring I soil contained five percent in the incipient A'2 horizon, in the Bx2 horizon and in the gray seam from the Bx2 horizon. The surface horizon of the Loring I soil contained 10 percent chloritized vermiculite. In the surface horizon of the Loring III soil, 30 percent was found, with none in the remainder of the profile. The Loring II soil was completely lacking in chloritized vermiculite, while the Grenada soil contained some in every horizon.

Minerals in the clay fraction, among profiles and within profiles had little variation. The main differences were in chloritized vermiculite, interstratified clay minerals, vermiculite, and smectite contents. Figure 7 shows smoothed tracings of x-ray diffractograms from 2 to 12 degrees 2θ of the B21t horizon from the Loring III soil. This series of patterns is typical of the clay mineralogy of many Weakley county soil horizons--evenly distributed with vermiculite, smectite, and interstratified minerals, with kaolinite and illite as minor components. In Figure 8 are the patterns from the Bxl horizon of the Loring soil, a horizon high in smectite. Patterns from the A horizon of the Grenada soil--high in vermiculite--are in Figure 9. The paleosol B horizon sampled at the Grenada site erosional surface was high in interstratified clay minerals. Its x-ray patterns are in Figure 10. The 110°C, K saturated treatment is lacking from this series of patterns. The surface horizon of the Loring III soil was high in chloritized vermiculite. Its x-ray patterns are in Figure 11. This group of x-ray pattern figures encompasses nearly all of the variation found in the clay minerals of the Weakley county samples.

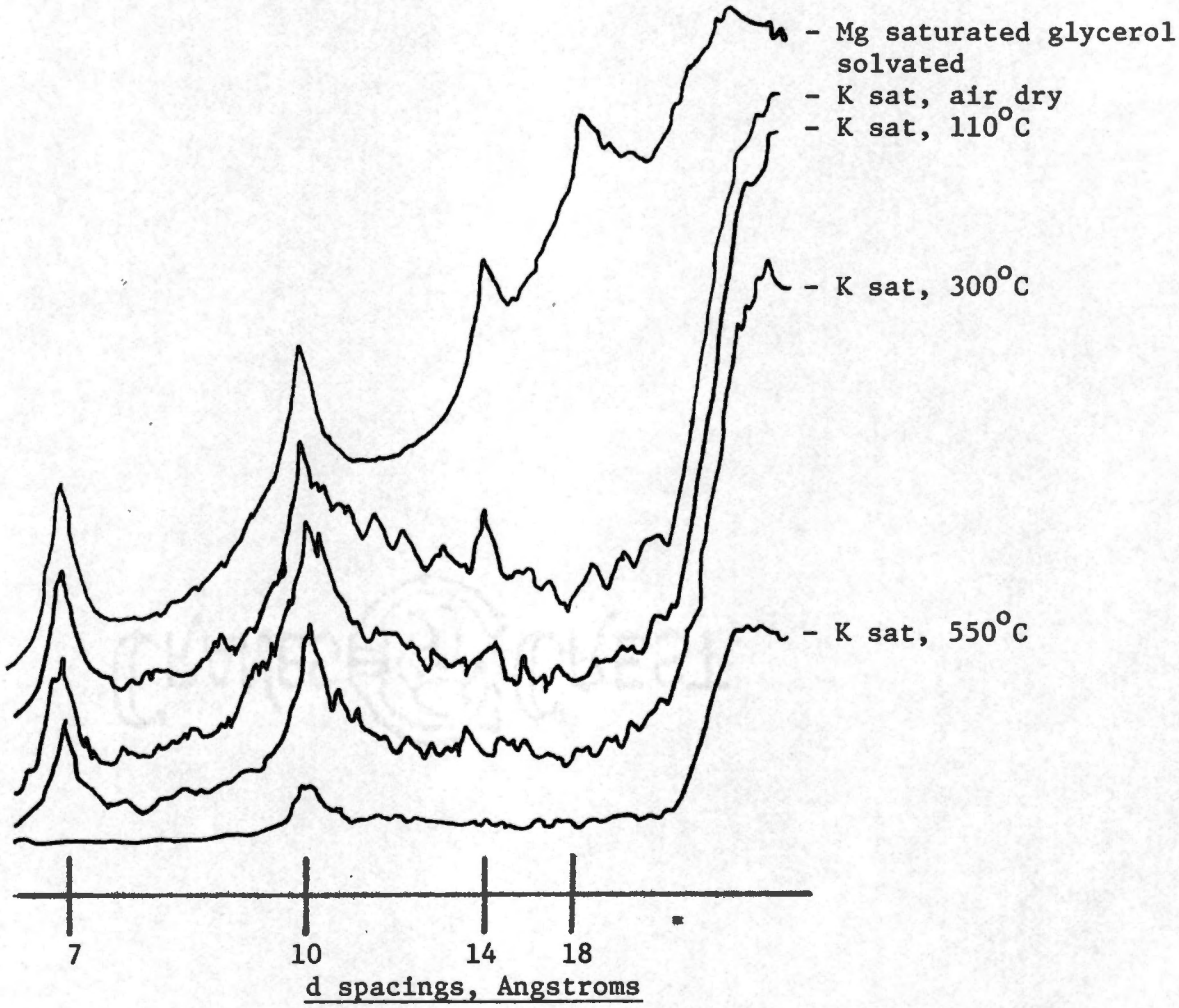


Figure 7. X-ray patterns from B21t horizon of Loring III soil , showing mineralogy typical of Weakley county soils.

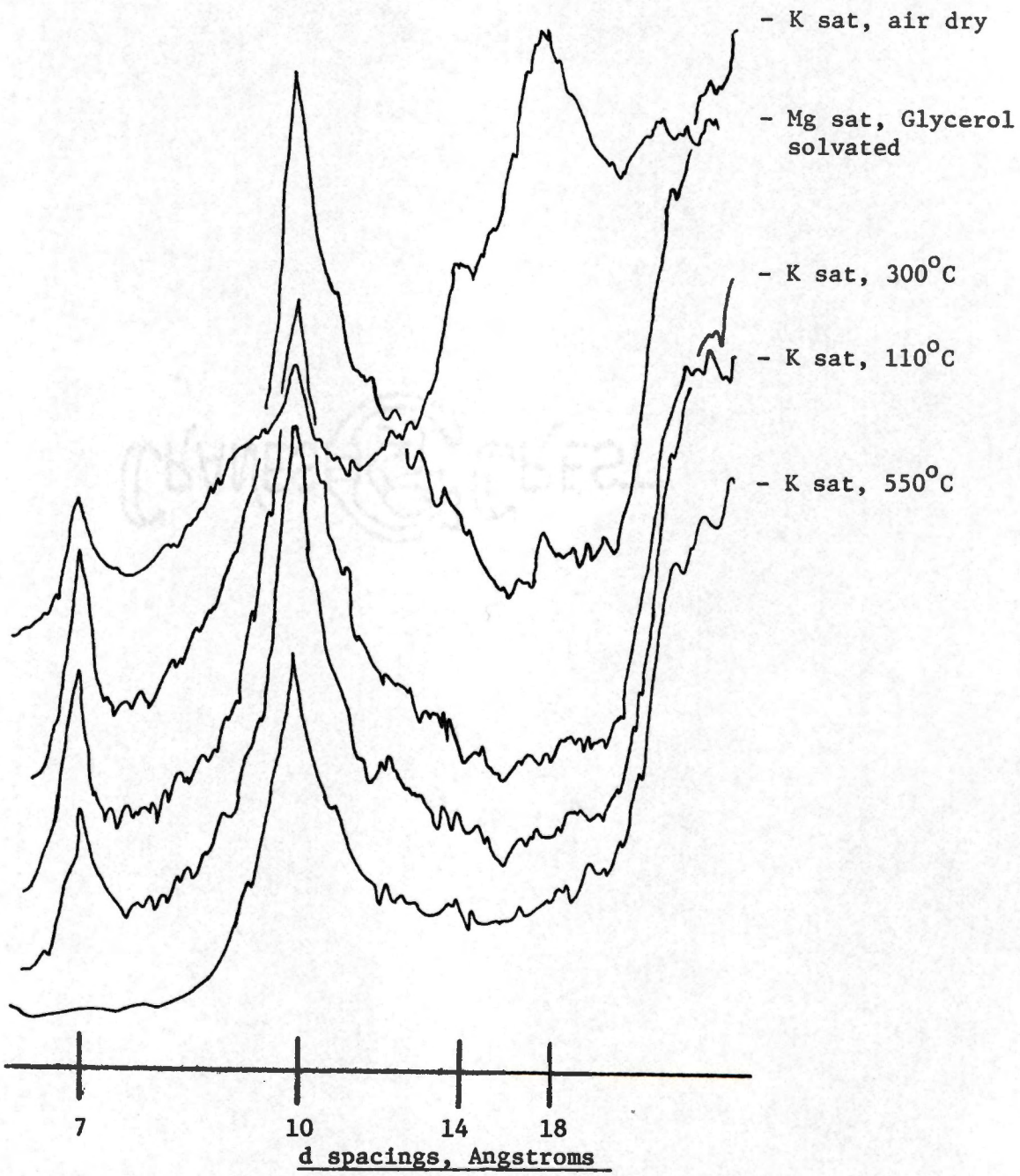


Figure 8. X-ray patterns from Bx1 horizon of Loring I soil, high in smectite.

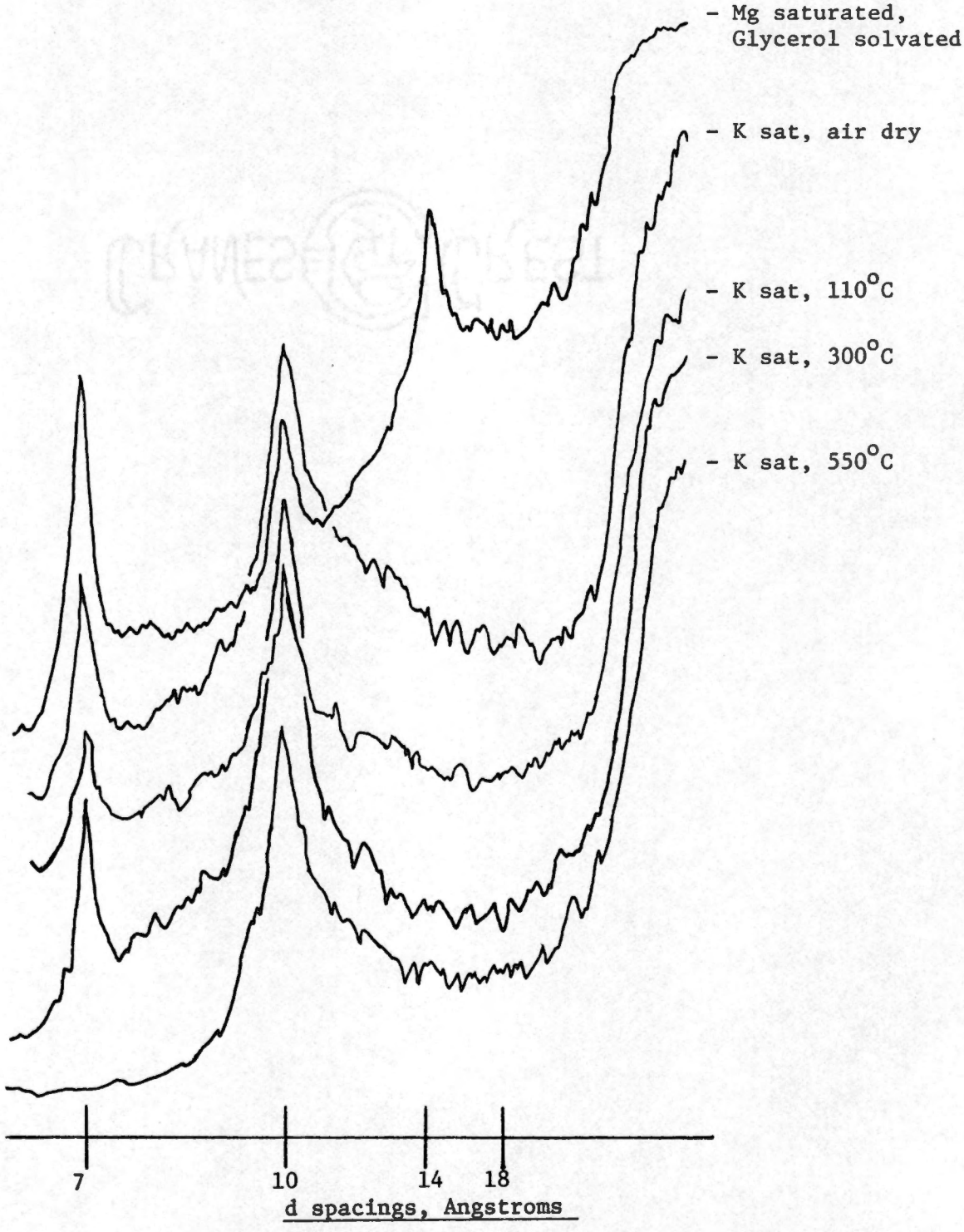


Figure 9. X-ray patterns from the A horizon of the Grenada soil, a high vermiculite horizon.

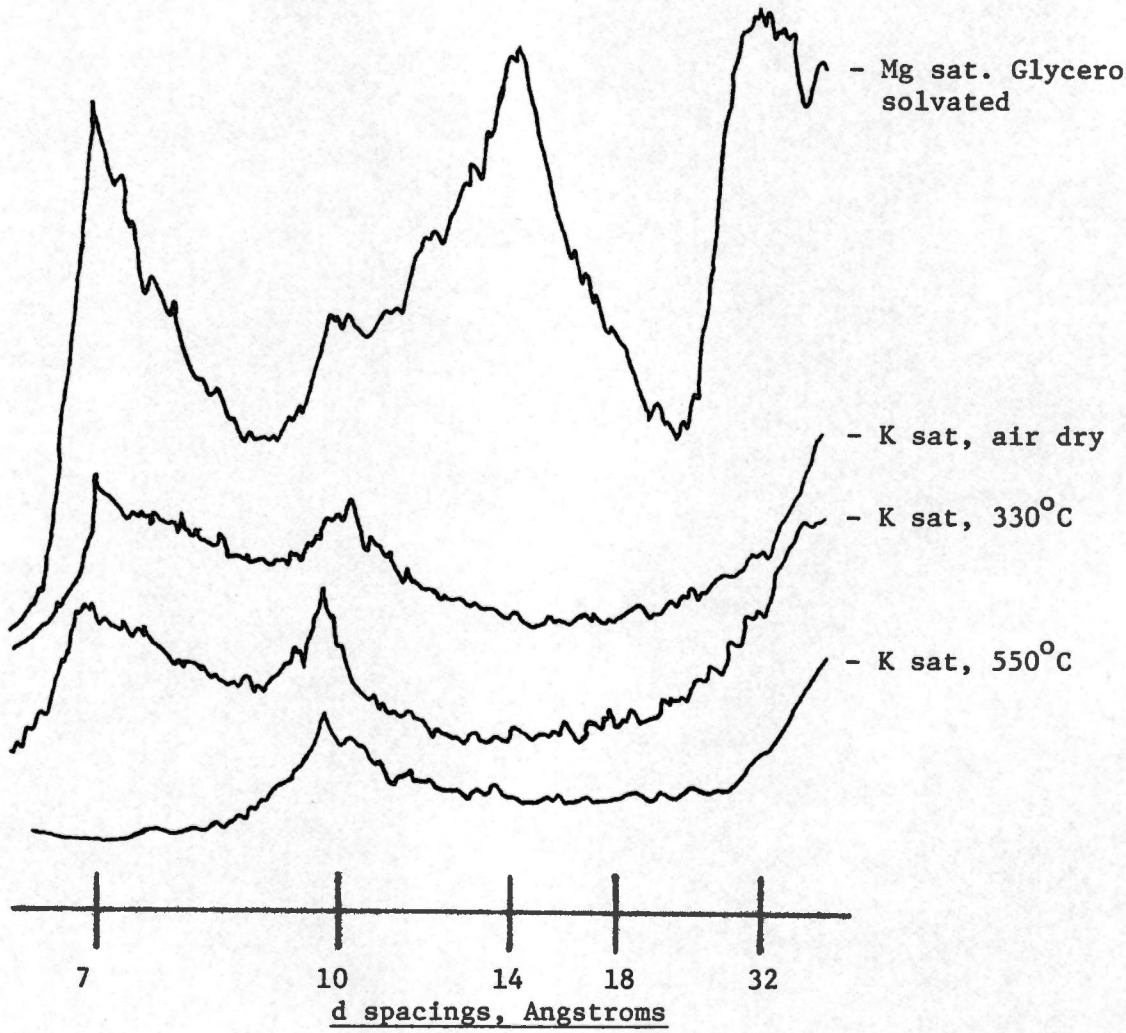


Figure 10. X-ray patterns of the paleosol B horizon from the Grenada site erosional surface, high in interstratified clay minerals.

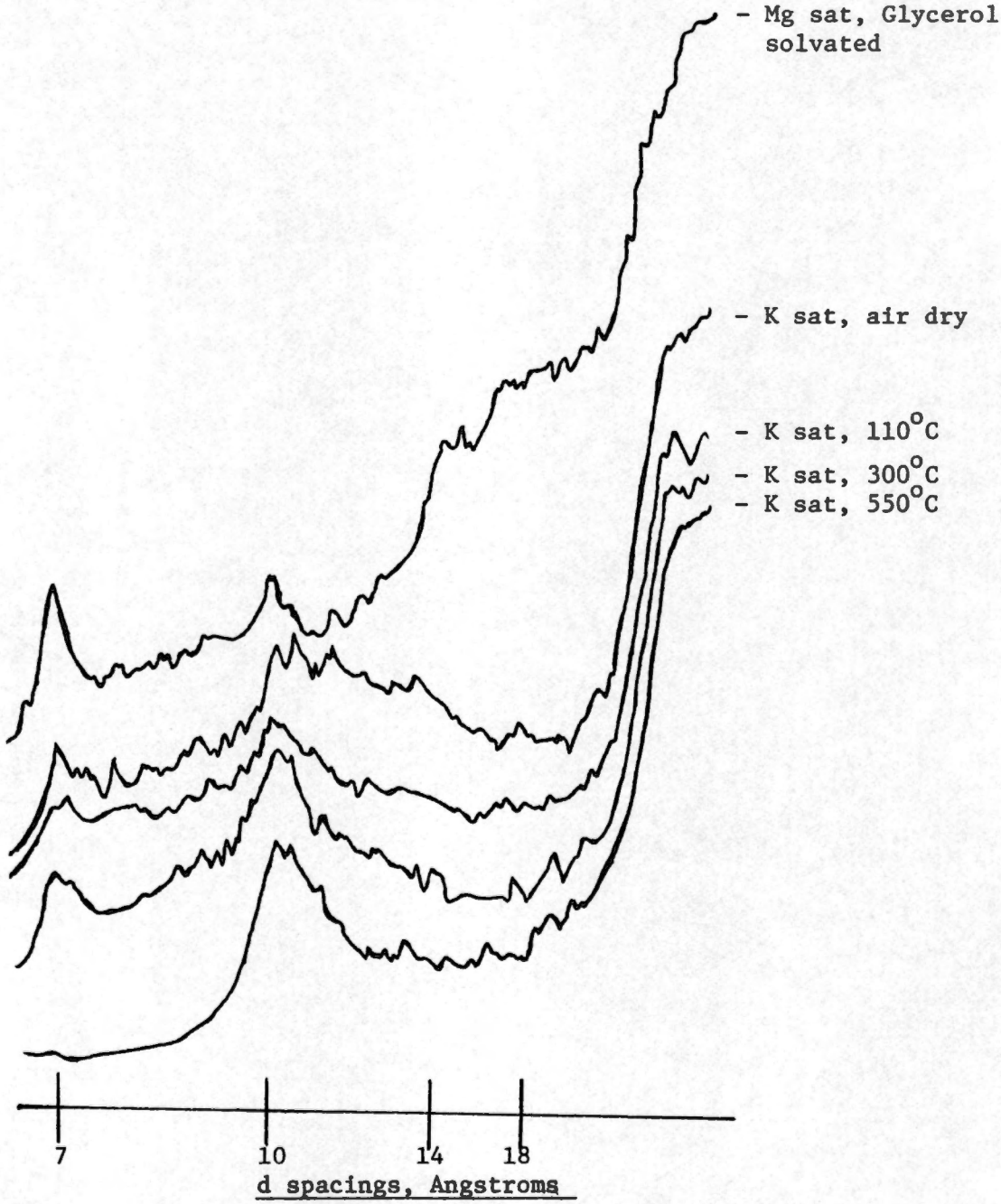


Figure 11. X-ray patterns from A horizon of Loring III soil, high in chloritized vermiculite

CHAPTER V

DISCUSSION

Results of field and laboratory investigations of upland soils in Weakley county identified differences within the soil series involved. The Loring series in particular was seen to vary considerably throughout the county. Differences in degree of weathering and drainage of the Loring soil were noted. Weathering differences were attributed to distance from the loess source, causing variation in age and thickness of soil parent material. Differences among soil series were also noted which were associated only with the slope shapes involved.

Pedon Soil Properties

Physical Properties

Particle size distribution revealed important information about all of the pedons (Table 3, page 66). Loring II, the westernmost pedon sampled in the county, has an argillic B horizon, but the clay maximum occurred in the Bx1 horizon. Of the four pedons sampled, Loring II was the only one which had its clay maximum below the B2 horizon. The present Loring II Bx1 horizon, therefore, could be the argillic horizon of a past soil which existed before total loess deposition was complete. Clay in the Bx1 has been increased by illuviation from upper horizons, observed as clay films on prism faces. Illuviation of clay into fragipan horizons has been well documented elsewhere (22, 28, 35). The Grenada pedon also exhibited illuviation of clay into the fragipan horizons. This clay probably originated in the A'2 horizon which was noticeably lower in clay.

In the Loring I pedon clay curve, the argillic horizon contained the greatest amount of clay, having 27.1 and 26.3 percent in the B21t and B22t horizons, respectively. Clay contents of the fragipan horizons, while above that of the C horizon, were not as great as that of the argillic horizon. The incipient A'2 horizon in the Loring I soil showed evidence of losing clay by eluviation, being lower in clay content than horizons above and below it.

The pedon farthest east in the county, the Loring III, had a unique clay curve. While the clay content of the other three pedons, from the upper fragipan down, decreased steadily to less than 18 percent, the Loring III clay curve did not. Instead it decreased from the upper part of the fragipan to the middle part, then became steady at 19.5 percent in the IIC horizon. This was caused by illuviated clay in the entire fragipan and IIC horizon as well. Since this soil formed in such thin loess, it inherited as part of its profile, former weathering zones of the entire Roxana loess column, which during its weathering, eluviated clay into the coastal plain paleosol. These older weathering zones--the coastal plain paleosol and the young soil in the Roxana loess--account for the clay content not decreasing with depth as much as in the other three soils. Another peculiarity in the Loring III clay curve was in the B22 horizon. It had less clay than the horizons immediately above or below. This horizon, it seems, was losing clay to the Bx1 horizon below. In addition, lateral flow of water is evidently causing additional clay loss giving the soil a bi-modal clay distribution.

The coarse silt/fine silt ratio of each horizon reflected changes in both silt sized fractions (Table 3, page 66). Surface horizons from all four pedons have an elevated coarse silt/fine silt ratio due to fine silt removal by eluviation. The coarse silt/fine silt minimum found in the B horizons of all four soils was caused by illuviation of fine silt into the B horizon. While this minimum extended through both the B21 and B22 horizons of the Loring I and III profiles, it existed only in the B21 horizon of the Loring II and Grenada soils where the B22 horizon coarse silt/fine silt ratio exhibited a slight increase over that in the B21 horizon. This increase could indicate that the present B22 horizons of these soils were once the surface of a weathering zone, due to the characteristic disappearance of fine silt from surface horizons, or that fine silt was not being illuviated into the B22 horizons.

Within the fragipan of all four soils, the coarse silt/fine silt ratio increased significantly. Since the fragipan restricts water movement, the weathering of soil particles within the fragipan was greatly slowed, relative to the B horizon. Chemical weathering of fine silt into clay and coarse silt into fine silt was reduced in the fragipan, thus giving fragipan horizons a higher coarse silt/fine silt value than the B horizons.

The ratio of fine sand plus very fine sand to total silt was another good indicator of weathering processes within profiles (Table 3, page 66). This particular ratio can also indicate lithologic discontinuities. The high value of this ratio in all four A horizons reflected the high weathering and eluviation rate in the surface

horizons which concentrated the sands relative to silt. Between the B21t and B22 horizons of the Loring II soil a twofold increase was seen indicating that the B22 horizon could have been the A horizon of a past soil. A sharp decrease in this ratio to the Bx1 horizon below supported this observation. A similar pattern existed between the B21 and B22 of the Grenada soil where the ratio more than doubled and then began to decrease in the A'2 horizon. In the Loring I soil, this ratio was consistently low, between .009 and .017, throughout the solum. In the C horizon a ratio of 0.043 indicated a probable change in loesses. The fine sand plus very fine sand/total silt ratio of the Loring III profile revealed a discontinuity between the Bx1 and Bx2 horizons by nearly doubling. Then, in the upper Bx3 horizon, the first influence of coastal plain mixing was revealed as the ratio increased to 0.092. It continued to increase with depth to 0.361 in the IIC horizon.

Chemical Properties

Several chemical properties indicate that the soils became more highly leached from west to east in the county (Table 4, page 70). When similar horizons of the Loring soils are compared, calcium steadily decreased by 3 to 6 meq/100 grams soils from the west side of the county to the east. Calcium in the Grenada soil compared favorably to the Loring III profile in A and B horizons. The fragipan horizons of the Grenada soil, though, resemble those of the Loring II profile in calcium content. The pH taken in N KCl (pHs) decreased by about 1 pH unit in the B horizons of the Loring soils sampled from west to east in the county. Base saturation, in addition, revealed greater leaching towards the east. Comparing similar horizons, excluding the

A, base saturations decreased 10 to 20 percentage points from west to east in the county, with the greatest differences occurring among the B2 horizons. This trend of increased leaching of soils eastward from the Mississippi river has previously been identified in Hapludalfs of West Tennessee (27).

When comparing Bx horizons with B horizons, sodium concentrations are consistently at least two times higher in the fragipan than in the B horizons of the same soil (Table 4, page 70). Magnesium was nearly always higher in fragipans than in the B horizons within profiles. This difference was most marked in the Grenada profile. Hutcheson, et al. (25) found that high values of Mg and Na were characteristic of fragipan horizons in loessal soils. Values of pHs differed by 0.3-1.0 pH unit between the B and Bx horizons of the Weakley county soils, with the fragipans being lower. Values of pHs in fragipans were similar throughout the county, while values in the B horizons decreased from west to east in the county. The equilibria governing reactions in the fragipans are definitely different from those in the B horizons. The B horizons become wet and dry much more often and rapidly, and are more permeable than fragipan horizons. Perhaps this creates different regimes of mineral weathering and clay formation, which can in turn influence the pHs and concentration of exchangeable cations in the soil.

Mineralogical Properties

The mineralogical analyses of these soils provide clues to the presence of past weathering surfaces within the soils as well as to the relative amount of weathering which has occurred within soil horizons. Quartz determined by thermal analysis was considered to be of greater reliance for comparative purposes than was quartz determined

through grain counts. Quartz percentages of the fine sand plus very fine sand indicate that throughout the Loring I soil profile, quartz was fairly unchanging until the C horizon where it exhibited a significant increase in quartz content (Table 6, page 78). This indicates that the C horizon could easily be in another loess. Quartz content in the Grenada profile greatly decreased with depth, indicating that weathering was greater toward the surface. The Loring III profile quartz content increased with depth showing that the horizons were more greatly weathered as the profile depth increased. The Loring II soil quartz values were lower than those of the other profiles due to the high percentage of manganese nodules found in the profile and because of lesser weathering of the profile.

Feldspar and mica precents as shown by grain counting results, fluctuate considerably (Table 5, page 74). In the Loring III profile, these percents decreased with depth to very low values, revealing the greater weathering with depth of this soil. Sand-sized clumps of silt particles average 36 percent in the Grenada fragipan and 10 percent in the Loring III fragipan suggesting some type of agent cementing particles in these fragipans.

High quartz contents in the coarse silt fraction show that surface horizons were much more weathered than the horizons below. The Loring III quartz contents indicate greater weathering with depth in the profile. In the Grenada profile the quartz percent decreased with depth until the C horizon where it increased by 11 percentage points from the B'x2 horizon above. This indicates more weathering in the C horizon or a different loess layer with a higher quartz content. If the C

horizon was more weathered, it could be a past weathering zone surface. The Loring II quartz content fluctuated with depth having a slight maximum in the B22 horizon. Similarly, the Loring I soil had a maximum in the Bx1 horizon. These maxima could be indicative of these horizons being surfaces of past weathering zones. The Loring II had a lower amount of quartz than the other soils, indicating it had experienced less weathering, or had formed in loess of lower quartz content than the other soils.

Quartz in the fine silt fraction has a maximum in the Bx1 of the Loring I soil, the B22 of the Loring II soil, the A'2 and the C horizons of the Grenada soil. These maxima could indicate past zones of weathering which would result in a higher quartz content. Quartz contents of the Loring III soil indicate greater weathering in the Bx2 horizon and below compared to horizons above. Quartz/feldspar and quartz/mica ratios from the x-ray diffractograms of fine silt in the Loring III profile indicate the Bx2 as the horizon of least weathering (Table 7, page 83). The small values show that little feldspar or mica had weathered relative to other horizons. Quartz/feldspar values in the other three profiles decreased steadily with depth, as might be expected with no lithologic discontinuities within the profile. Quartz/mica values in these three soils fluctuated considerably, presumably due to differences in the way these two minerals settled out of the loess cloud. Quartz, with a greater density and more spherical shape than mica, would settle out at a regular rate, whereas mica, with a lower density and a flatter shape would settle out irregularly, with a tendency to sail about in the loess-carrying winds.

Results from clay fraction analysis show that Grenada was a more highly weathered soil than the others as indicated by chloritized vermiculite throughout the profile (Table 8, page 85). The Loring III A horizon was also highly weathered, containing 30 percent chloritized vermiculite. The lower Bx3 and IIC horizons of the Loring III soil were also highly weathered as seen by the increased concentration of quartz. The maximum percent of smectite in all four profiles was in the Bx1 or Bx2 horizon, indicating a great deal of smectite clay movement into fragipan horizons. Since smectites are small they tend to move more rapidly than other clay minerals through the soil profile, and become concentrated in illuvial zones, or in fragipans due to slower permeability. The stability of smectite in the fragipan horizons reinforced the idea that these horizons have relatively less weathered than the B horizons above. The greatest smectite content was found in the Bx1 horizon of the Loring III soil (50 percent). High smectite content could be due to both present illuviation and illuviation which occurred when this horizon was part of an earlier weathering zone, as well as in-place smectite formation. In addition fragipans trap Na and Mg ions coming from less weathered loess above. Variations in clay mineral content between horizons and profiles were slight. Smectite-vermiculite and some smectite-illite interstratified clay minerals, plus discrete smectite and vermiculite were typically found abundantly and evenly distributed in the clay fraction of the Weakley county samples. Vermiculite was rather stable due to low CEC K content. Most of the feldspars were sodic. Apparently, clay mineralogical evidence of past weathering zones or paleosols was

lost as clay minerals in horizons which are old weathering zones become rejuvenated as cations leach from younger materials above. Illuviation of clays into older materials from younger ones also serves to mask signs of age in the older material. Evidence of soil materials moving from loess into older material below has been documented by Hutcheson and Bailey (25).

Morphology

The four pedons described had many similarities and differences. The Grenada soil of course stands out with a B horizon color of 10YR5/6 compared to the Lorings which all have 7.5YR4/4 in their B horizons. Grenada also had an A'2 horizon which was lacking in the other soils. The Grenada fragipan had a greater variety of and more strongly expressed features. Clay films and oxidized zones on prism faces are thicker and frequent concentrations of clay occur in thick seams and pockets. All of these features are indicative of the poorer drainage and greater age of the Grenada soil. It is this wetter environment which evidently creates a fragipan with more intense and greater variety of features. Workers in Illinois, New York, and North Carolina have found the greater intensity and variety of features in fragipans, which, like Grenada, are near the poorer drained extreme of the moderately well drainage class (9, 17,32). Morphologic differences among the three Loring soils were harder to detect. The Loring III soil had gray fragipan streaks of a 7.5YR hue while the other two Lorings were limited to 10YR hues in their fragipan streaks. This indicates that the Loring III soil was more highly oxidized and has been weathering for a longer period of time than the

other soils. Within the Loring II fragipan, prism interiors have some roots whereas in the fragipans of Loring I and III, and the Grenada fragipan, no roots exist within the prisms, indicating that the Loring II fragipan was more easily penetrated and less compact than the fragipans of the other soils. In the Loring I soil there was an incipient A'2 horizon similar to that in the Grenada soil. However, the Loring I soil was unlike the Grenada soil in most other ways.

Parent Materials

The Loring II pedon was located furthest west in the county. At this site, the depth to coastal plain material was 417 cm. Morphological differences in this pedon and the loess column below do not indicate where the Peoria-Roxana loess contact is. An increase in sand content to about 10 percent was noted below a depth of 284 cm at the pit site. This type of increase, at some transect deep borings, was associated with the Roxana loess. Judging from known depths at which the Peoria-Roxana loess contact exists throughout the county, the Peoria-Roxana contact at the Loring II site occurs below the upper C horizon boundary. This contact, at deep borings throughout the county, generally, was reached after a penetration of about 52 percent of the total loess column. Using this average, the Peoria-Roxana loess contact at the Loring II site was near a depth of 221 cm. The actual contact probably occurred between this 221 cm point, and 294 cm, where the sand increase was first noticed. Further evidence to indicate that the Peoria-Roxana contact occurred at this point are that no major changes--physical, chemical, or mineralogical--were found within the solum.

Morphologic change was found in the presence of the fragipan, but this need not suggest a change in loesses. The major color of 7.5YR4/4 remained the same throughout the profile. Subtle changes around the B22 horizon however, did suggest two loess layers within the solum. These, of course, would necessarily be separate layers of the Peoria loess. The clay maximum in the Bx1 horizon, being an illuvial zone of an earlier weathering surface, was the first suggestion of separate loess layers in this soil. If the Bx1 horizon was a B horizon at one time, the B22 horizon would then have been an A horizon, now being somewhat mixed with an upper layer of loess. The fine sand plus very fine sand/ total silt and coarse silt/fine silt ratios suggest this, as they both have a maximum in the B22 horizon. A coarse silt/fine silt ratio increase with depth was to be expected when entering the fragipan (as seen in the Loring I and III soils), but this increase occurred prematurely in the B22 horizon, suggesting the discontinuity. A quartz maximum in the coarse silt of the B22 horizon also suggested this change in loess depositions. The high concentration of smectite in the Bx1 horizon also implies that the B22 horizon was once a surface horizon. It can be concluded from these data, that a different layer of Peoria loess was encountered between the B21t and B22 horizon in the Loring I soil.

The Grenada soil, only 8 km east of the Loring II soil, fits into the same category. The indications of a second loess sheet within the profile are less pronounced however, due to more intense soil forming processes. As at the Loring II site, the Peoria-Roxana loess contact was not seen in the field. Using the average percent of loess as

Peoria from the deep borings where the Roxana loess was identified, the Peoria-Roxana loess contact would be located at a 193 cm depth. The C horizon of the Grenada soil was sampled over this point. A five percent increase in coarse silt from the B'x2 to the C horizon is the only particle size data which might identify the transition to Roxana loess. Mineralogical data do suggest however, that the C horizon was in a different material. Fifty percent of the fine sand plus very fine sand fraction was observed as silt clumps, an increase of 20 percentage points over the B'x2 horizon. Feldspar content in this fraction in both the B'x2 and C horizons is 14 percent which represents a dramatic decrease from upper horizons. Quartz increased from 20 to 31 percent between the B'x1 and C horizon in this same fraction. A similar increase is seen in the quartz content of the coarse silt fraction, from 36 to 47 percent. These data suggest that the C horizon of the Grenada soil was in the Roxana loess or in a mixed Peoria-Roxana loess zone.

Within the Grenada solum, there was a significant increase in the fine sand plus very fine sand/total silt ratio from the B21 to B22 horizons. The coarse silt/fine silt ratio increased slightly over the same distance. These suggest a change in Peoria loess layers, but since no other data reinforce this, the change in Peoria loess was uncertain. However, since the Loring II soil is closeby, it is reasonable to assume that the sequence of loesses in the Loring II soil should appear at similar depths in the Grenada soil, with the discontinuity greatly obscured by pedogenic processes.

The Loring I soil was 4 km east of the Grenada soil. At this site there is 315 cm of total loess. Using the 52 percent average of Peoria loess for the county puts the Peoria-Roxana contact at 167 cm below the surface in the lower part of the Bx2 horizon. It seems likely then, that the C horizon of the Loring I soil was in the Roxana loess. Particle size analysis results support this conclusion. The C horizon contains 6.1 percent sand, an increase of 4.6 percent over the Bx2 horizon. This sand increase was similar to that found at a similar depth at the Loring II site. The fine sand plus very fine sand/total silt and coarse silt/fine silt ratios increase from the Bx2 to the C horizon, reinforcing the idea that the C horizon was in Roxana loess. Percent quartz in the fine sand plus very fine sand incrases from the Bx2 to the C horizon. Vermiculite content also increased by 10 percent from the Bx2 to the C horizon and chloritized vermiculite appeared in the C horizon. These data indicate greater weathering of the C horizon than the Bx2, and to basic changes in the nature of the material in the C horizon in comparison to the Bx2 horizon. These soil property changes identify the C horizon as part of the Roxana loess. Therefore, like at the Loring II and Grenada sites, the solum at the Loring I site has formed entirely within the Peoria loess. Finding layers within the Peoria loess of the Loring I soil was difficult. The only indication of a second layer of the Peoria loess was an increase in coarse silt quartz of 7 percent from the B22t to the Bx1 horizon.

For the Loring III soil the change in parent materials from the lower Bx3 to the IIC horizon is obvious. There is higher sand content,

higher quartz content, reduced feldspar and mica content, as well as a greater concentration of weathered coastal plain material in the IIC horizon. The Peoria-Roxana loess contact must be within the Loring III solum and is farily easily identified. From the Bx1 to Bx2 horizons, the sand content doubles, changing from 1.6 to 3.4 percent. A slightly greater increase of this kind was found marking the Peoria-Roxana contact at the Loring I and II sites. The fine sand plus very fine sand/total silt ratio nearly doubled between the Bx1 and Bx2 horizons. Quartz in the fine sand plus very fine sand increased by 10 percentage points between those horizons, as did quartz in the fine silt. Both feldspar and mica in the fine sand plus very fine sand fraction decreased dramatically from the Bx1 to the Bx2 horizon, indicating that the Bx2 was in a much more highly weathered zone. The upper part of the Bx2 horizon, then, was likely the upper boundary of the Roxana loess.

Figure 12 shows the relationship of the four pedon sola to the parent materials found. Of the four pedons ampled, three had their sola within the Peoria loess. In accord with this, West, et al. (59), studied Loring soils on Crowley's Ridge in Arkansas and found them to be entirely within the Peoria loess. In addition, Bartelli (3) examined the Grenada soil of the lower Mississippi river valley and determined that it was entirely in the youngest loess. Buntley, et al. (6) however, propose that fragipans in West Tennessee are always coincident with the Roxana loess. In Weakley county this association was only seen in the Loring III profile.

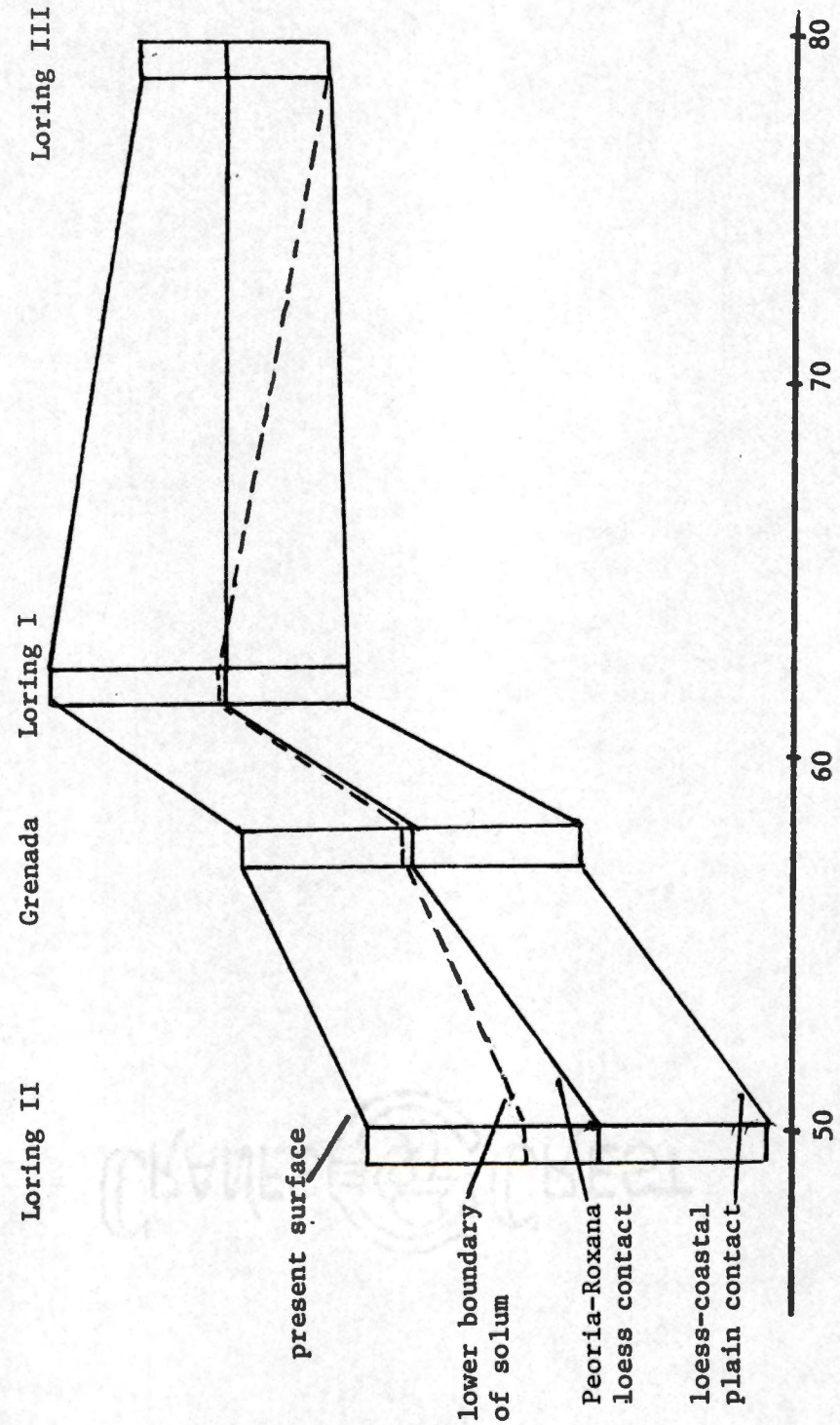


Figure 12. Geologic strata and soil sola at sampling pedon sites.

Variation Within and Among Soil Series

Loring

This series is the most common upland soil in Weakley county and has the greatest variability of the upland soils. The change in parent materials from east to west across the county accounts for most of this variation. The Loring in the west part of Weakley county is younger than that in the east. It is a less oxidized soil, with colors that are less red. In west Weakley county, some of the Loring soil has 10YR hues and lower B horizon clay amounts, comparable to the Grenada soil. Loring fragipan horizons become more compact and brittle with distance from west to east.

Loring in the west has decreased clay with depth in the fragipan whereas in the east it remains uniform into the coastal plain paleosol. Sand from coastal plain material is lacking in the west side Loring while in the east sand reaches well into the fragipan.

Loring in west Weakley county has a higher base status, particularly with respect to calcium. East side Loring is more acid, as indicated by pHs and extractable acidity measurements.

Mineralogically, differences are found in the quartz content, which is much lower in the west than in east Weakley county Lorings, indicating that less weathering has occurred in the west. Weatherable minerals are less abundant in eastern than western Lorings. Feldspar and mica nearly disappear from the fine sand plus very fine sand fraction in the east side Loring. Clay in the eastern Loring soil shows slightly more weathering, although clay mineral composition is fairly uniform in Loring soil throughout the county.

A line delineating the two types of Loring would correspond to a total loess depth of 210 to 230 cm. It is at loess depth thicker than this that the characteristic west Weakley county Loring should occur. In loess thinner than this, the more highly weathered east Weakley county Loring should occur. The line corresponding to this thickness (220 cm) of loess is shown in Figure 13.

Changes in the Loring soil with respect to slope position appear minimal. Morphologically, differences were not noted. The Loring II pedon, although in a nearly level area, was not at a high point on the landscape, being downslope from a Memphis mapping unit. Data suggesting differences within the Loring series due to slope position in this case were not found.

The variations found throughout the county are considerable and not to be ignored. The more oxidized soil of east Weakley county with a harder, less permeable fragipan, fewer weatherable minerals, and shallower depth to a paleosol will certainly require more intensive management than the west Loring soil to obtain similar yields. Also the Loring common in west Weakley county, with a Grenada-like upper B horizon, has poorer drainage than the Loring with a B horizon of 7.5YR hue. Though both these types of Loring are moderately well drained, differences cannot be neglected.

In spite of variations, Loring soils of Weakley county stray very little from the range of characteristics for the present concept of this series. In Weakley county, Lorings have value/chroma color readings of 5/8 and 4/6 in the B horizon, neither of which are in the present series description. Clay films are not always present in the B horizon,

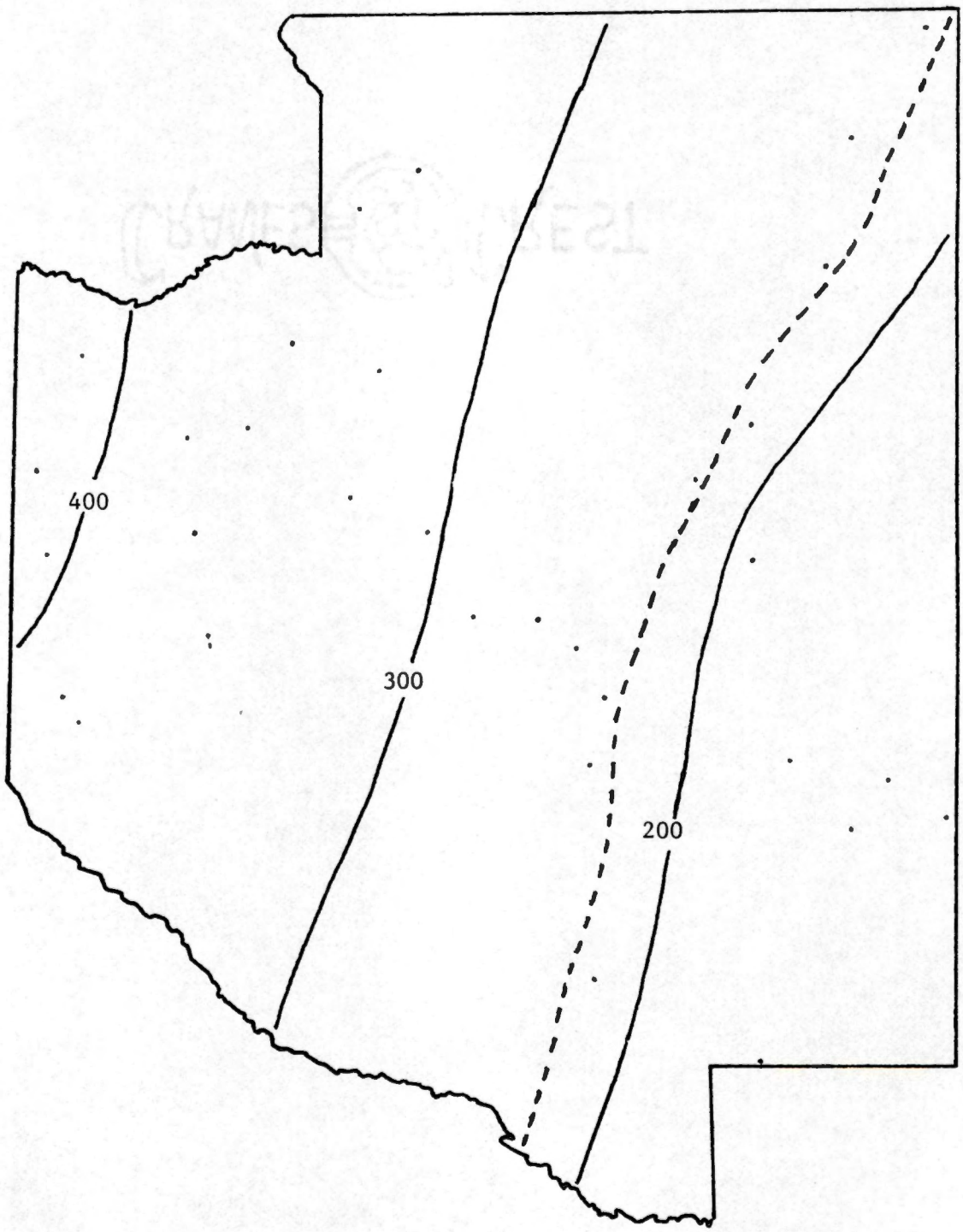


Figure 13. Lines of constant total loess depth (cm) in Weakley county with additional dotted line (220 cm total loess) separating thin loess Loring from thick loess Loring and points indicating individual measurements of total loess depth.

a case which is outside the present concept of Loring. The incipient A'2 horizon of some Weakley county Lorings is not within the present Loring concept. Another discrepancy is that the mottles in the Bx horizon of Weakley county Lorings rarely have a chroma of two as called for in the present description, and ordinarily will have a chroma of three. Otherwise, the Weakley county Loring soil fits the present concept.

In order to accomodate the variation of this series, a phase distinction could be made between younger Loring found in intermediate thicknesses of loess and older Loring with a harder fragipan, and which has fewer weatherable minerals, and is shallow to the coastal plain paleosol. Further distinction could be made separating the two drainage types found in west Weakley county. Additional study beyond the Weakley county borders is required to define the extent of these distinct types within the present Loring series before creating additional phases, taxadjuncts, or new soil series.

Grenada

Variation within the Grenada soil of Weakley county was observed mostly in that the fragipan became harder from west to east. Sand content in the lower part of the solum also increased in the same fashion. These variations were noted within the Loring soil as well. It is expected that Grenada follows the same pattern of increased profile weathering to the east as is found within the Loring soil.

The Grenada soil, when in the same loess thickness as a Loring soil, is considerable more weathered. For pedons sampled in west Weakley county, the Grenada has lower pHs. Chloritized vermiculite in the clay

fraction is the salient feature of all the Grenada horizons. This mineral is lacking in the Loring soils, indicating the Grenada is more highly weathered.

Morphologic differences between Grenada on level, broad upland summit areas and Grenada on concave slope segments were not noted.

Compared with the present concept of Grenada, the Weakley county Grenada fits well, although some differences stand out. The color 10YR 4/4 commonly found in Weakley county Grenada, is not within the presently used range of characteristics. The B horizon color of 10YR5/8 is found often in Weakley county, but is not within the series concept. The A'2 and gray mottles in the fragipan rarely have a chroma of two, but generally have a chroma of three. Other than these, inconsistencies are rare.

Providence

Providence soil in Weakley county is not nearly as common as the Loring or Grenada soils, and not as much data was gathered on it. That which was observed is in good agreement with the present series concept except that it occasionally contains an A'2 horizon. It is expected that Providence in Weakley county would be much like the east side Loring, with even greater weathering and sand content within the profile.

Soil-Parent Material Relationships

As previously mentioned, the changing parent material of soils across Weakley county profoundly effects soil properties. The loess thins to the east, causing soils to exist in differing layers of loess

and finally in coastal plain material. Because the loess in east Weakley county is thinner, yet was deposited over the same amount of time as the loess in west Weakley county, it accumulated at a slower rate than that in the west. It was not covered up as rapidly as the west Weakley county loess was. Therefore, the entire loess column in east Weakley county was exposed to weathering agents for a longer time than the loess column in west Weakley county. The loess in the west became only slightly weathered before it was covered up by more loess, whereas in the east all of the loess deposited was exposed to weathering forces during most of the time of deposition. Over the period of 16,000 years that the Peoria loess was deposited, less than a meter was deposited and weathered in east Weakley county. In the west, over two meters was deposited, much of it remaining unweathered, except for one or more zones weathered during periods of little or no loess deposition. The Roxana loess deposition was similar, except the weathering period was about 45,000 years. Therefore, soils in loess of east Weakley county are effectively older than those in the west. Also contributing to the greater weathering of soils in east Weakley county is the smaller mean particle size diameter of the loess. This is indicated by coarse silt/fine silt ratios of similar horizons becoming smaller towards the east in Weakley county. These factors are pointed out by Ruhe (45) as he describes weathering in loess soils.

The effective age difference among the soils of Weakley county manifests itself in many ways. Soils in east Weakley county are more highly weathered. Horizons, such as the Loring argillic, which were

sometimes a 10YR hue and sometimes a 7.5YR hue in the west half of the county, were nearly always a 7.5YR hue in the east half. Gray streaks within Loring fragipans had 7.5YR hues in east Weakley county, while those in the west had 10YR hues, indicating a longer period of iron oxidation. Base saturations of like horizons decrease toward the east as well as do exchangeable Ca and pHs values. Horizons were leached more rapidly in the east because thinner loess layers had fewer total carbonates than thicker layers along with an effectively longer time of leaching. Soils in east Weakley county have greater quartz contents. Fragipans change across the county also. Regardless of soil series, fragipans were seen to become tougher, more compact, and less penetrable progressing to the east. This was judged by difficulty in making soil augerings and digging soil pits. Additionally, in the Loring II soil, the westernmost pedon sampled, the fragipan prisms contained some roots whereas the other three pedons sampled had no roots in their fragipan prisms. The hardness was noticed in soil augering particularly in soils where the total loess depth was less than 220 cm. It is at a 220 cm loess depth that the Roxana loess comes to within about 100 cm of the soil surface. It is because of this older material becoming a greater part of the solum and because of the Peoria loess above it becoming effectively older, that the fragipan becomes a harder, more compact feature. Findings similar to this are known in southern Indiana and in Illinois (17,21).

Fragipan thickness was also related somewhat to parent material. Often in the east part of the county, at soil augerings and deep borings, many fragipans were observed to have their lower boundary

coincident with the coastal plain surface. However, this was not always the case, as the fragipan continued directly into the coastal plain paleosol at times. The same situation was observed with fragipans in southern Indiana and West Tennessee (21,63). So, in thinner loess areas such as east central and southeast Weakley county, the parent material thickness often determines fragipan thickness. Parent material also influences fragipan thickness in the northeast quadrant where the total loess ranged from 200-250 cm thick and the fragipans were found to be quite thick. This was due to the presence of Roxana loess being within the fragipan. The brittle, weathered Roxana loess, when beneath fragipan material which is in Peoria loess, apparently makes the fragipan thicker, because of its fragipan-like properties.

The upper boundary of fragipans may also be influenced by parent material differences. In three of the pedons described, a parent material discontinuity was found at or near the fragipan upper boundary. The Loring II soil had a discontinuity between the B21 and B22 horizons, as did the Grenada soil. A discontinuity within the Loring III soil was between the Bx1 and Bx2 horizons. A parent material discontinuity may trigger fragipan dvelopment near it. It is unlikely though, that a parent material discontinuity would consistently be coincident with the upper boundary of fragipans, however. This is because the parent material discontinuity separating two layers of Peoria loess found in the Loring II soil was found at 54 cm and this discontinuity would necessarily approach the surface as the loess thins to the east. Likewise, the Peoria-Roxana loess contact, found at about 250 cm at the Loring II site, approaches the surface as the loess thins and appears

in the Loring III soil at 91 cm. The depth to the top of fragipans in Weakley county, while having a wide range of values, does not follow a pattern of nearing the surface, as parent material discontinuities do. While a parent material discontinuity may be a force promoting fragipan development, its position being at the fragipan upper boundary is not crucial (9, 20, 21, 40).

Grossman, et al. (17), in a study of southern Illinois fragipans, concluded that "reversible induration may be a property inherent in the nature of loessal parent materials and is not specific to the fragipan therein." Strengthening this supposition are findings of Jared (27) of weak prismatic structure in B horizons of Memphis and Lexington soils, two soils without a fragipan. In addition, this study has found weak prismatic structure in the B horizons of Loring and Grenada soils, suggesting compaction of material above the fragipans. Since, in this study, changes in parent material do not coincide with upper fragipan boundaries, the conclusion can be drawn that a change in parent material is not the only cause for a fragipan, but that the loess itself has a tendency to become indurated, given proper conditions. This induration can be enhanced by a loess discontinuity occurring near the fragipan upper boundary. The fragipan, initiated by compacting forces--tree root expansion, freeze-thaw and wet-dry cycles--and aided by a cementing agent weathered from the upper horizons and precipitated in the fragipan zone, is further enhanced by a weathered, already leached horizon near the upper fragipan. The weathered horizon could promote the precipitation of a cementing agent or, if the weathered zone itself was brittle and compact, add

its hardness to that caused by modern pedogenic processes (63). Either case would promote increasing degrees of fragipan induration.

Since the loess is of uniform thickness down slopes, changes in soils and soil properties associated with position on slopes are not generally parent material related.

Soil-Topography Relationships

The relation between topography and soils in very important in Weakley county with the shape of the land surface, in particular, determining not only drainage, but fragipan occurrence and how the fragipan appears. Throughout the county on rounded hilltops and narrow convex ridge tops, fragipans often do not occur. When fragipan soils do occur on hilltops or ridges, they are usually Loring or Providence soils. Convex areas, shoulders on slopes, or hilltops are generally better drained than surrounding areas, usually containing Loring or Memphis soils. Grenada soils occur on flat, level, upland areas and in concave positions on hillslopes. Although all of these fragipan soils--Loring, Grenada, and Providence--are classified in the moderately well drained drainage class, differences do exist in their drainage. Loring and Providence are similarly drained and Grenada is more poorly drained. Therefore, the shape of the land surface determines the drainage of the soils, and the soil series to be found.

The thickness of fragipans is apparently, to some degree, controlled by land form. The fragipans in the northwest and southwest quadrants differ in thickness while the total loess thickness is fairly constant. Differences between the two quadrants relate to slope shape and steepness. The southwest quadrant is composed of broad, low hills without

much elevation change from hilltops to foot slopes. In the northwest quadrant, slopes are somewhat steeper and the land is hillier. Apparently, gentler slopes are conducive to thicker fragipans. Fragipan morphology--thickness as well as drainage and its associated features--is highly affected by slope shape. Slope steepness has less to do with fragipan morphology, as fragipans occur in all slopes of Weakley county regardless of steepness.

Loess Characteristics of Weakley County

The loess of Weakley county has a very definite pattern of thinning to the east. A map of Weakley county showing lines of constant total loess thickness derived from data supplied by deep borings is shown in Figure 13, page 111 . The pattern shown is expected, the depositional winds bringing silt from the west have less and less to deposit with greater distance from the loess source. The direction of these lines is in agreement with the lines of constant depth for Peoria loess alone drawn by Wascher, et al. (55) being parallel to the loess source.

The total loess blanket as well as individual loess sheets were found to be of uniform depth from top to bottom of slopes and from one side of a hill to another, with modern erosion causing minor fluctuations. When the loess was deposited, wind movement near the ground evidently was not sufficient to concentrate the loess in selected areas, e.g., lee slopes. In addition, mass wastage, e.g. creep and erosion, or other geomorphic processes, since the time of loess deposition have not resulted in a thickening of loess

down slopes or its loss on convex shaped slope segments in Weakley county. Thus, the present land surface still closely resembles the shape of the Roxana and the underlying old coastal plain surfaces. However, total loess depth can vary considerably within a small locality, due to different erosion rates, variation in loess carrying winds, and perhaps the influence of local rivers as secondary loess sources.

Mixing of loess and coastal plain sediments occurs at the contact of the two materials. The mixed layer varies in thickness throughout the county but in no characteristic pattern. The thickness of the total loess in the range that it exists in Weakley county, has no apparent relation to the mixed layer thickness. When the total loess is 130 cm or less, the mixing of the coastal plains material extends into all of the loess layers, which is in agreement with the findings of Jared (27) and Wascher, et al. (55).

Progressing from ridges or hill crests down slope, the mixed layer does increase in thickness, although not by the same amount at different slopes. This increase in thickness must be traced to circumstances occurring when the mixed layer formed. Either the mixed material was able to be transported by colluvial movement down slopes, while the loess deposited later was not, perhaps due to vegetational and/or climatic changes, or, forces promoting mixing such as tree throw and animal activity were greater towards slope bottoms than hilltops. The former appears more likely. That the increase in mixed layer thickness was not consistent from one hillslope to another is perhaps because of the great variety of slope gradients and shapes.

Concerning the identification of the individual loess sheets, the lowest loess known to occur in the area, the Loveland, was not positively identified in Weakley county. Wascher, et al. (58) found the Loveland to be the thinnest of the three loess layers. It appears that Weakley county is distant enough from the loess source to create a situation in which the Loveland is so thin as to be entirely within the mixed coastal plain-loess layer or at least obscured by that mixed layer and the mixed zone between the Loveland and the Roxana loess, just above it.

The top of the Roxana loess was identified in various places throughout the county. When observed, it appeared to have been weathered somewhat, as evidenced by its blocky structure and slight brittleness. In a few instances, a paleosol was identified in its upper part by the clay maximum of a B horizon. This is in agreement with the findings of Wilman and Frye (61), who found a young soil in the upper Roxana loess. The characteristics which best identify the Roxana loess are morphologic, but they do not occur consistently. These characteristics are the 7.5YR3-4/4 color and some brittleness--as seen by Buntley, et al. (6) in West Tennessee--along with a moderate to strong grade of medium blocky structure. Along with these, at times there is a bleached A'2 zone immediately above the Roxana loess.

At several sites the Roxana loess contained noticeably more sand than the Peoria loess. The particle size analysis of the Loring I C horizon bears this out. This horizon, at a depth at which Roxana loess would be expected, has a sand content of 6.1 percent, more than twice that of any horizon above. The fine sand plus very fine sand/total silt

ratio also increases by almost four fold from 0.011 to 0.043 from the Bx2 to the C horizon of the Loring I soil. Also, the Bx2 and upper Bx3 horizon of the Loring III soil, horizons within the Roxana loess, have sand contents of 3.4 and 9.6 percent, respectively. The Bx2 horizon contains twice as much sand as the Bx1 directly above. The upper Bx3 horizon contains a three fold increase over the Bx2 horizon, exhibiting slight mixing of coastal plain material. From the Bx1 to the Bx2 horizon, the fine sand plus very fine sand/total silt ratio nearly doubles, identifying the coarser Roxana loess. These data indicate that the Roxana loess contains a sand content 3 to 6 percent higher than the Peoria loess.

Jared (27) noticed a slight sand increase at similar depths in intermediate loess of West Tennessee and attributed it to loess mixing with coastal plain material. From evidence found in Weakley county, it seems as though the generally higher sand content in the Roxana loess, when compared with the Peoria loess, is a characteristic of the material which blew in to form the Roxana loess layer. This is pointed out be the fact that the upper boundary of the Roxana loess was 1.3 to 2.0 meters above the coastal plain contact in cases where the sand increase was noted. The sand content remained steady throughout the Roxana loess and then increased rapidly at the loess-coastal plain material mixed layer. Since the mixed layer averaged 63 cm and rarely exceeded 100 cm, it follows that the sand found in the Roxana loess, though more than that in the Peoria loess, was not a result of mixing of loess and coastal plain material, but was carried in by wind with the loess.

This sand could be the result of local flood plains contributing to the loess cloud, since there could easily have been coastal plain sands in the local flood plains of the area. This would account for not finding the increased sand content in all of the places where the Roxana loess occurred. Alternatively, the sand in the Roxana loess could have had its origins in the Mississippi river flood plain, if winds were sufficiently strong to carry the sand across West Tennessee. If this were the case, the sand increase should occur consistently throughout Weakley county. This could be the case since field detection of such small differences in sand content are difficult and may only be detected in cases of greatest Roxana loess sand content.

Chemical property changes which can be used to differentiate Roxana and Peoria loesses were not found. The samples taken from the erosional surface at the Loring I site, one from weathered Peoria loess, and one from weathered Roxana loess, show remarkable chemical similarity, both to each other and to the samples of the Loring I soil horizons. The Loring I C horizon, which is weathered Roxana loess, resembles closely the horizons above it, which are weathered Peoria loess. The erosional surface sample at the Grenada site has similar chemical properties to the Grenada soil horizons. Horizons of the Loring III soil formed in Peoria and Roxana loesses are very similar in the chemical attributes determined.

Mineralogical identification of the Roxana loess was only slightly successful. The samples taken from the erosional surface at the Loring I site, one each in the Peoria and Roxana loesses, proved to be very similar mineralogically. Perhaps both were actually in the Peoria-Roxana loess mixed zone. The Roxana loess paleosol sampled at the

Grenada site erosional surface did display unique properties. It was quite weathered relative to the Grenada soil, having considerably more quartz in the coarse and fine silt fractions. Its clay mineralogy was quite different from other samples. Kaolinite and interstratified clay minerals each comprised 30 percent of the clay fraction, with other clay minerals making only minor contributions. Other horizons known to be in Roxana loess--the C horizons of the Loring I and Grenada soils and the Bx2 and Bx3 horizons of the Loring III soil--show no difference in their clay mineral percents from surrounding horizons. They do, however, contain significant increases in percent quartz over horizons directly above them, either in the fine sand plus very fine sand fraction, coarse silt, or fine silt fractions.

The Roxana loess is very sporadic in its manifestations. When there is a paleosol in the Roxana, it is fairly easy to recognize by clay mineralogical analysis, thermal analysis of various fractions to determine quartz, and by particle size analysis. But the Roxana paleosol does not occur uniformly. Lack of mineralogical differences between the Peoria and Roxana loesses is in accord with findings of Wascher, et al. (58). The findings of Fehrenbacher, et al. (11) that the Roxana loess contains less illite, more chlorite, and more kaolinite than the Peoria loess are not supported by this study. This study, however, does support their findings of high amounts of smectite and vermiculite in both loess deposits.

Within the Peoria loess of Weakley county, two separate layers can be identifed. These layers could not be identified in the field, but laboratory analyses made it possible using breaks in the fine sand plus very fine sand fraction and coarse silt fraction quartz percents, or

breaks in the fine sand plus very fine sand/total silt and the coarse silt/fine silt ratio. Significant increases in any of these parameters with depth can indicate the presence of a past weathering zone. Jared (27) found two separate subdivisions of the Peoria loess using coarse silt/fine silt ratios. Subdivisions within the Peoria loess of Illinois were separated by clay mineralogy by Kliess (31), most likely because of an addition loess source--the Illinois river flood plain. Such separation was not found in this study.

CHAPTER VI

SUMMARY AND CONCLUSIONS

This study was initiated (1) to garner information on the upland soils of Weakley county, (2) to understand more fully the role of parent materials and that of topography to Weakley county upland soils, and (3) to achieve a more precise concept of the soil series involved, particularly the Loring series.

In order to characterize the upland soils of Weakley county according to morphology and distribution, 32 transects of hillslopes throughout the county were made. Sixteen of the transects were positioned to form an "X" shape over the county. The remainder were made at random locations throughout the county. Four pedons of representative soils were described and sampled by horizon or subhorizon to a minimum depth of 165 cm. Characterization of physical, chemical, and mineralogical properties were accomplished by analyses of samples taken from the four representative pedons. Results revealed differences within and among soil series in individual soil properties which were related to topography as well as age and thickness of parent materials.

Soil parent materials identified in Weakley county were coastal plain material, Roxana loess, and Peoria loess. The two loesses were spread over the coastal plain surface, thinning to the east, with Peoria the uppermost loess. Loess was of uniform thickness down slopes. Soils were found to be formed solely in Peoria loess in west Weakley county. In east Weakley county, soils extended through the loess column into the coastal plain material.

Fragipans in Weakley county, regardless of soil type were seen to become harder and more brittle towards the east. This trend was related to the increasing effective age of the loess and to the increasing presence of Roxana loess in the soil sola in an eastward direction. Fragipan thickness was seen to vary, not according to soil series, but according to thickness of parent materials, age of parent materials, and topography. Depth to fragipan upper boundaries was not related to parent material thickness or distance from slope summits.

Presence or absence of fragipans and drainage of soils, crucial to soil classification, were related to slope shapes. Weathering of soils and hardness of fragipans were related to thickness and age of parent materials. Fragipans are considered to be products of modern soil forming processes whose hardness is enhanced by a past weathering zone existing near the fragipan upper boundary. Modern processes of compaction--tree root expansion, wetting and drying--and leaching of cementing agents into the fragipan zone spawn the fragipan. Past weathering zones, already leached, intensify the ability of the cementing agents to create a brittle, hard fragipan.

The soil series appearing on a particular landscape was related to the shape of slopes. The Loring and Memphis soils were found on convex slope segments while Grenada was found on concave or level slope segments. Typifying the county were hillslopes with Loring soil on both the hilltop and side slope. Slopes with Memphis soil on the hilltop and Loring on the side slope were common as were slopes with Grenada on a broad level ridge and Loring on the side slope. Providence soil was found only in the eastern part of the county where loess thinned

enough that coastal plain material was within 120 cm of the surface. Otherwise Providence soils generally occurred on slopes similar to those where Loring would be if the loess were thicker.

The Loring soil was found to have three variants. One, prevelant in the eastern half of the county, was characterized by a high degree of weathering and a very compact and brittle fragipan. The greater weathering of the Loring soil towards the east is indicated by low CEC, low base saturation, low exchangeable bases, (Particularly calcium), and low salt pH, when compared with Loring soil of west Weakley county. Further displays of this high degree of weathering were revealed by high quartz/feldspar ratios in the fine sand plus very fine sand fraction of the east Weakley county Loring soil, and lower ratios in the west Loring soils. The two other Loring variants were distributed evenly in the western half of the county. Both had experienced low amounts of weathering, as indicated by high feldspar contents, and had fragipans less hard and brittle than those in east Weakley county. The difference between the two west Loring variants was in their drainage. One was better drained and had 7.5YR hues in the B horizon which was an argillic horizon. The more poorly drained Loring had a Grenada-like B horizon--low in clay content, lacking clay films and 10YR in hue.

The Grenada soils was also found to have a harder fragipan when occurring in the east half of the county. Being more poorly drained than the Loring soil, the Grenada was more highly weathered and contained morephologic features greater in number and intensity

than the Loring soil. The high amount of weathering in the Grenada soil is illustrated in the clay mineralogy. Every horizon of Grenada soil sampled contained moderate amounts of chloritized vermiculite. However, when the Grenada fragipan was compared with that of the Loring in a given locale, no difference in hardness was detected.

This study found substantial differences between the Loring soils in the east versus west Weakley county to propose that a shallow loess phase of the Loring series be created in loess thicknesses less than 220 cm. Whether new phases or taxadjuncts will be created to accomodate Loring series variations found in this study will depend on future study outside the borders of Weakley county. The geographic extent of the variants found in this study must be defined. In any case, the factors of fragipan hardness and degree of weathering should not be ignored.

LITERATURE CITED

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VITA

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