SURFACE GEOLOGY-SOIL-SITE RELATIONSHIPS IN WESTERN GULF COASTAL PLAIN AND INLAND AREAS

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CHAPTER I

INTRODUCTION

Background to Problem

Considerable time and effort have been devoted to soil genesis studies, yet it is generally conceded in the United States that soil classification and mapping are timely and practical investments.

Douchafour's (13) description of the French, German and American (7th Approximation) soil classification systems stresses that ten to twelve fundamental synthetic categories have been set up. He describes the three stages in pedology and why the first stage was abandoned. He also states:

> Most efforts ....are frustrated by the near-impossibility of finding characters, or evolutionary processes, distinct enough to define from the very beginning these two or three fundamental, sharply distinct divisions (p. 150).

This implies a desire to search out and define the basic evolutionary process as a first investment. However, for the lack of knowledge or time it has been considered satisfactory to set up a synthetic classification system and use this as a practical, operational interim tool for soil classification, interpretation and mapping.

Ultisols, Alfisols and Psamments in the Gulf and Atlantic Coastal Plain (formerly classed as red-yellow podzolic soils) are considered to be residual soils, i.e., weathered *in situ* from various outcrops of marine sands and clays (54) or antecedent bedrock (8).

Soils are viewed as the product of the interaction between geologic materials, climate, biotic factors, topography and time. It is noteworthy that modal Psamment, Ultisol and Alfisol soils have a common nature throughout the Coastal Plain despite extreme variations in two of the environmental factors, while climate, topography and biotic conditions are fairly uniform. Of the latter three factors, climate appears to vary the most, especially in respect to total precipitation and number of frost-free days. Pine-hardwood forests that are found above these soils are fairly uniform and vary most in number of species or associations that can thrive on certain sites within the province.

Geologic materials in the Coastal Plain available for weathering range from Mississippian-Pennsylvanian sandstones and shales; calcareous Cretaceous limestone, marl and chalk; Eocene sandstones; Miocene fine sandstones and calcareous clays, and acidic and unconsolidated Pleistocene sands and clays.

Time available for rock weathering and soil formation is as much as 300 million years for Mississippian-Pennsylvanian materials and 100 million years for Cretaceous materials (31). The youngest calcareous Miocene (Fleming) member was exposed to erosion and soil development some eight million years ago. Thus, geologic parent materials and time for soil development vary considerably across the Coastal Plain.

In view of the extreme variation in these latter two variables, it seems somewhat peculiar that the Ultisols and Alfisols are so common in nature regardless of location within either the western or eastern or upper or lower Coastal Plain. Furthermore, there are sizeable disjunct "islands" of red-yellow podzolic soils in areas of less than 33 inches of annual precipitation that support "lost pine islands" and the usual associate hardwoods. Soil profiles in these latter areas are like profiles in zones where precipitation averages over 55 inches. One questions whether the plants slowly invaded the more xeric environment by ecotype adaptation and helped form the favorable soil, or whether the soil was already in place and the plants spread rather rapidly from the east, across a continuum of favorable compensatory soil into the more xeric area. It seems that subsequent erosion and dissection could then isolate these soil-plant associations into disjunct areas. It was speculated in 1959 (46) that favorable existing soil profiles served as a compensatory factor for plant migration to the "lost pine islands".

Doering (11) described the Citronelle Formation in general terms and mapped its location in the lower Coastal Plain in 1956 (Figure 1). The 1960 U. S. Geologic Map (S.E. Quarter) (53) shows this material as Pliocene alluvial deposits. Doering (11) and Bernard, LeBlanc and Major (3) considered the materials as alluvial plain deposits, formed by a series of meandering and/or braided streams that coalesced even at major interstream divides. Doering primarily used physiographic features, with a slope of 15 to 20 feet per mile, to control area for mapping. Moreover, he did not identify the master slope or source area for materials or study paleocurrent direction, gravel type or minerals in the fluvial materials.

The Problem and Justification for Study

Since Psamments, Ultisols and Alfisols above the Citronelle Formation appear to be physically comparable to red-yellow podzolic soils of the middle and upper Coastal Plain it seems valid to ask if the latter might have a similar geologic history and be related to the Citronelle

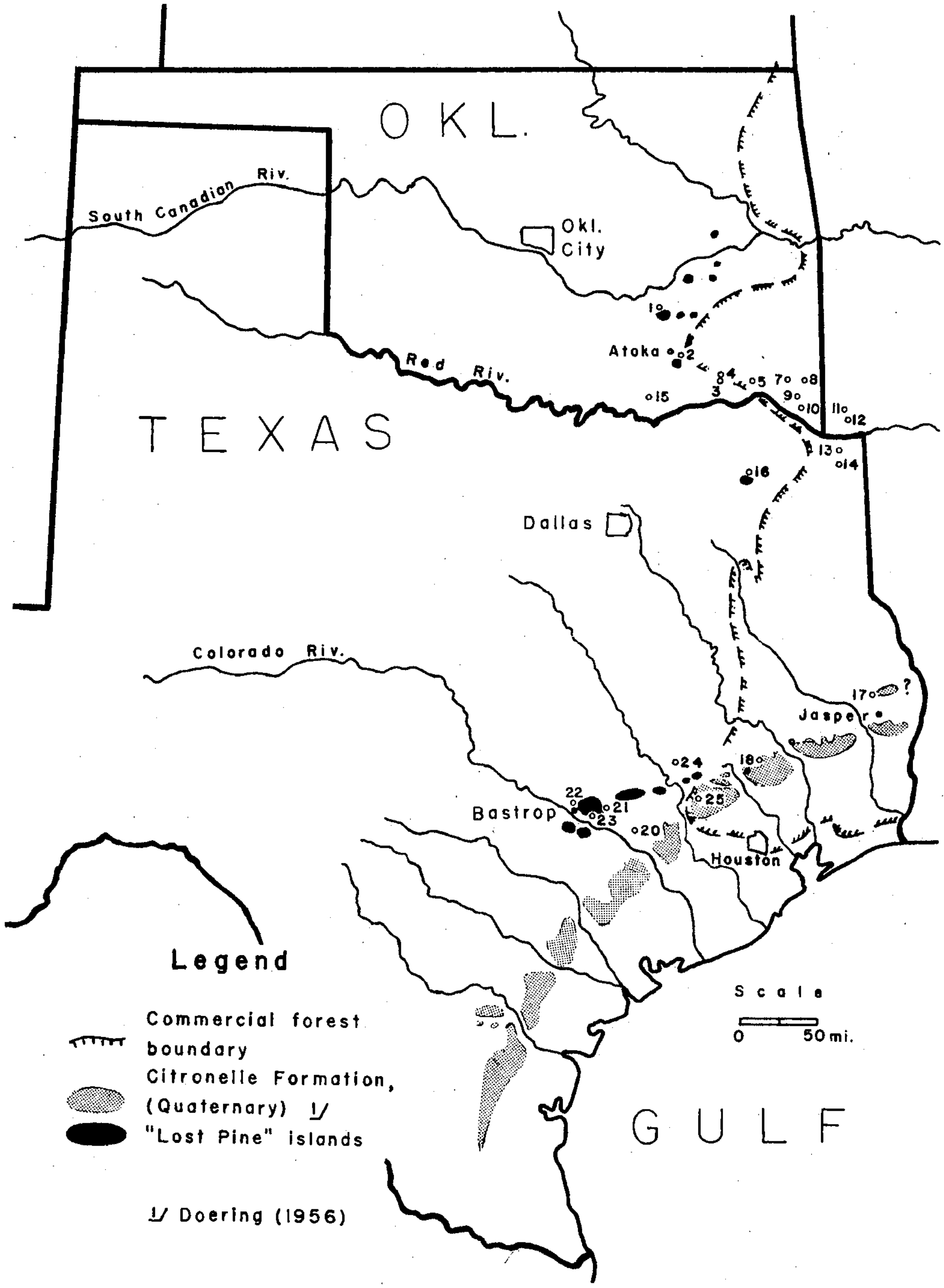

Figure 1. Citronelle Formation (after Doering) and Relation to Study Locations

materials. If Psamments, Ultisols and Alfisols in the middle and upper Coastal Plain are found to be physically and/or mineralogically similar to those above the Citronelle Formation one could then ask for them to be mapped and viewed as part of the same ecosystem. This would provide a more liberal interpretation of ecosystem nature, as follows:

(a) Alluvial materials would be antecedent to plant establishment, and therefore could be considered an independent variable, not subject to definitive weathering action by plants and climate.

(b) Plants could be considered as dependent variables, with their association, distribution and function largely controlled by the moisture storage and retention capacity of the A_1 - A_2 horizons of the solum (48).

(c) Plant associations could be assigned greater credibility as major respondents to fluvial surficial geology materials and "indicators" of this geologic control and discrete land management classes established by the deposits.

(d) Plants in disjunct communities, or "lost pine islands", could be mutually evaluated for genetic-ecologic controls. Pine in these "islands" are currently assumed to be drought-resistant stock (56) (having migrated to the areas through slow, ecotype adaptation?).

Objectives

This study was initiated to determine if Ultisols and Alfisols of the upper Western Coastal Plain: (a) have been weathered *in situ* or have some other genetic history, and (b) may be physically similar and geologically related to soils on the Citronelle Formation of the lower Coastal Plain.

Null hypotheses will be followed; i.e., (a) sampled Ultisol and Alfisol soils of the western Gulf Coastal Plain have physical and mineralogical features that show they have been weathered in situ from various rock outcrops (are residual soils) and cannot have some other genetic history, and (b) soils in inland positions are physically and mineralogically similar to Ultisols and Alfisols above the Citronelle Formation but cannot have a similar geologic history. Should data document that Ultisols and Alfisols (and presumably adjacent Psamments) have not been weathered in situ but are the sum of fluvial deposits, the following could be considered: (a) Fluvial deposits are antecedent to plant establishment, (b) texture and depth of sequential strata of the soil have largely been controlled by source materials and processes depositing the material, (c) plants and climate have made only minor contributions to modification of these red-yellow podzolic soils, (d) depth and texture of soil strata have largely controlled available soil moisture and adaptation, distribution and association of plants (ecosystem relationships offered in a "wedge chart", Silker 1965), and (e) plants can be considered a dependent variable (respondents), thus enhancing their credibility as "indicators" of the geologic control and land classes established by the deposits.

It is hoped this research will lead to a better understanding of the evolutionary process controlling the red-yellow podzolic "soil profile" environment. Various disciplines could then relate to the total ecology at play in the Coastal Plain ecosystem when making land class delineations and interpretations or instruction investments.

CHAPTER II

LITERATURE REVIEW

View of Alfisol and Ultisol Genesis

Comment was made in the Introduction that Alfisols and Ultisols of the Coastal Plain are considered as materials weathered *in situ* from various bedrock units. This view is solidified in the symbolism portrayed in Figure 2, and material from the 1970 text edition of Buckman and Brady (8):

> These red and yellow soils have been developed from all sorts of parent materials, yet they have many attributes in common. It is remarkable that climate and its accompanying vegetation has been able to mold them into such noticeable uniformity (p. 332).

Recent geological classification and mapping shows that the Citronelle Formation occupies extensive areas in the lower Gulf and Atlantic Coastal Plain, in interstream divide positions. Doering (11) delineated materials in the lower Gulf Coastal Plain in 1956, and mapped deposits of like lithology in 1960 in the Atlantic Coastal Plain (12). The former areas were shown on the 1960 U. S. Geologic Map (53) but materials in the Atlantic Coastal Plain were not included.

WEATHERING AND SOIL FORMATION

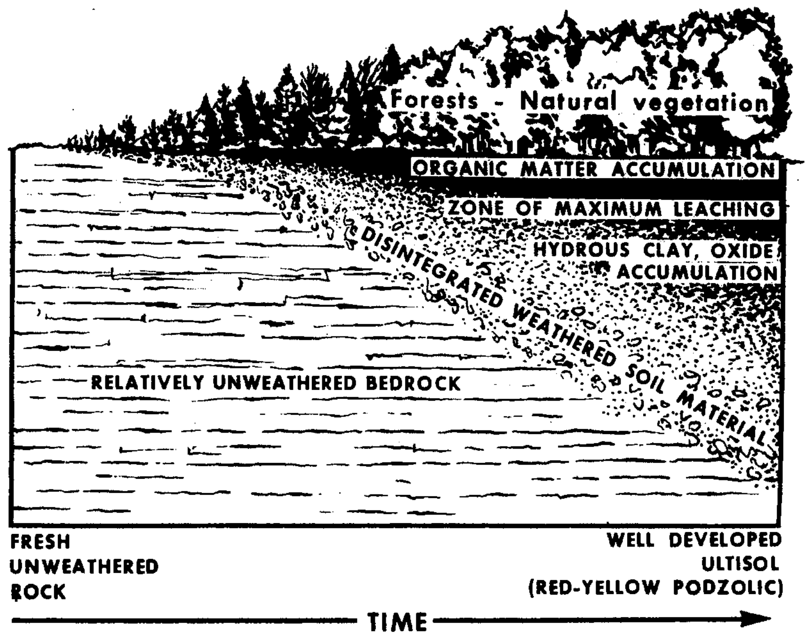

Figure 2. Genetic Interpretation for Ultisols, from Buckman and Brady, 1970 (8)

Nature of Citronelle Formation

Historical Overlook

The common feature of early descriptive effort is variability. The variable opinion about the Citronelle Formation (or Willis or Lafayette) appears to stem from study of portions of the whole, which appears to be an extensive "system".

Potter (38) states:

> Widely distributed throughout portions of middle and eastern United States is a distinctive lithology which at an early date was referred to the Cenozoic. This deposit consists almost entirely of insoluble clastic elements--gravel, sand, silt and clay--the whole highly oxidized and commonly stained by oxides of iron and manganese (p. 1).

Potter notes the deposit was recognized as early as 1791 by Bartram, discussed by H. D. Rogers in 1836 and many others including Lyell in 1846. Potter (38) cited Fisk's opinion about variability in views:

> By 1891 so many different names had been applied to the gravel beds of the Gulf Coast region that a meeting of eminent geologists was held in San Francisco to establish a suitable name (p. 2).

The name of Lafayette was chosen over all names that had been suggested later. Most writers assigned it to late Pliocene, while some held out for early Pleistocene. The U. S. Geological Survey adopted at an early date the Tertiary age for the deposit and then in 1909 adopted Pliocene (?) as its specific age based on studies by T. W. Vaughan.

In 1915 the U. S. Geological Survey abandoned the name Lafayette and adopted Citronelle Formation for the nonmarine Pliocene deposits of the Gulf Coastal Plain extending from western Florida into Texas and northward into Mississippi.

Geometry

Geography. Potter (38) described the north edge of the formation after making studies in southern Illinois, western Kentucky and Tennessee:

> ....the formation is a unit varying from place to place in local characters yet indivisible throughout its area of 250,000 square miles. ....It occurs as local blanket* deposits in western Kentucky in an area of 1,300 square miles, as lenticular terrace and channel deposits and as small isolated deposits, generally poorly exposed beneath glacial drift, in glaciated regions (pages 2, 3).

Priddy (40) notes that Pleistocene or recent terrace sands in Mississippi commonly cap the higher hills cut by U. S. Highway 80 in Lauderdale County. He says:

> The material is the weathered remnant of an alluvial deposit which once covered much of Mississippi. ....Where terrace sands are draped over hills of clay or silty shale they are easily distinguished. But where they cap Wilcox sands or Meridian sands they are difficult to identify except where they contain some coarse grit of quartz or small pebbles of quartz or concentrations of petrified wood fragments (p. 33).

Doering has made the greatest contribution in delineating the considered boundaries of the Citronelle Formation. Along the Atlantic Coast he shows portions of it as isolated "residual islands", or disjunct areas, exceeding 700 feet in elevation. Where there has been less extensive post-depositional erosion, it blankets broad areas.

In the western Gulf Coast, Doering (11) restricts the Citronelle generally to elevations less than 600 feet and uses physiographic patterns as a main criteria to limit its distribution. He indicates that it is usually found on surfaces with slopes of 15-20 feet gradient per

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*Underlining done by writer to feature special points of cited material.

mile, and he believes it cannot be extended inland from his mapped zone and be considered as similar lithologic material* under the "lost pines" that are found from Navasota to Bastrop, Texas.

Pirkle, et al (36) suggest a greater extension of these deposits than the area Doering mapped in Florida:

> Slightly micaceous quartz sands and clayey sands, locally containing important percentages of small quartz or quartzite gravel and larger discoid quartzite pebbles are common throughout extensive areas in the central part of the Florida peninsula ....most workers have considered these sediments as part of the Citronelle Formation of Pliocene or early Pleistocene age (p. 105).

Thickness. Potter (38) states that the Lafayette (Citronelle) deposits range in thickness from a mere veneer to 200 feet or more. They thicken considerably in a seaward direction. Russell (44) notes that the terrace formations, or four Pleistocene cycles of deposition described by Fisk (17), "individually vary from about 90 to 300 feet in thickness** along master streams and are much thinner along tributaries ....with subsequent erosion extending the area of Tertiary exposures" (p. 1218). This suggests there may have been either: (a) thicker deposition, by aggradation, along the master streams and/or (b) greater inter-stage erosion after deposition, in the tributary headwaters.

Vertical Position. Potter (38) notes that: "In hypsographic distribution the formation ranges from altitudes of 700 to 800 feet to probably some distance below sea level" (p. 2). Doering (12) likewise

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*Hypothesized by the writer in personal correspondence to Doering, November 14, 1960, as in Figure 1.

**Six times the thickness of channel deposits made by streams such as the modern Red River.

showed isolated "islands" of Citronelle material above 700 feet near Star, North Carolina, and material extending to near sea level around Mobile, Alabama.

Pirkle (35) describes distribution in Florida where percent topographic differences are not as great:

> The base of the Citronelle Formation occurs at different elevations throughout peninsular Florida. In some areas the lower contact is as much as 140 feet above sea level [as in parts of southwestern Clay County] and in other places its base is below sea level [as in parts of Highlands County](p. 1397).

The writer has photographed Citronelle-like material above 720 feet, at maximum Coastal Plain elevations expressed near Rusk, Texas, and Corrine, Oklahoma. It is present on Cedar Mountain, northwest of Broken Bow, Oklahoma, to an elevation above 700 feet. Honess (24) delineated the latter material in 1918 but did not offer a firm explanation for it--in fact, the insert on his map reads: "Covered with alluvium?, and gravel?"

<u>Boundaries</u>. The gravels and accompanying sands and clays are not limited to the Coastal Plain boundary. Doering (12) shows Citronelle Formation materials overlapping the "Fall Line" and extending across the Piedmont to Carthage, North Carolina. Potter (39) also discussed the upper boundary in western Kentucky:

> (a) Pre-Lafayette erosion produced a low scarp between the resistant cherts of the Highland Rim peneplain and the sediments of the Coastal Plain, (b) Gravel deposition was initiated along the major drainageways ....and culminated in an <u>alluvial fan</u> that eventually <u>overlapped</u> onto the <u>flanks of the Highland</u> Rim, (c) Subsequent marginal erosion by the Tennessee River regraded portions of this ...., producing the present scarp and <u>isolating</u> these <u>once-continuous</u> remnants (pages 117, 119).

The writer also has sampled and photographed many disjunct communities of longleaf pine (Pinus palustris Mill.) and turkey oak (Quercus Catesbaei Michx.) above Citronelle-like material that lies considerably inland from the Fall Line normally thought to be the northern boundary of the Coastal Plain. Notable areas are those near Jasper, and Rockford, Alabama and east of Macon, Georgia (51).

There is more general agreement that the basal contact is abrupt and represents a pre-scoured or eroded landform. Doering (11) stated: "The unconformity at the base of the Citronelle appears to be a fairly important one" (p. 1858). Bernard, LeBlanc and Major (3) reported:

> The Willis has been considered to be of Late Pliocene or Early Pleistocene age [equivalent to the Citronelle] by Doering (1935, 1956). Because it unconformably overlies Pliocene beds, the authors believe that the Willis is Early Pleistocene in age. The Willis is equivalent to the Williana terrace in Louisiana (Fisk, 1940) (p. 210).

One other comment on basal contact is worth special mention. Pirkle (35) summarized a 1960 paper by tying the usual lithology to unconformity patterns:

> Thick sections of kaolinitic sediments occur in the Lake Wales Ridge area of peninsular Florida. These materials, usually referred to as the Citronelle Formation, consist largely of quartz sand and gravel with a binder of kaolinite. In exposures the sediments often can be divided from the surface downward, into three zones: (a) loose surface sands, (b) red and yellow clayey sands and (c) white clayey sands (p. 1382).

In a 1965 paper Pirkle, et al (37) discussed the basal contact for the upper zone:

> Relationships of the loose surface sands to the surface topography and to the underlying clayey sands are exceptionally well shown [at the Clermont Sand Mine, Lake County]. The base of the surface sands as seen in the pit faces is very irregular, with the surface sands at places projecting abruptly downward for more than 40 feet as if filling old valleys or sinks. The upper surface of the sands forms a level to slightly undulating plain (p. 29).

The basal unconformity is best expressed by the mapping of Citronelle Formation material in the Atlantic Coastal Plain by Doering (12). He shows disjunct areas both inland and down-slope from the "Fall-Line". Field observation indicates some units are only two to six feet thick above Precambrian to Miocene bedrock, at elevations above 700 feet in North and South Carolina and extending to 100 feet above sea level in Georgia. Pirkle (35) indicates the base of Citronelle materials occurs at different elevations throughout peninsular Florida. He says in some areas the lower contact is as much as 140 feet above sea level and extends downslope below sea level. This distribution suggests materials were deposited over a landform somewhat like that which exists today.

Lithology. Doering's (12) evaluation statements on lithology for the Citronelle in the Atlantic Coastal Plain are comparable to those of other workers:

> (a) .... consists chiefly of fine to coarse reddish pebbly sand, generally massive but in places crossbedded and commonly mottled or streaked with grey veins or spots, ... (b) In the northern part of South Carolina the Citronelle gravelly sands, in thicknesses up to 100 feet, are present, capping the hills and ridges of a considerably dissected area, overlapping the Tuscaloosa [Cretaceous], and resting on the Piedmont rocks [pre-Cretaceous] at points near Kershaw, and ....(c) The Citronelle is a variable formation locally, but it is rather uniform regionally. The section at Claxton, Georgia, for instance, is very similar in appearance to sections of Citronelle in Texas (pages 189, 191, 195).

Structure. Pirkle, et al (36) reported on 41 units sampled on one face of the Grandin Sand Mine in north-central Florida:

> The bedding of the upper Citronelle sediments is essentially horizontal. ...Sediments of this type cover a vertical range of 19 feet. Beneath these horizontally laminated sediments and occupying the central portion of the face are beds characterized by conspicuous crossbedding. ...These ...sediments cover a vertical distance of 27 feet (p. 117).

Potter's (38) study of the upper-Mississippi embayment area was quite detailed as to structural and textural relationships. The feature points are:

> (a) Torrential crossbedding is well developed, (b) Thicknesses of 20 feet do occur. Thick units, are in general, found in or adjacent to areas underlain by Paleozoic rocks, (c) In Coastal Plain areas, well-removed from the surrounding Paleozoic, exposures having multiple sedimentation units of the order of 2-4 feet are more abundant, implying a lesser degree of channel stability (p. 12).

Constituents. Fisk (18) showed a predominance of zircon, tourmaline, garnet and staurolite as the heavy mineral suite in a sample of the Williana Formation (Citronelle equivalent) on Crowley's Ridge near Jonesboro, Arkansas. Pirkle, *et al* (37) indicated the surface sands (upper strata of Citronelle) are relatively high in the heaviest of heavy minerals (ilmenite, leucoxene, rutile and zircon) and relatively low in the lightest heavy minerals (kyanite and sillimanite).

Rosen (42) studied the Citronelle Formation in eastern Louisiana and samples from the Tuscaloosa, McShan, Eutaw and Tombigbee formations in Alabama. He reported that:

> .... an East Gulf Province heavy mineral suite [kyanite, staurolite, zircon, tourmaline], typical of the Cretaceous and Tertiary sediments of the Gulf Coastal Province, is present throughout the Citronelle and older Louisiana terrace deposits (p. 1552).

Rosen further concluded from his findings that:

> Epeirogenic uplift of the continental interior ...resulted in the erosion of Cretaceous clastic deposits which, as evidenced by outliers of Cretaceous rocks in the southern Appalachians, once extended farther north than at present; very likely, the Tertiary sands also extended farther north and served as a source for some of the material in the Citronelle east of the Mississippi Valley and probably all of the Citronelle west of the Mississippi Valley (p. 1563).

Rosen's effort at correlation between heavy minerals of the Citronelle and clastic outlier materials of the southern Appalachians as source materials is interesting. Two of the heavy minerals reported for the East Gulf Province (epidote and amphibole-pyroxene) make up about 20 percent each of the total heavy minerals in the assemblage, but neither are reported among the heavy minerals shown for the Citronelle samples.

General Interpretation. Potter (39) believes:

> .... the Lafayette gravel is not of glacial origin .... Lafayette sedimentation in the uppermost portions of the Mississippi embayment must have occurred prior to the earliest glaciation (p. 122)..... This depositional surface is regarded as the product of [a series of] coalescing alluvial fans with high-velocity braided streams ....[that formed predominantly channel deposits] which derived much of their sediment from local sources (p. 119).... The Lafayette sediment is not only pre-glacial but ante-dates a period of deep bedrock erosion that produced much of the Cache, Tennessee and Mississippi [River] entrenchment. This physiographic evidence constitutes the basis for assigning a Pliocene age (p. 122).

Pirkle, et al (36) state: "The Citronelle sediments ....are believed to represent alluvial and other terrestial materials deposited as a prograding delta built southward into Florida (Bishop, 1956)" (pages 130-131).

Bernard, LeBlanc and Major (3) suggested in 1962 that the Quaternary coastwise plains of southeast Texas represent:

> .... a series of coalescing, alluvial and deltaic plains which were developed by the seven river systems during the high-standing sea level substages of each interglacial stage. The erosional surfaces beneath each sedimentary sequence were developed during the lower sea level substages of each glacial age (p. 176).

Frye and Leonard (20) suggested the most complete ecological interpretation for the fluvial mantle in 1957:

From our studies of the stratigraphy and paleontology of the Neogene and Quaternary of the central and southern Great Plains have emerged data including an almost complete succession of fossil molluscan faunas, abundant plant remains through middle to late Neogene time, well preserved and extensive burried soil profiles from latest Neogene and Quaternary time, a distinctive sequence of clastic sediments, and the history of geomorphic development. It is our purpose here to reconstruct the succession of gross environmental conditions that obtained in this region through Pliocene and Pleistocene time.

A. The Sub-Ogallala Surface: The early Neogene drainage, generally aligned west to east, initiated sedimentation in the deepest parts of the major valleys and their principal tributaries. ....Moving laterally from linear initial areas along the streams, sedimentation produced an intricately complex degradational-constructional surface of which the existing record is primarily the depositional portion.

B. The Ogallala Formation: ...the initial deposits of the Ogallala consist generally of fine to medium sand and locally coarse gravel representing channel and nearby channel floodplain deposits of major streams.

C. Pliocene-Pleistocene Unconformity: The relationships associated with the ...unconformity have obvious ecological implications. Neogene deposition culminated in a plain of low relief. ...This practically featureless surface maintained stability for a significant but unknown period of time, and indications of a declining water table reached a maximum. ...The equilibrium of this surface was interrupted with relative suddenness throughout the plains by what is judged to be the sharpest climatic change of the late Cenozoic. That stream incision was, at least locally, governed by climatic rather than tectonic factors is suggested by the fact that it took place along streams that rose on the plains surface as well as along those that flowed through the plains from the mountainous regions to the west. This initial episode of dissection, coming between the culmination of Ogallala deposition and the initiation of the Blancan-Nebraskan deposition, is considered to mark the break between the Pliocene and Pleistocene.

D. The Pleistocene Formations: The depositional history of the Pleistocene contrasts strongly with that of the Neogene. ...the Pleistocene is marked by comparatively shorter and more violent episodes of stream incision and alluviation alternating with intervals of equilibrium recorded by widespread buried soils ...the first episode of deposition was characterized by coarse gravels--generally coarser than the Ogallala deposits of the same region--grading upward into finer-textured clastics. ...In drainageways originating in the plains, these sediments are largely reworked Ogallala and the coarser texture is due to removal of fines; but in through-flowing streams, Rocky Mountain derived gravels

> locally are coarser than the coarsest elements of the adjacent Ogallala. ...Kansan alluviation ...displays a coarse texture and is indicative of a degree of stream competence somewhat greater than in the Nebraskan (pages 1-6).

Frye and Leonard close their evaluation with:

> The reversed climatic trend toward moist and tolerant conditions reached its climax during Kansan time. The deep stream entrenchment and coarse-textured deposits throughout the plains was accompanied by a resurgence of varied branchiate gastropod assemblage. ...Following the Kansan, a strong, distinctive, but oscillating trend toward increasing aridity in the Great Plains continued into recent time (pages 9-10).

The above could thus be considered a partial interpretation for ecologic events leading to fluvial deposition in down-slope positions.

Problems to Evaluate

Alfisols and Ultisols of the Gulf Coastal Plain have been considered as residual soils, weathered from various bedrock units of Mississippian-Pennsylvanian to Pliocene age. Soils in these orders that lie in the upper Coastal Plain have the same nature as similar profiles in the lower Coastal Plain (east Texas to Florida) that lie above the Citronelle Formation. The latter formation is recognized on the 1960 U. S. Geologic Map as fluvial mantle laid down as an alluvial plain during the Pliocene age.

Materials of similar lithology and geologic history have been mapped since 1960 throughout the Atlantic Coastal Plain and classed as Citronelle sediments. Potter (38) intensively studied surficial materials in southern Illinois, western Kentucky and Tennessee and reported a similar lithology and geologic history. He discussed the materials as the Lafayette Formation (name synonymous with Willis and Citronelle).

The writer photographed the area in Figure 3 in 1960. Note the reddish, grey-mottled material in 3A has an unconformable contact with the soft, grey, fine sandstone of the Catahoula Formation (above dashed line). This subsoil strata has a lithologic nature comparable to that of the Citronelle. Loose, unconsolidated sands that make up the A_1 - A_2 horizons lie unconformably above the red-grey mottled stratum.

The material in Figure 3B lies at the north end of this same new road cut (relocated Highway 63, 13.5 miles south of Zavalla, Texas). Note there is a marked discontinuity in the red-grey clay loam substratum at the upper center of the photo. The clay that once apparently was continuous across this portion has been stripped away and the surface sand lies in direct contact with the sandy Catahoula bedrock. This observation posed questions as to whether this Ultisol had been developed through weathering of the bedrock or more likely represented sequential fluvial deposits with the following history: (a) was the red-grey clay loam deposited in the first fluvial cycle across an unconformable surface of the Catahoula fine sandstone?, (b) did subsequent erosion remove the clay in the center of Figure 3B?, and (c) does the surficial sand in the center of 3B represent a final cycle of fluvial deposition that placed this material in direct contact with the Catahoula Formation? These strata and the interpretation in the above compare favorably with the 1965 interpretation of Pirkle, et al (37) of the three zones in Citronelle sediments in Florida.

The material in Figure 3A and B lies considerably inland from Doering's northern edge for the Citronelle Formation. This prompted the

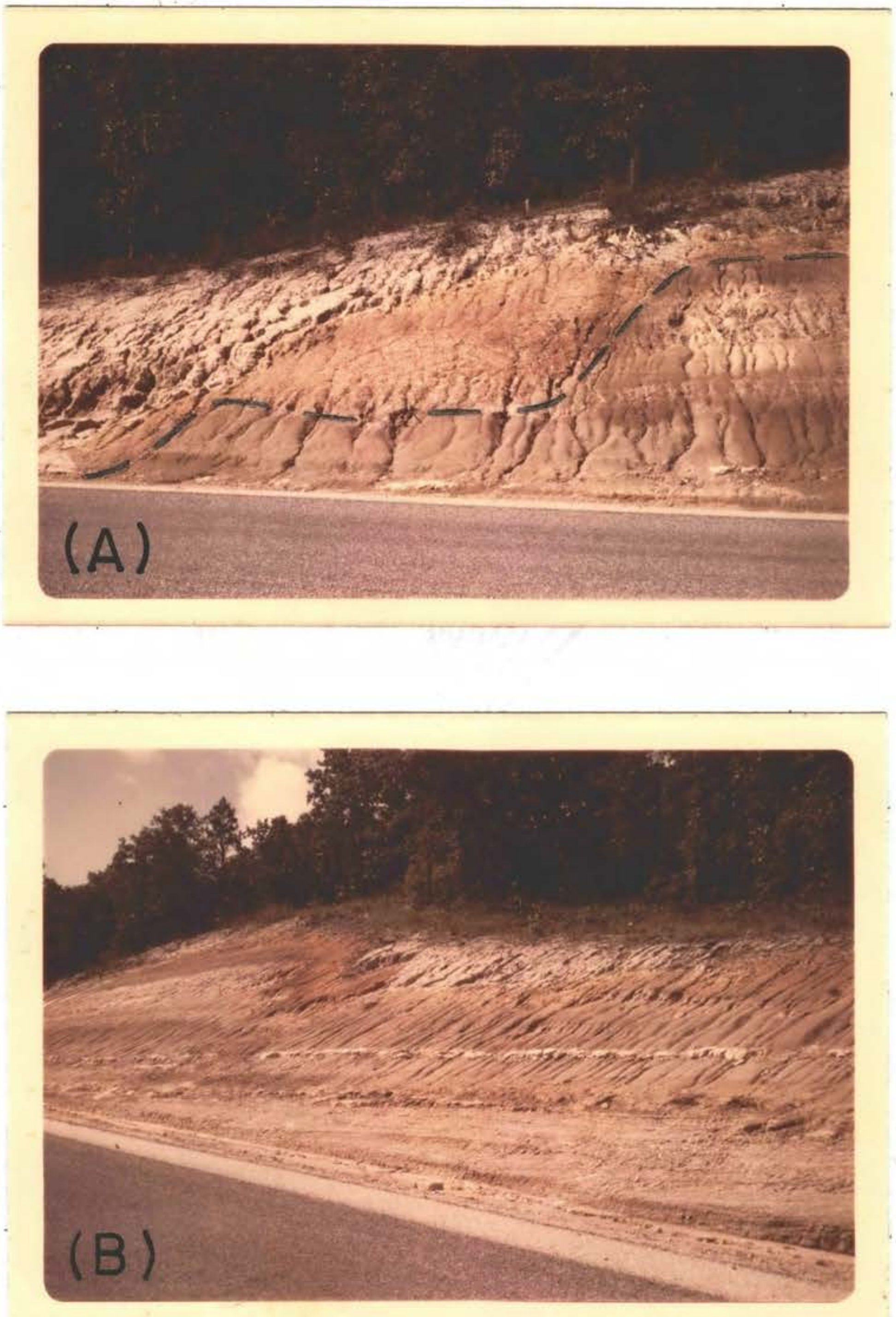

Figure 3. Citronelle-like Material, with Discontinuity in Strata and Unconformable Contact, Over a Catahoula Fm., Inland From Mapped Citronelle Fm., 1960.

writer to inquire of Doering* as to the possibility of Citronelle materials being present in up-slope areas; i.e., could there have once been a continuous, compensatory soil mantle that would have allowed pine and associate hardwoods to migrate rapidly into up-slope areas such as the "lost pine islands" from Navasota to Bastrop, Texas, that are now tension-zone environments? Doering did not encourage this as a possibility.**

Subsequently the writer came across Roy's (43) 1939 comments:

> Doering (1935) concluded that the Willis must be either Pliocene or Pleistocene. He recognized widespread gravel deposits landward from the outcrop of the Willis ["Willis cuesta"] and considers them to be residual deposits derived largely from the destruction of the interior extensions of the Willis Formation (p. 1558).

This interpretation, the lithology and suggested sequential history of materials in Figure 3A and B and numerous other inland areas, and Potter's (38) description of surficial materials in inland Coastal Plain positions in western Kentucky and Tennessee prompted this intensive study. An interdisciplinary approach was thought essential to maximize comprehension of the total ecology.

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*Personal communication of November 14, 1960.

**Personal communication of November 23, 1960.

CHAPTER III

PROCEDURE

The Study Area

Field locations for study were chosen so as to provide as much physical and chemical differences as possible between bedrock outcrop of various systems, from Mississippian-Pennsylvanian to Pliocene-Pleisto-cene age. This permitted sampling from the extreme northern edge of the upper Coastal Plain in southeastern Oklahoma to the southern edge of the central Coastal Plain near Jasper and Willis, Texas.

The U. S. Geological Survey (53) map shows the area to be a vast basin once covered by the sea. The north edge butts against, or lies over foothill portions of the Ouachita Mountains, composed mainly of folded rocks, Mississippian-Pennsylvanian to Cambrian in age. Recession of the sea, after erosion of the land surface, left behind a series of on-lapping deposits that are mostly marine in nature. Lower Cretaceous deposits sampled are primarily limestone. Upper Cretaceous bedrock units sampled include marls and chalks.

Distribution of study areas is shown in Figure 1. Data in Table I show geologic age and nature of bedrock outcrop for each plot location. Thus, the samples span an area some 300 miles wide.

Sample distribution provided for five locations over Pennsylvanian formations, three over Early Cretaceous, three over Middle Cretaceous,

TABLE I

AGE, NAME AND NATURE OF BEDROCK OUTCROP AT EACH STUDY LOCATION

Plot	Geologic Age	Rock Unit	Rock Nature
2	Pennsylvanian	Stanley	Soft sandstone
3	Pennsylvanian	Stanley	Grey-green shale
4	Pennsylvanian	Stanley	Hard sandstone
7	Cretaceous (Early)	DeQueen	Hard limestone
8	Cretaceous (Early)	DeQueen	Hard limestone
15	Cretaceous (Early)	Washita	Hard limestone
9	Cretaceous (Middle)	Goodland	Macro-fossil. limestone
10	Cretaceous (Middle)	Brownstown	Grey marl
11	Cretaceous (Late)	Annona	Light grey chalk
12	Cretaceous (Late)	Marlbrook	Grey-olive marl
13	Cretaceous (Late)	Annona	Light grey chalk
14	Cretaceous (Late)	Annona	Light grey chalk
22	Tertiary (Early Eocene)	Sabinetown	Brown siltstone
21	Tertiary (Late Eocene)	Sparta	Yellow sandstone
20	Tertiary (Late Miocene)	Oakville ?	Soft, calcareous sandstone
17	Pliocene-Pleistocene	Citronelle	Unconsol., acidic sands and clays
18	Pliocene-Pleistocene	Citronelle	Unconsol., acidic sands and clays
25	Pliocene-Pleistocene	Citronelle	Unconsol., acidic sands and clays
	Supplemental Plots		
1	Pennsylvanian	Thurman	Hard sandstone
5	Pennsylvanian	Jackfork	Hard sandstone
16	Tertiary (Early Eocene)	Wilcox	Fine sandstone
23	Tertiary (Early Eocene)	Sabinetown	Buff, fine sandstone
24	Tertiary (Late Eocene)	Yegua	Grey, fine sandstone

four over Late Cretaceous, four over Eocene, one over Miocene, and three over the Pliocene?-Pleistocene Citronelle Formation.

Past mapping standards for the U. S. Geological Survey (53) map require that only the outcrops of major rock units be delineated. The 1960 map shows the Citronelle Formation in the lower Coastal Plain as an outcrop band of alluvial plain deposits 20 to 110 miles wide but does not show this formation in the Atlantic Coastal Plain, also designated by Doering in 1960 as Pleistocene fluvial deposits (49). A few small "islands" of unconsolidated Quaternary (Pleistocene) materials are mapped as mantle above the major geologic units in the Coastal Plain portion of the Geologic Map of Oklahoma (32).

The 1966 Geologic Atlas of Texas (Texarkana sheet) (1) is one of the first of recent maps to show extensive surface materials of Quaternary age above older rock units. Five dissected Quaternary terraces are mapped along the Red River, from Paris to Texarkana, Texas. Some fluvial materials are mapped 16 miles from the present Red River channel. Terrace 4 and 5 materials are mapped under plots 11 and 12. Some of the mapping was done from high-altitude aerial photographs, and only materials 10 feet or more in thickness are usually designated. This latter standard would exclude considerable acreage of similar but thinner deposits in the Coastal Plain and up-slope areas thought to control timber species distribution and land management class and be of interest in environmental evaluation and planning (urban construction, sanitation, road location, etc.).

The landscape of the study area is a mildly to steeply-rolling plain that has been heavily dissected by rivers and small tributaries flowing southeasterly. Elevations range from 700 down to 250 feet.

Average annual precipitation ranges from 33 inches near western samples in east-central Texas to 55 inches in eastern Texas. A humid, temperate climate prevails.

Plots 2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13 and 14 are influenced by 42 to 46 inches of precipitation per year. Plots 17 and 18 are influenced by over 55 inches of annual precipitation. Days free of frost per year vary from 240 (plots 2 through 14) to 235 for plots 17 and 18. Plots 20 through 25 receive 37 to 33 inches of precipitation, respectively, and have approximately 263 frost-free days per year (52).

Sample Guideline

Sample locations were usually chosen in recently-exposed road cuts or at the heads of intermittent drainage lines where relatively recent dissection had exposed bedrock in the outcrop area.

A red-yellow podzolic soil (Ultisol or Alfisol) that is common on much of the Gulf and Atlantic Coastal Plain was chosen as a representative unit for study. Surface materials are usually loamy sands or sandy loams, and B horizons are usually red-yellow-grey mottled and have a clay loam to clay texture. A Boswell soil series (Ultisol) was sampled whenever possible and Vaiden or Oktibbeha (Alfisol) soils were sampled over calcareous bedrock. Plots 1, 5, 16, 23 and 24 were selected over Bowie or Bowie-like soil series (Ultisols) and considered as supplemental plots that might provide desirable information.

Field Sampling

Where there were road cuts, the face of each cut was dressed off so a vertical, fresh soil surface was exposed. Soil pits were dug down to and into the rock formation at least a foot at other locations, where formations were soft chalk, marl or were clayey. A soil scientist of the Soil Conservation Service observed and classified each profile down to the rock strata, or to a depth of at least 60 inches, or to greater depths where samples could be collected with a three-inch bucket auger.

A 12-inch square sample six inches thick was cut out of each soil horizon with a hand trowel, where possible, from the most representative portion of the profile and placed in labeled plastic bags. Where horizons were less than six inches thick a complete horizon sample was collected, or at least a two-inch layer was obtained. Occasionally, a second sample was collected from a horizon where matrix texture did not seemingly change but washed gravel was concentrated in lines or bands.

Two undisturbed cores 7.6 x 7.6 x 12.7 cm were cut out of each horizon, marked as to vertical orientation, and placed in covered paper cartons for later use as thin-section slide material and texture and carbonate analysis.

Where underlying bedrock was soft, a pickax was used to cut at least a foot, and preferably three feet, into the formation so bulk samples and undisturbed cores could be obtained. Where bedrock samples were hard, a metal bar was used to strip off upper layers of rock and expose clean, unweathered rock portions. Other samples were extracted with the aid of a 1.3-inch diameter rock-core drill.

Azimuth direction readings were taken with a hand compass of dip direction in all prominent crossbedded units at or near sample profile positions in order to obtain estimates of paleo-river flow pattern. Readings per location ranged from 2 to 13.

Physical Analysis of Samples

Bulk samples of friable material were sifted through a 1/4-inch sieve to sort out 1/4-inch and larger washed gravel and rock fragments. Root material was also sorted and discarded. The total bulk soil sample was oven-dried to constant weight and then exposed to room air for 24 hours to stabilize at atmospheric conditions before a gross weight was determined. One-fourth of the gross weight was used as a representative sample and washed through a 2 mm sieve to determine gravel percent in the fraction. This dried fraction weight was multiplied by four and added to the weight of washed and dried 1/4-inch and larger gravel for an estimate of total gravel percent per horizon sample.

Samples with a heavy clayey texture were oven-dried to a constant weight and then exposed to stabilize at atmospheric conditions before a bulk weight was determined. The total sample was then washed through a 2 mm sieve. The rock and gravel fragments were dried and weighed to obtain percentage.

Particle size determination of silt and clay was made by using a Bouyoucos hydrometer and the Day (9) procedure. Material from undisturbed core samples was passed through a 2 mm sieve to separate gravel and rock fragments. Thirty gram lots of the dried material were dispersed in deionized water and a 10 percent $NaCO_3$ solution, to bring the suspension to a pH of 9.0 to 10.0 prior to the particle size distribution analysis.

Percent of sand, silt and clay was calculated by entering hydrometer, time and temperature observations in a program for a CPS terminal that would allow plotting of spline functions, according to Erh (16).

Following the particle-size determination, each suspension was washed through a 270 mesh (0.053 mm) sieve to separate the sand. The silt and clay fraction was washed (100 + times for shale samples) by sedimentation, until all clay had been siphoned off. Jackson's (27) nomograph was used to set a sedimentation time of 4.5 hours for a settling distance of seven inches, at a temperature of 19.5° C. This schedule permitted recovery of 30μ (micron) and larger silt particles that could be used later for mineralogical evaluations.

The dried bulk sand and silt samples were gently boiled in an oxalic acid solution for 20 minutes, according to Leith's (29) procedure, to remove iron oxide coatings and prepare grains for optical mineralogy evaluations.

The cleaned sand samples were passed through 1.0, 0.5, 0.25, 0.177, 0.125, 0.088, 0.062 and 0.053 mm sieves mounted in a portable sieve shaker, operated for 20 minutes, to determine grain size and percentage of the bulk sand sample.

Calcareous bedrock samples were partially disaggregated by breaking the rock into pea-size particles. Thirty grams of dried particles were used for particle size distribution tests. These lots were completely disaggregated by dissolving the carbonates with acetic acid, as recommended by Brewer (7). The sample was washed and centrifuged three times so the acetic acid could be removed with the supernatant. The sand, silt and clay remaining was used for the particle size distribution analysis. Sand and silt were separated by sieving and sedimentation, respectively, and samples were stored for subsequent evaluations. Separate bulk lots of up to 544 grams of fine-textured calcareous bedrock had to be disaggregated in order to collect enough terrigenous particles to make the sieve analysis for sand grain size.

Consolidated sandy rocks were partially disaggregated into pea-size particles with a hammer and then completely disaggregated by tapping gently in a mortar-pestle in order to avoid alteration of grain-size.

All sieved lots of sand grains were checked under a petrographic microscope to determine if iron oxide coatings were sufficiently removed and grains met disaggregation limits. A maximum of 25 percent aggregation was allowed, according to Folk's (19) standards. Any lot exceeding this limit was re-treated with oxalic acid and sieved again. However, most lots had less than two percent aggregation and the rare maximum was 20 percent.

Chemical and Mineralogical Evaluation

Three replicates of 5 or 16.7 grams of calcareous bedrock, or unconsolidated material of pH 6.5 or more, that had been sieved to remove 2 mm or larger particles, were used to determine $CaCO_3$ percent. A standardized 1-normal solution of acetic acid was used to dissolve the carbonates and a standardized 0.1 normal NaOH solution was used for titration.

The original plan was to make a petrographic microscopic examination of sand grains collected from all bedrock and lower B horizons in order to determine heavy mineral status (similarity or difference in minerals resistant to weathering). Sand grain recovery from disaggregated, fine-grained calcareous bedrock was too meager, however, and the time available for additional work required an adjustment in plans. Silt samples were adequate so one location per geologic system and age was studied (one bedrock and lower B horizon from one location of the following: Pennsylvanian, Early Cretaceous, Mid-Cretaceous, Late Cretaceous, Citronelle Formation and "lost pines" area).

In view of the time limit the "heavy minerals" were not concentrated according to the procedure suggested by Barsdate (2) and by Blatt and Sutherland (4). Cleaned silt grains were dispersed in an oil with refractive index of 1.540, and the slide was scanned until a minimum of 200 "heavy" grains was identified per slide, or supplemental slides. This approach eliminated the time required to concentrate heavy grains and make thin-section mounts. There was also an advantage of using the "Becke-line concept" to check relative index and mineral relief and use mounts in other refractive index oils to occasionally check on relief and birefringence.

Heavy mineral frequency tallies were analyzed by the Chi-square test, as suggested by Eisenhart (15), to determine if grains in B horizons showed departure from homogeneity with grains in undisturbed bedrock.

Petrographic analysis of silts or sand grains from the remaining two samples per geologic unit will subsequently be made and reported.

CHAPTER IV

RESULTS AND DISCUSSION

The objectives of this study were to check the validity of two null hypotheses connected with a major theme: no difference will be found between the data collected and the current view about soil genesis and geologic history for sampled Ultisols and Alfisols of the western Gulf Coastal Plain; i.e., (a) soils will have physical and mineralogical features that show they have been weathered in situ from various rock outcrops (are residual soils) and cannot have some other genetic history, and (b) soils in inland positions will be physically and mineralogically similar to Alfisols and Ultisols above the Citronelle Formation but cannot have a similar geologic history.

The above requires collection of quantitative data from bedrock and soil horizons (especially B horizons) that will support or refute the hypotheses. The most reliable diagnostic evidence used to judge bedrock versus B horizon nature and genetic history of soils included: (a) textural (or grain size) differences in terrigenous particles, (b) presence or absence of washed gravel, (c) presence or absence of sedimentary structural patterns in materials, and (d) frequency differences in "heavy minerals" such as zircon, tourmaline, sphene, garnet, spinel, staurolite, rutile, fluorite, epidote, kyanite, etc. (minerals resistant to weathering).

Physical Analysis of Samples

Data on soil horizon and bedrock nature, color, field pH, texture, gravel percent and percent $CaCO_3$ are presented in Tables VI through XXVIII of the Appendix. These tables also indicate plot location, soil classification, soil order, soil series and plot elevation.

Sand Grain Analysis

Sand grain size, as determined by dry-sieving, for argillic B horizons and underlying bedrock, was plotted in Figures 9 through 16, as shown in the Appendix. These histograms feature the difference in sand grain size from disaggregated bedrock material and that in B horizons, especially where large grain sizes occur in B horizons but are absent as terrigenous particles in underlying bedrock.

Nine of the 18 formal study plots and two of the five supplemental plots have large sand grains in the B horizons that are not represented in disaggregated bedrock material. Differences are illustrated in Figures 9 through 16 (Appendix) for plots 2, 3, 4, 7, 10, 12, 13, 16, 18, 20 and 23, respectively. Small terrigenous particle size was expected for bedrock material for the following geologic outcrop areas because of lithologic features: Pennsylvanian (Stanley Fm.) shale (plot 3), Lower Cretaceous (DeQueen Fm.) limestone (plots 7 and 8), Upper Cretaceous (Brownstown Fm.) marl (plot 10), Upper Cretaceous (Anonna Fm.) chalk (plots 11, 13 and 14), Upper Cretaceous (Marlbrook Fm.) marl (plot 12), and Lower Eocene (Sabinetown Fm.) fine sandstone (plots 22 and 23).

One should not assume from Figure 9 of the Appendix that the fabric of soil that could develop from weathering of shale bedrock underlying plot 3 would have a mean grain size of approximately 0.88 mm. Only 0.45 gram of sand size material was obtained from 70.4 grams of disaggregated bedrock. Microscopic examination of quartz and rock fragments in thin-sections made of undisturbed bedrock cores showed that most quartz and chert grains were fine silt size. Likewise, the mean size value for sand obtained from chalk bedrock underlying plot 11 (Figure 11, Appendix) might suggest a false inference. Only 0.03 gram of sand was obtained from 326 grams of disaggregated bedrock. The few grains representing most of the sand weight were 0.5 and 1.0 mm in size. In contrast, 9.8 grams of silt were recovered, in keeping with expectations. This ratio of silt to sand could result in the fine-textured silty clay loams from weathering of chalk bedrock.

If the solum weathered from various bedrock units to the point of having well-developed argillic (clayey) B horizons one should expect to find quartz and chert grains in the B horizons of comparable or slightly smaller diameter as a result of bedrock disaggregation and particle weathering. Finding larger sand grains in B horizons calls for further evaluation. One might ask: (a) did the larger grains in B horizons result from secondary formation (silica solution, and subsequent formation of crystals in place)? or (b) could the larger grains result from primary deposition by some process such as fluvial?

Washed Gravel Analysis

Washed gravel percent, by soil horizon, is presented in Tables VI through XXVIII of the Appendix and in Table II, following. The latter provides comparison with underlying bedrock, a view on frequency patterns of gravel within the solum and a comparison between plot location with

TABLE II

PERCENT GRAVEL, BY HORIZONS, IN ULTISOLS AND ALFISOLS ON UPLAND SURFACES OR HIGH TERRACES IN WESTERN GULF COASTAL PLAIN OR INLAND AREAS

Soil Horizon	PLOTS SAMPLED 1[1/]	2	3	4	5	7	8	9	10	11	12	13
A_1	1.22	11.02	61.42	21.42	1.61	2.19	4.10	0.94	1.54	1.95	21.25	0.32
A_2	0.87	8.11	81.85	52.06	1.43	5.76	-	1.04	14.46	-	-	-
B_1	-	-	-	-	1.19	-	-	0.54	-	0.41	-	-
B_{21t}	1.58	2.65	3.27	19.02	1.24	0.06	0.26	0.55	6.15	0.06	17.05	0.0
B_{22t}	0.71	6.35	0.35	3.61	1.45	0.01	0.13	0.42	1.67	0.13	1.27	0.71
B_{22t}	35.07	-	-	-	1.23	-	0.02	-	-	-	-	-
B_{23t}	-	-	-	-	-	0.00	-	-	0.28	-	14.51	0.18
$B_{23t/A'2}$	-	-	-	-	3.36	-	-	-	-	-	-	-
B_{24t}	-	-	-	-	-	0.03	-	-	-	-	-	0.09
B_{25t}	-	-	-	-	-	0.65	-	-	-	-	-	T
B_{26t}	-	-	-	-	-	8.00	-	-	-	-	-	-
B_3	-	-	24.65	-	-	-	-	-	-	-	-	-
IIC	-	-	-	-	-	-	-	-	-	0.20	0.61	-
C	-	-	-	-	34.36	-	-	0.95	-	1.57	-	T
Underlying Bedrock:												
R	0	0	0	0	0	0	0	0	0	0	T[2/]	0
	Pennsylvanian Sandstone	Pennsylvanian Sandstone	Pennsylvanian Shale	Pennsylvanian Sandstone	Pennsylvanian Sandstone	Cretaceous Limestone	Cretaceous Limestone	Cretaceous Limestone	Cretaceous Marl	Cretaceous Chalk	Cretaceous Marl	Cretaceous Chalk

TABLE II (Continued)

Soil Horizon	PLOTS SAMPLED 14	15	16	17 3/	18 3/	20 4/	21 4/	22 4/	23 4/	24	25 3/
A_1	1.95	1.72	-	0.49	39.84	1.31	35.88	60.21	5.45	7.70	0.81
A_2	-	-	0.93	0.42	41.32	-	51.55	56.34	3.18	7.79	3.57
A_2	-	-	-	-	-	-	-	-	-	-	7.74
B_1	-	-	0.18	-	-	-	-	-	-	-	-
B_{21t}	0.73	1.63	0.03	0.98	0.17	0.17	7.82	38.97	6.13	1.84	2.13
B_{22t}	0.94	4.45	0.01	1.92	0.03	-	2.24	36.26	0.19	3.23	0.80
B_{22t}	-	-	0.01	0.53	-	-	-	-	-	-	-
B_{23t}	0.58	-	0.07	-	0.04	-	0.81	34.73	19.43	8.08	0.02
B_{24t}	1.58	-	-	-	4.03	-	-	-	-	-	0.02
B_{25t}	-	-	-	-	0.02	-	-	-	-	-	-
B_3	-	-	-	-	-	-	-	3.34	-	-	-
C_{ca}	-	-	-	-	-	0.40	-	-	-	-	-
C	2.60	3.59	0.18	-	-	0.64	-	0.00	-	2.63	-
C	17.68	-	-	-	-	-	-	-	-	1.02	-
C_{ca}	-	-	-	-	-	8.11	-	-	-	-	-
C_{ca}	-	-	-	-	-	7.67	-	-	-	-	-
C	-	-	-	-	-	0.72	-	-	-	-	-
C	-	-	-	-	-	2.21	-	-	-	-	-
					Underlying Bedrock:						
R	0	0	0	0	T 5/	0	0	0	0	0	T 6/
	Cretaceous Chalk	Cretaceous Limestone	Eocene Fine Sandstone	Miocene Fine Sandstone	Miocene Calcic Clay	Miocene Calcic Sandstone	Eocene Fine Sandstone	Eocene Fine Sandstone	Eocene Fine Sandstone	Eocene Fine Sandstone	Miocene Calcic Clay

1/ South Canadian River Watershed
2/ T = Trace (1 grain, 3mm.)
3/ Citronelle Formation outcrop materials
4/ "Pine island" locations
5/ T = Trace (2 grains, 5mm. diam.)
6/ Trace (1 grain, 3mm.)

bedrock of a certain physical nature. Note that washed gravel was present in most of the solum horizons but was absent in all but three of the antecedent bedrock samples. Bedrock samples of plots 12 and 25 had one grain each, of 3 mm size, while bedrock of plot 18 had two grains 5 mm in diameter. Moreover, there is a consistent pattern of gravel showing a higher frequency at the base of A_1 - A_2 horizons and again in lower B or C horizons, just above contact with the bedrock.

Outstanding discontinuities in gravel frequency between A_1 - A_2 zones and upper B horizons are shown in Table II for plots 2, 3, 4, 7, 8, 9, 10, 11, 13, 14, 15, 16, 18, 20, 21, 24 and 25. This discontinuity appears to be a common pattern irrespective of watershed sampled, position above the Citronelle Formation or position inland from the Citronelle Formation; i.e., it is a common pattern on: (a) geomorphic surfaces within watersheds of the modern Red, Neches, Trinity, Brazos and Colorado rivers, (b) within two of the three soils above the Citronelle Formation, and (c) within three of the five soils located in the "lost pine island" region inland from the Citronelle Formation, near Bastrop, Texas, and at a "lost pine island" area at plot 16, Lone Pine, Texas (west of Mt. Pleasant). The latter is at an extreme inland position and at a major stream-divide location.

Figures 4, 5 and 6 more vividly illustrate the gravel concentration in A_1 - A_2 horizons and the strong textural discontinuity at contact with upper B horizons. Figure 4A also illustrates the gravel concentration found in plot 3 just above grey shale bedrock--in this case a Pennsylvanian shale. Figure 4B is of plot 4, 140 feet north, above alternating sandstone bedrock northwest of Antlers, Oklahoma. These

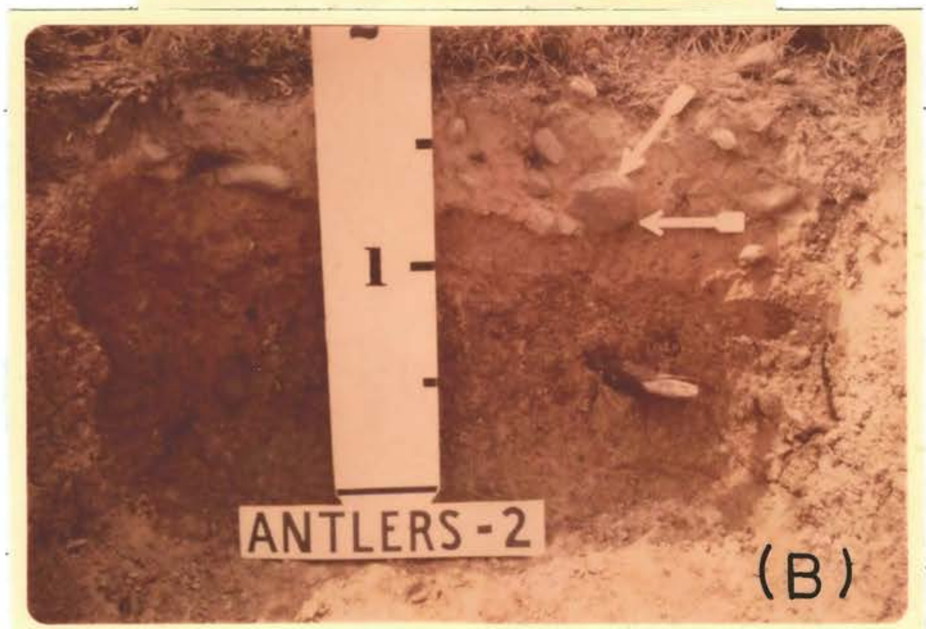

Figure 4. Alfisols Overlying Pennsylvanian Shale (A), and Sandstone (B), Antlers, Oklahoma

Figure 5. Alfisol at Plot 25, on the Citronelle Fm., overlying Miocene Calcareous Clay, North of Hempstead, Texas

Figure 6. Alfisol at Plot 21, overlying Eocene Sandstone, at Edge of Major "Lost Pine Island", Smithville, Tex.

plots represent red-yellow podzolic soils within the Red River watershed, at the northern edge of the Coastal Plain.

The Alfisol shown in Figure 5 occurs above the recognized western edge of the Citronelle Formation (Bernard, LeBlanc and Major 1962), seven miles north of Hempstead, Texas. Note the washed gravel is concentrated throughout the lower five inches of the A_2 horizon (arrow) and the B horizon expresses a marked textural discontinuity. The plot lies within the Brazos River watershed.

The Alfisol illustrated in Figure 6 overlies a Late Eocene, loosely-consolidated sandstone, at the edge of a major "lost pine island" that extends from Smithville to Bastrop, Texas. The rounded gravel concentrated in the A_1 - A_2 horizons is largely quartz and chert. Smaller gravel can be recognized as infrequent pebbles (small arrow) in clay or clay loam B horizons. This plot lies in the Colorado River watershed.

Two patterns resulting in concentration of washed gravel in the sandy A_1 - A_2 horizons could be considered: (a) Gravel could have been randomly deposited in poorly-sorted antecedent deposits. Subsequent erosion could have selectively sorted out the clays and fine sands and left the gravel behind as a lag layer, unconformably overlying remnant clays. Subsequent deposition of sandy materials over the gravel and movement of sand grains into interstices could give the appearance of a heterogenous primary deposit, or (b) gravel and sand were laid down as a last-stage, primary deposit by braided-channel streams that had a high competence. In the latter case most accompanying clay and silt could have stayed in suspension and been swept to more distant downslope positions (into marine environments).

Support for the latter view above is tenuous but Pirkle's (35) recent studies of kaolinitic sediments in the Lake Wales Ridge area of peninsular Florida offer a comparable view:

> These materials, usually referred to as the Citronelle Formation, consist largely of quartz sand and gravel with a binder of kaolinite. In exposures the sediments often can be divided from the surface downward, into three zones: (a) loose surface sands, (b) red and yellow clayey sands and (c) white clayey sands (p. 1382).

In 1963 Pirkle, et al (36) evaluated the two upper zones and concluded:

> ...that field relationships indicate the possibility that clay has migrated downward [out of the loose sandy surface] into the red and yellow zone, leaving behind a blanket of loose surface sands (Sellard, 1912), (p. 122).

In 1965, however, Pirkle, et al (37) reported:

> Heavy mineral data and sedimentary features given in the present report [for the first time] make it difficult to consider the sand blanket at the site of the measured sections as a residual sand plain developed *in situ* through weathering ...actually, the sedimentary features of the surface sands reflect primary deposition (p. 35).

The view above could allow surficial sands (and gravel) to be considered a fluvial bed deposited over an unconformable surface as a last stage by braided streams that coalesced and blanketed the entire south plains and Coastal Plains.

Data in Table II and Figure 4A also show that there is a strong concentration of washed gravel at or just above contact with the gravel-barren antecedent bedrock at plots 1, 3, 5, 7, 9, 11, 12, 14, 15, 16, 17, 20, 23 and 24. Comparison of gravel percentages in the lower B or C horizons with texture class changes by horizon (Tables VI through XXVIII, Appendix) suggests that many of the lower horizons are equivalent of fluvial beds. Gravel, sand, silt or clay concentrations per horizon appear to be products of fluvial sorting that left variable and alternating "beds" of different texture and composition.

The "alternating bed" condition is best illustrated in plots 12 and 20. Nelson (33) reported on the bedrock and solum for plot 12-M near Foreman, Arkansas (Table XVI, Appendix). He stressed the rapid textural change between the B_{23t} horizon and the IIC horizon below and the shift in gravel frequency. The IIC designation is in itself a recognition of a textural discontinuity and use of soil classification symbolism that recognizes that the IIC material is not similar to the material from which the A and B horizons formed. The B_{21t} and B_{22t} horizons that lie above also have sand-clay ratio changes that are concommitant with strong gravel frequency shifts.

Plot 20, east of LaGrange, Texas, has conditions that similarly suggest lower horizons are fluvial bed equivalents. Note that horizon C, 32-48" depth (Table XXIII, Appendix), has a sandy Ca classification. The Ca designation denotes 4 to 5 inch diameter fragments of chalk, admixed with some washed gravel. Chalk fragments have a lithology like the outcrop Austin chalk bedrock, at up-slope positions at Austin, Texas. The next lower C horizon (38-46") has a silty matrix, but imbedded in this are similar chalk fragments that are only 1 to 2 inches in diameter. The C_{ca}, 46-54 inch, horizon changes to sand and again carries 4-5 inch diameter fragments of chalk and smaller, dense gravel. These patterns are repeated in lower strata, through the 114 inch depth, along with sand-silt ratio changes.

Sedimentary Structures and Paleocurrent Directions

Roadcuts or gravel pits at or near plot locations were used when possible to collect azimuth readings on direction of dip in crossbed units, as an expression of paleocurrent direction at the time surficial alluvial plain materials were deposited. Two to thirteen azimuth observations were collected for each of 23 field locations. Figure 7 shows a mean paleocurrent azimuth of S 70° E, as expressed by dip direction in crossbed units in substrata of the Citronelle Formation, 7 miles north of Hempstead, Texas, and 1/2 mile southwest of plot 25. A horizontal gravel line just above the arrow marks a discontinuity and shift to massive structure in the red-grey mottled material above. The latter is typical of most upper substrata under red-yellow podzolic soils of the Coastal Plain. The gravel in the photo is predominantly quartz, chert and petrified wood. Petrified wood is common to abundant in many samples, including those in the South Canadian, Red, Neches, Trinity, Brazos and Colorado River watersheds.

Average paleocurrent azimuth is shown in Figure 8 for the 23 field locations sampled. The average paleocurrent azimuths essentially parallel the present drainage directions of the Colorado, Brazos, Trinity, Neches and Red rivers. This suggests the master slope and source area for the surficial sediments headed in the Llano Estacado (High Plains) and eastern front of the Rocky Mountains.

Comparative Textural and Mineralogical Status of Selected Samples

Data on textural and mineralogical status of selected samples is presented in Table III in order to show similarity or difference between bedrock sampled and data available in the literature. It is thought this summary will also minimize descriptive phrases.

Estimated median grain diameters of bedrock samples from this study agree quite well with estimates of samples from similar bedrock, as

Figure 7. Mean Paleocurrent Azimuth of S 70° E, Expressed in Alluvial Crossbeds (arrow), in Substrata of Citronelle Fm., North of Hempstead, Texas

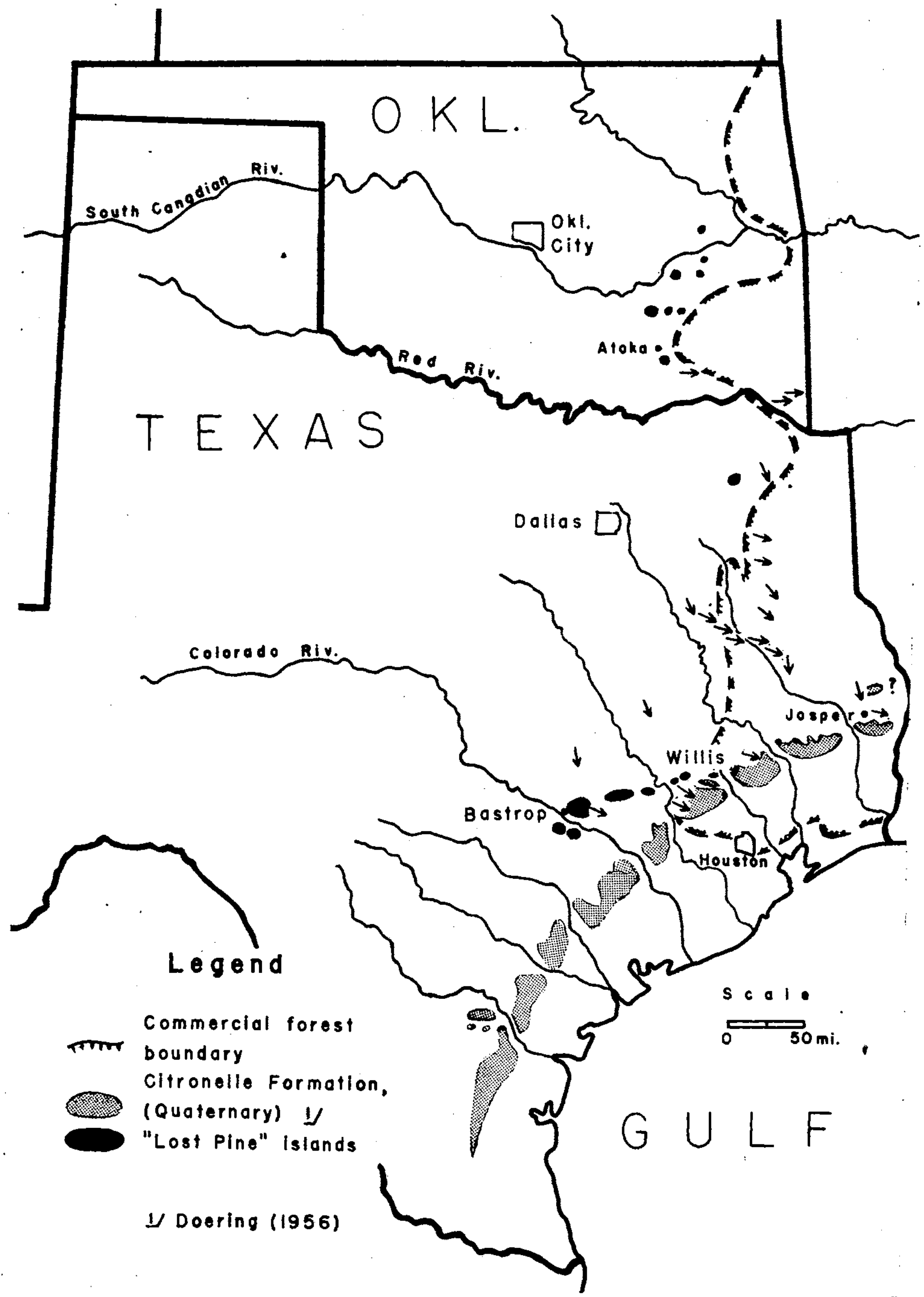

Figure 8. Average Paleocurrent Azimuth (arrows) from Crossbedded Structures in B or C Horizons, at or Near Sample Plots

TABLE III

TEXTURAL AND MINERALOGICAL STATUS OF SELECTED SAMPLES

Sample	Median Grain Diam. - mm	Frequency of Heavy Minerals in Silt Grains - Percent												
		A[1]	Z	S	F	G	Sp.	Pl.	T	R	St.	K	H	E
Stanley Fm., Bokman (5)	< .036													
Stanley Fm., Shale, Plot 3R	< .062	4.8	11.8	0	15.8	3.5	32.9	0.9	30.3	0	0	0	0	0
Stanley Fm., Bokman, (5)	< .083	0-5	10-15	T	-	70-85	-	-	2-5	2-5	T	-	T	T
Stanley Fm., Sandstone, Plot 4R	> .062	4.1	14.8	0.4	39.5	0	30.9	0	8.2	1.2	0.8	0	0	0
Jackfork Fm., Bokman (5)	< .125	T	80-95	T	-	T	-	-	2-5	2-5	T	-	T	T
Jackfork Fm., Sandstone, Plot 5R	> .088	4.5	41.2	0.8	33.7	4.1	3.7	0	9.9	1.7	0.4	0	0	0
DeQueen Fm., Hambric (21)	< .053-.088													
DeQueen Fm., Limestone, Plot 7R	> .062	4.3	57.4	1.0	4.8	1.0	1.9	1.4	20.6	1.9	5.7	0	0	0
DeQueen Fm., Limestone, Plot 8R	< .088	3.1	43.8	0.9	12.5	4.0	6.7	0.5	27.7	0.9	0	0	0	0
Catahoula Fm., Paine et al (34)	.1 - .2	-	C-A[2]	-	-	-	-	-	S-C	S-C	S	S-A	S-C	S-A
Catahoula Fm., Sandstone, Plot 17R	> .062	3.2	31.2	0.7	56.9	0.3	2.0	0	4.2	1.2	0.3	0	0	0
Fleming Fm., Sellards et al (45)	< .088-.177													
Fleming Fm., Bornauser (6)	-	-	80.0	0.2	-	9.0		-	5.1	3.0	1.6	1.0	-	-
Fleming Fm., Calc. clay, Plot 18R	< .125	11.4	31.9	0	12.4	21.3	8.9	0	12.8	0.7	0.7	0	0	0
Oakville ? Fm., Sellards et al (45)	< .250													
Oakville ? Fm., Bornhauser (6)	-	-	52.7	3.0	-	9.3	-	-	4.0	6.0	8.9	6.0	T	11.3
Oakville ? Fm., Calc. SS, Plot 20R	< .125	1.3	46.6	0	9.1	7.3	28.5	0	0.9	2.2	4.3	0	0	0
Sabinetown Fm., Harris (22)	< .092	5.0	26.0	10.0	0	34.0	-	-	5.5	2.0	0	5.0	0	0
Sabinetown Fm., Fine SS, Plot 22R	< .062	5.2	34.8	0	7.1	7.1	10.5	0	34.8	0.4	0	0	0	0

1/ A = Apatite, Z = Zircon, S = Sphene, F = Flourite, G = Garnet, Sp = Spinel, Pl = Pleonaste, T = Tourmaline, R = Rutile, St = Staurolite, K = Kyanite, H = Hornblende, E = Epidote.

2/ Levert (30), Louisiana Samples; S = Scarce, C = Common, A = Abundant, VA = Very abundant, T = Trace reported in available literature (see Table III). There are some differences in estimates of mineral status.

Heavy mineral frequency for sandstone bedrock in plot 4 was comparable to that reported by Bokman (5), except for fluorite, garnet and spinel. Bokman (5) reported that: "...one striking feature of the heavy mineral assemblages is the presence in the Stanley sands west of the approximate longitude of McCurtain County, Oklahoma, of a flood of garnet" (p. 166). He later described two subspecies of garnet observed as white and pink. It is also noted he did not report spinel as present in the Stanley samples. The latter is colorless (white) without crossed nicols, is opaque like garnet under crossed nicols and has a refractive index near garnet (1.72-1.74 and 1.72-1.89, respectively). Spinel was the most frequent heavy mineral found in the plot 4 bedrock. Possibly Bokman listed spinel under his garnet tally.

Comparison of data also indicates Bokman did not report fluorite in the Stanley shale samples. If one excludes fluorite from the total heavy minerals in the plot 4 sample the adjusted value for spinel then becomes 51.02 percent (strongly predominant, although not rating the 70-85 percent range that Bokman credited for garnet).

Heavy mineral frequency in plot 5 bedrock was somewhat comparable to values reported for the Jackfork sandstones by Bokman (5). He showed a range of 80-95 percent for zircon but did not report any fluroite. Again, if one excludes fluorite from the total heavy minerals the adjusted value for zircon then becomes 62.11 percent in the plot 5 sample.

Tally of heavy minerals in plot 17 bedrock was comparable to values reported by Paine, et al (34) for the Catahoula sandstone in Louisiana

(Levert, 1959). Levert (30) did not report fluorite presence. If fluorite is excluded from the total heavy minerals the adjusted value for zircon becomes 72.41 percent in the plot 17 sample. Since Levert's sample was from Louisiana the odds are greater that kyanite, hornblende, and epidote frequency would be higher as a result of longshore current contributions of reworked materials from high-rank metamorphic sources in the Eastern Gulf province (Hsu, 1960).

Bornhauser (6) reported using dilute hydrochloric acid to dissolve carbonate compounds in bedrock materials and dilute hydrochloric and nitric acid to remove pyritiferous and limonitic constituents and aid petrographic analysis. These treatments may have dissolved apatite grains from his Fleming and Oakville Formation samples. If apatite, fluorite and spinel tallies in plot 18 bedrock samples are excluded from the total heavy minerals the adjusted value for zircon then becomes 47.37 percent. If these deletions are made in plot 20 bedrock tallies the adjusted value for zircon would become 76.06 percent.

Plot 22 bedrock mineral tally is similar to data reported by Harris (22) for the Sabinetown Formation except for sphene, fluorite, garnet, spinel, tourmaline and kyanite. Frequency differences of 10 or more, as in the case of sphene, garnet and tourmaline, appear meaningful.

Mineralogical Analysis of Samples

Cleaned silt grains from bedrock and overlying B horizons were immersed in oil and identified with a petrographic microscope and optical mineralogy techniques. A minimum of 200 "heavy mineral" grains, exclusive of micaceous material and opaques such as magnetite, pyrite, hematite and ilmenite, were talled per slide. Grain counts are shown in Table IV.

Data in Table IV were analyzed by the Chi-square test, as suggested by Eisenhart (15). The objective was to determine if the null hypothesis could be accepted or rejected, i.e., no difference would be found between heavy minerals (resistant to weathering) from bedrock or B horizon strata. If no difference is found between heavy mineral frequency in bedrock and B horizon samples, one would then accept the null hypothesis and conclude B horizons had indeed weathered from the bedrock. Eisenhart indicates that the nearer the values observed are to the independent frequencies the smaller the Chi-square value should be, or, "the magnitude of X^2 is an indication of the degree of departure from homogeneity" (p. 140).

Eisenhart's caution was followed in the analysis of Table IV data:

> ...it must be remembered that the tables of probability have been calculated on the assumption of large samples. It has been found that this calculated distribution is not very closely realized for very small class frequencies, and therefore, to play safe one should try to have the smallest independence frequency greater than 10 [a minimum] (p. 141).

Columns in Table IV with values less than 10 were accordingly deleted from the analysis.

Chi-square test data are shown in Table V. Total X^2 value for each of the six tables comparing mineral frequency in bedrock and B horizons exceeded the table value of Chi-square at the .01 probability level. This indicates observed frequency, or proportions for some of the minerals, did not fall within limits for expected independent frequencies. Since the total X^2 values exceeded the tabular value ($X^2_{.01}$ level) one can be confident that differences are significant at the .01 level.

TABLE IV

HEAVY MINERAL GRAINS IN SILT FRACTION

Plot	Sample	A [1/]	Z	S	F	G	Sp.	Pl.	T	R	St.	Total Grains
3	B_{22t}	9	21	0	35	62	9	1	76	1	0	214
	Pa. shale	11	27	0	36	8	75	2	69	0	0	228
7	B_{23t}	13	110	3	14	20	2	4	75	3	0	244
	Cret. limestone	9	120	2	10	2	4	3	43	4	12	209
12	B_{23t}	38	85	0	9	63	18	0	83	0	2	298
	Cret. marl	8	15	0	91	27	4	0	84	1	2	232
17	B_{22t}	6	45	0	184	6	1	1	20	2	0	265
	Miocene sandstone	13	126	3	230	1	8	0	17	5	1	404
20	B_{2t}	51	46	0	65	67	11	0	42	1	1	284
	Miocene calcic SS	3	108	0	21	17	66	0	2	5	10	232
22	B_{3t}	17	120	3	19	10	3	0	71	8	1	252
	Eocene fine SS	14	93	0	19	19	28	0	93	1	0	267

[1/] A = Apatite, Z = Zircon, S = Sphene, F = Fluroite, G = Garnet, Sp = Spinel, Pl = Pleonaste, T = Tourmaline, R = Rutile, St = Staurolite

TABLE V

CHI-SQUARE ANALYSIS OF HEAVY MINERAL TALLIES IN SELECTED BEDROCK AND OVERLYING B HORIZONS

Plot	Horizon		A[1]	Z	F	G	Sp	T	St	Total
3	B_{22t}	Observed	9	21	35	62	9	76		212
		Expected	10	23	34	34	41	70		
		X^2 value	.05	.21	.01	23.34	24.65	.48		
	Bedrock	Observed	11	27	36	8	75	69	Deleted	226
		Expected	10	25	37	36	43	75		
		X^2 value	.04	.20	.01	21.89	23.12	.45		
	TOTAL		20	48	71	70	84	145		438
	Total	X^2 value	.09	.42	.02	45.23	47.77	.93		94.46**

Tabulated $X^2_{.01}$ = 15.09, d.f. = 5

Plot	Horizon		A	Z	F	G	Sp	T	St	Total
7	B_{23t}	Observed	13	110	14	20		75	0	232
		Expected	12	125	13	12		64	7	
		X^2 value	.10	1.73	.08	5.47		1.90	6.50	
	Bedrock	Observed	9	120	10	2	Deleted	43	12	196
		Expected	10	105	11	10		54	5	
		X^2 value	.11	2.04	.09	6.47		2.25	7.70	
	TOTAL		22	230	24	22		118	12	428
	Total	X^2 value	.21	3.77	.16	11.94		4.16	14.20	34.44**

Tabulated $X^2_{.01}$ = 15.09, d.f. = 5

TABLE V (Continued)

Plot	Horizon		A[1]	Z	F	G	Sp	T	St	Total
12	B_{23t}	Observed	38	85	9	63	18	83		296
		Expected	26	56	56	51	12	94		
		X^2 value	5.61	14.53	39.82	2.96	2.52	1.32		
	Bedrock	Observed	8	15	91	27	4	84	Deleted	229
		Expected	20	44	44	39	10	73		
		X^2 value	7.25	18.78	51.47	3.83	3.26	1.71		
	TOTAL		46	100	100	90	22	167		525
	Total	X^2 value	12.87	33.30	91.28	6.79	5.79	3.03		153.06**

Tabulated $X^2_{.01}$ = 15.09, d.f. = 5

Plot	Horizon		A	Z	F	G	Sp	T	St	Total
17	B_{22t}	Observed	6	45	184			20		255
		Expected	8	68	165			15		
		X^2 value	0.32	7.79	2.26			1.89		
	Bedrock	Observed	13	126	230			17		386
		Expected	11	103	249	Deleted	Deleted	22	Deleted	
		X^2 value	0.21	5.15	1.49			1.25		
	TOTAL		19	171	414			37		641
	Total	X^2 value	0.53	12.94	3.76			3.15		20.38**

Tabulated $X^2_{.01}$ = 11.34, d.f. = 3

Table V (Continued)

Plot	Horizon		A[1/]	Z	F	G	Sp	T	St	Total
20	B_{2t}	Observed	51	46	65	67	11	42	1	283
		Expected	30	85	48	47	43	24	6	
		X^2 value	14.77	18.22	6.26	8.92	23.56	12.66	4.27	
	Bedrock	Observed	3	108	21	17	66	2	10	227
		Expected	24	69	38	37	34	20	5	
		X^2 value	18.41	22.71	7.80	11.12	29.37	15.79	5.32	
	TOTAL		54	154	86	84	77	44	11	510
	Total	X^2 value	33.18	40.93	14.06	20.04	52.93	28.45	9.59	199.18**

Tabulated $X^2_{.01}$ = 16.81, d.f = 6

Plot	Horizon		A[1/]	Z	F	G	Sp	T	St	Total
22	B_{3t}	Observed	17	120	19	10	3	71	Deleted	240
		Expected	15	101	18	14	15	78		
		X^2 value	0.36	3.56	.05	1.03	9.32	0.59		
	Bedrock	Observed	14	93	19	19	28	93		266
		Expected	16	112	20	15	16	86		
		X^2 value	0.32	3.21	.05	0.92	8.41	0.53		
	TOTAL		31	213	38	29	31	164		506
	Total	X^2 value	0.68	6.78	0.10	1.95	17.72	1.13		28.36**

Tabulated $X^2_{.01}$ = 15.09, d.f. = 5

[1/] A = Apatite, Z = Zircon, F = Flourite, G = Garnet, Sp = Spinel, T = Tourmaline, St = Staurolite

The wide difference in total X^2 values above tabulated $X^2_{.01}$ suggests a considerable departure from homogeneity between heavy mineral grains in bedrock and B horizon samples.

For plot 3 it is apparent that garnet and spinel contributed the most to the high X^2 value. In plot 7 proportions between garnet and staurolite have contributed heavily to the total X^2 value. Proportions of apatite, zircon, and fluorite have contributed heavily to total X^2 value in plot 12. For plot 17 the proportions of zircon have contributed heavily to the total X^2 value. Apatite, zircon, garnet, spinel and tourmaline proportions have heavily influenced the high total X^2 value in plot 20, while spinel proportions have made the heaviest impact on plot 22 total X^2 value.

CHAPTER V

SUMMARY AND CONCLUSIONS

Common soil series, within Psamments, Alfisols, and Ultisols that are considered weathered in situ in the Coastal Plain and contiguous physiographic provinces, are found above various bedrock units varying from Precambrian to Pleistocene. Even though there has been an extremely variable time factor available for soil weathering and there is a wide diversity in physical and chemical nature of bedrock units (sandstone, shale, limestone, marl, chalk and calcareous clay) there has been general agreement that climatic and biotic factors have been primary agents in the development of common soil units (8).

The enigma is further confounded when one finds two contrasting soil orders (Psamments and Ultisols) may be contiguous and above the same bedrock unit, within the same climatic and physiographic control area. This makes one strive for comprehension of order in soil genesis and ecosystem nature.

Unconsolidated Pliocene?--Pleistocene sands and clays are mapped as the Citronelle Formation (a fluvial mantle) in the lower Coastal Plain. Other extensive areas were mapped in the Atlantic Coastal Plain by Doering (12) in 1960 but not included in the U. S. Geologic Map reprinted the same year. They lie unconformably above Precambrian to Miocene formations. Moreover, they show remarkable correlation with the longleaf pine (Pinus palustris Mill.) type as mapped by the U. S. Forest

Service (23) in 1963 and with disjunct units in northern Alabama and Georgia yet to be recognized, as if there is a cause-effect relationship (51).

Soil series within the Alfisol and Ultisol orders are common to both the mapped Citronelle Formation and areas inland in the upper Coastal Plain. The Citronelle Formation is recognized as a dissected remnant of a once-continuous alluvial plain in the lower Coastal Plain. This poses a question as to the possibility that Alfisols and Ultisols in inland positions might also be disjunct remnants of the alluvial plain that formed the Citronelle unit.

Twenty three soil pits were studied in Susquehanna-like and Bowie soils and underlying bedrock units on uplands (southeastern Oklahoma, southwestern Arkansas and eastern Texas, including the Citronelle Formation and "Bastrop Lost Pine" areas). Underlying bedrock studied included Pennsylvanian sandstone and shale; Cretaceous limestone, marl and chalk; Eocene sandstone; and Miocene sandstone and calcareous clay.

Two null hypotheses were used as focal points of a major thrust: no difference will be found between the data collected and the current view about soil genesis and geologic history for sampled Ultisols and Alfisols of the western Gulf Coastal Plain; i.e., (a) soils will have physical and mineralogical features that show they have been weathered in situ from various rock outcrops (are residual soils) and cannot have some other genetic history, and (b) soils in inland positions will be physically and mineralogically similar to Alfisols and Ultisols above the Citronelle Formation but cannot have a similar geologic history.

Samples were collected and studied to determine if differences might be found in washed gravel status, sand grain size and heavy mineral frequency. Wherever possible the dip direction of crossbeds in B and C horizons was recorded to indicate azimuth for paleocurrents, which would document directions that rivers flowed and suggest source areas for transported materials.

The four sets of data complement each other and suggest that the two null hypotheses be rejected because:

(a) Nine of the 18 formal study plots on Susquehanna-like soils and two of the five supplemental plots on Bowie soils had large sand grains in B horizons that are not represented in disaggregated bedrock material. If the solum weathered from various bedrock units to the point of having well-developed argillic (clayey) B horizons one should expect to find quartz and chert grains in the B horizons of comparable or slightly smaller diameter as a result of bedrock disaggregation and particle weathering.

One might wonder if the larger quartz grains in the B horizons might have resulted from secondary formation (crystallization). Microscopic examination of thin-section slides and cleaned silt fractions, however, shows that B horizon samples contain a mix of angular to well-rounded (recycled) quartz grains with straight extinction, as well as some crystal-oriented, polycrystalline quartz (with undulatory extinction). The latter apparently originated in metamorphic rock.

The larger sand grains in the B horizons and the poorly sorted nature of grains compared to small and rather uniform sizes of terrigenous grains in fine-textured bedrock such as Pennsylvanian shale, Cretaceous chalk and Miocene fine sandstone

(Catahoula Fm.) indicate the former materials are foreign to the environment in which the bedrock formed. These quantitative differences suggest an outside source contributed the large sand grains in the solum.

(b) Washed gravel (predominantly quartz, chert, quartzite, petrified wood and local rock) was found concentrated in A_1 - A_2 horizons with loamy sand to silty loam materials, in a few lenses in B horizons, or in heavy bands just above bedrock. Some gravel in A_1 - A_2 horizons and contact zones above bedrock ranged up to 5 inches in diameter. Washed gravel was absent in underlying bedrock, except for trace amounts at three locations (one 3 mm grain in each of a Cretaceous marl and Miocene calcareous clay and two 5 mm grains in a second Miocene calcareous clay). Thus, a sharp basal contact exists with bedrock units.

Some gravel is only slightly rounded and its lithologic type suggests it was plucked off the surface of the outcrop of the next lower stratigraphic unit at up-slope positions. This was especially suggested by chalk found in plot 12 material near Foreman, Arkansas. The chalk appears to be similar to the Annona chalk outcrop to the northwest.

Frequency, position and size of the gravel in the solum suggests the gravel could not have been weathered from underlying bedrock but was transported to the site by streams on an alluvial plain.

Gravel and predominantly loamy sand in surficial soil horizons frequently had an abrupt boundary with the upper, finer-textured B horizons. These conditions suggest another depositional episode during which gravel and sand were laid down as a last-stage deposit by strong fluvial currents that could carry a load of coarse, heavy materials. Because this was a common pattern in all watersheds studied, it suggested that there was possibly a common interaction in the source area for all the paleorivers, involving climate and/or geologic structure. Gravel and sand in the surficial layer (especially at present interstream divide positions such as at plots 16, 17 and 18 at Lone Pine, Jasper and Willis, Texas, respectively) suggest these materials were carried by a series of streams with braided channels that coalesced to form a very extensive deposit.

Ipshording and Lamb (26) in 1971 reported that sands and gravels predominated in the surficial unit of the Citronelle Formation studied in Alabama:

> The more typical sands, gravels and clays ...that overlie the clay bed are thought to be the product of increased fluvial activity along the southern margin of the Coastal Plain that resulted from epeirogenic uplift of the continental interior at this time (p. 777).

(c) The cumulative evidence listed below suggests the Alfisols and Ultisols studied achieved most of their state through a history of primary deposition in a fluvial environment of Pliocene?--Pleistocene age, because:

1. The sharp basal contact of the Alfisols and Ultisols is unconformable above various bedrock units, across a master slope that generally decreases in elevation

as one proceeds toward the Gulf from plots 1, 2 to 15, 3 to 16, 22 to 20, 24 to 17 (Figure 1), as follows: 700, 590, 600, 510, 510, 500, 610, 425, 375, 355, 410, 370, 460, 420, 510, 420, 450, 500, 375, 315, 300, 250, and 250 feet.

2. The literature indicates that the study area has been in an emergent condition since late Miocene time, voiding the possibility that marine environments could have contributed to depositional features found in surficial materials. Also, no marine fauna or flora were found in the surficial materials.
3. The sharp basal contact (gravelly and strongly-variegated sands and clays, Figure 3A) and range in dip direction of crossbed units of lower B or IIC horizons (Figures 7, 8) suggest the materials were deposited by meandering and/or braided-channel streams. A deposit of a single stream is expressed by a sharp basal contact in a linear trend; coalescing, braided-channel streams, however, would form a sharp basal contact over very extensive areas.
4. The average azimuth directions of crossbed units at 23 field locations indicate the rivers headed in areas west and/or northwest of the study, or in the eastern part of the Rocky Mountains and the Llano Estacado. Average paleocurrent directions are comparable to the trends of the present rivers flowing across the western

Gulf Coastal Plain and agree with slope direction indicated by decreasing elevation in item 1 above.

(d) A Chi-square analysis was made of heavy minerals identified in silt-size grains obtained from six matching sets of B horizon and underlying bedrock samples. Total χ^2 values exceeded tabulated values for the .01 significance level. This magnitude of difference indicates a strong departure from homogeneity between bedrock and B horizon samples. The heavy minerals are strongly resistant to weathering. If soluble constituents, such as calcium carbonate cementing agents, are dissolved by weathering action the resistant minerals and quartz could accumulate in B horizons as the fabric of the solum. However, if one finds significantly fewer grains of a given mineral species in B horizons than in samples from underlying bedrock one must conclude the proportions result from inherent frequency in discrete units before weathering and are not a consequence of weathering from bedrock. Limited grain tallies in B horizons were recorded for spinel in plot 3; staurolite in plot 7; fluorite in plot 12; zircon in plot 17; zircon, spinel and staurolite in plot 20; and spinel in plot 22.

The proportions of heavy mineral grains found in matched pairs of B horizon and bedrock samples suggest materials in B horizons gained their frequency from inputs in an environment in each watershed that was different than the environment prevailing when the various bedrock units were formed.

First Null Hypothesis

The cumulative evidence of data presented in items a, b, c and d above suggest the C, B and A soil horizons are the equivalent of sequential fluvial beds. The first null hypothesis is therefore rejected. The Alfisols and Ultisols studied are considered as not having been weathered *in situ* from various bedrock units.

Second Null Hypothesis

The lithology of subsoils and general physical pattern in A_1 - A_2 horizons were found to be the same, whether samples were above the mapped Citronelle Formation or found in positions up-slope or inland from the Citronelle unit. These patterns were also common irrespective of soil location and watershed, whether in the South Canadian, Red, Neches, Trinity, Brazos or Colorado river watersheds. Conditions listed under (c) above indicate the Alfisols and Ultisols in both upper and lower-watershed positions are of alluvial plain nature and have a common paleocurrent azimuth and general source area. This suggests the fluvial mantle on upland surfaces in inland positions could be unrecognized Pliocene?--Pleistocene material of age comparable to the Citronelle. The second null hypothesis is rejected. The soils in inland positions are, therefore, considered physically and mineralogically similar to Alfisols and Ultisols above the Citronelle Formation and are considered to have a geologic history similar to that of the Citronelle unit.

Projections for Future Consideration

The spline function described by Erh (16) can be programmed for computers to enable rapid classification of sand, silt and clay percent from hydrometer readings. The facility of this tool can forestall laborious and time-consuming hand-plotting and calculation procedures. It should find growing use where many hydrometer readings need to be converted.

Geomorphic patterns in the study area suggest: (a) immediately after geologic deposition ceased there was a nearly continuous fluvial mantle (alluvial plain) that provided favorable to compensatory environments for plant migration, even into climatic tension-zone areas at the western periphery (Bastrop Lost Pine Islands in east-central Texas), (b) plant migration moved rapidly (in geologic time) across the favorable mantle, rather than by slow soil building and genetic adaptation ("drought resistant" ecotype adaptation), (c) severe erosion and dissection of the mantle followed as streams were rejuvenated, leaving disjunct plant communities stranded above disjunct Alfisols and Ultisols largely undisturbed at interfluve positions, (d) there are significant areas inland from the mapped Citronelle Formation that are not yet recognized as upland fluvial deposits; extension of surficial geologic mapping and inclusion of these areas would aid in ecosystem interpretation and land-use planning, i.e., allow the forest associations to be considered <u>respondents</u> to the fluvial mantle (rather than modifiers of various bedrock units) and thereby enhance their credibility as indicators of the primary control factor of the ecosystem and land class. Surficial geologic mapping of fluvial mantle two feet or more thick would materially aid land-class interpretation and delineate significant acreage that is not currently recognized. Only units 10 feet or more in thickness are currently mapped.

Recognition of inland areas as disjunct units of the Pliocene?--Pleistocene ecosystem would expand the system scope and understanding of land management parameters. Classification of the system as remnants of a dissected alluvial plain would focus on several physical features: (a) larger and more productive units are concentrated along interfluve divides or contiguous slopes where headward erosion of intermittent streams is of lesser magnitude, (b) slope gradient and susceptibility to continued or aggravated erosion make down-slope areas higher-risk and lower productivity units as continued-cultivation provinces, (c) workability of these soils and their relative productivity potential is largely related to the depth and texture of the A_1 - A_2 loamy sand and capacity to store and retain moisture within effective root zones of preferred crops (48); if this segment of the solum attained its present state through fluvial deposition and not through antecedent bedrock weathering we would not expect current weathering of lower strata to provide replacement material of comparable textural capacity, and (d) the the foregoing would lead us to consider that the Alfisol and Ultisol (and possibly Psamment) mantle studied has been a gratuitous gift of Providence, it has a management threshold that cannot be exceeded without dire consequences to the plant and animal kingdom, and that a soil weathering concept cannot be relied upon to replace unwarranted drafts on resource capital (i.e., careless soil disturbance or management that leads to unwarranted soil erosion).

If the residual depth and texture of the A_1 - A_2 horizons are recognized as having been controlled by a last-stage fluvial deposit we then have a new outlook on ecosystem relationships and sequence. Relative moisture storage and retention classes of A_1 - A_2 horizons could then be interpreted as the area for major control over land class and concomitant plant distribution, association and function on red-yellow podzolic soils, as suggested in the "wedge chart" offered in 1963 (48).

LITERATURE CITED

(1) Barnes, Virgil E. "Geologic Atlas of Texas, Texarkana Sheet." Austin: Bur. Econ. Geol., University of Texas, Map, 1966.

(2) Barsdate, Robert J. "Rapid Heavy Mineral Separation." Jour. Sedimentary Petrology, 32 (1962), 608.

(3) Bernard, H. A., R. J. LeBlanc and C. F. Major. "Recent and Pleistocene Geology of Southeast Texas." Geol. of the Gulf Coast and Central Texas, and Guidebook of Excursions. Houston: Houston Geol. Soc. (E. H. Rainwater and R. P. Zingula, ed.), (1962), 175-224.

(4) Blatt, Harvey and Berry Sutherland. "Intra-stratal Solution and Non-opaque Heavy Minerals in Shales." Jour. Sedimentary Petrology, 39, 2 (1969), 591-600.

(5) Bokman, John. "Lithology and Petrology of the Stanley and Jackfork Formations." Jour. of Geology, 61 (1953), 152-170.

(6) Bornhauser, Max. "Heavy Mineral Associations in Quaternary and Late Tertiary Sediments of the Gulf Coast of Louisiana and Texas." Jour. Sedimentary Petrology, 10, 5 (1940), 125-135.

(7) Brewer, Roy. Fabric and Mineral Analysis of Soils. New York: Wiley, 1964.

(8) Buckman, Harry Oliver and Nyle C. Brady. The Nature and Property of Soils. New York: MacMillan, 1970.

(9) Day, P. R. "Report of the Committee of Physical Analysis." Soil Sci. Soc. Amer. Proc., Vol. 20 (1956), 167-169.

(10) Doering, John A. "Post-Fleming Surface Formations of Southeast Texas and Louisiana." Bull. Amer. Assoc. Pet. Geol., 19, 5 (1935), 651-688.

(11) Doering, John A. "Review of Quaternary Surface Formations of Gulf Coast Region" Bull. Amer. Assoc. Pet. Geol., 40, 8 (1956), 1816-1862.

(12) Doering, John A. "Quaternary Surface Formations of Southern Part of Atlantic Coastal Plain." Jour. Geol., 68, 2 (1960), 182-202.

(13) Douchafour, Ph. "Soil Classification--a Comparison of the French and American Systems." Jour. Soil Sci., 14, 1 (1963), 149-155.

(14) Eargle, D. H. and R. T. Foust, Jr. "Tertiary Stratigraphy and Uranium Mines of the Southwest Texas Coastal Plain, Houston to San Antonio, via Goliad." Geol. of the Gulf Coast and Central Texas, and Guidebook of Excursions. Houston: Houston Geol. Soc. (E. H. Rainwater and R. P. Zingula, ed.), (1962), 225-253.

(15) Eisenhart, Churchill. "A Test for the Significance of Lithological Variations." Jour. Sedimentary Petrology, 5, 3 (1935), 137-145.

(16) Erh, K. T. "Application of the Spline Function to Soil Science." Soil Sci., 114, 5 (1972), 333-338.

(17) Fisk, H. N. "Geology of Grant and LaSalle Parishes." La. Geol. Surv. Bull. No. 10 (1938), pp 246.

(18) Fisk, H. N. "Loess and Quaternary Geology of the Lower Mississippi Valley." Jour. Geol., 59 (1951), 333-356.

(19) Folk, Robert L. Petrology of Sedimentary Rocks. Austin: Hemphills, 1968.

(20) Frye, John C. and A. Byron Leonard. "Ecological Interpretations of Pliocene and Pleistocene Stratigraphy in the Great Plains Region." Amer. Jl. Sci, 225, 1 (1957), 1-11.

(21) Hambric, Burt E. "Petrology and Trace Element Geochemistry of the DeQueen Formation (Cretaceous), Southwest Arkansas." (Unpub. Ph.D. thesis, Univ. Okla., 1965.)

(22) Harris, J. Richard. "Petrology of the Eocene Sabinetown--Carrizo Contact, Bastrop, Texas." Jour. Sedimentary Petrology, 32, 2 (1962), 263-283.

(23) Hedlund, Arnold and Paul Janssen. Major Forest Types in the South. New Orleans, La. and Asheville, N. C.: U. S. Forest Service, South and Southeast. For. Exp. Sta., Map, 1963.

(24) Honess, C. W. "Geology of the Southern Ouachita Mountains of Oklahoma." Okla. Geol. Surv. Bull., Part I (map enclosure), (1923), pp 278.

(25) Hsu, J. Jinghwa. "Texture and Mineralogy of the Recent Sands of the Gulf Coast." Jour. Sedimentary Petrology, 30, 3 (1960), 380-403.

(26) Ipshording, Wayne C. and George M. Lamb. "Age and Origin of the Citronelle Formation in Alabama." Geol. Soc. Amer. Bull., 82 (1971), 775-780.

(27) Jackson, M. L. Soil Chemical Analysis--Advanced Course. Madison: Univ. Wisc., Dept. Soils, 1956.

(28) Johnson, Kent E. "Sedimentary Environment of Stanley Group of the Ouachita Mountains of Oklahoma." Jour. Sedimentary Petrology, 38, 3 (1968), 723-733.

(29) Leith, Carlton J. "Removal of Iron Oxide Coatings from Mineral Grains." Jour. Sedimentary Petrology, 20, 3 (1950), 174-176.

(30) Levert, C. F., Jr. "Lower Catahoula Equivalents of Louisiana." (Unpub. M.S. thesis, La. Sta. Univ., 1959.)

(31) Menard, H. W. Geology, Resources and Society. San Francisco: W. H. Freeman and Co., 1974.

(32) Miser, Hugh D. Geologic Map of Oklahoma. Norman: U. S. Geol. Surv. and Okla. Geol. Surv., 1954.

(33) Nelson, Robert L. "The Gulf Coastal Plain Ultisol and Alfisol Ecosystem: Surface Geology, Soils and Plant Relationships." (Unpub. M.S. thesis, Oklahoma State University, 1973.)

(34) Paine, William R. and A. A. Meyerhoff. "Catahoula Formation of Western Louisiana and Petrographic Criteria for Fluviatile Depositional Environment." Jour. Sedimentary Petrology, 38, 1 (1968), 92-113.

(35) Pirkle, E. C. "Kaolinitic Sediments in Peninsular Florida and Origin of the Kaolin." Econ. Geol., 55, 7 (1960), 1382-1405.

(36) Pirkle, E. C., W. H. Yoho, A. T. Allen and Allen C. Edgar. "Citronelle Sediments of Peninsular Florida." Quat. Jl. Fla. Acad. Sci., 26, 2 (1963), 105-149.

(37) Pirkle, E. C., W. H. Yoho and A. T. Allen. "Hawthorn, Bone Valley and Citronelle Sediments of Florida." Quat. Jl. Fla. Acad. Sci., 28, 1 (1965), 7-58.

(38) Potter, P. E. "The Petrology and Origin of the Lafayette Gravel, Part I: Mineralogy and Petrology." Jl. Geol., 63 (1955), 1-38.

(39) Potter, P. E. "The Petrology and Origin of the Lafayette Gravel, Part II: Geomorphic History." Jl. Geol., 63 (1955), 115-132.

(40) Priddy, Richard R. "Geologic Study Along Highway 80 From Alabama Line to Jackson, Mississippi." Miss. Geol. Surv. Bull. No. 91 (1961), pp 62.

(41) Ragsdale, James A. "Petrology of Miocene Oakville Formation, Texas Coastal Plain." (Unpub. M.S. thesis, University Texas, 1960.)

(42) Rosen, Norman C. "Heavy Minerals and Size Analysis of the Citronelle Formation of the Gulf Coastal Plain." Jour. Sedimentary Petrology, 39, 4 (1969), 1552-1565.

(43) Roy, C. J. "Type Locality of Citronelle Formation, Citronelle, Alabama." Amer. Assoc. Pet. Geol., 23 (1939), 1553-1559.

(44) Russell, Richard Joel. "Quaternary History of Louisiana." Geol. Soc. Amer. Bull., 51 (1940), 1199-1234.

(45) Sellards, E. H., W. S. Adkins and F. B. Plummer. "The Geology of Texas." The Univ. Texas Bull. No. 3232 (1958), pp 1007.

(46) Silker, T. H. and R. A. Darrow. "Hardwood Control for Pine Release and Forage Production." Texas Agr. Aviation Conf. Proc. College Station: Texas A & M College, 1959, pp I: 1-4.

(47) Silker, T. H. "A Prospective Use of Total Site-Silvicultural Classification as an Equitable Basis for Forest Land Evaluation." Proc. Texas Chap. S.A.F.. Vol. No. 1 (1961), 7-20.

(48) Silker, T. H. "Plant Indicators Communicate Ecological Relationships in Gulf Coastal Plain Forests." Forest Soil Relationships in North America. (Chester T. Youngberg, ed.). Corvallis, Oregon: Oregon State University Press, 1965, 317-329.

(49) Silker, T. H. "Bio-economic Assay of Conditions Related to Pine Management on Tension-zone Sites." The Ecology of Southern Forests. (Norwin E. Linnartz, ed.). Baton Rouge: La. State Univ. Press, 1969, 166-181.

(50) Silker, T. H. "Disjunct Forest Communities: Relationship to Red-Yellow Podzolic Soils, Fluvial Quaternary Mantle and Need for Inter-disciplinary Study." Amer. Quaternary Assoc., Abstracts. Abstracts. Bozemon, Montana: 1970, 122.

(51) Silker, T. H. "Pliocene-Pleistocene Fluvial Mantle: Control for Disjunct Pine-Hardwood Communities North of Fall-Line?" Okla. Agric. Exp. Sta. Res. Rep., P-682 (1973), pp 16.

(52) U.S.D.A., Climate and Man, Yearbook of Agriculture, Washington, D.C.: U. S. Govt. Print. Off., (1941), pp 1066, 1131, 1133.

(53) U. S. Geological Survey. Geologic Map of United States. Washington, D. C., 1960.

(54) Walker, Laurence C. "The Coastal Plain Southern Pine Region." Regional Silviculture of the United States, (John W. Barrett, ed.), New York: The Ronald Press, 1962, 246-295.

(55) Weinberg, George H. and John A. Schumaker. Statistics an Intuitive Approach. Belmont, Calif.: Brooks/Cole, 1969.

(56) Zobel, Bruce. "The Tree Improvement Program of the Texas Forest Service." Proc. 2nd Sou. Conf. on Forest Tree Improv., Tech. Rep. No. 9 (1953), 53-55.

APPENDIX

TABLE VI

COALGATE, OKLAHOMA, PLOT NO. 1

County: Coal
Region: "Pine Island"
Soil Description: Aquic Hapludalf, fine, loamy, mixed, thermic

Soil Order: Alfisol
Soil Series: (Bowie-like)
Underlying Bedrock: Thurman SS (Pt)
Elevation: 700 feet

Horizon	Depth (Inches)	Color	Field pH	Texture	Particle Size Distribution % Sand	Silt	Clay	Gravel %	$CaCO_3$ %
A_1	0- 4	10 YR 5/4	6.5	Fine sandy loam	77.37	17.84	4.79	1.22	0.0
A_2	4- 8	10 YR 5/6	6.0	Fine sandy loam	61.49	22.09	16.41	0.87	0.0
B_{21t}	8-20	10 YR 5/6	5.8	Light sandy clay loam	63.59	21.28	15.13	1.58	0.0
B_{22t}	24-30	-	6.2	Sandy clay loam	63.73	20.30	10.96	0.71	0.0
B_{22t}	41-44	-	-	Gravelly, sandy clay loam	(Not analyzed)			35.07	0.0
R	44+	Pink	-	Sandstone, Pa. (Thurman Fm.)	89.96	3.43	6.61	0.0	0.0

TABLE VII

ATOKA, OKLAHOMA, PLOT NO. 2 [1/]

County: Atoka
Region: Upper Coastal Plain
Soil Description: Ultic Hapludalf, fine, mixed, thermic

Soil Order: Alfisol
Soil Series: (Susquehanna-like)
Underlying Bedrock: Soft SS (PMs)
Elevation: 590 feet

Horizon	Depth (Inches)	Color	Field pH	Texture	Particle Size Distribution %			Gravel %	$CaCO_3$ %
					Sand	Silt	Clay		
A_1	0- 4	10 YR 5/2	6.5	Gravelly, fine sandy loam	58.33	30.00	11.67	11.02	0.0
A_2	4-10	10 YR 5/4	5.7	Gravelly, fine sandy loam	63.33	25.00	11.67	8.11	0.0
B_{21t}	10-20	5 YR 5/6	5.5	Clay loam	40.00	23.30	36.67	2.65	0.0
B_{22t}	20-28	2.5 Y 5/2	5.5	Clay loam	43.33	25.00	31.67	6.35	0.0
R	28+	Olive	6.5	Soft sandstone, M-Pa., (Stanley Fm.)	15.97	54.21	29.82	0.0	0.0

[1/]Major portion of data from M.S. candidate.

TABLE VIII

ANTLERS, OKLAHOMA, PLOT NO. 3 [1/]

County: Pushmataha
Region: Upper Coastal Plain
Soil Description: Albaquic Hapludalf, fine, mixed thermic

Soil Order : Alfisol
Soil Series: (Susquehanna-like)
Underlying Bedrock: Grey shale (PMs)
Elevation: 510 feet

Horizon	Depth (Inches)	Color	Field pH	Texture	Particle Size Distribution % Sand	Silt	Clay	Gravel %	$CaCO_3$ %
A_1	0- 3	10 yr. 6/3	6.0	Gravelly, very fine sandy loam	43.33	40.00	16.67	61.42	0.0
A_2	3-12	10 yr. 6/4	5.5	Gravelly, very fine sandy loam	43.33	35.00	21.67	81.85	0.0
B_{21t}	12-24	2.5 yr. 3/6	5.5	Clay	10.00	20.00	70.00	3.27	0.0
B_{22t}	24-32	5 y 5/2	6.3	Clay	5.00	18.33	76.67	0.35	0.0
B_3	32-40	5 y 5/2	7.0	Clay	23.33	10.00	66.67	24.65	0.0
R	40+	Olive-grey	7.0	Shale, (Miss.-Pa.) (Stanley Fm.)	19.29	54.25	26.46	0.0	0.0

[1/] Major portion of data from M.S. candidate.

TABLE IX

ANTLERS, OKLAHOMA, PLOT NO. 4 [1/]

County: Pushmataha
Region: Upper Coastal Plain
Soil Description: Albaquic Hapludalf, fine, mixed, thermic

Soil Order: Alfisol
Soil Series: (Susquehanna-like)
Underlying Bedrock: Yellow SS (PMs)
Elevation: 510 feet

Horizon	Depth (Inches)	Color	Field pH	Texture	Particle Size Distribution %			Gravel %	$CaCO_3$ %
					Sand	Silt	Clay		
A_1	0- 2	10 YR 5/2	6.6	Gravelly, fine sandy loam	48.33	38.34	13.33	21.42	0.0
A_2	2- 7	10 YR 5/4	6.2	Gravelly, fine sandy loam	46.67	43.33	10.00	52.06	0.0
B_{21t}	7- 9	2.5 YR 4/6	5.4	Clay	(Not analyzed)			-	0.0
B_{21t}	10-15	2.5 YR 4/6	5.4	Clay	23.33	28.34	48.33	19.02	0.0
B_{22t}	15-20	2.5 Y 6/2	6.3	Clay	23.33	23.34	53.33	3.61	0.0
R	20+	Yellow	-	Sandstone, (Miss.-Pa.) (Stanley Fm.)	65.37	29.94	4.69	0.0	0.0

1/ Major portion of data from M. S. candidate.

TABLE X

ANTLERS, OKLAHOMA, PLOT NO. 5

County: Pushmataha
Region: Upper Coastal Plain
Soil Description: Glossic Hapludalf, fine, loamy, mixed, thermic

Soil Order : Alfisol
Soil Series: Bowie
Underlying Bedrock: Sandstone (Pj)
Elevation: 500 feet

Horizon	Depth (Inches)	Color	Field pH	Texture	Particle Size Distribution %			Gravel %	$CaCO_3$ %
					Sand	Silt	Clay		
A_1	0- 2	10 yr. 4/2	6.5	Fine sandy loam	60.42	33.75	5.83	1.61	0.0
A_2	2- 5	10 yr. 5/6	6.3	Fine sandy loam	60.56	30.48	8.96	1.43	0.0
B_1	5-10	10 yr. 5/6	6.0	Light sandy clay loam	50.70	28.88	20.43	1.19	0.0
B_{21t}	10-19	10 yr. 5/6	6.0	Sandy clay loam	52.02	30.14	17.84	1.24	0.0
B_{22t}	19-24	-	6.3	Sandy clay loam	44.06	36.69	19.25	1.45	0.0
B_{22t}	30-35	-	6.3	Sandy clay loam	42.13	33.24	24.63	1.23	0.0
B_{23t}/A'_2	35-50	10 yr. 6/3	6.2	-	46.23	34.67	19.10	3.36	0.0
C	48-54	-	-	-	-	-	-	34.36	-
R	50+	Pink	-	Sandstone, Pennsylvanian (Jackfork Fm.)	76.48	18.60	4.92	0.0	0.0

TABLE XI

LUKFATA CREEK, OKLAHOMA, PLOT NO. 7[1/]

County: McCurtain
Region: Upper Coastal Plain
Soil Description: Albaquic Hapludalf, fine, mixed, thermic

Soil Order: Alfisol
Soil Series: (Susquehanna-like)
Underlying Bedrock: Limestone (K dq)
Elevation: 610 feet

Horizon	(Inches)	Color	Field pH	Texture	Particle Size Distribution %			Gravel %	$CaCO_3$ %
					Sand	Silt	Clay		
A_1	0- 3	10 YR 4/2	7.0	Silty loam	35.00	55.00	10.00	2.19	0.0
A_2	3- 9	7.5 YR 5/4	6.4	Silty loam	40.00	48.33	11.67	5.76	0.0
B_{21t}	9-15	5 YR 4/4	5.6	Clay	23.30	36.70	40.00	0.06	0.0
B_{22t}	15-19	2.5 Y 6/2	5.6	Clay	55.00	6.67	38.33	0.01	0.0
B_{23t}	19-26	2.5 Y 6/2	6.0	Clay	15.00	45.00	40.00	0.00	0.0
B_{24t}	26-32	2.5 Y 5/2	7.5	Clay	10.00	36.67	53.33	0.03	0.0
B_{25t}	32-40	5 Y 5/2	7.5	Clay	17.50	30.00	52.50	0.65	0.0
B_{26t}	40-56	5 Y 6/2	8.0	Clay	16.67	36.67	46.67	8.01	13.66
-	66-70	-	-	Sand lens	(Not analyzed)			-	0.0
R	70+	Grey	-	Hard limestone, Lower Cret. - (DeQueen Fm.)	61.16	31.92	6.92	0.0	71.99

[1/] Major portion of data from M.S. candidate

TABLE XII

EAGLETOWN, OKLAHOMA, PLOT NO. 8 [1/]

County: McCurtain
Region: Upper Coastal Plain
Soil Description: Albaqultic Hapludalf, fine, mixed, thermic

Soil Order: Alfisol
Soil Series: Vaiden
Underlying Bedrock: Limestone (K dq)
Elevation: 425 feet

Horizon	Depth (Inches)	Color	Field pH	Texture	Particle Size Distribution % Sand	Silt	Clay	Gravel %	$CaCO_3$ %
A_1	0- 3	10 YR 4/2	7.0	Gravelly, silty loam	48.33	45.00	6.67	4.10	0.0
B_{21t}	3- 8	2.5 YR 4/6	5.5	Clay	18.33	23.34	58.33	0.26	0.0
B_{22t}	8-17	R 2.5 4/8	5.8	Clay	23.30	23.37	53.33	0.13	0.0
B_{22t}	17-24	R 2.5 4/8	5.8	Clay	16.67	40.00	43.33	0.02	0.0
R	24+	Grey	-	Macro-fossiliferous limestone (Lower Cret.--DeQueen Fm.)	19.83	35.29	44.88	0.0	63.58

[1/] Major portion of data from M.S. candidate.

TABLE XIII

GOODWATER, OKLAHOMA, PLOT NO. 9-S

County: McCurtain
Region: Upper Coastal Plain
Soil Description: Albaquic Hapludalf, fine, mixed thermic

Soil Order: Alfisol
Soil Series: Cadeville
Underlying Bedrock: Limestone (K gl)
Elevation: 375 feet

Horizon	Depth (Inches)	Color	Field pH	Texture	Particle Size Distribution % Sand	Silt	Clay	Gravel %	$CaCO_3$ %
A_1	0- 3	10 YR 4/2	6.0	Gravelly, silty loam	34.32	55.54	10.14	1.42	0.0
A_2	3- 7	2.5 YR 6/4	5.5	Gravelly, silty loam	27.80	62.20	10.00	2.24	0.0
B_1	7-12	5 YR 5/6	5.5	Silty clay loam	15.40	54.60	30.00	1.50	0.0
B_{21t}	12-20	2.5 Y 5/4	5.5	Clay	9.40	48.60	42.00	0.48	0.0
B_{22t}	20-46	10 YR 6/2	6.0	Clay	7.20	38.80	54.00	0.61	0.0
B_{23t}	46-62	5 Y 5/3	6.5	Clay	7.40	20.60	72.00	0.32	0.0
R	62+	Grey	-	Macro-fossiliferous limestone, Mid-Cret. (Goodland Fm.)	37.40	7.22	55.39	0.0	92.92

1/ Major portion of data from unpublished M.S. thesis, OSU

TABLE XIV

McKINNEY CREEK, OKLAHOMA, PLOT NO. 10-E [1/]

County: McCurtain
Region: Upper Coastal Plain
Soil Description: Albaqultic Hapludalfs, fine, mixed, thermic

Soil Order: Alfisol
Soil Series: Cadeville
Underlying Bedrock: Marl (Kbr)
Elevation: 355 feet

Horizon	Depth (Inches)	Color	Field pH	Texture	Particle Size Distribution % Sand	Silt	Clay	Gravel %	$CaCO_3$ %
A_1	0- 3	10 YR 2/2	5.0	Gravelly, silty loam	25.97	65.70	8.33	1.54	0.0
A_2	3- 8	10 YR 6/6	5.0	Gravelly, silty loam	33.33	50.02	16.65	14.46	0.0
B_{21t}	8-18	2.5 YR 4/6	5.6	Clay	17.65	45.72	36.63	6.15	0.0
B_{22t}	18-30	2.5 YR 4/6	5.9	Clay	12.32	39.40	48.28	1.67	0.0
B_{23t}	30-36	10 YR 4/6	5.9	Clay	3.99	21.19	74.92	0.28	0.0
R	47+	Creamy	8.0	Marl, Mid-Cretaceous, (Brownstown Fm.)	1.80	61.20	37.00	0.00	55.97

[1/] Major portion of data from unpublished M.S. thesis, OSU.

TABLE XV

FOREMAN, ARKANSAS, PLOT NO. 11 [1/]

County: Little River
Region: Upper Coastal Plain
Soil Description: Vertic Hapludalf, very fine, montmorillonitic, thermic

Soil Order: Alfisol
Soil Series: Oktibbeha (Approaching lithic)
Underlying Bedrock: Chalk (Kan)
Elevation: 410 feet

Horizon	Depth (Inches)	Color	Field pH	Texture	Particle Size Distribution % Sand	Silt	Clay	Gravel %	$CaCO_3$ %
A_1	0- 5	10 YR 3/3	7.5	Fine sandy loam	63.30	20.00	16.67	1.95	0.0
B_1	5-10	10 YR 5/6	7.5	Fine sandy loam	50.00	18.33	31.67	0.41	0.0
B_{21t}	10-16	2.5 YR 4/6	7.5	Clay	26.67	15.00	52.33	0.06	0.0
B_{22t}	16-20	2.5 YR 4/6	7.5	Clay	20.00	6.67	73.33	0.13	0.0
II C	20-23	2.5 YR 6/6	7.5	Clay	21.67	5.00	73.33	0.20	0.0
C	23-25	-	8.0	Clay	53.33	10.00	36.66	1.57	0.0
R	25+	Grey	-	Chalk, Upper Cretaceous, (Annona Fm.)	0.10	42.33	57.58	0.00	94.28

1/ Major portion of data from M. S. candidate.

TABLE XVI

FOREMAN, ARKANSAS, PLOT 12-M [1/]

County: Little River
Region: Upper Coastal Plain
Soil Description: Vertic Hapludalf, very fine, montmorillonitic, thermic

Soil Order: Alfisol
Soil Series: Oktibbeha
Underlying Bedrock: Marl (Kmb)
Elevation: 370 feet

Horizon	Depth (Inches)	Color	Field pH	Texture	Particle Size Distribution % Sand	Silt	Clay	Gravel %	$CaCO_3$ %
A_1	0- 3	10 YR 3/1	6.0	Silty clay	30.97	40.73	28.30	21.25	0.0
B_{21t}	3-12	5 YR 5/8	5.5	Clay	19.98	25.10	54.92	17.05	0.0
B_{22t}	12-20	5 YR 5/8	5.0	Silty clay	6.99	30.72	63.27	1.27	0.0
B_{23t}	20-26	2.5 Y 6/6	5.0	Silty clay	22.04	65.54	12.42	14.51	15.61
II C	34-62	2.5 Y 6/6	7.5		5.33	40.72	44.94	0.61	54.41
R	62+	Grey	8.0	Marl, Upper Cretaceous, (Marlbrook Fm.)	0.62	41.07	58.31	0.00	54.73

1/ Major portion of data from unpublished M.S. thesis, OSU.

TABLE XVII

WHITEROCK, TEXAS, PLOT 13-N [1/]

County: Red River
Region: Upper Coastal Plain
Soil Description: Vertic Paleudalfs, fine, montmorillonitic, thermic

Soil Order: Alfisol
Soil Series: Bryarly
Underlying Bedrock: Chalk (Kan)
Elevation: 460 feet

Horizon	Depth (Inches)	Color	Field pH	Texture	Particle Size Distribution % Sand	Silt	Clay	Gravel %	$CaCO_3$ %
A_1	0- 3	10 YR 3/2	7.5	Clay loam	11.32	52.15	36.63	0.32	0.0
B_{21t}	3- 6	7.5 YR 5/6	7.0	Clay	4.99	48.39	46.62	0.00	0.0
B_{22t}	6-13	5 YR 5/8	7.0	Clay	6.66	46.72	46.62	0.71	1.38
B_{23t}	13-21	10 YR 5/4	5.0	Clay	5.32	34.74	59.94	0.18	0.0
B_{24t}	21-29	10 YR 5/4	8.0	Clay	6.60	15.40	78.00	0.09	2.44
B_{25t}	29-45	10 YR 5/6	8.0	Clay	5.66	67.70	26.64	T	0.40
C	45-61	10 YR 7/3	8.0		4.88	41.12	55.40	T	51.38
R	61+	Grey	8.0	Chalk, Upper Cretaceous, (Annona Fm.)	3.90	42.00	54.10	0.0	77.74

[1/] Major portion of data from unpublished M.S. thesis, OSU.

TABLE XVIII

CLARKESVILLE, TEXAS, PLOT NO. 14

County: Red River
Region: Upper Coastal Plain
Soil Description: Vertic Paleudalf, fine, montmorillonitic, mixed, thermic

Soil Order: Alfisol
Soil Series: Bryarly
Underlying Bedrock: Chalk (Kan)
Elevation: 420 feet

Horizon	Depth (Inches)	Color	Field pH	Texture	Particle Size Distribution %			Gravel %	$CaCO_3$ %
					Sand	Silt	Clay		
A_1	0- 6	10 YR 3/2	7.5	Clay loam	26.29	51.16	22.55	1.95	0.0
B_{21t}	6-13	2.5 YR 5/8	6.0	Clay	14.30	39.41	46.28	0.73	0.0
B_{22t}	13-26	10 YR 6/1	4.5	Clay	13.77	41.62	44.61	0.94	0.0
B_{23t}	26-58	10 YR 5/1	6.0	Clay	19.41	64.67	15.92	0.58	0.0
B_{24t}	58-65	10 YR 6/1	8.0	Clay	12.02	42.17	45.81	1.58	-2/
C	65-68	-	-	Clay	14.63	41.91	43.46	2.60	3.84
C	94-114	-	-		-1/	-	-	17.68	-2/
R	114+	Grey	-	Chalk, Upper Cretaceous, (Annona Fm.)	1.24	19.98	78.79	0.0	89.17

1/ Sample not located

2/ Not analyzed

TABLE XIX

DURANT, OKLAHOMA, PLOT NO. 15

County: Bryan
Region: Upper Coastal Plain
Soil Description: Aquic Hapludalf, fine, mixed, thermic

Soil Order: Alfisol
Soil Series: (Vaiden-like)
Underlying Bedrock: Limestone (K w)
Elevation: Approximately 600 feet

Horizon	Depth (Inches)	Color	Field pH	Texture	Particle Size Distribution % Sand	Silt	Clay	Gravel %	$CaCO_3$ %
A_1	0- 4	10 YR 4/3	7.0	Heavy loam	61.42	23.86	14.72	1.72	2.34
B_1	4- 9	5 YR 5/6	7.0	Clay loam	46.63	23.22	30.15	0.00	0.0
B_{21t}	9-15	Red YR dom.	6.5	Clay loam	40.54	22.39	37.07	1.63	4.88
B_{22t}	15-27	10 YR 6/2	6.5	Sandy loam	60.87	32.74	6.38	4.45	2.93
R	27+	Grey	-	Fossiliferous limestone, Lower Cret., (Washita Fm.)	85.05	5.96	8.99	0.0	64.98

TABLE XX

PINE FOREST, TEXAS, PLOT NO. 16

County: Hopkins
Region: "Pine Island," Upper Coastal Plain
Soil Description: Glossaquic Paleudalf, fine, loamy, siliceous, thermic

Soil Order: Alfisol
Soil Series: Freestone (Bowie-like)
Underlying Bedrock: Fine sandstone, (Ew)
Elevation: 510 feet

Horizon	Depth (Inches)	Color	Field pH	Texture	Particle Size Distribution % Sand	Silt	Clay	Gravel %	$CaCO_3$ %
A_1	- 1/	-	-	-	-	-	-	-	-
A_2	0- 9	10 YR 6/3	6.5	Fine sandy loam	75.44	19.21	5.35	0.93	0.0
B_1	9-14	10 YR 5/4	6.0	Sandy clay loam	59.08	15.89	25.03	0.18	0.0
B_{21t}	14-20	10 YR 5/6	5.8	Sandy clay loam	55.92	12.82	31.26	0.03	0.0
B_{22t}	20-32	-	5.4	Sandy clay loam	62.24	19.05	18.71	0.08	0.0
B_{23t}	32-44	-	5.8	Sandy clay loam	56.84	24.81	18.35	0.01	0.0
B_{24t}	44-50	-	5.8	Light sandy clay loam	69.08	18.26	12.66	0.02	0.0
B_{24t}	80-116	-	5.8	Light sandy clay loam	77.63	13.68	8.69	0.07	0.0
B_{25t}	116-140	-	-	Clay	21.07	47.80	31.13	0.00	0.0
B_{25t}	164-188	Light grey	-		(Not analyzed)			0.18	0.0
R		Yellow-grey	-	Fine SS, Eocene, (Wilcox Fm.)	31.50	40.01	28.48	0.00	0.0

1/ Eroded

TABLE XXI

JASPER, TEXAS, PLOT NO. 17

County: Jasper
Region: Lower Coastal Plain (Mapped Citronelle Fm.)
Soil Description: Aquic Hapludalf, fine, loamy, mixed, thermic

Soil Order : Alfisol
Soil Series: Susquehanna-like
Underlying Bedrock: Qct (Citronelle Fm.), overlying Miocene, fine sandstone
Elevation: 250 feet

Horizon	Depth (Inches)	Color	Field pH	Texture	Particle Size Distribution %			Gravel %	$CaCO_3$ %
					Sand	Silt	Clay		
A_1	0- 5	10 yr. 5/1	6.5	Loamy fine sand	68.81	26.78	4.41	0.49	0.0
A_2	5- 9	10 yr. 6/2	6.5	Loamy fine sand	69.29	23.62	7.09	0.42	0.0
B_{21t}	9-16	7.5 yr. 4/4	6.0	Light sandy clay loam	41.41	28.53	30.06	0.98	0.0
B_{22t}	16-23	7.5 yr. 4/4	6.0	Light sandy clay loam	55.96	25.62	18.42	1.92	0.0
B_{22t}	23-30	7.5 yr. 4/4	6.0	Light sandy clay loam	56.45	26.68	16.87	0.53	0.0
R	32+	Creamy	5.5	Soft, fine sandstone Mio., (Catahoula Fm.)	27.74	52.14	20.12	0.0	0.0

TABLE XXII

WILLIS, TEXAS, PLOT NO. 18

County: San Jacinto
Region: Lower Coastal Plain (Mapped Citronelle Fm.)
Soil Description: Aquic Paleudalf, fine-loamy, mixed, thermic

Soil Order: Alfisol
Soil Series: Susquehanna-like
Underlying Bedrock: Qct (Citronelle Fm.), overlying Miocene calc. clay
Elevation: 250 feet

Horizon	Depth (Inches)	Color	Field pH	Texture	Particle Size Distribution % Sand	Silt	Clay	Gravel %	$CaCO_3$ %
A_1	0- 1	10 YR 4/2	7.5	Loam	79.64	8.99	11.37	39.84	0.0
A_2	1- 2	5 YR 5/6	6.0	Loam	77.04	13.62	9.34	41.32	0.0
B_{21t}	2-13	2.5 YR 4/6	5.5	Sandy clay	51.02	9.46	39.52	0.17	0.0
B_{22t}	13-22	10 YR 7/1	5.3	Sandy clay loam	64.39	8.46	26.88	0.03	0.0
B_{23t}	22-33	10 YR 7/1	5.3	Sandy clay loam	73.58	8.01	18.41	0.04	0.0
B_{24t}	33-53	5 Y 8/2	5.8	Sandy clay loam	62.80	7.44	29.76	4.03	0.0
B_{25t}	53-67	10 YR 6/8	7.5	Sandy clay loam	42.65	23.12	34.23	0.02	3.32
R	67-109	-	-	Yellow-grey, calc. clay	(Not analyzed)			-	
R	109+	Olive	-	Calc. clay, Miocene (Fleming Fm.)	50.74	14.74	34.52	T	41.68

T = trace (2grains, 5/16")

TABLE XXIII

LA GRANGE, TEXAS, PLOT NO. 20

County: Fayette
Region: Lost Pines
Soil Description: Aquic Haplustalf, fine, mixed, thermic

Soil Order: Alfisol
Soil Series: Vaiden-like
Underlying Bedrock: Miocene (Oakville ? Fm.)
Elevation: 375 feet

Horizon	Depth (Inches)	Color	Field pH	Texture	Particle Size Distribution % Sand	Silt	Clay	Gravel %	$CaCO_3$ %
A_1	0- 5	10 YR 4/2	7.7	Loamy fine sand	56.55	10.03	33.42	1.31	9.47
B_{2t}	5-18	2.5 YR 4/6	7.5	Clay	41.36	12.00	46.64	0.17	14.06
C_{ca}	18-32	-	8.0	Clay	49.76	26.72	23.52	0.40	48.80
C	32-38	-	8.0	Sandy, C_a	- 1/	-	-	-	-
C	38-46	-	8.0	Silty, C_a	- 1/	-	-	0.64	-
C_{ca}	51-46	-	8.0	Sandy, C_a	53.88	21.05	25.07	8.11	3.88
C_{ca}	57-63	-	8.0	Silty, C_a	44.91	41.10	13.98	7.67	- 2/
C	70-76	-	8.0	Sandy, C_a	63.06	27.13	9.81	0.72	- 2/
C	76-108	-	8.0	Sandy, C_a	77.41	5.53	17.06	2.21	- 2/
C_{ca}	108-114	-	8.0	Silty, C_a	36.78	45.51	17.71	-	- 2/
R	168+	-	-	Soft, calc. sandstone Upper Mio. (Oakville ? Fm.)	85.16	3.95	10.89	0.00	69.66

1/ Sample not located

2/ Not analyzed

TABLE XXIV

SMITHVILLE, TEXAS, PLOT NO. 21

County: Bastrop
Region: Lost Pines
Soil Description: Aquic Paleustalf, fine, mixed thermic

Soil Order: Alfisol
Soil Series: Susquahanna-like
Underlying Bedrock: Sandstone (Eocene)
Elevation: 450 feet

Horizon	Depth (Inches)	Color	Field pH	Texture	Particle Size Distribution %			Gravel %	$CaCO_3$ %
					Sand	Silt	Clay		
A_1	0- 4	5 YR 4/3	8.0	Loam	47.78	29.11	23.11	35.88	0.0
A_2	4- 6	5 YR 5/3	5.0	Loam	44.19	37.73	18.08	51.55	0.0
B_{21t}	6-20	2.5 YR 4/6	5.0	Clay	12.17	9.49	78.34	7.82	0.0
B_{22t}	20-26	2.5 YR 4/6	5.5	Clay	9.67	19.08	71.25	2.24	0.0
B_{22t}	26-40	10 YR 6/2	7.0	Clay	8.78	24.09	67.13	0.00	0.0
B_{23t}	40-48	-	-	Clay	5.83	42.05	52.12	0.81	0.0
R	96-109	Yellow	-	Soft sandstone, Upper Eoc., (Sparta Fm.)	14.38	69.69	15.93	0.00	0.0

TABLE XXV

BASTROP, TEXAS, PLOT NO. 22

County: Bastrop
Region: Lost Pines
Soil Description: Aquic Haplustalf, loamy-skeletal, mixed, thermic

Soil Order: Alfisol
Soil Series: Vaiden-like
Underlying Bedrock: Soft Sandstone (Eocene)
Elevation: 420 feet

Horizon	Depth (Inches)	Color	Field pH	Texture	Particle Size Distribution % Sand	Silt	Clay	Gravel %	$CaCO_3$ %
A_1	0- 3	7.5 YR 6/6	7.0	Gravelly sandy loam	68.40	12.13	19.47	60.21	0.0
A_2	3- 7	7.5 YR 7/6	7.0	Gravelly sandy loam	54.00	10.01	35.99	56.34	0.0
B_{21t}	7-13	2.5 YR 4/4	4.5	Clay loam	46.02	15.82	38.16	38.97	0.0
B_{22t}	13-24	2.5 YR 4/4	4.8	Clay loam	36.54	31.33	32.14	36.26	0.0
B_{23t}	24-30	7.5 YR 5/6	6.0	Gravelly clay loam	41.13	30.97	27.90	34.73	0.0
B_3	30-42	7.5 YR 5/6	6.0	Clay loam	37.90	27.18	34.92	3.34	0.0
C	42-68	-	6.0	Sandy clay loam	(Not analyzed)			0.00	0.0
R	68+	Brown	-	Sandstone, Lower Eoc., (Sabinetown Fm.)	10.13	70.58	19.30	0.00	0.0

TABLE XXVI

BASTROP, TEXAS, PLOT NO. 23

County: Bastrop
Region: Lost Pines
Soil Description: Aquic Paleustalf, fine-loamy, mixed, thermic

Soil Order: Alfisol
Soil Series: Vashti-like
Underlying Bedrock: Soft, fine SS, (Eocene)
Elevation: 500+ feet

Horizon	Depth (Inches)	Color	Field pH	Texture	Particle Size Distribution % Sand	Silt	Clay	Gravel %	$CaCO_3$ %
A_1	0- 4	10 YR 5/3	7.0	Fine sandy loam	75.30	18.54	6.15	5.45	0.0
A_2	4-14	7.5 YR 6/4	7.0	Fine sandy loam	78.24	16.23	5.52	3.18	0.0
B_{21t}	14-24	10 YR 5/6	6.0	Sandy clay loam	58.07	19.64	22.29	6.13	0.0
B_{22t}	24-46	2.5 YR 4/6	5.5 1/	Sandy clay--S.C.l.	57.88	21.82	20.30	0.19	0.0
B_{23t}	46-106	-	-	Sandy loam	75.89	16.58	7.52	19.43	0.0
R	106+	Buff	-	Soft, fine sandstone Lower Eocene, (Sabinetown Fm.)	18.41	61.99	19.60	0.00	0.0

1/ pH 6.0 at base

TABLE XXVII

COLLEGE STATION, TEXAS, PLOT NO. 24

County: Brazos
Region: Lost Pines
Soil Description: Aquic Paleustalf, fine, montmorillonitic, thermic

Soil Order: Alfisol
Soil Series: Susquehanna-like
Underlying Bedrock: Fine SS, (Eocene)
Elevation: 315 feet

Horizon	Depth (Inches)	Color	Field pH	Texture	Particle Size Distribution %			Gravel %	$CaCO_3$ %
					Sand	Silt	Clay		
A_1	0- 2	10 YR 5/2	7.2	Fine sandy loam	66.37	28.11	5.52	7.70	0.40
A_2	2- 5	10 YR 6/2	5.5	Fine sandy loam	71.23	25.67	3.10	7.79	0.00
B_{21t}	5-11	2.5 YR 4/6	5.5	Clay	22.53	18.98	58.49	1.84	0.00
B_{22t}	11-19	-	5.5	Clay	36.47	25.37	38.17	3.23	0.00
B_{23t}	19-32	10 YR 5/2	8.0	Clay	36.39	26.75	36.86	8.08	0.00
C	32+	-	8.0	-	28.16	51.07	20.77	2.63	0.00
C	47-51	-	-	-	34.69	55.42	9.90	1.02	2.64
R	51+	Grey	-	Soft, fine sandstone, Upper Eoc.,(Yegua Fm.)	30.14	49.84	20.02	0.00	2.64

TABLE XXVIII

HEMPSTEAD, TEXAS, PLOT NO. 25

County: Waller
Region: Lower Coastal Plain (Mapped Citronelle Fm.)
Soil Description: Arenic Paleudalf, loamy, siliceous, thermic

Soil Order: Alfisol
Soil Series: Susquehanna-like (Deep phase)
Underlying Bedrock: Qct (Citronelle Fm.), overlying Miocene calc. clay
Elevation: 300 feet

Horizon	Depth (Inches)	Color	Field pH	Texture	Particle Size Distribution % Sand	Silt	Clay	Gravel %	$CaCO_3$ %
A_1	0- 4	10 YR 4/3	5.0	Loamy sand	80.72	14.14	5.14	0.81	0.0
A_2	8-14	10 YR 5/6	7.0	Loamy sand	84.42	9.71	5.87	3.57	0.0
A_2	15-21	10 YR 5/6	7.0	Loamy sand	84.55	11.65	3.80	7.74	0.0
B_{21t}	21-26	7.5 YR 5/6	6.0	Sandy clay loam	69.53	16.63	13.79	2.13	0.0
B_{22t}	26-78	10 R 4/6	5.0	Sandy clay loam--clay l.	62.14	13.57	24.30	0.80	0.0
B_{23t}	78-84+	2.5 YR 4/6	6.5	Sandy clay loam	76.51	3.87	19.62	0.02	0.0
B_{24t}	144-210	5 YR 5/6	6.5	Loamy sand	79.45	6.36	14.19	0.02	0.0
R	210+	Olive-grey	-	Calcareous clay, Miocene (Fleming Fm.)	36.37	16.68	46.95	0.0	39.78

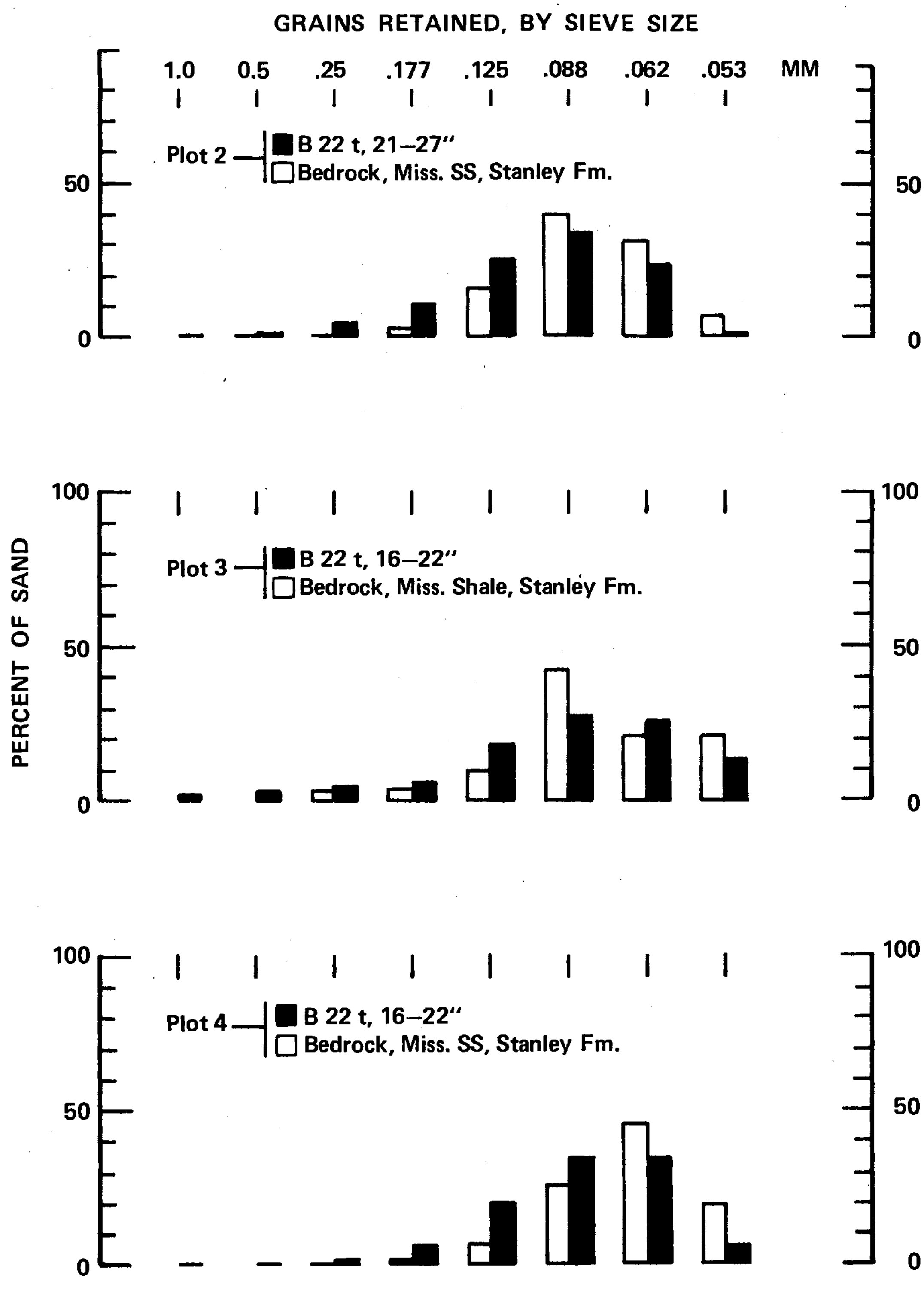

Figure 9. Grain-size of Sand From B Horizons of Ultisols and Underlying Pennsylvanian Bedrock

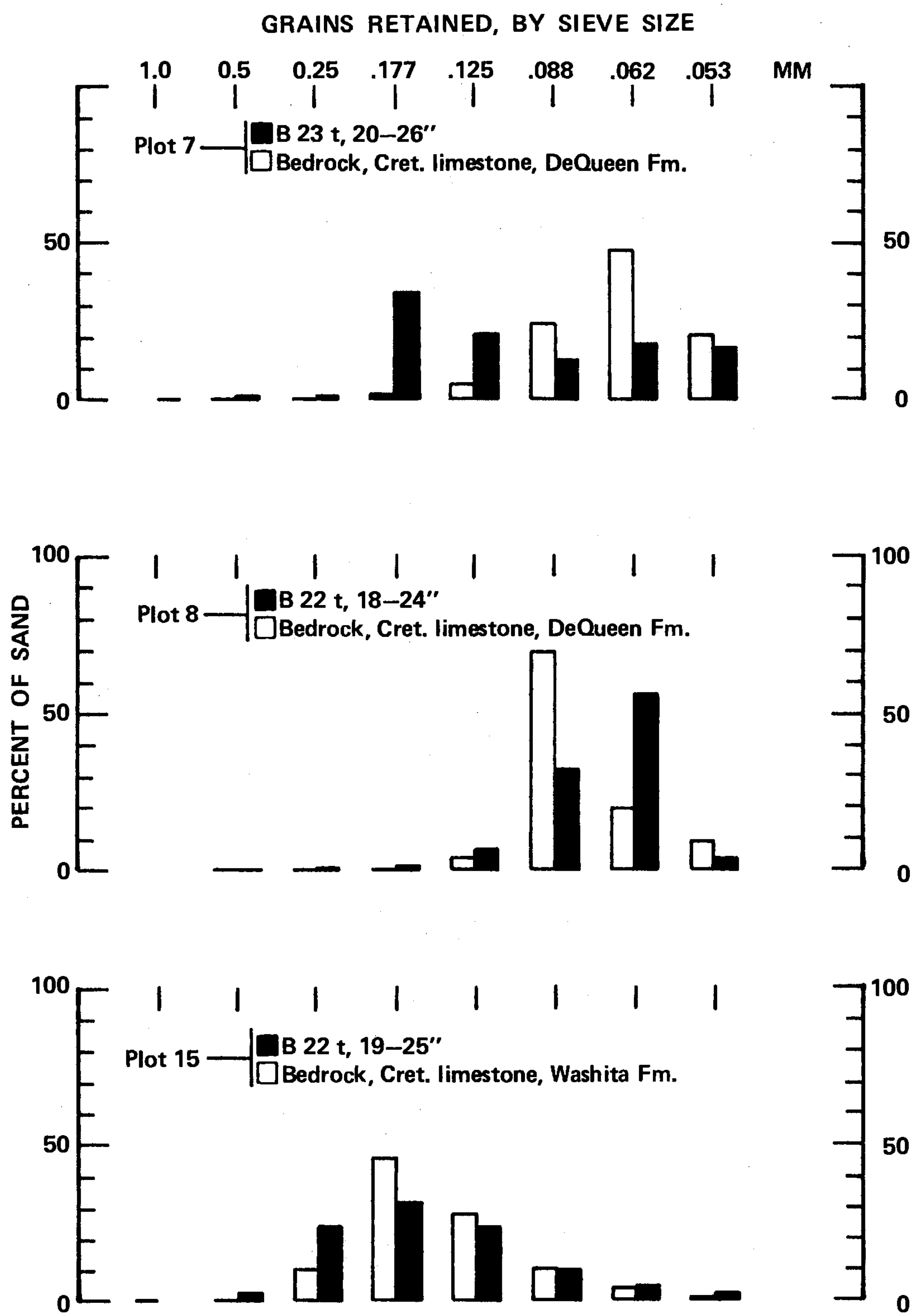

Figure 10. Grain-size of Sand From B Horizons of Alfisols and Underlying Lower-Cretaceous Bedrock

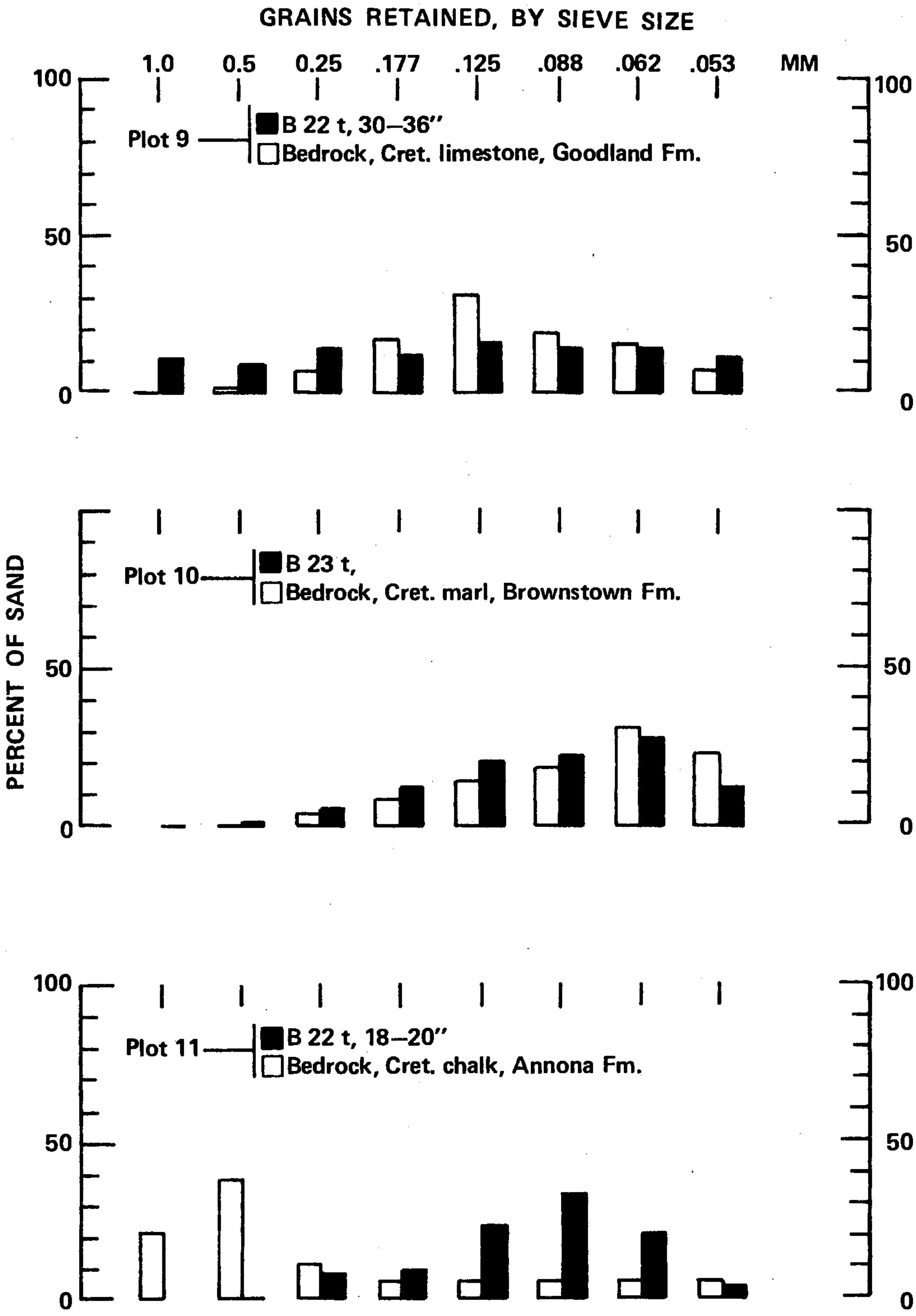

Figure 11. Grain-size of Sand From B Horizons of Alfisols and Underlying Middle and Upper-Cretaceous Bedrock

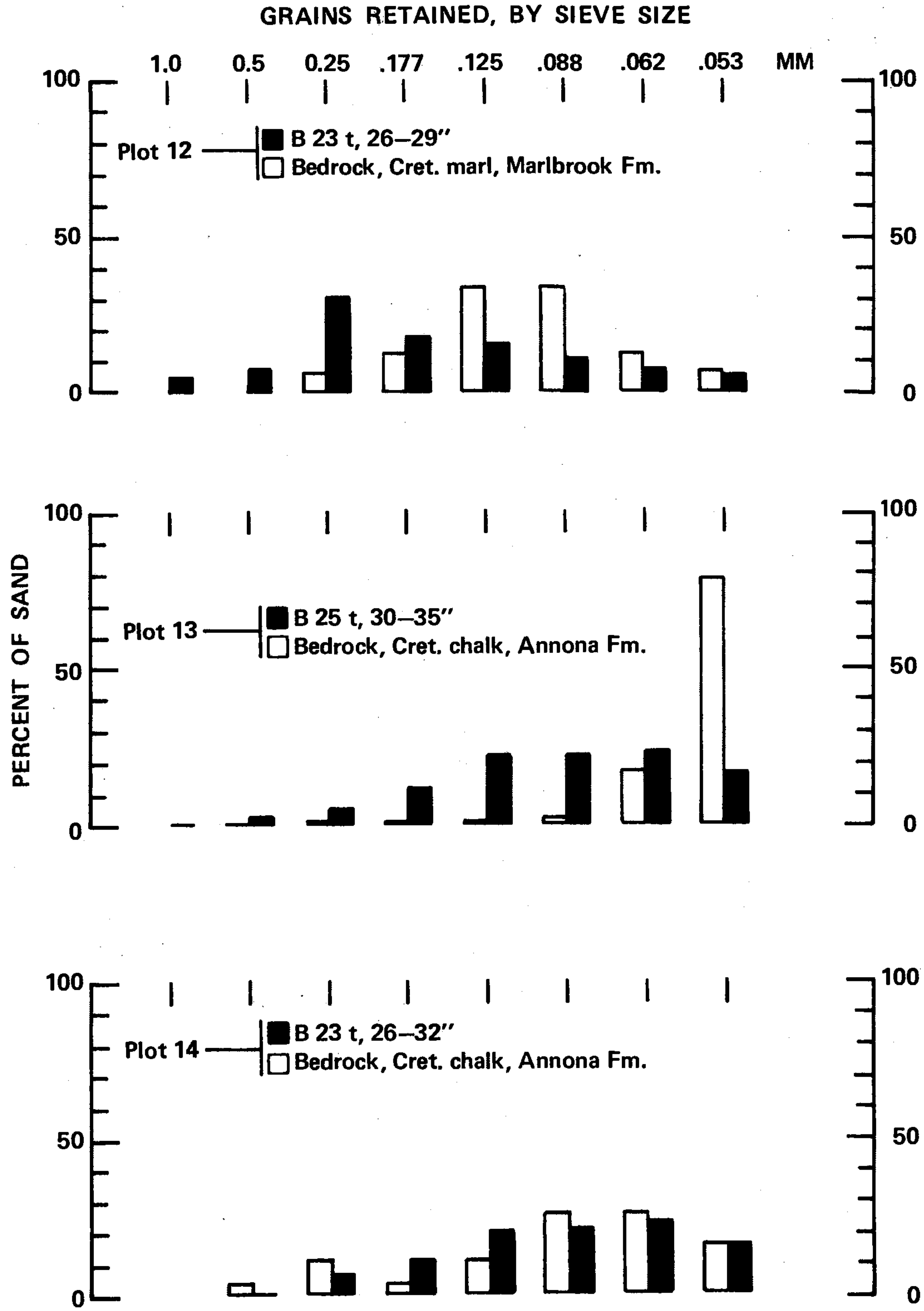

Figure 12. Grain-size of Sand From B Horizons of Alfisols and Underlying Upper-Cretaceous Bedrock

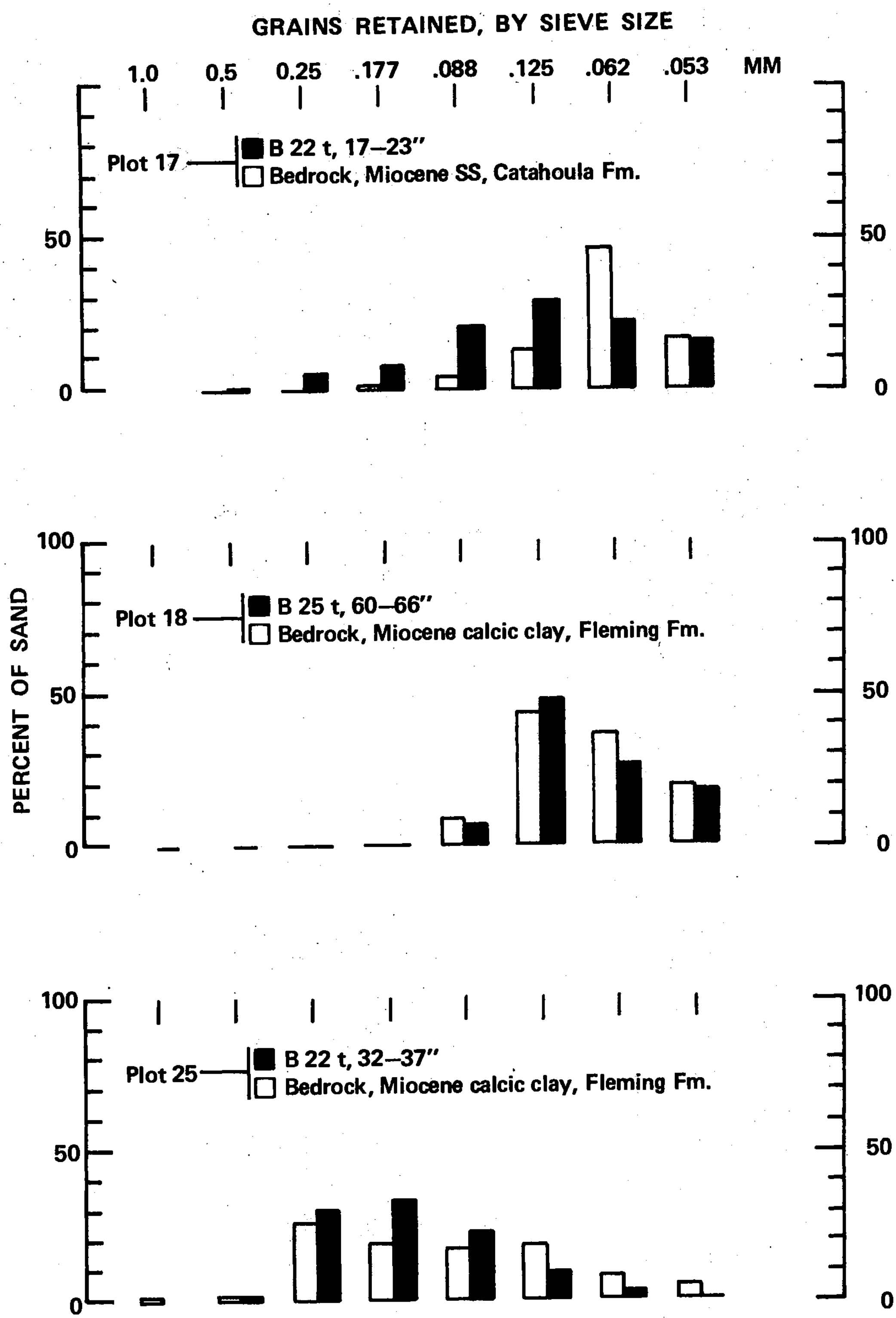

Figure 13. Grain-size of Sand From B Horizons of Ultisols and Alfisols (Citronelle Fm. area) and Underlying Bedrock

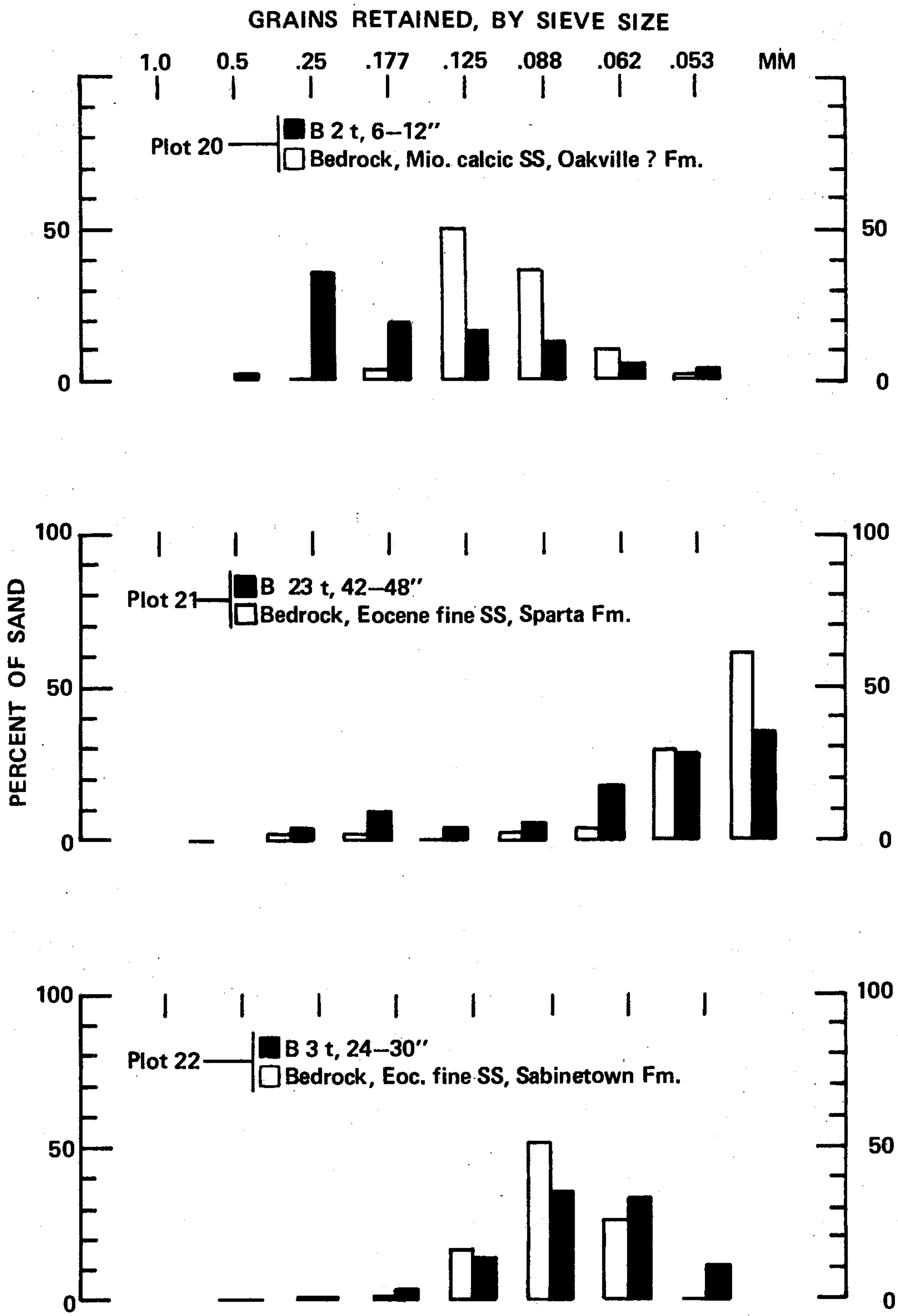

Figure 14. Grain-size of Sand From B Horizons of Alfisols, Ultisols and Underlying Bedrock in East Texas "Lost Pines" Area

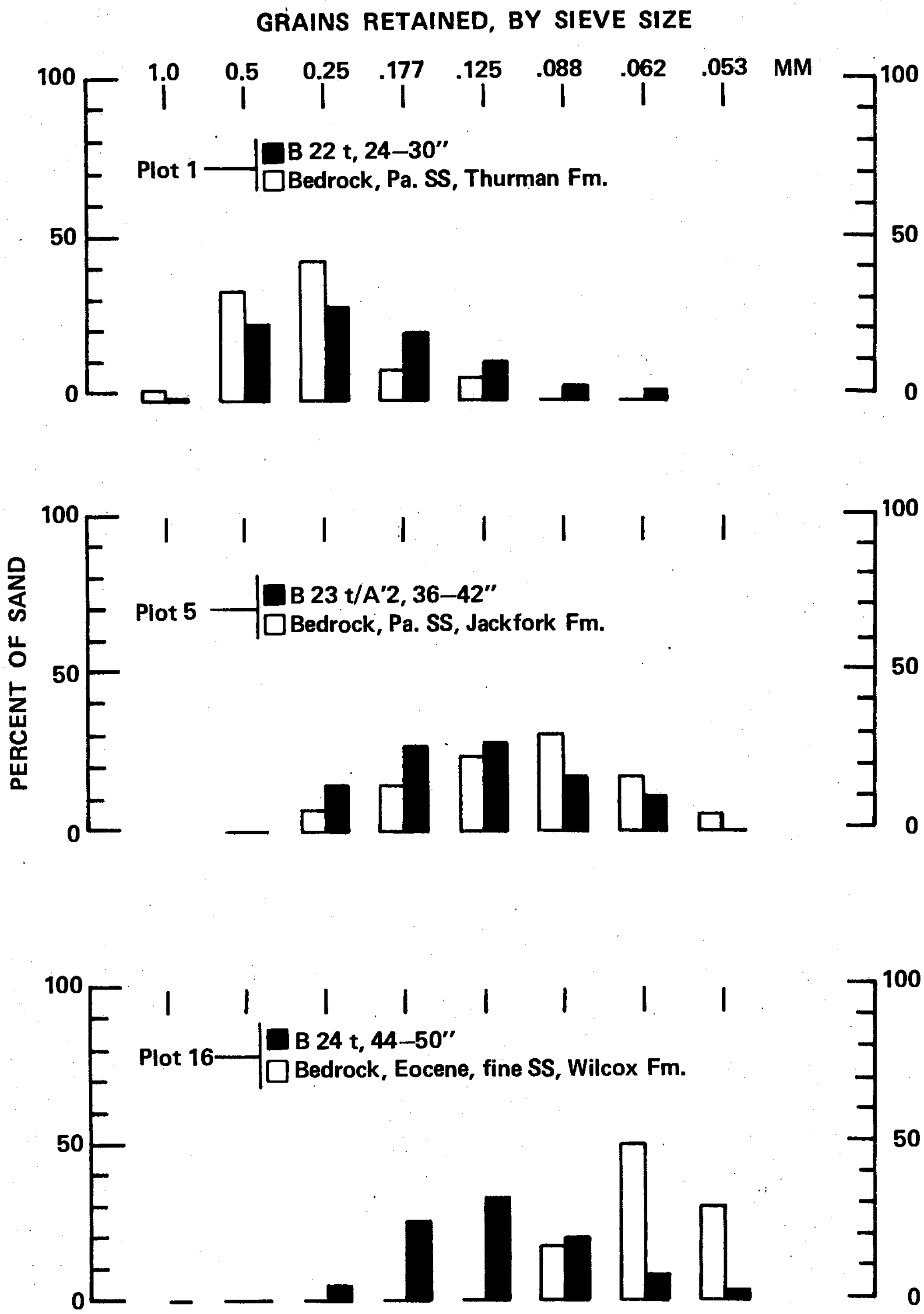

Figure 15. Grain-size of Sand From B Horizons of Ultisols, Alfisols and Underlying Bedrock

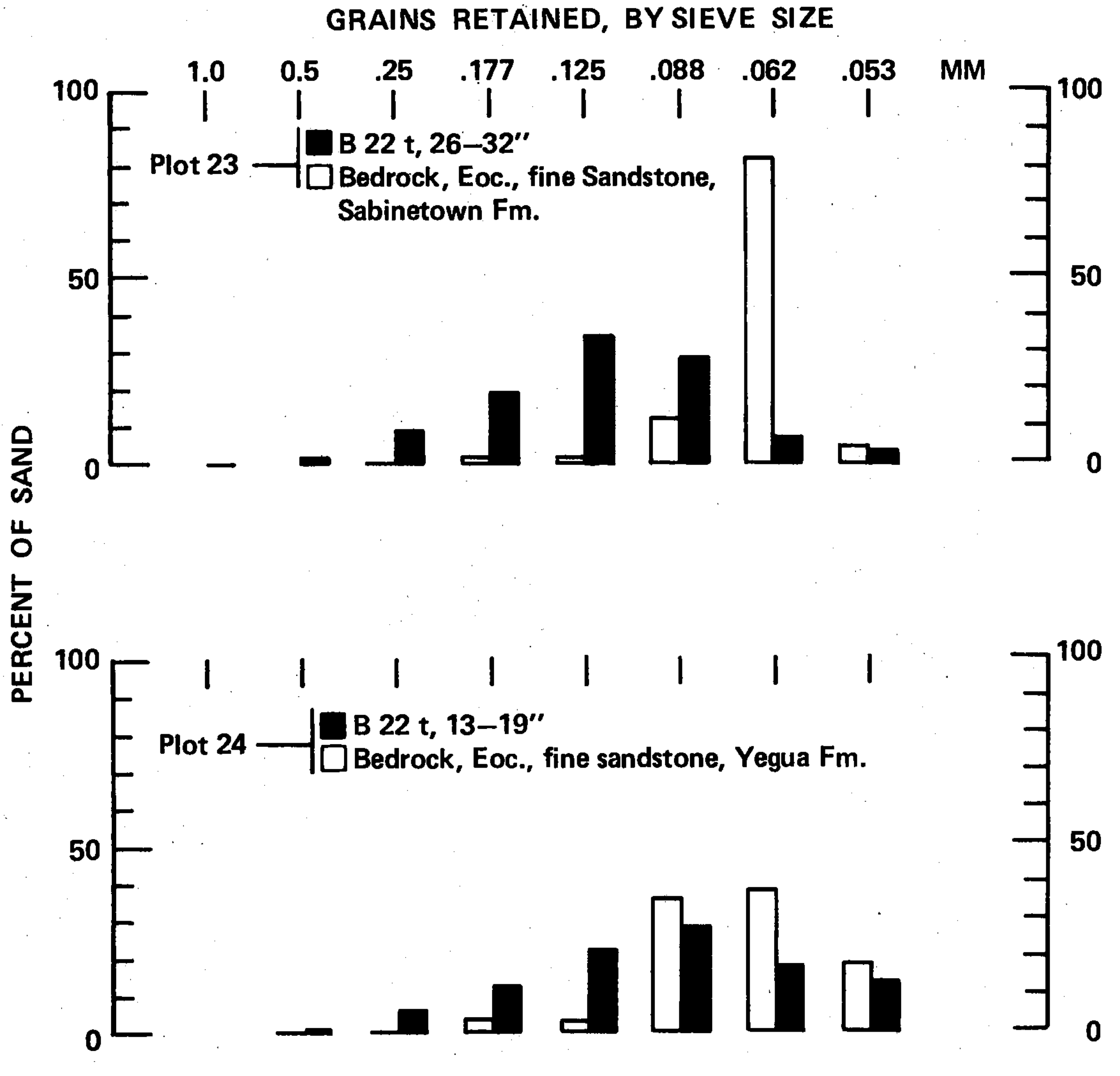

Figure 16. Grain-size of Sand From B Horizons of Alfisols and Underlying Bedrock

VITA

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