THE GULF COASTAL PLAIN ULTISOL AND ALFISOL ECOSYSTEM: SURFACE GEOLOGY, SOILS AND PLANT RELATIONSHIPS

By

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figure Page

Figure Page

CHAPTER I

INTRODUCTION

Land classification systems have often been set up without in-depth studies of the interrelationships between the primary factors of the ecosystem. Increasing interest in ecosystem comprehension now demands that we intensify efforts to collect quantitative data about a system. By relating the interdisciplinary interest of geology, pedology, and forest ecology, it is thought that a greater comprehension of the environment will result.

Silker has noted that the monoclimax concept is generally favored to explain the development of Ultisols and Alfisols on the Gulf Coastal Plain. Others consider the possibility that concepts included in the polyclimax theory have been more influential in controlling development of Ultisols, Alfisols, and Psamments on the Southern Coastal Plains of the United States (25).

Effort will be made in this study to determine the interrelationships of the geologic, edaphic, physiographic, climatic, and biotic factors that compose the total ecosystem in the northwestern portion of the Coastal Plain.

A determination will be made of plant associations across soil boundaries between contiguous calcareous, silty soils and Ultisols and Alfisols with loamy sand surfaces. There appears to be two discrete plant associations on the two contiguous soils within the same climatic area.

Soils will be analyzed to determine if all the soils have weathered in situ, or if some have been transported and deposited as fluvial material. If fluvial soils are found to exist on upland surfaces, it would be apparent the soils must have been deposited before the plants became established. The sequence, depth, and texture of the soil strata could then be largely influential in controlling the kinds and associations of plants adapting to a site. The distribution of tree species and associated plants then could be shown to be a major diagnostic indicator of soil profile patterns and variations in the Coastal Plain ecosystem.

By using various parameters of the plant associations found on these soils and understanding the processes that brought about the "formation" of these soils, a better understanding of the total ecosystem should emerge. These data may also enhance the credibility of using certain plant indicator groups to delineate geologic boundaries and to establish useful land management classes.

This report is a study of plant associations and their occurrence on the Gulf Coastal Plain near the three-state corners of Texas, Arkansas, and Oklahoma.

The major objectives of this study are:

1. To study plant associations along transects across a contact zone between calcareous Cretaceous outcrops and recently-mapped Quaternary fluvial mantles or unmapped but similar acid soils.
2. To determine if there are any anomalies between mapped geologic outcrops, mapped soil boundaries, and plant association group patterns.
3. To describe soil profiles in the various environments and analyze horizons for textural nature, presence or absence of gravel and other physical evidence for soils weathering *in situ* or showing a history of fluvial transport and deposition as a mantle.

CHAPTER II

LITERATURE REVIEW

Climax Theories

There are two theories that have developed relative to soil, the nature of sites, plant composition, and the plants functions thereon. These two contrasting theories are the monoclimax theory and the polyclimax theory.

Spurr (28) covers the usual view about the monoclimax concept:

> . . . given indefinite time and no disturbance to the community or site, the plant associations in a given climatic region would approach the same composition and structure.

This cites Clement's theory that climate is the dominant community-forming factor. It also implies that soil profiles developing above certain landforms will be similar regardless of underlying geologic strata. Toumey and Korstian (32) stated the monoclimax theory as follows:

> In any particular climatic type (having similar rainfall and temperature conditions) the soils developed will be inherently similar, if given enough time, regardless of the nature of parent materials even though they are as different in properties as native granite and calcareous glacial drift.

Spurr (28) offers the following as a view of the polyclimax concept:

> . . .for any combinations of organisms and environment, succession will move towards a climax but the specific nature of the climax will vary with the specific environment and biotic condition.

Therefore, under the polyclimax concept plant succession is not dependent on climate but is controlled by combinations of factors belonging to the local environment, i.e., geology, soils, plant competition, and climate.

Site Index

Site is a concept that is well known and frequently used by American foresters. Site is comprised of the complex associations of trees, shrubs, soils, climate and animals that compose the forest ecosystem. Toumey and Korstian (32) state that:

> The environment of a forest is very commonly referred to by the term site. Site as used by foresters is the exact equivalent of habitat as used by ecologists.

Tansely (31) defines habitat as "the sum of the effective conditions under which a plant or plant community lives." Spurr (28) explains forest site quality in a very similar manner:

> The forest site quality, thus, is defined as the sum total of all the factors affecting the capacity to produce forests or other vegetation.

Site quality can be determined in three ways according to both Heiberg (17) and Spurr (28).

1. Directly by measuring parameters of light, temperature, and moisture, that have an influence on the vegetation in question.
2. Indirectly in terms of an index that reflects a parameter of the site factors or the vegetation itself. Soil and vegetation evaluation are examples of the indirect approach.
3. By measuring the actual vegetation production; this can be accomplished by measuring volume or height growth.

For direct measurements of forest sites, the height-age relationship of trees, or the site index method is the most universal means of determining site quality.

Meyer, et al (21) state that:

> Site index for an even-aged stand is defined as the average height of the dominant and co-dominant trees at a certain age, in the East usually 50 years, in some western forests 100 years.

Site index is thus obtained by drawing curves and comparing the height to age.

The reason for the use of the site index procedure stems from the fact stated by Husch (20) that:

> Height has been found closely correlated with the ultimate measure--volume. In addition, the

> two requisite measurements, height and age, are quickly and easily determined. Finally, site index has been popular because it provides a numerical expression for site quality rather than a generalized qualitative description.

Site index curves cannot always be used to determine site quality because of uneven-aged stands and inadequately stocked forest land. Husch (20) states that in uneven-aged stands of several species, height in relation to age cannot be used to express site quality. The height growth of a species in this type of a stand is not closely related to age, but more to the varying stand conditions by which it has been affected during its life. With extremes in the stand density, Spurr (28) states that, "under such circumstances, site-index curves should be developed separately for different stand density classes. . ."

Soil-Site Index

Because of the reasons stated by Husch and Spurr in the above paragraph and because an area may no longer support a habitat or population which includes trees, site index curves may not express actual site quality. For these reasons soil-site relationships have been devised to determine site quality of a given area. Husch (20) states that determining site quality from soil characteristics has several advantages. The soil is comparatively stable and changes slowly. An evaluation of site quality can also be made regardless of the presence or absence of the forest. An area may support a dense forest or be cut over, but the site quality based on the soil will be little affected.

Many investigators have tried to determine the relationships between various soil properties and site quality. Haig (15) studied the relationship between the site index of red pine (*Pinus resinosa*, Ait.) and the collodial content of the soil horizons. He found out that for very sandy soils, as the red pine site index increased, so did the percent of silt and clay in the A horizons.

Another attempt to relate site quality to soil factors was made by Arend and Collins (1). They correlated both the site index and diameter growth of eastern red cedar (*Juniperus virginia*) with the total depth of the soil to unconsolidated parent material.

Coile studied soil-site relationships throughout the South for many years. Cpile's study (4) of soil-site relations for shortleaf pine (*Pinus echinata*, Mill.) in North Carolina covered the following factors:

1. Depth of the A horizon.
2. Relation of the silt-plus-clay to the moisture equivalent of the B horizon.
3. Depth to the C horizon.

4. Imbibitional water value of the soil (difference between moisture and xylene equivalents of a soil).
5. Combinations of the above variables.

Coile's final analysis showed the following to be significant in the soil-site relationships of shortleaf pine: (a) the depth of the A horizon; (b) imbibitional water value; and (c) the combination of the variables.

By modifying Coile's procedure and applying it to the Coastal Plain regions of Texas, Louisiana, and Arkansas, Zahner (35) developed a more practical evaluation technique for field foresters to use. He did this by eliminating the imbibitional water value and substituting in its place a measurement of soil consistency.

Wilson (34) states that the soil-site relationship technique has received wide acceptance and has been shown to be applicable to a wide range of species, as well as a wide range of soil types. This procedure is relatively simple and accurate, but its field application requires considerable training and experience in soil science and texture determination. The procedure can be complicated by soil series that contain large percentages of gravel in their horizons. Another method, vegetative interpretation, can help to simplify and perhaps speed up site and management classifications in Southern forests.

Soil-Site-Vegetation Method: An Estimate of Total Site

Total site evaluation is a means by which the many variables that affect the site and plant requirements are evaluated. Understanding that there is more to measuring site quality than obtaining a site index is an insight into the total site method. Hodgkins (19) states:

> In total site classification site index is relegated to the status of one of the many attributes of the site, and there is no longer the basis for classification. This does not constitute a deemphasis of site index, but rather a recognition that other attributes of the site are also important.

The use of plant indicator species and plant associations, as respondents to the environment has been studied by many investigators over the years. Spurr (28) believes:

> The presence, relative abundance, and relative size of the various species in the forest reflect the nature of the forest ecosystem of which they are a part and thus may serve as indicators of site quality.

Spurr calls the plants that indicate a measure of site quality, phytometers.

By using associate vegetation and plant indicator species several researchers have been able to develop methods of site evaluation. Cajander (3) was one of the earliest proponents to advocate the use of plant indicators as a forest site evaluation tool. Cajander placed all areas having the same capacity for growing timber into quality classes. These classes are based on the site quality as evaluated from indicator plants on the forest floor. Toumey and Korstian (32) state that:

> Cajander's theory of forest types is really based on the classification of forest soils, indicator plants employed in the classification being indices of soil qualities.

Spurr's (28) total site evaluation consisted of establishing indicator plant groups according to the site classes set up. In this case, site classes were arranged in order from the most xeric and infertile to the most moist and fertile sites. The plant indicator species are then checked as being present, common, or abundant. The position of curves for given species gives the relative site quality.

A total site evaluation concept was also developed by Hills (18). He combined all the factors which determine variations in forest production. Hills stated that the combination of soil, climate, and organisms can be instrumental in determining the trend in succession of a forest stand.

By using ground flora, brush species, and overstory hardwoods as plant indicators Hodgkins (19) was able to predict the site index for longleaf pine (*Pinus palustris*, Mill.) in Alabama. A species inventory was taken and a mean tree site index was calculated for each species by finding the average longleaf site index for all plots containing the species. Therefore, the site index for any plot on which an indicator species existed was weighted according to the dominance rating of this species on that plot. For example, for any one indicator species the longleaf site index would be as follows:

$$\text{S.I.} = \frac{\text{(Tree-Site Index X Dominance of the Species)}}{\text{(All of Dominance Values for the Species)}} \quad (1)$$

The indicator species were then ranked by moisture needs from driest to wettest sites. At first, indicator species were ranked from lowest to highest based on the mean longleaf site index values, but this proved unsatisfactory.

Understory species, although not as stable an entity as tree species, can be used for site quality indicators because in many cases they have a more restricted ecological tolerance than tree species. Gehrke and Steinbrenner (13) mapped the Weyerhaeuser Company lands in the Pacific Northwest using the California-Soil-Vegetation survey method. Their maps gave the following information:

1. Timbered and non-timbered areas.
2. Age classes.
3. Sawtimber density.
4. Total conifer density.
5. Total vegetation density.
6. Plant species present.
7. Soil series.

Because of inadequate information from the above seven items, understory vegetation was added to maps because of its relationship with the _potential_ overstory vegetation.

Studies of total site evaluation in Western states have been carried out for several years by numerous researchers. Dyrness and Youngberg (10) studied the soil and vegetation relationships of the central pumice region of Oregon. Similar research was carried out by Corliss and Dyrness (5) in studies of vegetation and soil relationships on the west side of the Cascade Mountains in Oregon. Daubenmire (6) studied soil and vegetation relationships in the ponderosa pine (_Pinus ponderosa_, Laws.) country of eastern Washington. Dyrness and Youngberg's study evaluates understory brush associations that can be used in determining site quality for ponderosa pine in central Oregon. They determined that changes in plant associations are not always accompanied by morphological changes in the soil profile. Rather, relationships between soil and vegetation often involves less obvious soil properties such as soil moisture and soil fertility. They concluded that the occurrence of various plant communities under ponderosa pine is largely determined by amounts of available soil moisture (see Table I). Within the study area, four distinct understory species associations could be located on the same soil series. This seems to indicate that subtle differences within a given soil series can influence species presence. Each understory type indicates a completely different effective environment for the major species present in terms of regeneration potential, density, survival, and tree quality. Dryness and Youngberg (10) state:

> Accordingly, in areas such as this where differences in the forest environment are often not reflected in readily discernible soil characteristics, the understory vegetation serves as a much more sensitive indicator of changes in the many variables regulating growth.

Studying ponderosa pine in eastern Washington and northern Idaho, Daubenmire obtained good results when he used plant associations to predict in advance the probable

TABLE I

PONDEROSA PINE, AVAILABLE SOIL MOISTURE, AND PLANT INDICATORS 1/

Available Soil Moisture	Plant Indicators Associated Species	Ponderosa Management Chances
Very Low	Bitterbrush	Low; ponderosa found only in scattered areas
Low	Bitterbrush-Idaho fescue	Low; ponderosa found only in scattered areas
Medium	Bitterbrush-manzanita	Good; lodgepole pine also present
High	Snowbrush-bitterbrush	Good, but strong white fir competition; fir is the climax species at this position 2/

[1] Adapted from: C. T. Dyrness and C. T. Youngberg, "Soil-Vegetation Relationships in the Central Oregon Pumice Region," in: First North American Forest Soils Conference, ed. R. L. Cook and T. D. Stevens, Michigan State University Press, 1958, pp. 57-66.

[2] To maintain ponderosa pine in the snowbrush-manzanita type, which is the most productive for ponderosa pine, more intensive management than normal will be necessary to remove the strong competitors, such as white fir and lodgepole pine.

growth rates of ponderosa pine. Daubenmire (6) stated:

> Most forest stands encountered in the field have been burned or grazed and so support an admixture of species indicative of disturbance. Yet, the valuable indicators remain for those who know what to look for. The oft-expressed notion held by many American foresters that lower vegetation is of no value on disturbed lands is not founded on detailed study, but upon impressions resulting from the great differences in physiognomy that are induced by disturbance, but which are really superficial and can be treated accordingly after the synecology of a forest mosiac has been worked out.

Tree species are useful site indicators because they usually are long-lived and fairly easily identified in all seasons. Particular species demand a certain ecological niche in the forest ecosystem and serve as good indicators of the environment. Other species have a wide ecological niche and their presence as an indicator is of little value. However, these same species may be indicators of site quality by their relative abundance or size.

Climax forest associations can be used as a guide to the species that are best suited to a site. According to Westveld (33), "A climax forest is the combination of tree species best adapted to the site." Toumey and Korstian (32) state that the recognition of these climax associations makes possible the "typing" of the forest on an ecological basis. Wilson (34) states that:

> The use of plant indicators generally coincides with the continuum climax theory of plant ecology. A plant may be able to survive over a wide range of sites, but it will show maximum expression, in relative frequencies to associate plants, only on its climax site.

Using hardwood climax plant associations, Silker (24) studied the soil-site-plant associations of the soils on the Gulf Coastal Plain in Texas and southeastern Oklahoma. He developed a complete systems analysis of the biome by using understory and overstory hardwoods and various pine species as plant indicators. Plant indicators were used to predict the total site values in terms of soil moisture availability, pine regeneration class, associate species competition, and economic silvicultural treatment for certain land management classes.

The main premises Silker used as background for his study were as follows:

1. Soil moisture is usually the most important factor controlling plant adaption to a site, when other minimums are met.
2. The most critical period for soil moisture demand appears to be in the early seedling stage.
3. Groups of hardwoods species are practical, natural, statistical expressions of total

site factors affecting physiological minimums or maximums, or, we might say that species frequency and commercial bole length and form are mirror images of what the total environment may express.

4. Hardwoods used to assay site should be common species that will occur throughout broad geologic, physiographic, and climatic provinces.
5. Hardwoods should be reliable indicators because (a) most are climax plants; (b) they are less subject to rapid change than ground flora that are readily affected by fire, cutting and grazing; (c) they usually reflect an age or minimum time expression of 50 to 150+ years; and (d) they are usually conspicuous and readily identified by foresters and others.

The use of hardwood and pine frequencies is desirable because they directly reflect the effective environment of the total site in easy-to-understand terms. Silker developed a wedge chart (see Figure 1) to illustrate the relationship between the thickness of the surface soil horizons and plant associations present in the Coastal Plain due to the apparent increasing or decreasing moisture storage and

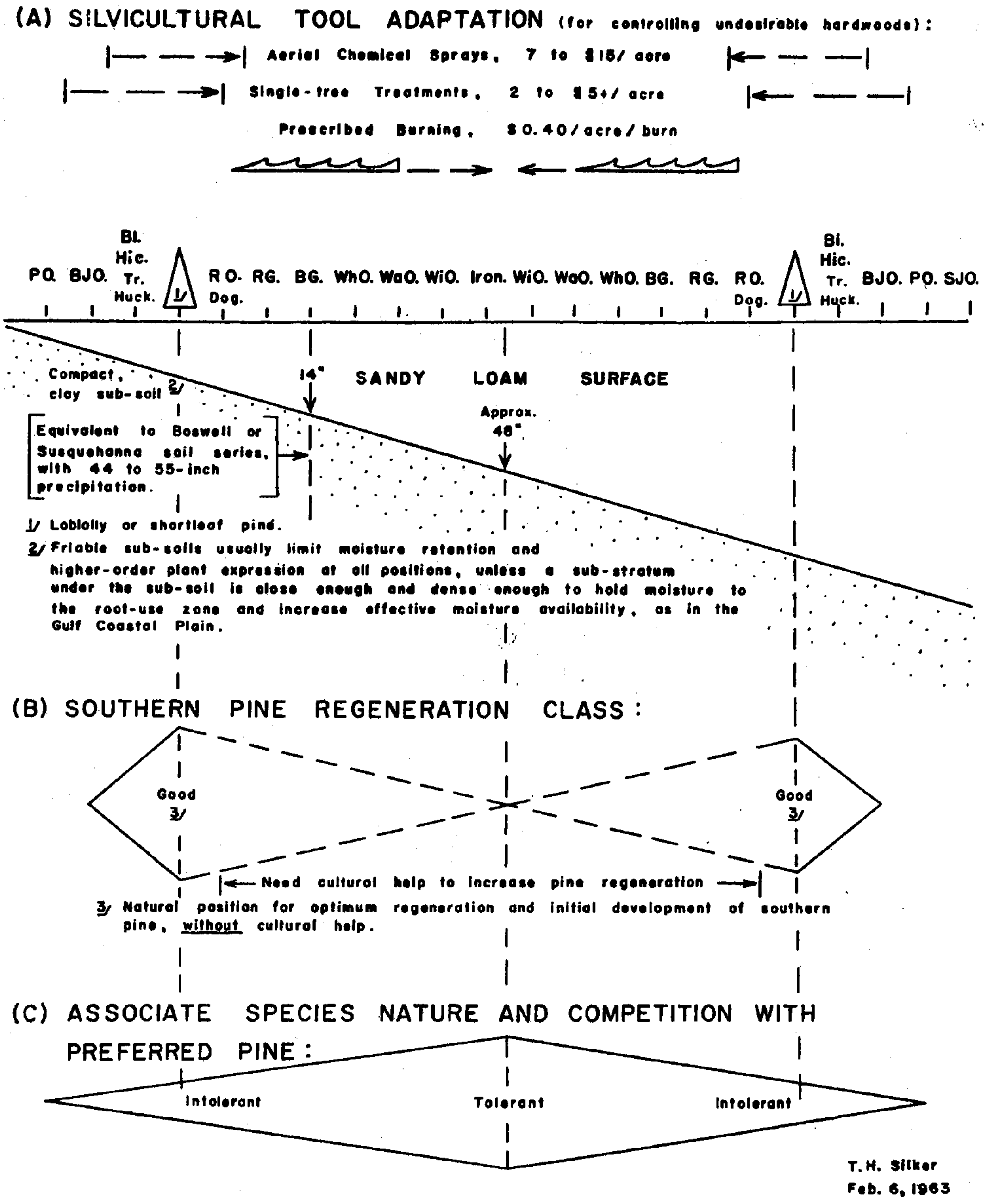

Figure 1. "Total Site Classification" by the use of Plant Indicators and Position of Predominant and Common Hardwoods in Reflecting Soil Moisture Availability

TABLE II

AN EXPLANATION OF SPECIES ABBREVIATIONS USED IN SILKER'S WEDGE CHART (FIGURE 3)

Abbreviation on Wedge Chart	Common Name	Generic Name
P.O.	Post Oak	Quercus stellata, Wang.
B.J.O.	Blackjack Oak	Quercus marilandica, Muench.
Bl. Hic.	Hickory	Carya spp.
Tr. Huck	Tree Huckleberry	Vacinium arboreum, Marsh.
↑	Pine	Pinus echinata, Mill. or P. taeda, L.
R.O.	Southern Red Oak	Quercus falcata, Michx.
Dog.	Flowering Dogwood	Cornus florida, L.
R.G.	Red or Sweetgum	Liquidambar styraciflua L.
B.G.	Black Gum	Nyssa sylvatica, Marsh.
Wh.O.	White Oak	Quercus alba, L.
Wa.O.	Water Oak	Quercus nigra, L.
Wi.O.	Willow Oak	Quercus phellos, L.
Iron	Ironwood	Ostrya virginiana, (Mill.) K. Koch.
S.J.O.	Sandjack Oak	Quercus cinerea, L.

retention capacity. By using plant indicator groups as indices of the total site Silker suggested the following may be found:

1. Minimal needs of each species.
2. Optimum ecological position of each commercial species.
3. Relation of commercial species to their normal associates (associate plant competition).
4. Economic treatments that will create a biological condition favorable to optimum development of a desired species.

"Thus, plant indicators should help assay bio-economic relationships or total site classification of forest sites." (24).

Using Silker's hardwood plant associations, Wilson (34) studied possible correlations between shortleaf pine site index, associated plants, and soil characteristics. He observed four plant associations on the Gulf Coastal Plain of southeastern Oklahoma and found a positive correlation between the site index of shortleaf pine and the hardwood groups with which they were growing. The relationships are illustrated in Table III. From his work he concluded that specific plant groups can be used to

TABLE III

HARDWOOD PLANT ASSOCIATIONS AND CORRESPONDING SITE INDEX FOR ASSOCIATE SHORTLEAF PINE ON SOILS OF THE COASTAL PLAIN IN OKLAHOMA 3/

Plant Associations	Shortleaf Pine Site Index
1. Post Oak-blackjack oak-hickory-tree huckleberry	64
2. Post oak-blackjack oak-red oak	71
3. Red oak-sweet gum	79
4. Sweet gum-black gum-white oak	90

[3] Adapted from: W. Dale Wilson, "Shortleaf Pine Site Index--Soils and Plant Associations on the Coastal Plain of Southeastern Oklahoma," unpublished master's thesis, Oklahoma State University, 1968.

delineate discrete soil moisture-availability classes and the corresponding site index of shortleaf pine. For example, an association of post oak, blackjack oak, black hickory and tree huckleberry corresponds to a site index of 64 for shortleaf pine. While an association of sweet gum, black gum and water oak corresponds to a site index of 90 for shortleaf pine.

Endicott (11) also studied Silker's concepts and related them to an economic analysis of the plant associations and shortleaf pine production capabilities in the Ouachita Highlands of southeastern Oklahoma. He studied three plant associations: (1) post oak-hickory; (2) post oak-hickory-tree huckleberry; and (3) post oak-hickory-red oak. The site index of shortleaf pine associated with these three hardwood groups was found to be 50.7, 54.2 and 60.7 feet, respectively. Endicott then computed the economic returns of investment management for pine pulpwood for each pine-hardwood plant association. He found the minimum breakeven point for shortleaf pine management to be a site with a minimum site index of 60, assuming a sliding value schedule and an optimum rotation length of 25 years. This site index establishes the post oak-hickory-southern red oak plant association as the minimum plant association for pine management in the area. When evaluated by a fixedscale value schedule and a rotation length of 20 years the minimum breakeven point can be lowered to a site index of 55. The post oak-hickory-tree huckleberry association can then be used as a minimum index for pine management in the area.

Geologic Relationships

In the area of study in southeastern Oklahoma, southwestern Arkansas, and northeastern Texas the U. S. Geologic Atlas of 1960, Southeastern Section (29) shows only the major Cretaceous and Eocene rock units of bedrock in the upper Coastal Plain. This map also shows that a recently-dissected Pliocene-Pleistocene unit (Citronelle Formation) predominates across lower Coastal Plain surfaces. The Citronelle Formation is identified as a continental deposit (river and estuarine terrace deposits). The Geologic Map of Oklahoma (22) likewise mainly identifies members of the Cretaceous system on Upper Coastal Plain land areas. The latter map does show a few small disjunct areas of Quarternary materials (high terrace deposits) above various Cretaceous outcrops paralleling the Red River in southeastern Oklahoma.

The Geologic Atlas of Texas, Texarkana Sheet, released in 1966 (2), appears to be the first of modern maps to illustrate locations of Quaternary fluvial terrace deposits in southeastern Oklahoma, Arkansas, and Texas. Five terraces, in various stages of dissection, are shown paralleling the Red River. Some terraces are as much as 16 miles from the side of the present river channel. This delination of high terrace deposits would make the Quaternary materials post-depositional to members of the predominately calcareous Cretaceous formations in the area. The Quaternary materials are very similar to the Citronelle Formation in lithology and character and have the same general soil series and plant associations occuring on them as the Citronelle. This indicates that thin Quaternary (Pliocene-Pleistocene) beds were deposited unconformably on Cretaceous rock units. It should be noted that the map was compiled largely from high altitude aerial photographs and does not show the minimum terrace thickness or surface extent necessary for map representation. Therefore, small areas of terrace deposits and terrace deposits with shallow profiles could be easily omitted from mapping.

Doering (8) mapped the Citronelle Geologic Formation on the lower Coastal Plain from east Texas to Florida in 1956. His work indicates the Citronelle Formation was deposited as a Pliocene-Pleistocene alluvial plain. His maps suggest that eventually erosion along the major drainage lines isolated portions of this mantle as ridgetop "islands."

Ultisols and Alfisols are associated with the Citronelle Formation that overlies several different members of Eocene, Miocene, and Cretaceous formations. The pine-hardwood plant associations usually thrive on Boswell, Susquehanna, Cuthbert, Vaiden, Caddo, Bowie, Lakeland, and Ruston soil series that are predominant among the Ultisols and Alfisols found above the Citronelle Formation. There is no explanation for the co-existence of two contiguous, contrasting soils such as the acidic red-yellow podzolic Ultisol and Alfisol "islands" surrounded by calcareous, black Mollisols, Vertisols or Inceptisols. Both soils are seemingly derived from a calcic bedrock outcrop of the Cretaceous system that underlies the two contiguous soils. However, on the Ultisol and Alfisol sites one can commonly find washed quartz, sandstone, and quartzite gravel in the soil horizons above the underlying calcareous Cretaceous rocks.

Biotic Relationships

By studying plant associations and areas of occurrence, Pessin (23) and Silker (24) (25) both observed that similar geologic patterns and formations occurred under the same plant associations. These studies showed the need for relating biotic conditions to the total-site in order to understand the complete interaction of all the environmental factors affecting plant establishment, growth, and association on a given site. In the 1930's Pessin studied the plant associations on the uplands of the lower Gulf Coastal Plain. He noted:

> That late in the Tertiary Period a <u>blanket</u> of material, known now as the Lafayette Formation, was deposited on the Coastal Plain. The Lafayette is composed of a <u>mantle</u> of reddish or yellowish loams and sands frequently interspersed with beds of water-worn pebbles. In many areas this formation has been or is now being removed by erosion. The principal soils are the yellowish sandy loams of the Ruston and Norfolk series and the reddish soils of the Orangeburg and Susquehanna series.

Pessin seems to reject the monoclimax theory of plant ecology and favors the polyclimax theory when he states:

> Although the climatic conditions are more or less similar throughout the Gulf Coastal Plain, the vegetation is not altogether uniform. It seems that the edaphic conditions play a decided part in determining the character of the vegetation.

Pessin recognizes four distinct plant habitats based on waterholding capabilities. These are as follows: (1) sandy ridges; (2) sandy flats; (3) loamy flats; and (4) depressions, stream and pond margins.

Each habitat described by Pessin is characterized by a different association of plant species. Occurring on sandy ridges are associations of turkey oak-post oak-longleaf pine.[4] Sandy flatland associations include longleaf pine-turkey oak-post oak-blackjack oak-blue jack oak.[5] On the sandy loams the association changes to longleaf pine, sweet gum, southern red oak, blackjack oak, and dogwood. In flatwoods with hardpans and in depressions the predominant pine is slash pine (Pinus caribea, Morglet.).

Silker studied total-site classification on the Gulf Coastal Plain and in doing so observed several problems relating to the plant association groups and the soils upon which they occur. His field studies suggested that there is a compensatory factor that overrides all other environmental factors as a control element in plant distribution and function. He observed that Ultisol and Alfisol soil orders seem to have a distinctly disjunct distribution (26). Some areas appear to be "islands" or "outliers" existing as acidic soil caps above underlying calcareous soils with a nature like the Crockett and Houston soil series. The

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[4] Plants identified as (Quercus catesbaei, Mich.) (Quercus stellata, Wang.) and (Pinus palustris, Mill.) respectively.

[5] The last two species are identified as (Quercus marilandica, Muench.) and (Quercus cinerea, Michx.).

pine-hardwood association of Silker's "wedge" chart seems to thrive on these Ultisols and Alfisols, while being closely surrounded by associations of prairie grasses or chinkapin oak-bois d'arc-big shellbark hickory-hackberry that predominate on calcareous soils.[6]

Silker studied the "pine islands" of Texas that are approximately 90 miles west of the commercial pine hardwood boundary that follows the 42-inch isohyet.

> Where ideal soil profiles (Ultisols and Alfisols) prevail there is enough soil moisture storage and retention capacity to compensate for the low precipitation of about 35 inches and to offset evapotranspiration. (24)

He also stated that apparently the pine and hardwood associates spread westward on these compensating environments (Ultisols and Alfisols) before subsequent erosion along major drainages removed portions of these soils and exposed calcareous strata. Thus, stream dissection was credited as isolating these acid-tolerant plant communities. These communities exist today as "plant islands" or disjunct communities mostly above Ultisol, Alfisol and Psamments soils.

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[6] Plants are identified as (Quercus muehlenbergii, Engelm.); (Maclura pomifera, Schn.); (Carya laciniosa, Michx.f.); and (Celtis occidentalis), respectively.

Silker also noted an apparently strong correlation between longleaf pine type distribution, particularly in North and South Carolina, and Doering's 1960 mapping of the Citronelle Formation. The U. S. Forest Service type map of 1963 (16) shows that disjunct "islands" of longleaf pine-blackjack oak-turkey oak associations discretely superimpose the "islands" of the Citronelle Formation as mapped by Doering in 1960 (9). This suggests that the geologic material under the "plant islands" has had a strong influence on plant distribution and function.

Pessin referred to the fluvial mantle in the Coastal Plain as the Lafayette Formation. Silker has noted that as additional geologic studies were made, there was agreement that the name Lafayette should not be retained. In 1915 the U. S. Geological Survey abandoned the name Lafayette and adopted Citronelle Formation for the non-marine Pliocene deposits of the Gulf Coastal Plain extending from western Florida into Texas and northward into Mississippi.[7] Thus, Pessin and Silker have independently arrived at a similar view about a common lithology that seems to have controlled plant distribution and function. Silker's view

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[7] M. S. Project 1512, Okla. Ag. Exp. Sta.

indicates that during the Pliocene-Pleistocene the entire Gulf and Atlantic Coastal Plain was blanketed by "Citronelle like" materials, upon which occur similar soils and plant communities.

The distinct nature of the Ultisols, Alfisols, and Psamments overlying these depositional formations and their admixture with the calcareous soils within one climatic zone points to a contradiction in current concepts. As Silker (25) stated:

> If climate is a primary control factor, abetted by plant weathering of the parent rock, why do we not have one common soil above a given rock strata?

Because of these conflicting ideas, Silker suggested using plant association groups as respondents of the soil environment to indicate geologic and soil control.

CHAPTER III

METHODS AND PROCEDURES

The area of study includes the southeastern corner of Oklahoma, southwestern Arkansas, and northeastern Texas (Figure 2). Plots were located near Goodwater and Tom, Oklahoma; Foreman, Arkansas; and White Rock, Texas (Figure 3). All the areas studied are considered as Gulf Coastal Plain sites.

The Gulf Coastal Plain land surfaces in the study area were formed during several geologic periods of repeated marine inundation during the Cretaceous Age. Most material consists of unconsolidated or weakly cemented sands, clays, chalks and marls. The topography is generally level to rolling and varies from 300 to 700 feet above sea level. Topography has been controlled by action of the Red River and contributing secondary and intermittent streams.

The climate is warm and humid. Average annual precipitation is 46 inches per year but severe summer droughts are common due to the high summer temperatures and high evapotranspiration. The frost-free period varies from 220 to 240

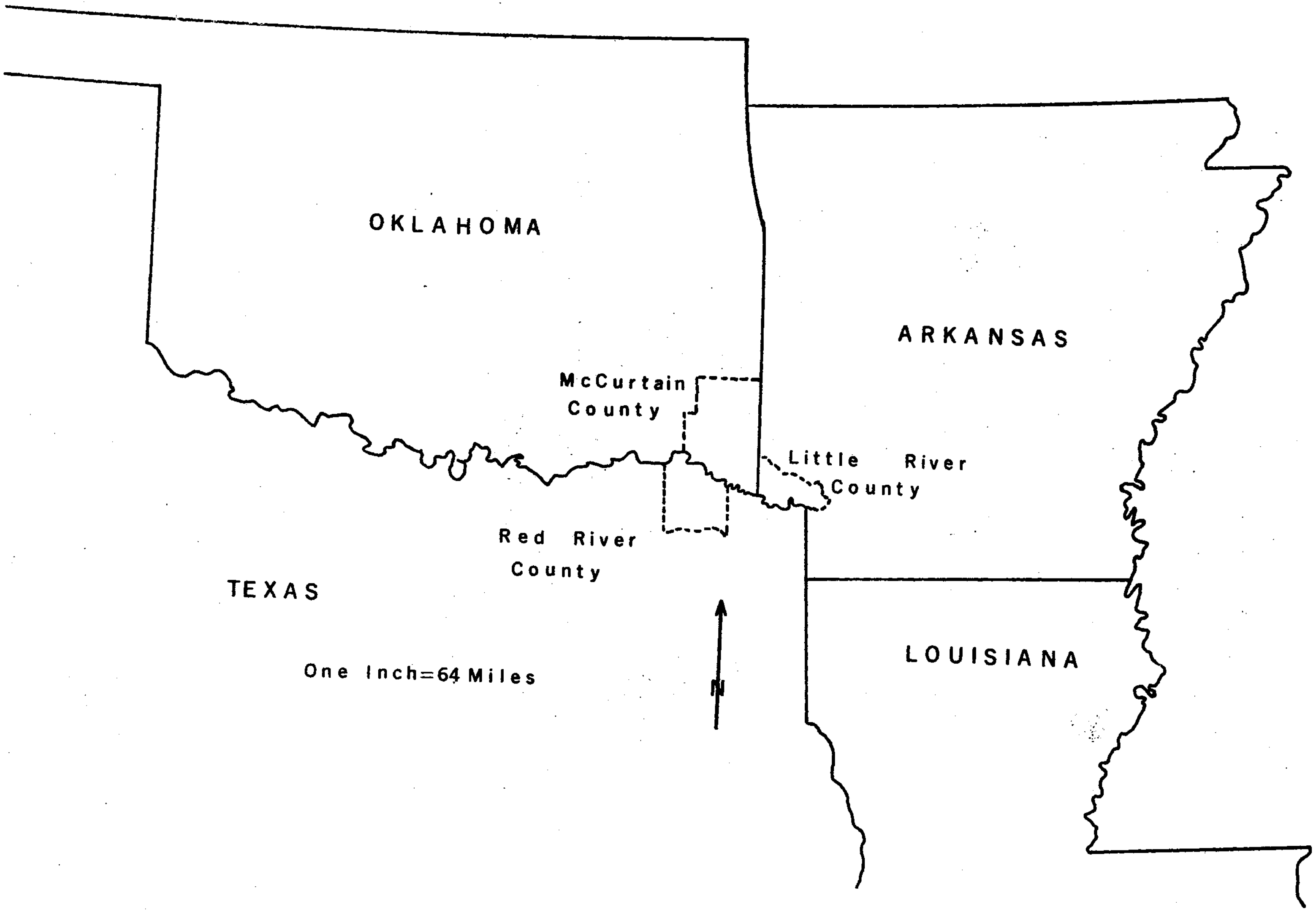


Figure 2. Area of Study Map

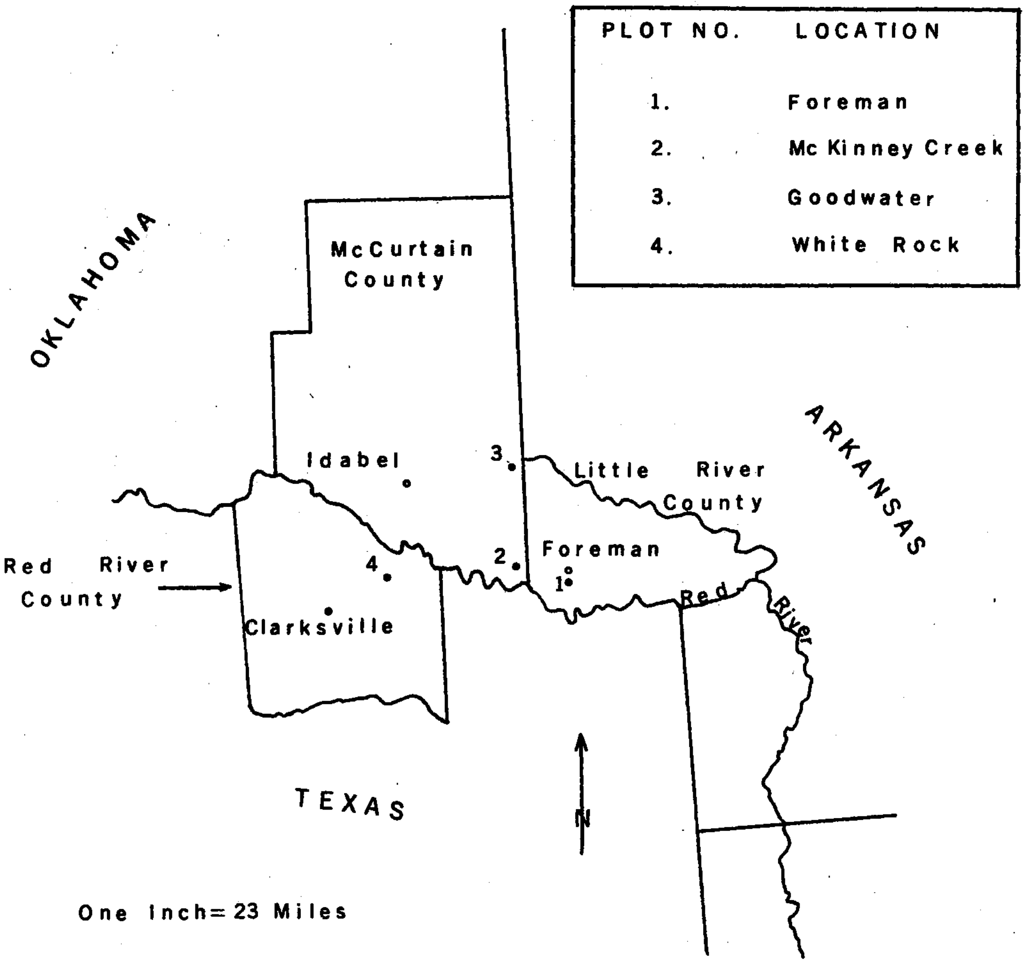
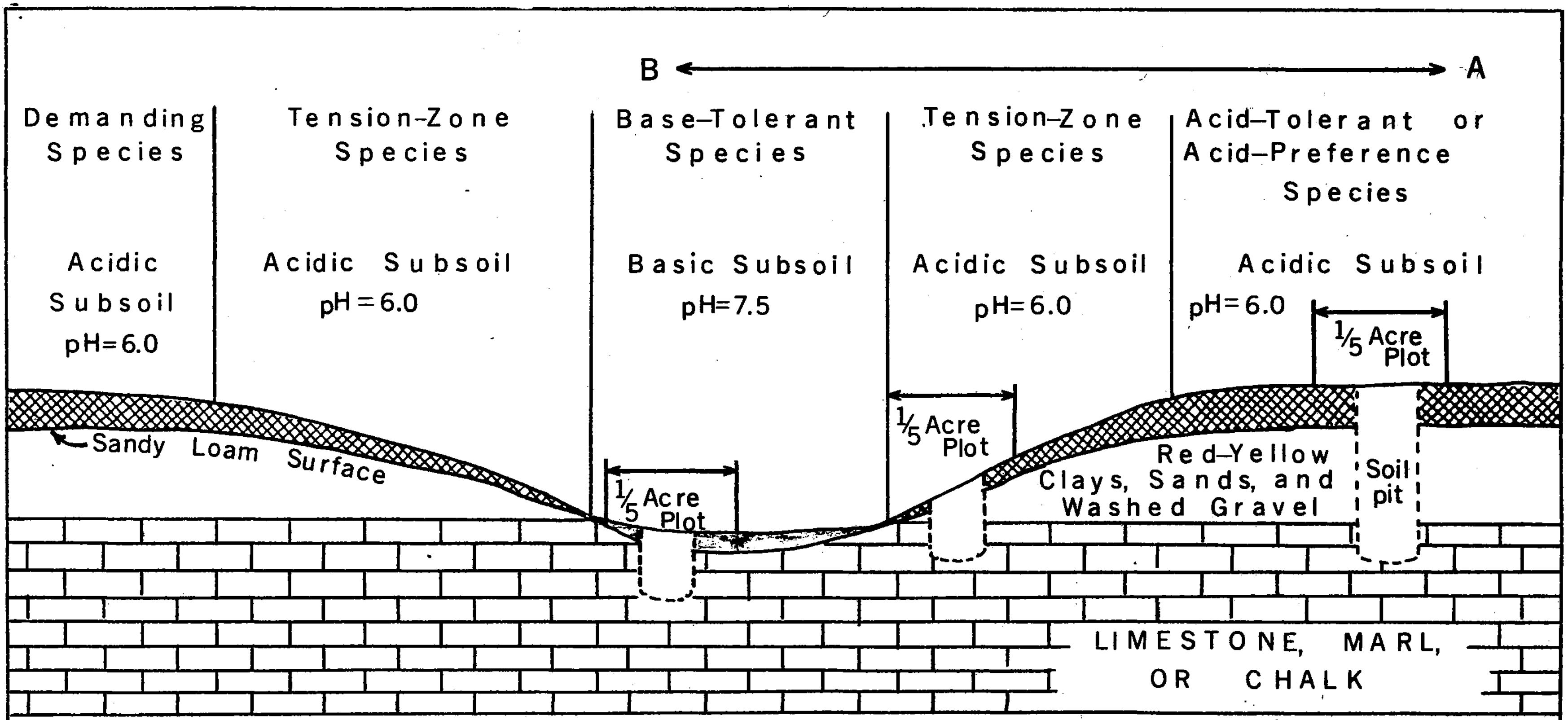


Figure 3. Localized Area of Study: Showing Plot Locations

days per year, Gray and Galloway (14). The entire study area is within one climatic zone, which varies in conditions or intensities only slightly.

Four transects were studied on Alfisol soils on Gulf Coastal Plain sites. The locations were chosen so rock strata beneath the Alfisols were contrasting in physical and chemical nature with the overlaying Alfisols. The transects were established over Goodland Limestone at Goodwater, Oklahoma; Brownstown marl at Tom, Oklahoma; Marlbrook marl at Foreman, Arkansas; and Annona chalk near White Rock, Texas.

Four ten-foot wide transects varying from 310 to 660 feet in length were used to collect data on plant distribution. Transects were run perpendicular to the outcrop of the calcareous formation present. All woody plants two feet in height or more were tallied as to species, diameter, height, crown class and vigor. The transects were used to show the natural boundaries of the plant associations on the Alfisols and the calcareous soils, and to locate supplemental 1/5-acre plots and soil pits (see Figure 4). The 1/5-acre plots were chosen by using trends of plant associations in the transect data. At least one 1/5-acre plot was located where base-tolerant or base-preference plants thrived above silty calcareous soils. Another 1/5-acre plot was located



Transect tallies run across the depression from ridge crest to ridge crest where possible; if not the transects run from point A to point B.

Figure 4. Plot and Transect Locations Showing Natural Boundaries of Plant Associations and Geologic Conditions

just inside the apparent minimum threshold for acid-tolerant or acid preference plants, above thin-natured Alfisols. A third plot was established where Alfisols were deeper and where higher-order, acid-tolerant or acid-preference plants thrived. All woody species were tallied on the 1/5-acre plots in the same manner as transect tallies.

On all 1/5-acre plots a soil pit was dug at least a foot into the calcareous strata, where possible. Soil scientists from the Soil Conservation Service described the soil profiles by horizons and classified the soils. Samples were taken from each horizon for laboratory analysis of soil textures, percent carbonates present, and amount of washed gravel.

Soil Physical Analysis

All soil horizon samples were dry-worked through a 1/4 inch sieve to remove any rock fragments or washed gravel greater than 1/4 inch in diameter. Each horizon sample was oven-dried and then allowed to stabilize at air-dry condition before being weighed. Then one-quarter (by weight) of the stabilized air-dried sample was removed and wet-sieved through a 2mm sieve to remove any rock fragments or washed gravel. All gravel obtained from both the 1/4 inch and the 2mm sieving was then washed, dried, and weighed. The percent gravel per horizon was then calculated by adding the weight of gravel from the 1/4-inch sieve to 4 times the weight of gravel from the 2mm sieve, dividing this total gravel weight by the (gross) weight (total soil and gravel) per horizon and multiplying by 100 to get percent gravel by horizon.

Additional soil samples were taken from all horizons, air-dried and sieved through a 2mm sieve. Samples with an expected organic matter content were treated with 30 percent hydrogen peroxide in a water bath to remove organic matter. Thirty gram soil samples were then weighed and particle size determination of silt and clay was made by using a Bouyoucos hydrometer and the Day (7) procedure. The sand was separated from the sample by sieving through a standard 270 mesh (0.053mm) sieve and later recording its air-dried weight. For samples that were determined to have an excess of carbonates, which could interfer with particle size dispersion in the Day procedure, three treatments of 1 N. pH 4.8 Na Acetate + Acetic Acid ($NaCH_3CO_2$) were added to remove the carbonates and aid in particle size dispersion. After the last treatment two washings in a centrifuge were used to remove the charged supernatent. The Day procedure is then followed after centrifuging.

Soil Chemical Analysis

The percentage of carbonates per horizon was determined by reacting a five-gram weight of soil (20 mesh) with 1 N, Acetic Acid (CH_3OOH). After 12 hours the sample was filtered and a 2 ml aliquot was taken from each sample to be titrated with a standard base (NaOH) to determine the percent carbonates present per horizon. This procedure was adapted from the work of the Russian soil scientist, K. K. Gedroits (12).

Soil Relationships

The soils studied in this research project were located on upper Gulf Coastal Plain soils orders, as classified by soil scientists of the Soil Conservation Service of Oklahoma, Arkansas, and Texas. The Alfisols found on the ridges had sandy surface horizons with high percentages of washed gravel, as compared to the calcareous Mollisols, Inceptisols and Vertisols (see Appendix, Tables XV-XXVII). Washed gravel predominates in the A horizons (in nine of thirteen profiles) and is secondary in abundance in the lower B or C horizons (see Appendix, Tables XV-XXVII and Figures 5, 6, 7, and 8).

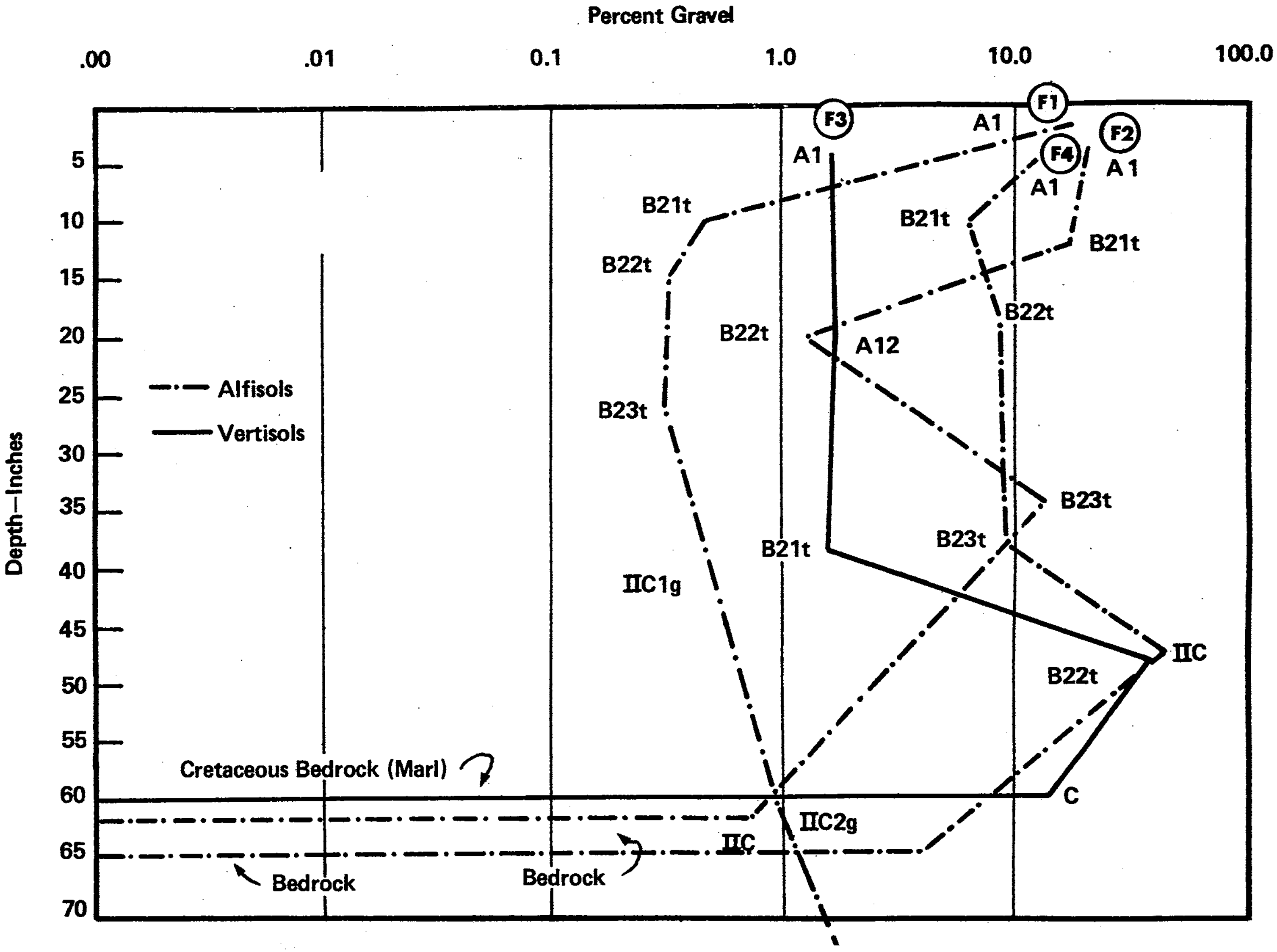


FIGURE 5 Gravel Percent by Gross Weight and Depth for Plots at Foreman, Arkansas

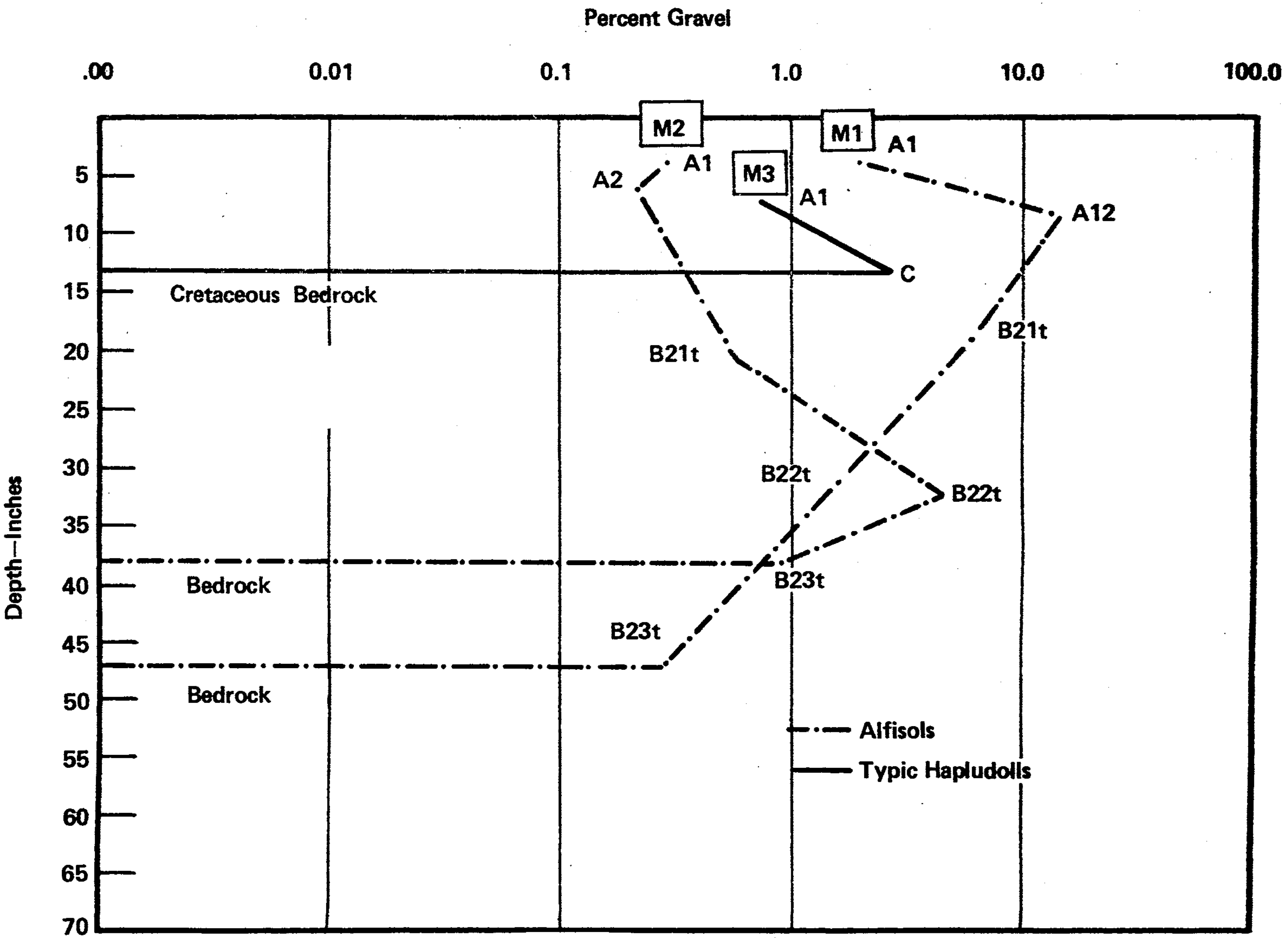


FIGURE 6 Gravel Percent by Gross Weight and Depth for Plots at McKinney Creek, Oklahoma

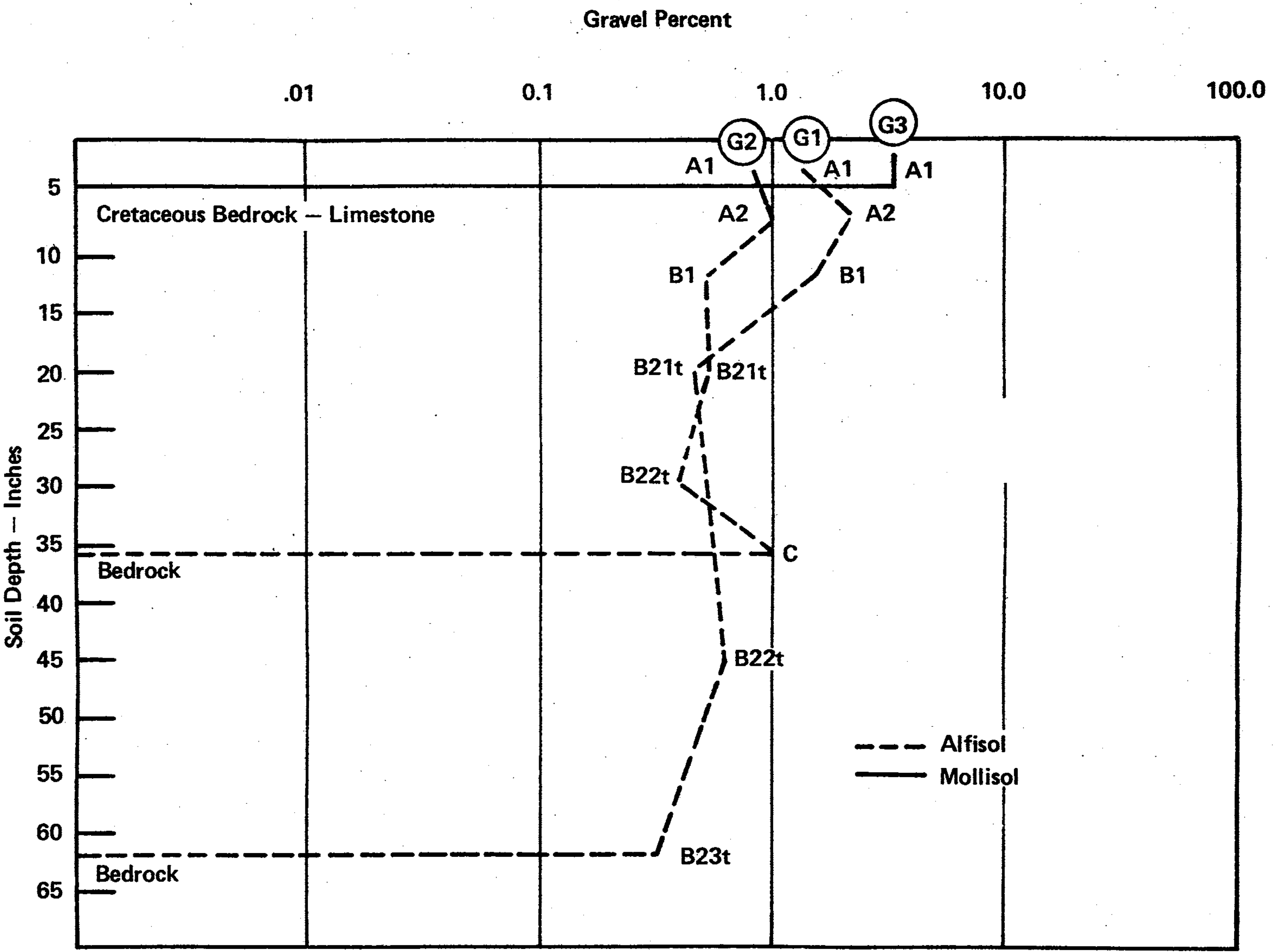


FIGURE 7 Gravel Percent by Gross Weight and Depth for Plots at Goodwater, Oklahoma

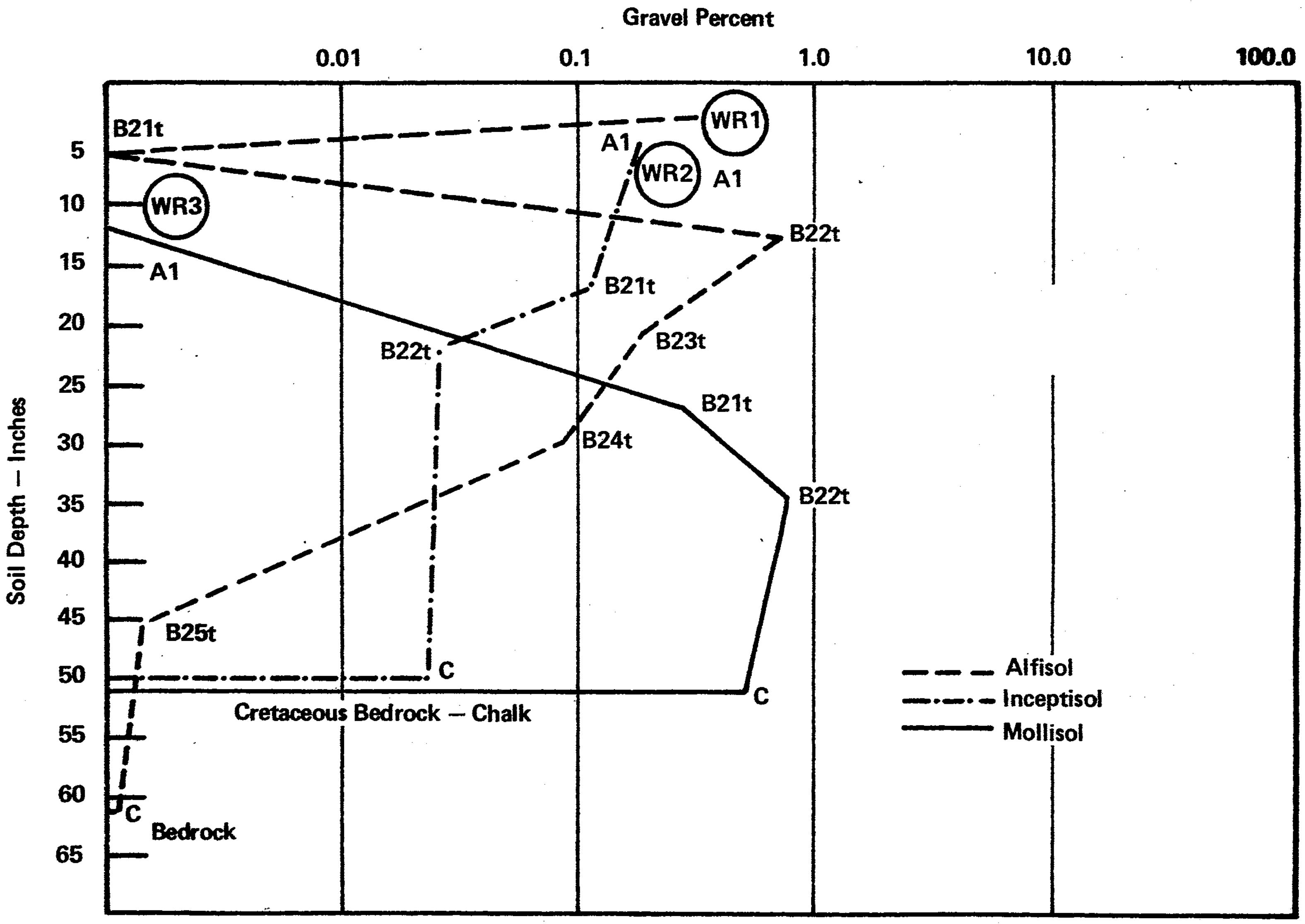


FIGURE 8 Gravel Percent by Gross Weight and Depth for Plots at White Rock, Texas

By studying the graphs of gravel concentration (Figures 5, 6, 7, and 8) one can readily observe that (in all the sampled profiles) the gravel percent by weight shows a strikingly abrupt discontinuity. In Figure 5, (Plot F1) the same resulting discontinuity occurs at 16 feet and as a result cannot be plotted on this graph. In all cases this discontinuity occurs between the lowest soil horizon and the underlaying bedrock material (see Appendix, Tables XV-XXVII). This would indicate that the Alfisols and the bedrock material below the Alfisols are lithologically different.

Washed gravel in the Mollisols and Inceptisols was more sparse and occurred throughout the profiles. Gravel was also absent from the underlying calcareous bedrock. (See Appendix, Tables XVII, XXI, XXIV, XXVI and Figures 5, 6, 7, and 8.) This suggests that the gravel in the Mollisol and Inceptisol soil profiles occurred as: (a) lag material left behind when erosion stripped away the associate sands and clays of an overriding surface fluvial mantle; (b) material carried to the site by sheet erosion or gravity from the adjacent upslope Alfisol positions, or more likely; (c) gravel left on the uncomformable surface of consolidated or semi-consolidated Cretaceous bedrock, along with calcareous fragments removed off adjacent upslope bedrock by fluvial action. Subsequent weathering of the calcareous fragments would provide the silty, calcic matrix with interspersed washed gravel that is found on the Mollisol and Inceptisol plots. The later possibility can be seen in Figure 9, where washed quartz and quartzite gravel is largely concentrated just above consolidated chalk bedrock. Note the gravel at (a) is also present within the profile yet is located in small-scale fluvial beds along with angular calcareous fragments that have not yet weathered. These textural discontinuities are also apparent when studying the Appendix, Table XVII Plot 3 at Foreman, Arkansas. This Mollisol shows a marked change below the B_{22t} horizon in $CaCO_3$ content, gravel percent, and sand content. The adjacent Alfisol (Appendix, Table XV) also has marked discontinuities below the B_{23t} horizon, as evidence by the IIC1g, IIC2g, and IIIC2g horizons. In the Appendix, Table XVI, fluvial bedding is suggested by the strong textural changes and widely varying gravel percentages found in alternate soil horizons. Note the strong textural change in the B_{23t} and the discontinuity classified by Soil Conservation Service personnel in the IIC horizon.

The Alfisol soil orders had a smaller percentage of carbonates, $CaCO_3$, than did corresponding horizons of Mollisols and Inceptisols (see Appendix, Tables XV-XXVII).

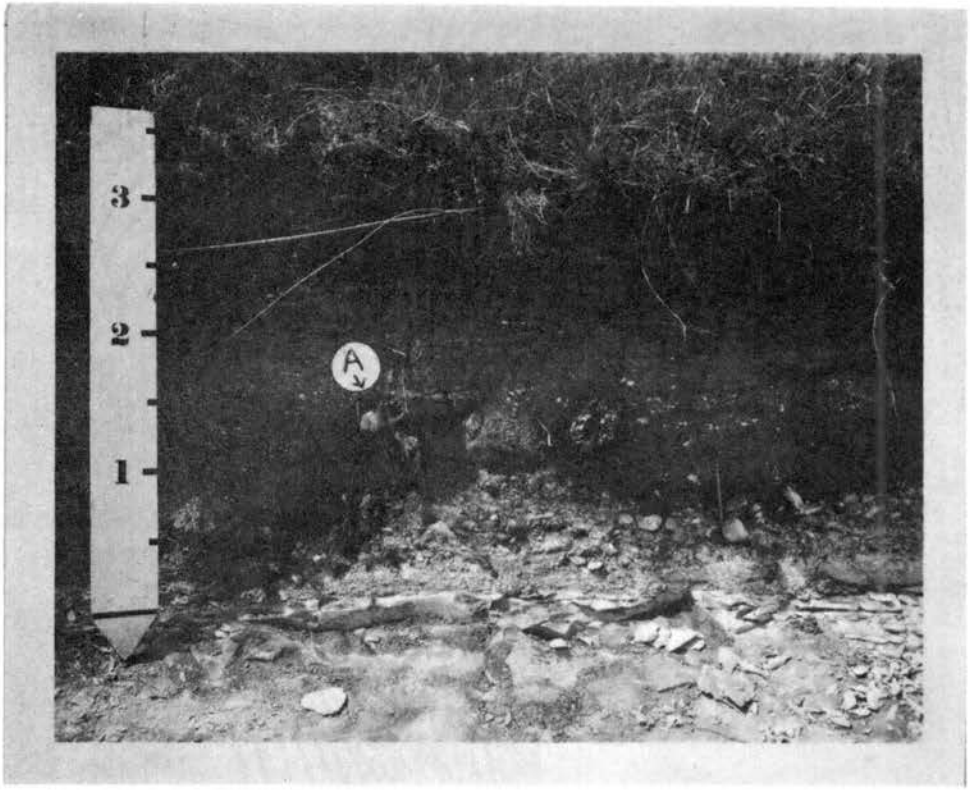


Figure 9. Photograph at White Rock, Texas Showing Calcareous Fragment Matrix, Interspersed with Washed Quartz and Quartzite Gravel Directly above the Calcareous Bedrock

Only when the lower horizons, i.e., B_{23t}, B_{24t}, IIClg, etc. of the Alfisols came into close contact with the highly calcareous Cretaceous geologic substratum did they have a high carbonate percentage. The high carbonate percent could also be accounted for by the plucking of calcareous fragments from adjacent bedrock by fluvial action. The surface horizons at Plot Nos. 1 and 4 at Foreman, Arkansas (see Appendix Tables XV, XVII) both had moderately high carbonate percent that could be attributed to the cycling effects of plants growing on these soils.

When the field pH was studied all the plots that were classified as Alfisols showed acidic or slightly acidic upper horizons, becoming basic in nature toward the bottom of the profile. (See Appendix Tables XV, XVI, XVIII, XIX, XX, XXII, XXIII, XXV.) All Mollisols, Inceptisols, and Vertisols had predominantly basic horizons (see Appendix Tables XVII, XXI, XXIV, XXVI, XXVII).

Statistical Analysis

Plant Associations-Soil Relationships

By observing the plant associations that have developed on the adjacent Alfisols and Mollisols, Inceptisols and Vertisols one can visually distinguish differences in the tree species that occur on each soil. Visual observation shows that post oak, blackjack oak, red oak, winged elm, and tree huckleberry[8] seem to predominate above the Alfisols. Redbud, cedar elm, hackberry, hickory lacioniosa, bois d'arc, and chinkapin oak[9] predominate above the Mollisol, Inceptisol and Vertisol plots found entirely on the black calcareous soils in the low-lying depressions or eroded borders of small intermittent streams (see Figure 10).

A graph (Figure 11) of the means of all the plant frequencies from the Alfisols plots and the Mollisol, Inceptisol and Vertisol plots confirms the visual observations of the species predominating on each soil order.

A statistical analysis of the collected species data was made to determine if any groups of species are directly correlated to a specific soil order and, if so, could these groups of plants be used as indicators of a particular soil order.

By using techniques of classification the species were placed into groups which are as distinct as possible.

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[8] The last three species are identified as (Quercus falcata, Michx.), (Ulmus alata, Michx.) and (Vaccinium arboreum, Marsh.)

[9] Species not previously identified are: Redbud (Cercis canadensis, L.), and cedar elm (Ulmus crassifolia, Nutt.).

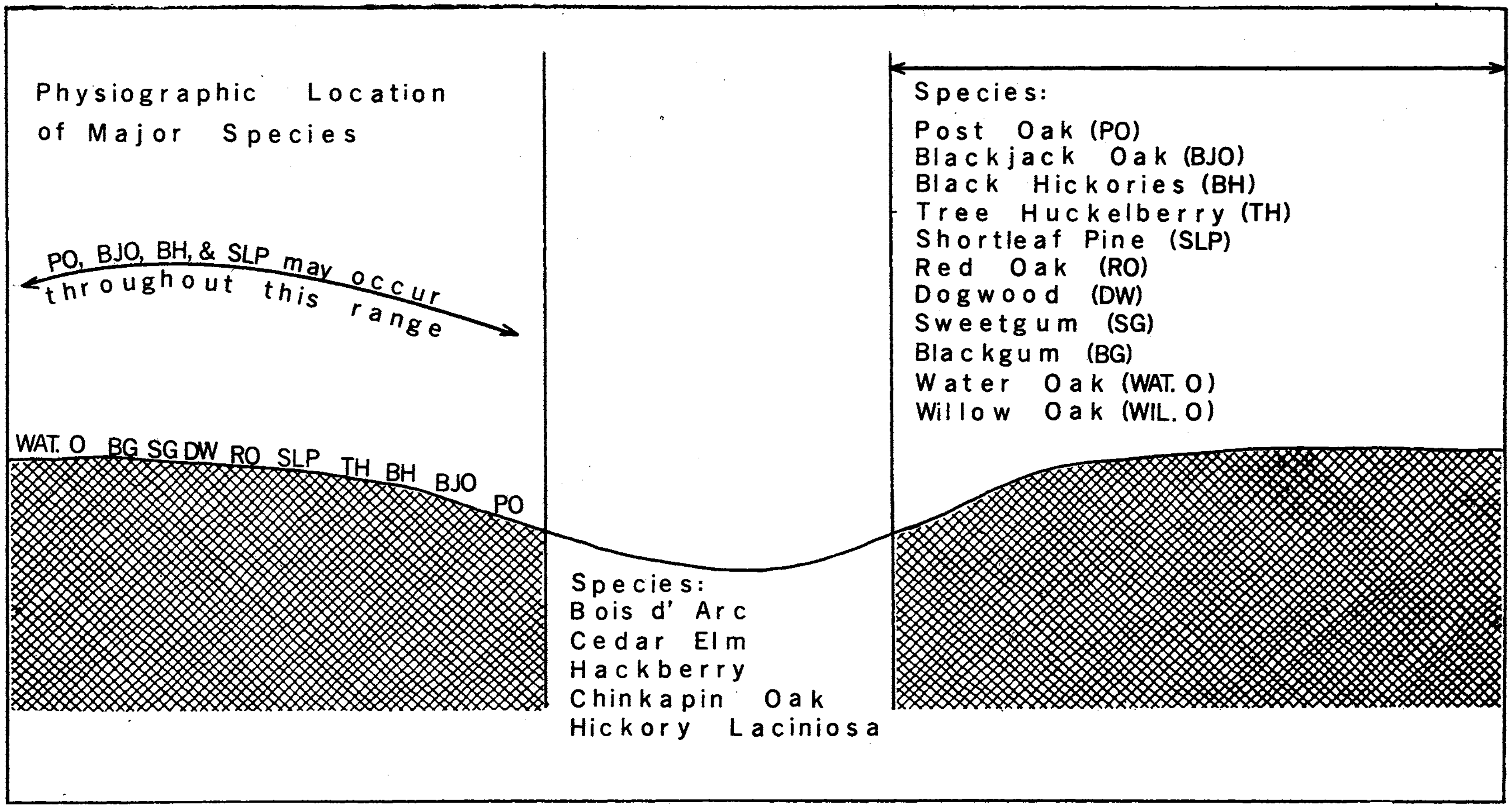

Figure 10. Physiographic Location of Major Species

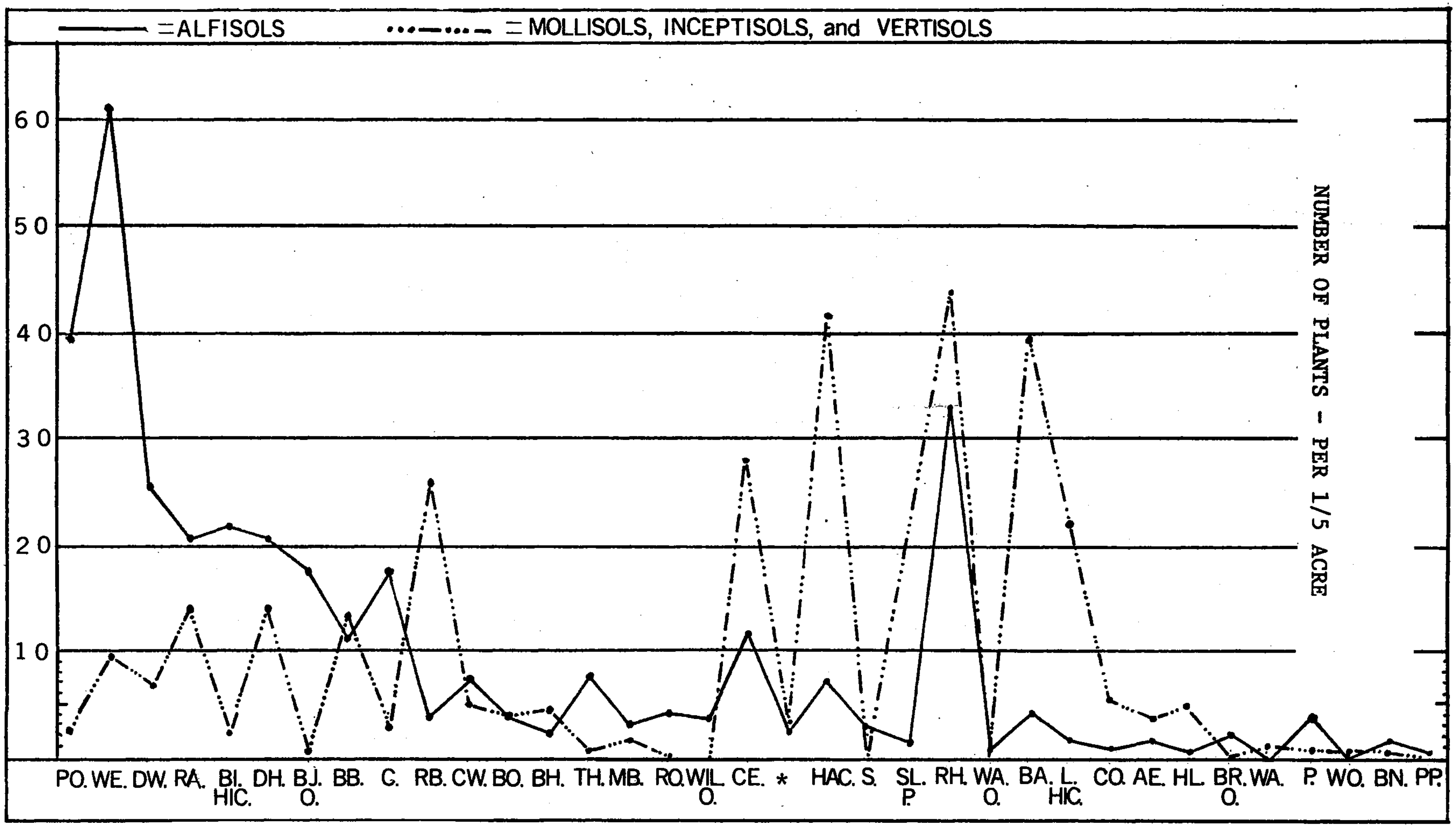

Figure 11. Mean Plant Frequencies for Alfisols, Mollisols, Inceptisols, and Vertisols

TABLE IV

AN EXPLANATION OF SPECIES ABBREVIATIONS USED IN FIGURE 11

Abbreviation	Explanation
P.O.	Post Oak
WE.	Winged Elm
OW.	Dogwood
RA.	Red Ash
Bl. Hick.	Black Hickories
D.H.	Deciduous Holly
B.J.O.	Blackjack Oak
BB.	Buck Brush
C.	Eastern Red Cedar
RM.	Redbud
CW.	Chittam Wood
BO.	Black Oak
BH.	Black Haw
TH.	Tree Huckleberry
MB.	Mulberry
RO.	Southern Red Oak
Wil.O.	Willow Oak
CE.	Cedar Elm
*	Other
HAC.	Hackberry
S.	Sumac
Sl.P.	Shortleaf Pine
R.H.	Red Haw
Wa.O.	Water Oak
BA.	Bois d'arc
L. Hic.	Hickory laciniosa
CO.	Chinkapin Oak
AE.	American Elm
HL.	Honey Locust
BR.O.	Burr Oak
WA.	White Ash
P.	Persimmon
WO.	White Oak
BN.	Button Bush
PP.	Pawpaw

According to Stuart and Kendall (30):

> In classification we are given a sample of individuals, or the whole population, and the problem is to classify them into groups which shall be as distinct as possible.

Stuart and Kendall further explain classification by stating that:

> For a given population of unknown origins, we may wish to see whether they fall into natural classes, natural in the sense meaning that the members in a group are close together in resemblance, but that the members of one group differ considerably from those of another.

In this study the groups are the topographic designations for the 1/5-acre plots at (a) the ridge crest, (b) ridge slope, and at (c) the intermittent stream border or depression (see Figure 12).

The individuals to be classed as distinct to a certain topographic location are the specific plant species.

Due to programming limitations the individual plant species were combined to form plant association groups. The individual species were grouped by comparing species means by topographic position and combining species with approximately the same means. Transect data was handled in the same manner except all species were classified into two instead of three groups. The first group included the ridge crest and ridge slope positions (Alfisols) and the second group included the intermittent stream border

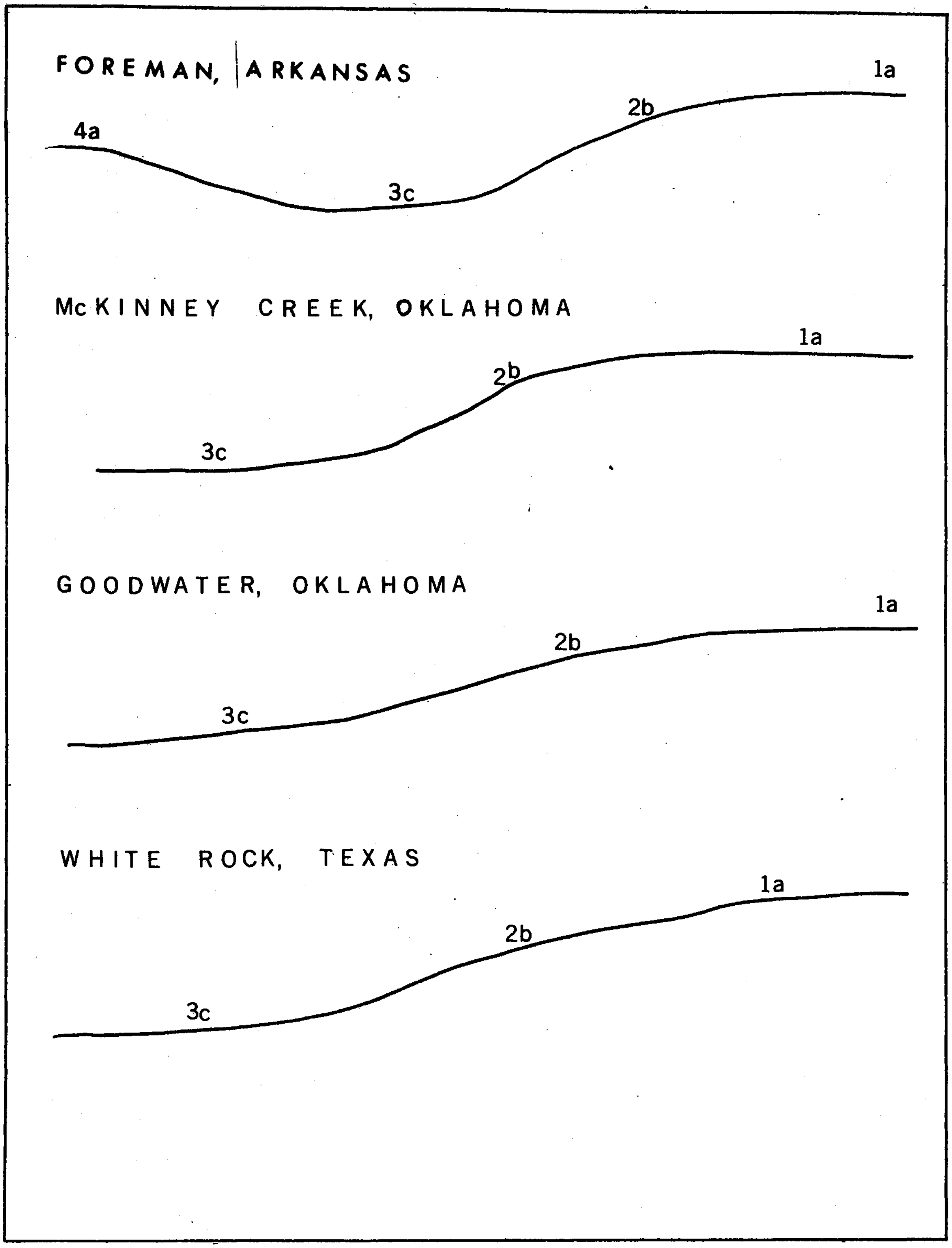

Figure 12. Topographic Positions of 1/5-Acre Plots

positions (Mollisols or Inceptisols). A list of the plant associations, as compiled according to a 1/5-acre plot, is found in Table V, while the plant associations compiled from the transects are found in Table VI. Program BMDO5M, of the Biomedical Computer Programs, was used to direct the classification of plant associations into one of the several topographic position groups.

The group assignment procedure followed by this program is derived from a model of a multivariate normal distribution of observations within groups so that the covariance matrix is the same for all groups. Plant associations are classified according to the group for which the estimated probability density is the greatest. The equivalent computational procedure followed evaluates the computed linear function corresponding to each of the groups and assigns an individual to the group for which the value is the largest.

Explanation of Classification Procedures

Mean data totals of the nine plant association groups were determined for each topographic plot position (Alfisol ridgecrest position, Alfisol ridgeslope position, and Mollisol, Inceptisol or Vertisol depression position).

TABLE V

PLANT ASSOCIATIONS: GROUPED BY MEANS ACCORDING TO TOPOGRAPHIC POSITION, FOR 1/5-ACRE PLOTS

Group	Description
1.	Post oak-blackjack oak-black hickories*-winged elm.
2.	Dogwood-red oak-tree huckleberry-willow oak-water oak-shortleaf pine-burr oak.
3.	Cedar elm-bois d'arc-chinkapin oak-hackberry-hickory laciniosa-redbud.
4.	Deciduous holly-black haw-honey locust-American elm-white ash.
5.	Red ash-red haw-buck brush-chittam wood.
6.	Indian cherry-pawpaw-service berry-prickly ash-buttonbush.
7.	White oak-black oak-black cherry.
8.	Persimmon-wild plum-mulberry-other.
9.	Cedar-summac.

*Includes mockernut hickory-black hickory.

TABLE VI

PLANT ASSOCIATIONS: GROUPED BY MEANS ACCORDING TO TOPOGRAPHIC POSITION, FOR TRANSECTS

Group	Description
1.	Post oak-blackjack oak-black hickories*-winged elm.
2.	Dogwood-red oak-tree huckleberry-willow oak-water oak-shortleaf pine-burr oak.
3.	Cedar elm-bois d'arc-chinkapin oak-hackberry-hickory laciniosa-redbud.
4.	Deciduous holly-black haw-honey locust-American elm-white ash.
5.	Red ash-red haw-buckbrush-chittamwood.
6.	Pawpaw-serviceberry-prickly ash-buttonbush-box elder-green ash-poison oak.
7.	Black oak-black cherry.
8.	Wild plum-mulberry-blackgum-black locust-black walnut-American holly-other.
9.	Cedar-summac.

*Includes mockernut hickory-black hickory.

A matrix of cross products of deviations from the means, a dispersion matrix and an inverse dispersion matrix for each location was calculated.

A Mahalanobis D square test was calculated to test the hypothesis that the vector means were the same for three topographic positions using the 9 plant association plant groups. That is, we tested the hypothesis:

$$H : \mu_1 + \mu_2 = \mu_3$$

$$\text{Where } \mu_1 = \begin{matrix} \mu_{1_1} \\ \mu_{1_2} \\ \vdots \\ \mu_{1_9} \end{matrix} \qquad (2)$$

μ_{ij} represents the population average of the jth classification variable for the ith topographic position. This hypothesis was rejected in all cases at the .01 significance level.

The goal of the procedure is to classify topographic positions on the basis of the 9 plant association groups.

The function $B_0+B_1 \cdot GP_1+B_2 \cdot GP_2+ \cdot \cdot \cdot +B_9 \cdot GP_9$ is used to set up the classification functions. An example of the derivation of the "probabilities" of A plant group occurrences for the 1/5-acre plot with 9 plant association groups follows:

Example:

From Table VII the computed discrimination functions are drawn: B_1, B_2, . . . B_9, (in this case the numbers are drawn from Column 1). From Table VIII the plant association group means are taken: GP_1, GP_2. . . GP_9. (In this case the numbers are drawn from Row 1.) B_0 is the computed constant. To calculate the classification for the Foreman, Arkansas Type No. 1 Alfisol position (ridgecrest) the formula would be: -40.63089 + .28230 · 121 + .42305 · 39 + .10116 · 4 + (-1.83024) · 12 + .02571 · 43 + (-1.10187) · 0 + 1.6211 · 9 + 3.77928 · 8 + (-0.23797) · 11 = 31.78921. For the Type No. 2 Alfisol position (ridgeslope) the formula would be -41.53741 + .54688 · 121 + (0.32411) · 39 + (-.30898) · 4 + 12.50769 · 12 + .30636 · 43 + (03.89861) · 0 + (-7.12843) · 9 + (-13.93099) · 8 + (-0.33967) · 11 = -5.31554. For the Type No. 3 Mollisol, Inceptisol, Vertisol position (depression or intermittent stream) the formula would be: -354.37085 + 1.35282 · 121 + (-2.40059) · 39 + 01.03254 · 4 + 46.87427 · 12 + 0.89317 · 43 + 013.09659 · 0 + (-27.49242) · 9 + (-53.27272) · 8 + (0.47948) · 11 = -366.42307.

Classification of the plant associations according to the soil where they occur is shown by taking the computed discriminate function values and scaling them as shown in the following example:

TABLE VII

DISCRIMINATION FUNCTIONS: 1/5-ACRE PLOTS WITH 9 VARIABLES

Plant Association	(1) Alfisol Ridgecrest	(2) Alfisol Ridgeslope	(3) Mollisol, Inceptisol or Vertisol: Depression
1	0.28230	0.54688	1.35282
2	0.42305	-0.32411	-2.40059
3	0.10116	-0.30898	-1.03254
4	-1.83024	12.50769	46.87427
5	0.02571	0.30636	0.89317
6	-1.10187	-3.89861	-13.09659
7	1.62211	-7.12843	-27.49242
8	3.77928	-13.93099	-53.27272
9	-0.23797	-0.33967	-0.47948
Constants	-40.63089	-41.53741	-354.37085

TABLE VIII

MEANS OF PLANT ASSOCIATION GROUPS FOR 1/5-ACRE PLOTS

	Plant Association Groups								
Location	1	2	3	4	5	6	7	8	9
F1	121	39	4	12	43	0	9	8	11
G1	156	43	9	4	30	0	1	6	6
M1	194	7	33	2	117	0	4	5	0
W1	186	81	95	6	90	1	2	4	80
F2	73	25	21	13	114	4	3	8	7
G2	93	10	15	2	69	1	0	0	1
M2	166	3	19	3	90	2	6	1	0
W2	57	89	139	15	66	4	2	3	14
F3	2	18	122	31	38	0	2	10	0
G3	29	2	134	17	120	2	1	1	0
M3	18	4	183	39	96	14	13	9	0
W3	8	5	216	19	47	1	0	0	12

	Soil 1	Soil 2	Soil 3
Fi_*	31.79	-5.32	-366.42
$Fi_*-\text{max. } fi_*$	0.00	-37.11	-398.21
$e^{fi-\text{max. } fi_*}$	1.00	0.00	0.00
$\sum_{i=1}^{3} e^{fi-\text{max. } fi_*}$	1.00	1.00	1.00
$Pi = \dfrac{e^{fi-\text{max. } fi_*}}{\sum_{i=1}^{3} e^{fi-\text{max. } fi_*}}$	1.00	0.00	0.00

The sample is then classified into the group for which it has the largest "associated probability," Pi. From Table IX it can be shown that the plant associations present at each topographic position are correctly classified. That is, by using the classifications functions as described, each plant association group is classified correctly according to soil type.

To make a clearer comparison of the plant species distribution as indicators and respondents to the soil and geologic environment, only the species with contrasting high means for the different soil types were compared in the following tests of the 1/5-acre plots and transect plots: For the 1/5-acre plots the contrasting plant association groups used were associations 1, 2, and 3. For the transects the plant association group 1 and 3 were used. For the 1/5-acre plots the number 1 association (post oak-blackjack oak-black hickories-winged elm) was classified into the

TABLE IX

EVALUATION OF CLASSIFICATION OF PLANT ASSOCIATIONS BY SOIL ORDERS FOR 1/5-ACRE PLOTS WITH NINE PLANT ASSOCIATION GROUPS

Plant Associations at	Soil 1 Alfisol	Soil 2 Alfisol	Soil 3 Mollisol Inceptisol Vertisol	Largest Probability	Type Classification
Foreman 1	1.00000	0.0	0.0	1.00000	1
Goodwater 1	1.00000	0.0	0.0	1.00000	1
McKinney Creek 1	1.00000	0.0	0.0	1.00000	1
White Rock 1	1.00000	0.0	0.0	1.00000	1
Foreman 2	0.0	1.00000	0.0	1.00000	2
Goodwater 2	0.0	1.00000	0.0	1.00000	2
McKinney Creek 2	0.0	1.00000	0.0	1.00000	2
White Rock 2	0.0	1.00000	0.0	1.00000	2
Foreman 3	0.0	0.0	1.00000	1.00000	3

TABLE IX (Continued)

Plant Associations at	Soil 1 Alfisol	Soil 2 Alfisol	Soil 3 Mollisol Inceptisol Vertisol	Largest Probability	Type Classification
Goodwater 3	0.0	0.0	1.00000	1.00000	3
McKinney Creek 3	0.0	0.0	1.00000	1.00000	3
White Rock 3	0.0	0.0	1.00000	1.00000	3

Alfisol ridgecrest position in all cases (see Table X). The number 3 association of cedar elm-bois d'arc-chinkapin oak-hackberry-hickory laciniosa-redbud was classified into the Mollisol, Inceptisol or Vertisol depression position in all cases (see Table X).

The number 2 association of dogwood-red oak-tree huckleberry-willow oak-water oak-shortleaf pine and burr oak always occurred on Alfisol sites but was classified as belonging in the number 1 plant association group at the McKinney Creek No. 2 position (see Table X). This misclassification of the associated Pi's was quite close and the resulting misclassification is therefore not meaningful as a single value. Because this position is a tension zone between the "better" Alfisols and the Mollisols, Vertisols, and Inceptisols, the opportunity for species variability is greater than on a modal soil.

For the transects only two associations were run: No. 1 (post oak-blackjack oak-black hickories-winged elm), and No. 3 (cedar elm-bois d'arc-chinkapin oak-hackberry-hickory laciniosa-redbud). Classification of association 1 was to the Alfisols while classification of plant association 3 was into the Mollisol, Inceptisol and Vertisols (see Tables

TABLE X

EVALUATION OF CLASSIFICATION OF PLANT ASSOCIATIONS BY SOIL ORDERS ON 1/5-ACRE PLOTS WITH THREE PLANT ASSOCIATION GROUPS

	Soil 1	Soil 2	Soil 3		
Plant Associations	Alfisol	Alfisol	Mollisols Inceptisols Vertisols	Largest Probability	Type Classification
Association 1					
Foreman	0.73111	0.26889	0.00000	0.73111	1
Goodwater	0.99020	0.00980	0.00000	0.99020	1
McKinney Creek	0.94354	0.05646	0.00000	0.94354	1
White Rock	0.99973	0.00027	0.00000	0.99973	1
Association 2					
Foreman	0.00232	0.99768	0.00000	0.99768	2
Goodwater	0.00336	0.99664	0.00000	0.99664	2
McKinney Creek	0.56909	0.43091	0.00000	0.56909	1
White Rock	0.00566	0.99434	0.00000	0.99434	2
Association 3					
Foreman	0.00000	0.00001	0.99999	0.99999	3
Goodwater	0.00000	0.00000	1.00000	1.00000	3
McKinney Creek	0.00000	0.00000	1.00000	1.00000	3
White Rock	0.00000	0.00000	1.00000	1.00000	3

XI, XII, XIII and XIV). Again the classification techniques resulted in perfect classification as can be seen from Table XIV.

Soil-Geology Relationships

The Alfisols studied on all the plots seemed very similar lithologically to the formation described by Doering (23) and Silker (25) when discussing fluvial materials laid down by Pliocene-Pleistocene deposition. Subsoils of the Alfisols studied have the same typical red-yellow color with many common and distinct mottles, as reported for Pliocene-Pleistocene deposits mapped by Doering as the Citronelle Formation. The Alfisols studied also contained the typical washed gravel, as reported by Pessin in his Lafayette Formation. Washed gravel was found in this study to be largely concentrated in lenses or bands in the A horizons of the soil profiles. (See Appendix Tables XV-XXVII.)

The calcareous Mollisols and Inceptisols found in the depressions are, for the most part, similar in lithology and nature to the Cretaceous substratum below. They have a high carbonate ($CaCO_3$) percent, silty or clayey texture and a high (basic) pH. The relatively sparse amount of washed gravel in the upper solum is in strong contrast to the

TABLE XI

MEANS OF PLANT ASSOCIATION GROUPS FOR TRANSECTS

	Plant Association Groups								
Location	1	2	3	4	5	6	7	8	9
FA	76	15	11	6	54	2	12	9	9
GA	73	11	2	3	24	4	1	2	0
MA	111	3	14	0	58	2	6	3	0
WA	50	23	21	5	28	1	1	0	23
FB	5	0	40	2	10	1	0	8	0
GB	58	1	232	40	167	6	8	13	3
MB	20	3	221	42	144	13	10	5	2
WB	0	0	105	10	17	2	0	1	2

A = Alfisols
B = Vertisol, Mollisol, and Inceptisol

TABLE XII

DISCRIMINATE FUNCTIONS: TRANSECTS WITH TWO VARIABLES

Association Group No.	Alfisol (1)	Mollisol, Inceptisol or Vertisol (3)
1	0.16099	-0.02358
3	-0.03140	0.39400
constant	-6.04997	-2.70084

TABLE XIII

DISCRIMINATE FUNCTIONS: 1/5-ACRE PLOTS WITH THREE VARIABLES

Association Group No.	Alfisol (1)	Alfisol (2)	Mollisol, Inceptisol or Vertisol (3)
1	0.23133	0.13544	-0.02527
2	0.26699	0.14586	-0.16026
3	-0.07088	-0.02578	0.13013
constant	-23.42186	-8.27593	-9.89352

TABLE XIV

EVALUATION OF CLASSIFICATION OF PLANT ASSOCIATIONS BY SOIL ORDERS ON TRANSECTS

Plant Associations	Soil 1 Alfisol	Soil 2 Mollisol, Inceptisol or Vertisol	Largest Probability	Type Classification
Association 1				
Foreman	0.99995	0.00005	0.99995	1
Goodwater	0.99995	0.00005	0.99995	1
McKinney Creek	1.00000	0.00000	1.00000	1
White Rock	0.98778	0.01222	0.98778	1
Association 3				
Foreman	0.00518	0.99482	0.99482	2
Goodwater	0.00011	0.99989	0.99989	2
McKinney Creek	0.00000	1.00000	1.00000	2
White Rock	0.00002	0.99998	0.99998	2

absence of gravel, or the presence of only a trace amount in the bedrock at one pit (see Appendix Tables XV-XXVII).

The Alfisols on the ridges seem to be very different lithologically from the Cretaceous substratum below. The Alfisols have a red-yellow color, a high percentage of sands, washed gravel (up to 6 inches in diameter), and low carbonate percentages (see Appendix Tables XV-XXVII). The four different Cretaceous bedrock members are essentially free of washed gravel, have a low sand content and do not appear to be pedologically related to the Alfisol soils above them.

At each location the Alfisols on the ridges and the Mollisols and Inceptisols in the depressions were located over one geologic formation. For example, the adjacent Alfisols and Inceptisols at the McKinney Creek, Oklahoma location both occur directly above the Brownstown marl. In essence, the occurrence of two contiguous unlike soil orders over one geologic formation refutes the monoclimax theory that one soil should develop from one parent material or geologic formation as a direct result of climatic and biotic weathering. These two adjacent soils, seemingly weathered from one geologic formation, indicate that the polyclimax theory would be more appropriate to explain functions in the ecosystem. The data indicate that the soil development and the resulting plant succession are not dependent on climate alone, but are controlled primarily by geologic factor differences. The great physical and chemical differences found on all plots between the adjacent Alfisols and Mollisols (or Inceptisols) overlying the same geologic formation leads one to believe that the Alfisols on the ridges are depositional in nature and are in no way directly related to the geological strata they cover. Thus, one could visualize a second, distinct and younger, geologic material laying above the mapped Cretaceous bedrock formations.

The washed gravels and discontinuities found in the Alfisol horizons and the relatively close proximity of the locations to major streams or rivers suggests that all the Alfisols could be alluvial mantle deposits or soils derived from sequential terraces. All locations are within 20 miles of the Red River and two locations(Foreman, Arkansas and McKinney Creek, Oklahoma) are above high, fluvial Quaternary terraces mapped on the 1966 Geologic Atlas of Texas.

The concept of Alfisols being a mantle or blanket deposition over an existing formation could be considered a valid concept when the work of Pessin, Doering, and Silker is studied. This mantle material seems to have been produced by groups of coalescing streams or rivers during cycles of deposition and deformation in the Pliocene-Pleistocene. It appears that the basic character of the topography today is much the same, except for some surface dissection, as it was before deposition of the fluvial mantle (Figure 13). Deposition (Figure 14) covered a vast area (as mapped by Doering and observed by Pessin and Silker) from Florida to southeastern Texas. Silker (24) (26) (27) has stated that similar fluvial material appears to mantle the surface, especially at interstream-divide positions, considerably upslope from the mapped Citronelle Formation, even to southern Oklahoma and western Arkansas. Subsequent erosion (Figure 15) by permanent or intermittent streams within the area removed portions of this mantle and exposed the antecedent formation. The remaining Pliocene-Pleistocene depositional material remains at interstream-divide positions and is conspicious (by its red-yellow color and large quantities of washed gravel) in comparison to the surrounding black, silty or clayey calcareous soils developed from Cretaceous formations.

The sequential terrace concept and Pliocene-Pleistocene mantle concept could both be used to explain the depositional nature of the Alfisols, but further

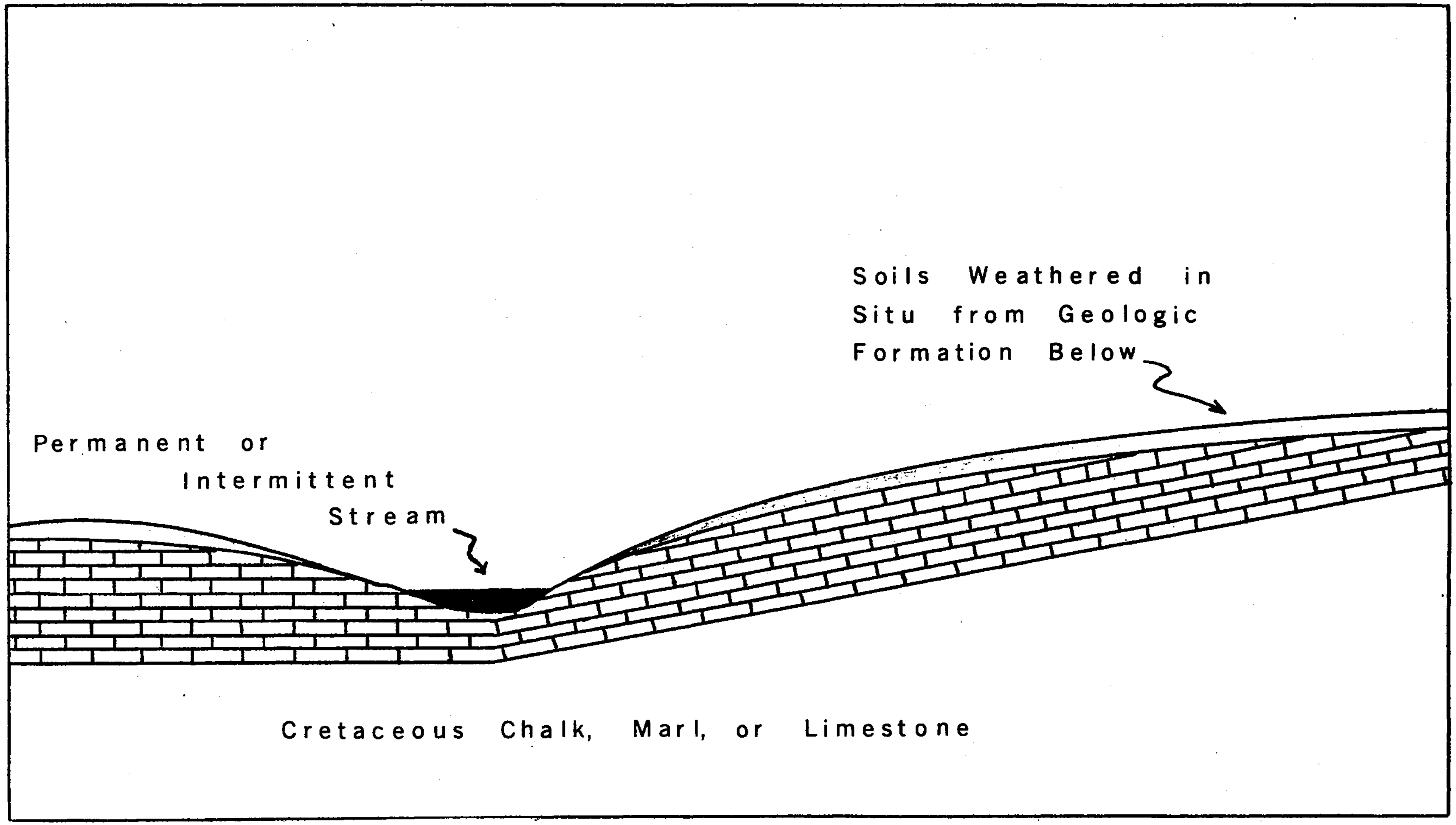

Figure 13. Idealized Conception of Predepositional Landform

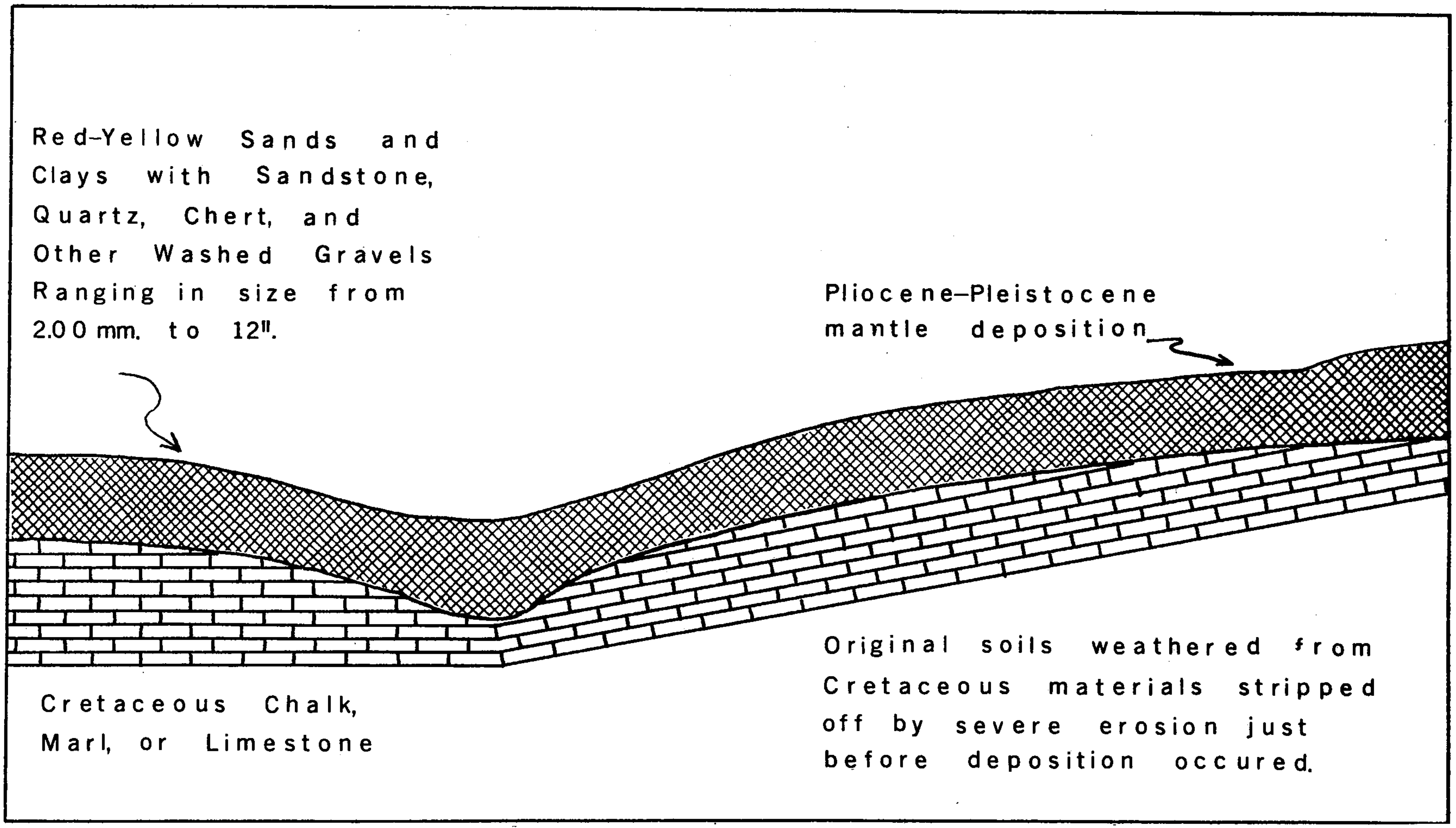

Figure 14. Idealized Conception of the Deposition of the Pliocene-Pleistocene Mantle

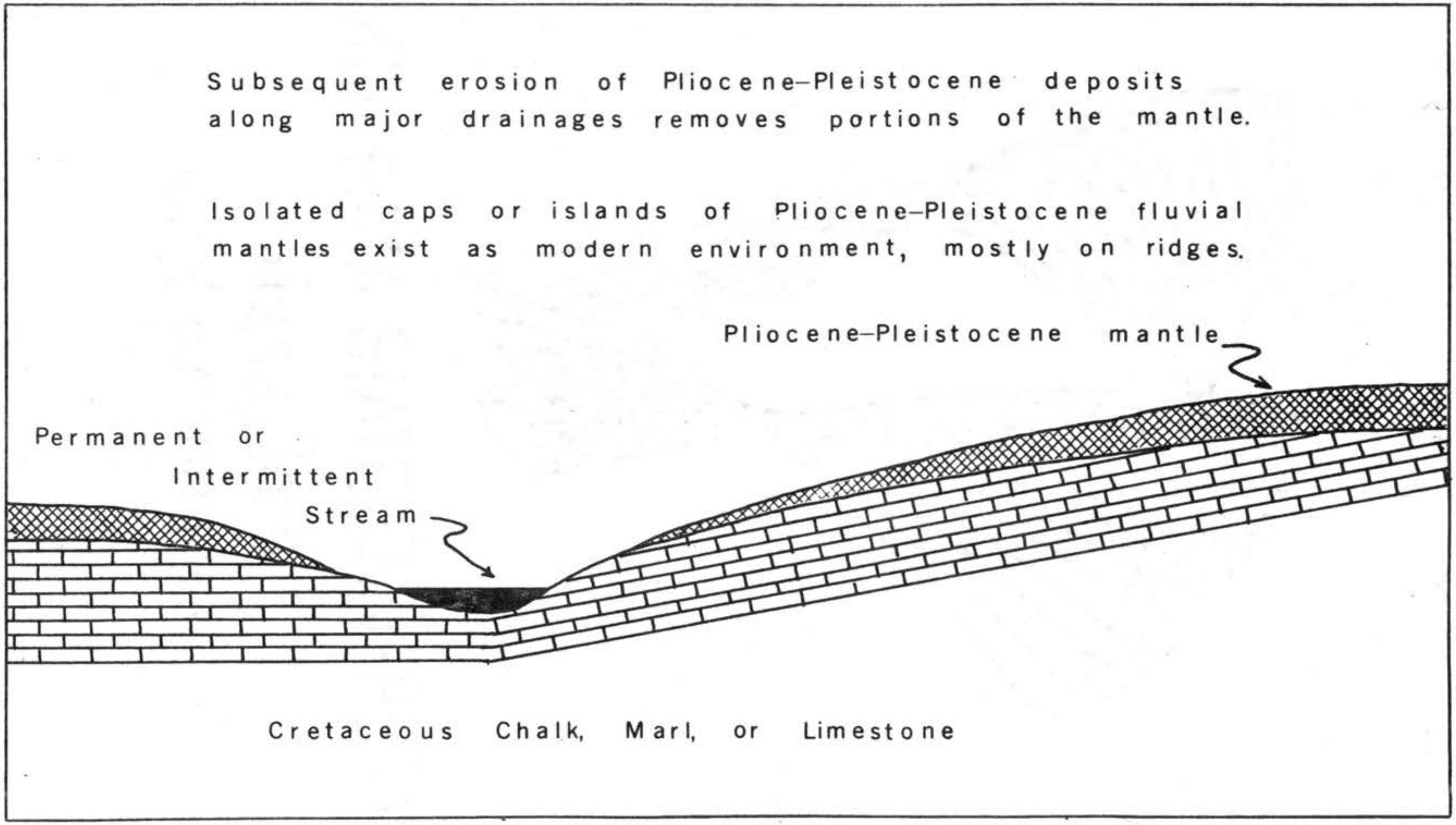

Figure 15. Idealized Conception of the Post-Depositional Pliocene-Pleistocene Mantle Showing Subsequent Erosion

research is needed to show which of the two concepts is valid in explaining the depositional process.

CHAPTER V

SUMMARY AND CONCLUSIONS

The findings of this study indicate that: (a) there is a strong correlation between the soil orders and the plant association groups growing on them; (b) the Alfisols studied were not weathered <u>in situ</u> but were the end result of a fluvial depositional process, as yet undefined; (c) the polyclimax theory can be used to explain the development of Gulf Coastal Plain soils.

The post oak-blackjack oak-black hickories-winged elm plant association group was found to be an almost direct respondent of the Alfisol soil order. The dogwood-red oak-tree huckleberry-willow oak-water oak-shortleaf pine-burr oak plant association group was also a good respondent of the Alfisol soil order. The cedar elm-bois d'arc-chinkapin oak-hackberry-hickory laciniosa-redbud plant association group was also an almost direct respondent of the calcareous Mollisol, Inceptisol and Vertisol soil orders.

The Alfisols are shown to be the result of fluvial deposition by the presence of washed gravel in the solums of all soil profiles and the absence of washed gravel in the underlying geologic formations from which these soils were previously thought to have weathered.

The polyclimax theory can now be given more credence in explaining the development of Alfisol, and apparently Ultisol and Psamments soils, on Gulf Coastal Plain and up-slope sites as follows: (a) Alfisol (red-yellow podzolic) soils on upland topography, formerly considered as weathered _in situ_ from variable bedrock, can be considered as originating from fluvial deposits; (b) because the soils are fluvial they must have been deposited before plants became established; therefore, the plants can be considered _respondents_, not only to the regional climate but more so to the edaphic and geologic patterns that prevail over the Gulf Coastal Plain; (c) the sequence, depth, and texture of the fluvial strata of the Gulf Coastal Plain can largely influence the kinds and associations of plants adapting or responding to a site; (d) the distribution of tree species and associated plants can then be used as a major diagnostic indicator of soil profiles, patterns, variations, and orders in the Gulf Coastal Plain ecosystem.

By studying the plant associations found on the Gulf Coastal Plain soils and the processes that contributed to these soils "formation" a more systematic concept of the Gulf Coastal Plain ecosystem should emerge.

This study enhances the credibility of using plant associations to delineate soil and geologic boundaries, i.e., association group 1 (post oak-blackjack oak-black hickories-winged elm) occurred with a high degree of probability on Alfisols. This delineation of soil groups or geologic systems by plant associations would greatly aid in the interdisciplinary interpretation of:

(a) Soil-site identification.

(b) Shallow or deep phases of a given soil series.

(c) Soil productivity potential or land management classes.

(d) Fair land tax assessment.

(e) Rock outcrop mapping.

(f) Environmental geology interests.

SELECTED BIBLIOGRAPHY

(1) Arend, J. L., and R. F. Collins. 1948. "Site Index of Eastern Red Cedar," *Soil Sci. Soc. Am.* Proc., Vol. 13, pp. 510-511.

(2) Barnes, Virgil E. 1966. *Geologic Atlas of Texas*, Texarkana Sheet, Scale 1: 250,000, University of Texas.

(3) Cajander, A. K. 1926. "The Theory of Forest Types," *Acta for Fenn.*, Vol. 29, pp. 1-108.

(4) Coile, T. S. 1948. "Relation of Soil Characteristics to Site Index of Loblolly and Shortleaf Pines in the Lower Piedmont Region of North Carolina." Duke University School of Forestry, Bul. 13.

(5) Corliss, J. F., and C. T. Dyrness. 1965. "A Detailed Soil-Vegetation Survey of the Alsea Area in the Oregon Coast Range," *Forest Soil Relationships in North America*. Youngberg, C. T., editor, Oregon State University, pp. 457.

(6) Daubenmire, R. 1961. "Vegetative Indicators of Rate of Height Growth in Ponderosa Pine," *For. Sci.*, Vol. 7, pp. 25-34.

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

(8) Doering, John A. 1956. "Review of Quaternary Surface Formations of Gulf Coast Region," *The Bulletin of the American Association of Petroleum Geologists*. Vol. 40, pp. 1816-1862.

(9) Doering, John A. 1960. "Citronelle Age Problem," *The Bulletin of the American Association of Petroleum Geologists*. Vol, 42, pp. 764-786.

(10) Dyrness, C. T., and C. T. Youngberg. 1958. "Soil-Vegetation Relationships in the Central Oregon Pumice Region," *Proceedings First North American Forest Soils Conference.* Cook, R. L. and T. D. Stevens editors, Michigan State University, p. 57.

(11) Endicott, R. L. 1971 "Bio-Economic Analysis of Even-Aged Shortleaf Pine Stands in Southeastern Oklahoma," (unpub. M. S. thesis, Oklahoma State University).

(12) Gedroits, K. K. *Chemical Analysis of Soils*, trans. from Russian by National Science Foundation by Israel Program for Scientific Translations, U. S. D. A., p. 36.

(13) Gehrke, F. E. and E. C. Steinbrenner. 1965. "Soil Survey Methods Used in Mapping Weyerhaeuser Company Lands in the Pacific Northwest," *Forest Soil Relationships in North America.* Youngberg, C. T., editor, Oregon State University, p. 485.

(14) Gray, Fenton, and H. M. Galloway. 1959. *Soils of Oklahoma.* Oklahoma State University Misc. pub. 56.

(15) Haig, I. T. 1929. "Collodial Content and Related Factors as Indicators of Site Quality." Yale University School of Forestry, Bul. 24.

(16) Hedlund, Arnold, and Paul Janssen. 1963. Major Forest Types in the South. Southern Forest Experiment Station, U. S. F. S., New Orleans, Louisiana.

(17) Heiberg, S. O., and D. P. White. 1956. "A Site Evaluation Concept," *Journal of Forestry* 54:7-10.

(18) Hills, G. A. 1958. "Soil-Forest Relationships in the Site Regions of Ontario," *First North American Forest Soils Conference*, edited by Cook, R. L. and J. D. Stevens, Michigan State University, p. 190.

(19) Hodgkins, E. J. 1960. "Estimating Site Index of Long-Leaf Pine through Quantitative Evaluation of Associated Vegetation," Proc. Soc. Amer. For., Washington, D. C., p. 28.

(20) Husch, Bertram. 1963. Forest Mensuration and Statistics, Ronald Press, New York, p. 474.

(21) Meyer, H. A., et al. 1961. Forest Management, Second edition, Ronald Press, New York, p. 202.

(22) Miser, Hugh D. Geologic Map of Oklahoma, Scale 1: 500,000, Oklahoma Geologic Survey.

(23) Pessin, L. J. 1933 "Forest Associations in the Uplands of the Lower Coastal Plain (Longleaf Pine Belt)," Ecology, Vol. 14, p. 1.

(24) Silker, T. H. 1965. "Plant Indicators Communicate Ecological Relationships in Gulf Coastal Plain Forests," Forest-Soil Relationships in North America, C. T. Youngberg, editor, Oregon State University, pp. 317-331.

(25) Silker, T. H. 1972. "Mineralogy and Texture Differences of Red-Yellow Podzol (Ultisol) Subsoil Strata: Fluviatile Genesis for Upper Coastal Plain Soils?" (Unpub. research, Oklahoma State University).

(26) Silker, T. H. 1970. "Disjunct Forest Communities: Relationship to Red-Yellow Podzolic Soils, Fluviatile Quaternary Mantle, and Need for Interdisciplinary Study," Abstracts: First American Quaternary Assoc. Conf., Yellowstone Park and Montana State University, Bozeman, Montana.

(27) Silker, T. H. 1969. "Bio-Economic Assay of Conditions Related to Pine Management on Tension-Zone Sites," The Ecology of Southern Forests, Norwin E. Linnartz, editor, Louisiana State University Press (proced. 17th Ann. Forest Symposium; Baton Rouge, Louisiana, April 10-11, 1968).

(28) Spurr, Stephen H. 1964. Forest Ecology, Ronald Press, New York, p. 352.

(29) Stose, G. W. and O. A. Ljungstet. 1932. Geologic Map of the United States, Appalachian Region and Eastern Mississippi Valley (1960 Reprint), Scale 1:2,500,000, U. S. Geological Survey.

(30) Stuart, Alan and M. G. Kendall. 1958. The Advanced Theory of Statistics, Vol. 3, Hafner Pub. Co., New York.

(31) Tansley, A. G. 1923. Practical Plant Ecology, Dood, Mead, and Company, New York.

(32) Toumey, James W. and Clarence F. Korstian. 1947. Foundations of Silviculture Upon an Ecological Basis, John Wiley and Sons, New York, p. 468.

(33) Westveld, M. 1952. A Method of Evaluating Forest Site Quality from Soil, Forest Cover, and Indicator Plants, U. S. F. S., N.E. Forest Experiment Station, paper 48.

(34) Wilson, Dale. 1968. "Shortleaf Pine Site Index-Soils and Plant Associations on the Coastal Plain of Southeastern Oklahoma." (unpub. M. S. thesis, Oklahoma State University).

(35) Zahner, R. 1954. "Estimating Loblolly Pine Sites in the Gulf Coastal Plain," Journal of Forestry, Vol. 52, p. 448.

APPENDIX

TABLE XV

FOREMAN, ARKANSAS, PLOT NO. 1

County:	Foreman, Arkansas	Slope:	1-3%
Location:	TWP 12S,R32W,NW1/4 Sec. 35	Cover:	Post oak-blackjack oak-hickory
Region:	Upper Coastal Plain	Soil Order:	Alfisol
Elevation:	375'	Soil Series:	Oktibbeha
Position:	Ridge Crest	Parent Material:	Marlbrook marl

Horizon	Depth (Inches)	Yr. Color	Field pH	Texture	Particle Size Distribution % Sand	Silt	Clay	Gravel* %	$CaCO_3$ %
A_1	0- 2	10 4/3	6.5	Silty Clay	16.20	48.80	35.00	15.04640	15.00
B_{21t}	2-10	2.5 5/8	5.5	Clay	5.56	32.44	62.00	0.41194	0.00
B_{22t}	10-15	2.5 5/8	5.0	Clay	5.60	34.40	60.00	0.31128	2.06
B_{23t}	15-27	10 6/1	5.0	Clay	5.10	50.90	44.00	0.30699	0.00
IIC_1g	27-41	10 6/1	5.5	Clay	6.25	27.97	65.79	0.52149	24.62
IIC_2g	41-60	10 6/1	5.5	Clay	7.40	20.60	72.00	0.95519	32.09
$IIIC_2g$	60-192	10 6/1	8.0	Clay	12.20	14.63	73.17	1.56048	54.43
R	192+	Grey	8.0	(Marl)	0.33	28.34	71.33	0.00000	54.98

*Percent of gross sample weight.

TABLE XVI

FOREMAN, ARKANSAS, PLOT NO. 2

County: Little River	Slope: 5-7%
Location: TWP 12S,R32W, NW1/4, Sec. 35	Cover: Blackjack-post oak-hickory
Region: Upper Coastal Plain	Soil Order: Alfisol
Elevation: 370'	Soil Series: Oktibbeha
Position: Ridgeslope	Parent Material: Marlbrook marl

					Particle Size Distribution %				
Horizon	Depth (Inches)	Yr. Color	Field pH	Texture	Sand	Silt	Clay	Gravel %	$CaCO_3$ %
A_1	0- 3	10 3/1	6.0	Silty Clay	30.97	40.73	28.30	21.25131	0.00
B_{21t}	3-12	5 5/8	5.5	Clay	19.98	25.10	54.92	17.04701	0.00
B_{22t}	12-20	5 5/8	5.0	Silty Clay	6.99	30.72	63.27	1.27126	0.00
B_{23t}	20-34	2.5 6/6	5.0	Silty Clay	22.04	65.54	12.42	14.50842	15.61
IIC	34-62	2.5 6/6	7.5	Silty Clay	5.33	40.72	44.94	0.61107	54.41
R	62+	Grey	8.0	(Marl)	0.62	41.07	58.31	0.00093	54.73

TABLE XVII

FOREMAN, ARKANSAS, PLOT NO. 3

County: Little River
Location: TWP 12S, R32W, NW1/4 Sec. 35
Region: Upper Coastal Plain
Elevation: 360'
Position: Branch Bottom
Slope: 0-1%

Cover: Cedar elm-hickory laciniosa-redbud
Soil Order: Vertisol
Soil Series: Houston
Parent Material: Marlbrook marl

Horizon	Depth (Inches)	Yr. Color	Field pH	Texture	Particle Size Distribution %			Gravel %	$CaCO_3$ %
					Sand	Silt	Clay		
A_1	0- 7	10 3/1	7.0	Clay	11.10	57.90	31.00	1.67355	1.89
A_{12}	7-21	10 3/1	5.5	Clay	10.26	35.74	54.00	1.70014	0.00
B_{21t}	21-38	2.5 5/2	7.5	Clay	18.20	31.80	50.00	1.53408	22.40
B_{22t}	38-48	5 5/2	7.5	Clay	15.00	54.00	31.00	35.59014	23.44
C	48-60	2.5 6/6	8.0	Clay	5.00	78.00	17.00	12.56148	57.67
R	60+	Grey	8.0	(Marl)	0.67	75.78	23.05	0.00000	56.47

TABLE XVIII

FOREMAN, ARKANSAS, PLOT NO. 4

County: Little River	Slope: 7%
Location: TWP 12S, R32W, NW1/4 Sec. 35	Cover: Post oak-dogwood-red oak
Region: Upper Coastal Plain	Soil Order: Alfisol
Elevation: 385'	Soil Series: Kipling
Position: Ridgeslope	Parent Material: Marlbrook marl

Horizon	Depth (Inches)	Yr. Color	Field pH	Texture	Particle Size Distribution % Sand	Silt	Clay	Gravel %	$CaCO_3$ %
A_1	0- 4	10 4/2	6.5	Silt Loam	36.00	56.00	8.00	12.48818	19.91
B_{21t}	4-10	10 5/6	6.5	Silty Clay	26.38	45.62	28.00	6.38304	0.00
B_{22t}	10-18	2.5 5/8	6.5	Silty Clay	24.00	40.00	36.00	8.00703	5.46
B_{23t}	18-38	10 6/1	5.0	Silty Clay	16.67	50.00	33.33	9.19092	0.00
B_{24t}	38-47	10 5/3	5.5	Silty Clay	17.00	36.34	46.66	43.49195	0.00
IIC	47-65	10 6/1	7.5	Silty Clay	11.90	48.10	40.00	3.75717	37.55
R	65+	Grey	8.0	(Marl)	2.40	77.60	20.00	0.00000	52.73

TABLE XIX

McKINNEY CREEK, OKLAHOMA, PLOT NO. 1

County: McCurtain
Location: TWP 9S, R27E, SE1/4 Sec. 29
Region: Upper Coastal Plain
Elevation: 355'
Position: Ridge crest
Slope: 7%

Cover: Post oak-dogwood-red oak
Description: Albaquultic Hapludalfs, fine, mixed, thermic
Soil Order: Alfisol
Soil Series: Cadeville
Parent Material: Brownstown marl

Horizon	Depth (Inches)	Yr. Color	Field pH	Texture	Particle Size Distribution %			Gravel %	$CaCO_3$ %
					Sand	Silt	Clay		
A_1	0- 3	10 2/2	5.0	Gravelly Silt Loam	25.97	65.70	8.33	1.54178	0.13
A_{12}	3- 8	10 6/6	5.0	Gravelly Silt Loam	33.33	50.02	16.65	14.45605	0.00
B_{21t}	8-18	2.5 4/6	5.6	Clay	17.65	45.72	36.63	6.14975	0.00
B_{22t}	18-30	2.5 4/6	5.9	Clay	12.32	39.40	48.28	1.67201	0.00
B_{23t}	30-47	10 4/6	6.0	Clay	3.99	21.19	74.92	0.27809	1.09
R	47+	Grey	8.0	(Marl)	1.80	61.20	37.00	0.00000	55.97

TABLE XX

McKINNEY CREEK, OKLAHOMA, PLOT NO. 2

County: McCurtain
Location: TWP 9S, R27E, SE1/4 Sec. 29
Region: Upper Coastal Plain
Elevation: 350'
Position: Ridge scope
Slope: 3-5%

Cover: Post oak-blackjack oak-hickory
Description: Albaquultic Hapludalfs, fine, mixed, thermic
Soil Order: Alfisol
Soil Series: Cadeville
Parent Material: Brownstown marl

					Particle Size Distribution %				
Horizon	Depth (Inches)	Yr. Color	Field pH	Texture	Sand	Silt	Clay	Gravel %	$CaCO_3$ %
A_1	0- 3	5 2/2	6.0	Silt Loam	17.98	47.06	34.96	0.29569	0.00
A_2	3- 6	10 5/6	6.0	Silt Loam	14.31	51.23	34.46	0.21794	0.00
B_{21t}	6-20	7.5 5/6	6.0	Clay Loam	16.65	47.21	35.14	0.54955	0.00
B_{22t}	20-32	2.5 3/6	6.0	Clay	14.31	45.80	39.89	4.52647	0.00
B_{23t}	32-38	2.5 3/6	7.0	Clay	7.66	45.72	46.62	0.81125	4.90
C	38-46	2.5 7/2	8.0	(Marl)	3.04	41.72	55.24	0.00000	59.44
R	46+				1.67	-----	-----	0.00000	59.50

TABLE XXI

McKINNEY CREEK, OKLAHOMA, PLOT NO. 3

County: McCurtain
Location: TWP 9S, R27E, SE1/4 Sec. 29
Region: Upper Coastal Plain
Elevation: 335'
Position: Depression
Slope: 1-3%

Cover: Hickory laciniosa-hackberry-chinkapin oak
Description: Rendollic Eutrochrepts, fine-silty, carbonatic, thermic
Soil Order: Inceptisol
Soil Series: Sumter
Parent Material: Brownstown marl

Horizon	Depth (Inches)	Yr. Color	Field pH	Texture	Particle Size Distribution %			Gravel %	$CaCO_3$ %
					Sand	Silt	Clay		
A_1	0- 7	10 2/2	8.0	Silty Clay Loam	8.66	57.12	34.22	0.70019	16.02
C	7-13	10 5/3	8.0	Clay	1.78	58.21	39.01	2.99972	51.30
R	13+	10 5/3	8.0	(Marl)	0.33	60.37	39.30	0.00000	61.92

TABLE XXII

GOODWATER, OKLAHOMA, PLOT NO. 1

County: McCurtain	Cover: Post oak-blackjack oak-southern red oak
Location: TWP 7S, R27E, NW1/4 Sec. 19	Soil Order: Alfisol
Region: Upper Coastal Plain	Soil Series: Cadeville
Elevation: 375'	Parent Material: Goodland Limestone
Position: Ridge Crest	
Slope: 1-2%	

Horizon	Depth (Inches)	Yr. Color	Field pH	Texture	Particle Size Distribution %			Gravel %	$CaCO_3$ %
					Sand	Silt	Clay		
A_1	0- 3	10 4/2	6.0	Gravelly Loam	34.32	55.54	10.14	1.41528	0.00
A_2	3- 7	2.5 6/4	5.5	Gravelly Silt Loam	27.80	62.20	10.00	2.23602	0.00
B_1	7-12	5 5/6	5.5	Silty Clay Loam	15.40	54.60	30.00	1.49535	0.00
B_{21t}	12-20	2.5 5/4	5.5	Clay	9.40	48.60	42.00	0.48406	0.00
B_{22t}	20-46	10 6/2	6.0	Clay	7.20	38.80	54.00	0.61266	0.00
B_{23t}	46-62	5 5/3	6.5	Clay	7.40	20.60	72.00	0.31764	0.00
R	62+	-----	----	Limestone	-----	-----	-----	--------	-----

TABLE XXIII

GOODWATER, OKLAHOMA, PLOT NO. 2

County: McCurtain
Location: TWP 7S, R27E, NW1/4 Sec. 19
Region: Upper Coastal Plain
Elevation: 370'
Position: Ridge Slope
Slope: 2-5%

Cover: Post oak-blackjack oak-hickory
Description: Albaquultic Hapludalfs, fine, mixed, thermic
Soil Order: Alfisol
Soil Series: Cadeville
Parent Material: Goodland Limestone

Horizon	Depth (Inches)	Yr. Color	Field pH	Texture	Particle Size Distribution %			Gravel %	$CaCO_3$ %
					Sand	Silt	Clay		
A_1	0- 3	10 4/3	5.5	Silt Loam	24.00	53.67	13.33	0.94069	0.00
A_2	3- 7	10 5/4	5.5	Silt Loam	16.32	70.36	13.32	1.03724	0.00
B_1	7-12	10 6/6	5.5	Silty Clay	15.67	61.00	23.33	0.53936	0.00
B_{21t}	12-20	10 6/6	5.5	Clay	12.65	57.38	29.97	0.54828	0.00
B_{22t}	20-30	5y 5/2	6.0	Clay	9.00	54.33	36.67	0.41961	1.02
C	30-36	Grey	7.5	Clay	7.40	8.60	84.00	0.95145	4.58
R	36+	-----	----	Limestone	-----	-----	-----	--------	-----

TABLE XXIV

GOODWATER, OKLAHOMA, PLOT NO. 3

County: McCurtain
Location: TWP 7S, R27E, NW1/4 Sec. 19
Region: Upper Coastal Plain
Elevation: 360'
Position: Lower slope of Ridge
Slope: 3-5%

Cover: Hickory laciniosa-hackberry-bois d'arc
Description: Lithic Hapludolls, clayey skeletal, montmorillonitic, thermic
Soil Order: Mollisol
Soil Series: Swink
Parent Material: Goodland Limestone

Horizon	Depth (Inches)	Yr. Color	Field pH	Texture	Particle Size Distribution % Sand	Silt	Clay	Gravel %	$CaCO_3$ %
A_1	0-4	5.0 2/2	7.5	Silt Loam	25.20	51.80	23.00	3.34627	3.08
R	4+	-------	---	Limestone	-----	-----	-----	-------	----

TABLE XXV

WHITE ROCK, TEXAS, PLOT NO. 1

County: Red River
Region: Upper Coastal Plain
Position: Ridge Crest
Slope: 3-5%
Cover: Post oak-blackjack oak-hickory

Description: Vertic Paleudalfs, fine, Montmorillonitic, thermic
Soil Order: Alfisol
Soil Series: Bryarly
Parent Material: Annona Chalk

					Particle Size Distribution %				
Horizon	Depth (Inches)	Yr. Color	Field pH	Texture	Sand	Silt	Clay	Gravel %	$CaCO_3$ %
A_1	0- 3	10 3/2	7.5	Clay Loam	11.32	52.15	36.63	0.32331	0.00
B_{21t}	3- 6	7.5 5/6	7.0	Clay	4.99	48.39	46.62	0.00000	0.00
B_{22t}	6-13	5 5/8	7.0	Clay	6.66	46.72	46.62	0.71183	1.38
B_{23t}	13-21	10 5/4	5.0	Clay	5.32	34.74	59.94	0.18261	1.28
B_{24t}	21-29	10 5/4	8.0	Clay	6.60	15.40	78.00	0.08803	2.44
B_{25t}	29.45	10 5/6	8.0	Clay	5.66	67.70	26.64	0.00140	0.40
C	45-61	10 7/3	8.0	Clay Loam	4.88	41.12	55.40	0.00117	51.38
R	61+	Grey	8.0	(Chalk)	3.90	42.00	54.10	0.00000	51.38

TABLE XXVI

WHITE ROCK, TEXAS, PLOT NO. 2

County: Red River
Region: Upper Coastal Plain
Position: Ridgeslope
Slope: 3-5%
Cover: Post oak-blackjack oak-hickory

Description: Typic Ustochrepts, coarse-silty, carbonatic, thermic
Soil Order: Inceptisol
Soil Series: Bryarly
Parent Material: Annona chalk

Horizon	Depth (Inches)	Yr. Color	Field pH	Texture	Particle Size Distribution %			Gravel %	$CaCO_3$ %
					Sand	Silt	Clay		
A_1	0- 5	10 3/1	7.0	Clay Loam	15.00	63.33	21.67	0.18098	0.00
B_{21t}	5-17	7.5 4/4	8.0	Clay	7.00	54.67	38.33	0.11857	0.00
B_{22t}	17-22	10 4/4	8.0	Clay	9.00	51.00	40.00	0.02675	0.00
C	22-50	10 5/4	8.0+	Clay Loam	8.66	39.73	51.61	0.02384	42.58
R	50+	Grey	8.0+	Chalk	4.20	51.80	44.00	0.00000	45.20

TABLE XXVII

WHITE ROCK, TEXAS, PLOT NO. 3

County: Red River
Region: Upper Coastal Plain
Position: Stream Bottom
Slope: 3-5%
Cover: Post oak-blackjack oak-hickory

Description: Typic Haplustolls (Calciustolls) fine-silty, carbonatic, thermic
Soil Order: Mollisol
Soil Series: Austin
Parent Material: Annona chalk

Horizon	Depth (Inches)	Color	Field pH	Texture	Particle Size Distribution %			Gravel %	$CaCO_3$ %
					Sand	Silt	Clay		
A_1	0-12	10 YR3/1	8.0	Clay Loam	30.40	44.60	25.00	0.00013	7.02
B_{21t}	12-27	2.5 Y 4/4	7.5	Clay Loam	16.00	64.00	20.00	0.28915	3.55
B_{22t}	27-35	2.5 Y 4/4	7.5	Clay	10.60	79.40	10.00	0.77059	18.76
C	35-50	2.5 Y 4/4	8.0	Clay	8.80	76.20	15.00	0.50448	38.71
R	50+	Grey	8.0+	Chalk	9.20	68.80	22.00	0.00000	43.36

TABLE XXVIII

ALPHABETICAL LIST OF SPECIES AND THEIR SCIENTIFIC NAME

Common Name	Generic Name
American Elm	Ulmus americana, L.
American Holly	Ilex opaca, Ait.
Big Shellbark Hickory	Carya laciniosa, Michx.
Black Cherry	Prunus serotina, Erh.
Black Gum	Nyssa sylvatica, Marsh.
Black Haw	Viburnum rufidulum, Raf.
Black Hickory	Carya texana, Buckl.
Black Locust	Robinia pseudoacacia, L.
Black Oak	Quercus velutina, Lam.
Black Walnut	Juglans nigra, L.
Blackjack Oak	Quercus marilandica, Muench.
Bluejack Oak	Quercus cinerea, Michx.
Bois d'Arc	Maclura pomifera (Raf), Schn.
Box Elder	Acer negundo, L.
Buck Brush	Symphoricarpos orbiculatus, Moench.
Button Bush	Cephalanthus occidentalis, L.
Burr Oak	Quercus macrocarpa, Michx.
Cedar Elm	Ulmus crassifolia, Nutt.
Chinkapin Oak	Quercus muehlenbergii, Engelm.
Chittam Wood	Bumelia lanuginosa (Michx.), Pers.
Decidious Holly	Ilex decidua, Walt.
Dogwood	Cornus florida, L.
Eastern Red Cedar	Juniperus virginiana, L.
Green Ash	Fraxinus pennsylvanica Var. lanceolata (Borkh.), Sarg.
Hackberry	Celtis occidentallis, L.
Honey Locust	Gleditsia triacanthos, L.
Indian Cherry	Rhamnus caroliniana, Walt.
Longleaf Pine	Pinus palustris, Mill.
Mockernut Hickory	Carya tomentosa, Nutt.
Mulberry	Morus rubra, L.
Pawpaw	Asimina triloba (L.), Dunal.
Persimmon	Diospyros virginiana, L.

TABLE XXVIII (Continued)

Common Name	Generic Name
Ponderosa Pine	Pinus ponderosa, Laws.
Post Oak	Quercus stellata, Wang.
Prickly Ash	Zanthoxylum americanum, Mill.
Red Ash	Fraxinus pennsylvanica, Marsh.
Redbud	Cercis canadensis, L.
Red Hawthorn	Crataegus spp.
Red Pine	Pinus resinosa, Ait.
Sandjack Oak	Quercus cinerea, L.
Service-Berry	Amelanchier arboria (Michx.) ferm.
Shortleaf Pine	Pinus echinata, Mill.
Slash Pine	Pinus elliottii, Engelm.
Sumac	Rhus glabra, L.
Southern Red Oak	Quercus falcata, Michx.
Sweetgum	Liquidambar styraciflua, L.
Tree Huckleberry	Vaccinium arboreum, Marsh.
Turkey Oak	Quercus Catesbaei, Michx.
Water Oak	Quercus nigra, L.
White Ash	Fraxinus americana, L.
White Oak	Quercus alba, L.
Wild Plum	Prunus spp.
Willow Oak	Quercus phellos, L.
Winged Elm	Ulmus alata, Michx.

VITA

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2