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Soils of Knox county in relation to physiography and parent material

Li Lien Chieh

To the Graduate Council:

I am submitting herewith a thesis written by Li Lien Chieh entitled "Soils of Knox county in relation to physiography and parent material." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agronomy.

Eric Winters, Major Professor

We have read this thesis and recommend its acceptance:

R. P. Moore

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

August 1, 1941

To the Committee on Graduate Study:

I am submitting to you a thesis written by Li Lien Chieh entitled "Soils of Knox County in Relation to Physiography and Parent Material." I recommend that it be accepted for nine quarter hours credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agronomy.

Eric Winters
Major Professor

We have read this thesis
and recommend its acceptance:

R.P. Moore

H.C. Amick

Accepted for the Committee

C.P. Smith
Dean of the Graduate School

SOILS OF KNOX COUNTY IN RELATION TO

PHYSIOGRAPHY AND PARENT MATERIAL

A THESIS

Submitted to
The Committee on Graduate Study
of
The University of Tennessee
in
Partial Fulfillment of the Requirements
for the degree of
Master of Science

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by..

Li Lien Chieh

August 1941

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CHAPTER I

INTRODUCTION

Pedology, the study of the soil as a natural body, is a very young science. The background of observation upon which the generalizations of this young science rests is as yet comparatively limited. A final statement of many fundamental principles has not yet been reached. Thus, every addition to the body of observations and each restatement of principle from a slightly different point of view has some value. This is the justification for the type of study here presented, which attempts to describe in a qualitative, rather than a quantitative, manner certain observations and interpretations about relationships of the soil to parent material and physiography.

Soil may be defined as a natural body having a definite morphology developed by the forces of weathering from organic and mineral materials at the surface of the earth. Thus, the soil as a natural body is recognized as the product of the environment in which five major factors are differentiated--climate, parent material, relief, biologic agents, and time.(1) These natural factors are interdependent, each modifying the other. It is through the reaction and interaction of these factors, that a soil comes into existence.

The contribution of a given factor to soil development is evident only when all the other factors are constant. Within a limited area,

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(1) Byers, H. G., Kellogg, C. E., Anderson, M. S., and Thorp, J. "Formation of Soil". Soils and Men. Year Book of Agriculture, 1938. Washington, D.C. United States Government Printing Office. 1938. p. 949.

such as Knox County, where climate and vegetation are essentially constant, the variables of the environment are parent material, relief, and time. Relief and time can both be treated under the general topic of physiography, as will be explained below.

Physiography as a field of research includes the description, classification, and correlation of land forms and the active processes by which these land forms are developed. All features of the natural land forms constitute the factor of relief. This systematic study of relief from the physiographical viewpoint will help explain its present relation to the natural distribution of soils.

The study of the evolution of land forms requires a clear understanding of the chronological order of the erosional stages which, in turn, tells directly the sequence of land-form development. Soils coexist with their particular land forms. Thus, the time relationships of soils can also be traced in a region where the physiography is well understood.

Parent material is defined as the unconsolidated residue of rock weathering from which soils develop. It may be shallow or deep, coarse or fine, acid or alkaline; it may be exceedingly resistant to change or it may be subject to rapid alteration. Because such variations have a great influence on the course of soil development, and the properties of the resultant soils, an understanding of the parent material is a basic step in soil study.

The purpose of this study, then, is to describe the physiography and parent material of Knox County, and correlate these factors of the environment with the properties of the associated soils.

CHAPTER II

METHOD OF PROCEDURE

Knox County contains a wide variety of both land forms and parent materials within its limited area. Furthermore, there is but little exaggeration of relief to cause difference in climate or vegetative covers. For these reasons, in addition to its accessibility to Knoxville, this area was considered an excellent one for the proposed study.

Numerous field trips were taken during the academic year of 1940-1941, some by the author alone, and others in company with local soil experts. Particularly detailed observations were made in the northern section between Fountain City and Norris Dam where geologic exposures and relief are displayed in full. Road cuts, gullies, and other excavations were utilized to examine the soil profiles and the parent material beneath the soils. Auger borings were resorted to wherever suitable exposures could not be found. Such borings, because of their shallow depth, which is about three feet, usually disclose only the soil profile.

Available geologic and pedologic data were collected from many sources. The descriptive data of local soils are chiefly from unpublished work by Mr. J. W. Moon of the United States Department of Agriculture, and Mr. Wallace Roberts of the Tennessee Agricultural Experiment Station. Geologic information was obtained from various publications of the State Geologic Survey and of the United States Geologic Survey. These various sources were supplemented with general information from standard references in both pedology and geology. In addition, frequent personal conferences were utilized to verify and coordinate the interpretation of field notes and reference material.

CHAPTER III

DESCRIPTION OF THE AREA

Location and General Physical Features

Knox County is in the central section of the Great Valley of East Tennessee. On the east are the Smoky Mountains, the highest point of which is over six thousand feet, and to the west is the Cumberland Plateau with an average height of about two thousand feet. The Valley, with an average base level of eight hundred feet, is well marked in contrast to the surrounding higher regions. For reference, the City of Knoxville is located at 36° N latitude.(1)

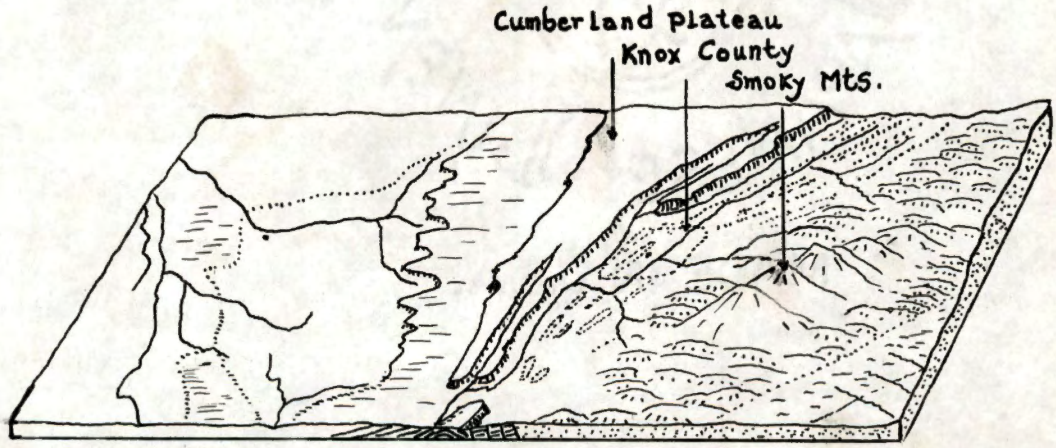

Figure 1. Location and topography of Knox County and its surrounding regions

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(1) Fenneman, N. M., Physiography in Eastern United States. First Edition. New York: McGraw-Hill Book Company. 1938. pp. 265-278.

Topographically, the County is hilly and contains a series of continuous ridges, running parallel in a northeast - southwest direction. They are generally low-lying. Valleys vary in width and run parallel to the ridges. Rivers and creeks are numerous in Knox County. The large rivers are the Tennessee River and its tributaries, the Holston and French Broad Rivers.

Sink holes, basins, and sinking creeks are found in many places that are underlain by soluble rocks; however, typical karst topography does not exist extensively.

Climate

The climate of the County is characterized by an abundant and well-distributed rainfall, relatively long growing season, mild temperature, and relatively high percentage of possible annual sunshine. Due to absence of exaggerated relief, the climate of Knox County is essentially uniform.

According to C. E. Allred and others[2], the average temperatures in this region of Tennessee are as follows: Annual 58.9° F., winter 40.8° F., spring 58.4° F., summer 76.3° F., fall 60.0° F. The average annual precipitation is 45-50 inches, while the relative humidity at Knoxville is 73.5 percent.

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(2) Allred, C. E., Atkins, S. W., and Raskoph, B., "Climate", Human and Physical Resources of Tennessee. Monograph No. 40. Agricultural Economics and Rural Sociology Department, Tennessee Agricultural Experiment Station. 1937.

Stratigraphy

The stratigraphy of Knox County is very complicated. Although detailed geologic work has been done in the general area, the formation names most recently proposed are not available in published form. In view of this fact, only a generalized outline of stratigraphy, based on Keith's work, is given in Table I.[3]

Crustal Movements

Since the regional rocks are wholly of sedimentary origin, they must originally have been laid down in nearly horizontal layers; but, in this area, they are inclined at all possible angles. However, the prevailing dip is to the southeast. It is believed that the rocks have undergone crustal movements, chiefly lateral compressions which produced in the first stage a series of folds. Hayes gives the following description relating to crustal movements.[4]

> As the compression continued beyond the strength of the beds, they were in many cases fractured along the steep sides of the folds, and wherever this took place the anticline was thrusted over upon the adjacent syncline. Thus, the strata, particularly throughout the valley belt in Tennessee, are in the form of narrow, closely compressed folds, intersected by a large number of fault planes. They are thus cut in to long, narrow blocks which overlap each other, all dipping steeply to the southeast.

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(3) Keith, Arthur, "Maynardville Folio, No. 75", United States Geological Survey., Washington, D. C., United States Government Printing Office. 1901.

(4) Hayes, C. W., "Physiography of Chattanooga Districts in Tennessee, Georgia, and Alabama", Nineteenth Annual Report of U. S. Geological Survey. Washington D. C. United States Government Printing Office. 1899. p. 20.

TABLE I

GENERALIZED STRATIGRAPHY OF KNOX COUNTY

	Formation Names	Thickness feet	Character of Rocks	Character of Topography
Silurian	Rockwood formation	400-700	Red and brown calcareous and sandy shales with local beds of white sandstone and fossiliferous red hematite	Valleys and sharp, even-topped ridged
	Clinch sandstone	150-500	Massive white limestone	High sharp mountains
Ordovician	Bays formation	200-500	Red, calcareous and agrillaceous sandstones	Valleys and low slopes
	Sevier shale	1100-1300	Light blue sandy and calcareous shale with beds of shaly limestones	Irregular ridges and knobs
	Tellico sandstones	100-350	Bluish gray calcareous sandstone and sandy shale	High rounded ridges and knobs
	Moccasin limestone	600-800	Red and gray flaky limestone and calcareous shale	Low ground with irregular knobs
	Holston marble	200-400	Varigated marble--red, brown, gray, and white	Smooth open valleys and rounded hills and knobs
	Chickamauga limestone	500-700	Blue limestone, and argillaceous limestone	Low and rolling valleys
	Knox dolomite	2600-3500	Cherty magnesian limestone, light blue and white	Broad ridges and irregular rounded hills
Cambrian	Nolichucky shale	500-600	Yellow, red, and brown calcareous shale with a few limestone beds	Narrow valleys and steep slopes of Knox dolomite ridges
	Maryville limestone	300-600	Massive blue limestone	Lines of knobs
	Rogersville shale	100-225	Bright green shale with a limestone bed	Valleys and low knobs
	Rutledge limestone	180-500	Massive blue limestone	Open valleys
	Rome formation	350-400	Red, green, yellow and brown shale with layers of sandstones	Sharp ridges and notches with many water gaps. Steep slopes

The folds as well as faults are all long and straight and the resultant ridges and valleys follow suit.

It is clear that the crustal movement has not only laid the foundation of the geological structure, but has also affected the subsequent weathering. First of all, folded, faulted, and fractured beds of rocks resulted in a diversity of rock exposures of varying resistance on which differential weathering could take place. Secondly, the accumulation of thick weathered residue would be favored by the tilted structure and fractured condition of the beds of rocks because water can penetrate deeply along the tilted bedding planes, and chemical action can take place to great depths, causing the rocks to crumble, if not decompose entirely.

Surface Occurrence of Rocks

As a result of folding and faulting the exposures of strata of rocks have been frequently repeated on the surface. The Rome formation, for instance, is repeated several times, forming three distinct ridges on the northern section of the County known as Bull Run, Beaver, and Sharp Ridge. The Knox dolomite is exposed in the same manner as the Rome formation, the cherty dolomite forming ridges, and the non-cherty dolomite forming broad valley floors. Due to its unusual thickness, the dolomite covers more area in the County than any other rock formation--roughly 40 percent of the entire County. Other formations, such as Chickamauga limestone, Sevier shale, Holston marble, and Tellico sandstone, are all repeated. The only formation that has not been highly folded is the Clinch sandstone capping House Mountain, which after all, covers rather a limited area and relatively unimportant position.

Superficial Deposits

Overlying all other formations are the superficial deposits which have been little studied and consequently, rarely described in any available literature. These deposits, in the area under study, consist of recent alluvium, colluvium, and Pliocene deposits. A detailed description of the deposits is given below.

The Pliocene deposits, as they appear today, are always found in terrace position along large rivers. These deposits are stratified and show all indication of water deposition. They consist, wherever found within the County, of a top layer, from one to several feet thick, of fine silt and clay material with variable amounts of quartz or angular sandy grains. This is underlain by stratified gravels, highly mixed with sandy deposits or even rock debris probably derived from the weathered bed rocks. The gravels are chiefly water-worn and rounded in shape and the size varies from a few millimeters to at least a foot in diameter. The major materials found are sandstones or other siliceous gravels, but it is hardly true that the gravels were totally siliceous when they were first deposited. This naturally suggests that a long lapse of time has taken place since their deposition, during which the less resistant material has been weathered and leached away. These terrace deposits are remnants of an old flood plain and their distribution was probably far more extensive than it is now.

The recent alluvium consists of both river and creek bottom deposits. All the large rivers, such as the Holston, French Broad, Tennessee, and the

Clinch, have narrow alluvial deposits along their first bottoms. These deposits are, in general, silty to loamy in texture, and their depth varies from a few inches to several feet. They occur, in most cases, at the inside curves of the meanders where the currents or flow of the river is slow.

The creek bottom deposits consist of coarse, angular fragments of rocks, together with fine materials, such as sand, silt, and clay. The character of these deposits is highly influenced and controlled by the rocks forming the ridges nearby. To a certain extent, they may be considered colluvial.

Physiography

Physiographic Stages

A succession of stages of physiographic development have been detected in the area. The perfection with which each stage of erosion and deposition has left its record on the land forms varies greatly in different places, but the sequence of major events appears to be identical or conformable to the type-localities. It is noticeable that since the Cretaceous period the Valley has gone through severe erosional changes, both surface and subaerial. Deposition, except Pliocene and post-Pliocene deposits, is rarely recorded.

A brief recapitulation of the physiographic stages is given below in chronological order, beginning with the oldest.

Cumberland Peneplane. This peneplane is recognized as the oldest physiographic stage in the area. Any ridges or hills in the Valley with a height over 2,000 feet can be correlated with the standard region of the Cumberland Plateau. The only locality that bears the evidence of this stage in the area is House Mountain, which owes its relief partly to the presence of an exceptionally resistant stratum of sandstone.

Highland Rim Peneplane. This stage was developed through a series of erosional cycles during the early Tertiary period. The existence of this peneplane is manifested by the presence of the common altitude of 1,150 feet above sea level, or roughly 300 feet above local base level, to which the majority of the hills reach. Some ridges that represent this physiographic stage are Chestnut, Copper, and Black Oak.

Pliocene Deposition. The Pliocene deposits are found on the lower levels of the Highland Rim stage, chiefly on the spurs of the ridges and remnant hills along the large rivers and creek valley bottoms. The relief during which the deposition took place was probably more moderate than it is at present. Wherever they are, these deposits are preserved in terrace position and even in the form of remnant hills. The composition and nature of the deposits were previously described under "Stratigraphy".

Coosa Peneplane. Following the Pliocene deposition came a stage of dissection. The rivers which were probably sluggish during the preexisting stage, revived their activity and much of the gentle relief that existed in the deposition epoch was modified. The Coosa Peneplane locally is confined to areas of easily erodible rocks along the old river channels. Its altitude is locally about 800 feet above sea level and it is only found along the Tennessee River and main tributaries.

Present Stage. The degradation introduced by the Coosa peneplanation opened a new relief upon which the present land forms are sculptured. The present stage is a continuation of dissection by which the river valleys have been entrenched and incised. Deposition in this area is negligible and is chiefly confined to bottom lands along the meander curves of the rivers. As a whole, the present landscape with its rugged ridges and ramified drainage pattern, has reached a stage of maturity.

Physiographic Features in Relation to Geologic Structure and Rock Composition

It is found, even at a cursory examination, that the ridges are generally formed on the anticlinal axis parallel to each other in a remarkable regularity paralleling the fault lines. Again, it is true that most, if not all, of the ridges are composed of more resistant rocks. The Rome formation, with its resistant sandstones and hard shales, always forms steep relief in contrast to the mild relief of associated weaker formations. The dolomitic limestones, too, form high ridges, due to their abundant impurities, chiefly chert, which remains after solution of the carbonates. The fact that chert fragments function as a protective cover to both weathered products and the underlying rocks has not been fully appreciated by casual observers. It is, however, noticeable that when large amounts of chert nodules are present they can protect the surface material from impact of raindrops, and the movement of water is also impeded. Thus, it is due in part to the slow erodibility engendered by these impurities that the dolomitic limestone ridges stand in higher relief.

The position of the streams is largely dependent on geologic structure. The master streams flow in general parallel to the ridges, following the outcrops of the soft rocks. The Tennessee River and its major tributaries have courses mainly on limestone.

Parent Materials

The parent materials of the regional soils are derived from two main sources: (1) The consolidated rocks, limestone, sandstone, and shale, (2) The unconsolidated rocks, colluvium and alluvium. The colluvial and alluvial deposits, due to their loose physical nature, can be considered as parent material even without further weathering. The nature and distribution of these parent materials are identical with that for the "Superficial Deposits" described above. However, a brief description is needed for the more important parent materials derived from consolidated rocks, because of their diverse character.

Parent Material Derived from Cherty Dolomitic Limestone

The most important and widespread parent material in this area is that derived from the dolomitic limestone. It constitutes 40 percent of the total parent material exposed, and is distributed chiefly on the rolling ridges where it underlies a number of the well developed soils. It is unusually thick, and the depth is not easily determined, since the bed rocks are seldom exposed. North of Fountain City, where Highway 33 cuts through Black Oak Ridge, an exposure of about 50 feet is seen. In many other places it is not uncommon to see the residue to depths of 30 or 40 feet.

The color of the residue is generally bright, highly mottled with red, yellow, and gray. Chert fragments, and other siliceous rock fragments, are abundant but irregularly distributed. Occasional masses of partly weathered limestone are found within the residue. The irregularity of the accumulation shows a complicated background, which will be dealt with in the subsequent discussion.

Parent Material Derived from More or Less Pure Limestone

The leading rocks of this group are the Chickamauga limestone and Holston marble. These two formations are not widespread sources of parent material but nevertheless important as they underlie the more fertile soils on the comparatively gentle topography in the valleys. The weathered material consists of clay, the depth of which varies considerably from a few inches to several feet, but the depth is generally much less than that of the residue overlying the cherty dolomitic limestone.

The thick residue is nearly always bright colored and not much different from that derived from cherty dolomitic limestone, except for the absence of chert. Where the accumulation is thin, the color of the residue is dull and much affected by soil-forming processes. The accumulation of the residue on these rocks in some places is insufficient to form a continuous cover and, as a result, bed rock outcrops here and there.

Parent Material Derived from Shale

The shale generally outcrops on steep slopes where natural erosion has been active and, as a result, the residue from the weathering of shale is generally shallow. In a few places, however, where the slope is mild and the shale contains a little limestone, a residue between two and four feet thick has formed. This residue resembles that left by the limestone, except that it is chiefly yellow instead of red, is free from chert, and contains numerous fragments of shale.

Parent Material Derived from Sandstone

Sandstone can be classified into acid and calcareous types. The calcareous sandstone does not differ much from sandy limestone, and when weathered, it gives rise to red colored residue. Weathered products of Tellico sandstone represent this type of residual accumulation, and they are comparatively important since they are extensively distributed in the southeastern section of the County.

The acid sandstone is not an important parent rock. The residue accumulated on this rock is usually thin.

Soils

The great soil groups of Knox County can be described under three orders--(1) zonal, (2) intrazonal, and (3) azonal.[5]

Zonal Soils

The zonal soils of Knox County fall into the Red and Yellow Podzolic group. Variations of color, texture, friability, erodibility, degree of leaching, and depth between different series are wide. The surface soils exhibit shades of color from gray through brown to dark-

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(5) Baldwin, Mark, Kellogg, C. E., and Thorp, James, "Soil Classification". Soils and Men. Year Book of Agriculture, 1938. Washington, D.C., United States Government Printing Office. 1938. p. 987.

brown, while the subsoils are chiefly either red or yellow. The textural range is wide, and there is a tendency for the surface soil to be light, generally a silt loam, and subsoil to be heavy, usually a clay or silty clay.

Four soils selected to illustrate the characteristics of the Red Podzolic group are Decatur, Dewey, Tellico, and Cumberland.

The Decatur soils represent the least podzolized series of the Red Podzolic group. They are developed on the parent material derived from marble, as well as limestones and dolomitic limestones of high grade. The surface soil, within a depth of about 12 inches, is a brown to dark-brown smooth, mellow, very friable silt loam, which tends to crumble to soft granules on slight pressure. The subsoil, within a depth of 70 inches, which is considered as a horizon of illuviation or accumulation, has a color range from brownish-red to maroon-red. The structure of this horizon varies from soft granular in the upper portion to sub-angular at the lower depth. The friability of the horizon decreases with the depth and the plasticity increases. There are numerous tiny black concretions, particularly in the middle portion. Below 80 inches is the heavy, plastic, slightly mottled, though dominantly red, clay.

The Dewey soils represent the normal Red Podzolic soils in the area as they have both podzolic and lateritic features well shown in their morphology. They are developed on the parent materials derived from high-grade dolomitic limestones. The surface soils, within a depth of 12 inches, are grayish-brown, mellow, weakly, granular silt loams containing a few chert fragments. The B horizon, having a depth of about 4 or 5 feet, is a red friable silty clay or silt clay loam. The structure is subangular.

Both tiny black concretions and chert fragments of different sizes are present. The ranges of friability and plasticity vary with the depth in the same way as in the Decatur soils. Below 4 or 5 feet, the subsoils are heavy, stiff and sticky clay, with red, yellow and olive mottlings. Not many concretionary bodies are seen, but chert fragments are usually present. The depth of the materials underlying the soils is unknown, but it is estimated that it approaches 15 or 30 feet in many places. Red Podzolic soils are also found on the parent materials derived from calcareous sandstones and unconsolidated Pliocene deposits which give rise to the Tellico and Cumberland series, respectively.

The Tellico soils on steep hillsides are characterized by their reddish-brown, friable, fine sandy loam surface, about 10 inches deep, and brownish-red to yellowish-brown sandy clay loam subsoils. The weathered products underlying the solum are usually friable material, the depth of which varies greatly.

The Cumberland series, which resemble the Decatur in appearance, occur on the higher stream terraces. They are chiefly distributed in the southeastern part of the County. These soils are characterized by a dark-brown to reddish-brown mellow loam surface soil, and dark-red to maroon silty clay loam subsoil. Well rounded water-worn gravel, siliceous in nature, are found in the subsoils. Angular quartz grains are also present. Tiny black concretionary bodies, similar to those found in Decatur, Dewey and other soils, are also present here.

The Yellow Podzolic soils are represented by Clarksville and Sequoia series developed on cherty dolomitic limestones and interbedded limestones and shales, respectively. They are characterized by their highly podzolized surface soils and yellow subsoils.

The surface soils of the Clarksville series, within a depth of 10 inches, are gray to yellowish-gray loose cherty loam to loam. Considerable numbers of large chert fragments are present.

The B horizon, having a depth of about 2 feet, is a yellow to reddish-yellow silty clay loam. A few tiny black concretions are found, but chert fragments are present in abundance. The lower subsoils consist of cherty silty clay loam, predominantly yellow, but mottled by reddish-brown, ocher and gray. The weathered material, in most places, extends to a depth of more than 50 feet.

The Sequoia soils are distributed on rolling topography in the valleys. The surface soil is gray to light brownish-gray silt loam, about 10 inches deep. The subsoil is firm, compact reddish-yellow silty clay to clay, angular in structure, hard when dry, and plastic when wet. Tiny black concretions are present in abundance. The underlying rocks occur in most places at a depth of about 40 inches.

Intrazonal Soils

Intrazonal soils occur on most parent materials where the topography is level and internal drainage is slow. Their properties are quite different from zonal soils on similar parent material. A typical representative of the intrazonal soils is the Tyler series, found on the stream terraces.

The Tyler soils are developed on the materials consisting of old river deposits, and they occur on level or depressed areas in the valley.

The surface soil is light-gray silt loam, in places speckled with yellow, and rust brown, about 16 inches in thickness. The subsoil is dominantly drab, mottled with yellow, gray, and rust brown. It consists of a tough, plastic silty clay of low permeability.

Azonal Soils

The azonal soils can be described under two groups, the lithosols, which occur on steep hillsides, and the alluvials, which occur on the very recent colluvial and alluvial deposits. They are characterized by their undeveloped or slightly developed profiles, reflecting the nature of their parent materials.

The lithosols are chiefly developed on the weathered products of shale or sandstone, or mixtures of both. Respresentative series are Montevallo and Muskingum.

The Montevallo soils consist chiefly of grayish-brown to yellowish-gray shaly soil material that ranges from about 4 to 18 inches in depth over slightly weathered shale. In some of the virgin areas, a skeleton profile has developed which manifests a gray surface layer and a yellow subsoil layer.

The Muskingum series have grayish-brown sandy surface soils over yellow-brown friable sandy subsoils, passing into the partly disintegrated parent material at less than 2 feet. These are usually shallow soils, and loose sandstones from 5 inches to 1 foot or more in diameter are abundant on the surface and throughout the whole profile. Under a forest cover, organic matter is usually sufficient enough to stain the topmost inch of the soil.

The profiles on recent local alluvial and colluvial materials are essentially similar on both upland and bottomland. There is no well-developed B horizon in any of the profiles. They are chiefly differentiated on the basis of the character of parent material, which is closely associated with its sources. For instance, the Huntington soils are characterized by brown mellow silt loam or very fine sandy loam to a depth ranging from 18 to 24 inches. This material is underlain by grayish-brown heavy silt loam or silty clay loam. The underlying material is variable, depending on accidents of stream deposition. In most places it is mottled. This soil resembles Abernathy developed in depressions.

CHAPTER IV

DISCUSSION

The major objective of the following discussion is to point out certain of the more important relationships between soil properties and certain factors of environment. Some of these relationships are self-evident from an inspection of the descriptive material presented. However, those relations of major importance to Pedology deserve emphasis, and particular attention will be directed to them in the following discussion. Furthermore, it is desirable to offer an explanation for the observed relationships wherever possible. No attempt at a complete and exhaustive treatment of relations is proposed since that would involve a discussion of undue length.

Relation of Soil Properties to Parent Material

Acid and Basic Material

Throughout the entire county a striking and consistent relationship exists between the soils and their parent materials and the rocks from which the latter are derived. Lateritic, or red soils, occur chiefly on parent material derived from basic rocks and podzolic soils on parent materials from acid rocks. Four series of well-developed soils may be used to illustrate this point, namely, Decatur, Dewey, Fullerton, and Clarksville. The parent material of these soils is derived from limestone, but the impurities, chiefly chert, vary tremendously. The Decatur parent material contains little chert, while chertiness increases from Dewey through Fullerton to a maximum in Clarksville. The resultant effects on the properties expressed in each soil are numerous. First of all, there is a color relationship. The color of the surface soil in going from Decatur to Clarksville changes from dark reddish-brown to light-gray, and the color of the subsoil from maroon-red to yellow. Secondly, the degree of podzolization, indicated by the intensity of the bleaching of the A_2 horizon, of each soil varies in direct proportion to its chertiness. The solum is the thickest in Decatur and thinnest in Clarksville. It is obvious, therefore, judging by the few important properties described, that the Decatur series is the most lateritic while the Clarksville is the most podzolic. The Dewey and Fullerton are then transitional in nature.

These properties are significant in relation to both the direct and indirect effect of the parent material in the development of soils. Directly it is the presence in large quantity of the basic minerals, such as Ca and Mg salts, in the more or less pure limestone that results in a moderate pH level at which the Fe and Al oxides are rendered less soluble and remain as end-products, while the soluble minerals, including part of the silica, are removed in solution. Thus, a lateritic soil is formed as an end-product consisting of a high percentage of hydrous oxides and some insoluble quartz grains. The dilution of basic material with siliceous material in limestones and dolomites causes a lower pH, more solution of the hydrous oxides, and results in a podzolic profile.

Indirectly, it is the nutrient cycle which varies on different materials that brings another effect in the development of the soils. On acid material, vegetative growth is scanty and only acid-tolerant plants grow, and the nutrient cycle is weak. The acid organic residue associated with a weak nutrient cycle increases the acidity of the weathering products, and Fe and Al oxides, together with soluble silica, are thus leached. On basic material, where grasses and deciduous trees thrive, a moderate nutrient cycle results in a less acid organic residue and a higher pH of the weathering products which favors the retention of the Al and Fe oxides in the upper horizons.

The chertiness of each parent material and its relation to the development of soil properties can be diagrammatically expressed by the following figures.

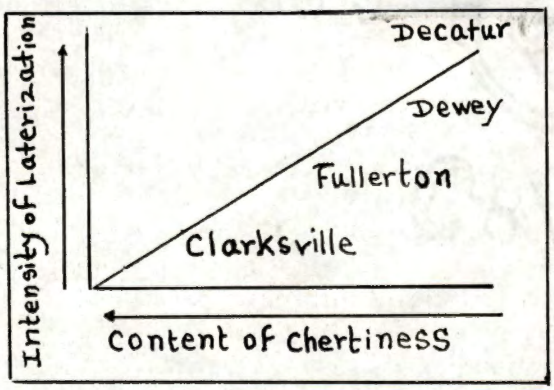

Figure 2

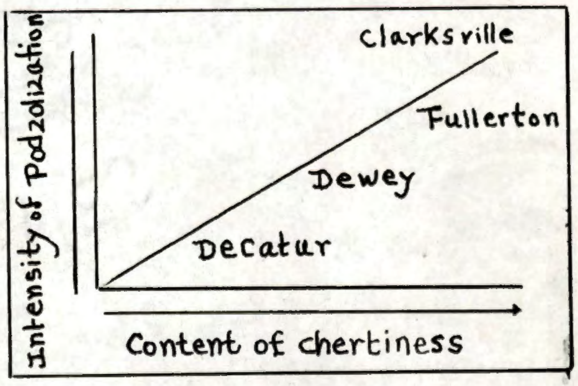

Figure 3

Argillaceous Material

Throughout the entire County, red or lateritic soils do not occur on highly argillaceous material. Parent materials derived from limestone usually give rise to red soils but where the relief is mild and natural erosion is not rapid parent materials derived from interbedded limestone and shale generally give rise to Yellow Podzolic soils.

The Sequoia series, previously described, developed on interbedded limestone and shale with highly podzolized surface and heavy plastic reddish-yellow subsoil, illustrates this relationship between its properties and argillaceous parent material. It is evident that the major influence of the parent material on the resultant soil properties is due to the excess of the clay content. These shales are composed of materials which resulted from long-continued weathering and their composition, therefore, is but little affected by disintegration and hydrolysis. The vegetative cover is presumably not vigorous and, therefore, the nutrient cycle apparently is weak. The shallowness of the soil profile is directly contributed to by the inertness of the parent material and the heavy sticky material renders the internal drainage slow. The removal of silica is impeded which in turn favors eluviation and formation of a podzolized profile.

Relation of Soil Properties to Physiography

The relation of physiography to the development of soil properties is not as easily comprehended as that of the parent material. As given above, physiography, as a topic of research, deals with land forms, in a strict sense relief, and their evolution. It is desirable to divide the discussion into two parts: First, the relation of relief to soil properties, and second, the relation of evolution of land forms and its related problem, age, to the soil properties.

Relief in Relation to Soil Properties

The influence of relief upon weathering is due largely to its controlling effect upon run-off and geological erosion. Water tends to stay in a level or depressed topography, and runs off quickly on steep slopes. Where water stays it tends to penetrate the unconsolidated soil material, and where it runs off it tends to erode the material underneath, particularly where the steep relief lacks vegetative cover. It is evident from the foregoing that the character of the relief partly controls the properties of the resultant soil.

Exaggerated Relief. Neither steep nor depressed relief favors the development of normal soil properties. On steep relief, except in a few cases where parent material is very permeable, hydrolysis of rocks, because of the scarcity of H_2O, can never be very effective, and rapid erosion gives little chance for veneering materials to stay long enough to give rise to well-developed soil profiles. Thus, only azonal soils are formed here. The Lehew and Muskingum series, on the steep ridges of Rome formation, with their only slightly developed, shallow and skeleton profiles, are examples of this effect of relief.

Depressed and level areas are usually characterized by slow runoff and percolation. Where the percolation is slow, the rate of removal of end-products of weathering, chiefly silicic acid, is slowed down and, therefore, the hydrolysis is retarded. However, in the region under study, where extensive areas are underlain by limestone with its subterranean caverns and crevices, depressed relief does not necessarily have slow percolation. A factor that may prevent soils from their normal development here is the constant washing in of materials from higher land. Locally, such accumulations take place at the bases of slopes and in sink holes, particularly where slopes are long and erosion is active. Three soil series, Emory, Abernathy, and Leadvale, which belong to the azonal group, are developed this way. Profile development in each of these soils has not reached an advanced stage and is characteristically variable because of intermittant parent material accumulation.

Where the drainage condition is poor, the excess water excludes O_2 and the low R-O potential causes reduction of Fe and Mn compounds with resultant gray mottlings in the subsoil. Of the several local soils that have developed under conditions of poor drainage only the Tyler and Guthrie series need be mentioned. Both of these two soils have glei-like horizons in their subsoils, mottled with gray and yellow.

Average relief. Exaggerated drainage conditions do not exist on average relief. The run-off of water on such relief surface is only moderate and erosion is comparatively slight. Under such conditions weathering can proceed under a more balanced action of natural agents. The properties of the parent material can then find ready expression in the resultant soil profiles in the manner previously described.

Evolution of Physiographic Stages in Relation to Soil Properties

Soils Formed During the Cumberland and Highland Rim Stages. Because soils coexist with their particular relief, the physiographic stages given in the foregoing chapter should each have its particular soil. However, soils formed during the formation of the remote stages, such as the Cumberland and Highland Rim, have been entirely obliterated by the subsequent erosional cycles. Soils that are found today on these land forms bear little evidence of their history. They are, due to exaggerated relief, under constant erosion and have never developed normal profiles. They are mainly azonal soils--lithosols.

Soils Formed During the Pliocene Deposition Stage. The Pliocene deposition period, due to the preservation of its material, offers clues for tracing the relationship between soil formation and the evolution of physiographic stages. Soils formed during the Pliocene deposition period were probably not lateritic soils but something similar to the soils occurring on the bottom lands, such as Huntington, Lindside, and Melvin series. Judging by the distribution of the deposits, chiefly along and above the large river channels and some on the comparatively elevated creek bottoms, the relief during which the deposition took place was more moderate than it is at present. This stage probably lasted a long time and the process of erosion was rather slow and run-off of rainfall was sluggish so that mechanical transportation of sediment was not noticeable. The rivers then were rendered sluggish and braided. Headward erosion on the ridges never ceased to be active, but erosional activity was confined chiefly to these high reliefs. As run-off was checked, the meteroic water had to soak into the unconsolidated material as its final outlet. The meteroic water was active in breaking down the complex of silicates and carbonates in the rocks. Moreover, it moved very slowly underneath the ground, as the gradient of the water table was gentle on such deposits. Therefore, it lingered in the deep subsurface, permitting weathering processes, in particular,solution and hydrolysis, ample time for deliberate operation; but, on the other hand, its movement apparently was enough to remove the end-products of weathering so that weathering could continue.

The weathering of the limestone was also highly intensified during this period. With the advantage of the comparatively level relief, water can penetrate into the tilted beds of rocks very easily. Where the rocks were overlain by the unconsolidated deposits, serving as catchment material, more water could filter into the deep seated rocks. Deep penetration of meteroic water in this manner had resulted in the formation of the huge mass of weathered material from limestone. Weathering of both the superficial and deep-seated limestone had prepared the way for the formation of the lateritic soils that are prevailing at the Coosa stage and the present time.

Soils Formed During the Coosa Peneplane Stage. The formation of the lateritic soils and their associated normal groups began approximately at the beginning of this denudation stage, with the changing of relief from a locally gentle one to a moderately rolling one, and with the subsequent changes in drainage conditions. The limestone region, in part, gave rise to rolling ridges and valleys, depending locally on the nature and structure of the rocks. The superficial deposits were cut into terrace positions. It is on the average relief thus produced that the zonal soils have developed--the Cumberland and Etowah soils on the terraces, the Decatur and Dewey in the limestone valleys, and the Fullerton and Clarksville on the rolling ridges.

Soils Formed at the Present Stage. The soils that are formed on the present alluvial deposits are chiefly undeveloped azonal soils due to relief and time factors. Until the present landforms change, these soils will probably remain as azonal soils--alluvial soils.

CHAPTER V

SUMMARY

As a basis for understanding the relation of soil properties to the variable factors of the environment, descriptions of the soils, physiography, and parent materials in Knox County are presented. The data for these descriptions were obtained by field observation, reference reading, and consultation with specialists. The following generalizations about the distribution of soils with different properties were reached:

Lateritic soils, such as Decatur, occur on parent materials derived from basic rocks, as pure limestones. Podzolic soils, such as Fullerton and Sequoia, occur on parent material derived from rocks high in acidic impurities, including chert and clay.

Extremes of relief give rise to intrazonal or azonal soils. Azonal lithosols, such as Muskingum, occur on steep relief. Intrazonal planosols, such as Tyler, occur on level relief where internal drainage is slow. Average relief favors zonal soil development and allows free expression to the parent material factor.

Physiography and the time scale are correlated with soil occurrence as follows:

Soils originally formed on the Cumberland and Highland Rim stages do not exist today. The present soils on remnants of these stages are chiefly lithosols and bear no evidence of their history. Lateritic soil formation began at the beginning of the Coosa peneplanation and has continued ever since. These soils have developed on parent materials that were extensively formed to great depths during the Pliocene deposition stage. Formation of new soils at the Present Stage consist chiefly of youthful azonal alluvial soils, such as Huntington.

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