SOME CATENA RELATIONSHIPS IN THE SOILS OF SALINE COUNTY, KANSAS

by

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INTRODUCTION

A detailed, basic soil survey was initiated in Saline County, Kansas during the summer of 1946. This survey was cooperative between the Kansas Agricultural Experiment Station and the Division of Soil Survey and the Soil Conservation Service, United States Department of Agriculture. The writer represented the Kansas Agricultural Experiment Station initially.

Saline County was selected as being representative of several counties in North Central Kansas. None of these counties had been mapped in detail and soils information was extremely meager. As mapping progressed, it became apparent that several soil catenas existed.

The purpose of this study was (1) to determine the relationships between three of the major catenas and (2) to determine the relationships of soils within each catena. While it was beyond the scope of this study it was hoped that some information would be disclosed concerning the three great soil groups believed to be represented in the county, namely Prairies, Chernozems and Planosols.

By definition, a soil catena is a group of soils within one zonal region developed from similar parent material but differing in characteristics of the solum owing to differences in relief or drainage. The soils selected for this study have developed from parent material weathered from four distinct sources. The parent rocks were: Wellington formation, Ninnescah shale, Kiowa shale and Quarternary loess. Since the soil catenas have not been named, identifying names have been assigned according to the parent rock for the purpose of this study only. Soils formed on parent material weathered from the Wellington formation are referred to as the Wellington formation catena. The Wellington formation catena includes Kipp silt loam, Idana silt loam, Assaria silt loam, and Ladysmith silt loam. Soils formed on parent material weathered from Ninnescah shale are grouped in the Ninnescah shale catena. The Ninnescah shale catena includes Vernon silty clay loam, Galt silt loam, and the reddish subsoil phase of Idana silt loam. Soils formed on parent material weathered from Quarternary loess are grouped in the Quarternary loess catena. The Quarternary loess catena includes Elmo silt loam, Berg silt loam and Lockard silt loam. Only one soil formed on parent material weathered from Kiowa shale was included in the study, therefore, there is no catena in this case. This particular soil was mapped extensively but the other catenary members had not been positively identified when the samples were collected. This soil was included for study because of its similarity to the mature member of the Wellington formation catena.

REVIEW OF LITERATURE

In 1935 Milne (24,25) proposed the word catena and defined it as a group of soils which fall wide apart in a natural system of classification but are linked in their occurrence by conditions of topography and are found in the same relationship to each other wherever the same conditions are met. Subsequent to his first definition it was discovered that there are two different classes of catenas. In one class the parent material remained constant and in the other class there are two superimposed formations.

Thorp (35) stated that in a catena, one may find zonal, intrazonal and azonal soils represented by several soil series and an equal or greater number of soil types. The catena concept was established in the United States to provide a convenient method for classifying soil series into geographic groups. Brown and Thorp (4) state that in the United States the catena concept is used as a means of making sure that new soil series are established systematically according to profile characteristics corresponding to definite drainage differences where it is necessary to establish several series on one kind of parent material within one soil zone.

Bushnell (7) reported that the most frequent and extensive use of "catena" in the United States is for grouping soils in relation to hydrologic sequence. He holds that all soils may be classified in regard to water regime -- hence there are no non-catenary soils.

Norton and Smith (28) found that as slope and drainage increase, the depth to the zone of accumulation decreases, texture change from heavy clay to silt loam; structure from large angular aggregates which are columnarily arranged to relatively small subangular particles, and consistence from tight compact, plastic and slowly pervious to friable, loose, and open irrespective to rate or amount of surface material removed by erosion or accumulated by deposition. Slight change in slope on nearly level topography has much more effect on the profile than an equal change on rolling topography.

In 1935, Marbut (21) in showing the distribution of the great soil groups of the United States drew the boundary line separating the Northern Chernozem soils from the Northern Prairie soils through Saline county. This same boundary line also served as the boundary line between the Pedocals in the Western part of the United States and the Pedalfers in the Eastern part. In showing the distribution of soils without normal profiles, the eastern part of Saline county was shown as having soils with claypans.

In 1938, the Division of Soil Survey, United States Department of Agriculture (32) in presenting the Soil Associations of the United States showed the eastern part of Saline county as the Crete-Hastings-Idana soil association under Planosols. The distinguishing feature of Planosols is an accumulation of a well defined layer of clay or cemented material at varying depths below the surface. This development has taken place on nearly level areas where drainage is more or less restricted. These soils are commonly referred to as claypan soils. The native vegetation is mixed short- and tallgrass associations.

The climate of Saline county and the surrounding area has been classified according to Thornthwaite (33) as sub-humid with a P/E index of approximately 48. Flora (10) lists the normal annual precipitation for the county as 27.00 inches. The normal annual mean temperature is 55.9° F.

Moore, Frye and Jewett (26) have shown the main divisions of outcropping rock in Saline county to be Cretaceous and Permian and have described the Wellington formation, the Ninnescah shale, the Kiowa shale and the Quarternary deposits. Plummer and Romary (30) have studied the Kiowa shale in the county and presented a correlated outcrop section. They found the dominant clay mineral to be illite associated with varying amounts of montmorillonite. Cretaceous beds studied were deposited under varying conditions of a nearly continuously rising sea level or subsiding basement. They believe that the dark, fissile shale of the Kiowa was probably deposited as a black mud containing some organic matter.

Climate is an active soil-forming factor and is believed to exert the most influence of any of the recognized factors. Jenny (14) rated climate as the outstanding factor which controls the nitrogen level of loamy soils within the United States. He believed that vegetation was next in importance in controlling nitrogen levels. Baver (2) stated that as rainfall becomes greater, chemical weathering is intensified and clay formation increases. This increase in clay content of the surface soil obtains until the rainfall becomes great enough to cause eluviation of the clay from the A to the B horizon. Jenny and Leonard (15) collected and analyzed numerous soil samples along the 11° C. isotherm which is approximately Kansas' northern boundary line. Neutral reaction in the surface soil was reached at about 25 inches of rainfall. Exchangeable hydrogen ions appear at 26 inches of rainfall. Saturation capacity varied from 12 m.e. to 27 m.e. per 100 gm of soil in going from semi-arid conditions to the semi-humid region. Exchangeable bases exhibited a maximum of 21 m.e. at rainfall 26 i inches. The arid-humid boundary was at the 25 to 26 inch rainfall area on the 11° C. isotherm. Jenny (13) further reports that the maximum for the exchangeable base curve corresponds to the Chernozem belt.

Thorp (34) states that dark-colored Prairie and Chernozem soils and associated Planosols show maximum effects of true grasses and other grass-like plants on soil formation. Planosols of the Prairie and Chernozem soil zones are intrazonal soils characterized by grassy vegetation. Claypans are really not as impervious as they appear. It has been demonstrated that grass roots will pierce them if nutrients and moisture are there to attract them. Byers, Alexander and Holmes (8) found the upper layer of a Prairie soil (Carrington) a little less acid than the layers immediately beneath because of the bases combined with the organic matter. Calcium is an important constituent of the grasses and the accumulation may be attributed to the decayed grass residues. Brown (6) in analyzing Iowa soils found the surface soils richer in phosphorus than the subsoil. He believed that the assimilation of phosphorus from the lower layers by the plant growth, the subsequent translocation of a portion of it up to the stems and leaves to accumulate on the surface and reduce the subsoil was the explanation. Joffe (16) outlined why he believed phosphorus accumulates in the A horizon of Prairie and Chernozem soils. First, organic matter accumulates in the A horizon. Second, the excess calcium decreases the solubility of the phosphates. Third, dry summers enhance the conversion of colloidal phosphates to less soluble crystalline form.

Marbut (23) listed four tests which a soil without a lime horizon must pass before it may be classed as a Pedalfer. First the soil must be virgin thus guaranteeing that the lime horizon has not been destroyed artificially. Secondly it must occupy "normal topography". This means slightly rolling land surface. Third, the parent material must be such as to be able to produce alkali earth carbonates. Fourth, the profile must be mature.

Jenny (12) reported that a carbonate zone may form in the absence of vegetation provided precipitation is low and evaporation is high. Vegetation with its transpiration allows a calcium zone formation throughout semi-arid and semi-humid belts. Vegetation decreases water and increases carbon dioxide. Nikiforoff (27) presented the idea that lime accumulation may be caused either by shifting upward solution or by downward translocation of it by leaching of the upper soil horizons. Neither chemical nor physical characteristics of the horizon of carbonate accumulation are as distinct as those of the horizons of humus accumulation.

Whiteside (36) in studying two Planosols (Putnam and Cowden) found that claypan clay accumulation was due to movement. The largest proportion of the movement was in the finest clay fraction. Brown, Rice and Byers (5) in studying claypan soils in Southern Nebraska found that the colloid as a whole is translocated from the surface downward by dispersion and eluviation. They found claypan soils in areas with an annual rainfall of 27 inches which had developed from parent material weathered from loess. Transfer is from a point of lower toward one of higher pH value. It seems probable that originally the parent material contained calcium carbonate and calcium silicate. As a result of leaching, calcium bicarbonate was formed and transported downward through the parent material in periods of excess precipitation. During dry periods, the bicarbonate would decompose and precipitate as the carbonate in the stratum of maximum mean water penetration. The soluble calcium salts just above the carbonate layer would tend to flocculate dispersed colloid and its accumulation thus tends to decrease the permeability of this layer. Where rainfall is sufficiently high; this layer may become sufficiently dense as to be practically impermeable. It appears that it is immaterial whether the water reaches the soil by rainfall or by drainage from higher areas. Where rainfall is still higher, the layer of $CaCO_3$ cannot form because of nearly constant underdrainage. Where rainfall is less the concentration of colloids in the B horizon is not so great and the claypan is not so dense or impermeable.

Smith (31) reported that if geologic erosion is disregarded, the general direction of soil development of loessial soils in Iowa is toward the condition of a claypan or Planosol. Bray (3) in discussing claypan formation found downward movement through crack and root channels as a result of water action on discrete particles of the superfine fraction of a high-ratio colloidal silicate. The mechanism of claypan formation is interpreted as being due to dispersion by mechanical forces, followed by movement and redistribution when these forces become ineffective. Marbut (22,23) thought that either topography or parent material may be responsible for claypans.

Joffe (17) stated that soil formation is the counter action to the reaction of weathering. Were it not for the process of soil formation, the weathering forces would extend deeper into the native rock. The B horizon is built from the bottom up and growth ceases with the maturity of the soil body. The B horizon is the support and mainstay of the soil body, preventing its destruction. Kellogg (18) called the soil a three dimensional solid, the upper surface of which is the surface of the land. The lower limit is defined by the lower limit of biological forces and the sides are the boundaries with other soil types.

Baldwin, Kellogg and Thorp (1) observed that similar parent material may be produced from different geological deposits and in different ways, and unlike parent material may be produced from the same rocks because of differences in weathering. Byers, Kellogg, Anderson and Thorp (9) stated that over a long period of time, the effects of parent material on soil is obliterated. Many soils may be examined from the surface to a depth of 2 or 3 feet without finding any inkling as to the nature of the parent rock from which the soil material was derived. Heavy, waxy clays, whether calcareous or not, are very resistant to soil forming processes and may retain their essential parent material nature through long periods.

Krusekopf (20) believed that laboratory analysis in soil survey is apparent but can be used only as corroborative evidence. Field classification must precede, not follow, laboratory analysis. He also suggested that greater range in type variations is permissible in young soils than in mature ones.

DESCRIPTION OF SOIL PROFILES STUDIED

Table 1 shows the soils studied, the geological parent rocks, and the normal slope range.

Table 1. Saline county, Kansas soils included in the catenary study.

Soil	Geological parent rock	Normal slope range
Kipp silt loam	Permian - Wellington formation	6-12%
Idana silt loam	Permian - Wellington formation	2-6%
Assaria silt loam	Permian - Wellington formation	2-4%
Ladysmith silt loam	Permian - Wellington formation	0-2%
Vernon silty clay loam	Permian - Ninnescah shale	6-12%
Galt silt loam	Permian - Ninnescah shale	6-9%
Idana silt loam (reddish subsoil phase)	Permian - Ninnescah shale	2-6%
Longford loam	Cretaceous - Kiowa shale	2-6%
Elmo silt loam	Quarternary loess	2-6%
Berg silt loam	Quarternary loess	2-4%
Lockard silt loam	Quarternary loess	0-2%

Figures 1, 2, and 3 show a cross section of the topography of each catena.

All of the soil profile descriptions that follow were taken from the legend prepared for the detailed basic survey in Saline

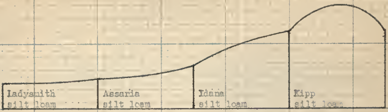

Figure 1. Cross section showing topography of the Wellington formation catena.

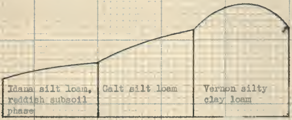

Figure 2. Cross section showing topography of the Ninnescah shale catena.

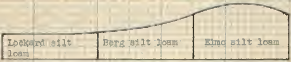

Figure 3. Cross section showing topography of the Quarternary loess catena.

county. The series names are all tentative and must remain so until such time as the survey is completed and a final inspection and correlation is made. The reader is especially cautioned to bear this in mind.

Wellington Formation Soil Catena

The kipp series consists of shallow to medium depth, friable, calcareous soils which have developed from fine textured calcareous parent materials weathered from interbedded limestones and shales of Permian age. They normally occur on moderately sloping convex ridge crests and slopes and are characterized by dark, friable, granular topsoils, and friable, granular limy subsoils and parent materials.

These soils are found in association with Idana soils. They differ from Idana soils in having no claypan.

The soil characteristics are listed below.

0-7" Weak-brown, friable, noncalcareous fine granular silt loam.

7-16" Brownish-black friable, highly granular noncalcareous silty clay loam.

16-24" Dark yellowish-brown firm, irregularly cloddy, calcareous clay loam. Horizon contains much modular and myceliated lime.

24-60" Dark yellowish-brown, firm, massive calcareous clay with an occasional lime nodule.

The Idana series consists of deep, mature, claypan soils which have developed from fine-textured parent materials weathered from shales and limestones of Permian age. They have weak-brown, friable topsoils, dark-brown, hard, blocky, clay subsoils and moderate brown, friable parent materials. They normally occur on gently sloping convex portions of the upland, and have moderately rapid external drainage, and very slow internal drainage. The virgin soils support a dense cover of high quality grass.

These soils are found in association with soils of the Kipp, Ladysmith and Assaria series. They differ from Kipp soils in being deeper, more mature and in having a heavy claypan subsoil. They have a catenary relationship to soils of the Ladysmith and Assaria series, but have lighter colored solums. They differ from Ladysmith soils in having developed on more strongly sloping relief. The Ladysmith soils have developed on flat or slightly depressed upland areas. The Assaria soils are developed on similar relief but are darker colored.

The soil profile characteristics are listed below.

0-10" Dusky-brown, friable noncalcareous highly granular silt loam.

10-14" Dark-brown, firm, prismatic, noncalcareous silty clay loam.

14-28" Dark-brown, hard, noncalcareous, blocky clay. Blocky structure is strongly developed, and surface of the structural units is covered by a colloidal sheen. Blocks crush with pressure to hard coarse granules that are resistant to further breakage.

28-38" Moderate-brown, hard, irregularly cloddy, clay.

Horizon does not have the structural characteristics of the horizon above.

38-50" Dark yellowish-brown, firm, massive silty clay loam. Horizon is not uniformly calcareous but contains scattered concretions of lime.

The Assaria soils consist of deep, dark colored claypan soils which have developed on moderately sloping upland areas from fine textured parent materials weathered from shales and limestones of Permian geologic age. They have dark, friable topsoils, dark, hard, blocky subsoils, and deep, moderately friable parent materials. They occur on slopes greater than 2 percent but less than 5 percent and have moderately rapid surface drainage and slow internal drainage.

The Assaria soils hold a catenary relationship to soils of the Idana and Ladysmith series with which they are associated geographically. They closely resemble the Ladysmith soils but have slightly shallower solums; occur on more sloping areas and have a weaker zone of lime accumulation. They are darker colored than the Idana soils which occur on similar but normally slightly steeper relief.

The soil characteristics are listed below.

0-8" Weak-brown to dusky-brown, friable, noncalcareous, fine granular silt loam.

8-16" Dusky-brown to brownish-gray, coarse granular non-calcareous silty clay loam. This horizon has a definite gray cast and the surface of the granules are coated with gray.

16-28" Dusky-brown, hard, noncalcareous clay. Horizon has a well developed blocky structure and the blocks have much colloidal staining.

28-38" Dark yellowish-brown, firm irregularly cloddy clay. Horizon is faintly calcareous throughout and contains scattered lime concretions.

38-48" Moderate yellowish-brown, mottled with olive and green, massive clay and partially decomposed calcareous shale.

The Ladysmith series consists of dark, deep, mature claypan soils which have developed on nearly level to very gently sloping upland flats from fine textured parent materials weathered from shales and limestones of Permian age. Ladysmith have dusky-brown to brownish-black topsoils, hard blocky, dusky-brown subsoils, and deep friable fine textured parent materials. They occur only on very flat or slightly depressed relief and have slow internal and external drainage.

These soils are found in catenary association with soils of the Idana and Assaria series. They differ from Idana soils in having darker colored topsoils and subsoils and in developing on flats or slightly depressed areas. They closely resemble Assaria soils, but have developed on nearly level topography, and have slightly deeper solums and parent materials overlying shale. They normally have more pronounced zones of lime accumulation than Assaria soils.

The soil characteristics are listed below.

0-8" Dusky-brown to brownish-black friable, noncalareous find granular silt loam.

8-16" Dusky-brown to brownish-black friable, coarse granular noncalcareous silty clay loam.

16-28" Dusky-brown, hard, noncalcareous clay. Horizon has pronounced blocky structure, with the faces of the structural aggregates having much colloidal staining.

28-34" Brownish-gray, firm, noncalcareous clay. Horizon has irregularly cloddy to weakly developed blocky structure.

34-48" Dark yellowish-brown, firm, irregularly cloddy calcareous clay. Pronounced zone of lime accumulation. Horizon is calcareous throughout and contains much modular lime.

Ninnescah Shale Soil Catena

The Vernon series consists of reddish-brown lithosols or shallow soils which have developed from fine textured calcareous reddish-brown and olive Ninnescah shales of Permian age. In Saline county these parent shales overlie the gray shales of the Wellington formation, but lie lower than the gravelly deposits believed to mark the base of the Kiowa shale. These soils are found in association with those of the Galt soils.

The soil characteristics are listed below.

0-5" Dark reddish-brown friable, granular silty clay loam.

5-14" Dark reddish-brown firm, massive silty clay.

14-24" Reddish-brown fine textured calcareous shales. Interbedded shales vary in color from pale olive to olive yellow.

The Galt series consists of medium depth, fine textured, reddish-brown soils which have developed on ridge crests and slopes from calcareous fine textured, dark reddish-brown shale of Permian age. They have brown surface soils, reddish-brown friable subsoils and dark reddish-brown calcareous parent materials.

Soils of the Galt series are found in association with the reddish subsoil phase of the Idana series. They resemble the reddish subsoil phase of the Idana soils but have shallower, less mature profiles.

The soil characteristics are listed below.

0-6" Brown, friable, fine, granular to soft crumb structured silt loam.

6-12" Dark reddish-brown friable, coarse granular (granulation very strong), silty clay loam.

12-26" Dark reddish-brown highly granular silty clay loam.

The reddish subsoil phase of the Idana series have developed on red Permian shales. These soils are associated with soils of the Vernon and Galt series and are considered to be the mature member of the catena including these three soils. They occur on more gentle slopes than do the other two soils.

The soil characteristics are listed below.

0-13" Pale brown to dusky-brown friable noncalcareous fine granular silt loam.

13-24" Weak reddish-brown, hard, noncalcareous clay. Horizon has weakly developed prismatic structure.

24-36" Weak reddish-brown, to moderate reddish-brown, hard noncalcareous clay. Horizon is more reddish in color than horizon above, and has developed a weak blocky structure.

36-48" Weak reddish-brown, to moderate reddish-brown, firm calcareous clay. Horizon is uniformly calcareous and contains visible lime in modular and myceliated forms.

The Longford series consists of deep, mature claypan soils which have developed from fine textured parent materials weathered from Kiowa shale of Cretaceous age. They have dark colored friable surface soils, dark to moderately dark colored, hard blocky subsoils, and deep fine-textured parent materials. These soils do not have a true zone of lime accumulation though lime concretions are usually present at about 40 inches.

The soil characteristics are listed below.

0-10" Weak brown, friable, noncalcareous loam.

10-20" Dusky brown, firm, noncalcareous silty clay loam. Horizon breaks out into irregular clods which are moderately resistant to pressure but may be crushed to coarse granules.

20-36" Dark-brown, hard, blocky clay. Vertical and horizontal cleavage lines are well developed and there is much colloidal staining.

36-48" Dark yellowish brown, hard irregularly cloddy clay. Horizon does not appear to be uniformly calcareous but occasional small lime concretions are found.

Quarternary Loess Soil Catena

The Elmo series consists of brown to reddish-brown, deep friable noncalcareous, silty soils which have developed from deep, friable loess-like parent materials on undulating portions of the upland. Normally the Elmo soils have friable, granular grayish-brown surfaces, brown to reddish-brown subsoils and brown friable parent materials. The Elmo soils do not have free lime within the upper four feet but have been observed to have a lime horizon at six or seven feet below the soil surface. Such a lime horizon is usually one to two feet in thickness and grades in to non-calcareous material below.

The soil characteristics are listed below.

0-10" Grayish-brown to dark grayish-brown friable, crumb structured, noncalcareous silt loam.

10-18" Brown, friable, granular, noncalcareous silty clay loam.

18-32" Brown to reddish-brown friable, prismatic to nuciform structured silty clay loam.

32-48" Brown to reddish-brown friable, massive, non-calcareous silty clay loam.

Soils of the Berg series consist of grayish-brown, deep, claypan soils which have developed on low undulating hills in and bordering on old geologic terraces and drainage ways from fine textured brown to grayish-brown loess-like deposits.

These soils have very dark brown, friable, slightly acid, silty surface soils, dark grayish-brown to brown, hard claypan subsoils, and brown to grayish-brown, friable, silty clay loam parent materials. These soils have a well developed lime horizon between 3 and 5 feet and overlay loess-like beds of material which is neutral to slightly alkaline in reaction.

These soils are found in association with those of the Lockard series from which they differ in having browner colored solums and more friable silty parent materials.

The soil characteristics are listed below.

0-10" Grayish-brown to dark grayish-brown, friable, crumb structured, slightly acid silt loam.

10-16" Grayish-brown to dark grayish-brown friable, highly granular silty clay loam. Granulation is pronounced in this horizon.

16-24" Brown to dark grayish-brown friable to firm, granular to irregularly cloddy silty clay loam.

24-38" Brown to grayish-brown hard blocky to nuciform silty clay. Pronounced claypan development. Soil aggregates show much colloidal staining.

38-48" Yellowish-brown to brown friable, massive, calcareous silty clay loam. Lime is visible in modular and myceliated forms.

The Lockard series consists of weak-brown claypan soils which have developed on old high terraces of geologic drainageways from moderate olive-brown plastic alluvial clays. They have dark friable silty surface soils, weak brown, hard blocky clay subsoils and moderate olive-brown, alkaline but not calcareous parent materials.

The soil characteristics are listed below.

0-8" Very dark gray to dark gray friable, crumb structured silt loam.

8-16" Grayish-brown to dark grayish-brown friable, massive to crumb structured silty clay loam.

16-24" Brown to dark brown firm nuciform to coarse granular silty clay.

24-38" Yellowish-brown to brown, hard, massive, to ill-defined blocky silty clay.

38-48" Light brownish-gray to grayish-brown, hard, massive irregularly cloddy clay.

EXPERIMENTAL METHODS

The sampling sites were selected by means of serial photographs on which the soil mapping had been completed. A minimum of six areas in widely scattered locations in the county were examined. The most representative profile for each soil type was then completely exposed and each genetic horizon was sampled. Each soil profile was in an area of native grassland. The location of the sampling sights are given below.

Kipp silt loam
150' E N ¼ cor. Sec. 18, T 14 S, R 1 W

Idana silt loam
1340' E S ¼ cor. Sec. 21, T 16 S, R 3 W

Assaria silt loam
500' S W ¼ cor. Sec. 36, T 14 S, R 1 W

Ladysmith silt loam
1000' S E ¼ cor. Sec. 36, T 14 S, R 1 W

Vernon silty clay loam
1340' S NW cor. Sec. 29, T 16 S, R 4 W

Galt silt loam
1340' N SE cor. Sec. 36, T 16 S, R 3 W

Idana silt loam, reddish subsoil phase
E ¼ cor. Sec. 28, T 16 S, R 3 W

Longford loam
650' W NE cor. Sec. 15, T 13 S, R 5 W

Elmo silt loam
S ¼ cor. Sec. 11, T 16 S, R 3 W

Berg silt loam
500' E SW cor. Sec. 33, T 15 S, R 3 W

Lockard silt loam
900' E NW cor. Sec. 9, T 16 S, R 3 W

The samples were air dried, crushed to pass a 2 mm sieve and stored. Soil thus prepared was used for pH determinations, cation exchange capacity, exchangeable calcium, magnesium and potassium according to methods outlined by Peech, Alexander, Dean and Reed (29). The soil was crushed to pass a 100 mesh sieve for total nitrogen determinations according to the Gunning-Hibbard procedure.

To determine the readily soluble phosphorus, 4 gram samples from each horizon were placed in a 600 ml shaking bottle with 400 ml of 0.002 N sulfuric acid extracting solution buffered with ammonium sulfate. The suspensions were shaken for 30 minutes in an end-over-end shaker. The agitated solution was then filtered and the phosphorus content was determined colorimetrically by molybdenum reduction of the phosphomolybdate. The transparency was measured at 650 Mu with a photoelectric colorimeter.

The cation exchange capacity was determined by placing a 50 gram sample of air-dry 2 mm soil in a 250 ml Erlenmeyer flask to which 100 ml of normal, neutral ammonium acetate solution was added. The flask was agitated for several minutes and allowed to stand overnight. Filtering was accomplished using a small Buchner funnel and gentle suction. This filtrate was designated as Solution A and was saved for exchangeable cation determinations.

The ammonium saturated soil on the Buchner funnel was washed with 95 percent ethyl alcohol to remove the excess ammonium acetate. The absorbed ammonium was extracted by leaching the soil with acidified sodium chloride solution. The sodium chloride extracts were transferred to a Kjeldahl falsk and sodium hydroxide was added. About 200 ml were distilled into standard sulfuric acid. The excess acid was titrated with standard sodium hydroxide.

The exchangeable calcium was determined by using an aliquot of Solution A and adding oxalic acid to precipitate the calcium as calcium oxalate. The calcium oxalate was dissolved in sulfuric acid and the resulting solution was titrated with standard potassium permanganate solution.

The exchangeable magnesium was determined by using another aliquot of Solution A and precipitating the magnesium as magnesium ammonium phosphate. This precipitate was dissolved in standard sulfuric acid. The resulting solution was then titrated with standard sodium hydroxide.

Exchangeable potassium was determined using a third aliquot of Solution A and precipitating the potassium as potassium cobaltinitrite. The potassium cobaltinitrite was dissolved in concentrated sulfuric acid in the presence of standard potassium permanganate. An excess of oxalic acid was added and the excess oxalic acid was titrated with standard permanganate.

Total nitrogen was determined by placing 5 gm of 100 mesh soil into Kjeldahl flasks. Concentrated sulfuric acid and digestion salt mixture were added and the mixture was digested. Water and sodium hydroxide were added and the contents of the Kjeldahl flask were distilled into boric acid. The distillate and boric acid were than titrated using standard sulfuric acid. The pH measurement was made using a 1:1 soil-water ratio and glass electrode pH meter.

EXPERIMENTAL RESULTS

The studies undertaken are divided into three distinct phases with one partial exception and each phase is represented by a soil catena. The Longford loam is not a member of any of the catenas studied. It was included in this study because of its observed similarity to Idana silt loam of the Wellington formation catena. The Longford loam will be discussed in conjunction with the Wellington formation catena throughout the remainder of this report in order that its similarities and differences may be pointed out.

In a study such as this, not all of the soils have the same number of horizons nor are all the horizons identical. However, all soils do have an A_1 horizon, a B_2 horizon and a C horizon and these three horizons are always referred to when direct comparisons are made.

Wellington Formation Soil Catena

As stated above, Longford loam is being included in this group for comparative study. Analytical results for soils in this catena are shown in Table 2.

Soil pH values for this catena are shown graphically in Fir. 4. The Kipp silt loam showed a higher pH value in the A_1 horizon than in the horizons immediately beneath. Idana silt loam and Assaria silt loam have almost identical pH curves. For both soils, the pH reaches a maximum in the B_3 horizon and falls off in the C horizon. The Ladysmith silt loam showed little change in pH value from the A_1 horizon through the B_2 horizon but has the highest value of the four soils of the catena in the C horizon. The Longford loam has a pH curve similar to Idana and Assaria, but reaches a higher value in the B_2 horizon.

Fig. 5 shows readily soluble phosphorus contents of the soils in terms of pounds of P_2O_5per acre. All A_1 horizons showed virtually the same amount of readily soluble phosphorus. The Kipp silt loam, Idana silt loam and Ladysmith silt loam showed more phosphorus in the A_1 horizon than in the horizon immediately beneath. In the B_2 horizon, the Kipp, Idana and Ladysmith soils showed similar amounts of phosphorus. The Assaria silt loam had more than twice as much phosphorus as did either the Kipp, Idana or Ladysmith. The Kipp and Ladysmith exhibited the same amount of phosphorus in the C horizon. Idana and Assaria showed more than five times the amount of phosphorus in the C horizon than did Kipp and Ladysmith. The Longford silt loam showed several times more phosphorus in all horizons except the A_1 horizon than did the above soils, and many times more in the B_2, B_3, and C horizons.

Table 2. Chemical analysis of the soils in the Wellington formation catena.

Horizon	Depth	pH	lbs. of readily soluble P_2O_5 per 2,000,000 lbs. of soil	Total nitrogen percent	Exchange capacity M. E. per 100 gm	Exchange capacity M.E. per 100 gm	Exchange Mg M.E. per 100 gm	Exch. K M.E. per 100gm	Total exch. bases	Exch. H M.E. per 100 gm	Percent base saturation
					Kipp silt loam						
A_1	0-6	7.16	40.62	0.182	23.4	14.3	6.7	0.71	21.8	1.6	93.2
B_1	6-10	6.70	19.52	0.140							
B_2	10-18	6.26	13.27	0.114							
C	18-26	6.70	29.68	0.086							
					Idana silt loam						
A_1	0-10	5.88	34.76	0.120	19.4	11.2	4.3	0.46	16.0	3.4	82.5
B_1	10-14	6.46	12.88	0.090							
B_2	14-28	7.34	24.22	0.065							
B_3	28-38	7.94	29.30	0.044							
C	38-48	7.69	172.00	0.024							
					Assaria silt loam						
A_1	0-8	5.98	25.00	0.142	21.5	10.8	5.9	0.68	17.4	4.1	80.9
A_2	8-16	6.12	29.68	0.096							
B_2	16-28	7.22	105.85	0.072							
B_3	28-38	7.99	82.42	0.055							
C	38-48	7.72	219.40	0.056							
					Ladysmith silt loam						
A_1	0-8	6.24	35.15	0.152	17.3	9.8	4.1	0.79	14.8	2.5	85.6
A_2	8-16	6.24	21.88	0.124							
B_2	16-28	6.40	44.92	0.089							
B_3	28-34	7.17	113.68	0.068							
C	34-48	8.00	23.05	0.052							
					Longford loam						
A_1	0-10	5.98	32.02	0.138	18.8	10.6	3.4	0.82	14.8	4.0	78.7
B_1	10-20	6.56	117.19	0.092							
B_2	20-36	7.84	352.44	0.060							
C	36-48	7.78	1088.75	0.034							

Figure 4. Soil pH values of the horizons of the Wellington shale catena and Longford loam.

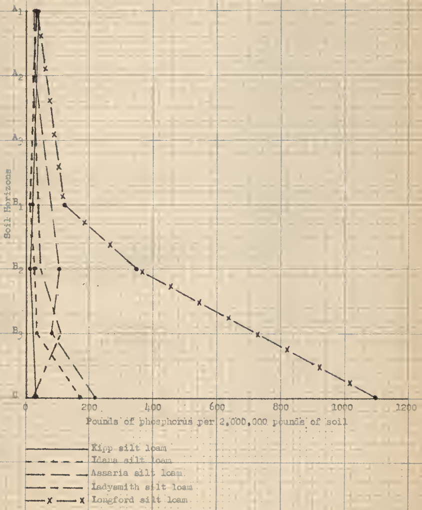

Figure 5. Readily soluble phosphorus values in relation to soil horizons of the Wellington shale catena and Longford loam.

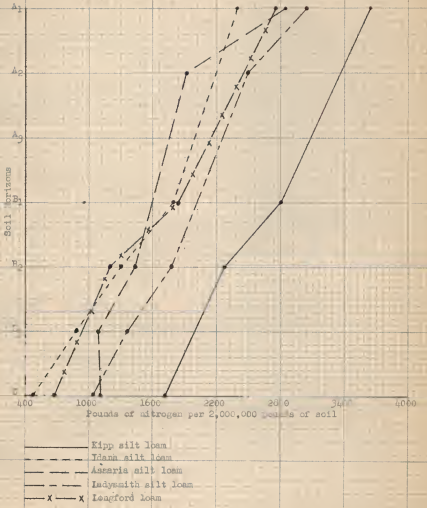

Figure 6. Total nitrogen values in relation to soil horizons of the Wellington shale catena and Longford loam.

The exchange capacity, exchangeable calcium, magnesium and potassium were determined for only the A_1 horizons of the soils in this catena.

Kipp silt loam showed the greatest exchange capacity followed by Assaria silt loam, Idana silt loam and Ladysmith silt loam in that order (Table 2). Longford silt loam had an exchange capacity less than Idana but more than Ladysmith. Kipp silt loam contained the most exchangeable calcium followed by Idana silt loam, Assaria silt loam and Ladysmith silt loam in that order. Longford loam showed a higher exchange capacity than Ladysmith but less than Assaria. Kipp silt loam had the greatest amount of exchangeable magnesium followed by Assaria silt loam, Idana silt loam and Ladysmith in that order. Longford loam had the least amount of exchangeable magnesium. The greatest amount of exchangeable potassium was found in Ladysmith silt loam followed by Kipp silt loam, Assaria silt loam and Idana silt loam in that order. Longford loam had slightly more exchangeable potassium than did Ladysmith, the highest of the above four.

Fig. 6 shows the total nitrogen for these soils. The Kipp silt loam showed definitely the highest total nitrogen in the Wellington formation catena followed by Ladysmith silt loam. Assaria silt loam showed somewhat more nitrogen than did the Idana silt loam and both were less than Kipp and Ladysmith. Longford loam was almost identical with Idana silt loam.

Ninnescah Shale Soil Catena

Analytical results for these soils are given in Table 3.

Fig. 7 is a graphical presentation of the soil pH values. The Vernon silty clay loam exhibited the highest pH throughout its profile. The curve was almost a straight line with the A_1 horizon having a slightly lower pH than did the C horizon. The Galt silt loam exhibited the lowest A_1 horizon pH but was mid-way between Vernon and reddish subsoil phase of Idana silt loam in the B_2 and C horizons. The reddish subsoil phase of Idana had a slightly higher pH than did the Galt in the A_1 horizon. The B_2 and C horizons were the lowest of the three soils.

Readily soluble phosphorus values for these soils are shown in Fig. 8. The A_1 horizons of Galt silt loam and the reddish subsoil phase of Idana silt loam showed the same amount of readily soluble phosphorus. The Vernon silty clay loam exhibited slightly more than twice as much phosphorus in the A_1 horizon as did Galt and the reddish subsoil phase of Idana. Vernon and the reddish subsoil phase of Idana had practically identical amounts of phosphorus in the B_2 and C horizons. Galt showed ten times more phosphorus in the B_2 horizon and twenty times more in the C horizon than did the above two.

The exchange capacity, exchangeable calcium, magnesium and potassium were determined for only the A_1 horizons of the soils in this catena. Referring to Table 3, it can be seen that the exchange capacity of the reddish subsoil phase of Idana silt loam was largest followed by Galt silt loam and Vernon silty clay loam in that order. In exchangeable calcium, Vernon silty clay loam was largest followed by the reddish subsoil phase of Idana silt loam and Galt in that order. Galt silt loam contained the most exchangeable magnesium followed by the reddish subsoil phase of Idana silt loam and Vernon silty clay loam. The reddish subsoil phase of Idana silt loam had the most exchangeable potassium followed by Vernon silty clay loam and Galt silt loam.

Fig. 9 shows the amount of total nitrogen for these soils. The Vernon silty clay loam and the reddish subsoil phase of Idana silt loam were very nearly identical in their total nitrogen content. Galt silt loam showed only a little more than half as much nitrogen in the A_1 horizon as did Idana or Vernon. The B_2 horizon of Galt contained slightly more total nitrogen than did the A_1 horizon. The Galt C horizon contained more nitrogen than did the other two soils.

Quarternary Loess Soil Catena

Analytical data for these soils are given in Table 4. The Lockard silt loam showed the highest pH value in the A_1 horizon, the lowest value in the B_2 horizon and is mid-way between the other two soils in the C horizon, as shown in Fig. 10. Berg silt loam and Elmo silt loam had essentially the same pH value in the A_1 horizon. The pH curve of Elmo was almost a straight line value with pH rising gradually with depth. The pH value of Berg increased very abruptly in the B_2 horizon and decreased somewhat in the C horizon.

Table 3. Chemical analysis of the soils in the Ninnescah shale catena.

Horizon	Depth	pH	Lbs. of readily soluble P_2O_5 per 2,000,000 lbs. of soil	Total nitrogen percent	Exchange capacity M.E. per 100 gm	Exchange capacity M.E. per 100 gm	Exchange Mg M.E. per 100 gm	Exch. K M. E. per 100 gm	Total exch. bases	Exch. H M.E. per 100 gm	Per-cent base saturation
					Vernon silty clay loam						
A_1	0-8	7.78	125.39	0.160	18.6	25.5	2.5	0.69	28.7*	--*	--*
B_2	8-12	8.00	12.48	0.103							
C	12-23	8.07	41.86	0.071							
					Galt silt loam						
A_1	0-8	6.56	44.92	0.094	21.9	10.0	8.7	0.37	19.0	4.9	86.8
B_2	8-12	7.24	465.62	0.100							
C	12-22	7.78	1129.37	0.078							
				Idana silt loam, reddish subsoil phase							
A_1	0-13	6.84	48.88	0.158	23.3	15.9	3.6	1.26	20.7	2.6	88.8
B_2	13-24	6.10	33.20	0.096							
B_3	24-36	6.51	79.68	0.072							
C	36-48	7.31	38.68	0.058							

*Free $CaCO_3$ present.

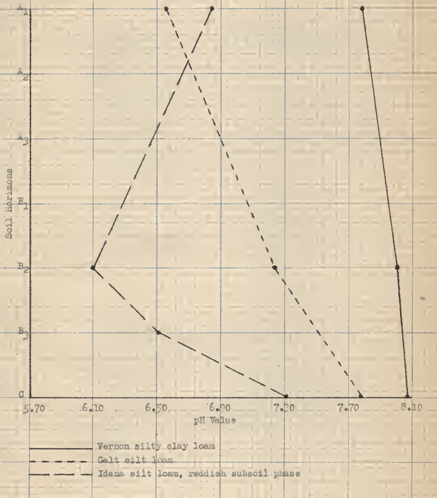

Figure 7. Soil pH values of the horizons of the Ninnescah shale catena.

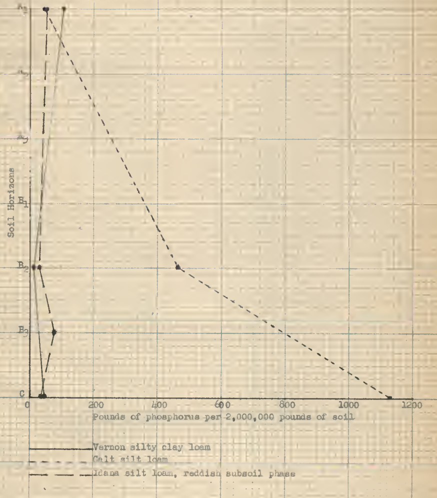

Figure 8. Readily soluble phosphorus values in relation to soil horizons of the Ninnescah shale catena.

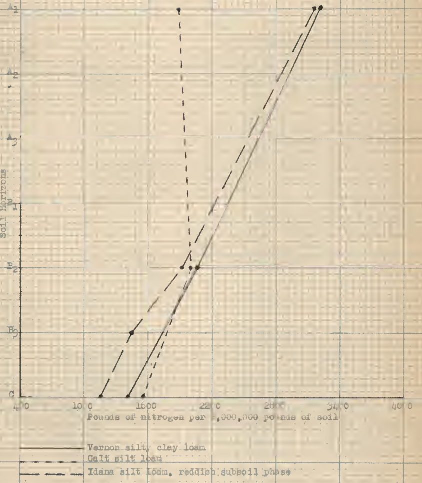

Figure 9. Total nitrogen values in relation to soil horizons of the Ninnescah shale catena.

Table 4. Chemical analysis of the soils in the Quarternary loess catena.

Horizon	Depth	pH	Lbs. of readily soluble P_2O_5 per 2,000,000 lbs. of soil	Total nitrogen percent	Exchange capacity M.E. per 100 gm	Exchange capacity M.E. per 100 gm	Exchange Mg M.E. per 100 gm	Exch. K M.E. per 100 gm	Total exch. bases	Exch. H M.E. per 100 gm	Percent base saturation
					Elmo silt loam						
A_1	0-10	5.72	37.49	0.130	17.7	10.1	2.8	0.58	13.3	4.4	75.1
A_3	10-18	6.10	23.05	0.086							
B_2	18-32	6.35	35.92	0.074							
C	32-48	6.76	11.72	0.064							
					Berg silt loam						
A_1	0-10	5.75	30.08	0.130	20.0	11.1	4.1	0.78	16.0	4.0	80.0
A_3	10-16	6.20	28.90	0.092							
B_1	16-24	6.81	124.61	0.070							
B_2	24-38	8.04	81.64	0.052							
C	38-48	7.81	250.78	0.044							
					Lockard silt loam						
A_1	0-8	6.30	42.18	0.153	20.0	12.0	3.7	0.92	16.6	3.4	83.0
A_3	8-16	6.02	20.69	0.128							
B_2	16-24	6.10	22.66	0.090							
B_3	24-38	6.53	87.50	0.057							
C	38-48	7.16	196.88	0.045							

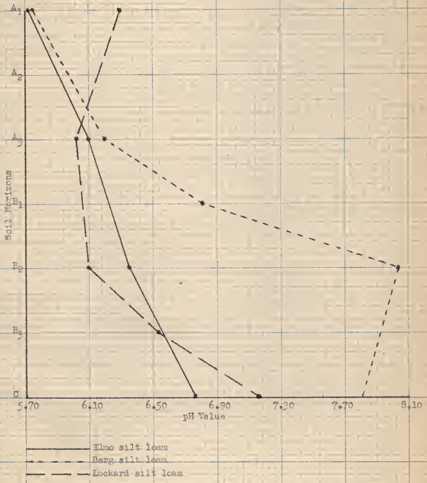

Figure 10. Soil pH values of the horizons of the Quarternary loess catena.

Figure 11. Readily soluble phosphorus values in relation to soil horizons of the Quarternary loess catena.

In all three soils, the A_1 and A_3 horizons were practically identical in readily soluble phosphorus (Fig. 9.). All three soils showed slightly less phosphorus in the A_3 horizon than in the A_1 horizon. Elmo silt loam and Lockard silt loam had essentially the same phosphorus content in the B_2 horizon as did either of the other two soils. In the C horizon, phosphorus in the Elmo soil decreased to almost zero while the phosphorus in both Berg and Lockard increased considerably.

As in the case of the other two catenas, the exchange capacity, exchangeable calcium, magnesium and potassium were determined for only the A_1 horizons of the soils in this catena. In Table 4 it can be seen that Berg silt loam and Lockard silt loam have the same exchange capacities. Elmo silt loam has an exchange capacity considerably below the Lockard and Berg soils. Lockard silt loam had the greatest amount of exchangeable calcium, followed by Berg silt loam and Elmo silt loam; however, all three were rather close together. In exchangeable magnesium, the Lockard and Berg soils contained the same amount and the Elmo soil was somewhat lower. The exchangeable potassium content of the Lockard soil was the greatest, followed by the Berg and Elmo soil.

The Lockard silt loam contained the most total nitrogen in the A_1 and B_2 horizons (Fig. 12). The Berg silt loam and the Elmo silt loam contained similar amounts of nitrogen in the A_1 horizons but the Elmo was ahead of the Berg in both the B_2 and C horizons. The Elmo was greatest of the three in total nitrogen in the C horizon.

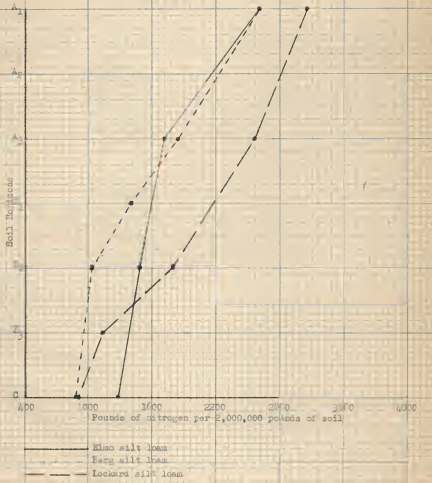

Figure 12. Total nitrogen values in relation to soil horizons of the Quarterhary loess catena.

DISCUSSION

The purposes of this study were: to determine the relationship between the Wellington formation catena, the Ninnescah shale catena and the Quarternary loess catena; to determine the relationships among the soils in each catena; and, where possible, to assign each soil to a great soil group.

The relationships among the soils in each catena will be discussed first. The Wellington formation catena is composed of Kipp silt loam which occupies the steeper than normal topography. Marbut (24) has defined normal relief as smooth undulating or rolling, with a relation to drainage such that the permanent water table lies entirely below the bottom of the solum. Idana silt loam occupies normal topography, Assaria silt loam occurs on topography slightly more level than normal topography and Ladysmith silt loam occurs on level or slightly depressed topography.

The Idana, Assaria and Ladysmith soils were described in the soil survey legend as claypan soils. The pH curves of Idana silt loam and Assaria silt loam which reach a maximum in the B_3 horizon and falls off in the C horizon are believed to be characteristic of the Chernozem type of soil formation. Calcium determinations were made only on the surface soils but visual inspection disclosed scattered lime concretions in this horizon and the soil in this horizon would effervesce when treated with dilute hydrochloric acid.

The Ladysmith soil reached its maximum pH in the C horizon. This soil occupies level topography and consequently has only limited slow runoff. A lime horizon does not accumulate in the solum because of above average amounts of water moving through the soil. The Longford loam pH curve, being similar to the pH curves of Idana and Assaria soils, is considered characteristic of the Chernozem type of soil formation.

All of the soils in this catena except Assaria silt loam exhibit higher readily soluble phosphorus in the A_1 horizon than in the horizon immediately beneath. This is in line with the findings of Brown (6) and Joffe (16). The Longford loam showed several times more phosphorus in the B_2 and C horizons than did the members of the Wellington formation catena.

The A_1 horizon calcium content of Kipp silt loam was highest as would be expected (Fig. 13). This soil, occupying rather steep slopes, would lose a fairly high percentage of rainfall by runoff. The calcium contents for the remainder of the soils in this catena showed a decline as effective moisture increases with decreasing slope. The calcium curve is very striking for this catena.

The magnesium contents show the same relationships to each other as do the exchange capacities. The potassium contents did not vary a great deal except for the Idana silt loam which was considerably lower than the others. The Longford loam had a lower magnesium content than did the members of the Wellington formation catena.

The Kipp soil showed the greatest amount of nitrogen throughout the profile. The Idana, Assaria and Longford soils had similar nitrogen curves. The Ladysmith soil was intermediate between the

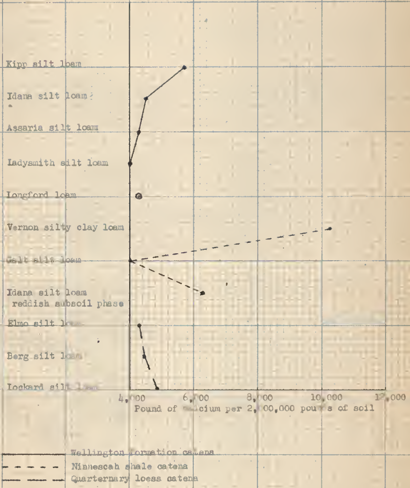

Figure 13. Exchangeable calcium of the A_1 horizon of soils studied in Saline county.

high and the low. Even though the areas were all in native grassland, there had undoubtedly been differential grazing for the last half of a century or more and this would probably show up first in the total nitrogen.

The Ninnescah shale catena is composed of Vernon silty clay loam, which occupies the steep slopes, Galt silt loam which occurs on less steep slopes and the Idana, reddish subsoil phase which occurs on normal relief. The flat topography member of this catena has not been identified. Of these three soils, only the reddish subsoil phase of Idana silt loam was listed as a claypan in the soil survey legend.

The soils at the Ninnescah shale catena exhibited three dissimilar pH curves. The Vernon silty clay loam profile was alkaline throughout. The Galt silt loam and the Idana silt loam, reddish subsoil phase were alkaline only in the C horizon. The Idana soil showed a considerably higher pH in the A_1 horizon than in the underlying horizon. This same thing was true with the Kipp silt loam. Various workers attribute this to the bases combined with the organic matter. Calcium is an important mineral constituent of the grasses and the accumulation may be attributed to the decayed grass residue.

The readily soluble phosphorus curves showed the Vernon silty clay loam and reddish subsoil phase of Idana with rather similar curves. The only difference being that the Vernon soil had considerably more phosphorus in the A_1 horizon. Both soils had more phosphorus in the A_1 horizon than in the B_2 horizon. The Galt had the same amount of phosphorus in the A_1 horizon as did the Idana soil. In the B_2 horizon, it had ten times more phosphorus than the other two and twenty times more in the C horizon. The readily soluble phosphorus content of the Galt soil bears no apparent relationship to that of the other soils in this catena.

The Vernon soil had the greatest amount of exchangeable calcium (Fig. 13) and Galt had the least with the Idana soil being intermediate. The low calcium content of Galt would certainly indicate it was not related to the other two soils of this catena. Galt silt loam contained a large amount of exchangeable magnesium and a small amount of exchangeable potassium. The Galt silt loam showed a small amount of nitrogen in the A_1 horizon and more nitrogen in the B_2 horizon than in the A_1 horizon. Again the Galt soil is radically different from the other two soils in this catena.

The Quarternary loess catena is composed of Elmo silt loam which occupies normal topography, Berg silt loam which occurs on topography somewhat more flat than normal topography, and Lockard silt loam which occurs on level topography. Lockard and Berg are both listed as claypan soils in the soil survey legend. The Berg soil pH curve reached a maximum in the B_2 horizon, much the same as did the Assaria, Idana and Longford soils, again indicating Chernozem type of soil formation. Some small lime concretions are visible in the B_3 horizon.

In readily soluble phosphorus values, the Berg and Lockard soils appear to be similar. The phosphorus curve for the Elmo soil is practically a straight line value. On the basis of readily soluble phosphorus content, the Elmo soil appears to have a different parent material from the Berg and Lockard soils.

The Elmo soil has a considerably lower exchange capacity than the Lockard or Berg and also a lower calcium, magnesium and potassium content. In total nitrogen, the Lockard silt loam is greatest in all horizons except the B_3 and C horizons.

In the Wellington formation catena, pH, phosphorus and nitrogen (Table 5) exhibit maximum values on slopes from 6 to 12 percent, minimum values on slopes from 2 to 6 percent, and intermediate values on slopes from 0 to 2 percent. The other two catenas are not represented by all three slope groups but the data indicates trends similar to the Wellington formation catena, with the exception of nitrogen in the Ninnescah shale catena which gives distorted data because of the Galt silt loam having less nitrogen in the A_1 horizon than in the B_2 horizon.

The Wellington formation catena, represented by Idana silt loam and Assaria silt loam and the Quarternary loess catena represented by Berg silt loam have members which show a pH curve believed to be characteristic of Chernozem type of soil formation. The Ninnescah shale catena does not have such a member.

The Lockard soil reached a maximum pH in the C horizon as did the Ladysmith soil in the Wellington formation catena. The Lockard soil occupies level topography similar to that of the Ladysmith soil. Runoff is limited and slow and a lime horizon does not accumulate in the solum because of above normal amounts of water moving through the profile.

The effect of slope and topography on soil formation is shown in Fig. 5. The slopes were divided into three ranges, namely, 0-2%, 2-6% and 6-12%. In the Wellington formation catena, pH, nitrogen and base saturation exhibited maximum values on slopes from 6 to 12 percent, minimum values on slopes from 2 to 6 percent and intermediate values on slopes from 0 to 2 percent. Readily soluble phosphorus values are the same for the 0-2 and 2-6 slopes.

In the Ninnescah shale catena, pH, P_2O_5 and base saturation are greater on slopes from 6 to 12 percent than on slopes of 2 to 6 percent. The nitrogen values are the same for the two slopes. No soil representing the 0 to 2 percent slope was included in this catena.

In the Quarternary loess catena, pH, P_2O_5, nitrogen and base saturation are greater on slopes from 0 to 2 percent than on slopes of 2 to 6 percent. This is in accordance with the data of the other two catenas. This catena has no soil member representing the 6 to 12 percent slope.

The 6 to 12 percent slopes showed the highest pH, percent base saturation, phosphorus and nitrogen values. Runoff would be great with little chance for water to percolate through the soil profile. This would account for the high pH and base saturation values. Nitrogen would be high due to the favorable pH for grass growth. Phosphorus and nitrogen accumulate in the surface horizon in much the same manner. The 2 to 6 percent slopes showed the lowest pH, percent base saturation, phosphorus and nitrogen values. Runoff would be less with more water percolation through the soil profile. The more acid soil reaction would account for the low base saturation percent and would be less favorable for grass growth and consequently for nitrogen and phosphorus accumulation.

The 0 to 2 percent slopes showed intermediate values for pH, P_2O_5, nitrogen and base saturation. Surface drainage is slow and runoff from the upper slopes collects. This runoff deposits eroded soil material and would account for the intermediate values shown for pH, base saturation, phosphorus and nitrogen even though more water would move through the soil than in the steeper slope groups.

Table 5. The A_1 horizon pH, P_2O_5, N, and base saturation percent values by slope groupings as shown in Table 1.

	Wellington formation catena				Ninnescah shale catena				Quarternary loess catena			
Slope	pH	P_2O_5 #/acre	N per-cent	Base satur. %	pH	P_2O_5 #/acre	N per-cent	Base satur. %	pH	P_2O_5 #/acre	N per-cent	Base satur. %
6-12%	7.16	41	0.18	93	7.78	125	0.16	100				
2-6%	5.88	35	0.12	82	6.84	49	0.16	89	5.72	37	0.13	75
0-2%	6.24	35	0.15	86					6.30	42	0.15	83

SUMMARY

The chemical characteristics of the Wellington formation soil catena, the Ninnescah shale soil catena and the Quarternary loess soil catena in Saline county, Kansas have been studied. A separate soil, the Longford loam developed on Kiowa shale, was included for comparative purposes because of its observed similarity to Idana silt loam of the Wellington formation catena. All soil series and soil catena names used in this report are tentative and must remain so until the final correlation and inspection is made by the Division of Soil Survey, United States Department of Agriculture. The laboratory determinations include pH values, readily soluble phosphorus, and total nitrogen on all genetic horizons of each profile and exchange capacity, exchangeable calcium, exchangeable magnesium and exchangeable potassium on the A_1 horizon of each profile.

The results of the study indicate that Galt silt loam should not be included as a member of the Ninnescah shale catena. The other two soils, Vernon silty clay loam and reddish subsoil phase of Idana silt loam, of this catena do show catenary relationships. In the Quarternary loess catena, the Elmo silt loam is a rather questionable member of this catena. Further studies are needed in this catena.

The Wellington formation catena soils show definite relationship to each other. From this study it appears that the Assaria soil is very similar to the Idana soil and the two soils could probably be combined.

Idana silt loam, Assaria silt loam, Longford silt loam and Berg silt loam all have similar pH curves. The curves are characterized by a maximum pH in the B horizon. It is believed that this type of pH curve is characteristic of the Chernozen type of soil formation. Complete profile calcium determinations would confirm this.

This study reveals the fact that the Idana silt loam and the Longford loam are very similar soils with one exception. The Longford loam contained 352 and 1089 pounds of readily available phosphorus in the B_2 and C horizons whereas the Idana silt loam contained 24 and 172 pounds of readily soluble phosphorus in the corresponding horizons.

The Kipp silt loam, Vernon silty clay loam, Galt silt loam all occupy steeper than normal topography, are without well developed profiles and would be classed as Azonal soils.

The Idana silt loam, Assaria silt loam, Longford loam and Berg silt loam all occupy normal topography, have what is believed to be characteristic Chernozen type of pH curves and yet have claypans. However, these soils appear to be zonal soils. The reddish subsoil phase of Idana silt loam occupies normal topography, has a claypan but lacks the pH curve characteristic curve of the Idana, Assaria, Longford and Berg soil. This soil is believed to be a Prairie soil.

The Ladysmith silt loam and Lockard silt loam occupy level topography, exhibit claypan horizons and would be classified as Intrazonal soils.

The Elmo silt loam occupies normal topography, has a developed profile and would be a zonal soil. It does not have a lime horizon and thus would be a Prairie soil.

The slopes were divided into three ranges, namely, 0-2%, 2-6% and 6-12% to study the effect of topography on soil formation. The 6 to 12 percent slopes showed the highest pH, percent base saturation, phosphorus and nitrogen values. These high values are apparently due to excessive runoff, slight water percolation and a favorable pH for grass growth. The 2 to 6 percent slopes showed the lowest pH, percent base saturation, phosphorus and nitrogen values. Less runoff, more water percolation and a more acid reaction is believed to be responsible for the low values. The 0 to 6 percent slopes showed intermediate values for pH, percent base saturation, phosphorus and nitrogen. Surface drainage is slow and runoff from the upper slopes collects. Eroded soil material would be deposited to give intermediate values even though more water moves through the soil than on the steeper slopes.

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