THE RELATION OF SOIL PROFILE DEVELOPMENT TO TERRACE LEVELS OF THE KANSAS RIVER VALLEY

by

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TABLE OF CONTENTS

INTRODUCTION

Time is a recognized factor in soil formation. While weathering forces are the active agents in soil genesis, their influences are drastically modified by a number of different factors. These determine in a large degree the kind of soil that finally develops. For purposes of discussion they may be grouped under two headings: climatic forces and soil material.

Climate determines in part the nature of the weathering that occurs, or better, the coordinated influence of the forces effective. Vegetation and the changes induced thereby may be considered as phases of climate. The magnitude of the combined influences is, of course, a function of time. Soil material, as everyone admits, is tremendously variable from place to place, in respect to texture, structure, mineralogical, and chemical composition. Hence it provides an endless variety of environments for weathering activities. The interlocking of all of these variables, climatic and geologic, accounts for the soil heterogeneity that we expect to encounter in the field.

When soil formation begins, the characteristics of the parent mass are almost entirely those of the soil material. They are lithological or inherited. There is no profile in a soil sense, although layering may be evident. If so, it is geological, that is, related to the deposition of the regolith. Such materials for purposes of classification are spoken of as azonal or belonging to no well-defined soil group. Nevertheless, they usually support plant growth and in this sense at least, are soils. Sands and alluvium are good examples.

As the influence of weathering becomes constructive in a soil sense and the presence of organic matter begins to exert its influence, a young soil gradually develops. Acquired characteristics which are those induced largely by climate, are noticeable but those inherited from the parent material are still in the ascendancy. The soil profile, however, since the constructive agencies have not had time to impress their pattern, is by no means fully developed. Examples of acquired characteristics are: the accumulation of organic matter in the A horizon, the accumulation of clay and the development of blocky or prismatic structure in the B horizon. Certainly, profile layering and the development of granular and prismatic structural forms within the various horizons are due largely to climatic and vegetative influences.

In the sequence of events described above, soil age is accorded special significance. While time is, of course, involved, the development and stabilization of the profiles are the real criteria of soil maturity.

A soil survey conducted in 1951-1952 revealed four minor terrace levels in the Kansas River Valley in which the soil profile characteristics were developed from essentially the same parent material. These minor terrace levels provided an opportunity to observe the effect of time in the relation of soil profile development of these various terrace levels. It was the purpose of this investigation to study some of the physical and chemical properties of these terrace levels in order to determine the manner in which soils develop with time, from similar parent materials. Locations were carefully selected from areas that had been mapped previously in order to obtain soil profiles of the same general type. Pits were excavated to a depth of six feet and soil samples were taken from each observed horizon.

REVIEW OF LITERATURE

The subject of profile development of alluvial soils on river flood-plains is one that has had little study. A great many authors state that such alluvial soils are merely azonal soils without profile characteristics. Others refer to them as youthful soils with undeveloped profiles in which the soil characteristics are dominated by the parent material. All are in agreement, however, that where time has sufficed, development can occur on alluvial material just as on any other kind of parent material.

The geologic age of the youngest <u>major terrace</u> and the flood-plain of the Kansas River Valley ranges from Wisconsin to Recent time. According to Davis and Carlson (1952) the Newman terrace is the youngest major terrace in the Kansas River Valley. This terrace is considered extremely youthful, in a geologic sense, and is still being aggraded by exceptionally severe floods.

The flood-plain contains many surface irregularities and minor scarps which may be interpreted as representing one or more <u>minor terrace</u> levels. Harbaugh (1950) suggested that the radii of curvature of the meander scars have increased greatly during the last stages of flood-plain development. This fact would partially explain the development of these so called minor terraces. Davis and Carlson (1952) indicated that the point bar accretion slopes in abandoned meanders are so gentle that they appear horizontal and give the appearance of being terraces.

There are deep alluvial fills in the Kansas River Valley which reach a maximum thickness of 90 feet. Davis and Carlson (1952) observed that in a test drilling in the Kansas River Valley the deeper alluvial fills, in general, graded upwards from a coarse cobble fill in the deepest portion to a fine sand or silt at the surface. Sediments encountered while test drilling in the Kansas River Valley indicated that the first 40 feet was similar to sediments transported by the Kansas River at the present time.

Storie Index Rating

Storie (1937) in his index rating for the agricultural value of soils made a list of soil profile groups. The first five of these profile-groups contain secondary soils which become progressively shallower and more dense and impervious in the subsoil. These profile groups are as follows:

Profile-group I. Soils on recent alluvial fans, flood-plains or other secondary deposits having undeveloped profiles underlain by unconsolidated material. These profiles show no accumulation of clay in the subsoil resulting from the downward movement of particles from the surface horizon.

Profile-group II. Soils on young alluvial fans, flood-plains or other secondary deposits having slightly developed profiles underlain by unconsolidated material. These profiles show slight compaction or slight accumulation of clay as the result of leaching from the surface horizon.

Profile-group III. Soils on older alluvial fans, alluvial plains or terraces having moderately developed profiles underlain by unconsolidated material. These profiles have moderate accumulation of clay in the subsoil as the result of the continued movement of particles from the surface horizon.

Profile-group IV. Soils on older plains or terraces having strong accumulations of clay in the subsoil underlain by unconsolidated material. These are claypan soils in which the pans are relatively near the surface and very slowly permeable to the downward movement of water.

Profile-group V. Soils on older plains and terraces having hardpan subsoil layers, usually underlain by unconsolidated material. These rock-like hardpan horizons may be lime, lime-iron, or iron cemented, and do not soften or disintegrate in water. They are the result of the downward movement of the cementing materials from the surface horizon.

DESCRIPTION OF THE SOILS

The soils of the Kansas River Valley were developed from alluvial material. The age of this alluvial material ranges from Wisconsin to Recent. The soil types selected for study are as yet unnamed, however, they have been assigned symbols by the U. S. Soil Conservation Service.

Soil Profile: F83/8

This soil profile lies adjacent to the river on the flood-plain. It may be considered the most youthful soil since due to its location it has had the least amount of time for development. The site selected for this soil profile was located approximately two and one-half miles south-east of Perry, Kansas. (NW¼ of NE¼, S. 1, T. 12S., R. 18E.). There was a 32 inch alluvial deposit at the sampling site which resulted from the July 1951 flood. This recent depositional layer was of no interest in this study, and sampling began with the underlying pre-flood surface.

Soil Profile Description.

1.	A_{1P}	0-6"	Grayish-brown (10YR5/2 dry) to dark gray (10YR4/1 moist) sandy loam of very weak fine granular to crumb-like structure.
2.	A_1	6-8"	Grayish-brown (10YR5/2 dry) to dark gray (10YR4/1 moist) silt loam of very weak medium to fine blocky structure that breaks into weak medium to fine granular structure with gentle pressure.
3.	AC	8-12"	Light brownish-gray (10YR6/2 dry) to dark grayish-brown (10YR4/2 moist) silt loam of weak medium to fine granular structure.
4.	C_1	12-30"	Light brownish-gray (10YR6/2 dry) to yellowish-brown (10YR5/4 moist) silt loam, stratified, moderate to weak, medium to fine granular structure.

5. C_2 30-45" Light brownish-gray (10YR6/2 dry) to yellowish-brown (10YR5/4 moist) silt loam of very weak, fine granular structure.

6. C_3 45/" Light brownish-gray (10YR6/2 dry) to yellowish-brown (10YR5/4 moist) silt loam of very weak fine granular to single grain structure.

Soil Profile: H83

This soil profile lies adjacent to the F83/8 profile on a higher minor terrace level. The site selected for this soil profile was located approximately three-fourths mile south of Perry, Kansas. (NW¼ of SW¼, S. 26, T. 11S., R. 18E.). There was a 15-inch 1951 flood deposit at the sampling site. This depositional layer was removed prior to sampling and samples were taken beginning with the pre-flood surface.

Soil Profile Description.

1. A_{1P} 0-5" Gray (10YR5/1 dry) to very dark gray (10YR3/1 moist) silt loam of very weak, fine granular to crumb structure.

2. A_1 5-9" Grayish-brown (10YR5/2 dry) to dark gray (10YR4/1 moist) silt loam of stratified, very weak, fine granular structure.

3. AC 9-14" Grayish-brown (10YR5/2 dry) to dark gray (10YR4/1 moist) silt loam of weak, fine granular structure.

4. C_1 14-29" Light brownish-gray (10YR6/2 dry) to dark grayish-brown (10YR4/2 moist)silt loam of moderate to weak, medium to fine granular structure.

5. C_2 29-44" Light brownish-gray (10YR6/2 dry) to dark grayish-brown (10YR4/2 moist) silt loam of stratified, very weak, fine granular structure.

Soil Profile: 1H83

This soil profile is located on a progressively higher minor terrace level and is adjacent to the H83 soil profile. The site selected for sampling was located approximately one and three-fourths miles southeast of Perry, Kansas. (SE¼ of NW¼, S. 36, T. 11S., R. 18E.). Deposition from the July 1951 flood was slight and tillage operations had incorporated it with the pre-flood surface so that it was indistinguishable in the soil profile. Therefore sampling began with the soil surface.

<u>Soil Profile Description</u>.

1. A_{1P}	0-7"	Grayish-brown (10YR5/2 dry) to very dark gray (10YR3/1 moist) silt loam of very weak, fine granular to crumb structure.
2. A_1	7-12"	Grayish-brown (10YR5/2 dry) to very dark gray (10YR3/1 moist) silt loam of weak medium to fine granular structure.
3. AC	12-18"	Light gray (10YR7/2 dry) to dark grayish-brown (10YR4.5/2 moist) silt loam of weak, fine granular structure.
4. C_1	18-31"	Light yellowish-brown (10YR6/4 dry) to dark brown (10YR4/3 moist) silt loam of very weak medium blocky structure that breaks easily into weak medium to fine granular structure.
5. C_2	31-42"	Light yellowish-brown (10YR6/4 dry) to dark brown (10YR4/3 moist) silt loam of very weak blocky structure that easily breaks into very weak, fine granular structure.
6. C_3	42-60"	Light yellowish-brown (10YR6/4 dry) to dark brown (10YR4/3 moist) silt loam of stratified, very weak, fine granular to single grained structure.

Soil Profile: T83

This soil profile lies at a greater height above the river than the previously described soils. While it has not been mapped as a part of the Newman terrace it occupies a position in height similar to the Newman terrace. It is the oldest soil profile sampled for the investigation. The site selected for this soil profile was located approximately one and one-fourth miles southeast of Perry, Kansas. (SE$\frac{1}{4}$ of SE$\frac{1}{4}$, S. 26, T. 11S., R. 18E.). There was no evidence of deposition from the July 1951 flood at this site.

Soil Profile Description.

1.	A_{1p}	0-5"	Gray (10YR5/1 dry) to very dark gray (10YR3/1 moist) loam of very weak, fine granular to crumb structure.
2.	A_1	5-9"	Gray (10YR5/1 dry) to very dark grayish-brown (10YR3/2 moist) sandy loam of weak, platy structure that breaks easily into weak, fine granular structure.
3.	A_{12}	9-17"	Light brownish-gray (10YR6/2 dry) to very dark gray (10YR3/1 moist) loam of moderate to weak blocky structure that breaks with moderate pressure into moderate fine granular structure.
4.	AC	17-26"	Gray (10YR5/1 dry) to dark gray (10YR4/1 moist) loam of moderate to weak, medium blocky structure that breaks with strong pressure into moderate to weak, fine granular structure.
5.	C_1	26-34"	Pale brown (10YR6/3 dry) to dark brown (10YR4/3 moist) sandy loam of weak medium to fine blocky structure that breaks with moderate pressure into moderate, medium and fine granular structure.

6. C_2 34-42" Pale brown (10YR6/3 dry) to yellowish-brown (10YR5/4 moist) sandy loam of stratified very weak, fine blocky to fine granular structure.

7. C_3 42-60" Pale brown (10YR6/3 dry) to yellowish-brown (10YR5/4 moist) loamy sand of stratified single grained structure to very weak, fine granular structure.

EXPERIMENTAL PROCEDURES AND RESULTS

In a study of the physical and chemical properties of the soil, numerous methods of investigation are necessary in order to characterize these properties. The following determinations were chosen in order to characterize the soil profiles in this study: particle size analyses; aggregate analyses; organic matter content; pH; cation exchange determinations; exchangeable calcium; and exchangeable magnesium determinations. These determinations have been made on the four profiles chosen for this investigation.

Particle Size Analyses

Ten gram samples of each horizon, which previously had been pulverized and passed through a 10 mesh sieve, treated with 30 per cent H_2O_2 to oxidize most of the organic matter, washed five times by means of a short Pasteur-Chamberland suction filter, weighed after drying in an oven at 105°C, and then dispersed by use of a sodium hexametaphosphate dispersing agent, were fractionated into the following: sand, silt, and clay separations. The procedure followed was the pipette method as described by Kilmer and Alexander (1949).

Separations of the sand fraction were made at: 1.0-0.5mm., 0.5-0.25mm., 0.25-0.10mm., and 0.10-0.05mm. The silt fraction consisted of particles in the 0.05-0.002mm. range, and the clay fraction consisted of less than 0.002mm. particles. Table I shows the size distribution of the four profiles.

The results of the particle size determination show all horizons of the four profiles to contain less than one per cent sand in the 1.0-0.5mm. range. Particles larger than 1.0mm. were absent in all horizons. In the 0.5-0.25mm. range the T83, 5-9" horizon is outstanding in sand content, containing 17.5 per cent whereas all horizons of this and the other three profiles range from less than 1.0 to 1.5 per cent. In the 0.25-0.10mm. size range the F83/8 profile contains the largest quantity of sand in the first two horizons with the sand content decreasing with depth while the T83 sand content increases greatly with depth. The H83 profile contains lesser amounts of sand and tends to decrease in sand content with an increase in depth. The 1H83 profile contains small amounts and there is no particular trend in the sand content with regard to the various horizons. In the 0.10-0.05mm. range the T83 profile has the largest sand content with the percent of this fraction decreasing with depth. The F83/8 is next in line with its sand content remaining fairly constant throughout the profile. The H83 and 1H83 profiles are quite similar and they have the highest sand content in their lowest horizon. With regard to the total sand content, it can be stated that they follow the same general trend of the 0.10-0.05 sand fraction.

The H83 and 1H83 profiles contain the greatest quantity of silt, with all horizons containing approximately 60 per cent. The F83/8 profile has the least amount (29.7 per cent) of silt in the 0-6" horizon with the silt content increasing from 50 per cent in the 6-8" horizon to 64.8 per cent in the last horizon. In the T83 profile the silt content varies slightly, averaging about 35 per cent in the first five horizons, with the last two horizons decreasing sharply, to only 5.6 per cent silt in the last horizon.

The clay content of the first four horizons of all soil profiles is nearly constant with the H83 profile having a slightly larger amount of clay.

The lower horizons of the F83/8 profile contain about the same amount of clay as the upper horizons, while the lower horizons of the other three profiles decrease to about 8 per cent clay.

During the determinations of the 0.1-0.05mm. sand fraction it was noted that there was a considerable quantity of material on the 0.05mm. sieve which passed through the sieve only after prolonged shaking of the sieve. A microscopic analysis of this material showed that much of this material fell into the 0.04-0.045mm. range. This would explain the fact that the texture of the soil in these three profiles feels much like that of a very fine sandy loam although according to the U. S. D. A. textural classification it must be placed into the silt loam class because these particles are coarse silt rather than very fine sand.

Table I. Particle size analyses of soil profiles which occur on each of four terrace levels of the Kansas River Valley. Results are average of duplicate determinations and are expressed as per cent by weight.

Horizon	Depth (in.)	Diameter in millimeters 1.-.5	.5-.25	.25-.1	.1-.05	Total Sand	Total Silt	Total Clay
F83/8 Profile*								
A_{1P}	0-6	0.04	0.92	31.91	24.69	57.66	29.72	12.62
A_1	6-8	0.02	0.20	10.17	22.74	33.13	50.06	16.81
AC	8-12	0.01	0.14	2.29	29.54	31.99	54.76	13.25
C_1	12-30	----	0.20	1.86	27.70	29.76	58.48	11.76
C_2	30-45	----	0.33	1.69	22.54	24.56	63.30	12.14
C_3	45/	0.11	0.10	1.48	22.86	24.44	64.82	10.74
H83 Profile*								
A_{1P}	0-5	----	0.02	4.64	13.06	17.72	62.91	19.37
A_1	5-9	----	0.02	4.09	13.10	17.21	61.83	20.96
AC	9-14	----	0.01	4.32	14.74	19.07	62.45	18.48
C_1	14-29	----	0.01	2.95	9.33	12.29	66.90	20.81
C_2	29-44	----	0.07	2.54	33.02	35.63	55.94	8.43
1H83 Profile*								
A_{1P}	0-7	0.04	0.54	1.59	18.81	20.98	64.80	14.22
A_1	7-12	0.08	0.50	1.48	17.15	19.21	66.09	14.70
AC	12-18	0.10	0.47	0.89	16.39	17.85	67.42	14.73
C_1	18-31	0.33	1.49	2.56	13.66	18.03	70.32	11.65
C_2	31-42	0.40	2.36	4.11	15.74	22.61	66.98	10.41
C_3	42-60	----	0.08	0.73	29.17	29.98	61.91	8.11
T83 Profile*								
A_{1P}	0-5	0.06	0.25	11.64	35.78	47.73	37.59	14.68
A_1	5-9	0.03	17.51	9.17	33.64	60.35	25.60	14.05
A_{12}	9-17	0.07	0.27	9.44	35.06	44.84	39.56	15.60
AC	17-26	----	0.23	8.85	37.20	46.28	40.05	13.67
C_1	26-34	----	0.39	26.41	28.03	54.83	35.60	9.57
C_2	34-42	0.02	0.68	40.29	22.24	63.23	28.57	8.20
C_3	42-60	0.04	0.63	69.26	16.83	86.76	5.61	7.63

* F83/8 profile occurs on the first terrace level;
H83 profile occurs on the second terrace level;
1H83 profile occurs on the third terrace level;
T83 profile occurs on the highest terrace level.

Aggregate Analyses

Soil structure is commonly defined as the arrangement of the naturally occuring soil particles. Some workers have carried this definition a step farther by defining soil structure as the arrangement of soil particles into secondary units or aggregates, as compared to soil texture--the individual particles. Under natural conditions in most soils a high proportion of particles fail to function as individuals but are associated into secondary units called aggregates. The physical behavior of a soil is strongly affected by the number, size, arrangement, and stability of these secondary particles. Since aggregates vary greatly in size and shape and in their ability to resist dispersion, these are the characteristics that have been used to describe them. Of the numerous techniques that have been developed for evaluating size and stability, the technique of aggregate-size determination by wet-sieving is most widely used for aggregate analyses at present.

Fifty gram samples of each horizon which had been sampled for soil structure determinations (aggregate analyses) were sieved through a 4-mesh sieve and all large lumps were gently crushed to pass the 4-mesh sieve. Yoder's method of wet-sieving as described by Russell (1949) was used for this determination, and the per cent by weight of aggregates were determined in the following sizes: larger than 2.0mm., 2.0-1.0mm., 1.0-0.5mm., and 0.5-0.25mm. Table 2 shows state of aggregation (weight of aggregates minus the

Table II. Aggregate analyses of selected horizons of soil profiles which occur on each of four terrace levels of the Kansas River Valley. Results are average of three determinations and are expressed as per cent by weight.

Horizon	Depth (in.)	2.0	2.0-1.0	1.0-0.5	0.5-0.25	Total
		Diameter in millimeters				
F83/8 Profile*						
A_{1P}	0-6	9.25	5.93	10.45	12.85	38.48
A_1	6-8	8.60	4.85	5.13	6.12	24.70
AC	8-12	0.88	2.49	4.34	5.97	13.68
C_1	12-30	----	0.29	0.96	2.73	3.98
H83 Profile*						
A_{1P}	0-5	2.89	4.37	6.22	8.11	21.59
A_1	5-9	6.07	6.72	8.82	9.38	30.99
AC	9-14	1.76	2.95	6.67	11.46	22.84
C_1	14-29	0.22	0.77	1.91	3.45	6.35
1H83 Profile*						
A_1	7-12	1.81	2.50	4.58	7.06	15.95
AC	12-18	0.25	1.27	3.37	5.42	10.31
C_1	18-31	----	0.19	0.77	2.42	3.38
T83 Profile*						
A_1	5-9	1.06	2.41	7.10	11.73	22.30
A_{12}	9-17	0.14	0.69	3.59	7.36	11.78
AC	17-26	0.20	0.39	2.16	5.16	7.91
C_1	26-34	----	0.16	0.89	2.66	3.71
C_2	34-42	----	0.15	0.79	2.05	2.99

* F83/8 profile occurs on the first terrace level;
H83 profile occurs on the second terrace level;
1H83 profile occurs on the third terrace level;
T83 profile occurs on the highest terrace level.

weight of primary particles in each size range), and tabulated as per cent aggregation.

Results include the old plow layer (0-6") of the H83 and F83/8 soil profiles. However, it is recognized that there is little aggregation in a plow layer, and consequently such information is of little value in a study of this kind. Aggregates larger than 2.0mm. were confined to the upper twelve inches of all soil profiles. Below this depth there was less than one per cent aggregation in the larger than 2.0mm. range. In the smaller size ranges there was a general increase in per cent aggregation and again aggregation decreased with depth in all horizons of the four soil profiles. The H83 profile contained the largest total aggregation followed by the F83/8, T83, and 1H83 soil profiles.

Soil Reaction

A Beckman pH meter was used to determine the soil reaction on a suspension of soil in distilled water. Ten grams of soil was weighed into a 50 ml. beaker, then 10 ml. of distilled water was added with a pipette. The mixture was stirred thoroughly with a stirring rod and allowed to stand 30 minutes. The electrodes of the instrument were immersed in the soil and water mixture, which was stirred again prior to immersion, and the pH read directly from the instrument scale. Results are listed in Table 3.

The pH of all horizons increased with depth, with the F83/8 soil profile having the highest pH throughout the profile whereas the H83 and 1H83 profiles were similar throughout all horizons.

The field from which the T83 soil profile was taken had been limed and therefore this greatly affected the reaction of the 0-5" horizon. The remainder of the horizons were quite uniform with a gradual increase in pH with depth.

Organic Matter Determinations

Organic matter determinations were made on two gram samples of soil from each horizon. The soil was ground to pass a 0.5mm. screen and the soil was digested with chromic and sulphuric acids as outlined in the procedure of Walkley and Black's Rapid Titration Method (1934). Results were reported as per cent organic matter by soil weight as listed in Table 3.

The first two horizons of all soil profiles contained the highest organic matter. The remaining horizons decreased rapidly in organic matter content, containing approximately 0.2 per cent. The soil profile contained the highest per cent organic matter followed by the F83/8 profile. The 1H83 and T83 profiles were nearly identical with regard to organic matter content.

Cation Exchange Determinations

Cation exchange determinations were made on all horizons of the four soil profiles. Determinations were made with the Beckman Flame Photometer using the rapid determination of the cation exchange capacity of soils with the flame photometer, a procedure adapted from Rendig (1947). Two gram samples of air-dried, 20-

mesh soil were used for the determinations. Results are listed in Table 3 as milliequivalents per hundred grams of soil.

The cation exchange determination results show a greater value for the upper horizons of each profile. The H83 profile shows higher exchange capacities in the upper 30 inches of the profile. With the exception of the 6-8 inch horizon of the F83/8 profile, which has a slightly higher value, the cation exchange values of the corresponding horizons of the F83/8, 1H83, and the T83 soil profiles are approximately the same.

Exchangeable Calcium Determinations

Calcium exchange determinations were made on the Beckman Flame Photometer and the following procedure was employed. Twenty-five grams of 10-mesh soil was weighed into a 250ml. Erlenmeyer flask and 50 ml. of 1 N ammonium acetate solution was added. The contents were agitated for 30 minutes on an end-over-end shaker. The suspension was filtered on a 9 cm. Beuchner funnel through Watman No. 42 filter paper. Gentle suction was applied to give a filtration rate not faster than one drop per second. The flask was rinsed three times with 10 ml. aliquots of ammonium acetate. Each rinsing was added to the funnel after the previous addition had completely passed through.

By using a small glass funnel, the contents of the suction flask were transferred to a 100 ml. volumetric flask. The suction flask and small glass funnel were rinsed twice with not more than 7 ml. of ammonium acetate from a fine tipped wash bottle. The solution in the volumetric flask was made up to volume by the addition of ammonium acetate.

A five ml. aliquot was then pipetted from the volumetric flask, placed in a 50 ml. beaker, and taken down to dryness on a steam table. The beaker and its contents were then carefully rinsed with 0.4 N HCL and the solution transferred to another 100 ml. volumetric flask. This solution was brought up to volume by the addition of 0.4 N HCL and the calcium was determined with the Beckman Flame Photometer. The dial reading of the flame photometer was converted to parts of calcium per million by reference to a standardization curve. Results are listed in Table 3 as milliequivalents per hundred grams of soil.

The exchangeable calcium content of the various horizons was closely related to the cation exchange capacity as might be expected. The general trend was a decrease in the exchangeable calcium content with depth. Exceptions to this general trend were the 14-20 inch horizon of the H83 profile and the 6-8 inch horizon of the F83/8 profile. Both of these horizons contained the highest exchangeable calcium content.

Exchangeable Magnesium Determinations

Exchangeable magnesium determinations were made on the Beckman Flame Photometer using the same procedure employed for the calcium exchange determinations. Results are listed in Table 3 as milliequivalents per hundred grams of soil.

Table III. A partial chemical analyses of soil profiles which occur on each of four terrace levels of the Kansas River Valley. Results are average of duplicate determinations.

Horizon	Depth (in.)	Exch. Cations	Exch. Ca	Exch. Mg	Organic Matter % by wt.	pH
		(me./100g. soil)				
F83/8 Profile*						
A_{1P}	0-6	9.44	6.74	0.99	1.24	7.0
A_1	6-8	14.16	11.40	1.02	2.38	6.9
AC	8-12	9.84	7.93	0.99	0.57	7.1
C_1	12-30	8.48	7.15	0.90	0.32	7.5
C_2	30-45	8.64	8.20	0.77	0.31	7.7
C_3	45/	7.36	6.73	0.80	0.26	7.9
H83 Profile*						
A_{1P}	0-5	14.00	9.60	2.14	2.88	6.3
A_1	5-9	15.40	9.33	1.70	1.82	6.0
AC	9-14	12.00	8.60	1.65	0.92	6.4
C_1	14-29	13.20	10.20	2.42	0.46	6.6
C_2	29-44	5.92	4.00	1.10	0.08	7.7
1H83 Profile*						
A_{1P}	0-7	10.48	7.33	1.18	1.76	5.9
A_1	7-12	11.28	7.07	2.04	1.43	6.2
AC	12-18	9.68	6.80	1.01	0.64	6.5
C_1	18-31	8.71	6.87	0.99	0.48	6.8
C_2	31-42	7.84	5.53	0.90	0.29	6.9
C_3	42-60	6.40	4.27	0.91	0.12	7.0
T83 Profile*						
A_{1P}	0-5	10.48	9.00	1.46	1.74	7.3
A_1	5-9	9.92	6.07	1.07	1.52	6.6
A_{12}	9-17	9152	7.33	1.65	0.96	6.6
AC	17-26	10.00	6.67	1.35	0.60	6.6
C_1	26-34	6.88	4.93	1.41	0.24	6.7
C_2	34-42	5.56	3.47	1.02	0.22	6.8
C_3	42-60	3.25	2.20	1.13	0.16	6.9

* F83/8 profile occurs on the first terrace level;
H83 profile occurs on the second terrace level;
1H83 profile occurs on the third terrace level;
T83 profile occurs on the highest terrace level.

The exchangeable magnesium content remained quite constant throughout the various horizons of the four soil profiles. In the 1H83 and F83/8 profiles there appeared to be a tendency for the exchangeable magnesium content to decrease with depth. However, this decrease was slight and could very well be due to experimental error.

DISCUSSION

Particle Size Analyses

Silt Content. The abundance of silt in the horizons of the H83 and 1H83 soils, as revealed by the particle size analyses, appears to be misleading to anyone familiar with these soils. Under field conditions the "feel" of the texture of these soils, especially in the A horizons exhibited the characteristics of containing rather large amounts of very fine sand. Actually the silt fractions isolated by the particle size analyses proved to have a texture which resembled extremely fine sand. Because the U. S. D. A. diameter limits of various soil separates were followed during this analyses, the diameter of the silt fraction was set at 0.05-0.002 millimeters. Hence those particles that fell in this size range were automatically classified as silt. An ocular micrometer was employed to observe the diameters of several of the silt fractions and it was observed that in some horizons as much as twenty per cent of the total silt particles had diameters of 0.045 to 0.040 millimeters. A large proportion of these particles were quartz.

Sand Fraction. The sand fraction of the sampled horizons were subdivided into coarse, medium, fine, and very fine sand using the U. S. D. A. diameter limits. All four soil profiles contained little coarse sand. Less than five-tenths per cent was observed in all horizons. The H83 and 1H83 profiles were nearly identical in their sand contents, the greatest percentage of the sand fraction being in the fine and very fine sand range. The F83/8 and T83 profiles contained significant amounts of fine sand and the greatest percentage of very fine sand. A striking contrast between the total sand and silt content was observed in the F83/8 and T83 soil profiles. In the T83 profile, which was the most distant from the river, the silt content decreased with depth whereas the sand content increased with depth. In the F83/8 profile, which was adjacent to the river, the reverse was true. This predominance of the sand throughout the older soil profile suggests that it has developed from somewhat coarser materials.

Clay Content. The clay content of all four soil profiles decreased with depth. The A_1 horizons of the F83/8, H83, and 1H83 profiles and the A_{12} horizon of the T83 profile contained the greatest per cent of clay. However, this increased amount was so slight in all cases that one could not conclude accurately that this increase was due to eluviation and not to formation from the soil materials present, because the accumulation takes place at approximately the same depth in all four profiles. One could also argue that if accumulation is due to eluviation it should occur at a greater depth in the older profiles. Since this, obviously, is not the case, one can only conclude that the slight differences in the A horizon are probably due to geological deposition.

Aggregate Analyses

The aggregate analyses showed that the per cent of water-stable aggregates in the horizons below the plow-layer decreased rapidly with depth. The aggregates with diameters from 1.0-0.5 millimeters comprised the largest per cent of the total aggregation. Many pedologists believe the development of structure in the B horizon to be a criteria of the effect of time on profile development. The soils analyzed for this study, being extremely youthful alluvial soils, did not possess a true B horizon. However, it was assumed that the AC horizon was a potential B horizon. If this assumption is valid the results of the aggregate analysis did not substantiate the correlation of aggregation with time as the older soil profiles possessed the smallest per cent aggregation.

It should be mentioned that while the wet-sieving method is probably the most widely used procedure for determining aggregate size determinations, the results obtained may give a false picture, especially in the analysis of dried soil samples from subsurface horizons that rarely become dry under natural conditions. Under normal moisture contents there may be little evidence of aggregation. However, when these soils are dried and then wetted, they slake into a large number of aggregates. Hence if a true picture of the structure of a soil is desired it seems evident that samples should not be completely dried before an aggregate analysis determination is made.

Conditions made it impossible to conduct these analyses before the soil samples became air-dried. Therefore, additional work should be performed before drawing specific conclusions concerning the relationship between age and aggregate development.

Soil Reaction

Soil reaction (pH) determinations showed an increase in pH with depth for all profiles with the exception of the A_{1P} horizon of the T83 profile which has the highest pH in the surface; however, at the time of sampling the soil the landowner stated that this soil had been limed.

The pH of the F83/8 profile was substantially greater than the other profiles largely due to the presence of water-soluble calcium materials present which had not had sufficient time to leach from the soil profile.

Organic Matter

Analyses revealed the highest organic matter content to be in the upper portion of the A horizons and a corresponding rapid decrease with depth in all soil profiles.

Cation Exchange

The exchange capacity of the F83/8, H83, and 1H83 profiles exhibited the same general trend of increasing with depth to the A_1 horizon and thereafter decreasing with depth to the rather constant value of six to seven milliequivalents per 100 grams of soil. In the T83 profile there was a gradual decrease in the exchange capacity with depth to three milliequivalents per 100 grams of soil in the C_3 horizon.

Exchangeable Calcium

In the younger soil profiles, (F83/8 and H83), the exchangeable calcium closely followed the pattern set by the cation exchange as indicated in Figs. 1 and 2. In the 1H83 profile the exchangeable calcium decreased gradually down to the C_1 horizon and thereafter decreased more rapidly. The A_{1p} horizon of the T83 profile appeared to contain the largest amount of exchangeable calcium, however, this was due to the effect of liming. The overall trend would seem to follow that of the cation exchange as shown in Fig. 4.

Exchangeable Magnesium

Exchangeable magnesium, expressed in milliequivalents per 100 grams of soil, remained relatively constant throughout all four soil profiles. The results of the determinations were so small that differences may have been largely due to experimental error. However, it seems logical to assume that the shape of the curves for exchangeable magnesium should follow closely the cation exchange curves.

SUMMARY

Some of the more important conclusions which have been drawn from this investigation follow.

Results of the particle size distribution analyses reveal large amounts of silt in the three younger soil profiles and their A_{1p} horizons contained the largest per cent of clay. In the potential B horizon of the four profiles, the T83 or older soil profile contained a slightly larger per cent of clay as compared to the younger 1H83 and F83/8 soil profiles. This would seem to substantiate the fact that the oldest soil profile should have the greatest accumulation of clay in this horizon, assuming that all soil profiles studied in this investigation were formed from the same type of parent material. However since these differences in clay content are slight, (ranging from 13.3 to 15.6 per cent), there is not sufficient evidence present to conclude definitely that this clay accumulation is due to the effect of time alone. Another factor which would invalidate this hypothesis is the higher clay content of the A and C_1 horizon of the H83 soil profile. Since its position places it adjacent to the most youthful soil profile, this profile presents a substantial problem with regard to using clay content as a criteria in correlation time and soil profile development. It seems quite evident that the alluvial materials which created this soil possessed a higher clay content than the other alluvial depositions. (Fig. 5)

The size distribution of particles in the T83 profile seem to indicate that this soil profile was produced under different conditions than the younger profiles.

The organic matter content of the A_1 horizon of the younger soils is slightly higher than in the two older profiles. This difference may be due to organic materials carried in by flood depositions in more recent years. The 1H83 and T83 profiles contain almost identical amounts of organic matter and in all cases the organic matter content decreases with depth.

Aggregate analyses suggest a close relationship between the amount of water-stable aggregates and the amount of clay, organic matter, and exchangeable cations. In general, highest aggregation occurs in those horizons having the greatest amount of these components. Any evidence of increased aggregation with time in the soil profiles examined is not substantiated by this method of aggregate analysis.

The relation between clay content and exchangeable cations, exchangeable calcium and magnesium was closely associated in all horizons below the A_{1p}, or plow-layer. The oldest profile appears to have lost some of its exchangeable cations from its A horizons. This loss might be attributed to leaching which had occurred for a greater period of time in this older soil profile.

In general, the close similarity of the chemical and physical analyses of these four alluvial soil profiles of different age suggests that the time interval between the deposition of these soils has not been sufficient to cause an appreciable variation in the chemical and physical characteristics that can be measured in the laboratory. Rather, the soil profiles appear to be more dependent upon the nature of the materials which were deposited by the process of alluviation.

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APPENDIX

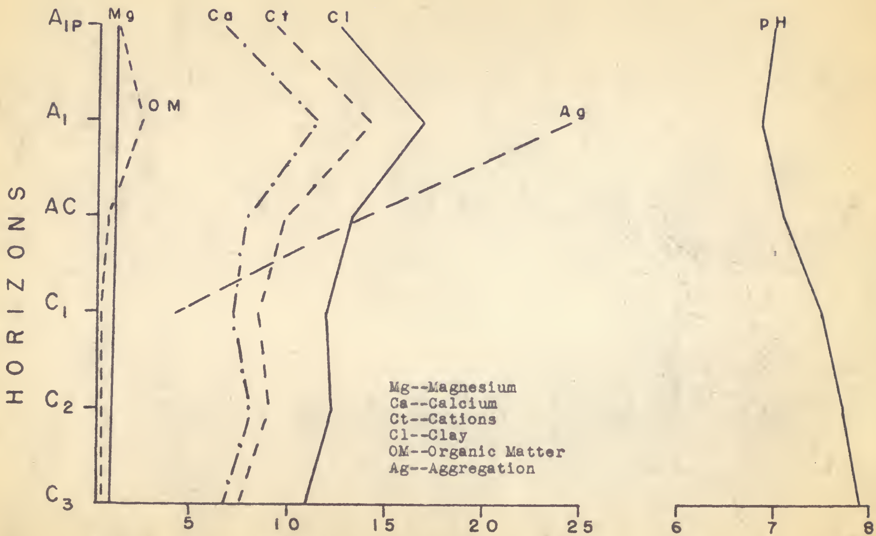

Fig. 1. Chemical and physical characteristics of the F83/8 soil profile. Exchangeable Ca, Mg, and Cations expressed as me. per 100 gms soil. Organic Matter and Aggregation expressed as percent by weight.

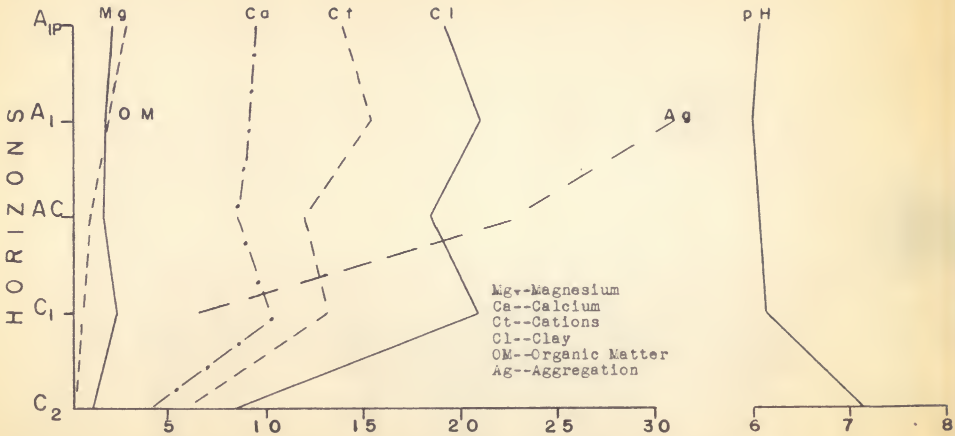

Fig. 2. Chemical and physical characteristics of the H83 soil profile. Exchangeable Ca, Mg, and Cations expressed as me. per 100 gms soil. Organic Matter and Aggregation expressed as percent by weight.

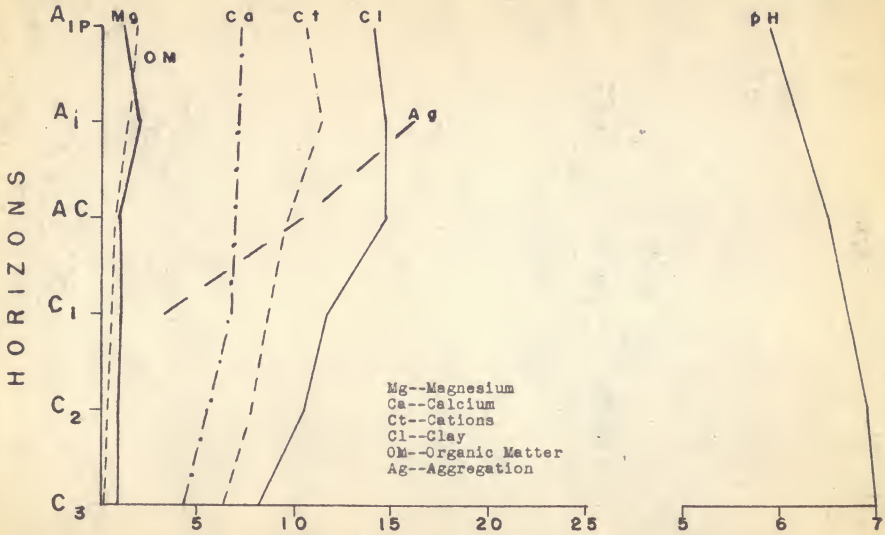

Fig. 3. Chemical and physical characteristics of the 1H83 soil profile. Exchangeable Ca, Mg, and Cations expressed as me. per 100 gms soil. Organic Matter and Aggregation expressed as percent by weight.

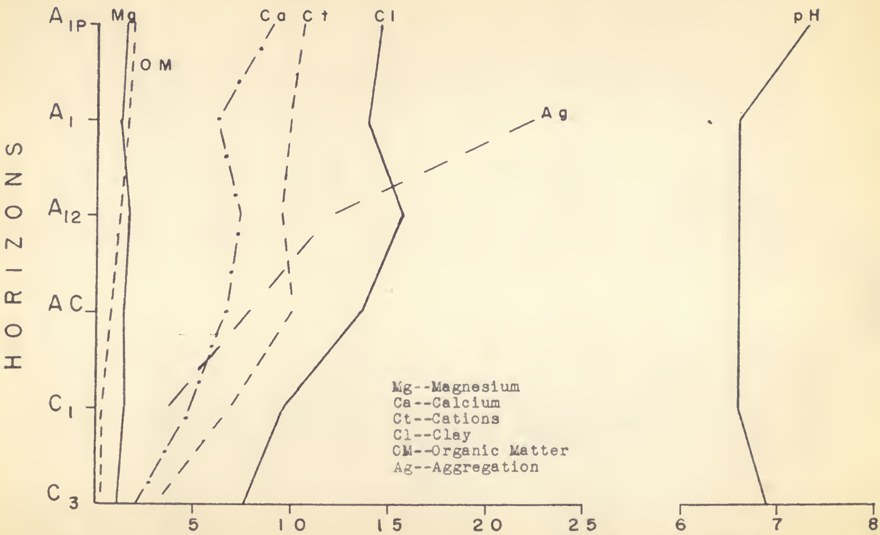

Fig. 4. Chemical and physical characteristics of the T83 soil profile. Exchangeable Ca, Mg, and Cations expressed as me. per 100 gms soil. Organic Matter and Aggregation expressed as percent by weight.

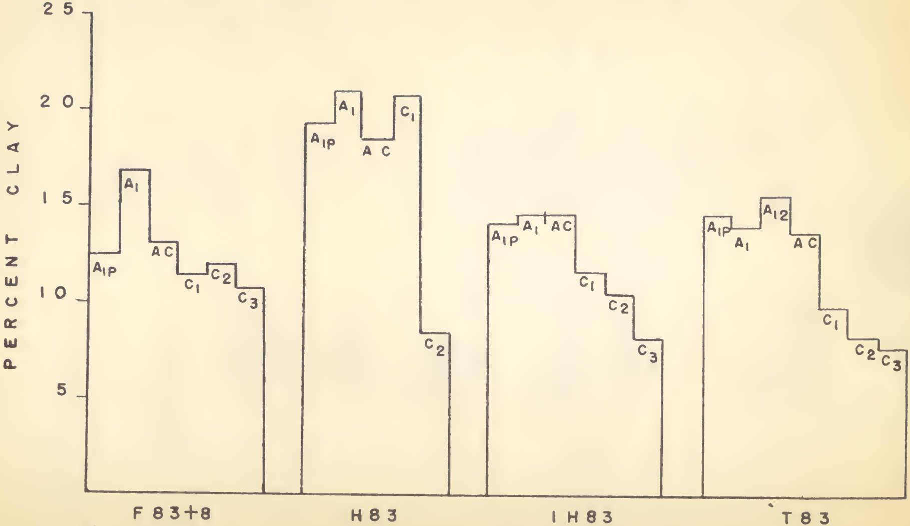

Fig. 5. Clay content in the A and C horizons of the four soil profiles.

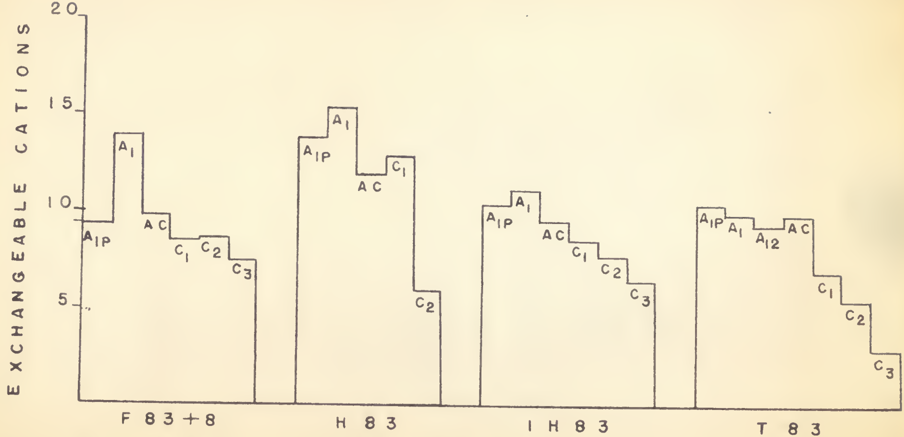

Fig. 6. Exchangeable Cations, (me./100 gms soil), in the A and C horizons of the four soil profiles.

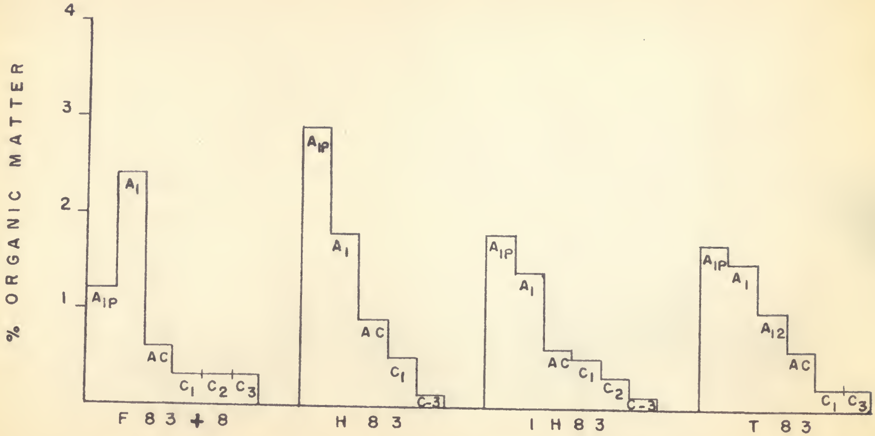

Fig. 7. Organic Matter content in the A and C horizons of the four soil profiles.

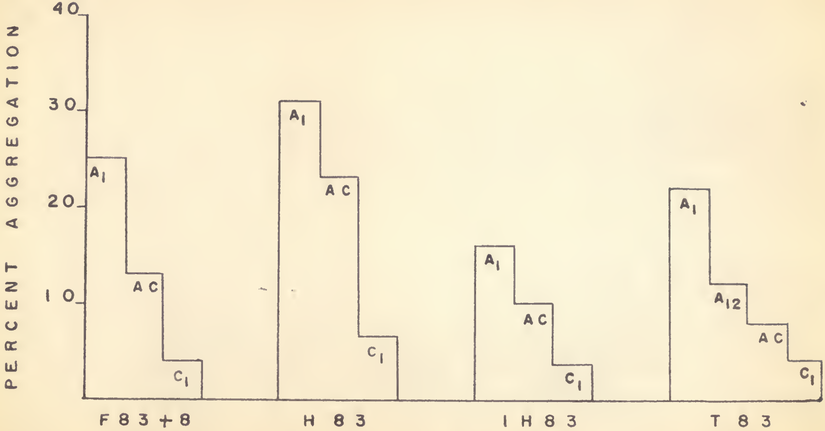

Fig. 8. Percent Aggregation in the A and C_1 horizons of the four soil profiles.

THE RELATION OF SOIL PROFILE DEVELOPMENT TO TERRACE LEVELS OF THE KANSAS RIVER VALLEY

by

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Four terrace levels on which to study the effect of time on soil profile development from essentially the same parent materials were observed in the Kansas River Valley during the Soil Survey conducted in 1951-1952. It was the purpose of this investigation to study some of the physical and chemical properties of selected soils on these terrace levels in order to determine the manner in which they developed with time.

These alluvial soils have been assigned symbols by the U. S. Soil Conservation Service, as they are as yet unnamed. The F83/8 profile lies adjacent to the river and is considered to be the most youthful because of its position. The progressively older profiles are H83, 1H83, and T83. They are so designated because they appeared on subsequently higher levels above the F83/8 soil.

In a study of the physical and chemical characteristics of these soils, numerous methods of investigation are necessary in order to characterize the soil profile development. The following determinations were made: (1) particle size analyses; (2) aggregate analyses; (3) soil reaction; (4) organic matter content; (5) exchangeable cations; (6) exchangeable calcium; and (7) exchangeable magnesium.

Results of the particle size analyses revealed that the oldest soil profile, the T83, which occurred on the highest level contained the smallest amount of silt. The silt fraction of the H83 and 1H83 profiles contained an abundance of particles which approached the very fine sand fraction in size. The more sandy T83 profile apparently developed in somewhat coarser materials than the other profiles.

Aggregate analyses suggest a close relationship between the amount of water-stable aggregates and the amount of clay, organic matter, and exchangeable cations. Any evidence of increased aggregation with time in the soil profiles analyzed is not substantiated by the method of aggregate analysis employed during this investigation.

The relation between clay content and exchangeable cations, exchangeable calcium, and exchangeable magnesium was closely associated in all horizons below the plow-layer.

In general, the close similarity of the chemical and physical analyses of these four alluvial profiles of different age suggest that the time interval between the deposition of these soils has not been sufficient to cause an appreciable variation in the chemical and physical characteristics that can be measured in the laboratory. Rather, the soil profiles appear to be more dependent upon the nature of the materials which were deposited by the process of alluviation.