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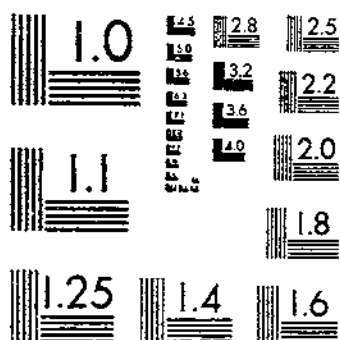
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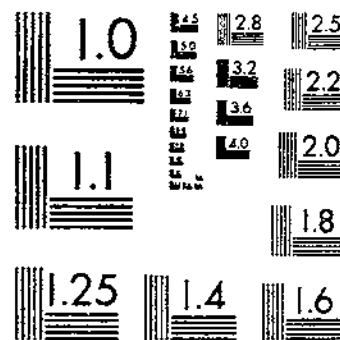
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PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE SOILS FROM THE EROSION.
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UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

PHYSICAL AND CHEMICAL CHARACTERISTICS
OF THE SOILS FROM THE EROSION
EXPERIMENT STATIONS

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INTRODUCTION

Soil erosion is a problem which has confronted agriculturists as long as land has been cultivated. When fertile virgin soil is plentiful, little attention is paid to erosion, but when tillable land becomes scarce, soil preservation becomes economically necessary. The extension of eroded areas within the United States has only recently caused a serious scientific study of this problem of national soil conservation. The first attempt to determine the quantity of run-off and erosion from a limited area of soil was carried out in 1915 by the Forest Service in the Manti National Forest, Utah. (25).¹ Since that time erosion stations have been established by the Missouri Agricultural Experiment Station at Columbia, Mo. (8), the Texas Agricultural Experiment Station at Spur, Tex. (4), the Forest Service at San Bernardino, Calif. (12), and the Bureau of Agricultural Engineering at Raleigh, N. C.² In general, the purpose of establishing these stations has been to demonstrate and evaluate the enormous damage that is done to the soil by soil erosion. The pioneer work of these stations furnishes a meritorious introduction to the

¹ Italic numbers in parentheses refer to Literature Cited, p. 49.

² BARTLE, F. O. PROGRESS REPORT ON SOIL EROSION AND RUN-OFF EXPERIMENTS AT NORTH CAROLINA EXPERIMENT STATION FARM. U. S. Dept. Agr., Bur. Pub. Roads, Div. Agr. Engin. [Mimeographed.]

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more extended study which is now being carried on by the Department of Agriculture and cooperating agencies.

The first step in this extended study was a reconnaissance survey made during 1928-29 for the purpose of locating and outlining the boundaries of the severely eroded areas in the United States. Eighteen districts were recognized in which soil erosion has become a serious menace.

When the attention of the Seventieth Congress was called to the national scope of the problem, an appropriation was made and authorization was given for the establishment of erosion-prevention and moisture-conservation stations in these areas. The first station established under this authorization was at Guthrie, Okla. This station has been in operation since July 1, 1929. Other stations have been established at Temple, Tex.; Statesville, N. C.; Hays, Kans.; Tyler, Tex.; Bethany, Mo.; Pullman, Wash.; and Clarinda, Iowa. A program of research is being carried out by the Bureau of Chemistry and Soils, in cooperation with the Forest Service and the Bureau of Agricultural Engineering, which anticipates the establishment of other stations as rapidly as sites and funds are made available.

Previous studies of erosion have been made by this bureau. In a bulletin published in 1911, McGee (13) described the damage caused by soil erosion and discussed means of control. In 1913 a paper by Davis (5) called attention to the economic waste of soil erosion. In 1915 Davis (6) made a survey showing the effects of erosion in the Southern States. A circular by Bennett and Chapline (1), published in 1928, served to focus attention on the problem, and, together with the work of the various erosion experiment stations noted above, stimulated interest in a more intensive study of erosion. In 1930, Middleton (17) published the results of a study on certain erosive and nonerosive soils and in this connection developed a measure of erosivity which at least has excellent qualitative significance. In 1931 there appeared a bulletin by Slater and Byers (26) in which a study was made of the composition of soils with respect to their percolation rate.

In connection with the establishment of erosion stations, this bureau plans to do extensive laboratory work on the soils, run-off, and eroded material. This publication is a report of the studies so far made of the soils on which erosion stations have been established.

OUTLINE OF INVESTIGATION

This bulletin includes the chemical and physical determinations which have been made on the soils of the erosion experiment stations established by this bureau and shows certain correlations between laboratory data and the available plot data. Large profile samples were obtained from each station which are representative of the soil on which the experimental plots are laid out. A small subsample of each of these was taken for the present study, and the remainder placed in storage so that at any future time a sample of the original material will be available. These subsamples were subjected to complete chemical and physical examination, including extraction and chemical analysis of the colloid.

At each station, plot samples were obtained, in addition to the profile samples mentioned. These samples represent each horizon or layer of each plot. A standardized method of sampling was used which makes each sample a composite for the horizon it represents. The samples were subjected to physical examination only.

EXPERIMENTAL METHODS

The mechanical analyses were made by the method outlined by Olmstead and others (18). The colloid by water-vapor adsorption was determined by the method of Robinson (21). The moisture equivalent was determined by the method of Briggs and McLane (2). The suspension percentage and the dispersion and erosion ratios were determined by the methods outlined by Middleton (17). Percolation ratios were computed by the formula of Slater and Byers (26). Colloids were extracted by the methods outlined by Holmes and Edgington (10). Chemical analyses of the soils and colloids followed the procedure of Robinson (23). The pH determinations were made electrometrically, by means of the hydrogen electrode.

DESCRIPTION OF SOIL SAMPLES

The soils from the first eight severely eroded districts in which erosion stations have been established are representative of widely separated areas and great variation in climatic conditions. They are however, all located in regions of agricultural importance. The following descriptions include a general description of each soil series, taken from the files of the division of soil survey of this bureau, together with specific descriptions of the several samples of the types obtained from the erosion stations.

HOUSTON SERIES

The Houston series is developed in the calcareous prairie regions of Alabama, Mississippi, and Texas. The soils are derived from the weathering of calcareous clays, chalk beds (Selma chalk), and soft limestones. The surface ranges from almost level to undulating or gently rolling. Natural surface drainage is good, but internal drainage is retarded by the heavy character of the upper subsoil. The soils are characterized by the high content of lime in the subsoils and by the presence of calcareous material in most places within a depth of 3 feet.

In Alabama and Mississippi, soils of the Houston series have grayish-brown, rust-brown, or almost black heavy clay surface soils to a depth of about 6 or 8 inches. The subsoils to a depth ranging from 18 to 24 inches are brownish-yellow or drab heavy plastic clay which grades into greenish-yellow plastic clay, streaked or mottled with whitish soft lime nodules. Anywhere between a depth of 30 and 40 inches a white or light-yellow soft limestone or Selma chalk is present. The surface soil and upper subsoil are heavy plastic clays when wet, but they crack and become hard on drying. In cultivated fields the surface 2 or 3 inches crumbles down to a fine-granular structure. The Houston soils are adapted to the production of alfalfa, Melilotus, and other forage crops, including Johnson grass

and Bermuda grass. Cotton, formerly grown on these soils in Alabama and Mississippi, has been discontinued largely on account of the boll weevil. Corn does fairly well.

The Houston series in the Texas area differs from that in the Alabama-Mississippi area in that the soils are derived from Austin chalk and Taylor marl rather than from Selma chalk. The resultant differences in the soils derived from these formations, however, are so slight that the description of the soil survey for the Alabama-Mississippi area may be taken as descriptive of the Texas area as well. The Houston are regarded as among the most productive soils in the Texas area. The samples of Houston black clay used in this investigation were collected by G. W. Musgrave in January, 1930, at the erosion station 2 miles south of Temple, Tex. These samples contain more lime in the surface soil than is implied in the series description. The samples were described as follows:

(1) From 0 to 3 inches, black clay which is very plastic and sticky when wet but crumbles readily and is easily tilled when dry; (2) from 14 to 20 inches, grayish-black clay; (3) from 24 to 36 inches, gray clay; and (4) from 36 to 50 inches, yellowish-gray clay. The lighter-colored lower layers are more readily tilled when wet. The soil profile when saturated readily seals itself to penetration of surface waters.

KIRVIN SERIES

The Kirvin series is developed in the coastal-plain region, and the soils occur in close association with the Susquehanna soils. They differ from the Susquehanna in having reddish-brown or brown surface soils, a red upper subsoil, and a red or light-red, mottled with yellow, lower subsoil. The subsoils are stiff, rather compact but brittle clays as contrasted to the plastic, sticky subsoils of the Susquehanna. These soils are derived from beds of heavy clays or heavy sandy clays. Scattered over the surface in many places are large quantities of reddish-brown iron concretions or fragments. These soils occupy ridges, hillocks, and slopes, and they are naturally well drained. The Kirvin soils are somewhat more productive than the Susquehanna and are used mainly for growing cotton, corn, and forage crops.

The samples of Kirvin fine sandy loam were collected in July, 1930, by B. H. Hendrickson at the erosion station 9 miles northwest of Tyler, Tex. This area is strongly marked by deep gully erosion. The samples were described by Mr. Hendrickson as follows:

(1) From 0 to 12 inches, grayish-red loamy fine sand, including a thin organic surface layer; (2) from 12 to 24 inches, brick-red clay; (3) from 24 to 51 inches, brick-red clay mottled with gray; (4) from 51 to 63 inches, brick-red and light bluish-gray mottled very fine sandy clay with a seam of dark iron sandstone at a depth of 63 inches; and (5) from 63 to 75 inches, mainly yellow compacted fine sand.

VERNON SERIES

The soils of the Vernon series are Indian red or reddish brown. The upper subsoil is essentially like the surface soil of the Indian-red members, the color persisting to a depth ranging from 18 to 30 inches. The lower subsoil is yellowish red or Indian red and is

highly calcareous. The subsoil, except in the heaviest members, is somewhat heavier than the surface soil, but there has not been much translocation of clay into the subsoil and no formation of a definite clay pan. The soils are developed from the "Red Beds" of the Western States. In places where the soil, through erosion, consists essentially of the disintegrated parent rock, the calcareous subsoil may not have been developed.

The samples of Vernon fine sandy loam were collected by S. W. Phillips in June, 1930, at the erosion station located 4 miles south of Guthrie, Okla. The area is marked by severe gully erosion. The samples do not show the zone of lime accumulation which is mentioned in the series description. They are described by Mr. Phillips as follows:

(1) From 0 to 3 inches, dark-brown fine sandy loam containing some organic matter; (2) from 3 to 10 inches, red fine sandy loam; (3) from 10 to 27 inches, compact red slightly sticky sandy clay; (4) from 27 to 58 inches, gritty heavy tough clay, with sandy clay in streaks or layers, showing some evidence of the alternating shales and sandstone which comprise the parent rock. The predominant color is red, with some gray and pale-yellow layers of friable clay at a depth of about 50 inches. Some fragments of soft sandstone and shale are present in this layer.

SHELBY SERIES

The Shelby soils are dark-brown or almost black in their surface soils, and most of them are shallow. The subsoils are composed of yellow, reddish-brown, or brown sticky sandy clay, much of which contains coarse sand and gravel. Lime concretions and streaks of calcareous material occur in many places in the lower subsoil. As a rule, the subsoil becomes more clayey and compact and the percentage of clay increases with depth. The Shelby soils are derived from the sandy Kansan drift. The topography in most places is gently rolling to sharply rolling, as the soils occur on slopes where the sandy drift is exposed. Soils of this series differ from the Lindley soils only in the darker color of the surface soil.

The samples of Shelby silt loam were collected by R. E. Uhland in August, 1930, at the erosion station 6 miles west of Bethany, Mo. This area is subject to both sheet and gully erosion. There is but little waste land in the area as yet, although damage is serious and promises to become more serious with further cultivation. The samples were described by Mr. Uhland as follows:

(1) From 0 to 7 inches, a very dark brown surface soil; (2) from 8 to 12 inches, a drab-brown subsurface soil, containing some mottling; (3) from 12 to 20 inches, yellowish-brown heavy very sticky plastic clay; (4) from 20 to 24 inches, lighter-brown material than in layer 3, much less plastic, with a few small lime concretions (a transitional zone); (5) from 24 to 48 inches, a chalky layer containing many lime concretions (some of which, occurring at a depth of about 4 feet, are extremely large), many gravel of different sizes, and an occasional sand pocket; and (6) from 60 to 84 inches, rust-brown joint clay which breaks readily into cubes ranging from 1 to 1½ inches in diameter. The material caves very badly. Very few lime concretions occur at this depth.

COLBY SERIES

The surface soils of the Colby series are dark gray or dark brownish gray. The upper subsoil is of similar or slightly lighter color, of heavier texture, of compact structure, and ranges from 2 to 8 inches in thickness. The deeper subsoil is a light-brown or yellowish-brown silt loam of mealy consistence and friable character. The members of this series are composed of loessial deposits which have been in their present position for a comparatively long period. The surface portion, comprising the surface soil and upper subsoil material, has been considerably weathered. The topography ranges from nearly level to sharply rolling. These soils are well drained and are adapted to general farm crops under favorable climatic conditions.

The samples of Colby silty clay loam from the erosion station on the Fort Hayes Branch Station, State Agricultural Experiment Station, located 1 mile south of Hays, Kans., were collected by R. H. Davis in July, 1930. This soil is a true chernozem. Erosion is generally of the sheet type. The low rainfall of the area makes this station important not only from the standpoint of erosion but also from that of moisture conservation. The samples were described by Mr. Davis as follows:

(1) From 0 to 10 inches, brown or dark grayish-brown heavy silt loam or silty clay loam. The material of this horizon, especially at the lower depth, is mixed or splotted with more yellowish-brown material which has been brought up from below, probably by deep tillage. It is of fine-granular structure. Although only a few lime concretions are in evidence, the soil will effervesce freely with hydrochloric acid. According to the soil and erosion survey, from 3 to 6 inches of the original surface soil of this particular soil has been lost by erosion since the area has been in cultivation. (2) From 10 to 20 inches, light-brown or yellowish-brown silty clay loam of granular structure, the granules being larger than in the layer above. The insides of the granules are lighter in color than the outsides. Lime concretions occur in this layer. There are, however, wide local variations in the depth at which the lime accumulations occur, and within a few feet the depth may vary from 15 to 30 inches. The layers or veins of lime may be either on a horizontal, an inclined, or, in a few places, on a vertical plane. (3) From 20 to 33 inches, yellowish-brown silty clay loam containing a large number of lime concretions. The material tends to approach a columnar structure, and blocks break and crush easily. (4) From 33 to 47 inches, brownish-yellow or buff-colored silty clay loam which is high in lime and similar in structure to the horizon above. (5) From 47 to 60 inches, material of similar color and structure as the above layer, but parts or splotches of this layer appear to be of finer texture. Lime concretions are less abundant. (6) From 60 to 72 inches, buff-colored material which is of slightly coarser texture than the layer above, being of a rather silty character. Some fine sand is found in many places at this depth. Lime is present but not in abundance as in the above horizon.

CECIL SERIES

The Cecil series is the most widely distributed and the most extensive series of soils in the southern piedmont plateau. The soils

of this series are derived from granites, gneisses, and locally from schist. They occupy almost level to smooth and undulating broad interstream areas and gently rolling to rolling hilly and steep areas bordering the larger stream valleys. Excellent natural drainage exists everywhere, and it is even excessive on the slopes and hillsides, thus causing destructive washing and erosion. Two kinds of surface soils are found in soils of the Cecil series—soils which have a normally developed profile and include the sandy loams and loams and soils which have a mutilated profile, that is, one from which the original surface material has been removed, thus giving a B-C soil. The red members of this series belong to the latter class. A profile description of Cecil sandy loam in a virgin area is as follows:

A₁, 0 to 2 inches, dark-gray or brown sandy loam carrying a noticeable amount of organic matter. A₂, 2 to 8 inches, pale-yellow or brownish-yellow light sandy loam, containing practically no organic matter and leached of soluble minerals. A₃, 8 to 11 inches, reddish-yellow or yellowish-red heavy sandy loam grading into friable sandy clay. This is the gradational layer between the light-textured and light-colored sandy material and the typical red clay of the B horizon. B₁, 11 to 42 inches, bright-red or deep-red, stiff but brittle clay, which is sticky and slick when wet and hard when dry. The clay breaks into irregular-shaped lumps having no definite breakage or cleavage lines, but along the breakage lines the surfaces are slick. The large lumps can be crushed into smaller lumps and soil aggregates and finally into a granular angular mass. The color is uniform, but a cut surface is yellowish red. B₂, 42 to 60 inches, light-red friable and crumbly clay, which is slightly mottled with yellow in the lower part. It contains more mica and is much more friable than the clay of the B₁ horizon. C, 60+ inches, mottled light-red, yellow, and gray soft disintegrated rock, the parent material, which varies greatly in color from place to place, as it may be light red and yellow in one place and light gray, whitish, and yellowish only a few feet distant.

The B horizon varies greatly in thickness and in many places extends to a depth of several feet, particularly in some of the clay loam areas. A few mica scales are noticeable throughout the profile but are more abundant immediately below the parent material, and sharp angular quartz sand and veins of quartz rock are characteristic of the subsoil.

The samples of Cecil sandy clay loam from the erosion station located 10 miles west of Statesville, N. C., were collected in October, 1930, by J. W. Snyder. This is the only erosion station located on a lateritic soil. Such soils are not usually erosive, but the sandy character of the surface soil makes it erode readily when not protected by a vegetative cover. The area has suffered because of the prevailing type of agriculture which is chiefly the growing of corn and cotton. The samples are described by Mr. Snyder as follows:

(1) From 0 to 6 inches, the A horizon of light-brown sandy loam containing very little organic matter but more than either horizons B₁ or B₂. The surface soil in most places is friable and very easily worked unless it is eroded so that only a few inches of surface soil remain. (2) From 6 to 32 inches, the B₁ horizon of red clay loam which is very uniform and compact. (3) From 32 to 60 inches, the

B₂ horizon of red clay loam with brown mottlings. This material is very compact when exposed and has a tendency to crack.

PALOUSE SERIES

The surface soils of the Palouse series are dark, dull brown, or black, the brown tint being most pronounced under dry field conditions when the soil is viewed from certain angles. When wet, the surface soils are nearly black. The organic-matter content is high. The upper subsoils are brown or light brown and are of similar or heavier texture and more compact structure than the surface soils. The upper subsoil rests on a deeper subsoil of yellowish-brown color and of silty or silty clay texture, which is underlain by a tawny-yellow substratum of unstratified, homogeneous, loessial or wind-borne deposits. The parent material is derived from an undetermined wide range of rocks, and the soils are noncalcareous except in the deeper substratum. The topography is rolling or undulating, and the area covered is treeless. Drainage is well developed.

The samples of Palouse silt loam from the erosion station located 3 miles northwest of Pullman, Wash., were collected by W. A. Rockie in June, 1931. This area is characterized by steep slopes and light rainfall. Erosion is of the sheet type. The samples are described as follows:

(1) From 0 to 20 inches, dark-brown silt loam or silty clay loam containing much organic matter; (2) from 20 to 30 inches, yellowish-brown or brown silty clay; (3) from 33 to 62 inches, yellowish-brown or brown silty clay; (4) from 62 to 75 inches, yellowish-brown or brown silty clay loam; and (5) from 75 to 84 inches, yellowish-brown or brown silt loam or silty clay loam.

MARSHALL SERIES

The surface soils of the Marshall series are dark brown or black, and the subsoils are light brown or yellow. The texture of the subsoil is silty and little, if any, heavier than the surface soil. The structure is loose and friable. Both surface soil and subsoil are calcareous, the subsoil effervescing with acid. The topography ranges from gently to sharply rolling. The Marshall soils are derived from loess in which weathering has not reached an advanced stage, mainly from the newer loess along Missouri River. Corn is the principal crop, with grasses and alfalfa ranking next in importance.

The samples of Marshall silt loam were collected by G. W. Musgrave at the erosion station located 9 miles west of Clarinda, Iowa, in August, 1931. This area is marked by both sheet and gully erosion. The samples differ from the series description in that they contain no calcium carbonate. They are described by Mr. Musgrave as follows:

(1) From 0 to 13 inches, dark-brown silt loam which becomes plastic and cohesive when wet but has good natural drainage, and when dry is readily tilled; (2) from 13 to 24 inches, light-brown silt loam; (3) from 24 to 45 inches, material showing occasional grains of sand and slight evidence of drift; and (4) from 45 to 71 inches, rather gritty yellow silt loam (glacial drift).

COMPOSITION AND PROPERTIES OF THE PROFILE SAMPLES

PHYSICAL PROPERTIES

The mechanical analyses and other physical data, including also the hydrogen-ion concentration, of the samples described, are presented in Table 1.

The mechanical analyses are of value in determining the texture of the soils. Since the pipette method was employed in making the determinations, the textural classification does not correspond to that given in Circular 419 (7). The terminology employed is that used for these soils by the soil survey. The mechanical analyses also show the colloid content as defined by the maximum size limit of 0.002 mm and the approximate organic content recorded as solution loss by treatment with hydrogen peroxide. The percentages given are on the basis of the oven-dry sample.

The mechanical analyses reveal that two distinct groups are represented by the soils of the eight erosion stations—those in which the texture is variable within the profile and those with uniform texture throughout. To the former group belong Kirvin fine sandy loam, Vernon fine sandy loam, and Cecil sandy clay loam. These soil profiles are separated on the basis of horizons, and the Kirvin profile presents the A horizon (0 to 12 inches), the B₁ (12 to 24 inches), the B₂ (24 to 51 inches), the B₃ (51 to 63 inches), and the C₁ (63 to 75 inches). The Vernon profile is divided into the A₁ (0 to 3 inches) and the A₂ (3 to 10 inches) horizons, the B horizon (10 to 27 inches), and the C horizon (27 to 58 inches). The Cecil profile presents the A (0 to 6 inches), the B₁ (6 to 32 inches), and the B₂ (32 to 60 inches) horizons. The C horizon is not represented. These terms will be used in referring to the various samples.

The A horizon of the Kirvin soil and the A₁ of the Vernon are almost identical in texture. The B₁ and B₂ horizons of the Kirvin and the B₁ and B₂ of the Cecil are very similar. The B₂ horizon of the Kirvin becomes lighter in texture and the C horizon is somewhat similar to the A horizon. The C horizon of the Vernon soil consists of the disintegrated soil material, together with considerable clay, and is exceptionally high in silt, clay, and colloid, and very dissimilar to the A₁ horizon. It may also be noted that the B horizon of the Vernon is strikingly different from the corresponding horizons of the Kirvin and Cecil soils. Corresponding similarities and differences in erosional characteristics of these soils may therefore be expected. Soils of this group are characterized by sandy surface soils over light or heavy clay. They show evidences of more weathering and leaching than do the soils of the other group, but these evidences are much less marked in the Vernon than in the Cecil and Kirvin soils. The last two are to be considered as mature soils. Indeed in some respects, shown by other data, the Cecil may be considered as past maturity and approaching senility.

TABLE 1.—Mechanical analyses¹ and physical data of typical profiles of erosion-station soils

Sample No.	Soil type	Depth	Station	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay	Solution loss	Colloid 0.002 mm	Colloid by water vapor adsorption	Moisture equivalent	Dispersal ratio	Ratio of colloid to moisture equivalent	Erosion ratio	Suspension percentage	Percolation ratio	pH
6096	Houston black clay	0-3	Temple, Tex.	P. ct. 0.6	P. ct. 0.8	P. ct. 0.9	P. ct. 4.1	P. ct. 4.5	P. ct. 28.0	P. ct. 60.4	P. ct. 2.8	P. ct. 44.9	P. ct. 41.1	P. ct. 30.5	P. ct. 10.9	P. ct. 1.35	P. ct. 8.1	P. ct. 9.42	P. ct. 6.98	P. ct. 8.1
6097	do	14-20	do	0.3	0	0.7	3.7	4.3	25.1	64.1	1.1	46.6	40.2	27.6	5.4	1.46	3.7	4.80		8.1
6098	do	24-36	do	0.3	0	0.7	5.9	4.8	27.0	61.8	0.8	44.1	35.6	24.4	6.7	1.46	4.6	5.92		8.2
6099	do	36-50	do	0.2	0.5	0.6	5.6	7.1	31.0	54.6	0.3	36.2	26.7	20.6	10.1	1.30	7.8	8.68		8.2
6678	Kirvin fine sandy loam	0-12	Tyler, Tex.	2.6	1.0	2.9	43.8	24.9	15.5	8.5	0.9	5.6	5.9	7.9	37.7	0.75	50.2	9.04	12.05	6.2
6679	do	12-24	do	1.2	0.6	1.5	14.7	13.1	7.3	60.9	0.9	59.4	56.6	30.5	13.4	1.86	7.2	9.15		4.5
6680	do	24-51	do	0	0.2	1.0	10.4	25.3	9.6	53.4	0.2	50.0	49.5	28.5	12.4	1.74	7.1	7.84		4.2
6681	do	51-63	do	0	0.4	1.9	18.0	31.0	13.2	35.4	0	32.3	32.8	21.2	16.6	1.65	10.7	3.05		3.8
6682	do	63-75	do	0.3	0.4	0.6	38.1	48.5	2.8	9.2	0	7.3	10.0	6.7	24.9	1.49	16.7	2.99		4.0
6718	Vernon fine sandy loam	0-3	Guthrie, Okla.	0.2	0.2	1.3	45.1	25.3	18.2	8.0	1.8	6.2	7.4	9.6	23.7	0.78	30.3	6.20	7.95	7.6
6719	do	3-10	do	0.2	0.2	11.3	37.5	25.0	12.9	12.0	0.8	9.9	8.3	9.1	17.3	0.91	19.0	4.31		7.0
6720	do	10-27	do	0.2	0.2	1.2	37.9	20.3	12.3	27.0	0.9	23.8	21.5	17.7	16.7	1.21	13.8	6.57		6.4
6721	do	27-58	do	0	0	0	14.0	18.1	34.8	32.2	0	27.4	19.4	18.4	25.9	1.05	24.7	17.36		6.7
6797	Shelby silt loam	0-7	Bethany, Mo.	1.0	3.4	5.4	9.3	4.6	44.5	27.0	3.5	24.3	23.1	24.5	27.1	0.94	28.8	19.36	20.60	5.4
6798	do	8-12	do	1.2	2.9	3.9	6.4	6.1	37.1	51.8	2.1	45.7	49.6	34.9	13.2	1.42	9.3	10.45		5.6
6799	do	12-20	do	1.3	2.9	4.1	10.7	7.9	28.5	41.8	1.2	45.4	49.4	34.2	16.0	1.44	11.1	12.50		5.7
6800	do	20-24	do	1.9	4.8	7.1	11.2	7.2	28.3	36.5	0.2	37.8	37.2	27.1	22.0	1.37	16.5	15.52		5.8
6801	do	24-48	do	2.7	5.9	0.4	11.4	8.0	29.5	37.2	0	31.0	27.0	23.0	27.8	1.17	24.2	18.31		5.8
6802	do	48-60	do	2.4	5.1	0.4	11.4	8.0	29.5	37.2	0	31.0	27.0	23.0	27.8	1.17	23.8	18.50		5.8
6802A	Shelby silt loam (sand pocket)	48	do	4.6	14.0	18.4	18.5	6.3	16.4	21.7	0	18.5	16.5	16.1	41.4	1.02	40.4	15.76		5.7
6802B	Shelby silt loam	60-84	do	2.0	5.1	6.4	15.8	5.5	26.2	36.1	0	58.6	27.3	31.7	40.2	0.86	46.7	26.23		5.7
6842	Colby silty clay loam	0-10	Hays, Kans.	2.0	1.0	1.4	2.9	12.6	45.2	34.0	2.7	30.2	32.1	27.3	15.3	1.18	13.0	12.14	10.28	8.3
6843	do	10-20	do	0.3	0.8	1.4	2.9	13.2	42.3	38.0	1.1	32.4	30.7	25.2	10.8	1.22	8.8	8.66		8.4
6844	do	20-23	do	0.2	0.3	0.5	1.9	11.0	47.0	38.7	0.4	30.3	29.0	24.1	18.8	1.20	15.7	16.10		8.5
6845	do	33-47	do	0.1	0.4	0.8	1.2	10.5	47.7	38.2	0.4	28.6	28.1	23.6	24.3	1.23	19.8	20.89		8.5
6846	do	47-60	do	0.1	0.4	0.8	1.5	8.3	50.8	38.3	0.3	29.0	29.9	24.8	35.7	1.21	28.5	31.81		8.5
6847	do	60-72	do	0.1	0.5	1.8	4.2	11.4	46.1	35.7	0.3	26.8	26.5	23.7	33.6	1.12	30.0	27.47		8.5
6977	Cecil sandy clay loam	0-6	Statesville, N. C.	2.1	6.8	9.2	20.3	13.4	20.2	25.5	2.7	17.3	20.0	20.0	22.9	1.00	22.9	10.48	10.48	5.6
6978	do	6-32	do	1.5	4.5	5.3	11.6	7.7	12.0	56.7	0.7	51.2	45.7	26.6	11.3	1.72	8.5	7.74		4.9
6979	do	32-60	do	2.6	4.2	3.9	9.0	6.4	17.1	56.8	0	48.6	50.0	28.7	9.6	1.74	5.5	7.08		4.6
8069	Palouse silt loam	0-20	Pullman, Wash.	0	0.1	0.1	0.3	5.9	64.0	27.5	2.1	24.0	26.4	25.1	20.4	1.05	19.4	18.03	17.75	6.7
8070	do	20-33	do	0	0.1	0.1	0.4	5.3	55.6	37.5	1.1	33.8	35.6	27.8	16.2	1.28	12.7	15.10		6.9
8071	do	33-62	do	0.1	0.1	0.1	0.3	6.4	58.2	35.4	0.4	32.0	35.8	27.6	21.6	1.30	16.6	20.20		7.0
8072	do	62-75	do	0	0.2	0.1	0.3	6.6	63.0	29.8	0.2	28.6	30.4	25.5	28.6	1.19	24.0	26.70		7.1

8073	do	75-84	do	.0	.2	.1	.4	5.9	64.0	29.2	.3	25.9	30.8	25.5	26.2	1.21	21.7	24.30		7.3
8736	Marshall silt loam	0-13	Clarinda, Iowa	.1	.1	.1	.2	1.6	69.0	35.3	3.6	32.4	33.9	30.1	16.1	1.13	14.2	16.21	13.40	5.8
8737	do	13-24	do	.0	.1	.1	.2	1.1	58.5	30.4	2.7	34.6	30.4	31.3	7.9	1.24	6.4	7.59		5.6
8738	do	24-45	do	.0	.5	.6	.8	1.3	61.6	33.8	1.1	28.2	33.1	20.3	18.2	1.13	16.1	17.37		5.6
8739	do	45-71	do	.6	3.5	3.9	4.4	5.7	55.2	26.5	.2	20.3	21.4	23.3	31.8	.92	34.6	26.00		6.7

¹Determinations by L. T. Alexander, H. W. Lakin, and T. M. Shaw.

The second group comprises Houston black clay, Colby silty clay loam, Palouse silt loam, and Marshall silt loam. These soils are characterized by a very striking uniformity of texture throughout their profiles. Shelby silt loam is also included in the group, though its profile is not quite so uniform as those of the other soils. These soils all belong to the prairie and chernozem groups and show no true horizontal characteristics. The various depth limits of the parts of each profile are given in the table and will be referred to as strata, or layers.

The Colby profile is unusually uniform in texture, there being less than 4 per cent variation in the clay content of the various strata. This textural uniformity is the more striking when we consider the variations in organic matter and carbonate content in the different layers, as shown in Table 2.

Houston black clay is also almost uniform in texture in the upper three layers, but in the fourth there is a decrease in both clay and colloid. This soil contains the highest clay content of the series under consideration and shows the widest divergence between clay and colloid—a difference ranging between 15 and 18 per cent in the different layers. Whether this difference is due to the existence in the soil of a large proportion of noncolloidal clay or to the cementing effect of the colloidal calcium carbonate does not appear from the evidence. That the latter is the case seems probable from the fact that hydrogen peroxide treatment of the soil is ineffective in removing organic matter but becomes effective when the carbonates are removed. In either case the relatively large particles of clay may be expected to influence the erosional character of the soil. This soil, as shown in data given in Table 2, is remarkably high in carbonate content throughout the profile, and the data in Table 3 show a very considerable fraction of the carbonate to be in colloidal form.

The Marshall profile offers about the same textural variation in the first three layers as does the Houston profile. The fourth layer, which consists largely of glacial-drift material, differs sharply in many particulars from the upper layers which are of loessial origin. This textural difference in the deeper strata has its bearing on the erosional characteristics of the soil, as shown both by laboratory data and field behavior.

The Palouse profile, though reasonably uniform, shows a closer similarity between the first and fifth strata than these show to the other layers. The chief difference between the first and fifth layers is in the solution loss, that is, in the organic content. The difference between the upper layer and those beneath it seems to be due to eluviation and not to differences in the character of the colloid content, as will be pointed out in connection with the discussion of the composition of the colloids. The textural differences shown are such as not to indicate marked erosional differences at different levels in this soil.

The Shelby profile shows sufficient differences between the first and second layers to place it in the group of soils with divergent profile characteristics, but the remainder of the soil layers proper are very similar. When the lower layers are reached, these, except the

sand pocket represented by sample No. 6802A, are again similar in texture. The wide textural differences between Shelby silt loam and Marshall silt loam are to be ascribed to the differences in soil material noted in the soil descriptions. The influence of the drift material appears in the lowest layer of the Marshall soil, and in this layer the similarity of the two profiles appears.¹ These textural variations may be expected to find reflection in erosional characteristics, particularly when the lower levels are reached.

In a previous bulletin Middleton (17) has called attention, through a study of soils of known qualitative erosional character, to certain relations of the physical characteristics of soils which are indicative of erosional behavior. The soils of the erosion experiment stations have been subjected to the same determinations, and from the data the relationships in question have been calculated. These data and ratios have been included in Table 1 with the mechanical analyses.

The colloid by water-vapor adsorption (21) is determined because, although in general it gives numerical values not greatly different from those obtained by mechanical analysis, it affords a direct measure of the relation of the soil to the humidity of the air. It is, in this respect, independent of the accuracy with which the colloid is determined and of size definition. The values obtained are dependent on the character of the colloid, at least to some extent, and, except for the precedent established in the previous bulletin, it would perhaps be as well to use the value of water-vapor adsorption directly determined without conversion by an arbitrary factor to presumed colloid content.

The moisture equivalent (2) is dependent on the sand, silt, and noncolloidal clay, as well as on the colloid content. It measures the tenacity with which moisture is held by soil and, by implication, the avidity with which it is adsorbed when opportunity offers.

The suspension percentage used in determining the dispersion ratio^a is a measure of the behavior of soil with quantities of water in excess of the adsorbent power of the soil. It is measured arbitrarily by determining the fraction of the soil which remains suspended for a specified time when dispersed under specific conditions. The method, as described (17, p. 2-3), is as follows:

A sample of air-dry soil equivalent to 10 grams of oven-dry soil was placed in a tall cylinder of approximately 1,200 cubic centimeter capacity fitted with a rubber stopper. Sufficient distilled water was added to make the volume a liter. The cylinder was closed with the stopper and was shaken end over end 20 times. The suspension was then allowed to settle until a 25 cubic centimeter sample which was pipetted at a depth of 30 centimeters consisted of particles of a maximum diameter of 0.05 millimeter. * * * From the dry weight of the pipetted fraction, the total weight of silt and clay in the suspension was calculated.

This quantity divided by the weight of the soil multiplied by 100 is the suspension percentage.

This empirically determined value is a measure of the ease of dispersion and of the rapidity of deposition of a soil. It is probable that any accurate measure of this relation carried out under specific conditions would give like relative values. This relation gives a quantitative expression to the behavior of a soil in the presence of water in excess of that required for saturation.

^a The suspension percentage and the dispersion ratio are similar to the dispersion factor of Puri and Keen (20) and the dispersion coefficient of Puri (19), respectively, except that they take 0.002 mm as the point of division rather than 0.05 mm as used by the writers.

These relations, including the texture measurements, give laboratory measurements for all the soil characteristics which are believed to be involved in erosion, except structure. No quantitative, or even qualitative, expression involving structural effects on erosional behavior has been formulated. It is certain, however, that so far as the structural units are not destroyed by the process of determining the suspension percentage, these units influence the value so determined.

The dispersion ratio, given in Table 1, is the ratio, expressed in percentage, of the suspension percentage to the percentage of the total silt and clay in the soil, as determined by mechanical analysis. This ratio is the fraction of the silt and clay which is most easily removed by water, and since it is to be assumed that through erosion the lighter particles, the silt and clay, are the particles most extensively removed, it would seem to follow that in a series of soils in which all other conditions are the same, the values of this ratio would express the relative erosivity of the soils. Such conditions do not in fact occur.

The ratio between the colloid and the moisture equivalent is a direct comparison of these values. When the ratio of these values is low, it is to be inferred that the colloid in question adsorbs water more readily or holds it more firmly than when the ratio has a higher value. It is, therefore, a measure of the degree of adsorption of water per colloid unit and indirectly of the relative effect on run-off produced by the colloid.

The erosion ratio is the quotient obtained by dividing the dispersion ratio by the colloid-moisture equivalent ratio. The dispersion ratio is independent of the texture of the soil, but it is dependent on the mobility of those particles most easily moved by water movement in the soil. The colloid-moisture equivalent ratio, on the other hand, is not independent of the texture since the moisture equivalent is to a large degree dependent on the space dimensions, which, in turn, are determined by soil-particle size. In the previous study by Middleton (17) it was found that these ratios tend to vary inversely and that when their relation to each other is considered, high values are shown for soils known to be readily eroded, and, conversely, soils not readily eroded give low values. This inverse relation appears to depend on the facts that when soils disperse readily, the erosion tendency increases and that any condition which diminishes the relative run-off likewise diminishes the opportunity for movement of material.

The erosion ratio has so far only qualitative application but in that connection has not failed, in any case, to qualitatively differentiate erosive from nonerosive soils. To what degree it is a quantitative expression can only be learned when sufficient data from field observations have been accumulated.

The percolation ratio (26), developed in an attempt to find a laboratory method for determining the field percolation rates of soils, is the ratio between the suspension percentage and the colloid-moisture equivalent ratio. It is held to be of qualitative significance, and present data indicate that it is applicable only in the comparison of surface soils. That it indicates permeability seems to depend on the fact that in the more easily dispersed soils the muddy percolation waters more effectively close the naturally occurring water passages with silt and colloid. The effect obviously decreases with in-

creasing depths because of the deposition of suspended material, as well as because of other conditions in the lower horizon, which tend to produce a less porous structure.

When soils are air-dry, the presence in them of air may be expected to have an effect on their water relationships, and this effect should vary not only with the size of the interstitial spaces but also with the character of the successive strata through which gravitational water seeks to pass. That such effect is produced has been demonstrated in this laboratory, but the incomplete data obtained are not yet ready for publication. It appears, however, that all percolation data obtained by the use of open tubes are afflicted with an error of undetermined magnitude, owing to the fact that soils in the field are not provided with free flow after leaving a given fraction of the profile. Therefore, although it is obvious that the percolation rate is a factor which affects erosional behavior, it is not at all certain that the properties of the soil which influence it are reflected by the determined data.

The pH values of the soils of the erosion stations have been included with the physical data. The known effect of moderate alkalinity on the dispersability of soils would lead to the expectation that, other conditions being equal, the acid intensity would affect erosional behavior. Such equality of conditions can not be expected to occur often with simultaneous differences of pH. It may therefore be remarked at once that, although these soils furnish a pH range between the extreme values of 3.8 and 8.7, no direct relationship to erosional behavior has been established.

Examination of the data given in Table 1 shows a fairly wide variation in the colloid content, as indicated by water-vapor adsorption and moisture equivalent, and suspension percentage. These variations are reflected in the ratios determined. Were the other great soil groups represented by the station soils, the variation in properties would probably be much more diverse and the study of them of increased value. It may be remarked, however, that the stations were located primarily because of recognized injury through erosion, and the soils are therefore to be expected to be, for the most part, of highly erosional character. The erosional characteristics of a soil are not the only factors involved in the damage which is produced, since the quantity and character of rainfall and the kind of agriculture and the methods employed also have bearing on the results. It is to be noted then that the soils represented are not all easily eroded, at least throughout the profile. The most striking fact which appears in the erosional data is the lack of uniformity within the profiles even when texturally they are uniform. The colloid by water-adsorption and moisture-equivalent values follows textural uniformity when it occurs, but the suspension percentage most decidedly does not.

Normally it may be considered that the part of the soil of paramount importance to erosional behavior is the surface layer, or horizon. It must not be forgotten, however, that the lower strata have a decisive bearing not only on the total damage due to erosion, but that they also frequently determine the type of erosion which occurs. The soils of the stations furnish two groups so far as their surface layers are concerned, but the grouping is not the same as that of the textural relationships. The Houston, Colby, and Marshall surface

soils are least erosive, as indicated by the erosion ratio, and the erosivity increases by steps through the Palouse, Cecil, and Shelby soils to the most erosive surface layer, that of the Kirvin soil.

It seems desirable to consider each soil profile with respect to the physical data and to relate these to what is known of the field behavior of the soils. It is hoped that these considerations may help to point out the missing data which are needed, the field observations which should be made to obtain a clearer picture of the relations between soil composition and erosional behavior, and to point the way to the most helpful methods of control.

The Houston soil has an exceptionally low erosion ratio which, by comparison with that of the other soils, is remarkably uniform throughout the profile. Nevertheless, its surface layer is much more erosive than the layer lying immediately below. These relations would seem to require that erosion of the Houston soil should be uniform and of the kind known as sheet erosion, since gullying is produced by reason of marked increase in erosivity of some stratum lying beneath the subsoil. The soil data given class this soil as relatively nonerosive, but as the discussion of the plot data (Table 7) indicates, the field data show extensive damage. This damage appears to be owing to a group of influences not considered at all or only in part by the measurements given. The pH of the soil is high, largely because of the calcium content. This results in a low relative suspension percentage. On the other hand, the very large content of clay and its high shrinkage value, not included in the determinations made, produce extensive cracking of the soil on drying, and, so far as the surface soil is concerned, results in the production of a fine, granular structure the component units of which are cemented by colloidal carbonates. The result is that a highly fluid suspension of these fine particles readily forms on the surface and follows the lines of drainage, in which are included the large subsoil cracks previously mentioned. A striking peculiarity of the Houston clay, at least in the neighborhood of the experiment station, is the sinusoid character of the line of cleavage between the second and third layers of the soil. Whether this has been produced through erosion or is due to some other cause, the result is an irregular exposure of subsoil on the surface as erosion proceeds, with consequent effect on soil productivity. In addition to these soil characteristics the rainfall of the region occurs at infrequent intervals and is torrential in character. The relative run-off is therefore excessive, and the carrying power of the moving water is likely to be high because of the velocity of the flow. These conditions, taken together, result in greater soil injury than would be indicated by the soil characteristics given in Table 1.

The Colby soil has erosional properties somewhat higher than those of the Houston but is still to be classed, on the basis of these properties, as a nonerosive soil particularly as respects the upper layers. However, its surface soil is more erosive than the stratum immediately beneath it. When the profile characteristics are considered in conjunction with the low rainfall it appears that, so far as erosion occurs, it should be sheet erosion, and when the calcium carbonate content is considered, together with the high plastic clay content with the consequent fine granulation of the surface soil when dry, wind erosion is indicated. However, were the rainfall sufficient

to produce continuous run-off, gully formation would occur with rapidity after the depth of cutting had exceeded 4 feet. That such erosion does not occur is doubtless due to the amount and also the character of the precipitation. The greater suspension percentage of the surface layer, as compared with the subsoil of both the Colby and the Houston soils, as well as that of the Marshall soil, although the other data are uniform, is doubtless to be associated with the structural relations produced by air drying. The finely granulated surface-soil particles disperse more readily than the larger granules of the subsoil. This difference disappears when the soil samples are taken when the surface soil is moist. (See composite-plot data.)

The Marshall soil, like the Houston and Colby soils, shows a striking contrast between the surface soil and the subsoil in suspension percentage, and therefore in the erosion ratio, though otherwise the two layers are similar. As already mentioned, this indicated difference in erosional behavior is reflected in the observed field behavior of the soil, although the measurements based on the plots have not, as yet, been received. The streams in this area, as is usual in prairie regions, are notably turbid with suspended colloid. The explanation of the indicated erosional difference between subsoil and surface soil is, as before, to be attributed to structural differences. The air-dry surface soil becomes extremely fine and in consequence is more readily suspended and removed by flowing water than the more compact subsoil. The data would also indicate the probability of lateral water movement occurring not only at the surface but, with sufficient rainfall, also at the surface of the subsoil, and in cultivated fields at plow depths. So far as this occurs, the removal of the surface soil is greatly accentuated. The data also indicate that when gullies are cut to the level of the glacial drift, undercutting occurs, owing to the greater erosivity of the drift, and the gullies become U-shaped, with overhanging projections of the upper strata.

The Palouse soil has somewhat greater erosional character than the Marshall. The data for this soil do not indicate a highly erosive material, but because of the steep slopes on which it occurs, the soil is subject to damage from erosion to a degree probably not commensurate with the rainfall. The difference between the surface layer and the second layer, in suspension percentage and erosion ratio, is not so marked as in the soils so far considered. It is to be noted, however, that the surface layer is of unusual depth. There are notable differences also in the other soil characteristics, especially in the silt and clay content. It is therefore difficult to say to what extent the erosional differences are due to structural differences. The data lead to the belief that even if the rainfall were adequate, gully formation would not readily occur.

The Cecil soil, as already mentioned, is exceedingly nonerosive so far as its B₁ and B₂ horizons are concerned. The relatively high erosional characteristics of the A horizon are to be ascribed in part to the lack of structure, which accompanies the high silt and sand content, in contrast with the low colloid content which results in a higher suspension percentage in the A than in the B horizons. The numerical value of the colloid-moisture equivalent ratio of the surface soil

apparently is due to the organic matter and to the retentive capacity for water of the silt and very fine sand being added to that of the colloid itself. This textural difference is reflected in the erosion ratio. The soil damage from erosion in the Cecil areas is accentuated by the relatively high rainfall as well as by the type of agriculture. The chief crops are cotton, tobacco, and corn, and grass or other cover crops are not common. The result is that much of the Cecil area now has no A horizon. These mutilated profiles are non-erosive. The data given in Table 1 do not include the C horizon and therefore no indications of the relation of the soil to gully formation are presented. Since, however, the description of the soils notes gully formation on steep slopes, it is to be inferred that the erosional characteristics of the C horizon are more marked than those of the B horizon.

The Shelby soil presents an interesting profile in that its surface layers offer the same relationships in general as those of other prairie soils. In the lower strata are found increased sandy components of coarser type. These result in low values for the colloid-moisture equivalent ratio and the dispersion ratio. As a consequence, the erosion ratio is increased. These indications are reflected in the field by the formation of deep gullies with overhanging ledges of the less erosive intermediate layers, and they include at times the surface layer which, although somewhat more erosive than the layers beneath it, is often held in place by grass roots.

The suspension percentage of the surface layer is high, a fact reflected by the turbid condition of surface water even when flowing through meadows. The relative erosivity of the surface layer is much higher than that of the second layer. This difference is clearly attributable in part to textural differences in silt and clay content but must also be attributed in part to the structural differences already noted in the other prairie soils, since the lower strata, which do not show the textural differences so markedly, gradually increase in erosional character.

The Vernon soil has a low content of silt and clay in the A₁ and A₂ horizons, the fine sand and very fine sand being correspondingly high. In consequence the moisture equivalent is low. Nevertheless the colloid-moisture equivalent ratio is very low by reason of the retention of moisture by the noncolloidal parts of the soil, which are relatively very large. The suspension percentage is numerically low but, relative to the total silt and clay, it is very high. The result is a high dispersion ratio. The combination of these ratios necessarily results in a high erosion ratio for both parts of the A horizon. The suspension percentage of the A₁ horizon is, however, relatively much greater than that of the A₂, with consequent normal relation of greater erosivity for the surface layer. The B horizon has a numerically higher suspension percentage than the A₁ and A₂ layers, but relative to the total clay and silt content it is much smaller. The colloid-moisture equivalent ratio is greater than in the upper strata. We have, therefore, a gradually decreasing erosion ratio through the A and B horizons. The C horizon contains, in addition to the disintegrated soil material, considerable quantities of weathered clay, and, although it is somewhat more erosive than the B horizon, the relative difference between the lowest stratum and those above it, so far as the erosion ratio is concerned, is not exceptionally marked.

We have in this soil, therefore, the conditions for ready gully formation of the V-shaped type. Because of the low colloid content of the surface soil, erosion is particularly destructive in this soil whenever the surface is not protected by a vegetative cover.

The Kirvin soil is characterized by the highest erosion ratio for the surface soil of any of the soils of the stations and by the strongest contrast between the A and B horizons. The A horizon has its abnormally low content of colloid associated with the water-holding capacity of the silt and sands. The colloid is relatively nonplastic. The suspension percentage of the A horizon is abnormally high, being, in fact, greater than the total amount of clay present. This may be taken to mean that the soil is readily dispersed, despite the low silica-sesquioxide ratio. (Table 3.) It would seem that the colloid may be regarded as dispersed in the sand. The gravel content and the presence of stones, of greater than gravel size, also favor rill formation. We have then in the surface soil most favorable conditions for erosion. The contrast with the erosion ratios of the B horizon can at once be ascribed in part to the difference in suspension percentage. Although the numerical value is slightly greater in the B horizon than in the A horizon, it is actually less than one-seventh of the clay content. To what extent this low suspension percentage is due to structure is not known, but the clay is brittle, and the soil is not readily penetrated by water by reason of the high clay content. We have, therefore, in this soil the conditions for gully erosion of the V-shaped type. Also, as in the Vernon soil, there is special susceptibility to damage through erosion since the colloid content of the surface soil is low.

Taken as a whole, the soils of the erosion stations offer a very interesting variety of physical properties and consequent erosional characteristics. Continued study of these will throw much additional light on the conditions which determine erosional behavior. It is unfortunate for this purpose that the station soils do not offer a more varied assortment of soil classes and do not present examples of more soil groups of widely divergent character.

Throughout the study of these profiles the bearing of structural relations on the erosional behavior of the soil has impressed itself on the writers. At present the expressions of variations in structure are so lacking in quantitative significance as to render hopeless any attempt to evaluate their relation to the other influences which affect erosional behavior. The study of this phase of the subject will amply reward the investigator who is able to develop a satisfactory method of approach.

CHEMICAL COMPOSITION OF THE SOILS

The complete chemical analyses of the whole soil, which are given in Table 2, are perhaps less significant of erosional relations than the physical data and the colloid data given in Tables 1 and 3. They are recorded for the purpose of presenting all possible chemical data on the soils. Without these analyses of the soils the chemical analyses of the colloids and the mechanical analyses of the soils do not present a complete picture of the genetic and classification relations of the soils on which the erosion stations are located. A discussion of these relations is necessarily deferred until the colloid analyses have been presented.

TABLE 2.—Chemical analyses of typical profiles of erosion-station soils

Sample No.	Soil type	Depth	Station	SiO ₂	TiO ₂	Fe ₂ O ₃	Al ₂ O ₃	MnO	CaO	MgO	K ₂ O	Na ₂ O	P ₂ O ₅	SO ₃	Ignition loss	Total	N ₂	CO ₂ from carbonates	Organic matter	Ratio of organic matter to nitrogen
6096	Houston black clay. ¹	0-3	Temple, Tex.	P. d. 24.74	P. d. 0.34	P. d. 2.68	P. d. 6.09	P. d. 0.03	P. d. 32.81	P. d. 1.23	P. d. 0.65	P. d. 0.21	P. d. 0.34	P. d. 0.31	P. d. 30.30	P. d. 100.33	P. d. 0.18	P. d. 25.09	P. d. 2.94	16.3
6097	do	14-20	do	22.80	.32	2.84	6.98	.05	34.34	1.13	.50	.27	.38	.25	30.52	100.34	.11	23.82	1.88	17.1
6098	do	24-36	do	19.91	.32	2.65	6.08	.05	37.25	.95	.48	.19	.40	.25	31.72	100.23	.06	29.16	1.10	15.3
6099	do	36-50	do	13.17	.24	2.55	4.48	.04	42.52	.94	.39	.29	.44	.28	34.90	100.24	.04	33.88	.51	12.8
6678	Kirvin fine sandy loam. ²	0-12	Tyler, Tex.	91.03	.49	3.76	2.06	.02	.18	.15	.32	.06	.07	.08	1.09	100.50	.04	.00	.54	13.5
6679	do	12-24	do	61.89	.57	9.95	18.15	.008	.16	.48	.61	.10	.13	.13	7.45	99.53	.05	.00	.81	16.2
6680	do	24-51	do	69.90	.62	7.55	15.51	.006	.30	.40	.51	.10	.10	.16	5.21	100.27	.02	.00	.24	12.0
6681	do	51-63	do	80.06	.57	4.98	10.29	.008	.08	.34	.35	.00	.07	.12	3.28	100.15	.01	.00	.14	14.0
6682	do	63-75	do	91.65	.26	3.38	2.98	.003	.10	.14	.46	.00	.04	.11	1.13	100.25	.01	.00	.05	5.0
6718	Vernon fine sandy loam. ³	0-3	Guthrie, Okla.	90.81	.25	1.68	3.42	.07	.10	.31	.70	.10	.06	.12	2.34	100.06	.08	.00	1.81	22.6
6719	do	3-10	do	90.28	.40	1.76	4.14	.05	.36	.42	.60	.06	.05	.07	1.40	100.13	.03	.00	.62	20.7
6720	do	10-27	do	83.06	.44	3.92	7.70	.06	.36	.66	.99	.15	.05	.07	2.32	100.67	.04	.00	.63	15.7
6721	do	27-58	do	80.32	.76	2.60	10.35	.018	.28	.61	1.33	.26	.08	.04	2.61	99.51	.02	.00	.28	14.0
6787	Shelby silt loam. ²	0-7	Bethany, Mo.	75.91	.62	3.95	9.13	.02	.62	.63	1.50	1.72	.29	.23	5.42	100.24	.16	.02	3.23	20.2
6798	do	8-12	do	66.54	.63	6.45	14.33	.04	.95	1.14	1.38	1.41	.30	.30	6.80	100.27	.11	.01	2.17	19.7
6799	do	12-20	do	68.75	.71	6.03	14.05	.03	1.06	1.16	1.38	1.55	.12	.17	5.24	100.25	.09	.07	1.59	17.7
6800	do	20-24	do	68.25	.64	6.39	13.62	.03	1.64	1.17	1.47	1.64	.44	.11	5.03	100.43	.07	.32	.82	11.7
6801	do	24-43	do	65.12	.54	4.33	10.30	.06	7.05	1.15	1.39	2.03	.45	.16	7.67	100.30	.03	5.05	.27	8.0
6802	do	43-60	do	65.84	.55	4.64	10.22	.03	6.74	1.03	1.38	1.63	.30	.17	7.41	99.95	.02	4.85	.14	7.0
6802A	Shelby silt loam. ² (sand pocket).	4 feet.	do	71.09	.44	5.30	8.56	.05	4.34	1.57	1.43	1.75	.38	.11	5.37	100.37	.02	3.24	.18	9.0
6802B	Shelby silt loam. ²	60-84	do	66.65	.62	6.52	9.95	.04	5.20	1.22	1.67	1.55	.46	.14	6.00	100.12	.02	4.08	.07	3.5
6842	Colby silty clay loam. ⁴	0-10	Hays, Kans.	68.50	.62	3.52	11.70	.07	4.30	1.11	2.58	.98	.16	.14	6.49	100.17	.15	2.98	2.82	18.8
6843	do	10-20	do	62.92	.53	2.40	11.55	.06	8.22	1.09	2.27	.90	.15	.14	9.63	99.86	.07	6.07	1.11	15.9
6844	do	20-33	do	59.76	.49	2.64	11.00	.06	10.54	1.17	1.87	1.02	.14	.14	10.75	99.55	.04	7.55	.65	16.2
6845	do	33-47	do	59.30	.53	2.64	11.35	.05	11.08	1.19	2.23	1.08	.19	.15	10.30	100.09	.03	8.27	.32	10.7
6846	do	47-60	do	61.50	.53	3.04	12.35	.06	10.00	1.25	2.27	1.17	.16	.14	8.60	101.07	.03	7.32	.13	4.3
6847	do	60-72	do	61.20	.53	3.52	10.06	.06	10.80	1.15	2.38	.87	.17	.14	9.53	100.41	.03	7.90	.14	4.6
6977	Cecil sandy clay loam. ¹	0-6	Statesville, N. C.	75.06	1.24	4.16	10.80	.21	.32	.36	.61	.04	.12	.10	6.84	99.73	.09	.00	3.21	35.7
6978	do	6-32	do	61.12	1.33	9.76	19.56	.06	.28	.29	.59	.03	.14	.11	7.30	100.57	.04	.00	.45	11.3
6979	do	32-60	do	57.32	1.51	11.20	22.16	.06	.26	.28	.43	.00	.13	.17	7.27	100.79	.04	.00	.34	8.5
8069	Palouse silt loam	0-20	Pullman, Wash.	66.15	.85	5.42	14.69	.15	1.77	.76	2.34	1.93	.28	.03	5.22	99.59	.13	.00	2.18	16.7
8070	do	20-33	do	65.40	.82	5.65	15.90	.15	1.61	.95	2.06	1.76	.30	.02	4.96	99.58	.12	.00	.96	8.0
8071	do	33-62	do	66.10	.82	5.73	16.01	.15	1.65	1.04	2.06	1.80	.16	.02	4.43	99.97	.05	.00	.46	9.2
8072	do	62-75	do	66.90	.82	5.63	15.79	.16	1.79	.93	2.07	1.81	.16	.00	3.85	99.91	.04	.00	.36	9.0

8073	do	75-84	do	67.10	.82	5.70	15.71	.16	1.53	1.03	2.10	1.85	.17	.00	3.71	100.23	.03	.00	.21	9.0
8736	Marshall silt loam.	0-13	Clarinda, Iowa	70.70	.60	4.10	12.44	.12	.89	.78	2.16	1.21	.22	.03	5.57	100.26	.19	.00	3.22	17.0
8737	do	13-24	do	69.85	.73	4.35	13.42	.14	.91	1.00	2.12	1.01	.16	.12	6.21	100.03	.13	.00	2.29	17.0
8738	do	24-45	do	72.60	.70	3.92	13.07	.12	.98	.72	2.05	1.03	.14	.08	4.40	99.81	.07	.00	.98	13.7
8739	do	45-71	do	78.75	.65	2.94	10.23	.10	.83	.64	1.82	1.03	.13	.06	2.35	100.05	.06	.00	.40	7.7

¹ CO₂ time factor of 0.471.

Determinations by J. G. Smith.

¹ Determinations by G. J. Hough.

Aside from this major purpose, these analyses offer certain items of information not shown by any of the other data. These will be summarized, but before doing so two items regarding the analyses should be noted. These have reference to the organic-matter and carbon-dioxide determinations.

The organic matter was determined by combustion, using the conventional factor of 0.471 to convert carbon dioxide percentages to organic matter. They are therefore subject to the inaccuracies inherent in this factor. Carbon dioxide from carbonates was determined only in those horizons which gave qualitative evidence of the presence of carbonates. Consequently, a number of profiles are shown as having no carbonates when undoubtedly traces would have been shown to be present under the more exact procedure described by Alexander and Byers.*

The discussion of the chemical analyses of these soils as here presented is admittedly brief, but the attempt has been to eliminate from the discussion those items which must necessarily be repeated in a discussion of the colloids of these soils. In discussing the chemical analyses of the colloids, constant reference will be made to the chemical analyses of the soils as well as to the mechanical analyses.

Percentages of calcium carbonate show considerable variation in the different types of soil. The samples of the Kirvin, Vernon, Cecil, Palouse, and Marshall soils contain no carbonates, or, at the most, but traces. The lower layers of the Shelby soil and the entire profile of the Colby are highly calcareous. On the basis of percentages of CO_2 and CaO , the surface soil of the Houston soil contains 57 per cent of calcium carbonate, and the deepest layer of the Houston contains 75 per cent. Such high percentages of calcium carbonate profoundly affect the physical as well as the chemical properties of the soil. Where the entire soil exhibits such unusual characteristics of composition as does the Houston, the soil analysis becomes particularly informative.

The chemical analyses show that the Shelby, Colby, Palouse, and Marshall soils are particularly rich in potash, not only in the surface soil but throughout the profile. The potash content of the Houston soil decreases with depth, whereas the Vernon shows an increase in potash below a depth of 10 inches. The Kirvin and Cecil also show an increased percentage of K_2O in the B horizon. These increases are found to correspond with increases in the clay content of the soils as shown by the mechanical analyses.

The percentages of P_2O_5 in general vary but little for each profile. A relative deficiency is noted in the Shelby soil between depths of 12 and 20 inches. The Marshall, Cecil, and Palouse soils are noticeably richer in phosphorus in the upper horizons, but the lower horizons are by no means deficient in this essential plant-food element.

Values for the organic matter throughout each profile show sharp decreases at the lower depths, but the depth at which these decreases occur varies in each soil type. The Houston, Shelby, Colby, Palouse, and Marshall soils all maintain excellent percentages of organic matter to a depth of 20 or more inches. The organic matter of the

* ALEXANDER, L. T., and BYERS, H. G. A CRITICAL LABORATORY REVIEW OF METHODS OF DETERMINING ORGANIC MATTER AND CARBONATES IN SOILS. U. S. Dept. Agr. Tech. Bul. 317. (In press.)

Vernon and Cecil soils is largely concentrated in the surface 6 inches of soil. The Kirvin soil, which contains little organic matter at any depth, shows a higher percentage in the heavy clay B horizon than it does in the sandy surface soil. In general, the values for nitrogen parallel the values for organic matter throughout each profile.

In the last column of Table 2 are given the organic matter-nitrogen ratios for the profile of each soil. It is to be noted that there is no constant value shown, either as between the profiles or in relation to depth. Only in the Shelby soil is there a close approach to the conventional ratio of 20. The trend shows a decrease in the ratio with increasing depth. This fact for these soils is in accord with the data presented by Leighty and Shorey (11) and by McLean (14) and with the as yet unpublished data presented by Russell at the meeting of the American Society of Agronomy in November, 1931. The significance of these relations to erosion is not clear but may become evident when adequate field data are available.

So far as the chemical components of fertility are concerned, it appears that in the removal of the surface soil by erosion the most severe result will be a loss of nitrogen and organic matter. The potash and phosphorus content are, comparatively, high enough in the lower horizons to furnish a basis for the belief that for these soils, even though badly eroded, rehabilitation can be accomplished through the laborious process of building up reserves of organic matter and nitrogen. But the assumption must not be made that the potash and phosphorus content of the lower horizons is as available as that of the surface soil. These constituents become available slowly by weathering and by the action of soil bacteria in the presence of organic matter.

CHEMICAL COMPOSITION OF THE COLLOIDS

The erosion stations are established primarily for the purpose of determining the amount, causes, and means of control of erosion. However, in the course and prosecution of these studies much information will be obtained which concerns the properties and utilization of the various soils. Since the physical properties of a soil are determined, to a large extent, by the type of colloid it contains, and since erosional behavior is directly dependent on these physical properties, a careful study of the colloids of these soils has been made.

The colloids, except those of the two lower layers of the Cecil profile, were extracted without the use of any dispersing agent. To extract these colloids, sufficient ammonia was added to make the dispersed suspension approximately neutral to phenolphthalein. The dispersion was repeated from three to seven times until the yield of colloid by centrifuging was materially decreased. The "percentage of total colloid" extracted is the fraction obtained of the amount shown to be present by mechanical analysis. It is not to be expected that in any case the extracted colloid would reach 100 per cent, since the particle size limit of the extracted colloid is 1 micron and the mechanical analyses include particles up to 2 microns. The quantities obtained ranged between the values of 80 per cent for the third layer of Shelby silt loam to 42 per cent for the surface layer of Colby silty clay loam. As applied to the total colloid, the validity of the analytical data rests on the assumption that the extracted colloid is essentially the same as that not extracted. Brown

and Byers⁵ have shown that essential differences do exist between the easily extractable and difficultly extractable parts of a soil colloid. However, their findings do not invalidate the above assumption, since by their methods the difficultly extractable part represents only a small fraction of the total colloid.

In all the colloids the organic matter was determined by repeated treatment with hydrogen peroxide. The values reported are therefore slightly low, but they represent the relative quantities of similar material in these profiles.

The carbon dioxide reported was determined by the use of the apparatus developed by Alexander and Byers⁶ details of which are being prepared for publication. Data obtained with this apparatus indicate the small relative quantities of carbon dioxide present in colloids which are ordinarily classed as carbonate free or non-calcareous.

The colloids from the soils selected show a very wide range in chemical composition. In fact two maxima for American soil colloids are shown, the 0.90 per cent MnO for the Vernon fine sandy loam colloid, and the 15.1 per cent CaCO₃ (equivalent to 6.69 per cent CO₂) for the Houston black clay colloid (24).

In general, the analyses of the colloids of these soils show the usual relationships to the complete analyses of the soils themselves. The silica is lower and the iron and alumina are higher in the colloid fraction. The apparent exception in the Houston colloid is due to the extremely large calcium carbonate content of the soil, only a relatively small part of which appears in the colloid. A much larger relative amount of calcium carbonate is found in the Colby colloid.

It seems probable that the colloidal carbonate material is due to the solution of the carbonate as calcium bicarbonate during wet periods and its redeposition in a state of very fine subdivision on drying. The colloidal carbonate appears in all layers of both Houston clay and Colby silty clay loam. In Shelby silt loam it appears in more than traces only in the lower horizons.

In horizons which reveal only traces of carbonates the usual relation is an increase in the calcium of the colloid as compared with that of the soil. This indicates that a large part of the calcium is colloiddally held. The same statement holds for all horizons of all soils for magnesium. The percentage concentration is greater for magnesium than for calcium. The difference is due primarily to the more extensive leaching of calcium.

The same tendency toward concentration in the colloid fraction is shown by the organic matter except in the surface layer of the Cecil profile. The soil sample from this horizon contains a large amount of undecomposed organic matter. A less definite trend toward concentration in the colloid fraction is shown by manganese, titanium, and phosphorus. No trend toward concentration in the colloid fraction is to be observed for sodium or sulphur. A relative deficiency in the proportion of potash-bearing material in the profiles of Houston clay, Kirvin fine sandy loam, and Vernon fine sandy loam is shown by the markedly increased percentages in the

⁵ BROWN, I. C., and BYERS, H. G. THE FRACTIONATION, COMPOSITION, AND HYPOTHETICAL CONSTITUTION OF CERTAIN COLLOIDS DERIVED FROM THE GREAT SOIL GROUPS. U. S. Dept. Agr. Tech. Bul. 319. (In press.)

⁶ ALEXANDER, L. T., and BYERS, H. G. Op. cit. (See footnote 4.)

colloids, as compared to the soils. This may partly, and perhaps wholly, be attributed to the presence of quartz sands in the last two soils and to the large content of calcium carbonate in Houston clay.

Further consideration of the colloid analyses shows that two widely divergent types of colloid are included. This is indicated by the silica-sesquioxide ratios and more emphatically by the silica-alumina ratios. Representative of one extreme is the colloid from Cecil sandy clay loam which is distinctly lateritic, and representative of the other is the colloid of Colby silty clay loam. The former has a silica-alumina ratio of 1.65 in the surface layer and the latter a ratio of 4.25.

Of the other colloids, those of the Houston, Marshall, Shelby, and Palouse soils have silica-alumina ratios of well above 3 throughout the profile. The Vernon colloid also appears to belong in this general group, although the silica-alumina ratio drops below 3 for the subsoil colloids.

With the exception of the Vernon, the soils of this group contain large quantities of colloidal material, and the type of colloid found in them is such as to make the soils plastic and sticky when wet and also highly impermeable to water. The fate of incident water is thus affected by the type and quantity of colloid in the soil. The effects are of course modified, as in the Houston and Colby soils, when the soils contain calcium carbonate or other flocculating material.

The only colloid which may be classed with the Cecil is the Kirvin. Although there is a good deal of difference between the two when judged by the ratios of the major constituents, the classification is justified on other data. Both colloids are red, contain much less exchangeable base than any other of the colloids under discussion, and the soils they represent are markedly acid in reaction. The Vernon colloid is also red, but in this connection it must be remembered that the Vernon soil is derived from the red shales, and color indications may, therefore, in the Vernon colloid, be deceptive. The relatively unweathered state of the Vernon soil is indicated not alone by the high silica-alumina ratio of its colloid but by the high content of exchangeable bases as well. The Vernon profile is not so acid in any horizon as the least acid of the horizons of either the Kirvin or Cecil soils. (Table 1.) To establish more completely the proper chemical classification, colloids from the B horizon of each of these soils were submitted to S. B. Hendricks for X-ray examination (9). He submits the following report:

Samples Nos. 6097, 6799, 6843, 8070, 8737 (Houston, Shelby, Colby, Palouse, Marshall) are Ordovician bentonite (montmorillonite quartz). Nos. 6679, 6720, 6978 (Kirvin, Vernon, Cecil) are more complicated than ordinary clay mineral photographs, and are evidently mixtures. Of these, No. 6720 (Vernon) is predominantly Ordovician bentonite. The other two (Kirvin and Cecil) are mixtures of a clay mineral with some other substance or substances.

Any relationships shown by the inorganic composition of the colloid are also modified by the quantity, character, and distribution of the organic matter present. Such data can not be given quantitative expression at present, but it is of interest to point out that in the two calcareous soils which have organic contents not widely at variance in the surface horizons, the distribution within the profiles is

quite different. In the Shelby and Palouse profiles there is a marked difference in the organic content of the surface layers but an equally marked similarity of distribution.

The 22d column of Table 3 gives the organic matter-nitrogen ratios for the extracted colloids. In this case the organic matter was determined by the hydrogen-peroxide method, and it is known that not all of the organic matter is so removed (22). The ratios are therefore numerically smaller than they would be had the combustion method been employed. The outstanding relation shown by these ratios is the uniform decrease in ratio with depth. This relation may be interpreted to mean that the organic matter at lower levels has been longer subject to the processes of decay and that the nonnitrogenous material decays more readily than nitrogenous bodies. That the nonnitrogenous matter is oxidized more readily by hydrogen peroxide has been shown by McLean (15, 16). This assumption is valid only so far as we assume that the organic matter at lower levels has been carried down from above. This latter assumption is not wholly true in any case and perhaps to but a limited degree in the soils not subject to podzolization. In the colloids, as in the soils, the relation between the composition of the organic matter and the erosional behavior must await fuller knowledge of data both on field behavior and the variation of composition of the organic matter.

The erosional behavior of the Kirvin, Vernon, and Cecil soils is influenced by the small content of colloid in the surface layers (Table 1), and this influence tends to obscure the effects consequent on colloid composition in these horizons. The iron-oxide content of the two colloids of highest apparent weathering, the Kirvin and the Cecil, is notably high, as shown by silica-iron oxide ratios. The data at hand do not clearly indicate what erosional relations exist between sesquioxide colloids and aluminous silicates, but it is in general true that laterites and lateritic soils are not readily eroded. Of the soils under discussion, those which contain notable quantities of ferric oxide in their colloids undoubtedly have their erosional relations influenced by its presence.

Detailed examination of the profiles of these series leads to some observations which have a bearing not only on erosional behavior but also on general soil relationships. As already mentioned, the Houston soil has a very high carbonate content throughout the profile. A considerable fraction of this carbonate finds its way into the colloidal fraction in each of the successive layers. The lower layers are much richer in colloidal carbonate than the surface layers, a condition which is to be expected in a region of high rainfall, and the same general relation holds for the total carbonate content of the soil.

Except for variations in the amounts of organic matter and carbonates, the colloid of the Houston soil is essentially the same throughout the profile. This constancy is emphasized by the ratios of the major constituents as given in Table 3. Such minor variations as appear are to be found in the relative quantities of iron oxide, as shown by the silica-iron oxide and iron oxide-alumina ratios. The silica-alumina ratios are practically identical for the complete profile. This constancy of composition of the colloids of the chernozem and prairie soils has been noted by Byers and Anderson (3). Such variation as may occur is a measure of the extent to which podzolization or laterization has occurred.

TABLE 3.—Chemical analyses of colloids in typical profiles of the erosion-station soils

Sample No.	Soil type	Depth	Station	Colloid extracted	SiO ₂	TiO ₂	Fe ₂ O ₃	Al ₂ O ₃	MnO	CaO	MgO	K ₂ O	Na ₂ O	P ₂ O ₅
		Inches		Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
6096	Houston black clay	0-3	Temple, Tex.	55	43.55	0.53	5.92	18.94	0.07	9.28	2.50	1.13	0.27	0.22
6097	do.	14-20	do.	55	41.72	.54	5.92	18.08	.07	11.73	2.41	1.11	.27	.21
6098	do.	24-36	do.	57	42.25	.54	5.95	18.33	.09	12.35	2.25	.99	.25	.22
6099	do.	36-50	do.	48	43.30	.58	6.25	18.53	.07	12.00	2.63	1.07	.27	.22
6078	Kirvin fine sandy loam	0-12	Tyler, Tex.	70	41.97	.90	14.74	25.96	.10	.64	.46	.89	.48	.30
6079	do.	12-24	do.	77	39.95	.77	14.37	29.78	.01	.35	.69	.84	.34	.13
6080	do.	24-51	do.	60	42.19	.81	12.72	29.63	.01	.25	.81	.70	.36	.16
6081	do.	51-63	do.	55	44.30	.81	11.07	30.16	.01	.19	.78	.70	.39	.15
6082	do.	63-75	do.	46	41.10	.79	15.96	28.30	Trace.	.04	.65	.64	.31	.17
6718	Vernon fine sandy loam ¹	0-3	Guthrie, Okla.	46	42.40	1.74	9.87	20.90	.90	1.30	1.80	2.13	.67	.39
6719	do.	3-10	do.	72	45.03	1.90	10.70	24.44	.25	.79	1.99	2.25	.90	.28
6720	do.	10-27	do.	79	45.10	1.44	10.53	25.00	.15	.68	2.08	2.34	.70	.15
6721	do.	27-58	do.	63	46.99	.84	9.55	27.71	.05	.66	2.62	2.41	.93	.10
6797	Shelby silt loam ¹	0-7	Bethany, Mo.	46	45.89	.67	9.23	23.51	.07	1.31	1.37	1.19	.21	.30
6798	do.	8-12	do.	73	47.49	.67	9.99	24.41	.06	1.28	1.98	1.12	.20	.12
6799	do.	12-20	do.	81	48.29	.68	10.31	2.490	.08	1.36	2.02	1.26	.29	.12
6800	do.	20-24	do.	75	47.98	.71	11.14	24.24	.09	1.62	2.17	1.31	.38	.16
6801	do.	24-48	do.	73	48.48	.74	11.49	23.03	.11	2.15	2.06	1.62	.44	.16
6802	do.	48-60	do.	53	48.26	.75	11.84	23.12	.08	2.34	2.06	1.66	.41	.16
6802A	Shelby silt loam (sand pocket)	4 ft.	do.	67	47.20	.49	11.11	26.12	.11	1.80	1.93	1.80	.41	.20
6802B	Shelby silt loam ¹	60-84	do.	60	49.62	.72	14.83	19.43	.10	2.22	2.12	1.83	.42	.16
6842	Colby silty clay loam	2-10	Hays, Kans.	42	49.31	.52	7.10	19.67	.11	4.35	2.71	2.30	.28	.15
6843	do.	10-20	do.	52	46.95	.49	6.76	19.03	.11	7.68	2.77	2.09	.17	.14
6844	do.	20-33	do.	55	48.60	.49	6.96	19.23	.12	7.28	3.07	2.11	.26	.14
6845	do.	33-47	do.	57	48.00	.50	6.28	19.09	.11	8.83	3.14	2.10	.37	.14
6846	do.	47-60	do.	62	49.00	.48	6.72	19.00	.11	7.40	3.21	2.03	.23	.14
6847	do.	60-72	do.	43	47.20	.46	6.55	18.31	.10	10.23	3.15	2.11	.24	.13
6977	Cecil sandy clay loam	0-5	Statesville, N. C.	59	32.81	1.56	12.57	33.68	.43	.66	.81	.57	.24	.32
6978	do.	6-32	do.	60	33.35	1.49	12.20	36.44	.14	.47	.63	.47	.17	.26
6979	do.	32-60	do.	70	35.75	1.40	16.17	32.22	.10	.47	.34	.35	.19	.31
8009	Palouse silt loam	0-20	Pullman, Wash.	60	44.86	.82	11.13	23.59	.18	1.59	2.28	2.12	.32	.36
8070	do.	20-33	do.	77	45.73	.89	12.85	23.43	.15	1.60	2.33	1.38	.43	.25
8071	do.	33-62	do.	78	46.00	.86	12.20	24.07	.14	1.53	2.32	1.64	.30	.17
8072	do.	62-75	do.	89	47.86	.76	12.53	23.56	.14	1.67	2.48	1.17	.22	.20
8073	do.	75-84	do.	79	48.00	.86	12.50	23.26	.14	1.69	2.46	1.46	.41	.20
8736	Marshall silt loam	0-13	Clarinda, Iowa	63	46.90	.60	9.10	21.55	.16	1.17	2.35	2.14	.09	.29
8737	do.	13-24	do.	66	47.69	.62	9.42	22.10	.15	1.11	2.53	1.86	.09	.22
8738	do.	24-45	do.	69	49.72	.65	9.86	22.63	.13	1.09	2.48	1.58	.16	.18
8739	do.	45-71	do.	65	49.30	.65	9.60	22.41	.13	1.02	2.31	1.69	.08	.20

¹ Analyses of these soils are averages of duplicate samples.

TABLE 3.—Chemical analyses of colloids in typical profiles of the erosion-station soils—Continued

Sample No.	Soil type	Depth	Station	SO ₂	Ignition loss	Total	Nitrogen	CO ₂ from carbonates	Organic matter	Ratio of organic matter to nitrogen in colloid	Mols SiO ₂ /Fe ₂ O ₃	Mols SiO ₂ /Al ₂ O ₃	Mols Fe ₂ O ₃ /Al ₂ O ₃	Mols SiO ₂ /R ₂ O ₃
		Inches		Per cent	Per cent	Per cent	Per cent	Per cent	Per cent					
6006	Houston black clay	0-3	Temple, Tex.	0.19	18.09	100.69	0.38	4.91	3.86	10.2	19.56	3.90	0.200	3.26
6097	do	14-20	do	.11	18.25	100.42	.22	6.16	3.13	14.2	18.75	3.92	.209	3.24
6098	do	24-36	do	.11	16.85	100.18	.18	7.05	1.67	9.3	18.88	3.91	.207	3.25
6099	do	36-50	do	.09	16.10	101.11	.14	6.69	1.12	8.0	18.45	3.97	.216	3.25
6678	Kirvin fine sandy loam	0-12	Tyler, Tex.	.15	13.28	99.87	.21	.95	2.52	12.0	7.58	2.75	.383	2.02
6679	do	12-24	do	.09	12.14	99.51	.14	.07	.82	5.8	7.39	2.28	.308	1.74
6680	do	24-51	do	.11	11.57	99.32	.11	.02	.35	3.2	8.81	2.42	.274	1.69
6681	do	51-63	do	.09	10.89	99.54	.09	.02	.24	2.7	10.61	2.48	.264	2.03
6682	do	63-75	do	.17	11.29	99.42	.07	.01	.26	3.7	6.94	2.47	.360	1.80
6718	Vernon fine sandy loam ¹	0-3	Guthrie, Okla.	.19	18.05	100.43	.70	.06	8.55	12.2	11.40	3.45	.279	2.44
6719	do	3-10	do	.09	11.45	100.07	.21	.04	2.02	9.6	11.20	3.12	.269	2.34
6720	do	10-27	do	.08	10.62	99.87	.15	.02	.95	6.3	11.38	2.94	.221	2.35
6721	do	27-58	do	.10	8.66	100.62	.10	.00	.25	2.5	13.07	2.88	.221	2.35
6797	Shelby silt loam ¹	0-7	Bethany, Mo.	.14	16.34	100.73	.37	.05	5.90	16.1	13.22	3.31	.252	2.65
6798	do	8-12	do	.09	13.24	100.65	.19	.03	2.81	13.7	11.42	3.30	.262	2.62
6799	do	12-20	do	.12	11.81	100.95	.16	.01	2.07	12.9	11.18	3.28	.265	2.60
6800	do	20-24	do	.11	10.75	100.62	.11	.01	1.34	12.2	11.47	3.36	.293	2.60
6801	do	24-48	do	.10	9.76	100.14	.08	.17	.64	8.0	11.22	3.57	.319	2.71
6802	do	48-60	do	.10	9.74	100.30	.07	.40	.56	8.0	10.84	3.54	.326	2.67
6802A	Shelby silt loam (sand pocket)	4 ft.	do	.10	0.03	100.62	.06	.43	.45	7.5	8.89	4.33	.487	2.91
6802B	Shelby silt loam ¹	60-84	do	.09	9.03	100.05	.30	1.85	4.07	13.6	19.41	4.25	.230	3.45
6842	Colby silty clay loam	2-10	Hays, Kans.	.14	13.41	100.05	.17	3.74	1.79	10.5	18.47	4.18	.227	3.41
6843	do	10-20	do	.13	13.69	100.02	.17	3.85	.62	6.9	18.55	4.20	.231	3.47
6844	do	20-33	do	.09	12.12	100.77	.09	4.65	.53	5.9	20.32	4.27	.210	3.52
6845	do	33-47	do	.09	11.57	99.98	.06	4.23	.23	3.8	19.39	4.38	.326	3.57
6846	do	47-60	do	.10	12.25	100.83	.06	5.11	.21	3.5	18.17	4.37	.328	3.56
6847	do	60-72	do	.08	16.95	100.68	.15	.05	2.30	15.3	6.94	1.65	.233	1.34
6977	Cecil sandy clay loam	0-6	Statesville, N. C.	.04	14.25	99.91	.07	.04	.27	3.9	7.27	1.69	.233	1.28
6978	do	6-32	do	.04	12.94	100.28	.06	.06	.09	1.5	7.35	1.88	.256	1.43
6979	do	32-60	do	.15	13.36	100.74	.32	.04	3.81	11.9	10.92	3.23	.301	2.48
8069	Palouse silt loam	0-20	Pullman, Wash.	.11	11.25	100.40	.15	.00	1.69	11.3	9.52	3.31	.350	2.45
8070	do	20-33	do	.09	10.86	100.18	.12	.00	1.00	8.3	10.02	3.25	.324	2.45
8071	do	33-62	do	.06	9.93	100.58	.09	.00	.62	5.8	10.15	3.45	.339	2.57
8072	do	62-75	do	.06	9.82	100.88	.10	.00	.52	5.2	10.21	3.50	.343	2.61
8073	do	75-84	do	.35	16.03	100.73	.36	.02	6.47	18.0	13.68	3.69	.270	2.91
8736	Marshall silt loam	0-13	Clarinda, Iowa	.29	14.28	100.36	.27	.01	4.81	17.8	13.45	3.66	.272	2.88
8737	do	13-24	do	.24	11.85	100.57	.19	.02	2.36	12.4	13.40	3.72	.278	2.91
8738	do	24-45	do	.24	11.85	100.57	.19	.02	2.36	12.4	13.40	3.72	.278	2.91
8739	do	45-71	do	.24	11.18	99.81	.22	.01	2.57	11.7	13.65	3.57	.262	2.83

¹ Analyses of these soils are averages of duplicate samples.

Variations in the erosional behavior of the different layers of the Houston profile are obviously not due to variations in the type of colloid, and causes for such variation must be sought elsewhere. The colloidal content, as shown by the mechanical analyses, varies to some degree, though even in this respect Houston black clay is remarkably constant. It is apparent, therefore, that this soil, in contrast with others to be discussed later, has suffered but little translocation of colloidal material. The several soil layers show considerable variation in organic matter, and this is undoubtedly responsible for the inversion of relative amounts of colloid in the first two layers, as shown by the water-adsorption method. Taken collectively, with other minor variations, the differences in amount of organic matter and calcium carbonate produce a very evident variation in the profile when examined in the field. The change is most marked at a depth of about 36 inches. However, the general constancy of texture of the soil and composition of the colloid may be considered a fairly satisfactory explanation of the fact that, in this soil, erosion is for the most part of the variety known as sheet erosion. Sheet erosion appears to be characteristic of other soils with uniform texture and colloid.

The erosion ratio given in Table 1 for the surface layer of Houston black clay, although low as compared with other soils, is still much higher than that for the layer lying below it. This lowering of the erosion ratio for the soil layer immediately below the surface soil is not confined to the Houston soil, but appears to be general in all soils. In the Houston soil the immediate cause is seen in the suspension percentage given in Table 1. The cause of this divergence, in turn, might be ascribed to the smaller quantity of colloidal carbonates in the surface soil. However, since the pH of the surface soil is the same as that of the layer immediately below it, there can scarcely be said to be a lower concentration of calcium ions; indeed, the greater quantity of organic matter would seem to call for an increased base content for the same pH.

It is a matter of observation that the surface part of the Houston soil, on drying, fractures into very small easily suspended particles, whereas the more slowly drying subsurface soil fractures into masses of larger size. The ease with which these small particles are transported or suspended presumably accounts for the high erosivity of the Houston soil, in spite of its low erosion ratio, and may account for differences in the suspension percentage. In this connection a laboratory observation is recorded. Whenever the thick suspension (from a Pasteur-Chamberland filter) of a series of colloids is evaporated to dryness on the steam bath, the tendency to fracture is most strikingly marked in those colloids of high organic matter. By application of this observation it is believed that the organic matter of the Houston soil is associated with the peculiar manner in which this soil disintegrates under field conditions. The physical effects of organic matter, the cementing properties of dissolved and reprecipitated calcium carbonate, together with the flocculating effect of the calcium ion, are held to be amply sufficient cause for the peculiar erosive characteristics of this soil.

Kirvin fine sandy loam offers in many respects a striking contrast to Houston clay in that the colloid content of the various horizons

is markedly variable. (Table 1.) The colloid composition is likewise unusually varied. The calcium, potassium, and phosphorus content of the colloid of the surface horizon are higher than in the B horizon colloid, differences which may be referred to the ash content of the vegetation. The pH value of the surface soil is correspondingly increased. The relative percentages are of course greatly modified in the whole soil by reason of the extreme textural changes in the various horizons. The manganese and organic matter are sharply concentrated in the colloid of horizon A. The combined water (ignition loss minus organic matter) of the colloid of the various horizons is approximately 11 per cent. The variations are roughly consistent with the variations in iron oxide content, as shown by the silica-iron oxide ratio. The silica-sesquioxide ratio when considered alone indicates a fair constancy of colloid composition. The average value of this ratio is 1.9, which approximates the theoretical value of 2.0 for kaolinite or halloysite. The iron oxide content is relatively high, and if the assumption is made that all the iron is present as free oxide, the silica-alumina ratio indicates a much higher silica content.

That the iron oxide content is at least partly free is indicated by the color of the organic-free colloid, which is bright red, and also by the change in the iron oxide-alumina ratio in the upper four strata. That free colloidal quartz is probably present in the colloid of the A horizon is indicated, though not proved, by the difference in the relative values of the iron oxide-alumina and the silica-iron oxide ratios, as well as by the slightly greater silica-alumina ratio in the surface horizon as compared with the second horizon. There has been no podzolization of the soils, and laterization, although indicated, has not progressed to any extent. In general, the relative changes in the various ratios tend to indicate an unrelated degree of weathering which may be the result of lateral leaching of the colloid. This is not improbable, in view of the marked changes in the texture of the different horizons of this soil.

Perhaps the most important inference to be drawn from the data for Kirvin fine sandy loam, as affecting erosion, is obtained through a consideration of the quantities of colloid fraction shown in the different layers. It is clear that the increase of colloid from 5.6 per cent in the 0 to 12 inch layer to 59.4 per cent in the 12 to 24 inch layer indicates removal of enormous quantities of colloid from the upper horizon, either by erosion or eluviation.

That the colloid percentage is highest in the B horizon shows clearly that eluviation has taken place. That the quantity of colloid so transferred is large is indicated by the decrease in colloid content as lower levels are reached. The effect of thus "sealing" the B horizon with colloid is not so marked in soils with colloids of low silica-sesquioxide ratio as in less weathered soil, but in a soil with so marked an alteration of texture as the Kirvin, the effect of this sealing on permeability must be great, and therefore must in turn affect the erosion of the surface soil.

Attention should also be called to the increased erosional characteristics of the lower strata of this soil as represented by the increase of very fine sand and decrease of colloid content. This is reflected in the increased erosion ratios of the lower layers. These in turn affect the character of erosional effects in flood periods when erosion

reaches the lower levels, with resultant gullying from the more rapid erosion of the deep-lying material. Gully formation in the Kirvin soil is strikingly marked.

Vernon fine sandy loam is similar to the Kirvin soil so far as the color of the organic-free colloid is concerned. There are, however, some very striking differences. The silica-alumina ratio is high, approaching that of unweathered soils. The base content and, by inference, the base-exchange capacity are also very greatly in excess of the usual values for red soils. Despite the red color of the colloid the iron content is not excessive, and its alteration in quantity relative to silica through the first 27 inches is but slight. Evidence of chemical fractionation of the colloid is shown by the alteration of the silica-alumina and iron oxide-alumina ratios. On the basis of the changes in composition shown by these ratios, such weathering as has occurred can not be classed as podzolic, and the high silica-alumina ratio precludes the possibility of extensive laterization.

The evidence of eluviation is not clearly marked, despite the marked increase of colloid in the B horizon, since in the C horizon the quantities of clay and colloid are equally great. The conclusion seems to be warranted that the relatively small quantity of colloid in the surface soil is due to a lateral selective erosion of the finer fractions of the soil. The coarser materials have eroded at a slower rate, but in summation the total erosion has been rather severe. In this connection it should be noted that this particular sample of Vernon soil does not contain a calcareous layer, although by reason of the general character and location of the soils of the Vernon series such a stratum would normally be present. In this soil, as in the Kirvin, gully formation is prevalent. The presence of a highly erosive substratum, as shown by the erosion ratio, again offers a satisfactory explanation of this type of erosion.

Shelby silt loam is a prairie soil, and the characteristics of its colloid are similar to those of the colloids derived from the Houston, Marshall, and Palouse soils, except that, unlike the Houston, it has only small quantities of carbonates which occur mainly in the colloids from the lower strata. Throughout the profile the colloids of this soil are very uniform, particularly in the upper 24 inches.⁷ They have the usual characteristics which accompany a high silica-sesquioxide ratio, are easily dispersable in water, and have a high base content and base-exchange capacity. When free from organic matter the colloids are light gray, which indicates that the iron is not present in the form of hydrated oxide.

The high silica-alumina ratio indicates the relatively unweathered condition of the colloid, and no evidence of podzolization is found in the iron oxide-alumina ratios. The amount of colloid present in the surface layer is approximately half that of the second layer between depths of 8 and 12 inches, which in turn is greater than the amount to be found in the 24 to 48 inch layer. This is taken to mean that the strata between 8 and 24 inches have been enriched by illuviation, but the relative deficiency of colloid in the surface layer also indicates that the topsoil has lost a part of its colloid in

⁷ In considering the relative values shown, it should also be noted that there is included in the profile the colloid (No. 6802A) obtained from a sand pocket. The inclusion of this sample indicates certain nonuniform conditions which are characteristic of the Shelby soil, but the sample is not properly a part of this particular profile.

the surface run-off water. The upward trend of the silica-alumina ratio at depths below 24 inches, together with a decreasing colloid content, serve to explain the increase with depth of the erosion ratio. This gradual increase of erosivity in the lower horizons results in the formation of broad U-shaped gullies when this soil is subjected to heavy rainfall. With more moderate rains, and by reason of its surface erosional characteristics, sheet erosion becomes prevalent in this type of soil.

Colby silt loam is a true chernozem, and its colloid possesses all the characteristics of this soil group. The colloid is practically constant in character throughout the profile and has the highest silica-sesquioxide and silica-alumina ratios of any of the soils covered in this investigation. The high values for these ratios are in accord with the results of the X-ray examination which showed the colloid to be of the montmorillonitic variety and in accord with the high base content of both colloid and soil. A summation of the evidence to be derived from the ratios of the major constituents shows markedly the unweathered condition of this soil. There is also only the slightest evidence of concentration of colloid in the second stratum at the expense of the surface soil. The differences in erosional characteristics shown by the different strata are not to be specifically ascribed to variations in the inorganic colloid or to alteration of textures, which are remarkably constant. The differences which do appear in the suspension percentage (Table 1) and in the moisture equivalent, which are reflected in the dispersion and erosion ratios, are to be attributed in part to alteration in structure. To what extent the structural differences are to be associated with the kind and quantity of organic matter is a question not answered by the data. Some of the differences between the surface layer and those beneath it are to be associated with differences in calcium carbonate content and to the slightly higher silt and lower clay content of the surface layer as compared with those of the soil immediately beneath it.

Cecil sandy clay loam is the only definitely lateritic soil on which an erosion station has been established. The silica-sesquioxide ratio is well below 1.5. If, however, we consider the silica-alumina ratio, it appears that if all free silica has been eliminated by solution, the degree of hydrolysis of the alumino-silica complex has not gone far beyond the halloysitic stage, the latter being assumed to have a ratio of 2. The lateritic characteristics of this soil may perhaps be attributed to its high content of iron oxide which is hydrated to a considerable degree, as shown by the difference between the ignition loss and the organic content.

The colloid is characterized by a low base content and base-exchange capacity and is in general typical of the series as determined by Holmes and Edgington (10). There is some indication of podzolization shown in the altering of the silica-iron oxide and iron oxide-alumina ratios, but the absence of a sample from the C horizon (below 60 inches) leaves some doubt as to the extent of podzolization of this particular profile. The transfer of colloidal material from the surface layer to lower strata, or its removal by erosion, is very marked, as shown by the percentages of this component which varies from 17.3 per cent in the 0 to 6 inch layer to

51.2 per cent in the 6 to 32 inch stratum. The percentage of colloid is nearly as high throughout the B horizon to a depth of 60 inches. From other samples of this same soil type, it is known that the C horizon is low in colloid.

Soils of this type are usually nonerosive in character, and this is indicated for the lower layers of this profile by the erosion ratios and also by the field data. The relative ease of erosion of the surface layer is due in large part to its low colloid content. The cultivation of corn and cotton on such a soil aggravates erosive conditions by destroying roots and leaf cover, which otherwise would bind and protect this noncoherent surface layer.

Palouse silt loam has the highest silt content of any of the station soils. When this is considered, along with the fact that it is not a weathered soil and that much of the area on which this soil is found is markedly rolling, it is realized that erosion is a serious problem despite the low rainfall of the region.

The silica-alumina ratio, as well as the X-ray examination, indicates that this soil has a colloid of the montmorillonitic type. The alteration of the silica-iron oxide and iron oxide-alumina ratios between the 0 to 20 inch and the 20 to 33 inch layers indicates that considerable podzolic effect accompanies whatever illuviation has taken place. The evidence of podzolization and the presence of as much as 24 per cent of colloid in the surface layers indicates that but little surface erosion has occurred in the profile sample. If such be the case, it would appear that the rainfall is so meager and at the same time so distributed that the natural grass cover of this soil type offers ample protection from the small run-off which occurs. However, the erosion ratio shows this soil to be decidedly erosive, and under cultivation severe erosion may be expected. The data from the station are not available to give a quantitative expression of this statement.

Marshall silt loam is a typical prairie soil and, as such, its colloid is characterized by uniformity throughout the profile. The silica-alumina ratio indicates a colloid of the montmorillonitic type and this is confirmed by the X-ray examination of this type reported by Hendricks and Fry (9), as well as by the examination made of this particular sample. As in Palouse silt loam, evidence of podzolization is slight but distinct; also, there is a large amount of colloid in the surface soil. Taken together they indicate the lack of surface erosion in this profile, owing no doubt to the excellent protection offered by the natural grass cover of the soil. Although not shown to be so erosive by the dispersion and erosion ratios, the character of this soil lends itself to easy erosion, as shown by the suspension percentage and by the percentage of total colloid extracted by centrifuging. The percentage of total colloid extracted is also high for other colloids of like type.

The erosion ratios which represent the Marshall profile are much more varied than might reasonably be anticipated in a soil so uniform in texture when so little variation in colloid is present. Chemically the most important differences in the profile are shown by the organic-matter percentage, both in the soil and in the colloid; yet the amounts bear no relative value to the suspension percentage or the

moisture equivalent, which, in turn, affect the dispersion and erosion ratios. The variations may be explained by attributing them in part to variations in soil structure, but this avoids rather than answers the question, unless causes are assigned to account for these structural differences. At present this can not be done. However, it is known that the erosion ratio is often lowest in the second soil layer and that usually this is in the zone of greatest compaction of the soil. In this respect Marshall silt loam is similar to the Houston, Shelby, and Colby soils included in this investigation. A decreasing amount of colloid in the two lower layers of the Marshall soil may, in the presence of a large percentage of silt, lower the cohesive property of the soil to an extent that would account for the increased erosivity of these strata. Whether these assumptions are correct or adequate the data at hand are not sufficient to determine. It will be of interest to learn from the field data, when assembled, whether the general relations indicated exist in fact.

PROPERTIES OF COMPOSITE PLOT SAMPLES

Composite samples of each tank plot at the erosion stations were obtained for the dual purpose of ascertaining the degree of uniformity of the soils over the area on which erosion data were to be collected and of furnishing a basis for comparison of such changes as may occur in these plots through varied cultural and other treatment. These samples were taken according to the following instructions:

* * * A composite sample, aggregating at least 1 pound in weight, should be taken for each of the several soil layers through the vertical section of each plot, to a depth of 48 inches, wherever this depth is attainable. To make the composite sample, the sampling should begin 5 feet from the lower end of each plot (in the middle), and extend up the slope, at 10-foot intervals, to the rear (or upper) end of the plot. A soil auger or core sampler (King sampler) should be used for taking these, and the same amount of soil should be taken from each layer, thus making a thoroughly representative plot composite.

The samples were transferred to glass jars in this laboratory, and the material remaining from this study will be carefully preserved for comparison with samples to be taken in the future, in order that the changes caused by erosion may be determined.

Composite samples of Marshall silt loam, from Clarinda, Iowa, and of Palouse silt loam, from Pullman, Wash., have not been included in this study because of the recent installation of these stations. The samples from the six stations from which samples were received were subjected to the following determinations: Colloid by water-vapor adsorption, moisture equivalent, dispersion ratio, and complete mechanical analysis. From the results of these determinations the colloid (by water-vapor adsorption)-moisture equivalent ratio and the erosion ratio were calculated. The average value of each determination for all the plots (except desurfaced plots) at each station was computed for each horizon,^s and the standard devi-

^s In the following discussion and tables the term "horizon" is used to designate the horizon, or layer, represented by the sample, regardless of whether the soil exhibits true horizontal characteristics.

ation and the coefficient of variability⁹ were calculated. The results of these determinations and calculations are shown in Table 4. For the purpose of comparison the same determinations on the profile samples as are shown in Table 1 are repeated.

The sites for the erosion stations were selected with great care, particularly in regard to securing a representative area of the soil type to be studied, and the location of the experimental plots on this area was carefully considered so that they would have as uniform slope and as uniform soil conditions as possible. The data in Table 4 show that, in general, the plots at each station are remarkably uniform in their characteristics. In many cases the differences between the value of the highest and the lowest determinations for any particular horizon are probably within the limits of experimental error. The greatest differences usually occur in the long or short plots,¹⁰ indicating that the greatest variations in soil characteristics occur along, rather than across, the slope.

The short plots on the Cecil soil (No. 12), Kirvin (No. 1), and Vernon (No. 1) are noticeably at variance with the rest of the plots in several of their properties. The long plot on the Shelby soil was divided and sampled in two parts, and it may readily be noted that the upper half (which extends up the slope beyond the main body of the plots) is much heavier in texture and shows greater variation in its other properties than the rest of the plots.

The surface soil of the desurfaced¹¹ plots (listed in Table 4 as the second horizon) does not correspond to the second horizon in the Houston, Cecil, and Vernon soils, but in the others the agreement is quite close. This is no doubt due to the fact that the plot was not desurfaced to the same depth as the surface horizon of the profile sample.

The differences between the profile samples and the average values of the composite samples are greater than was expected. However, in most cases, the greatest differences can be ascribed to differences in depths of sampling. For example, the first horizon of the Cecil profile sample was taken to a depth of 6 inches, whereas the composite samples were taken to a depth of 7 inches. Since the B horizon of the Cecil soil is very heavy in texture, as compared with the A horizon, the greater depth of sampling included more of this material, resulting in much heavier texture for the composite samples than is normal for the A horizon.

⁹ The formulas used were standard deviation, $\sigma = \sqrt{\frac{\sum d^2}{n}}$, and coefficient of variability.

$C = \frac{\sigma}{M} \times 100$, where d represents the deviation of each determination from the mean M of the whole number of determinations n .

¹⁰ The plots at all stations are 6 feet wide and the normal-length plots are 72.6 feet long, making an area of one one-hundredth of an acre. The short plots are 36.3 feet long (one two-hundredth of an acre) and the long plots are 145.2 feet long (one fiftieth of an acre).

¹¹ The surface soil of one or more plots at each station was removed to simulate a severely eroded condition and to compare the quantity of run-off and erosion with the normal surface condition.

TABLE 4.—Analyses of composite samples by horizons from the erosion-station plots

PHYSICAL PROPERTIES

Sample and location	Plot No.	Colloid by water-vapor adsorption in horizon—					Moisture equivalent in horizon—					Dispersion ratio in horizon—					Ratio of colloid to moisture equivalent in horizon—					Erosion ratio in horizon—				
		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Houston black clay, Temple, Tex.	P	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent															
	1	41.1	40.2	35.6	26.7	24.0	30.5	27.6	24.4	20.6	22.6	10.9	5.4	6.7	10.1	-----	1.35	1.46	1.46	1.30	-----	8.1	3.7	4.6	7.8	-----
	2	38.6	39.2	34.1	25.8	24.2	29.7	31.2	27.9	24.3	22.6	12.5	14.9	15.9	20.0	20.8	1.30	1.20	1.22	1.00	1.06	9.6	11.8	13.0	18.8	19.0
	3	36.4	37.1	33.5	28.9	29.2	29.8	31.0	31.0	25.9	25.0	12.3	11.4	14.4	18.9	16.8	1.22	1.20	1.24	1.09	1.17	10.1	9.5	11.6	17.3	14.4
	4	35.6	40.8	34.6	27.9	24.0	30.8	31.0	28.0	26.0	23.4	9.7	13.5	14.6	17.6	22.1	1.25	1.32	1.24	1.07	1.03	7.8	10.2	11.8	16.4	21.4
	5	30.3	41.1	36.0	29.2	25.5	30.2	31.8	28.9	25.7	23.2	11.9	14.2	11.0	17.2	22.4	1.30	1.29	1.25	1.14	1.10	9.1	11.0	8.9	15.1	18.6
	6	40.2	38.4	32.7	26.4	25.1	30.5	29.0	27.1	24.6	23.4	9.2	12.2	15.1	18.2	18.6	1.32	1.28	1.21	1.07	1.07	7.0	9.5	12.5	17.0	17.4
	7	39.0	37.5	33.8	27.7	23.3	31.1	29.0	26.2	24.6	21.9	11.2	13.4	10.8	13.7	20.5	1.25	1.25	1.29	1.13	1.00	9.0	10.7	8.4	12.1	20.5
	8	39.8	38.1	31.4	27.6	24.2	31.2	29.6	25.5	24.3	22.3	9.6	12.8	14.6	21.1	19.5	1.36	1.29	1.23	1.14	1.10	7.1	9.9	11.9	18.5	17.7
	9	39.2	38.5	33.4	27.2	24.2	29.3	30.6	27.5	24.3	22.3	8.4	15.1	14.2	15.2	19.1	1.30	1.26	1.21	1.12	1.09	6.5	12.0	11.7	13.6	17.5
	10	39.0	39.1	32.5	25.0	23.4	30.1	30.2	26.2	22.9	22.7	13.4	14.9	16.1	15.7	19.6	1.30	1.29	1.24	1.09	1.03	10.3	11.5	13.0	14.4	19.0
	11	39.4	36.9	33.0	27.0	26.5	29.9	29.6	26.6	23.8	23.0	11.8	15.6	15.6	16.6	18.1	1.32	1.25	1.24	1.13	1.15	8.9	12.5	12.6	14.7	15.7
Average ¹		38.9	38.7	34.0	27.2	24.9	30.1	30.5	27.5	24.6	23.1	11.0	13.8	14.2	17.4	19.6	1.29	1.27	1.24	1.10	1.08	8.5	10.9	11.5	15.8	19.2
Standard deviation.....		1.0	1.4	1.9	1.2	1.7	0.6	0.7	1.5	9.8	3.1	1.6	1.3	1.8	2.1	1.4	.03	.03	.05	.05	1.3	1.0	1.0	1.6	2.1	2.0
Coefficient of variability.....		2.5	3.5	5.6	4.3	6.8	1.9	2.3	5.5	3.8	3.4	14.4	9.5	12.5	12.2	7.3	2.0	2.4	1.8	2.7	4.3	15.1	8.9	13.5	13.0	11.0
Cecil sandy clay loam, Statesville, N. C.	P	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent															
	1	20.0	45.7	50.0	-----	-----	20.0	26.6	28.7	-----	-----	22.4	11.2	9.6	-----	-----	1.00	1.72	1.74	-----	-----	22.4	6.5	5.5	-----	-----
	2	-----	42.0	51.7	-----	-----	-----	25.3	29.4	-----	-----	-----	15.4	10.6	-----	-----	-----	1.60	1.70	-----	-----	-----	9.3	6.0	-----	-----
	3	-----	38.8	49.4	-----	-----	-----	23.3	29.8	-----	-----	-----	16.7	9.8	-----	-----	-----	1.67	1.66	-----	-----	-----	10.0	5.9	-----	-----
	4	-----	43.0	53.1	-----	-----	-----	26.0	29.6	-----	-----	-----	14.3	10.9	-----	-----	-----	1.65	1.79	-----	-----	-----	8.7	6.1	-----	-----
	5	29.5	47.8	49.3	-----	-----	22.4	26.5	28.8	-----	-----	19.8	12.3	9.8	-----	-----	1.32	1.80	1.71	-----	-----	15.0	6.8	5.8	-----	-----
	6	27.4	47.7	49.8	-----	-----	22.5	27.1	30.0	-----	-----	20.8	12.1	9.7	-----	-----	1.22	1.76	1.66	-----	-----	17.1	6.9	5.9	-----	-----
	7	28.9	47.0	55.6	-----	-----	22.6	26.7	31.1	-----	-----	22.0	13.9	10.7	-----	-----	1.28	1.76	1.79	-----	-----	17.2	7.9	6.0	-----	-----
	8	32.2	48.9	57.9	-----	-----	23.0	28.0	32.4	-----	-----	21.6	11.7	8.3	-----	-----	1.39	1.75	1.79	-----	-----	15.5	6.7	4.7	-----	-----
	9	32.7	49.3	51.0	-----	-----	22.3	28.8	32.2	-----	-----	21.6	10.7	8.4	-----	-----	1.47	1.71	1.58	-----	-----	14.7	6.2	5.3	-----	-----
	10	30.4	51.2	57.8	-----	-----	23.1	29.4	32.0	-----	-----	17.6	8.7	8.2	-----	-----	1.32	1.74	1.81	-----	-----	13.4	5.0	4.5	-----	-----
	11	32.1	50.3	57.4	-----	-----	23.8	28.0	30.1	-----	-----	22.7	9.5	7.4	-----	-----	1.35	1.80	1.91	-----	-----	17.2	5.3	3.9	-----	-----
	12	29.7	47.2	51.3	-----	-----	21.8	26.7	29.2	-----	-----	19.4	9.3	9.5	-----	-----	1.36	1.77	1.76	-----	-----	14.3	5.2	5.4	-----	-----
Average ¹		31.0	49.5	52.0	-----	-----	22.8	27.9	30.6	-----	-----	20.5	11.0	9.0	-----	-----	1.36	1.78	1.75	-----	-----	15.2	6.2	5.2	-----	-----
Standard deviation.....		2.4	2.7	3.5	-----	-----	0	1.1	1.3	-----	-----	1.5	1.6	1.0	-----	-----	.09	.05	.09	-----	-----	1.6	.8	.4	-----	-----
Coefficient of variability.....		7.7	5.4	6.7	-----	-----	2.6	4.1	4.2	-----	-----	7.5	14.6	10.8	-----	-----	6.8	2.8	5.1	-----	-----	10.7	13.5	8.5	-----	-----

Kirvin fine sandy loam, Tyler, Tex.

Average ¹.....
Standard deviation.....
Coefficient of variability.....

Vernon fine sandy loam, Guthrie, Okla.

Average ¹.....
Standard deviation.....
Coefficient of variability.....

Shelby silt loam, Bethany, Mo.

Average ¹.....
Standard deviation.....
Coefficient of variability.....

¹ Profile sample.² Short plot (one two-hundredths of an acre).³ Long plot (one-fiftieth of an acre).⁴ Desurfaced plot.⁵ Average does not include profile sample or desurfaced plots.⁶ Lower half of plot 1 (long plot).⁷ Upper half of plot 1 (long plot).

P	5.9	56.6	49.5	32.8	10.0	7.9	30.5	28.5	21.2	6.7	37.2	13.3	12.4	16.6	24.9	0.75	1.86	1.74	1.55	1.49	49.6	7.2	7.1	10.7	16.7
1	5.1	50.6	49.5	50.5	---	7.8	31.1	30.6	21.7	---	28.8	20.1	18.4	12.2	---	.65	1.63	1.65	1.59	---	44.3	11.2	11.2	7.7	---
2	6.7	60.9	62.0	48.0	---	8.5	33.6	34.5	30.1	---	31.2	19.8	15.7	16.6	---	.79	1.81	1.90	1.59	---	39.5	10.9	8.7	10.8	---
3	6.7	66.3	67.4	43.7	---	8.4	37.0	36.5	30.2	---	33.6	16.7	19.3	23.1	---	.80	1.79	1.86	1.45	---	42.0	9.3	10.4	15.9	---
4	6.1	63.6	58.5	43.8	---	7.9	35.6	35.9	29.7	---	33.3	13.9	23.3	21.0	---	.77	1.79	1.63	1.47	---	43.3	13.5	14.3	14.3	---
5	6.0	64.1	68.6	51.9	---	8.0	35.9	37.3	30.5	---	25.3	19.7	20.1	14.2	---	.75	1.78	1.84	1.70	---	33.7	11.1	10.9	8.3	---
6	6.1	69.7	59.4	49.6	---	8.2	36.9	34.9	29.7	---	29.7	20.4	21.2	21.3	---	.74	1.89	1.70	1.68	---	40.0	10.8	12.5	12.7	---
7	6.3	64.9	66.0	47.5	---	8.3	37.0	36.2	30.5	---	27.3	18.6	19.0	19.5	---	.76	1.75	1.32	1.56	---	35.9	10.6	10.4	12.5	---
8	6.7	66.5	61.1	47.9	---	8.7	36.6	37.0	29.6	---	22.0	18.7	16.4	18.3	---	.77	1.82	1.65	1.62	---	28.6	10.3	9.5	11.3	---
9	7.5	61.7	66.5	47.4	---	8.6	35.6	37.3	30.2	---	27.6	21.5	17.8	15.7	---	.57	1.73	1.78	1.57	---	31.6	12.4	10.0	10.0	---
10	---	61.2	61.3	49.7	---	---	35.3	36.7	31.0	---	---	14.8	19.1	17.1	---	---	1.73	1.67	1.60	---	---	8.6	11.4	10.7	---
11	---	62.3	53.7	46.4	---	---	35.0	32.7	29.2	---	---	15.2	17.2	19.6	---	---	1.78	1.64	1.59	---	---	8.6	10.5	12.3	---
12	---	57.4	61.9	49.1	---	---	32.9	34.0	30.2	---	---	14.9	19.0	15.7	---	---	1.74	1.79	1.63	---	---	8.6	10.6	9.6	---
Average ¹	6.4	63.1	62.4	47.8	---	8.3	35.5	35.5	30.2	---	28.7	19.9	19.0	18.0	---	.8	1.8	1.8	1.6	---	37.7	11.1	10.9	11.5	---
Standard deviation.....	.6	5.4	5.7	2.6	---	.3	1.9	2.2	.6	---	3.5	1.9	2.2	3.3	---	.06	.04	.08	.08	---	5.2	1.1	1.0	2.5	---
Coefficient of variability.....	9.7	8.5	9.1	5.4	---	3.6	5.2	6.1	2.1	---	12.3	9.5	11.6	18.5	---	7.1	2.4	4.4	5.0	---	13.7	10.8	14.4	22.0	---
P	7.4	8.3	21.5	19.4	---	9.6	9.1	17.7	18.4	---	23.3	17.2	16.6	25.7	---	.77	.91	1.21	1.05	---	29.9	18.9	13.7	24.5	---
1	5.2	6.2	20.7	18.4	---	7.1	7.7	17.6	16.5	---	41.6	36.9	28.2	39.2	---	.73	.81	1.18	1.12	---	57.3	45.6	23.9	34.1	---
2	7.0	7.8	20.1	16.5	---	9.5	9.1	16.8	15.8	---	33.0	26.9	20.9	27.2	---	.74	.86	1.20	1.04	---	44.0	31.3	17.4	25.1	---
3	6.4	7.0	19.3	18.9	---	9.4	10.7	17.7	16.3	---	32.3	24.1	24.6	23.4	---	.61	.82	1.09	1.16	---	46.8	29.4	22.6	20.1	---
4	7.6	8.1	21.5	18.7	---	9.4	10.0	18.6	15.2	---	32.7	35.0	26.7	26.6	---	.81	.87	1.16	1.03	---	40.3	40.3	23.0	27.7	---
5	6.4	8.1	22.5	20.2	---	9.8	9.3	18.2	16.2	---	40.7	36.5	28.4	25.0	---	.75	.87	1.24	1.09	---	62.6	40.2	21.8	22.9	---
6	7.4	8.4	17.0	16.8	---	10.1	10.3	16.6	17.1	---	36.1	29.5	26.1	25.5	---	.73	.82	1.02	1.08	---	49.4	35.9	25.6	26.0	---
7	7.3	8.4	20.7	16.9	---	10.5	8.7	18.6	16.5	---	33.5	31.8	23.7	27.4	---	.70	.97	1.11	1.02	---	47.9	32.8	21.3	26.8	---
8	7.2	9.2	23.4	24.5	---	10.5	11.7	19.7	19.7	---	31.3	32.2	22.6	25.6	---	.69	.79	1.19	1.24	---	45.4	40.7	19.0	20.7	---
9	---	13.4	21.8	19.3	---	---	13.3	19.7	19.2	---	---	23.1	21.3	29.4	---	---	1.01	1.11	1.06	---	---	22.0	19.2	27.7	---
Average ¹	6.8	8.1	20.7	18.9	---	9.5	9.6	18.0	17.3	---	35.2	31.6	24.9	27.6	---	.72	.85	1.15	1.09	---	49.3	37.3	21.8	25.6	---
Standard deviation.....	.7	.8	1.8	2.4	---	1.0	1.1	1.0	1.1	---	3.8	4.4	2.3	4.3	---	.04	.05	.07	.08	---	7.0	5.4	2.5	4.2	---
Coefficient of variability.....	10.9	10.2	8.9	12.9	---	10.6	11.6	5.3	6.1	---	10.7	13.9	9.0	15.5	---	6.1	6.2	5.7	7.3	---	14.2	14.5	11.8	16.4	---
P	23.1	49.6	49.4	37.2	27.0	24.5	34.9	34.2	27.1	23.0	26.2	13.0	15.8	22.5	28.2	0.64	1.42	1.44	1.37	1.17	27.9	9.2	11.0	16.4	24.1
1	24.7	40.3	46.9	36.2	---	24.3	29.8	31.9	29.7	---	25.4	23.7	26.3	30.3	---	1.02	1.35	1.47	1.22	---	24.9	17.5	17.9	24.8	---
2	27.1	29.9	37.6	46.8	---	27.0	27.0	27.8	32.6	---	28.3	22.3	20.1	31.3	---	1.00	1.11	1.35	1.43	---	28.3	20.1	22.3	21.9	---
3	25.0	45.3	41.7	44.7	---	24.3	32.1	34.8	38.2	---	30.7	18.9	19.3	27.9	---	1.03	1.41	1.50	1.17	---	29.5	13.4	19.6	23.8	---
4	24.3	37.9	48.5	35.0	---	25.0	30.6	33.1	27.6	---	26.6	23.2	23.8	29.8	---	.97	1.23	1.40	1.27	---	27.4	18.0	16.3	23.5	---
5	24.5	35.9	44.1	38.7	---	24.7	27.2	30.1	31.1	---	29.8	24.3	24.6	30.6	---	.69	1.32	1.47	1.24	---	30.1	18.4	16.7	24.7	---
6	26.1	32.5	46.6	30.8	---	25.3	26.1	32.2	28.4	---	24.7	23.0	26.3	36.0	---	1.03	1.25	1.45	1.08	---	26.6	19.1	18.2	33.8	---
7	26.0	45.8	47.5	39.9	---	24.9	31.0	31.6	28.8	---	27.8	21.7	23.0	30.1	---	1.04	1.48	1.50	1.39	---	26.7	17.4	15.3	21.6	---
8	25.1	44.8	43.3	40.2	---	24.3	31.1	31.0	28.2	---	26.1	24.7	22.6	28.6	---	1.03	1.44	1.40	1.43	---	25.3	17.1	16.2	20.0	---
9	27.5	48.6	43.2	41.5	---	25.5	33.1	34.9	30.2	---	26.7	20.2	25.0	29.6	---	1.08	1.47	1.24	1.37	---	24.7	13.7	20.1	21.6	---
10	25.8	45.8	45.8	37.7	---	25.6	31.1	31.5	27.4	---	26.9	21.2	31.3	32.0	---	1.01	1.47	1.45	1.38	---	26.6	14.4	14.7	23.2	---
Average ¹	25.6	40.7	44.5	39.2	---	25.1	29.9	31.9	30.2	---	27.6	22.4	24.7	30.6	---	1.02	1.35	1.40	1.30	---	27.0	17.0	17.7	23.0	---
Standard deviation.....	1.0	6.2	3.2	4.4	---	.8	2.2	2.0	3.1	---	1.6	1.8	2.4	2.1	---	.03	.11	.10	.11	---	1.8	2.3	2.3	3.6	---
Coefficient of variability.....	4.0	15.3	7.2	11.3	---	3.1	7.5	6.3	10.2	---	5.7	8.0	9.5	6.9	---	2.8	8.6	7.0	8.8	---	6.7	13.2	12.7	15.1	---

TABLE 4.—Analyses of composite samples by horizons from the erosion-station plots—Continued

PHYSICAL PROPERTIES—Continued

Sample and location	Plot No	Colloid by water-vapor adsorption in horizon—					Moisture equivalent in horizon—					Dispersion ratio in horizon—					Ratio of colloid to moisture equivalent in horizon—					Erosion ratio in horizon—				
		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Colby silty clay loam, Hays, Kans.	P	32.1	30.7	29.0	29.1	29.9	27.3	25.2	24.1	23.6	24.8	14.9	10.7	18.7	24.3	35.6	1.18	1.22	1.20	1.23	1.21	12.6	8.8	15.6	19.7	29.4
	1	29.3	29.7	27.7	27.4	27.3	25.2	24.2	23.5	22.3	22.7	22.7	20.5	26.0	31.9	-----	1.16	1.23	1.18	1.09	-----	19.6	16.7	22.0	29.3	-----
	2	32.0	29.6	27.1	27.1	-----	26.8	25.0	23.0	22.8	-----	18.0	19.8	22.4	26.7	-----	1.19	1.18	1.18	1.19	-----	15.7	16.8	19.0	22.5	-----
	3	30.6	28.7	26.5	26.3	-----	27.5	24.3	22.9	23.5	-----	19.9	19.8	27.0	33.8	-----	1.11	1.18	1.16	1.12	-----	17.9	16.7	23.3	30.2	-----
	4	31.6	30.1	27.5	28.9	-----	28.6	24.8	23.6	23.6	-----	18.4	22.5	26.5	34.5	-----	1.10	1.21	1.17	1.22	-----	16.7	18.6	22.7	28.2	-----
	5	31.9	30.0	27.4	28.0	-----	27.8	25.8	23.8	24.0	-----	19.5	23.0	30.1	33.2	-----	1.15	1.16	1.15	1.17	-----	16.8	19.8	26.1	28.4	-----
	6	31.1	29.4	28.6	28.8	-----	26.6	25.1	23.9	24.2	-----	20.5	22.2	29.5	34.4	-----	1.17	1.17	1.20	1.19	-----	17.5	19.0	24.5	28.9	-----
	7	30.1	28.9	27.7	26.3	-----	26.5	25.1	23.5	23.0	-----	19.0	21.7	31.4	31.3	-----	1.14	1.15	1.18	1.14	-----	16.7	18.9	26.6	27.5	-----
	8	30.3	26.1	26.7	26.6	-----	26.4	24.3	25.2	24.8	-----	18.8	21.3	25.0	32.3	-----	1.15	1.07	1.03	1.07	-----	16.3	19.9	23.5	30.2	-----
	9	29.9	27.7	26.2	26.6	-----	28.2	25.8	23.8	25.2	-----	17.5	22.9	32.0	32.1	-----	1.08	1.07	1.10	1.06	-----	16.6	21.4	29.1	30.3	-----
10	-----	26.7	27.7	27.6	27.8	-----	25.2	23.9	24.3	25.0	-----	25.5	28.3	35.6	35.4	-----	1.06	1.10	1.14	1.11	-----	24.1	24.4	31.2	31.9	-----
Average	-----	30.8	28.9	27.3	27.0	-----	27.1	24.9	23.7	23.7	-----	19.4	21.5	27.8	32.2	-----	1.14	1.16	1.15	1.14	-----	17.1	18.6	24.1	28.4	-----
Standard deviation	-----	.9	1.2	.7	1.4	-----	1.0	.6	.6	.9	-----	1.4	1.2	3.0	2.2	-----	.04	.05	.04	.05	-----	1.1	1.6	2.8	2.3	-----
Coefficient of variability	-----	2.9	4.2	2.6	5.0	-----	3.7	2.3	2.7	4.0	-----	7.3	5.5	10.8	6.9	-----	3.3	4.5	3.7	4.7	-----	6.3	8.3	11.5	8.0	-----

MECHANICAL ANALYSIS¹

Sample and location	Plot No.	Sand in horizon—					Silt in horizon—					Clay in horizon—					Colloid <0.002 mm in horizon—					Organic matter by H ₂ O ₂ in horizon—				
		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Houston black clay, Temple, Tex.	1 P	10.9	9.0	10.5	14.0	—	23.0	25.1	27.0	31.0	—	60.4	64.1	61.8	64.0	61.8	44.9	40.6	44.1	38.2	—	1.8	0.5	0.7	0.2	0.1
	1 1	11.1	9.7	9.9	13.9	16.5	23.9	26.5	25.1	30.4	23.3	62.9	62.9	64.0	64.0	64.0	44.2	45.0	40.7	35.5	33.3	1.8	0.5	0.7	0.2	0.1
	2	9.3	8.4	7.5	8.2	8.4	27.5	24.6	24.9	23.8	27.0	62.0	62.0	63.6	64.4	64.4	44.7	45.2	44.9	40.0	40.7	1.8	1.5	1.2	0.5	0.1
	3	9.5	7.0	8.0	9.9	14.2	21.6	24.3	27.3	30.4	31.2	62.6	66.8	63.6	65.2	64.2	54.2	45.4	40.4	42.4	38.8	1.2	0.8	0.4	0.4	0.2
	4	9.7	8.4	8.9	9.6	14.4	25.9	24.8	25.3	27.4	29.6	62.6	65.4	63.8	60.9	59.0	43.4	46.4	42.0	37.5	40.2	1.8	0.6	0.2	0.2	0.3
	5	9.3	8.7	9.0	9.5	10.1	24.9	25.1	23.6	29.4	30.5	64.8	67.9	64.4	60.6	57.8	45.7	47.0	42.4	38.8	34.3	1.0	0.4	0.3	0.3	0.3
	6	10.9	7.6	8.4	10.0	12.5	25.2	23.7	23.7	29.0	29.1	63.6	67.9	63.4	62.4	56.8	46.3	45.5	40.5	39.7	35.3	1.3	0.7	0.3	0.0	0.0
	7	9.3	7.2	9.2	9.2	13.0	25.3	24.3	27.0	28.2	29.9	65.7	65.4	66.1	63.4	59.8	46.0	45.9	43.5	39.8	36.8	1.3	1.0	0.0	0.0	0.0
	8	8.8	8.0	7.5	8.2	10.7	24.7	25.2	23.2	28.2	29.2	64.6	67.6	63.9	59.6	60.1	45.2	46.0	40.9	35.7	37.9	0.3	0.0	0.2	0.0	0.0
	9	9.6	7.3	9.0	11.6	10.6	25.1	24.9	25.8	28.5	29.0	64.6	67.6	63.9	59.6	60.1	45.2	46.0	40.9	35.7	37.9	0.3	0.0	0.2	0.0	0.0
	10	9.1	8.8	7.6	7.7	8.8	20.8	24.5	24.2	28.0	29.2	69.8	69.3	67.3	63.6	62.0	47.0	47.2	43.4	40.1	40.3	0	0.1	0.6	0.4	0.0
	11	—	8.1	8.4	9.3	8.9	—	23.8	28.2	28.3	28.9	—	64.8	63.2	62.2	62.0	—	37.3	38.2	38.3	40.2	—	0.1	0	0	0
Average ¹	—	9.7	8.2	8.6	9.8	11.9	25.0	24.5	25.0	28.6	29.3	64.3	66.2	64.8	61.2	53.5	46.8	46.3	42.0	38.8	36.9	0.8	0.5	0.4	0.2	0.1
Standard deviation	—	0.7	0.7	0.8	1.7	2.5	1.7	0.7	1.0	1.1	1.1	2.2	1.4	1.9	1.5	1.7	2.6	0.5	0.5	0.3	0.2	0.2	0.3	0.2	0.1	0.1
Coefficient of variability	—	7.3	9.0	9.0	17.7	21.0	6.8	2.9	3.8	3.9	3.7	3.4	2.2	1.6	2.4	5.2	5.6	2.0	3.6	4.3	6.0	66.2	64.0	80.0	90.0	100.0
Cecil sandy clay loam, Statesville, N. O.	1 P	53.1	30.8	23.1	—	—	20.7	12.1	17.1	—	—	23.2	57.1	50.8	—	—	17.8	51.6	48.6	—	—	—	—	—	—	—
	1 1	—	33.2	24.8	—	—	—	13.4	14.2	—	—	—	53.0	60.8	—	—	—	47.0	53.4	—	—	—	—	—	—	—
	2	—	34.0	23.3	—	—	—	14.8	14.2	—	—	—	50.2	62.2	—	—	—	44.1	55.1	—	—	—	—	—	—	—
	3	—	31.8	24.2	—	—	—	10.4	11.1	—	—	—	57.0	64.6	—	—	—	52.8	58.9	—	—	—	—	—	—	—
	4	40.3	29.2	20.5	—	—	12.9	9.6	10.9	—	—	45.8	60.8	62.6	—	—	—	40.7	57.2	57.2	—	—	—	—	—	—
	5	42.8	29.4	20.3	—	—	14.7	9.9	10.9	—	—	40.9	60.4	62.7	—	—	—	36.1	55.7	57.7	—	—	—	—	—	—
	6	42.9	30.9	23.3	—	—	10.4	8.6	13.6	—	—	48.1	60.3	62.8	—	—	—	40.4	48.2	57.0	—	—	—	—	—	—
	7	41.6	29.0	20.1	—	—	11.6	12.5	15.1	—	—	45.8	58.1	64.6	—	—	—	41.0	53.8	59.2	—	—	—	—	—	—
	8	41.1	28.0	22.6	—	—	12.4	12.6	14.8	—	—	45.6	59.0	62.6	—	—	—	39.6	54.0	56.3	—	—	—	—	—	—
	9	40.7	26.2	21.9	—	—	17.3	12.2	17.5	—	—	40.7	61.2	60.4	—	—	—	34.4	55.0	53.8	—	—	—	—	—	—
	10	40.0	29.3	23.4	—	—	18.2	14.0	22.2	—	—	41.2	56.2	64.2	—	—	—	35.2	51.0	48.8	—	—	—	—	—	—
	11	41.3	29.8	27.5	—	—	20.5	14.6	18.6	—	—	37.0	55.2	53.6	—	—	—	32.0	49.3	46.6	—	—	—	—	—	—
	12	37.5	25.6	25.2	—	—	9.9	15.3	20.3	—	—	51.3	58.8	54.4	—	—	—	44.3	52.2	45.5	—	—	—	—	—	—
Average ¹	—	40.9	23.6	24.1	—	—	14.2	12.1	16.0	—	—	43.9	58.6	59.8	—	—	—	38.2	52.9	53.6	—	—	—	—	—	—
Standard deviation	—	1.5	1.6	2.3	—	—	3.5	2.2	3.6	—	—	3.8	2.0	4.2	—	—	—	3.7	2.8	4.0	—	—	—	—	—	—
Coefficient of variability	—	3.7	5.7	9.5	—	—	24.6	18.2	22.5	—	—	8.7	3.3	7.0	—	—	—	9.7	5.4	9.2	—	—	—	—	—	—

¹ Profile sample.² Short plot (one two-hundredths of an acre).³ Long plot (one-fiftieth of an acre).⁴ Desurfaced plot.⁵ Average dose not include profile sample or desurfaced plots.⁶ Determinations by L. T. Alexander, H. W. Lakin, and T. M. Shaw.

TABLE 4.—Analyses of composite samples by horizons from the erosion-station plots—Continued

MECHANICAL ANALYSIS—Continued

Sample and location	Plot No.	Sand in horizon—					Silt in horizon—					Clay in horizon—					Colloid <0.002 mm in horizon—					Organic matter by H ₂ O ₂ in horizon—				
		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	3	3	4	5	1	2	3	4	5
Kilvin fine sandy loam, Tyler, Tex.	P	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
	1	75.8	31.1	36.9	51.3	87.9	15.7	7.4	9.6	13.2	2.8	8.6	61.5	53.4	35.4	9.2	5.7	59.9	50.0	32.3	7.3	—	—	—	—	—
	2	77.5	33.3	36.9	32.1	—	14.3	10.3	9.9	12.1	—	7.4	55.7	52.0	55.6	—	5.9	54.4	50.3	52.4	—	.5	.6	.4	0	—
	3	76.3	29.1	20.4	35.9	—	13.8	7.9	10.8	12.3	—	9.4	62.6	62.8	51.6	—	7.2	60.1	60.4	48.4	—	.4	.4	0	—	—
	4	76.1	22.0	19.1	30.3	—	15.4	8.6	13.8	13.5	—	7.7	68.0	66.6	55.0	—	5.5	65.9	63.5	48.7	—	.4	.9	.4	0	—
	5	76.2	23.6	20.6	28.0	—	15.2	8.5	12.6	18.7	—	7.8	66.8	66.2	53.0	—	5.9	64.2	64.3	49.7	—	.4	.8	.1	0	—
	6	76.0	22.9	20.2	31.6	—	14.7	8.1	11.8	15.7	—	8.5	68.3	67.4	52.4	—	7.2	67.0	66.5	49.5	—	.7	.6	.4	0	—
	7	76.8	22.1	23.5	31.5	—	13.8	8.1	13.2	18.9	—	8.7	69.4	63.0	51.5	—	6.4	68.9	59.4	47.7	—	.6	.3	0	—	—
	8	78.3	21.5	23.2	30.8	—	12.0	7.9	10.5	16.5	—	8.4	69.4	65.6	52.4	—	6.6	66.8	60.9	48.5	—	1.0	.8	.5	.3	—
	9	76.8	22.8	20.8	31.0	—	12.5	6.2	10.2	17.0	—	9.6	70.1	68.4	51.0	—	7.0	67.6	64.8	49.1	—	.8	.9	.5	.3	—
	10	79.2	24.9	19.7	31.3	—	10.7	7.6	11.1	16.5	—	9.3	66.4	68.4	52.7	—	7.6	64.6	65.4	48.0	—	.8	.9	.6	0	—
	11	—	24.9	22.7	26.4	—	—	6.3	12.4	18.7	—	—	67.9	64.6	54.4	—	—	65.6	61.6	50.3	—	.6	.2	.2	0	—
	12	—	24.2	20.8	31.8	—	—	7.2	11.9	18.0	—	—	67.9	56.8	50.1	—	—	65.0	54.2	45.8	—	.5	.2	0	—	—
Average	—	77.0	24.7	23.4	31.4	—	13.6	8.1	11.5	15.5	—	8.5	66.2	64.6	52.9	—	6.6	64.2	61.7	49.1	—	.6	.7	.3	.1	—
Standard deviation	—	1.0	3.7	5.3	2.0	—	1.5	1.0	1.3	2.2	—	8	4.3	5.3	1.5	—	.7	4.1	4.6	1.3	—	.2	.2	.2	.1	—
Coefficient of variability	—	1.4	15.1	22.4	6.2	—	10.9	12.5	11.4	14.0	—	8.8	6.5	8.5	2.9	—	10.3	6.3	7.5	2.7	—	35.0	30.0	70.0	12	—
Vernon fine sandy loam, Guthrie, Okla.	P	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
	1	73.3	74.8	60.3	32.3	—	18.5	13.0	12.4	35.1	—	8.1	12.1	27.2	32.5	—	5.3	10.0	24.0	27.6	—	—	—	—	—	—
	2	76.0	77.8	62.2	57.8	—	16.0	12.1	12.5	18.4	—	7.0	9.7	25.0	23.4	—	5.6	8.1	23.3	20.5	—	.7	.2	.1	.1	—
	3	72.0	76.6	61.7	60.7	—	17.0	12.3	12.0	15.7	—	9.0	10.7	25.3	23.2	—	6.7	9.4	23.1	19.5	—	.9	.3	.2	.1	—
	4	73.1	75.5	59.8	48.1	—	17.0	12.6	12.4	25.0	—	8.5	11.4	27.2	26.5	—	6.7	9.5	23.4	21.2	—	1.0	.4	.4	.1	—
	5	72.9	74.2	53.9	40.0	—	16.1	12.2	16.0	31.1	—	9.8	13.0	28.9	28.5	—	7.6	10.9	24.7	23.2	—	1.0	.5	.4	.2	—
	6	74.0	74.8	50.7	44.3	—	15.8	12.7	17.0	23.8	—	8.8	12.0	32.0	31.7	—	6.6	9.6	27.3	26.1	—	1.1	.4	.1	0	—
	7	71.8	72.4	60.4	53.6	—	16.8	14.2	15.0	20.4	—	10.0	12.7	24.4	25.8	—	8.1	10.8	21.0	19.5	—	1.2	.6	0	.1	—
	8	72.5	72.5	46.9	52.4	—	17.1	16.6	23.7	24.9	—	9.9	10.1	29.1	22.5	—	7.9	9.0	18.4	24.3	—	1.4	.5	0	0	—
	9	70.5	74.0	41.2	32.4	—	19.2	7.7	25.3	27.7	—	9.1	17.7	32.8	39.5	—	7.5	13.0	27.7	32.6	—	1.0	.4	0	.4	—
	10	—	65.8	36.2	37.6	—	—	14.9	30.0	32.1	—	—	18.6	33.3	29.9	—	—	16.2	26.3	24.2	—	.5	.5	.3	.2	—
Average	—	72.8	74.7	54.6	48.7	—	16.9	12.5	16.9	23.4	—	9.0	12.2	28.1	27.6	—	7.1	10.0	23.6	23.4	—	1.0	.4	.2	.1	—
Standard deviation	—	1.6	1.8	7.3	8.9	—	1.0	2.3	4.7	4.7	—	.9	2.4	3.0	5.3	—	.8	1.4	2.9	4.2	—	.2	.12	.18	.12	—
Coefficient of variability	—	2.2	2.4	13.3	18.2	—	5.9	18.6	27.9	20.0	—	10.2	19.3	10.6	19.3	—	11.0	14.1	12.2	17.9	—	20.0	30.0	90.0	120.0	—

Some differences may be noted in the dispersion and erosion ratios between the profile samples and the composite samples. The composite samples agree very well with each other, and several determinations made on the profile samples at various times are in close agreement. The reason for these discrepancies has not yet been definitely ascertained. It is believed to be due to structural variations resulting from seasonal differences in the taking of the samples. The coefficients of variability are low in nearly all cases, indicating a high degree of uniformity. In order that the variability of the different soils might be compared, the average value of the coefficient was computed for all determinations, with the exception of the organic-matter determination, for each horizon of each soil. The results are shown in Table 5.

TABLE 5.—Average¹ coefficients of variability of composite plot samples

Horizon	Houston black clay	Cecil sandy clay loam	Kirvin fine sandy loam	Vernon fine sandy loam	Shelby silt loam	Colby silty clay loam
1.....	6.3	9.1	8.6	9.1	5.7	4.8
2.....	4.7	8.1	8.5	12.3	11.8	4.8
3.....	6.4	9.3	10.6	11.6	9.4	5.6
4.....	7.8		8.8	14.8	9.1	5.8
5.....	7.7					
Average.....	6.5	8.8	9.1	11.9	9.0	5.2

¹ Coefficients of variability for organic matter are not included.

These results indicate that the second horizon of the Houston soil is the most uniform and the fourth horizon of the Vernon the least uniform. However, the average of all horizons shows the Colby to have the most uniform profile and the Vernon, the least uniform. These figures correspond very closely to the results obtained by Holmes and Edgington (10) on the colloids from the Leonardtown, Miami, Chester, and Cecil soils.

Although it is obviously undesirable to make complete chemical analyses of the soil and colloid of the whole series of composite samples because of their great number, it seemed desirable to select a pair of the Houston composite samples which showed wide variation in physical properties in order to determine to what extent this variation is reflected by the chemical composition. In the Cecil composites, two plots showed very similar physical properties, and they were analyzed in order to determine to what extent this uniformity was reflected by the chemical composition. To these were added a pair of the samples from the desurfaced plots. It is to be expected that erosion will alter these more than the surface soils. The analyses are therefore available for comparison with future samples from the same plots. The results of these analyses are given in Table 6.

TABLE 6.—Chemical composition of selected composite plot samples¹

Station	Soil type	Plot No.	Horizon	SiO ₂	TiO ₂	Fe ₂ O ₃	Al ₂ O ₃	MnO	CaO	MgO
				P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
Temple, Tex.	Houston black clay.	*2	3	22.94 (66.78)	0.37 (1.08)	2.68 (7.80)	5.97 (17.38)	0.05 (.15)	33.58	6.98 (2.85)
		7	3	18.18 (53.02)	1.34 (1.22)	2.42 (8.66)	4.91 (17.56)	.04 (.14)	37.00	.84 (3.00)
Statesville, N. C.	Cecil sandy clay loam.	6	1	69.39	1.31	5.65	14.48	.29	.30	.68
		7	1	68.37	1.29	5.95	15.28	.32	.20	.06
		1	*2	60.90	1.47	8.49	19.43	.09	.43	.85
		2	*2	60.96	1.65	8.73	19.24	.11	.29	1.02

Station	Soil type	Plot No.	Horizon	K ₂ O	Na ₂ O	P ₂ O ₅	SO ₃	Loss on ignition	N ₂	CO ₂ from carbonates	H ₂ O at 110° C.
				P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
Temple, Tex.	Houston black clay.	*2	3	0.65 (1.89)	0.22 (.84)	0.30 (.87)	0.12 (.35)	31.94	0.14	28.69	4.60
		7	3	.50 (1.79)	.21 (.75)	.28 (1.00)	.24 (.86)	34.89	.08	29.94	4.15
Statesville, N. C.	Cecil sandy clay loam.	6	1	.56	(.9)	.08	.15	7.95	.09	.00	1.58
		7	1	.56	(.9)	.07	.19	8.00	.08	.00	1.61
		1	*2	.61	.04	.14	.23	7.07	.04	.00	1.94
		2	*2	.45	.10	.17	.09	7.07	.05	.00	1.92

¹ Determinations by J. G. Smith and G. Edgington.² Long plot (one-fiftieth of an acre).³ Trace.⁴ Surface of desurfaced plot.

[Figures in parentheses are for analyses calculated on carbonate-free basis]

The third horizon of plot 2 (long plot) and plot 7 on Houston black clay are unusual in that the colloid by water adsorption, the moisture equivalent, and the clay and colloid by mechanical analysis are the highest and the lowest, respectively, of any of the plots in this horizon. The chemical analyses reveal considerable differences in the various constituents, particularly CaO, but when the analyses are recalculated on the carbonate-free basis (figures in parentheses) the results are practically identical. This indicates that the properties of the third horizon of plot 7 are lower, owing to the greater dilution with CaCO₃.

The physical properties of the surface horizons of plots 6 and 7 on the Cecil soil are practically identical, except for the colloid by water-vapor adsorption and the organic matter by H₂O₂, which are higher in the latter. The chemical analyses indicate that there is a little more silica and less iron and alumina in the former, the rest of the constituents being almost uniform.

The analyses of the first two desurfaced plots of the Cecil soil reveal them to be practically identical in composition. The physical analyses indicate that plot 1 is slightly heavier in texture, but the slight differences are not reflected in the chemical analyses.

RUN-OFF AND EROSION DATA

Only four of the eight erosion stations were established in time to secure any run-off and erosion data during 1930. Of these, the stations at Guthrie, Okla., Hays, Kans., and Temple, Tex., were in operation during the entire year. The station at Tyler, Tex., was

in operation only during the latter part of the year. The year 1930 was unusual in many respects and was particularly notable on account of the unprecedented drought in practically all sections of the country. The station at Tyler reported no rain producing run-off from June to October. At Temple there was no run-off from May 23 to August 25. However, the stations at Temple and Hays each had a total rainfall for the year within a quarter of an inch of the normal, and the station at Guthrie had 0.61 inch more than the normal. This condition was brought about by unusually heavy rains in the spring and fall. The run-off and erosion data for each plot, together with the erosion ratio of the surface soil as shown in Table 4, are given in Tables 7, 8, 9, and 10.

TABLE 7.—Run-off and erosion data from Temple, Tex., erosion station, 1930

[Total rainfall, 33.01 inches; Houston black clay; slope, 3.75 per cent]

Plot No.	Erosion ratio	Run-off	Erosion	Erosion per inch of run-off	Treatment
		<i>Per cent</i>	<i>Tons per acre</i>	<i>Tons per acre</i>	
1 ¹	9.6	16.45	20.88	8.8	Cotton.
2 ²	10.1	18.45	14.67	2.4	Do.
3 ¹	7.8	6.28	3.01	1.5	Do.
4	9.1	21.36	25.29	3.6	Cotton (green manure).
5	7.0	27.77	24.63	2.7	Cotton (subsoiled).
6	9.0	20.89	27.83	4.0	Grass.
7	7.1	11.90	13.77	3.5	Cotton (green manure).
8	6.5	12.68	10.52	2.5	Cotton (subsoiled).
9	10.3	10.72	11.89	3.3	Cotton (green manure).
10	8.9	12.11	11.24	2.8	Cotton (subsoiled).
11 ³	4.7	12.12	6.03	1.5	Cotton.
Average	8.2	15.52	15.43	2.9	

¹ Short plot.² Long plot.³ Record for 5.55-inch rain of May 10 not included because tank overflowed.⁴ Desurfaced plot.

TABLE 8.—Run-off and erosion data from the Hays, Kans., erosion station, 1930

[Total rainfall, 22.78 inches; Colby silty clay loam; slope, 5 per cent]

Plot No.	Erosion ratio	Run-off	Erosion	Erosion per inch of run-off	Treatment
		<i>Per cent</i>	<i>Tons per acre</i>	<i>Tons per acre</i>	
1 ¹	19.6	12.68	1.99	0.69	Wheat.
2 ²	15.7	12.49	3.22	1.1	Do.
3	17.9	12.72	2.13	.75	Do.
4	16.7	.69	.27	1.7	Grass (clipped).
5	16.8	12.56	3.37	1.2	Wheat.
6	17.5	15.96	6.95	1.9	Fallow.
7	16.7	19.01	3.65	.70	Kafir.
8	16.3	19.25	4.54	1.03	Do.
9	16.6	.06	.01	.70	Grass (not clipped).
10 ³	24.1	12.17	2.62	.95	Wheat.
Average	17.8	11.76	2.82	1.07	

¹ Short plot.² Long plot.³ Desurfaced plot.

TABLE 9.—*Erosion and run-off data from the Guthrie, Okla., erosion station, 1930*

[Total rainfall, 33.56 inches; Vernon fine sandy loam; slope, 7.7 per cent]

Plot No.	Erosion ratio	Run-off	Erosion	Erosion per inch of run-off	Treatment
		<i>Per cent</i>	<i>Tons per acre</i>	<i>Tons per acre</i>	
1 ¹	57.3	11.55	21.20	5.5	Cotton.
2 ¹	44.6	10.04	14.49	4.3	Do.
3 ¹	46.8	13.11	17.50	4.0	Do.
4 ¹	40.3	13.36	3.09	.69	Oats.
5 ¹	62.6	9.76	.51	.16	Sweetclover.
6 ¹	49.4	11.95	13.32	3.3	Cotton.
7 ¹	47.9	2.83	.064	.067	Grass.
8 ¹	45.4	22.95	18.09	2.3	Bare.
9 ¹	22.9	26.39	35.26	4.0	Cotton.
Average	46.4	13.55	13.73	2.7	

¹ Short plot.¹ Long plot.¹ Desurfaced plot.TABLE 10.—*Erosion and run-off data from the Tyler, Tex., erosion station, October to December, 1930*

[Total rainfall, 11.57 inches; Kirwin fine sandy loam; slope, 8.75 per cent]

Plot No.	Erosion ratio	Run-off	Erosion	Erosion per inch of run-off	Treatment
		<i>Per cent</i>	<i>Tons per acre</i>	<i>Tons per acre</i>	
1 ¹	44.3	5.2	5.19	8.4	Cotton.
2 ¹	39.5	5.4	7.80	11.7	Do.
3 ¹	42.0	5.4	5.18	8.1	Do.
4 ¹	43.3	6.0	6.84	9.6	Do.
5 ¹	33.7	5.8	2.61	3.8	Do.
6 ¹	40.0	5.8	2.63	3.8	Corn.
7 ¹	35.9	5.6	2.40	3.6	Kobe Lespedeza.
8 ¹	23.6	9.3	.62	.56	Grass.
9 ¹	31.6	11.2	1.80	1.35	Bare.
10 ¹	8.6	.8	.06	.63	Cotton.
11 ¹	8.6	2.5	.03	.10	Do.
12 ¹	8.6	2.9	.25	.73	Do.
Average	30.4	5.5	2.93	4.4	

¹ Short plot.¹ Long plot.¹ Desurfaced plot.

It is not within the province of this bulletin to discuss the effect of the different crop treatments in the control of erosion. However, the correlation of the physical and chemical properties of the soil with its erosional characteristics is an important consideration. The dispersion ratio, the colloid-moisture equivalent ratio, and the erosion ratio are the only criteria that have been developed for estimating, in advance of actual measurement, the erosivity of a soil (17). These tests, of necessity, leave out of consideration differences in topography, climate, vegetation, and treatment, which are of primary importance in determining actual erosion except so far as these factors have previously influenced the character and properties of the soil itself. In consequence of these variables the degree of reliability of the erosional characteristics of the soils can not be estimated by com-

parison of the run-off and wash-off data of the different stations, but can only be arrived at by a study of the results obtained in successive years on plots under like treatment at a given station. However, some interesting relations may be brought out by the following discussion.

Houston black clay (Table 7), although it has the least slope and the lowest erosion ratio, shows the greatest average annual erosion and the highest percentage of run-off of the four soils for which data are available. It also has the greatest quantity of erosion per inch of run-off of the three soils for which data are available for the entire year.

The physical properties of this soil, such as the dispersion ratio, erosion ratio, and colloid-moisture equivalent ratio, would indicate that it is relatively nonerosive. The average dispersion ratio of the surface soil, 11.0, is within the tentative limit set by Middleton (17) for nonerosive soils, but the average of the colloid-moisture equivalent ratio, 1.29, is much below the lower limit of 1.5 which was established for this ratio. However, the average value of the erosion ratio of the surface soils, 8.5, is within the limit established for nonerosive soils. It is evident that some other property or combination of properties must operate in this particular soil to produce more erosion than would be expected from its physical properties. This soil is very stiff and plastic when wet and on drying shrinks and cracks into very hard lumps which adsorb water very slowly. Slow penetration of water, together with the high intensity of rainfall which occurs in this region, produces a large quantity of run-off. Under these conditions cultivation, such as is necessary in the growth of cotton, induces a large quantity of erosion because the loose surface soil is swept off by the run-off water. The low dispersion ratio is undoubtedly caused by the slow penetration of water into the aggregates of the soil and the high content of calcium which tends to hold them together so that under the conditions of this test only a small fraction of the material is dispersed. The dispersion and erosion ratios of the surface layer of the desurfaced plot (plot 11) are approximately half of the corresponding values of the normal surface soil, and the actual erosion is also approximately half as much. The colloid-moisture equivalent ratios are practically the same, so that in this case the dispersion ratios and consequently the erosion ratios indicate the relative degree of erosion.

The Houston soil is one of the most uniform soils that has been investigated in this work (Table 5); yet on two plots of this soil receiving identical treatment the erosion and run-off on one is nearly two and one-half times that on the other. (Plots 5 and 8.) The difference in the erosion ratios and in the other properties of these two plots (Table 4) give no indication of the cause of these differences. The erosion per inch of run-off is practically the same in each case, which is in accord with the physical and chemical data. The causes of these variations and discrepancies are not known at present. It is possible that they may disappear in later data; if so, they may be ascribable to local variations in treatment or in the establishment of the plots. The grass plot (No. 6) had the most erosion of any of the plots. However, this erosion all occurred in the first half of the year and no doubt was caused by difficulty in getting the grass estab-

lished. The effect of this is more or less counterbalanced in the average by plot 3, where the tank overflowed during the most destructive rain of the year.

Colby silty clay loam (Table 8) has the lowest annual rainfall, the lowest quantity of erosion, and the lowest erosion per inch of run-off of the four soils considered. The surface horizon of the plots, however, has a higher erosion ratio than that of the Houston soil and a much lower ratio than have the Vernon and Kirvin soils. The Houston and Colby are both calcareous soils, but the surface soil of the Colby is much lower in carbonates than the Houston surface soil. The variation noted may therefore undoubtedly be ascribed to the effect of the high carbonate content on the structure of the Houston soil. The erosion ratio for the desurfaced plot (No. 10) is not only higher than for the corresponding depth of the normal plots, but is also higher than for the surface layers of the same plots. Nevertheless, its actual loss by erosion is less than that of plot 5 and greater than that of plot 3, which have received identical cultural treatment. It may again be assumed that the exposure of the subsurface soil has resulted in structural alterations affecting its erosional behavior. It is to be noted that the upper layer of the desurfaced plot has an erosion ratio approximately threefold that of the material at approximately like depth in the profile sample (Table 4).

Vernon fine sandy loam (Table 9) has nearly the same percentage of run-off and total erosion as the Houston soil, with practically the same total quantity of rainfall. The Vernon soil is on a steeper slope, which produces more erosion per inch of run-off on the cotton plots than on the cotton plots of the Houston soil. The erosion ratio of the Vernon is more than double that of the Colby, and the average erosion is nearly five times as much. On plots receiving somewhat similar treatment, such as the oat and grass plots on the Vernon soil as compared to the wheat and grass plots on the Colby, the erosion is practically the same, with the Vernon showing less erosion per inch of run-off. However, the bare plot on the Vernon shows two and one-half times as much erosion as the fallow plot on the Colby. Taking the differences of slope, rainfall, crop conditions, and treatment into consideration, it is evident that the Vernon is a much more erosive soil than the Colby, as is indicated by their erosion ratios.

The desurfaced plot on the Vernon soil (plot 9) shows an unusual quantity of run-off and erosion, considering its erosion ratio and other physical properties. The erosion per inch of run-off is the same as for the normal plot 3. We are not able to offer a satisfactory explanation for this at present. It will be very interesting to see whether these differences continue to appear in successive years.

The data for Kirvin fine sandy loam (Table 10) cover only a part of a year, but they indicate that, considering the slope, the erosion ratio, and the high erosion per inch of run-off, this soil is highly erosive. The dispersion ratio, colloid-moisture equivalent ratio, and erosion ratio of the exposed horizon of the desurfaced plots are all within the limits tentatively established for nonerosive soils. The limited data show that these plots erode markedly less than any of the normal plots, regardless of treatment.

GENERAL REMARKS

The data presented in this bulletin concerning the chemical and physical properties of the soils on which erosion experiment stations have been established represent the beginning of an intensive laboratory study of the properties of soils which affect erosion and of the effect of erosion on soils. As the experiments proceed, these data will be used as the basis to which future analyses will be referred in order to determine the changes, if any, which are brought about in the soil by erosion. It is evident that when the chemical and physical properties are uniform throughout the soil profile, as in the Colby, Houston, Marshall, and Palouse soils, erosion will not extensively change the fundamental properties of these soils. The greatest change will be in the loss of organic matter from the surface soil, with consequent changes in water-holding capacity, plasticity, and structure. In the soils which are not uniform throughout their profiles, greater changes may be expected, particularly where the surface soil is of a sandy texture. It is to be expected that the removal of the surface soil will ultimately result in the present subsoil becoming the surface layer, except as the subsoil itself may be modified by erosion. This transformation will be gradual and will be greatly modified by cultural practices. With the present data and reserve material for future determinations, it will be possible to follow these progressive changes.

There will undoubtedly be great differences in the quantity of erosion which takes place on the different soils and on the same soils with different crop and fertilizer treatments. The field data at the time of writing this report are too meager to warrant the drawing of any definite conclusions. It is recognized, however, that any quantitative estimate of the validity of the laboratory data must be based on the field data when they shall have been obtained in adequate quantity. From the laboratory data at hand it is possible to predict with a high degree of certainty the type of erosion which will occur on a given soil type. It is also possible to predict which part of the profile will be most susceptible or most resistant to erosion. However, it is not possible to estimate the quantity of erosion, owing to differences in slope, quantity and character of rainfall, and type of agriculture. The whole investigation points to the urgent need for some method of ascertaining the relationship between structure and seasonal changes in structure and erosional behavior. It is probable that a complete picture should also include determinations of plasticity, percolation, and shrinking and swelling. It is highly probable that some determinations of this kind, together with the data reported herewith, may be correlated with the field data when available so that an adequate approximation of the field erosional behavior of soils may be made which will be extremely valuable in determining the need for, and methods of, erosion control in areas where for any reason the establishment of field stations is impossible.

SUMMARY

Mechanical analyses and gross chemical analyses have been made of representative profile samples of each of the soil types on which erosion experiment stations have been established.

Detailed chemical analyses of the colloids of each soil type have been made.

The physical characteristics affecting erosional behavior have been determined and a study made of their relation to each other, to the chemical composition of the colloid, and to field erosional behavior, so far as the latter is known at the present time.

The physical characteristics of composite samples from each tank plot at six of the stations have been determined.

An analytical basis has been established, to which may be referred the future field behavior of these soils when it has been determined, so that a quantitative expression of anticipated behavior may be developed.

The need for accurate quantitative expression of the effect of soil structure on erosional behavior has been pointed out.

LITERATURE CITED

- (1) BENNETT, H. H., and CHAPLINE, W. R.
1928. SOIL EROSION A NATIONAL MENACE. U. S. Dept. Agr. Circ. 83, 36 p., illus.
- (2) BRIGGS, L. J., and McLANE, J. W.
1910. MOISTURE EQUIVALENT DETERMINATIONS AND THEIR APPLICATION. Jour. Amer. Soc. Agron. 2: 138-147, illus.
- (3) BYERS, H. G., and ANDERSON, M. S.
1932. THE COMPOSITION OF SOIL COLLOIDS IN RELATION TO SOIL CLASSIFICATION. Jour. Phys. Chem. 36: 348-366.
- (4) CONNER, A. B., DICKSON, R. E., and SCOATES, D.
1930. FACTORS INFLUENCING RUN-OFF AND SOIL EROSION. Tex. Agr. Expt. Sta. Bul. 411, 60 p., illus.
- (5) DAVIS, R. O. E.
1914. ECONOMIC WASTE FROM SOIL EROSION. U. S. Dept. Agr. Yearbook 1913: 207-220, illus.
- (6) ———
1915. SOIL EROSION IN THE SOUTH. U. S. Dept. Agr. Bul. 180, 23 p., illus.
- (7) ——— and BENNETT, H. H.
1927. GROUPING OF SOILS ON THE BASIS OF MECHANICAL ANALYSIS. U. S. Dept. Agr. Circ. 419, 15 p., illus.
- (8) DULEY, F. L., and MILLER, M. F.
1923. EROSION AND SURFACE RUN-OFF UNDER DIFFERENT SOIL CONDITIONS. Missouri Agr. Expt. Sta. Research Bul. 63, 50 p., illus.
- (9) HENDRICKS, S. B., and FREY, W. H.
1930. THE RESULTS OF X-RAY AND MICROSCOPICAL EXAMINATIONS OF SOIL COLLOIDS. Soil Sci. 29: 457-479, illus.
- (10) HOLMES, R. S., and EDGINGTON, G.
1930. VARIATIONS OF THE COLLOIDAL MATERIAL EXTRACTED FROM THE SOILS OF THE MIAMI, CHESTER, AND CECIL SERIES. U. S. Dept. Agr. Tech. Bul. 229, 24 p., illus.
- (11) LEIGHY, W. R., and SHOREY, E. C.
1930. SOME CARBON-NITROGEN RELATIONS IN SOILS. Soil Sci. 30: 257-266.
- (12) LOWDERMILK, W. C.
1928. INFLUENCE OF FOREST LITTER ON RUN-OFF, PERCOLATION, AND EROSION. Jour. Forestry 28: 474-491, illus.
- (13) MCGEE, W. J.
1911. SOIL EROSION. U. S. Dept. Agr., Bur. Soils Bul. 71, 60 p., illus.
- (14) MOLEAN, W.
1930. THE CARBON-NITROGEN RATIO OF SOIL ORGANIC MATTER. Jour. Agr. Sci. [England] 20: 348-354.
- (15) ———
1931. EFFECT OF HYDROGEN PEROXIDE ON SOIL ORGANIC MATTER. Jour. Agr. Sci. [England] 21: [251]-262.

- (16) McLEAN, W.
1931. THE NATURE OF SOIL ORGANIC MATTER AS SHOWN BY THE ATTACK OF HYDROGEN PEROXIDE. Jour. Agr. Sci. [England] 21: [595]-611, illus.
- (17) MIDDLETON, H. E.
1930. PROPERTIES OF SOILS WHICH INFLUENCE SOIL EROSION. U. S. Dept. Agr. Tech. Bul. 178, 18 p.
- (18) OLMSTEAD, L. B., ALEXANDER, L. T., and MIDDLETON, H. E.
1930. A PIPETTE METHOD OF MECHANICAL ANALYSIS OF SOILS BASED ON IMPROVED DISPERSION PROCEDURE. U. S. Dept. Agr. Tech. Bul. 170, 23 p., illus.
- (19) PURI, A. N.
1930. STUDIES IN SOIL COLLOIDS. II. FACTORS INFLUENCING THE DISPERSION OF SOIL COLLOIDS IN WATER. India Dept. Agr. Mem., Chem. Ser. 11: 39-51.
- (20) ——— and KEEN, B. A.
1925. THE DISPERSION OF SOIL IN WATER UNDER VARIOUS CONDITIONS. Jour. Agr. Sci. [England] 15: 147-161, illus.
- (21) ROBINSON, W. O.
1922. THE ABSORPTION OF WATER BY SOIL COLLOIDS. Jour. Phys. Chem. 26: [647]-653.
- (22) ———
1927. THE DETERMINATION OF ORGANIC MATTER IN SOILS BY MEANS OF HYDROGEN PEROXIDE. Jour. Agr. Research 34: 339-356.
- (23) ———
1930. METHOD AND PROCEDURE OF SOIL ANALYSIS USED IN THE DIVISION OF SOIL CHEMISTRY AND PHYSICS. U. S. Dept. Agr. Circ. 139, 20 p.
- (24) ——— and HOLMES, R. S.
1924. THE CHEMICAL COMPOSITION OF SOIL COLLOIDS. U. S. Dept. Agr. Bul. 1311, 42 p.
- (25) SAMPSON, A. W., and WEYL, L. H.
1918. RANGE PRESERVATION AND ITS RELATION TO EROSION CONTROL ON WESTERN GRAZING LANDS. U. S. Dept. Agr. Bul. 675, 35 p., illus.
- (26) SLATER, C. S., and BYES, H. G.
1931. A LABORATORY STUDY OF THE FIELD PERCOLATION RATES OF SOILS. U. S. Dept. Agr. Tech. Bul. 232, 24 p., illus.

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